



DEPARTMENT OF THE ARMY
UNITED STATES MILITARY ACADEMY
WEST POINT, NEW YORK 10996

June 21, 1999

REPLY TO
ATTENTION OF

Directorate of Housing and Public Works

SUBJECT: Resource Conservation Recovery Act – Subpart X Permit, Part B, Interim Status Resolution

Ms. Michelle Cheng
New York State Department of
Environmental Conservation
50 Wolf Road – Room 448
Albany, New York 12233-7251

Dear Mrs. Cheng:

As discussed during our conference telephone call on June 7, 1999, we are forwarding herein, a copy of our letter with enclosures dated July 30, 1992. We sent this to Mr. John Middlekoop, P.E. of your office, and to Mr. Andrew Bellina, P.E. of the US Environmental Protection Agency to resolve our Subpart X permit issue. The enclosed material includes a closure plan for the detonation area located inside our impact area. (Section I). Based on our October 28, 1992 meeting with the New York State Department of Environmental Conservation in Albany, and our subsequent submittal on December 11, 1992 of information requested at the meeting, we understand that this issue was resolved.

The United States Military Academy originally submitted a Resource Conservation and Recovery Act Part B permit application for its hazardous waste operations in November 1988. The original permit application covered container storage and open burning/open detonation. On January 28, 1991, we closed our container storage area and restricted storage of our hazardous waste operations to keeping hazardous waste on post for no more than 90 days. A copy of the New York State Department of Environmental Conservation's letter recognizing this, is at Enclosure 2. Use of our detonation area was discontinued in the winter of 1991-92, when the Explosive Ordnance Detachment assigned to the United States Military Academy relocated to Fort Monmouth, New Jersey. Since then, no routine detonations for the purpose of ordnance disposal have taken place at West Point. With the closure of our container storage and the cessation of open detonation, there was no longer a requirement for a permit to cover our hazardous waste operations. We began to communicate this to the US Environmental Protection Agency, Region II, and the New York State Department of Environmental Conservation through briefings and written correspondence in the spring of 1992.

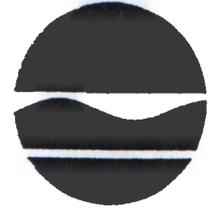
RECEIVED
NYSDEC

JUN 22 1999

BUR. OF HAZARDOUS WASTE
MANAGEMENT
DIVISION OF SOLID &
HAZARDOUS MATERIAL

New York State Department of Environmental Conservation
50 Wolf Road, Albany, New York 12233

May 9, 1991



Thomas C. Jorling
Commissioner

Mr. Joseph Deschenes
Acting Chief, Environmental Mgt. Office
Dept. of the Army, U. S. Military Academy
West Point, New York 10996

Dear Mr. Deschenes:

RE: Closure of RCRA Storage Areas at West Point
EPA Identification Number: NY8210020915

This letter is to confirm the receipt of owner/operator and independent professional engineer's certification dated January 23, 1991, of RCRA closure for this facility. We now consider this facility officially closed. Your authority to operate as a Treatment, Storage, and Disposal Facility (TSDF) is terminated and you are released from the financial security requirements of Sections 373-2.8 and 373-3.3.

Please be advised that the United States Environmental Protection Agency has determined that the corrective action provisions of the Hazardous and Solid Waste Amendments (HSWA), Section 3008(h), apply to all TSDF's which have acquired interim status.

The New York State Department of Environmental Conservation has established a program to evaluate the corrective action measures necessary at closed and closing facilities within the State. Once the corrective action provisions of HSWA have been met by the facility or determined not to be necessary at the facility, the facility can have their interim status terminated.

If you have any questions regarding your closure or regulatory status, please contact Mr. Gary Belcher at (519) 457-9361.

Sincerely,

Salvatore J. Carlomagno, P.E.
Chief, Regional Permit Section
Bureau of Haz. Waste Facility Compliance
Division of Haz. Substances Regulation

cc: J. Gorman
J. Desai
M. O'Neil
M. Dominguez - Region 3
G. Belcher

SJC:scy
(deschene.gb)

2/10/91 HSWA #17

Encl 2



DEPARTMENT OF THE ARMY
UNITED STATES MILITARY ACADEMY
WEST POINT, NEW YORK 10996

30 JUL 92

REPLY TO
ATTENTION OF

SUBJECT: EPA ID No. NY8210020915; United States Military Academy, West Point, New York, RCRA Subpart X Permit Application

Mr. John L. Middlekoop, P.E.
Director, Bureau of Hazardous Waste Compliance
New York State Department of
Environmental Conservation
50 Wolf Road
Albany, New York 12233-7252

Dear Mr. Middlekoop:

Pursuant to my telephone conversation with Ms. Ellen Parr-Doering on July 21, 1992, this letter is submitted to respond to (1) the Notice of Deficiency (NOD) received by the United States Military Academy (USMA) from the United States Environmental Protection Agency (USEPA), Region II, with respect to the Resource Conservation and Recovery Act (RCRA) Subpart X permit application previously submitted by USMA; and (2), the letter received by USMA from USEPA Region II, dated June 4, 1992, with respect to the RCRA Subpart X permit (the June letter). This letter is also being addressed to Mr. Andrew Bellina of the USEPA. USMA believes that none of the activities identified in the NOD and the June letter require a RCRA Subpart X permit; however, USMA submits with this letter a partial closure plan for the Open Detonation Area. USMA's reasoning for this belief is summarized in the Executive Summary, which is followed by a more detailed explanation of each activity and USMA's reasoning with respect to each activity.

USMA believes that this letter may resolve all open issues regarding the RCRA Subpart X permit except the open burning of excess propellant. Therefore, USMA proposes that appropriate representatives of USEPA Region II, the New York State Department of Environmental Conservation (NYSDEC), USMA, and any other appropriate parties meet at a mutually agreeable time and place to discuss the issue of open burning. If a meeting is not possible, a conference call could be an alternative although face-to-face discussions would be more effective.

ENC 1

Executive Summary

The following chart summarizes the activities identified by USEPA Region II as requiring a RCRA Subpart X permit and USMA's position regarding the activity:

<u>Activity</u>	<u>USMA POSITION</u>
1. Open burning (OB) of excess propellant.	RCRA Subpart X permit not required, based on training exception. Further discussions with USEPA Region II and NYSDEC requested.
2. Open detonation (OD) of unexploded ordnance, pyrotechnics, etc.	RCRA Subpart X permit not required. In place detonations are not subject to permit requirements. Collection and OD of unexploded ordnance has been discontinued.
3. OB and OD of explosives confiscated by civilian law enforcement agencies.	RCRA Subpart X permit not required. This practice has been discontinued.
4. Emergency OD operations.	RCRA Subpart X permit not required at this time. No U.S. Army EOD unit is assigned to USMA. If the need arises, emergency permits will be requested as required by applicable USEPA regulations.
5. Partial closure and final closure of OD area.	A partial closure plan is enclosed. Final closure is not practical as the OD area is within the impact area.

Open Burning of Excess Propellant

USMA believes that the open burning of excess propellant is an integral part of training that does not constitute treatment/disposal of solid or hazardous waste and, therefore, is not subject to RCRA Subpart X permit requirements. USMA understands that its position on this

matter is consistent with the position of the Department of the Army. USMA recognizes that it may not have clearly articulated it's reasoning with respect to this matter in previous correspondence and that modification to current open burning practices may be required. Since this matter is somewhat complex and is an important concern to USMA, we propose that further discussions be held, as described in the conclusion of this letter, prior to exchanging any additional written correspondence regarding this issue.

Open Detonation

USMA has ceased all activities in the Open Detonation Area which may require a RCRA Subpart X permit. The limited open detonation activities which will continue at USMA do not require a RCRA Subpart X permit based on the policy set forth in the June letter.

USEPA Region II stated the following regulatory interpretation on page 2 of the June letter:

"Current Environmental Protection Agency (EPA) policy holds that ordnances used during training does not constitute treatment/disposal of solid or hazardous waste.... This would also extend to the unexploded ordnance that falls to the ground during training exercises."

USEPA Region II further stated in the June letter:

"Since not all ordnances detonated when dropped, any unexploded ordnances are within the normal use pattern of training; subsequent in-place detonation is not subject to RCRA.... On the other hand, if at any point unexploded ordnances are collected and brought to a place other than the training range to be burned or detonated, then that open burning/open detonation activity is subject to the full permitting requirements of RCRA."

USEPA Region II also stated in the June letter:

"Range waste, such as dud rounds, unexploded small arms ammunition, excess propellants and trip flares is commonly generated from military training. These types of waste were previously open detonated or open burned at the Open Detonation Unit or the Open Burning Unit and it appears that this activity is continuing."

The conclusion that the dud rounds are a waste is inconsistent with USEPA Region II's policy described above, which considers unexploded ordnance to be within the normal use pattern of training with subsequent in-place detonation not subject to RCRA. Since "duds" are defined as rounds which do not explode upon impact, USMA believes, based on USEPA Region II's policy, that the detonation of duds within the impact range is not subject to RCRA Subpart X permit requirements.

USEPA states a belief that the activity at the Open Detonation area is continuing. This is not the case. All activity at the Open Detonation area has ceased. The EOD unit which conducted activities at the OD facility is no longer present at USMA on a regular basis. An EOD unit will be detailed to USMA during artillery training and will be assigned to detonating duds in place on the range. Military items that were previously treated by the EOD unit are being returned to stores or shipped to other facilities. The only remaining detonation activity will be in-place detonation of duds resulting from training activities, exempt from RCRA.

Therefore, USMA believes that the OD area is not subject to RCRA Subpart X permit requirements, since the activity cited as requiring the permit is not taking place, and the only detonation activity taking place is not subject to RCRA.

OB/OD of Confiscated Explosives

USMA no longer conducts, and will not conduct, open burning or open detonation of explosives confiscated by civilian law enforcement agencies. Therefore, a RCRA Subpart X permit is not required.

Emergency OD Operations

As stated above under "Open Detonation" all activity at the OD area has ceased. An EOD unit will no longer be assigned to USMA, but will be temporarily detailed to USMA during training to detonate duds in-place on the range. Based on the June letter, this activity does not require a RCRA Subpart X permit. If circumstances arise which may require an emergency permit, USMA would request an emergency permit.

Closure of the OD Area

The June letter requires that a closure plan be submitted if the Open Detonation area will no longer be used to manage hazardous waste. Since the Open Detonation area is no longer being used, USMA's closure plan for the OD unit is included in Enclosure 2 as Section I.

USEPA Region II has acknowledged that the location of the OD area within the impact area makes it impractical to perform either "clean" or "landfill closure." Therefore, USMA is submitting a partial closure plan which would consist of detonation of any unexploded ordnances identified in the OD area. Final closure activities are not described at this time. The OD area is only a small portion of the impact zone and in terms of any contaminants is indistinguishable from the rest of the impact zone. It would be impractical to devise any closure activity for the OD area independent of any activities for the impact zone which would take place if USMA were to be closed and the impact zone no longer used.

Response to NOD

Responses to certain of the items listed in the NOD and to certain of the items normally associated with a RCRA Subpart X permit application are enclosed as Enclosures 1 and 2, respectively. These responses have been provided to facilitate an exchange of information. Responses to the NOD which are related to procedures dictated by open burning permit requirements have not been provided, since USMA understands that this issue will be discussed in the near future and USMA believes that this activity is not subject to RCRA Subpart X permit requirements.

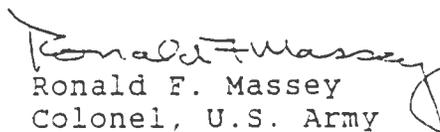
Interim Status

Based on my telephone conversation with Ms. Parr-Doering, USMA understands that USEPA Region II believes that USMA is proceeding in good faith with respect to this matter and will not terminate its interim status if a decision regarding its RCRA Subpart X permit has not been finalized by November 3, 1992. USMA requests that USEPA Region II inform USMA if this understanding is incorrect.

Conclusion

USMA greatly appreciates the cooperation of USEPA Region II with respect to this matter. USMA proposes that a meeting be held at a mutually convenient time and place to discuss the open burning of excess propellant. If USEPA Region II desires to discuss any other issues, USMA requests that you notify us of the need for such discussions.

Sincerely,


Ronald F. Massey
Colonel, U.S. Army
Garrison Commander

Enclosures

1. Certain NOD Responses
2. Additional Information

SECTION B
FACILITY LOCATION

Date: 07/26/92

SECTION B

This section provides information on the location, operation, and administration of the open burning (OB) unit at the United States Military Academy (USMA). It provides the information required by 40 CFR 270.14(b)(1),(10),(11), and (19), and the corresponding New York State regulations at Title 6, NYCRR 373-1.4(a), 373-1.5(a)(2) (i),(x),(xi), and (xix).

B-1 GENERAL DESCRIPTION [NYCRR 373-1.5(a)(2)(i)]

The USMA at West Point, New York, is located in the southeastern part of Orange County along the west bank of the Hudson River, approximately 80 km (50 mi.) north of New York City and 23 km (14 mi.) south of Newburgh. Refer to Figure B-1 for details. The installation consists of nearly 6,480 ha (16,000 acres), which includes the academy's campus area or Main Post of 1,020 ha (2,520 acres). The remaining 5,460 ha (13,480 acres) comprise the Military Reservation, which is a largely undeveloped tract consisting of firing ranges and bivouac areas. Open burning operations are conducted in a hilly part of the Military Reservation approximately 4.8 km (3 miles) west southwest of the Main Post (see Figure B-2).

The primary mission of USMA, since its inception in 1802, has been the training and education of officers seeking careers in the United States Army. Among the activities involved in training are artillery firing exercises at ranges in the Military Reservation. Most firing exercises generate excess bags of propellant powders which are removed from 105-mm howitzer shells and 60, 81, and 105-mm mortar shells to limit the distances projectiles are hurled. These excess bags cannot be returned or otherwise recycled, so they are burned under carefully controlled conditions.

A concrete pad has been constructed to support a steel burn pan containing two removable sections in which propellants are burned. All residues remaining after each burn are retained in the pan until cool, and are then transferred to 55-gallon drums for proper disposal. Refer to Section C for additional details on the characteristics of the materials being burned. Details of the OB process itself are provided in Section D.

Date: 07/26/92

A series of photographs with accompanying legends has been provided as Appendix B to aid in developing an understanding of the OB area and its physical characteristics. Refer to Appendix B for views of the entrance gate into the OB area, the layout of the area itself from a number of different angles, the concrete pad and steel burn pan placement, and other features of the site and surrounding area.

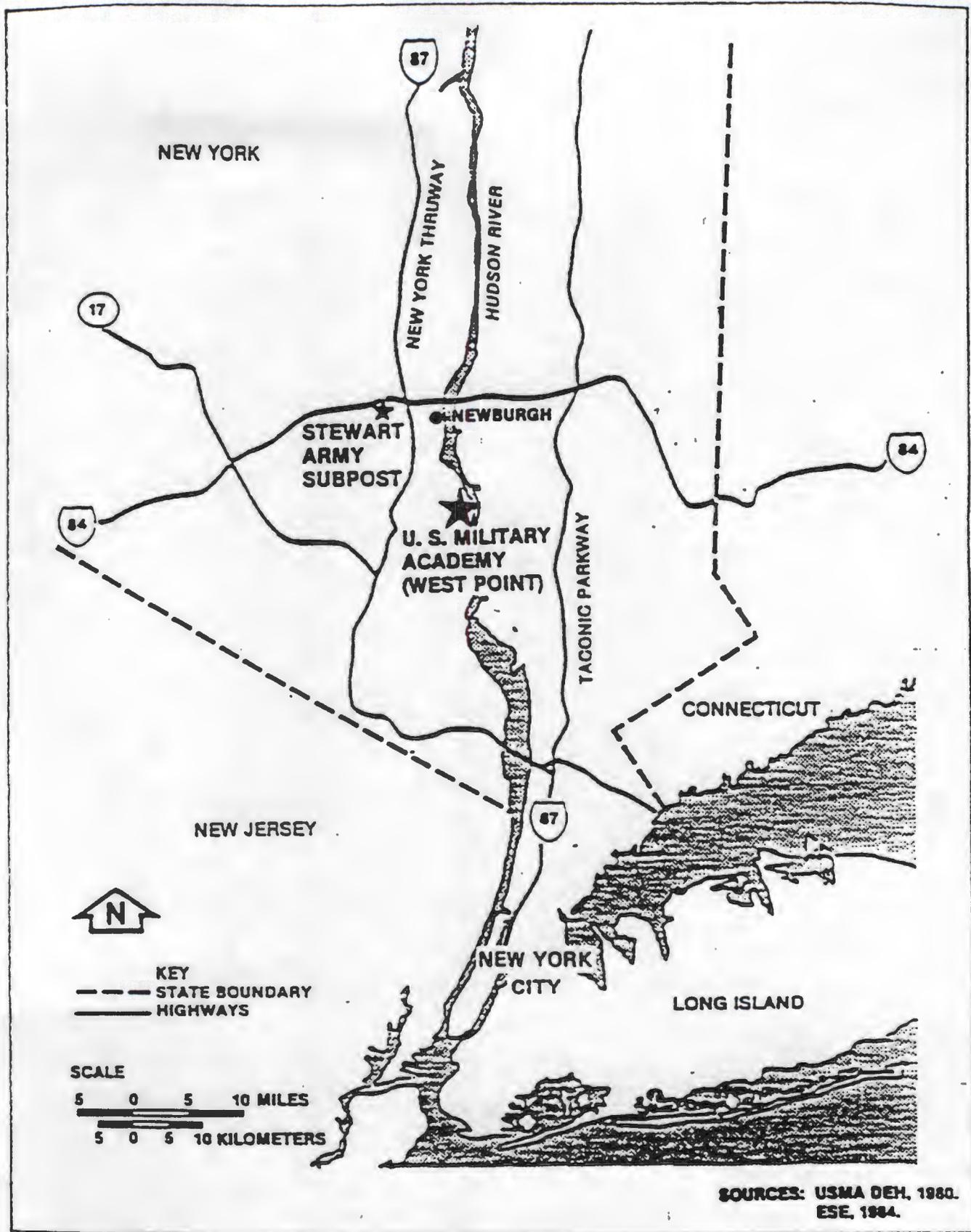
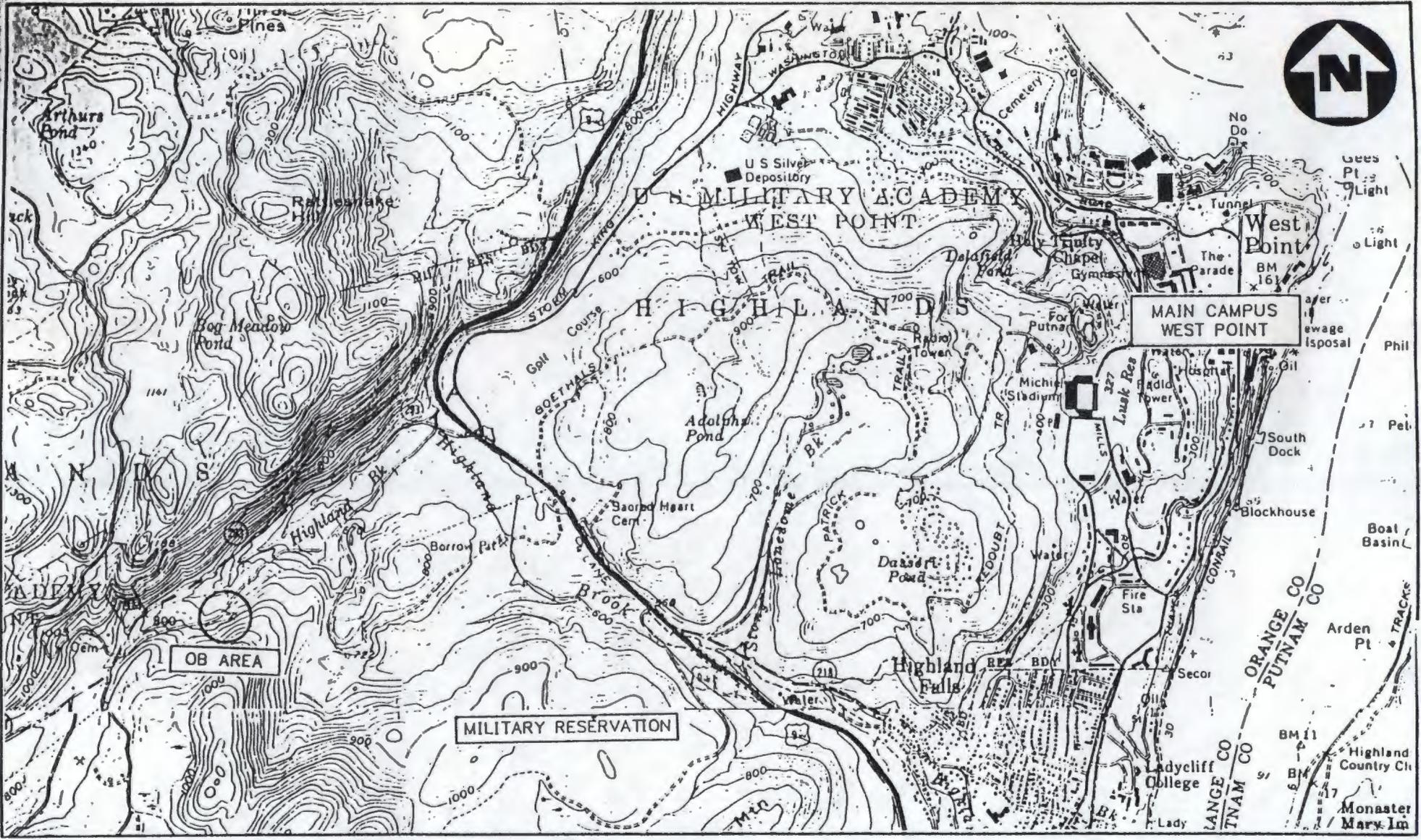


FIGURE B-1

LOCATION MAP OF THE
U.S. MILITARY ACADEMY
USMA, WEST POINT, NEW YORK



HALLIBURTON NUS
Environmental Corporation



B-3

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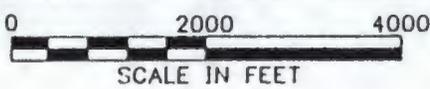


FIGURE B-2

LOCATION MAP
USMA, WEST POINT, NEW YORK



HALLIBURTON NUS
Environmental Corporation

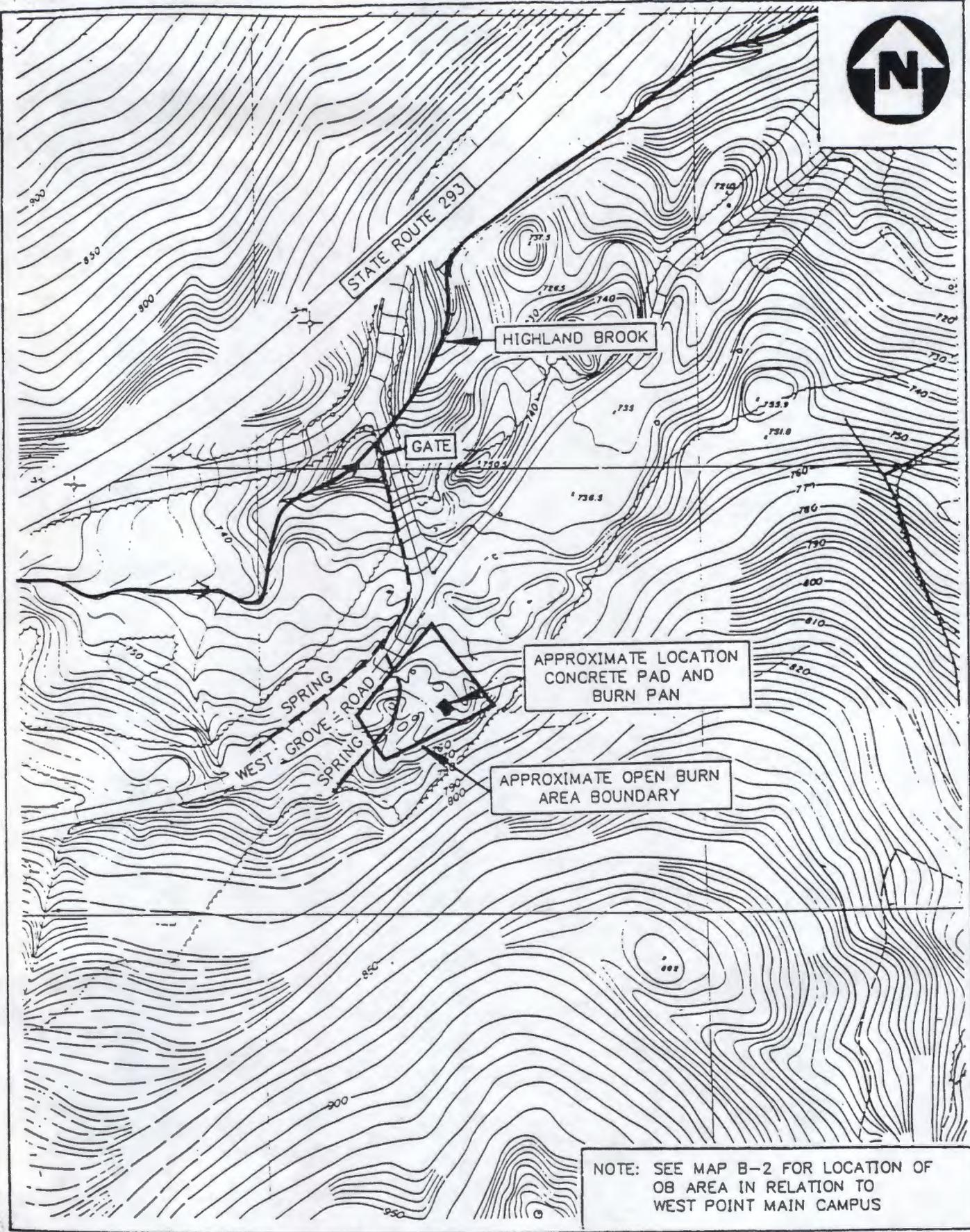
Date: 07/26/92

B-2 TOPOGRAPHIC MAP [NYCRR 373-1.5(a)(2)(xix)]

Because of the need for different map scales, several topographic maps are necessary to provide all the information required by the regulations. Figure B-3 is provided to show the terrain in the vicinity of the OB area, and to locate the OB pad with respect to the nearby surface water bodies. An ephemeral stream crosses the corner of the OB site, fed by springs at the base of the high wall along the southern edge of the facility. These flows eventually reach Highland Brook near the access road to the site. Figure B-3 also indicates the approximate boundaries of the OB area, the gate which serves as access control, and the location of the OB pad and burn pan within the OB area. Figure B-4 shows the same information, but the map scale has been changed so that contours are more clearly visible for the immediate area around the OB site.

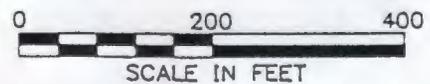
The topography of the USMA is very irregular, for the Hudson River has formed a gorge 0.4 to 0.8 km (0.25 to 0.5 mi) wide in the vicinity of the USMA. The land rises steeply from an elevation of 61 meters (200 ft) on the Main Post near the river to 435 meters (1,420 ft) at the highest point on the Military Reservation. Approximately one-third of the Military Reservation consists of slopes of 20% or greater. The reservation is heavily forested with deciduous trees and shrub, and dotted with numerous small swamps, marshes, and fresh water ponds.

Other required information related to the topographic maps is listed in NYCRR 373-1.5 (a)(2)(xix):



NOTE: SEE MAP B-2 FOR LOCATION OF OB AREA IN RELATION TO WEST POINT MAIN CAMPUS

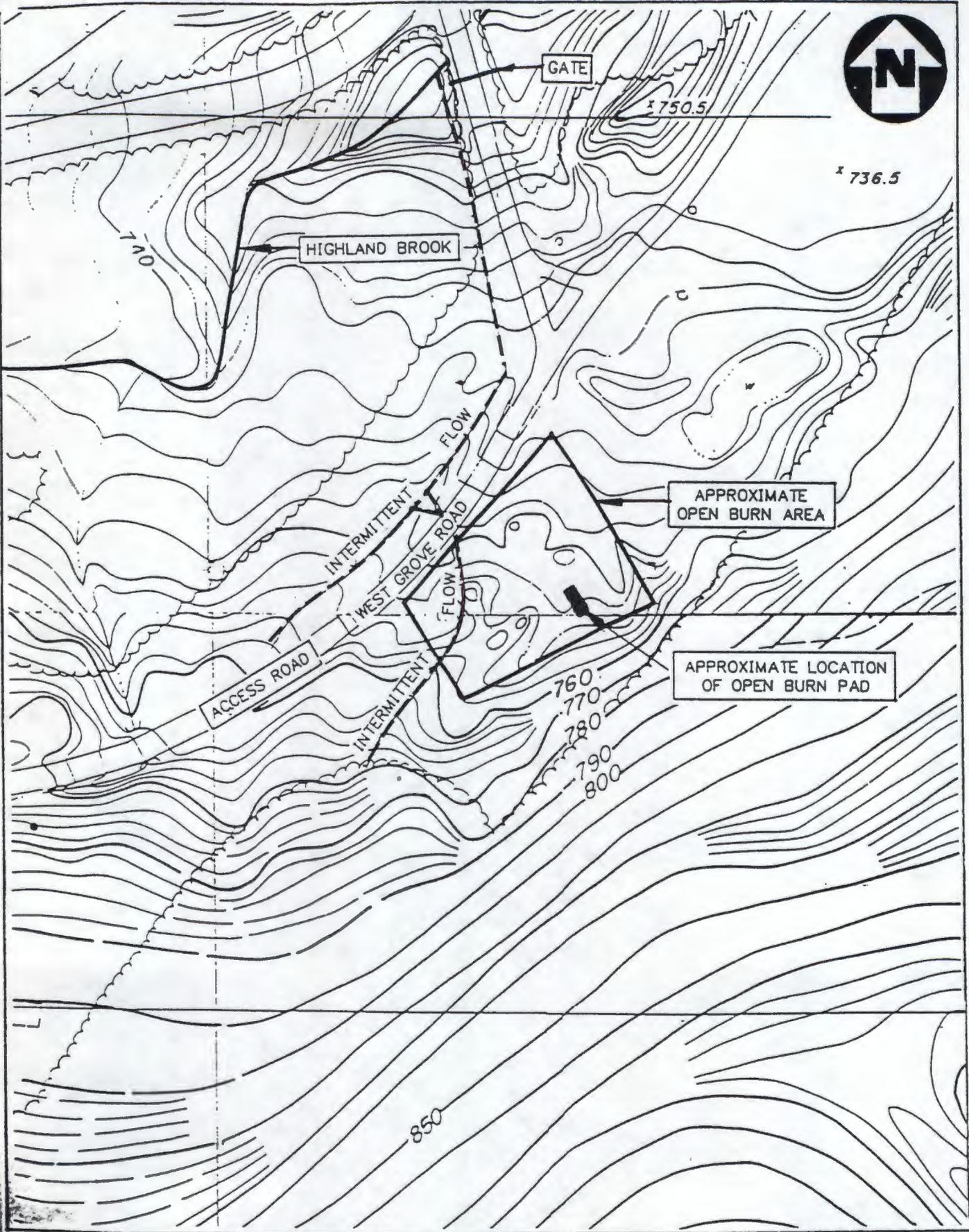
FIGURE B-3



OPEN BURN AREA LOCATION
 USMA, WEST POINT, NEW YORK



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 001749P0000



(B4)

MB

9/19/82

STAVELAND

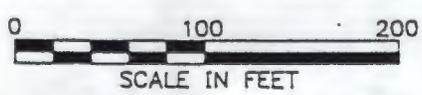


FIGURE B-4

OPEN BURN AREA LOCATION
USMA, WEST POINT, NEW YORK



Date: 07/26/92

- a. Map scale and date: Scales are indicated on each topographic map provided for this application. The date is not shown on the figures, but all maps reflect present conditions as of July, 1992.
- b. 100-year floodplain area: The OB unit is not located within the 100-year floodplain. The 100-year floodplain elevations nearest to the OB area reach as high as 144 meter (472 ft) above MSL, according to Flood Insurance Administration maps for the Town of Highlands, of which much of the reservation is a part. As can be seen in Figure B-4, most of the OB site lies above the 229 m (750 ft) elevation, and all of it is above 227 meters (744 ft). This means that the OB operations take place at least 83 meters (272 ft) above the 100-year floodplain. Since the OB unit is immune from flooding, no floodproofing or flood protection measures such as those described in NYCRR 373-1.5(a)(2)(xi)(b) are required.
- c. Surface waters including intermittent streams: This information is provided on Figures B-2, 3, and 4.
- d. Surrounding land uses (residential, commercial, agricultural, recreation): Land uses in the area surrounding the USMA are strongly influenced by the rugged terrain which places severe limits on commercial and agricultural development. As a result most of the surrounding land is forest, most suitable for recreational purposes. Contiguous to the USMA's southern boundary is the extensive Palisades Interstate Park system, including Bear Mountain and the Anthony Wayne Recreation Area. To the north of the USMA lies another section of the Palisades Interstate Park which includes Storm King Mountain. The Hudson River forms the eastern boundary of USMA, and Constitution Island lies directly opposite the Main Post area. The western edge of the USMA abuts the Woodbury Creek valley where some residential communities and agricultural activities coexist. The towns of Central Valley, Cornwall, Highlands, Highland Falls, Highland Mills, Newburgh, New Windsor, and Woodbury are located near the USMA, and have a total population of about 130,000 people. Several light industries are based in some of these centers of population (particularly in Newburgh) but reportedly there are no heavy industrial activities anywhere near the vicinity of the USMA.

Date: 07/26/92

- e. A wind rose (i.e., prevailing wind speed and direction): This information is provided in Section E where the impact of OB operations on regional air quality is discussed.
- f. Orientation of the map (north arrow): Each map provides this information.
- g. Legal boundaries of the HWM facility site: The approximate boundaries of the OB area are shown on Figures B-3 and 4. No official "legal" boundaries have been defined for OB activities because the entire OB site represents only a small fraction of the USMA reservation, and lies entirely within USMA.
- h. Access control (fences, gates): The road leading into the OB area has a locked gate to control access, and has a number of warning signs posted in each direction of approach to notify unauthorized persons of the potential hazards.
- i. Injection and withdrawal wells both on-site and off-site: As stated above, the nearest known withdrawal wells are at least 1,590 m (5,200 ft) from the OB site. There are no injection wells anywhere on or near the reservation.
- j. Buildings; treatment, storage, or disposal operations; or other structures: There are no buildings in the vicinity of the OB site. The remains of the foundations of two abandoned buildings in the Highland Brook valley adjacent to the OB site have been overgrown with vegetation, and are of no archeological interest. Refer to Figure B-5 for a general arrangement sketch showing the pad and burn pan in relation to the other structures at the site (a rubble pile, a low concrete block wall, two sets of power lines overhead, utility poles, and access roads).

The waste residues generated by OB operation and from cleaning out the burn pans after a treatment cycle are placed in containers and handled as hazardous waste until sampling and analysis of the ash residues proves that the waste is not hazardous. Any precipitation which may have accumulated in the burn pans during the cool down period is also collected, sampled and analyzed in the same manner. Wastes that are verified as being nonhazardous are disposed of in permitted on-site facilities. If the analysis proved that the residues were still hazardous wastes (a situation

Date: 07/26/92

that has not occurred as yet) disposal would take place at an approved off-site facility contracted to handle such materials. No storage of hazardous wastes is involved because all waste propellants are treated and disposed of on the same day that they become excess. There are no sanitary facilities at the OB site, and no sewerage or water distribution systems.

Date: 07/26/92

onto New York State Route 293, a paved two-lane roadway with speed limits in the 35 to 50 MPH range. This roadway is more heavily traveled during morning and evening rush hours, as it connects West Point with US Route 6 and the New York State Thruway at Central Valley. Trucks carrying excess propellant would not be using this road during rush hours. Moreover, the total travel distances on NY 293 would never exceed 5 km (3 mi.), so there is limited risk to trucks while traveling this road. Again, trucks coming from NY 293 would exit onto West Grove Road to reach the OB site, but their travel distance along West Grove would be less than 300 meters (1,000 ft).

Date: 07/26/92

With respect to loading/unloading facilities, waste bags of propellants are brought to the site by truck directly from the firing range where they are discarded as excess. The bags are transferred manually to the concrete burn pad, cut open, and the powder is loaded directly into the burn pan. No temporary storage or separate unloading operations are involved. Refer to Section D for a description of the OB process.

- k. Barriers for drainage or flood control: Run-on/run-off controls at the Military Reservation are relatively undeveloped because of the rugged nature of the terrain. Unimproved roads are served by rudimentary drainage controls as necessary, but water from springs and seeps often runs down or across such roads. Flood controls at the OB site are non-existent because of its location far above the 100-year floodplain.
- l. Location of operational units within the HWM site: Refer to Figure B-5 for details on this issue.

B-3 LOCATION INFORMATION [40 CFR 264.18 and NYCRR 373-1.5 and 2.2]

B-3 TRAFFIC INFORMATION [NYCRR 373-1.5(a)(2)(x)]

Traffic in and out of the OB area is limited to the trucks which bring excess propellant bags to the site for thermal treatment. Most of the materials will originate at Range 2 firing points (Buena Vista) which is connected to the OB site by an unimproved roadway, West Grove Road. Traffic on this portion of the road is strictly controlled, and is only present whenever range firing activities are scheduled at Range 2. A truck typically makes no more than two trips a day to the OB site carrying excess propellant. A typical daily schedule for Range 2 would be to fire up to 200 rounds in the morning, thus generating up to 1,000 excess bags. Those bags would then be brought to the OB area for burning. The afternoon exercise would fire up to another 200 rounds, yielding an additional 1,000 bags for treatment. The truck would make a second trip in mid-afternoon. The process would be repeated only about 15 to 25 days a year, so the amount of traffic generated in this fashion is minimal.

Whenever waste propellants are transferred from other ranges to the OB unit for treatment, part of the route takes the trucks out



APPROX.

B-9

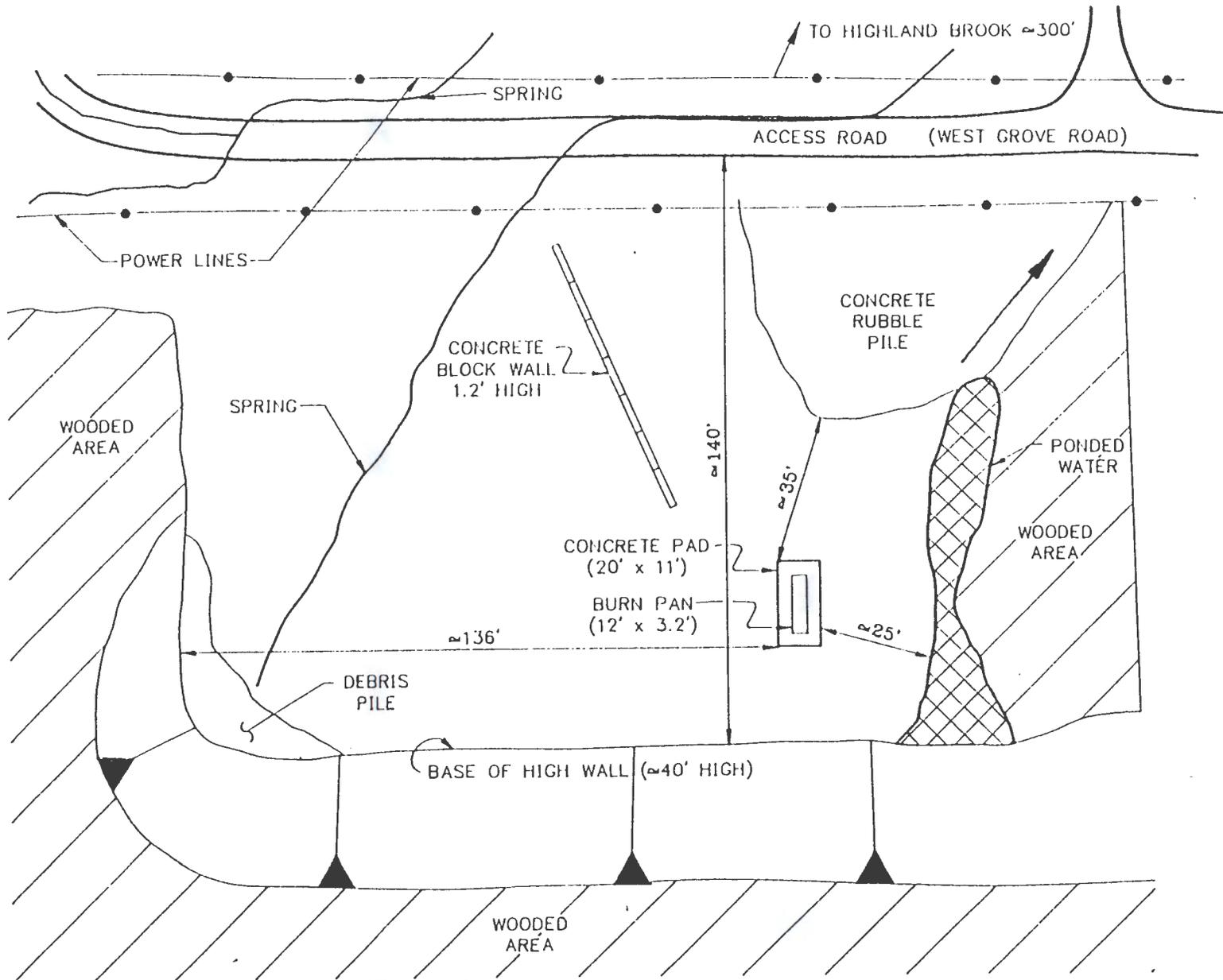


FIGURE B-5

GENERAL ARRANGEMENT SKETCH
OPEN BURN AREA
USMA, WEST POINT, NEW YORK



HALLIBURTON NUS
Environmental Corporation

SECTION C

PROPELLANT CHARACTERISTICS

40 CFR 270.14(b)(2), 264.13(a), and
NYCRR 373-1.5(a)(ii), 373-1.5(a)(iii)

Date: 07/26/92

SECTION C

C. PROPELLANT CHARACTERISTICS [40 CFR 270.14(b)(2), 264.13(a), and NYCRR 373-1.5(a)(ii) and 373-1.5(a)(iii)]

The physical and chemical characteristics of materials treated at the Open Burning (OB) area are described in this section of the permit application. All materials handled at the OB facility have the hazardous characteristic of reactivity (D003) and are potentially toxic. Reactive materials from ordnance can be classed as propellants, explosives, or pyrotechnics (PEP). Only propellants are treated at the OB area. The general chemical and physical characteristics of the PEP are described in Section C-1. Section C-2 contains a waste analysis plan that addresses procedures for sampling, testing, and evaluating the residue generated from OB activities. The information submitted has been developed in accordance with the requirements of NYCRR 373-1.5(a)(ii) and 373-1.5(a)(iii).

C-1 CHEMICAL AND PHYSICAL ANALYSES [40 CFR 270.14(b)(2), 264.13(a) and NYCRR 373-1.5(a)(ii), 373-2.2(e)(1)]

C-1a Containerized Waste [40 CFR 270.15 and NYCRR 373-1.5(b)]

USMA does not store containerized waste.

C-1b Waste in Tank Systems [40 CFR 270.16 and NYCRR 373-1.5(c)]

USMA does not use tanks to store or treat hazardous waste.

C-1c Waste in Piles [40 CFR 270.18 and NYCRR 373-1.5(e)]

USMA does not use waste piles to store or treat hazardous waste.

C-1d Landfilled Wastes [40 CFR 270.21 and NYCRR 373-1.5(d)]

USMA does not dispose of hazardous waste in landfills.

C-1e Wastes Incinerated and Wastes Used in Performance Tests [40 CFR 270.19 and NYCRR 373-1.5(f)]

USMA does not incinerate hazardous waste.

Date: 07/26/92

C-1f Wastes to be Land Treated [40 CFR 270.20 and NYCRR 373-1.5(g)]

USMA does not use land treatment for hazardous materials.

C-1g Materials in Miscellaneous Treatment Units [40 CFR 270.23 and NYCRR 373-1.5(j)]

Following is a general discussion of the chemical and physical properties of propellants, explosives, and pyrotechnics. This general discussion is provided to give general information on PEP, although only propellants will be burned at the USMA OB area. Energetic materials are chemical compounds or mixtures of chemical compounds, and can be divided into three classes according to use: 1) propellants, 2) explosives, and 3) pyrotechnics (PEP). Burning of energetic materials from ordnance is an exothermic chemical reaction. The reaction is self-sustaining until completion, after an initial activating energy has been supplied. Propellants and explosives, when initiated, evolve large quantities of gas in a short time. The difference between propellants and explosives is the rate at which the reaction proceeds. In explosives, a fast reaction produces a very high pressure shock in the surrounding medium. This process is referred to as a detonation and is capable of shattering objects. In propellants a slower reaction produces lower pressure over a longer period of time. This process is referred to as a deflagration and is used to propel objects.

Classes of Energetic Materials

Propellants

When ignited, the propellant produces large quantities of hot, gaseous products. Complete combustion or deflagration of the propellant occurs in milliseconds in guns and the pressure produced accelerates the projectile down the barrel. In propellants, a slower reaction produces lower pressure over a longer period of time. This lower sustained pressure is used to propel objects or to power auxiliary devices. Propellants can be distinguished from high explosives by the chemical rate of reaction. Propellants characteristically react (burn) at a rate that is much slower than the reaction rate of explosives. It is difficult to distinguish between propellants and explosives based

Date: 07/26/92

on chemical composition alone. Propellants are characterized by their ability to burn at reproducible, controllable, and predetermined rates. When confined to the breech and barrel of a gun, the evolved gases produce high pressures, which provide the propulsion for the projectile. Under certain conditions, however, propellants can be made to detonate, and conversely, explosives that characteristically detonate may simply burn if the proper conditions of confinement, dimensions, degree of consolidation, and other factors are chosen. Propellants can be grouped into five classes. Division into these classes is on the basis of composition, not use. A given propellant composition may be suitable for use in several applications.

1. Single-base propellant compositions are used in cannons, small arms, and grenades. These compositions contain the propellant nitrocellulose as their chief ingredient. In addition to containing a stabilizer, they may also contain inorganic nitrates, nitro-compounds, and nonexplosive materials such as metallic salts, metals, carbohydrates, and dyes. These are low cost propellants that have a low flame temperature and low energy content.
2. Double-base propellant compositions are used in cannons, small arms, mortars, rockets, and jet propulsion units. This term generally applies to compositions containing both nitrocellulose and nitroglycerine. They can also be defined as a propellant containing nitrocellulose and a liquid organic nitrate which will gelatinize nitrocellulose. The presence of an active gelatinizer makes double-base propellants more energetic than single-base propellants. The ballistic potential is increased correspondingly. The flame temperature and resulting barrel erosion is also increased. Additives are frequently used in addition to a stabilizer.
3. Triple-base propellant compositions are used in cannon units. This term is applied to propellants containing three explosive ingredients, with nitroguanidine as the major ingredient and the other two usually consisting of nitroglycerine and nitrocellulose. The nitroguanidine as an additional energizer increases the energy content of the formulation without raising the flame temperature. This reduces gun barrel erosion with no sacrifice in performance.

Date: 07/26/92

Mixed nitrate esters are a propellant composition developed to replace the triple-base composition during a time of nitroguanidine shortages. As an example, the XM35 composition contains nitrocellulose, TMETN (1,1,1-trimethylolethane trinitrate), TEGDN (triethylene glycol dinitrate), and DEGN (diethylene glycol dinitrate). As another example, the XM34 composition contains nitrocellulose, BTTN (1,2,4-butanetriol trinitrate), TMETN, and TEGDN. The combination of mixed nitrate ester yields a higher gas volume and lower flame temperatures than the use of nitroglycerine alone.

4. Composite propellants contain neither nitrocellulose nor an organic nitrate. They are usually a physical mixture of a fuel such as metallic aluminum, a binder (which is normally a synthetic rubber that is also a fuel), and an inorganic oxidizing agent such as ammonium perchlorate. Composite propellants are used primarily in rocket assemblies and chemical fuel jet propulsion units.
5. Ball propellants are used for small arms. The main ingredients are nitrocellulose and nitroglycerin.

Ammunition cartridges and mortars used at USMA are shipped with a complete propelling charge, an ignition cartridge, and a primer. The propelling charge is contained in increments (known as charges) in bags. Firing tables are used to determine the correct number of bags or charges to be used for firing. The number of charges used depends upon the distance from the firing point to the impact point. Charges not needed are excess and must be burned. In combat and training situations these charges are burned in the field. At USMA the cartridges include seven bags of propellant. Only two bags are used. The remaining excess bags are burned in the burn pans.

Explosives

USMA does not treat explosives or pyrotechnics by OE. However, a discussion of explosives and pyrotechnics follows because this information is relevant to the closure of the OD unit that is discussed in Section I.

Date: 07/26/92

Explosives are substances or mixtures capable by chemical reaction, of producing gas at high temperature and pressure. Explosives can include high explosives, low explosives, propellants, igniters, primers, initiating, and pyrotechnic compositions. For explosives, a fast reaction produces a very high pressure shock in the surrounding medium capable of causing significant disruption or damage to the surrounding medium.

The variation in the properties of explosives is put to practical use in armaments by an arrangement referred to as an explosive train. An explosive train consists of elements arranged according to decreasing sensitivity and increasing potency. Normally, the following are the major energetic components of explosive ordnance.

The first element, the initiator or primary explosive, consists of a small quantity of highly sensitive material.

1. Primary explosives are often used in ordnance items in small quantities to initiate an explosive reaction. Primary explosives are very sensitive and relatively easy to detonate by heat, impact, or friction. In large quantities these materials are extremely hazardous because of their great sensitivity. Primary explosives can be used in combination with fuels and oxidizers in ordnance. Other ingredients are used to increase the sensitivity of the mixture to the desired property such as percussion or heat. These primary explosives are:

Lead azide $Pb(N_3)_2$

- Lead azide is a salt of hydrazoic acid, is white, solid, and has a molecular weight of 291.26. The pure compound has two crystal forms: orthorhombic and monoclinic. The orthorhombic form is very sensitive and the formation of this crystal during manufacturing must be avoided. There are several forms of lead azide used for military purposes. These include: dextrinated lead azide, service lead azide, colloidal lead azide, polyvinyl alcohol lead azide, RD-1333 lead azide, and dextrinated colloidal lead azide.

Mercury fulminate $Hg(ONC)_2$

Date: 07/26/92

- Mercury fulminate is a salt of fulminic or paracyanic acid. The acid undergoes polymerization very rapidly in both aqueous and ethereal solutions, and so cannot be isolated, thus the structure is undetermined. Mercury fulminate is no longer used by the United States military because of poor stability. The usual stability tests are not applicable to mercury fulminate, due to explosion in a relatively short time at temperatures above 85°C. The products of deterioration are nonexplosive solids rather than gases.

DDNP (diazodinitrophenol)

- This explosive is also known as 4,5-dinitrobenzene-2-diazo-1-oxide, dinol, diazol, and DADNP. The compound is a greenish-yellow to brown solid with tabular crystals and a molecular weight of 210.108. DDNP is used as an ingredient in priming compositions and in commercial blasting caps. Tests indicate that DDNP is less sensitive to impact than lead azide or mercury fulminate.

Lead styphnate

- Two forms of lead styphnate are used as primary explosives: basic and normal. Basic lead styphnate has a molecular weight of 705.53 and has two crystal forms: yellow needles with a density of 3.878 grams per cubic centimeter and red prisms with a density of 4.059 grams per cubic centimeter. Normal lead styphnate has a molecular weight of 468.38 and is yellow-orange or reddish-brown, rhombic, needle-like crystals, with a density of 3.02 grams per cubic centimeter at 30°C. Normal lead styphnate is slightly less sensitive to impact than mercury fulminate or DDNP, but is more sensitive than lead azide.

Tetracene

- Tetracene is also known as guanyldiazoguanyltetrazene and 4-guanyl-1-(nitrosoaminoguanyl)-1-tetrazene and is a colorless to pale yellow, fluffy material with needle-like crystals. Tetracene can be used in

Date: 07/26/92

detonators when initiated by another primary explosive. In such cases, the tetracene functions as an intermediate booster or as a sensitizer to flame or heat. In some cases, tetracene is used in primers where as little as two percent tetracene in the composition results in uniformity of percussion sensitivity. Tetracene is of the same order of sensitivity as mercury fulminate and DDNP.

KDNBF (potassium dinitrobenzofuroxane)

- KDNBF is a red crystalline solid with a molecular weight of 264.20. KDNBF is used in primary compositions. The sensitivity is between that of mercury fulminate and lead azide.

LMNR (lead mononitroresorcinate)

- LMNR has a molecular weight of 360.30 and forms microscopic reddish-brown crystals. The compound is used in electric detonators with dextrinated lead azide as the spot charge to initiate a pentaerythritol tetranitrate (PETN) base charge, as an upper charge, and as an ingredient in primary compositions.

Primary Compositions

- Primary compositions are mixtures of primary explosives, fuels, oxidizers, and other ingredients used to initiate detonation in high explosive charges or to ignite propellants and pyrotechnics. Fuels commonly used in priming compositions are lead thiocyanate, antimony sulfide, and calcium silicide. The last two also serve to sensitize the composition to friction or percussion. Oxidizing agents include potassium chlorate and barium nitrate. Several other ingredients may include primary explosives and binders. The major determining factor in ingredient selection is the momentum which is needed to detonate the priming composition. The types of impetus commonly used are percussion and electrical. Percussion type primers are used

Date: 07/26/92

extensively for the ignition of propellant. Stab detonators are used to directly initiate secondary explosives. Electrical primers are used to ignite the charge which may then undergo a deflagration to detonation transfer. There are several types of electrical primers, these include: exploding bridge wire, hot wire bridge, film bridge, conductive mixture, and spark gap.

2. The second element in the explosive train is the booster, which contains a larger quantity of less sensitive but more powerful material called a secondary high explosive. The booster is used either as an intermediate stage to detonate material that is too insensitive to be detonated by the relatively weak initiator, or to ensure complete deterioration of the main charge. The main charge is also a secondary explosive. It is the least sensitive material but comprises the bulk of the explosive charge. Secondary explosives differ from primary explosives in three major ways: 1) small uncombined charges of secondary explosives, even though ignited, do not transfer easily from a burning or deflagration reaction to a detonation; 2) ignition by electrostatic spark is difficult, except in the case of dust clouds; 3) the shock required for ignition is much greater for a secondary explosive. Secondary explosives can be divided into several classes that are less sensitive than primary explosives. These consist of the following:

Aliphatic nitrate esters

- There are several common compounds in this category. These compounds are prepared by attaching an oxygen atom to the compounds being nitrated.
- * 1,2,4-Butanetriol Trinitrate (BTN) is a good gelatinizer for nitrocellulose and can be used as a substitute for nitroglycerin in double-based propellants.
- * Diethyleneglycol Dinitrate (DEGN) can be used as an explosive and can be used in propellants as a colloidizing agent for nitrocellulose. Propellants based on DEGN and nitrocellulose develop relatively low

Date: 07/26/92

temperatures and cause relatively little erosion of guns, but are unduly volatile.

- * Nitrocellulose (NC) is a mixture of nitrates obtained by nitrating cellulose. There are five recognized and used grades of nitrocellulose that include pyroxylin, pyrocellulose, guncotton, high nitrogen nitrocellulose, and blended nitrocellulose.
- * Nitroglycerin (NG) is a clear, colorless, odorless, oily liquid with a sweet, burning taste and a molecular weight of 227.1. Nitroglycerin is used extensively in propellant compositions as a gelatinizing agent for nitrocellulose as well as in dynamites and for the shooting of oil wells.
- * Nitrostarch (NS) is a mixture of nitrates obtained by nitrating starch. The structure of nitrostarch is the same as for nitrocellulose, with the exception that the polymer chains are spiral rather than straight. Nitrostarch has a wide variety of gelatinizing agents and is used rather than nitrocellulose in explosive compositions chiefly as a substitute for nitroglycerin. These compositions have the major advantage of being nonfreezing and not subject to the desensitization that accompanies the freezing of nitroglycerin explosives. Nitrostarch explosives have been used as successfully in the Antarctic and Arctic regions as in temperate climates.
- * Pentaerythritol Tetranitrate (PETN) is a white solid with a molecular weight of 316.2. PETN is used in the explosive core of industrial detonating fuses, in the charge of commercial blasting caps, and as the entire explosive charge in exploding bridge wire detonators. PETN is also used in certain plastic bound explosives and in a mixture with 2,4,6-trinitrotoluene (TNT) called pentolite.

Date: 07/26/92

- * Triethylene Glycoldinitrate (TEGN) is a light yellow, oily liquid with a molecular weight of 240.20. TEGN is used as a gelatinizing agent for nitrocellulose in propellants or as a component in a liquid explosive, a plasticizer in the fabrication of flexible explosive sheets, and as a plasticizer in pyrotechnic flares.

- * 1,1,-Trimethylolethane Trinitrate (TMETN) is a slightly turbid, viscous oil with a molecular weight of 255.15. TMETN can be used as a flash and erosion reducing additive in propellants and an ingredient of commercial explosives.

Nitramines

Compounds in this class include:
Cyclotetramethylenetetranitramine (HMX),
Cyclotrimethylenetrinitramine (RDX), Ethylenediamine
Dinitrate (EDDN), Ethylenedinitramine (Haleite),
Nitroguanidine (NQ), and 2,4,6-
Trinitrophenylmethylnitramine (Tetryl).

Nitroaromatics

Compounds in this class include: Ammonium
Picrate, 1,3-Diamino-2,4,6-Trinitrobenzene (DATB),
2,2',4,4',6,6'-Hexanitroazobenzene (HNAB),
Hexanitrostilbene (HNS), 1,3,5-Triamino-2,4,6-
Trinitrobenzene (TATB), and TNT.

Ammonium nitrate

Ammonium nitrate is in the crystal form with a
molecular weight of 80.05.

Compositions

Compositions are explosives in which two or more
explosive compounds are mixed to produce an explosive
with suitable characteristics for a particular
application. Normally the characteristics of the

Date: 07/26/92

compositions are an intermediate between the characteristics of the individual explosive ingredients. Compositions can include binary mixtures, ternary mixtures, and quaternary mixtures.

* Binary Mixtures

Amatols are mixtures of ammonium nitrate and TNT. Composition A consists of a series of formulations of RDX and a desensitizer. Composition B consists of mixtures of RDX and TNT. Composition C is a plastic demolition explosive that was used by the British and could be shaped by hand. Composition C contains about 88.3 percent RDX and 11.7 percent of a nonexplosive oily plasticizer. Composition CH6 is an explosive mixture containing RDX, calcium stearate, graphite, and polyisobutylene. Composition CH6 is primarily used for boosters and leads. Ednatols are mixtures of halite and TNT. Ednatols are used for the satisfactory bursting of charges in ammunition.

Octols are mixtures of HMX and TNT. Octols are used as an oil well formation agent and in fragmentation and shaped charges.

Pentolites are castable explosive mixtures containing PETN and TNT.

Picratol is a mixture of ammonium picrate and TNT.

Tetrytols are mixtures of TNT and tetryl. The United States no longer uses tetrytols, however these mixtures are still used by other nations. Tetrytols are cast into munitions.

Tritonal is a mixture of TNT and flaked aluminum. Tritonal is used as a filler in bombs and shells.

* Ternary Mixtures

Amatex 20 consists of RDX, TNT, and ammonium nitrate and is used as filler in ammunition items. Ammonals are mixtures containing as principle ingredients, ammonium

Date: 07/26/92

nitrate and powdered aluminum incorporated with high explosives such as TNT, DNT, and RDX. The major use of this composition is as a projectile filler.

High blast explosives have three compositions HBX-1, HBX-3, and H-6. HBX-1 and HBX-3 consist of RDX, TNT, aluminum, wax and lecithin. The formulation of H-6 is the same except for the deletion of TNT.

HMX, TNT, and aluminum mixture 3 (HTA-3) is cast as a munition.

Minol-2 consists of TNT, ammonium nitrate, and aluminum and is used in four types of ordnance: underwater depth bombs, block buster bombs, concrete fragmentation bombs, and general purpose bombs.

Torpex consists of RDX, TNT, aluminum powder, and wax and is cast into munitions.

* Quaternary Mixtures

The depth bomb explosive (DBX) is the only explosive covered under this category and consists of TNT, RDX, ammonium nitrate, and aluminum.

Plastic bonded explosives (PBX)

PBX is the term applied to the group of explosive mixtures which have high mechanical strength, good explosive properties, excellent chemical stability, relative insensitivity to handling and shock, and high thermal input sensitivity.

Industrial explosives

Dynamites are commercial blasting explosives which have a composition of nitroglycerin and kieselguhr. Kieselguhr is a chemically inert, but porous, material.

Date: 07/26/92

Ammonium nitrate fuel oil explosives (ANFO) require a high explosive booster containing pentolite, composition B, or another similar high explosive.

Water gel and slurry explosives consist of ammonium nitrate with or without other oxidizing agents, explosive or nonexplosive sensitizers, fuels, and gelatin forming compounds in an aqueous medium. Slurry explosives contain the same ingredients with additional compounds that bond the solid particles and prevent water from defusing in and out of the slurry.

Pyrotechnics

Pyrotechnics is the technology of utilizing exothermic chemical reactions that, generally speaking, are non-explosive, relatively slow, sub-sustaining, and self-contained. All pyrotechnic compositions contain oxidizers and fuels. Additional ingredients present in most compositions may include binding agents, retardants, and waterproofing agents. Some compositions may also include smoke dyes and color intensifiers.

Pyrotechnics evolve large amounts of heat, noise, smoke, light, or infrared radiation but much less pressure than propellants or explosives.

Determination of Chemical Compositions

Routine Materials

Table C-1, General Chemical Composition of Propellants Burned at the United States Military Academy, gives the general chemical composition of typical propellants. The specific chemical composition of energetic propellant materials currently burned by OB are given in Appendix C-1, Chemical Composition of Propellants Currently Burned at the United States Military Academy.

The propellants requiring treatment by OB are not usually sampled and analyzed because of the large amount of information available concerning their physical and chemical characteristics. Sampling and analysis is not required to gather sufficient chemical and physical data to treat the propellants. This information comes from historical data, military specifications, and ordnance publications.

Date: 07/26/92

The propellants treated are contained in bags. Each round of artillery or mortar contains 3 - 7 bags of propellants known as charges. When used in training exercises at USMA only 2 bags are needed. The remaining bags of propellant must be burned. One bag of propellant burned for each round contains a lead foil weighing up to 3.4 ounces. This, lead-foil-lined bag is burned along with the propellant from that round.

Date: 07/26/92

TABLE C-1
GENERAL CHEMICAL COMPOSITION OF PROPELLANTS
BURNED AT THE
UNITED STATES MILITARY ACADEMY

Propellants	
Name	Chemical Formula
Nitrocellulose	$C_{12}H_{16}(ONO_2)_4O_6$
Nitroglycerine	$C_3H_5N_3O_9$
Nitroguanidine	$CH_4N_4O_2$

These three primary constituents can be used alone or in various combinations along with metals, metallic salts, and organic polymer binders.

Source: Military Explosives, Department of the Army, Technical Manual, TM9-1300-214, September 1984

Date: 07/26/92

Unidentifiable Materials

All materials treated at USMA are identifiable. Therefore, it is not necessary to address a procedure to identify unknown materials. Unidentified materials will not be treated.

Unusual Cases/Emergencies

In the event that a determination is made that an energetic-containing item could cause substantial endangerment to human health and/or the environment, immediate treatment by OB or Open Detonation may be required. When treatment of an energetic-containing item is required, a request will be made to the Director for a temporary emergency permit to allow treatment of items not covered by the permit. This request will be oral (by phone) and will be followed by a written notification of the emergency activity. If the emergency event occurs during a time when the Director is unavailable (e.g., during off-hours, weekends and holidays), the Director will be informed by phone during normal hours followed by a written notification.

New Propellants Requiring Burning

Items not included in Appendix C-1 must be shown to meet the environmental performance standards described in Section E. This process will consist of the following steps:

1. The chemical composition of the energetic materials in the item will be determined. References used may include, but not be limited to, historical data, military specifications and ordnance publications. The new item will be characterized according to energetic constituents and their weight percents as in Appendix C-1.
2. Compare the chemical composition of the new item with the items in Appendix C-1. If the new item contains identical energetic constituents and weight percents as an existing item then the new item may be treated in quantities which comply with the allowable quantities established for that item.

Date: 07/26/92

3. If the new item is not identical to an existing item a POLU modelling run must be completed for the new item. Refer to Section E-3 for POLU modeling description and output analysis. The POLU output must be analyzed by comparing the combustion products to the table for air criteria in Section E-3. Combustion products and energetics other than those in Table E-3-17 must be reviewed to determine if Federal or state ambient air standards or guidelines exist for these compounds. If standards or guidelines are found they must be added to the Table of Air Criteria. Emission factors for all combustion products and energetics with air criteria will then be developed from the POLU output or by calculating emission factors for energetics using a 99.99% DRE.
4. Allowable treatment quantities will be calculated for each contaminant and its corresponding exposure periods using the following equation:

$$x = \frac{Y}{x^1 y^1}$$

Where:

x = allowable treatment quantity (lbs of propellant) per exposure period specified by y

y = air criteria from Table E-3-17 (ug/m³ for each exposure period)

x¹ = dispersion factor from Table E-3-16 for exposure period corresponding to y

y¹ = emission factor lb. pollutant/lb. propellant

5. Construct a table similar to Table E-3-19. Review the treatment quantities for each contaminant and exposure period and calculate which are the most restrictive quantities. These quantities will allow treatment of the propellant while complying with all ambient air standards and guidelines. Add the new item and its most restrictive short term treatment quantities to Table E-3-20.

Date: 07/26/92

Post-Burn Activities

After each burn, the immediate area surrounding the burn pan and concrete pad unit is inspected (see Section F). Any unburned propellant would be collected and held at USMA until the next scheduled burn. The OB unit containment pans are covered when not in use to prevent precipitation from entering the burn pans.

Prohibited Items

Certain items are prohibited from OB by Army regulation (AR-200-1). These include military chemical warfare agents or related compounds, or materials contaminated with these agents. Typical military chemical warfare agents and related compounds include, but are not limited to, the following classes of agents:

- choking agents
- nerve agents
- blood agents
- blister agents
- incapacitating agents
- vomiting compounds
- herbicides

A second group of items are prohibited from routine treatment but may be treated under emergency conditions.

Smokes

- Titanium tetrachloride (FM)
- Sulfur trioxide - chlorosulfonic acid (FS)
- Hexachloroethane (HE) mixture (6.68% grained aluminum, 46.66% zinc oxide, and 46.66% hexachloroethane)
- White phosphorous (WP)
- Bulk red phosphorous (RP)
- Plasticized white phosphorous (PWP)
- Oil smoke
- Colored smokes (red, yellow, green, violet, white, etc.)

Date: 07/26/92

Incendiaries

Eutectic white phosphorous (EWP)
Napalm B (50% polystyrene, 25% benzene, and 25% gasoline by weight)
Thermite mixtures (i.e. TH3 which contains 68.7% thermite, 29.0% barium nitrate, 2.0% sulfur, and 0.3% oil as a binder)
Tear producing compounds

In some cases, treatment will be allowed with special item-specific restrictions as necessary to meet the standards. Such restrictions would include identification of the appropriate treatment technology and OB quantity limits per event or over a period of time. As determined on an item-by-item basis, ordnance not meeting the environmental performance standards established in Section 3 will also be prohibited from treatment by OB. Finally, OB of any material that is not reactive (D003) is prohibited.

Date: 07/26/92

SECTION D
PROCESS INFORMATION

Date: 07/26/92

SECTION D

D. PROCESS INFORMATION

This section provides information on the facilities, equipment, and management practices pertaining to the burn unit at the USMA facility. The burn unit consists of the Open Burn (OB) unit on Range 2. Section D-8 provides details on the OB unit.

D-1 CONTAINERS [40 CFR 270.15 and NYCRR 373-1.5(b)]

USMA does not store hazardous waste in containers.

D-2 TANK SYSTEMS [40 CFR 270.16 and NYCRR 373-1.5(c)]

USMA does not manage hazardous waste in tank systems.

D-3 WASTE PILES [40 CFR 270.18 and NYCRR 373-1.5(e)]

USMA does not manage hazardous waste in waste piles.

D-4 SURFACE IMPOUNDMENTS [40 CFR 270.17 and NYCRR 373-1.5(d)]

USMA does not manage hazardous waste in surface impoundments.

D-5 INCINERATORS [40 CFR 270.19 and NYCRR 373-1.5(f)]

USMA does not manage hazardous waste in incinerators.

D-6 LANDFILLS [40 CFR 270.21 and NYCRR 373-1.5(h)]

USMA does not manage hazardous waste in landfills.

D-7 LAND TREATMENT [40 CFR 270.20 and NYCRR 373-1.5(g)]

USMA does not manage hazardous waste in land treatment units.

D-8 MISCELLANEOUS UNITS: OPEN BURNING (OB) [40 CFR 270.23 and NYCRR 373-1.5(j)]

D-8a Description of Miscellaneous Units [40 CFR 270.23 and NYCRR 373-1.5(j)]

Date: 07/26/92

D-8a(1) Description of Burning Trays (Pans) and Materials Treated [40 CFR 270.23(a) and NYCRR 373-1.5(j)(1)]

USMA conducts thermal treatment of various propellant wastes using OB. All propellants treated are reactive materials. OB is the most effective and safe treatment available. A general description and historical summary of the OB area and operations are provided in Section B.

OB, as currently performed, is the controlled burning of propellant materials in metal pans located within the designated OB area of USMA. The burn pans are located inside of metal trays which serve as secondary containment. The pan is placed on top of a concrete pad to provide additional containment. The OB area consists of a gravel lot approximately 100 feet by 200 feet. The area is approximately 300 feet from Route 293 as shown in Figure B-1. A padlocked metal gate is located at the roadway entrance to the site. A sign reading "Danger - Range Area - Authorized Personnel Only" is posted behind the gate.

The frequency of burn and the quantity of propellants contained in, and the number of items treated annually at USMA varies from year to year. Future frequencies and quantities will depend on future DOD activities. The primary influencing factor is the level of training activities.

The burn pan assembly consists of an outer containment pan with a cover and an interior burn pan. The containment pan was constructed using 1/4-inch thick steel boiler plate. The containment tray is a simple rectangular box with the dimensions of 3-feet, 2-inches wide by 12-feet long by 1-foot high. The containment pan is fitted with an aluminum cover, equipped with handles. The cover can be manually lifted over the pan and fitted down over its sides. The interior burn pan was constructed using 1/4-inch thick steel boiler plate. Two parallel steel beams, 8-inch in height, extending along the length of the underside of each pan, prevent the interior burn pan from contacting the floor of the containment pan. The interior burn pan is lined with 3-inch thick heat resistant fire-clay anchored to the inside of the pan with stainless steel anchors. A drawing of the burn pan assembly is included in Appendix D-1. The condition of the pan will be determined before each use. Although highly unlikely, because of the nature of the burning pan construction, any leaks of material from the burning pan will be detected by visual inspection.

Date: 07/26/92

USMA conducts one type of burn. A brief description of this OB activity follows.

After the day's training exercises, the excess bags of propellant will be placed into the burn pan. The propellant will be ignited and allowed to burn. The burn will last from 5 to 20 seconds.

After the propellants are burned and the pans have cooled, operators will collect any remaining ash from the pan with a brush or whisk broom, shovels and a dust pan. The pan covers will be placed back on the pans and remain in place until the next use of the pans. Ash from each individual burn will be visually evaluated for any physical characteristics indicating that the propellant was not successfully treated. Items would be present as a plug or a granule of propellant. Treated propellant is present as an ash. The non-reactive burn pan ash will be emptied at least once per week during the active use of the burn site (summer months). TCLP analysis performed on the ash residue indicates this material is toxic due to its lead content. The ash residue will be containerized into a steel container and plainly marked "Hazardous Waste". This drum will be retained at the OB ground. It will have a secure lid which will be kept closed unless ash is being added, removed, or sampled. After training the drum will be shipped to a permitted RCRA facility offsite for treatment and disposal according to the Land Disposal Restrictions in 6 NYCRR Part 376. If the ash does not exhibit the characteristic of toxicity, it will be disposed of in a suitable solid waste disposal facility. The handling of the ash residue is discussed in more detail in Section D-3a(1)2.3 and Section C.

Date: 07/26/92

D-8a(2) Documentation of Protection of Human Health and the Environment [40 CFR 270.23(c) and NYCRR 373-1.5(j)(3)]

The operating provisions that will be employed to protect human health and the environment during OB operations are described below. The analyses to be undertaken to demonstrate that these provisions are adequate to protect human health and the environment are contained in Section E of this permit application.

D-8a(2.1) Control of Ejected Material During Burning

This section addresses the possibility that ashes, embers, or other solid material derived during the burning of propellant will be ejected from the burn pan onto the ground during burning operations. This could potentially start an uncontrollable fire and/or cause environmental contamination via the soil, surface-water, and groundwater pathways. This potential problem will be minimized by several preventive measures. The 1-foot depth of the pans is sufficient to prevent most stray particles from doing anything more than bouncing off the inside walls of the pans. The pans are placed on top of a concrete pad. This makes the detection and collection of any ejected propellant much easier to accomplish. Periodic cleaning of the pans following burning operations and the use of lids in between burns will reduce the potential for release of ash. Pre-burn inspections will be conducted of the burn pans to ensure that they have retained their structural integrity. Finally, post-burn inspections of the area surrounding the pan will reveal the presence of the larger sized ejected materials. These materials will be collected from the burn area and reburned if necessary, or managed as hazardous waste until testing can be done to determine the nature of the waste.

It is unsafe to approach the burn pans for ash removal and inspection until a sufficient period of time has passed, allowing all materials in the pan to cool to the touch. Approximately 30 minutes are allowed to pass before approaching the pans.

D-8a(2.2) Integrity of Burn Pans

This section addresses the concern that ash residue or wastes may be released from burn pans if they should develop a leak, or should break or crack. Such releases will be minimized through pre-burn and post burn inspections to determine burn pan integrity. Any significant deterioration will result in

Date: 07/26/92

integrity. Any significant deterioration will result in cessation of burning operations. Double containment is provided for the burn pan. The burn tray is placed inside a second steel pan. This pan is located on top of a concrete pad. If the primary pan should develop a leak, it would be contained by the secondary pan.

D-8a(2.3) Deterioration or Malfunction Procedures

The most serious deterioration or malfunction during OB would be the loss of integrity of, or the development of a leak in, one of the burn pans. Should an accidental release occur, the released materials will be collected and either treated in the next burn (if reactive) or taken to a disposal site. All materials treated are solids, which can be easily collected if released. If the pre-burn inspection shows that the pan integrity has been compromised, it will not be used. Where post-burn inspections show that the pan is deformed or its integrity has been compromised, it will be taken out of service and repaired.

D-8a(2.4) Prevention of Accumulated Precipitation Within Burn Pans

The accumulation of precipitation within the burn pan could provide a means by which hazardous constituents in the ash could be released to the environment. Dampness in the pans would not inhibit the burning of the propellant because of its extremely reactive nature once reaction is initiated. During non-operational periods the use of pan covers will prevent precipitation from accumulating in the burn pans. Each cover will be equipped with handles to allow operations personnel to move it easily on and off the pan. These covers, the specifications for which are given in Appendix D-1, are tight fitting and will remain on the pans during non-operational periods.

In the unlikely event that water accumulates in a burning pan and could inhibit treatment effectiveness, it will be removed either by pumping into a drum or it will be squeegeed into a drum, sampled and analyzed in accordance with procedures outlined in Section C, and disposed in accordance with appropriate regulations. Any accumulated precipitation would not be a reactive waste. If analyses determine that the water is contaminated with propellant constituents it will be disposed of in accordance with appropriate regulations.

Date: 07/26/92

D-8a(1)2.5 Ash/Residue Management

Ash and untreated energetic material is potentially generated at two locations in and around the burn pan; within the pan as a result of the burning process, and surrounding the pan because of the potential ejection of propellant. Following a burn, the ash from the burn pan will be collected and placed in a labeled steel container with secured lids. If any untreated propellant is kicked out of the pan during treatment, it will be collected and treated in the next burn.

D-8a(1)2.6 Fire Hazard Minimization

Ejection of energetic material during the burn can result in the deposition of hot embers on the ground adjacent to the burn pan. The fire hazard will be minimized during open burning simply by the fact that the pan is in the OB area, located on top of a concrete pad, with the immediate surrounding area cleared of combustible material. In addition, during a burn operation, fire-fighting personnel and equipment are on alert and available. The fire department will wet down the area with water prior to burning in order to minimize any fire hazard and remain there with a fire truck during the burn. Procedures and equipment made available for protection, in the unlikely event that an uncontrolled fire starts, are discussed in Section G (Contingency Plan).

D-8a(1)2 Standard Operating Procedures

After the day's training exercises, the bags of propellant will be placed into the burn pan. The propellant shall be ignited and allowed to burn.

OB operations will not be conducted during electrical storms or thunderstorms.

OB operations will be restricted during periods of high wind velocity.

No OB operation will be left unattended during the active portion of the operation (i.e., during the actual burn).

OB operations will not be conducted during periods of local air quality advisories/alerts.

Date: 07/26/92

Dry grass, leaves, and other extraneous combustible material that has blown in or been brought inadvertently into the burn area will be removed from the concrete pad and the area adjacent to the pad. Then the burn pan will be inspected to ensure that it is in good condition and has been properly prepared for burn operations. In particular, the inspection will ensure that there is no excessive rust, no excessive buckling or warping of the pan because of excessive heat, no splitting or holes in the pan, no deterioration of welded seams, no evidence of metal fatigue, and that the pan is free of debris, trash, refuse, unburned or incompletely burned material or ordnance, or any other material that is not supposed to be there. If conditions are not otherwise safe, the burn pan will not be used until safe conditions are restored.

Once the burn pan has been prepared, operators will check to see that the materials placed in the burn pan are those specified, and that no other materials of any type are in the pan. The contents of the pan will be allowed to burn until combustible materials are consumed. This will take less than one minute.

OB operations are conducted in accordance with Department of Defense SOPs as well as Military Service-specific SOPs. The generic procedure for OB is documented in USMA REG 385-11. This reference is periodically reviewed and updated.

D-8b Propellant Characterization [40 CFR 264.601(a)(1),
264.601(b)(1), and 264.601(c)(1)]

The chemical and physical characteristics of materials typically burned in the OB area are presented in Section C of this permit application. The maximum weight of material burned at any one time in the burning pan is based on the net explosive weight of the material being burned. The net explosive weight limitations for open burning are set forth in Section E-3.

D-8c Burn Effectiveness

The initial evaluation of burning effectiveness is based on visual inspection. Successful burning of propellant is demonstrated by destruction of the physical form of the propellant from a granule or plug to a fine ash. If the physical form of propellant has not been changed, the burn would be considered to be ineffective and the material would be reburned in the next burn. After it is determined that the burn is

Date: 07/26/92

successful, the ash will be collected and placed into a container.

SECTION E-3

AIR PATHWAY

Date: 07/26/92

E-3 AIR PATHWAY

An air pathway analysis was conducted for open burning (OB) operations at the United States Military Academy (USMA) located in West Point, New York. The USMA is situated on the west bank of the Hudson River, approximately 50 miles north of New York City and 14 miles south of the town of Newburgh as shown in Figure E-3-1. Information regarding the OB air emissions and the components of the air pathway analysis are described in this section. The information is partitioned into two (2) principal subject areas. These areas are:

Environmental Setting
OB Emissions

Each of these areas contain information addressing the existing environment at the USMA, the criteria used to develop the environmental performance standards, and an assessment of the air emissions and their impacts relative to establishing environmental performance standards for the USMA site.

E-3-1 ENVIRONMENTAL SETTING

E-3-1.1 Facility Description

The USMA installation consists of approximately 15,974 acres, which includes the Main Post or campus area and the Military Reservation which is a largely undeveloped area consisting of firing ranges and bivouac areas. Approximately 12,500 acres (78 percent) of the USMA is located in the Town of Highlands. The remainder of the USMA property is in the Town of Woodbury (approximately 2,300 acres), the Town of Cornwall (approximately 400 acres), and across the Hudson River in Putnum County on Constitution Island (280 acres). The OB unit is located within the Military Reservation portion of the installation at Range 2 which is shown in Figure E-3-2.

The primary mission of the USMA is the education and training of undergraduate cadets for careers as officers in the United States Army. Military training activities that are a part of the USMA education program include range activities which involve firing of various artillery. National Guard units are also trained in artillery at the USMA. As part of these training sessions, excess propellant powder is removed from the 105-mm shells. The excess propellant powder is thermally treated by OB in the Range 2 burn

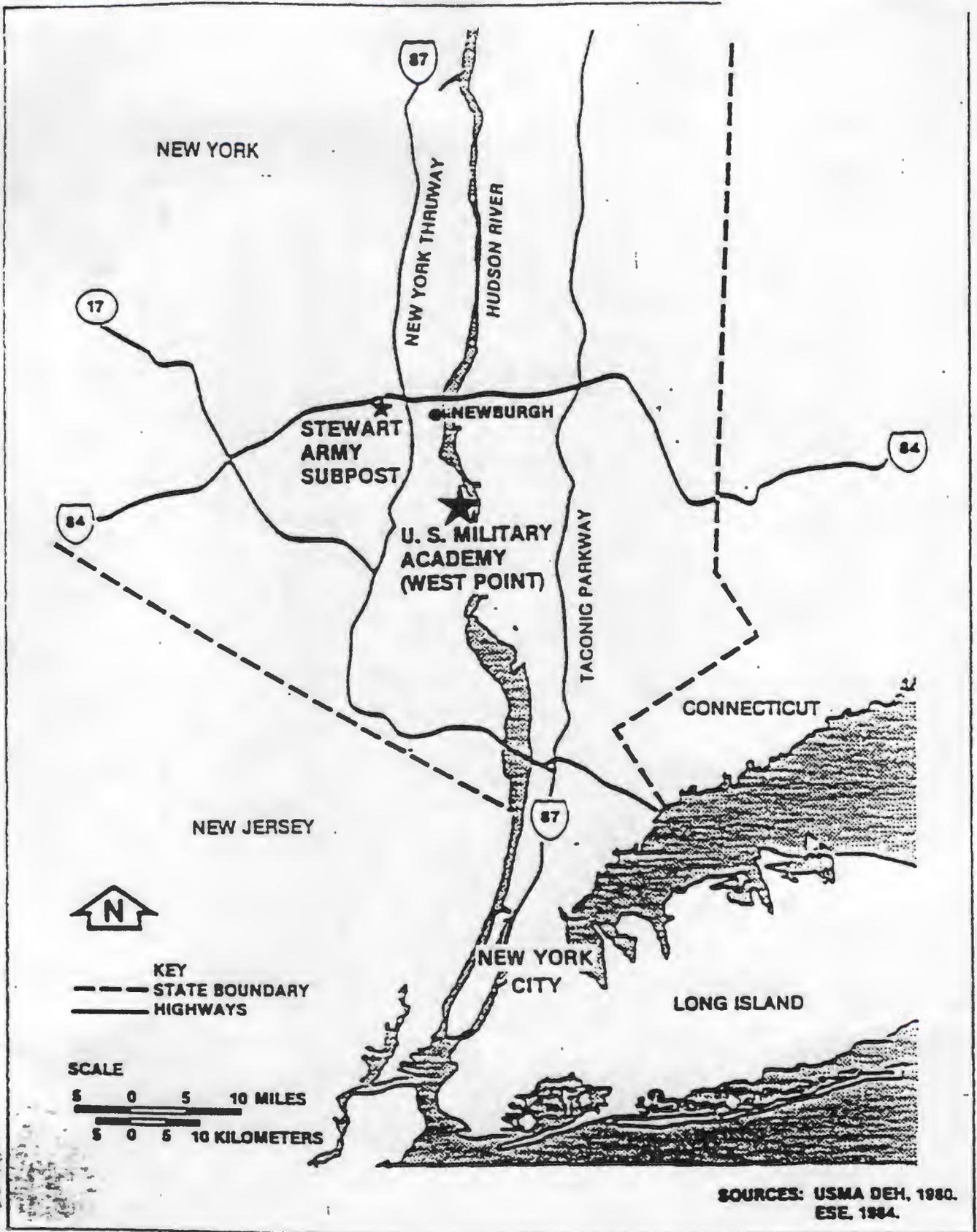


FIGURE E-3-1

LOCATION MAP OF THE
U.S. MILITARY ACADEMY
USMA, WEST POINT, NEW YORK



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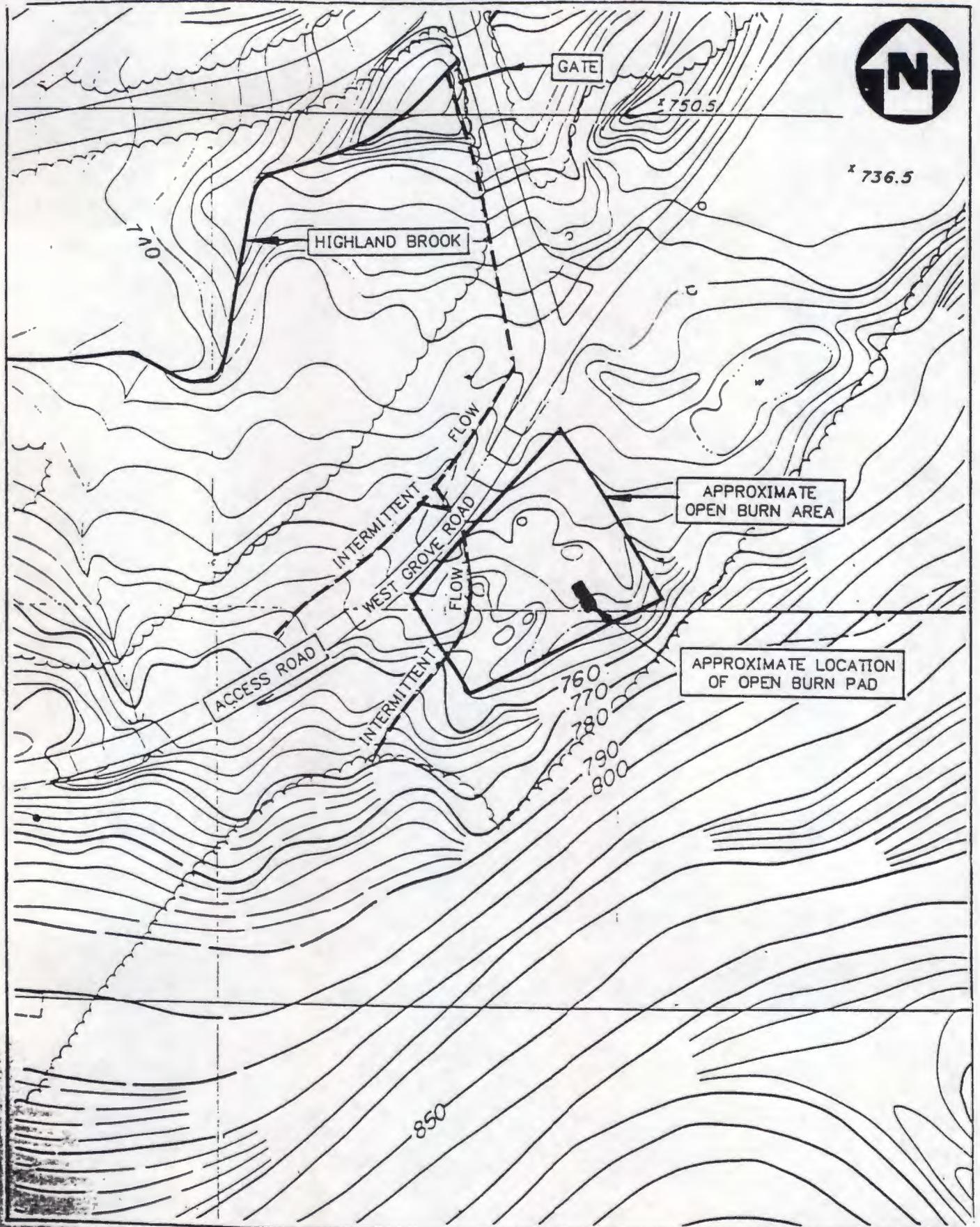
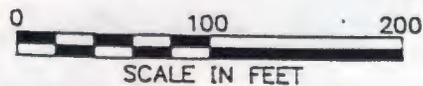


FIGURE E-3-2



OPEN BURN AREA LOCATION
USMA, WEST POINT, NEW YORK



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Date: 07/26/92

area which is equipped with a burn pan. Excess propellant from mortar rounds fired at Range 6 is also transported to the Range 2 burn area for thermal treatment.

E-3-1.2 Topography

The USMA is located in the geologic formation known as the Hudson Highlands section of the New England physiographic province. These hills extend in a southwest to northeast direction and comprise about 14 miles of the river front between Cornwall and Stony Point, New York.

The topography of the Military Reservation is extremely irregular. The Hudson River has formed a gorge one-quarter to one-half mile wide through the Hudson Highlands. The land rises sharply from an elevation of 200 feet on the occupied area of the Main Post to an elevation of 1,420 feet within the Military Reservation at Bull Hill. Approximately one-third of the total area of the Military Reservation consists of slopes of 20 percent grade or steeper. Extensive forests, predominantly deciduous trees and shrubs, cover much of the rugged terrain. Small swamps, marshes, and fresh water ponds and lakes are also located on the Military Reservation.

The OB burn area is located within a narrow valley that runs northeast-southwest through the OB site. Terrain rises to the east, south and north of the site.

E-3-1.3 Land Use Classification

The USMA is located in an area characterized by rugged topography, with predominantly residential, agricultural and recreational land uses. Contiguous to the southern boundary of USMA is the extensive Palisades Interstate Park; to the north is the Storm King State Park; the Hudson River flows along the eastern boundary; and to the east of Constitution Island across the Hudson River is a 269 acre parcel marshland owned by the Taconic State Park Commission and administered by the National Audubon Society.

The towns of Woodbury, New Windsor, Newburgh, Cornwall, and Highlands, are located on the west side of the Hudson River, near the USMA. The combined population of these towns in 1980 was 102,500 or 38 percent of the total population of Orange County. Light industries exist in these population centers, but,

Date: 07/26/92

reportedly, no heavy industry occurs in the vicinity of the USMA installations in Orange County.

Date: 07/26/92

E-3-1.4 Meteorology/Climatology

The climate of the USMA is primarily continental in character, but is subject to influence by the nearby Atlantic Ocean which lies approximately 50 miles to the east and south. The moderating effect on temperatures is more pronounced during the warmer months than in the winter when outbursts of cold air sweep down from Canada. In the warmer seasons, temperatures rise rapidly in the daytime. However, temperatures also fall rapidly after sunset so that the nights are relatively cool. Occasionally there are extended periods of oppressive heat up to a week or more in duration.

Winters are usually cold and sometimes fairly severe. Maximum temperatures during the colder winters are often below freezing and nighttime low temperatures are frequently below 15 degrees. Sub-zero temperatures occur about 8 times a year. Snowfall can be quite variable throughout the area and snow flurries are quite frequent during the winter months. Precipitation is evenly distributed throughout the year and is sufficient to serve the needs of the area for most years and only occasionally do periods of drought exist. Most of the rainfall in the summer is from thunderstorms while large extratropical storms provide precipitation in the fall and winter months.

The USMA does not maintain an onsite meteorological monitoring station for the purpose of recording local meteorological conditions. The closest reporting surface weather observation station is at the Stewart Airfield in Newburgh, New York, which is located about 12 miles northwest of the OB treatment site. This site has been chosen to represent the climatological variations of wind speed, wind direction and temperature that exist at the USMA installation. Climatological data for the 27-year period 1942 through 1969 are discussed below.

Temperatures for the area can be characterized as being moderate with the warmest month being July. Winters are reasonably cold with the coldest temperatures occurring in the month of January. Persistent northwesterly flow in the winter can produce periods of severe cold. During the climatological period of record the lowest temperature reported for the area was -20 degrees F in 1967. The warmest temperature recorded was 102 degrees F, which occurred in 1953. A summary of the mean monthly and annual temperatures are provided in Table E-3-1.

Date: 07/26/92

TABLE E-3-1

SUMMARY TABLE FOR MEAN
MONTHLY AND ANNUAL TEMPERATURE FOR THE
UNITED STATES MILITARY ACADEMY,
WEST POINT, NEW YORK

Month	Temperature (°F)
January	26.1
February	27.7
March	36.4
April	48.2
May	58.5
June	68.2
July	72.8
August	70.7
September	63.5
October	53.3
November	41.7
December	29.4
Annual Mean	49.9

Based on observations for the period 1942-1969 at Stewart Airfield,
Newburgh, New York.

Date: 07/26/92

Normal annual liquid precipitation for the area is approximately 45 inches and is well distributed throughout the year. The mean annual Class A pan evaporation for the area is about 40 inches per year. Approximately 75% of the annual pan evaporation takes place during the period May through October.

A summary of the annual wind frequency distribution for the 1942 through 1969 period of record is given in Table E-3-2. The information is given for 16 directional sectors plus the calm category. The prevailing annual wind direction for the area is from the west with secondary prevailing direction of west-southwest. The annual average wind speed for the area is 7.8 miles per hour.

E-3-1.5 Existing Air Quality

Information was obtained from the New York State Department of Environmental Conservation (NYSDEC) in an attempt to characterize the air quality in the vicinity of the USMA installation. The USMA is located in Orange County, New York. Unfortunately, the NYSDEC does not operate an extensive air quality monitoring network in Orange County in order to determine the attainment status for all pollutants regulated by the National Ambient Air Quality Standards (NAAQS). In 1990, the NYSDEC only operated a total of 3 ambient monitoring stations within a 20 mile radius of the USMA OB site.

The State of New York has adopted the Federal ambient air quality standards for sulfur dioxide, carbon dioxide, nitrogen dioxide, lead and PM₁₀ (inhalable particulate). The state has developed its own ambient air quality standards for photochemical oxidants, total suspended particulates, and various other pollutants. The only pollutants monitored within a 20 mile radius of the USMA OB site in 1990 were sulfur dioxide, lead, PM₁₀ and TSP.

As of 1990, the NYSDEC operated only one (1) monitoring station in Orange County which was located in Wallkill (Middletown), approximately 19 miles west-northwest of the USMA OB site. This site measured ambient concentrations of total suspended particulate (TSP) and lead. In 1990, this site reported no violations of the Federal and state air quality standards for both pollutants. Quarterly concentrations of lead reached a maximum concentration of 1.48 ug/m³, which is slightly below the Federal and state standard of 1.5 ug/m³. This site also collected 24-hour concentrations of TSP in 1990 for comparison to

Date: 07/26/92

the state's 24-hour and annual standards of 250 ug/m³ and 55 ug/m³, respectively. The maximum 24-hour average concentration in 1990 was 99 ug/m³, while the annual average was reported at 37 ug/m³.

Date: 07/26/92

TABLE E-3-2

SUMMARY TABLE OF WIND
FREQUENCY DISTRIBUTION FOR THE
UNITED STATES MILITARY ACADEMY,
WEST POINT, NEW YORK

Wind Sector	Percent Frequency (%)
N	3.4
NNE	3.4
NE	5.1
ENE	3.8
E	3.6
ESE	2.4
SE	2.6
SSE	2.9
S	3.4
SSW	3.9
SW	9.0
WSW	11.2
W	11.5
WNW	8.4
NW	5.8
NNW	3.0
CALMS	16.6

Annual Average Wind Speed: 7.8 mph

Based on 238,655 observations for the period 1942-1969 at Stewart Airfield, Newburgh, New York.

Date: 07/26/92

Ambient concentrations of sulfur dioxide were collected at Bear Mountain State Park, which is located south-southeast of the USMA OB site in Rockland County. In 1990, 3-hour, 24-hour and annual concentrations of sulfur dioxide were well below the Federal and state air quality standards. The maximum 3-hour sulfur dioxide concentration was 376 ug/m^3 , which is 29% of the Federal standard and 58% of the New York standard. The maximum 24-hour sulfur dioxide concentration was 115 ug/m^3 , which is 32% of the Federal standard and 44% of the New York standard. The annual average sulfur dioxide concentration in 1990 was 27 ug/m^3 , which is 34% of both the Federal and State of New York standards.

The closest monitoring site to the USMA OB site that collects ambient PM_{10} concentration data is located in Mt. Ninham which is located 16 miles to the east-northeast in Putnam County. The maximum 24-hour concentration reported in 1990 was 29 ug/m^3 , which is 19% of the 150 ug/m^3 Federal and state standard. The 1990 annual average concentration was 14 ug/m^3 , which is only 28% of the Federal and state standard.

E-3-1.6 Local Emissions Data

Air emissions from the USMA OB operations will include various products of complete and incomplete combustion. Some of these same OB emission contaminants may be emitted by other sources in the local area.

In order to assess the potential contribution from other sources within the local area, emission inventory data was requested from the NYSDEC for all sources located within two (2) miles of the USMA OB site. Emissions data for other sources of criteria and volatile organic compounds within two miles of the USMA OB site as of June, 1992 are shown in Table E-3-3.

Table E-3-3 includes emission data in lbs/yr for sources of the criteria pollutants SO_2 , NO_x , CO, particulate matter, and volatile organic compounds. The only other sources inventoried by the NYSDEC within a 2 mile radius of the OB site are located at the USMA. These sources include build up boilers, a package boiler, paint spray booths, a sand blasting unit, tumble dryers and a sterilization unit.

A majority of the emissions from these sources are for the volatile organic group which totals 134,105.1 lbs/year. All of these

Date: 07/26/92

volatile organic emissions are associated with the paint spray booths and the tumble dryers. Identification of the specific volatile organic compounds for these sources was not available. The second highest quantity of emissions for this group is

Date: 07/26/92

TABLE E-3-3

SUMMARY OF EMISSION SOURCES
WITHIN TWO MILES OF THE
UNITED STATES MILITARY ACADEMY,
WEST POINT, NEW YORK

Source Description/Facility	Location/County	Pollutant Emissions (lbs/year)					
		Particulate Matter	Sulfur Dioxide	Nitrogen Oxide	Carbon Monoxide	Volatile Organics	Other
Build Up Boiler/USMA	West Point/Orange	1.3	1.2	8	1.2		
Build Up Boiler/USMA	West Point/Orange	1.3	1.2	6.4	6.4		
Package Boiler/USMA	West Point/Orange	7.5	6.8	5.1	3.1		
Build Up Boiler/USMA	West Point/Orange	3.4	3.1	1.9	3.8		
Build Up Boiler/USMA	West Point/Orange	241	28.97	326.34			
Build Up Boiler/USMA	West Point/Orange	241	28.97	326.34			
Paint Spray Booth/USMA	West Point/Orange	80.23				19236.8	
Paint Spray Booth/USMA	West Point/Orange	80.23				19236.8	
Sand Blasting Unit/USMA	West Point/Orange	1.04					
Tumble Dryer/USMA	West Point/Orange					70073.64	
Tumble Dryer/USMA	West Point/Orange					23357.83	
Paint Spray Booth/USMA	West Point/Orange	13.3				490	
Sterilization Unit/USMA	West Point/Orange						336*
Paint Spray Booth/USMA	West Point/Orange					1710	
TOTAL		670.3	70.24	674.08	14.5	134105.1	336*

*Other category for the Sterilization Unit includes 40 lb/yr of ethylene oxide and 296 lb/yr of Freon 12.

Date: 07/26/92

associated with particulate matter and nitrogen oxide. Annual emission levels for these pollutants are about 670 and 674 lbs/year, respectively, and are associated primarily with the operation of boilers at USMA.

E-3-2 Potential OB Air Emissions

The air pathway assessment conducted in this permit application considered the air emissions relative to the OB treatment processes. The air emissions from OB treatment processes include products of combustion, products of incomplete combustion, energetics, metals and inorganics. These sources of air emissions are discussed in further detail within Section E-3-3.1.1.

E-3-2.1 Products of Combustion and Incomplete Combustion

Energetic compounds are composed principally of carbon, hydrogen, nitrogen and oxygen. The primary air emissions from OB treatment operations are products of combustion, which typically include the following:

- carbon monoxide
- carbon dioxide
- nitrogen and nitrogen oxides
- water
- sulfur dioxide
- methane
- ammonia

Secondary air emissions include various products of incomplete combustion (which can include energetic materials, organics and trace metals). A list of the potential OB products of combustion and incomplete combustion for propellants treated at the USMA OB site is given in Table E-3-7. This list represents a compilation of potential emission constituents (based on U.S. Army studies) considering the wide range of ordnance, munitions and propellants which are treated by the military services and the propellants to be treated at the USMA OB site. It is important to note that not all of these combustion products will be emitted from every OB treatment. The emission products will be a function of the actual propellants treated which are described in more detail below.

A primary list of all propellants which are subject to OB treatment at the USMA are listed in Table E-3-8. The list shows

Date: 07/26/92

9 propellants, the chemical or energetic constituent of each propellant, and the approximate weight percent composition of each constituent. This air pathway analysis used the POLU-11 combustion products model to calculate the emission products for the USMA OB propellants given in Table E-3-8.

TABLE E-3-8

ENERGETIC ITEMS TO BE TREATED BY
OPEN BURNING AT THE
UNITED STATES MILITARY ACADEMY,
WEST POINT, NEW YORK

Item Number	Item	Energetic Constituent	Weight (%)
1	M720-HE 60 mm Mortar propellant charge	Nitrocellulose Diphenylamine Potassium Sulfate Graphite	97.9 1 1 0.1
2	M83 Illum 60 mm Mortar propellant charge	Nitrocellulose Nitroglycerin Potassium Nitrate Ethyl Centralite Diethylphthalate	52.2 43.0 1.3 0.6 3.0
3	M49A4 HE 60 mm Mortar propellant charge	Nitrocellulose Nitroglycerin Potassium Nitrate Ethyl Centralite Diethylphthalate	52.2 43.0 1.3 0.6 3.0
4	M50A3 TP 60 mm Mortar propellant charge	Nitrocellulose Nitroglycerin Potassium Nitrate Ethyl Centralite Diethylphthalate	52.2 43.0 1.3 0.6 3.0
5	M362 HE 81 mm Mortar propellant charge	Nitrocellulose Nitroglycerin Potassium Nitrate Graphite Barium Nitrate Ethyl Centralite	82.0 15.0 0.8 0.3 1.4 0.6
6	M374A3 HE 81 mm Mortar propellant charge	Nitrocellulose Diphenylamine Potassium Sulfate Graphite	97.9 1.0 1.0 0.1
7	M444 HE 105 mm Mortar propellant charge	Nitrocellulose Dinitrotoluene Diphenylamine Dibutylphthalate	84.16 9.90 0.99 4.95
8	M548 HE 105 mm Howitzer propellant charge	Nitrocellulose Nitroglycerin Nitroguanidine Ethyl Centralite Cryolite	27.5 23.9 46.8 0.3 1.5
9	Cartridge CTG 105 mm HE M1 propellant charge	Nitrocellulose Dinitrotoluene Diphenylamine Dibutylphthalate	85.0 10.5 1.0 4.0

Date: 07/26/92

E-3-2.2 Combustion Products Model

The POLU-11 model was developed by the U. S. Navy to estimate air emissions from OB operations where energetic materials are treated (Baroody and Tominack, 1987). The model also has the capability of estimating air emissions for open detonation treatment. The POLU-11 model includes a file of heat capacity coefficients and enthalpy/entropy constants for numerous potential combustion products. Currently, there are over 1,400 chemical species in the file.

The POLU-11 model is designed to operate with up to nine (9) chemical constituents, plus air, per run. The model chooses the compounds to consider in the combustion calculations based on the elemental composition of the energetic material burned. If the energetic material burned contains the elements carbon, hydrogen, oxygen or nitrogen, the program considers the elements possible combustion products. The total number of combustion products and products of incomplete combustion considered for each calculation is listed in the output data. This combustion product library contains most of the species formed from energetic materials that are used by the Army.

Because the exact material/air ratio where complete oxidation occurs is not known for a given energetic material, the POLU-11 program predicts products of combustion at various material-to-air ratios and displays these results in the output. Evaluation of these output data reveal the trend in composition of the combustion products as the material-to-air ratios vary. For most energetic materials, complete oxidation occurs at 60 to 70% air intake (i.e., material-to-air ratios of 40:60 and 30:70). This conclusion was reached based on a preliminary onsite evaluation of the POLU-11 program at the Dugway Proving Grounds, in Utah, on May 22, 1986. This combustion product evaluation was based on burning waste Navy explosives in 5,000- and 2,500-lb sections. A helicopter, passing through the gaseous clouds formed from these burns, sampled two major indicator gases, carbon monoxide and hydrogen chloride. The measured carbon monoxide concentration fell between the POLU-11 predicted values for the 40:60 and 30:70 material air ratios. For the purpose of this analysis, it has been assumed that the POLU-11 model output contained in the 40:60 and 30:70 material-to-air ratios is most representative of the OB treatment processes.

Additional technical information on the POLU-11 model is presented in Appendix E-3-A.

Date: 07/26/92

POLU-11 OB Modeling

When used for OB predictions, the POLU-11 model calculates emissions based on the energetic material first being mixed with air and then burned to form atmospheric pollutants. The necessary thermodynamic data for the various energetic ingredients and air; weight ratios of material/air; and two pressure values (1,000 and 14.7 psia), are read into the program as input data. The flame temperature; combustion products, moles of gas, entropy and other pertinent data are calculated for the material/air mixtures under a pressure of 1,000 psia. The volumes of the combustion products are then expanded to 14.7 psia, which causes the temperature of the combustion products to drop. At this lower temperature, referred to as the "frozen temperature" of the gas, the products may have a different composition than at 1,000 psia. The program goes through a similar routine to recalculate the combustion products, flame temperature, and other variables that were changed because of the expansion. The products calculated at 14.7 psia are then reported as the pollutants in the output data.

Even though the calculations are conducted at 1,000 and 14.7 psia, the energetic material does not have to be thermally treated at these conditions in order to predict the pollutants. The calculations are performed at these conditions based on the following assumptions:

These pressures simulate the drop in temperature as the gases cool to ambient conditions.

The combustion products "freeze" in composition before they reach ambient temperature.

The combustion products of energetic materials formed during combustion calorimeter testing are in good agreement with the products predicted by POLU-11.

The heats of explosion calculated from the program closely approximate the actual values determined from the calorimetric data.

The POLU-11 modeling output for OB treatment is provided in Appendix E-3-B. Summaries of emission factor results and other combustion data at 14.7 psia precede the POLU-11 output data. Specific combustion products having health criteria identified in

Date: 07/26/92

Tables E-3-4 to E-3-6 were used to establish the performance standards for the USMA.

Other POLU-11 model output, such as the OB "frozen temperature" at 14.7 psia, was used to represent the gas temperature of the OB plume in the air quality dispersion modeling analysis. The POLU-11 emission factor output data were used in conjunction with the air quality modeling dispersion factors and health criteria to establish treatment limits for various pollutants and energetic compounds.

A compilation of the worst case POLU-11 emission factors for all pollutants are given in Table E-3-9. For the OB process at USMA, all particulate matter emissions were assumed to have diameters of 10 microns or less. The emission factors represent the maximum values calculated for either the 40:60 or 30:70 material-to-air ratios. Also shown in Table E-3-9 are emission factors for various other pollutants.

To maintain the "worst case" conservative approach of this analysis, emission rates for metals were developed on the basis of a mass balance assumption (i.e., "what goes in also comes out") from the weight (lbs) data contained in Table E-3-9 for each propellant containing metals. For the USMA, only propellant number 5 contains the metal barium. Therefore, the emission factor for the metal barium given in Table E-3-9 represents a conservative evaluation of the potential impact from the USMA OB operation. All of the pollutants given in Table E-3-9 have applicable Federal and state health criteria (identified in Tables E-3-4 through E-3-6) and are combustion products from the 9 propellants modeled with POLU-11.

Date: 07/26/92

TABLE E-3-9

SUMMARY OF MAXIMUM AIR EMISSION
FACTORS (POUNDS OF CONTAMINANT/
POUND OF MATERIAL)
UNITED STATES MILITARY ACADEMY,
WEST POINT, NEW YORK

	Treatment	
	OB	Propellant
Carbon Monoxide	0.24690	7
Nitrogen Oxide	0.000002	All
Sulfur Dioxide	0.003153	1,6
Ozone	0.000002	All
Lead	0.21250	All**
PM10	0.011024	8
Hydrocarbons	0.00001	All
Fluorides	0.0072	8
Hydrogen Sulfide	0.001124	1,6
Barium	0.00736	5
Nitroguanidine*	0.000047	8
Dinitrotoluene*	0.000010	9

*Assume a 99.99% destruction efficiency

**Maximum of 3.4 ounces of lead per propellant charge

SECTION E-4

GENERAL HYDROGEOLOGY INFORMATION

Date: 07/26/92

E-4. GENERAL HYDROGEOLOGY INFORMATION [40 CFR 270.14(c)(2)
and NYCRR 373-2.6]

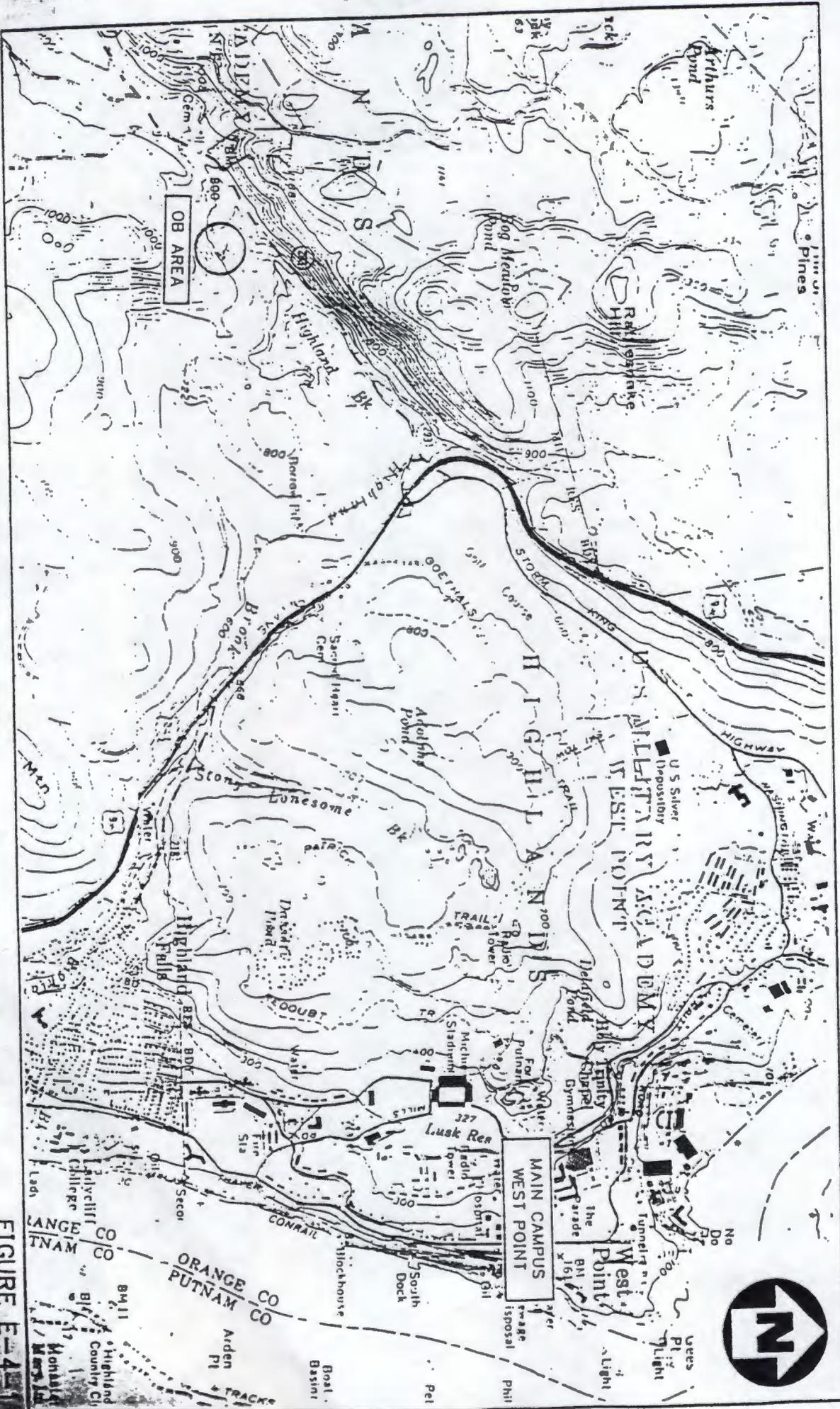
The information presented below describing the installation setting is from the Installation Assessment Study (ESE, 1984). This installation setting data was used in developing the proposed soil and surface water monitoring programs and will be used in evaluating the results of the program.

The USMA, West Point is located in Orange County, N.Y. on the west bank of the Hudson River, approximately 45 miles north of New York City and 13 miles south of Newburgh (Figure E-4-1). The reservation consists of 15,974 acres, of which 2,520 acres are the Main Post or "campus portion" of the Academy and contain the majority of the academic, residential, and support facilities. The remainder of the land area at USMA, known as the Military Reservation, is largely undeveloped and contains training facilities, such as the firing ranges and bivouac areas used during the summer to house and train cadets.

E-4.\ Physiography

USMA, West Point is located in the Hudson Highlands section of the New England physiographic province. The northeastern section of the installation is bounded by the Hudson River. This section contains the main cantonment area, which is situated on exposed bedrock and glacial alluvium. Much of the installation consists of erosion resistant granite and crystalline rocks, which form steep slopes in the southern and western sections. Elevations on USMA range from almost sea level (MSL) along the Hudson River to over 1450 feet in the northwestern section of the installation. Glaciers that once covered the area have deposited alluvium and till in the lowland areas and formed some relatively flat valley bottoms. Most building and development activities are restricted to these relatively flat-lying glacial valleys.

The Open Burn (OB) site is situated approximately 3 miles southwest of the main campus and approximately 500 feet southeast of state route 293 (Figure E-4-2). The OB area is approximately 160 x 140 feet and is located in a former quarry area. Highland Brook is located approximately 300 feet to the north of the OB area (Figure E-4-2).



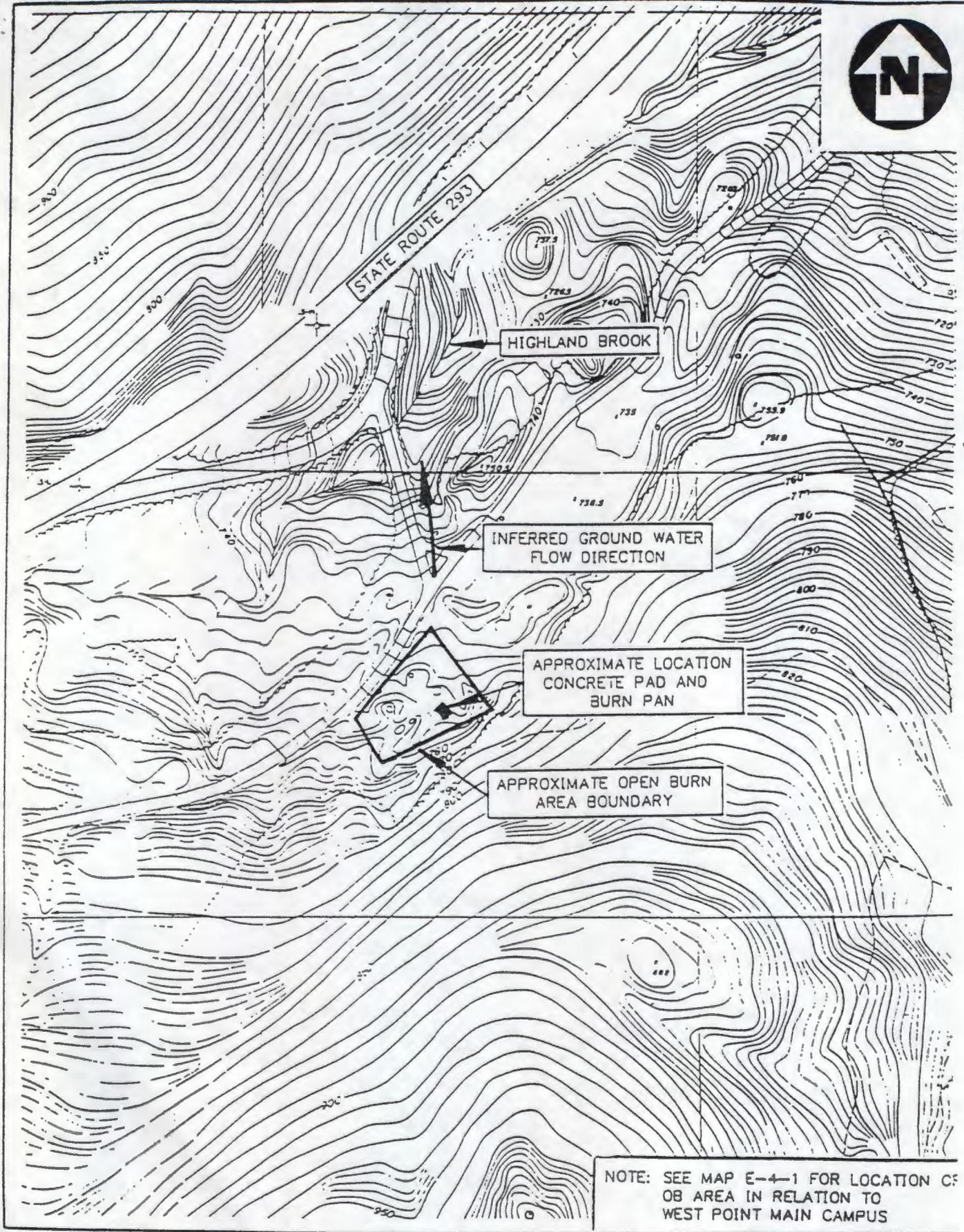
LOCATION MAP
USMA, WEST POINT, NEW YORK

FIGURE E-4-1



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NOTE: SEE MAP E-4-1 FOR LOCATION OF OB AREA IN RELATION TO WEST POINT MAIN CAMPUS

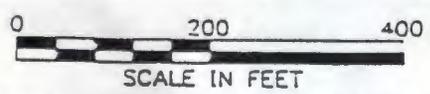


FIGURE E-4-2

OPEN BURN AREA LOCATION
USMA, WEST POINT, NEW YORK
E-4-4



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E-4.2 Surface Waters

USMA lies in the drainage basin of the Hudson River (Figure E-4-3), which flows along the eastern boundary of the installation. The installation is drained by many small tributaries which discharge into the Hudson River. Shallow soil, glacial geology, and abundant rainfall produce a regionally high water table, resulting in numerous swamps, lakes, and ponds. Most of the Main Post area is built on a Pleistocene terrace of the Hudson River and is not contained within the 100-year floodplain. The major surface water bodies are: Popolopen Lake, Stillwell Lake, Long Pond, Lusk Reservoir, Highland Brook, Long Pond Brook, and Deep Hollow Brook.

E-4.3 Geology

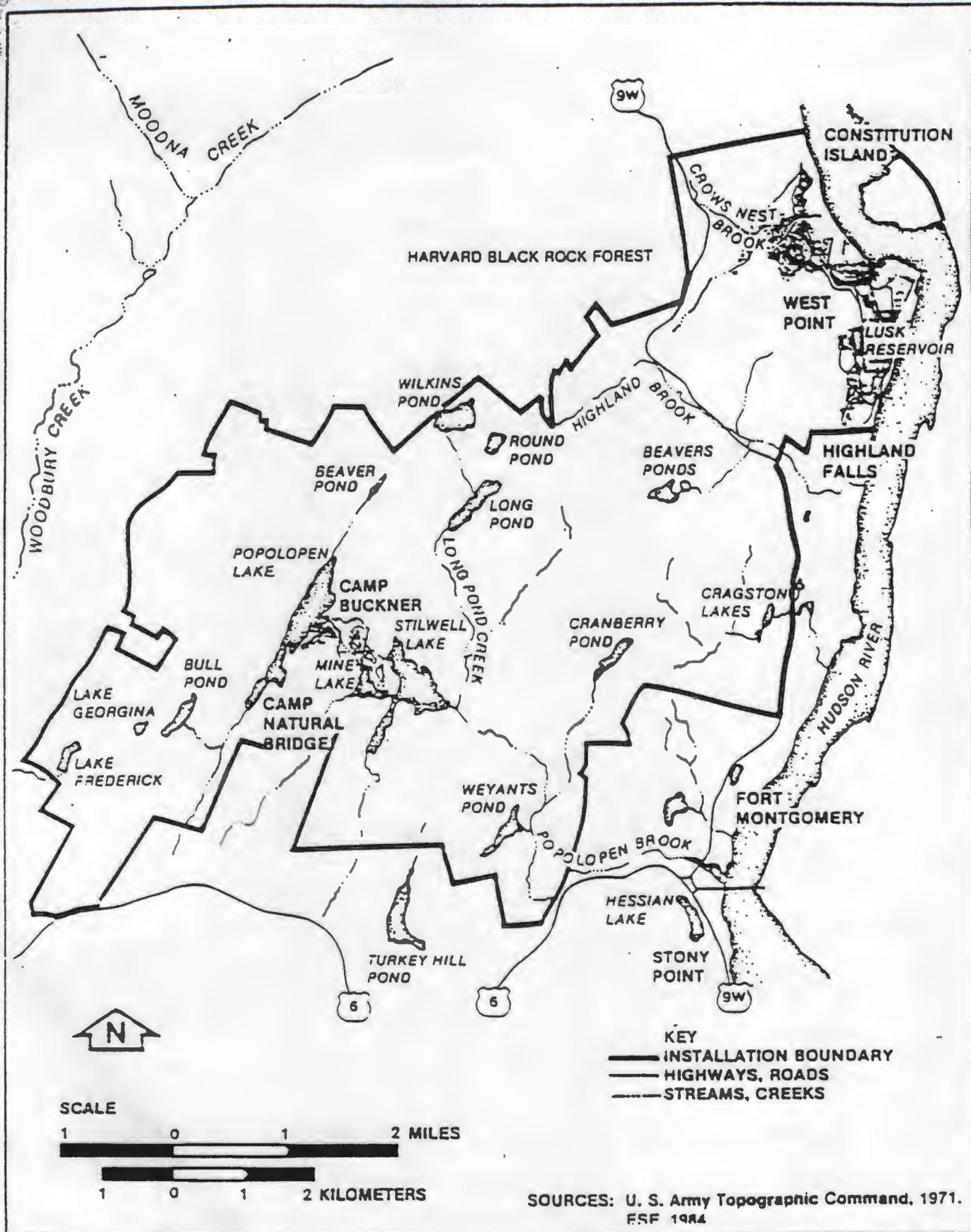
USMA is situated on crystalline bedrock, which in some areas is overlain by younger glacial alluvium (Figures E-4-4 and E-4-5). Crystalline bedrock underlies all of USMA and consists of Precambrian-age granite and gneiss. The granite is usually medium grained, with the major components being quartz, feldspar, and mica. Minor amounts of coarse-grained granites or pegmatites, may also be included in the bedrock. Gneiss is the less prevalent rock type, with the granite underlying the majority of the installation. Small outcrops of the Pochunk diorite may also be found on USMA.

Several faults have been mapped on USMA and are named as follows: Long Pond Fault and the Crown Ridge Fault, which are oriented northeast to southwest. Oriented northwest to southeast are the Highland Brook Fault and the Popolopen Fault. This information was taken from Military Geology of West Point, 1958 (Figure E-4-6).

Overlying the igneous and metamorphic bedrock is a thin veneer of Pleistocene-age glacial deposits. These deposits can be subdivided into unstratified and stratified drift. The unstratified drift consists of glacial till material that was deposited directly from glacial ice as it progressed or regressed across the area. The till consists of large boulders and lesser amounts of clay, sand and gravel. The larger boulders in the till were derived mainly from the more resistant granites and gneisses in the immediate area. In some areas, the till may be cemented to form a fairly hard aggregate in the subsurface. The stratified drift consists primarily of sand and gravel that was deposited in glacial lakes and streams. These deposits are found

Date: 07/26/92

in the larger river valleys such as the Hudson River. The youngest unconsolidated sediment on USMA is Recent-age stream deposits, which are thin and consist of clay, silt and sand. These deposits are present along the Hudson River and in the smaller streams on the installation.



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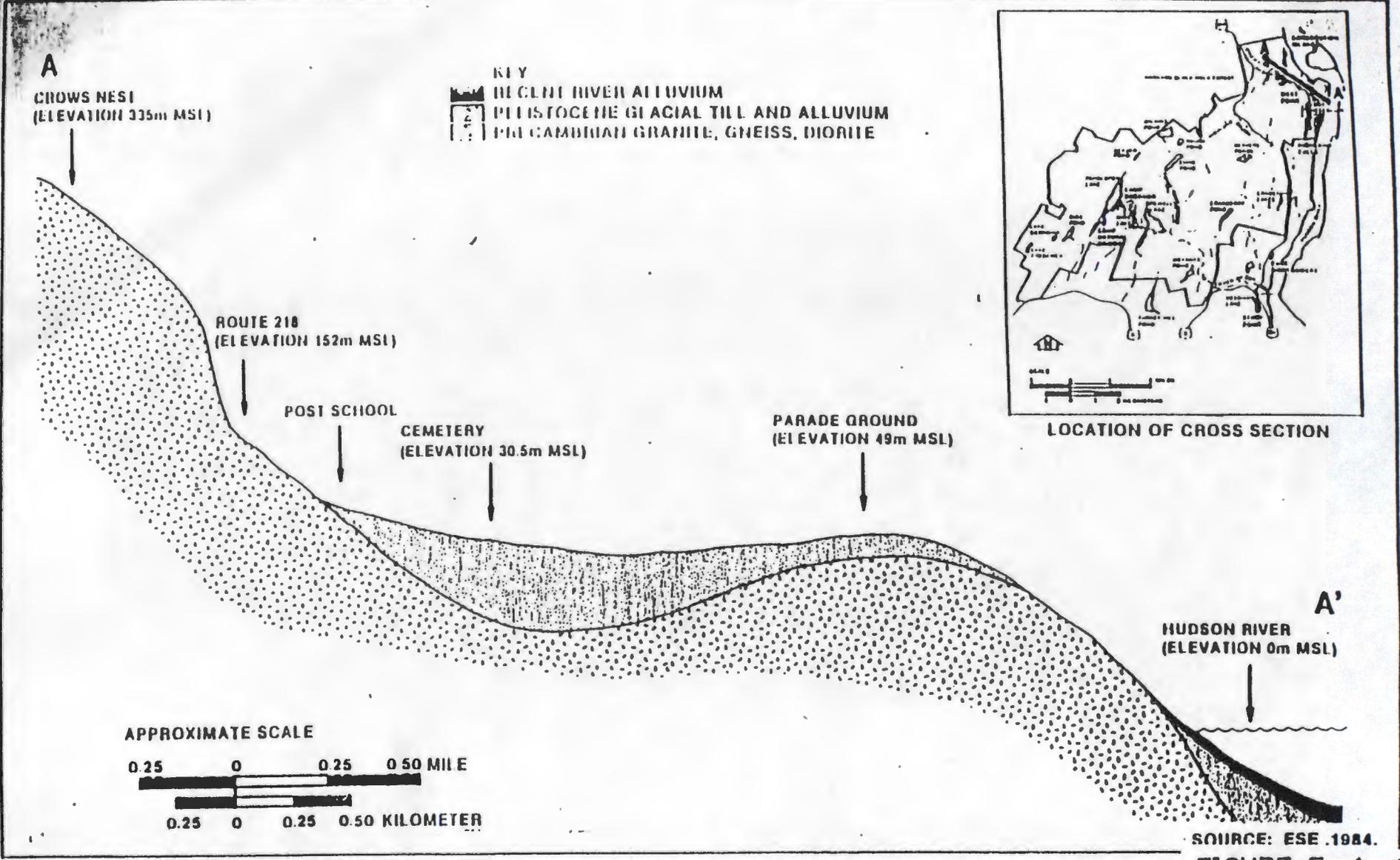
FIGURE E-4-3

SITE MAP AND
SURFACE DRAINAGE
USMA, WEST POINT, NEW YORK

E-4-6



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E-4-7

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GENERALIZED GEOLOGIC CROSS SECTION ACROSS THE MAIN POST AREA USMA, WEST POINT, NEW YORK

Age	Formation	Thickness (m)	Lithology	Water-bearing Characteristics		
Quaternary	Recent	Alluvium	0.3-6.1	Clay, silt, sand, gravel deposited by streams	Not major water source; limited extent and thickness	
	Pleistocene	Stratified Drift	Sand and gravel	0-61	Sand and gravel from glacial streams	Good water source in major stream valleys; average well yield is about 151 lpm
			Lacustrine deposits	0-30.5	Clay and silt from glacial lakes	Yield little water; acts as a confining bed
		Unstratified Drift	Till	0-30.5	Boulders, gravel, sand, clay from glacial ice	Relatively thin and impermeable; low water yields
Cambrian/Ordovician	Middle Ordovician to lower Cambrian	Stockbridge limestone	305	Marble, dolomitic limestone	Not present on USMA; crops out to west and east of installation; no solution cavities; yields average 38 lpm	
	Lower Cambrian	Cheshire quartzite	183	Cemented quartz grains	Not present on USMA; crops out to east and north of installation; limited extent, low well yields	
Precambrian	Pochuck diorite	Unknown	Feldspar, hornblende, pyroxene diorite	Limited extent; some yield in weathered and fractured sections		
	Granite and gneiss undifferentiated	Unknown	Granite with some schist, marble, and quartz	Most extensive bedrock formation on USMA; well yields of 42 lpm in weathered and fractured sections		

SOURCES: Frimoter, 1972.
ESE, 1984.

FIGURE E-4-5

GENERALIZED STRATIGRAPHIC SEQUENCE
USMA, WEST POINT, NEW YORK

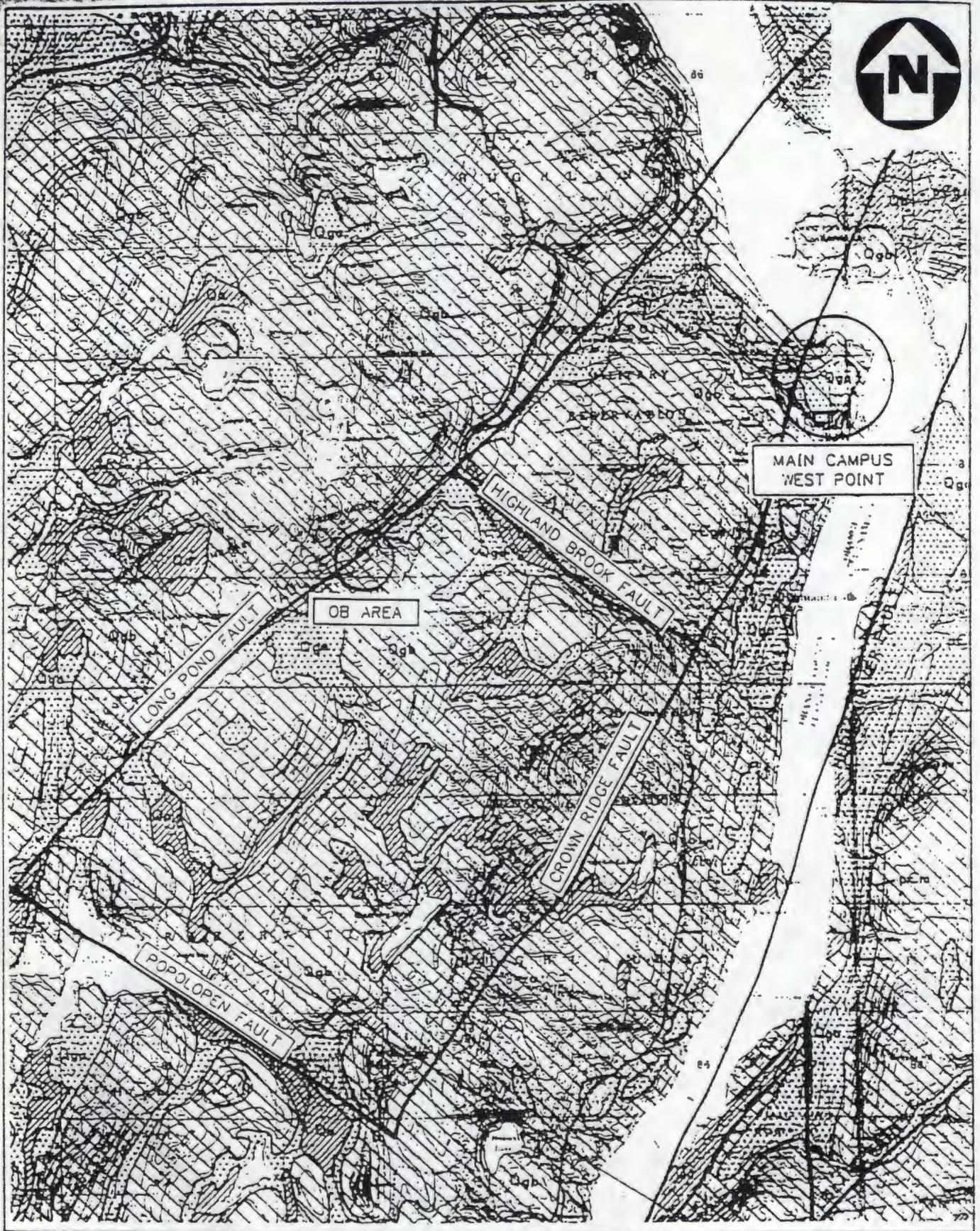


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SOURCE: MILITARY GEOLOGY OF WEST POINT, DEPT. ARMY, 1959

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SCALE IN FEET

FIGURE E-4-6

GENERALIZED GEOLOGIC MAP
USMA, WEST POINT, NEW YORK



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E-4.4 Soils

The soils found on USMA are classified as the Hollis-Rock Outcrop Association and are characterized by sloping to moderately steep, well-drained, medium texture soils that overlie crystalline bedrock. Areas of soil development are limited to the valley areas and flat-lying upland areas. The Hollis soils are gravel loams, with varying amounts of fine sand loam and sand loam. Permeability in this soil is fairly high, with values ranging from 1.2 to 12 feet per day. Figure E-4-7 shows three typical soil profiles from the Main Post area.

E-4.5 Hydrogeology

To date, there have been no major hydrogeology studies performed at the OB unit, thus the discussion presented here is based on limited site-specific and more facility-wide information. This information includes the ESE (1984) and the AEHA (1988) studies.

Groundwater underlying USMA is found in an unconsolidated aquifer of alluvial deposits and a consolidated bedrock aquifer. The aquifer systems are connected and both have low well yields and limited extent and are, therefore, incapable of large municipal supply.

Unconsolidated Aquifer

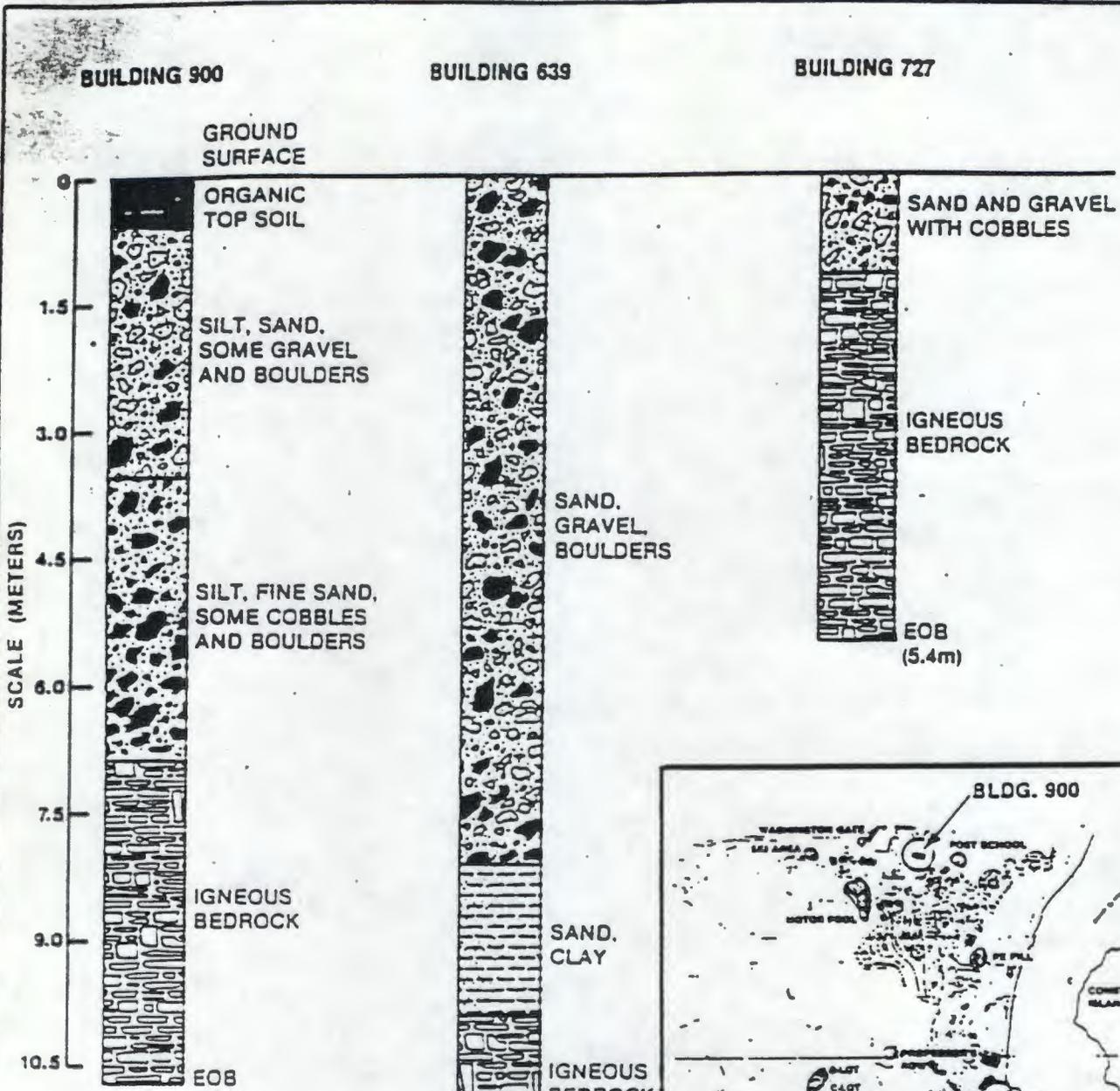
Stratified sand and gravel deposits are the most prolific sources of groundwater at the installation. The deposits are relatively thin and are capable of domestic supply because of fairly small well yields averaging 40 gallons per minute (gpm). Water in the unconsolidated aquifer usually occurs under water table conditions. Recharge to this aquifer is primarily because of local precipitation, although some upward seepage from bedrock does occur in the lowland areas. Glacial till deposits exhibit poor sorting and a high clay content that results in low porosity and permeability, making the unstratified till a poor aquifer system. Well yields are low, with an average of 2 gpm.

Consolidated Aquifer

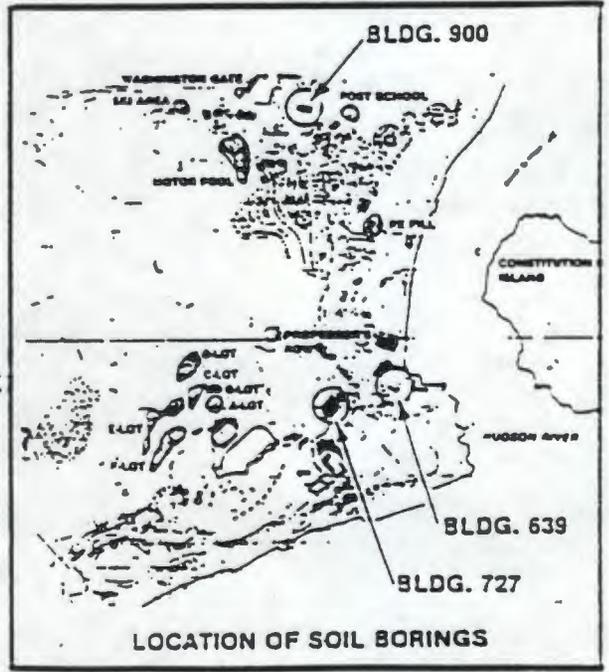
Consolidated rocks underlie all of USMA and contain recoverable quantities of water in the upper weathered and fractured portions. Wells open to the consolidated bedrock have sufficient yield for domestic and other small demands. Groundwater is found in the jointed, fractured, and weathered portion of the bedrock

Date: 07/26/92

and is under water-table conditions. Recharge occurs in the
upland



EOB = END OF BORING



SOURCES: USMA, Office of the Engineer, n.d.
 CE, New York District, 1962 and 1964.
 ESE, 1984.

FIGURE E-4-7

TYPICAL SOIL PROFILES ON
 THE MAIN POST AREA
 USMA, WEST POINT, NEW YORK
 E-4-11

SOIL) 6/2/82 6/2/82

Date: 07/26/92

sections by precipitation and discharges in the lowlands by springs and upward seepage. Permeability and groundwater movement in the consolidated bedrock is extremely slow because of limited joint and fracture systems.

Aquifer Summary

In most cases, the unconsolidated aquifer recharges the local streams with some percolation into the consolidated aquifer. Groundwater may be vulnerable to contamination in some areas because of the permeability of the soils and the shallow depth of the unconsolidated aquifer. However, because the majority of the groundwater from the unconsolidated aquifer recharges the surface water, the first indication of contamination in the groundwater will more than likely be a decline in the surface water quality in the immediate area of contamination (AEHA, 1988).

Existing Wells

There are no wells, active or inactive within close proximity to the OB area. The majority of potable water for USMA is supplied by surface water sources with treatment at the water treatment plant. Seventeen small diameter, shallow wells are used to supply potable water to outlying range, bivouac, and recreational facilities. Table E-4-1 gives information regarding these wells. Well logs were not available at USMA. The wells most likely draw from the sand and gravel alluvium and possibly the top of weathered bedrock. Well depths range from 25 to 40 feet, with fairly low yields of between 3.4 and 5.8 gpm.

Date: 07/26/92

TABLE E-4-1

USMA WELL INFORMATION
 UNITED STATES MILITARY ACADEMY
 WEST POINT, NEW YORK

Area	Building No.	Type Source	Capacity (gpm)
Stony Lonesome	1265	Drilled Well	NA
	1200	Drilled Well	4
	1235	Drilled Well	NA
	1280	Drilled Well	NA
Round Pond	1354	Drilled Well	5
	1340	Drilled Well	NA
	1330	Drilled Well	NA
Long Pond	1400	Drilled Well	4
	1404	Drilled Well	3.4
	1412	Drilled Well	NA
Popolopen	1652	Hand Dug Well	5.8
	1656	Drilled Well	NA
	1666	Drilled Well	4
Morgan Farm	2010	Drilled Well	5
	2020	Drilled Well	NA
Constitution Island	1182	Drilled Well	NA
Popolopen Intake	1970	Drilled Well	NA

NA = Not available or unknown.

Source: USAEHA, 1976.

SECTION E-6

SURFACE ENVIRONMENT

E-6 PROTECTION OF SURFACE WATERS, WETLANDS, AND SOIL SURFACES; [64.601(b), 270.23(b) and (c)]**E-6.1 HYDROLOGIC CHARACTERISTICS OF THE UNIT AND SURROUNDING AREA**

The major surface water system potentially impacted by OB operations at the USMA is the Highland Brook system, which originates just west of the military reservation's boundary. Its headwaters include two large impoundments - Bog Meadow Pond and Jim's Pond - along with a small subsidiary pond - Little Bog Meadow Pond - into which both large ponds drain. These features are shown on Figure E-6-1. The capacities and catchment areas of these three bodies of water are given in Table E-6-1.

Augmented by the flow from Cascade Brook (see Figure E-6-1), Highland Brook is the major source of raw water for the production of potable water at the Highland Falls Water Treatment Plant, which serves the community of Highland Falls, New York. Highland Brook drains the network of ponds, flowing southward from the Little Bog Meadow Pond overflow for about 320 meters (1,050 feet). It then turns northeastward and passes between the OB area and NY State Route 293. After flowing another 1,520 meters (5,040 feet), the brook turns southeast and merges with Cascade Brook. From that merge point Highland Brook flows 1,220 meters (4,000 feet) to the Highland Falls Water Treatment Plant intake structure. The water plant withdraws anywhere from 300,000 to 1,200,000 gallons per day, averaging 410,000 gallons per day. The remaining flow of Highland Brook continues southeast through the Town of Highland Falls, entering the Hudson River after flowing 2,440 meters (8,000 feet) beyond the water plant's intake.

The OB pad and burn pans are approximately 100 meters (330 feet) from the nearest point on Highland Brook. However, several springs and seeps that approach within 30 meters (100 feet) of the burn pad eventually discharge into Highland Brook. As a result, there is a potential pathway for OB-generated contaminants to reach the Highland Brook system and the Highland Falls Water Treatment Plant. A limited amount of data currently exists on the amounts of metals, nitrates, or chlorides in the surface streams which tend to show no measurable impact from OB operations. There are no similar data on surface water concentrations of explosives or other energetic materials, but the absence of any effects from nitrates tends to indicate that such contaminants are not present either.

B-6-2

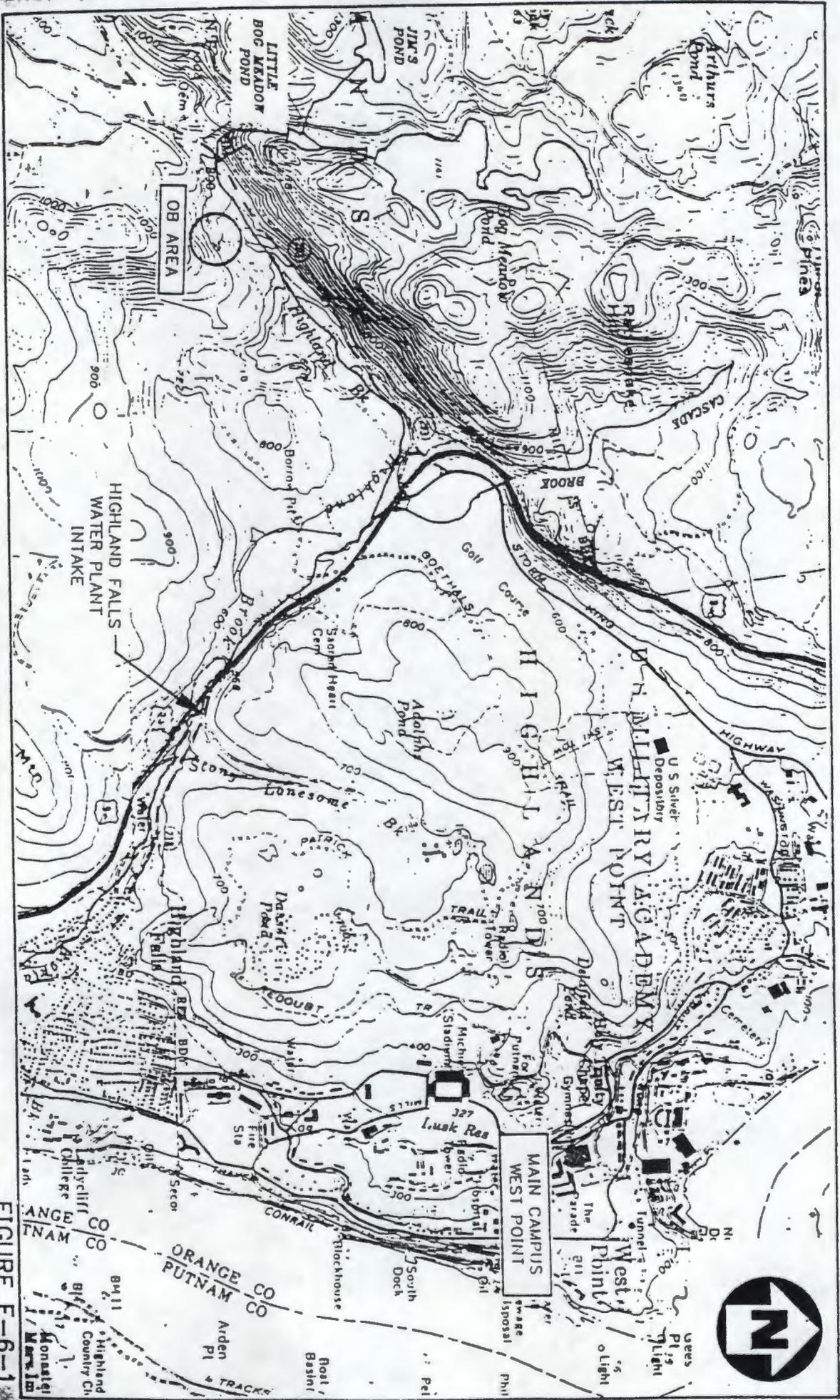


FIGURE E-6-1

USMA, WEST POINT, NEW YORK

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TABLE E-6-1

UNITED STATES MILITARY ACADEMY - WEST POINT
DIMENSIONS OF PONDS ON HIGHLAND BROOK SYSTEM

Identity	Nominal Capacity (gallons)	Catchment Area (square miles)
Bog Meadow Pond	100,000,000	0.45
Jim's Pond	20,000,000	0.14
Little Bog Meadow Pond	5,000,000	0.71
TOTAL	125,000,000	1.30

Source: Water Supply Report, Town of Highland Falls, Hazen & Sawyer, August 1965.

E-6.2 EXISTING QUALITY OF SURFACE WATERS IN THE OB AREA AND DOWNSTREAM

Two studies of surface water concentrations have been conducted. The USEPA's STORET data base contains data for four points of interest - the Highland Falls Water Treatment Plant intake and three Hudson River locations. The Hudson River samples were taken from the river at Highland Falls, in midstream under the Bear Mountain Bridge, and in midstream at Bear Mountain State Park. Refer to Figure E-6-2 for specific locations.

Table E-6-2 summarizes the STORET data, supplemented with a few data points from the December 1984 Installation Assessment Report Number 346. The sample point most likely to be affected by OB operations at USMA is the Highland Falls Water Treatment Plant intake. That sample point yielded average concentrations of nitrate-nitrogen, total Kjeldahl nitrogen, chlorides, iron, and lead that were lower than the Hudson River samples. Mercury concentrations were below detectable levels at all points sampled, while manganese concentrations were slightly higher in Highland Brook than in the Hudson River, probably due to natural causes. Manganese is not a constituent normally found in any of the materials treated at the OB burn pad. Note that the Highland Falls Water Treatment Plant intake samples are collected prior to treatment. All metals are treated to less than detectable levels by the treatment plant operations. An interview with the treatment plant manager who has operated the plant for 24 years revealed that he has had no problems using the quality of water in Highland Brook as his primary source of raw water. The three ponds hold back up to a year's supply of water, and the transfer to the intake via Highland Brook does not degrade the water quality to any measurable extent.

Figure E-6-3 provides locations and Table E-6-3 shows USMA data on surface water quality for four locations: one point upstream of the OB site (the Little Bog Meadow Pond outlet); and three points downstream, including the Highland Falls Water Treatment Plant's intake. As before, most contaminant concentrations appear to be unaffected during their passage downstream towards Highland Falls. The pH values are lowest at the reservoir outlet, then they improve with the addition of flows from Cascade Brook. Nitrate-nitrogen appears to increase slightly, partly due to increased biological activity as temperatures rise, but more likely impacted by Cascade Brook's higher nitrate concentrations. Nitrate-nitrogen could be a potential contaminant released from the OB site, but this survey seems to indicate that there is little or no effect on nitrate concentration until Cascade Brook enters Highland Brook.

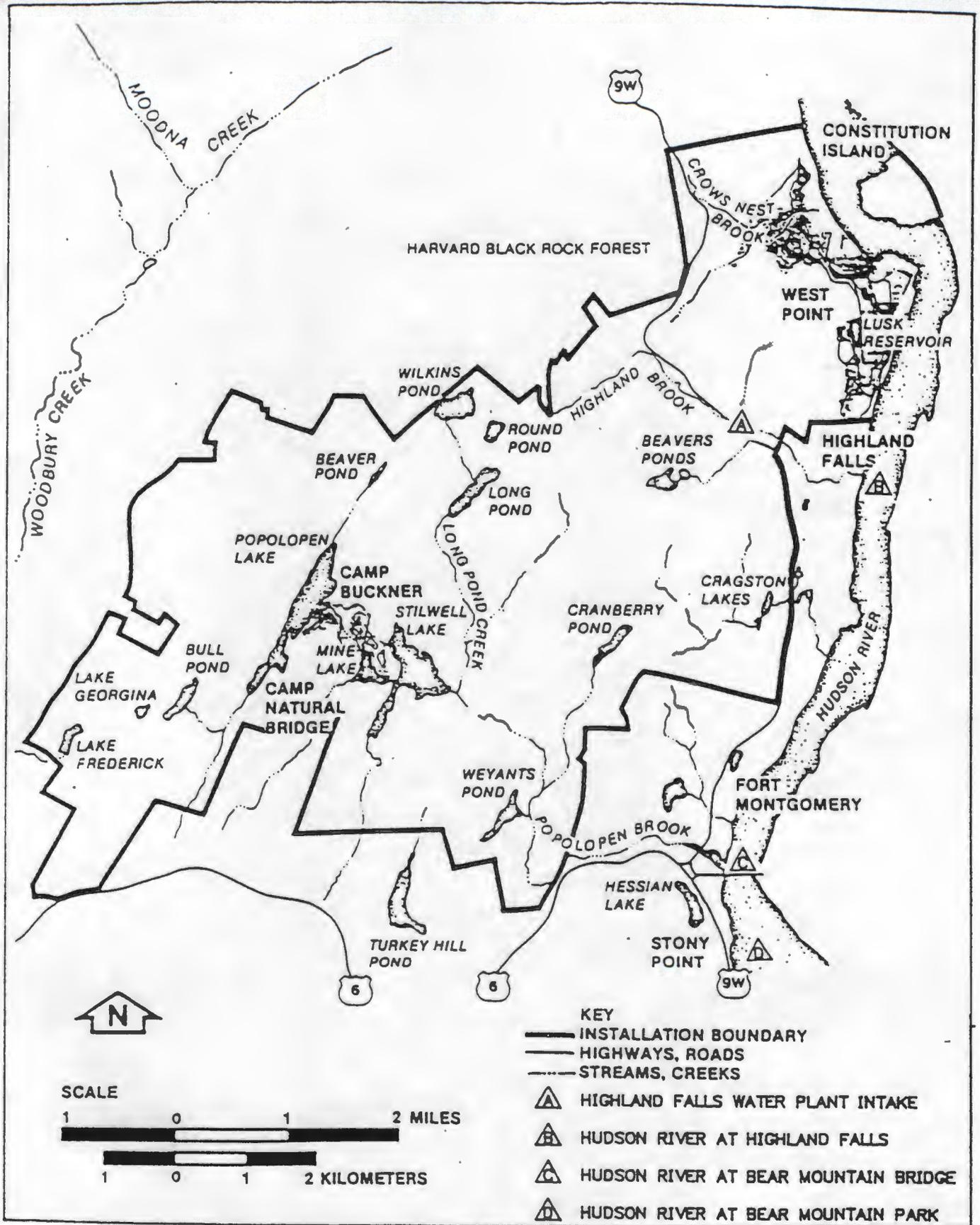


FIGURE E-6-2

SAMPLING SITES
IN STORET DATA BASE
USMA, WEST POINT, NEW YORK



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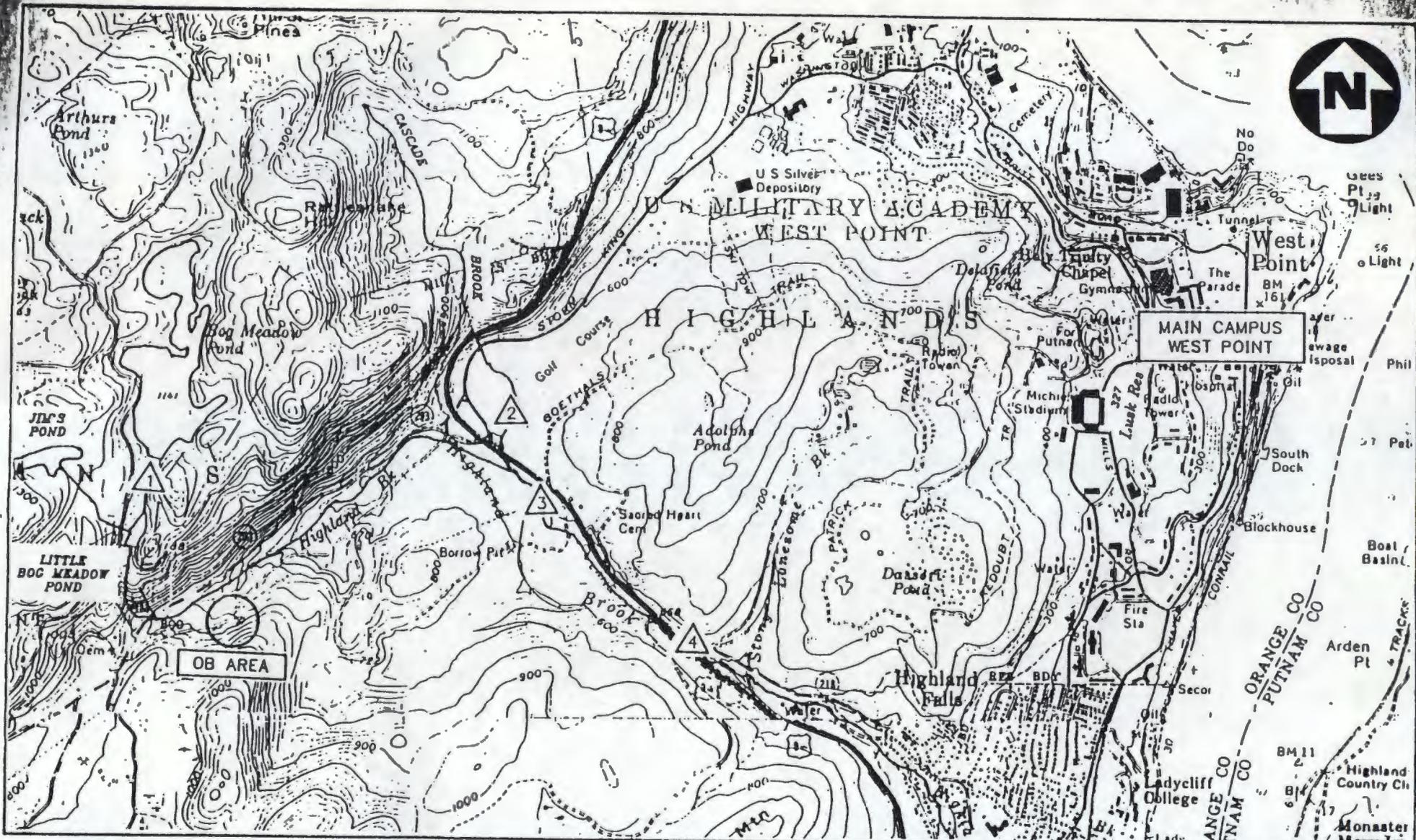
TABLE E-6-2

UNITED STATES MILITARY ACADEMY - WEST POINT
DOWNSTREAM SURFACE WATER QUALITY CHARACTERISTICS
(all data given as mg/l)

Contaminants	Highland Falls Water Plant Intake	Hudson River Locations		
		Highland Falls	Bear Mountain Bridge	Bear Mountain Park
Nitrate Nitrogen				
Tests	4	0	8	16
Mean	0.15	--	0.95	0.66
Range	<0.05-0.21	--	0.46-1.41	0.24-0.97
TKN, as NO ₃				
Tests	1	2	0	18
Mean	0.06	0.545	--	0.355
Range	--	0.53-0.56	--	0.20-0.65
Chlorides				
Tests	3	0	22	66
Mean	19.3	--	760	257
Range	12-27	--	130-10,000	5.6-1,800
Iron				
Tests	3	6	0	17
Mean	0.26	2.0	--	0.83
Range	0.25-0.27	0.8-5.0	--	0.09-1.40
Manganese				
Tests	3	6	0	35
Mean	0.144	0.105	--	0.046
Range	0.073-0.25	0.060-0.140	--	ND-0.170
Lead				
Tests	1	6	11	2
Mean	<0.004	0.013	0.0056	0.0275
Range	--	0.005-0.040	0.003-0.015	0.004-0.051
Mercury				
Test	1	0	8	7
Mean	<0.0005	--	0.000075	<0.0005
Range	--	--	0.00005-0.0002	<0.0005-0.0005

Source: STORET Data Base, USEPA; Installation Assessment Report No. 346, December 1984.

TKN = Total Kjeldahl nitrogen
ND = None detected (detection limit not specified)



E-6-7

LEGEND

△ SAMPLING POINTS



FIGURE E-6-3

STREAM STUDY SAMPLING POINTS
USMA, WEST POINT, NEW YORK



HALLIBURTON NUS
Environmental Corporation

Date: 07/26/92

TABLE E-6-3

UNITED STATES MILITARY ACADEMY - WEST POINT
(all data except pH and temperature as mg/l)

Location	DO	pH (S.U.)	Nitrates as N	TSS	BOD ₅	TDS	Temperature (°C)	Date of Sampling
1. Highland Brook at Little Bog Meadow Pond Outlet	12.9	6.0	<0.05	2	1.1	44	2.0	12/20/79
	12.7	6.0	<0.05	10	2.6	36	2.5	3/4/80
	11.8	5.8	0.08	5	1.1	30	9.5	4/8/80
2. Cascade Brook just above confluence with Highland Brook	13.3	7.7	--	4	<5.0	--	3.0	10/78
	13.1	7.7	<0.05	46	2.5	74	0.0	12/19/79
	12.8	6.6	0.16	24	2.3	28	1.0	3/4/80
	10.4	6.2	0.25	6	<1.0	72	11.3	4/8/80
3. Highland Brook below confluence with Cascade Brook	12.5	7.9	--	<2	<5.0	--	5.5	10/78
4. Highland Brook at Highland Falls Water Plant intake	13.7	7.0	<0.05	93	<1.0	78	0.5	12/20/79
	13.3	6.6	0.21	14	1.9	54	2.0	3/4/80
	12.1	4.3	0.13	2	<1.0	74	9.2	4/8/80

Source: Installation Assessment Report No. 346, December 1984

DO = Dissolved Oxygen
TSS = Total Suspended Solids
BOD₅ = Five-day Biochemical Oxygen Demand
TDS = Total Dissolved Solids

NOTE: All samples were also analyzed for Nitrites as N and total phosphorus; All results were reported as below the detection units as 0.01 mg/l for nitrites and 0.1 mg/l for total phosphorus.

Date: 07/26/92

In any case, nitrate-nitrogen appears at the Highland Falls Water Treatment Plant intake at about 2% of the 10 mg/l concentration normally used as a reference standard for that contaminant.

SECTION I

CLOSURE PLAN

SECTION I

CLOSURE PLAN

I-1 CLOSURE PLAN [40 CFR 264.112(a) AND 270.14(b)(13); NYCRR 373-2.7 AND 373-1.5(a)(2)(xiii)]

This Closure Plan has been prepared in accordance with the requirements of 40 CFR Part 264 Subparts G and X and NYCRR 373-2.7. The Closure Plan is incorporated into the Part 3 permit application in accordance with the requirements of 40 CFR 270.14(b)(13) and 270.23 and NYCRR 373-1.5(a)(2)(xiii).

Open Detonation Facility

The Open Detonation (OD) facility consisted of a series of pits located within the impact area of the USMA training range. These pits were used for treatment by open detonation of various explosive items such as artillery and mortar rounds.

The location of the OD treatment facility within the impact area makes clean closure of the open detonation area impractical. Any contaminants resulting from OD treatments would be indistinguishable from those contaminants resulting from the rounds exploding in the rest of the impact area. During periods of training, the OD area also receives impacts of training rounds. The OD area will continue to serve as part of the impact area. Thus, if clean closure was conducted, the OD area would immediately be recontaminated as a result of training activities.

Furthermore, no practical purpose could be served by clean closure. The OD area is only a small portion of the impact area and could not be used for any other purposes, even if clean closure was conducted. As long as the USMA conducts training activities, the OD area will be used as an impact area.

The location of the OD area within the impact area also presents practical problems for normal post-closure activities. If a RCRA cap were to be installed over the OD area, its integrity would be destroyed as soon as an artillery round impacted in the OD area. Similarly, the integrity of any monitoring wells would be destroyed by explosions of rounds impacting nearby. It would be

Date : 07/26/92

impractical to devise any closure strategy for the OD unit independent of any activities for the impact zone which would take place if USMA were to be closed and the impact area no longer used.

Because of the impracticality of conducting normal closure activities, USMA intends only to conduct a partial closure activity at this time. This partial closure will consist of detonation of any unexploded ordnance identified at the OD unit. This activity will be conducted as part of normal post training range clearance activities. After clearance of any unexploded ordnance the OD unit will continue to be used as part of the impact area.

APPENDIX E-3-A

POLU-11 COMBUSTION PRODUCTS MODEL

COMPUTER PREDICTIONS OF POLLUTION PRODUCTS FROM OPEN BURN
AND OPEN DETONATION OF NAVY EXPLOSIVES AND PROPELLANTS

EDWARD E. BAROODY

NAVAL SURFACE WEAPONS CENTER/WHITE OAK

and

IVAN L. TOMINACK

HEAD, ORDNANCE ENVIRONMENTAL SUPPORT OFFICE

NAVAL ORDNANCE STATION, INDIAN HEAD, MD

JANUARY 1987

TABLE OF CONTENTS

<u>Heading Title</u>	<u>Page</u>
Abstract.....	ii
Background.....	1
Theory and Assumptions for Open Burn/Open Detonation..... Calculations	2
Limitations in Open Burn/Open Detonation (OB/OD) Calculations....	5
Description and Operation of the Pollution Computer Program.....	7
Identification of Numbers on Sample of Output Data.....	14
Sample of Output Data.....	16
Limitations.....	18
Disposal of Navy Waste (at Dugway, Utah 22 May 1986).....	20
Calculated Emissions of Individual Navy Propellant..... and Explosives	23
References.....	30

TABLES

<u>Table</u>	<u>Page</u>
1 - Navy Waste Burned.....	23
2 - Elemental Composition of Navy Waste.....	24
3 - Navy Manufacturers Waste.....	25
4 - Gaseous Emissions Detectcd by Helicopter from 500 Pounds.. of Navy Manufacturers Waste, Burned 22 May 1986	29

APPENDICES

Appendix

A - OB/OD Calculations.....	32
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ABSTRACT

There is a growing need to predict the pollution products at open burn sites. Under the sponsorship of the Ordnance Environmental Support Office, Naval Ordnance Station, Indian Head, a computer program has been developed to predict the combustion products when explosives or like materials are openly burned or detonated. This report explains the theory, assumptions, problem/solution applications of the computer program written for this purpose.

The computer model was challenged using production wastes. The actual data closely followed the predicted data proving the validity of the predictive model.

BACKGROUND

Under the sponsorship of the Ordnance Environmental Support Office at the Naval Ordnance Station, Indian Head, Maryland, a computer program has been developed to predict the pollution products caused by the open burning or open detonation (OB/OD) of explosives and like materials. Since the program is a modification of the Propellant Evaluation Program (PEP), written at the Naval Weapons Center, China Lake¹, a brief history of the PEP program is discussed below. The PEP program was designed and written by the collaboration of many contributors. Work on the program started in 1951 at NWC and continued until 1968.

Combustion products are calculated from high temperature chemical equilibria. To accomplish this, a large set of nonlinear algebraic equations must be simultaneously solved and computer codes must be general enough to handle any particular system. There have been three historic approaches to the problem.

One approach, presented by White et al², is the free-energy criterion for chemical equilibrium. This procedure is the method of steepest descent, which is a general method for the numerical solution of nonlinear algebraic equations.

The second approach by Brinkley³ uses equilibrium constants. For this approach, a basis of subset molecular species is chosen that has as many species as there are chemical elements. From this basis all other species are formed by chemical reaction. A set of equations then establishes the equilibrium relationship of each nonbasis species to the basis. Another set of equations establishes the gram-atom amount of each chemical element. Both sets of equations are solved simultaneously by the Newton-Raphson method, which is a general method for the numerical solution of nonlinear algebraic equations. Huff et al⁴ and Browne⁵ later introduced the concept of optimized basis, in which the components are present in the greatest possible molar amounts.

The reaction-adjustment method of Villars^{6,7} is the third approach. In theory, the chemical system is divided into a number of subsystems, each relating a nonbasis species to the basis. The subsystem with the greatest discrepancy in its equilibrium relationship is corrected stoichiometrically. In this way the gram-atom amounts do not change. Villars' method does not require the inversion of large matrices which simplifies coding. Its speed is greatly dependent on the choice of the basis which is quite slow. The PEP program is a combination of Villars' method and Browne optimum basis method.

The pollution computer program uses many of the PEP program's routines. Modifications of this program were made to calculate pollution products under the special conditions encountered in open burns and open detonations of explosives and propellants. These modifications are described under the general description of the pollution computer program.

THEORY AND ASSUMPTIONS FOR OPEN BURN/OPEN DETONATION CALCULATIONS

The computer program calculates the pollution combustion products under two different conditions:

1. Open Burn (OB) - under these conditions the material is mixed with air and they burn together to form the pollution products.
2. Open Detonation (OD) - under these conditions the material is detonated first, after which air is mixed with the detonation products that react to form the pollution products.

Open Burn

The necessary thermodynamic data for the material's ingredients and air, the weight ratios of material/air and the two pressure values of 1000 and 14.7 psi are read into the computer as input data. The flame temperature, combustion products, moles of gas, entropy, and other pertinent data are calculated for the material/air mixtures under a pressure of 1000 psi. The volume of the combustion products are then expanded to 14.7 psi which causes a temperature drop in the products. At this lower temperature, the products have a different composition from that at 1000 psi. The computer procedure goes through a similar routine it did at 1000 psi to recalculate the combustion products, flame temperature and other variables that changed because of expansion. The products calculated at 14.7 psi are reported as the pollution products in the output data.

Even though the calculations are conducted at 1000 and 14.7 psi, the material does not have to be disposed of under these conditions to predict the pollution products. The calculations are conducted in this manner for the following reasons:

1. It simulates the drop in temperature as the gases cool to ambient conditions.
2. The combustion products "freeze" in composition before they reach ambient temperature.
3. The combustion products of explosives and propellants formed in the combustion calorimeter are in good agreement with the products calculated by the computer³.
4. The heats of explosion calculated from the PEP computer program closely approximates the actual values determined from calorimetric data⁸.

Simulating a Drop in Temperature

Initially, flame temperatures above 3500 K (5840 F) at the burn site can be reached by some materials burned alone or with air. The temperature then cools to the ambient temperature of the surroundings. It is important to account for this drop in temperature, because the composition of the combustion products for the initial high temperature at the burn site will be different from the composition cooled to ambient temperature.

In effect, the combustion product's temperature change can be simulated by calculating the temperature of the material burning under a pressure of 1000 psi and after the combustion products have expanded to 14.7 psi.

Frozen Combustion Products

The composition of the combustion products will continually change with temperature until a "freeze" temperature is reached. Afterwards, the composition of the products remain constant, both quantitatively and qualitatively, even though they continue to cool to ambient temperature. The products are said to "freeze" when they no longer change with temperature. This freeze temperature is unknown and varies with each material burned. In his detonation calorimetric work, Ornellas⁹ reported that the frozen temperature is between 1500 to 1800 K for most explosives. The frozen temperature for the combustion products in this study is assumed to be the temperature that is calculated when the products are expanded to 14.7 psi. For most of the explosives and propellants used by the services, this computer program calculates this temperature to be in the range of 1200 to 1500 K.

Calculated Versus Determined Combustion Products

In this laboratory approximately a dozen explosives and propellants have been burned in a combustion calorimeter under an atmosphere of 450 psi of helium. The combustion products analyzed were in good agreement with the calculated composition of the products after they had been expanded from 1000 to 14.7 psi.

Calculated Versus Determined Heats of Explosion

The heats of explosion have been calculated from the composition of the combustion products, expanding from 1000 to 14.7 psi, from the PEP program for numerous explosives and propellants. In general, there is good agreement between the experimental and calculated values using the PEP output data⁸. The close agreement between the calculated and the determined values for both the combustion products and heats of explosion determined at the NSWC Laboratory, is the basis for using the pressure values of 1000 and 14.7 psi.

Detonation Burn

The same input data is used for both the open burn and open detonation calculations. In open burn, the material and the air are mixed and burned together at 1000 psi and then the combustion products of this mixture are expanded to 14.7 psi. In detonation burns, the following conditions are assumed:

1. The material explodes first, forming combustion products that do not initially react with the surrounding air.
2. During the explosion, the hot gases expand, shock waves are created, etc., causing an energy loss of the combustion products.
3. The combustion products at the reduced energy are then reacted with the surrounding air to form the pollution products.

Materials Explode First

In the open burn calculations, the air is mixed with the air initially at 1000 psi and allowed to react together. In open detonations the material explodes, forming combustion products without mixing with air.

Loss of Energy

When an explosive detonates, shock waves and other processes occur that cause a loss of energy and a drop in temperature. The program assumes that this energy is lost before the combustion products react with air at the burn site.

Combustion Products at Reduced Energy

The calculated energy loss is subtracted from the total energy of the explosive before the combustion products are reacted with air. The calculations then follow the open burn procedure discussed above. That is, the combustion products at a reduced energy level are mixed with air at 1000 psi and allowed to expand to 14.7 psi. This is the major difference between open burn and open detonation calculations.

LIMITATIONS IN OPEN BURN/OPEN DETONATION (OB/OD) CALCULATIONS

Material/Air Weight Ratios

A major problem in calculating pollution products is the material/air weight ratio that burns at the site. The weather, quantity of material to dispose of, wind speed, location, etc., are factors that greatly influence the material/air weight ratios.

To circumvent this uncontrollable variable, a series of material/air weight ratios from 100/0 to 10/90 in increments of -10/10 were calculated. The output data shows the trend in the composition of the pollution products as the ratios vary. Even though the approximate ratio isn't known, the calculations show the extremes expected of the products' compositions for disposal of materials by burning.

Formation of Carbon Dioxide and Water

How much carbon goes to carbon dioxide and hydrogen to water would depend upon a number of factors. Two main factors would be the presence of other elements and the freeze temperature. For example, boron carbide, HCl, and HF would form if boron, chlorine and fluorine were present. Some hydrocarbons would likely form in many cases. Above the freeze temperature, most of the residual carbon and hydrogen would form carbon dioxide and water if enough oxygen were present. The ideal conditions would be for this to occur in OB/OD burns.

If analyses of future OB/OD burns could verify that this does occur, then the material/air weight ratios could be varied until all of the residual carbon and hydrogen went to those two products. That particular material/air weight ratio would then be used to predict the combustion products formed.

Even if not verified, the material/air weight ratios should be varied until all the residual carbon and hydrogen are burned to carbon dioxide and water. It would predict what combustion products are formed under ideal conditions for OB/OD burns.

Calculating Temperature Change

As discussed above, the temperature change is simulated by calculating the material burning at 1000 psi and allowing the combustion products to expand to 14.7 psi. These two pressure values chosen were based on experimental data determined at this laboratory. As mentioned, the theoretical combustion products and heats of explosion calculated under these conditions were in good agreement with the experimental calorimetric data for

the gases formed and the heats of explosion determined. Since temperature is a function of both gases formed and heat released, the calculated temperature change between the pressures of 1000 and 14.7 psi is used for predicting pollution products.

The temperature calculated at 1000 psi simulates the initial high flame temperature of the material at the burn site before it expands. This calculated temperature is slightly higher than the calculated flame temperature if ambient pressure were used instead. For example, the flame temperature for TNT is 1992K at 1000 psi, and 1976 K at 14.7 psi (with no expansion). With such close agreement at these two pressures, it wasn't felt necessary to program the computer to obtain an initial flame temperature at ambient pressure before calculating the temperature drop. This is especially true when the initial flame temperature is subject to the conditions of the environment.

Homogeneity of Materials

Often different types of materials are burned together. In such cases, all of the ingredients in the materials are combined and treated as one homogeneous material in the calculations.

Detonation of Materials in Different Containers

Materials come in many types of containers. Those contained in shells, grenades and other metallic casings will be more difficult to predict than in paper containers. Such containers will influence the chemical reactions at the burn site.

DETONATION REACTIONS BEFORE REACTING WITH AIR

Detonation burn calculations are less accurate than open burn calculations. The material explodes before it reacts with the air. For this reason two assumptions concerning pressure changes and loss of energy were made. They are discussed below.

Pressure Changes in Detonations

Unlike an open burn, there is an initial high pressure from the detonation. It is difficult to calculate what products are formed under high pressures. This computer program uses the ideal equations of state for the combustion products that would not apply to gases under such conditions.

Since the objective is to predict pollution products at ambient conditions, these gases would not be of interest. As the combustion products decrease in pressure, their behavior is assumed to obey the ideal equations of state for gases.

Loss of Energy

The detonation of the explosives sets up shock waves, does work against the environment that expends energy. Since energy is a major factor in determining what products are formed, the calculations assume a loss of energy by the combustion products before they react with air. The loss for each material is at best an estimation. The energy consumed in shock waves is reported by Price¹⁰ and Dyson¹¹ to be 20% to 25% of the total energy of an explosive. The computer program estimates the energy loss to be 25%, plus or minus 5%, depending on the explosive. This percentage can be modified later if and when better experimental data becomes available. As discussed under detonation burn, the combustion products are then calculated at a reduced energy level by the same procedures used in open burn calculations.

DESCRIPTION AND OPERATION OF THE POLLUTION COMPUTER PROGRAM

Modifications of Propellant Evaluation Program

The Propellant Evaluation Program (PEP) was designed for rocket calculations and could not be used in its present form. Since many of PEP's subroutines were compatible for pollution calculations, it was easier to modify this program than to start from scratch. The following major changes were made:

1. INPUT DATA FORMAT - A different format was used for the special type of calculations for pollution work. This format is described below.
2. OUTPUT FORMAT - The PEP output was designed for data important to rocket designs. An example of the output format and data for pollution data is described below.
3. REACTION WITH AIR - The OB/OD burns are mixed with air. the program is designed to automatically mix the materials with air and calculate the results.
4. ENERGY LOSS IN DETONATIONS - The OD burns are assumed to lose energy before they react with air. A modification of several subroutines was made to account for this loss.
5. OB/OD CALCULATIONS - To facilitate the use of the program, it was designed to do either an OB or OD calculation using the same input data. As described below, only one variable must be changed to accomplish this.

General Description

The main computer program, POLU10, has two auxiliary programs to handle the necessary input data for its operation. The three programs are described as follows:

- A. POLU10 - This is the source file for the main program. It is written in the FORTRAN IV language. An explanation of the input data and format is included below. The program was purposely written in FORTRAN IV to facilitate its transfer to other types of computers with the least amount of trouble.
- B. PEPAUX - This is the auxiliary source file program that manages the thermodynamic data for the combustion species. The JANNAF Thermochemical Tables¹² is the source for most of this data. Heat capacity equations, entropy and enthalpy constants are stored in this program for over 1400 combustion species. Gases, liquids and solids are included. Thus, the program can predict solids and liquids as well as gaseous pollution products. When this program is run, a binary file of the data is compiled that POLU10 calls in and searches for the appropriate combustion species. The compiled form of the data must be assigned to TAPE 12 when running POLU10.
- C. INGDATA - This is the auxiliary source file program that manages the ingredients that compose the propellants, explosives or other materials that are disposed of by burning. The names, heats of formation, densities, and the elemental compositions of the ingredients are included as part of the data handled by this program. The ingredients are selected from numbers by the main program. This eliminates reading in the necessary data for the ingredients every time they are used. Two data files are generated by this program:
 1. File on TAPE 11 - This file has the ingredients data arranged in the format used by the main program. the data from this file must be assigned to TAPE 11 before POLU10 is run.
 2. File on TAPE 6 - The INGDATA program also prints the ingredients data on TAPE 6. A copy of this file is obtained for reference by the users of the pollution program. It lists the ingredients by numbers. When a particular ingredient is used in the calculations, this number is entered as input data. The data for that ingredient will then be called in by POLU10.

Explanation and Format Data

The data must be entered in the following sequence:

Line 1

<u>Column No.</u>	<u>Data</u>	<u>Description of Data</u>
3	0	This is always 0. It controls the species data coming from PEPAUX.
4	1	1 or 0. When set to 1, the pressure is entered as lb/sq. in (psi). When set to 0, the pressure is entered in atmospheres
9	1	1 or 0. When set to 1, all of the ingredients are read from TAPE 11 by numbers. When set to 0, some or all of the ingredients are read in directly. This is explained in Line 4.
20	3	0,1,2,3 or 4. This controls what decimal place the concentrations of the combustion products are printed in the output data. Three is recommended.

<u>setting</u>	<u>decimal place</u>
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0	1xE-5*
1	1xE-10
2	1xE-17
3	1xE-4
4	1xE-25

*E = the exponential of 10

29-30	1-10	This is the number of ingredients in the propellant or explosive, plus 1 for air. For example, if an explosive has 3 ingredients, this value must be 4 (right adjusted). Ten ingredients is the limit. If more than 10, two or more of the ingredients must be combined into one.
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39-40	1-10	This is the number of calculations or runs to be made. The output format limits this number to 10 (right adjusted).
46-47	20	When all of the ingredients are read in by numbers, this is set to 20. If any of the ingredients are not read in by numbers, this number (right adjusted) must equal the number of ingredients not read in by numbers.
48-50	1,2	When set to 1 (right adjusted), the computer does open detonation calculations. When set to 2, the computer does open burn calculations. They both use the same input data and format.
51-53	1,2	When set to 1, the output data for the pollution products are given in grams products/100 g material. When set to 2, the products are also given (both units) in grs products/liter of gases formed at STP (273.15 degrees Kelvin and 1 atmosphere pressure).

Line 2

This line is for naming of the material burned and other identifying information.

Line 3

In a sequence of calculations, the weight percent of air is changed. This line is for the different weights of air that changes with each calculation. As many as ten different weights of air can be entered. Starting at column 1, each weight has a field of 6 columns. Weight 1 goes into columns 1 - 6; weight 2, into columns 7 - 12, etc.

Line 4

The INGDATA file contains data for many of the ingredients that are used in propellants and explosives. If this file does not have the ingredients needed for the calculations, the data for these ingredients can be read in. In Line 1, column 9 must have a value of 0 and columns 46 - 47 must have the number of ingredients (right adjusted) that are read in under the format below.

When adding new ingredients to the INGDATA data file, this same format is used. The INGDATA data can also be entered under the format adopted by Cruise at China Lake. The position of the data under Cruise's format is marked in the data file.

<u>Column No.</u>	<u>Description of Data</u>
1 - 20	Name of the ingredient
21 - 27	Heat of formation of the ingredient in cal/g.
28 - 32	Density of ingredient in lb/cubic inch.
33 - 38	Number of atoms of the first element in the ingredients.
39 - 40	Symbol of the first element (left adjusted).
41 - 46	Number of atoms of the second element in the ingredients.
47 - 48	Symbol of the second element (left adjusted). This sequence continues for a limit of six elements.
49 - 54	Atoms of third element.
55 - 56	Symbol of third element.
57 - 62	Atoms of fourth element.
63 - 64	Symbol of fourth element.
65 - 70	Atoms of fifth element.
71 - 72	Symbol of fifth element.
73 - 78	Atoms of sixth element.
79 - 80	Symbol of sixth element.

Line 5

The numbers assigned to the ingredients by the INGDATA file are entered here. Starting at column 1, each field has 5 columns. The number for the first ingredient goes into columns 1 - 5, the second ingredient into columns 6 - 10, etc. For example, if 23 is assigned to aluminum by the INGDATA file, 23 should go in columns 1 - 5 (right adjusted). Aluminum is the first ingredient in the material. It is imperative that the ingredient number for air always be the last number in this line. If it is desired to burn the materials in pure oxygen, then the ingredient number for oxygen is used instead of air.

Line 6

<u>Column No.</u>	<u>Data</u>	<u>Description of Data**</u>
1 - 6	1000.	This is the pressure of the chamber in which the material is initially burned. This value is normally 1000 psi for pollution calculations. Atmospheres can be used (see explanation in Line 1). The data in this line is for the first calculation.
7 - 12	14.7	This is the pressure that the combustion products expand to in the calculations. The value 14.7 psi is normally used here. It can also be expressed in atmospheres.
13 - 18	—	<p>This is the weight of the first ingredient. The field for each successive ingredient is 6 columns long. For the second ingredient, columns 19 - 24; the third, columns 25 - 30, etc. The tenth and last ingredient is in columns 67 - 72.</p> <p>The weights of the ingredients are entered with air as the last ingredient. Air is normally set at zero weight percent. Under some circumstances, the initial weight of oxygen is not zero. This is discussed later. The weight of air is automatically increased and the material weights decreased by the same increments in Line 3.</p>
73 - 80	—	This is optional. Additional information can be entered here to help identify the output data. Such information is normally entered in Line 2.

Lines 7 - 15

1 - 6	1000.	The data is the same as in columns 1 - 6 in Line 5.
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7 - 12

14.7

The data is the same as in columns 7 - 12 in Line 5. It isn't necessary to enter the weights of the material or air again. The program automatically adjusts these weights with the data in Line 3. The number of these lines is always one less than the total number of calculations made. If 10 calculations are to be computed, enter 9 of these lines with just these two values on each line.

** All numerical data must have a decimal point.

IDENTIFICATION OF NUMBERS ON SAMPLE OF OUTPUT DATA

- NO.
1. Identifies the type of calculation. This is either open burn or open detonation.
 2. Name of the material burned is identified here.
 3. Name of the ingredients in the material.
 4. Symbol for the elements in the ingredients. Also, the number of atoms for that element divided by 1000. This number is often in decimal form when the elements are expressed in gram-atoms.
 5. Weight of the ingredient in the material.
 6. Heat of formation of the ingredient in cal/gr.
 7. Density of the ingredient in lbs/cu in.
 8. Symbol for the elements that compose the material. Also, the elemental composition of the elements that compose the material. If the atomic wt. of the element is multiplied by the elemental composition, the total mass of the element in the material can be calculated (example: $12.01 \times 3.081786 = 37.01$ grs of carbon).
 9. Weights of the material and air used in the calculations.
 10. For open burn calculations: This is the initial flame temperature of the material/air burned before the gases start to cool. The enthalpy of the combustion products is given in kcal/gfw (gfw = gram formula weight). The temperature is expressed in both Kelvin and Fahrenheit degrees.

For open detonation calculations: This is the temperature of the combustion products after there is a loss of energy due to detonation. The detonation products cool to this temperature before they react with air.
 11. The temperature of the combustion products (for both OD/OB burns) after they have expanded from 1000 to 14.7 psi. This is also the "frozen" temperature of the products.
 12. The computer can calculate the weights of the combustion products to 1.00E-17. For this work the concentration is rounded off to the value shown.

13. Symbols for the combustion products formed. They are identified in the JANNAF Thermochemical Tables¹²
14. Weights of the products formed in grams products/100 grams of material burned (or lbs products/100 lbs material burned).
15. Total combustion products considered in the calculations. Of the 73 products listed, 12 with concentrations $1.00E-04$ or higher are listed above.

LIMITATIONS

Thermodynamic Data for Combustion Products

The program contains an auxiliary data file (PEPAUX) for the combustion products. Heat capacity coefficients, enthalpy and entropy constants are stored for each of the combustion products. Most of the data in this file is from the JANNAF Thermochemical Tables¹². Currently, there are over 1400 species in this file. It contains compounds in the gaseous, liquid and solid states. The program chooses the compounds to consider in the calculations from the elemental composition of the material burned. If the material contains the elements C, H, O, N, the program searches the library for all species containing these elements and considers them as possible pollution products. The total number of combustion products considered for each calculation is listed in the output data. Obviously, any products formed at the burn site and not in this file cannot appear in the calculations. This library contains most of the species that are formed from explosives and propellants used by the armed services.

The file does not contain a large number of species for the metallic additives that are used in military explosives. There will probably be some products formed from metals that are not in the file. Since aluminum is used extensively, there is an adequate amount of species for this metal under most circumstances.

Most of the species in the thermodynamic file consist of solids and gases. The liquids and solids are identified by asterisks and dollar signs, respectively, in the output data. The PEP program is designed to calculate combustion products at high temperatures. The file does not include organic solvents or other organic compounds that cannot survive high temperatures.

High Temperature Species

Some of the species formed only exist at high temperatures. These species would disappear as ambient temperature is approached. For example, ions would be in this category. These species normally disappear in the calculations as more air is added. In evaluating the pollution products, these species are assumed to disappear. For most explosives and propellants, these high temperature species comprise only a small percentage of the total.

Temperature Limitations

If the materials burned do not obtain a flame temperature above 300 K, the computer will issue a warning. For example, if a hydrocarbon without oxygen is attempted there will be no reaction above 300 K. This can occur

with a mixture of material and air if there is not sufficient amount of oxygen or fuel to properly react. In such cases several trial runs can be made by changing the material/air ratios until the program runs.

Mixing Air With Materials

In most calculations, the first material/air weight ratios start with 100/0. The computer will accept this ratio as long as the material contains the elements oxygen and nitrogen. If a material, such as a hydrocarbon is burned with zero weight percent of air, the program cannot run. With air as an ingredient, the computer will select those species from the PEP AUX library composed of these two elements. The concentrations of these species cannot be calculated as the elemental composition of oxygen and nitrogen will be zero. When burning hydrocarbons and similar materials, the percent of air cannot be zero.

Precautions With Detonation Calculations

The first material/air weight ratios in a series of detonation calculations must be 100 g material/0 g air, or the material burned alone. The program must use the data from this first calculation to determine the energy loss from the detonation. Since most explosives and propellants contain nitrogen and oxygen, the problem discussed in the paragraph above does not apply. Some materials, (tetrazoles, azides, etc.) do not contain oxygen or nitrogen. For detonation calculations, a small amount of air must be included in the first calculation. The air would be considered as part of the explosive's composition in the first calculation. A minimum percent of air should be used that can be determined by trial and error.

Combustion Products Printed Twice

The thermodynamic data covers a wide temperature range. In some species (notably solid carbon and aluminum oxide), the data is stored as two heat capacity equations to properly cover the temperature range. Therefore, some species appear twice in the output data. When this occurs, one or the other of the symbols representing that species is zero. This does not affect the results.

DISPOSAL OF NAVY WASTE

On 22 May 1986, approximately 7500 lbs of Navy waste propellants were disposed of by openly burning the propellants at Dugway, Utah. The pollution products were investigated by two methods, evaluation by computer calculations and on-site evaluation.

Comparative Analyses. Computer Predictions Versus Actual Emission Data

The composition of the Navy waste that was disposed of at Dugway is given in Table I. Combined, this waste consisted of eight elements. The percentage and total weight of each element is listed in Table II. For example, 2.97% or 222.7 lb of the combined waste consisted of the hydrogen element. Metals are usually a concern at waste disposal sites. The amounts of Al, Zn and Pb in the waste material are also listed. Tables III and IV contain the computer output data for the Navy waste burned in air. The combined composition is read into the computer as Navy waste 1, Navy waste 2, zinc and lead. Since the waste/air weight ratio burned at the site was not known, a series of ten waste/air weight ratios were calculated. The output data lists the pollution products formed and their changes in concentrations for the various waste/air ratios. The fate of the elements is discussed below

- a. HYDROGEN - Most of the hydrogen goes to the formation of H₂O, H₂, and HCl. As the percentage of air increases, the percentage of water increases at the expense of H₂. The HCl concentration remains fairly constant until 30% waste/70% air is reached.
- b. CARBON - CO and CO₂ are formed with carbon. As the percentage of air increases, the percentage of CO₂ increases at the expense of CO.
- c. NITROGEN - the predominate product is N₂. Some traces of NO₂ may exist in the 20% waste/80% air ratio.
- d. OXYGEN - Oxygen combines with all of the elements except zinc.
- e. ALUMINUM - From the first to the last calculation, all of the aluminum goes to Al₂O₃\$ (\$ stands for solid). In most propellants oxygen reacts with aluminum first to completely oxidize it. The Al₂O₃\$ concentration is constant throughout the series. Note that Al₂O₃\$ is shown twice in the output data (the 5th and 27th products). This compound has its thermodynamic data stored in two heat capacity equations. Which equation is used depends upon the temperature.

- f. CHLORINE - HCl and the chlorides of zinc and lead are formed. HCl is the most prominent of the chlorine products formed. HCl will immediately be absorbed in any moisture present to form hydrochloric acid.
- g. ZINC - Most of the zinc metal will form its chlorides. The chlorides increase with increase in the air weight and at the expense of HCl. The zinc products will be mostly solids.
- h. LEAD - Lead reacts similarly to zinc and will form chlorides.

At the end of the output data is a list of the total combustion species considered by the computer. There are 155 (some species listed twice) shown that the computer considered as possible combustion products. Those whose concentrations equaled or were greater than 0.0001 are listed above.

On-Site Evaluation at Dugway, Utah, 22 May 1986

The waste was burned in 5000- and 2500-lb sections. The gaseous products formed from these burns were sampled by a helicopter passing through the clouds.

The interscan instruments used to detect the gaseous emissions in the plume were not specific for each individual gas. As a result, some instruments suffered from interferences and would give indications of the presence of a measured gas when it actually was responding to an interferent gas. This was the case for the apparent detection of SO₂ and H₂S when there were no sulfur compounds in the Navy waste that was burned. The responses on these instruments were due to the presence of HCl which produces a positive response on these two instruments. Since the chemical reactions of the detector cells in the instrument are either oxidative or reductive, depending on the instruments, it is possible for an interferent to produce a negative interferent gas. It is likely that the negative values recorded by the Cl₂ instrument resulted from a negative interferent gas. Based on the theory that there should be no NO, the response was probably also due to an interferent. (Explanation of the data in Table V is based upon a letter and private communication by Mark Zaugg, Director for Ammunition Equipment, Tooele Army Depot, Tooele, Utah.)

Only a limited amount of the on-site data collected, Table V, was useful for evaluation. The helicopter sampled the two major indicator gases as emissions from the Navy waste:

1. Carbon Monoxide - In Table V, the concentration of CO is 0.07 and .06 lb CO/100 lb Navy waste for the 5000 and 2500 lbs respectively. This concentration of CO falls between the computer values of 40/60 and 30/70 Navy waste/air weight ratios (Tables III and IV).

2. Hydrogen Chloride - In Table V, the concentration of HCl is 1.19 and 1.21 lb HCl/100 lb Navy waste for 5000 and 2500 lbs respectively. This concentration of HCl falls between the computer values of 20/80 and 10/90 Navy waste/air weight ratios (Tables III and IV).

Based on the above data, the climatic conditions experienced and the burn pan configuration at the Dugway site allowed for sufficient oxygen to completely oxidize the Navy manufacturing waste. The composition/concentrations remained constant above the 60-70% air intake. It is at this point where all of the residual carbon and hydrogen atoms are oxidized to carbon dioxide and water. It is expected that most of the PEP "mixes" of Navy manufacturing waste will be completely oxidized to these two products. For most of the individual Navy propellants, the calculations below show complete oxidation at the 60-70% air intake. Some, like the AA2 and the HEN-12, are completely oxidized with 50-60% air intake. The percentage of air consumed depends upon the initial oxygen content of the material.

In the predictive mode, the metals that are present are considered to be completely oxidized early in the burn, and the remaining oxygen is used to oxidize the residual carbon and hydrogen.

In the interest of a proof continuum, a comparative analyses predicted vs actual emission should be made of future burns/detonations of both Army and Navy PEP waste.

CALCULATED EMISSIONS OF INDIVIDUAL NAVY PROPELLANTS AND EXPLOSIVES

Emissions from each individual propellant and explosive were calculated in a manner similar to those in Table III. These calculations predict the pollution emissions of the individual material. They were done for open burn and open detonation conditions. A list of these calculations is given below.

TABLE I

NAVY WASTE BURNED

<u>Propellant</u>	<u>Weight (lbs)</u>	<u>Weight %</u>
NOWIE-80-1 (MK 23)	70	2.8
X256 (MK 12)	1200	48.0
N-60 (Smokey Sam)	20	0.8
N-50 (5" G.P.)	100	4.0
AA2 (MK 90)	410	16.4
AA6 (ZUNI)	240	9.6
N-5 (ASROC and MK 22)	190	7.6
BX-180/BX 185 (MK 18)	5	0.2
BX-180 H (CKU-5/A)	15	0.6
TPH-9001 (CKU-7/A)	30	1.2
PBXN-106 (MK 115)	40	1.6
PBXW-109 (MK 83)	20	0.8
NOSIH 9 BC-10) (MQM-107)	40	1.6
XM39 (LOVA)	70	2.8
PBXN-103	50	2.0

TABLE II

Elemental Composition of Navy Waste

<u>Element</u>	<u>% of Element</u>	<u>Wt. Element in 7500 Lbs</u>
H	2.97	222.7
C	23.28	1746.0
N	13.45	1008.8
O	52.88	3966.0
Al	3.83	287.2
Cl	2.25	168.8
Zn	0.32	24.0
Pb	1.02	76.5

OPEN BURN---MATERIAL DOES NOT DETONATE BEFORE REACTING WITH AIR---
 MATERIAL- NAVY MANUFACTURERS WASTE (OPENLY BURNED MAY 22, 1986)

	H	C	N	O	AL	CL	ZN	PB				
NAVY WASTE 1	.001	.001	.000	.001	.000	.0000	.0000	.0000	.0000	.0000	.0000	
NAVY WASTE 2	.002	.001	.000	.002	.000	.0000	.0000	.0000	.0000	.0000	.0000	
TIME	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0010	0.0000	0.0000	0.0000	0.0000	41.890
LEAD	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-285.
AIR	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0010	0.0000	0.0000	0.0000	0.0000	-208.
IRAN AION AMOUNTS FOR MATERIAL	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	.0556
(H)	(C)	(N)	(O)	(AL)	(CL)	(ZN)	(PB)	()	()	()	()	.0574
2.949434	1.938620	.959393	3.305057	.141947	.063547	.004925	.004988					.2580
II. MATERIAL	100.000	90.000	80.000	70.000	60.000	50.000	40.000	30.000	20.000	10.000	0.000	.4883
II. AIR	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000	0.000	.0884

---COMBUSTION CONDITIONS: THE MATERIAL AND AIR ARE BURNED TOGETHER AT 1000.00 PSI---

LAME TEMP. T(K)	3348.384	3323.983	3295.611	3261.034	3215.566	3147.747	3023.902	2731.903	2131.039	1311.640
LAME TEMP. T(F)	5547.691	5523.749	5472.699	5410.461	5320.619	5204.544	4903.624	4458.025	3376.471	1901.552
MIHALPY KCAL/GFM	-20.372	-10.335	-14.290	-14.240	-12.223	-10.186	-8.149	-6.112	-4.074	-2.037

---COMBUSTION CONDITIONS: THE COMBUSTION PRODUCTS FROM MATERIAL AND AIR AFTER EXPANDING FROM 1000.00 PSI TO 14.70 PSI---

LAME TEMP. T(K)	1401.386	1466.469	1451.255	1435.946	1421.140	1408.430	1404.435	1292.020	860.042	462.684
LAME TEMP. T(F)	2567.095	2540.245	2512.059	2485.339	2458.666	2435.709	2432.182	1866.236	1103.076	373.431
MIHALPY KCAL/GFM	-102.139	-97.153	-92.177	-87.211	-82.253	-77.272	-72.034	-60.390	-44.060	-25.615
.VOL. GASES--LITERS	89.072	96.000	105.657	116.933	131.967	153.012	184.563	246.532	376.504	766.246
GASES AT 61P)										

COMBUSTION PRODUCTS ROUNDED OFF TO 1.00E-04

-----GRAMS PRODUCTS/100 GRAMS (08/0) MATERIAL BURNED-----

CO	41.9856	39.8389	37.0072	33.1385	27.6106	19.2366	5.4997	.0000	.0000	.0000
CO2	19.3530	22.7259	27.1750	33.2536	41.9391	55.0963	76.6799	85.3209	85.3210	85.3210
N2	13.4391	22.2002	33.1517	47.2321	66.0059	92.2094	131.7144	197.3985	320.0390	723.0911
H2O	12.8589	14.1242	15.6105	17.3747	19.4892	22.0410	25.1093	26.1722	26.1002	26.4900
AL2O3	7.2365	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
NaCl	2.2610	2.2570	2.2526	2.2454	2.2344	2.2129	2.1222	1.6010	1.5713	.2019
H2	1.4713	1.3299	1.1630	.9666	.7303	.4454	.1045	.0000	.0000	.0000
PB	.7733	.7602	.7441	.7230	.6925	.6390	.4661	.0000	.0000	.0000
ZN	.3113	.3090	.3078	.3040	.2990	.2890	.2330	.0000	.0000	.0000

TABIF III

POCL	.2714	.2853	.3022	.3239	.3514	.4049	.5367	.0120	.0000	.0000
ZMCL2	.0222	.0254	.0297	.0359	.0443	.0600	.0830	.0713	.0000	.0000
POCL2	.0008	.0099	.0113	.0133	.0167	.0236	.0567	1.3251	.4713	.0000
PO	.0044	.0051	.0059	.0072	.0074	.0155	.0541	1.3251	1.3649	.0000
PRH	.0012	.0010	.0009	.0007	.0004	.0004	.0001	.0203	.0000	.0000
CL	.0005	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
H	.0002	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
H10	.0002	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
CL2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
HOCL	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0013	.0000	.0000
O2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0012	.0000	.0000
PRCL4	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0006	.0010	1.2015
NO	.0000	.0000	.0000	.0000	.0000	.0000	.0000	13.5132	.0010	.0002
CL	.0000	.0000	.0000	.0000	.0000	.0000	.0000	40.7050	154.2525	.0007
H	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0026	.0021	.0000
PRCL20	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0050	.0001	.0000
ZMCL20	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
AL2030	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	1.3645
NO2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.4712
										7.2365
										7.2365
										.0000
										.0000

---LIST OF TOTAL COMBUSTION PRODUCTS CONSIDERED---

CO2	H2O	H2	F8	ZN	PBCL	ZMCL2	PRCL2	P80	P8H	CL
H10	CMH	CMHO	NO	CMO	ALCL2	CM4	COCL	ALCL3	ALOCL	CL2
HOCL	O	MI	MI0	CMCL	CH3CL	OCL	H2O2	CMO	H	C2H2
COCL2	HOCL	MI02	AL	M2H2	C2O	CH2	ALH	ALH02	C2H2	CH2CL2
C2HCL	FBCL4	M2H4	C3O2	CM2	NO	M2O4	ALCL2	CMO	ALCL	C2
M2O3	C	C2CL2	CL	AL2CL4	CMCL3	OCL2	HO	AL202	ALHO	C4H2
C2H4O	M2O5	CM2	ALH	AL202	CJ	CM	MH03	H3O	H	C2CL4
O3	FRJ040	CM2	FBCL20	FB020	CMCL6	PR00	PR00	PR00	PR00	PR00
AL4C30	ALCLJ0	AL2030	AL2030	M2040	M2040	ALC	ALC	ALC	ALC	ALC
C4H10	MH4CL0									
H200										

TABLE 'III' CONTINUED

OPEN BURN--MATERIAL DOES NOT DETONATE BEFORE REACTING WITH AIR---
 MATERIAL - NAVY MANUFACTURERS WASTE (OPENLY BURNED MAY 22, 1986)

	H	C	N	O	AL	CL	ZM	FB	
NAVY WASTE I	.801	.001	.000	.001	.000	.000	.000	.000	.000
NAVY WASTE 2	.002	.001	.000	.002	.000	.000	.000	.000	.000
ZINC	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
LEAD	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
AIR	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
GRAM AMOUNTS FOR MATERIAL WEIGHTS OF 100.000									
(H)	(C)	(N)	(O)	(AL)	(CL)	(ZM)	(FB)		
1.150279	.756045	3.007810	2.095300	.055359	.024784	.001921	.001914		
WT. MATERIAL	39.000	30.000	37.000	34.000	35.000	34.000	33.000	32.000	31.000
WT. AIR	61.000	62.000	63.000	64.000	65.000	66.000	67.000	68.000	69.000

---COMBUSTION CONDITIONS: THE MATERIAL AND AIR ARE BURNED TOGETHER AT 1000.00 PSI---

FLAME TEMP. 1(K)	3805.362	2985.107	2942.917	2938.550	2911.771	2892.277	2849.794	2814.055	2774.820
FLAME TEMP. 1(F)	4950.252	4913.793	4073.850	4030.004	4701.780	4720.699	4670.232	4605.980	4535.276
ENTHALPY KCAL/GFM	-7.945	-7.741	-7.530	-7.334	-7.130	-6.924	-6.723	-6.519	-6.315

---COMBUSTION CONDITIONS: THE COMBUSTION PRODUCTS FROM MATERIAL AND AIR AFTER EXPANDING FROM 1000.00 PSI TO 14.70 PSI---

FLAME TEMP. 1(K)	1600.600	1612.674	1610.660	1562.240	1515.302	1469.463	1424.374	1379.039	1335.725
FLAME TEMP. 1(F)	2436.239	2443.417	2439.707	2352.647	2240.143	2185.633	2104.477	2024.311	1944.904
ENTHALPY KCAL/GFM	-71.440	-70.774	-69.964	-60.775	-67.494	-66.154	-64.749	-63.344	-61.883
T.VOL.GASES--LITERS (GASES AT STP)	180.601	192.041	197.456	203.275	209.445	215.902	222.919	230.295	238.150

COMBUSTION PRODUCTS ROUNDED OFF TO 1.00E-04

-----GRAMS PRODUCTS/100 GRAMS (08/0) MATERIAL BURNED-----

	N2	CO2	H2O	AL2O3	CO	HCL	POCL	PB	ZNCL2	TARIF IV
N2	136.7609	142.0092	147.6031	153.5039	159.0369	166.4620	173.4927	180.9630	188.9150	188.9150
CO2	79.5772	82.4392	85.2531	85.3080	85.3141	85.3190	85.3201	85.3204	85.3200	85.3200
H2O	25.4479	25.7940	26.1074	26.1243	26.1372	26.1490	26.1500	26.1656	26.1699	26.1699
AL2O3	7.2363	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
CO	3.4556	1.7068	.0432	.0082	.0031	.0013	.0005	.0002	.0001	.0001
HCL	2.0059	2.0139	1.0190	1.7704	1.7250	1.6036	1.6403	1.6239	1.6009	1.6009
POCL	.5450	.5926	.3256	.2049	.1508	.1063	.0693	.0421	.0230	.0230
PB	.4104	.3094	.0297	.0072	.0020	.0011	.0004	.0001	.0000	.0000
ZNCL2	.2355	.3438	.6522	.6684	.6705	.6710	.6712	.6712	.6712	.6712

TABLE V

Gaseous Emissions Detected by Helicopter from 5000 Lbs of
Navy Manufactureres Waste, Burned 22 May 1986*

Emissions from 5000 Lbs Open Burn

Pass No.	1	2	3	4	5	6	7
GAS	—————lb gas /5000 lb Navy Waste—————						lb gas/100 lb <u>Navy Waste**</u>
SO2	31.19	24.85	17.48	9.65	10.92	22.12	0.3
Cl2	-8.63	-10.65	-8.30	-2.67	0.00	-24.49	0.1
HCl	—	76.65	61.84	46.770	43.50	69.25	1.1
NO	23.80	22.53	12.87	6.78	10.23	20.73	0.3
NO2	1.35	5.18	4.48	6.93	13.07	11.92	0.1
H2S	7.01	2.98	3.32	0.00	0.00	0.00	0.0
CO	3.88	2.45	4.37	0.00	0.00	0.00	0.0

Emissions from 2500 Lbs of Navy Waste

SO2	3.07	23.59	17.64	4.52	2.22	—	0.4
Cl2	-4.15	-20.12	-13.02	-2.50	0.00	—	-0.3
HCl	8.44	38.08	65.26	26.98	11.40	—	1.2
NO	2.88	9.96	5.51	1.06	1.56	—	0.1
NO2	0.37	1.94	3.52	4.05	0.00	—	0.08
H2S	0.45	2.06	1.04	0.60	0.00	—	0.0
CO	—	—	1.29	—	1.95	—	0.06

* The open burning of the PEP military wastes, collection of pollution products and cloud sampling was conducted under the direction of Mark M. Zaugg, Ammunition Equipment Directorate (AED), Tooele Army Depot, Tooele, Utah. This table (Table V) is from the reduction of the helicopter data by the program SUMMARIZ developed by AED. The columns represent the analyses of six passes made by the helicopter through the cloud plume after the Navy waste was burned.

** The average of total runs.

10. Donna Price, Energy Partition in Underwater Explosions of Organic Explosives: Applications to Waxed and Aluminized Explosives (U) Chemistry Research Department, U.S. Naval Ordnance Laboratory, White Oak, Silver Spring Maryland, NAVORD Report 6829, 8 March 1960.
11. E. Swift and J. C. Decius, Measurement of Bubble Pulse Phenomena Radius and Period Studies. Underwater Research Laboratory, Woods Oceanographic Institution, 11 Sept 1947.
12. D. R. Stull, H. Prophet, Project Directors, JANNAF Thermochemical Tables. Office of Standard Reference Data, National Bureau of Standards, Washington, D.C., NSRDS-NBS 37.

APPENDIX E-3-B

POLU-11 MODEL OUTPUT FOR OB TREATMENT

Worst Point / CB		SUBSTANCE (16/16) X using 100% Fin. emission factor										Lowest Emission Factor
CO	NO ₂	SO ₂	O ₃	C ₂ H ₄ (PM _{2.5})	Hydrocarbons (PM _{2.5})	Fluorides (Total) as F	H ₂ S, SO ₂ , Sulfide	Lead	Ba	Topsoil (OK)		
1	.00002	.003153	.00002	—	.00001	—	.001124	—	—	1070		
2	.00001	—	.00002	—	.00001	—	—	—	—	955		
3	.00001	—	.00002	—	.00001	—	—	—	—	955		
4	.00002	—	.00002	—	.00001	—	—	—	—	955		
5	.00002	—	.00002	—	.00001	—	—	—	.00736	998		
6	.00128	.003153	.00002	—	.00001	—	.001124	—	—	1070		
7	.2469	—	.00002	—	.00001	—	—	—	—	1101		
8	.00001	—	.00002	—	.00001	.0090	—	—	—	846		
9	.2085	—	.00002	—	.00001	—	—	—	—	—		
10	.2474	—	.00002	—	.00001	—	—	—	—	—		
11	.2321	—	.00002	—	.00001	—	—	—	—	1119		

OPEN BURN---MATERIAL DOES NOT DETONATE BEFORE REACTING WITH AIR---
 MATERIAL=M720 HE 60mm MORTAR

	H	C	N	O	S	K								
NITROCELLULOSE(12.6)	.008	.006	.002	.010	.000	.000	.000	.000	.000	.000	.000	97.900	-625.	.0600
DIPHENYLAMINE - DPA	.011	.012	.001	.000	.000	.000	.000	.000	.000	.000	.000	1.000	178.	.0419
POTASSIUM SULFATE	.000	.000	.000	.004	.001	.002	.000	.000	.000	.000	.000	1.000	-1966.	.0962
CARBON (GRAPHITE)	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.100	0.	.0816
AIR - (C)	.000	.000	.006	.001	.000	.000	.000	.000	.000	.000	.000	.000	0.	.0000

GRAM ATOM AMOUNTS FOR MATERIAL WEIGHT OF 100.000

1.0000

	(H)	(C)	(N)	(O)	(S)	(K)						
	2.778496	2.235656	.986447	3.581045	.005738	.011477						
WT. MATERIAL	100.000	90.000	80.000	70.000	60.000	50.000	40.000	30.000	20.000	10.000		
WT. AIR	.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000		

---COMBUSTION CONDITIONS: THE MATERIAL AND AIR ARE BURNED TOGETHER AT 1000.00 PSI---

FLAME TEMP. T(K)	2393.249	2450.426	2510.721	2574.620	2641.668	2705.540	2718.260	2434.207	1852.052	1149.821		
FLAME TEMP. T(F)	3848.448	3951.367	4059.898	4174.916	4295.603	4410.571	4433.468	3922.173	2874.293	1610.278		
ENTHALPY KCAL/GFW	-62.960	-56.664	-50.368	-44.072	-37.776	-31.480	-25.184	-18.888	-12.592	-6.296		

---COMBUSTION CONDITIONS: THE COMBUSTION PRODUCTS FROM MATERIAL AND AIR AFTER EXPANDING FROM 1000.00 PSI TO 14.70 PSI---

FLAME TEMP. T(K)	1063.824	1091.934	1122.740	1156.115	1192.398	1232.487	1278.873	1070.313	729.779	394.570		
FLAME TEMP. T(F)	1455.482	1506.081	1561.532	1621.607	1686.916	1759.077	1842.571	1467.163	854.203	250.825		
ENTHALPY KCAL/GFW	-118.997	-112.418	-105.844	-99.276	-92.726	-86.192	-79.601	-65.781	-47.044	-26.820		
T.VOL.GASES--LITERS (GASES AT STP)	91.381	98.429	107.210	116.494	133.532	154.583	186.200	247.743	377.725	767.660		

COMBUSTION PRODUCTS ROUNDED OFF TO 1.00E-04

-----GRAMS PRODUCTS/100 GRAMS (GS/G) MATERIAL BURNED-----

CO	38.8197	36.8515	34.2867	30.8148	25.6944	18.4169	6.1286	.0001	.0001	.0003		
CO2	37.3446	40.4660	44.5042	49.9607	57.6908	69.4374	88.7484	98.3885	98.3880	98.3785		
N2	12.4160	21.1774	32.1291	46.2097	64.9837	91.2673	130.6923	196.3967	327.8174	722.0681		
H2O	6.7764	10.1333	11.7846	13.8030	16.3085	19.4363	23.3636	24.9233	24.9223	24.9194		
H2	1.7929	1.6438	1.4599	1.2344	.9541	.6042	.1654	.0000	.0000	.0000		
HNO	.5986	.5967	.5949	.5937	.5940	.5931	.6141	.6423	.0007	.0006		
H2O2	.1859	.1853	.1850	.1843	.1832	.1808	.7174	.0001	.0002	.0003		
N	.0301	.0318	.0334	.0344	.0343	.0313	.0200	.0001	.0002	.0004		
CSO	.0163	.0169	.0176	.0187	.0203	.0226	.0168	.0002	.0003	.0006		
CH4	.0143	.0042	.0010	.0002	.0000	.0000	.0000	.0001	.0001	.0002		
KCN	.0021	.0013	.0007	.0003	.0001	.0001	.0002	.0002	.0002	.0007		
NH3	.0009	.0008	.0007	.0005	.0003	.0001	.0000	.0001	.0001	.0002		
N2O6	.0001	.0001	.0001	.0001	.0002	.0002	.0002	.0003	.0005	.0009		
S2O	.0001	.0001	.0001	.0001	.0001	.0002	.0002	.0003	.0004	.0008		
SO3	.0001	.0001	.0001	.0001	.0001	.0002	.0002	.0020	.0004	.0008		
CS2	.0001	.0001	.0001	.0001	.0001	.0002	.0002	.0003	.0004	.0008		
S2	.0001	.0001	.0001	.0001	.0001	.0004	.0048	.0002	.0003	.0006		
SO2	.0001	.0001	.0001	.0001	.0001	.0011	.1253	.3153	.3631	.3587		
CAH10	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0002	.0003	.0006		
CAH8	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0002	.0003	.0006		
KNO2	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0002	.0003	.6389		
KNO3	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0002	.0003	.0006		
KNO2V	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0002	.0003	.0006		
KO	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0002	.0003	.0006		
SO	.0000	.0001	.0001	.0001	.0001	.0001	.0005	.0002	.0002	.0005		
OS	.0000	.0001	.0001	.0001	.0001	.0001	.0001	.0002	.0002	.0005		

CO2	.0000	.0000	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001
CS	.0000	.0000	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0002	.0004
C3H6	.0000	.0000	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0002	.0004
KH	.0000	.0000	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0002	.0004
CHH	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0001	.0003
HS	.0000	.0000	.0000	.0001	.0002	.0004	.0000	.0001	.0001	.0002	.0003
H02	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0001	.0002	.0003
S	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0001	.0002	.0003
O2	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	12.5908	47.8604	153.6181
NH0	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0001	.0002	.0003
C2H6	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0001	.0002	.0003
CH20	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0001	.0002	.0003
H0	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0001	.0002	.0003
CH0	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0001	.0003
C2H4	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0001	.0003
C2H2	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0001	.0003
H20T	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0002
H0	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0002
H0	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0002
G	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0002
NH	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0002
CH2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001
H	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001
CH	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001
C	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001
CS	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001
C6	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001

---LIST OF TOTAL COMBUSTION PRODUCTS CONSIDERED---

CO	CO2	N2	H2O	H2	KH0	H2S	K	CS0	CH4	KCH	NH3	K2O4	S2O	S03
CO2	S2	S02	C4H10	C4H8	KH0L	KH0L	KH0T	K0	SC	GS	HS	H02	C3H6	CS
C3H6	KH	CHH	HS	H02	S	O2	NH0	C2H6	CH20	H0	CH0	C2H4	C2H2	H20T
H0	H0	G	NH	CH2	H	CH	C	C6	C6	H				

CO	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0000
C2H4	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0000
CO	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0000
C2H2	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0000
H2O*	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0000
HO	.0000	.0000	.0000	.0000	.0000	.0001	.0007	.0001	.0001	.0000
HO	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0000
CH4	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0000
O	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0000
NH	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0000
CH2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001
H	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001
CH	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001
C	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001
CO	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001
CO	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001

---LIST OF TOTAL COMBUSTION PRODUCTS CONSIDERED---

CO	CO	H2O	H2	H2	KHO	K	K2Oz	NH3	KCN	KH	C4H10	C4H8	KHOz	KHOz
NHO*	NO	O3	NO2	C3H8	C3H6	HO2	O2	NHO	C2H6	CH2O	HO	CHO	C2H4	CNH
C2H2	H2O*	HO	HO	CH4	O	NH	CH2	H	CH	H	C	CO	CO	

CHO	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0001
C2H4	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0003
CNH	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0003
C2H2	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0003
H2O*	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0002
HO	.0000	.0000	.0000	.0000	.0000	.0001	.0007	.0001	.0001	.0002
HG	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0002
CH4	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0002
O	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0002
NH	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0002
CH2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0001
N	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001
CH	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001
C	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001
CL	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001
CL	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001

---LIST OF TOTAL COMBUSTION PRODUCTS CONSIDERED---

CO2	CO	H2O	N2	H2	KHO	K	K2O2	NH3	KCN	KH	C4H10	C4H8	KHO2	KHO2
KHO*	KO	O3	NO2	C3H8	C3H6	H3O	O2	NHO	C2H6	CH2O	NO	CHO	C2H4	CNH
O2H2	H2O*	HO	H5	CH4	O	NH	CH2	N	CH	H	C	CL	CL	

OPEN BURN---MATERIAL DOES NOT DETONATE BEFORE REACTING WITH AIR---
 MATERIAL=M50A3 TP 60 == MORTAR

	H	C	N	O	K											
NITROCELLULOSE(12.6)	.008	.006	.002	.010	.000	.000	.000	.000	.000	.000	.000	.000	.000	52.150	-625.	.0600
NITROGLYCERIN - NG	.005	.003	.003	.009	.000	.000	.000	.000	.000	.000	.000	.000	.000	43.000	-392.	.0578
DIETHYL PHTHALATE	.014	.012	.000	.004	.000	.000	.000	.000	.000	.000	.000	.000	.000	3.000	-810.	.0400
ETHYL CENTRALITE-EC	.020	.017	.002	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.600	-117.	.0451
POTASSIUM NITRATE	.000	.000	.001	.003	.001	.000	.000	.000	.000	.000	.000	.000	.000	1.250	-1165.	.0762
AIR -(G	.000	.000	.006	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	0.	.0000

GRAM ATOM AMOUNTS FOR MATERIAL WEIGHT OF 100.000 1.0000

	(H)	(C)	(N)	(O)	(K)										
	2.625871	1.916727	1.053924	3.692784	.012363										
WT. MATERIAL			100.000	90.000	80.000	70.000	60.000	50.000	40.000	30.000	20.000	10.000			
WT. AIR			.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000			

---COMBUSTION CONDITIONS: THE MATERIAL AND AIR ARE BURNED TOGETHER AT 1000.00 PSI---

FLAME TEMP. T(K)	3017.782	3016.111	3010.297	2995.698	2961.120	2876.896	2667.465	2253.009	1704.459	1064.185
FLAME TEMP. T(F)	4972.608	4969.600	4959.134	4932.856	4870.617	4719.013	4342.036	3596.017	2608.626	1456.133
ENTHALPY KCAL/GFW	-53.411	-48.070	-42.729	-37.388	-32.047	-26.706	-21.365	-16.023	-10.682	-5.341

---COMBUSTION CONDITIONS: THE COMBUSTION PRODUCTS FROM MATERIAL AND AIR AFTER EXPANDING FROM 1000.00 PSI TO 14.70 PSI---

FLAME TEMP. T(K)	1456.077	1459.348	1463.259	1468.316	1475.901	1493.145	1259.726	955.484	653.474	358.513
FLAME TEMP. T(F)	2161.539	2167.426	2174.466	2183.568	2197.221	2228.260	1808.107	1260.472	716.854	185.923
ENTHALPY KCAL/GFW	-122.141	-115.217	-108.299	-101.379	-94.425	-87.223	-74.614	-58.997	-42.222	-24.242
T.VOL.GASES--LITERS	84.463	91.479	100.249	111.525	126.558	147.602	185.041	250.033	380.011	769.952
(GASES AT STP)										

COMBUSTION PRODUCTS ROUNDED OFF TO 1.00E-04

----GRAMS PRODUCTS/100 GRAMS (OS/G)MATERIAL BURNED-----

CO2	38.9520	42.9879	48.2255	55.2393	65.0530	79.6146	84.3537	84.3525	84.3503	84.3434
CO	28.8974	26.3267	22.9951	18.5309	12.2847	3.0167	.0001	.0001	.0001	.0003
H2O	15.8723	16.8635	18.0242	19.4015	21.0493	23.0130	23.5407	23.5406	23.5397	23.5368
H2	14.7632	23.5243	34.4758	48.5561	67.3300	93.6134	133.0256	199.7451	330.1636	724.4139
H2	.8866	.7495	.6195	.4651	.2805	.0599	.0000	.0000	.0000	.0000
KHO	.5614	.5691	.5789	.5919	.6110	.6503	.6924	.7335	.0003	.0005
K	.0918	.0965	.0796	.0705	.0571	.0296	.0001	.0001	.0002	.0004
N2O6	.0001	.0001	.0001	.0001	.0002	.0002	.0002	.0002	.0003	.0009
nH3	.0001	.0001	.0001	.0000	.0000	.0000	.0000	.0000	.0001	.0002
KCN	.0001	.0001	.0001	.0001	.0001	.0001	.0002	.0002	.0003	.0007
KN	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0004
C4n10	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0004
C4n8	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0004
KNO6	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0004
KNO6	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0004
KNO7	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0004
KO	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0004
OS	.0000	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0004
NO2	.0000	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0004
OSHO	.0000	.0000	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0004
OSHO	.0000	.0000	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0004
nO2	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0004
O2	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0004
KNO	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0004
O2HO	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0004

CH3	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0000
C2H4	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0000
CNH	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0000
C2H2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0000
H2O†	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0007	.0001	.0001	.0000
HO	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0000
HC	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0000
CH4	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0000
O	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0000
NH	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0000
CH2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0000
N	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0000
CH	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0000
C	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0000
C%	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0000
Cl	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0000

---LIST OF TOTAL COMBUSTION PRODUCTS CONSIDERED---

CO2	CO	H2O	N2	H2	KHO	K	K2O%	NH3	KCN	KH	C4H10	C4H8	KHO%	KHO%
KHO†	KO	O3	NO2	C3H8	C3H6	HO2	O2	NHO	C2H6	CH2O	NO	CHO	C2H4	CNH
C2H2	H2O†	HO	HO	CH4	O	NH	CH2	H	CH	H	C	C%	C%	

NHO	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0002	.0003
C2H6	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0002	.0003
CH2O	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0002	.0003
NO	.0000	.0000	.0000	.0000	.0001	.0001	.0224	.0054	.0002	.0003
CHO	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0003
C2H4	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0003
CNH	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0003
C2H2	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0003
H2O*	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0003
HO	.0000	.0000	.0000	.0000	.0000	.0000	.0011	.0001	.0001	.0002
HO	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0002
O	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0002
NH	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0002
CH2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0002
N	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001
CH	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001
C	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001
Cz	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001
Cz	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001

---LIST OF TOTAL COMBUSTION PRODUCTS CONSIDERED---

CO2	CO	N2	H2O	H2	BaOz	KHO	K	NH3	Ba	KCN	K2Oz	CH4	C4H10	C4H8
KHOz	KHOz	KHO*	KO	O3	HO2	C3H8	C3H6	KH	HO2	O2	NHO	C2H6	CH2O	NO
CHO	C2H4	CNH	C2H2	H2O*	HO	HO	O	NH	CH2	N	CH	C	Cz	Cz

π

OPEN BURN---MATERIAL DOES NOT DETONATE BEFORE REACTING WITH AIR---
 MATERIAL=M374A3 HE 91mm MORTAR

H C H O S K

NITROCELLULOSE(12.6)	.008	.006	.002	.010	.000	.000	.000	.000	.000	.000	.000	.000	97.900	-625.	.0600
DIPHENYLAMINE - DPA	.011	.012	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	1.000	178.	.0419
POTASSIUM SULFATE	.000	.000	.000	.004	.001	.002	.000	.000	.000	.000	.000	.000	1.000	-1966.	.0962
CARBON (GRAPHITE)	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.100	0.	.0816
AIR	.000	.000	.006	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	0.	.0000

1.0000

GRAM ATOM AMOUNTS FOR MATERIAL WEIGHT OF 100.000

(H)	(C)	(N)	(O)	(S)	(K)	(I)									
2.778496	2.235656	.886447	3.581045	.005738	.011477										
WT. MATERIAL		100.000	90.000	80.000	70.000	60.000	50.000	40.000	30.000	20.000	10.000				
WT. AIR		.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000				

---COMBUSTION CONDITIONS: THE MATERIAL AND AIR ARE BURNED TOGETHER AT 1000.00 PSI---

FLAME TEMP. T(K)	2393.249	2450.426	2510.721	2574.620	2641.668	2705.540	2718.260	2434.207	1852.052	1149.821
FLAME TEMP. T(F)	3948.448	3951.367	4059.898	4174.916	4295.603	4410.571	4433.468	3922.173	2874.293	1610.278
ENTHALPY KCAL/GFW	-62.960	-56.664	-50.368	-44.072	-37.776	-31.480	-25.184	-18.888	-12.592	-6.296

---COMBUSTION CONDITIONS: THE COMBUSTION PRODUCTS FROM MATERIAL AND AIR AFTER EXPANDING FROM 1000.00 PSI TO 14.70 PSI---

FLAME TEMP. T(K)	1063.824	1091.934	1122.740	1156.115	1192.398	1232.487	1278.873	1070.313	729.779	394.570
FLAME TEMP. T(F)	1455.482	1506.081	1561.532	1621.607	1686.916	1759.077	1842.571	1467.163	954.203	250.825
ENTHALPY KCAL/GFW	-118.997	-112.418	-105.844	-99.278	-92.726	-86.192	-79.601	-65.781	-47.044	-26.826
T. VOL. GASES--LITERS	91.381	98.429	107.210	118.494	133.532	154.583	186.200	247.743	377.725	767.660
(GASES AT STP)										
COMBUSTION PRODUCTS ROUNDED OFF TO										1.00E-04

-----GRAMS PRODUCTS/100 GRAMS (GS/G) MATERIAL BURNED-----

CO	38.8197	36.6515	34.2867	30.8148	25.8944	18.4169	6.1288	.0001	.0001	.0003
CO2	37.3446	40.4660	44.5042	49.9687	57.6968	69.4374	88.7484	98.3885	98.3880	98.3785
N2	12.4160	21.1774	32.1291	46.2097	64.9837	91.2673	130.6923	196.3967	327.8174	722.0681
H2O	8.7764	10.1333	11.7846	13.8030	16.3885	19.4363	23.3636	24.9233	24.9223	24.9194
H2	1.7929	1.6438	1.4599	1.2344	.9541	.6042	.1684	.0000	.0000	.0000
H2O	.5986	.5967	.5949	.5937	.5940	.5991	.6141	.6423	.0007	.0006
H2S	.1859	.1855	.1850	.1843	.1832	.1808	.1174	.0001	.0002	.0003
H	.6301	.6318	.6334	.6344	.6343	.6313	.6290	.0001	.0002	.0004
CS2	.0163	.0169	.0176	.0187	.0203	.0226	.0168	.0002	.0003	.0006
CH4	.0148	.0042	.0010	.0002	.0000	.0000	.0000	.0001	.0001	.0002
HCN	.0021	.0013	.0007	.0003	.0001	.0001	.0002	.0002	.0001	.0002
NH3	.0009	.0008	.0007	.0005	.0003	.0001	.0000	.0001	.0001	.0002
K2O4	.0001	.0001	.0001	.0001	.0002	.0002	.0002	.0003	.0005	.0009
S2O	.0001	.0001	.0001	.0001	.0001	.0002	.0002	.0003	.0004	.0008
S2S	.0001	.0001	.0001	.0001	.0001	.0002	.0002	.0003	.0004	.0008
SS2	.0001	.0001	.0001	.0001	.0001	.0002	.0002	.0003	.0004	.0008
S2	.0001	.0001	.0001	.0001	.0001	.0004	.0048	.0002	.0003	.0006
S2O	.0001	.0001	.0001	.0001	.0001	.0011	.1253	.3153	.3631	.3587
C4H10	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0002	.0003	.0006
C4H8	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0002	.0003	.0006
KH04	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0002	.0003	.0006
KH06	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0002	.0003	.0006
KH07	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0002	.0003	.0006
K0	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0002	.0003	.0006
SO	.0000	.0001	.0001	.0001	.0001	.0001	.0005	.0002	.0002	.0005
OS	.0000	.0001	.0001	.0001	.0001	.0001	.0001	.0002	.0002	.0005

C3H8	.0000	.0000	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0002	.0004
CS	.0000	.0000	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0002	.0004
C3H6	.0000	.0000	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0002	.0004
KH	.0000	.0000	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0002	.0004
CNH	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0001	.0003
HS	.0000	.0000	.0000	.0001	.0002	.0004	.0008	.0001	.0002	.0003	
HD2	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0001	.0002	.0003
S	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0002	.0003	
O2	.0000	.0000	.0000	.0000	.0001	.0001	.0001	12.5908	47.8604	153.6181	
NH3	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0002	.0003	
C2H6	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0002	.0003	
CH2O	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0002	.0003	
NO	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0002	.0003	
CHO	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0003	
C2H4	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0003	
C2H2	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0003	
H2O ⁺	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0003	
HG	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0002	
HO	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0002	
O	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0002	
NH	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0002	
CH2	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0002	
H	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	
CH	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	
C	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	
Cl	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	
Cl	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	

---LIST OF TOTAL COMBUSTION PRODUCTS CONSIDERED---

CO	CO2	N2	H2O	H2	KHO	H2S	K	CSO	CH4	KCN	NH3	K2O	S2O	SO3
CS2	S2	SO2	C4H10	C4H8	KHO2	KHO2	KHO ⁺	KO	SO	O3	NS	NO2	C3H8	CS
C3H6	KH	CNH	HS	HD2	S	O2	NH3	C2H6	CH2O	NO	CHO	C2H4	C2H2	H2O ⁺
HC	HO	O	NH	CH2	N	CH	C	Cl	Cl	H				

OPEN BURN---MATERIAL DOES NOT DETONATE BEFORE REACTING WITH AIR---
 MATERIAL=M444 HE 105mm HOWITZER

H C N O

NITROCELLULOSE-12.51	.008	.006	.002	.010	.000	.000	.000	.000	.000	.000	.000	.000	.000	54.160	-25.	.0600
DINITROSTOLUENE - DNT	.006	.007	.001	.004	.000	.000	.000	.000	.000	.000	.000	.000	.000	9.900	-51.	.0415
DIPHENYLAMINE - DPA	.011	.012	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.990	175.	.0415
DIETHYLPHTHALATE-DEP	.022	.016	.000	.004	.000	.000	.000	.000	.000	.000	.000	.000	.000	4.950	-727.	.0375
AIR -15	.000	.000	.006	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	0.	.0000

1.0000

GRAM ATOM AMOUNTS FOR MATERIAL WEIGHT OF 100.000

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
0.11436	0.56577	.571514	0.347270										
WT. MATERIAL	100.000	70.000	30.000	70.000	60.000	50.000	40.000	30.000	20.000	10.000			
WT. AIR	.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000			

---COMBUSTION CONDITIONS: THE MATERIAL AND AIR ARE BURNED TOGETHER AT 1000.00 PSI---

FLAME TEMP. T(1)	1875.120	1936.197	2040.235	2150.964	2249.433	2396.818	2532.215	2627.554	2103.524	1710.374
FLAME TEMP. T(2)	2549.216	3023.755	3213.079	3412.733	3625.580	3854.873	4096.587	4267.052	3367.127	1895.273
ENTHALPY KCAL/GR	-56.573	-50.921	-45.264	-39.606	-33.948	-28.290	-22.632	-16.974	-11.316	-5.658

---COMBUSTION CONDITIONS: THE COMBUSTION PRODUCTS FROM MATERIAL AND AIR AFTER EXPANDING FROM 1000.00 PSI TO 14.70 PSI---

FLAME TEMP. T(1)	956.465	956.634	949.258	940.445	970.365	1031.626	1101.332	1182.882	868.285	661.844
FLAME TEMP. T(2)	1231.244	1321.141	1349.245	1336.802	1292.657	1397.526	1522.977	1669.758	1103.513	671.915
ENTHALPY KCAL/GR	-104.605	-95.078	-73.738	-56.597	-35.595	-76.641	-73.707	-48.755	-51.387	-29.285

COMBUSTION PRODUCTS BOUNDED OFF TO 1.00E-04

-----GASEOUS PRODUCTS FROM OPEN BURN OF MATERIAL BURNED-----

H2	1.1577	45.1245	44.9728	40.8810	40.4484	34.3274	24.6947	5.7591	.0001	.0007
CO	11.9577	74.0274	73.1251	40.7022	50.1120	59.6847	73.1377	104.6434	113.9570	113.9570
CO2	11.9577	11.9577	11.9577	48.8575	64.7714	81.0370	100.4825	191.1217	327.6075	721.5551
CH4	1.1574	1.7953	6.1114	1.7711	9.1230	17.0507	15.4257	25.7117	25.0512	25.0421
C2H6	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0001	1.0001
C2H4	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C3H8	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C3H6	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C4H10	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C4H8	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C5H12	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C5H10	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C6H14	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C6H12	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C7H16	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C7H14	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C8H18	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C8H16	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C9H20	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C9H18	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C10H22	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C10H20	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C11H24	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C11H22	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C12H26	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C12H24	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C13H28	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C13H26	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C14H30	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C14H28	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C15H34	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C15H32	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C16H38	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C16H36	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C17H42	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C17H40	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C18H46	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C18H44	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C19H50	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C19H48	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C20H54	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C20H52	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C21H58	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C21H56	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C22H62	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C22H60	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C23H66	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C23H64	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C24H70	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C24H68	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C25H74	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C25H72	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C26H78	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C26H76	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C27H82	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C27H80	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C28H86	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C28H84	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C29H90	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C29H88	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C30H94	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C30H92	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C31H98	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C31H96	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C32H102	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C32H100	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C33H106	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C33H104	1.1575	1.5701	1.5701	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
C34H110	1.1575	1.5701	1.5701	1.0000	1.0000	1.000				

OPEN BURN---MATERIAL DOES NOT DETONATE BEFORE REACTING WITH AIR---
 MATERIAL-CARTRIDGE CTG 105 == HE M-1 PROPELLING CHARGE

	H	C	N	O													
NITROCELLULOSE(12.6)	.008	.006	.002	.010	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	85.000	-625.	.0600
DINITROTOLUENE - DNT	.006	.007	.002	.004	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	10.000	-58.	.0419
DIPHENYLAMINE - DPA	.011	.012	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	1.000	178.	.0419
DIBUTYLPHTHALATE-DBP	.022	.016	.000	.004	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	4.000	-727.	.0378
ATR	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	0.	.0000

GRAM ATOM AMOUNTS FOR MATERIAL WEIGHT OF 100.000

	(H)	(C)	(N)	(O)											
WT. MATERIAL	3.066508	2.557427	.090226	3.366344	100.000	90.000	80.000	70.000	60.000	50.000	40.000	30.000	20.000	10.000	
WT. ATR	.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000					

---COMBUSTION CONDITIONS: THE MATERIAL AND ATR ARE BURNED TOGETHER AT 1000.00 PSI---

FLAME TEMP. T(K)	1903.572	1997.100	2096.256	2201.791	2314.697	2435.902	2563.367	2626.737	2181.369	1296.817
FLAME TEMP. T(F)	2967.030	3135.380	3315.861	3503.823	3707.054	3925.223	4154.661	4269.726	3323.065	1874.870
ENTHALPY KCAL/GFW	-56.418	-50.776	-45.134	-39.493	-33.851	-28.209	-22.567	-16.925	-11.284	-5.642

---COMBUSTION CONDITIONS: THE COMBUSTION PRODUCTS FROM MATERIAL AND ATR AFTER EXPANDING FROM 1000.00 PSI TO 14.70 PSI

FLAME TEMP. T(K)	966.777	952.654	949.402	955.895	993.826	1032.551	1119.717	1199.799	956.187	455.945
FLAME TEMP. T(F)	1280.799	1268.177	1249.524	1261.211	1329.488	1435.191	1556.091	1700.238	1081.736	361.301
ENTHALPY KCAL/GFW	-105.300	-99.797	-94.461	-89.290	-84.205	-79.147	-74.107	-69.012	-50.879	-29.004
T.VOL. GASES--LITERS	99.722	106.763	115.557	127.793	143.647	164.819	196.404	249.034	376.802	766.743
GASES AT STP:										
COMBUSTION PRODUCTS ROUNDED OFF TO										1.00E-04

----GRAMS PRODUCTS/100 GRAMS (85%) MATERIAL BURNED----

CO	45.4662	45.3770	45.0302	45.1958	39.3861	33.2782	23.2142	3.9290	.0001	.000
CO2	31.6453	34.6575	38.5762	43.7623	50.5469	60.2596	76.0773	106.5346	112.5463	112.54
N2	12.3281	21.0885	32.0397	46.1202	64.8949	91.1793	130.6050	196.3138	327.7299	721.98
H2O	5.4838	5.7342	6.0565	7.2430	9.8008	13.7205	19.1535	26.5315	27.6266	27.61
H2	2.3021	2.2753	2.2422	2.1954	1.9817	1.5545	.9473	.1219	.0000	.00
O2	2.0553	1.2671	.3723	.0000	.0000	.0000	.0000	.0000	.0001	.00
CH4	.6955	.6865	.6762	.3359	.0446	.0021	.0000	.0000	.0001	.00
HCN	.0034	.0030	.0033	.0035	.0024	.0012	.0004	.0001	.0001	.00
CNH	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0002	.0003
C4H10	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0002	.0002
C4H6	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0002	.0002
CS	.0000	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0002
H2O2	.0000	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0002
C5H8	.0000	.0000	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0002
C5H6	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0001	.0002
H2O2	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0001	.0002
O2	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0001	.0002
H2O	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0001	.0002
C2H6	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0001	.0002
CH2O	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001	.0001	.0002
H2	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001
CH2	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001
C2H4	.0000	.0000	.0000	.0000	.0000	.0000	.0001	.0001	.0001	.0001

APPENDIX C-2

TCLP RESULTS FOR ASH RESIDUE FROM BURN

LAB SAMPLE ID : 40863

DATE : Nov 12, 1991

U.S.M.A. Westpoint
R.E. Warringer
MAEN-EV
Westpoint, NY 10996

SAMPLE SOURCE	: RESIDUE FROM GUN POWDER
ORIGIN	: 40861 <i>92-54</i>
DESCRIPTION	: ZHE EXTRACT
SAMPLED ON	: 10/25/91
DATE RECEIVED	: 11/04/91
PWS ID	: Contract # DAAG60-91-M-7362

* Key	Method	Analyst	Date Analyzed	Notebook Reference
1	SW846/8010/8020/8015/5030	PC	11/10/91	91-229-054

Compound Detected	Concentration	Units	Key *
Benzene	ND<0.02	mg/L	1
Trichloroethene	ND<0.02	mg/L	1
Tetrachloroethene	ND<0.02	mg/L	1
Chlorobenzene	ND<0.02	mg/L	1
1,4-Dichlorobenzene	ND<0.02	mg/L	1
Vinyl Chloride	ND<0.02	mg/L	1
1,1-Dichloroethene	ND<0.02	mg/L	1
Chloroform	ND<0.02	mg/L	1
Carbon Tetrachloride	ND<0.02	mg/L	1
1,2-Dichloroethane	ND<0.02	mg/L	1
Methyl ethyl ketone	ND<0.10	mg/L	1

For questions regarding this report, please call and ask for Linda Shoemaker, Manager, Customer/Technical Services.

The reported concentrations are those in the leachate resulting from the extraction procedure. This material ~~IS~~ **IS NOT** toxic according to EPA 1311 for the listed analytes.

APPROVED BY:

Judith A. Siliti
MANAGER

The information in this report is accurate to the best of our knowledge and ability. In no event shall our liability exceed the cost of these services. Your samples will be discarded after 14 days unless we are advised otherwise.

DATE : Nov 18, 1991

LAB SAMPLE ID : 40862

U.S.M.A. Westpoint
 R.E. Warringer
 MAEN-EV
 Westpoint, NY 10996

SAMPLE SOURCE	: RESIDUE FROM GUN POWDER
ORIGIN	: 40861
DESCRIPTION	: TCLP EXTRACT
SAMPLED ON	: 10/25/91
DATE RECEIVED	: 11/04/91
PWS ID	: Contract # DAAG60-91-M-7362

ANALYSIS	RESULT	UNITS	DATE	ANALYSIS DONE BY
METROD 8270				
Pyridine	ND<0.1	ng/l	11/11/91	LAB ID 10145
1,4-Dichlorobenzene	ND<0.05	ng/l		
o-Cresol	ND<0.1	ng/l		
m,p-Cresol	ND<0.1	ng/l		
Hexachloroethane	ND<0.05	ng/l		
Nitrobenzene	ND<0.05	ng/l		
Hexachlorobutadiene	ND<0.05	ng/l		
2,4,5-Trichlorophenol	ND<0.1	ng/l		
2,4,5-Trichlorophenol	ND<0.1	ng/l		
2,4-Dinitrotoluene	ND<0.05	ng/l		
Hexachlorobenzene	ND<0.05	ng/l		
Pentachlorophenol	ND<0.2	ng/l		

For questions regarding this report, please call and ask for Linda Shoemaker, Manager, Customer/Technical Services.

cc :

APPROVED BY

Ludsey B...
 MANAGER

The information in this report is accurate to the best of our knowledge and ability. We warrant only our liability except the cost of these services. Your samples will be discarded after 14 days unless we are advised otherwise.

LAB SAMPLE ID : 40862

DATE : Nov 14, 1991

U.S.M.A. Westpoint
R.E. Warringer
MAEN-EV
Westpoint, NY 10996

SAMPLE SOURCE	: RESIDUE FROM GUN POWDER
ORIGIN	: 40861
DESCRIPTION	: TCLP EXTRACT
SAMPLED ON	: 10/25/91
DATE RECEIVED	: 11/04/91
PWS ID	: Contract # DAAG60-91-M-7362

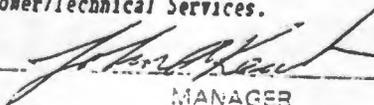
Analysis Performed	Result	Units	Maximum Contaminant Level	Date Analyzed	Method	Notebook Reference
Arsenic	ND<1.22	ng/L	5.0	11/11/91	EPA 6010	91-230-3
Barium	0.040	ng/L	100.0	11/11/91	EPA 6010	91-230-3
Cadmium	0.134	ng/L	1.0	11/11/91	EPA 6010	91-230-3
Chromium	ND<0.300	ng/L	5.0	11/11/91	EPA 6010	91-230-3
Lead	497	ng/L	5.0	11/11/91	EPA 6010	91-230-3
Mercury	ND<0.02	ng/L	0.2	11/06/91	EPA 7470	91-081-11
Selenium	ND<0.700	ng/L	1.0	11/11/91	EPA 6010	91-230-3
Silver	ND<0.060	ng/L	5.0	11/11/91	EPA 6010	91-230-3

The reported concentrations are those in the leachate resulting from the extraction procedure.
This material ~~IS~~ IS NOT toxic according to EPA 1311 for the listed analytes.

For questions regarding this report, please call and ask for Linda Shoemaker, Manager, Customer/Technical Services.

cc :

APPROVED BY


MANAGER

The information in this report is accurate to the best of our knowledge and ability. In no event shall our liability exceed the cost of these services. Your samples will be destroyed after 90 days unless we are notified otherwise.

LAB # 3252 PA LAB # 58160 NJ LAB # 73162 MA LAB # 10000000

ORIGINAL

R. LAB EPA LAB

NY LAB

LAB SAMPLE ID : 40861

DATE : Nov 7, 1991

U.S.M.A. Westpoint
R.E. Warringer
MAEN-EV
Westpoint, NY 10996

SAMPLE SOURCE	RESIDUE FROM GUN POWDER
ORIGIN	92-54
DESCRIPTION	GRAB
SAMPLED ON	10/25/91
DATE RECEIVED	11/04/91
PWS ID	Contract # DAAG60-91-M7362

Analysis Performed	Result	Units	Date Analyzed	Method	Notebook Reference
TCLP Extraction	*		11/05/91	EPA 1311	91-158-119
ZNE Extraction	*		11/06/91	EPA 1311	91-111-25
% Total Solids	100	percent	11/05/91	EPA 1311	91-158-119

For questions regarding this report, please call and ask for Linda Shoemaker, Manager, Customer/Technical Services.

APPROVED BY:


MANAGER

The information in this report is accurate to the best of our knowledge and ability. In no event shall our liability exceed the cost of these services. Your samples will be discarded after 14 days unless we are advised otherwise.

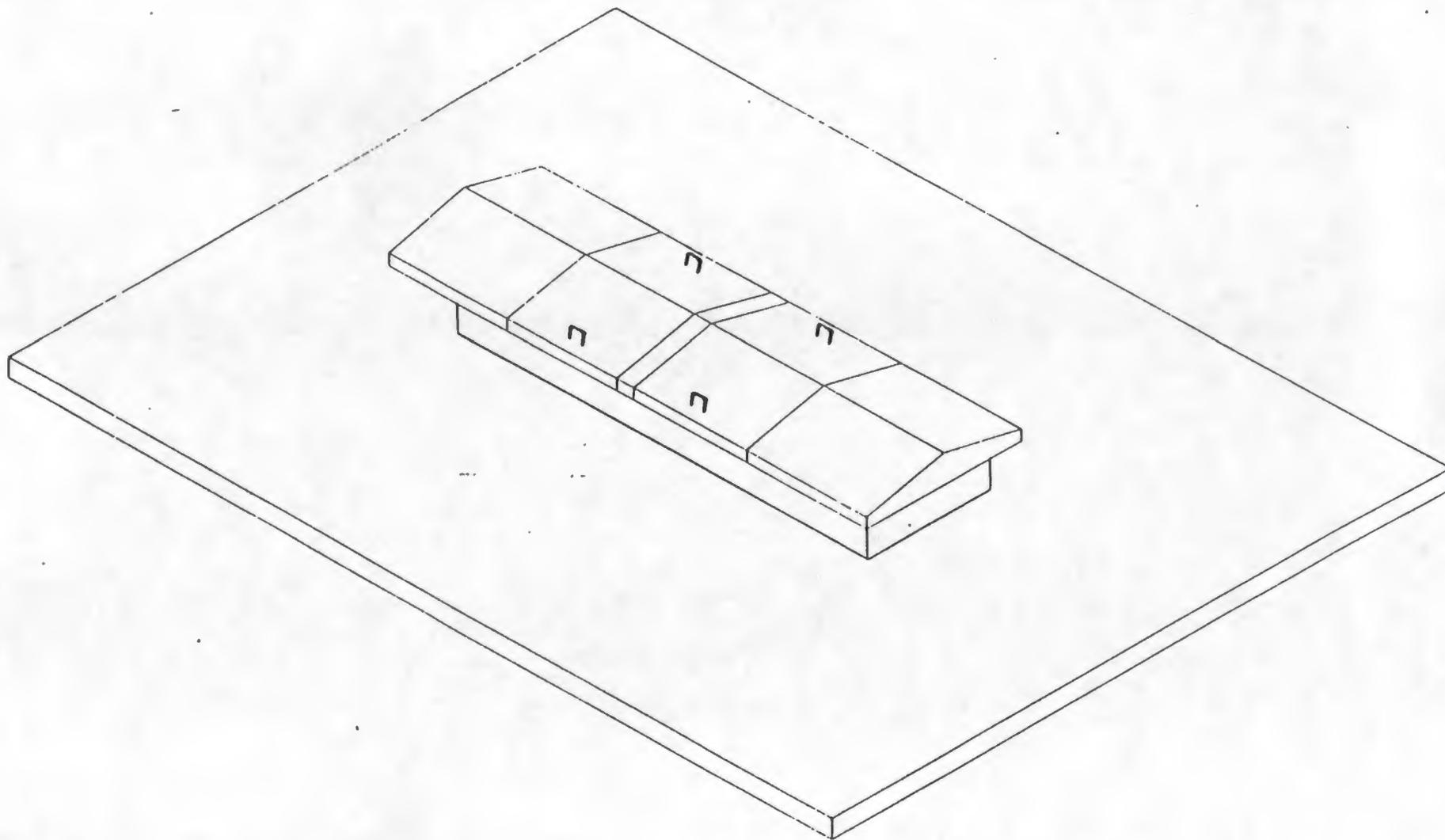
LAB # 10252 PA LAB # 68180 NJ LAB # 73168 MA LAB # AA000046

ORIGINAL

RI LAB # AAL-049C3 EPA LAB # NY 032 NYCLAP # 1350

APPENDIX D-1

BURN ASSEMBLY DRAWING



 **HALLIBURTON NUS**
Environmental Corporation

861 ANDERSEN DRIVE
PITTSBURGH, PA 15220

CLIENT
USMA

DATE
JULY 8, 1992

ACFILE NAME
3N87\ PAPER.DWG

CONTRACT
3N87

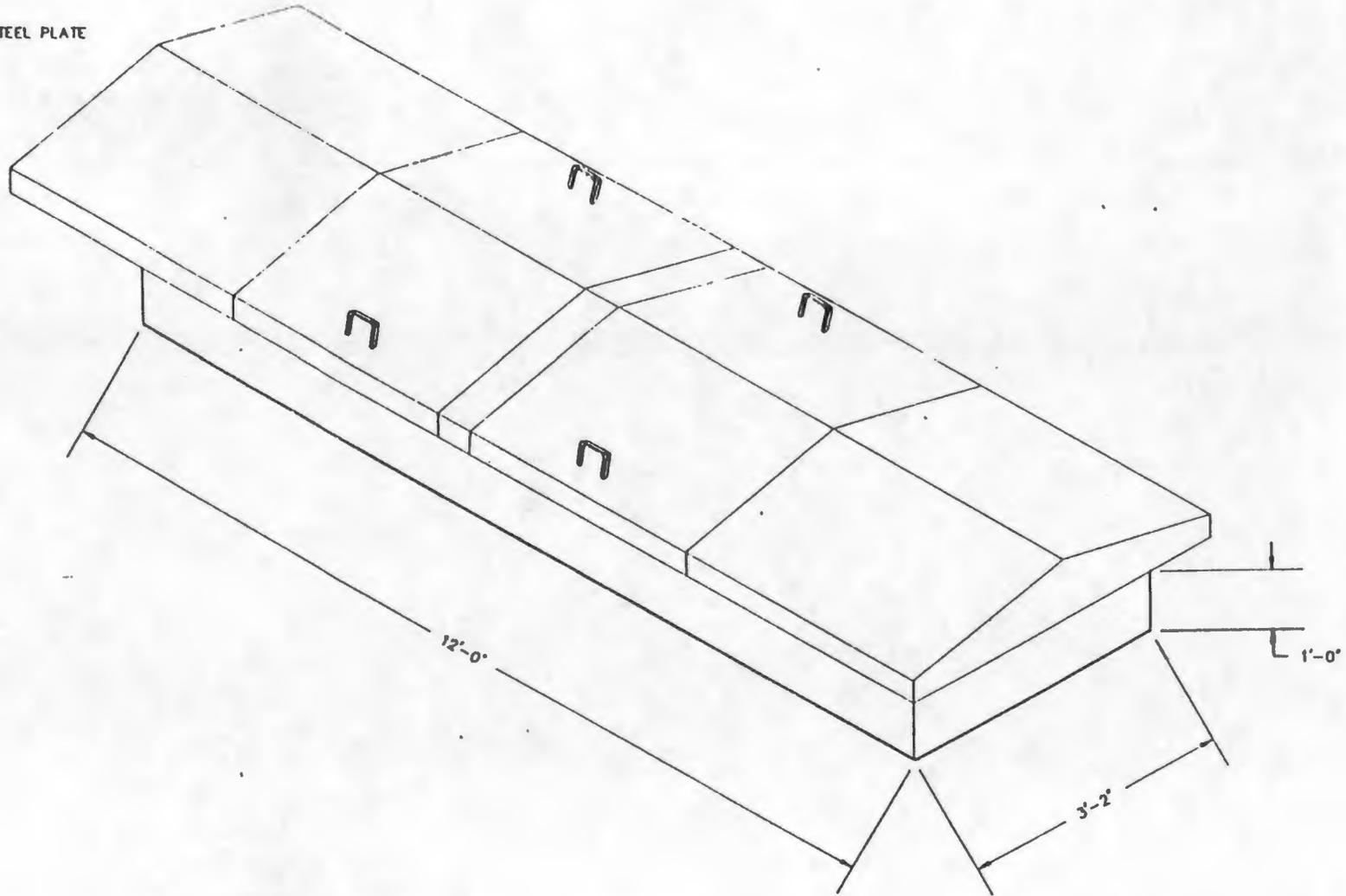
SHEET **1** OF **6**

REV.
0

**BURNING TRAY ASSEMBLY
FOR PROPELLANTS**

UNITED STATES MILITARY ACADEMY WEST POINT, NY

NOTES:
 1. MATERIAL, STEEL PLATE



HALLIBURTON NUS
 Environmental Corporation

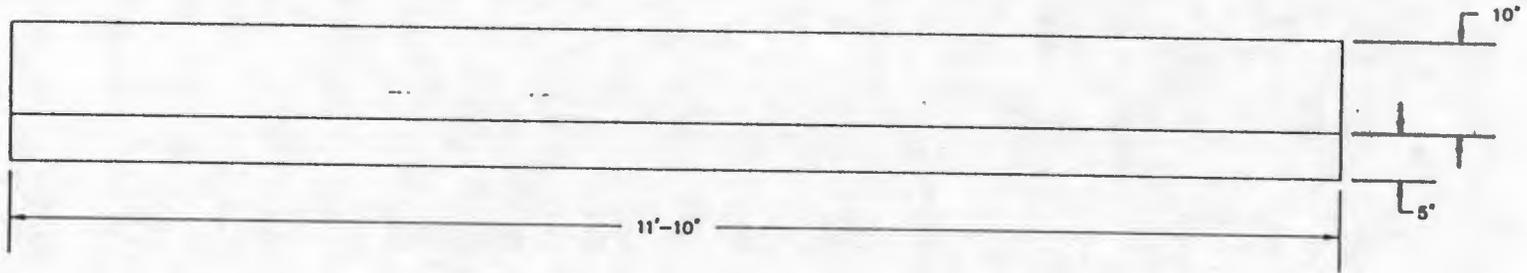
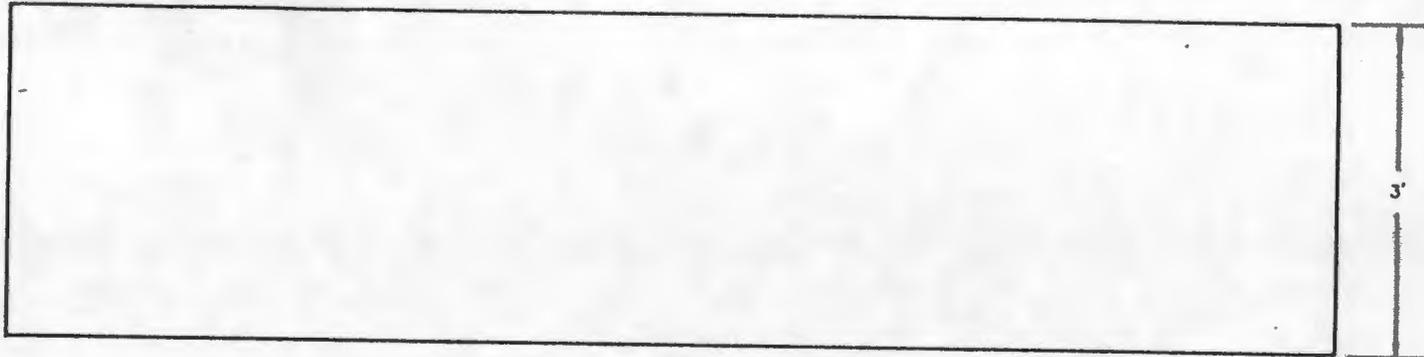
661 ANDERSEN DRIVE
 PITTSBURGH, PA 15220

CLIENT	USMA	CONTRACT	3N87
DATE	JULY 8, 1992	SHEET	2 OF 6
ACFILE NAME	3N87\ PAPER.DWG	REV.	0

**BURNING TRAY
 FOR PROPELLANTS**

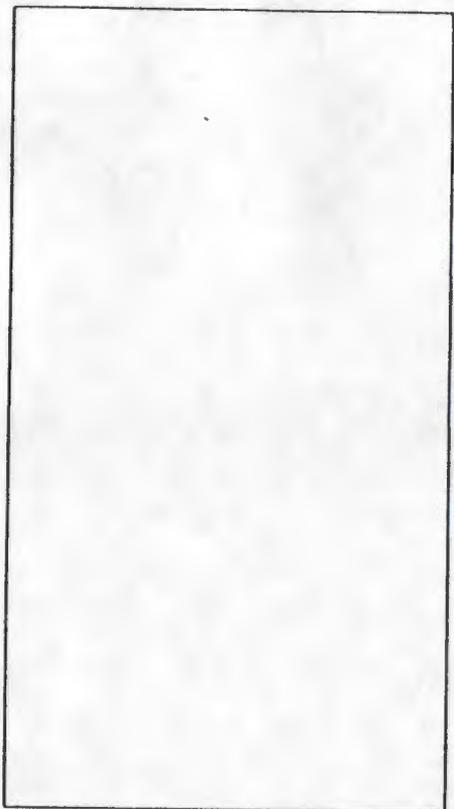
UNITED STATES MILITARY ACADEMY WEST POINT, NY

NOTES:
1. MATERIAL, STEEL PLATE

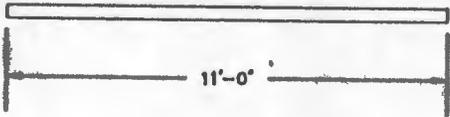


881 ANDERSEN DRIVE
PITTSBURGH, PA 15220

CLIENT USMA	CONTRACT 3N87	INTERIOR BURNING TRAY
DATE JULY 8, 1992	SHEET 3 OF 6	
ACFILE NAME 3N87\ PAPER.DWG	REV. 0	
		UNITED STATES MILITARY ACADEMY WEST POINT, NY



20'-0"



4"



NOTES:
 1. MATERIAL, CONCRETE



661 ANDERSEN DRIVE
 PITTSBURGH, PA 15220

CLIENT
 USMA

CONTRACT
 3N87

DATE
 JULY 8, 1992

SHEET 4 OF 6

ACFILE NAME
 3N87\ PAPER.DWG

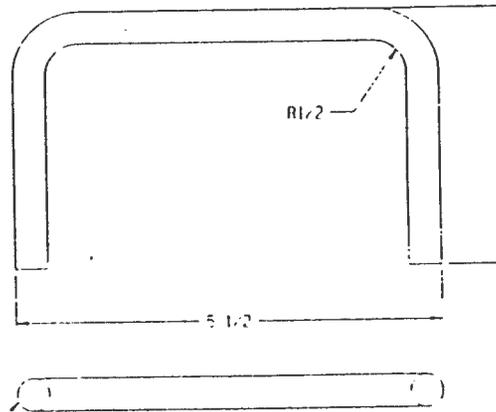
REV.
 0

CONCRETE PAD

UNITED STATES MILITARY ACADEMY WEST POINT, NY

NOTES:

1. MATERIAL, ALUMINUM BAR PER 6061-T6 OR EQUAL



661 ANDERSEN DRIVE
PITTSBURGH, PA 15220

CLIENT
USMA

DATE
JULY 8, 1992

ACFILE NAME
3N87\ PAPER.DWG

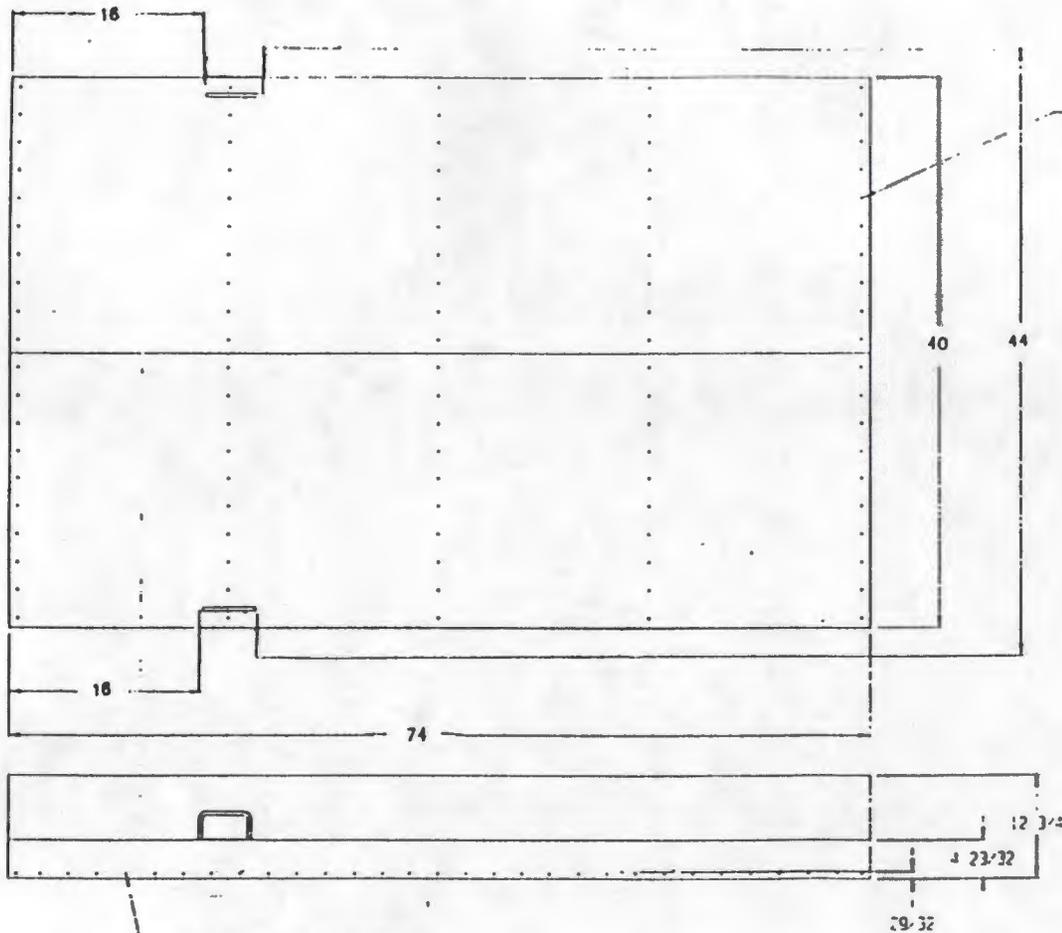
CONTRACT
3N87

SHEET **5** OF **6**

REV.
0

**BURNING TRAY
COVER HANDLE**

UNITED STATES MILITARY ACADEMY WEST POINT, NY



DRILL 9/32 THRU AT PILOT HOLE
LOCATIONS AND INSTALL SS
MS20470- RIVETS EACH SIDE

DRILL 9/32 THRU AT PILOT HOLE
LOCATIONS AND INSTALL SS
MS20470- RIVETS EACH SIDE

 **HALLIBURTON NUS**
Environmental Corporation

861 ANDERSEN DRIVE
PITTSBURGH, PA 15220

CLIENT	USMA	CONTRACT	3N87
DATE	JULY 8, 1992	SHEET	6 OF 6
ACFILE NAME	3N87\ PAPER.DWG	REV.	0

**ONE-HALF OF BURNING TRAY
COVER ASSEMBLY**

UNITED STATES MILITARY ACADEMY WEST POINT, NY

COMPUTER PREDICTIONS OF POLLUTION PRODUCTS FROM OPEN BURN
AND OPEN DETONATION OF NAVY EXPLOSIVES AND PROPELLANTS

EDWARD E. BAROODY

NAVAL SURFACE WEAPONS CENTER/WHITE OAK

and

IVAN L. TOMINACK

HEAD, ORDNANCE ENVIRONMENTAL SUPPORT OFFICE

NAVAL ORDNANCE STATION, INDIAN HEAD, MD

JANUARY 1987

APPENDIX F-1

USMA FIRE DEPARTMENT EQUIPMENT LIST

ENGINE 1 - INVENTORY
1000 GPM PUMP

COMPARTMENT 1	1 - 6" Hard Suction Strainer
	2 - Hose Straps
	1 - Manhole Hook
	2 - 4" Spanner Wrenches
	2 - 2-1/2" Spanner Wrenches
	1 - Hydrant Wrench
	1 - Rubber Mallet
COMPARTMENT 2	1 - Air Pack
	1 - Manhole Hook
	1 - Wire Cutter
	1 - Bolt Cutter
	1 - Underground Hyd Wrench
COMPARTMENT 3	3 - 2-1/2" Dbl Females
	2 - 2-1/2" Dbl Males
	2 - 2-1/2" Nozzles
	1 - 1-1/2" Nozzle
	1 - Bressnen Distributor
	1 - Chimney Nozzle
	1 - Master Stream Set (Straight)
COMPARTMENT 4	4 - Air Pack Bottles
COMPARTMENT 5	1 - 4" Stortz to 2-1/2" Gated Manifold
	4 - 1-1/2" Dbl Males
	5 - 1-1/2" Dbl Females
	1 - 50' Section 2-1/2" Hose
COMPARTMENT 6	1 - Smoke Ejector/Adaptor
	1 - Ejector Hanging Bracket
	1 - Triple Twist

ENGINE 1 - INVENTORY
1000 GPM PUMP

COMPARTMENT 7	1 - Standpipe Pack
	1 - 2-1/2 Gal. AFFF Ext.
	1 - Box Road Flares
	1 - Sprinkler Kit
	1 - Closet Hook
	1 - Hose/Air Inflation Device
COMPARTMENT 8	1 - Standpipe Adaptor Bag
	1 - 2-1/2" Gal. Water Ext.
	1 - Dry Chemical Ext.
	1 - 10 lb. CO ₂ Ext.
	1 - Tool Box
	1 - 50' Utility Rope
COMPARTMENT 9	1 - 5 Gal. Can of Speedi Dry
	2 - 5 Gal. Can of AFFF
	1 - Foam Eductor
	1 - 4" Hose Roller

Dated: 9/18/90

**ENGINE 5 - INVENTORY
1000 GPM PUMP**

REAR MIDDLE COMPARTMENT ABOVE WHEEL WELL	1 - 2-1/2" 250 GPM Variable Nozzle
	2 - 1-1/2" 250 GPM Variable Nozzle
	2 - 2-1/2" x 1-1/2" x 1-1/2" Gate Wye
	3 - 2-1/2" Double Female
	2 - 1-1/2" Double Female
	1 - 1-1/2" Double Male
	1 - 2-1/2" 1,000 GPM Variable
	1 - 2-1/2" Celler Nozzle
	1 - 2-1/2" x 1-1/2" Female to Male
	2 - 2-1/2" Double Males
	1 - 1-1/2" Akron Pistol Grip Home Made Nozzle
	TOP COMPARTMENT REAR OF PUMP PANEL
1 - Lifeguard	
BOTTOM COMPARTMENT REAR OF PUMP PANEL	1 - 4" to 2-1/2" x 2-1/2" x 2-1/2" Manifold
	1 - Wooden Wheel Chock
	1 - Hose Roller
	1 - Hydrant Wrench
	1 - 100' 3" Hose
LEFT FRONT COMPARTMENT	2 - Spanner Mounted on Interior of Door
	2 - 4-1/2" Female x 4" Female
	1 - 4-1/2" Intake Cap
	1 - 2-1/2" Female to 2-1/2" Male Gate
	1 - 1-1/2" 250 GPM Variable Nozzle
	2 - 1-1/2" x 1-1/2" Double Female
	1 - 1-1/2" x 1-1/2" Double Male
	3 - 2-1/2" DFM

ENGINE 5 - INVENTORY
1000 GPM PUMP

REAR STEP AREA	1 - 2-1/2" Gallon AFFF Ext.
	1 - 2-1/2" x 1-1/2" x 1-1/2" Gated Wye Mounted to Discharge #7
	1 - Canvas Hydrant Bag Containing: <ul style="list-style-type: none"> • 2 - 4" Spanner Wrenches • 1 - Hydrant Wrench • 3 - 4" x 4" Stortz • 2 - Hose Straps • 1 - 18" Pipe Wrench
HOSE REEL COMPARTMENT	1 - Short Spade
	1 - Hose Reel Manual Crank Handle
	1 - 1-1/2" Variable Nozzle on 200'
	1 - 1" Booster Line
	1 - Hose Clamp Mounted
LEFT REAR TOP COMPARTMENT	4 - 4.5 Scott Bottles
	1 - Adjustable Rod for Hanging Exhaust Fans
LEFT REAR LOWER COMPARTMENT	1 - Electric Reel
	1 - Extension Cord 110V Twist
	1 - Exhaust Fan (Electric) with Twist 110V Plug
	1 - 110 Standard to 110 Twist
	1 - 110V Twist to 110 Standard
	1 - Electric Junction Box
FRONT RIGHT COMPARTMENT	1 - 5/8" Line
	1 - 1/2" Line
	1 - Blue Tarp
	1 - Box Containing Sprinkler Heads, Clamps, Chocks, and Various Wrenches
	1 - Canvas Bag Containing Lineman Gloves
	1 - Wooden Box Containing Flares
	1 - Burlap Bag Containing Hose Inflation Equipment for Water or Ice Rescue

ENGINE 5 - INVENTORY
1000 GPM PUMP

MIDDLE RIGHT COMPARTMENT	1 - 15 lb. CO ₂ Extinguisher
	1 - 2-1/2 Gal. AFFF Ext.
	1 - 10 lb. Dry Powder Ext.
	1 - 2-1/2 Gal. Pressurized Water Ext.
	1 - 2-1/2 Gal. Biosolve Ext.
REAR RIGHT COMPARTMENT	1 - Portable O ₂
	1 - First Aid Kit
	1 - Ambulance Bag Kit
	1 - Bottle Oxygen
	1 - 5 Gal. Can Speedi Dry
MOUNTED ON RIGHT SIDE	1 - 16' Extension Ladder
	1 - 12' Roof Ladder
	1 - Attic Ladder
	1 - 12' Pike Pole
	1 - Sheet Rock Hook
FRONT BUMPER AREA	1 - Stortz 4" to 4-1/2" to 4-1/2" x 4"
	1 - Stortz 4" on Intake
	1 - Pony Length 4" with Stortz Couplings
	1 - 4" Spanner
	1 - Rubber Mallet
	1 - Hydrant Wrench in Tray
	1 - Hydrant Wrench in Holder on Bumper
BEHIND CAB JUMP SEAT AREA/DRIVER'S SIDE	1 - Scott Pak
	1 - Lifeguard
	1 - Handlight
	1 - Flat Hand Ax
	1 - Halogen Tool
	1 - Standpipe Pack

ENGINE 5 - INVENTORY
1000 GPM PUMP

BEHIND CAB JUMP SEAT/PASSENGER SIDE	1 - Scott Pak
	1 - Lifeguard
	1 - Handlight
	1 - Pik Head Ax
CANVAS BAG CONTAINING STANDPIPE TOOLS & FITTINGS	1 - 1-1/2" Adjustable Nozzle
	2 - 1-1/2" x 1-1/2" Reducer
	1 - 1-1/2" x 1-1/2" Double Female
	1 - 1-1/2" x 1-1/2" Double Male
	2 - Standpipe Wrenches
	2 - Brake Light 2-1/2" x 1-1/2" Reducer
	1 - 14" Pipe Wrench
	1 - 1-1/2" Female to 1-1/2" Male Reducer - Brass
	1 - 2-1/2" Female to 2-1/2" Male Reducer - Brass
	2 - Spanner Wrenches
	1 - 2-1/2" to 1-1/2" x 1-1/2" Gated Wye

ENGINE 5 - INVENTORY
1000 GPM PUMP

FRONT LEFT COMPARTMENT	2 - 2-1/2" Double Female
	1 - 2-1/2" Male Cap
	1 - Hack Saw
	1 - Closet Hook
	1 - Ripping Bar
	1 - Large Bolt Cutter
	1 - Manhole Hook
	1 - Gas Shutoff Key
	1 - Hydrant Ratchett Wrench
	1 - Hydrant Wrench
	1 - Rubber Mallet
	1 - Wire Cutter
	4 - 4" Spanner with Mounting
	1 - Spanner
	1 - Double End Box Wrench
	1 - Tool Box Containing 1 - 4' Stortz Intake 200 PSI
	CAB AREA
1 - Handlight	
1 - 4.5 Scott Pak	
1 - Lifeguard	
1 - Set Rubber Gloves	
1 - Pair Goggles	
1 - Roll Barrier Tape	
1 - Hazmat Book	
2 - Sets Keys	
1 - Seatbelt Cutter	
HOSE BED AREA	3 - Garden Rakes
	1 - Brush Rake
	1 - 2-1/2" x 2-1/2" x 1-1/2" Gate

Dated: 05/15/92 -

APPENDIX B

PHOTOGRAPHS TAKEN IN THE OB AREA
MAY 20, 1992

INDEX TO APPENDIX B

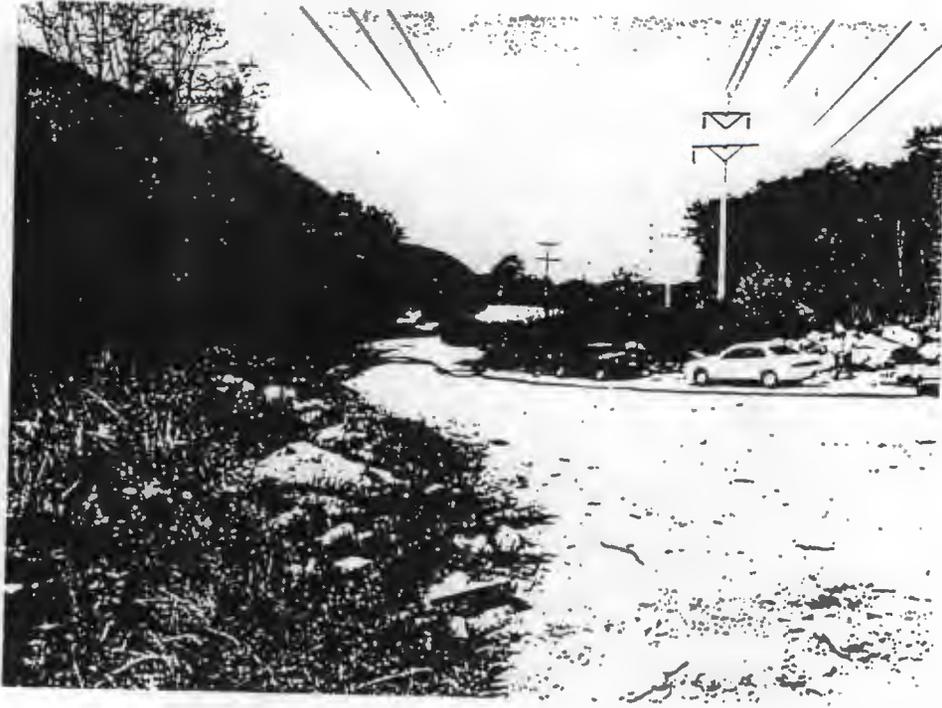
Photograph Number	Description
AB-1	Access Road, locked gate, and warning sign
AB-2	Access Road inside gate, note warning sign and surface water drainage
AB-3	West Grove Road adjacent to OB site
AB-4	West Grove Road upgradient of OB site
AB-5	West Grove Road 200 feet southwest of OB site. Note flow from spring upgradient of OB site.
AB-6	General view of OB site's parking area and pathway to pad. Note rubble pile near center of picture
AB-7	View of OB pad and Burn Pan from top of high wall
AB-8	View of OB pad and Burn Pan from gravel pile. Note flow from spring crossing site.
AB-9	View of OB pad and Burn Pan from parking area. Note flow from spring crossing site
AB-10	Closer view of OB pad and Burn pan from parking area
AB-11	Close-up view of OB pad and Burn Pan looking northeast toward wooded area
AB-12	Close-up view of OB pad and Burn Pan looking southeast toward high wall
AB-13	Close-up view of rubble pile. Barricade is moved to block roadway when OB activity begins.
AB-14	Close-up of pooled water along eastern edge of OB site
AB-15	Close-up of pooled water in wooded area adjacent to OB site
AB-16	Spring flow originating in southwest corner of OB site, flowing north across site
AB-17	Spring flow in southwest corner of OB site, near spring
AB-18	Spring flow in southwest corner of OB site, near its point of origin
AB-19	Close-up of rock strata along high wall. Note 8½ x 11 inch notebook sheet for size comparison



AB-1 - Access Road, Locked Gate, and Warning Sign



AB-2 - Access Road Inside Gate - Note warning sign and surface water drainage.



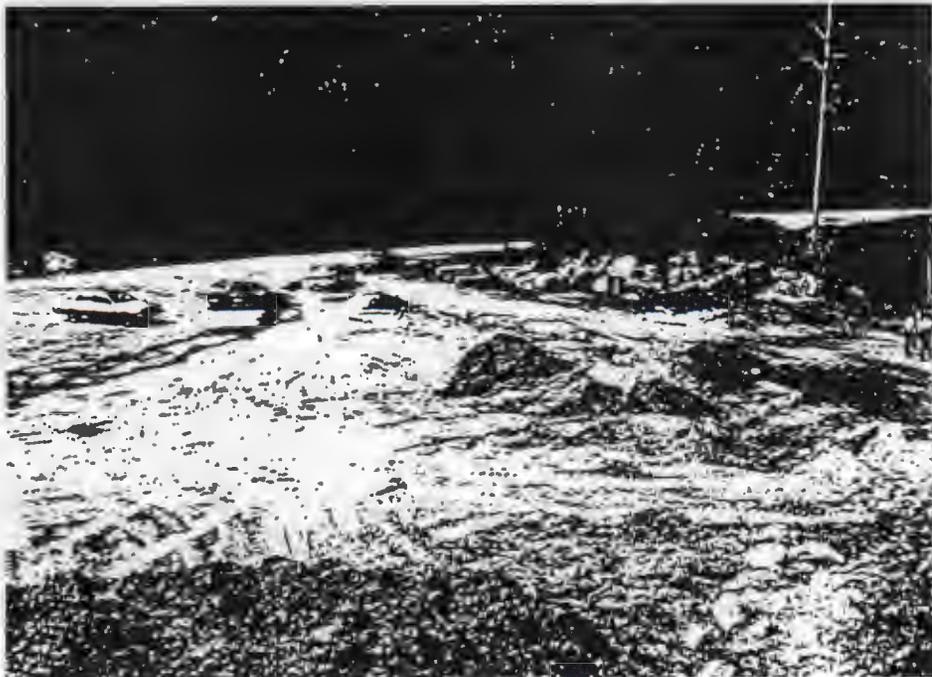
AB-3 - West Grove Road adjacent to OB Site



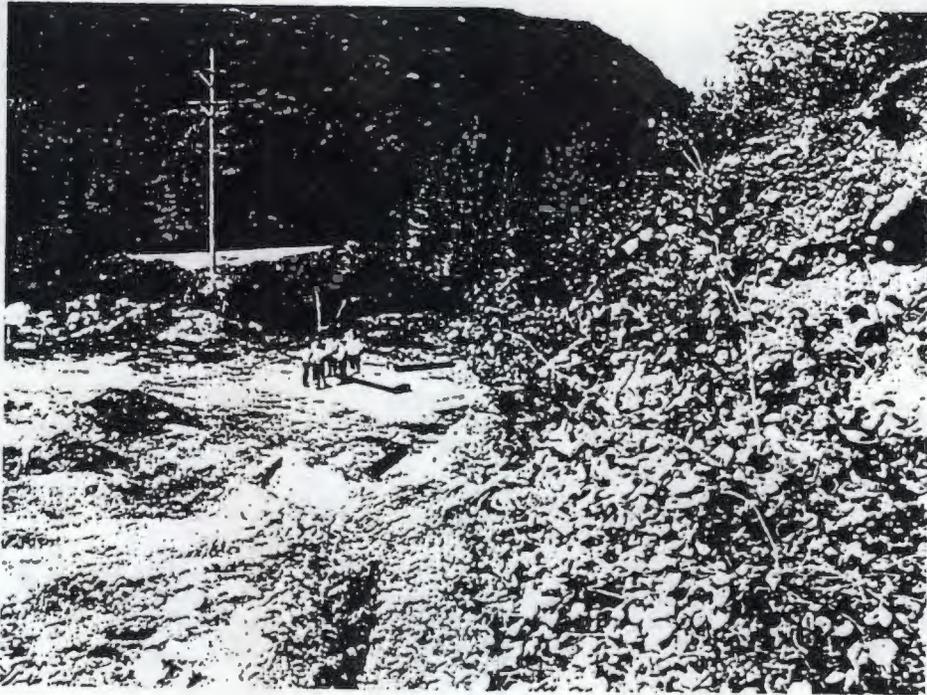
AB-4 - West Grove Road upgradient of OB Site



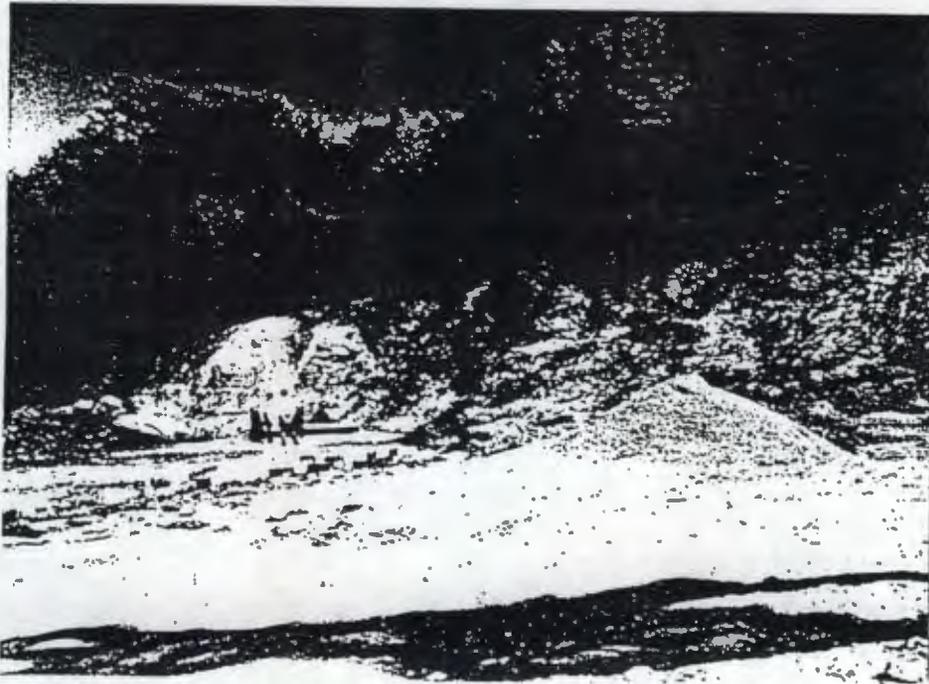
AB-5 - West Grove Road 200 feet southwest of OB Site.
Note flow from spring upgradient of OB Site.



AB-6 - General view of OB Site's parking area and
pathway to pad. Note rubble pile near center
of picture.



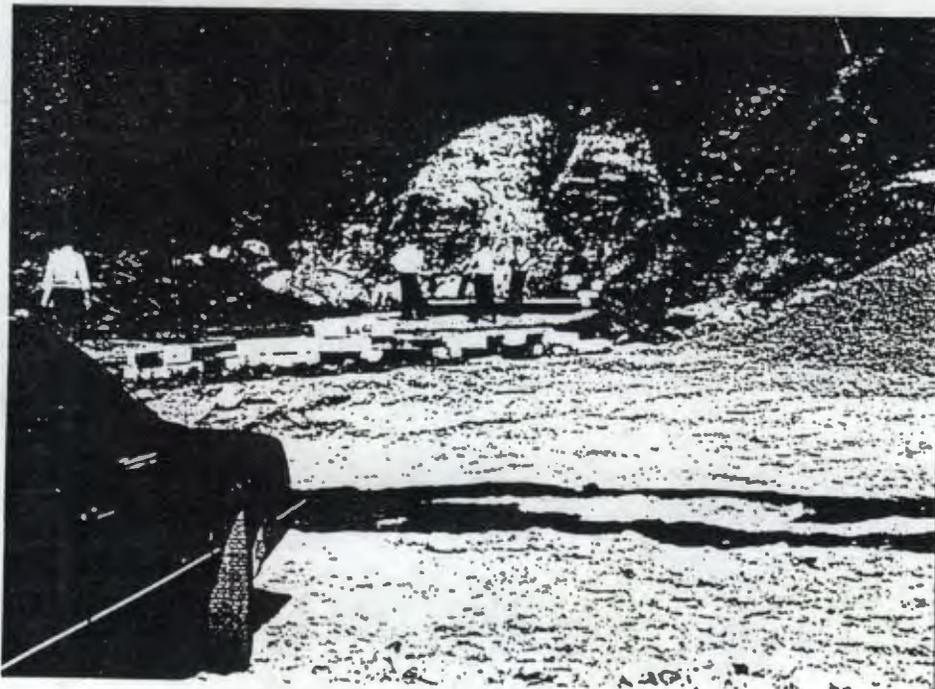
AB-7 - View of OB Pad and Burn Pan from top of highwall.



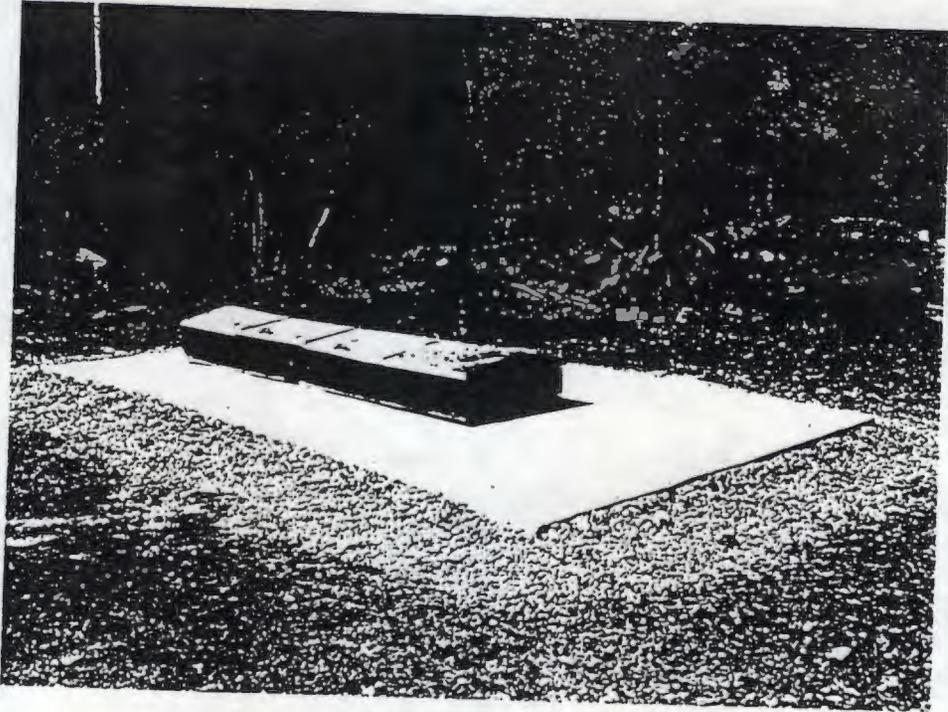
AB-8 - View of OB Pad and Burn Pan from gravel pile. Note flow from spring crossing site.



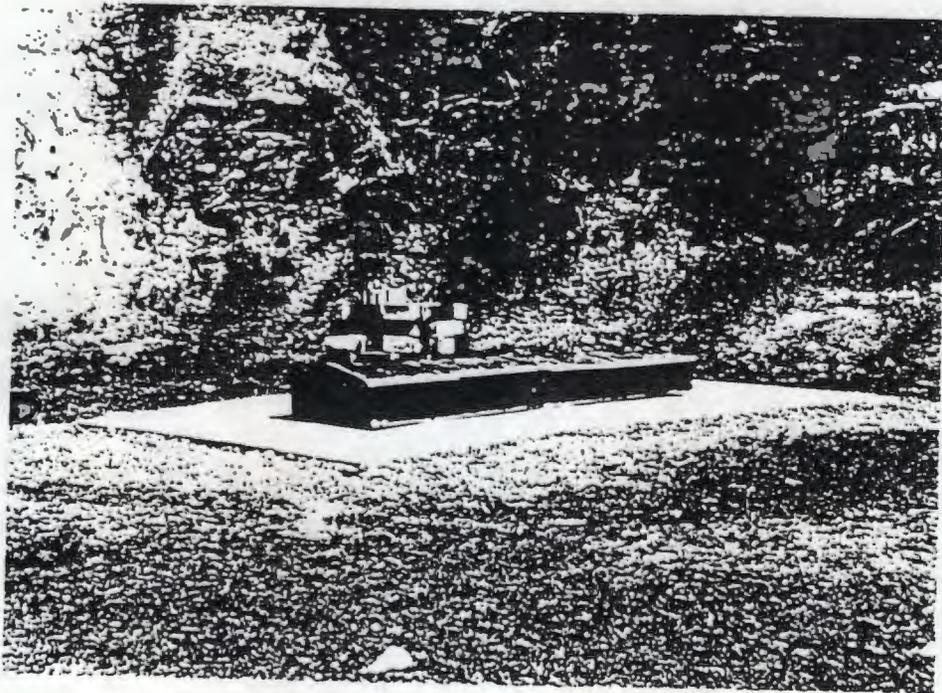
AB-9 - View of OB Pad and Burn Pan from parking area.
Note flow from spring crossing site.



AB-10 - Closer view of Pad and Burn Pan from parking
area.



AB-11 - Close-up view of OB Pad and Burn Pan, looking northeast toward wooded area.



AB-12 - Close-up view of OB Pad and Burn Pan, looking southeast toward high wall.



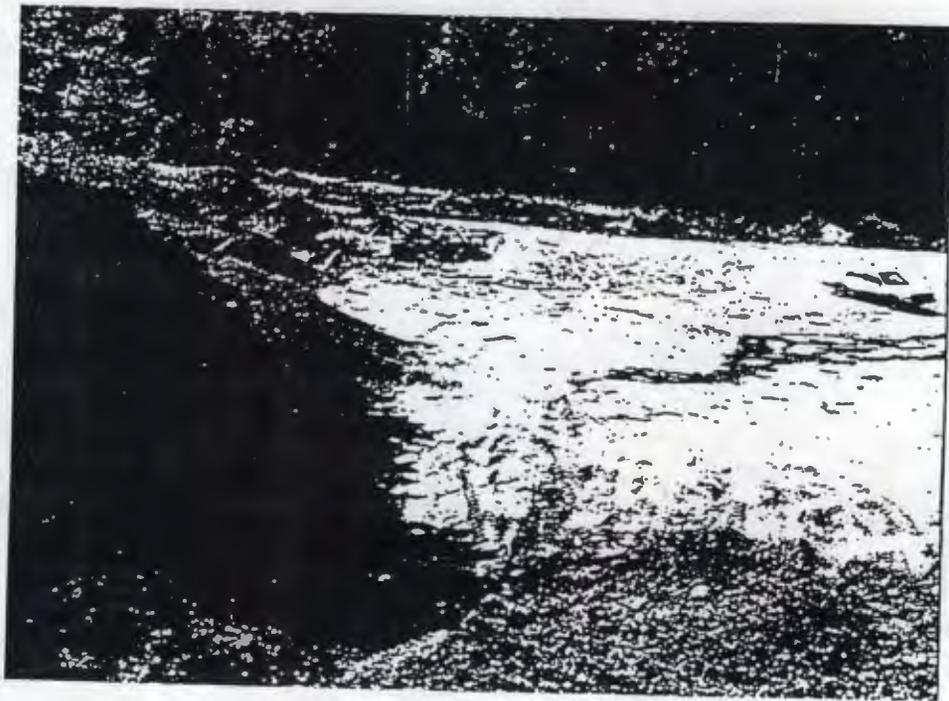
AB-13 - Close-up view of rubble pile, barricade is moved to block roadway when OB activity begins.



AB-14 - Close-up of pooled water along eastern edge of OB site.



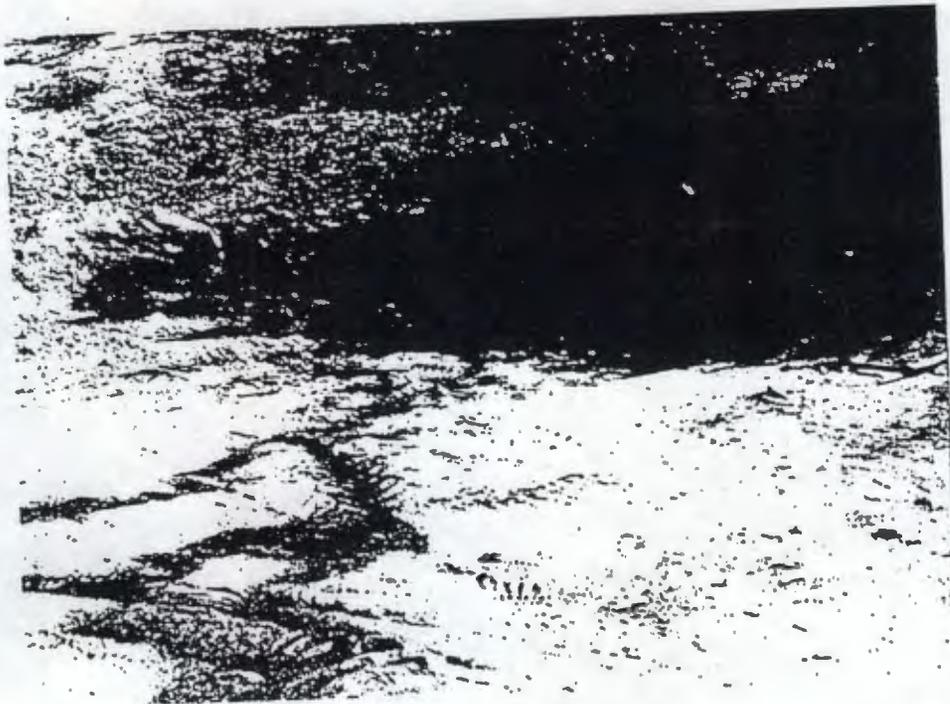
AB-15 - Close-up of pooled water in wooded area adjacent to OB site.



AB-16 - Spring flow originating in southwest corner of OB site and flowing north across site.



AB-17 - Wall along southwest corner of OB site near spring.



AB-18 - Spring flow in southwest corner of OB site near its point of origination.



AB-19 - Close-up of rock strata along highwall. Note:
8 1/2 x 11 inch notebook sheet for size
comparison.