CONTROL ROOM HABITABILITY STUDY

FOR

CALVERT CLIFFS NUCLEAR POWER STATION

Prepared for:

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1.0 INTRODUCTION

The Calvert Cliffs Nuclear Power Station is located in southern Calvert County, Maryland. The county is bordered on the east by the Chesapeake Bay, on the south and west by the Patuxent River, and on the north by Anne Arundel County.

The economy of the area is primarily agricultural. The site is accessible by State Highway 2 & 4 which passes along the west side of the site.

This report provides information regarding the potential effects on the safe operation of the nuclear facility of all industrial, transportation, mining, and military installations in the site area. A survey was carried out to determine the amount of hazardous material being transported, manufactured, or stored within 5 miles of the site and significant quantities at greater distances. Potential accidents involving these hazardous materials were evaluated as to their effect on the control room personnel.

2.0 LOCATIONS AND ROUTES

2.1 Mining

There are no mining operations within 5 miles of the Calvert Cliffs site.

2.2 Military Installations

There are no military installations in Calvert County or within 5 miles of the site, but there are several in the surrounding counties. Figure 1.1 shows the locations of the military installations in the area (Ref. 1).

2.3 Airports

There are no airports within 5 miles of the Calvert Cliffs site, but there are 3 airports within 11 miles of the site.

The Chesapeake Ranch Airport is a small private airstrip located 5.6 miles south-southeast of the site. The airstrip has 1 runway (2640') but has no regular air traffic (about 1 plane every 2 weeks) (Ref. 2).

St. Mary's County Airport, located 10.5 miles south-southwest of the site, has 1 runway (3250') with operations of 5 to 10 planes per day. The planes that use the airport are mostly light twin engine planes used by private corporations (Ref. 3).

Patuxent Naval Air Station is a miliary airport, located 10.5 miles south-southeast of the site. The type of aircraft that use the station are:

> Tanker - KA-3 Skywarrior; Trainer - A-4 Skyhawk, T-2 Buckeye, T-38 Talon, Light Bomber - A-7 Corsair, AV-8 Harrier; Medium Bomber - A-6 Intruder; Fighter - F-4 Phantom, F-14 Tomcat, F-18 Hornet, Early Warning - E-2 Hawkeye; Anti-submarine - S-3 Viking; Patrol - P-3 Orion; Cargo - C-130 Hercules; Utility - U-1 Beaver, U-6 Otter, UC-12B King Air, T-39 Saberliner; Helicoptor - AH-1 Cobra, H-2 Sea Sprite, H-3 Sea King, H-46 Sea Knight, H-58 Jet Ranger.

Patuxent has had 8,811 radar approaches in 1979 and a slight increase is expected in the future. The air traffic at Patuxent NAS is much less than the 50,000 per year (500 d^2 where d is distance from the site in miles) needed to be considered for a hazard analysis (Ref. 4). The flight patterns which lie within 5 miles of the Calvert Cliffs site are shown in Figure 1.2. The two Ground Control Apporach (GCA) patterns represent approximately 40 percent of the total GCA traffic at Patuxent NAS. There are 4 runways at the station. The two primary runways are Runway 13/31 (9,700') and Runway 6/24 (11,800'). Runway 2/20 (6,400') gets much less usage than the previous ones and Runway 9/27 (3,400') is a very low use utility runway. Presently, Patuxent foresees no plans for future expansion of airspace or patterns except for those of a temporary nature to meet specific real-time testing requirements (Ref. 5).

Commercial airport facilities are available at Washington National Airport, located 43 miles northwest of the site; the Baltimore Washington International Airport, located 53 miles north-northwest of the site; and Dulles International Airport, located 65 miles northwest of the site. An air route map for the area within 50 miles of the site is provided in Figure 1.3 (Ref. 6).

Statistics on aircraft accidents have not been provided since the airports do not meet the NRC Regulatory Guide 1.70 criteria such that the effect of aircraft accidents due to the station safety operation need to be analyzed: "airports with projected operations greater than 500 d^2 movements per year within 10 miles and airports with projected operations greater than 1000 d^2 movements per year outside 10 miles, where d is the distance from the site in miles" (Ref. 4).

2.4 Columbia LNG Corporation at Cove Point

The only major industrial facility in the area is the Columbia LNG Corporation at Cove Point, located approximately 3.5 miles south-southeast of the Calvert Cliffs site. The Columbia facilities consist of an onshore processing plant and storage tanks, an unloading dock about one mile offshore, and a connecting tunnel from the dock to the onshore facilities.

During normal operations, Liquified Natural Gas (LNG) tankers with a planned capacity of 125,000 cubic meters will moor at the unloading dock and transfer their LNG cargo through the connecting tunnel to the onshore tanks. The LNG is then stored in the onshore tanks until it is sold to consumers (Ref. 7).

There are 4 onshore LNG storage tanks at the Columbia LNG Corporation facility with a nominal total capacity of 1.5 million barrels. The facility also has a helicopter landing area, but it is seldom used (only 2 landings since its installation in November, 1979) (Ref. 8).

2.5 Pipeline

Columbia LNG Corporation owns and operates a 36 inch high-pressure LNG pipeline within its right-of-way in Calvert County. The line, buried 3 feet deep and operating at a pressure of 1250 psig, was placed in operation in 1977. Ball type (36 inch) isolation values are used throughout the line. The distance from the valve in the plant, at the beginning of the line, to the first valve in the line is approximately 35,900 feet. The distance between the valves after that varies.

The pipeline runs south and west of the Calvert Cliffs site and is approximately 1.76 miles southwest of the site at the closest point (Ref. 8).

2.6 Land Transportation Routes

State Highway 2 & 4 is the major land transportation route within 5 miles of the site. The highway runs along the west side of the site and is approximately 1.2 miles west southwest of the site at the closest point. In 1979, State Highway 2 & 4 averaged 6400 movements per day (Ref. 9). The hazardous materials transported on State Highway 2 & 4 are primarily local gasoline, fuel oil, and propane deliveries. Table 1.1 provides the size and frequency of the transports of these materials (Ref. 10, 11, 12, 13, & 14).

2.7 Water Transportation Routes

The Chesapeake Bay adjoins the Calvert Cliffs site to the east and is a major shipping route. The navigable channel is about 4 miles wide and is approximately 0.68 miles east of the site at the closest point. In 1978, there was 42,419,046 tons of material transported on the Bay, of which 12,037,414 tons was hazardous material (Ref. 15). Table 1.2 provides information on the hazardous material transported on the Chesapeake Bay in 1978.

Table 1.3 summarizes the information on the transportation of materials within 5 miles of the Calvert Cliffs site and Figures 1.4a and 1.4b show the transportation routes.

2.8 Onsite Chemical Storage

There is a wide range of chemicals stored at the Calvert Cliffs site. Table 1.4 provides a complete list of the types and quantities of chemicals stored at the site along with the chemical storage locations (Ref. 16).

The chemicals identified as having the potential to affect the control room personnel are:

ammonia	nitrogen
acetone	hydrogen
carbon dioxide	#2 fuel oil
sulfuric acid	transformer oil

Liquid ammonia, NH_3 at 28% concentration, is stored in 55 gallon drums in a warehouse 550 feet from the control room intake. Normal storage quantities consist of 15 - 55 gallon drums.

Liquid acetone, CH_5COCH_3, is stored in 4 liter bottles and 55 gallon drums in the warehouse 550 feet from the control room intake. Normal storage quantities consist of 8 - 4 liter bottles and 6 - 55 gallon drums.

Liquid carbon dioxide, CO_2 at 100% concentration, is stored in 20 pound and 4 ton containers at a level of 12 feet in the Turbine Building, 360 feet from the control room intake. Normal storage quantities consist of 225 - 20 pound containers and 1 - 4 ton container.

Nitrogen gas, N_2 at 100% concentration, is stored in 15 ft^3 cylinders in the East Service Building and in Room A223 on level 5 of the Auxiliary Building. Normal storage quantities consist of 3 - 15ft^3 cylinders. Also, a maximum of 45,000 ft^3 (34 cylinders) is stored on a truck parked at the Bayfront, a distance of 650 feet from the control room intake.

Liquid sulfuric acid, H_2SO_4 at 98% concentration, is stored in a 10,800 gallon capacity tank in the Tank Farm, 630 feet from the control room intake.

Hydrogen gas, H_2 at 100% concentration, is stored in 6,889 SCF containers in the Tank Farm, 425 feet from the control room intake. Normal storage quantities consist of 9 - 6,889 SCF containers.

No. 2 fuel oil is stored in 125,000 gallon tanks outside the diesel rooms at a distance of 200 feet from the control toom intake. Normal storage quantities consist of 2 - 125,000 gallon capacity tanks with normal tank volumes of 90,000 gallons.

There are several transformers onsite which contain transformer oil. Two of the transformer sites are located 600 feet north and 600 feet south of the con- trol room air intake. At each of these transformer sites, there are 6 trans- formers: 3 with 202,500 lbs of transformer oil each and 3 with 19,500 lbs of transformer oil each. Two other transformers with 196,800 lbs of transformer oil each are located 300 feet west of the control room air intake.

The onsite hazardous chemical storage locations are shown in Figure 1-5.

2.9 Off-Site Chemical Storage

Two companies, Trueman Gas Company and Columbia LNG Corporation store large quantities of chemicals within 5 miles of the site.

The LNG storage facility was discussed in Section 2.4.

Trueman Gas Company is located in St. Leonard, Maryland, approximately 4.2 miles northwest of the site. There are two 10,000 gallon gasoline tanks at the Trueman gas facility, but only one tank is in service. Table 1.5 provides the information on the chemical storage at these two locations (Ref. 8, 17). Figure 1.6 shows the location of the chemical storage facilities within 5 miles of the Calvert Cliffs site.

3.0 EVALUATION OF POTENTIAL ACCIDENTS

On the basis of the information provided in Section 2.0, the potential affects on the plant from accidental release of the hazardous materials were considered in terms of design parameters (e.g., overpressure and missile energies) or physical phenomena (e.g., concentration of flammable or toxic cloud outside the control room intake).

3.1 Explosions

As described in Section 2.6 , the closest land transportation route to the Calvert Cliffs site that would be used by trucks carrying explosive materials through the area would be State Highway 2 & 4. As indicated on Table 1.1, the largest explosive transport on State Highway 2 & 4 would be an 8,000 gallon gasoline tanker truck. In the event of a tanker truck crash, assuming all the gasoline explodes instantaneously, the equivalent weight of TNT would be 4.78×10^4 lb which would cause a peak overpressure of 1 psi to occur at a distance of 1,700 feet from the accident site (Ref. 18). Since the closest point of State Highway 2 & 4 to the Calvert Cliffs site is 6,336 feet

(1.20 miles), no hazard to the plant due to a gasoline tanker explosion is expected.

The 36 inch, 1,250 psi, LNG pipeline that passes 1.76 miles southwest of the site was analyzed for potential explosion. Although the pipeline is buried 36 inches deep, a rupture in an exposed portion of the line due to accidental excavation was assumed. The LNG in the pipeline is composed primarily of gaseous methane (Ref. 19). It was found that methane, though flammable, will not explode in an unconfined area (Ref. 20). Also, the products of combustion from a fire caused by pipeline rupture will have negligible concentrations at the control room air intake due to the distance separation of 1.76 miles. Therefore, the LNG pipeline poses no hazard to the control room personnel.

3.2 Flammable Vapor Clouds (Delayed Ignition)

Flammable gases in the liquid or gaseous state can form a vapor cloud which can drift toward the plant before ingition occurs. The possibility of the cloud then exploding depends upon its concentration being within the flammability limits for the particular gas released.

The most hazardous chemical transported near the site in terms of a delayed ignition is propane gas. As indicated in Table 1.1, the largest expected propane transport in State Highway 2 & 4 would be a 2,400 gallon truck. In the event of a propane truck crash and conservatively assuming 45% of the propane instantaneously flashes to vapor, the propane vapor cloud can drift 1,200 meters away from the accident site and still be within the flammable limits. The effective distance that the cloud could travel and still be within flammable limit was estimated to be 1,254 meters. This radius, 1,254 meters, is less than the distance between the plant site and the closest point of State

Highway 2 & 4, 1,900 meters (1.2 mile). The propane vapor cloud explosion at that distance would produce an overpressure less than 1 psi at the Calvert Cliffs site (Ref. 18). Therefore, a propane truck crash poses no hazard to the control room personnel.

3.3 Toxic Chemicals - Onsite

Section 2.8 discussed the hazardous chemicals stored onsite. As indicated in Table 1.4, there is no chlorine stored onsite and the existing propane tank is being drained. The toxic chemicals identified as potentially hazardous to the safety of the control room personnel are:

ammonia	nitrogen
acetone	sulfuric acid
carbon dioxide	

Liquid ammonia, NH_3 at 28% concentration, is stored onsite in 55 gallon drums in a warehouse 550 feet from the control room intake. In the event of storage drum failure, assuming an ambient temperature of 30°C and a continuous ground level release, the NH_3 concentration would be 30.0 ppm at the control room air intake. This is much less than the NH_3 toxicity limit of 50 ppm (Ref. 21), therefore, the ammonia storage drum failure poses no hazard to the control room personnel.

Liquid acetone, CH_5COCH_3, is stored onsite in 55 gallon drums in a warehouse 550 feet from the control room air intake. In the event of an acetone spill and assuming an initial spill radius of 0.5 meters, the acetone gas concentration at the control room air intake would be 1.21×10^{-4} ppm. This is much less than the acetone toxicity limit of 2,000 ppm (Ref. 22), therefore, an acetone spill poses no hazard to the control room personnel.

Liquid carbon dioxide, CO_2, is stored onsite in a 4 ton tank ($0^{\circ}F$, or 314.7 psi), 360 feet from the control room air intake. In the event of tank failure, the CO_2 puff concentration reaching the control room intake would be 1.64 mg/m^3. This is much less than the CO_2 toxicity limit of 18,400 mg/m^3 (Ref. 22), therefore, the CO_2 storage tank failure poses no hazard to the control room personnel.

Liquid nitrogen, N_2 at 2,000 psi and ambient temperature, is stored in 1,323.5 ft^3 capacity cylinders, 650 feet from the control room air intake. In the event of storage cylinder failure, the N_2 puff concentration reaching the control room air intake would be 4.4 g/m^3. The maximum N_2 concentration in the control room would be 0.57 g/m^3. This N_2 concentration (0.05%) would not displace a significant fraction of the control room air, hence, would not axphyxiate (Ref. 22). Therefore, nitrogen storage cylinder failure poses no hazard to the control room personnel.

Liquid sulfuric acid, H_2SO_4 at 98% concentration, is stored onsite in a 10,800 gallon capacity tank 630 feet from the control room. In the event of tank failure, assuming an ambient temperature of $35^{\circ}C$, a spill radius of 3.8 meters and a continuous ground level release, the concentration of H_2SO_4 reaching the control room air intake would be 0.1×10^{-6} mg/m^3. This is much less than the H_2SO_4 toxicity limit of

2 mg/m^3 (Ref. 22), therefore, failure of the sulfuric acid storage tanks poses no hazard to the control room personnel.

It was concluded that the toxic chemicals stored onsite pose no hazard to the control room personnel. In each case, worse case meteorological conditions were identified and used. Results of the analysis of the toxic chemicals stored onsite is summarized in Table 1.6.

3.4 Toxic Chemicals - Offsite

As shown in Table 1.2 and discussed in Section 2.7, large quantities of chemicals are transported on the Chesapeake Bay. The chemicals identified as potentially hazardous to the control room personnel are:

benzene	sulfur
toluene	#6 fuel oil

Liquid benzene, C_6H_6, is transported on the Chesapeake Bay. In the event of a ship accident 0.68 miles offshore causing a benzene spill, assuming a vessel load of 11,000 tons (Ref. 23), a spill radius of 50 meters, and a continuous ground level release, the C_6H_6 concentration reaching the control room air intake would be 29.3 ppm. This is less than the C_6H_6 toxicity limit of 50 ppm (Ref. 22), therefore, a benzene spill in the Chesapeake Bay poses no hazard to the control room personnel.

Liquid toluene, $C_6H_5CH_3$ is transported on the Chesapeake Bay. In the event of a ship accident causing a toluene spill, assuming a vessel load of 11,000 tons (Ref. 23), a spill radius of 50 meters, and a continuous ground level release, the $C_6H_5CH_3$ concentration reaching the control room intake would be 12.2 ppm. This is much less than the toluene toxicity limit of 200 ppm (Ref. 21), therefore, a toluene spill in the Chesapeake Bay poses no hazard to the personnel in the control room.

Sulfur is also transported on the Chesapeake Bay. Sulfur is shipped as a liquid, at temperatures between 235°F and 300°F. When an accident occurs, the leaking sulfur will solidify as the temperature falls below the melting point. The solid sulfur will stay on the vessel and confine the spillage to a limited area. Any solid sulfur that does spill into the water will sink. Except when in the presence of lamp black, carbon black, charcoal, and a few less common substances, spontaneous ignition of sulfur is practically non-existent (Ref. 24).

As indicated in Table 1-2, several types of fuels are transported on the Chesapeake Bay. No. 6 fuel oil was analyzed since it represents the largest volume of fuels transported. Assuming a vessel load of 11,000 tons (Ref. 23) and a No. 6 fuel oil burning rate of 8 inches/hour (Ref. 25), two accident cases were considered: (1) fire is confined to the vessel and (2) oil from the damaged vessel drifts to the Bayfront and catches fire. For both cases, due to vigorous buoyancy generated by the oil-fire, wind speeds greater than 63 meters/sec are required to bend the extremely hot plume toward the control room air intake to affect the control room personnel. The frequency of such a high wind from the east is zero (Ref. 26), therefore, no hazard is expected to the control room personnel.

It was concluded that materials transported on the Chesapeake Bay will pose no hazard to the control room personnel. Results of the offsite toxic chemcials analysis is also summarized in Table 1.6.

3.5 Fire

The chemicals stored onsite that were identified as potentially ha..ardous due to fire were:

No. 2 fuel oil

hydrogen

transformer oil

There are 2 - 125,000 gallon capacity (24 feet in height and 40 feet in diameter) No. 2 fuel oil storage tanks located onsite near the diesel room. Tank number 11, enclosed by a tank dike, is located 220 feet northwest of the control room. The other tank is located 220 feet southwest of the control room in Building No. 21 (refer to Figure 1-5 for the building locations).

Assuming an accident occurs when a high wind (Stability D and a wind speed of 16.0 m/s) is blowing from the storage site toward the control room, three cases will be considered:

Case 1

The oil fire is restricted to the oil tank, hence a continuous elevated release (24 feet) is assumed. The concentration of CO_2 reaching the control room intake would be 2,020 mg/m^3. This is much less than the CO_2 toxicity limit of 18,400 mg/m^3 (Ref. 22), hence there will be no hazard to the control room personnel.

Case 2

The oil fire spills into the dike area around storage tank number 11, hence a continuous ground level release is assumed. The CO_2 concentration reaching the contro room intake would be $5,590 \times 10^{-3}$ mg/m^3. This is much less than the toxicity limit of 18,400 mg/m^3 (Ref. 22), hence there will be no hazard to the control room personnel.

Case 3

The oil fire spills from the tank onto the floor of Building No. 21 (floor area 1,764 ft^2) hence, a continuous ground level release is assumed. The CO_2 concentration reaching the control room intake would be 3,400 mg/m^3. This is much less than the toxicity limit of 18,400 mg/m^3 (Ref. 22), hence there will be no hazard to the control room personnel.

Hydrogen gas is also stored onsite in 6889 SCF containers in the Tank Farm, 425 feet from the control room intake. Studies (Ref. 27) show that hydrogen-air mixtures do not go through a transition from ordinary flame to detonation wave if they exist in the open air (without any accumulation), unless the ignition source impacts with considerable extra energy in the form of a shock wave. Hence, an unconfined hydrogen-air mixture will burn rather than explode. If the hydrogen gas is not ignited upon impact, but a vapor cloud drifts from the ruptured tank toward the control room, the hydrogen concentration inside the control room is estimated at 0.55 g/m^3 which would be 0.67% by volume in the air mixture. As the flammable limits of hydrogen range from 4.0% to 74.2% by volume, the air inside the control room is not flammable. Therefore, a hydrogen tank rupture poses no hazard to the control room personnel.

Transformer oil quantities and locations were discussed in Section 2.8. Assuming a high wind (Stability D and a wind speed of 15.0 m/s) blowing from the transformer toward the control room, a continuous release from the aggregate rock bed under the transformer, and only one transformer fails, two cases were considered.

Case 1

There is a transformer oil fire in the aggregate rock bed 600 feet from the control room air intake involving 202,500 lbs of transformer oil. The CO_2 concentration reaching the control room air intake would be 8.87×10^{-28} mg/m^3. This is much less than the CO_2 toxicity limit of 18,400 mg/m^3 (Ref. 22), therefore no hazard to the control room personnel is expected.

Case 2

There is a transformer oil fire in the aggregate rock bed 300 feet from the control room intake 196,800 lbs of transformer oil. The CO_2 concentration reaching the control room air intake would be 37 mg/m^3. This is much less than the CO_2 toxicity limit of 18,400 mg/m^3 (Ref. 22), therefore, no hazard to the control room personnel is expected.

Results of onsite storage of No. 2 fuel oil, hydrogen and transformer oil analysis is also summarized in Table 1.6.

Danger to the Calvert Cliffs control room personnel due to forest fires was also investigated. The closest forest to Calvert Cliffs Nuclear Power Station is Calvert Cliffs State Park which adjoins the power station site to the south. Calvert Cliffs State Park is a 1,300 acre state park with a predominant vegetation of mixed hardwoods and pines. The park is very fire conscious and there has been no fire at the park for at least the last 7 years (Ref. 28)

On a county wide basis, Calvert County averages 20 forest or brush fires per year. County fire protection is considered very good with a short travel time to all areas from fire stations and most fires are limited to less than 1/4 acre burned (Ref. 29). Therefore, a calculation was done that considered the combustion of 1/2 acre of forest nearest the plant. Using data accumulated from the Maryland Forest Service (Refs. 35 & 36) the calculation showed that a forest fire poses no threat to control room habitability.

3.6 The issue of the potential hazards to Calvert Cliffs from operations at Cove Point LNG Terminal has been analyzed and discussed at length in numerous investigation reports and meetings between BG&E and the NRC. The resolution of the issue was at follows: the NRC concluded that Cove Point operations would present no unacceptable hazard to Calvert Cliffs provided that BG&E prepare a contingency plan for the possibility of a methane cloud engulfing plant structures. The NRC's technical conclusion is contained in referene 37 and is reaffirmed in paragraph 3.0 of their Safety Evaluation accompanying License ammendment Nos. 42 and 25 for Calvert Cliffs Unit I and Unit 2 respectively dated March 10, 1980. BG&E's contingency plan, fulfilling NRC requirements, is contained in the Calvert Cliffs Emergency Response Plan which has been reviewed in draft form by NRC and which will be submitted in final form on December 31, 1980. These documents, the Safety Evaluation and the Emergency Response Plan, show that there is adequate assurance that the Calvert Cliffs Control room will be protected in the extremely unlikely event of methane cloud intrusion.

3.7 Collision with Intake Structure

The intake structure is situated to the east of the main plant and is primarily a reinforced concrete structure. It houses 12 circulating water pumps which supply water from the Chesapeake Bay to the condensers and to 6 salt water pumps. The intake structure is protected by a baffle wall. The baffle wall would exclude pleasure craft, while ships of a size which could penetrate the baffle was would run aground far offshore. Therefore, collision with the intake structure will not affect plant operations.

Plant service water is supplied by ground water wells, therefore, collision with the intake structure presents no hazard to the control room personnel. (Ref. 30)

3.8 Liquid Spills

The accidental release petroleum products or corrosive liquids upstream of the intake structure will not affect operation of the plant. Normal operations of the water intake structure pumps require submergence;

the suctions extend from elevation -12.0 feet to -9.6 feet. Liquids with a specific gravity less than one will float on the surface of the water and consequently are not likely to be drawn into the water intake.

Plant service water is supplied by ground water wells. Therefore, liquid spills present no hazard to the control room personnel (Ref. 30).

3.9 Equations Used in the Analysis

1. The diffusion equation for an instantaneous (puff) ground level release is:

$$\frac{\chi}{Q_I} = \left[7.87\left(\sigma_{x,y}^2+\sigma_I^2\right)\left(\sigma_z^2+\sigma_I^2\right)^{1/2}\right]^{-1}\cdot\exp\left[-\frac{1}{2}\left(\frac{x^2}{\sigma_x^2+\sigma_I^2}+\frac{y^2}{\sigma_y^2+\sigma_I^2}+\frac{z^2}{\sigma_z^2+\sigma_I^2}\right)\right] \quad \text{(Ref. 22)}$$

where:

$\frac{\chi}{Q_I}$ = unit concentration at coordinates x, y, z from the center of the puff, m^{-3}

$\sigma_x, \sigma_y, \sigma_z$ = standard deviations of the gas concentration in the horizontal alongwind, horizontal crosswind, and vertical crosswind directions, respectively (assume $\sigma_x = \sigma_y$), m

$7.87 = (2)^{1/2}\,(\pi)^{3/2}$

σ_I = initial standard deviation of the puff, m^3

$= \left[\frac{Q_I}{7.87\chi_o}\right]^{1/3}$ where Q_I is the puff release quantify, g and χ_o is the density of the gas at standard conditions, g/m^3.

x,y,z = distance from the puff center in the horizontal alongwind, horizontal crosswind, and vertical crosswind directions, respectively, m.

2. For liquified gases and low boiling point liquids, the heat balance in the instantaneous puff formation assuming an adiabatic change is given by:

$$M_v = \frac{1}{H_v} M_t \, C_p \, (T_o - T_b) \qquad \text{(Ref. 33)}$$

where:

M_t = total initial mass of the liquid (g)

C_p = heat capacity of the liquid (cal/g°C)

T_o = ambient temperature (°C)

T_b = normal boiling point of the liquid (°C) $< T_o$

M_v = mass of the instantaneously vaporized liquid (g)

H_v = leat of vaporization of the liquid (cal/g)

3. The equation for the TNT energy equivalent, Q, of a fuel tank explosion is:

$$Q = \frac{\alpha(\Delta H)W}{2000} \qquad \text{(Ref. 31)}$$

where:

Q = TNT equivalent yield (lb)

ΔH = heat of combustion (Btu/lb)

W = weight of fuel oil to be evaluated (lb)

α = empirical factor

The U.S. Bureau of Mines advises using α=0.1 as a safe upper limit for an explosion whenever the characteristics are not known.

4. The equation for the buoyancy flux, F, of a hot source is:

$$F = \frac{gQ_H}{\pi C_p \rho T} \simeq 3.7 \times 10^{-5}\ Q_H \left[\frac{m^4/sec^3}{cal/sec}\right] \qquad \text{(Ref. 32)}$$

where:

Q_H = heat emission (cal/sec)

C_p = specified heat of air at constant pressure

ρ = ambient density

T = source temperature

5. The equation for estimating the surface area, A(t), of a spill is:

$$A(t) = \pi \left\{ r_o^2 + 2t \left[\frac{gV_o}{\pi} \left(\frac{\rho_1 - \rho}{\rho_1}\right) \right]^{1/2} \right\} \qquad \text{(Ref. 33)}$$

where:

r_o = initial radius of spill (m)

V_o = volume of the spill (cm^3) = $\pi(r_o)^3$

ρ_1 = density of the liquid or gas (g/cm^3)

ρ = density of air (g/cm^3)

t = time (sec)

6. The equation for the rate of vapor diffusion, dm/dt, in still air is:

$$\frac{dm}{dt} = \frac{A(t)p\ \rho_v x10^4}{P} \left(\frac{D}{\pi t}\right)^{1/2} \quad \left(\frac{g}{s}\right) \qquad \text{(Ref. 33)}$$

where:

$A(t)$ = surface area of the spill @ time, t (m^2)

p = vapor pressure of the liquid (mm Hg)

ρ_v = vapor density of the liquid (g/cm^3)

D = diffusion coefficient of the liquid into air (cm^2/s)

7. The equation for the dilution factor, F, of air taken into the control room air intake is:

$$F = 1-\exp\left[\frac{-Wr}{V_r}\right] \qquad \text{(Ref. 33)}$$

where:

W = air flow rate into control room

V_r = control volume

r = time duration

8. The equation for the height of the plume centerline, Δh, of a buoyant plume is:

$$\Delta h = 1.6F^{1/3}\ x^{2/3}/u \qquad \text{(Ref. 32)}$$

where:

F = buoyancy flux

x = distance

u = wind speed

9. The diffusion equation for the concentration, x, of a continuous ground level release is:

$$\chi = \frac{Q}{\pi \sigma_y \sigma_z u} \text{ Exp}\left[- \frac{1}{2} \left(\frac{H}{\sigma_z}\right)^2 \right] \quad \text{(Ref. 34)}$$

where:

Q = release rate (g/s)

σ_y, σ_z = standard deviations in horizontal and vertical directions (m)

u = wind speed (m/s)

H = effective height (m)

10. The rate of total heat transfer, in cal/sec of the spilling liquid is:

$$\frac{dQ}{dt} = A(t) \left\{ g_r + h_c (T_a - T_b) + 197 (T_E - T_b)/t^{1/2} \right\} \quad \text{(Ref. 33)}$$

where:

g_r = solar and atmospheric radiation fluxes

h_c = heat transfer coefficient (cal/m^2-sec-$^\circ$C)

T_a = ambient temperature ($^\circ$C)

T_b = boiling point ($^\circ$C)

T_E = ground temperature ($^\circ$C)

t = time (sec)

11. The evaporation rate, in g/sec of the spilling liquid is:

$$\frac{dM_v}{dt} = \frac{1}{H_v} \left(\frac{dQ}{dt}\right) \quad \text{(Ref. 33)}$$

where:

M_v = mass of the vapor

4.0 CONCLUSION

It is concluded that the industrial, transportation, and military installations in the site area will not adversely effect safe operation of the Calvert Cliffs Nuclear Power Plant. Chemicals stored on the power plant site pose no hazard to the control room personnel. Chemicals stored and transported in the site vicinity (within 5 miles of the power plant) also pose no hazard to the control room personnel. To further insure control room personnel safety, Table 1.7 lists additional safety equipment in the control room.

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TABLE 1.1

HAZARDOUS MATERIALS TRANSPORTED ON STATE HIGHWAY 2 & 4
WITHIN 5 MILES OF THE CALVERT CLIFFS SITE

Hazardous Material	Transporting Company	Truck Capacity (gal)	Frequency of Transports
Gasoline	Trueman Gas Co.	1900	5 trips/week
"	Southern Maryland Oil Co.	3000	1 trip/week
"	Reliable Oil Co.	8000	1 trip/week
"	"	3000	1 trip/day
"	R.S. Leitch Co.	8000	4 trips/week
"	"	3600	2 trips/day
Fuel Oil	Southern Maryland Oil Co.	3000	2 trips/week
"	Reliable Oil Co.	3000	3 trips/day
"	R. S. Leitch Co.	2200	2 trips/day
"	"	8000	4 trips/week
Propane	Pargas, Inc.	2400	2 trips/month
"	"	3-100lb cylinders	2 trips/day

TABLE 1.2

HAZARDOUS MATERIAL TRANSPORTED ON THE CHESAPEAKE BAY IN 1978

Hazardous Cargo	Amount (short tons) Foreign	Coastwise	Internal	Total
Crude petroleum	421,661	30,598	193,301	645,560
Sulphur, liquid	-	40,189	-	40,189
Sodium hydroxide	-	50,718	-	50,718
Crude tar, oil, gas products	46	56,507	606	57,159
Alcohols	327	7,289	-	7,616
Benzene and toluene	-	1,494	23,854	25,348
Sulphuric acid	-	37,050	230,178	267,228
Basic chemicals and products, NEC	238,245	7,514	6,600	252,359
Gum and wood chemicals	360	184	-	544
Nitrogenous chemical fertilizers	184,813	13,855	61,570	260,238
Potassic chemical fertilizers	-	52	-	52
Phosphatic chemical fertilizers	40,125	4,000	1,250	45,375
Fertilizer and materials, NEC	7,571	24,588	6,300	38,459
Miscellaneous chemical products	44,410	1,682	50	46,142
Gasoline	1,558	398,129	565,520	965,207
Jet fuel	-	3,733	2,852	6,585
Kerosene	68	3,802	15,482	19,352

TABLE 1.2 (Contd.)

HAZARDOUS MATERIAL TRANSPORTED ON THE CHESAPEAKE BAY IN 1978

Hazardous Cargo	Amount (short tons) Foreign	Coastwise	Internal	Total
Distillate fuel oil	24,438	580,013	480,254	1,084,705
Residual fuel oil	2,077,765	1,825,009	1,283,012	5,185,786
Lubricating oils and greases	29,614	12,187	34,410	76,211
Naphtha, petroleum solvents	–	30,774	9,096	39,870
Asphalt, tar and pitches	18,533	770,587	210,616	999,736
Coke, petroleum coke	713,418	3	–	713,421
Liquefied gases	1,112,166	340	–	1,112,506
Petroleum and coal products, NEC	14,115	77,332	5,601	97,048
Total hazardous cargo	4,929,233	3,977,629	3,130,552	12,037,414
Total cargo	31,846,630	5,227,937	5,344,479	42,419,046
Hazardous percentage of total cargo	15.48%	76.08%	58.58%	28.38%

TABLE 1.3

SUMMARY OF MATERIALS TRANSPORTED WITHIN 5 MILES OF THE SITE

Mode of Transportation	Distance from Site (Miles)	Year	Traffic Volume
State Highway 2 & 4	1.20 WSW	1978	Total movements: 6400/day hazardous transports: 13/day
Chesapeake Bay	0.68 E	1978	Total cargo: 42,419,046 tons/yr hazardous cargo: 12,037,414 tons/yr
Columbia LNG Pipeline	1.76 SW	1979	36" pipeline at 1250 psig

TABLE 1.4a

CHEMICALS STORED ONSITE

Chemical	Quantity	Containers	Location	Concentration
Acetylene	14 bottles 1 bottle 17 bottles	250 ft^3/bottle 250 ft^3/bottle 250 ft^3/bottle	East Serv. Bldg. Room A223 Warehouse	100% 100% 100%
Ammonia	15 drums	55 gal. drums	Warehouse	28%
CO_2	225 containers 4 tons	20 lb containers one container	Various/12' level Turbine Bldg.	100% 100%
Dry Resins	Cation 370 ft^3 Anion 230 ft^3	5 ft^3 drums 5 ft^3 drums	Warehouse Warehouse	– –
Freon R-12	150#	3 bottles @ 50# ea.	Warehouse	100%
Freon R-22	1800# 400#	36 bottles @ 50# ea. 8 bottles @ 50# ea.	Warehouse East Serv. Bldg.	100% 100%
Hydrogen	62000 SCF Max.	9	Tank Farm	100%
Hypochlorite Solution	16 drums 4000 gals.	55 gal. drums Storage tank	Warehouse Waterfront	16% 16%
Lube Oil	23,400 gals.	13	Tank Farm	–
Nitrogen	30 ft^3 15 ft^3 45000 ft^3 max.	2 cylinders 1 cylinder 34 cylinders on truck	East Serv. Bldg. Room A223 45' Level Bayfront	100% 100% 100%
No. 2 Fuel Oil/Diesel	180,000 gal. norm/ 250,000 gal. max.	6	West of Aux. Bldg. Outside Diesel Rooms	100%
Chlorine	None			

TABLE 1.4a (Contd.)

CHEMICALS STORED ONSITE

Chemical	Quantity	Containers	Location	Concentration
Oxygen	12 bottles	224 ft^3/bottle	East Serv. Bldg.	-
	1 bottle	224 ft^3/bottle	Room A223	-
	37 bottles	224 ft^3/bottle	Warehouse	-
Paints and Solvents	Table 1.5b			
Polymers (vinyl chlorides)	Table 1.5b			
Propane*	38 ft^3 total	2 tanks	Tank Farm	100%
Sodium Hydroxide	6100 gal. norm/ 25,000 gal. max.	4	12' East Serv. Bldg.	50%
Sodium Hypochlorite	See hypochlorite solution			
Sulfuric Acid	4300 gal. norm/ 12000 gal. max.	4	Tank Farm	98%
Halon 1301	3000 lbs/room	19 cylinders/room	Room #A302/A306	10%
	3060 lbs/room	9 cylinders/room	Room #A311/A317	10%
	150 lbs/room	8 cylinders/room	Room #A406/A431	10%
Transformer Oil	200,000 lbs/trans.	4 transformers	Transformer Pads	-

*Propane tank will be drained since it is no longer used.

TABLE 1.4b

CHEMICALS STORED ONSITE

Paints, Solvents, Polymers:

The materials listed below reflect normal supplies stocked in Warehouse No. 2.

Paint

Rust-Oleum Black Spray (16 oz.) #40-334	24 cans
Red Marking (17 oz.) #40-993	13 cans

Enamel

E1770 Black (16 oz.) #61-026	24 cans
Yellow Lac. (16 oz.) #61-415	12 cans

Acetone

Fisher A-18 (4 liter bottles) #92-782	8 bottles
55 Gal. Approx. B58 # Drum #93-999	6 drums

The material listed below reflect present (and normal) supplies stocked in Catalytic's Paint Department.

Epoxy Paint

810 Gallons (5 gal. containers - various colors)
80 - 5 Gal. buckets of Cat 89-T-1
19 - 5 Gal. buckets of Surfing Compound
15 Gallons - red 20-R-9
20 Gallons Zinc Chromate Primer/Curring Agent 13-T-2

Enamel Paint

850 Gallons (5 Gal. containers - various colors)
64 Gallons (1 Gal. containers)

Solvents & Thinners

25 Gallons 7-T-45 Thinner
40 Gallons 33 Thinner
10 Gallons 35 Thinner
90 Gallons 38 Thinner

Miscellaneous

405 Gallons Vinyl Primer 80-R-8
330 Gallons Vinyl - White - 80-W-9
60 Gallons Dimecote
30 Gallons Antifouling Seven Seas Hy-Build - 1087
60 Gallons Alkyd Flat Wall Finish
20 Gallons Zinc Chromate Base Component 13-R-56

TABLE 1.5

CHEMICALS STORED OFFSITE

Company Name	Distance From Site (mi)	Chemicals Stored	Description
Columbia LNG Corp.	3.5 SE	liquified natural gas	4 tanks with total nomical capacity of 1.5 million barrels
Trueman Gas Co.	4.2 NW	gasoline	2 tanks each with a 10,000 gallon capacity but only 1 tank is in service

TABLE 1.6

MAXIMUM GAS CONCENTRATION AT THE CONTROL ROOM AIR INTAKE

Chemical	Quantity	Distance From Control Room Intake	Toxicity Limit	Maximum Concentration At Control Room Intake	Assumptions Used in Analysis[1]
Ammonia NH_3	55 gal drum (28% conc. liquid)	550 feet	50 ppm (OSHA)	30.0 ppm	c, d
Acetone CH_5COCH_3	55 gal drum	550 feet	2000 ppm (Reg Guide 1.78)	0.21×10^{-4} ppm	a, d
Carbon Dioxide CO_2	4 tons (liquid @ $0^{o}F$, 314.7 psia)	360 feet	18400 mg/m^3 (Reg Guide 1.78)	1.64 mg/m^3	a, f
Nitrogen N_2	1323.5 ft^3 (liquid @ 2000 psi)	650 feet	NA[2]	0.57 g/m^3*	a, f
Sulfuric Acid H_2SO_4	10,800 gal (98% conc liquid)	630 feet	2 mg/m^3 (Reg Guide 1.78)	0.1×10^{-6} mg/m^3	a, d
Benzene C_6H_6	11,000 tons (liquid)	0.68 miles	50 ppm (Reg Guide 1.78)	29.3 ppm	a, d
Toluene $C_6H_5CH_3$	11,000 tons (liquid)	0.68 miles	200 ppm (OSHA)	12.2 ppm	a, d
Hydrogen H_2	6889 SCF (gas @ 2000 psi)	425 feet	NA[2]	0.55 g/m^3*	a, e
#2 Fuel Oil (fire) CO_2 conc.	125,000 gal	220 feet	18,400 mg/m^3 (Reg Guide 1.78)	Case 1: 2020 mg/m^3 Case 2: 5590×10^{-3} mg/m^3 Case 3: 3400×10^{-3} mg/m^3	Case 1: b, g Case 2 & 3: b, d
Transformer Oil (fire) CO_2 conc.	202,500 lbs 196,800 lbs	600 feet 300 feet	18,400 mg/m^3 (Reg. Guide 1.78)	8.87×10^{-28} mg/m^3 37 mg/m^3	b, d b, d

[1] Assumptions used in analysis:

a) Meteorology - Stability E
b) Meteorology - Stability D
c) Meteorology - Stability F
d) Continuous ground level release
e) Instantaneous (puff) ground level release
f) Instantaneous (puff) elevated release
g) Continuous elevated release

[2] NA - Defined as asphyxiates in Regulatory Guide 1.78.

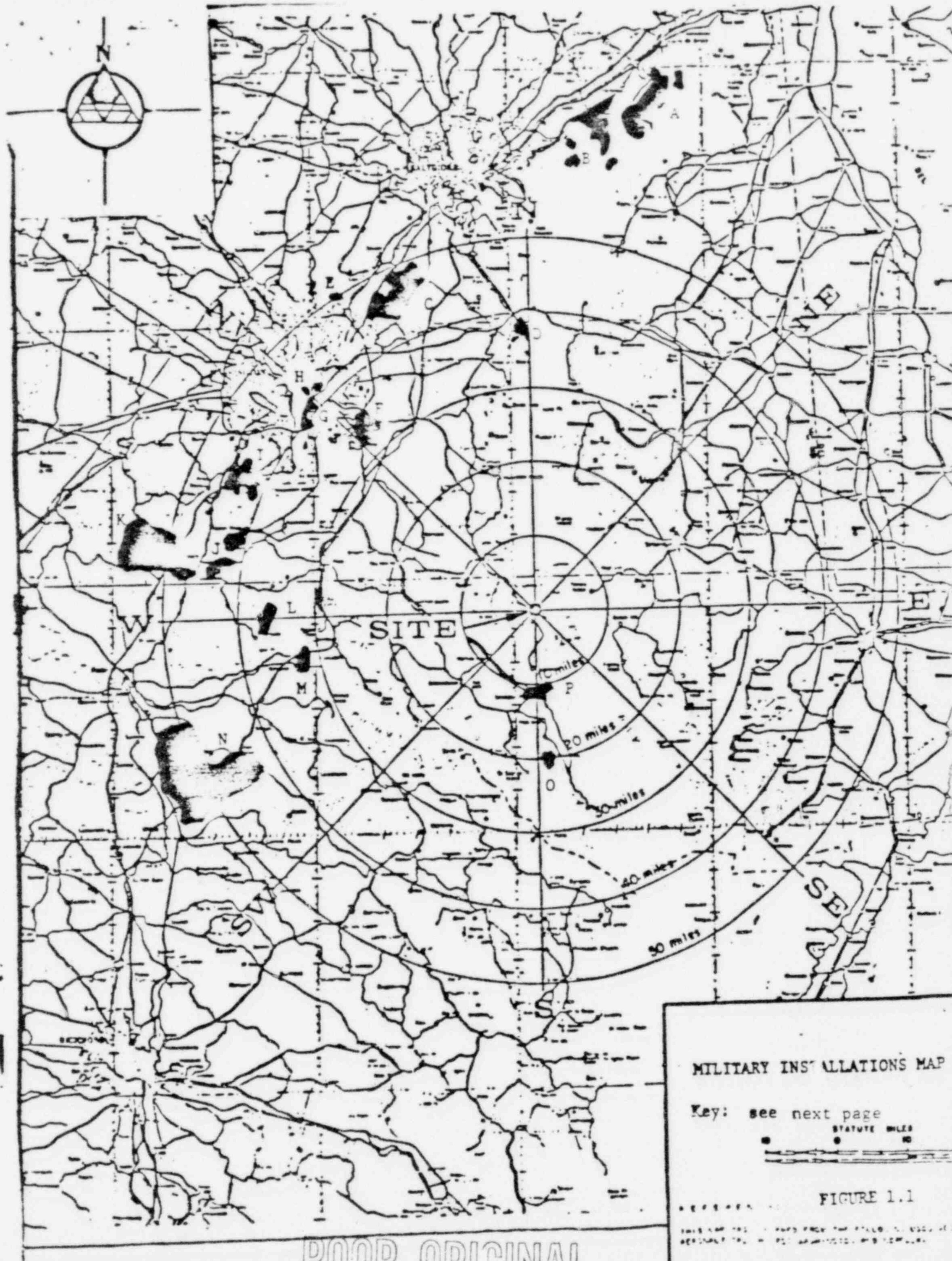
* After dilution in the control room air intake system

TABLE 1.7

CONTROL ROOM CHARACTERISTICS

Item	Control Room
a. Self-cont. breathing apparatus-number location	2
b. Bottled air supply - hours	4 (½ hr ea.)
c. Personnel capacity - normal/emergency	5/8
d. Potassium/oxide drug supply	See below*
e. Chlorine/toxic gas detectors	3 (O_2 detectors)

* Potassium iodide is stored in medical office; 4000 tablets, 35 oz. liquid.



MILITARY INSTALLATIONS MAP

Key: see next page

FIGURE 1.1

MILITARY INSTALLATIONS WITHIN 50 MILES OF THE SITE

(KEY FOR FIGURE 1.1)

A Aberdeen Proving Ground

B Edgewood Arsenal

C Fort George G. Meade

D Naval Ship R & D Center

E Naval Surface Weapons Center

F Andrews Air Force Base

G Naval Station

H Fort McNair

I Fort Belvoir U.S. Army

J U.S. Naval Ordance

K Quantico U.S. Marine Reservation

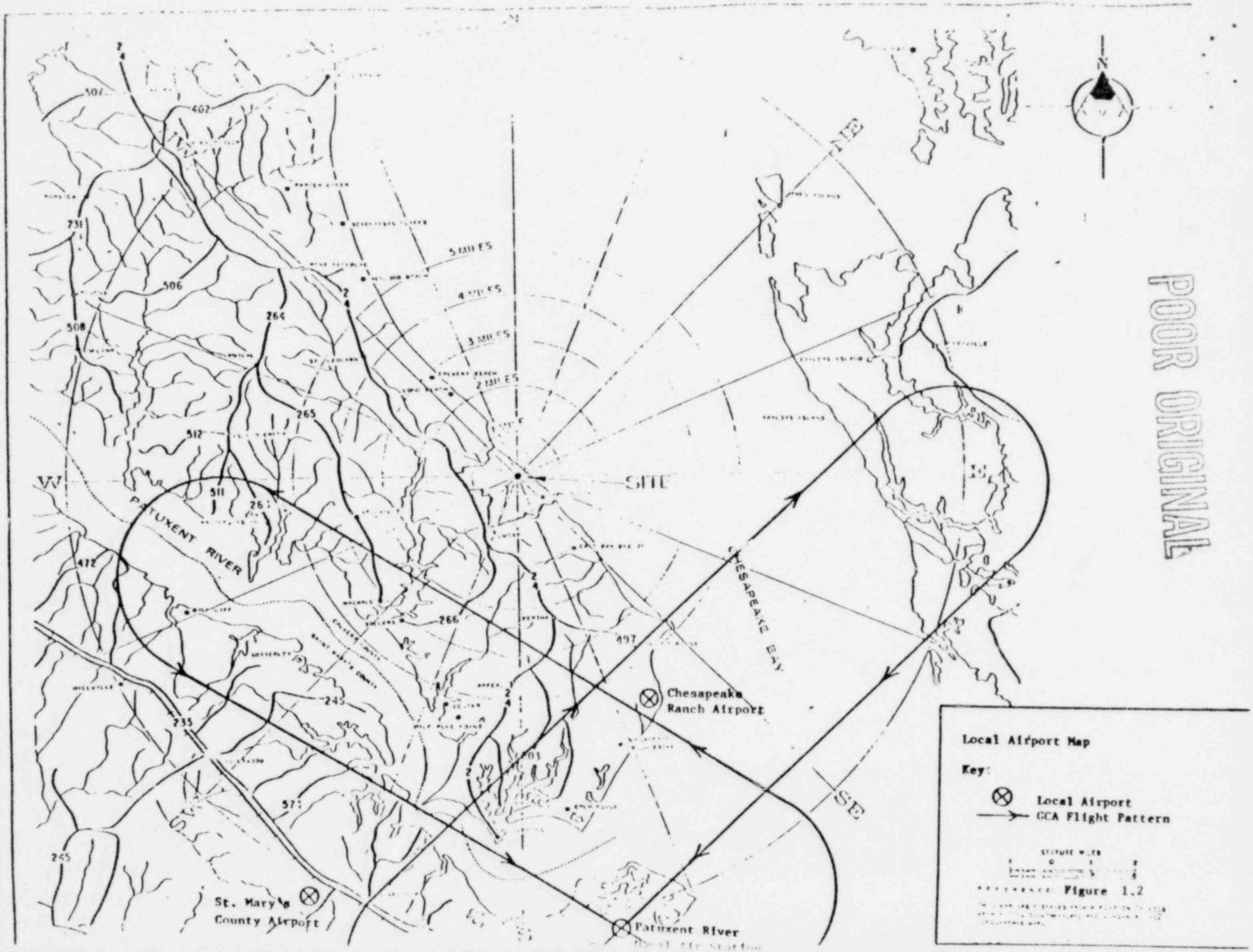
L Blossom Point Proving Grounds

M Naval Surface Weapons Center

N A. P. Hill U.S. Army Reservation

O Naval Electric Test Facility

P Patuxent Naval Air Test Center



N
NE
SE
S
W
SITE
5 MILES
4 MILES
3 MILES
2 MILES
CHESAPEAKE BAY
PATUXENT RIVER
Chesapeake Ranch Airport
St. Mary's County Airport
Patuxent River
507
402
231
506
508
264
265
512
511
472
266
497
245
235
Local Airport Map
Key:
Local Airport
GCA Flight Pattern
Figure 1.2

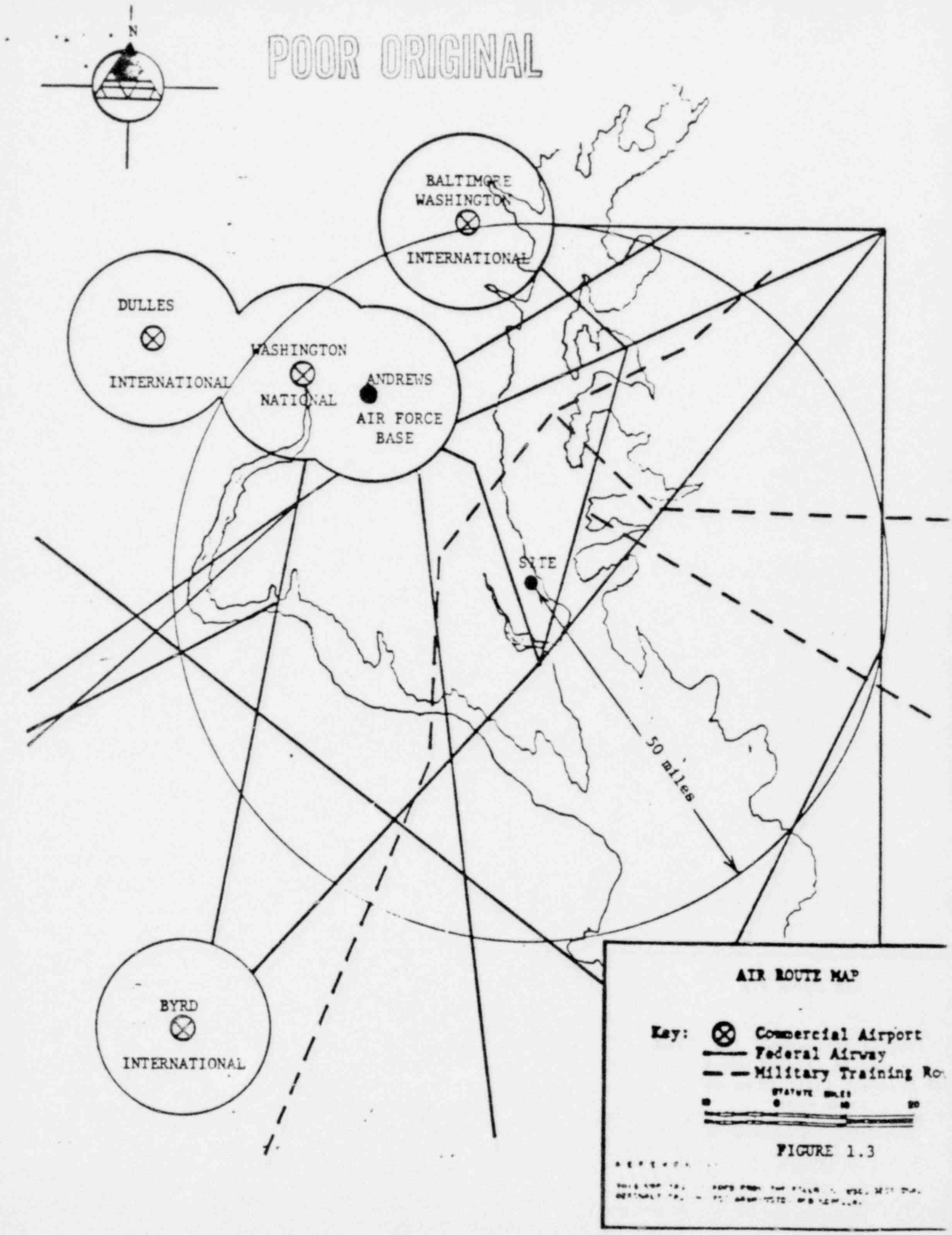
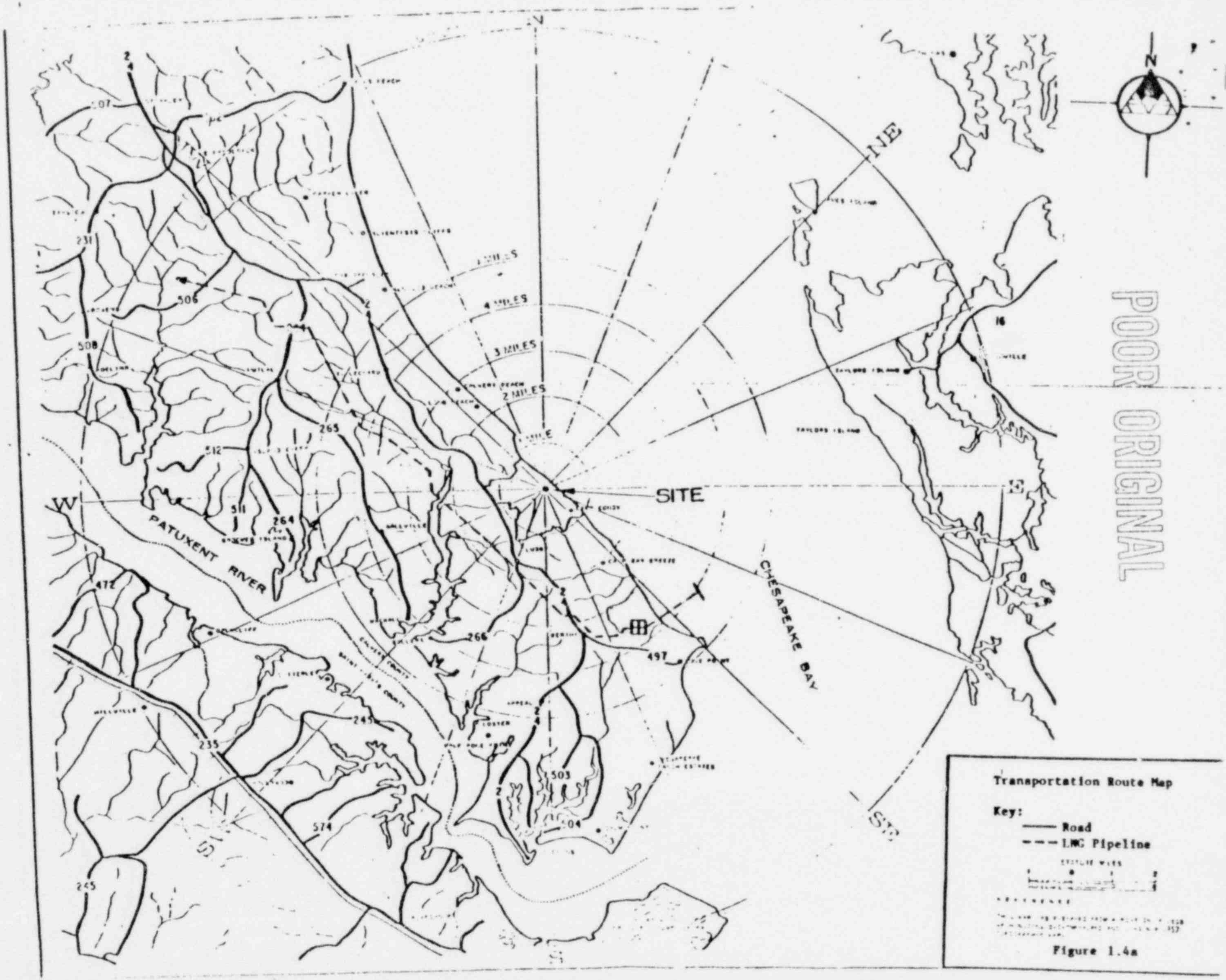
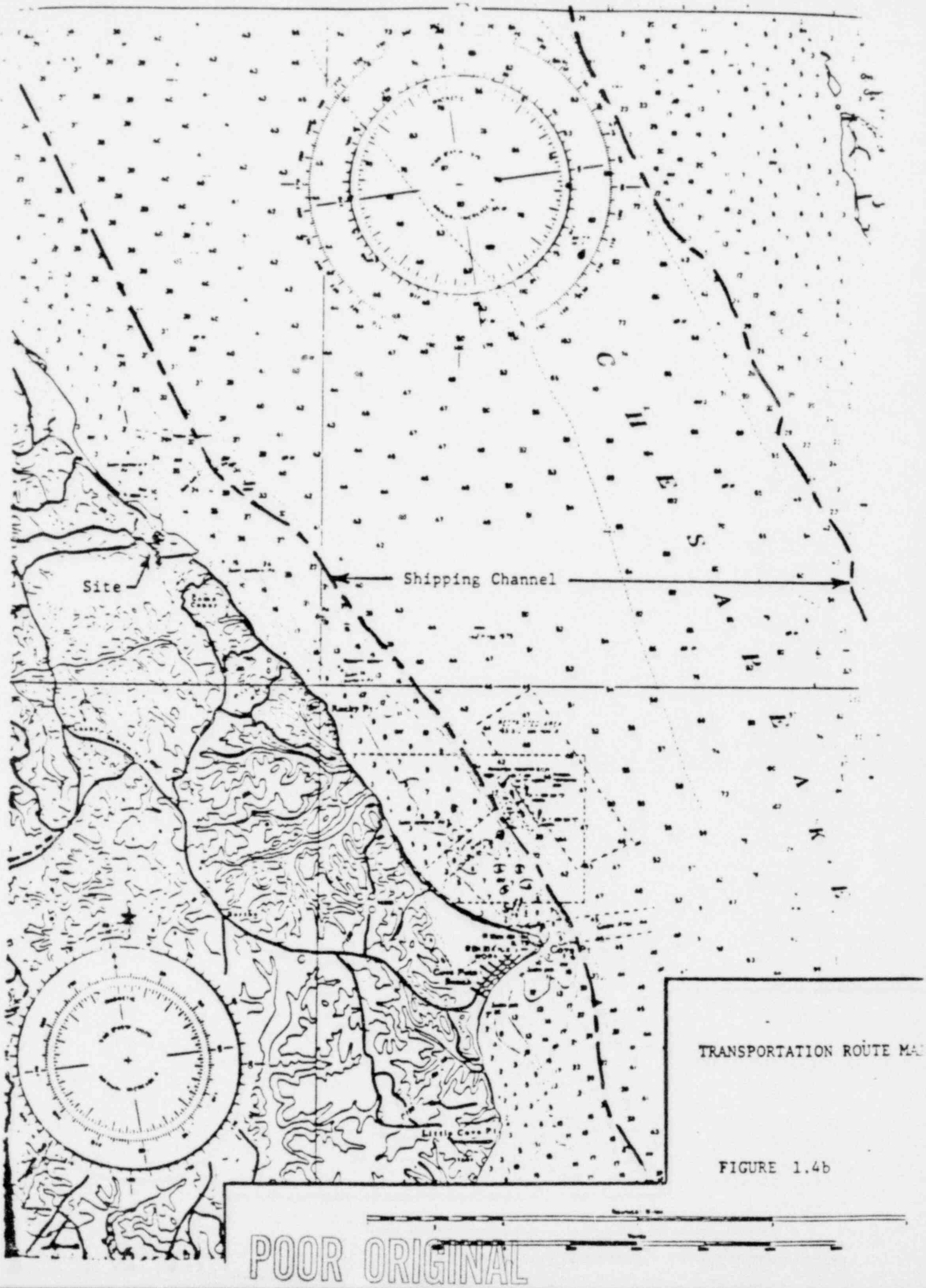

N
BALTIMORE
WASHINGTON
INTERNATIONAL
DULLES
INTERNATIONAL
WASHINGTON
NATIONAL
ANDREWS
AIR FORCE
BASE
SITE
50 miles
BYRD
INTERNATIONAL
AIR ROUTE MAP
Key:
Commercial Airport
Federal Airway
Military Training Ro

FIGURE 1.3

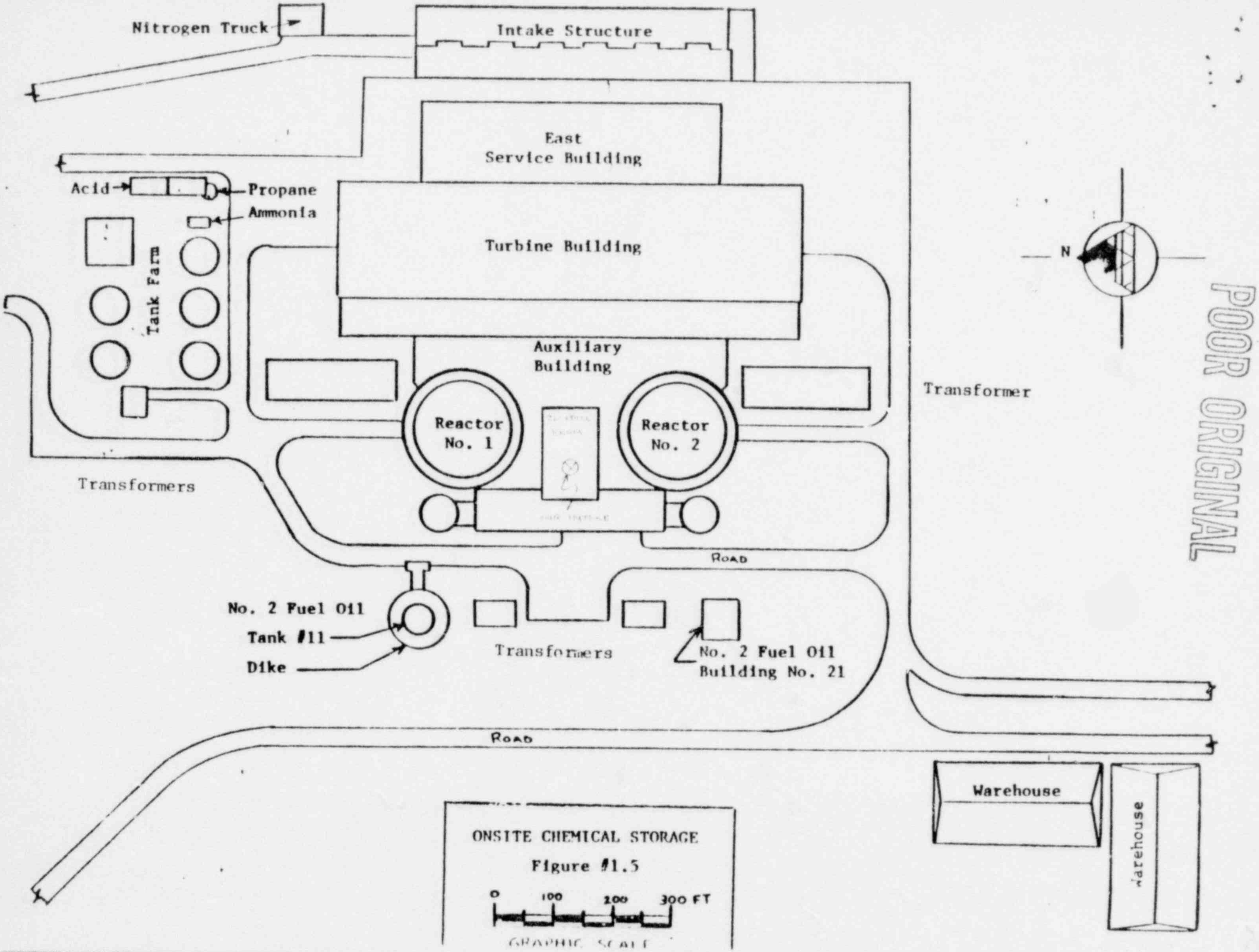


N
NE
E
SE
S
W
SITE
CHESAPEAKE BAY
PATUXENT RIVER
1 MILE
2 MILES
3 MILES
4 MILES
5 MILES
2
16
207
231
235
245
264
265
266
472
497
503
504
506
508
511
512
574
Transportation Route Map
Key:
—— Road
- - - LNG Pipeline
Figure 1.4a



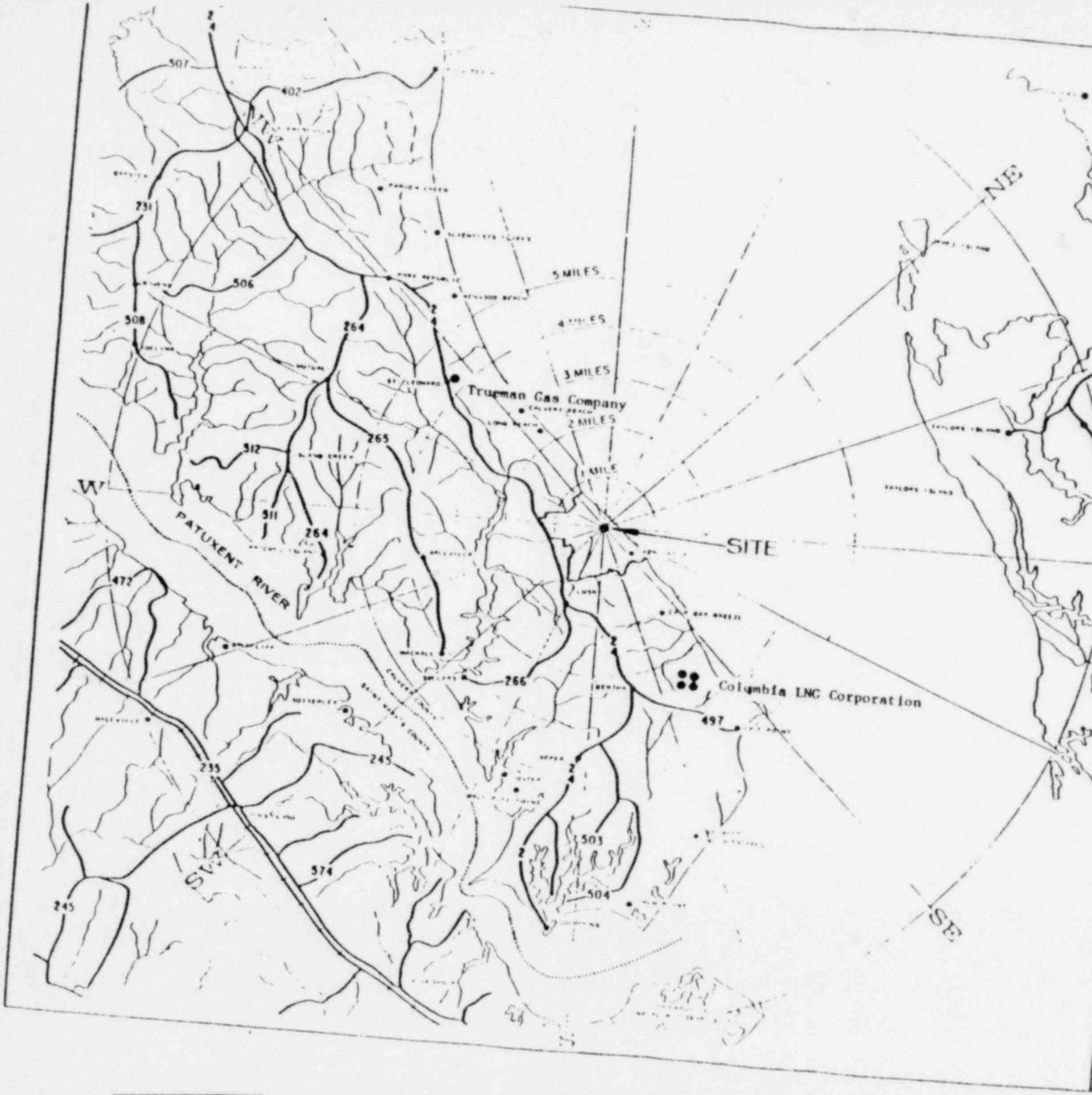
TRANSPORTATION ROUTE MA

FIGURE 1.4b



ONSITE CHEMICAL STORAGE

Figure #1.5



CHEMICAL STORAGE MAP

Key:

● Storage Tank

FIGURE 1.6

Attachment 2

The location of the control room serves to minimize radiation from all direct streaming sources. The control room doorways and stairwells do not open into any areas where radioactive materials would be present following a design basis accident.

The room is isolated from the remainder of the Auxiliary Building by its two foot thick concrete walls and floors. There are no containment penetrations that point at the control room on the elevation of the control room. Additionally, a new shield wall is being added (following a shielding analysis per NUREG 0578) to prevent any streaming through a pipe chase into the control room from below.