SITE EVALUATION for NUCLEAR INDUSTRY

GEOLOGIC REPORT SERIES No. 5

NEW JERSEY GEOLOGIC SURVEY

DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT

Prepared by

AMF ATOMICS

A division of AMERICAN MACHINE & FOUNDRY COMPANY

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FOR

STATE OF NEW JERSEY

DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT

H. MAT ADAMS, COMMISSIONER

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BUREAU OF GEOLOGY AND TOPOGRAPHY

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TRENTON, NEW JERSEY

1961

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SECTION I

INTRODUCTION

With the steady growth of the Atomic Power Industry in this country, especially in the northeastern section and overseas, the need and market potential for a nuclear fuel reprocessing facility, in this area, is increasing. Anticipating the needs of such an industry, the State of New Jersey has conducted an intensive investigation of possible site locations in this State to find one which would be not only economically feasible but also economically desirable.

Such a site has been found in the northwest section of Cumberland County, near the Delaware River in Southern New Jersey. Centered approximately 4-1/2 miles west of Bridgeton City, the site lies within the area enclosed by Roadstown, Shiloh, and Fifthian's corner. It comprises approximately 500 acres permitting an exclusion radius of 1/2 mile. (Fig. 1)

The criteria used to evaluate this site will be evidenced throughout this report. However, the most obvious advantage to this site is its geographical location in relation to the national and international industrial complex it would serve.

Due to the increasing amounts of spent fuel which has to be processed and the high cost presently involved in shipping irradiated materials from a reactor site to one of the few existing reprocessing facilities, a plant location which provides shorter and more direct shipping routes, closer proximity to centers of transportation, and access to the sea, is highly desirable.

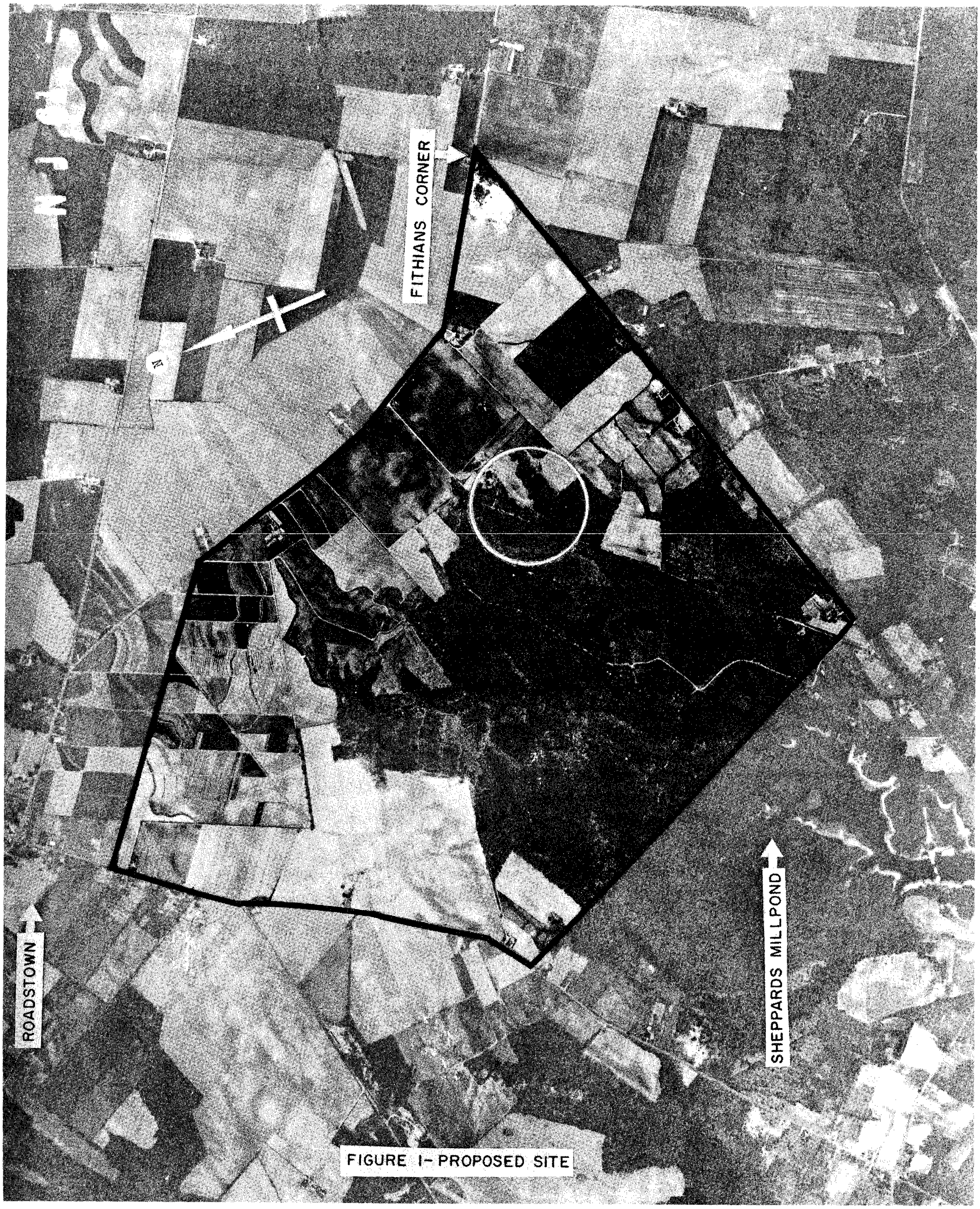


FIGURE 1- PROPOSED SITE

The site location proposed has these desired characteristics:

1) The site is located in the northeast section of the country, in the midst of the majority of research and power reactors now in operation in this country, (see Appendix A, Tables A-1 and A-2). It therefore, offers a shorter and more direct route than plants presently available to these reactors. (Fig. 2)

2) The site is located close to many major cities (Fig. 3) to benefit from their facilities, and yet remote enough to present no undue hazard to populated areas. As a result, major transportation terminals and junctions are convenient to the site and thus offer to the reactor facilities more diversity in the means and methods of transporting irradiated materials.

3) The site is acceptable from a hazards viewpoint. A preliminary hazards review indicates that a nuclear fuel reprocessing plant can be built and operated at the proposed site, without creating any undue hazard to the general public.

4) The proposed site location is within a few miles of deep water, the Delaware River, and access to the sea. The installation of a pier and seven miles of railroad tracks on a rail bed which already exists for part of the way increases the market potential for a reprocessing plant by including the refueling of nuclear powered ships, and the ability to directly handle spent fuel shipments from overseas reactor

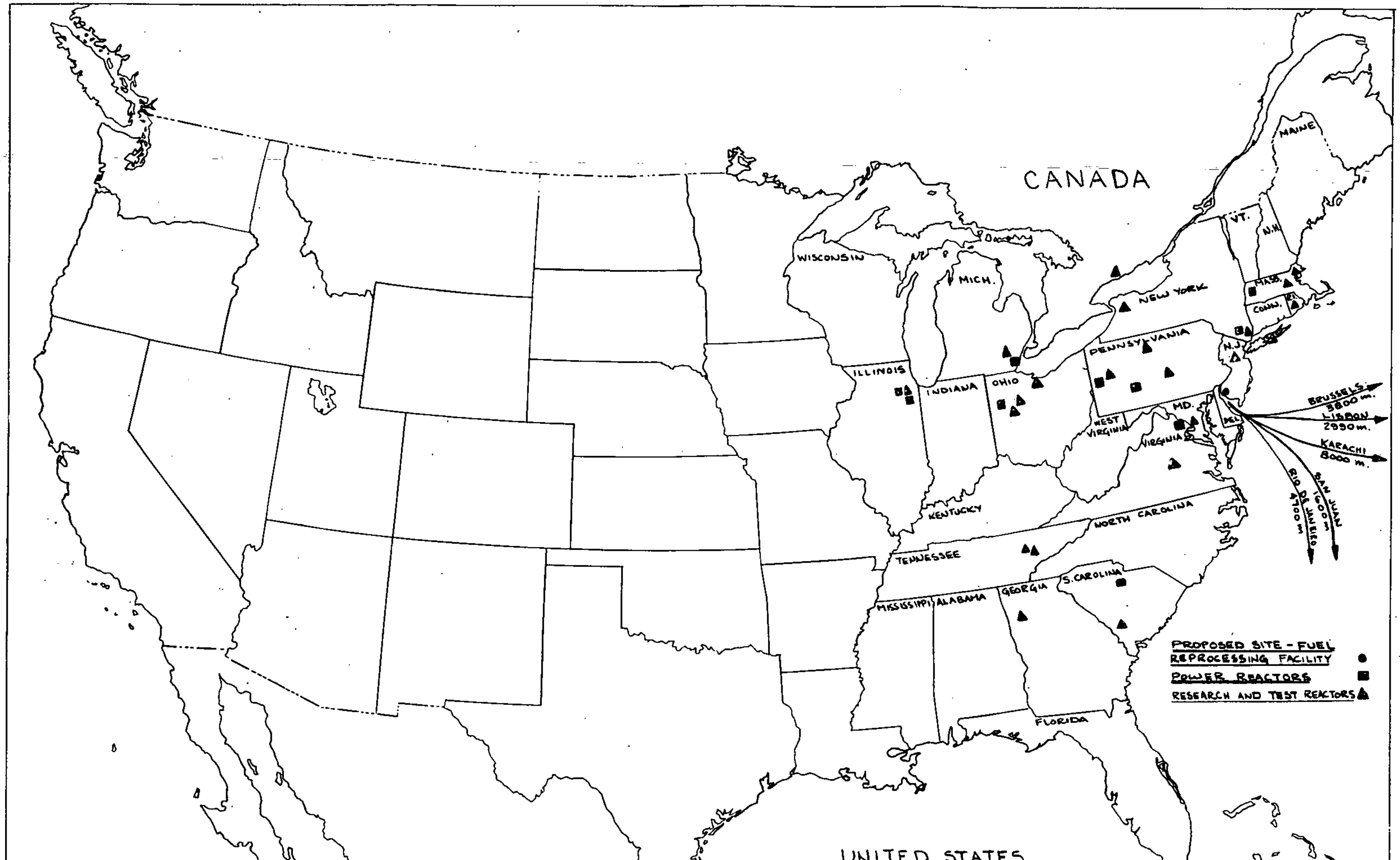
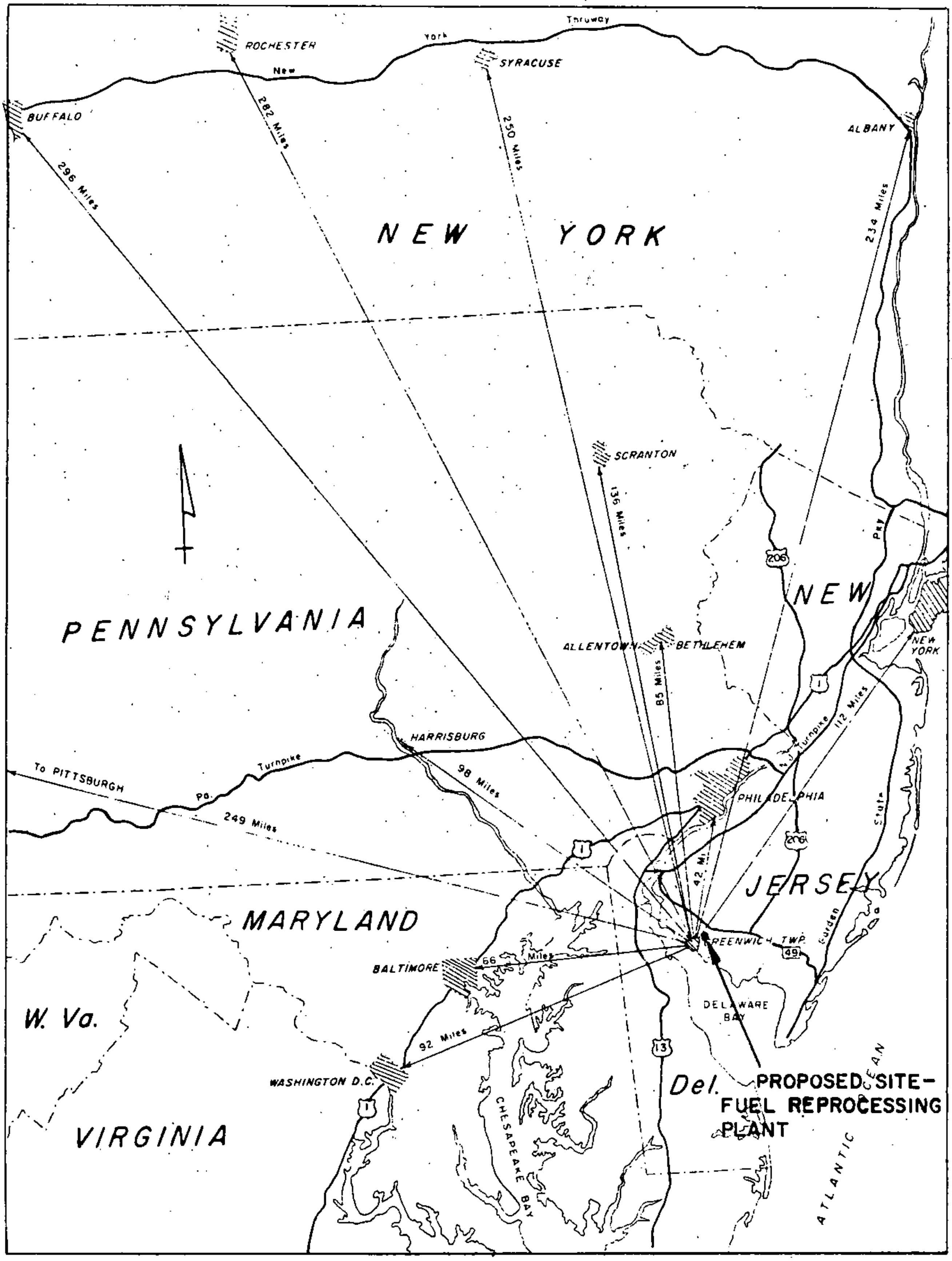


FIGURE 2. LOCATION OF POWER, TEST & RESEARCH REACTORS - EASTERN UNITED STATES



PROXIMITY OF PROPOSED SITE TO MAJOR CITIES

FIGURE 3

facilities. (See Appendix A Table A-3). A description and cost breakdown for such a marine facility is included in this report as Appendix B.

5) The site is also desirable from a personnel viewpoint. Sufficient housing is available at reasonable cost. The major metropolitan centers of Philadelphia and New York are within easy reach, as are a wide variety of recreational centers and activities. There are many advanced educational and research institutions in the State of New Jersey, and adjoining states, which can provide technical contacts and consultation and opportunities for professional advancement.

The body of this report then, constitutes an evaluation of the proposed site location from the many aspects necessary for the construction and operation of a nuclear fuel reprocessing plant and other related operations. An estimate of site development costs is included in this report as Appendix C.

The State of New Jersey has adopted and developed industrial policies which have made it one of the leading industrial communities of the nation. It is the State's policy to continue to attract and encourage industrial development by continuing its policies which have brought on a favorable industrial climate.

The need and market for a nuclear fuel reprocessing facility exists, and the State of New Jersey desires to encourage its development for the general public welfare. To this end, a site location for such a plant is hereby proposed.

SECTION II

STATE POLICIES ON INDUSTRIAL DEVELOPMENT

The State of New Jersey's industrial development program places primary emphasis on information and co-operation. Information, because the best promotion the State can have is accurate data on every subject a company may want to consider before making a plant location decision. Co-operation, because the States industrial plant program acts as a catalyst bringing together in one unified effort all interested agencies, public, and private.

1. LONG-RANGE INDUSTRIAL ATTITUDE.

The State of New Jersey recognized the necessity for proper planning for industrial development with the passage of a law, G. 13. 1B-7 Article II, Chapter 448 Laws of 1948, which empowers a Department of the Division of Planning and Development to:

1) Promote and encourage the expansion and development of markets for New Jersey products.

2) Promote and encourage the location and development of new business in this State as well as the maintenance and expansion of existing business, and for that purpose to co-operate with State and local agencies, individuals, and officers both within and outside the State.

3) Plan and develop an effective business information service both for the direct assistance of industry of this State and for the encouragement of industry outside the State to use business facilities within the State.

4) Co-operate with interstate commissions, agencies, and authorities engaged in formulating and promoting the adoption of interstate compacts and agreements helpful to business, industry and commerce.

5) Conduct or encourage research designed to further new and more extensive uses of the natural and other resources of the State and to develop new products.

6) Advise and co-operate with municipal, county, regional, and other local agencies and officers within the State to plan and otherwise co-ordinate the development of a system of air routes, airports, and landing fields within the State and to protect their approaches.

7) Co-operate with interstate commissions and authorities, State departments, and with councils, commissions, and other State agencies, and with appropriate Federal agencies, and with interested private individuals and clubs in the co-ordination of plans and policies for the development of air commerce and air facilities.

As a result of this directive, the Department of Conservation and Economic Development is responsible for the States economic vitality. This Department endeavors to provide job opportunities for all its citizens;

foster the free enterprise system; encourage new business and industries; protect returns on investments, and assure and increase the tax-producing revenues of the State and its communities. The Bureau of Commerce of the Department acts as the nerve center for all activities of State government as it concerns business and industry.

A major role of the Department of Conservation and Economic Development is that of a catalyst, bringing into play and co-ordinating the activities of all the interests in the community with a stake in the industrial development of New Jersey. To co-ordinate and channel the cumulative effort, the State has developed a unique co-operative, the New Jersey Industrial Development Family.

This effective organization, composed of men experienced in industrial development with a first hand knowledge of plants and site, consists of the States industrial realtors, and representatives of all utilities, railroads, local and county industrial commissions, the New Jersey State Chamber of Commerce and the New Jersey Manufacturers Association. It is maintained because the State, regardless of the political complexion of its administration, has scrupulously avoided any hint of favoritism among the areas, realators, utilities, or railroad lines. Because of this policy of fairness to all, it keeps the respect and co-operation of the Industrial Family, and New Jersey is better equipped to serve all potential new industries.

Another State development group which has been formed to assist in this program is called the Economic Ambassadors. It is composed of 100 business and industrial leaders, appointed by the Governor, representing every segment of the State's economy. Their essential task is to promote New Jersey's economic welfare for existing industry as well as for prospective new industry. They contact financial, industrial, and business leaders. These ambassadors also serve as consultants and advisors. A 14-man advisory committee group itself meets periodically to consider and discuss major subjects related to the economy and vital to the development of State. Discussions include such matters as the tax climate, future water development, labor, State budgeting, and other major governmental policies. Based on the belief of some Economic Ambassadors that New Jersey needed a credit corporation, the New Jersey Business Development Corporation was formed in October 1959 to assist business and industrial financing. Supported by leading banks, insurance companies, and industries the corporation operates as a public service, under state regulations and with full state co-operation. It has the power to make loans and investments for the purpose of bringing new industrial, mercantile, recreational, agricultural, mining, and business establishments into the State, and assisting existing businesses and industries to remain in the State.

The Advertising Co-ordinating Committee serves as a liaison between the Department of Conservation and Economic Development and all of the public and private development agencies throughout the State, in order to develop a common theme for advertising and promoting the State; to co-ordinate use of advertising media; to arrange wherever possible for co-operative advertising programs and special projects to insure maximum coverage and results; and to provide and circulate schedules to permit industrial realtors and local groups to tie-in and gain full advantage from collective advertising enterprises.

Considerable success has come to New Jersey as a result of special attention to planning and formation of effective groups and corporations. One outstanding by-product of planning in New Jersey has been the spectacular growth of privately developed industrial parks. There has been a constant increase in acreage available in properly subdivided tracks with desirable features of design, utilities, planning, compatability, and good management to the point where New Jersey now has more industrial parks per square mile than any state in the nation. In co-operation with the New Jersey Industrial Development Family, the Department of Conservation and Economic Development maintains standards for the operation of these industrial parks and through the Bureau of Planning, works with municipalities to develop comprehensive land use controls which, in the future, will maintain desirable conditions in contiguous areas. Planning is meant to protect the old as well as to attract the new. It is hoped and desired that the fuel reprocessing facility will be the nucleus around which an "Atomic Park" will develop.

In concert with planning and development program, the State has established the Division of Water Policy and Supply to protect, conserve, develop, and distribute equitably both surface and sub-surface water. In addition, the Division formulates all long-range planning with the same exploitation of water resources.

With regard to the business climate between labor and management, it is a fact that relations are, on the whole, quite harmonious. Studies of work stoppage in the nations 9 most heavily industrialized states during the period of 1939-1956, show that only one state has a lower percentage of total man-days lost due to strikes. This record of achievement is particularly significant when it is remembered that the 19 years period study embrace the closing years of our greatest depression, the post-war re-adjustment period, two minor recessions, and several years of un-presidented prosperity.

The development of smooth labor relations in New Jersey has been greatly facilitated by the work of the State Board of Mediation. Established by the legislature in 1941, the Board is composed of 7 members; three, representing the public, two, representing management, and two, representing labor. The Board's primary function is the mediation of labor disputes with the purpose of avoiding strikes and of minimizing the damage caused by those strikes which do occur. In addition to the mediation services, the Board provides facilities for the voluntary arbitration of labor disputes. The usefulness of the Board's services and its acceptance by both management and labor are proven by the fact that since 1947 requests for arbitration have increased at the rate of about 10 per cent per annum. Since its establishment in 1941, the Board has aided in the settlement of virtually every major industrial dispute in the State.

2. THE INDUSTRIAL ENVIRONMENT OF NEW JERSEY AT A GLANCE.

As a leading industrial state, New Jersey has the following economic advantages to offer its industrial family:

1) Markets - New Jersey is in the geographic center of the world's richest market. Within a 250 mile radius of New Jersey there are 12 states and the District of Columbia with 52,000,000 people having a net effective buying income of 91 billion dollars.

2) Transportation - New Jersey as a center of world transportation has more miles of railway-more miles of super highway, for its size, than any other state. It lies between two of the world's great seaports and it has convenient air service to everywhere.

3) Labor - In New Jersey there is a diversification of skilled and semi-skilled workers who rate high in productivity and a technical, professional, and engineering pool ratioed highest in the nation.

4) Research - New Jersey has the greatest concentration of industrial research, electronic, and nuclear developments. Ten per cent of the total funds allocated by industry for research throughout the nation are spent within New Jersey.

5) Government - The public services of New Jersey are performed so effectively, efficiently, prudently, and with the highest standards of integrity that they have and will continue to encourage the expansion of business and industrial enterprises.

6) <u>Education</u> - New Jersey places considerable emphasis on the attainment of the high level of education by its citizens, including specialized vocational training to meet the growing technological challenge of our times.

7) <u>Planning</u> - New Jersey has the highest percentage of municipalities with professional planning to assure the future of these communities and their existing and new industries.

8) <u>Utilities</u> - In New Jersey electric power is served in virtually "every inch of the land" while natural or manufactured gas is available throughout every developed section of the state.

9) <u>Financing</u> - In New Jersey there is a combination of private institutions, private developers, and a state-wide development corporation with investment funds, yet no legislation to impose governmental costs on existing tax-paying industries for the purpose of attracting new industries.

10) <u>Taxes</u> - In New Jersey will be found state and local governments where industry is welcomed and where the balanced economy retains the soundness of the taxing climate, without sales or income taxes.

11) <u>Industrial Parks</u> - There are more Industrial Parks per square mile in New Jersey than in any other state in the union.

12) <u>Industrial Diversification</u> - New Jersey has the type of industrial complex that provides not only every diversification, but sources, resources, supplies, and outlets for almost every type of manufacturing.

13) Land Sites - In New Jersey there is an abundance of sites suited to any specification, large or small, with every economic factor satisfied for the individual need.

14) Resources - New Jersey has many modern utilitarian, man-made, resources that support the natural advantages of the area for manufacturing.

15) Water - New Jersey has the natural, evenly distributed rainfall required for the continued growth of the State's economy. Also, New Jersey is the first State in the nation to adopt a state-wide, long-range water resources development program to meet water needs through the year 2000 and beyond.

16) Environment - New Jersey has all the attributes necessary in which to operate an industrial enterprise; locate the plant within reach of cultural centers, great shopping areas, fine seashore and lake land resorts; and provide a choice of urban, suburban, or rural living.

SECTION III

PHYSICAL ENVIRONMENT

1. INTRODUCTION.

A study of the physical environment of the proposed site has been conducted to determine the suitability of the location for a nuclear fuel reprocessing plant. The areas investigated were:

1) Topography
2) Geology
3) Hydrology
4) Meteorology and Climatology
5) Occurrence of Severe Natural Phenomena

The findings of this study indicate that the physical environment of the site is well suited for a nuclear fuel reprocessing facility.

The importance of the physical environment of the site is graphically illustrated in the Preliminary Hazards Analysis (Section V of this report), as it pertains to the determination of the maximum credible accident and the effects of an accident on the surrounding physical and geographical environments.

The elevation of the site, and its geologic and hydrologic conditions, make it suitable for the installation of radioactive waste storage tanks.

Other considerations which were evidenced by the findings were a good basic drainage pattern, abundant rainfall, predominately flat terrain, an altitude between 100 and 115 feet above sea level, no severe climatic condition, and no threat of earthquakes or flood.

2. TOPOGRAPHY.

The proposed site location, elevation 100 to 115 feet, is characterized by predominantly flat terrain with some rolling hills. Most of the site area is 110 feet above sea level. (Fig. 4, Back Cover Pouch) Drainage from the site is controlled primarily by Mill Creek, a tributary of the Cohansey River. Small ravines of three intermittent Mill Creek tributaries, having a maximum relief of approximately 40 feet, drain the area to the south. The northern and eastern rim of the site is on a flat-topped drainage divide between Mill Creek and another tributary of the Cohansey River, Barrett Run, which flows north of Bridgeton. However, all drainage can be directed into the Mill Creek watershed.

South of the site, the tributaries of Mill Creek flow into Sheppards Millpond which has an elevation of 18 feet. From the dam at Sheppards Millpond, Sheppards Creek flows approximately two miles south to empty into the Cohansey River. From Sheppards Millpond to the Cohansey River, the land slopes downward, generally to the south, until the elevation in the area of the River is approximately 10 feet. This elevation remains the same as far as the salt marshes along Delaware Bay.

3. GEOLOGY.

Sands, silts, gravels, and clays of the Bridgeton, Cohansey, and Kirkwood formations are found at the surface in the site area. The Bridgeton gravels, with a probable maximum thickness of 20 feet, cap the highest part of the site. Beneath these gravels the Cohansey sand, with an average thickness of about 150 feet, underlies the area down to an elevation of -40 approximately. The Kirkwood formation, which is alternating sands and clays, is found beneath the Cohansey sand with a thickness of about 150 feet, down to an elevation of approximately-110 to -120. Other sand, clay, and marl formations of the Coastal Plain geologic province underlie the area to a depth between 1500 and 2000 feet. Beneath the lowest Coastal Plain formations are the crystalline rocks of the Precambrian basement. These rocks out-crop north and northwest of the Delaware River in Delaware, Maryland, and Pennsylvania. (Fig. 5)

4. HYDROLOGY.

The State of New Jersey has abundant rainfall, which is evenly distributed, throughout the year. It is estimated that the average annual surface runoff is in the order of 0.85 million gallons per day per square mile, (Fig. 6). As a result of this rainfall and the sponge-like qualities of the area, high quantities of water are retained. The coastal Plain ground aquifers and surface streams provide a large potential reserve of water for the needs

SEDIMENTARY ROCKS

Cenozoic

Quaternary—Recent deposits of the last 10,000 years are chiefly beach sands forming Sandy Hook and the offshore bars. Pleistocene or ice age starting 1,000,000 years ago. Widespread thin deposits of till and outwash covering older formations are not shown on this map. Mineral production—peat moss, sand, and gravel.

Tertiary—Starting 70,000,000 years ago. Unconsolidated sands, gravels, and clays. Forms the outer Coastal Plain. Marked by three different periods of invasion by sea, separated by erosional periods of dry land. Mineral production—brick and terracotta clays; glass sands; ilmenite (titanium ore).

Mesozoic

Cretaceous—Starting 125,000,000 years ago. Unconsolidated sands, clays, and greensand marls Forms the inner Coastal Plain. Appalachian Province uplifted and coast depressed; fast moving rivers deposited sediments in marine environment. Mineral production—fireclay, brick clay, greensand marls.

Triassic—Starting 200,000,000 years ago. Shales, argillites, sandstone, and some conglomerates. Forms Piedmont Plain. Appalachian Mts. uplifted and long thin depressed basins formed between ridges; fast moving rivers deposited sediments in these basins. Mineral production—Stockton sandstone (brownstone) for building stone; negligible amounts of copper found in some shales.

Paleozoic

Devonian—Starting 330,000,000 years ago. Sediments occur in two areas, 1) fossiliferous, calcareous shales and limestones in Appalachian Plateau, 2) sandy shales, sandstones, and conglomerates in valley south of Greenwood Lake in Highlands. No significant mineral production.

Silurian—Starting 360,000,000 years ago. Coarse conglomerates, sandstone, shale and, limestone. Occur to the southeast of Devonian sediments. From early Devonian, when sea receded to early Upper Silurian, N.J. was dry land.In late Silurian, the sea receded for a very short period and then re-invaded land. No significant mineral production.

Ordovician—Starting 420,000,000 years ago. Limestone, shales, and slates. Found in the Highlands and Appalachian Plateau. Three different invasions of land by sea, with erosional periods of dry land in between. Mineral production—cement rock and slate.

Cambrian—Starting 500,000,000 years ago. Quartzite followed by limestone. Found in the Highlands and Appalachian Plateau. During first and last parts of Cambrian time N.J. was covered by seas, while in Middle Cambrian time it was dry land

Precambrian—Franklin limestone—more than 500,000,000 years old. Typically a white crystalline limestone. Found in a narrow belt and a few isolated masses in the Highlands. Mineral production—zinc deposits at Franklin and Ogdensburg; limestone for flux and cement rock.

IGNEOUS ROCKS

Triassic—Diabase and Basalt—The same basic rock formed from cooling molten material. Differ in texture. Diabase is coarse grained due to slow cooling beneath the surface while basalt is fine grained due to quick cooling of lava at the surface. Diabase forms the Palisades and its extensions to the south in the Princeton area. Basalt forms the Watchung Mts. and the two small masses at New Germantown and Sand Brook. Diabase and basalt are extensively quarried for concrete, road metal, and railroad ballast.

Precambrian—Gneiss and Granite. Granite is a coarse grained igneous rock characterized by predominant alkali feldspar and quartz. Gneiss is a crystalline rock with a secondary rough foliation developed as a result of pressure on the solidified rock; bands or lenses in gneisses are commonly unlike. Metamorphic rocks are included in this zone, some of them having been derived from sediments. These rocks form "The Highlands of New Jersey". Mineral production—magnetite (iron ore), crushed stone and prospects for uranium, monazite, and rare earths.

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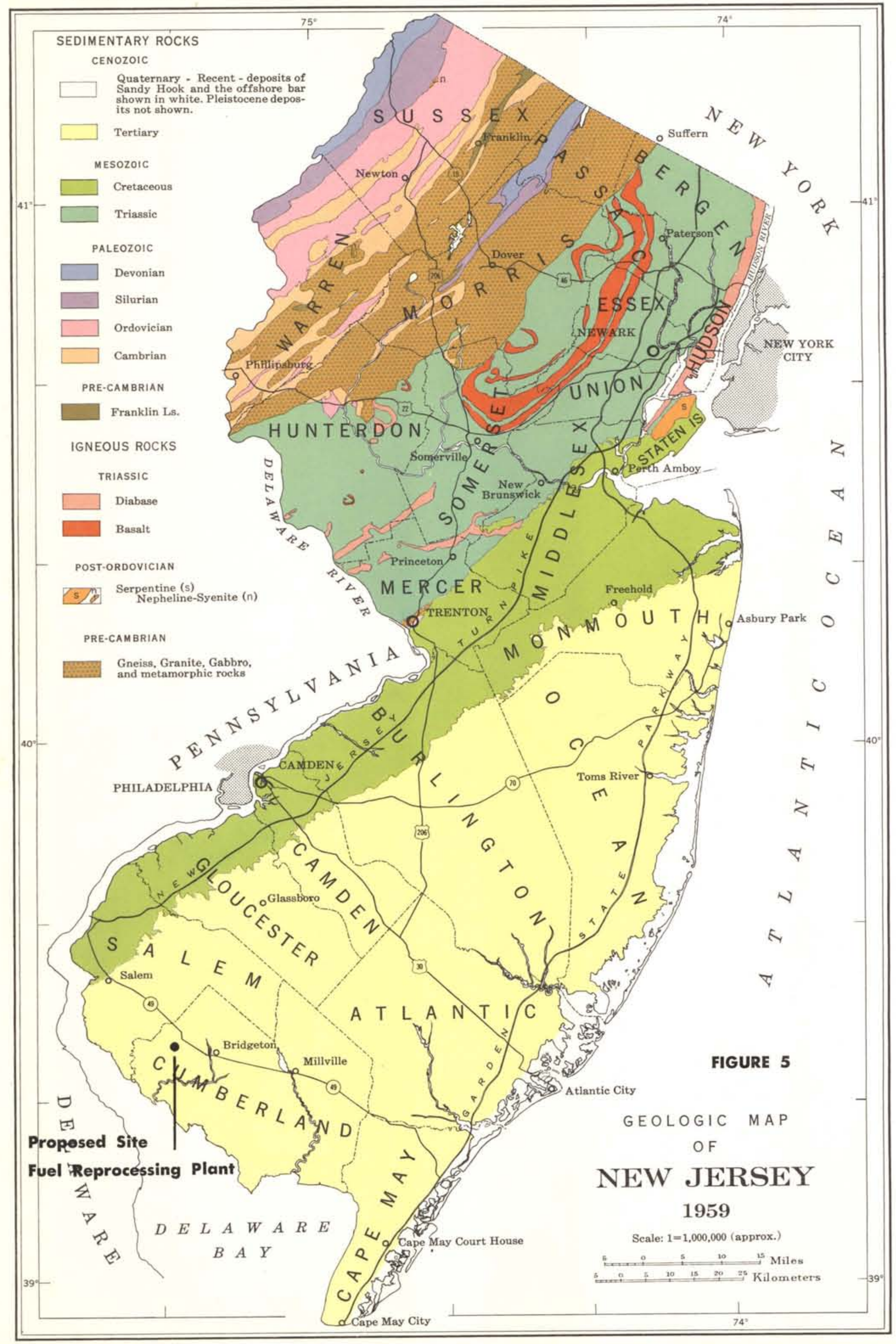


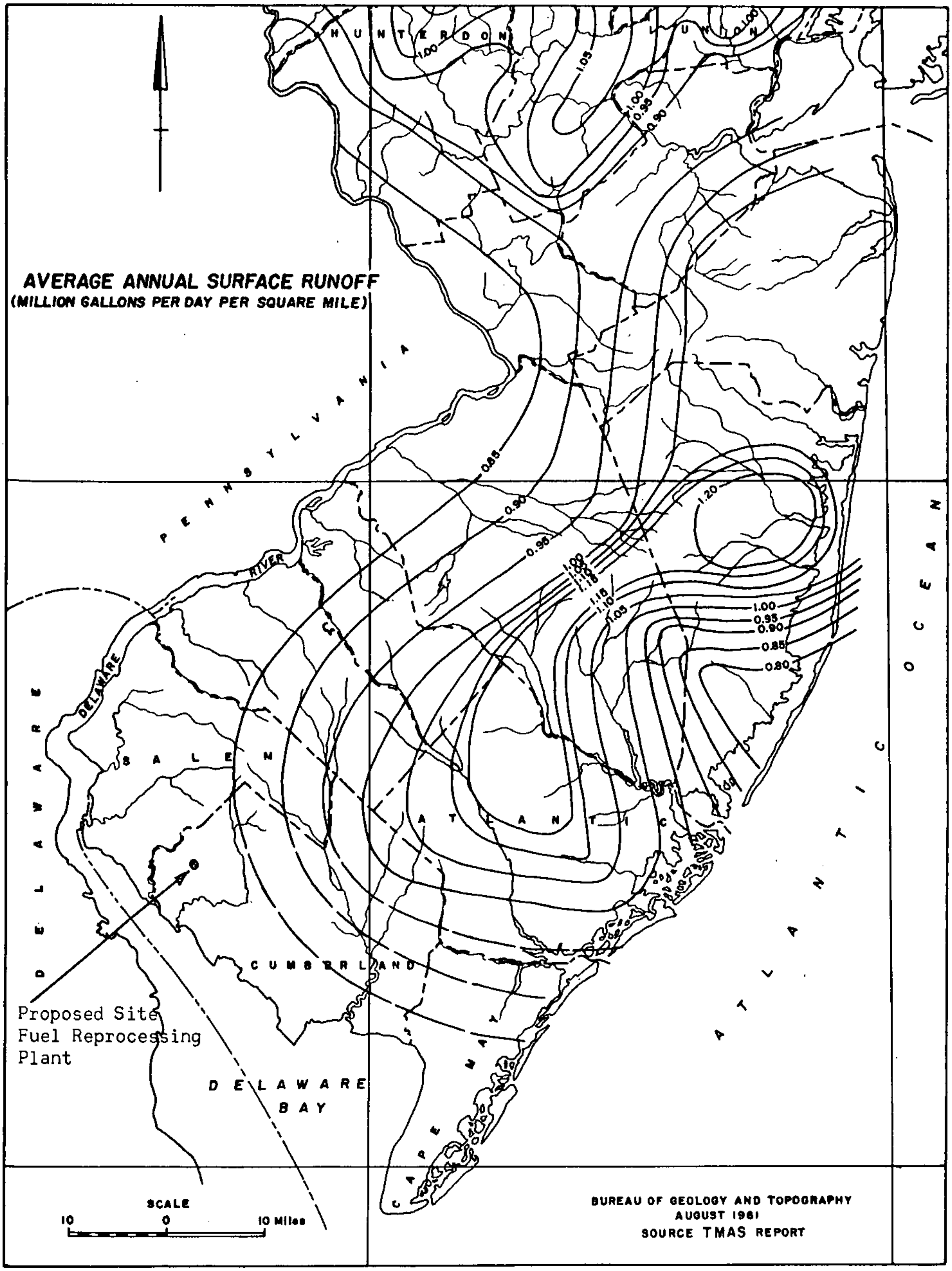

AVERAGE ANNUAL SURFACE RUNOFF
(MILLION GALLONS PER DAY PER SQUARE MILE)
HUNTERDON
UNION
PENNSYLVANIA
DELAWARE RIVER
DELAWARE
SALEM
ATLANTIC
CUMBERLAND
CAPE MAY
DELAWARE BAY
ATLANTIC OCEAN
Proposed Site
Fuel Reprocessing
Plant
1.00
1.05
0.95
0.90
0.85
0.80
1.10
1.15
1.20
SCALE
10 0 10 Miles
BUREAU OF GEOLOGY AND TOPOGRAPHY
AUGUST 1961
SOURCE TMAS REPORT

FIGURE 6

of southern New Jersey. It is anticipated that this reserve is ample for all conceivable needs, for the next 40 years, for both the steadily growing industrial and population rise forecast.

In the site area the sands and gravels of the Bridgeton formation, and the sands of the Cohansey formation can be considered a single hydrological unit. In general, the near surface flow of ground water will be southward to Sheppard's Millpond and Mill Creek. In the northern and eastern part of the site area some ground water may flow northeasterly into the drainage of Barrett Run. In the extreme western part of the site area some ground water may move toward tributaries of the Stowe Creek drainage.

The sand layers, particularly in the upper part of the Kirkwood formation, yield moderate supplies of water and, for all practical purposes, they may be considered as part of the same hydrological unit as the overlying Cohansey. However, the collective thickness of clays and marls of the lower part of the Kirkwood, Shark River, and Manasquan formations, all of which are below sea level in the site area, can be considered as aquacludes which will limit or prevent deep water circulation. Beneath these formation there are other aquifers, but the lower part of the 1,600 foot well at Bridgeton and the lower thousand feet of a recently drilled well near Smyrna, Delaware, which reached the Precambrian basement, suggests that the lower thousand feet of the coastal plain sediments in this area will contain salt water.

The zone of permanent saturation, or depth to the ground water table, beneath the site is believed to be between 40 and 50 feet below the surface of the higher points of the area or at approximately elevation 60. This will permit the installation of radioactive waste storage tanks.

Three minor tributaries of Mill Creek have permanent flow at elevations 60 and 45. At Fifthians Corner, a sand pit, excavated approximately 20 feet deep, was dry at the bottom and an auger hole indicated no water for an additional 15 feet. Under most of the site, therefore, it is believed that a zone of permanent saturation is not above elevation 60.

Subterranean flow from the site into wells in the general area, if any, has not been determined for this report.

5. METEOROLOGY AND CLIMATOLOGY.

The general climate of the area in Southern New Jersey is mild. The humidity for the area ranges between 70 and 75% with clear sunshine about 65% of the time. The mean clear average days total about 140, with 120 days cloudy or rain and the remainder, scattered sunshine.

The average temperature for the seasons from 1931 to 1955 was as follows:

Winter	37.5°F
Spring	62.5°F
Summer	73.1°F
Fall	46.5°F

The average monthly temperatures, for the same period are shown in Table III-1.

The annual precipitation in southern New Jersey averages 45 inches and is distributed quite evenly during the year. For this particular site location the average annual precipitation is 43.5 inches. The average monthly precipitation for the Bridgeton area is shown also in Table III-1. The typical annual precipitation for a dry and wet year at the site is 29.5 inches in 1930 and 45 inches in 1952. (Figs. 7, 8, 9)

The prevailing winds from October to March are predominantly NW and from April to September predominantly SW. (Figs. 10, 11, 12, 13)

The velocity of these winds as recorded at the Philadelphia International Airport for the period between November 1949 and October 1954 for each of the months were as follows:

Month	Av. Speed, MPH
January	10.1
February	11.0
March	12.2
April	11.2
May	8.9
June	9.0
July	7.8
August	7.2
September	7.9
October	8.5
November	9.5
December	10.0

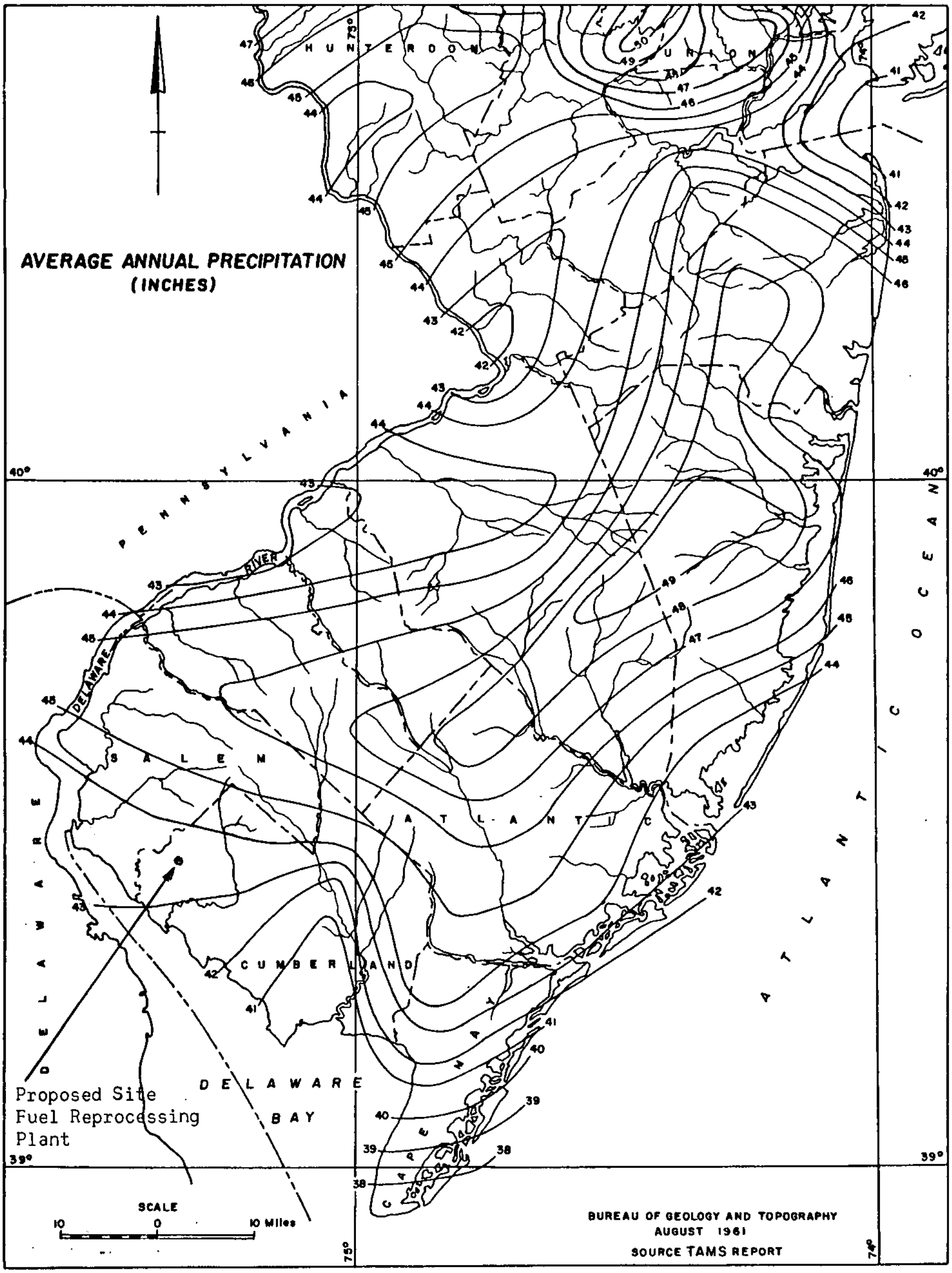
TABLE III-I

MEAN TEMPERATURE AND PRECIPITATION

FROM 1931 - 1955

BRIDGETON, N.J.

Month	Temperature, °F	Precipitation, Inches
January	34.8	3.67
February	34.8	2.81
March	42.8	3.84
April	52.5	3.13
May	63.3	4.20
June	71.8	3.44
July	76.6	3.86
August	74.7	5.10
September	68.0	3.91
October	57.3	3.12
November	46.1	3.64
December	36.1	3.12
Annual	54.9	43.84


AVERAGE ANNUAL PRECIPITATION
(INCHES)
HUNTERDON
UNION
PENNSYLVANIA
DELAWARE RIVER
SALEM
ATLANTIC
CUMBERLAND
CAPE MAY
DELAWARE
DELAWARE BAY
ATLANTIC OCEAN
Proposed Site
Fuel Reprocessing
Plant
SCALE
10 0 10 Miles
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AUGUST 1961
SOURCE TAMS REPORT
40°
39°
75°
74°

FIGURE 7

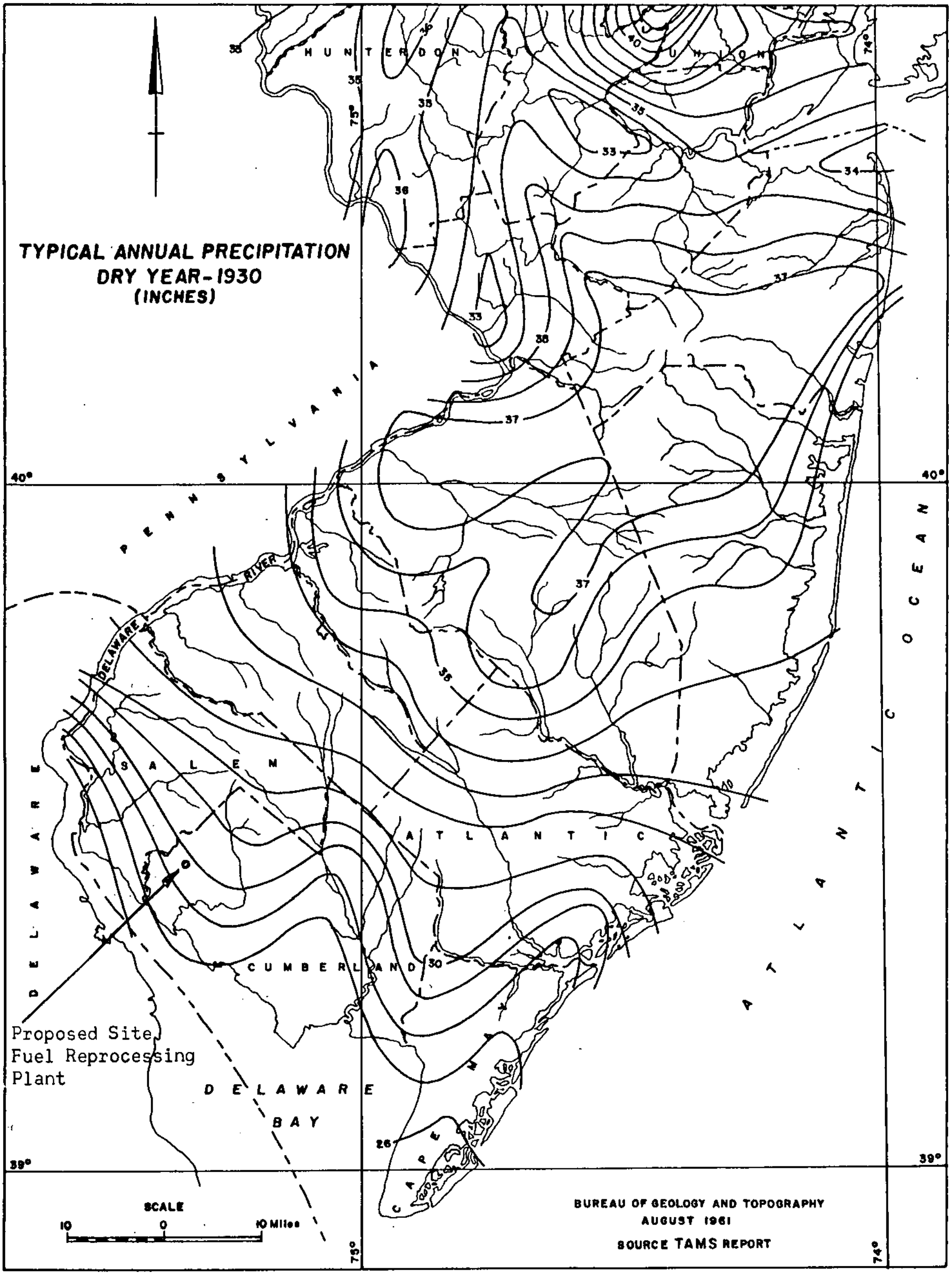
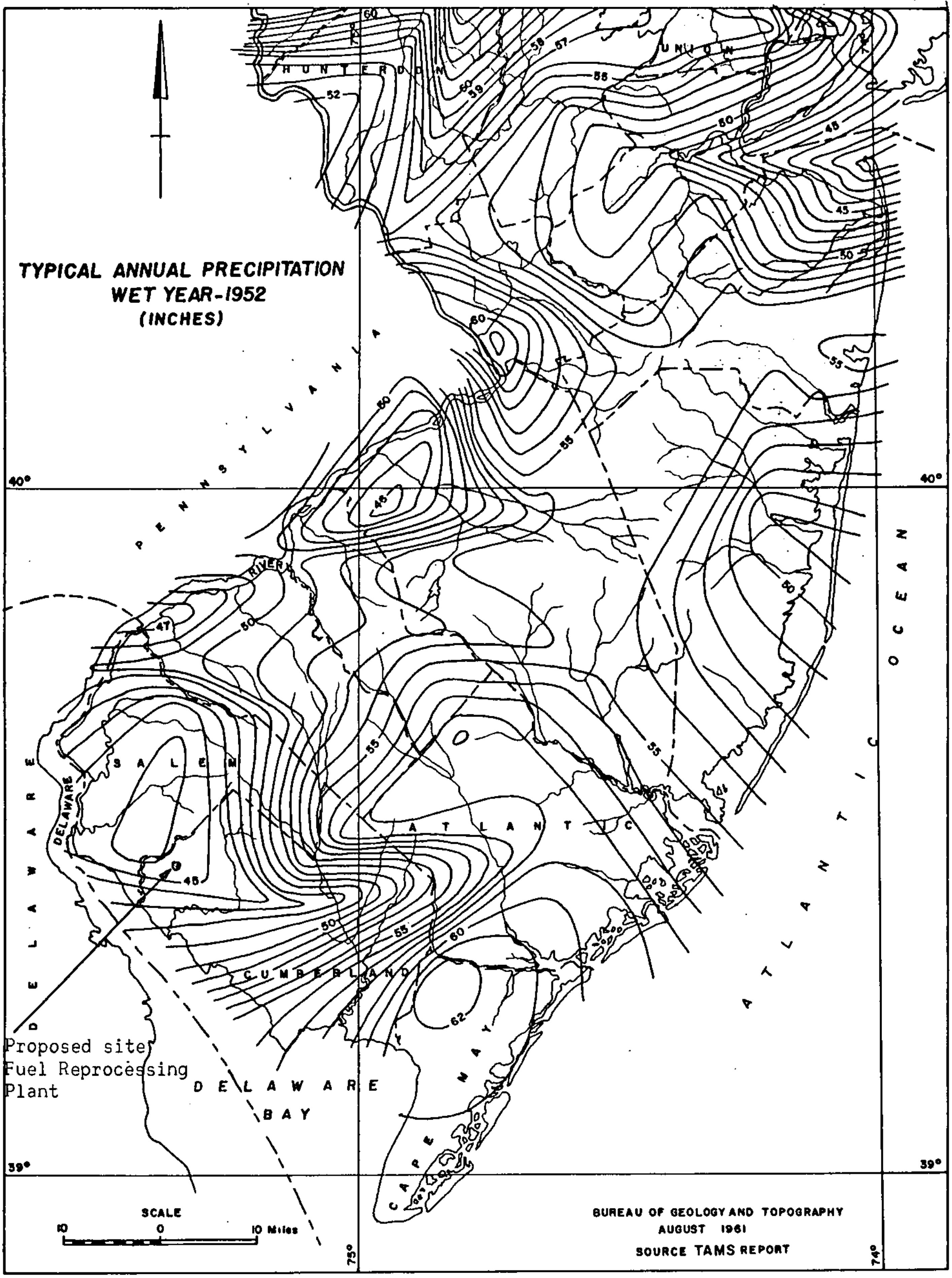

TYPICAL ANNUAL PRECIPITATION
DRY YEAR-1930
(INCHES)
HUNTERDON
UNION
PENNSYLVANIA
DELAWARE RIVER
SALEM
ATLANTIC
CUMBERLAND
CAPE MAY
DELAWARE
DELAWARE BAY
ATLANTIC OCEAN
40°
39°
75°
74°
Proposed Site
Fuel Reprocessing
Plant
SCALE
10 0 10 Miles
BUREAU OF GEOLOGY AND TOPOGRAPHY
AUGUST 1961
SOURCE TAMS REPORT

FIGURE 8


TYPICAL ANNUAL PRECIPITATION
WET YEAR-1952
(INCHES)
HUNTERDON
UNION
PENNSYLVANIA
RIVER
DELAWARE
SALEM
ATLANTIC
CUMBERLAND
CAPE MAY
DELAWARE BAY
ATLANTIC OCEAN
Proposed site
Fuel Reprocessing
Plant
40°
39°
75°
74°
SCALE
10 0 10 Miles
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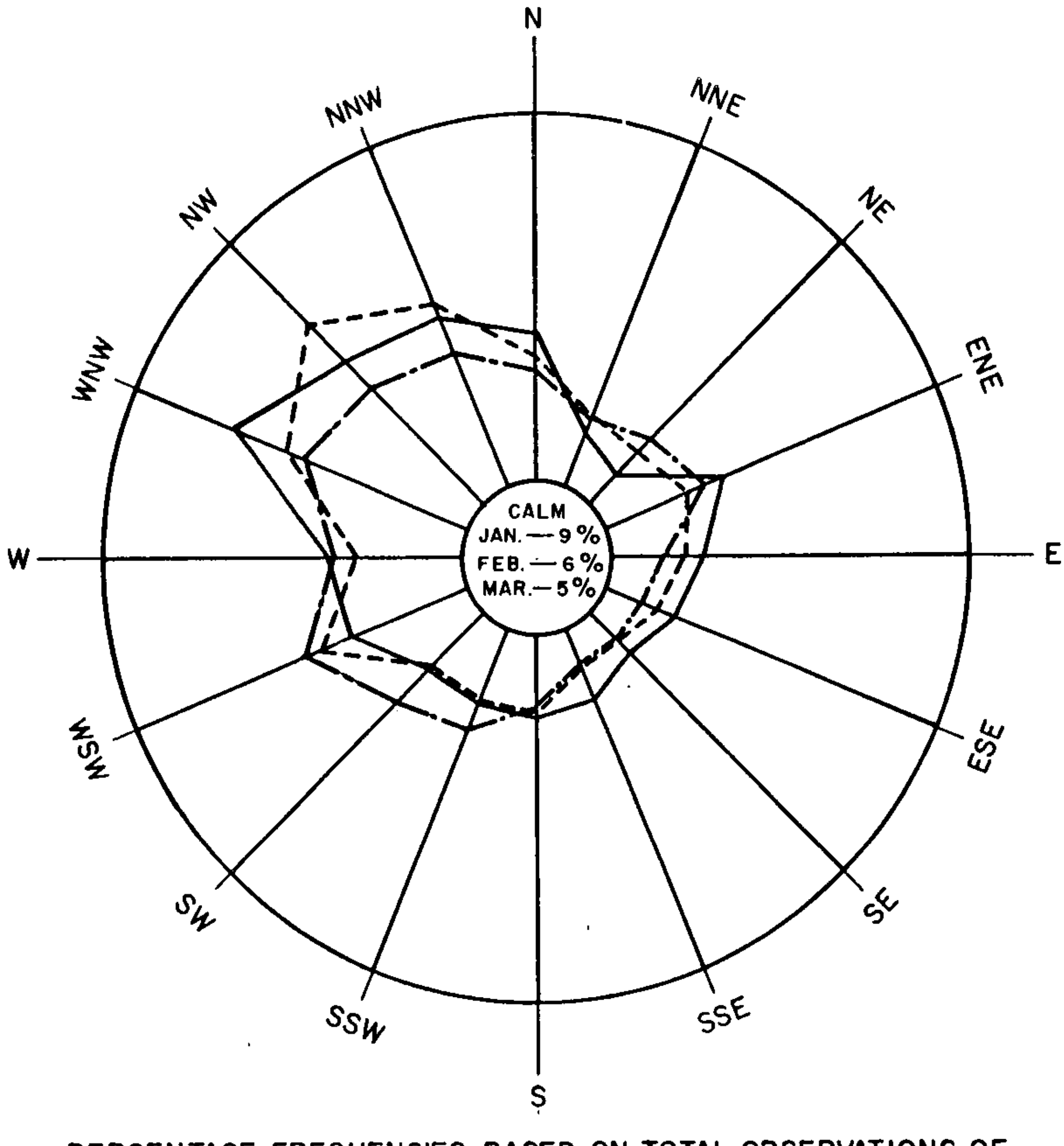
SOURCE TAMS REPORT

FIGURE 9

PERCENTAGE FREQUENCIES OF WIND DIRECTION

RADIAL SCALE 1" = 10%



PERCENTAGE FREQUENCIES BASED ON TOTAL OBSERVATIONS OF

—·— JANUARY ———— 3720 HOURS

– – – FEBRUARY ———— 3384 HOURS

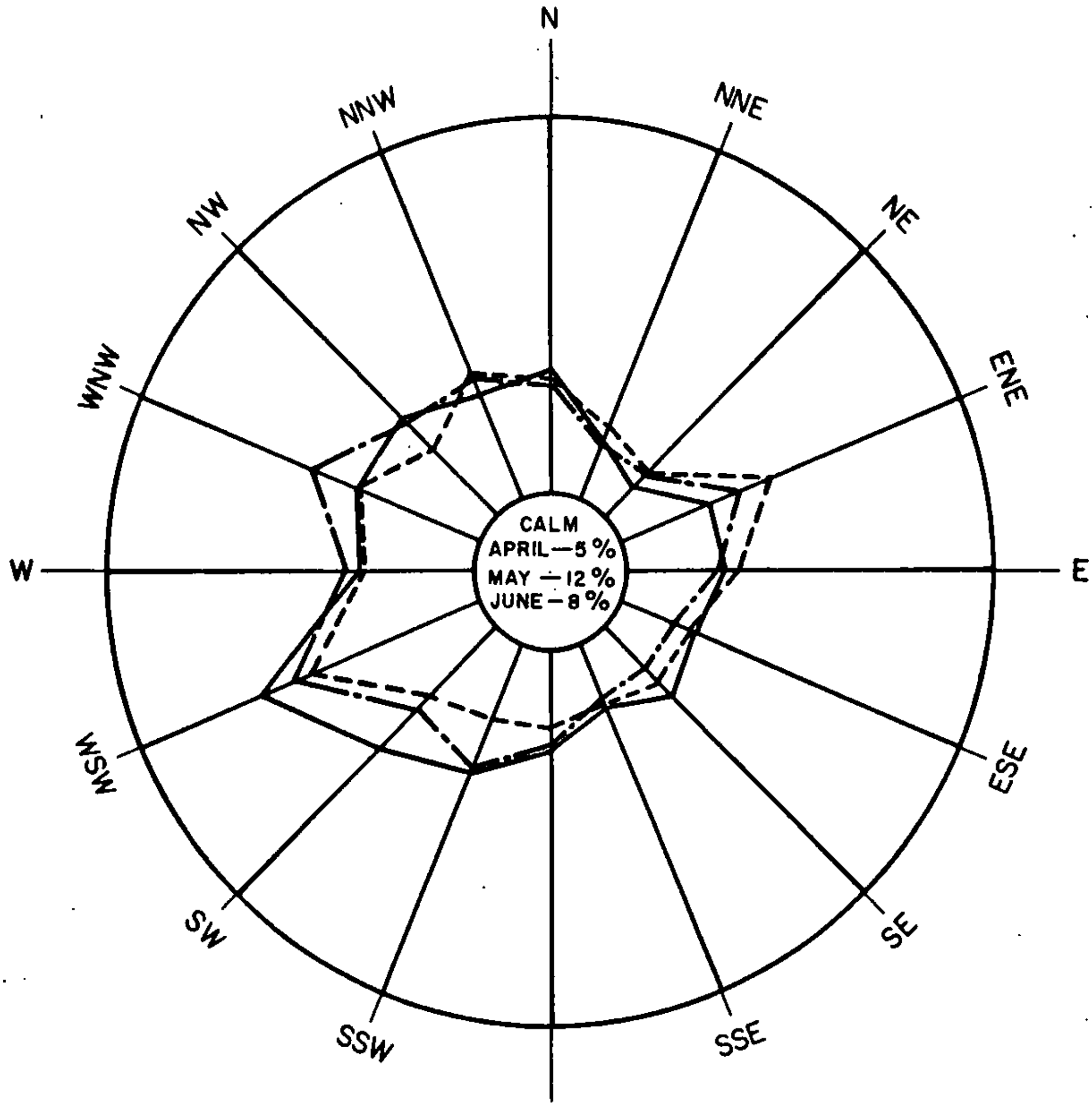
——— MARCH ———— 3720 HOURS

FIGURE 10

PERIOD COVERED — NOV. 1949 - OCT. 1954 PHILADELPHIA INTERNATIONAL AIRPORT

PERCENTAGE FREQUENCIES OF WIND DIRECTION

RADIAL SCALE 1" = 10%



PERCENTAGE FREQUENCIES BASED ON TOTAL OBSERVATIONS OF

— · — APRIL ———— 3600 HOURS

– – – MAY ———— 3720 HOURS

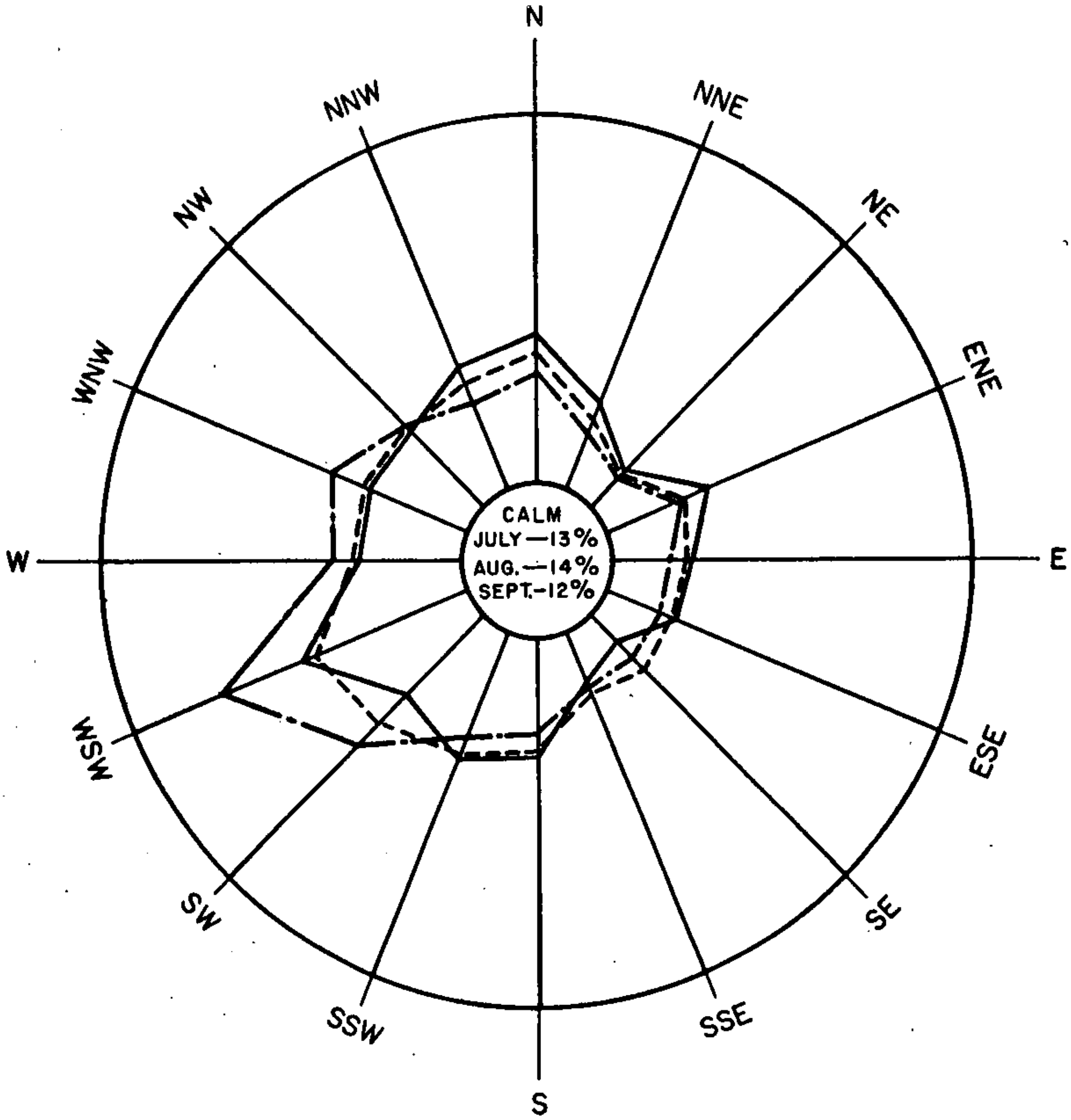
——— JUNE ———— 3600 HOURS

FIGURE 11

PERIOD COVERED — NOV. 1949 - OCT. 1954 PHILADELPHIA INTERNATIONAL AIRPORT

PERCENTAGE FREQUENCIES OF WIND DIRECTION

RADIAL SCALE 1" = 10%



PERCENTAGE FREQUENCIES BASED ON TOTAL OBSERVATIONS OF

—·— JULY ———— 3720 HOURS

- - - - AUGUST ———— 3720 HOURS

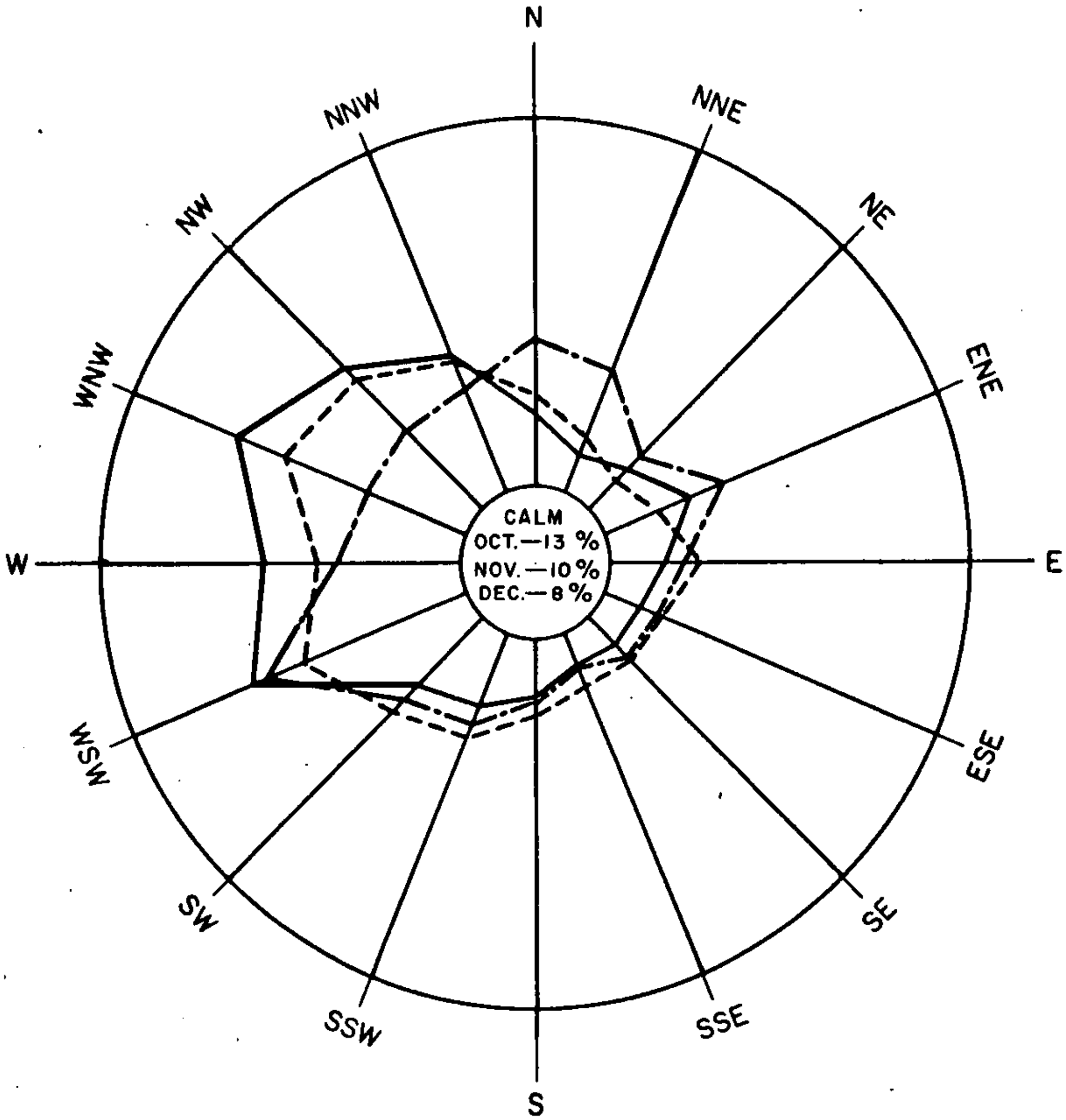
——— SEPTEMBER ———— 3600 HOURS

FIGURE 12

PERIOD COVERED — NOV. 1949 - OCT. 1954 PHILADELPHIA INTERNATIONAL AIRPORT

PERCENTAGE FREQUENCIES OF WIND DIRECTION

RADIAL SCALE 1" = 10%



PERCENTAGE FREQUENCIES BASED ON TOTAL OBSERVATIONS OF

OCTOBER ———— 3720 HOURS
NOVEMBER ———— 3600 HOURS
DECEMBER ———— 3720 HOURS

FIGURE 13

6. OCCURRENCE OF SEVERE NATURAL PHENOMENA.

The occurrence of severe natural phenomena, such as earthquakes and floods, is an over-all consideration necessary to the siting of any type of plant.

7. SEISMOLOGY.

According to the Uniform Building Code, the State of New Jersey is seismologically rated as zone C since this area has a low probability of damaging earthquakes. This makes the site desirable from this viewpoint. The earthquake history for the area is as follows:

1) September 10, 1877 – Delaware Valley. Felt from Trenton to Philadelphia over twenty miles wide with center near Burlington, New Jersey. Intensity of 4-5 on the Mercalli Scale. *

2) March 25, 1879 – Delaware River below Philadelphia, Pa. Felt from Chester Pa. to Salem, New Jersey, over a distance of thirty miles. Felt most strongly on east side of river. Intensity of 4-6 on the Mercalli Scale.

3) April 23, 1910 – Atlantic City to Cape May, New Jersey, and Snow Hill, Maryland. While these shocks do not appear to have exceeded intensity 4. on the Mercalli Scale, they were so widespread that they are included. At 21:30 there was a similar shock near Catensville, Maryland.

4) November 4, 1939 – Salem County, New Jersey, Epicenter 39° 39' north 75° 13' west. About 6,000 square miles affected. Intensity of 5. on the Mercalli Scale.

Note: *Modified Mercalli intensity Scale of 1931 (abridged)

8. FLOODING.

The proposed site location is located on the major stream divide elevation 110-115 feet above sea level between Cohansey Creek and Stowe Creek in an area of porous sandy soils, as a result, there is adequate drainage for large volumes of surface water. Numerous gullies draining to the south, towards the Delaware, are incised into the stream divide and these would serve as relief features for any excess of precipitation. The chance of flooding in this site area is negligible, therefore the site is desirable from this viewpoint.

A preliminary hazards review indicates that a nuclear fuel reprocessing plant can be built and operated at the proposed site, without creating any undue hazard to the general public.

SECTION IV

GEOGRAPHIC ENVIRONMENT

1. INTRODUCTION.

A study of the geographic environment of the proposed site was conducted to determine the economic character and facilities available in the local area of the site location. The subject areas investigated were:

1) A County Economic Survey
2) Population Density
3) Labor Market
4) Planning, Zoning, and Housing
5) Transportation Facilities
6) Utilities

The findings of this study were all considered favorable for the siting of a nuclear fuel reprocessing plant. It should be noted here that the interpretation of the findings of this study were made specifically for a nuclear facility, e.g., a low population density and predominately rural community are ideal factors for a nuclear facility but they would not necessarily be desirable for another type of industry.

In addition to being centrally located with respect to its market, the site is well located in consideration of services and facilities. Little effort has to be expended to connect to existing road and rail facilities and bring to the site services and utilities. An adequate labor supply is available. Major sea and air transportation centers are within easy reach.

One outstanding conclusion that was drawn from this study was that this site location, rural by nature, has within easy access more metropolitan facilities than many industrial cities in the country.

2. COUNTY ECONOMIC SURVEY.

In the last eight years the economic development of Cumberland County has increased considerably. When measured in terms of retail the total has almost doubled to $173,000,000 in 1958. Similarly, the net effective buying income per capita has increased by the same proportion. The development of business enterprises for both the retail and wholesale trade, for the period from 1948 to 1954, or 6 years, increased by 60 and 84% respectively to totals of $134,000,000 and $60,600,000. However, in the 1950-1958 period, the insured number of employees in the county has risen only by 14% to a total of approximately 31,000. The total number of manufacturing establishments for almost the same number of years increased.

3. POPULATION DENSITY.

Based on the 1960 Census, the population density of the towns in Cumberland County is estimated to be as follows:

Area in Sq. Miles	Towns	Census	Density Persons Per Sq. Mile
6.5	Bridgeton City	20,797	3,200
34.0	Commercial Township	3,235	97
16.7	Deerfield Township	2,022	121
55.8	Down Township	1,839	73
43.0	Fairfield Township	3,886	90
19.0	Greenwich Township	1,077	57
31.4	Hopewell Township	3,599	115
35.6	Lawrence Township	2,614	73
94.7	Maurice River Township	3,117	33
44.3	Millville City	19,007	429
1.3	Shiloh Boro	549	422
18.8	Stowe Creek Township	1,009	54
31.8	Upper Deerfield Township	5,917	186
69.5	Vineland City	37,609	541
502.4		106,277	210

The low population density of the county as a whole is desirable for a fuel reprocessing plant.

4. LABOR MARKET.

In regard to the labor force in the general geographic area of Cumberland County, it is noted that for the 1950 to 1958 period, there was a population increase of 16% to a total of 103,000. The age groups for this count is distributed as follows:

Under 5 years of age	c. 10%
Over 21 years of age	c. 65%
65 years of age	c. 9.5%

According to the 1950 census, there were approximately 68,000 people over 14 years of age providing a civilian labor force of 38,000. Excluding self-employed and governmental workers, the total working force, numbered about 31,000 and has varied only by 14% in the 1950-1958 period. This total is subdivided into the following categories:

Construction	1,300
Transportation	1,100
Communication and Utilities	700
Trade (wholesale and retail)	4,500
Finance, Insurance	1,100
Service	1,000
Other (non manufacturing)	850

The major occupational groups as based on the 1950 census were divided as follows:

Professional, technical	2,200
Farmers and farm workers	2,200
Manager, Officials and Prop.	2,800
Clerical and Kindred	2,900
Sales Workers	2,000
Craftsmen, Foremen, etc.	5,150
Operative and Kindred	10,500
Private Household Workers	650
Service Workers	1,800

Farm Laborers (except unpaid and foremen)	2,600
Farm Laborers (unpaid family)	400
Unreported	650

of this total 30% were females

For these categories and groups, it is found that the wage rates for both skilled and unskilled labor vary slightly according to the industry. For the city of Millville in which 70% of the total work force of 6,000 are employed in the glass products manufacturing business, the rates are, according to the Millville Board of Trade, as follows:

	Range	Average
Skilled labor	$1.80 to $2.82/Hr.	$2.21
Unskilled labor	$1.57 to $1.68/Hr.	$1.67

Wages of other industries, such as apparel manufacturers and utilities offices, are in the same order of magnitude and are reflected in the average rate.

The area can readily provide an adequate labor force for the fuel reprocessing plant.

5. PLANNING, ZONING, AND HOUSING.

According to the Municipal Zoning Ordinances 420, as of June 1950, there is no record of zoning laws for Cumberland County. This data was supplied by the municipalities through questionnaires now on file in the State Planning Bureau Office. The site area, situated between Readstown, Davis Mill and north of Othello, is not governed by any existing zoning ordinance.

It is presently anticipated that some of thetowns, such as Greenwich, will prepare zoning ordinances to designate areas in which residential and industrial construction is permissable. Hopewell Township, the municipality in which most of the site is located, has a planning study under way.

There is sufficient housing in the area to provide for the needs of plant personnel. New homes are being built in Bridgeton, ranging in price from $12,000 for a three bedroom home on a half acre, up to $50,000. In addition, older homes are available in the area. Acreage for new homes can be obtained at prices ranging from about $200 to $600 an acre. (Figs. 14, 15, 16, 17, 18.)

6. TRANSPORTATION FACILITIES.

a. Railroad Service.

The extensive railroad system of New Jersey is the result of its location between the centers of population and commerce, New York and Philadelphia. (Fig. 19.) The largest group of roads, including the Lehigh Valley, Lackawanna, Erie, Central of New Jersey, Susquehanna, and West Shore (New York Central), enter New York City from Northern Pennsylvania and Western New York with bridgeheads established on the Jersey side of New York Harbor. Two of these roads, the Lehigh Valley and Lackawanna, extend as far west as Buffalo, while the lines of the New York Central and Erie stretch to Chicago. The Jersey Central is a key terminal link in the Baltimore & Ohio system, which also includes the Reading line. Between

FIGURE 14

VIEW LOOKING SOUTHEAST TOWARDS THE SITE FROM NEAR ROADSTOWN

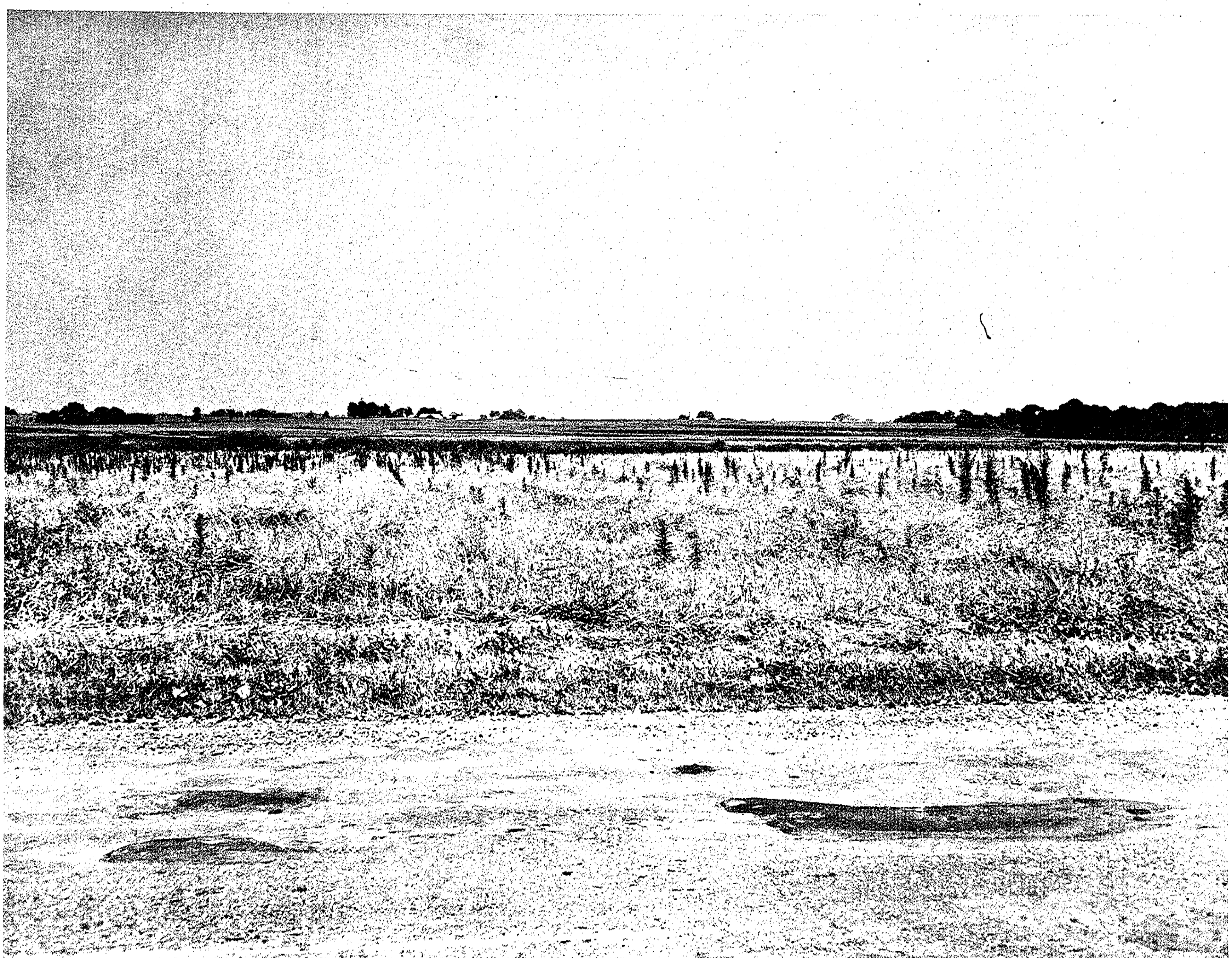


FIGURE 15

VIEW OF THE SITE AREA LOOKING EAST FROM THE ROADSTOWN-SPRINGTOWN ROAD

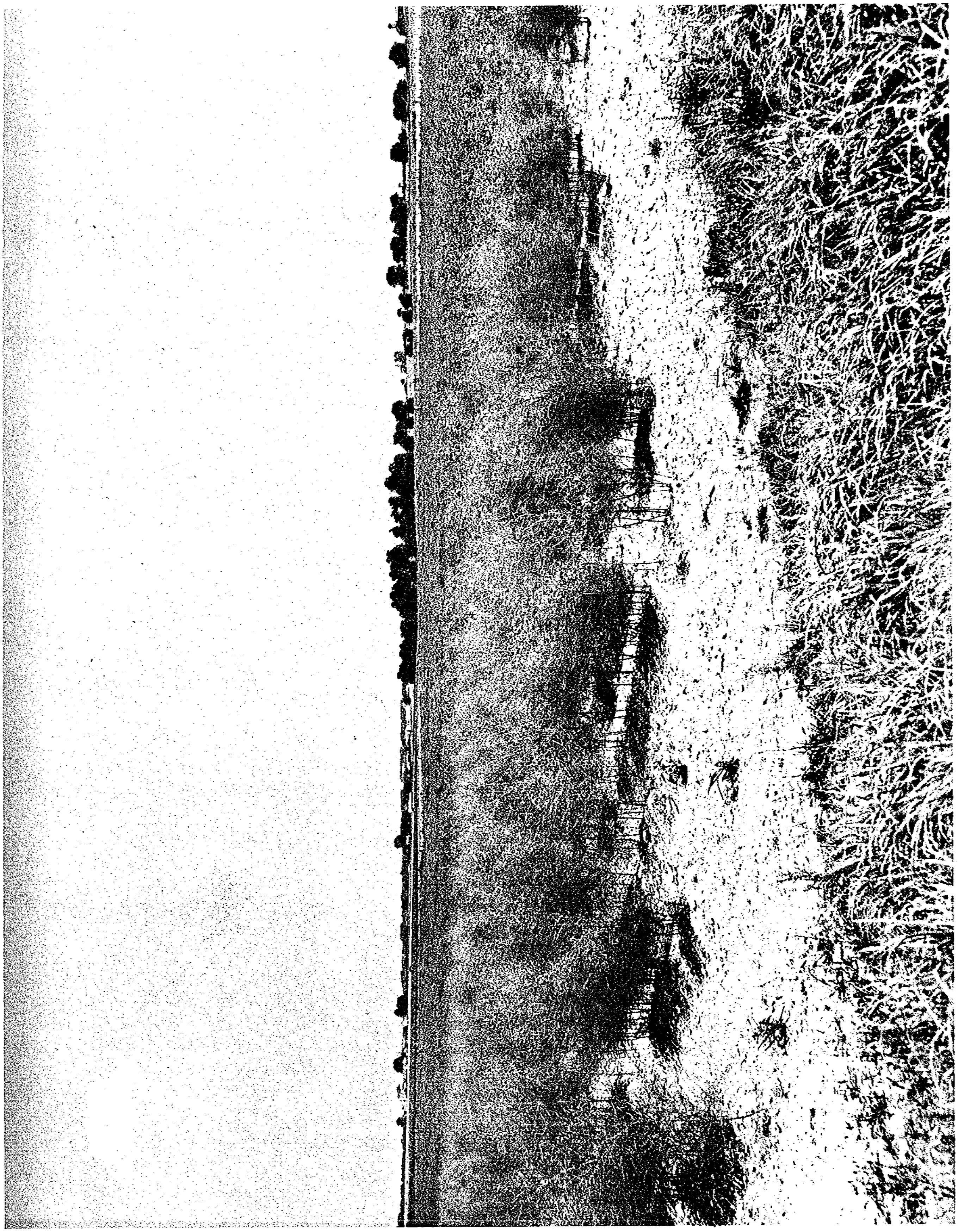


FIGURE 16

VIEW LOOKING N.E. FROM THE NORTHERN EDGE OF THE SITE

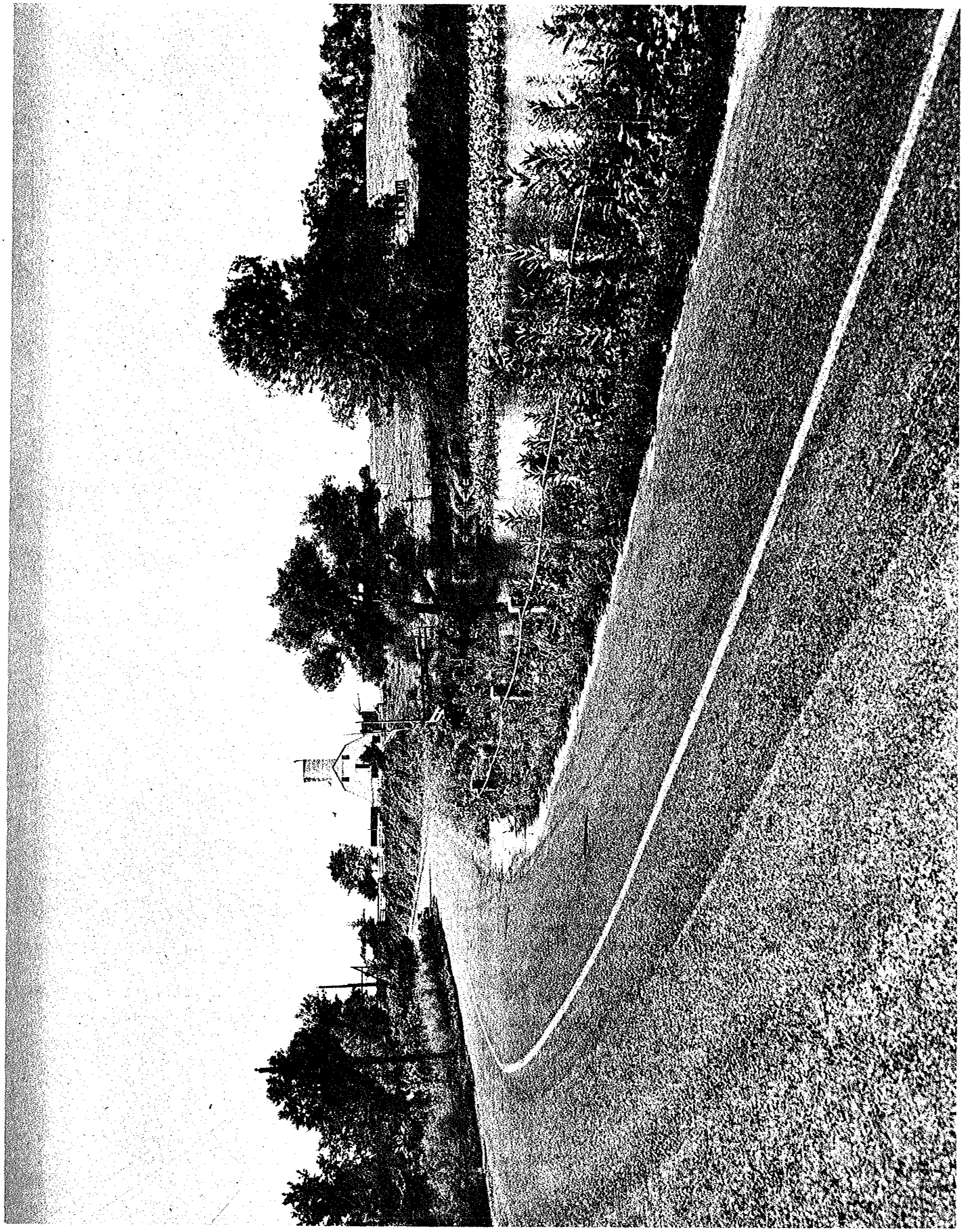


FIGURE 17
VIEW LOOKING NORTH ACROSS DAVIS MILL POND

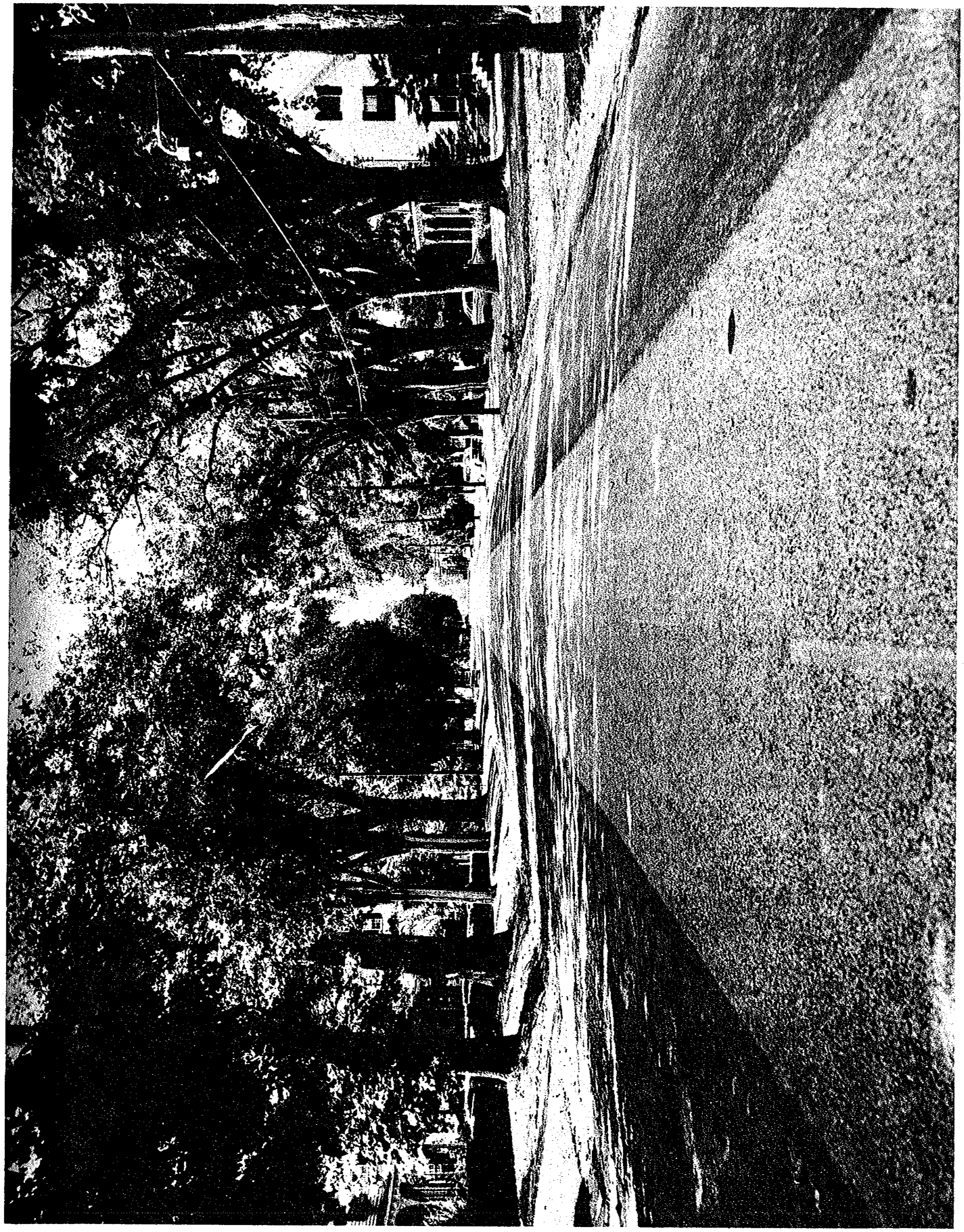
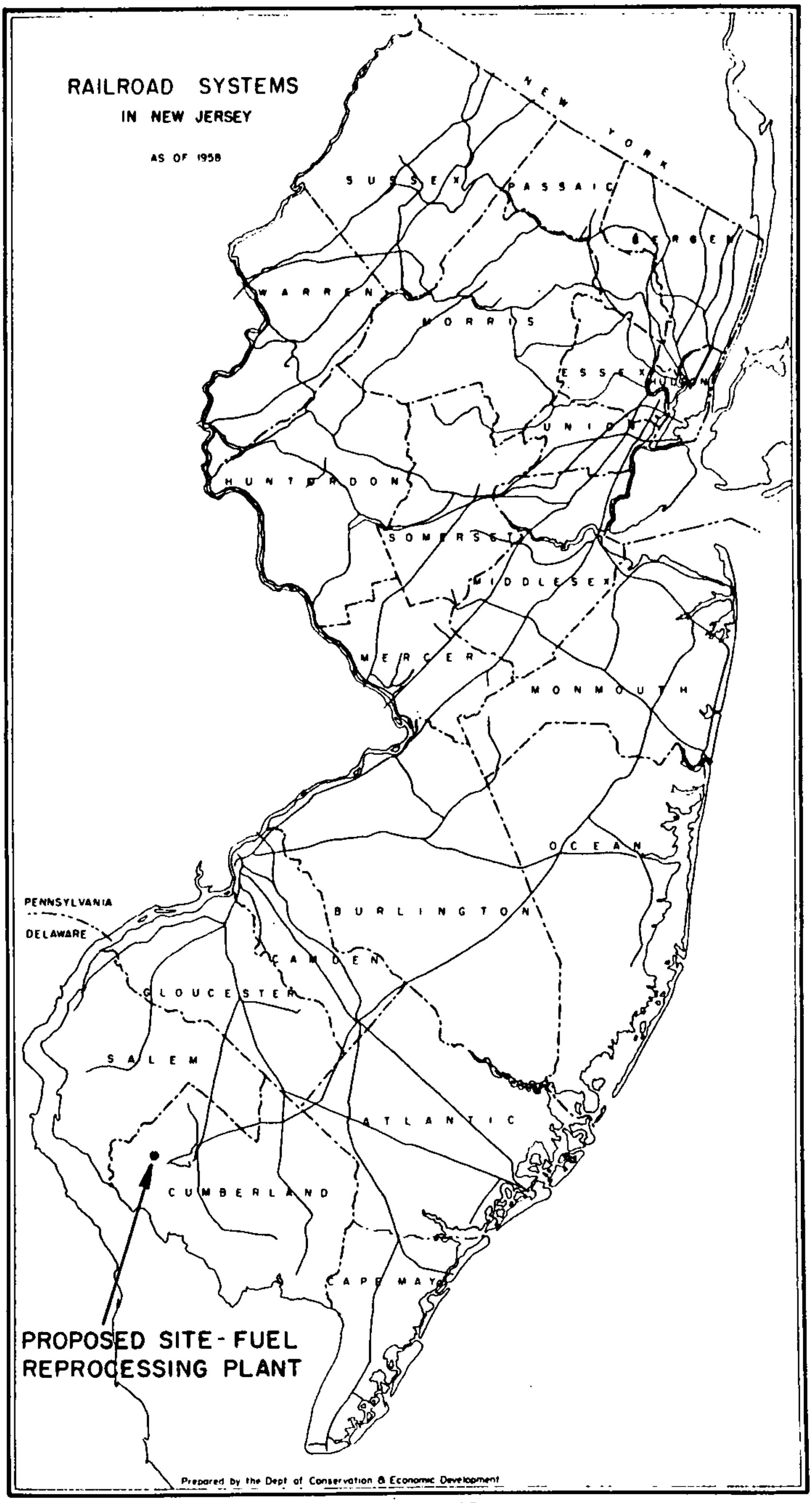


FIGURE 18
VIEW LOOKING NORTHWEST UP THE GREAT STREET



RAILROAD SYSTEMS
IN NEW JERSEY
AS OF 1958
NEW YORK
SUSSEX
PASSAIC
BERGEN
WARREN
MORRIS
ESSEX
HUDSON
UNION
HUNTERDON
SOMERSET
MIDDLESEX
MERCER
MONMOUTH
OCEAN
PENNSYLVANIA
DELAWARE
BURLINGTON
CAMDEN
GLOUCESTER
SALEM
ATLANTIC
CUMBERLAND
CAPE MAY
PROPOSED SITE - FUEL
REPROCESSING PLANT
Prepared by the Dept of Conservation & Economic Development

FIGURE 19

them, the Reading and Jersey Central operate nearly 500 miles of track in the State, the most important of which link New York and Philadelphia by way of Bound Brook, Plainfield, and Elizabeth. Another line of the Jersey Central taps the shore and southern New Jersey through Amboy, Long Branch, and Lakehurst.

The Pennsylvania Railroad, the nation's largest carrier, handles the greatest traffic in New Jersey. In addition to its main trunk between New York and Philadelphia, the Pennsylvania operates lines to Sea Girt and Seaside Park, and the Camden and Amboy Division. The New York and Long Branch railroad, owned jointly by the Pennsylvania and the Jersey Central, and operated by the latter, connects the lines of these two carriers along the Shore.

The Pennsylvania-Reading Seashore lines, third in size within the State, radiates from the Philadelphia-Camden area and services resort and agricultural counties of South Jersey.

Freight service between Camden and Bridgeton is maintained on a daily schedule by the Pennsylvania-Reading Shore line with shipments leaving Bridgeton at 6 P.M. A spur, operated by the CRR of New Jersey, connects the town of Bowentown with Bridgeton. This spur also extends beyond Bowentown and presently terminates at a point adjacent to the proposed site for the reprocessing plant. From this terminal point, it is possible to install tracks on the present roadbed which runs to the Town of Bayside on the Delaware River to connect to a future ship loading and unloading facility.

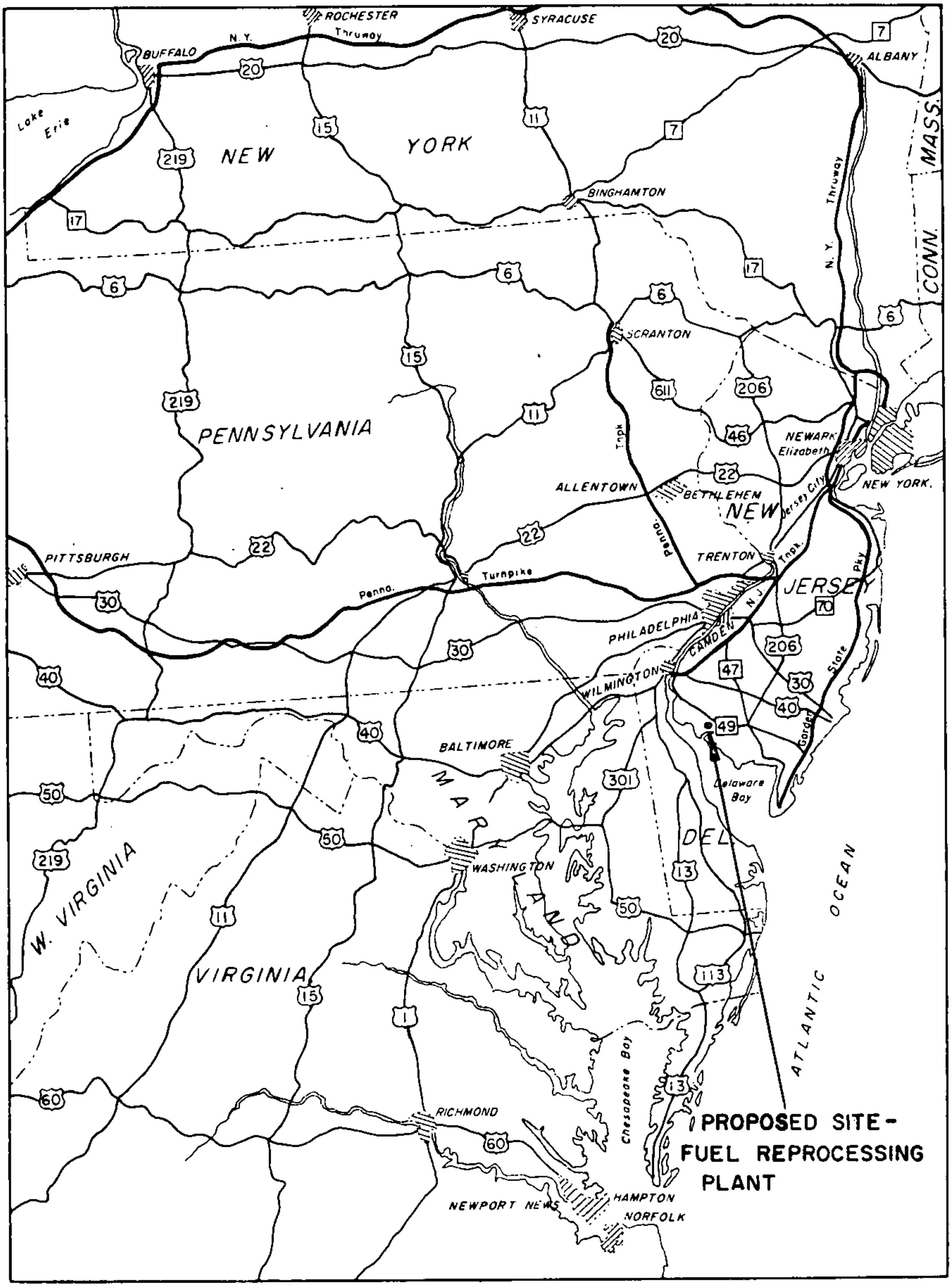
b. Highways and Trucking.

The State of New Jersey maintains one of the finest networks of highways in the country which enables industries to reach their markets in the shortest time and at the lowest rates. The highways also permit rapid transit by automobile to plants, communities, and nearby recreational facilities.

The outstanding roads are the New Jersey turnpike, the Garden State Parkway, (Fig. 20, 21) and the many Freeways interconnecting the Turnpike with the Parkway. Many of the existing roads are being dualized to ease the flow of traffic throughout the State.

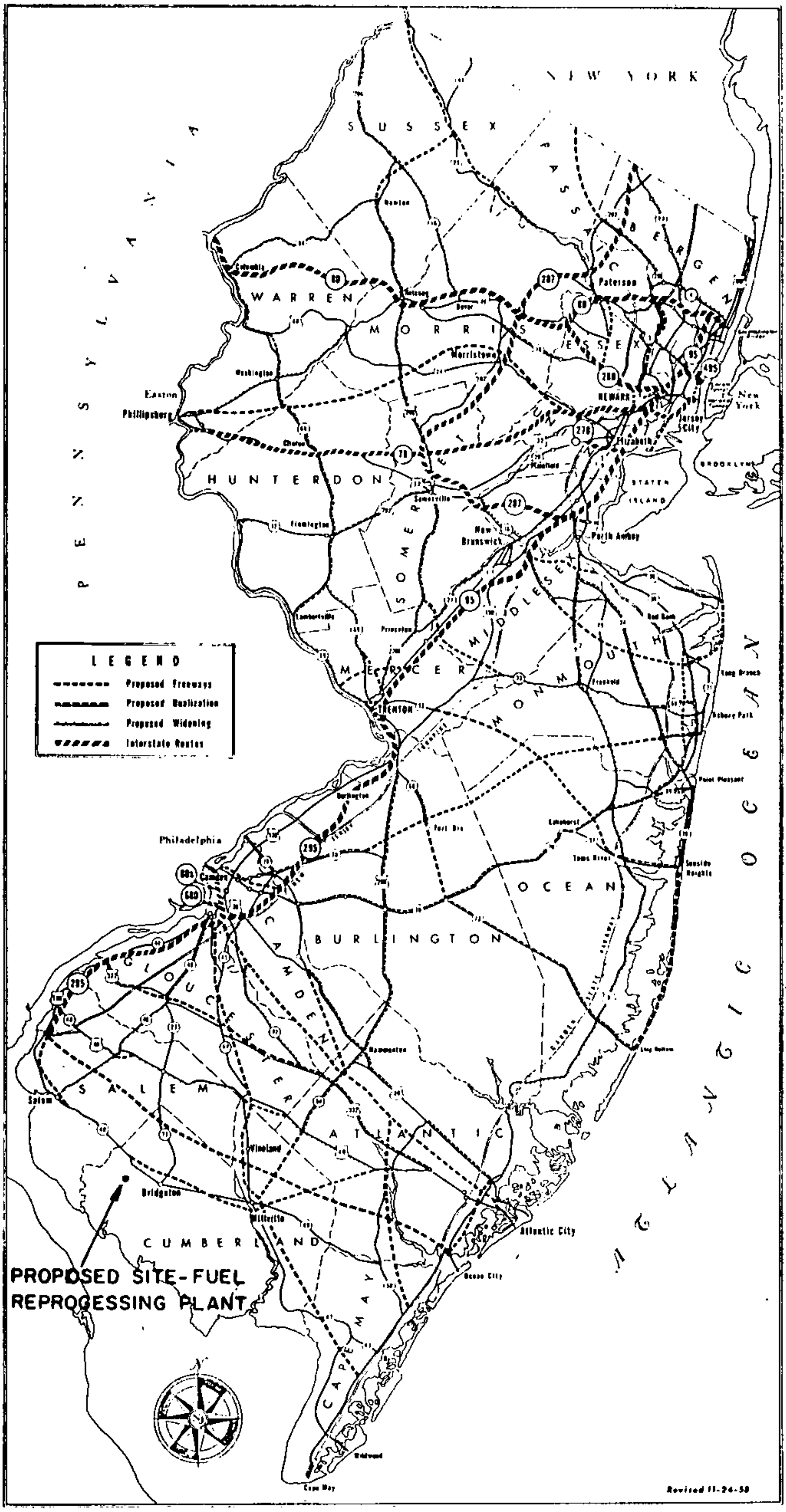
There is a proposal to build another bridge spanning the Delaware River between New Jersey and Delaware. This bridge would connect Sea Breeze in New Jersey with a point on Bombay Hook in Delaware. Both ends of the bridge would be built across marsh lands and connect the Towns of Fairton in New Jersey and Smyrna in Delaware. This bridge will facilitate transportation from the proposed site to the Southern States.

With many roads criss-crossing the State, the proposed area for the plant is readily accessible from either the Turnpike of the Parkway through State road No. 49. It is presently anticipated that route 49 will be modernized and widened to further facilitate accessibility to the site. In addition, another east-west freeway has been proposed just north of and parallel to Route 49. The proposed new roads are shown in Fig. 21.



INTERSTATE HIGHWAYS

FIGURE 20



EXISTING AND PROPOSED STATE HIGHWAYS

FIGURE 21

The trucking industry provides numerous, scheduled, common carriers of freight which satisfy the hauling needs of New Jersey's industrial facilities. There are more than 20,000 vehicles in the industry, which are serviced by approximately 200 terminals.

Truck transportation, to and from the site, will be more than adequate.

c. Water Transportation.

The site location lies between the two major shipping areas of the country, the port of New York and the Delaware River Port. These two facilities handle the bulk of shipping from foreign countries. By means of their close location to the site, these ports can handle the transfer of irradiated elements returned to the U.S. for reprocessing, throughout the year.

The Port of New York Authority operates, in addition to those facilities, in New York City and Brooklyn, Port Newark and Port Elizabeth.

The Delaware River Port is a series of waterfront units stretching from Trenton to Delaware Bay, with Camden and Trenton constituting the major ports of New Jersey. Camden's facilities include a wharf over 1,000 feet long and a 38 foot wide apron with double ship-side railroad tracks. Terminals supply ample storage space. Terminal trackage connects to the Pennsylvania Railroad and Pennsylvania Reading Seashore Lines which serve the site area.

Trenton's facilities also provide a 1200 foot wharf with storage facilities, railroad connections to all lines, and trucking lines accessible to the major highways.

Serving both the domestic and the overseas shipping lanes, the geographical positions of the Port of New York and the Delaware River Port areas permit convenient transhipment of materials to the site by either the adjacent railroad or by trucking facilities.

The site is thus well located between these two major port areas, to handle water shipment of spent fuels.

d. Air Transportation.

The proposed site for the plant is conveniently located near several airports, (Fig. 22) maintaining both scheduled passenger and freight facilities.

The Philadelphia International Airport is located about 45 miles from Bridgeton. This International Airport is used by 10 scheduled airlines and, in addition, it serves six domestic trunk lines flying 18 jet flights daily. Moreover, an all-freight line operates out of Philadelphia. The terminal comprises over 300,000 square feet with an additional 80,000 square feet for freight operations alone. At present the facilities are being enlarged by 40,000 square feet of area.

The Millville Municipal Airport is located about 11 miles from Bridgeton. Traffic is limited to private and industrial aircraft. The airport has four asphalt runways, each about 5000 feet long, and can handle aircraft as large as the DC-6B. Terminal facilities are also available.

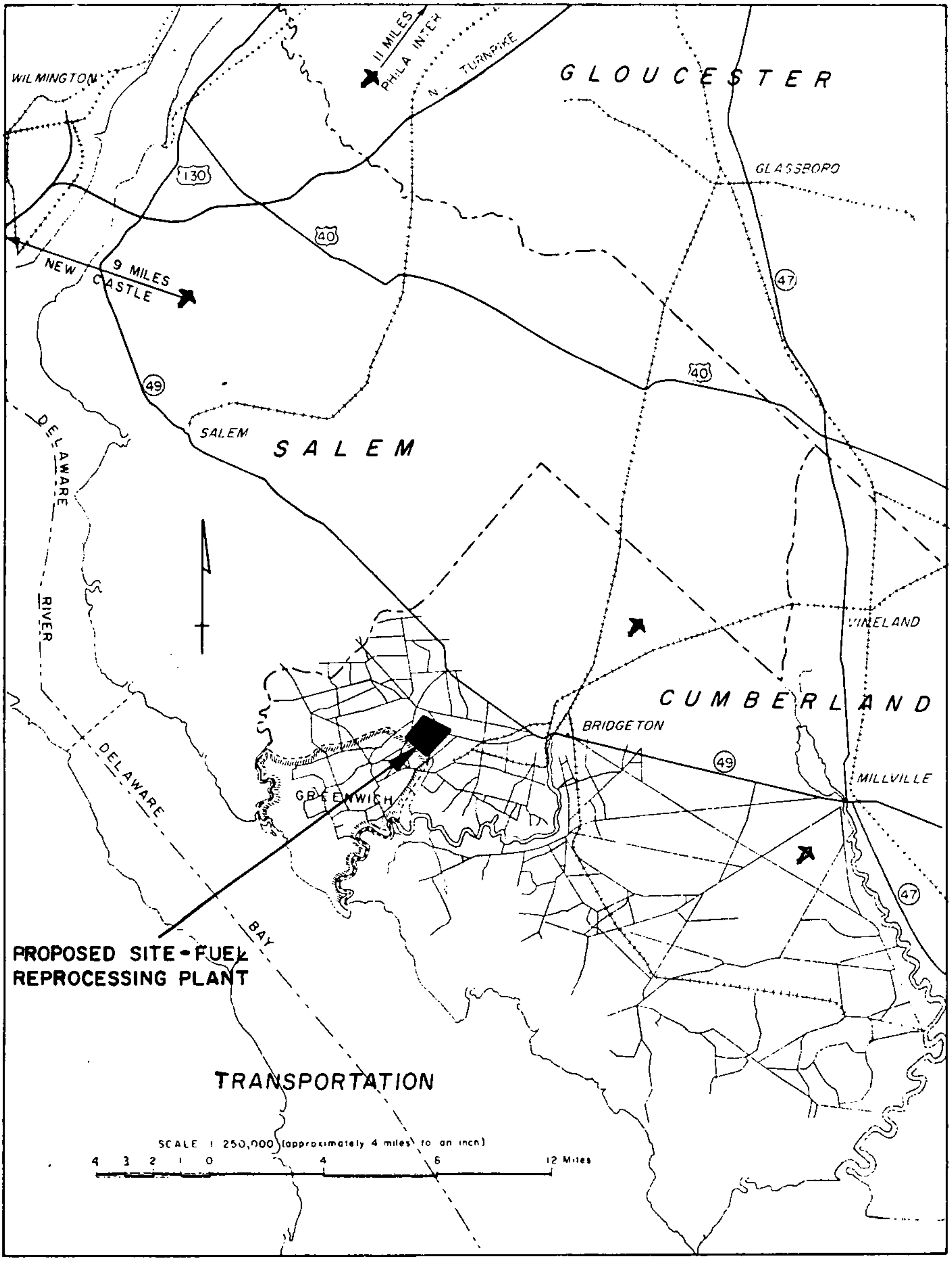

WILMINGTON
11 MILES
PHILA INTER
N. J. TURNPIKE
GLOUCESTER
GLASSBORO
130
40
47
9 MILES
NEW CASTLE
49
SALEM
SALEM
DELAWARE
RIVER
VINELAND
CUMBERLAND
BRIDGETON
MILLVILLE
GREENWICH
DELAWARE
BAY
PROPOSED SITE - FUEL REPROCESSING PLANT
TRANSPORTATION
SCALE 1:250,000 (approximately 4 miles to an inch)
4 3 2 1 0 4 8 12 Miles

FIGURE 22

Air shipments and travel can be readily handled from the Philadelphia Airport, and in addition the Millville Airport can be utilized for special situations or convenience.

7. UTILITIES.

a. Electric Power.

The Bridgeton and Millville area is served by the Atlantic City Electric Company which provides power for the southern one-third of the State; and ample industrial power is available immediately in the area. In order to accommodate the anticipated industrial and population growth in this part of the State, the Company plans to supply 2-1/2 billion kilowatt hours in 1965. See Fig. 23.

Generating stations are located at Deepwater and Greenwich, on the Delaware River, and at Atlantic City. These stations provide a total capacity of 411, 000 Kw; and, are also, interconnected with the New Jersy Pennsylvania-Maryland Power Pool. A new station is under construction at Beesley's Point, on Great Egg Harbor, Cape May County, and will add 125, 000 Kw to this capacity by 1962. Millville is the center of the system with transmission lines of 138, 000 volts and 69, 000 volts, assuring continuity of service.

At the present time, a 69, 000 volt transmission line ends at a switchyard at Shiloh about 1. 75 miles from the proposed plant site. Distribution lines at 12, 000 volts go through the site area.

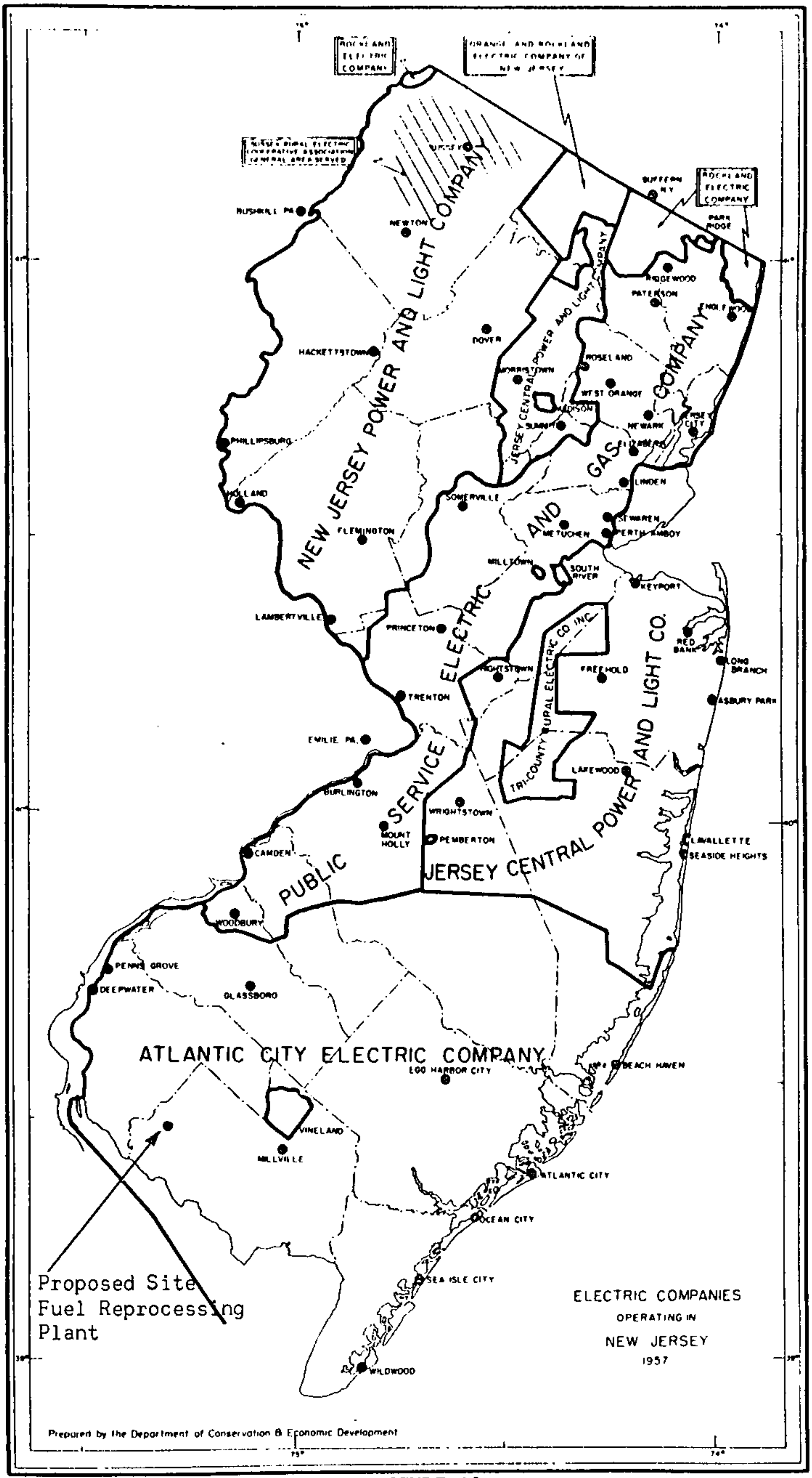

ROCKLAND ELECTRIC COMPANY
ORANGE AND ROCKLAND ELECTRIC COMPANY OF NEW JERSEY
NEW JERSEY POWER AND LIGHT COMPANY
PUBLIC SERVICE ELECTRIC AND GAS COMPANY
JERSEY CENTRAL POWER AND LIGHT CO.
TRI-COUNTY RURAL ELECTRIC CO. INC.
ATLANTIC CITY ELECTRIC COMPANY
NEWTON
HACKETTSTOWN
PHILLIPSBURG
HOLLAND
FLEMINGTON
LAMBERTVILLE
DOVER
MORRISTOWN
ROSELAND
WEST ORANGE
MADISON
SUMMIT
NEWARK
ELIZABETH
LINDEN
PATERSON
RIDGEWOOD
SUFFERN N.Y.
PARK RIDGE
SOMERVILLE
METUCHEN
SEWAREN
PERTH AMBOY
MILLTOWN
SOUTH RIVER
KEYPORT
RED BANK
LONG BRANCH
ASBURY PARK
FREEHOLD
PRINCETON
TRENTON
LAKEWOOD
WRIGHTSTOWN
PEMBERTON
MOUNT HOLLY
BURLINGTON
CAMDEN
WOODBURY
LAVALLETTE
SEASIDE HEIGHTS
PENNS GROVE
DEEPWATER
GLASSBORO
EGG HARBOR CITY
BEACH HAVEN
VINELAND
MILLVILLE
ATLANTIC CITY
OCEAN CITY
SEA ISLE CITY
WILDWOOD
Proposed Site Fuel Reprocessing Plant
ELECTRIC COMPANIES OPERATING IN NEW JERSEY 1957
Prepared by the Department of Conservation & Economic Development

FIGURE 23

The company can and will supply 5, 000 Kw looped service within five miles of the Shiloh switchyard at no cost to the user for the new lines, if the user will provide his own transformer equipment and accept 69,000 volt service. Depending on the load factor, this power will be supplied at a rate between $. 012 and $. 095 per kilowatt. An even lower rate for interrupted service is being considered.

The Filed Tariffs include the following:

G.S. (General Service)	Block Type rate for requirement up to 50 KW.
C.P. (Capacity Power)	Block Type for requirements of 50 to 1000 KVA.
Q.P. (Quantity Power)	Capacity rate for requirements of 1000 to 4000 KVA.
H.L.F. (High Power Factor)	Capacity rate for loads of 4000 KW and over.

Adequate power is thus available at the site, without the need for construction of new power transmission facilities.

b. <u>Gas and Oil</u>.

Gas is supplied at a General Service Rate ranging from $0. 30 for 4800 cubic feet to $0. 12 for over 10, 000 cubic feet. Special contract rates are available for large volume industrial usage, over 200 cubic feet per day. (Fig. 24.)

An oil storage depot is located on the south side of Bridgeton and is served by barges which come up the Cohansey River.

Gas and oil can be provided from nearby existing facilities.

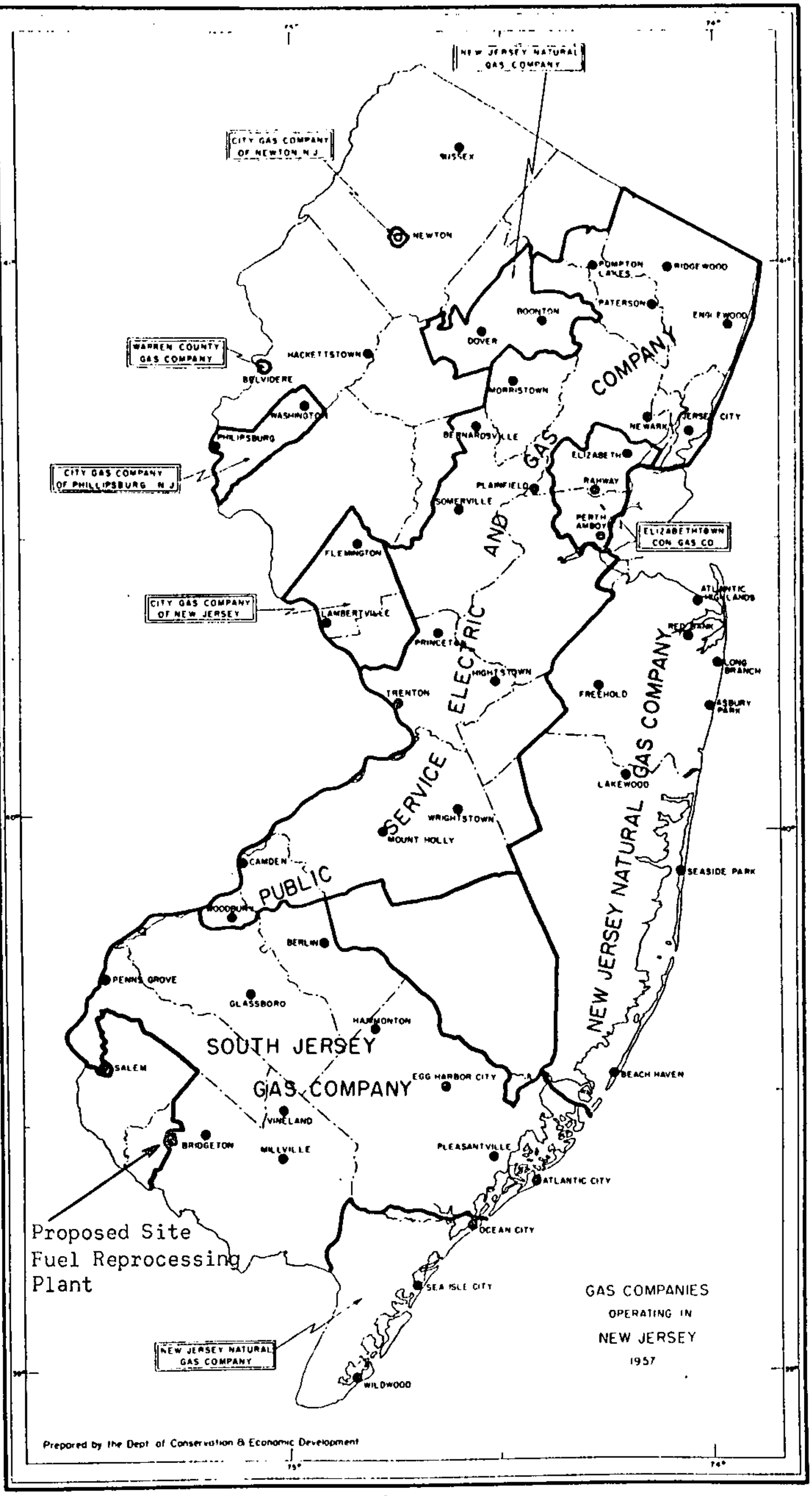

NEW JERSEY NATURAL GAS COMPANY
CITY GAS COMPANY OF NEWTON N.J.
SUSSEX
NEWTON
WARREN COUNTY GAS COMPANY
BELVIDERE
HACKETTSTOWN
WASHINGTON
PHILIPSBURG
CITY GAS COMPANY OF PHILLIPSBURG N.J.
POMPTON LAKES
RIDGEWOOD
PATERSON
ENGLEWOOD
BOONTON
DOVER
MORRISTOWN
NEWARK
JERSEY CITY
BERNARDSVILLE
ELIZABETH
RAHWAY
PLAINFIELD
SOMERVILLE
PERTH AMBOY
ELIZABETHTOWN CON. GAS CO.
FLEMINGTON
CITY GAS COMPANY OF NEW JERSEY
LAMBERTVILLE
PRINCETON
HIGHTSTOWN
TRENTON
ATLANTIC HIGHLANDS
RED BANK
LONG BRANCH
FREEHOLD
ASBURY PARK
LAKEWOOD
WRIGHTSTOWN
MOUNT HOLLY
CAMDEN
WOODBURY
SEASIDE PARK
BERLIN
PENNS GROVE
GLASSBORO
HAMMONTON
SALEM
EGG HARBOR CITY
BEACH HAVEN
VINELAND
BRIDGETON
MILLVILLE
PLEASANTVILLE
ATLANTIC CITY
OCEAN CITY
SEA ISLE CITY
WILDWOOD
PUBLIC SERVICE ELECTRIC AND GAS COMPANY
NEW JERSEY NATURAL GAS COMPANY
SOUTH JERSEY GAS COMPANY
Proposed Site Fuel Reprocessing Plant
NEW JERSEY NATURAL GAS COMPANY
GAS COMPANIES OPERATING IN NEW JERSEY 1957
Prepared by the Dept. of Conservation & Economic Development

FIGURE 24

SECTION V

PRELIMINARY HAZARDS EVALUATION

1. INTRODUCTION.

A preliminary hazards evaluation considers, in general, plant and site factors, and current AEC safety criteria for protection of the local population.

Since an actual plant is not available, this preliminary hazards evaluation was based on a hypothetical plant design and hypothetical maximum credible accident, which required a number of assumptions to be made. All assumptions were purposely conservative so that when the final detailed hazards analysis is performed for an actual plant, the resultant calculated hazards will be less severe than reported here.

The approach taken for this analysis was to find the maximum credible hazards to the local population in the absence of plant containment. The single exception was that all radioactive leakage from the plant was assumed to be emitted from a stack. Then, with current AEC safety criteria as a guide, the required degree of plant containment was determined.

The conclusion of this analysis is that the plant site is acceptable from a hazards viewpoint.

2. HISTORY OF REPROCESSING PLANT ACCIDENTS.

A brief history of reprocessing plant accidents follows in order to provide a basis for evaluating the pessimistic assumptions made for the hypothetical maximum credible accident.

a. Oak Ridge Y-12 Plant (June 16, 1958)

An accidental nuclear excursion occurred in a 55-gallon stainless steel drum which was to be used to collect water during the leak testing of process tanks. A portion of enriched uranyl nitrate was inadvertently transferred first to the piping and "safe" tanks. The solution subsequently entered the drum, preceding the drain water from the tank being cleaned. The energy release oscillated several times for about twenty minutes. No physical damage resulted. Radiation exposure was incurred by in-plant operating personnel only. The causes of the accident are believed to have been:

1) Use of a temporary, improvised arrangement.

2) An "unfortunate" interpretation of rules for leak testing.

3) Poor communication between shifts of personnel.

b. Los Alamos Plutonium Processing Plant (December 30, 1958)

A nuclear excursion occurred in a geometrically unsafe solvent-treating tank, normally used to process solutions of non-critical concentration, which resulted in a nuclear energy release of about 5 MW-sec. No physical damage was noted. An in-plant technician died from radiation over exposure 36 hours later. The accident was attributed, in part, to this operator, who did not follow precisely the directions of his supervisor.

c. Idaho Chemical Processing Plant (October 16, 1959)

In this accident, a process solution was siphoned from a safe to an unsafe geometry. The resulting nuclear excursion produced about 4×10^{19} fissions (1,500 MW-sec.). Over half the critical solution volume of 800 liters was left, the remainder having been forced out the various inlet pipes. The storage vessel and piping were not damaged. Activity, mainly gaseous and composed of short-lived isotopes, was released unfiltered through a stack 250 feet high. No hazardous activity release was detected. It is estimated that less than 800 grams out of a total of 34,000 grams of uranium escaped. Most of the particulate activity was retained in the tanks and pipes.

The cause of this accident was apparently a weakness in administrative control, since an operator had not been warned of a change in instrumentation.

d. ORNL Thorex Pilot Plant (November 20, 1959)

A non-nuclear explosion occurred during the cleaning of a cell used for processing wastes to recover plutonium. The explosion released 1 to 5 grams of plutonium into the cell, blew open the cell door, and scattered about 600 milligrams of plutonium over about four acres of ground, buildings, and roof tops. No one was injured, but extensive decontamination procedures were required. Cause of the accident was attributed to explosion of an organic cleaning solvent, resulting, perhaps, from poor judgment in undertaking "short cut operational improvements". In addition, the facilities in use were inadequate to withstand minor explosions.

Following the ORNL Thorex Pilot Plant accident, the ORNL authorities shut down all high level radio-chemical operations for a re-evaluation of hazards. New ORNL criteria were evolved as follows:

1) The maximum credible accident must be contained or confined, to preclude discharge into the environs of amounts of radioactive material injurious to health or interfering with other laboratory programs.

2) Two lines of defense must be present to prevent the escape of radioactive materials.

The ORNL regulations also require a formal hazards report for those operations involving more than 1 gram of plutonium or more than 1,000 curies of beta and gamma emitters.

It is expected that similar criteria will be established by the AEC for all proposed U. S. nuclear fuel reprocessing plants.

3. SCOPE OF A COMPLETE REPROCESSING PLANT HAZARDS ANALYSIS.

The initial preliminary hazards analysis performed before the site study, plant design, and operating procedure details are completed, presumes a hypothetical maximum credible accident which is likely to be more severe than that which is ultimately determined. The results of the preliminary analysis should be used to establish plant design criteria for reducing the likelihood and consequences of accidents. A preliminary hazards analysis, dealing as it does with many unknown design factors, is intended to show the general feasibility of operating a plant at a particular site without undue hazard to the surrounding population. A complete analysis after detailed features of the plant and site are specified, provides a more rigorous indication of safety.

Major considerations in preparing a complete hazards analysis report include:

1) Analysis of plant operations.
2) Conditions leading to a maximum credible accident.
3) Assumed release of fission products.
4) Effect of radioactivity release on surrounding environment.
5) Biological hazards evaluation.
6) Airborne diffusion of radioactivity.
7) Criteria for acceptable hazards.

The above listed items are discussed in detail in Appendix D.

4. CONDITIONS LEADING TO MAXIMUM CREDIBLE ACCIDENT IN THE PROPOSED REPROCESSING PLANT.

In defining the maximum credible accident for this plant, many assumptions must be made, since sufficient plant details are not available for a complete analysis. The quantity of radioisotopes available, the amount which could be released, and the conditions of release have been considered. The following assumptions have been made:

1) The total fission product inventory constitutes an upper limit. The assumed inventory contains isotopes which would exist in one day's processing capacity of 1 ton of slightly enriched fuel. The fuel has cooled for 120 days (time lapse between reactor shutdown and fuel reprocessing). The radioactive materials are fission products, and plutonium isotopes which are formed from U-238 transmutation.

2) A nuclear criticality excursion occurs. This excursion may not cause the most severe dispersal of isotopes, but it would add to the radioactive inventory a considerable quantity of short-lived fission products which are not present in the fuel because of the 120 day decay. The energy release in the excursion is assumed to be 3,000 MW-sec. An energy release half as large occurred at the Idaho Processing Plant in 1959, the largest energy release to have occurred to date at a fuel reprocessing plant.

3) The plant ventilation system is designed so that contaminated air is released only through the plant stack. Passage through the stack takes place rapidly enough to constitute an instantaneous release.

4) Calculations of airborne diffusion of radioactivity are made on the assumption that the entire fission product inventory is released into the atmosphere at stack height. The results, which are considered in the next section, are then used to estimate the degree of containment which would be required to reduce environmental effects to currently acceptable levels.

5. ENVIRONMENTAL EFFECTS OF RADIOACTIVITY RELEASE.

This section summarizes the effects of radioactive release from the plant to the atmosphere at the time of the maximum credible accident, the details of which are given in Appendix E.

Activity concentrations in the air at ground elevation were estimated for three meteorological conditions:

1) Lapse, representing a typical daytime condition.

2) Inversion, representing a typical night condition.

3) Fumigation, representing a break-up of an inversion at sunrise.

The parameters were "typical" ones used in a reactor nuclear power accident study. Maximum concentrations resulted from the fumigation conditions, which occur for a maximum period of 2 to 3 hours per day.

The concept of acceptable emergency dose (AED) was used to evaluate the population hazards. An AED is defined as a "once in a lifetime" accidental or emergency dose, which may be disregarded in the determination of the lifetime radiation exposure status of a readiation worker. Separate AED levels are specified for whole body dose and the dose to individual critical organs. AED values for internal dose are used for isotopes which are inhaled, ingested, or which enter the blood stream through a wound. The AED values used in this study are indicated in the Appendix E.

The definitions of low population zone and population center distance in terms of AED are not officially spelled out. Reasonable definitions can be deduced as follows in the light of AEC site criteria.(Appendix D, Section 7)

1) Any individual on the outer boundary of the low population zone shall receive no more than one AED.

2) An individual beyond the population center distance shall receive no more than 0.1 AED.

Inhaled and external radiation doses were calculated as a function of distance from the reprocessing plant using the previously described assumed release of activity. Strongly adverse meteorological conditions were assumed — a highly stable atmosphere and heavy rainfall which maximize the nearby concentrations of radioactivity, were assumed. These calculations are presented in detail in Appendix E.

An indication of the calculated dose magnitudes, in terms of AED units, is shown in the following table, using a distance of 1,000 feet from the plant as a reference point.

POPULATION DOSE AT 1,000 FEET FOR A 100% ACTIVITY RELEASE

FOLLOWING A 3,000 MW-SEC NUCLEAR EXCURSION

Organ	Dose Source	Dose in AED Units
Whole body	Airborne gammas	1.6
	Airborne betas	0.75
	Deposition gammas (Cs-137)	3,600.
Thyroid	Iodines	0.05
Bones	Sr-89, Sr-90 Ce-144 and plutonium	98.
Lungs	Beta emitters	0.44
	Plutonium	50.

CAUTION

These doses were computed as an extreme case solely for the purpose of establishing plant design criteria. They are not to be considered as the amount of radiation exposure which could occur for an operating plant.

These results indicate that deposited radioactivity is the primary hazard. Under the assumptions described in Appendix E, deposition of Cs-137 is the predominant dose contributor. The dose from Cs-137, in AED units, is shown as a function of distance from the plant stack in Figure E-10.

The Cs-137 dose versus distance graph can be used to find the maximum permissible fractional release of activity from the plant which gives 0.1 AED at any pre-assigned population center distance, and the resulting low population zone outer boundary distance.

Population Center Distance (Miles)	Maximum Permissible Release Fraction (Percent)	Low Population Zone Outer Boundary Distance from Stack (miles)
3	0.022	0.15
6	0.039	0.33
10	0.062	0.65
25	0.23	3.2

The nearest population center is the town of Bridgeton, with a current population of 21,000 and a projected population of over 25,000. Since its distance from the site is about 4-1/2 miles, it appears that the maximum permissible release fraction should be in the order of 0.02%.

Based on deposition alone, the resulting low population zone outer radius would be 0.15 miles.

However, location of the boundary depends upon an additional consideration of gamma radiation from activity contained in the plant. If radiation attenuation by materials in the building wall is ignored, the low population boundary must be increased to 3,000 feet, to maintain an acceptable dose from the plant.

The exclusion area, as distinguished from the low population zone, will have a radius of 450 feet from the building.

The site provides adequate area to meet the above requirements, which are based on extremely pessimistic assumptions.

6. SUMMARY OF RESULTS.

The airborne hazards resulting from an accidental complete release of fission products from a fuel reprocessing plant have been calculated on a conservative basis. It was assumed that plant leakage is limited to emission from a 250 foot stack.

It was found that a leakage attenuation factor of about 5,000 is required to approximate AEC criteria on dose levels at "Population Centers". The critical population center is Bridgeton, at a distance approximately 4-1/2 miles.

With this attenuation factor in effect, the Low Population Zone radius is about 3,000 feet.

The exclusion area radius will be 450 feet from the nearest facility location.

7. DISCUSSION OF RESULTS.

The following observations can be made concerning the application of this preliminary hazards analysis to the design of a safe fuel reprocessing plant.

1) Two conditions must be met for the reprocessing plant. First, accidental release of radioactive effluent must be confined to the facility stack. Secondly, the activity of the stack effluent must be a factor of 5,000 below the activity obtained from the maximum fission product inventory.

2) The former condition requires that suitable gas containment barriers be incorporated into the plant so that radioactive effluents do not have a path to the outer atmosphere near ground level. These barriers must be designed to withstand pressures resulting from the worst accident which could credibly occur, and which involves vaporization of radioactive materials. Failure of containment will reduce the expected radioactivity attenuation of airborne activity escaping the facility, and will also increase downwind dose levels by removing the advantage of elevated effluent release.

3) The required stack effluent attenuation factor of 5,000 does not appear difficult to achieve. The 1959 Idaho Processing Plant accident, as an example, involved an energy release of about half the hypothesized maximum credible accident. All major radioactivity was localized in the tanks, piping, and stack. Based on the estimated stack release of a "small fraction" of 800 missing grams of uranium, out of a total of 34,000 grams in the boiling solution, a particulate attenuation factor the order of 100 can be deduced. This resulted from the processes of distillation, settling, and plating on surfaces without the benefit of filtration in the effluent air lines. An additional factor of 50

should be readily available by the use of standard pressure and attenuation procedures such as the combination of a quench,tank and ab solute filters.

8. CONCLUSION

The conclusion of this analysis is, that a fuel reprocessing facility can be constructed at the proposed site, using conventional construction techniques, materials § equipment presently in use in the nuclear industry, and that such a plant site would be acceptable from all aspects of public safety.

SECTION VI

APPENDICES

APPENDIX "A"

TABLE A-1

POWER REACTORS

EASTERN UNITED STATES

DESIGNATION	COMPANIES	LOCATION
Yankee	Yankee Atomic Electric Co.	Rowe, Mass.
CETR	Consolidated Edison Co.	Indian Pt., N. Y.
Shippingport	AEC and Duquesne Light Co.	Shippingport, Pa.
Saxton	Gen. Public Utilities Corp.	Saxton, Pa.
Piqua OMR	AEC and City of Piqua M. C. P.	Piqua, Ohio
Enrico Fermi	PRDC and Detroit Edison	Monroe, Michigan
EBWR	Argonne National Lab	Lemont, Illinois
Dresden	Commonwealth Edison Co.	Norris, Illinois
SM-1	AEC and ALCO Products	Ft. Belvoir, Va.
CVTR	Carolina-Virginia Nuclear Power Assoc.	Parr, So. Carolina

APPENDIX "A"

TABLE A-2

RESEARCH & TEST REACTORS 100KW AND ABOVE EASTERN UNITED STATES

Designation	Operator	Location
Tank, D_2O	Mass. Inst. of Technology	Cambridge, Mass.
Pool, H_2O	U.S. Army Ordnance Corp.	Watertown, Mass.
Pool, H_2O	Univ. of Rhode Island	Providence, R.I.
Pool, H_2O	Union Carbide Nuclear Corp.	Sterling Forest, N.Y.
Tank, H_2O	Brookhaven Nat'l. Lab.	Upton, L.I., N.Y.
Tank, H_2O	Univ. of Buffalo	Buffalo, N.Y.
Pool, H_2O	Industrial Reactor Labs.	Plainsboro, N.J.
Pool, H_2O	Penn. State University	University Park, Pa.
Tank, H_2O	Westinghouse Elect. Corp.	Waltz Mill, Pa.
Pool, H_2O	Curtis-Wright Corp.	Quehanna, Pa.
Tank, H_2O	NACA	Sandusky, Ohio
Pool, H_2O	Battelle Memorial Inst.	Columbus, Ohio
Tank, H_2O	U.S. Air Force	Wright-Patterson AFB, Ohio
Pool, H_2O	Univ. of Michigan	Ann Arbor, Mich.
Pool, H_2O	Naval Research Lab.	Washington, D.C.
Pool, H_2O	Univ. of Virginia	Charlottesville, Va.
Pool, H_2O	Union Carbide Nuclear Corp.	Oak Ridge, Tenn.
Tank, H_2O	Union Carbide Nuclear Corp.	Oak Ridge, Tenn.
Tank, H_2O	Lockheed Aircraft Corp.	Dawsonville, Ga.
Tank, D_2O	Georgia Inst. of Technology	Atlanta, Ga.
Pressure Vessel D_2O	E. I Du Pont de Nemours & Co.	Aiken, So. Carolina
Pool, H_2O	AEC	Mayaguez, P.R.

APPENDIX A

TABLE A-3

POWER AND RESEARCH REACTORS – FOREIGN

Designation	Operator	Location
Pool H_2O	Thailand R. R.	Bangkok, Thailand
Pool H_2O	Forechung Reaktor Muenchen	Munich, Germany
Pool H_2O	Junta de Energia Nuclear	Lisbon, Portugal
Pool H_2O	Greek A. E. C.	Athens, Greece
Pool H_2O	Turkish A. E. C.	Istanbul, Turkey
Pool H_2O	Israel A. E. C.	Rehovath, Israel
Pool H_2O	Sorin	Seluggia, Italy
Pool H_2O	McMaster University	Hamilton, Ontario, Canada
Tank H_2O	Austrian A. E. C.	Vienna, Austria
Pool H_2O	Gesellschaft fur Vernenerg-ieverwertung in Schiffbau und Schiffahrt in b. h.	Hamburg, Germany
Pool H_2O	IVIC	Caracas, Venezuela
Pool H_2O	Reactor Ltd.	Wurenlingen, Switzerland
Pool H_2O	Atomic Energy Establishment	Trombay, India
Pool H_2O	Atomic Energy Institute	Sao Paulo, Brazil
Pool H_2O	Danish A. E. C.	Riso, Denmark
Pool H_2O	Pakistan A. E. C.	Rawalpindi, Pakistan
Pool H_2O	Philippine A. E. C.	Quezon City, Philippines
Tank H_2O	Reactor Centrum Nederland	Petten, Netherlands
Tank D_2O	CNRN	Ispra, Varese, Italy
Boiling Water Reactor	Rheinisch-West faelisches Elektrizitaetswerk Ag.	Kahl/Main, West Germany
Dounreay Fast Reactor	U. K. A. E. C.	Dounreay, Scotland

APPENDIX B

ARNOLD POINT MARINE FACILITY

1. MARINE TERMINAL.

A preliminary cost estimate for a marine terminal was prepared by Professor Irish and Associates of Princeton University. The feasibility of the project was checked out with the United States Army Corps of Engineers, Philadelphia District, and consideration was also given to the possible interest in the project by the State of New Jersey, Division of Shell Fisheries and the Bureau of Navigation. There was further consultation with several naval operations officers and assurance received that large vessels in Delaware Bay could back out of the 300-foot channel for a distance of 1 1/2 miles as easily or more easily than they could turn around. As a result of this information, it was concluded that a turning basin was not necessary. (Fig. 25)

The proposed facility is designed to accommodate the equivalent of the Aircraft Carrier U. S. S. Kitty Hawk. The pier would have a double track decked railroad trestle suitable for both highway and rail use from the existing railroad bed near Bayside to a point approximately 3000 feet north of Arnolds Point. Dredging costs were balanced against the cost of trestles and railroad fill to establish roughly a position 1200 feet offshore for a pier head approximately 80 feet wide, 1500 feet long, capable of supporting heavy lift equipment.

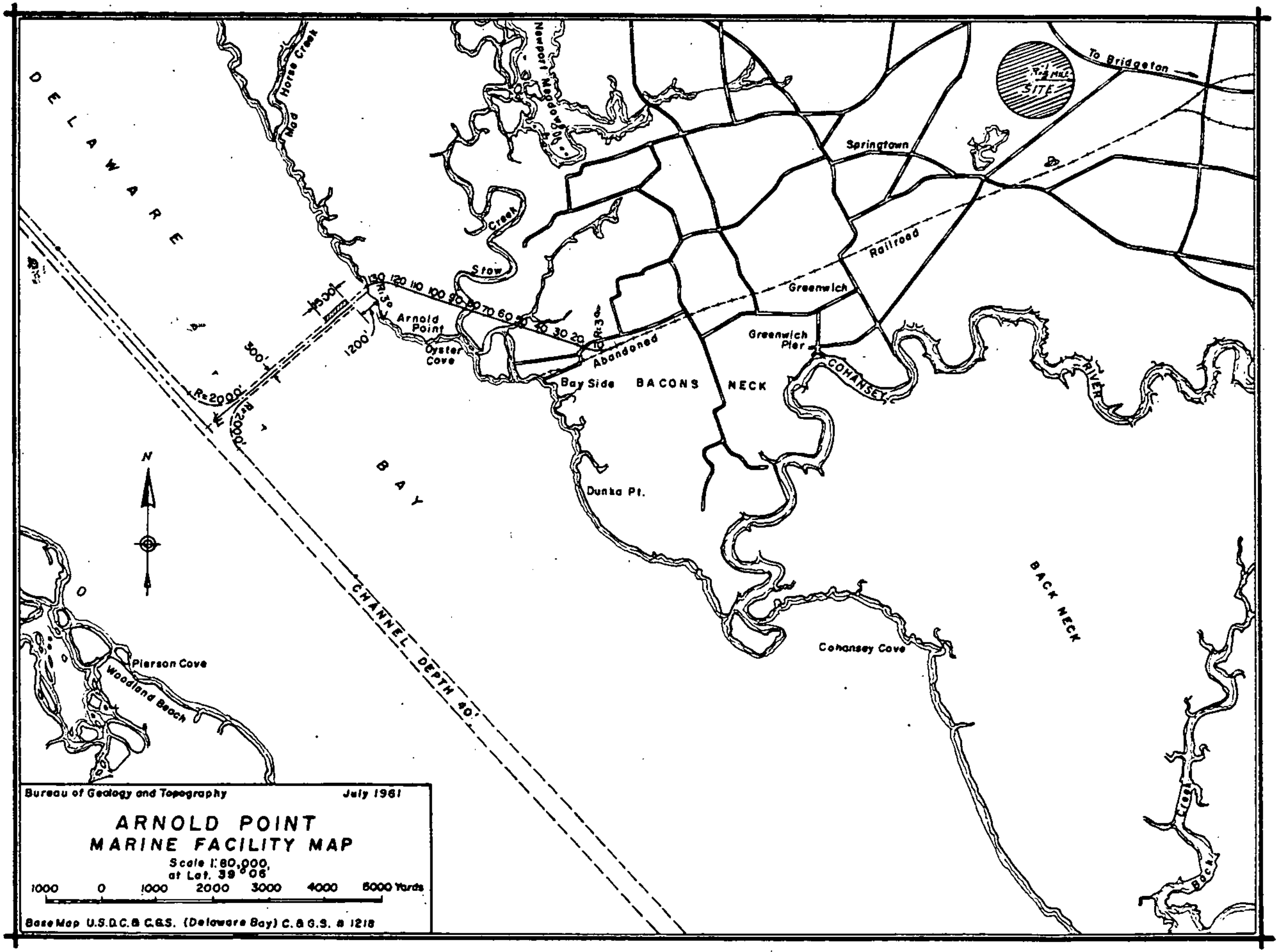

To Bridgeton
SITE
Springtown
Railroad
Greenwich
Greenwich Pier
COHANSEY
RIVER
Abandoned
Bay Side
BACONS
NECK
Dunks Pt.
BACK NECK
Cohansey Cove
DELAWARE
BAY
CHANNEL DEPTH 40'
Mad Horse Creek
Newport Meadows
Stow Creek
Arnold Point
Oyster Cove
300'
1200'
R=2000'
N
Pierson Cove
Woodland Beach
Bureau of Geology and Topography
July 1961
ARNOLD POINT
MARINE FACILITY MAP
Scale 1:80,000
at Lat. 39°06'
1000 0 1000 2000 3000 4000 5000 Yards
Base Map U.S.D.C.& C.G.S. (Delaware Bay) C.& G.S. # 1218

FIGURE 25

A detailed cost breakdown of figures for this project, which is believed to be maximum for the proposed facility, has been prepared showing each of the major items of construction. See table B-1. It has not yet been determined whether any or all of this could be constructed with State and/or federal funds, but it would seem logical to assume that under the circumstances there might be an interest in developing this facility on the part of both the state and federal government.

TABLE B-1

COST SUMMARY FOR ARNOLD POINT MARINE FACILITY

1.	Pier		
	Basic Structure	1,296,000	
	Building	100,000	
	Utilities	38,000	
	Mechanical Equipment	250,000	
			1,684,000
2.	Trestle		
	Basic Structure	518,000	
	Utilities	30,000	
			548,000
3.	Dredging Channel		
	Channel	1,568,000	
	Approaches	404,000	
			1,972,000
4.	Railroad Construction		
	Muck	345,000	
	Fill	468,000	
	Trestle Stow Creek	130,000	
	Railroad	154,000	
	Utilities	345,000	
			1,442,000
5.	Contingencies	847,000	
			847,000
6.	Engineering and Legal	649,000	
			649,000
	TOTAL		7,142,000

Railroad track from existing rail head to pier - 34,000 feet	400,000

APPENDIX C

ESTIMATED SITE DEVELOPMENT COSTS

Item	Total Cost
Land Acquisition	$ 360,000
Clearing, Grading, Roads	117,000
Railroad Trackage	185,000
Utilities	130,000
Engineering	118,000
Legal	45,000
TOTAL	$ 995,000

APPENDIX D

CONSIDERATIONS IN PREPARING A COMPLETE HAZARD ANALYSIS REPORT.

1. ANALYSIS OF PLANT OPERATIONS.

An analysis of plant operations would include all routine procedures followed from the arrival of spent fuel elements at the plant to the ultimate packaging of processed fuel and the disposal of wastes. Also considered would be the steps in shutting down, maintenance, decontamination, and emergency procedures.

More specifically, the following questions would be considered:

1) What is the total plant capacity and the capacity in each stage? What types of fuel are to be accepted?

2) What is the physical arrangement of equipment?

3) How much shielding is provided for personnel?

4) What operations are automatic and what operations are manually controlled? Is there a system of interlocks?

5) What protective instrumentation is provided, including not only the customary chemical engineering controls for temperature, pressure, and fluid flow but also such instrumentation as radiation monitors?

6) How does the ventilation system for removal of hot off-gases and gaseous fission product wastes operate? How are these wastes disposed of? What are the pressure relationships in different parts of the plant?

7) What provisions are made for emergencies? Are there pressure reduction devices in the event of an accident? How leak tight is the building? How pressure-proof and leak tight are the process vessels and isolation cells? Is there an adequate filter system? Is there a defense system of back-up devices? Is the fire fighting equipment adequate? What are the procedures for emergency evacuation and decontamination?

8) What administrative controls are maintained? What supervision is adequate? How much judgement is permitted an operator? How adequate is communication between shifts?

2. CONDITIONS LEADING TO A MAXIMUM CREDIBLE ACCIDENT.

To specify a maximum credible accident the following factors should be known:

1) The chemical and physical conditions involved in each reprocessing stage, and the sequence of events that would be required to produce conventional chemical explosions and nuclear excursions.

2) The probability of combined failures of safety devices.

3) The accident consequences in terms of energy release, pressure and shock wave propagation, physical damage to equipment, and release of radioactivity.

3. ASSUMED RELEASE OF FISSION PRODUCTS.

The quantity of fission products assumed to be ejected into the building air or ventilation system, and the possible manner and magnitude of subsequent leakage into the atmosphere must be determined.

In the absence of a plant design, one may always postulate the release of the entire fission product inventory at ground level. This is conservative in the extreme. A more reasonable initial assumption is that of a plant design which eliminates ground level leakage. Such planned containment construction has become standard practice in the construction of nuclear reactor facilities.

Leakage control may be accomplished by limiting vaporization of radioactive solutions, confining gases, condensing vapors, filtering particulate matter, passing radioactive gases through a clean-up system, exhausting through a stack.

4. EFFECT OF RADIOACTIVITY RELEASE ON SURROUNDING ENVIRONMENT.

The term "environment" as used here refers primarily to the population and secondarily to the agricultural, industrial and leisure activity in the surrounding areas.

The release of fission products is ordinarily thought of as an escaping cloud of gases and microscopic particulates. A complete analysis should include the effects of a liquid release resulting from vapor condensation, fracture of a liquid processing stage, or fracture of the liquid waste disposal and storage system.

The effects of a cloud release are of both short and long duration. The short duration hazards, lasting for a period of approximately two hours, involve the immediate effect of the passing radioactive cloud on people; the long duration hazards involve contamination of the ground. An individual exposed to a radioactive cloud will receive a whole body dose from gamma rays emitted by the fission products dispersed in the cloud and a skin dose from beta rays. Inhalation of beta and alpha partical emitters in the cloud would result in radiation doses to specific internal organs, since some elements selectively concentrate in certain organs. Examples of this are iodine, which concentrates in the thyroid, and strontium, which settles in the bone. These hazards exist during the time of a cloud passage. Fission products will be deposited on surfaces as a result of fall-out in dry weather and rain-out during precipitation. Gamma emission from contaminated surfaces provides a longer lasting hazard.

In addition to the above effects resulting from the release of activity outside the plant, there is an effect close to the facility, due to gamma rays from activity which is confined to the building but which is dispersed outside the normally well-shielded areas.

5. BIOLOGICAL HAZARDS EVALUATION.

The following analysis is required to evaluate the biological hazards which result from escaping airborne fission products:

1) Correlation of the dose received by the whole body or organ with the concentration of activity in the air or on the ground. This involves a knowledge of emitted particle energies and biological intake and elimination processes.

2) Calculation of the dispersion of released activity, subsequent air concentration and ground deposition, taking into account the meteorological and hydrological conditions at the plant site.

3) Calculation of the biological dose received, by considering the plant radioactivity release along with (1) and (2) above.

4) Definition of acceptable hazards in terms of permissible dose levels and the number of people subject to exposure.

The analysis of long term hazards to the food supply requires a study of the food consumption habits of the population, a study of the food cycle including absorption of minerals from the soil by vegetation and the consumption of vegetation by livestock, and a study of the mineral retention properties of the soil. A knowledge of the local hydrology is required to determine possible contamination levels of water supplies.

6. AIRBORNE DIFFUSION OF RADIOACTIVITY.

The downwind diffusion of airborne radioactivity released from the plant is strongly influenced by meterological conditions.

Meteorological conditions at a particular site are variable and rank in uncertainty with the specification of the maximum credible accident. Chapter 10 and 12 of the manual "Meteorology and Atomic Energy", U. S. Atomic Energy Commission, 1955, provide a checklist of meteorological and climatological conditions pertinent to a hazard analysis. In brief, reference is made to:

1) The nature of the radioactive source before diffusion begins - height of release, temperature and velocity of the effluent, distribution of particle sizes.

2) Meteorological parameters - atmospheric stability, as determined by the air temperature variation with height, the resulting diffusion parameters and wind speeds.

3) Effects of precipitation.

4) Diurnal and seasonal variations.

5) Effect of terrain.

Meteorological data should be acquired ideally at the proposed site. However, data from neighboring weather stations may be used if applicable. A weather observation center is normally set up at the plant to gather applicable specific data.

7. CRITERIA FOR ACCEPTABLE HAZARDS

The AEC's recent reactor site criteria guide (E-9.12) considers as acceptable an emergency dose of 25 rem to the whole body, and 300 rem received by the thyroid. It also defines exclusion, low population, and population center distances as follows:

1) Exclusion Area

The area under full control of the facility owner, within which residence is normally prohibited. An individual located on the area boundary for two hours immediately following the maximum accident shall not receive a whole body dose of 25 rem or a thyroid dose of 300 rem.

2) Low Population Zone

The area immediately surrounding the exclusion area, in which the number of residents must be small enough to permit complete evacuation if necessary. Any individual located on the zone outer boundary should not receive a total body dose from a radioactive cloud in excess of 25 rem or a thyroid dose of 300 rem. Note that for this low population zone, it is the total dose that is considered whereas the exclusion area is defined by the dose acquired only in the first two hours exposure.

3) Population Center Distance

The population center distance is that distance from the stack to the nearest boundary of a populated center containing more than about 25,000 people. This distance shall be at least 1-1/3 times the distance from the reactor to the outer boundary of the low population zone.

These criteria still leave certain "grey" areas which the hazards analyst must specify to the satisfaction of licensing authorities. Some of these "grey" areas are:

1) What criteria are to be adopted for whole body gamma dose from long term exposure to deposited activity, and what criteria for dose received by organs other than the thyroid?

2) Are the hazards to be based on the meteorological condition which produces the maximum dose or on more probable but less severe conditions?

3) How are future changes in population distribution accounted for?

APPENDIX E

HAZARDS CALCULATIONS

1. INVENTORY OF RADIOACTIVE ISOTOPES AVAILABLE FOR RELEASE.

a. Fission Products from Fuel Inventory.

The fission product inventory is assumed to be that contained in one metric ton, i.e., 1,000 kg of fuel with an initial enrichment of 2.5%, subject to the following conditions:

1) Full power reactor operating time, 600 days
2) Burnup = 15,000 Mwd
3) Cooling time = 120 days

From conditions 1) and 2), the operating power level per ton of fuel is 25 Mw. Since one watt corresponds to 3.3×10^{10} fissions per second, the equilibrium fission rate is 8.25×10^{17} fissions/second/ton. The decay rate of a long-lived nuclide which has a relatively short-lived parent will be

$$A = 8.25 \times 10^{17}\, Y\,(1 - e^{-\lambda t_o})\, e^{-\lambda t}\ \frac{\text{dps}}{\text{ton}}$$

where: Y = fractional fission yield

λ = decay constant

t_o = operating time

t = cooling time

The curie content is obtained by dividing the above expression by 3.7×10^{10} dps/curie.

In some cases, significant biological damage is produced by a short-lived daughter of a long-lived isotope, e.g., 28 year Sr^{90} decays to 64.3 hour Y^{90}, which yields 2.2 Mev beta particles. It is customary to combine the radiation of the daughter with that from the parent, and to consider the activity level and decay rate of the combination to be that of the parent.

Table E-1 lists important activities in curies under the assumed conditions. Short-lived daughters are given in parenthesis after the long-lived parent.

The processing procedure is assumed to be so regulated that regardless of the degree of fuel enrichment, the fission product inventory will be as given in Table E-1.

b. Plutonium Inventory.

Plutonium isotopes are bred from neutron reactions with U-238. The determination of the plutonium inventory requires a solution of a set of equations involving production and destruction rates of the various Pu isotopes, and is dependent on the location and cycle history of the fuel.

For this study, we assume that:

1) The plutonium production was 0.8 kg per ton of uranium for a burnup of 1,000 Mwd/ton. (Reference 4.)
2) The distribution among the isotopes, shown in Table E-2, is approximately as given in (Reference 11.)

TABLE E-1

FISSION PRODUCT INVENTORY

Operating Power = 25 MW/ton

Operating Time = 600 days

Cooling Time = 120 days

Isotope	Yield Y (%)	Half-life	A (curies)
Kr-85	0.293	10.3 y	6.7×10^3
Sr-89	4.79	51 d	2.1×10^5
Sr-90 (+ Y-90)	5.77	28 y	5.2×10^4
Y-91	5.4	58 d	2.8×10^5
Zr-95	6.2	65 d	3.8×10^5
Nb-95	6.2	35 d	1.3×10^5
Ru-103 (+ Rh-103m)	3.0	39.7 d	8.2×10^4
Ru-106 (+ Rh-106)	0.38	1.0 y	4.6×10^4
Te-127 m (+ Te-127)	0.035	105 d	3.5×10^3
Te-129 m (+ Te-129)	0.35	37 d	8.2×10^3
I-131	3.1	8.05 d	2.2×10^1
Cs-137 (+Ba - 137m)	6.15	29 y	5.4×10^4
Ba - 140 (+ La - 140)	6.32	12.8 d	2.1×10^3
Ce-141	6.0	33 d	1.1×10^5
Ce-144 (+ Pr-144)	6.0	285 d	7.7×10^5

After a 15,000 Mwd/ton burnup, one ton of fuel will contain 12 kg of plutonium distributed as shown in Table E-2. The activities are calculated from the standard equations:

$$A \text{ curies} = \frac{(\lambda \text{ sec}^{-1}) \text{ N atoms}}{3.7 \times 10^{10} \text{ dps/curie}}$$

$$N \text{ atoms} = \left(\frac{6.025 \times 10^{23}}{240 \text{ gm}}\right) \qquad (M \text{ gms})$$

TABLE E-2

PLUTONIUM INVENTORY PER TON OF LOW ENRICHMENT FUEL

Isotope	Percent of Total Pu	kg	Half-life (years)	A (curies)
239	68	8.15	2.44×10^4	5.0×10^2
240	23	2.75	6.6×10^3	6.2×10^2
241	7	0.84	13.2	9.4×10^4
242	2	0.24	3.8×10^5	9.4×10^{-1}

c. Fission Product Inventory from a 3×10^3 Mw-sec Burst.

The hazards due to fission products produced in the power burst are considered from three aspects. The total activity content is used to estimate the whole body gamma and beta exposure from the airborne cloud. The iodines, being volatile and more likely to be released, may give rise to an inhalation and a short-term deposition hazard. The long half-life nuclides are shown to constitute a hazard several orders of magnitude less than the reactor operation inventory.

(1) Total Activity.

Activities and abundances of fission products after a burst are given by Bolles and Ballou (Reference 10.). A 3×10^3 Mw-sec burst produces 10^{20} fissions. One minute after the burst, the activity is 6×10^{17} disintegrations/sec or 1.6×10^7 curies. The activity decay is given by the Way-Wigner formula

$$A_t = A_1 t^{-1.2}$$

where t is time in minutes after the burst, and A_1 is the activity at one minute. Since the excursion itself could extend over several minutes, the initial activity stated above in an upper limit. For decay times of the order of an hour or more, the burst duration is not significant.

During the first ten hours, the inert gases (Kr, Xe) and the halogens (Br, I) each contribute about 12% of the total activity.

(2) Iodine Activity.

A computation was made of the maximum activity of the iodines. Iodines having half-lives shorter than 2 minutes are neglected. The iodines are derived from tellurium precursors according to the following scheme:

Mass Number	Te	I
131	30 hours ↓	
	25 minutes →	8.05 day
132	77 hours →	2.3 hours
133	60 minutes →	20.8 hours
134	43 minutes →	52.5 minutes
135	<1 minute →	6.7 hours

The activity of a daughter isotope is

$$A_1(t) = YF\frac{\lambda_1\lambda_o}{\lambda_1 - \lambda_o}\left(e^{-\lambda_o t} - e^{-\lambda_1 t}\right)$$

where: t = time after burst

Y = fractional yield

F = fissions

The subscript o refers to the parent; subscript 1, to the daughter.

When $\lambda_1 \ll \lambda_o$ as in the case of I-131, 133 and 135, we will have

$$A_1(t) \approx YF\lambda_1 e^{-\lambda_1 t}$$

If $\lambda_1 \gg \lambda_o$ as in the case of I-132,

$$A_1(t) = YF\lambda_o e^{-\lambda_o t}$$

For I-134, $\lambda_i \simeq \lambda_o = \lambda$. Here A_1 (t) becomes $A_1(t) = YF\lambda^2 te^{-\lambda t}$

which has a maximum value at $t_{max} = 1/\lambda$

$$A_1(t_{max}) = YF\lambda e^{-1}$$

The maximum values of the iodine activities are shown in Table E-3.

TABLE E-3

MAXIMUM IODINE ACTIVITIES AFTER 3×10^3 MW-sec BURST

Mass Number	λ effective (sec-1)	YF Nuclides	A_1 (max) (curies)
131	1.0×10^{-6}	3.1×10^{18}	8.4×10^{1}
132	2.5×10^{-6}	4.7×10^{18}	3.2×10^{2}
133	9.3×10^{-6}	6.9×10^{18}	1.8×10^{3}
134	2.2×10^{-4}	7.8×10^{18}	1.8×10^{4}
135	2.9×10^{-5}	6.1×10^{18}	4.9×10^{3}

(3) Long Half-life Nuclides.

The maximum activity is $A_{max} = \dfrac{YF\lambda(sec^{-1})}{3.7 \times 10^{10} \text{ dps/curie}}$

Table E-4 lists these activities for the isotopes considered in Table E-1. They are seen to be considerably less than the activity from reactor operation. However, if the release of non-volatile products is limited, then the strontium nuclides formed from the escaping kryptons could conceivably have a higher relative release rate in the burst case.

TABLE E-4

FISSION PRODUCT ACTIVITIES

(OTHER THAN IODINES)

AFTER A 3×10^3 MW-sec BURST

Isotope	A_{max} (curies)
Sr-89	19
Sr-90	0.12
Y-91	20.
Zr-95	21.
Nb-95	39.
Ru-103	16.
Ru-106	0.22
Te-127m	0.072
Te-129m	2.0
Cs-137	0.13
Ba-140	110.
Ce-141	40.
Ce-144	4.6

2. ATMOSPHERIC DILUTION AND GROUND DEPOSITION FACTORS.

a. Introduction.

Activity is assumed to be released in a puff from a stack 80 meters high. An additional 20 meters is added because of the expected effluent velocity, resulting in an effective release height of 100 meters.

Atmospheric dispersal calculations are based on Sutton's theory. Typical lapse and typical inversion conditions using BNL parameters (Reference 1.) are considered. The lapse condition provides the greater hazard near the site, whereas the inversion condition presents the greater hazard far from the site. In addition, the expected concentration in a fumigation condition is given. This condition arises when the inversion layer near the ground is broken up at sunrise and the contaminant which has been aloft during the prior inversion period is brought to the ground.

All the quantities calculated are for a distance, d meters, downwind, on the centerline of the cloud, at ground level. This assumes that wind direction remains constant during the cloud movement. The diffusion equations were obtained from(Reference 2.). For an instantaneous or "puff" release of Q curies, the total exposure at any point in curie-sec/m^3, resulting from passage of the cloud, is equal to the steady-state exposure in curie/m^3 which would result from a continuous release of Q curies/second.

b. Equations.

(1) Atmospheric Dilution Factor.

Let Q = curies released from stack

$X(d)$ = time integrated concentration, in curie-sec/m^3, at the ground at a distance d meters downwind.

h = effective stack height, meters

u = wind speed at height h, m/second,

n = turbulence parameter, dimensionless

C_y = horizontal diffusion coefficient, $(m)^{n/2}$

C_z = vertical diffusion coefficient, $(m)^{n/2}$

$$X/Q = \frac{2}{u\pi C_y C_z d^{2-n}} e^{-\left(\frac{h^2}{C_z^2 d^{2-n}}\right)}$$

$$X_{max} = \frac{2Q}{\pi h^2 eu} \frac{C_z}{C_y}$$

at the distance

$$d_{max} = \left(\frac{h^2}{C_z^2}\right)^{\frac{1}{2-n}}$$

During the fumigation condition

$$\frac{X}{Q} = \frac{1}{(2\pi)^{1/2} C_y uHd^{(2-n)/2}}$$

where H meters is the height of the base of the inversion layer.

(2) Dry Deposition.

One may define a deposition velocity, V_g m/sec, as

$$V_g = \frac{\text{total deposition, curie/m}^2 \text{ of surface}}{\text{concentration at surface level, curie-sec/m}^3}$$

Then the deposition, Δ curies/m^2 per curie released is given by

$$\frac{\Delta}{Q} = V_g X \exp\left(\frac{-4V_g d^{n/2}}{nu\pi^{1/2} C_z}\right)$$

(3) Rainout Deposition.

The activity deposited as a result of rainfall, W_r curies/m^2, is obtained from

$$\frac{Wr}{Q} = \frac{\Lambda e^{-\left(\frac{\Lambda d}{u}\right)}}{u\pi^{1/2} C_y d^{(2-n)/2}}$$

where Λ is the removal rate of the contaminant, sec^{-1}

(3) Diffusion Parameters.

The diffusion parameters n, Cy, and Cz are assumed to be the BNL typical values (Reference 1). The wind speed at h = 100 meters is assumed to be 5 m/sec for the inversion case and 10 m/sec for the lapse case. For the fumigation case, typical inversion parameters are used since these will determine the cloud distribution just prior to the onset of the condition.

The deposition calculations are presented for the inversion case only, since the population exposure is greatest for this case. For the dry depositon, Vg is taken to be 1.0×10^{-3} m/sec. Two rainout removal factors are considered: 1.0×10^{-4} sec^{-1} corresponding to 1μ particles, and 5×10^{-4} sec^{-1} for larger particles. The 1μ value is used as the more realistic choice for particulates escaping the containment.

TABLE E-5

DIFFUSION PARAMETERS

Condition	n	Cy ($m^{n/2}$)	Cz ($m^{n/2}$)	u (m/sec)
Lapse	0.25	0.4	0.4	10
Inversion	0.55	0.4	0.05	5

(4) Results.

The quantities X/Q for lapse, inversion, and fumigation conditions, and Δ and W_r for the inversion case are plotted in Figures 1-2 as a function of distance from the stack. The maxima of X/Q are:

	d max (m)	Xmax/Q (sec/m^3)
Lapse	5.5×10^2	2.3×10^{-6}
Inversion	3.6×10^4	5.8×10^{-7}

3. BIOLOGICAL HAZARDS EVALUATION.

a. Acceptable Emergency Radiation Levels.

The concept of acceptable emergency dosage (AED) is commonly employed in reactor hazards analyses, e.g., WASH-740, and has recently received official AEC recognition (Reference 12). It is reasonable to apply the same standards to a processing plant safety analysis.

(1) AED Values.

1) External Gamma Dose - 25 r
2) Thyroid Dose from Iodines - 300 r
3) Skin Dose - 50 r
4) Other critical organs - 50 r

b. Conversion Factors from Exposure to Dose.

(1) External Dose.

(a) Dose from Airborne Cloud.

An estimate of the external whole body dose received downwind during passage of the cloud is made with the aid of the Holland nomograms presented in "Meteorology and Atomic Energy", (Reference 2).

The parameter "σ" which appears in the reference is defined as:

$$\sigma = (CyCz)^{1/2} d^{(n-2)} h$$

and is calculated using BNL values for the parameters. The initial cloud release height is h = 100 meters. Doses from the excursion fission products are calculated from Figure 8.1 of Reference 2. The results are shown in Figure E-3. Doses from the reactor operation products are calculated from Figure 8.3 of Reference 2, using the curve marked "KC" which gives the dosage per kilocurie for E_γ = 0.7 Mev and u = 1 m/second. To obtain the dosage for other wind speeds, the "KC" value is divided by u. The results are shown in Figure E-4.

(b) Beta Dose from Airborne Cloud.

On the assumption that the cloud concentration is essentially uniform over the range of beta radiation, (~1 to 10 meters for beta energies of 0.5 to 2 Mev), the energy absorbed in a volume of air is equal to that emitted from the same volume. This is the condition of radiative equilibrium for which the standard conversion factor for activity concentration to dose for betas of energy E_β(mev) applies:

Dose in roentgens = (X curie-sec/m^3) (0.55) (E_β mev)

Additional factors of 0.5 and 0.64 are introduced to account for the absorption of the human body and the presence of the earth's surface respectively. Taking $\bar{E}_\beta$ = 0.4 Mev, we have

$$1 \text{ curie-sec/m}^3 = (0.5)(0.64)(0.55)(0.4) \text{ r}$$

$$= 7.0 \times 10^{-2} \text{ r}$$

(2) Inhalation Dose.

(a) Iodines.

Reference 12 gives the following conversion factors:

Isotope	Dose (rem per c-sec/m^3)
I-131	329
I-132	12.4
I-133	92.3
I-134	5.66
I-135	25.3

(b) Bone Seekers.

The permissible inhaled activities for a 50 rad dose for the strontium* and cerium isotopes are based on the discussion in WASH-740. The activities for soluble plutonium isotopes are based on the "q" values for bone listed in NBS Handbook 69, relative to the q value for Sr-90. In addition, Table E-6 below presents the c-sec/m^3 exposure corresponding to 1 AED (50 r). This is based on the assumption that exposure to 1 c-sec/m^3 involves the inhalation of 220 uc.

TABLE E-6

Isotope	Inhaled Activity per AED (μc)	Air Concentration per AED (c-sec/m^3)
Sr-89	770.	3.5
Sr-90	7.	3.2×10^{-2}
Ce-144 (+Pr-144)	200.	1.1
Pu-239	1.4	6.4×10^{-3}
Pu-240	1.4	6.4×10^{-3}
Pu-241	3.1	1.4×10^{-1}
Pu-242	1.8	8.0×10^{-3}

*The Sr-90 limit is reduced to 2/3 of the WASH-740 value. The factor 2 results from the higher "q" value in NBS Handbook 69; the factor 1/3 results from a recent change of the effective half-life from 6 to 18 years.

(3) Lung Dose.

(a) From Beta Activity.

From WASH-740, page 34, the beta dose rate to the lungs is:

$$D = 5.9 \times 10^{-7} \, q \, E \quad \text{rad/sec}$$

$$= 2.1 \times 10^{-3} \, q \, E \quad \text{rad/hour}$$

where:

q = μc of activity retained in the lungs

q is given as 55 c for an exposure of 1 curie sec/m^3, assuming $\bar{e}$ = 0.4 Mev, we get

$$D = 4.6 \times 10^{-2} \text{ r/hr per c-sec/m}^3 \text{ exposure}$$

(b) From Plutonium Alpha Activity.

WASH-740 suggests 0.16μc of Pu-239 inhaled as 1 AED. AED values for the other plutonium isotopes are based on relative $(PMPC)_\alpha$ valueslisted in Table 1 of NBS Handbook 69 for Pu Insol, Lung.

TABLE E-7

Isotope	Inhaled Activity per AED (μc)	Air Concentration per AED (c-sec/m^3)
Pu-239	0.16	7.3×10^{-4}
Pu-240	0.16	7.3×10^{-4}
Pu-241	1.6×10^{2}	7.3×10^{-1}
Pu-242	0.16	7.3×10^{-4}

(4) Gamma Dose from Deposition.

The gammas from the long-lived fission products strongly predominate in this case. The criterion adopted is that the infinity integrated dose is produced by Cs-137 (+Ba-137m). Cs-137 is chosen since its volatility, curie content, long life, and gamma emission mark it as the significant hazard. No credit is taken for dilution by natural factors.

The dose rate 3 feet above a plane contaminated with an 0.7 Mev gamma emitter is 10.6 r/hr per c/m^2. (Ba-137 m emits an 0.67 Mev gamma in 100% of the disintegrations). The total integrated dose per unit disposition is:

$$\text{TID in } r/(c/m^2) = \frac{10.6 \text{ r/hr - } (c/m^2)}{\lambda\,(hr^{-1})}$$

$$\text{For Cs-137, } \lambda = 2.6 \times 10^{-6}\ hr^{-1}, \text{ and}$$

$$\text{TID} = 4.1 \times 10^{6}\ r/(c/m^2)$$

1 AED (25 r) corresponds to a deposition of 6.1×10^{-6} c/m^2 of Cs-137.

(5) Gamma Dose from Contained Fission Products.

The exposure to gammas which would result if all the fission products were confined to the air in the building is considered in a following section. The result is given in terms of dose rate. As in the ground deposition case, one may calculate a total integrated dose based on the Cs-137 release. At the shutdown time of 120 days, the Zr-95, Nb-95 isotopes contribute to about 90% of the unshielded dose rate. Since the Cs-137 activity shown in Table E-1 is about 10% of Zr-Nb activity, we compute the total integrated dose to be

$$\text{TID (roentgens)} = 0.1 \; \frac{\text{D(r/hr) from Figure E-5}}{2.6 \times 10^{-6}\ \text{hr}^{-1}}$$

$$= 3.8 \times 10^{4}\ \text{D}$$

1 AED (25 r) then corresponds to a dose rate of 6.6×10^{-4} r/hour.

c. <u>Consequences of a Full Fission Product Release.</u>

The maximum downwind dose is calculated assuming the entire fission product inventory from both burst and reactor operation are released through the stack in a puff. The results are then used to estimate the containment required to reduce the dose below 1 AED outside a 1,000 foot (300 meters) radius.

(1) <u>External Dose from Airborne Cloud.</u>

The total reactor operation inventory is 2×10^{6} curies. The total energy release in the burst is 3×10^{3} Mw-sec. To obtain the gamma dose, these figures are multiplied by the respective minimum values of r/curie or Mw-sec shown in Figures E-4 and 3. The beta dose is found from the burst inventory of 1.6×10^{7} curies, the conversion factor of 1 c-sec/m^3 = 7.0×10^{-2} r, and X/Q in Figure E-1.

	Dose		
	Burst	Reactor	Total AED
Gamma Dose	40 r	1.2 r	1.6
Beta Dose	33 r	4.2 r	0.75

(2) External Dose from Fission Products Dispersed in the Contained Air.

It is assumed that the fission product inventory is uniformly dispersed in the building after an incident. As a consequence, gamma radiation from the long-lived fission products will produce a dose rate which will decrease slowly with time. The source is the reactor operation inventory.

(a) Unshielded Dose Rate.

This situation is analyzed by referring to the computations by Geller and Epstein (Reference 14). In their model, the fission product release was assumed to be uniformly dispersed in a sphere of 95 foot radius, half of which is underground. The fission product inventory was that of a reactor operating for 600 days at 500 MW. The assumed release was 25% of all halogen and inert gases, and 1/16 of the remaining fission products. Figure 8 of their paper shows the unshielded dose rate versus distance from the sphere center, 100 days after the incident. For that cooling time, the curve represents the contribution of fission products other than halogens and inert gases, and thus corresponds to the inventory present in fuel operating at (500/16) MW. Since in this study we assume an inventory for 25 MW, we obtain the unshielded dose rates by multiplying the referenced curve by the factor 25/(500/16). The resulting dose rate is shown in Figure E-5 as a function of distance from containment center.

(b) Effect of Concrete Wall Shielding.

Assuming a linear attenuation coefficient for 0.7 Mev gammas of $\mu = 1.5 \text{ cm}^{-1}$ for ordinary concrete walls, and buildup factor B_R, corresponding to a material of atomic mass number Z = 18, we find the following transmission factors, $B_R' e^{-b}$:

Wall Thickness (Feet)	b = t m.f.p.'s	e^{-b}	B_R	$B_R e^{-b}$
1	4.5	1.1×10^{-2}	8	8.8×10^{-2}
2	9.0	1.2×10^{-4}	20	2.4×10^{-3}
3	13.5	1.3×10^{-6}	30	3.9×10^{-5}
4	18	2.4×10^{-8}	50	1.2×10^{-6}

3. Inhalation Hazard.

Iodines.

Combining the iodine airborne concentration-to-dose conversion factors with the maximum iodine inventory from the burst, we obtain the inhalation doses shown in Table E-8.

Bone Seekers.

At 300 meters, the maximum inhalation dose occurs under fumigation conditions.

$$(X/Q)_{300 \text{ meters}} = 3 \times 10^{-5} \text{ per curie}$$

The resulting hazard in AED units is then obtained by dividing X_{max} by the last column in Table E-6. The results are shown in Table E-9.

TABLE E-8

Isotope	(r) Conversion Factor c-sec/m^3)	A_{max} (curies)	Dose (rem/sec/m^3)
131	329	8.4×10^1	2.8×10^4
132	12.4	3.2×10^2	0.40
133	92.3	1.8×10^3	16.6
134	5.66	1.8×10^4	10.2
135	25.3	4.9	12.4
TOTAL			42.4×10^4

When the total of 42.4×10^4 rem/sec/m^3 is multiplied by the values of X/Q sec/m^3, shown in Figure E-1 it is seen that the iodine dosage beyond the 1,000 feet radius will be less than 15 r or 0.05 AED.

TABLE E-9

Isotope	X_m (c-sec/m^3)	AED
Sr-89	6.3	1.8
Sr-90	1.6	50.
Ce-144	23.1	21.
Pu-239	15×10^{-3}	2.3
Pu-240	18.6×10^{-3}	2.9
Pu-241	28.2×10^{-1}	20.
Pu-242	28.2×10^{-6}	0.0035
TOTAL		98.

Lung Dose.

From Beta Particles.

$$D = 4.6 \times 10^{-2} \text{ r/hr per c-sec/m}^3.$$

At 300 meters, $(X/Q)_{max} = 3 \times 10^{-5}$. Combined with a release of 1.6×10^7 curies, the maximum dose is 22 r or 0.44 AED.

From Plutonium.

The dose is found in a similar manner. The results are listed in Table E-10.

TABLE E-10

Isotope	X_{max} (c-sec/m^3)	AED
239	15×10^{-3}	20.5
240	18.6×10^{-3}	25.2
241	28.2×10^{-1}	3.8
242	28.2×10^{-6}	0.038
		49.5

Deposition Dose.

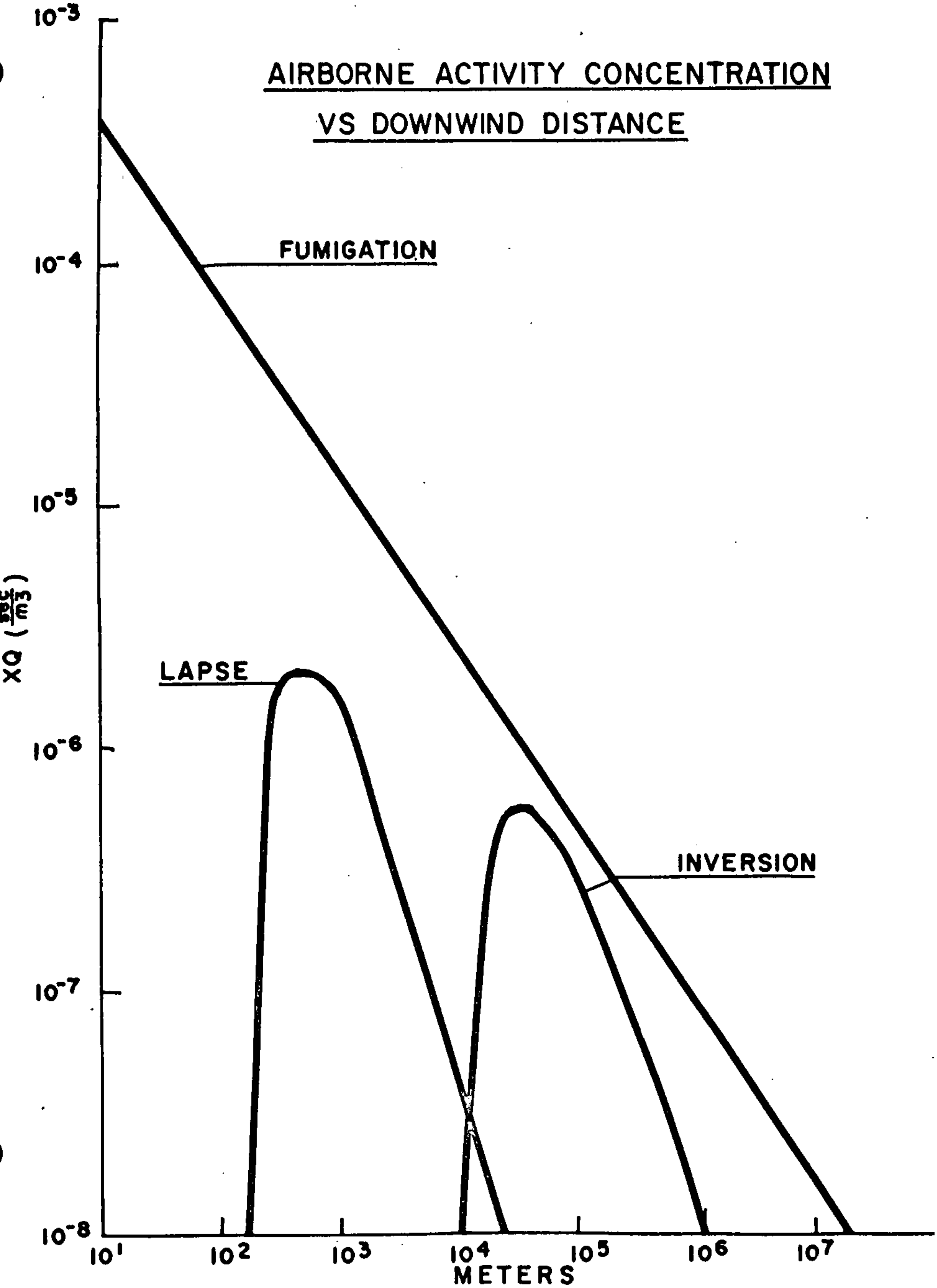
The maximum Cs-137 release is 5.4×10^4 curies. At 300 meters, the rainout deposition factor is 4×10^{-7} m^{-2}. The maximum deposition outside 300 meters will be 2.2×10^{-2} c/m^2, which results in an integrated dose of

$$4.1 \times 10^6 \ r/(c/m^2) \times 2.2 \times 10^{-2} \ c/m^2$$

$$= \quad 9.0 \times 10^4 \ r$$

$$= \quad 3.6 \times 10^3 \ \text{AED}$$

FIGURE E-1



AIRBORNE ACTIVITY CONCENTRATION
VS DOWNWIND DISTANCE
FUMIGATION
LAPSE
INVERSION
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
10⁻⁷
10⁻⁸
XQ (sec/m3)
10¹
10²
10³
10⁴
10⁵
10⁶
10⁷
METERS

FIGURE E-2

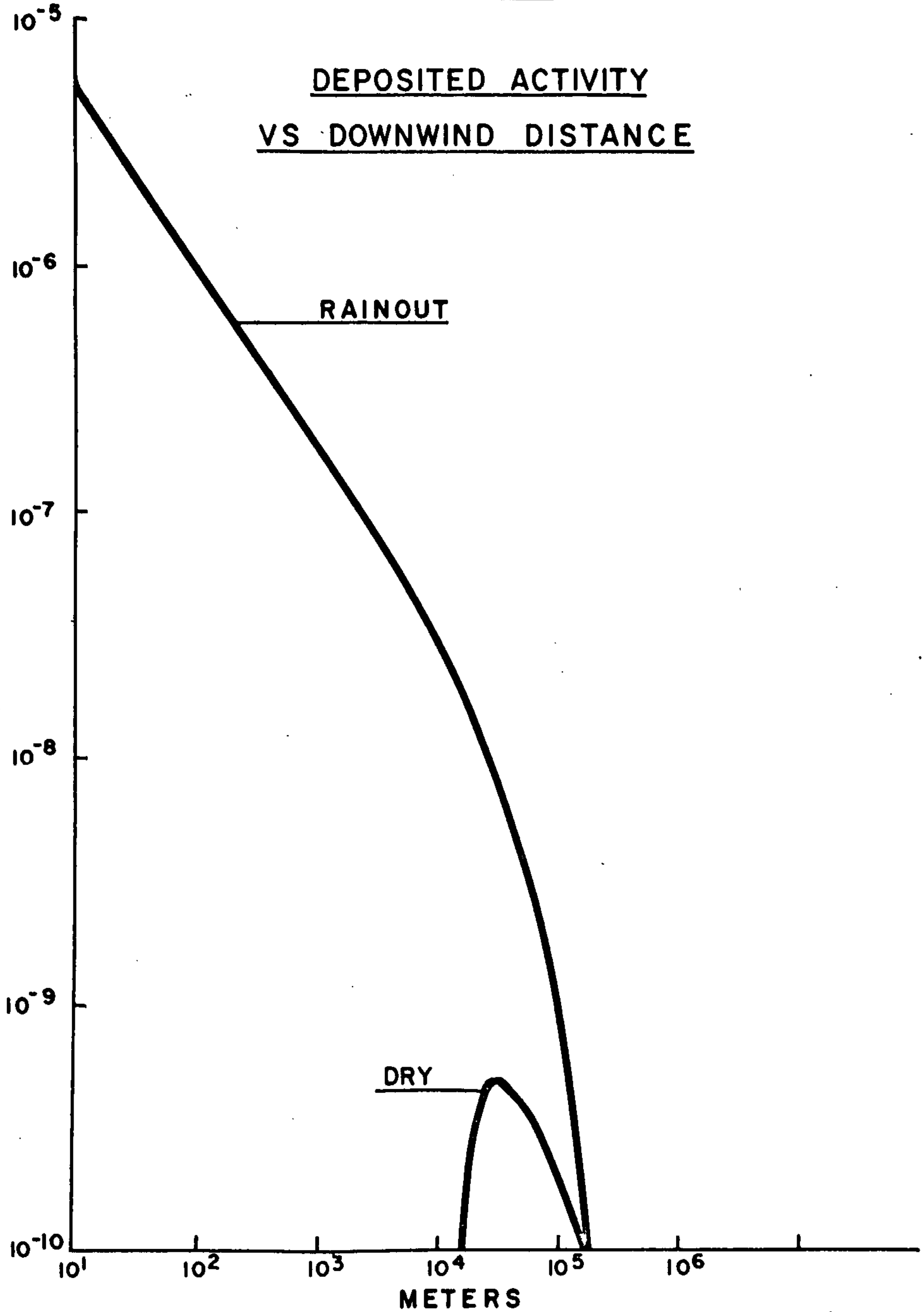

DEPOSITED ACTIVITY
VS DOWNWIND DISTANCE
RAINOUT
DRY
METERS-2
10-5
10-6
10-7
10-8
10-9
10-10
10¹
10²
10³
10⁴
10⁵
10⁶
METERS

FIGURE E-3

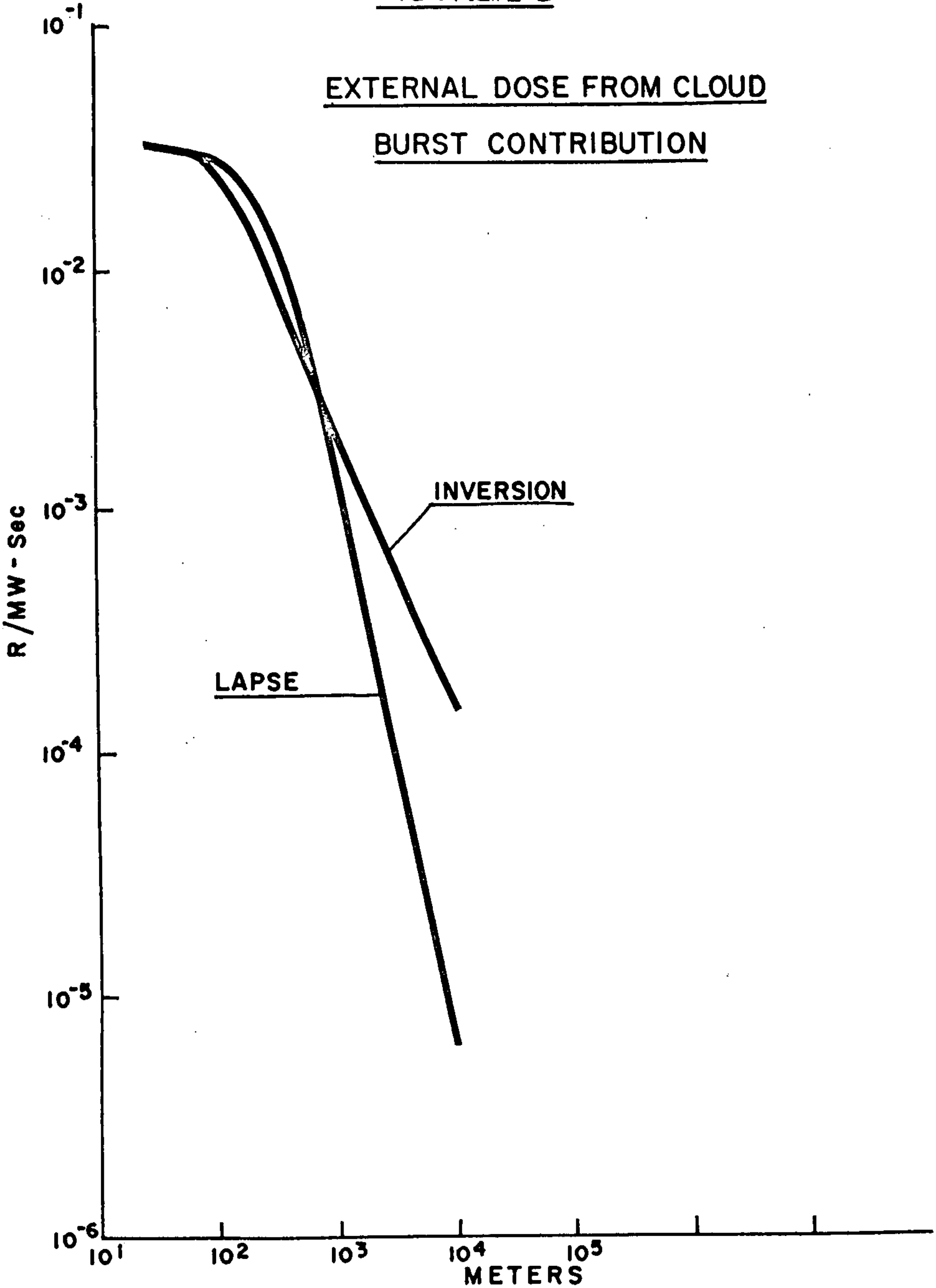

EXTERNAL DOSE FROM CLOUD
BURST CONTRIBUTION
INVERSION
LAPSE
R/MW - Sec
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{1}
10^{2}
10^{3}
10^{4}
10^{5}
METERS

FIGURE E-4

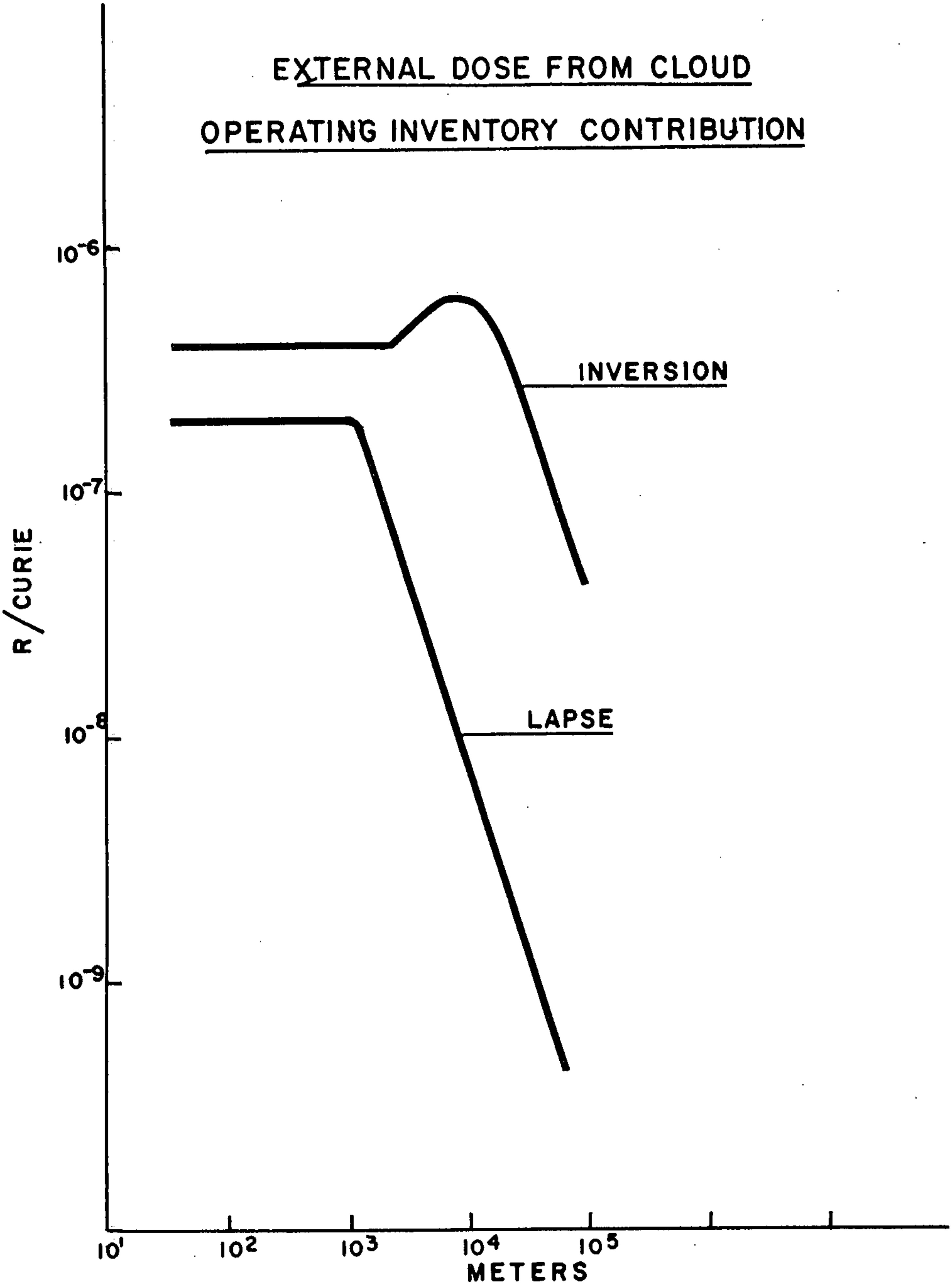
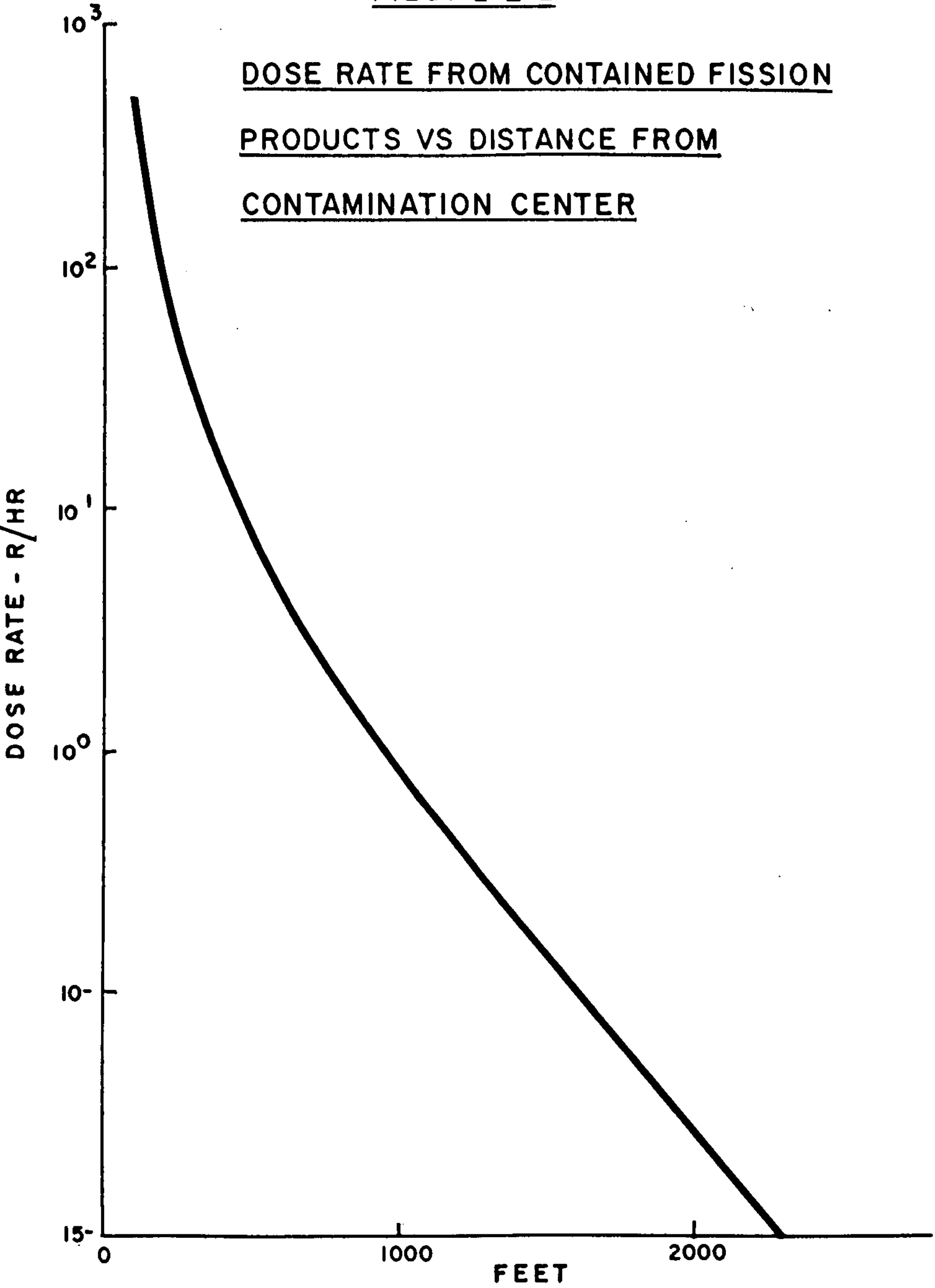
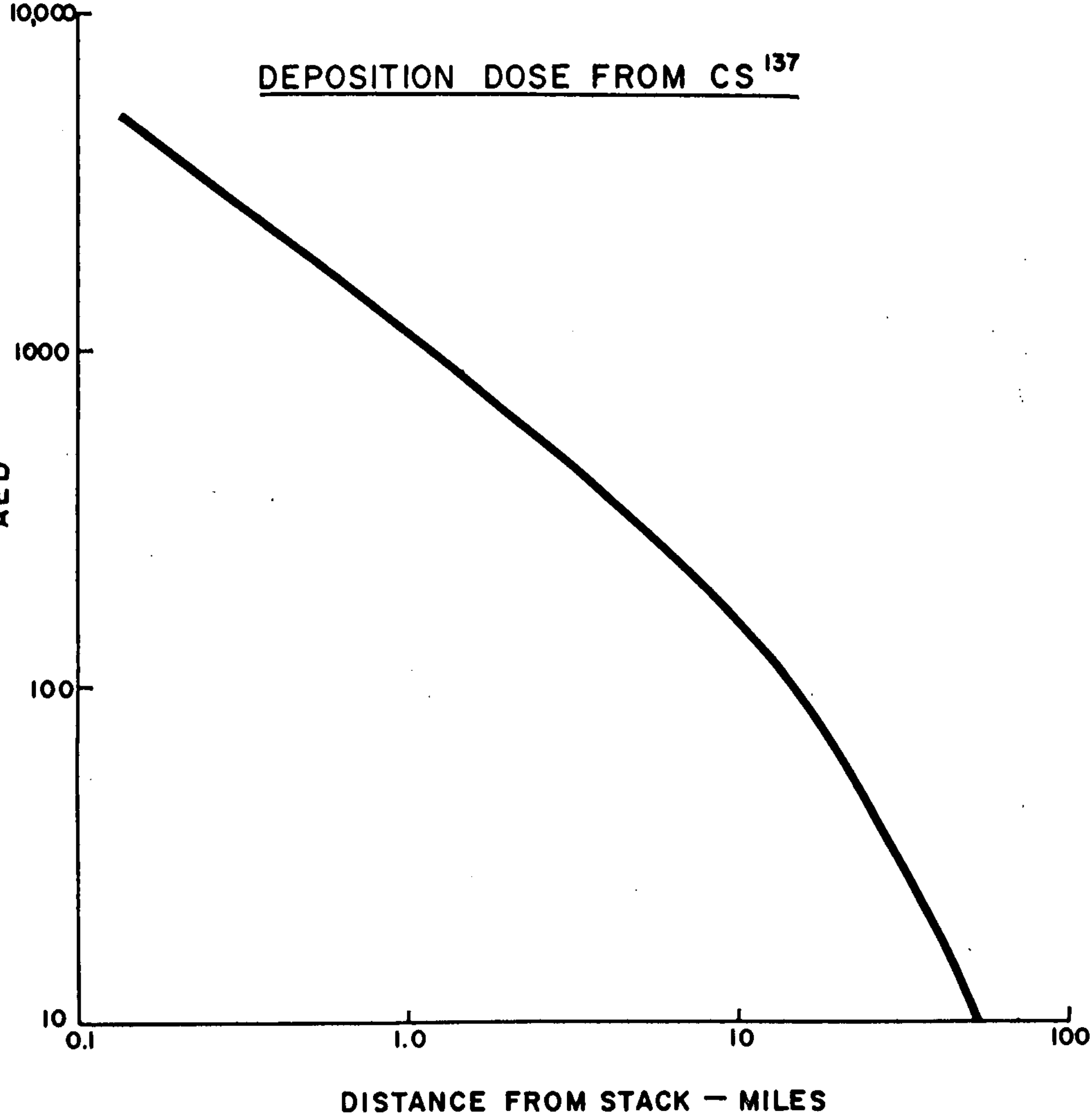

EXTERNAL DOSE FROM CLOUD
OPERATING INVENTORY CONTRIBUTION
10^{-6}
10^{-7}
10^{-8}
10^{-9}
R/CURIE
INVERSION
LAPSE
10^{1}
10^{2}
10^{3}
10^{4}
10^{5}
METERS

FIGURE E-5



DOSE RATE FROM CONTAINED FISSION PRODUCTS VS DISTANCE FROM CONTAMINATION CENTER
10³
10²
10¹
10⁰
10-
15-
DOSE RATE - R/HR
0
1000
2000
FEET

FIGURE E-6



DEPOSITION DOSE FROM CS 137
10,000
1000
100
10
AED
0.1
1.0
10
100
DISTANCE FROM STACK — MILES

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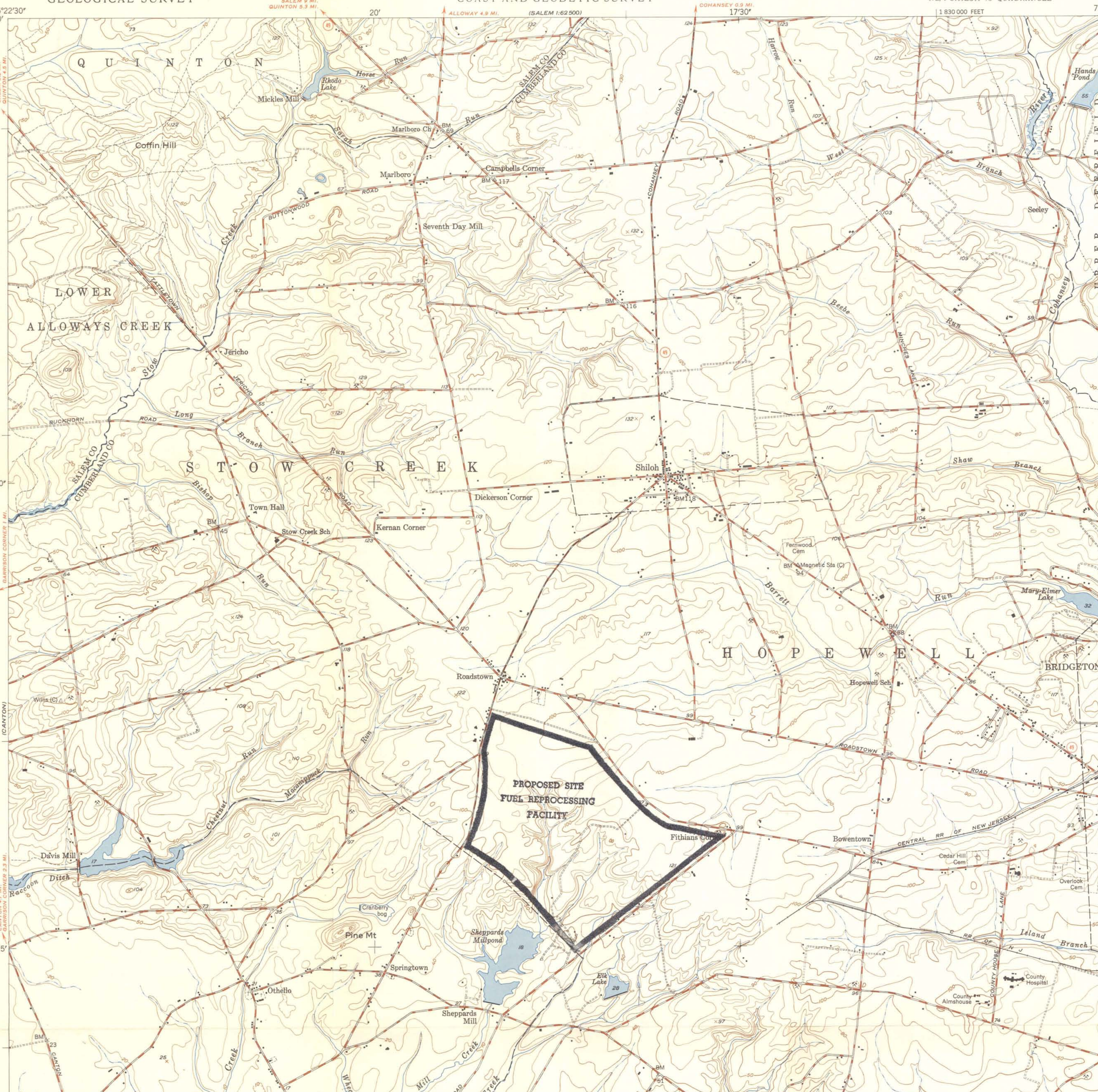
SHILOH QUADRANGLE
NEW JERSEY
7.5 MINUTE SERIES (TOPOGRAPHIC)
NE/4 SHILOH 15' QUADRANGLE



Mapped by U. S. Coast & Geodetic Survey
Edited and published by the Geological Survey

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Culture and drainage in part compiled from aerial photographs taken 1946
Topography by plane-table methods 1947

Polyconic projection. 1927 North American datum
10,000-foot grid based on New Jersey coordinate system

No distinction is made between dwellings, barns, commercial and industrial buildings

TRUE NORTH
MAGNETIC NORTH
8¾°
APPROXIMATE MEAN DECLINATION, 1947

SCALE 1:24000

CONTOUR INTERVAL 10 FEET
DATUM IS MEAN SEA LEVEL
SHORELINE SHOWN REPRESENTS THE APPROXIMATE LINE OF MEAN HIGH WATER
THE AVERAGE RANGE OF TIDE IS APPROXIMATELY 6 FEET

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, WASHINGTON 25, D. C.

USC&GS T-8757

ROAD CLASSIFICATION

HARD-SURFACE ALL WEATHER ROADS — DRY WEATHER ROADS
Heavy-duty — Improved dirt
Medium-duty — Unimproved dirt
Loose-surface, graded, or narrow hard-surface
U. S. Route — State Route

Figure 4

SHILOH, N. J.
NE/4 SHILOH 15' QUADRANGLE
N3922.5—W7515/7.5

EDITION OF 1949