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DESCRIPTION AND SAFETY ANALYSIS

FOR A CONCEPTUAL UNIT

AT INDIAN POINT

VOLUME I

Please Do Not Retain

RR-412

OCTOBER 1, 1965

3269

DESCRIPTION AND SAFETY ANALYSIS

FOR A CONCEPTUAL UNIT

AT INDIAN POINT

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1.0 INTRODUCTION AND SUMMARY

The proposed Indian Point Unit No. 2 is similar to the Connecticut Yankee Haddam Nuclear Generating Station. The basic design of this facility follows established design concepts, and the only significant differences between the proposed Indian Point facility and the Connecticut Yankee facility are as follows:

1. Reactor power level - 2758 MWt
2. The use of Zircaloy clad fuel
3. Partial safety injection with emergency on-site power
4. Pressurized double penetration in the containment

The facility is designed to minimize requirements for release of radioactive material to the environment during normal operation. The design also incorporates features which minimize the possibility of events which could lead to excess releases of radioactive material. Engineered safeguards are provided which, in the event of an unlikely major accident, minimize the consequences to the operating personnel and the general public. These safeguard systems are designed so that even with partial effectiveness, the limits of 10 CFR 100 will not be exceeded.

2.0 Site Investigations

Indian Point Unit #2 proposed by Consolidated Edison will be built adjacent to Unit #1 on a site of approximately 250 acres of land on a rocky promontory on the east bank of the Hudson River at Indian Point, Village of Buchanan in upper Westchester County, New York. The site is about 24 miles north of the New York City boundary line. The location and the character of the terrain and surrounding areas are shown on maps submitted as part of this report.

To determine the adequacy of the site for the purpose indicated, investigations have been made to cover the meteorology, seismology, geology, hydrology, and environmental radioactivity of the immediate area. Some of these investigations were made prior to construction of Indian Point Unit #1 in 1955, but due to the nature of the subject the results are applicable to Unit #2 in 1965. Where applicable some reports, such as seismology, have been supplemented to cover the past 10 years, and supplemented to cover information more recently of interest to the AEC, such as the surrounding reservoirs discussed in the hydrology section.

Meteorology

A contract was entered into with New York University on August 10, 1955, under which that organization investigated meteorological conditions at the site. New York University had made similar studies for the Consolidated Edison Company at other sites and also for the Brookhaven Laboratory and thus was well qualified. The program was a comprehensive one requiring purchase and delivery of various instruments and the erection of a 300 ft. test tower on the site, followed by two years of readings. The study was under the general direction of Dr. Harold K. Work and under the immediate direction of Prof. Benjamin Davidson, both of New York University. The detailed reports by Prof. Benjamin Davidson on the program are included herein. The meteorological characteristics of the site described in these reports have been applied in determining the radiological effects of the loss of coolant accident.

Seismology

For the study of earth movements in the area, the Edison Company retained the services of Reverend Joseph Lynch, S.J., Director of the Seismic Observatory at Fordham University, as that organization possessed the seismograph and a background of records and experience for the general area under consideration. The report of Father Lynch is included. Since he suggested that his report be reviewed by the Geophysics Department of the United States Coast and Geodetic Survey at Washington, D.C., there are included copies of correspondence with Captain Roberts of that section and also his report which confirms the findings of Father Lynch. The seismological history subsequent to these reports has been prepared by the engineering staff of Consolidated Edison, and is included herein. The reactor plant and containment will be designed to safely withstand an earthquake induced horizontal acceleration of 0.1 g. This acceleration corresponds to that resulting from an earthquake of severest intensity recorded in the plant area.

Geology

To investigate the geological features of the area, the Company retained Mr. Sidney Paige, Visiting Professor of Geology at Columbia University. Mr. Paige's work as a geologist is well known both around the United States and beyond. For many years he acted as consulting geologist for the northeastern district of the Army engineers and among the undertakings with which he was associated were the Panama Canal, the Straits of Mackinac bridge, and the Canol oil project in Canada. Mr. Paige's report is enclosed and constitutes this phase of the investigation. The report indicated that the bearing strength of the foundation rock far exceeds any load that might be put on it by any engineering structure.

Land Usage and Population

The land usage and population within a five and fifteen mile radius is shown on maps and tables compiled by the staff of Consolidated Edison.

Sources used in preparing these studies are the 1960 census, the zoning laws of the individual communities involved, and a report prepared by the Regional Plan Association.

Hydrology

The study of the hydrology of the site was undertaken by Mr. Karl R. Kennison, former Chief Engineer of the New York City Board of Water Supply and Consulting Civil and Hydraulic Engineer. His report is included.

The engineering staff of Consolidated Edison has made a detailed study of the potable water supplies within a 15 mile radius of the site and the findings are included. This study is based in part on data obtained from a report by the New York State Department of Health.

In addition, Consolidated Edison has contracted the consultant firm of Metcalf and Eddy to prepare an extensive hydrological study of the area.

Environmental Radioactivity

Consolidated Edison began in 1958 to make a comprehensive survey of environmental radioactivity at Indian Point Station and the surrounding area which is continuing with the operation of Unit #1. There is continuous sampling of air particulate, fallout, and Hudson River water, and periodic sampling of drinking water, vegetation, marine life, and soil. These samples are not limited to the Indian Point property but extend into areas of Westchester, Putnam, and Rockland counties. All samples are taken and analyzed by Indian Point personnel.

These measurements have shown that operation of Indian Point Unit #1 for more than three years has had no perceptible effect on the plant environment. During the past few years there have been minor changes in the radioactive background, but these have been due to fallout from nuclear weapons tests and not from Unit #1.

2.1 Meteorology

New York University under a contract with Consolidated Edison Company made extensive tests over a period of two years on the meteorological conditions at the Indian Point site. The testing program, began in 1955 and completed in 1957, was described in three technical reports prepared by the New York University staff under the immediate direction of Prof. Benjamin Davidson. These reports were submitted to the AEC in their entirety as Exhibits L-1, L-5, and L-6 of Docket 50-3, Indian Point Unit #1. Prof. Davidson has on several occasions in the past 10 years acted as consultant to Consolidated Edison on meteorological matters and thus has continued an association with the Indian Point site. This section is composed of the original New York University reports or applicable excerpts therefrom which have been reviewed by Prof. Davidson and the Consolidated Edison staff regarding the addition of a second nuclear unit adjacent to Unit #1.

NYU Technical Report 372.1, "A Micrometeorological Survey of the Buchanan, N.Y. Area", dated November, 1955, which was Exhibit L-1, Docket 50-3, is included in its entirety. The topography of the area surrounding the site is described and the effects of the topography on meteorological conditions is discussed. The testing equipment and location of the equipment is discussed in detail. The initial findings during 1955 are presented with a discussion of the diurnal and seasonal wind velocities and directions.

The second report is section 2 and 3 of NYU Technical Report 372.3, "Evaluation of Potential Radiation Hazard Resulting From Assumed Release of Radioactive Wastes to Atmosphere From Proposed Buchanan Nuclear Power Plant", dated April, 1957. This report was submitted to the AEC in its entirety as Exhibit L-5, Docket 50-3. The two sections discussing diffusive conditions and climatological data are includ[illegible] in this document and the discussion of radiation effects is included in anot[illegible] hibit of the Docket for Unit #2.

NYU Technical Report 372.4, "Summary of Climatological data at Buchanan, New York 1956-1957", dated March, 1958, was Exhibit L-6, Docket 50-3. This report summarizes the final meteorological testing at Indian Point and is included in its entirety.

NEW YORK UNIVERSITY
ENGINEERING RESEARCH DIVISION

REPORT NO. 372.1

A MICROMETEOROLOGICAL SURVEY OF THE BUCHANAN, NY AREA

SUMMARY OF PROGRESS TO 1 DEC. 1955

Prepared by Ben Davidson
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Prepared for
Consolidated Edison Company of New York
November 1955

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1. Introduction

1.1 Description of Topography

Indian Point Park, site of the proposed power plant, is located some two miles SW of the town of Peekskill which is the most densely populated area in the immediate vicinity of the site. Indian Point, itself, is on the east bank of the Hudson River which runs NE-SW at this point but makes a sharp right angled turn some 2 miles NE of the Point (see Fig. 1). The west bank of the Hudson is flanked by the steep, heavily wooded slopes of the Dunderberg and Ramapo peaks (heights close to 1,000 ft.) which extend further to the west by other names and gradually rise to slightly higher peaks.

The general orientation of this mass of high ground is NE to SW. One mile NW of the site, Dunderberg bulges to the east, and north of Dunderberg and the site, high ground reaching 900 ft. forms the east bank of the Hudson as the river makes a sharp turn to the northwest. To the NE of the site, the narrow beds of the Canapus and Peekskill creeks lie generally in a NNE to NE orientation. To the east of the site peaks are generally lower than those to the north and west. Spitzenberg and Blue Mts average about 600 ft. in height and there is a weak, poorly defined series of ridges which again seem to run in a NNE direction. The river south of the site makes another sharp bend to the southeast and then widens as it flows past Croton and Haverstraw.

1.2 Meteorological Effects of Topography

The site then lies in a bowl surrounded on almost all sides by high ground ranging from 600 to 1000 ft. Although the heights of the orographic features are relatively small when compared to classical Alpine or western United States valley studies, the topography surrounding the present site is nevertheless pronounced enough to decisively influence the meteorology of the valley. We may expect the topography to exert its influence in the following ways.

a) The orientation of the ridges serves to channel the air flow in the valley into preferred directions. We would therefore expect the frequency distribution of wind direction to be more peaked than it would be over level terrain.

b) The ridges act as a barrier to the descent of faster moving air to ground levels and for this reason wind speeds in the valley should be lower than over level terrain.

c) The differing radiational characteristics of the valley, valley sides and plain at the mouth of the valley combined with the sheltering effect of the ridges give rise to thermally induced local air circulations. These circulations, if present, should have a well marked diurnal period and should be seasonally dependent. When present in a pure and highly developed form, the thermally induced currents have well-defined vertical branches with systematic ascending or descending currents along the valley sides and center.

d) When prevailing winds are strong and normal to the ridges some sort of quasi-stationary eddy wind system may develop in the valley. This type of wind system may be very turbulent and in a rough statistical sense may also have preferred regions of sustained positive or negative vertical currents.

e) The effect of these valley systems on diffusion rates are largely unknown. Moreover, the vertical circulation branches - if they exist - can redistribute diffusing material in the vertical in a manner which is quite inconsistent with values of the traditional vertical diffusion coefficients derived from studies over level terrain.

1.3 Objectives of Project

The objectives of the present study are to evaluate the effect of topography on the diffusion climatology of the site. This involves collection of data describing the wind distribution in the vertical and horizontal, temperature gradients and interpretation of this data in terms of diffusion from a ground and elevated source.

2. Equipment

2.1 Wind Measuring Equipment

The project has on hand now five Bendix-Friez Aerovanes, the outputs of which are recorded continuously on twin chart recorders and are the primary source of our climatological wind data. Two highly sensitive Beckman Whitley anemometers are used for low level wind determinations and for special studies. Two very sensitive bivanes developed at M.I.T. (see Fig. 2) are used to determine the three dimensional wind direction. The bivanes when used with the Beckman Whitleys form a compatible system for quantitative determination of vertical currents. The output of both the Beckman and bivane can be recorded continuously (but not regularly) on standard 0-1 ma Esterline Angus recorders, four of which are in our posession now.

Also available to the project are two theodolites for use in double theodolite pibal ascents. It is hoped that the angular readings of the theodolites when following balloons can be recorded photographically at discrete intervals, thus making possible regularly scheduled ascents despite manpower limitations.

2.2 Temperature Measuring Equipment

Temperature is measured by Type A - Brown Resistance Thermometers. When placed in specially designed wells, the time constant of these thermometers is about 3 minutes in a wind of 20 fps. The bulbs are placed in shielded, gold leafed cylinders and are aspirated at about 20 fps. The output of the resistance bulbs is recorded on a 4 channel Brown Electronik Recorder, while differences in the output of matched bulbs are recorded on a 6 channel Brown Electronik recorder. The recording cycle is 2 minutes for the four channel recorder (channels sampled at 30 second intervals) and 3 minutes for the six channel temperature difference recorder. Four of these bulbs are now in our possession. Ten others are still on order with delivery now expected by mid-December.

2.3 Smoke Generating Equipment

The Chemical Corps has kindly loaned the project an M2A1 smoke generator. The generator operates at a capacity of 50 gallons per hour and should enable us to collect smoke trajectory observations in all but the strongest wind conditions. For use with the generator, the project has acquired a 700 cfm blower (at 1.5 psi) powered by a 7-1/2 hp 220 V. motor.

3. Observation Sites

3.1 Meteorological Tower

Figure 1 is a map of the area showing the principal observation points. The underlined names are sites of more or less contiguous observations. The meteorological tower is the focal point of all observations made in the valley. The tower is a 310 ft guyed trylon type (sides about 42 inches) with an inside ladder. The base of the tower is about 110 ft above river level. Seven 10 ft booms are mounted horizontally at 50 ft intervals for support of the meteorological instruments. Aerovanes are mounted on alternate booms at heights of 210, 310 and 410 ft above river level while Brown resistance bulbs will be mounted at 50 ft intervals, (see Fig. 2). A five inch galvanized pipe runs up one corner of the tower.

The smoke generator and blower are mounted at the foot of the tower and during operations the smoke is forced up the pipe by the blower. Ports are provided at about 300, 350 and 410 ft above river level enabling us to vary the height of emission of the smoke trail as conditions warrant. The output of the meteorological instruments are recorded in the Trailer, shown in Fig. 4.

3.2 Off-Tower Anemometer Sites

The U. S. Maritime Commission has kindly granted us permission to use several of the Reserve Fleet ships anchored in the Hudson off Stony Pt. as anemometer sites. Usable observations have been continuously recorded on the Hall and Jones (see Fig. 1) since 1 Sept. The anemometer on the Hall was removed 1 Nov. for installation on the tower. The Jones anemometer will operate continuously for the remainder of the project. It has a good exposure, close to the middle of the river, and presumably removed from the slope currents of the Dunderberg peak to the west.

A Beckman-Whitley anemometer began operation 15 Nov. on the roof of a dock on the east side of the river. The Jones and Dock observations (at about 70 ft above river) will fill in the details of the flow close to the valley.

An aerovane will shortly be mounted on the roof of the main building of the Peekskill Military Academy (elevation about 200 ft). This is the approximate site of a USWB station which made regular hourly observations during 1932, 1933 and part of 1934. Reactivation of the station will enable us to get the maximum information from the old records.

3.3 Chronology of Available Observations:

In summary, pertinent data available to the project for climatological purposes as of 1 Dec. follow:

Site	Ht.(above river).	Type	Dates of Availability
Hall	70	Wind	1 Sept - 30 Oct.
Jones	70	Wind	1 Sept on
Dock	50	Wind	15 Nov. on
Tower	210	Wind	1 Nov.
"	310	Wind	1 Nov.
"	410	Wind	1 Nov.
"	T(410-T(260)	Temp. diff.	8 Dec.*
"	T(160)-T(260)	Temp. diff.	8 Dec.*
"	at 50 ft intervals	" "	10 Jan.*
Water	0	Temp.	10 Jan.*
Peekskill Military	200	Wind	Jan. 1932-Sept.1934
Academy	200	Wind	8 Dec.*

* Estimated date of installation.

4. Discussion of Data

4.1 Diurnal Variation of Wind Direction

The most striking feature of the two months of Jones data which have been analyzed thus far is the diurnal variation of wind direction. At sunset There is a pronounced tendency for the wind to shift to NE. At sunrise there is again a tendency for the winds to shift to SW. On some days the shift is very abrupt and occurs just about at sunrise and sunset. On other days the shift is not so abrupt and may not take place till after midnight and then only after an hour or two of calm winds. NE winds, on occasion, persist until noon before southwesterly flow begins. On still other days, of course, the prevailing winds are so strong as to swamp any possible valley effect, and on those days there is no diurnal shift in wind direction.

A northeast wind parallels the valley orientation at the plant site and is directed down river towards the mouth of the Hudson. If we define the axis of the valley as a line running 040°-220°, and compute wind components along the axis of the valley and in the cross-valley direction, the diurnal variation of wind direction becomes quite apparent. Figure 5 is a plot of the median values of the up and down valley component of the wind as a function of time of day. The down valley component reaches its peak median value at about 0600 while the up-valley component reaches its peak median value at about 1600. The peak median value of the nocturnal down wind component is 5 mph while the peak value of the daytime median wind is about 3 mph. These peak values merely reflect the fact that statistically the night time northeasterly flow occurs more frequently than does its southwesterly daytime counterpart.

This is clearly seen in Figure 6 where the frequency distribution (calms omitted) of wind components along the axis of the valley (6a) and in the cross valley direction (6b) is shown for night (solid line) and day (dashed line). The distribution of the axial component is strongly bimodal for both night and day. At night the most frequent component is down valley (northeast) about 6 mph. A secondary mode is up-valley at about 5 mph but its freuency is about 1/3 the down valley frequency. In the daytime the principal mode becomes up-valley but a substantial down valley frequency is still observed. It is evident that two regimes are operating, one associated with the valley influence under relatively weak synoptic flow conditions, and one associated with rather strong synoptic flow which alternately swamps the day and nighttime valley influences. A third and weaker regime also operates, namely, a tendency for persistence of northeasterly winds until about noon on some days and a tendency for northeasterly winds to begin rather late at night on still other days. The latter regime is undoubtedly associated with cloudiness and other air mass radiational conditions.

The distribution of the cross-valley component (Fig. 6b) is very sharply peaked around zero at night indicating that during a great many nights the flow is substantially along the axis of the valley. In the day-time the zero peak is considerably reduced and the distribution broadens indicating a considerable cross-valley component which is generally super-imposed on the up-valley daytime flow. All in all, comparison of the two distributions indicate that night time stability conditions have the effect of channeling the flow along the axis of the valley, while in the daytime the channeling effect of the valley sides is not as evident, being partially overcome by descent of air from above the valley ridge lines. This can be clearly seen when we compare the r.m.s. wind component along the axis of the valley with the r.m.s. wind component in the cross-valley direction. At night the r.m.s. along-valley component is about twice the cross-valley r.m.s. value. During the day, the r.m.s. value of both components are about the same.

4.2. Distribution of Wind With Height and Across-Valley.

The observations discussed above were made on board the Jones anchored in midriver where presumably the down valley wind should exist in its purest form. There are two months of simultaneous data available from the Hall, anchored close to the west shoreline of the Hudson. Although not yet ready for presentation, preliminary analysis of the differences between the Jones and Hall indicate very little difference in the broad features of the flow pattern.

The project was fortunate in being able to acquire (from the U.S. Weather Bureau) a 2-3/4 year series of data made at the Peekskill Military Academy, Jan. 1932-Sept. 1934. As nearly as can be ascertained at the present time, these observations were made at a point at least 200 ft. above river level and about 2 miles NE of the site. Essentially the same diurnal variation of wind direction as discussed above was found with the old data. In addition to this, preliminary examination of tower winds for Nov. indicate that on at least some occasions the diurnal trend in wind direction is in evidence up to 420 ft. above river level. The tentative conclusion is that the down valley wind fills the breadth of the valley and on at least some occasions extends to over 400 ft. above river level.

4.3. Seasonal Dependence of Down-Valley Winds

To illustrate the seasonal dependence of night time northeasterly flow we have calculated the percent frequency that NNE to ENE winds were observed at Peekskill Military Academy, 1932-1934 as a function of time of day for the various seasons. The results are shown in Figure 7. As was to be expected, the diurnal variation of northeasterly winds reaches a maximum amplitude during summer and a minimum amplitude during winter. This result can be explained as due principally to the generally stronger snynoptic flow during winter than during summer. A secondary reason is perhaps the change in cloudiness and radiational conditions from summer to winter. The dashed line plot of Fig. 7 represents the percent frequency of occurrence of both calm and NNE to ENE winds. The reason for this presentation is that calm is an arbitrary designation depending on instrumental and observer thresh-holds. Considering the equipment in use in 1932 we believe that a large number of the recorded night time calms were characterized by a slow drift of air from the NE. This supposition is strengthened by the fact that a similar count for the Jones Sept - Oct. data indicates a maximum night time incidence of about 70% for NNE to ENE flow.

4.4. Presentation of Climatological Data

The frequency distribution of wind speed and direction by wind speed class and by night and day for the various seasons is presented in Tables 1 thru 4. The data is from the U.S. Weather Bureau station at Peekskill Military Academy (1932-1934). Day and night were arbitrarily defined with respect to sunrise and sunset of the middle of each month. It is believed that in this form the interpretation of the frequency distribution of wind in terms of diffusion parameters is facilitated. For example, the night time class of wind from any direction with speed 1-4 mph is undoubtedly characterized by a strong inversion. To assist in this kind of interpretation we have also available (but not presented in this report) the distribution of cloudiness for each class in Tables 1-4. Before making definite interpretations, however, we prefer to correlate the tower temperature measurements with the wind data we will shortly begin receiving from the Peekskill Military Academy.

5. Conclusions and Future Plans

5.1. Conclusions

We now have a fairly good idea of the general flow patterns at our observation points. Still unknown, is the distribution with height of the flow patterns we have discussed in the previous section. The meteorologically unique feature of the valley is, of course, the substantial night time incidence of northeasterly winds. This valley phenomenon is of great importance to our study primarily because low wind speed and presumably stable thermal stratification are associated with the night time winds. These conditions usually result in a narrow plume of relatively high concentration. However, because of the possibility - still unexplored - of sustained up or down vertical velocities it is still too early to make statements about ground concentrations.

In many ways it is fortunate that the night time winds are usually directed down valley away from Peekskill. On the other hand, it becomes of paramount importance to evaluate the effect of the bend of the river south of the site on the trajectories of sources emanating from Indian Point Park. It is also of great importance to evaluate the diffusive conditions associated with the day time up-valley winds which have a tendency to carry diffusing materials to Peekskill. This procedure must also be carried out for the occasions when night time flow associated with general weather conditions is directed up-valley.

5.2. Future Plans

Our future plans follow directly from our tentative conclusions and these are generally to evaluate trajectories and diffusive conditions under critical wind condition regimes. This will be done with the aid of our smoke installation, and as far as is consistent with horizontal visibility conditions, with quasi constant level balloon trajectories.

As winter draws on, it is apparent that our opportunity for studying the up and down valley winds will be curtailed. However, the generally stronger winter winds will afford us opportunity to examine the structure of possible eddy winds in the neighborhood of the site. These winds - if they exist at the proper height - may be instrumental in carrying smoke to the ground.

In the meanwhile we must complete our instrumental installation, iron out the bugs in the smoke system, and continue with the accumulation and analysis of climatological data.

TABLE I - Frequency distribution of wind speed for winter months (by day and night) as observed at Peekskill Military Academy, 1932-34.

Direction	DAY Speed (mph) 1-4	5-10	>10	Total	NIGHT Speed (mph) 1-4	5-10	>10	Total
N	.020	.031	.029	.080	.009	.019	.021	.049
NNE	.004	.003	.003	.010	.004	.004	.003	.011
NE	.048	.047	.035	.130	.077	.085	.029	.191
ENE	.006	.020	.031	.057	.006	.028	.022	.056
E	.017	.009	.001	.027	.038	.006	.001	.045
ESE	.002	.002	-	.004	.004	.002	-	.006
SE	.021	.006	.001	.028	.016	.005	-	.021
SSE	-	.005	.002	.007	.002	.004	-	.006
S	.022	.020	.003	.045	.028	.016	.001	.045
SSW	.005	.028	.011	.044	.005	.026	.011	.042
SW	.048	.051	.021	.120	.043	.045	.011	.099
WSW	.002	.015	.012	.029	.002	.001	.005	.008
W	.031	.028	.019	.078	.017	.020	.007	.044
WNW	.001	.028	.034	.063	.003	.017	.025	.045
NW	.014	.048	.103	.165	.013	.077	.094	.184
NNW	.002	.021	.034	.057	.004	.021	.035	.060
TOTAL	.243	.362	.339	.944	.271	.376	.215	.912
Calm				.056				.088
		Total		1.000		Total		1.000

TABLE II - Frequency distribution of wind speed for Spring months (by day and night) as observed at Peekskill Military Academy 1932-34.

	DAY				NIGHT			
	Speed (mph)				Speed (mph)			
Direction	1-4	5-10	>10	Total	1-4	5-10	>10	Total
N	.018	.029	.020	.067	.021	.023	.012	.056
NNE	.003	.014	.003	.020	.004	.009	.001	.014
NE	.035	.055	.007	.097	.127	.065	.010	.202
ENE	.004	.030	.026	.060	.010	.032	.015	.057
E	.012	.013	.002	.027	.041	.016	.004	.061
ESE	.002	.007	.002	.011	.004	.006	-	.010
SE	.018	.019	.003	.040	.029	.014	.002	.045
SSE	.007	.014	.006	.027	.008	.019	.002	.029
S	.036	.039	.014	.089	.040	.036	.002	.078
SSW	.012	.048	.021	.081	.010	.044	.010	.064
SW	.049	.074	.010	.133	.042	.037	.007	.086
WSW	.007	.008	.005	.020	.002	.001	.002	.005
W	.040	.026	.006	.072	.019	.011	.002	.032
WNW	.005	.028	.024	.057	.002	.010	.021	.033
NW	.022	.046	.045	.113	.012	.023	.014	.049
NNW	.002	.016	.012	.030	.002	.014	.012	.028
TOTAL	.272	.466	.206	.944	.373	.360	.116	.849
Calm				.056				.151
		Total		1.000		Total		1.000

TABLE III - Frequency distribution of wind speeds for Summer months (by day and night) as observed at Peekskill Military Academy, 1932-34.

	DAY				NIGHT			
	Speed (mph)				Speed (mph)			
Direction	1-4	5-10	>10	Total	1-4	5-10	>10	Total
N	.022	.030	.011	.063	.025	.017	.006	.048
NNE	.003	.008	-	.011	.002	.007	-	.009
NE	.064	.080	.013	.157	.200	.078	.006	.284
ENE	.008	.034	.016	.058	.010	.021	.009	.040
E	.014	.007	.001	.022	.051	.011	.001	.063
ESE	.002	.004	.001	.007	.004	.003	-	.007
SE	.017	.010	-	.027	.026	.015	.002	.043
SSE	.003	.009	.003	.015	.009	.007	.001	.017
S	.036	.040	.008	.084	.060	.031	.002	.093
SSW	.010	.060	.019	.089	.014	.030	.005	.049
SW	.069	.078	.006	.153	.042	.041	.002	.085
WSW	.006	.013	-	.019	.004	.001	-	.005
W	.026	.019	-	.045	.018	.005	-	.023
WNW	.005	.026	.008	.039	.001	.007	.001	.009
NW	.026	.063	.025	.114	.014	.041	.012	.067
NNW	.005	.014	.013	.032	.003	.009	.009	.021
TOTAL	.316	.495	.124	.935	.483	.324	.056	.863
Calm				.065				.137
		Total		1.000		Total		1.000

TABLE IV - Frequency distribution of wind speeds for Fall months (by day and night) as observed at Peekskill Military Academy, 1932-33.

	DAY				NIGHT			
	Speed (mph)				Speed (mph)			
Direction	1-4	5-10	>10	Total	1-4	5-10	>10	Total
N	.023	.038	.022	.083	.018	.024	.008	.050
NNE	.001	-	.001	.002	.001	.003	.005	.009
NE	.049	.073	.031	.153	.102	.092	.039	.233
ENE	.005	.037	.024	.066	.008	.038	.029	.075
E	.020	.010	-	.030	.052	.004	-	.056
ESE	.004	.004	.001	.009	.002	.004	-	.006
SE	.014	.004	.002	.020	.028	-	-	.028
SSE	.001	.013	.002	.016	.003	.006	.002	.011
S	.028	.031	.010	.059	.042	.024	.010	.076
SSW	.014	.034	.015	.063	.015	.028	.011	.054
SW	.052	.070	.014	.136	.039	.032	.005	.076
WSW	.001	.008	-	.009	.001	.007	.002	.010
W	.036	.025	.004	.065	.011	.020	.005	.036
WNW	.009	.026	.026	.061	.006	.018	.016	.040
NW	.013	.044	.063	.120	.021	.055	.044	.120
NNW	-	.012	.023	.035	.005	.009	.006	.020
TOTAL	.260	.429	.238	.927	.354	.364	.182	.900
Calm				.073				.100
		Total		1.000		Total		1.000

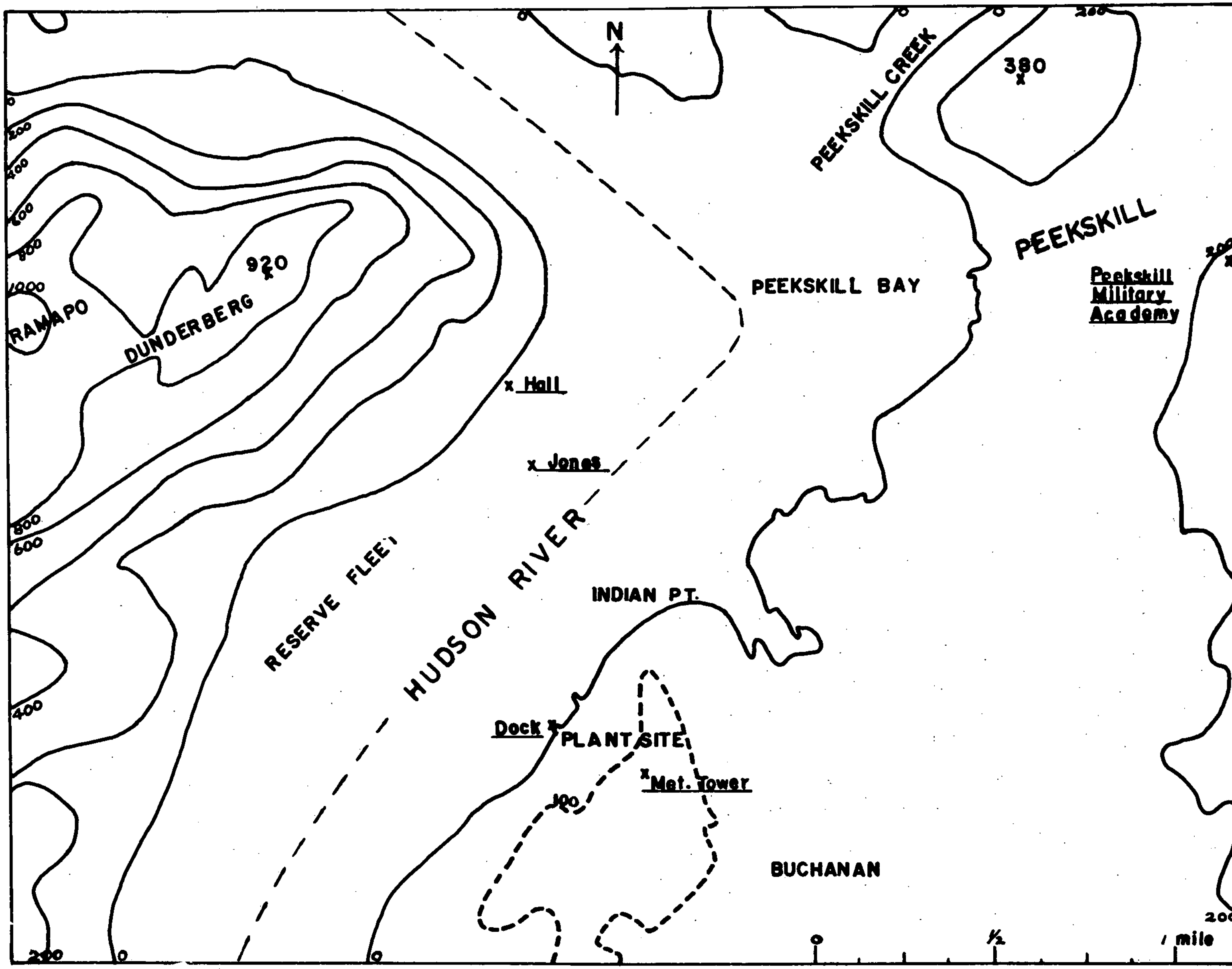

Fig. 1 Map of area surrounding meteorological tower. Underlined areas (Hall, Jones, Dock, Peekskill Military Academy) are sites of anemometer locations or sources of previous data.

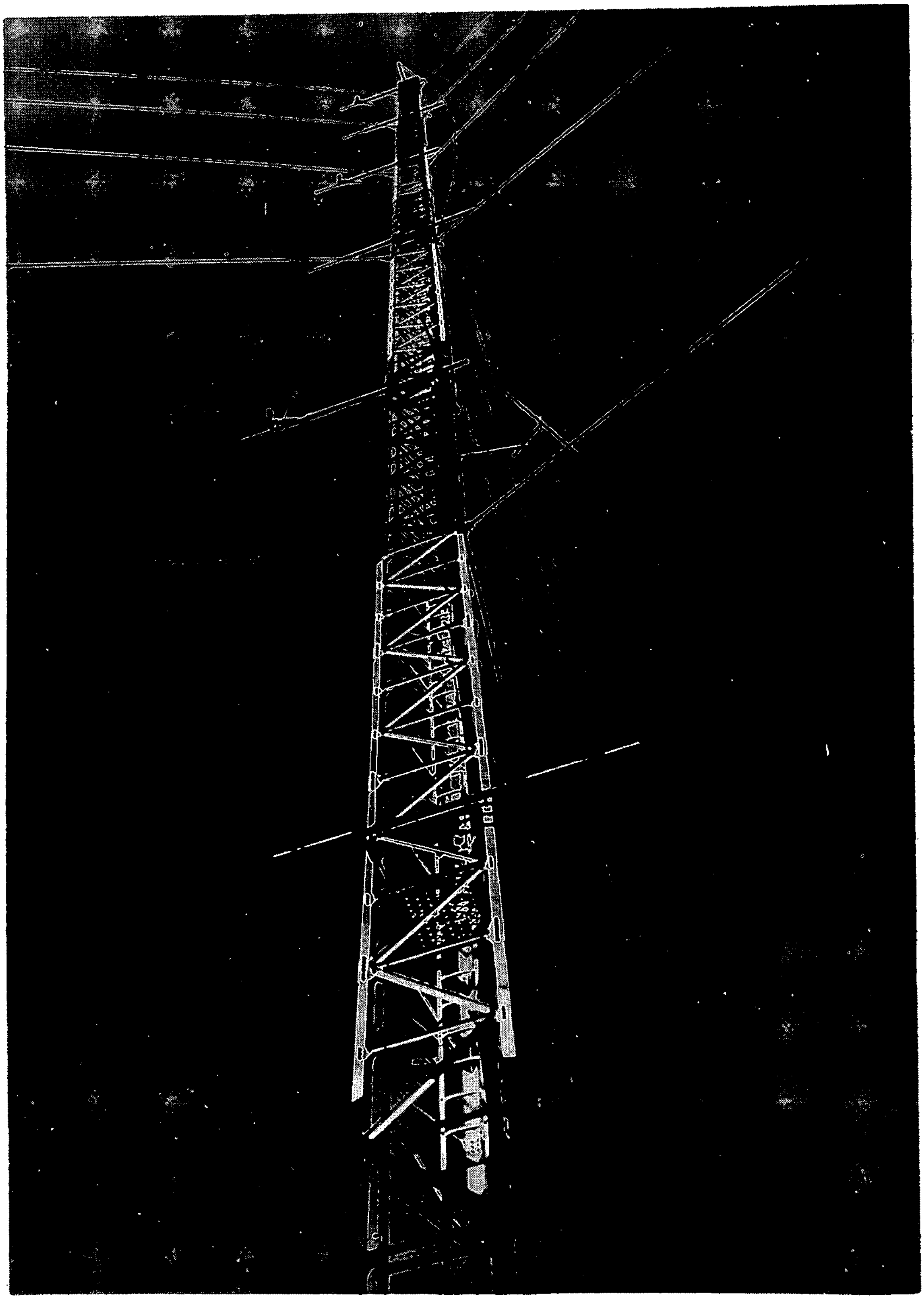

Fig. 2 Photograph of tower. Note Aerovanes at 100, 200 and 300 ft. levels.

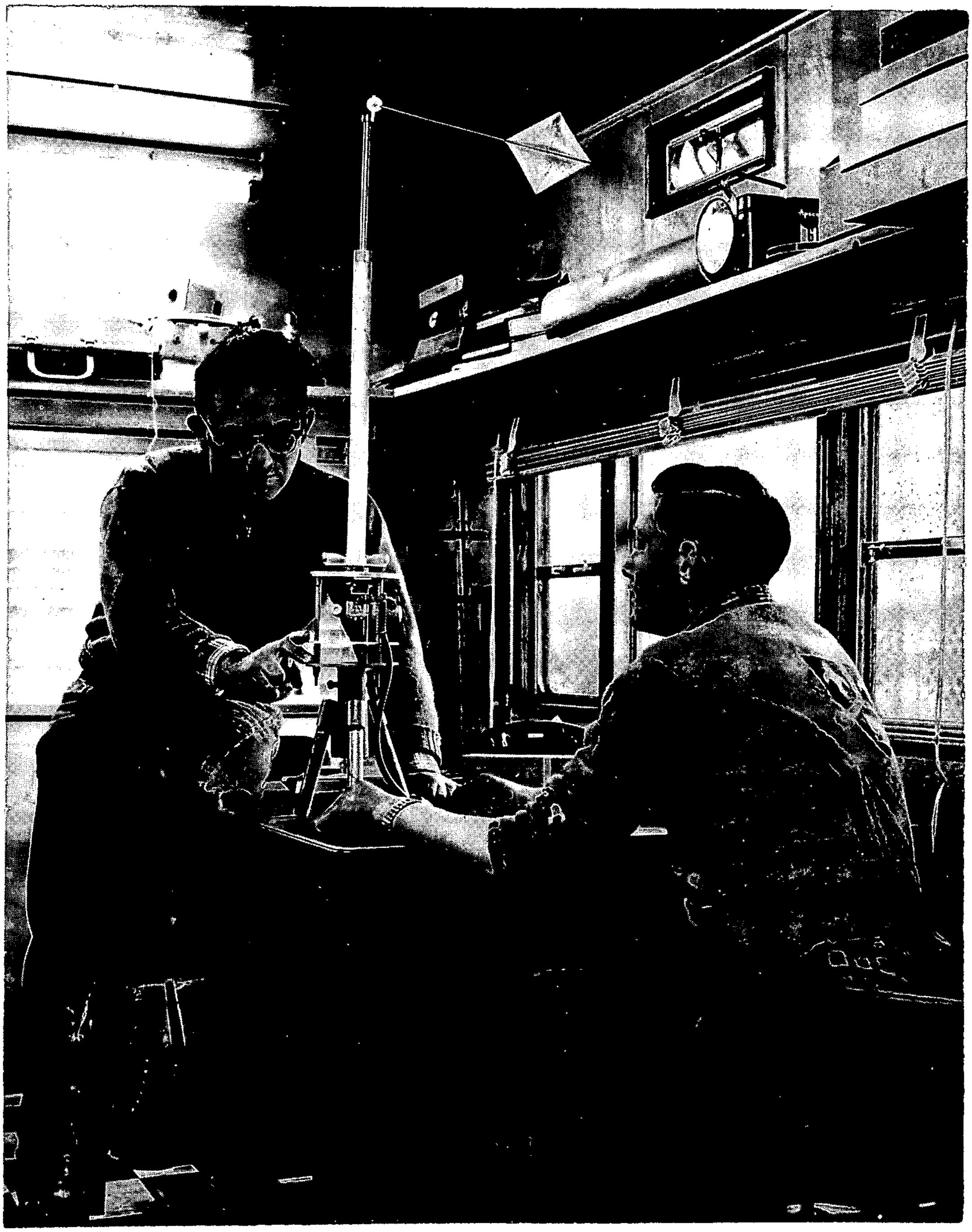

Fig. 3 Showing bivane in Trailer office before installation.

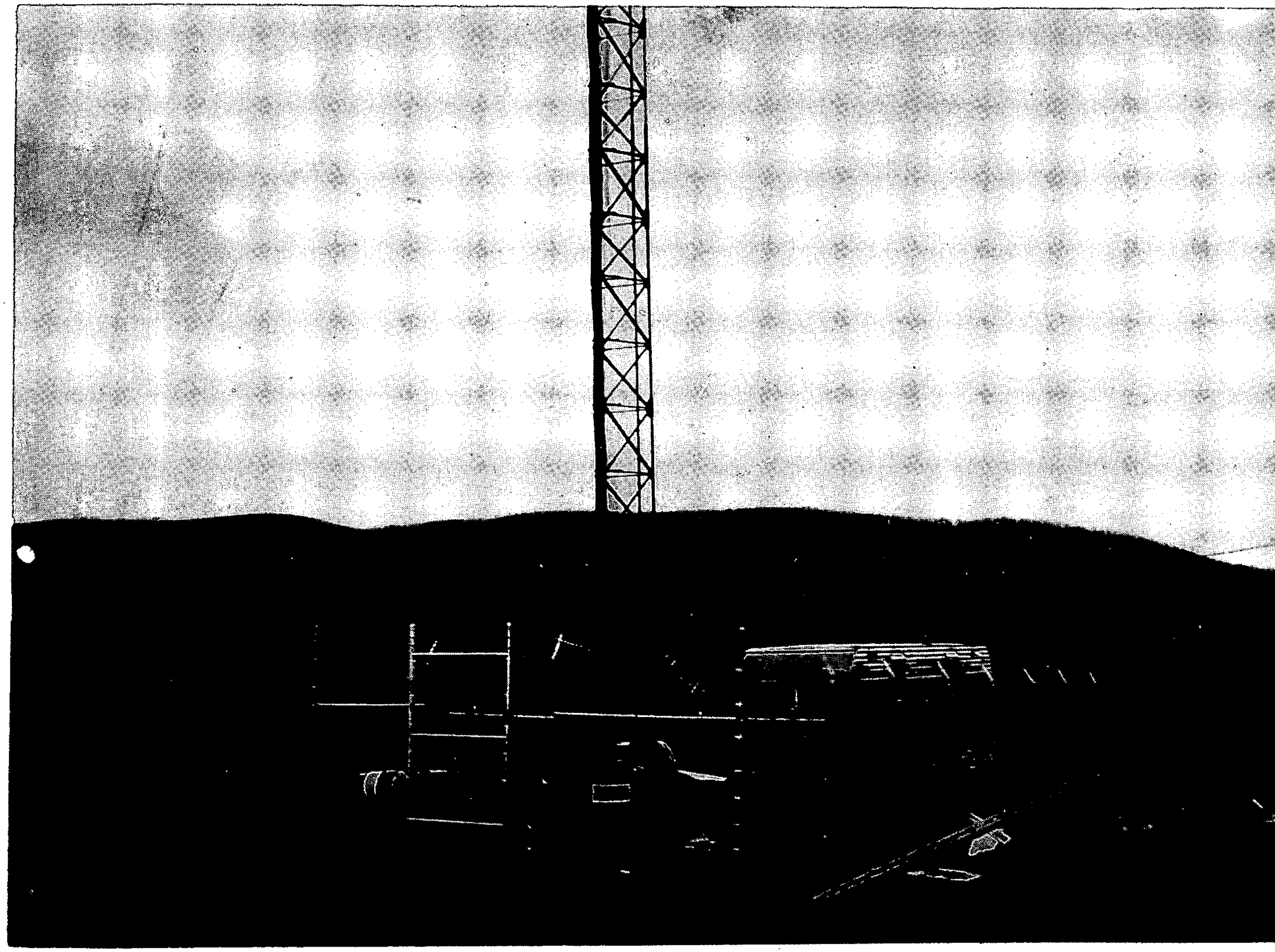

Fig. 4 Photograph showing base of tower, smoke producing apparatus, and trailer housing recorders. Note Dunderberg in background.

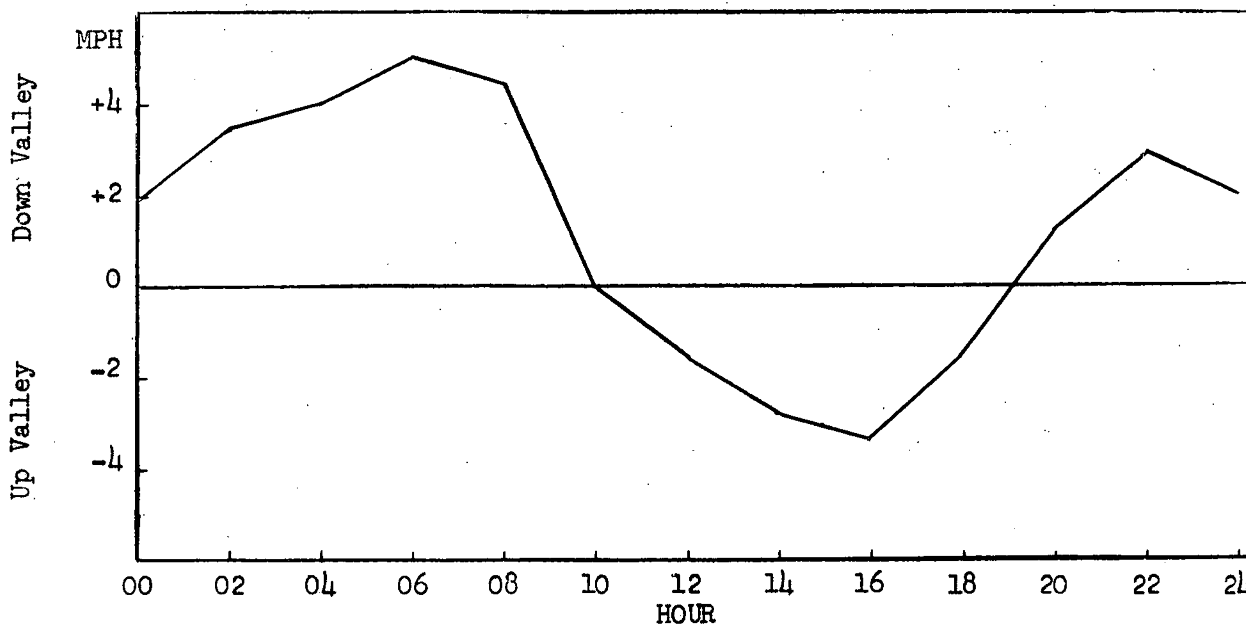

Fig. 5 - Diurnal Variation of wind component along axis of valley (040°= Down Valley, 220°= Up Valley), median values for indicated hours. (Data from Jones, 70 ft. above river, Sept., Oct. 1955)

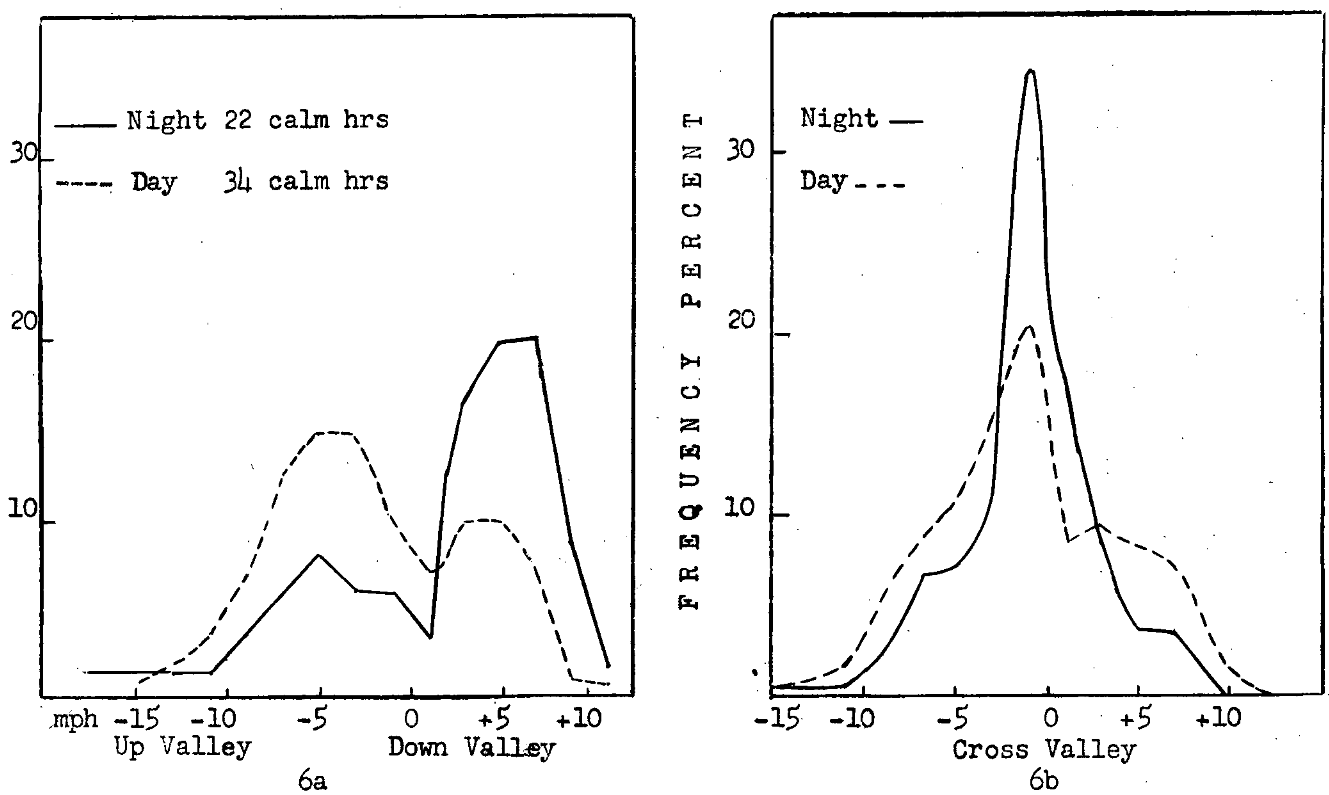

Fig. 6 - Frequency distribution of wind components along axis of valley, (040°= Down Valley, 220°= Up Valley) and in the cross valley direction (130°= +, 310°= -) by day and night (Data from Jones, Sept. Oct. 1955)

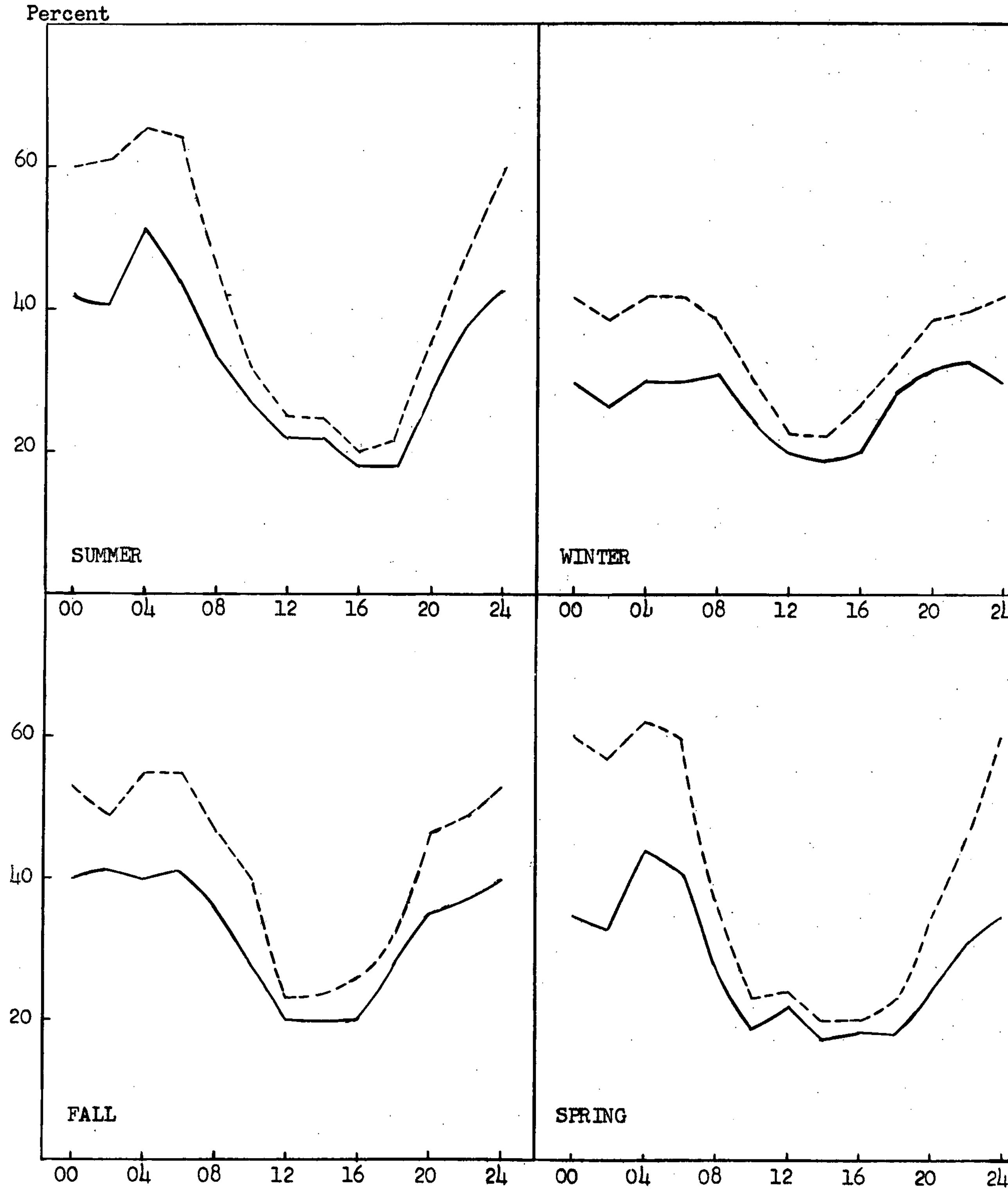

Fig. 7 - Illustrating the seasonal dependence of the diurnal variation of NErly wind direction. Solid line represents percent time wind was from NNE-ENE at the indicated hour. Dashed line represents percent time wind was either calm or from NNE-ENE. (Data from Peekskill Military Academy, Jan. 1932-Sept. 1934.)

NEW YORK UNIVERSITY

COLLEGE OF ENGINEERING
RESEARCH DIVISION
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Technical Report No. 372.3

EVALUATION OF POTENTIAL RADIATION HAZARD RESULTING FROM ASSUMED RELEASE OF RADIOACTIVE WASTES TO ATMOSPHERE FROM PROPOSED BUCHANAN NUCLEAR POWER PLANT

(Section 2 & 3 only)

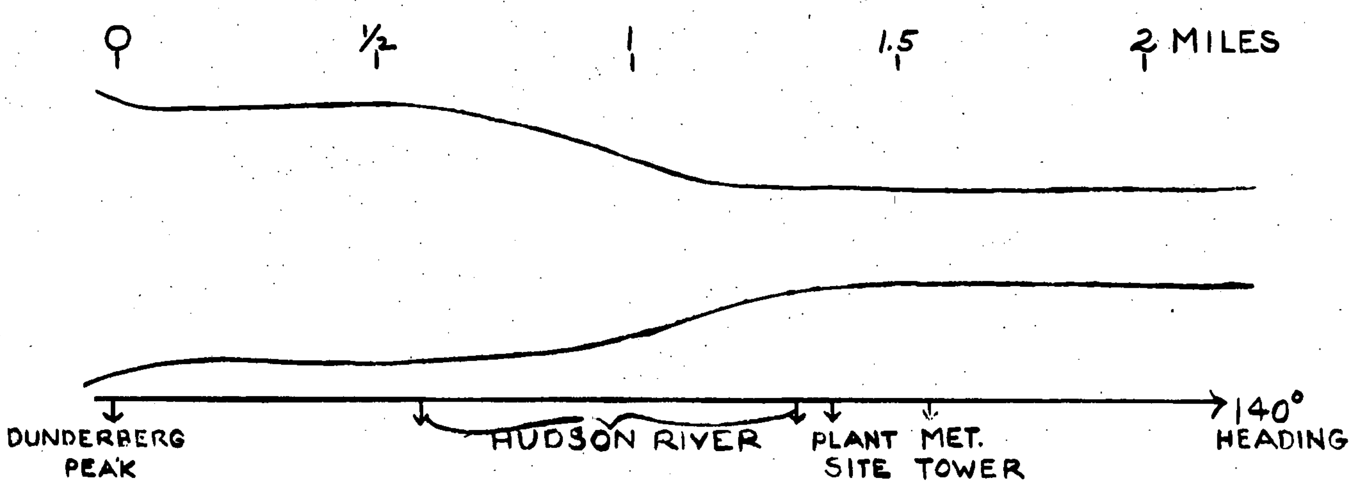
Prepared for
Consolidated Edison Co. of N. Y., Inc.
April, 1957

2. Diffusive conditions at site

2.1. Eddy wind structure in the valley

Meteorological conditions investigated were cases of daytime strong NW flow breaking over the Dunderberg peak. Data sources include instrumented aircraft runs (through cooperation of Cornell Aeronautical Laboratory), and (through the cooperation of the Meteorology Group at Brookhaven) comparison of three-dimensional wind vector distributions taken simultaneously at Buchanan and Brookhaven National Laboratory.

Unfortunately, the aircraft runs are not yet completely reduced, but sufficient information is available to serve our purpose here. Following is a schematic sketch of the envelope of turbulent fluctuations measured by the airplane on a run at 1000 ft, starting just over the Dunderberg peak and proceeding southeast over the meteorology tower.



The very large amount of turbulence associated with the breaking of air flow over the Dunderberg decays rather quickly downstream and the turbulent field settles down to a steady rms level at the east bank of the Hudson River. This uniform level is maintained for approximately five miles east of the site.

Comparison of an airplane run made at 400 ft elevation following the east bank of the Hudson with a run made the same day over the Brookhaven tower indicates that the rms turbulence at Buchanan is about 1.5 times greater than that observed at Brookhaven. The larger Buchanan rms value was due to the contribution of relatively strong, but highly intermittent gusts. Our conclusions are that the plant site is safely out of the very strong field of turbulence associated with the Dunderberg range, but that the site will be subject to occasional incursions of extreme gusts under strong northwest flow conditions.

This conclusion is further borne out by comparison of 10 second mean azimuth and elevation angle fluctuations at Brookhaven and Buchanan shown in fig. 2.1. The distributions cover about 3 hours of data taken under daytime strong northwest flow conditions. The azimuth angle distributions are directly comparable and indicate an rms azimuth fluctuation at Buchanan about 1.5 times that at Brookhaven. This ratio is consistent from hour to hour.

The elevation angles were measured by dissimilar instruments (ours having the faster response), but the 10 second mean should make

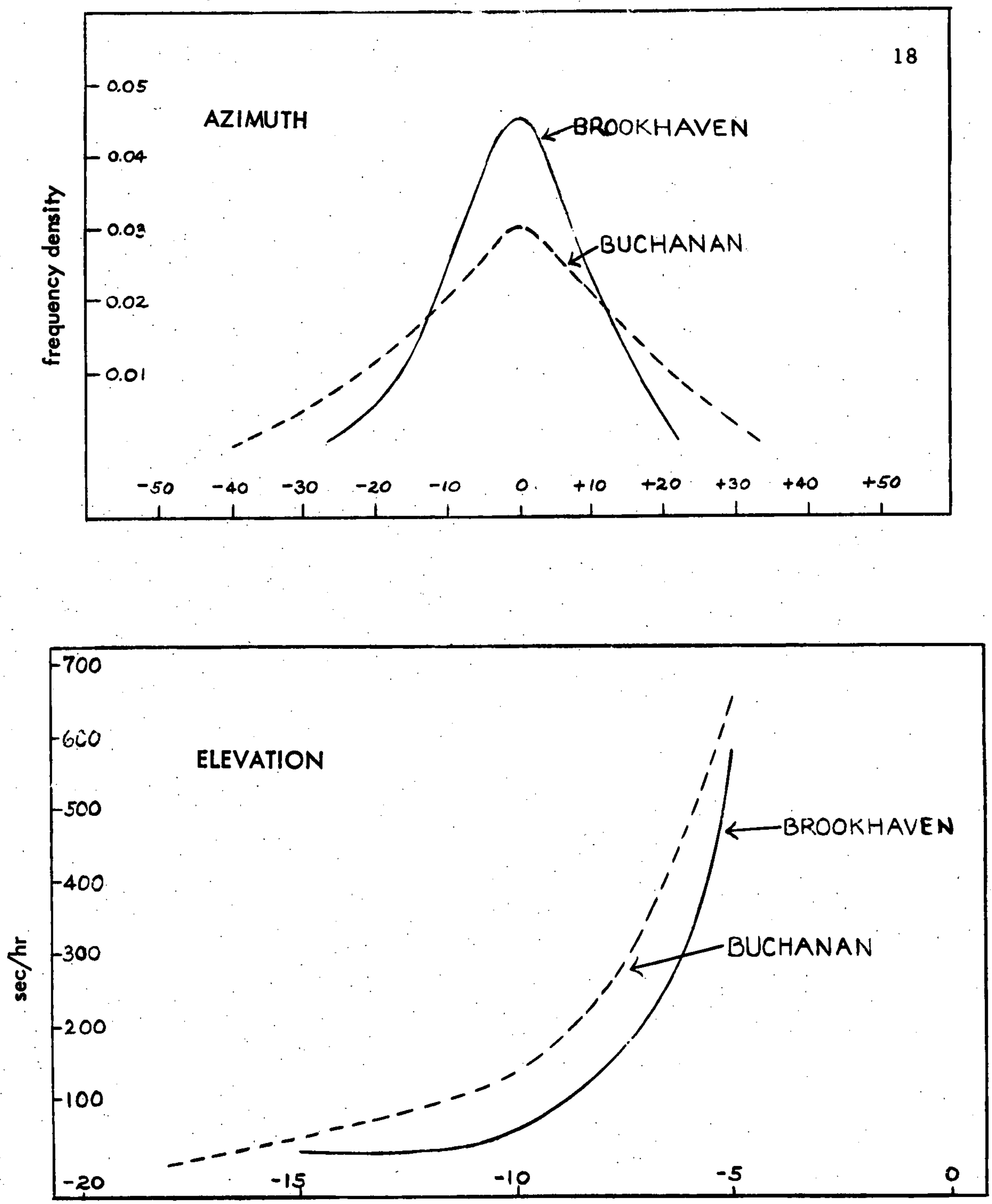


Fig. 2.1. Comparison of Brookhaven and Buchanan azimuth and elevation angle fluctuation traces.

the instrument readings comparable. There is a definite tendency toward more extreme downward directed vertical angles at Buchanan. However, this difference is not consistent from hour to hour, the major contribution to the difference coming from one hour of data; the other two hours showed but minor differences.

2.2. Diffusion coefficients

Smoke experiments were conducted at irregular intervals with a smoke generator source located 91 meters above ground. The behavior of the smoke for a distance of 1000 m from the source was documented by photographs usually made at 20 second intervals. The quantities abstracted from the film included the rate of expansion of the instantaneous plume, and a simple count of the number of times smoke was on the ground at given distances downwind. By assuming an inverse square law for concentrations, i.e., dividing smoke frequency by distance squared, we were able to estimate the point of maximum ground concentration.

For radiation calculations, it is desirable to find coefficients to fit a Sutton type concentration equation. This type of equation involves three parameters, C_y, C_z, and n. The diffusion coefficients at Buchanan were evaluated in a number of different ways. All of these approaches gave essentially the same answer. Since diffusion coefficients are fairly well known at Brookhaven, the simplest method was to use the relationship (see Ref. 8)

$$\text{Buch } C_y^{\,2} = \frac{\left[\dfrac{4}{(1-n)(2-n)}\left(\dfrac{N}{u}\right)^n \left(\overline{\alpha'^2}\right)^{1-n}\right]_{\text{Buch}}}{\left[\dfrac{4}{(1-n)(2-n)}\left(\dfrac{N}{u}\right)^n \left(\overline{\alpha'^2}\right)^{1-n}\right]_{\text{Brook}}} \; C_y^{\,2} \text{ Brook} \qquad (2.1)$$

where α'^2 is the variance of the azimuth angle fluctuation, and N is the macroviscosity. Here a small angle approximation has been made for $\sin\alpha$, and the correlation between u and α has been assumed zero.

Brookhaven fluctuation data were available for theirB condition. Under identical wind speed and stability conditions, the Reynolds stress $(\overline{\rho u'w'})$ was about the same for both sites. Similar stress values under identical large scale conditions imply similar roughness (z_o) values Since

$$N = (\overline{u'w'})^{1/2}\, z_o$$

the above indicates similar N values for both sites. As a first approximation n is assumed to be the same and equation (2.1) can be solved for Buch $C_y^{\,2}$ in terms of the known Brookhaven coefficient. The process is repeated using new values of n, until the solution converges.

A similar equation can be solved for $C_z^{\,2}$ (here only the variance in downward directed elevation angles was considered). Knowing the distance of maximum concentration from observation, the remaining parameter, n, can be determined from

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

For other meteorological conditions the same procedure was followed this time using the coefficients established at Buchanan for the previous case as known values. In summary we find:

Table 2.1. Summary of diffusion coefficients at Buchanan.

Condition	$C_y(m)^{n/2}$	$C_z(m)^{n/2}$	n
L_1 Lapse (light winds 1-3 m/sec)	0.60	0.48	0.20
L_2 Lapse (strong winds $>$ 4 m/sec)	0.53	0.43	0.30
N Adiabatic to isothermal temperature gradients	0.47	0.39	0.40

There was a great deal of variability in the coefficients determined for the the A case mostly because of large aperiodic changes in the mean wind direction.

The hourly lateral vertical diffusion coefficients (C_y) in Table 2.1 are large compared to the established Brookhaven values. The primary reason for this is the large azimuth oscillations which are due to the hills and rugged country surrounding the site. On an hourly basis, therefore, smoke plumes would diffuse more quickly at Buchanan than at most other flat terrain sites. On an annual basis, however, the restrictive influence of the valley channels the flow so that the long term annual spread is probably less at the Buchanan site.

2.3. Inversion plume

A few smoke runs were made under inversion conditions. These runs were documented by photographs from below and from an aircraft flying at

3000 ft. The results indicate a half-angle expansion of the instantaneous plume of about .05 radians with wind speeds of 4 mph. With wind speeds less than 2 mph the instantaneous half-angle expansion increases to about .09 radians. Under steady wind conditions azimuth angles fluctuate with a σ of about .065 radians.

The plume holds together as a compact mass for several miles. The ratio of width to height of the plume is on the order of 5 to 10. In general the inversion plume trajectory tends to follow the river around the bends north and south of the site.

3. Climatological Data and Diffusion Classes

Tables 3.1 and 3.2 summarize the wind and temperature gradient data taken at the 300 ft tower level (410 ft above river) for the winter and summer seasons. A similar yearly summary for the 100 ft tower level (210 ft above river) is presented in Table 3.3. The temperature gradient classification is defined as follows:

For 300 ft level:

I	=	Inversion class	$T_{300}-T_7 \geq 0$
N	=	Isothermal-Adiabatic class	$0 > T_{300}-T_7 \geq -1.8°F$
L	=	Lapse (unstable class)	$-1.8°F > T_{300}-T_7$

For 100 ft level:

I	=	Inversion class	$T_{150}-T_7 \geq 0$
N	=	Isothermal-Adiabatic class	$0 > T_{150}-T_7 \geq 0.9°F$
L	=	Lapse condition	$-0.9°F > T_{150}-T_7$

For visual purposes these data are summarized in Figs. 3.1 and 3.2. (Arrows are flying with the wind.) There is a tendency for winds to be along the axis of the valley for both the summer and winter seasons. With respect to populated areas, wind trajectories are towards Buchanan and Verplank for a substantial portion of the time. Wind trajectories towards Peekskill (the major population center in the area) are relatively infrequent.

The diurnal wind regime in the valley at low levels was discussed in some detail in NYU Report 372.1. The height variation of the diurnal wind regime in the valley is extremely complicated and quite variable. Most frequently, the 030° night-time flow extends to about 2 to 3 hundred ft above river with a slow southerly drift above the down river

TABLE 3.1. Frequency Distribution of Wind Speed and Direction at 300 Ft. Tower Level for Winter Season (Nov-April) According to Temperature Gradient Class.

I = inversion, $T_{300}-T_7 \geq 0$
N = isothermal-adiabatic $0 > T_{300}-T_7 \geq -1.8°F$
L = lapse condition $-1.8°F > T_{300}-T_7$

Wind Direction		Wind Speed (mph) 1 - 4	5 - 8	9-13	14-19	20-27	>27	Total
205-220	I	.0053	.0058	.0086	.0017	.0005	-	.0219
	N	.0053	.0034	.0024	.0010	.0007	.0002	.0130
	L	.0017	.0005	.0012	.0007	.0002	-	.0043
225-240	I	.0053	.0043	.0067	.0007	-	-	.0170
	N	.0010	.0017	.0034	.0007	.0010	-	.0078
	L	.0005	.0005	.0014	.0007	-	-	.0031
245-260	I	.0041	.0048	.0038	.0012	.0002	-	.0141
	N	.0005	.0007	.0034	.0077	.0019	.0002	.0144
	L	.0012	.0012	.0012	.0024	.0002	-	.0062
265-280	I	.0034	.0029	.0038	.0017	.0005	.0007	.0130
	N	.0014	.0022	.0053	.0048	.0029	.0017	.0183
	L	.0012	.0002	.0022	.0017	.0007	.0002	.0060
285-300	I	.0019	.0038	.0050	.0017	.0005	-	.0129
	N	.0010	.0038	.0168	.0170	.0089	.0014	.0489
	L	.0002	-	.0048	.0093	.0038	-	.0181
305-320	I	.0022	.0038	.0031	.0019	.0002	-	.0112
	N	.0014	.0074	.0201	.0321	.0122	.0026	.0758
	L	.0017	.0007	.0086	.0127	.0062	-	.0299
325-340	I	.0029	.0026	.0034	.0005	-	-	.0094
	N	.0007	.0034	.0173	.0206	.0103	.0034	.0557
	L	.0019	.0019	.0036	.0081	.0034	.0012	.0201
345-360	I	.0026	.0060	.0024	.0012	-	-	.0122
	N	.0026	.0065	.0216	.0168	.0185	.0031	.0691
	L	.0017	.0043	.0141	.0065	.0059	.0022	.0347

(continued on next page)

TABLE 3.1(Continued)

Wind Direction		Wind Speed (mph) 1 - 4	5 - 8	9-13	14-19	20-27	>27	Total
005-020	I	.0060	.0096	.0067	.0007	-	-	.0230
	N	.0058	.0175	.0302	.0115	.0134	.0002	.0786
	L	.0024	.0060	.0079	.0038	.0012	-	.0213
025-040	I	.0031	.0050	.0026	-	-	-	.0107
	N	.0050	.0077	.0105	.0048	.0024	-	.0304
	L	.0017	.0024	.0022	.0002	.0002	-	.0067
045-060	I	.0026	.0026	.0002	.0002	-	-	.0056
	N	.0034	.0036	.0053	.0036	.0002	-	.0161
	L	.0005	.0010	.0005	-	-	-	.0020
065-140	I	.0070	.0034	.0002	-	-	-	.0106
	N	.0103	.0080	.0048	.0012	-	-	.0243
	L	.0010	.0012	.0012	-	-	-	.0034
145-160	I	.0048	.0046	.0024	.0007	.0002	-	.0127
	N	.0026	.0053	.0024	.0014	.0002	.0005	.0124
	L	.0014	.0017	.0031	.0014	-	-	.0076
165-180	I	.0091	.0144	.0122	.0019	-	-	.0376
	N	.0098	.0089	.0091	.0079	.0029	.0017	.0403
	L	.0002	.0060	.0065	.0024	.0007	-	.0158
185-200	I	.0117	.0108	.0151	.0038	.0007	-	.0421
	N	.0070	.0086	.0115	.0038	.0007	.0005	.0321
	L	.0010	.0041	.0026	.0005	.0002	-	.0084
Calm	I							.0005
	N							.0084
	L							.0115
Total	I	.0719	.0846	.0764	.0180	.0029	.0007	.2550
	N	.0580	.0884	.1639	.1349	.0762	.0156	.5454
	L	.0182	.0316	.0611	.0506	.0230	.0036	.1996

TABLE 3.2. Frequency Distribution of Wind Speed and Direction at 300 Ft. Tower Level for Summer Season (May-October) According to Temperature Gradient Class.

I = inversion, $T_{300}-T_7 \geq 0$

N = isothermal-adiabatic $0 > T_{300}-T_7 \geq -1.8°F$

L = lapse condition $-1.8°F > T_{300}-T_7$

Wind Direction		Wind Speed (mph) 1 - 4	5 - 8	9-13	14-19	20-27	>27	Total
	I	.0074	.0122	.0053	.0005	-	-	.0254
205-220	N	.0023	.0038	.0058	.0015	.0003	-	.0137
	L	.0066	.0048	.0033	.0005	-	-	.0152
	I	.0084	.0071	.0043	.0003	-	-	.0201
225-240	N	.0010	.0041	.0038	-	-	-	.0089
	L	.0018	.0038	.0038	.0003	-	-	.0097
	I	.0064	.0056	.0031	.0003	-	-	.0154
245-260	N	.0013	.0018	.0033	.0005	.0003	-	.0072
	L	.0028	.0028	.0038	-	-	-	.0094
	I	.0036	.0025	.0025	.0008	-	-	.0094
265-280	N	.0019	.0005	.0031	.0033	.0010	-	.0098
	L	.0024	.0048	.0048	.0005	.0003	-	.0128
	I	.0043	.0028	.0048	.0008	.0008	-	.0135
285-300	N	.0003	.0013	.0053	.0048	.0038	-	.0155
	L	.0028	.0031	.0071	.0023	.0010	-	.0163
	I	.0056	.0038	.0051	.0015	.0005	-	.0165
305-320	N	.0010	.0028	.0064	.0046	.0031	-	.0179
	L	.0033	.0041	.0061	.0043	.0036	-	.0214
	I	.0069	.0076	.0028	.0010	-	-	.0183
325-340	N	.0008	.0015	.0074	.0038	.0018	-	.0153
	L	.0036	.0025	.0092	.0023	.0013	-	.1889
	I	.0076	.0186	.0140	.0010	-	-	.0412
345-360	N	.0013	.0031	.0125	.0064	.0023	.0005	.0261
	L	.0074	.0081	.0135	.0043	.0013	-	.0346

(continued on next page)

TABLE 3.2 (Continued)

Wind Direction		Wind Speed (mph) 1 - 4	5 - 8	9-13	14-19	20-27	>27	Total
005-020	I	.0094	.0244	.0196	.0005	-	-	.0539
	N	.0025	.0086	.0191	.0046	.0023	-	.0371
	L	.0053	.0122	.0099	.0028	-	-	.0303
025-040	I	.0122	.0089	.0036	.0005	-	-	.0252
	N	.0074	.0064	.0094	.0033	.0003	-	.0268
	L	.0064	.0056	.0031	.0012	-	-	.0164
045-060	I	.0043	.0015	.0003	-	-	-	.0061
	N	.0023	.0043	.0043	.0005	-	-	.0114
	L	.0018	.0015	.0020	.0010	-	-	.0063
065-140	I	.0076	.0038	.0031	-	-	-	.0145
	N	.0104	.0102	.0074	.0005	-	-	.0285
	L	.0043	.0046	.0028	.0003	-	-	.0120
145-160	I	.0079	.0038	.0071	.0010	.0003	-	.0201
	N	.0033	.0056	.0058	.0056	.0025	-	.0228
	L	.0025	.0053	.0074	.0043	.0015	-	.0210
165-180	I	.0084	.0117	.0117	.0018	-	-	.0336
	N	.0043	.0059	.0145	.0081	.0008	-	.0336
	L	.0076	.0160	.0142	.0074	.0003	-	.0455
185-200	I	.0109	.0165	.0140	.0010	-	-	.0424
	N	.0041	.0069	.0107	.0076	.0010	-	.0303
	L	.0081	.0173	.0084	.0020	.0020	-	.0378
Calm	I							.0244
	N							.0061
	L							.0020
Total	I	.1109	.1310	.1012	.0109	.0015	-	.3799
	N	.0440	.0666	.1188	.0551	.0193	.0005	.3104
	L	.0666	.0966	.0994	.0336	.0112	-	.3094

TABLE 3.3 Frequency Distribution of Wind Speed and Direction at 100 Ft. Tower Level for Entire Year According to Temperature Gradient Class.

I = inversion $T_{150}-T_7 \geq 0$
N = isothermal-adiabatic $0 > T_{150}-T_7 \geq -0.9°F$
L = lapse condition $-0.9°F > T_{150}-T_7$

Wind Direction		Wind Speed (mph) 1 - 4	5 - 8	9-13	14-19	20-27	>27	Total
	I	.0111	.0138	.0034	-	-	-	.0283
205-220	N	.0044	.0031	.0014	.0001	-	-	.0090
	L	.0039	.0047	.0017	.0005	-	-	.0108
	I	.0108	.0061	.0016	-	-	-	.0185
225-240	N	.0027	.0014	.0012	.0001	-	-	.0054
	L	.0034	.0041	.0024	.0001	-	-	.0100
	I	.0061	.0059	.0030	.0001	-	-	.0151
245-260	N	.0019	.0016	.0026	.0011	.0001	-	.0073
	L	.0016	.0027	.0014	.0001	-	-	.0058
	I	.0056	.0060	.0042	.0009	.0004	-	.0171
265-280	N	.0022	.0012	.0030	.0012	.0002	-	.0078
	L	.0017	.0036	.0037	.0022	.0006	.0001	.0119
	I	.0035	.0050	.0076	.0041	.0017	.0005	.0224
285-300	N	.0017	.0015	.0087	.0052	.0022	.0001	.0194
	L	.0044	.0036	.0088	.0061	.0009	-	.0238
	I	.0036	.0047	.0088	.0049	.0016	.0001	.0237
305-320	N	.0007	.0030	.0128	.0108	.0022	-	.0295
	L	.0032	.0021	.0092	.0070	.0014	-	.0229
	I	.0039	.0062	.0067	.0022	-	-	.0190
325-340	N	.0019	.0044	.0105	.0092	.0021	.0002	.0283
	L	.0035	.0051	.0075	.0022	.0007	.0001	.0191
	I	.0100	.0074	.0034	.0005	.0001	.0002	.0216
345-360	N	.0031	.0081	.0158	.0100	.0025	.0002	.0397
	L	.0056	.0132	.0120	.0030	.0007	-	.0345

(continued on next page)

TABLE 3.3(Continued)

Wind Direction		Wind Speed (mph) 1 - 4	5 - 8	9-13	14-19	20-27	>27	Total
005-020	I	.0173	.0324	.0113	.0008	-	-	.0618
	N	.0083	.0199	.0192	.0078	-	.0001	.0553
	L	.0072	.0128	.0078	.0011	-	-	.0289
025-040	I	.0176	.0303	.0095	-	-	-	.0574
	N	.0041	.0095	.0052	.0010	-	-	.0198
	L	.0046	.0051	.0017	.0002	-	-	.0116
045-060	I	.0100	.0055	.0010	-	-	-	.0165
	N	.0021	.0049	.0027	-	-	-	.0097
	L	.0024	.0031	.0014	.0004	-	-	.0073
065-140	I	.0156	.0030	.0010	-	-	-	.0196
	N	.0106	.0052	.0007	.0001	-	-	.0166
	L	.0047	.0034	.0021	-	-	-	.0102
145-160	I	.0049	.0047	.0006	.0004	-	-	.0106
	N	.0036	.0050	.0040	.0010	.0002	-	.0138
	L	.0014	.0056	.0072	.0024	.0002	-	.0168
165-180	I	.0105	.0122	.0044	-	-	-	.0271
	N	.0059	.0082	.0118	.0012	.0006	-	.0277
	L	.0071	.0138	.0128	.0026	-	-	.0363
185-200	I	.0111	.0172	.0060	.0004	-	-	.0347
	N	.0049	.0054	.0050	.0001	.0002	-	.0156
	L	.0067	.0111	.0047	.0011	-	-	.0236
Calm	I							.0188
	N							.0052
	L							.0024
Total	I	.1414	.1603	.0725	.0143	.0036	.0006	.4115
	N	.0583	.0821	.1053	.0492	.0106	.0007	.3114
	L	.0614	.0939	.0848	.0293	.0046	.0004	.2768

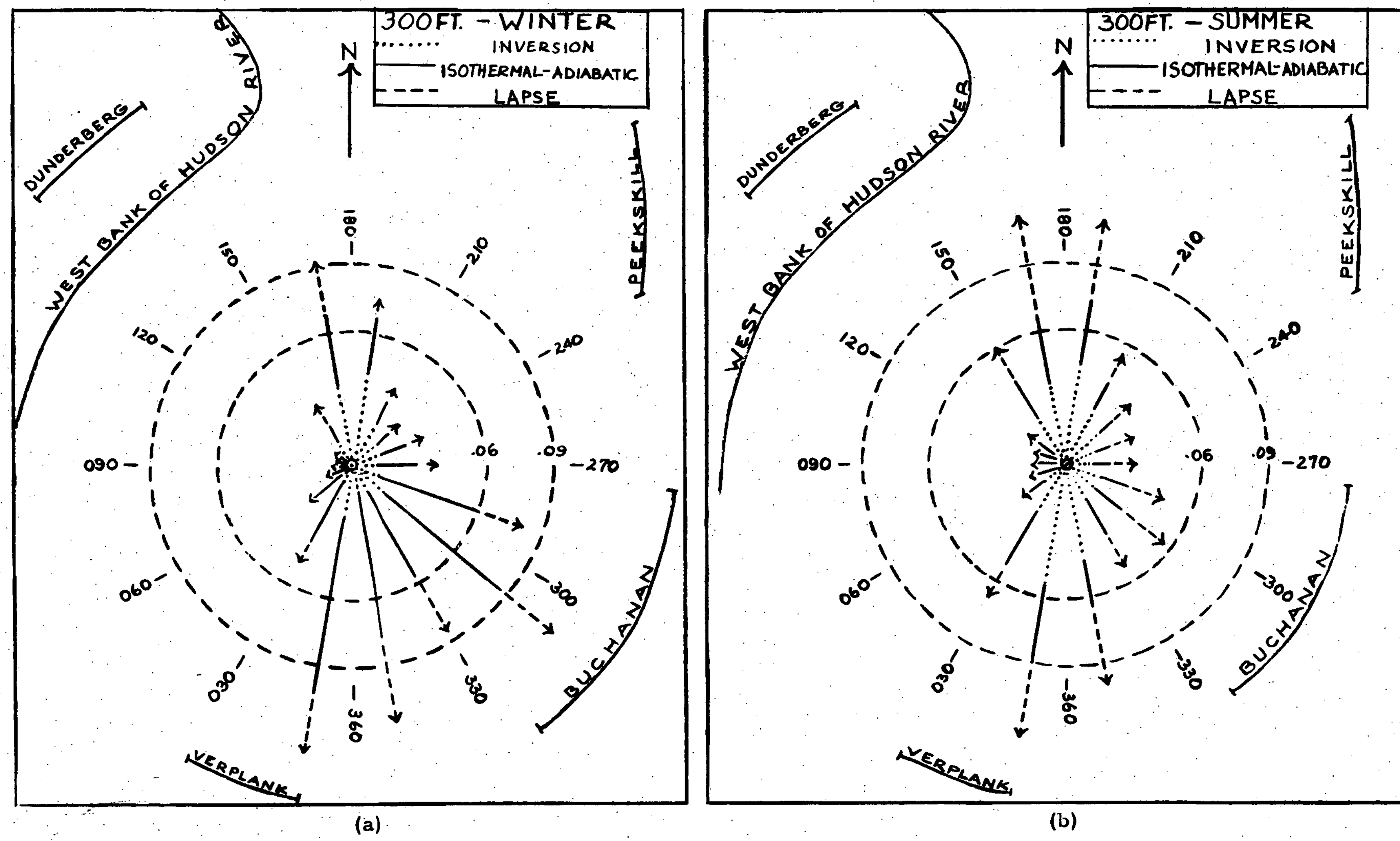


Fig. 3.1. Wind rose (300 ft) according to temperature gradient (a) winter, (b) summer.

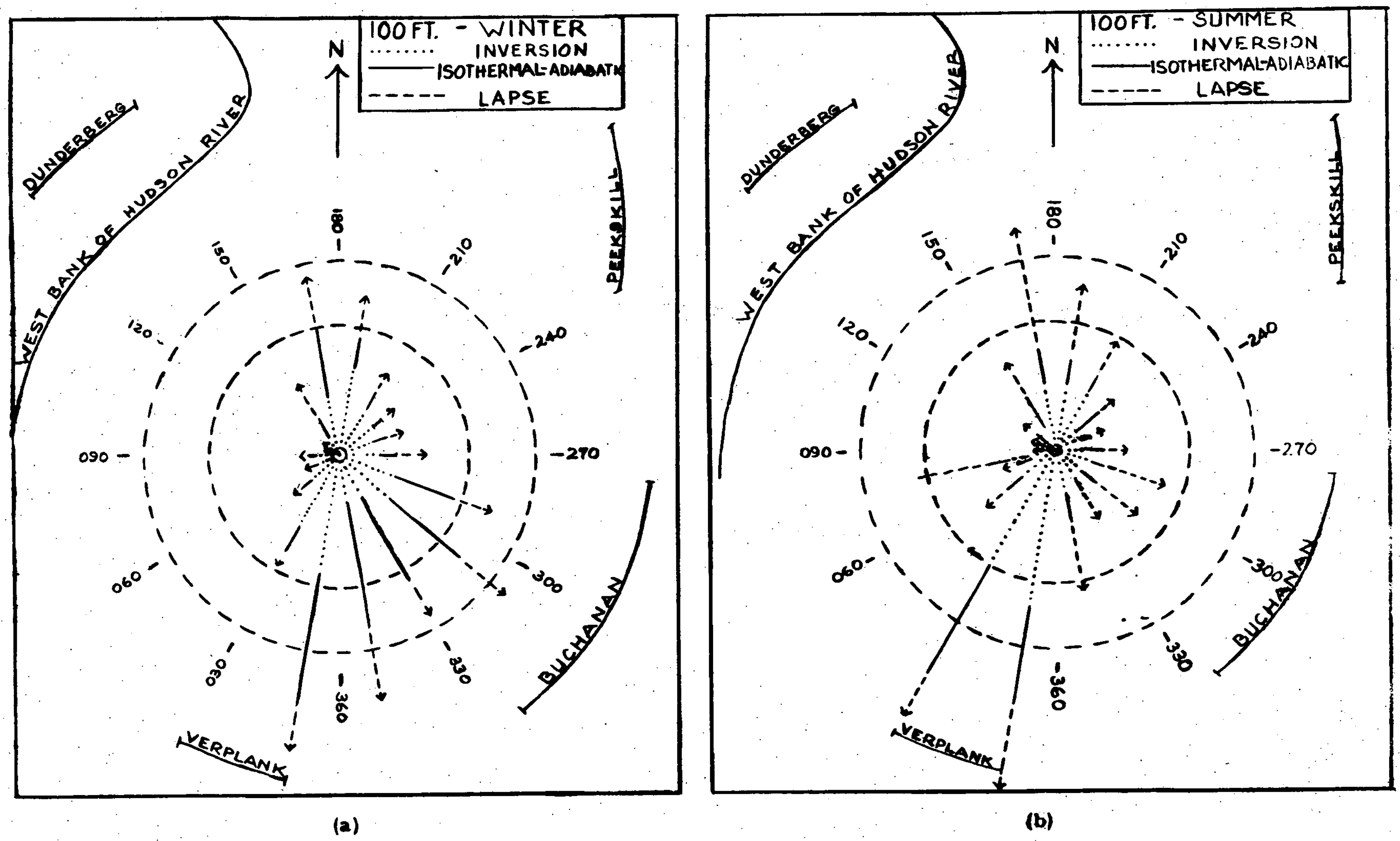


Fig. 3.2. Wind rose (100 ft) according to temperature gradient classes (a) winter, (b) summer.

flow. On occasion the 030° flow does extend to above 400 ft. (There is a lag of 2 to 4 hours in the onset of the 030 flow from 70 ft to 400 ft on these occasions.) The height to which the down valley flow extends does not appear to depend on the height or intensity of the inversion, but is probably related to very weak and unmeasurable prevailing pressure gradients.

For diffusion estimates, the following classes were defined:

- L_1 - Unstable Temperature gradient, winds < 8 mph
- L_2 - Unstable Temperature gradient, winds > 8 mph
- N - Adiabatic-Isothermal class
- I - Inversion class

The percent frequency of occurrence of each of these classes follow: (300 ft data)

	Winter	Summer
L_1	5	17
L_2	15	15
N	54	30
I	26	38

A substantial portion of all hours fall into the adiabatic-isothermal class. As it happens, it is this class which is the most difficult to interpret as far as diffusion behavior is concerned. Some hours which fall into this class are characterized by relatively shallow inversions up to 50 or 100 ft with adiabatic gradients above. Under these circumstances, it is difficult to state whether or not smoke will descend to the ground. However, this will not affect the radiation calculations seriously. In view of the heated source calculations, the N class will not enter seriously into the calculations until wind speeds of the order of 10-12 mph are attained. Study of our fluctuation traces at all levels indicate to us that smoke will descend to the ground under strong wind speed conditions.

RESEARCH DIVISION
COLLEGE OF ENGINEERING
NEW YORK UNIVERSITY

Department of Meteorology and Oceanography

Technical Report No. 372.4

SUMMARY OF CLIMATOLOGICAL DATA AT BUCHANAN, NEW YORK

1956-1957

Prepared by

Ben Davidson
Project Director

Prepared for
Consolidated Edison Co. of N. Y., Inc.
March 1958

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1. Introduction

A detailed summary of climatological data collected during 1956 is contained in Technical Report No. 372.3 - Evaluation of Potential Radiation Hazard, April 1957. The tower was run on a skeleton basis during 1957. Wind observations were made at 100 and 300 feet (200 and 400 feet above river level), while temperature was observed at 7, 150, and 300 feet above ground. Because of the relative infrequency of calibration and general maintenance during 1957 the 1956 data are considered far more accurate. The 300 ft 1957 data were processed in the same manner as the 1956 data. In the present report we summarize:

(a) The effect of climatological differences between 1956 and 1957 on the radiation calculations of Report 372.3.

(b) The local wind rose as a function of height above river, and

(c) The combined 1956-1957 wind rose at 300 feet as a function of stability and wind speed.

2. Comparison of 1956-1957 data

In Table I the essential features of the 1956 and 1957 300 ft data are summarized as a function of stability class. All definitions remain the same as in the previous report. In particular, Inversion conditions (I) are defined to occur when $T_{300} - T_7 \geq 0$; Isothermal-adiabatic conditions (N) when $0 > T_{300} - T_7 \geq -1.8°F$; and Lapse conditions (L) when $T_{300} - T_7 < 1.8°F$.

Table I. Frequency of Inversion (I), Neutral (N), and Lapse (L) conditions with associated mean wind speeds, $\bar{V}$ (mph) for 1956 and 1957.

Summer	I	$\bar{V}$	N	$\bar{V}$	L	$\bar{V}$
1956	0.38	6.5	0.31	10.4	0.31	11.6
1957	0.35	6.2	0.33	12.8	0.32	9.7
Winter						
1956	0.25	7.6	0.54	12.6	0.20	8.5
1957	0.33	7.1	0.48	13.1	0.19	9.0
All seasons						
1956	0.315	6.9	0.425	11.8	0.255	10.4
1957	0.340	6.6	0.405	13.0	0.255	9.4

There are minor differences, but on the whole, the data seem compatible. There were slightly more inversion hours in 1957 than in 1956 with a slightly lower wind speed. The yearly frequency for each temperature gradient condition does not vary more than 10 percent whilst the mean wind speed for each class is also within 10 percent of the 1956 figure. Almost all of the radiation calculations are inversely proportional to the mean wind speed or to the harmonic mean. There is not too great a difference between the two years and for this reason the total integrated dosage for the area should not vary too greatly, say within 10 to 20 percent, which is well within the range of uncertainty of the original calculations.

The areal distribution of radiation contained in Figs. 1.1 and 1,2 of the earlier report depends in the mean on the distribution of wind direction. Fig. 1 is a comparison of the annual distribution of wind direction for 1956 and 1957. Again the differences are not great; the 1957 distribution seems a bit more peaked than the 1956 data. This may be due in part to systematic individual differences in reading the charts. Whatever the cause, the differences in the distribution are well within the limits of accuracy of the initial calculations.

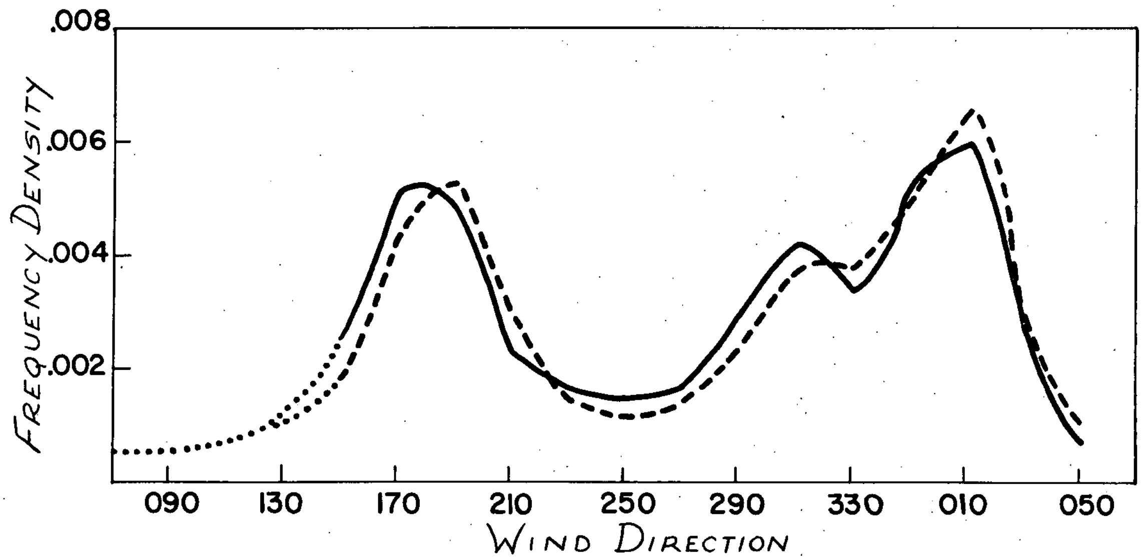

Fig. 1. Comparison of wind direction distribution for all stability classes (1956, solid line; 1957, dashed line).

3. Variation of wind direction with height

Some idea of the variation of wind direction with height may be gained from the 100 and 300 ft summer wind rose (Figs. 3.1 and 3.2 of the original report). To supplement this information, we compare in Fig. 2 the distribution of wind direction for the 1956 summer season at 400 ft (300 ft tower level), 200 ft (100 ft tower level) and 70 ft above river. The 70 ft data were obtained from an anemometer mounted on the "Jones", a ship anchored in mid-river. The ship site is about 0.8 mile northwest of the tower (see map in Report 372.1). It is evident that there are systematic differences in the three distributions. The most obvious is the build-up of southerly winds with height. The Jones distribution is flat from 150° to 250°, while the 100 and 300 ft tower

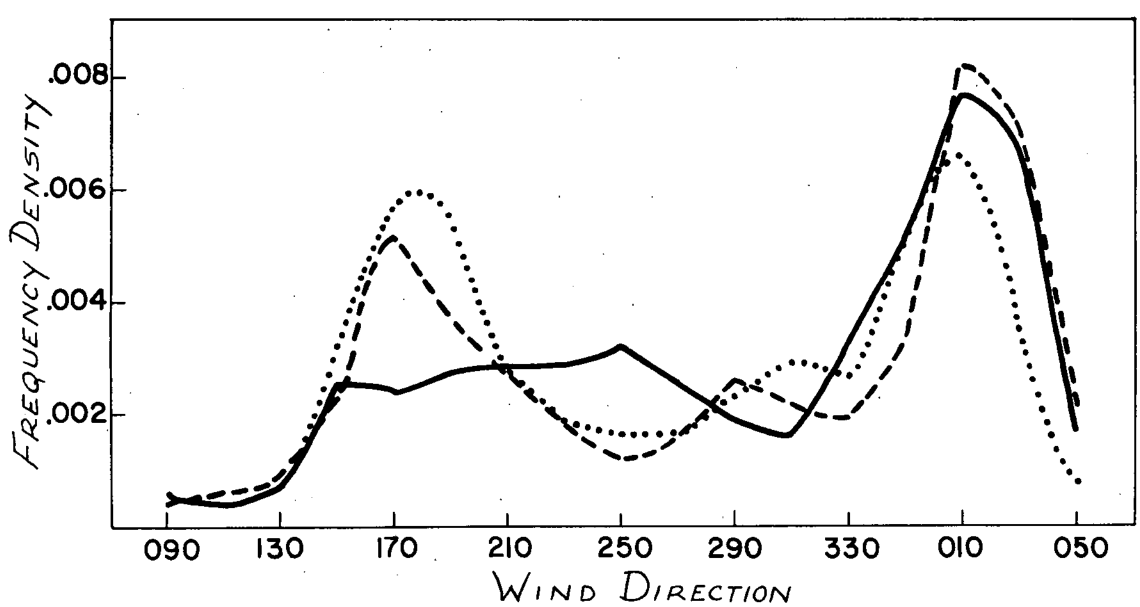

Fig. 2. Comparison of wind direction distribution for all stability classes, summer 1956. (Jones, solid line; 100 ft tower, dashed line; 300 ft tower, dotted line).

distributions peak fairly well at 170°. On the down valley side of the distribution (about 020°), The Jones and 100 ft tower level distributions are fairly well matched. The 300 ft tower level distribution does not reach nearly the same frequency at 030° as do the other two distributions. Some of the essential differences in the two distributions are summarized in the following table.

Percent time indicated wind direction ranges were observed at

Direction Range	Jones	100 ft Tower	300 ft Tower
340-040	38	37	30
360-040	28	30	19
160-220	16	23	27
160-200	10	18	22

Part of the difference between the distributions can be explained by the tendency for light southerly winds to be observed at the 300 ft tower level when the nocturnal NNE winds have set in at the Jones and 100 ft tower locations. The remainder appears to be a daytime phenomenon and indicates that The Jones distribution is affected by the proximity of the valley walls in a rather complicated fashion.

4. Wind rose presentation

In Fig. 3 we present wind roses based upon two years of data for inversion, neutral, and lapse conditions at the 300 ft level. The bars here are flying with the wind and pointing to the indicated meteorological wind direction. The length of the bar is proportional to the average frequency of occurrence per year of the appropriate wind direction and stability condition. For convenience in interpretation we indicate the general location of populated areas surrounding the site.

An interesting feature of the wind rose is the elongation along the axis of the valley during inversion hours. Wind trajectories towards Peekskill, the most densely populated area near the site, are relatively infrequent during neutral and lapse conditions. There is a sizeable frequency of 210° winds during inversion hours. This trajectory would just about brush the northern outskirts of Peekskill, but it is probable that terrain effects would tend to curve the trajectory so that it follows the river. In general, the inversion wind rose shows a high frequency of up and down valley wind directions.

During lapse and neutral conditions, the wind rose indicates a substantial frequency of northwest winds which are the prevailing winds over flat land in this area. Under these temperature gradient conditions, one may expect effluent concentrations on the ground. There are a substantial number of wind trajectories toward the villages of Buchanan, Montrose and Verplank during neutral and lapse conditions, and towards the village of Verplank during inversion conditions.

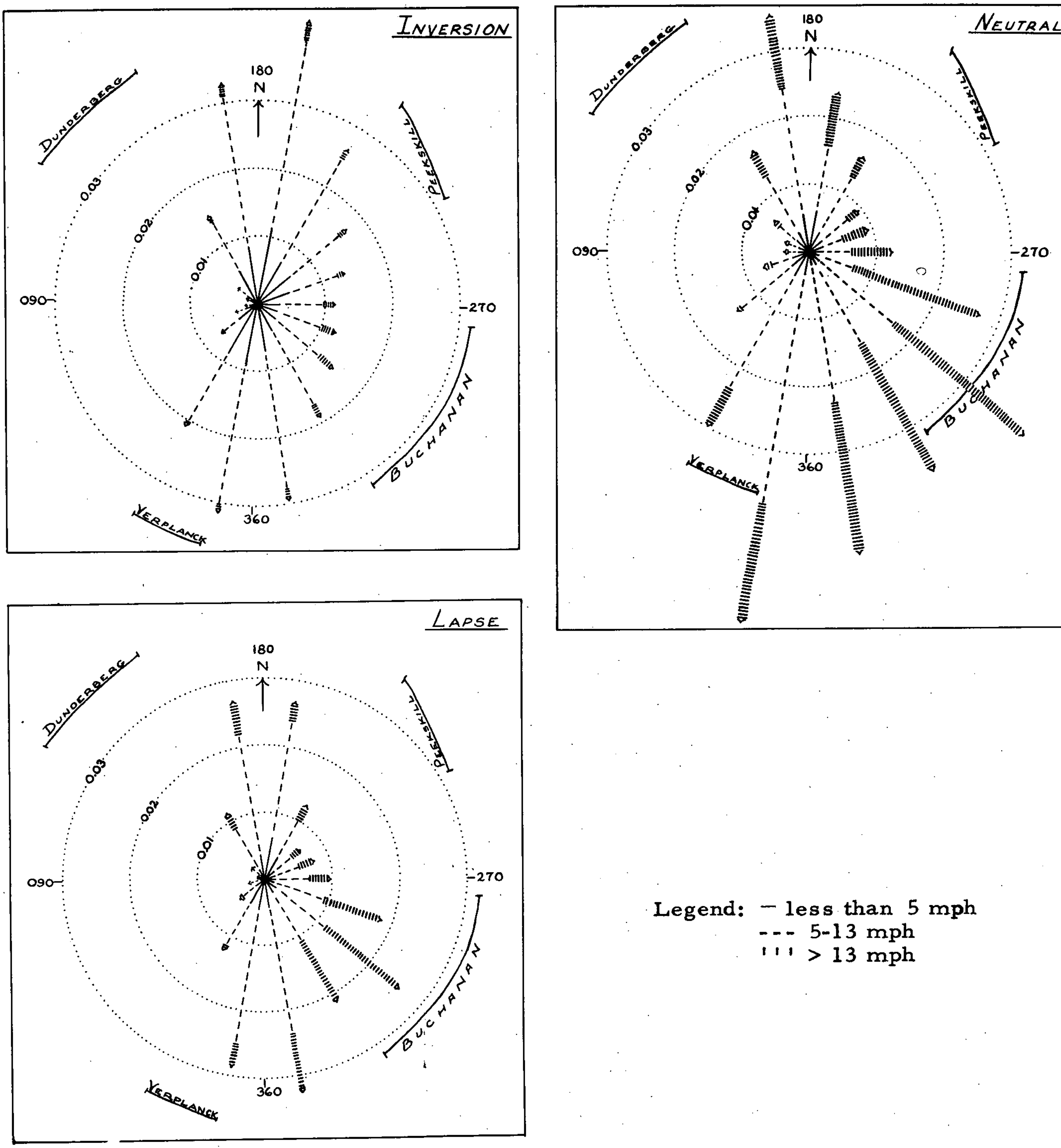

Fig. 3. Wind rose at 300 ft tower level for inversion, neutral and lapse conditions, based upon 1956-1957 data. (Bars are flying with the wind). Calm: Inversion .026; Neutral .0107; Lapse .0052 .

References

Davidson, B., and J. Halitsky, 1955: A micrometeorological survey of the Buchanan, N.Y. area. - Summary of progress to 1 December 1955. Technical Report No. 372.1, Research Division, New York University, College of Engineering.

Davidson, B., and J. Halitsky, 1957: Evaluation of potential radiation hazard resulting from assumed release of radioactive wastes to atmosphere from the proposed Buchanan nuclear power plant. Technical Report No. 372.3, Research Division, New York University, College of Engineering.

2.2 Seismology

The report of the Rev. J. J. Lynch, S.J., Director of the Seismic Observatory at Fordham University and the letter of Mr. Elliott B. Roberts, Chief of the Geophysics Division of the Department of Commerce, give information relative to the seismicity in the Indian Point area up to 1955.

The seismological history of the site between 1955 and 1965 has been prepared by the engineering staff of Consolidated Edison from the data supplied by Mr. James Dorman of the Lamont Geological Observatory of Columbia University.

RECENT SITE SEISMOLOGICAL HISTORY

Modified Mercalli Intensity Scale of 1931

Sept. 3, 1951	V @ 2 points in Rockland County IV elsewhere in vicinity Description of effects in "United States Earthquakes, 1951" Serial #762 U.S. Dept. of Commerce, U.S. Coast & Geodetic Survey.
Dec. 7, 1951	Poughkeepsie, N.Y. Light shock felt. (same publication)
(1952) USCGS	Serial #773 no events described in area.
(1953) USCGS Aug. 16, 1953	Serial #785 Maximum intensity IV felt in Bergen County N.J. andsome parts of Rockland and Manhattan.
(1954) USCGS	Serial #793 none reported in area.
(1955) USCGS	None reported.
(1956) USCGS	None reported.
(1957) USCGS	VI in W. Central New Jersey. Not reported felt in N.Y. State.
(1958) USCGS	None reported.
(1959) USCGS	None reported. Same 1960, 61, 62, although there have been a number of felt earthquakes (IV-V) in 200-300 mile radius.

LIST OF EARTHQUAKES

DATE	HOUR	LOCALITY	N. LAT.	W. LONG.	AREA SQ.MI.	INTENSITY
July 11, 1872	5:25	Near New York City.	40.9	73.8	100	6
Dec. 10, 1874	22:25	Westchester, N. Y.	40.9	73.8	2000	7
Oct. 4, 1878	2:30	Hudson River, N. Y.	41.5	74.0	600	5-6
Aug. 10, 1884	14:07	New York City Vicinity	40.6	74.0	31,000	7
Mar. 9, 1893	0:30	Near New York City	40.6	74.0	Local	6
June 8, 1916	16:15	Near New York City	41.0	73.8	Local	5
Sep. 3, 1951	-	Rockland County, N.Y. Bernardsville fault - eastern New Jersey across Southeast N. Y. to New England.	-	-	5500	5 (Peekskill-4)
Apr. 11, 1926	22:30	New Rochelle, N. Y.	40.9	73.9	150	5

MODIFIED MERCALLI INTENSITY SCALE OF 1931
(Abridged)

I. Not felt except by a very few under especially favorable circumstances. (I Rossi-Forel Scale)

II. Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing. (I to II Rossi-Forel Scale)

III. Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration like passing truck. Duration estimated. (III Rossi-Forel Scale)

IV. During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls made creaking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably. (IV to V Rossi-Forel Scale)

V. Felt by nearly everyone; many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop. (V to VI Rossi-Forel Scale)

VI. Felt by all; many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight. (VI to VII Rossi-Forel Scale)

VII. Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motor cars. (VIII Rossi-Forel Scale)

VIII. Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Disturbed persons driving motor cars. (VIII+ to IX Rossi-Forel Scale)

IX. Damage considerable in specially designed structures; well designed frame structures thrown out of plumb; great in substantial buildings with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken. (IX+ Rossi-Forel Scale)

X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks.

XI. Few, if any (masonry), structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipe lines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.

XII. Damage total. Waves seen on ground surfaces. Lines of sight and level distorted. Objects thrown upward into the air.

FORDHAM UNIVERSITY
SEISMIC OBSERVATORY
New York 58, N. Y.

JUL 27 1955

July 26, 1955

Mr. G. R. Milne
Mechanical Engineer
Consolidated Edison Company New York Inc.
4 Irving Place
New York, New York

Dear Mr. Milne:

Following up the meeting of several of your men in my office recently, I submit the following appraisal of earthquake risk in the Indian Head area, South of Peekskill.

1. With our present limited knowledge of the causes of earthquakes, it is impossible to make a dogmatic statement that there never will be earthquakes in this or any other area.

2. Present experience however indicates that minor Seismic activity is continuous (i.e. weekly or oftener) in regions where future major activity is to be expected e.g. in California, the Dominican Republic, Japan etc. minor shocks are constantly being recorded.

3. Our ~~shock~~ SHORT period records, in operation now some 20 years, indicate no continuous activity in this area or anywhere near it. Occasional shocks have been recorded from Poughkeepsie and around - but they have been very infreouent i.e. at intervals of years, not days. Morever these shocks seem to be resettlement shocks rather than an indication of fresh activity.

4. On the basis of some twenty years of such recording (we pick up all ground vibrations of whatever origin - blasts - traffic etc. etc.) I deem it safe to say that the probability of a serious shock occurring in this area for the next several hundred years is practically nill. The area therefore would certainly seem to be as safe as any area at present known.

5. I suggest you send this opinion to the Division of Seismology, U.S. Coast and Geodetic Survey, Washington D.C. for their criticism!

Sincerely,

Joseph Lynch S.J.

Joseph Lynch, S.J.
Director
Seismic Observatory

JJL:ggm

July 28-1955

The Reverend Joseph Lynch S J
Director - Seismic Observatory
Fordham University
New York 58 N Y

Dear Father Lynch

I have your letter of July 26 regarding the earthquake risk in the Indian Point area near Peekskill, New York, and want to thank you for your frank appraisal of the situation and for the courtesy you extended during our recent visit to your office.

In accordance with your suggestion, I have forwarded your opinion to Captain Elliott B Roberts, Chief of the Division of Geophysics at U.S. Coast and Geodetic Survey at Washington, D.C., and have asked for his comment on the situation. If there is any difference in view-point I shall contact you again.

Our Mr L K Murphy will get in touchwith you as to reimbursement for the work which was done.

Thanking you for your helpfulness, I am

Very truly yours,

G.R Milne

G R Milne
Mechanical Engineer

GRM/ecp

CC - Mr L K Murphy

July 28-1955

Captain Elliott B Roberts
Chief - Division of Geophysics
U S Coast and Geodetic Survey
Washington D C

Dear Captain Roberts

The Consolidated Edison Company is planning the construction of a nuclear steam electric generating station and has applied to the Atomic Energy Commission for the necessary license. The plant would be located on the east bank of the Hudson River at Indian Point, Village of Buchanan, Westchester County, New York, and the location is shown on the enclosed geodetic map of the area.

One of the considerations in the choice of a site suitable for a nuclear power plant is the relative freedom of the area from earthquakes or other seismic disturbances. Accordingly, we consulted with Father Joseph Lynch, Director of the Seismic Observatory at Fordham University, and he has given his opinion in his letter of July 26-1955 to us. In accordance with his suggestion in that letter, copy of which I am enclosing, I would like to obtain your opinion as to the earthquake risk in this area. Would you be kind enough, therefore, to comment on Father Lynch's letter or to offer any other comment you may care to make on the earthquake risk at this location. The particular peninsula on which the property is located is practically all limestone rock, and I am enclosing two of our aerial photographs to help you visualise the site conditions.

Thanking you in advance for your consideration, I am

Very truly yours,

G.R Milne

G R Milne
Mechanical Engineer

Encl.
GRM/eep

IN REPLY ADDRESS THE DIRECTOR
COAST AND GEODETIC SURVEY
AND NOT THE SIGNER OF THIS LETTER

AND REFER TO NO. 431:fr

DEPARTMENT OF COMMERCE
COAST AND GEODETIC SURVEY
WASHINGTON 25

August 10, 1955

Mr. G. R. Milne
Consolidated Edison Company
of New York, Inc.
4 Irving Place
New York 3, New York

AUG 1 2 1955

Dear Mr. Milne:

Receipt is acknowledged of your July 28, 1955 letter and enclosures requesting earthquake information for Buchanan, Westchester County, New York.

A review of our bulletin, Earthquake History of the United States, Part I, reveals seven earthquakes in the general area during the past 75 years. None of them caused damage in the cities (Peekskill, Tarrytown, Scarsdale, and New Rochelle) located near the epicenters, although the intensities range from 5 to 7 (Rossi-Forel). We are listing on an enclosure such pertinent data as approximate locations, intensities and felt areas. Further descriptive data are available in the above mentioned bulletin.

The range of expected horizontal accelerations of ground motion for earthquakes of intensity 6 and 7 is 60-100 cm/sec.^{2} near the epicenter. At a distance of 100 miles from the epicenter, the acceleration drops 50%. These are average accelerations based on data obtained from (1) accelerographs operated in California by the Coast and Geodetic Survey (2) instruments located on different geological formations and (3) earthquakes of various intensities.

We did not comment on Father Joseph J. Lynch's report since a copy was not enclosed with your letter. If you wish us to review his report, we will be happy to do so upon receipt of a copy. If we may be of further service to you, please do not hesitate write again.

Very truly yours,

Elliott B. Roberts

Elliott B. Roberts, Chief
Geophysics Division

Enclosures: (5)

August 12-1955

Captain Elliott B Roberts
Chief - Division of Geophysics
U S Coast and Geodetic Survey
Washington 25 D C

Dear Captain Roberts

Thank you for your letter of August 10, 1955, with enclosed data of earthquake information for Buchanan, Westchester, New York.

We regret that due to an oversight a copy of Father Joseph Lynch's report of July 26, 1955, was not enclosed with our letter of July 28, 1955.

Since it was Father Lynch's own suggestion that we forward his report to you for criticism, and since we would appreciate receiving your comments, we are enclosing, herewith, a copy for your review.

Thanking you for your kind cooperation and sorry we had to trouble you twice in this matter, we remain

Very truly yours,

G.R Milne

G R Milne
Mechanical Engineer

Enc.
GRM/ecp

IN REPLY ADDRESS THE DIRECTOR
COAST AND GEODETIC SURVEY
AND NOT THE SIGNER OF THIS LETTER

AND REFER TO NO. 431:fr
807.1

DEPARTMENT OF COMMERCE
COAST AND GEODETIC SURVEY
WASHINGTON 25

August 18, 1955

Mr. G. R. Milne
Consolidated Edison Company
of New York, Inc.
4 Irving Place
New York 3, New York

Dear Mr. Milne:

This is in reply to your request of August 12, 1955 that we comment on the report of Reverend J. J. Lynch, S. J. relative to the seismicity of Buchanan, Westchester County, New York.

The report of Father Lynch is in substantial agreement with the one submitted by this Office on August 10. His statement that occasional shocks have been recorded from Poughkeepsie and around, but they are very infrequent, agrees with our list of eight minor earthquakes in the past 83 years, approximately one every ten years.

If we may be of further service to you, please do not hesitate to write again.

Very truly yours,

Elliott B. Roberts

Elliott B. Roberts
Chief, Geophysics Division

Gem 8/19

2.3 Geology

A geologic report on the Indian Point site and the neighboring region was compiled by Sidney Paige, Consulting Geologiest, at the time of the application for Unit #1. This report follows and can essentially be applied to the proposed Unit No. 2. Specific information related to Unit No. 2, such as additional borings and probings, is contained in a supplement at the end of this report.

Prior to the construction of Unit No. 1 at Indian Point, borings were taken over an area extending approximately 300 feet to the north of the north wall of Unit No. 1 and 1000 feet east of the east bank of the Hudson River. These borings are shown on drawings included in the supplement to the geology report.

A study of the boring logs indicates that the rock in this area is of the same character as the rock under Unit No. 1. The geology report on the subsurface rock under Unit No. 1 will also be applicable to the subsurface rock immediately north of Unit No. 1.

A GEOLOGIC REPORT

on the

INDIAN POINT POWER HOUSE SITE

of the

CONSOLIDATED EDISON COMPANY, INC.

NEW YORK, NEW YORK

Sidney Paige,

Consulting Geologist

INTRODUCTION

The proposed Indian Point Power house site of the Consolidated Edison Company, Inc. of New York City is located approximately two miles southwest of the city of Peekskill, Westchester County, New York, on the east bank of the Hudson River. The site is part of a tract of 348 acres owned by the Consolidated Edison Company. (See figure 1 in folder).

The report that follows is divided into three parts:

I Regional geology and physiography
II Geology surrounding the site
III Engineering considerations at the site

REGIONAL GEOLOGY AND PHYSIOGRAPHY

The region we propose to briefly describe as a setting for the more detailed account of the geology surrounding the Power house site, embraces a number of physiographic provinces, namely, (1) the Atlantic Coastal Plain, with its submerged portion the continental shelf, (2) the Piedmont Plateau, (3) the New Jersey Highlands, (4) the Triassic Lowlands of New Jersey. (See physiography of the Eastern United States, Nevin M. Fenneman, McGraw-Hill Book Company, Inc., New York, 1938).

The Atlantic Coastal Plain

The Atlantic Coastal Plain is well developed along the New Jersey coast. It owes its plain-like features in part to the gently seaward dipping Cretaceous and Tertiary sandstones, shales and marls that underlie its surface; and to the fact that these beds have been only recently raised above the sea and eroded to a gently seaward dipping plain. This plain bevels the outcropping edges of successive sedimentary strata. North of the latitude of Long Island the plain is submerged beneath the waters of the Atlantic Ocean, and becomes a part of the Continental Shelf that borders the entire eastern United States from Maine to Florida.

We are not as much concerned with the sedimentary rocks of the Atlantic Coastal Plain Province, since these are not present in our immediate area of interest, as we are with the surfaces of erosion (pene-plains) that lie beneath them, and on which they were originally deposited. This relationship will be referred to later.

The Piedmont Plateau Province

The Piedmont Plateau Province, meaning the plateau at the foot of the mountains, extends from the inner boundary of the Coastal Plain at the "fall line" to the foot of the mountains, which rise sharply above it at most places along the atlantic seaboard. In the south these mountains are known as the Blue Ridge Mountains. To the north and in New Jersey they are known as the Reading Prong of the New England Province, or more commonly as the New Jersey Highlands.

The Piedmont Plateau is everywhere an uneven surface of erosion, a surface cut for the most part across complexly folded and faulted rocks of both pre-Cambrian and post-Cambrian age, sedimentary and igneous rocks alike. A striking characteristic of these rocks is the high degree of metamorphism which they generally exhibit. This is a result of their long and complex history which included deep burial, intense compression and deformation, and the emplacement of numerous masses of granite, diorite, and even more basic representatives of such intrusives. The structural and stratigraphic complexities of these rocks, and the attempts, successful or otherwise, to unravel their long history have given rise to many current controversies. With one of these we will be concerned below, in assigning an age to the rock beneath the Power house site which lies within the Piedmont Province, near the southern border of the New Jersey Highlands. Geologic reports covering the Piedmont of the Atlantic seaboard are voluminous.

There is a notable exception to the statement that the Piedmont Plateau is everywhere underlain by metamorphic rocks and their related plutonic masses. At a number of places, thick sequences of Triassic sediments have been down-faulted into the underlying pre-Cambrian basement and thus have been preserved from erosion. Such an area is that underlain by the Newark Series of New Jersey. This assemblage of conglomerates, sandstones and shales with their intercalated beds of basaltic lava, and the well known intrusive basaltic sill of the "Palisades", constitutes the Piedmont Plateau in a large area west of the Hudson River. The northern tip of this basin of deposition very closely approaches our area of interest on the opposite side of the river near Stony Point. (See figure 2).

The Blue Ridge-Reading Prong (New Jersey Highlands) Province

The Blue Ridge-Reading Prong comprises a number of sub-parallel mountain ridges extending from Georgia to northern New England where the Taconic and Green Mountains may be regarded as their most northern extension. This belt of mountains is actually the eastern border of the next physiographic province to the west, the "Ridge and Valley Province" of the Appalachian Highlands. With this latter province we are only slightly concerned. It includes in part, the lowland northwest of the New Jersey Highlands. In it are rocks generally quite free from appreciable metamorphism. This characteristic will be referred to again in discussing the geology of our immediate area of interest.

That part of the Blue Ridge-New Jersey Highlands Province which concerns us is the New Jersey Highlands portion adjacent to the Hudson River. Here the northeast trending ridges are underlain by complexly folded granitoid gneisses and schists, intricately involved with grano-dioritic intrusives. Prevailing dips in this entire region are steep towards the southeast. Because of forest and grass cover, and the presence of glacial deposits of sand, gravel and clay, it seems doubtful whether details of geologic structure and statigraphy will ever be accurately resolved and mapped. The bulk of the Highland rocks are pre-Cambrian in age, but these with which we are particularly concerned are in-faulted and in-folded strata of Cambro-Ordovician age.

With this brief introduction, we proceed to a more detailed description of the geology more closely associated with the Power house site area.

GEOLOGY OF THE AREA SURROUNDING THE POWER HOUSE SITE

The late Professor Charles P. Berkey of Columbia University, published the only detailed geologic report and map of the area in which the Power house site is located. We refer to a bulletin of the Albany, New York State Museum, entitled "Geology of the West Point Quadrangle, New York". It appeared in 1919. Since that time, although much work has been done in the surrounding area, and many controversies have arisen regarding the age of the rocks and their detailed structure, this is still the only paper embracing this region in such detail.

The report contains a geologic map on a scale of 1 : 62500. In a northwest-southeast direction the map embraces the entire width of the New Jersey Highlands, some 17 miles. In fact, the main body of the map lies within the New Jersey Highlands. Its generally mountainous character is quite evident. Only in the southern part of the area, in an irregular east-west strip roughly four miles wide does the Piedmont Plateau appear within the mapped area. It is with this southern part of the area for the most part that we are concerned. Figure 2 is a generalized redrawing of this southern portion of Berkey's geologic map, with a small addition at the south to include Stony Point. The map shows the principal formation boundaries, sedimentary and igneous, appearing on Berkey's map, and also includes the principal fault lines as determined by Berkey. We have added structural axes of folding to the map, and our correlation of the rocks east and west of the river is different from that of Berkey's.

Of particular interest on Berkey's original map are the sedimentary sequences designated Cambro-Ordovician in age, as contrasted with those other sedimentary sequences designated as of "doubtful" age, and a third sequence designated as of pre-Cambrian age (Grenville). We are concerned here only with the first two of these sequences. Most Geologists who have studied this area, including Dr. Berkey, are agreed that the sedimentary sequence of Poughquag Quartzite, 600' thick; Wappinger Limestone about 2000' thick; and Hudson River Phyllite 2000' or more thick; outcropping just north of Peekskill is of Cambro-Ordovician age. They believe them to be a metamorphosed phase of the quartzite, dolomite, and shales that lie to the north and west beyond the Highlands, where they appear as normal unmetamorphosed strata only slightly deformed.

The strata at Tomkins Cove, west of the river, well exposed in the large quarry at the New York Trap Rock Company, were likewise assigned a Cambro-Ordovician age. On the other hand, the sequence of dolomites and schists appearing south and southeast of Peekskill and at Indian Point on the east side of the river were correlated with the Inwood Limestone and Manhattan Schist of Manhattan Island. On Berkey's map their age is designated "doubtful".

Thus the dolomites on the east and west sides of the river well exposed in huge quarries, were regarded as of possibly very different age.

It is important to record here that the geologic map, of New York State, published in 1901, and described in bulletin 56 entitled State Geologic Map 1901 by F.J.H. Merrill, assigns a Paleozoic age to the dolomites on the east and west sides of the river; in fact to all the dolomites of the Peekskill region.[1]

The observations that follow, support the viewpoint of these earlier workers; that the Inwood Limestone and Manhattan Schists are the metamorphosed equivalent of the Wappinger Limestone and Hudson River Shale.

The quarry at Tomkins Cove is a roughly quadrangular opening 3000' or so in length, and some 1500' wide. The excavation is cut on several benches to a depth of several hundred feet. The dolomites are for the most part thin to medium bedded. They strike on the average N 35° E , and dip steeply to the southeast. Dips range from vertical to 70° southeast, or at somewhat lower angles on the east side of closely appressed folds. Beds vary in color from creamy white, through gray and blue; no attempt was made, however, to map distinct strata.

The west wall of the quarry is limited by phyllites or mica schists representing the Hudson River Shales. These schists likewise dip about 70° southeastward beneath the dolomites, and since they are stratigraphically higher

1. Paper entitled "Structural and Petrographic Studies in Dutchess County, N.Y. By - Robert Balk
Geological Society of America 1936 Vol 47 pp 685-774

than the dolomites, their relationship indicates that the beds here are overturned to the northwest. (See cross-section A-B on figure 2).

The notable structural features observed in the quarry are the prevailing steep southeastward dip, the occurrence of closely appressed nearly isoclinal folds along the west wall, and along the southern face, and the fact that dips are steepest on the western limb of small folds. All of this indicates overturning toward the northwest. Thus observations strongly indicate that the dolomites, originally laid down nearly horizontally, now appear in a tightly compressed fold overturned to the northwest.

The dolomites are succeeded to the east by phyllites or mica schists. These may be observed in the railroad cut at Stony Point. Beyond these schists in the railroad cut, there appears to the east intrusive igneous rock of the Cortlandt Complex.

To repeat, one cannot escape the conclusion, therefore, that Wappinger dolomite at this place is metamorphosed, thrown into a closely appressed over-turned anticline striking about N 35° E , and appears to plunge northeastward beneath the Hudson River.

About the center of the southern wall of the quarry, the dolomites are so intricately fractured that they are unsuitable as quarry rock. We suggest that this condition was caused by the violent and intense deformation of the dolomites near the axis of the over-turned closely folded anticline.

The eastern quarry, on the east bank of the Hudson north of Verplanck is somewhat smaller than the quarry at Tomkins Cove. Here, the northern wall of the quarry is a shear cliff in which the structure of the dolomites is clearly set forth. The quarry now contains a lake, but the use of a boat facilitated a close examination of all the walls of the quarry. In the north wall, beds of dolomite dip steeply southeast, about 70°. No over-turned folds were observed in this face. Along the southern face of the quarry, however, deformed beds may be seen accompanied by small faults. The heavy shooting of these banks necessary to supply rock for processing, so fractured the rock that the original joint patterns of these rocks is almost completely obscured.

The eastern face of the quarry is limited by the appearance of mica schists dipping steeply southeastward and striking with the long extension of the quarry, N 35° E; a strike similar to that in the quarry at Tomkins Cove. This strike in the dolomites of the eastern quarry would, if minor folding is excluded, continue across the river southwest directly into the Tomkins Cove quarry.

It thus appears to the writer as virtually established that the dolomites of the two quarries are identical, as are the phyllites or mica schists which stratigraphically overlie them.

The suggestion might be offered by someone that a north-south trending fault beneath the water of the Hudson separates these dolomites, and that they are of different ages. This view is opposed by the results of geophysical work in connection with the construction of the Nyack Bridge. It was discovered there, that Triassic strata (Newark Series) crosses the river in unbroken beds dipping 6° westward. (Personal communication--J.L.Worzel, Columbia University)

One of the considerations that in the past has confused the issue and made it difficult to correlate the dolomites and schists on the opposite sides of the river, and to correlate the beds that appear north and south of Peekskill, has been the different degrees of metamorphism displayed by these sequences. The writer feels that there is no valid basis for this confusion. The age of rocks should rarely, if ever, be determained by the degree of metamorphism they display. Degree of metamorphism is a result of factors independent of the age of the rock, to wit: depth of burial, crustal deformation, and the presence or absence of large intrusive bodies.

It may be shown here that these considerations can explain all differences between the dolomites and the phyllites north of Peekskill, generally accepted as of Cambro-Ordovician age, and the crystalline dolomites and mica schists south of Peekskill, by some thought of as pre-Cambrian in age, and designated in Berkey's report as Inwood Limestone and Manhattan Schist of "doubtful" age.

To clarify this discussion, figure 2 has been prepared. On it are the boundaries of the sedimentary sequences, the igneous rock of the Cortlandt Complex, and the faults which were mapped by Berkey. Details of the granitoid gneisses and granites are omitted. There have been added, lines indicating the position of structural axes of two folds, and the hypothetical outcrop of boundaries between schist and dolomite beneath the river. A dotted boundary of the Cortlandt Complex beneath the Hudson is also drawn to clarify the picture.

Two diagramatic cross-sections are offered. The one from Tomkins Cove eastward across the river through the eastern quarry to the Cortlandt Complex; the other from the Cambro-Ordovician strata north of Peekskill, southeast across a ridge of granitoid gneiss to and across Manhattan Schist(?) to the Cortlandt Complex. The strong faulting that affects the folding is symbolized in these cross-sections.

ENGINEERING CONSIDERATIONS AT THE SITE

The site of the Power house is shown in figure 1 and figure 2, the first a map of the property on a scale of 1" = 200', on which accurate positions and elevations can be readily determained. The foundations of the structure will be cut into the low hillside bordering the river to meet design requirements.

Alluvial or glacial overburden at the site is shallow, hence dolomite lies very near the surface. Depth to bedrock is shown on figure 3. Bedrock is a dolomite (Cambro-Ordovician in age, in the opinion of the writer) disposed in steeply dipping beds inclined generally 70° to the south-east. The beds strike about 35° to the northeast and are a continuation towards the northeast of the beds well exposed in the eastern quarry of the New York Trap Rock Company north of Verplanck. Structurally the site lies on the eastern limb of an overturned anticline, very near to the intrusive contact of the Cortlandt Complex.

Four diamond drill holes have, at this writing, been drilled as shown in figure 3 (in pocket). "Thin sections" have been cut from the drill cores, one near the top of each hole, and one near the bottom. Examination of these sections with a petrographic microscope gave the results recorded below.

DESCRIPTIONS OF THIN SECTIONS

K Tomkins Cove quarry--near southwest corner

Fine grained dark gray dolomite with thin bedding. Breakage seems due to ordinary compaction of sediments rather than tectonic folding, as jointing is perpendicular to bedding, and normally gives cubic blocks. Grains are slightly rounded, approximately .01 cm. in diameter, and do not have sutured contacts. This indicates that recrystallization has not occurred. The general dusty appearance of the section suggests clays and other impurities such as carbon.

N-1 Tomkins Cove quarry--west wall

Grains average .015 cm. in diameter, with sutured contacts. The rock is a fine grained dolomite or marble. Sutured contacts along with a few shards of muscovite or sericite indicate recrystallization of the rock.

N-2 Tomkins Cove quarry--west wall

Blue gray dolomite, fractured and rehealed by both calcite and cold water quartz. Breakage here is of a tectonic nature rather than jointing. Fractures bear no angular relationship to one another. The rock appears similar to specimen K except for the fracturing and rehealing.

N-3 Tomkins Cove quarry--west wall

Finely bedded blue gray dolomite with good bedding plane cleavage, and jointing normal to this plane. These joints have been filled by calcite. The impression is, that this is the same rock as specimen K, with recrystallization just beginning; perhaps 20% of the rock has interlocking crystal boundaries. Occasional grains of quartz make up 0.5% of the slide.

Drill Hole G-8 9'-14'

Dolomite or marble, blue gray with a slight suggestion of faint bedding. The rock is completely recrystallized with sutured contacts between grains. Quartz, muscovite, and a bit of potash feldspar make up perhaps 2% of the slide; an indication of the recrystallization of original argillaceous material. Grain size averages approximately .02 cm. for the calcite grains.

Drill Hole G-8 85'-90'

Blue gray dolomite or marble as specimen above. This slide shows more fracturing with indication of solution along the breaks, and partial rehealing. Specimen is recrystallized with minor quartz, potash feldspar, and muscovite as before. Grain size averages .02 cm.

Drill Hole H-8 20'-25'

Light colored recrystallized dolomite with fractures showing solution and iron staining. Grain size averages .03 to .04 cm. in diameter. Quartz, potash feldspar, and muscovite are again present to an extent of about 1%. Reflected light indicates that at least part of the small opaque matter is pyrite.

Drill Hole H-8 56'-61'

Light colored recrystallized dolomite as above, with fewer fractures but still slight traces of solution and iron staining. Grain size remains about .03 to .04 cm. in diameter, and quartz, potash feldspar, and muscovite make up 2% of the slide. Reflected light again shows opaque matter to be pyrite.

Drill Hole H-8 81'-86'

Blue gray dolomite with quartz filling joint plane 1/8 inch wide, partly open forming small vugs. Rock is completely recrystallized, with interlocking grains. Quartz, potash feldspar, and muscovite again make up 2% of the rock, with less than 0.5% opaque pyrite. Grain size averages about .02 cm. in diameter.

These thin sections indicate that the primary difference between the rocks on the east and west sides of the river is grain size, due to recrystallization of the calcite. The evident higher grade metamorphism of the dolomites on the east as contrasted with those on the west, may reasonably be explained by the nearby presence of the massive basic intrusive of the Cortlandt Complex.

The bedrock is fractured as are most rocks near the surface. Such fractures generally decrease as depth is attained. The percentage of recovery of core in the diamond drill holes, and the fracturing of the core indicate the prevailing conditions. Hole G-6 drilled to elevation -21', and G-8 drilled to elevation -16' have good recovery of core. G-10 drilled to elevation -54' has a generally poor recovery. H-8 drilled to elevation -28' had satisfactory recovery. Practically all the core recovered indicates the presence of hard dolomite, fractured to varying degrees.

The ground water-table as recorded by the diamond drill holes stood at elevation 55' in hole G-6; elevation 47' in hole G-8; elevation 38' in hole G-10; and elevation 49' in hole H-8. As might be expected, the lower reading in hole G-10 could be the result of more intense fracturing.

The bearing strength of the foundation rock far exceeds any load that will be superimposed upon it. In fact, the rock properly grouted could support any engineering structure that man might build. On the other hand, the fractured condition of the rock will call for a grouting program which can be undertaken after the foundations are opened up to grade. The desireability of "line drilling" during excavation to reduce "shooting" to a minimum is indicated.

A question always arises in evaluating the suitability of limestone or dolomite foundations, as to whether caverns exist beneath the surface. At this site, judging by observations in two very large nearby quarries, one may feel very sure that caverns do not exist. This conclusion will be doubly checked when the grouting program mentioned below is carried out after the foundations are opened up to grade.

The writer understands that it is not part of his responsibility to discuss ground water at length; the subject of "Hydrology" is reported on elsewhere.

Never the less, ground water is part of a foundation, an important part in many places, and in this case unusually so. Therefore, although the writer has made no systematic study of the water-table, nor of the flow of water beneath it, it is desireable to point out the nature of the problem, and to call attention to certain steps that should be undertaken in the treatment and design of the foundation.

The problem involves how best to prevent the contamination of ground water in the event of leakage from the plant, by accident or otherwise. The ground water-table is indicated on the diamond drill hole logs at the time of drilling. The water-table varies in position with the rainfall; falling in drought, and rising in wet seasons. The ground water beneath the hillside on which the plant will be built flows downward and outward to the Hudson

River. Beyond the crest of the hill to the east, some of the water will flow eastward to the low drainage area in that direction. The rocks to the east, schists and intrusive, are less permeable than the dolomites. Flow to the west, to the Hudson, through the more permeable dolomites will carry the bulk of the water beneath the plant.

The writer suggests in this connection that the position of the ground water-table be determained as accurately as possible in all directions from the plant, for a distance of half a mile. Engineers of the company can undertake this work by determining the position of the water in dug or driven wells throughout the area.

It is desireable to seal off from the ground water, that part of the plant from which contamination might arise. This can be done by thorough pressure grouting of the block of ground beneath the plant, and a block of ground equally deep surrounding that part of the plant where leakage might be dangerous. This second block should extend for at least 100' beyond the plant. That is, cut off the flow of ground water to or from the ground surrounding or beneath the plant. The shape and dimensions of this block of pressure grouted foundation can best be determined after final design of the plant is established, and the foundations have been opened up to grade.

There is another important aspect of this problem on which attention should be focused. It will be valuable to know in advance the radioactivity of the muds and sands along the shore of the river, of the water in nearby streams, and of water in domestic wells. This data should be carefully recorded for future reference, as a yardstick by which to study possible future contamination, or claims of contamination.

I have discussed this matter with Mr. Eugene Simpson a member of the United States Geological Survey, and presently studying for his doctorate at Columbia University.

Sidney Paige

Sidney Paige

Consulting Geologist
October 12, 1955

SUPPLEMENT TO THE

GEOLOGIC REPORT

ON THE

INDIAN POINT SITE

FOR

UNIT NO. II