CHAPTER 2
SITE AND ENVIRONMENT

2.1 SUMMARY AND CONCLUSIONS

This section of the FSAR sets forth the site and environmental data, which together formed the basis for the criteria for designing the facility and for evaluating the routine and accidental release of radioactive liquids and gases to the environment. These data support the conclusion that there will be no undue risk to public health and safety with the plant as designed and the environmental characteristics as described. This conclusion rests not only upon the data, but upon the scientific documentation of several independent consultants in their particular area of expertise-health physics, demography, geology, seismology, hydrology, and meteorology.

Environmental characteristics of the area have been documented by field measurements and studies conducted since 1958. These studies quantified the effects on the environment of the operation of nuclear power plants.

Conservative projections have been made of the probable growth of population in the area, and these projections have been taken into account in plant design both as to control of accidents and as to assumptions about operation.

[Historical Information] According to 1980 population estimates, about 50 people reside within a 1100-m radius of Unit 2 (most of them to the east-southeast), and approximately 2600 live within 1-mile. Approximately 75,000 people reside within a 5-mile radius of the facility. The largest concentration of population is in the City of Peekskill, the center of which is about 2.5-miles northeast of the site. The most densely populated 15-degree sector, within 5-miles, is toward Peekskill to the northeast.

The 1960 population within a 15-mile radius of the site was approximately 352,000, whereas in the year 2000 the estimated population is 1,107,195. The projections do not indicate, and there is no reason to conclude otherwise, that the land usage within this radius will shift appreciably during the intervening period. (The land is now zoned principally for residential and state park use, although there is some industrial activity and minor or isolated agricultural and grazing activity.)

The outer boundary of the low-population zone has been set at 1100 m from Unit 2.

Geologically, the site consists of a hard limestone in a jointed condition that provides a solid bed for the plant foundation. The bedrock is sufficiently sound to support any loads that could be expected up to 50 tons/ft^2, which is far in excess of any load that may be imposed by the plant. Although it is hard, the jointed limestone formation is permeable to water. Thus, if water from the plant should enter the ground (an improbable event since the plant is designed to preclude any leakage into the ground), it would percolate to the river rather than enter any ground-water supply.

About 80 million gallons of Hudson River water flow past the plant each minute during the peak tidal flow. This flow will provide additional mixing and dilution for liquid discharges from the facility. The assumption in the plant design is to treat the river water as if it were used for drinking and thus to reduce radioactive discharge, by dilution with ordinary plant effluent, to concentrations that would be tolerable for drinking water. There is a very low probability of flooding at the site.

[Historical Information] Seismic activity in the Indian Point area is limited to low-level microseismicity. Detailed field investigations[1-3] have been conducted in the immediate vicinity of

Indian Point and along the major faults in the region. To date, no evidence has been found in the rocks exposed at the surface or sediment overlying fault traces or in cores obtained in the vicinity of Indian Point that might support a conclusion that displacement has occurred along major fault systems within the New York Highlands, the Ramapo, or its associated branches during Quaternary time (the last 1.5 million years). In the vicinity of Indian Point, evidence that no displacement has occurred in the last 65 million years (since the Mesozoic) along specific major structures has been observed.

The plant is designed to withstand an earthquake of Modified Mercalli Intensity VII as required by Appendix A to 10 CFR 100 "Seismic and Geologic Siting Criteria for Nuclear Power Plants." The validity of the selection of an Intensity VII earthquake was adjudicated before the Atomic Safety Licensing Appeal Board. The Appeal Board's decision (ALAB-436) verified Intensity VII as the plant's design-basis earthquake.

Meteorological conditions in the area of the site were determined during a 2-year program (1955 to 1957). The validity of these conclusions has been verified by several programs, including that performed by the Atmospheric Services Department of York Services Corporation in completing a meteorological update for Consolidated Edison Company in 1981 (see Appendix 2A).

These data have been used in evaluating the effects of gaseous discharges from the plant during normal operations and during the postulated loss-of-coolant accident. The evaluations indicate that the site meteorology provides adequate diffusion and dilution of any released gases.

Environmental radioactivity has been measured at the site and surrounding area since 1958 in association with the operation of Indian Point Unit 1 and the construction and operation of Indian Point Units 2 and 3. Unit 3 is owned by Entergy Nuclear Indian Point 3, LLC. These measurements will be continued and reported. The radiation measurements of fallout, water samples, vegetation, marine life, etc., have shown no perceptible post-operative increase in activity. Noticeable increases in fallout have coincided with weapons-testing programs and appear to be related almost entirely to those programs. The New York State Department of Health in an independent 2-year postoperative survey[4,5] found that environmental radioactivity in the vicinity of the site is no higher than anywhere else in the State of New York.

[Historical Information] Consultants who have participated in the preparation of the various reports, measurements, and conclusions appearing in this chapter include Dr. Merril Eisenbud, director of Environmental Radiation Laboratory, Institute of Industrial Medicine, New York University; Dr. Benjamin Davidson (deceased), meteorologist and director, Geophysical Science Laboratory, New York University College of Engineering; Dr. James Halitsky, senior research scientist, Department of Meteorology and Oceanography, New York University, College of Engineering; Dr. Edgar M. Hoover, Regional Economic Development Institute, Inc.; Metcalf and Eddy Engineers, hydrology specialists; Quirk, Lawler, and Matusky Engineers, Environmental Science and Engineering Consultants; Mr. Karl R. Kennison, consulting civil and hydraulic engineer; and Woodward-Clyde Consultants, consulting engineers, geologists and environmental scientists.

REFERENCES FOR SECTION 2.1

1. Ratcliffe 1976.
2. Ratcliffe 1980.
3. Dames & Moore 1977.

4. Hollis S. Ingraham, Consolidated Edison Indian Point Reactor Environmental and Post Operational Survey - August, 1965, Division of Environmental Health Services, New York State Department of Health.

5. Hollis S. Ingraham, Consolidated Edison Indian Point Reactor Environmental and Post Operational Survey - July, 1966, Division of Environmental Health Services, New York State Department of Health.

2.2 LOCATION

2.2.1 General

[Historical Information] Indian Point is a multiunit site consisting of approximately 239 acres of land on the east bank of the Hudson River at Indian Point, village of Buchanan, in upper Westchester County, New York. Indian Point Units 2 and 3 (see Section 2.2.3) are located north and south, respectively, of Unit 1, which has been retired. The site is about 24-miles north of the New York City boundary line. The nearest city is Peekskill, located 2.5-miles northeast of Indian Point, with a population of about 20,000. An aerial photograph, Historical Figure 2.2-1, shows the site and about 58-mile^2 of the surrounding area.

2.2.2 Access

The site is accessible by several roads in the village of Buchanan. A paved road links the eastern boundary of the site to the existing plant. The existing wharf is used to receive heavy equipment as needed. The site is not served by rail.

2.2.3 Site Ownership And Control

Entergy owns the Indian Point Units 1 and 2 Nuclear Power Plants. As shown in Figure 2.2-3, the Algonquin Gas Transmission Company has a 26 inch gas mainline and a 30 inch gas mainline on a 65 foot wide right-of-way running east to west through the property. Unit 2 is 1450-ft north of the 26-in. Algonquin gas mainline. One 30 inch main and 2-24 inch mains pass under the river to a pipeline facilities station on the easement near the river. One 24 inch main is available as a bypass alternative and ends in the pipeline facilities station while the other two continue as the 30 inch and 26 inch mains.

The Algonquin Gas Transmission Company has installed a 42 inch gas mainline that crosses the Hudson River south of the site property and turns north. It passes through the south-easternmost corner of the site and then crosses Broadway between the Buchanan Switchyard and the GT 2/3 fuel oil storage tank. The 42 inch main joins the 30 inch and 26 inch mains north of the switchyard and east of the site. Potential hazards posed by the mainlines on IPEC structures and equipment have been evaluated.

The Georgia-Pacific Corporation has an easement, 1610-ft long and 30-ft wide, through the southerly part of the Indian Point site. The Georgia-Pacific easement is used for overhead electrical power and telephone lines and underground gas, water, and sewer lines. These easements permit Entergy to determine all activities within the right-of-way in order to ensure safe operation of the units.

Units 1, 2, and 3 have a security fence surrounding the "protected" areas. Access to the protected areas is controlled via security buildings that are manned on a 24-hr basis. In addition, spaces within the protected area designated as "vital areas" are provided with additional access control. All roads within the site are continuously patrolled by security personnel. A site plot plan is shown in Historical Figure 2.2-2.

2.2.4 Activities On The Site

The principal activities on the site are the generation, transmission, and distribution of electrical energy; associated service activities; activities relating to the controlled conversion of the nuclear energy of fuel to heat energy by the process of nuclear fission; and the storage, use, and production of special nuclear source and byproduct materials.

2.2 FIGURES

Figure No.	**Title**
Figure 2.2-1	Aerial Photo of Indian Point Site and Surrounding Area [Historical]
Figure 2.2-2	Indian Point Building Identification [Historical]
Figure 2.2-3	Algonquin Gas Transmission Pipeline Hudson River Crossing & Indian Point Nuclear Generation Facility

2.3 TOPOGRAPHY

[Historical Information] The Indian Point Generating Station is on the east bank of the Hudson River. The river runs northeast to southwest at this point but turns sharply northwest approximately 2-miles northeast of the plant. The west bank of the Hudson is flanked by the steep, heavily-wooded slopes of the Dunderberg and West Mountains to the northwest (elevations 1086 and 1257-ft, respectively, above mean sea level) and Buckberg Mountain to the west-southwest (elevation 793-ft). These peaks extend to the west and gradually rise to slightly higher peaks.

The general orientation of this high ground is northeast to southwest. One mile northwest of the site, Dunderberg bulges to the east. North of Dunderberg and the site, high grounds reaching 800-ft form the east bank of the Hudson River. At this location the Hudson River makes a sharp turn to the northwest. To the east of the site, peaks are generally lower than those to the north and west. Spitzenberg and Blue Mountains average about 600-ft in height, and there is a weak, poorly-defined series of ridges that run in a north-northeast direction. To the west of the site there are the Timp Mountains at an elevation of 846-ft. To the south of the site, elevations of 100-ft or less gradually slope towards Verplanck. The river south of the site makes another sharp bend to the southeast and then widens as it flows past Croton and Haverstraw.

Historical Figure 2.3-1 shows topographic features of the site and the surrounding areas.

2.3 FIGURES

Figure No.	**Title**
Figure 2.3-1	Topographical Map of Indian Point and Surrounding Area [Historical]

2.4 POPULATION AND LAND USE

2.4.1 Overview

The population within a 50-mile radius of the Indian Point site has been estimated for 1990. These population estimates were taken from statistics recently released by the U.S. Census Bureau. The population within the 50-mile radius of Indian Point has increased from the 1980 estimates by approximately 68,000 people, less than half of one percent.

2.4.2 Population And Land Use

According to 1990 estimates, approximately 15.465 million people live within a 50-mile radius of the Indian Point site. A major part of this number live in New York City, an area 25 to 50-miles south of the plant. Approximately 1650 persons, concentrated in sectors south to southeast of the station, live within 1-mile of the plant. Approximately 74,000 persons live within 5-miles of the plant.

The area surrounding the Indian Point site is generally residential with some large parks and military reservations. Some increased commercial development has occurred within a mile of the station since 1980. Most of the area to the east of the Hudson River within 15-miles of the site is zoned for residential uses. West of the Hudson within a 15-mile radius, the Palisades Interstate Park and residential areas are the dominant land uses. The only agricultural areas within 15-miles are south or northwest of the plant on the west side of the River.

Several maps and tables are included to illustrate the population distribution and land use of the area. Figure 2.4-1 and Figure 2.4-2 show the sector/zone approach to the population data and the area within a 50-mile radius of the Indian Point site. Historical Figures 2.4-3 through Figure 2.4-5 illustrate the 1980 population distribution radically by sectors out to 50-miles from the plant site. Historical Figure 2.4-6 through Figure 2.4-8 show, respectively, the land uses based on official zoning maps, areas served by public utilities, and areas served by sewage systems, all as of 1970. Table 2.4-1 explains the sector/zone designations for the population maps and tables that follow. Table 2.4-2 through Table 2.4-18 give the 1990 estimated populations for all sector/zones within a 50-mile radius of the Indian Point site.

The New York State Department of Commerce projects no substantial increases in population from 1986 to the year 2013 in any of the four counties in the vicinity of Indian Point.

[Historical] Table 2.4-19 and Table 2.4-20 show the estimated and projected land uses by County for 1960 and 1980, respectively. These estimates were developed by the Regional Economic Development Institute, Inc., from Regional Planning Association data.

2.4.3 Low-Population Zone

About 50 people reside within a 1100-m radius of Unit 2, most of them to the east-southeast. This distance was used as the outer boundary of the low population zone in the analysis of a postulated fission product release. The water boundary (Peekskill Bay) of the more densely populated area of Peekskill was used as the population center distance, which exceeds 1-1/3 times the distance from the reactor to the outer boundary of the low-population zone. A low-population zone outer boundary radius of 1100-m satisfies both 10 CFR 100.11(a)(3) and 10

CFR 50.67. The low-population zone population in the year 2010 is projected to be approximately 88.

2.4.4 Exclusion Area

The exclusion area for Indian Point Unit 2 includes plant property within a 520-m radius of the reactor containment. An exclusion radius of 520-m satisfies both 10 CFR 100.3(a) and 10 CFR 50.67.

2.4.5 Population Data Sources

The population data used in this section were developed from the following sources:

1. 1978 Official Population Projections for New York State Counties, prepared by the Economic Development Board, New York State Department of Commerce.

2. Population by Municipality 1970-2000, prepared by the Westchester County Department of Planning, October 1979.

3. Population of Rockland County, Capacity and Forecast, 1970-2000, prepared by the Rockland Planning Board, April 1978.

4. Population Estimate and Projections, Orange County, New York, prepared by the Orange County Planning Department, March 1980.

5. Putnam County Population Projections, prepared by the Putnam County Planning Board, 1977.

6. New Jersey Revised Total and Interim Age and Sex Population Projections, 1980-2000, prepared by the New Jersey Department of Labor and Industry, Division of Planning and Research, Office of Demographic and Economic Analysis, April 1979.

7. State of Connecticut Population Projections for Connecticut Municipalities and Regions to the Year 2000, prepared by the Office of Policy and Management, Comprehensive Planning Division, February 1980.

8. Pennsylvania Projection Series, Summary Report, Employment by Labor Market Area, and Population and Labor Force by County for 1980, 1985, 1990, 1995 and 2000, Report No. 78, PPS-1, prepared by the Office of State Planning and Development, State Economic and Social Research Data Center, June 1978.

TABLE 2.4-1
Sector and Zone Designators for Population Distribution Map[1]

Sector Nomenclature		Zone Nomenclature	
Centerline of Sector in Degrees True North From Facility	22.5° Sector[2]	Miles From Facility	Zone
0 and 360	A	0-1	1
22.5	B	1-2	2
45	C	2-3	3
67.5	D	3-4	4
90	E	4-5	5
112.5	F	5-6	6
135	G	6-7	7
157.5	H	7-8	8
180	J	8-9	9
202.5	K	9-10	10
225	L	10-15	15
247.5	M	15-20	20
270	N	20-25	25
292.5	P	25-30	30
315	Q	30-35	35
337.5	R	35-40	40

Notes:
1. An area is identified by a sector and zone alphanumeric designator (refer to Figure 2.4-1). Thus, area A1 is that area, which lies between 348.75- and 11.25-degrees true north from the facility out to a radius of 1-mile. Area G4 would be that area between 123.75- to 146.25-degrees and the 3- and 4-mile arcs from the facility.
2. The letters I and 0 have been omitted from sector designators so as to eliminate possible confusion between letters and numbers.

[Historical] TABLE 2.4-2
Population Estimates, 1990, For All Sectors

Zone	Population
1	1,644
2	15,130
3	18,428
4	14,225
5	24,508
6	25,922
7	28,096
8	25,967
9	36,930
10	46,488
15	342,852
20	488,652
25	920,850
30	2,171,399
35	2,276,172
40	3,451,123
45	3,416,140
50	2,199,601

[Historical] TABLE 2.4-3
Population Estimates, 1990, for Sector A (North)

Sector, Zone	Population
A1	0
A2	70
A3	0
A4	0
A5	400
A6	390
A7	5,301
A8	5,898
A9	2,474
A10	874
A15	4,132
A20	36,987
A25	31,000
A30	57,873
A35	39,998
A40	20,100
A45	17,689
A50	40,853

[Historical] TABLE 2.4-4
Population Estimates, 1990, for Sector B (North-Northeast)

Sector, Zone	Population
B1	0
B2	54
B3	139
B4	143
B5	1,721
B6	1,553
B7	867
B8	246
B9	2,123
B10	1,187
B15	4,343
B20	7,982
B25	20,310
B30	16,651
B35	4,800
B40	6,991
B45	8,457
B50	5,761

[Historical] TABLE 2.4-5
Population Estimates, 1990, for Sector C (Northeast)

Sector, Zone	Population
C1	0
C2	4,879
C3	9,102
C4	4,159
C5	5,534
C6	3,895
C7	2,382
C8	1,594
C9	630
C10	1,034
C15	10,371
C20	9,685
C25	8,200
C30	12,479
C35	13,687
C40	13,067
C45	7,901
C50	6,621

[Historical] TABLE 2.4-6
Population Estimates, 1990, for Sector D (East-Northeast)

Sector, Zone	Population
D1	49
D2	2,379
D3	2,691
D4	1,899
D5	2,324
D6	2,272
D7	4,667
D8	4,713
D9	5,982
D10	3,900
D15	32,854
D20	14,721
D25	8,961
D30	82,240
D35	21,876
D40	18,762
D45	12,991
D50	60,032

[Historical] TABLE 2.4-7
Population Estimates, 1990, for Sector E (East)

Sector, Zone	Population
E1	59
E2	560
E3	0
E4	289
E5	279
E6	345
E7	1,769
E8	1,138
E9	3,287
E10	3,762
E15	17,702
E20	5,099
E25	22,465
E30	20,987
E35	15,730
E40	159,720
E45	162,993
E50	101,121

[Historical] TABLE 2.4-8
Population Estimates, 1990, for Sector F (East-Southeast)

Sector, Zone	Population
F1	147
F2	305
F3	336
F4	689
F5	260
F6	987
F7	475
F8	860
F9	758
F10	1,999
F15	19,121
F20	11,728
F25	49,821
F30	120,701
F35	58,734
F40	33,691
F45	0
F50	29,199

[Historical] TABLE 2.4-9
Population Estimates, 1990, for Sector G (Southeast)

Sector, Zone	Population
G1	575
G2	2,298
G3	1,295
G4	769
G5	420
G6	3,702
G7	3,892
G8	2,672
G9	2,159
G10	6,890
G15	27,939
G20	23,849
G25	86,999
G30	44,001
G35	17,093
G40	79,903
G45	240,102
G50	328,012

[Historical] TABLE 2.4-10
Population Estimates, 1990, for Sector H (South-Southeast)

Sector, Zone	Population
H1	109
H2	1,782
H3	1,363
H4	741
H5	93
H6	0
H7	0
H8	78
H9	5,039
H10	5,752
H15	22,162
H20	103,969
H25	226,002
H30	252,482
H35	209,921
H40	535,969
H45	723,004
H50	469,960

[Historical] TABLE 2.4-11
Population Estimates, 1990, for Sector J (South)

Sector, Zone	Population
J1	531
J2	650
J3	20
J4	129
J5	1,351
J6	4,012
J7	3,133
J8	4,308
J9	5,189
J10	4,321
J15	40,993
J20	55,102
J25	220,032
J30	954,691
J35	1,472,384
J40	1,907,927
J45	1,601,010
J50	702,739

[Historical] TABLE 2.4-12
Population Estimates, 1990, for Sector K (South-Southwest)

Sector, Zone	Population
K1	174
K2	1,245
K3	1,282
K4	2,049
K5	8,093
K6	4,124
K7	2,526
K8	2,531
K9	6,291
K10	9,371
K15	86,297
K20	72,902
K25	146,895
K30	427,391
K35	321,209
K40	534,296
K45	444,572
K50	353,770

[Historical] TABLE 2.4-13
Population Estimates, 1990, for Sector L (Southwest)

Sector, Zone	Population
L1	0
L2	63
L3	1,621
L4	2,694
L5	2,184
L6	4,059
L7	2,876
L8	902
L9	2,087
L10	4,021
L15	26,019
L20	28,753
L25	41,514
L30	94,167
L35	31,725
L40	89,824
L45	124,188
L50	54,722

[Historical] TABLE 2.4-14
Population Estimates, 1990, for Sector M (West-Southwest)

Sector, Zone	Population
M1	0
M2	359
M3	188
M4	399
M5	169
M6	274
M7	170
M8	15
M9	96
M10	271
M15	5,139
M20	4,976
M25	14,343
M30	8,817
M35	21,625
M40	18,889
M45	47,849
M50	30,319

[Historical] TABLE 2.4-15
Population Estimates, 1990, for Sector N (West)

Sector, Zone	Population
N1	0
N2	292
N3	214
N4	0
N5	0
N6	0
N7	0
N8	23
N9	438
N10	63
N15	3,321
N20	8,827
N25	10,234
N30	7,794
N35	14,233
N40	9,028
N45	9,007
N50	2,109

[Historical] TABLE 2.4-16
Population Estimates, 1990, for Sector P (West-Northwest)

Sector, Zone	Population
P1	0
P2	85
P3	52
P4	0
P5	32
P6	58
P7	9
P8	626
P9	357
P10	2,004
P15	17,997
P20	9,983
P25	12,394
P30	47,277
P35	5,927
P40	9,121
P45	3,960
P50	3,917

[Historical] TABLE 2.4-17
Population Estimates, 1990, for Sector Q (Northwest)

Sector, Zone	Population
Q1	0
Q2	0
Q3	125
Q4	189
Q5	55
Q6	0
Q7	29
Q8	321
Q9	0
Q10	1,039
Q15	7,023
Q20	9,872
Q25	10,745
Q30	12,244
Q35	10,160
Q40	7,942
Q45	5,653
Q50	6,962

[Historical] TABLE 2.4-18
Population Estimates, 1990, for Sector R (North-Northwest)

Sector, Zone	Population
R1	0
R2	109
R3	0
R4	76
R5	1,593
R6	251
R7	0
R8	42
R9	20
R10	0
R15	17,439
R20	44,219
R25	10,935
R30	12,144
R35	17,070
R40	5,893
R45	6,764
R50	3,504

[Historical] TABLE 2.4-19
Estimated Land Use in 1960 and Projected Land Use in 1980[1]
Within a 55-Mile Radius

	Intensive 1960 and 1980			Nonintensive 1960			Nonintensive 1980					
	1	2	3	4	5	6	7	8	9	10	11	12
	Residential	Industrial/ Commercial	Total	Institutional and Park	Public Rights-of-Way	Total	Community Facilities Institutions	Parks Recreation	Public Rights-of-Way	Total	Open	Grand Totals
1960												
Square miles	1032	216	1248	696	418	1114					4062	6424
Percentage of total developed land	43	9	52	29	19	48						
High	58	12	45		22							
Low	32	2	15		15							
1980												
Square miles	2040	368	2408				876	784	682	2342	1674	6424
Percentage of total developed land	43	8	51				19	16	14	49		
1960-1980												
Square miles of land to be developed	1400	220	1620							1228		
Percentage of total land to be developed			58							42		

Notes:

1. The averages were derived from the data in "Table 3. The Use of Developed Land in Selected Areas of the Regions." RPA Bulletin Number 100, Page 21, September 1962. The data for square miles excludes Monmouth County from the original Regional Plan Association (RPA) totals.

[Historical] TABLE 2.4-20 (Sheet 1 of 2)
Land Use Projection by County for 1980 in Square Miles
Within a 55-Mile Radius

Counties in Con Ed Study Area				Intensive		Low Intensive		
State	In RPA Region	Outside RPA Region	Residential	Industrial/ Commercial	Community Facilities Community Institutions	Parks Recreation	Public Rights-Of Way	Open
Conn.	Fairfield		183	33	92	83	71	171
		Litchfield	[30][1]	[6]	[3]	[3]	[2]	[5]
		New Haven	[88]	[19]	[73]	[65]	[55]	[134]
N.J.	Bergen		118	22	20	19	16	38
	Essex		83	16	6	6	5	12
	Hudson		26	5	3	3	2	6
	Middlesex		126 (58)[2]	22 (10)	18	16	14	34
	Morris		130	23	69	63	54	129
	Passaic		75	14	23	21	18	43
	Somerset		71 (24)	13 (4)	16	15	12	30
		Sussex	[34]	[8]	[107]	[97]	[83]	[199]
	Union		63	12	6	6	5	11
		Warren	[3]	[1]	[9]	[9]	[7]	[18]
N.Y.	Dutchess		106	19	152	138	117	283
	Nassau		230	41	5	4	4	9
	Orange		110	20	154	140	119	286
	Putnam		37	6	42	38	32	79
	Rockland		56	10	25	23	19	46

[Historical] TABLE 2.4-20 (Sheet 2 of 2)
Land Use Projection by County for 1980 in Square Miles
Within a 55-Mile Radius

Counties in Con Ed Study Area			Intensive				Low Intensive	
State	In RPA Region	Outside RPA Region	Residential	Community Industrial/ Commercial	Facilities Community	Parks Recreation	Public Rights-Of Way	Open
N.Y.	Suffolk		279 (199)[2]	50 (35)	92	84	72	172
		Sullivan	[8][1]	[4]	[117]	[106]	[90]	[217]
		Ulster	[53]	[12]	[207]	[188]	[160]	[386]
	Westchester		162	31	53	48	42	99
	Bronx		25	4	3	3	2	5
	Kings		42	7	4	4	4	8
	New York		14	2	1	1	1	3
	Queens		65	11	7	7	6	13
	Richmond		39	7	3	2	2	5
P.A.		Pike	[7]	[1]	[76]	[69]	[59]	142
	Total RPA Region[3]		2040	368	794[3]*	724[3]*	617[3]*	1482[3]*
	Total Consolidated Edison Area		2078	383	1385	1261	1073	2583

Notes:
1. Figures in brackets are for those counties outside RPA's Region. They are added to the total for Con Ed's area.
2. Figures in parentheses are those portions of the RPA Region contained in the Con Ed area.
3. Total RPA Region figures followed by * indicate that only the portion of the counties in Con Ed's area are included.

2.4 FIGURES

Figure No.	Title
Figure 2.4-1	Schematic Sector/Zone Diagram
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Figure 2.4-3	Five Mile Sector/Zone Diagram [Historical]
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Figure 2.4-5	Fifty Mile Sector/Zone Diagram [Historical]
Figure 2.4-6	Map and Description Showing Land Usage [Historical]
Figure 2.4-7	Map and Description of the Area Showing Public Utilities
Figure 2.4-8	Map and Description of the Area Showing Sewage Systems

2.5 HYDROLOGY

The hydrologic features of the Indian Point site are relevant to the analysis of radioactive liquid discharges from the plant. These features are the Hudson River, ground water and wells, and surface-water reservoirs. During normal plant operation liquid wastes are discharged to the Hudson River through the circulating water discharge canal. Ground-water contamination from accidental ground seepage or leakage from the plant will flow to the river because of the higher elevation of the plant relative to the river.

Between 2005 and 2007, GZA GeoEnvironmental (GZA), performed a comprehensive hydrogeologic investigation of the site. This investigation was initiated to understand groundwater flow and contaminant transport. During this investigation numerous borings were advanced to study the site geology, hydrology and aquifer properties. Details of the geology, hydrology and aquifer properties can be found in the GZA report[5].

The hydrology in the environs of the Indian Point site has been extensively studied for Con Edison by numerous consultants, augmenting the data base established through the investigations of various governmental agencies. The initial Con Edison study was conducted in 1955 by Kennison,[1] who analyzed the flow characteristics of the river at the site. Metcalf and Eddy[2] further examined the river flow, and also investigated local groundwater hydrology and surface-water reservoirs. The salient aspects of these and other studies[3,4] are reported below.

The Hudson River below the dam at Troy (immediately below the confluence of the Hudson and Mohawk Rivers) is a tide-influenced, estuarine waterway. (see Figure 2.5-1.) Fresh water from the combined Hudson and Mohawk Rivers, as well as from numerous tributaries, discharges directly into the tidal portion of the river. Seawater enters the extreme lower reaches of the river through the Narrows and the Harlem/East River. The distribution of saltwater is influenced by fresh water flow, tides, physical characteristics of the river channel, and weather.

Flow in the Hudson River is controlled more by the tides than by the runoff from the tributary watershed. River width opposite the plant ranges from 4500 to 5000-ft. Water depths within 1000-ft of the shore near the site are variable with an average depth of 65-ft; at some points the depth exceeds 85-ft. River cross-sectional areas in the vicinity of the site range from 165,000 to 170,000-ft^2. Tidal flow past the plant is about 80 million gpm about 80-percent of the time, and it has been estimated that this frequency flow is at least 9 million gpm in a section 500-600-ft wide immediately in front of the facility. Mean tidal flow in the vicinity of the site is over 70 million gpm.

The average downstream flow (for a 17-year period preceding 1930) is in excess of:[2]

- 11,700,000 gpm 20-percent of the time.
- 6,800,000 gpm 40-percent of the time.
- 4,710,000 gpm 60-percent of the time.
- 3,100,000 gpm 80-percent of the time.
- 1,800,000 gpm 98-percent of the time.

The plant is designed to use the dilution characteristics of the large tidal flow and will be operated such that discharges into the river would not contravene regulatory limitations.

Historical flow patterns were further examined by Quirk, Lawler, and Matusky[3,4] who reported both long-term (monthly) river discharges and potential drought flows. Quirk, Lawler, and Matusky also

analyzed and reported on the hydraulic conveyance properties of the estuary and the effects of tide and salinity on movement in the estuary.

Review of historical records indicates that flooding at the site is non-existent. Flood stages are primarily the effect of tidal influence, with the secondary influence of runoff. The highest recorded water elevation in the vicinity of the site was 7.4-ft above mean sea level (MSL), which occurred during an exceptionally severe hurricane in November 1950. Subsequent to that occurrence, the highest water elevation recorded at the site was 9-ft 8-in. above MSL, which occurred during the extra-tropical Superstorm Sandy in November 2012. Since the river water elevation would have to reach 15-ft 3-in. above MSL before it would seep into any of the Indian Point buildings, the potential for any flooding damage at the site appears to be extremely remote.

Seven different flooding conditions governing the maximum water elevation at the site were investigated, including the following:

1. Flooding resulting from runoff generated by a probable maximum precipitation over the entire Hudson River drainage basin upstream of the site.

2. Flooding caused by the occurrence of any upstream dam failure concurrent with heavy runoff generated by a standard project flood.

3. Flooding due to the occurrence of a probable maximum hurricane concurrent with a spring high tide in the Hudson River.

The severest flooding condition revealed by the study results from the simultaneous occurrence of a standard project flood, a failure of the Ashokan Dam and a storm surge in New York Harbor at the mouth of the Hudson River resulting from a standard project hurricane. The water level under these conditions would reach 14-ft above MSL. Local wave action due to wind effects has been determined to add 1-ft to the river elevation producing a maximum water elevation of 15-ft above MSL at the Indian Point Site. Since this maximum water elevation is 3-in. lower than the critical elevation of 15-ft 3-in. noted earlier, it is reasonable to conclude that flooding in the Hudson River will not present a hazard to the safe operation of Indian Point.

The three most severe hurricanes to hit New York Harbor (September 21, 1821; November 25, 1950 (mentioned previously); and September 12, 1960) produced tidal surges at the Battery of 11-ft, 8.2-ft and 6.3-ft, respectively. Accordingly, these surges would appear as 7.5-ft, 5.5-ft, and 4.3-ft surges at Indian Point. The 5.5-ft surge predicted for the November 25, 1950, hurricane agrees well with the actual surge that produced the 7.4-ft-high watermark recorded for Indian Point on that date.

The Quirk, Lawler and Matusky report indicated that the combination of the maximum probable runoff, upstream dam failures and maximum ebb tide in the Hudson River is a less severe condition than the one postulated above. This latter scenario would cause the water level at Indian Point to be 11.7-ft above MSL, also below the critical control elevation.

The report also indicates that the combination of probable maximum hurricane, spring high tide, and wave run-up will cause the water level at Indian Point to reach 14.5-ft above MSL. This is also below the critical control elevation of 15-ft-3-in. Table 2.5-1 summarizes the Indian Point water surface elevations resulting from the various combinations.

In view of the recorded hydrologic history of the Hudson River and New York Harbor and the predicated maximum hurricane surge at Indian Point, flooding at the site is a highly unlikely possibility.

Within a 5-mile radius of the plant only one municipal water supply uses ground water. Other wells in this area are used for industrial and commercial purposes. The rock formations in the area and elevations of wells relative to the plant are such that accidental ground leakage or seepage percolating into the ground at Indian Point will not reach these sources of ground water, but will flow to the river.
Only two reservoirs within a 5-mile radius are used for municipal water supplies. The first, Camp Field Reservoir, is the raw-water receiving basin for the system, which serves the city of Peekskill. This system uses the Catskill Aqueduct and Montrose Water District as alternative sources of water supply. The second reservoir, the impounding reservoir for the Stony Point water system, serves the towns of Stony Point and Haverstraw, and the villages of Haverstraw and West Haverstraw. The Stony Point system is connected to the Spring Valley Water Company to provide an alternative source of supply. A third reservoir within 5-miles of the plant, Queensboro Lake, supplies water to a state park area only. The location of these reservoirs, and others within a 15-mile radius of the site, are shown on Figure 2.5-2. The city of New York's Chelsea Pumping Station is located about 1-mile north of Chelsea, New York, on the east bank of the Hudson River, about 22-miles upstream of the site. Water will be pumped from intakes in the river at the rate of up to 100 million gal per day into the city reservoir system as required to supplement the primary supply from watersheds during severe drought conditions. This source, however, was not used during the recent 1981 drought.

The discharge of any contaminant into a tidal estuary will result in its distribution throughout the estuary. Factors affecting this distribution include tide amplitude and current, river geometry, salinity distribution, and freshwater discharge. Quirk, Lawler, and Matusky investigated for Con Edison the influence of these factors and determined the effect of radioactive discharges on overall river concentrations, and specifically conditions at Chelsea Pumping station, as discussed in Section 11.1. During normal operations, the plant discharge will not exceed its maximum permissible concentration. Compliance with regulatory release limits is further discussed in Section 11.1.

REFERENCES FOR SECTION 2.5

1. Letter report of Karl L. Kennison, Civil and Hydraulic Engineer, to G. R. Milne, Con Edison, November 28, 1955.

2. Metcalf and Eddy Engineers, Hydrology of Indian Point Site and Surrounding Area, October 1965.

3. Quirk, Lawler, and Matusky Engineers, Transport of Contaminants in the Hudson River above Indian Point Station, May 1966.

4. Quirk, Lawler, and Matusky Engineers, Evaluation of Flooding Conditions at Indian Point Nuclear Generating Unit No. 3, April 1970.

5. GZA, Hydrogeologic Site Investigation Report for the Indian Point Energy Center, January 7, 2008.

TABLE 2.5-1
Water Surface Elevation at Indian Point
Resulting From Stated Flow and Elevation Conditions

Component Flow at Indian Point	Elevation at the Battery - Datum MSL (ft)	Flow at Indian Point (million cfs)	Elevation at Indian Point - Datum-MSL (ft)	Elevation at Indian Point Including Local Oscillatory Wave Height Datum MSL (ft)
1. Probable maximum flood	MSL 0.00	1.100	12.7	13.7
2. Probable Maximum flood and tidal flow	High water ±2.20	1.014	12.4	13.4
3. Probable Maximum flood and tidal flow	Low water −2.20	1.165	13.0	14.0
4. Standard project flood and Ashokan Dam failure	MSL 0.00	0.705	7.2	8.2
5. Standard project flood	Standard project hurricane +11.00	0.550	13.0	14.0
6. Standard project flood and Ashokan Dam failure	Standard project hurricane (+11.00)	0.705	14.0	15.0
7. Probable maximum hurricane and spring high tide	Probable maximum hurricane +17.5		13.5	14.5

2.5 FIGURES

2.6 METEOROLOGY

2.6.1 General

[Historical Information] Meteorological parameters related to atmospheric transport and diffusion have been extensively investigated in the Indian Point area since 1955. Studies of the wind flow characteristics, induced by the topography surrounding the site, illustrated the unique valley wind system and the channeling of low level winds.

Meteorological studies[1-3] were conducted from 1955 to 1957 by the Research Division of New York University, under the direction of Prof. Ben Davidson, in support of Unit 1 licensing activities. Data from these studies illustrated the channeling of the air flow by the terrain into downvalley (north-northeast) and upvalley (south-southwest) regimes. Historical data collected by the U.S. Weather Bureau in 1932 also illustrated the valley wind system.

Subsequent meteorological investigations were conducted from 1968 through 1972 by New York University School of Engineering and Science, Department of Meteorology and Oceanography, under the direction of Dr. James Halitsky and Mr. Edward J. Kaplin. These studies supported the earlier findings of the valley wind system by Prof. Davidson and are documented in Appendix 2A of this FSAR and in the FSAR for Indian Point Unit 3.

The most recent meteorological programs and data analyses conducted in the Indian Point environs since 1972 were documented in a York Services Corporation report (Meteorological Update, September 1981). This report is included in Appendix 2A. The 10-m elevation on the 100-ft meteorological tower used for the Unit 2 siting studies is the backup tower to the 400-ft (122-m) primary tower. The 10-m tower installed at the Buchanan Service Center is also available as an additional contingency.

The York Services Report summarizes the meteorological activities conducted for Indian Point from 1955 to 1981. Included are topographic effects, wind correlations, data collection, diurnal wind distribution, trajectory analyses, atmospheric stability, and wind distributions. The report substantiates previous studies conducted on the existence of the valley wind system in the environs of Indian Point.

2.6.2 Application of Site Meteorology to Safety Analysis of Loss-Of-Coolant Accident

The atmospheric dispersion factors required for the safety analysis of Chapter 14 have been computed for the worst possible meteorological conditions that could prevail at the Indian Point site.

A search of the records indicates that the most protracted consecutive period during which the wind direction was substantially from the same direction was 5 days. The winds in this case

were from the northwest and speeds ranged from 15 to 30 mph. Therefore, this case does not represent the most conservative meteorology associated with the loss-of-coolant accident.

The most frequent wind flow at low heights under inversion conditions is down the axis of the valley. This direction, roughly 10- to 30-degrees, is also the direction of maximum wind frequency. Because of the relatively high frequency of inversion conditions associated with this wind direction, the safety analysis assumes that the distribution of wind speed and thermal stability during the hypothetical accident is exactly that measured at the 100-ft tower level for the 5- to 20-degree wind direction.

The valley wind is diurnal in nature, that is, up-valley during unstable hours and down-valley during stable hours. In general, these local winds are most frequent under clear sky and relatively light prevailing wind conditions. The diurnal variation of the vector mean wind as measured 70-ft above river during September-October 1955 is shown in Figure 2.6-1 for conditions in which the large-scale flow was virtually zero (12 days) and in Figure 2.6-2 for conditions in which the large-scale flow (geostropic wind) was less than 16 mph (35 days). It may be seen that for these virtually stagnant prevailing wind conditions, there is a regular diurnal shift in wind direction and that the mean vector wind associated with the down-valley flow is approximately 6 mph.

A measure of the magnitude of the diurnal shift in wind direction is shown in Figure 2.6-3, where the steadiness of the wind (vector) mean speed over the mean scalar speed is shown as a function of time and the strength of the prevailing flow. Where the steadiness is close to one, the persistence of a given wind direction is very high. These data indicate that a consecutive 24-hr down-valley flow with light wind speeds and inversion conditions is extremely improbable due to the diurnal variation of the steadiness.

The safety analysis of the loss-of-coolant accident assumes that the accident occurs during down-valley inversion flow conditions and that this condition persists for 24 hr with average wind speeds slightly less than 2 m/sec. Figures 2.6-1 and 2.6-2 indicate that the duration of the down-valley flow is about 12 hr rather than 24 hr and that the vector mean wind speeds are approximately 2.5 m/sec.

In view of the discussion above, it must be concluded that the safety analysis for the first 24 hr is conservative to within a factor of about 2.

The remainder of the safety analysis assumes that for the next 30 days, 35-percent of the winds are in the 20-degree sector corresponding to the nocturnal down-valley flow and that wind speed and thermal stability are as observed over the period of 1 year as measured at the 100-ft tower location. If the observations were distributed uniformly throughout the year, slightly over 100 hr per month of 5- to 20-degree winds could be expected to occur. The analysis assumes that 276 hr of 5- to 20-degree winds occur in the first 31 days after the accident, and that about 130 of these hours are characterized by inversion conditions. Approximately 35 weak-pressure gradient days were observed in September-October 1955 or about 430 hr per month. From Figure 2.6-3, the hour during which the down-valley flow is quite persistent under weak-pressure gradient conditions are from 0 to 8 hr. Assuming that the steadiness is 1.0 during these hours (it is in fact about 0.9 or less), the number of down-valley inversion winds per month during September and October is on the order of 140 hr per month. This indicates that the meteorology assumed in the safety analysis beyond the first 24 hr is reasonable for the worst

months (September and October) and is undoubtedly conservative with varying degrees of conservatism for the remainder of the year.

The inversion frequency assumed for the 30-day accident case is conservative because the evaluation is made from concurrent assumptions concerning the postulated meteorological conditions, namely:

1. Inversion conditions prevail for 42.4-percent of the time.
2. The wind direction is within a narrow 20-degree sector for 35-percent of the time.

This is equivalent to assuming that in the model 20-degree sector, the inversion frequency is 14.8-percent for the 30-day period. The observed annual maximum inversion frequency for a 20-degree sector is 6.2-percent (p. 29, Table 3-3, Section 1.6 of Reference 3). If we assume that the inversion frequency is spread uniformly throughout the year, almost 3 months worth of inversions in the model 20-degree sector are considered to occur in the first 31-day month after the accident. The assumption of uniform spread of inversion frequency over the year is examined above where an attempt is made to isolate those local meteorological conditions at Indian Point, which might yield the highest 30-day dose. It is concluded that the "worst" meteorological conditions are associated with the nocturnal down-valley flow, which is most frequent during September and October.

REFERENCES FOR SECTION 2.6

1. New York University, Research Division, A Micrometeorological Survey of the Buchanan, N.Y., Area, NYU Technical Report 372.1, November 1955, which was Exhibit L-1, Docket 50-3, given in its entirety. The topography of the area surrounding the site is described and the effects of the topography on meteorological conditions are discussed. The types of data collected, the methods and frequencies of collection, the description and location of the equipment, and the general scope of the meteorological program are indicated in this report. Seasonal wind characteristics, including speeds, directions, and frequencies are tabulated.

2. New York University, Research Division, Evaluation of Potential Radiation Hazard Resulting From Assumed Release of Radioactive Wastes to the Atmosphere From Proposed Buchanan Nuclear Power Plant, Sections 1, 2, and 3 of NYU Technical Report 372.3, April 1957. This report was submitted to the NRC in its entirety as Exhibit L-5, Docket 50-3. These sections discuss the diffusive conditions and the climatological data of the site. The basis for evaluating the diffusion parameters selected for the safety analysis is given on pages 19 to 21. Section 3 contains tables of frequency distribution of diffusion classes and wind directions, and also wind roses.

3. New York University, Research Division, Summary of Climatological Data at Buchanan, N.Y., 1956-1957, NYU Technical Report 372.4, March 1958, was Exhibit L-6, Docket 50-3. This report summarizes the final meteorological testing at Indian Point.

2.6 FIGURES

2.7 GEOLOGY AND SEISMOLOGY

[Historical Information] The Indian Point site and surrounding area were studied in 1955 by Sidney Paige, consulting geologist, before the construction of Unit 1 In 1965, Thomas W. Fluhr, P.E., an engineering geologist, reviewed the geology of the site and made additional borings at the location of Unit 2.

In 1982, a report by Woodward-Clyde Consultants was done to update Section 2.7 of the FSAR. The previous studies are listed in the reference list of the report. The report is included in Appendix 2B.

Between 2005 and 2007, GZA GeoEnvironmental (GZA), performed a comprehensive hydrogeologic investigation of the site. This investigation was initiated to understand groundwater flow and contaminant transport. During this investigation numerous borings were advanced to study the site geology, hydrology and aquifer properties. Details of the geology, hydrology and aquifer properties can be found in the GZA report[1].

A seismic monitoring network exists in the vicinity of the site and data from this network is periodically evaluated.

REFERENCES FOR SECTION 2.7

1. GZA, Hydrogeologic Site Investigation Report for the Indian Point Energy Center, January 7, 2008.

2.8 ENVIRONMENTAL RADIOACTIVITY

Monitoring for environmental radioactivity in the vicinity of the Indian Point Station began in 1958, approximately 4 years before the operation of Unit 1. Measurements since that time have indicated that the present operation of Units 2 and 3 and the past operation of Unit 1 have had no significant effect on the environment. The monitoring program implements Section IV.B.2 of Appendix I to 10 CFR Part 50 and thereby supplements the radiological effluent monitoring program by verifying that the measurable concentrations of radioactive materials and levels of radiation are not higher than expected on the basis of the effluent measurements and the modeling of the environmental exposure pathways. Measurements of radioactivity in the environment are summarized in the Annual Radiological Environmental Operating Report, which is submitted annually as required by the plant's Technical Specifications.

Determinations of radioactivity in the environment are made regularly. Sample locations are defined in the Offsite Dose Calculation Manual (ODCM).

The overall objectives of the environmental monitoring program are as follows:

1. To establish a sampling schedule for Indian Point Units 1 and 2 that will recognize changes in radioactivity in the environs of the plant.

2. To ensure that the effluent releases are kept as low as is reasonably achievable (ALARA) and within allowable limits in accordance with 10 CFR 20.

3. To verify projected and anticipated radioactivity concentrations in the environment and related exposure from releases of radioactive material from the Indian Point site.

Results of environmental surveys conducted by Con Edison have been verified by the Bureau of Radiological Health Service of the New York State Health Department in previous years and presently, by the New York State Bureau of Environmental Radiation.[1, 2]

Environmental surveys have also been confirmed by Dr. Merril Eisenbud, Director of Environmental Radiation Laboratory, Institute of Environmental Medicine, New York University Medical Center, who has found that the levels of environmental radioactivity are associated with natural background and fallout of nuclear weapons testing.[2]

In a study of the radioactivity in the Hudson River, Mr. Sherwood Davis, Director, Bureau of Radiological Health Service, New York State Department of Health, et al., have concluded that the discharges from Indian Point Unit 1 "are a minute fraction of the federal limits."[4]

The above results were obtained in preoperational and operational periods of Units 1 and 2 in the late 1950s and in the 1960s. In the more recent years of the late 1970s, radiological impact evaluations have shown similar results. These evaluations of actual plant releases have been performed for inclusion in the effluent release reports and have shown that operation of the Unit 2 plant has had an insignificant impact on the environs.

REFERENCES FOR SECTION 2.8

1. New York State Department of Health, Division of Environmental Health Services, Consolidated Edison Indian Point Reactor, Post Operational Survey, August 1965.

2. New York State Department of Health, Division of Environmental Health Services, Consolidated Edison Indian Point Reactor, Post Operational Survey, July 1966.

3. New York University Medical Center Institute of Environmental Medicine, Ecological Survey of the Hudson River: Progress Report No. 2, submitted to Division of Radiological Health, USPHS, Contract PHS 86-95, Neg. 141, December 1966.

4. F. Cosolito, et al., Radioactivity in the Hudson River, Symposium on Hudson River Ecology, Hudson River Valley Commission of New York, October 4-5, 1966.

NOTE: This information is classified as Historical Information

APPENDIX 2A

FACILITY SAFETY ANALYSIS REPORT (FSAR)

CONSOLIDATED EDISON COMPANY
OF NEW YORK, INCORPORATED

INDIAN POINT NUCLEAR GENERATING UNIT NO. 2

METEOROLOGICAL UPDATE

SEPTEMBER, 1981

YSC PROJECT **+** 01-4122

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ATMOSPHERIC SERVICES DEPARTMENT

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1.0 GENERAL

1.1 HISTORICAL BACKGROUND

1.1.1 Introduction

Meteorological data were initially collected and evaluated with respect to Indian Point, Buchanan, New York and its environment during the period from 1955 through 1957. This work was accomplished under the direction of Professor Benjamin Davidson of New York University under contract with the Consolidated Edison Company of New York, Inc. (Con Edison). The data and studies during this period were the bases for the Environmental Reports relevant to Indian Point Nuclear Generating Units 1, 2 and 3.

With respect to the Facility Safety Analysis Report (FSAR) for Unit 2, the Environmental Report Supplement, Appendices Volume 1 as Appendices C, D and E contains:

- NYU Technical Report 372.1 (November, 1955), B. Davidson
- NYU Technical Report 372.3, Section 2 and 3, (April, 1957), B. Davidson and J. Halitsky
- NYU Technical Report 372.4 (March, 1958), B. Davidson

In 1968 under the direction and supervision of Dr. James Halitsky of New York University, Con Edison contracted to establish experimental meteorological monitoring, data collection and evaluation activities at the Indian Point site and at specified sites in its environment (Halitsky, Laznow and Leahy, February 1970). The original purpose of the above investigation, as noted in the reference, was modified after the studies had begun in order to provide the AEC Construction Hearings for Indian Point Unit 3 with clarification of aspects of the 1956-1957 meteorological data base for the Units 1, 2 and 3 diffusion models. This phase of data collection began in December, 1969.

A report dealing with the results of this latter phase (Halitsky, Kaplin and Laznow, NYU GSL Technical Report No. TR 7103, May 1971) appears as Appendix G in the FSAR Unit 2 Environmental Report Supplement Appendices Volume 1 and as Supplement 1 in the FSAR for Unit 3. The focus of the above report was to validate present site meteorology as representing no significant change in relation to site meteorology from the 1955-1957 period.

Data collection and evaluations continued under this program and a report was submitted by Kaplin and Laznow (1972) representing the data collection period from 1 January, 1970 through 31 December 1971. A copy of this report appears in FSAR for Unit 3 as Supplement 10 (January, 1973).

With respect to Indian Point on-site meteorological measurements, there were for the purpose of the reports that have been cited, three different meteorological towers at three different locations. These are specifically delineated in Figure 1 of Halitsky, Kaplin and Laznow (1971).

The meteorological data collected during the 1955-1957 were from the 300 Foot Tower designated as IP1. Meteorological data collected and reported by Halitsky, Kaplin and Laznow (1971) and Kaplin and Laznow (1972) were from the 100 Foot Tower designated as IP3. The base of IP3 Tower was about 200 feet from the base location of the original IP1 Tower.

Using input data meteorological data from Indian Point Tower (IP3), Bowline Point and the Cape Charles along with sequences of upper air pilot balloon observations Kaplin, Laznow and Wurmbrand (1972) provided Con Edison with input information for the location of the 90-percent probability air monitoring sites, overlay patterns for the prediction of the distribution of gaseous releases and evaluation of the requirements of the AEC Safety Guide 23 (1972).

All data on the IP3 Tower were collected in accordance with U.S. AEC Safety Guide No. 23, On-Site Meteorological Programs as delineated 2/17/71. The IP3 Tower was maintained from March 1972 through December 1973 by York Research Corporation, Stamford, Connecticut under contract with Con Edison. The last formal report for this tower was prepared and submitted to Con Edison by Kaplin and Kitson (1974) for the 1973 data collection period.

In April of 1973, York Research Corporation under contract with Con Edison began work on the erection of an on-site 400 Foot Meteorological Tower approximately 1725 feet-S and 1750 feet-W of the IP3 Tower. The function of this tower was to develop micro-climatological data suitable for the design of cooling towers and the evaluation of their potential environmental impact on the Indian Point site and its environs. Concurrent studies were conducted to develop three dimensional aspects of the local valley flow using pibal balloons, constant level tetroons and balloon-sondes. In addition, a concurrent study was conducted to develop background levels of ambient air salt concentrations. The results of these studies were submitted in two reports: Kaplin, Kozenko and Kirshner (1974) and Kaplin, Kitson and Kozenko (1974). This latter report compared meteorological data from the IP3 Tower. At the conclusion of 1973, the primary source of reduced on-site meteorological data were from the IP4, 400 Foot Meteorological Tower. IP3 Tower systems maintenance was continued in accordance with Safety Guide 23 through October 1, 1976 and meteorological data were recorded on analog charts. Data collection was transferred to the IP4 Tower on July 1, 1976. The 400 Foot Tower (IP4) servicing, maintenance and data collection and data selective processing is on-going. Its systems have been updated to meet present requirements of NUREG-0654 Appendix 2 (1980) and proposed Revision 1 to NRC Safety Guide 1.23 (1980).

The continued maintenance services, etc., of the 400 Foot Meteorological Tower by York Research Corporation/York Services Corporation was continuous under contract with Con Edison until September 30, 1978, and from October 1, 1978 through the present time under contract with the Power Authority of the State of New York (PASNY).

In September, 1979, York Services Corporation under contract with Con Edison began a study of north to south surface air trajectories analyses and evaluations based on “real-time” wind data available from the Indian Point vicinity. This study incorporated local wind velocity data from the 400 Foot Meteorological Tower at Indian Point, the Orange and Rockland Utilities, 350 Foot Meteorological Tower in Haverstraw, New York, as well as from selected U.S. Department of Commerce, NOAA, Weather Stations. For this study, meteorological data were analyzed and evaluated for the period from August 1, 1978 through July 31, 1979. The final results of this study were presented in reports: Kaplin, E.J. and B. Wuebber, (1979) and Kaplin, E.J. (1979). As an outgrowth of these studies an expended network of surface (10M) wind velocity monitoring stations were sited at key locations along the Hudson River Valley north and south of

Indian Point and inland to the east. This network consisted of new anemometer stations in addition to the Indian Point 400 Foot Meteorological Tower, the Bowline 350 Foot Meteorological Tower and the U.S. Department of Commerce, NWS Station at Westchester County. These wind data were digitalized and evaluated by New York Services Corporation under contract to Con Edison for the purposes of defining surface air flow patterns within a 10-15-mile range of Indian Point with emphasis on generating refined estimated of southward movements. As completed, ten consecutive months (March 1, 1980 - December 31, 1980) were evaluated and a total of 7,264 eight-hour parcel trajectories were created objectively using appropriate local one-hour wind velocity averages on a real time basis. The results of this study were submitted to Con Edison: Kaplin, Edward J. and B. Wuebber (1981).

For the purpose of this FSAR, second meteorological update, meteorological data have been analyzed and evaluated from the 400 foot (122 Meter) Indian Point Meteorological Tower for the two year period from January 1, 1979 through December 31, 1980.

1.1.2 Tower Siting and Instrumentation

1.1.2.1 Hudson River

There are a number of pertinent facts about the Hudson River itself that are relevant to its ability to induce and/or influence mesoscale flow phenomena that are dominant factors in the Indian Point environs. The most important factor is that it is not a river but, rather a tidal estuary. From New York City, 154-miles north to Troy, there is no drop in the surface elevation of the river. Except for spring runoff from the Andirondacks, which can smother the tide down to Albany, there is almost imperceptible downstream current.

Since there is no slope to the river surface, it will not support its own gravity flow. Any air movement within its canyons during minimal atmospheric pressure gradient periods can be strictly local cells, which may actually block continuous horizontal air movement over the water surface.

Thermally induced air movement of the Atlantic sea breeze follows the natural path of the river. It has been noted, however, that Iona Island 45-miles north of the tip of Manhattan is considered the point of maximum inland intrusion. The northward movement of sea breeze does not proceed up the Hudson River Valley and Hackensack River Valley at the same speed. The inland movement along the Hackensack Valley lags the Hudson Valley movement. The Hackensack River is on the west side of the Hudson and is specifically delineated because its headwaters are just south of the South Mountains and isolated from the Hudson River by the Hook Mountains and the Palisades. The South Mountains are the east-west extension of the Hook Mountains. The South Mountains abut the Ramapo Range and form a sheer wall from the Southern boundary of the west bank community of Haverstraw.

1.1.2.2 General Topography

Each of the reports cited in the Section 1.1.1 describe in some detail general topography in the Indian Point environs. The most recent was provided by Kaplin and Wuebber, 1981. Indian Point is located in the lower Hudson River Valley 27-miles due north of northern boundary of New York City (Manhattan Island).

The Indian Point area has been described by Halitsky, et. al., 1970, as being located roughly on the axis of a north-south valley enclosed by the Dunderberg and Buckberg Mountains to the west and Blue Mountain and Prickly Pear Hill on the east. The shape of the valley at the 200 foot and 400 foot elevation levels are given in Figures 1 and 2. At the 200 foot contour level the valley width is two miles at Dunderberg Mountain and opens southward to a width of five miles at Prickly Pear Hill.

The Hudson River, flowing southward through the valley, resembles a gourd with its curved ¾-mile thick northern neck nestling at the base of Dunderberg Mountain while the bulbous three mile thick body fills the southern part of the valley between South Mountain and Prickly Pear Hill. The Indian Point peninsula lies in the hollow of the curved neck.

Beyond its northern end, the valley is split into two branches by Manitou Mountain. The Hudson River passes through the steep, narrow northwest branch between Manitou and Dunderberg Mountains. The northeast branch, between Manitou and Blue Mountains, is about 1.5-miles wide at Manitou Mountain but degenerates with distance into three tributary valleys containing Annsville Creek, Sprout Brook and Peekskill Hollow Brook with sources in the mountainous region north of Peekskill.

South of Haverstraw Bay, the valley opens up rapidly to the southeast while the west bank of the Hudson River follows the blocking of the east-west orientated South Mountains to assume a southward course along the Hook Mountains to the Palisades Mountains.

At elevations higher than 200 feet the solidity of the eastern wall of the valley breaks, first between Blue Mountain and Prickly Pear Hill to form at 300 feet the irregular drainage system, which supplies Furnace Brook, and then at 400 feet into an irregular array of mountain tops. The western wall is till fairly solid at 300 feet but breaks at 400 feet into two well-defined valleys containing Cedar Pond and Minisceongo Creeks. However, just to the west are Ramapo Mountains whose elevations exceed 1000 feet. Figures 3 and 4 (Kaplin and Wuebber, 1981) show the elevations of significant mountain peaks and water courses in the region of Indian Point.

1.1.2.3 Site Configuration

The location of the specific meteorological towers associated with earlier studies in the Indian Point environs are available in Figure 1 of Kaplin and Laznow (1972), FSAR 3, Supplement 10, 1973 and in Figures 1a and 1d of Kaplin, Kitson and Kozenko (1974).

Table 1 lists the operational periods and the instrumentation associated with each tower. Not included in this listing are those wind monitoring sites that were used for the most recent study (Kaplin and Wuebber 1981, Sec. 2.4 & 2.5). In this study, an 11 site monitoring network was established equipped with Climatronics Mark III, wind speed and direction systems. This network was operable for all or part of the period from March, 1980 through December, 1980.

TABLE 1
TOWER AND INSTRUMENTATION RECORD
(INCLUDES PARAMETERS NOT REQUIRED BY PROPOSED SAFETY GUIDE 1.23)

Meteorological Station	Base Elevation Ft. MSL	Operational Period From	To	Parameter	Instrument	Exposure M. Above Grade
Indian Pt (IP1)	130	1956	1957	Wind	Aerovane	91 & 30
				Temp. Diff.	Honeywell	91-2 & 30-2
USS Jones (J)	0	1956	1957	Wind	Aerovane	21
Indian Pt (IP2)	60	1968	1969	Wind	Climet	30
				Temp. Diff.	Bristol	29 - 1.5
Montrose (MP)	60	1968	6/71	Wind	Climet	30
Bowline Pt (BP)	5	9/68	11/69	Wind	Climet	30
		11/69	8/72	Wind	Aerovane	30
		9/68	11/69	Temp. Diff.	Honeywell	30 - 3
		11/69	2/72	Temp. Diff.	Bristol	30 - 3
		2/72	8/72	Temp. Diff.	Climet-(Rosemont)	30 - 3
Bowline Tower	10	Note 2	Present	Wind	Climatronics	100, 50 & 10
		Note 2	Present	Temp. Diff.	Climatronics	100-10 & 50-10
Trap Rock (TR)	90	1969	7/72	Wind	Climet	30
USS Cape Charles (CC)	0	3/70	9/70	Wind	Aerovane	30
Indian Pt (IP3)	120	11/69	9/76	Wind	Aerovane	30
		11/69	9/76	Wind	Climet	30
		6/73	9/76	Wind	Climet	10
Backup Met System (IP3)		12/81	Present	Wind	Climatronics	10
		11/69	10/71	Temp. Diff.	Honeywell	29 - 2
		8/72	9/76	Temp. Diff.	Climet-(Rosemont)	30-3 & 9-3
		8/72	9/76	Amb. Temp.	Climet-(Rosemont)	9
		8/72	9/76	Dew Point	Climet-(Foxboro)	30,9 & 3
		8/72	9/74	Net Radiation	Teledyne Geotech	9
		5/70	12/70	Turbulence	Bivane*	30

Note 2 - Bowline Tower is located at approximately Latitude 41° 13'N and Longitude 73° 58' W. This location is about 3000 feet NW of the earlier Bowline Point Tower. It began operation in the 1972/73 time period.

* Intermittent usage.

TABLE 1 (Cont'd)

Meteorological Station	Base Elevation Ft. MSL	Operational Period From	To	Parameter	Instrument	Exposure M. Above Grade
Indian Pt (IP4) 122 M. Tower	117	9/73	Present	Wind	Climatronics	122, 38 & 10
		9/73	6/80	Wind	Climatronics	85 - Note 1*
		6/80	Present	Wind	Climatronics	60
		9/73	9/79	Amb. Temp.	EG & G	10
		9/79	Present	Amb. Temp.	Climatronics	10
		9/73	9/79	Dew Pt.	EG & G	122, 61 & 10
		9/79	Present	Dew Pt.	Climatronics	10
		9/73	9/79	Temp. Diff.	EG & G	122-10 & 61-10
		9/79	Present	Temp. Diff.	Climatronics	122-10 & 60-10
		1/74	Present	Net Rad.	Teledyne Geotech	10
		7/80	Present	Precipitation	Climatronics	1
Indian Pt (IP4) ** 10M Tower	117	9/73	7/77	Visual Range	EG & G FSM	10
Emergency Control Center #	135	7/24/80	11/81	Wind	Climatronics	11.8

Note 1* - 85 meter wind speed and wind direction moved from the 85 meter level to the 60 meter level as required by proposed Revision 1 to NRC Safety Guide 1.23.

** Tower and System Removed 07/22/80.
# Tower and System Removed 07/22/80.

2.0 122M METEOROLOGICAL TOWER

2.1.1 Siting

The relative locations of the existing meteorological towers in historic perspective are shown in Figure 5. Specific details of site location are shown in Figure 6.

2.1.2 Instrumentation

2.1.2.1 Sensor Configuration

The sensor configuration and exposure on the existing operational 122M Meteorological Tower are shown in Figures 7 and 8.

2.1.2.2 Instrumentation Specifications

The following specifications apply to specific operational sensors that are a part of the total meteorological support systems at Indian Point.

2.1.2.2.1 Climatronics F460 Wind Speed Transmitter

Accuracy: 0.07 M/S or 1%
Range: 0-56 M/S
Threshold: 0.22 M/S
Distance Constant: 1.5 M

2.1.2.2.2 Climatronics F460 Wind Direction Transmitter

Accuracy: ±2°
Range: 0-540°
Threshold: 0.22 M/S
Distance Constant: 1.5 M
Damping Ratio: 0.4 at 10° initial angle of attack

2.1.2.2.3 Climatronics TS-10 and TS-10WA Motor Aspirated Shields

Shield Effectiveness:	Under radiation intensities of 110 W/m^3 (1.6 $cal/cm^2/min$) radiation error not exceeding 0.1°C
Aspiration Rate:	3 M/S at sensor location

2.1.2.2.4 Climatronics 100087, 100087-3 - Temperature-Delta Temperature (matched thermistor)

Temperature:

Range:	-34 to +50°C
Accuracy:	± 0.2°C
Time Constant:	10 sec. To 63% (in TS-10 Shield)
Linearity:	± 0.2%

Delta Temperature:

Range:	± 10°F
Sensitivity:	0.02°F
Accuracy:	0.1°F or ± 5% of delta-T not to exceed 0.3°F
Response Time:	10 sec. To 63% in TS-10 Shield

2.1.2.2.5 Climatronics DP-10 Dew Probe (YSI Lithium Chloride)

Range:	-40° to 42°C
Accuracy:	± 0.5°C
Response Time:	1°C/min.

2.1.2.2.6 Climatronics 1000971 - Heated Rain - Snow Gauge (Tipping Bucket)

Accuracy:	± 1% up to 3"/hr
Resolution:	0.01"
Size:	8" diameter x 24" height
Conversion Accuracy:	± 0.2%

2.1.2.2.7 Data Collection Systems

Analog:

Wind Systems:	Esterline-Angus Model E1102R - Rectigraph Recorders
	Temperature, Dew Point, Delta Temperature: Tracer Westronics Model M11E, Multipoint
Precipitation:	Esterline-Angus Model MS 401C

Digital:

Climatronics Data Processor:	1MP/801
Tape Collection Interface:	Tandeberg TD1 10-50

2.1.3 <u>Meteorological Support System</u>

The meteorological systems at Indian Point are equipped, maintained and operated in compliance with the specification of NUREG-0654, Appendix 2 (1980); Proposed Revision 1 to NRC Regulatory Guide 1.23 (1980); and applicable regulatory requirements. The total system as presently operated is outlined in Figure 9.

2.2 DATA LOG

2.2.1 <u>Indian Point Tower IP3</u>

Meteorological data from the IP3 Tower were reduced and evaluated (Kaplin and Kitson, 1974) through December 1973. From the period 1974 through September 1976 the tower system was maintained, as previously noted. Analog records were provided to Con Edison for storage. Tower removed from service in September, 1976. (Reactivated as site for Backup Wind System: 12/01/81.)

2.2.2 122 Meter Meteorological Tower (IP4)

The data log for the 122 Meter Meteorological Tower for the period from October 1973 through August 1974 can be found in Kaplin, et. al., 1974. Subsequent to the completion of the above report and the data contained therein, the meteorological analog charts and the data collection magnetic tape were documented and transmitted to Con Edison for storage.

Commencing in August 1977, wind velocity data at the 10 and 122 meter levels and the delta temperatures: 60-10M and 122-10M were reduced to hourly averages and transmitted to Con Edison in addition to the analog charts. The summary of valid data for these parameters for the period from August 1977 - July 1981 is shown in Table 2 on concurrent and total hours basis. The concurrent basis assumes that if any parameter is missing. The total basis relates an individual missing data hour to the total number of possible data hours in a month.

On the concurrent basis, the average valid data collection was 92.4 ± 10.8-percent. On a total hour basis, the average valid data collection was 98.2 ± 2.5.

TABLE 2
VALID DATA LOG*

Month	1977 Concurrent	1977 Total	1978 Concurrent	1978 Total	1979 Concurrent	1979 Total	1980 Concurrent	1980 Total	1981 Concurrent	1981 Total
January	N/A	N/A	89.8	98.2	94.8	99.0	98.4	99.7	99.9	99.9
February	N/A	N/A	92.1	97.4	98.1	99.7	90.5	98.4	67.7	89.2
March	N/A	N/A	95.1	98.9	97.4	99.6	97.3	99.1	98.0	99.3
April	N/A	N/A	98.1	99.6	96.7	99.4	100.0	100.0	100.0	100.0
May	N/A	N/A	95.3	98.6	90.3	98.0	88.4	98.0	100.0	100.0
June	N/A	N/A	86.8	95.6	95.0	99.1	96.7	99.0	100.0	100.0
July	N/A	N/A	94.1	96.8	92.6	98.8	71.1	94.1	99.4	99.8
August	94.2	98.7	95.3	99.2	52.3	92.0	77.7	92.7		
September	84.7	94.4	99.7	99.9	57.5	92.3	98.3	99.7		
October	95.0	98.9	98.1	99.4	94.0	98.2	96.1	99.4		
November	98.9	99.5	98.8	99.6	98.3	99.7	99.6	99.9		
December	75.3	95.5	96.4	99.4	100.0	100.0	98.9	99.8		

Concurrent Average: 92.4 ± 10.8%
Total Parameter Hours: 98.2 ± 2.5%

* Based on six (6) parameters: wind data at 10 and 122M and delta-temperatures: 60-10M and 122-10M
NA - Values not available.

3.0 ANALYSES DATA

3.1 INDIAN POINT TOWER IP3

A FSAR documented study with respect to the Indian Point IP3 Meteorological Tower was prepared by Kaplin and Laznow (1972) [Referenced FSAR 3 Supplement 10, 1973]. This report covered the data collection period through 1971. Additional data were subsequently provided through 1972 to provide composite joint wind velocity frequency distribution for Pasquill Stability Categories (FSAR 3 Supplement 13 and 16, 1973). Kaplin and Kitson (1974) provided an analyses of IP3 for the period March 1973 through December, 1973.

This report confirmed the earlier study that wind data in the Indian Point environs based on monthly diurnal wind distributions, wind frequency distributions and joint wind stability categories are comprised of two "seasons" with little apparent transition. The "winter season" reflects little or no average diurnal variation in the hourly resultant winds, dominant winds from the west to north. The "summer season" is characterized by dominant north-northeast winds during the evening and early morning hours with a sharp transition to south to southwest winds during the day and another transition in late afternoon to the evening pattern.

The wind frequency distributions and joint frequencies as a function of Pasquill Stability Categories were comparable in 1973 with data collected in 1970 and 1971.

It is noted that the temperature gradients on the IP3 Tower were derived from delta-temperatures: 99-7 feet and wind measured at 105 feet above a grade elevation of 120 feet MSL.

Kaplin, et. al., (1974) compared three months (October - December, 1973) of IP3 wind data as measured at 105 feet above grade with concurrent three months of data from the 125 foot level on the 122 Meter Meteorological Tower (IP4) (grade elevation: approximately 117 feet MSL) using a two station wind correlation program (Appendix B, Kaplin, et. al, 1974).

Figures 10A and 10B show the relationships obtained for October and December, 1973. The November results were similar with the directional relationships falling between that obtained for October and December. The maximum variations between the two sites occurred with winds from E-ESE and SW to WSW. These corresponded to sectors of minimum average wind speeds. Deviations between the two sites can be attributed to local factors including terrain elevation, land use and ground cover.

The wind direction displacement effects found in the two station correlations were confirmed in the monthly diurnal analyses.

3.2 122M METEOROLOGICAL TOWER (IP4)

3.2.1 October 1, 1973 to August 31, 1974

The purpose of the 122M Meteorological Tower at Indian Point (IP4) was to develop a three dimensional micro-climatological data file to be used to assess the impact of proposed cooling towers and to provide the basis for design criteria as required. The results of one year of operation of this tower were presented in a final report (with Appendices) by Kaplin, et. al., 1974.

Except as noted in the previous section, the meteorological data collected and evaluated were not compared at the time of this study with historical meteorological data associated with FSAR 2.

This study determined that the two distinctive seasonal patterns existed at each of the four levels of wind velocity measurement: 10M, 38M, 85M and 122M. Wind directions tended to back with elevation assuming an orientation parallel to general terrain contours.

In times of weak synoptic pressure gradient patterns, there were abrupt transitions in the diurnal flow patterns consistent with valley flow winds particularly during the summer season. These transitions began at the surface and progressed up to the 122M level.

TABLE 3
COMPARISON OF ANNUAL PERCENT
OCCURRENCE OF STABILITY CATEGORIES

			Stability Category						
Year	Tower	Gradient (M)	A	B	C	D	E	F	G
1970	IP3	29 - 3	21.68	2.20	3.39	33.35	24.75	9.01	5.62
1971	IP3	29 - 3	19.17	2.75	2.97	22.74	30.87	11.69	9.75
1970-72	IP3	29 - 3	16.25	1.82	2.95	29.71	26.61	13.27	9.45
1970-72*	IP3	29 - 3	6.76	2.67	2.13	32.65	40.57	11.78	3.31
1973	IP3	29 - 3	23.14	3.16	3.70	20.87	25.02	13.89	10.23
1973-74	122M-IP4	60 - 10	10.35	3.21	2.94	25.38	44.86	11.35	1.91
1979	122M-IP4	60 - 10	12.27	3.25	3.86	29.30	40.39	8.83	1.31
1980	122M-IP4	60 - 10	13.32	4.06	4.60	29.81	33.97	11.34	2.07
1979-80	122M-IP4	60 - 10	12.80	3.66	4.23	29.56	37.17	10.08	1.69

* Temperature difference corrected by a factor of 0.605; (FSAR 3, Supplement 16, April 1973)

The morning transition during the summer season was sharply defined. At 0800 EST all levels had approximately the same resultant wind direction. The evening transition began just after 1800 EST and was sharply defined a the 10M and 38M levels. The 10M level reached its nocturnal northeast drainage wind by 2100 EST along with the somewhat more erradic 38M level. The 85M and 122M levels rotated systematically and did not reach their nocturnal directions (NNE-N) until 0200 EST. The systematic rotations are referenced to the average diurnal distributions on a real time basis, the upper wind levels could be "disconnected" from the lower wind levels with an intermediate shear zone generated by winds up to 180° out of phase.

The resultant winds of the 122M Tower (IP4) associated with the diurnal variation curves for the summer season, veered after the morning transition until about noontime, then steadied out at SW-WSW before backing into the nocturnal pattern after the evening transition. The resultant summer season winds for the IP3 Tower (Kaplin and Laznow, 1972) in 1970 and 1971 veered throughout the entire day. In Kaplin and Kitson (1974), the summer IP3 diurnal resultant winds exhibited the veering - backing trait. Kaplin and Laznow (1972) indicated that the question of backing or veering was related, on any given day, not only to strength of the valley drainage flow wind but also to relative strength of local land-sea circulations.

On an annual basis there were no significant differences between the percent frequency distribution of occurrences of stability categories (Pasquill) between the adjusted composite year 1970-1972 for IP3 (FSAR 3, Supplement 16, April 1973) and lower temperature gradient level on the 122M Tower (IP4). These comparisons are shown in Table 3. It is presumed that if all individual years of IP3 data were similarly adjusted prior to classification, they would also be reasonably comparable to results based on the temperature gradient 60-10M on the 122M Tower.

3.2.2 August 1, 1978 - July 31, 1979

Wind velocity data (10M level) from the 122M Meterological Tower at Indian Point and the Orange and Rockland Utilities, Inc. 100M Meteorological Tower were used to evaluate the path of air parcels in the Indian Point environs without considering stability (Kaplin and Wuebber, 1979 and Kaplin, 1979).

Each hour a parcel movement was initialized from Indian Point. Each parcel was projected forward for eight consecutive hours in hourly increments. The average wind velocity at 10M level of the 122M Tower was used to determine the speed and direction of the parcel for its initial hour increment. Subsequent movement of each parcel was determined by the location of the parcel after the initial hour on a zone of influence file that assigned a wind vector to that location: Indian Point or Bowline.

Prior to usage the wind velocity for selected 1978-1979 data were assessed by comparison with historical data files (1973-1974) at Indian Point. There were no variations that could not be accounted for by climatological variations of at least synoptic scale when assessed with reference to U.S. Department of Commerce, NOAA, EDS, LOCAL CLIMATOLOGICAL DATA for LA GUARDIA AIRPORT, NEW YORK and SIKORSKY AIRPORT, Bridgeport, CONNECTICUT.

In considering persistent southward movement of an air parcel from Indian Point assuming that Bowline would be representative of air movement south of Grassy Point, an examination of resultant winds for August 1978 and January, 1979 (typical "summer"

and "winter" seasons) indicated that such movements did not occur. While concurrent hourly average north winds were found 14 times in August and 17 times in January, these occurrences represent only 13.3-percent and 16.5-percent of all north winds relative to all north winds at Bowline. These results were anticipated, particularly during periods of light winds and weak synoptic pressure fields, from the opposing patterns of the diurnal variation curves for the two monitoring sites.

3.2.2.1 Surface Air Trajectories Analyses - Summary

Trajectory end points were derived on an objective basis using surface wind data from monitoring stations. The use of observed wind data appropriate to the moving air parcel's location at a given time is important since these data inherently account for local wind pattern aberrations that may be of topographic and/or unique micro-meteorological origin. No individual atmospheric stability category was explicitly considered.

The ability of the derived trajectories to generate realistic movement patterns is contingent on having sufficient wind monitoring sites to define the actual wind flow field in and around the area of interest on a concurrent real time basis.

The area of interest was limited to ten miles south of Indian Point. For practical purposes the study area was 21 x 21 square miles subdivided in a one mile grid as shown in Figure 11. Indian Point was located near the top center of the area at grid point 10, 16. This allowed for 15-miles of due south movement. The South, Hi Tor and Hook Mountains are emphasized because of the barrier that they form for air movement due south of Indian Point.

Trajectories were generated for each of the 12 months in the data file based on Indian Point and Bowline wind data. These were the only available data applicable to the study area. Trajectories were created for up to eight consecutive hours of movement.

For the first hour of the trajectory, Indian Point was used as the origin of an air parcel, which would travel a distance and in a direction determined by the hourly average wind velocity at the 33' (10M) level of the Meteorological Tower. Subsequent movement depended on the location of the trajectory end point after the first hour's movement. Zones for which the Bowline and Indian Point wind velocity measurements were considered as representative had been previously assigned. Trajectories for each hour of the month were computed. The end points were accumulated as summations of occurrences in their appropriate grid squares. In the process of generation, all end points were moved and accumulated whether or not they were in the 21 x 21-mile square. Only those end points within the study area boundary appear on tabular printouts. In any given period, an end point could pass out of the grid and move back in at a subsequent time interval.

For August, 1978, and January, 1979, two different patterns of weather station representative areas were used as shown in Figure 12. Pattern 1, which was used for all 12 months of data, had Bowline winds dominating after passage of a line three miles south of Indian Point (through Grassy Point). Pattern 2, used for August and January only, moved this line one mile further north (through Stony Point). The influence patterns are the same for the first hour's movement.

A summary of the August, 1978 and January, 1979, results in terms of percent of total possible trajectory end points remaining in the 21 x 21-mile area for selected trajectory time periods is shown in Table 4.

TABLE 4
SUMMARY OF TRAJECTORY END-POINTS

	August, 1978		January, 1979	
Pattern I	No. of Occur.	% Total	No. of Occur.	% Total
Hour 1	722 (729)	99.0	707 (721)	98.1
Hour 2	617 (728)	84.8	486 (720)	67.5
Hour 4	420 (726)	57.9	225 (718)	31.3
Hour 6	312 (724)	43.1	157 (716)	21.9
Hour 8	206 (722)	28.5	113 (714)	15.8
Pattern II				
Hour 1	722 (729)	99.0	707 (721)	98.1
Hour 2	595 (728)	81.7	486 (720)	67.5
Hour 4	414 (726)	57.0	226 (718)	31.5
Hour 6	308 (724)	42.5	157 (716)	21.9
Hour 8	207 (722)	28.7	115 (714)	16.1

( ) =Total number of trajectories generated.

The actual number of points within the grid network does not differentiate between those points that have never left the network and those that have recirculated. This feature takes on added importance if total distance of travel is a consideration.

Summaries of occurrences within designated grid sectors are shown in Table 5 for August, 1978 and Table 6 for January, 1979. In terms of totals in the grid area, there is no significant effect of influence pattern assignment. This effect does show up in Tables 5 and 6 when the occurrences south of Indian Point are totaled. For this purpose, a SW sector is defined encompassing the area below Indian Point from the grid edge to ordinate Line 9. The S sector extends one mile south of Indian Point along ordinate

TABLE 5
SUMMATION OF TRAJECTORY END POINTS
AUGUST, 1978
SECTOR KEY

17-21	NW	N	NE
16	W	I.P.	E
1-15	SW	S	SE
	1-9	10	11-21

					% TOTAL
HR 1		35	164	133	46.0
		26	8	15	6.8
		232	84	25	47.2
	% TOTAL	40.6	35.4	24.0	99.0

	PATTERN 1					PATTERN 2			
				% TOTAL					% TOTAL
	52	93	109	41.2		52	93	109	42.7
HR 2	20	10	7	6.0		18	10	7	5.9
	192	51	83	52.8		148	50	108	51.4
% TOTAL:	42.8	25.0	32.2	84.8	% TOTAL	36.6	25.7	37.6	81.7
				% TOTAL					% TOTAL
	43	38	40	28.8		44	38	36	28.5
HR 4	7	2	2	2.6		7	1	2	24.4
	128	27	133	68.6		111	29	146	69.1
% TOTAL:	42.3	16.0	41.7	57.9	% TOTAL	39.1	16.4	44.4	57.0
				% TOTAL					% TOTAL
	33	19	18	22.4		30	19	19	22.1
HR 6	7	0	1	2.6		6	0	1	2.3
	100	10	124	75.0		86	17	130	75.6
% TOTAL:	44.9	9.3	45.8	43.1	% TOTAL	39.6	11.7	48.7	42.5
				% TOTAL					% TOTAL
	28	6	4	18.4		28	6	4	18.4
HR 8	3	0	1	1.9		3	1	1	2.4
	67	7	90	79.6		53	15	96	79.2
% TOTAL:	47.6	6.3	46.1	28.5	% TOTAL	40.6	10.6	48.8	28.7

TABLE 6
SUMMATION OF TRAJECTORY END POINTS
JANUARY, 1979
SECTOR KEY

17-21	NW	N	NE
16	W	I.P.	E
1-15	SW	S	SE
	1-9	10	11-21

					% TOTAL
HR 1		25	52	86	23.1
		10	10	27	6.7
		154	72	271	70.3
	% TOTAL	26.7	19.0	54.3	98.1

	PATTERN 1					PATTERN 2			
				% TOTAL					% TOTAL
	22	21	58	20.8		24	21	56	20.8
HR 2	14	5	16	7.2		12	5	16	6.8
	133	41	176	72.0		100	45	207	72.4
% TOTAL:	34.8	13.8	51.4	67.5	% TOTAL	28.0	14.6	57.4	67.5
				% TOTAL					% TOTAL
	17	4	19	17.7		14	4	21	17.3
HR 4	7	0	3	4.4		7	0	3	4.4
	67	16	92	77.8		57	14	106	78.3
% TOTAL:	40.4	8.9	50.7	31.3	% TOTAL	34.5	8.0	57.4	31.5
				% TOTAL					% TOTAL
	16	2	7	15.9		15	2	8	15.9
HR 6	2	1	0	3.2		2	1	0	1.9
	46	8	73	80.9		39	8	82	82.1
% TOTAL:	40.8	7.0	51.0	21.9	% TOTAL	35.7	7.0	57.3	21.9
				% TOTAL					% TOTAL
	9	1	4	12.4		6	0	4	8.7
HR 8	3	1	0	3.5		3	1	0	3.5
	34	10	51	84.1		29	9	63	87.8
% TOTAL:	40.7	10.6	48.7	15.8	% TOTAL	33.0	8.7	58.3	16.1

Line 10 to the grid base. The SE sector comprises the remaining area to the east of the S line and below Indian Point. These results are summarized below in terms of number of occurrences and percentage of total possible observations:

TABLE 7
SUMMATION TRAJECTORY OCCURRENCES
SOUTH OF INDIAN POINT

August, 1978

	Pattern 1						Pattern 2					
	Southwest		South		Southeast		Southwest		South		Southeast	
	Occur	%	Occur	%	Occur	%	Occur	%	Occur	%	Occur	%
Hour 1	232	31.8	84	11.5	25	3.4	232	31.8	84	11.5	25	3.4
Hour 2	192	26.4	51	7.0	83	11.4	148	20.3	50	6.9	108	14.8
Hour 4	128	17.6	27	3.7	133	18.3	111	15.3	29	4.0	146	20.1
Hour 6	100	13.8	10	1.4	124	17.1	86	11.9	17	2.3	130	18.0
Hour 8	67	9.3	7	1.0	90	12.5	53	7.3	15	2.1	96	13.3

JANUARY, 1979

Hour 1	154	21.4	72	10.0	271	37.6	154	21.4	72	10.0	271	37.6
Hour 2	133	18.5	41	5.7	176	24.4	100	13.9	45	6.3	207	28.8
Hour 4	67	9.3	16	2.2	92	12.8	57	7.9	14	1.9	106	14.8
Hour 6	46	6.4	8	1.1	73	10.2	39	5.4	8	1.1	82	11.5
Hour 8	34	4.8	10	1.4	51	7.1	29	4.1	9	1.3	63	8.8

The effect of the pattern change is not so much as to alter the total; rather, it is to shift the number of occurrences from the SW sector to the S and SE sectors. There are anomalies found that may be associated with recirculation.

After five miles of southward movement from Indian Point, the results seem to indicate the anomaly of surface wind impaction against the South Mountain and High Tor Ridges. This anomaly occurred since there were no local wind measurements available to induce deflections.

Historical studies have shown such deflections do exist. The present results cannot account for terrain unless the trajectory paths are deflected by observed surface winds. This requires a larger monitoring network, strategically placed, than was available. This need for further definition of local wind field is confirmed by the differences that appear in the results generated by Patterns 1 and 2.

At the present time, based on historical studies, Pattern 2 is probably the better representation of local trajectories for the available data.

Assuming a continuous 1 M/S wind speed (2.2 MPH), the number of occurrences in the south sector represent those parcels that have traveled with the effective speed (neglecting recirculation). Of the totals given, only four have traveled greater than ten miles for August (1); five for August (2); six for January (2); six of January (1); and three for January (2). These points would have to had passed through or over the South, High Tor and Hook Mountain Ridge lines.

3.2.3 March 1980 - December 1980

3.2.3.1 General

The results of the Trajectory II Study conducted by York Services Corporation for Con Edison have been recently submitted (Kaplin and Wuebber, 1981).

It was concluded from the initial trajectory study (Kaplin and Wuebber, 1980; Kaplin, 1980) that a lack of directional persistence of low speed surface winds (10M) at Indian Point and Bowline make recirculation of local air probable. There were indications of both convergence and divergence of local air streams. Objectivity created surface air parcel trajectories generated anomalies by passing over or through abrupt terrain features. The two local monitoring sites available were unable to resolve these anomalies.

In the Trajectory II Study, a supplemental network of ten surface wind monitoring stations were established for the express purpose of objectively assessing the southward movement of air parcels from Indian Point (see Figures 3 and 4). Sites were selected, specifically, in an attempt to resolve anomalous flow patterns with respect to terrain and tributary river drainage basins. A listing of sites used is shown in Table 8. A listing of valid data collected for the period is shown in Table 9.

3.2.3.2 Wind Frequency Distributions

An historical evaluation of the representativeness of the data collected in 1980 was made for Indian Point and Bowline. Variations in wind frequency distributions were found to be associated with climatological variations on the synoptic-cyclonic scale.

These variations can be naturally expected between any given year or set of years. For example: Over a 20 year period (1960-1979) prior to 1980 Bridgeport, WBAS, for the month of July had an average wind directional frequency for a north wind of 6.5 $\pm$ 2.7-percent with an absolute maximum of 12.9-percent in 1974 and an absolute minimum of 3.0-percent in 1979. In 1980, the frequency set a new low of 2.8-percent. A further extreme example was found at La Guardia WBAS. Based on an eight year average (1972-1979) the northwest wind has a frequency of 12.2 $\pm$ 4.2-percent with minimum of 6.1-percent (1973) and a maximum of 16.5 (1974). In 1980, a new maximum of 18.2-percent was observed while in 1979, the frequency was 7.9-percent, which was the second lowest value in the period.

It was noted that the climatic variations of wind frequencies at Indian Point were generally minimal and less pronounced. This was attributed to topographic confinement. The wind frequency data for Indian Point and Bowline for the data collection period were adjudged to be representative (Figures 6.1-6.4, Kaplin and Wuebber, 1981). It was assumed that all concurrently collected wind velocities were representative of respective monitoring sites and relationships between sites could be evaluated.

It was found that wind frequency distribution patterns in themselves were deceptive representations of the continuity of air movement in the lower Hudson River valley unless there was an understanding of the patterns of wind velocity variations on a temporal basis.

TABLE 8
LOCATIONS OF STATIONS RELATIVE TO INDIAN POINT

Station	Distance (miles) from Indian Point	Direction (degrees)
Iona Island	2.50	334
Annsville	2.20	020
Watch Hill Road	3.15	132
Jurka	6.65	122
Croton Point	6.40	155
Ossining	8.80	151
Grassy Point	3.20	191
Bowline Point	4.15	190
South Nyack	13.60	174
Piermont	15.95	173
Kingsland	13.00	163
Eastview	11.90	145
Westchester County Airport	20.00	135

TABLE 9
YORK SERVICES CORPORATION
ONE RESEARCH DRIVE, STAMFORD, CT
CLIENT: CONSOLIDATED EDISON OF NEW YORK
VALID DATA FOR TRAJECTORY WIND SITES
PERIOD OF RECORD: 1980

SITE	PERCENT VALID DATA									
	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPT	OCT	NOV	DEC
01-Piermont	79.23	78.75	63.71	66.67	100.00	100.00	71.25	37.10	0.00	0.00
02-Ossining	98.59	100.00	100.00	100.00	100.00	99.80	99.93	96.77	100.00	100.00
03-Iona Island	96.77	53.75	85.28	69.72	53.76	95.63	100.00	99.46	100.00	82.80
04-Jurka/Grassy	78.76	55.97	0.00	0.00	0.00	0.00	0.00	81.85	100.00	84.95
05-Kingsland	87.57	94.65	17.47	59.79	98.66	100.00	100.00	100.00	74.03	93.55
06-Watch Hill	74.46	0.00	0.00	0.00	48.79	70.56	100.00	85.48	100.00	100.00
07-South Nyack	79.17	100.00	83.87	100.00	100.00	100.00	100.00	100.00	100.00	100.00
08-Annsville	100.00	100.00	90.86	100.00	77.28	100.00	71.81	98.92	100.00	100.00
09-Eastview	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
10-Croton Point	99.73	100.00	89.85	100.00	98.12	96.77	81.39	47.04	100.00	36.96
11-West Cty Apt	99.87	100.00	100.00	99.86	100.00	100.00	100.00	100.00	100.00	100.00
12-Indian Point	99.66	100.00	94.82	99.24	95.41	94.69	99.17	99.93	100.00	99.46
13-Bowline Point	72.45	99.72	98.91	85.97	92.41	98.52	96.53	96.98	96.46	86.16

3.2.3.3 Diurnal Wind Distributions

The diurnal variation curves for Indian Point and Bowline for the data collection period (March through December 1980) were found to be historically representative. For selected winter and summer months, they demonstrated all the attributes of the two "season" characteristics (Figure 6.21-6.27, Kaplin and Wuebber, 1981).

With some variation at selected monitoring sites, it was found that the diurnal wind distributions were not only seasonally characteristic but characteristic of the monitoring site locations. They could, almost without exception, be uniquely categorized as Hudson River "west bank"; Hudson River "east bank"; or "inland" (Figures 6.28-6.33, Kaplin and Wuebber, 1981).

The characteristics of this uniqueness were examined by combining all appropriate sites to generate "average" east and west bank diurnal wind distributions (Figures 6-38-6.42, Kaplin and Wuebber, 1981). The average diurnal curves for March, June and December, 1980 are shown in Figures 13, 14, and 15. A computer check revealed that individual days at any given site could be found that had observed 24 hour diurnal wind variation patterns that matched their own monthly average distributions and/or the appropriate east or west bank average diurnal distribution based on the criteria 16 or more hours of fit $\pm$ 45° (not necessarily consecutive).

While there are unique common characteristics to the diurnal wind distribution patterns in the Indian Point environs, variations in local meso-scale factors dictate that the ultimate path of an air parcel whose movement is determined by surface (10M level) wind velocities is governed by time of departure as well as point of departure. Between wind velocity monitoring sites in the region, persistent wind direction and wind speeds are not supported. This is most obvious during the "summer" season or at any time that the area is under the influence of a weak synoptic-cyclonic pressure gradient pattern. Between individual monitoring sites there is apparent divergence and convergence of surface air.

3.2.3.4 Resultant and Concurrent Hourly Winds

A first approach at the evaluation of southward movement of air for prolonged periods of time was made for the data collection period March 1, 1980 through December 31, 1980, by examining the frequency distribution of the 24 hour resultant winds (Kaplin and Wuebber, 1981). These results are shown in Table 10 as a function of persistence category (the ratio of the resultant to arithmetic average wind speeds). At persistence levels greater than 0.9, a north wind was found in only four out of 273 possible valid cases (1.4%). The average wind speed 2.75 M/S. The high wind speeds associated with all northerly winds implies strong synoptic-cyclonic scale pressure gradient systems are the generating mechanism.

Simple liner relationships between high persistent, 24-hour resultant winds between Indian Point and Piermont (bearing 173° about 16-miles from Indian Point) showed that an average 24-hour resultant wind direction of 012 $\pm$ 22° at Indian Point was related to an average 24-hour resultant wind at Piermont of 359 $\pm$ 24°. At the same time, for corresponding cases, the average resultant wind speed at Indian Point was about 2.5 $\pm$ 0.9 M/S and the concurrent average resultant wind speed at Piermont was 5.6 $\pm$ 1.2 M/S. The angular offset implies terrain tracking and high average resultant wind speeds indicate the necessity for a strong pressure gradient field.

Such replacements were also implied when concurrent hourly average wind data from the selected monitoring sites were correlated to Piermont. These results are shown in Table 11 for the available concurrent data collected during the period from March 1, 1980 through October 31, 1980. Out of 4,394 valid data hours, there were only 56 (1.3%) in which Indian Point and Piermont had concurrent winds from the north (350-011°). Almost half of these cases (26:0.59%) occurred in May, 1980. There was only one such hour out of 742 valid data hours in July, 1980. For July, in fact, for 3,355 concurrent data hours from five southern sites there was only one additional hour in which a site, South Nyack, had a north wind direction concurrent with Piermont.

TABLE 10
FREQUENCY DISTRIBUTION OF 24 HOUR RESULTANT WIND DIRECTIONS
INDIAN POINT (10 METER LEVEL)

Resultant Wind Direction	No. Obs.	Persistence > 0.9 Aver. SPDS (MPH) Result.	Mean	No. Obs.	Persistence > 0.8 <0.9 Aver. SPDS (MPH) Result.	Mean	No. Obs.
350-011	4	5.75	6.15	6	4.87	5.62	2
012-034	20	4.97	5.22	6	4.05	4.67	4
035-056	13	4.81	4.98	8	3.56	4.04	1
057-079	5	4.06	4.24	2	2.70	3.15	2
080-101	0			0			1
102-124	0			0			0
125-146	0			0			0
147-169	0			0			1
170-191	2	2.90	3.10	1	3.20	3.70	0
192-214	10	3.38	3.53	5	2.38	2.76	5
215-238	3	4.07	4.23	7	2.69	3.11	1
237-259	0			3	4.40	5.27	2
260-281	0			1	2.40	3.00	2
282-304	0			3	3.03	3.70	1
305-326	6	4.17	4.48	4	5.15	6.00	3
327-349	13	7.82	8.22	8	4.64	5.40	7
	76			54			31
Percent:	25.94			18.43			10.58

Number of Valid 24-hour Resultants (>17 hours): 293
Percent Valid Data: 97.39

TABLE 11
SUMMARY OF TWO-STATION WIND CORRELATIONS PIERMONT (SITE 1) REFERENCED TO SELECTED MONITORING LOCATIONS (SITE 2)

Month	Station (Site 2)	Total	Number of Observations: North Winds: Piermont	Number of Observations: North Winds: Site 2	Concurrent Winds: All Directions	Concurrent Winds: North	North Wind at Piermont, Resultant Wind @ Site 2: Direct.	North Wind at Piermont, Resultant Wind @ Site 2: Speed (mph)	North Wind at Piermont, Resultant Wind @ Site 2: Persist.	North Wind at Site 2, Resultant Wind @ Piermont: Direct.	North Wind at Site 2, Resultant Wind @ Piermont: Speed (mph)	North Wind at Site 2, Resultant Wind @ Piermont: Persist.
March	South Nyack	588	83	33	70	10	331	3.3	0.90	025	8.5	0.
	Kingsland	481	71	74	133	39	004	6.7	0.96	001	9.2	0.
	Ossining	586	83	25	31	4	327	3.8	0.92	023	7.5	0.
	Iona Island	565	76	16	65	3	327	5.0	0.73	042	9.4	0.
	Indian Point	589	83	67	137	7	035	4.2	0.89	334	9.3	0.
April	South Nyack	567	50	25	63	6	346	1.9	0.65	025	6.6	0.
	Kingsland	490	39	68	145	13	008	3.2	0.79	018	8.1	0.
	Ossining	567	50	28	45	2	316	2.6	0.85	030	8.8	0.
	Iona Island	354	30	21	26	2	308	4.5	0.73	043	11.0	0.
	Indian Point	567	50	58	129	6	020	2.4	0.64	340	8.5	0.
May	South Nyack	359	46	20	33	2	327	3.7	0.84	032	6.8	0.
	Kingsland	67	2	2	9	0	256*	2.1*	0.98*	031*	10.0*	1.
	Ossining	474	68	37	28	4	309	6.4	0.85	036	9.9	0.
	Iona Island	415	66	22	20	2	301	7.3	0.89	052	6.6	0.
	Indian Point	422	50	58	91	26	350	3.5	0.79	356	10.1	0.
June	South Nyack	480	17	19	57	2	332	4.0	0.92	036	8.2	0.
	Kingsland	284	5	2	30	1	301*	5.6*	0.95*	031*	5.4*	0.
	Ossining	480	17	16	41	0	318	7.3	0.90	046	6.7	0.
	Iona Island	368	12	8	16	0	301	8.5	0.88	062*	9.1*	0.
	Indian Point	475	17	28	80	4	326	3.1	0.73	006	5.6	0.
July	South Nyack	744	10	25	114	1	332	2.7	0.92	041	7.9	0.
	Kingsland	724	10	25	98	0	337	2.3	0.55	052	5.7	0.
	Ossining	744	10	37	66	0	326	4.5	0.79	047	6.8	0.
	Iona Island	401	5	9	45	0	302*	10.0*	0.95*	054*	5.7*	0.
	Indian Point	742	10	35	108	1	007	2.3	0.64	358	4.7	0.

* Less than 10 valid data points

TABLE 11 (Cont'd)

SUMMARY OF TWO-STATION WIND CORRELATIONS PIERMONT (SITE 1) REFERENCED TO SELECTED MONITORING LOCATIONS (SITE 2)

Month	Station (Site 2)	Total	Number of Observations: North Winds Piermont	North Winds Site 2	Concurrent Winds All Directions	Concurrent Winds North	North Wind at Piermont, Resultant Wind @ Site 2: Direct.	Speed (mph)	Persist.	North Wind at Site 2, Resultant Wind @ Piermont: Direct.	Speed (mph)	Persist.
Aug.	South Nyack	744	24	44	95	1	334	3.0	0.75	058	11.9	0.95
	Kingsland	744	24	52	93	1	313	4.8	0.74	054	11.7	0.92
	Ossining	741	24	58	96	2	336	6.9	0.84	047	10.5	0.87
	Iona Island	679	24	15	80	0	308	4.9	0.66	036	9.8	0.80
	Indian Point	719	24	32	139	3	037	2.5	0.70	332	5.2	0.73
Sept.	South Nyack	513	37	36	63	10	348	2.5	0.88	018	12.6	0.91
	Kingsland	513	37	22	42	3	345	4.6	0.79	026	9.6	0.90
	Ossining	512	36	36	87	9	354	5.0	0.86	010	9.4	0.84
	Iona Island	513	37	10	34	3	322	4.8	0.76	024	11.7	0.91
	Indian Point	501	37	38	102	4	031	3.4	0.83	339	7.2	0.85
Oct.	South Nyack	379	24	28	83	5	335	2.8	0.91	019	10.7	0.92
	Kingsland	379	24	25	64	5	018	3.0	0.73	019	11.4	0.96
	Ossining	379	24	31	69	4	007	4.0	0.85	016	11.8	0.95
	Iona Island	379	24	12	38	3	291	2.8	0.77	016	12.9	0.99
	Indian Point	379	24	24	89	5	031	2.9	0.95	009	7.5	0.86

Table 11 can be summarized in terms of the valid wind direction data from the five designated sites concurrent with wind directions at Piermont (Note: The data from these sites should not be presumed concurrent with each other simultaneously). This summary is shown in Table 12.

TABLE 12
CONCURRENCE OF TWO-STATION WIND DIRECTIONS
(Relative to Piermont)

	5 Site Total Concurrent Data	% Valid 6 Site Basis	Percent (Concurrent Data Basis) All Directions	Percent (Concurrent Data Basis) North Wind
March	2809	62.93	15.52	2.24
April	2545	58.91	16.03	1.14
May	1737	38.91	10.42	1.96
June	2087	48.31	10.73	0.34
July	3355	75.16	12.85	0.06
August	3627	81.25	13.87	0.19
September	2552	59.07	12.85	1.14
October	1895	42.45	18.10	1.16

Since these data are derived from hourly average wind directions, it is again shown that there is little likelihood of sustaining south bound movement of air from Indian Point beyond 15-miles.

3.2.3.5 Summary-Trajectory II Study

A modified version of the generic model TRAJECTORY (Kaplin and Wuebber, 1980) was used as a basis of a study, which involved the use of concurrent hourly average wind data from a network of 13-14 monitoring stations within 20-miles of Indian Point. All but four sites were located on the Hudson River shorelines. Only two sites were used to the north of Indian Point. As with the original study (Kaplin and Wuebber, 1980), emphasis was on the objective creation of the trajectories of air parcels originating hourly at Indian Point with a speed and direction equal to the average wind at the 10 meter level of Indian Point 122 Meter Meteorological Tower.

In the Trajectory II Study (Kaplin and Wuebber, 1981), each parcel of air was tracked for eight consecutive hours after its movement was initiated as dictated by two factors: The movement time interval and the wind velocity at the coordinate end point of the parcel at the end of movement time interval. As in the earlier study a 21 by 21-mile grid pattern of one mile squares was used to generate tabulations of the trajectory segment end-points. While the tabulations assumed each point to be located in the center of each square, the actual coordinates within the squares were used as a starting point for the next hourly trajectory segment. Subsequent movement of a parcel from a given set of coordinates was determined by the appropriate average hourly wind velocity assigned to grid square as determined by a "zone of influence" file. While trajectories were objectively created, the zone of influence file required the subjective assignment of each available wind velocity monitoring site to specific grid squares. The wind velocity for any given hour within these assigned grid squares would be the same as that of the specified control monitoring site.

Influence assignments were based on assessments of local wind patterns (historical and present) with some consideration for obvious meso-scale modification factors: topographic channeling, drainage flow patterns, thermally induced flow patterns, etc.

For the purpose of the study, all movements of parcels past the grid boundaries were assumed to continue their movements under the influence of the site whose wind was being used at the time that a boundary was crossed.

When only a few wind monitoring sites are available to cover a large area, movement controlled solely by a single site's non-variant hourly average wind was not a critical factor. As the number of monitoring sites increased and zones of influence became smaller, discrete movement based on a single wind in a given hour increment would allow a parcel to move through a zone of influence without modification of its controlling wind, which could be substantially different in direction and speed than that associated with the by-passed zone. In the TRAJ3 model, as used in this study, parcel end point coordinates at the end of each hour, which had been previously determined by the non-variant wind at the parcel source at the beginning of each hour, were the resultant of 30 discrete movements (two minute intervals) within the hour interval. On this basis, a wind speed of 30 mph was required in order for a parcel to travel with a non-variant wind for more than one mile. A discrete wind velocity was reassigned to a parcel according to its coordinates (zone of influence) at the end of each two minute intervals. In effect, a parcel could, in extreme, alter its direction and speed 30 times in a given hour and not apparently move at all if it were trying to move from one zone of influence to another at a boundary line between zones and the wind in the two zones were in opposition. Such apparent anomalies were found as a matter of routine.

Figure 16 shows the grid system that was used in the Trajectory 2 Study, Indian Point was located at coordinates 7,17. In the development of the trajectories recirculation was allowed. This is a parcel could leave the grid boundaries and be brought back onto the grid at a later time if dictated by a change in the wind at the monitoring site controlling its movement.

In the first hour of movement for the ten months of data, only 390 parcels out of 7,344 (5.3) left the grid system and did not return. Of these 345 (4.7%) were crossings of the northern grid boundary, 40 (0.5%) were crossings of the western grid boundary and 5 (0.1%) were crossings of the southern grid boundary. There were no crossings of the eastern grid boundary. Of the five points crossing the southern boundary, all occurred in December, 1980. To cross the southern boundary a minimum speed of 7.6 M/S (17 mph) was required.

During the ten months (206 days) of record there were only 35 days (11.4%) in which there are <u>no</u> rotation and/or recirculation (flow reversal) characteristics in at least one of the 24 trajectories created daily. This does not take into account any trajectories that may have experienced reversals wholly outside of the grid area.

If flow reversals and rotational trajectories were due solely to synoptic scale meteorological patterns, then randomness would be expected in the starting time occurrence frequency as a diurnal function. The actual pattern observed for those eight hour trajectories, which contained at least one on grid or on-off-on grid flow reversal is shown in Table 13. These results include those reversals of synoptic origin and can be interpreted as consistent with the local average diurnal wind patterns induced by meso-scale phenomena when the following factors are taken into account:

- Nocturnal flow patterns generally north to south with minimal with speeds
- Afternoon flow patterns generally south to north with maximum wind speeds

Summaries of the trajectory end-point counts and percentages are shown on a monthly basis in Tables 14 and 15 for selected time increments up to the complete eight hour trajectory. The idealized valley is shown in Figure 16. It is noted that the idealized valley contains 64 out of 441 (14.5%) possible grid box end-point coordinates: ten grid boxes are north of Indian Point; and 54 are on a line with Indian Point and south. With respect to total grid, 84 boxes are to the north and 357 are to the south.

The effect of dominant meso-scale factors are readily discernible in the results. Differences in north and south boundary crossings of trajectory points can be related to the normal seasonal distribution of local wind velocities as well as their diurnal distribution patterns. During the summer season it would take up to six hours of persistent north sector winds from Indian Point to Piermont to generate a south boundary crossing. Such a persistent diurnal time span is improbable. After eight hours, only 6.7 percent of all possible trajectory end-points for all time intervals in July 1980 (5,924 possible) were found to cross the southern boundary (a distance of 17-miles from Indian Point). The highest crossing percentage, 30.7 percent of 5,924 possible, occurred in December, 1980.

TABLE 13
Diurnal Distribution of Occurrences of
Eight-Hour Trajectories with On Grid Reversals

Starting Hour	End Hour	Number of Trajectory with Flow Reversals										
		Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
0100	0900	7	9	13	13	14	9	13	7	7	10	102
0200	1000	11	9	15	9	11	10	15	10	9	6	105
0300	1100	9	11	12	15	14	14	12	12	8	8	115
0400	1200	12	11	18	14	17	13	11	12	6	10	124
0500	1300	10	11	16	17	21	13	14	11	4	9	126
0600	1400	9	11	10	13	19	13	14	11	7	11	118
0700	1500	10	8	9	10	10	12	12	7	9	9	96
0800	1600	6	7	5	10	9	10	14	7	10	7	85
0900	1700	6	10	6	8	11	6	10	4	7	8	76
1000	1800	5	7	10	11	7	8	9	4	9	7	77
1100	1900	6	8	4	4	9	7	9	6	4	5	62
1200	2000	2	8	2	4	10	8	10	5	6	4	59
1300	2100	2	8	4	5	6	5	8	4	5	6	53
1400	2200	3	4	5	5	11	5	7	6	5	6	57
1500	2300	2	7	6	4	12	11	8	6	8	6	70
1600	2400	5	5	7	6	12	11	8	6	10	7	77
1700	0100	7	6	10	9	17	12	9	6	8	8	92
1800	0200	10	7	12	8	16	10	9	9	7	9	97
1900	0300	10	3	14	11	14	8	7	6	7	10	90
2000	0400	12	9	14	7	15	8	6	6	6	8	91
2100	0500	12	8	13	5	8	8	7	7	9	8	85
2200	0600	15	9	12	10	8	6	7	8	6	8	89
2300	0700	10	12	13	8	10	9	8	9	5	9	93
2400	0800	7	5	12	10	13	11	9	8	5	11	91
TOTAL		188	193	242	216	294	227	236	177	167	190	2130
TOTAL POSSIBLE		736	712	736	712	736	736	712	736	712	736	7264
OCCURRENCE (%)		25.5	27.1	32.9	30.3	39.9	30.8	33.1	24.0	23.5	25.8	29.3

TABLE 14
SUMMARY OF TRAJECTORY END-POINT COUNTS

		March	April	May	June	July	August	Sept	Oct	Nov	Dec
Number of Hours/Month		744	720	744	720	744	744	720	744	720	744
Total Number of End-Points		5924	5732	5924	5732	5924	5924	5732	5924	5732	5924
Elapsed Time						Number of End-Points					
2 Hours -	Number of Trajectories	742	718	742	718	742	742	718	742	718	742
	Within Grid	490	440	577	559	593	599	498	595	538	513
	In Valley (North of Indian Point)	41	29	49	65	51	57	36	39	30	44
	In Valley (Indian Point and South)	95	94	150	148	305	185	178	204	139	123
	Percent Grid Points in Valley	28.3	28.0	34.5	38.1	60.0	40.4	43.0	40.8	31.4	32.6
4 Hours -	Number of Trajectories	740	716	740	716	740	740	716	740	716	740
	Within Grid	275	244	356	355	433	361	328	371	285	297
	In Valley (North of Indian Point)	20	8	17	34	28	26	15	22	13	17
	In Valley (Indian Point and South)	43	59	118	106	139	146	109	156	97	78
	Percent Grid Points in Valley	22.9	27.5	37.9	39.4	38.6	47.6	37.8	48.0	38.6	32.0
6 Hours -	Number of Trajectories	738	714	738	714	738	738	714	738	714	738
	Within Grid	173	183	257	257	342	277	250	255	175	213
	In Valley (North of Indian Point)	8	5	9	13	20	9	6	16	7	11
	In Valley (Indian Point and South)	18	42	93	91	105	119	80	106	63	46
	Percent Grid Points in Valley	15.0	25.7	39.7	40.5	36.5	46.2	34.4	47.8	40.0	26.8
8 Hours -	Number of Trajectories	736	712	736	712	736	736	712	736	712	736
	Within Grid	121	135	190	194	276	226	199	188	130	160
	In Valley (North of Indian Point)	9	5	6	9	9	3	5	4	6	11
	In Valley (Indian Pint and South)	11	25	73	61	91	87	51	70	47	38
	Percent Grid Points in Valley	16.5	22.2	41.6	36.1	36.2	39.8	28.1	39.4	40.8	30.6
	Total Past South Boundary*	1643	958	1048	636	399	708	657	926	1706	1821
	Percent Past South Boundary	27.7	16.7	17.7	11.1	6.7	12.0	15.0	15.6	29.8	30.7
	Total Past North Boundary*	1013				1676					937
	Percent Past North Boundary	17.1				28.3					15.8

* This count includes all end-points for all time intervals.

TABLE 15
SUMMARY OF TRAJECTORY END-POINTS (Percent)

	2 Hours			4 Hours			6 Hours			8 Hours		
Month	Total Traj.	% On Grid	% In Valley	Total Traj.	% On Grid	% In Valley	Total Traj.	% On Grid	% In Valley	Total Traj.	% On Grid	% In Valley
March	742	66.0	18.3	740	37.2	8.5	738	23.4	3.5	736	16.4	2.7
April	718	61.3	17.1	716	34.1	9.4	714	25.6	6.6	712	19.0	4.2
May	742	77.8	26.8	740	48.1	18.2	738	34.8	13.8	736	25.8	10.7
June	718	77.7	29.7	716	49.6	19.5	714	36.0	14.6	712	27.2	9.8
July	742	79.9	48.0	740	58.5	22.5	738	46.3	16.9	736	37.5	13.6
August	742	80.7	32.6	740	48.8	23.2	738	37.5	17.3	736	30.7	12.2
September	718	69.4	29.8	716	45.8	17.3	714	35.0	12.0	712	27.9	7.9
October	742	80.2	32.7	740	50.1	24.1	738	34.6	16.5	736	25.5	10.1
November	718	74.9	23.5	716	39.8	15.4	714	24.5	9.8	712	18.3	7.4
December	742	69.1	22.5	740	40.1	12.8	738	28.9	7.7	736	21.7	6.7
Average		73.7	28.1		45.2	17.1		32.7	11.9		25.0	8.5
Standard Deviation		6.5	8.4		7.0	5.3		6.7	4.6		8.1	3.3

In any given month of the ten that were investigated and out of the 7,242 complete eight hour trajectories that were generated, there were a number of basic pattern types. There were those whose sequence of temporal end-points exhibited basic straight line tendencies. These were generally associated with high wind speeds. There were those whose sequence of end-points that rotated in a more or less smooth pattern but they were not usually associated with a meso-scale diurnal rotation or terrain induced deflections. In addition, there were those that exhibited characteristics of recirculation and those in which there were sharp reversals. These were induced by wind velocity changes of synoptic scale origin and/or most frequently they appeared in those trajectories, which included the morning or evening transitional periods, meso-scale induced. In the latter cases, of rotation, recirculation and reversals, the sequences may occur wholly on the grid or on-off-on on the grid.

Examination of details of specific trajectories and concurrent opposing winds suggests that three block regions can be projected in the lower Hudson Valley within the grid system. These regions are:

Peekskill Bay
Haverstraw Bay
Tappan Zee

The reality of the zones of divergence and convergence on a concurrent wind basis were premised on the continuity of air flow movements locally and for air streams that were projected to cross the Hudson River. This latter feature was not <u>uniquely</u> demonstrated with respect to surface (10 meter) level wind velocities. If some local wind patterns were induced by thermal differentials between land and water during periods of weak geostrophic pressure gradients in accordance with sea breeze concepts: during the day air will move from cool water to warm land with return flow aloft; at night, a reverse flow pattern may develop. If this occurred on opposite shorelines of a wide river, concurrently, then there should be vertical motions induced by convergence and divergence in the mid river area or a region of air flow directionally independent of the shoreline circulations. The light wind speeds that were normally found at Croton Point during periods of weak geostrophic flow may result from its proximity to a mid river transition zone. (During periods of strong northwesterly gradients Croton Point had a high frequency of west to west northwest winds implying a cross river flow parallel to South Mountains.)

In addition to the land-water effects in so far as they generate local on-shore and off-shore winds, the effect of nocturnal drainage winds should be considered. The Kingsland Park site was one example. A zone of convergence frequently develops at night between that site and Ossining. This was also apparent from the average diurnal monthly diurnal wind distributions. If only drainage winds are considered, from Figure 4, Ossining would reflect drainage from the Croton River and/or a secondary local river both of which would generate air movements from the north-northeast. Kingsland Park is, however, at the outfall to Gory Brook, while this drains from the north-northeast, it <u>hooks</u> in its final section and outfalls into the Hudson from the southeast. There were no measurements available upon which to alter these directions after the air streams flow into the Hudson River itself. For the objective creation of eight hour trajectories, these winds were presumed to extend into the Hudson River and generate local blocks on a concurrent hourly basis.

The dominance of mesoscale flow factors on surface winds in this study have been demonstrated over and over since local meteorological data have been collected. The surface wind data sets used for this study are from the most extensive network of

concurrent monitoring stations that have ever been deliberately located in the region. These data have been evaluated by many of the routine methodologies common to earlier local studies. All of the data sets were found to exhibit characteristics of complex meso-scale flow fields distortions. The east shore stations were found to share some common characteristics on a daily basis and the same was true for the west shore stations. These characteristics were frequently in opposition to each other. At the same time inland stations had characteristics that were entirely different from either the east or the west shore stations.

The creation and interpretation of eight hour trajectories from these data sets could not be truly separated from the concurrent flow fields on an hourly basis. The eight hour trajectories were a result of the constantly changing concurrent flow field. They were a distinct function of movement interval when based on hourly average wind velocities; and therefore, it may be presumed that in a dynamic flow field they would be equally sensitive to the wind averaging interval itself. As noted earlier, this study did not account for vertical air movement, the trajectories were therefore extremely sensitive to one crucial factor - the assumption of continuity of air movement across the Hudson River without midstream directional distortions.

The results of this study indicated that continued southward movement of air parcels in the Hudson River Valley could not generally be sustained past Piermont, if, in accordance with the data evaluated, Permont's winds are assumed to be representative of the full width of Hudson River.

3.2.4 January 1, 1979 Through December 31, 1980

3.2.4.1 Data Analyses

In the previous sections, with reference to the Trajectory I and Trajectory II studies, portions of 1979 and 1980 data from the Indian Point Meteorological Tower were analyzed and evaluated with reference to the studies that were in progress. Some of these analyses included references to historical data. In both of these studies it was concluded that the meteorological data being obtained at Indian Point were representative of that site and that any observed variations in wind frequency distributions and diurnal variations were assignable to transient climatological deviations from the norm on, at least, the synoptic-cyclonic scale of meteorological events. There was no indication that any changes could be attributed to local physical or dynamic modification, and/or in monitoring equipment and analyses techniques, which could introduce permanent data bias.

To maximize the recent data analyses, all of 1979 and 1980 have been evaluated and compared to historical data as available. The amount of valid data for these years has been previously tabulated in Table 2.

3.2.4.2 Wind Frequency Distributions

For Climatological perspective, historical comparisons have been made for selected months: March, July and December, between the wind direction, wind frequency distributions at the 10 meter level of the 122 Meter Indian Point Tower and climatological data available from Bridgeport, Connecticut and La Guardia Airport in New York City. These latter sites are within the synoptic-cyclonic scale range of Indian Point. The distributions are shown in Table 16. With respect to March and July, climatological

frequency extremes are noted on a nine year basis for La Guardia and a 21 year basis for Bridgeport.

The fluctuations of the frequency distributions and the extremes can be associated with the frequency distribution fluctuations at Indian Point when consideration is given to the fact that winds at Indian Point are channeled by the west bank terrain.

Tables 17 and 18 give the percent frequency distribution of wind direction at Indian Point at the on “seasonal” basis for the 10 meter and 122 meter sensor levels. These data are compared to comparable results for 1973-1974 (Kaplin, et. al.1974, Appendix D).

In the summer season (Table 17), there is a frequency shift at the 10 meter level from SW and SSW in 1974 to SSW and S in the 1979-1980 period. This shift (with a directional bias) can be related to a similar shifting pattern at Bridgeport and La Guardia as found for July in Table 15. This shift tendency is also found implied at the 122 meter level. There is no reason to expect that these pattern changes are permanent.

For the winter season (Table 18) there is a recent bias of wind frequencies to the NNW ad N sectors at both the 10 meter and 122 meter levels at Indian Point. These shifts have their counterpart in the March and December distributions of Table 16.

It is concluded that the wind velocity data that has been collected in recent years is consistent with the data base for FSAR 2 at all measurement levels when normal climatological variations are considered.

TABLE 16A
HISTORICAL COMPARISONS OF WIND FREQUENCY DISTRIBUTIONS
MARCH

	Indian Point			LaGuardia			Bridgeport		
	1974	1979	1980	1974	1979	1980	1974	1979	1980
N	.120	.078	.125	.044	.137*	.085	.044	.083	.077
NNE	.108	.093	.104	.032	.038	.016**	.012	.020	.040
NE	.115	.174	.173	.109	.105	.085	.097	.031	.052
ENE	.019	.039	.057	.085	.032	.061	.069	.043	.097
E	.008	.011	.030	.000**	.013	.024	.020##	.095	.061
ESE	.004	.009	.007	.008**	.013	.008**	.008	.018	.031
SE	.011	.004	.011	.008**	.023	.032	.016	.035#	.004##
SSE	.027	.014	.016	.040	.044*	.032	.012	.031#	.016
S	.057	.094	.085	.085	.199*	.145	.036	.082#	.069
SSW	.051	.133	.091	.036	.035	.057	.040	.051	.040
SW	.045	.065	.046	.052	.018	.024	.085	.057	.069
WSW	.020	.042	.024	.028	.024	.028	.057	.035	.032
W	.036	.049	.039	.089	.069	.048	.113	.065	.113
WNW	.076	.047	.024	.137	.097	.077	.145	.077	.101
NW	.124	.065	.034	.165	.079	.182*	.133	.097	.137
NNW	.129	.085	.134	.081	.066	.081	.093	.134	.048
CALM	.000	.000	.000	.000	.008	.016	.020	.047#	.012

* 9 Year High (1972-1980)
** 9 Year Low (1972-1980)
21 Year Low (1960-1980)
21 Year High (1960-1980)

TABLE 16B
HISTORICAL COMPARISONS OF WIND FREQUENCY DISTRIBUTIONS
JULY

	Indian Point			LaGuardia			Bridgeport		
	1974	1979	1980	1974	1979	1980	1974	1979	1980
N	.034	.066	.047	.093*	.036	.044	.129#	.030	.028##
NNE	.141	.112	.111	.032	.035	.040	.057	.012##	.016
NE	.148	.104	.158	.057	.059	.052	.028	.015	.012##
ENE	.054	.085	.073	.048	.055	.040##	.020	.028	.032
E	.026	.044	.045	.020	.013	.016	.069	.082	.057
ESE	.011	.019	.022	.012	.013	.008	.016	.054	.024
SE	.020	.013	.022	.044*	.031	.032	.048	.020	.016
SSE	.024	.028	.026	.016**	.032	.040	.020	.022	.020
S	.053	.079	.085	.081**	.184	.161	.073	.102	.129
SSW	.110	.212	.123	.069	.085	.073	.052##	.079	.113
SW	.129	.097	.094	.061**	.095	.133*	.085	.157	.125
WSW	.044	.028	.050	.081	.063	.040**	.154	.114	.109
W	.047	.038	.061	.149*	.073	.073	.145#	.105	.117
WNW	.043	.024	.031	.089	.063	.081	.048	.057	.052
NW	.034	.026	.024	.073	.067	.093	.004##	.069	.069
NNW	.015	.015	.031	.057	.043	.052	.048	.026	.069
CALM	.000	.000	.000	.020	.051	.020	.004	.030	.012

* 9 Year High (1972-1980)
** 9 Year Low (1972-1980)
\# 21 Year High (1960-1980)
\#\# 21 Year Low (1960-1980)

TABLE 16C
HISTORICAL COMPARISONS OF
WIND FREQUENCY DISTRIBUTIONS
DECEMBER

	Indian Point			LaGuardia			Bridgeport		
	1973	1979	1980	1973	1979	1980	1973	1979	1980
N	.068	.101	.082	.081	.044	.093	.101	.058	.048
NNE	.172	.071	.148	.077	.016	.044	.048	.019	.057
NE	.162	.067	.124	.081	.046	.065	.097	.030	.040
ENE	.041	.023	.061	.040	.046	.044	.044	.031	.020
E	.015	.018	.023	.020	.013	.008	.024	.035	.012
ESE	.004	.004	.011	.016	.009	.004	.016	.013	.000
SE	.004	.008	.016	.024	.011	.000	.024	.015	.004
SSE	.015	.030	.023	.040	.008	.004	.024	.012	.024
S	.033	.100	.070	.093	.047	.056	.044	.023	.016
SSW	.048	.091	.081	.040	.058	.056	.048	.020	.024
SW	.049	.042	.057	.061	.122	.081	.048	.040	.069
WSW	.019	.042	.024	.044	.071	.044	.028	.093	.085
W	.026	.108	.031	.089	.206	.081	.141	.233	.157
WNW	.044	.094	.057	.149	.144	.121	.141	.238	.157
NW	.126	.120	.070	.069	.078	.157	.101	.066	.153
NNW	.074	.062	.114	.069	.059	.133	.044	.036	.097
CALM	.016	.000	.000	.008	.022	.008	.024	.038	.036

TABLE 17
COMPARISON OF PERCENT WIND FREQUENCY DISTRIBUTIONS – SUMMER

Wind Direction	10 Meter Level 1974	10 Meter Level 1979	10 Meter Level 1980	10 Meter Level 1979-80	122 Meter Level 1974	122 Meter Level 1979	122 Meter Level 1980	122 Meter Level 1979-80
N	3.66	5.53	7.15	6.34	6.54	7.25	8.19	7.72
NNE	10.71	10.27	10.07	10.17	10.67	11.22	10.27	10.74
NE	15.89	12.58	13.68	13.13	6.40	4.85	5.31	5.08
ENE	6.20	7.46	7.78	7.62	2.41	1.88	2.26	2.07
E	2.85	2.68	3.27	2.97	1.83	1.88	1.60	1.74
ESE	1.59	1.59	1.97	1.78	1.66	1.00	1.28	1.14
SE	2.20	1.31	1.77	1.54	2.91	1.61	1.83	1.72
SSE	2.85	2.52	2.09	2.30	2.88	2.40	2.86	2.63
S	8.47	13.28	9.05	11.17	13.04	18.49	14.20	16.36
SSW	11.86	17.39	12.75	15.07	9.82	12.74	9.95	11.35
SW	12.23	9.14	8.17	8.65	10.64	10.22	8.32	9.28
WSW	3.63	3.26	4.08	3.67	5.56	5.14	5.21	5.18
W	3.08	4.28	4.95	4.62	4.44	4.12	5.24	4.68
WNW	2.61	2.74	3.88	3.31	4.17	3.85	4.37	4.11
NW	3.19	2.43	3.65	3.04	5.05	6.84	7.71	7.27
NNW	2.41	2.77	3.59	3.18	3.79	5.71	8.28	6.99
VAR.	6.51	0.00	0.00	0.00	1.56	0.00	0.00	0.00
CALM	0.07	0.00	0.00	0.00	0.14	0.00	0.00	0.00
MISS.	0.03	0.77	2.09	1.43	6.50	0.79	3.13	1.96
NO VALID HOURS	2951	4411	4407	8818	2952	4413	4373	8786
% HRS IN DISTR	100.	99.9	99.8	99.8	100.	99.9	99.0	99.5

TABLE 18
COMPARISON OF PERCENT WIND FREQUENCY DISTRIBUTIONS - WINTER

Wind	10 Meter Level				122 Meter Level			
Direction	1974	1979	1980	1979-80	1974	1979	1980	1979-80
N	7.19	10.73	11.90	11.32	7.23	11.15	10.97	11.06
NNE	13.67	10.34	10.05	10.20	13.67	13.22	14.33	13.78
NE	12.22	11.45	15.11	13.29	5.63	4.79	4.90	4.85
ENE	4.75	5.90	6.30	6.10	1.93	1.80	1.79	1.79
E	1.59	2.86	3.02	2.94	1.60	1.45	1.79	1.62
ESE	0.95	0.71	0.85	0.78	1.16	0.92	1.65	1.29
SE	0.99	0.67	1.26	0.96	1.36	1.75	1.44	1.60
SSE	1.81	1.98	1.49	1.73	1.79	1.82	1.76	1.79
S	6.44	6.50	5.63	6.06	8.67	10.57	8.26	9.41
SSW	7.39	8.11	7.65	7.88	8.25	8.64	8.04	8.34
SW	5.76	6.24	5.72	5.98	9.36	5.87	5.59	5.73
WSW	2.58	4.31	3.04	3.67	3.51	3.18	3.37	3.27
W	3.32	4.77	4.01	4.39	2.94	3.78	4.14	3.96
WNW	5.42	5.90	4.62	5.26	5.08	6.24	5.24	5.74
NW	11.88	9.63	7.10	8.36	14.01	14.56	13.46	14.01
NNW	8.80	8.80	12.07	10.44	10.42	10.27	13.28	11.78
VAR.	4.23	0.00	0.00	0.00	1.18	0.00	0.00	0.00
CALM	0.66	0.00	0.00	0.00	0.04	0.00	0.00	0.00
MISS.	2.80	1.11	0.18	0.64	5.50	0.00	0.00	0.00
NO VALID HOURS	4967	4341	4368	8709	4924	4342	4368	8710
% HRS IN DISTR	97.6	99.9	100.	100.	96.8	100.0	100.	100.

3.2.4.3 Diurnal Wind Direction Distributions

Seasonal diurnal distributions of the resultant wind directions for the combined 1979-1980 data period are shown in comparison to the 1973-1974 data collection period in Table 19 and in Figures 17 and 18.

The diurnal patterns with the exception of the summer season at the 122 meter level from the 2300 to 0900 are nearly identical for the 1979-80 data set and the historical 1973-74 data set. The deviation of the 122 meter level during the nocturnal hours is also consistent when considered with respect to the summer wind frequency shift at the 122 meter level to a sharply defined south wind maximum.

It is concluded on the basis of the diurnal wind distributions that the patterns at all levels are consistent with the data base for FSAR 2 at all measurement levels with consideration for normal climatological variations.

3.2.4.4 Wind Speed Distributions

All variable valid wind speeds at the 10 meter and 122 meter levels have been evaluated on a seasonal basis to determine their diurnal characteristics and the cumulative probability distributions. The results of these analyses are shown in Tables 20 and 21 for the summer season and Tables 22 and 23 for the winter season. For visual comparison, the diurnal variability is shown in Figure 19. The probability distributions are shown in Figure 20. In this latter Figure, the annual cumulative probabilities have been included. These curves were generated by combining the cumulative points in Tables 20-23.

The maximum average diurnal wind speeds from this data set can be compared with those of the 1973-1974 season as shown below in Table 24. There are no significant differences.

TABLE 19
COMPARISON OF DIURNAL RESULTANT WIND DIRECTIONS

	10 Meter Level				122 Meter Level			
	Summer		Winter		Summer		Winter	
Time	1974	1979-80	1973-74	1979-80	1974	1979-80	1973-74	1979-80
0100	051	034	357	359	351	300	327	329
0200	054	036	358	002	008	313	328	333
0300	050	036	359	003	007	321	329	334
0400	042	043	360	004	355	325	334	335
0500	048	048	001	003	004	327	335	335
0600	050	041	000	007	007	331	336	337
0700	042	040	001	007	011	338	339	338
0800	017	023	357	004	012	341	340	338
0900	337	348	352	356	350	334	337	339
1000	293	302	343	351	317	312	336	336
1100	258	269	335	344	260	279	325	331
1200	246	259	329	336	241	272	320	325
1300	246	247	327	336	248	261	319	321
1400	246	249	323	333	246	260	316	316
1500	233	246	322	332	233	251	313	316
1600	228	244	316	336	221	245	306	315
1700	230	233	321	337	223	239	307	312
1800	226	237	327	340	222	239	303	313
1900	232	245	330	345	233	239	308	317
2000	290	346	340	348	248	250	313	320
2100	049	033	345	355	259	263	315	325
2200	049	018	347	358	277	276	319	329
2300	055	033	351	358	297	282	321	331
2400	045	037	354	360	317	287	321	330

Job Number: 01-4122-00

TABLE 20

YORK RESEARCH CORPORATION
ONE RESEARCH DRIVE, STAMFORD, CONNECTICUT 06906
CLIENT: CON EDISON CO. OF NY
SITE: INDIAN POINT (10M)
PARAMETER: WIND SPEED (SUMMER SEASON)
UNITS: MPH

DIURNAL ANALYSIS

MAY 1, 79,80 – OCT. 31, 79,80

OBSERV #	PARAM AVG	PARAM STD DEV	MAX VALUE	RANGE	VALID PTS
1	2.775	1.643	10.500	10.000	362
2	2.748	1.634	9.000	8.500	362
3	2.780	1.643	10.000	9.500	362
4	2.805	1.713	10.000	9.400	362
5	2.748	1.615	9.500	8.900	359
6	2.813	1.790	10.000	9.500	358
7	2.936	1.867	13.000	12.500	358
8	3.103	1.806	12.000	11.400	363
9	3.323	1.899	10.500	9.900	363
10	3.481	1.663	10.000	9.400	361
11	3.809	1.712	10.500	9.900	362
12	3.969	1.618	10.000	9.400	363
13	4.133	1.801	14.000	13.400	363
14	4.104	1.825	12.000	11.000	362
15	4.019	1.833	12.500	11.500	361
16	3.825	1.804	13.000	12.400	359
17	3.562	1.759	12.000	11.400	360
18	3.076	1.641	9.000	8.500	361
19	2.669	1.609	12.000	11.500	362
20	2.593	1.634	10.000	9.500	361
21	2.706	1.763	12.000	11.500	361
22	2.702	1.752	10.000	9.500	361
23	2.710	1.744	10.000	9.500	361
24	2.694	1.684	10.000	9.500	362
TOTAL	3.171	1.802	14.000	13.500	8669

CUMULATIVE PROBABILITY DISTRIBUTION

MAY 1, 79, 80 - OCT 31, 79, 80

CATEGORY OP. LIMIT	CATEGORY POINTS	CATEGORY PERCENT	CUMULATIVE POINTS < LIMIT	CUMULATIVE PERCENT < LIMIT
0.500	39	0.4	39	0.450
1.000	1177	13.6	1216	14.025
2.000	1996	23.0	3212	37.047
3.000	1977	22.8	5189	59.850
5.000	2474	28.5	7663	88.385
7.000	772	8.9	8435	97.290
9.000	181	2.1	8616	99.377
12.000	48	0.6	8664	99.931
16.000	5	0.1	8669	99.988
23.000	0	0.0	8669	99.988
30.000	0	0.0	8669	99.988
40.000	0	0.0	8669	99.988
50.000	0	0.0	8669	99.988
70.000	0	0.0	8669	99.988

NUMBER OF VALID DATA POINTS = 8669
NUMBER OF MISSING DATA POINTS = 163
REPRESENTING 98.2-PERCENT VALID DATA

Job Number: 01-4122-00

TABLE 21
YORK RESEARCH CORPORATION
ONE RESEARCH DRIVE, STAMFORD, CONNECTICUT 06906
CLIENT: CON EDISON CO. OF NY
SITE: INDIAN POINT (122M)
PARAMETER: WIND SPEED (SUMMER SEASON)
UNITS: MPH

DIURNAL ANALYSIS
MAY 1, 79,80 – OCT. 31, 79,80

OBSERV #	PARAM AVG	PARAM STD DEV	MAX VALUE	RANGE	VALID PTS
1	7.821	5.161	30.000	29.500	357
2	7.595	5.070	24.000	23.500	356
3	7.581	5.153	26.000	25.400	355
4	7.413	5.097	27.000	26.500	356
5	7.233	5.043	32.000	31.400	353
6	7.436	5.383	35.000	34.500	354
7	7.499	5.616	47.000	48.400	355
8	7.332	5.442	47.000	48.400	359
9	7.717	5.320	38.000	37.400	360
10	8.086	5.399	33.000	32.000	362
11	8.881	5.312	30.000	28.500	361
12	9.595	5.217	28.000	26.000	359
13	10.232	5.394	40.000	39.000	358
14	10.409	5.450	36.000	34.500	359
15	10.762	5.485	30.000	28.000	357
16	11.087	5.397	32.000	31.000	355
17	11.262	5.184	31.000	30.400	353
18	10.764	4.780	25.000	23.500	354
19	10.266	4.919	33.000	32.000	354
20	9.879	5.015	28.000	27.000	354
21	9.256	5.022	27.000	28.400	356
22	8.781	5.299	28.000	27.400	356
23	8.383	5.140	28.000	27.400	356
24	8.070	4.944	26.000	25.500	357
TOTAL	8.888	5.388	47.000	46.500	8556

CUMULATIVE PROBABILITY DISTRIBUTION
MAY 1, 79, 80 - OCT 31, 79, 80

CATEGORY OP. LIMIT	CATEGORY POINTS	CATEGORY PERCENT	CUMULATIVE POINTS < LIMIT	CUMULATIVE PERCENT < LIMIT
0.500	7	0.1	7	0.082
1.000	169	2.0	176	2.057
2.000	511	6.0	687	8.029
3.000	638	7.5	1325	15.484
5.000	1303	15.2	2628	30.712
7.000	1205	14.1	3833	44.794
9.000	1132	13.2	4965	58.023
12.000	1565	18.3	6530	76.312
16.000	1258	14.7	7788	91.013
23.000	652	7.6	8440	98.633
30.000	99	1.2	8539	99.790
40.000	15	0.2	8554	99.965
50.000	2	0.0	8556	99.988
70.000	0	0.0	8556	99.988

NUMBER OF VALID DATA POINTS = 8556
NUMBER OF MISSING DATA POINTS = 276
REPRESENTING 98.9-PERCENT VALID DATA

Job Number: 01-4122-00

TABLE 22

YORK RESEARCH CORPORATION
ONE RESEARCH DRIVE, STAMFORD, CONNECTICUT 06906
CLIENT: CON EDISON CO. OF NY
SITE: INDIAN POINT (10M)
PARAMETER: WIND SPEED (WINTER SEASON)
UNITS: MPH

DIURNAL ANALYSIS

NOV 1, 79, 80 - APR 30, 79, 80

OBSERV #	PARAM AVG	PARAM STD DEV	MAX VALUE	RANGE	VALID PTS
1	4.508	2.958	21.000	20.500	362
2	4.462	2.940	14.000	13.500	362
3	4.524	3.163	18.000	17.500	362
4	4.453	3.043	16.000	15.500	361
5	4.298	2.886	15.000	14.400	361
6	4.292	2.961	15.000	14.500	362
7	4.461	3.102	18.000	17.500	363
8	4.556	3.141	15.000	14.400	363
9	4.906	3.212	17.000	16.400	363
10	5.153	3.182	16.000	15.400	363
11	5.310	3.050	16.000	15.500	361
12	5.556	2.995	16.000	15.400	362
13	5.731	3.163	18.000	17.400	362
14	5.702	3.240	16.500	15.900	362
15	5.589	3.109	17.000	16.400	361
16	5.336	3.243	20.000	19.400	360
17	5.030	3.084	20.000	19.500	360
18	4.671	2.858	15.000	14.400	360
19	4.611	2.906	16.000	15.500	361
20	4.502	2.883	15.000	14.400	361
21	4.500	2.972	16.000	15.400	362
22	4.457	2.970	16.000	15.400	361
23	4.381	2.855	16.000	15.400	361
24	4.398	2.874	18.000	17.500	362
TOTAL	4.808	3.088	21.000	20.500	8678

CUMULATIVE PROBABILITY DISTRIBUTION

NOV 1, 79, 80 - APR 30, 79, 80

CATEGORY OP. LIMIT	CATEGORY POINTS	CATEGORY PERCENT	CUMULATIVE POINTS < LIMIT	CUMULATIVE PERCENT < LIMIT
0.500	18	0.2	18	0.207
1.000	788	9.1	806	9.287
2.000	1332	15.3	2138	24.634
3.000	1178	13.6	3316	38.207
5.000	2122	24.4	5438	62.657
7.000	1591	18.3	7029	80.989
9.000	841	9.7	7870	90.679
12.000	614	7.1	8484	97.753
16.000	181	2.1	8665	99.839
23.000	13	0.1	8678	99.988
30.000	0	0.0	8678	99.988
40.000	0	0.0	8678	99.988
50.000	0	0.0	8678	99.988
70.000	0	0.0	8678	99.988

NUMBER OF VALID DATA POINTS = 8678
NUMBER OF MISSING DATA POINTS = 34
REPRESENTING 99.6-PERCENT VALID DATA

Job Number: 01-4122-00

TABLE 23

YORK RESEARCH CORPORATION
ONE RESEARCH DRIVE, STAMFORD, CONNECTICUT 06906
CLIENT: CON EDISON CO. OF NY
SITE: INDIAN POINT (122M)
PARAMETER: WIND SPEED (WINTER SEASON)
UNITS: MPH

DIURNAL ANALYSIS

NOV 1, 79, 80 - APR 30, 79, 80

OBSERV #	PARAM AVG	PARAM STD DEV	MAX VALUE	RANGE	VALID PTS
1	10.919	6.869	49.000	48.500	359
2	10.669	5.562	38.000	37.400	359
3	10.636	6.799	40.000	39.400	358
4	10.297	6.804	37.500	36.900	358
5	10.075	6.354	34.000	33.400	358
6	9.832	6.485	32.000	31.500	358
7	9.902	6.811	44.000	43.500	356
8	10.283	7.067	38.000	37.400	356
9	10.525	6.978	36.000	35.400	358
10	10.596	7.032	37.000	36.400	360
11	11.086	6.961	36.000	35.000	362
12	11.828	7.011	34.000	33.500	362
13	12.309	7.218	48.000	47.000	362
14	12.530	7.250	45.000	44.400	362
15	12.727	7.184	43.000	42.000	362
16	12.635	6.992	40.000	38.500	362
17	12.302	6.778	42.000	41.000	361
18	11.921	6.035	32.000	31.400	361
19	11.645	6.061	32.000	31.400	360
20	11.398	6.093	37.000	36.400	360
21	11.106	6.216	40.000	39.400	360
22	10.658	6.206	39.000	38.400	358
23	10.488	6.182	36.000	35.000	358
24	10.551	6.178	41.000	40.500	359
TOTAL	11.124	6.726	49.000	48.500	4629

CUMULATIVE PROBABILITY DISTRIBUTION

NOV 1, 79, 80 - APR 30, 79, 80

CATEGORY OP. LIMIT	CATEGORY POINTS	CATEGORY PERCENT	CUMULATIVE POINTS < LIMIT	CUMULATIVE PERCENT < LIMIT
0.500	6	0.1	6	0.070
1.000	105	1.2	111	1.286
2.000	418	4.8	529	6.130
3.000	458	5.3	987	11.437
5.000	910	10.5	1897	21.981
7.000	895	10.4	2792	32.352
9.000	1009	11.7	3801	44.044
12.000	1622	18.8	5423	62.839
16.000	1518	17.6	6941	80.429
23.000	1230	14.3	8171	94.681
30.000	372	4.3	8513	98.992
40.000	78	0.9	8621	99.896
50.000	8	0.1	8629	99.988
70.000	0	0.0	8629	99.988

NUMBER OF VALID DATA POINTS = 8629
NUMBER OF MISSING DATA POINTS = 83
REPRESENTING 99.0-PERCENT VALID DATA

TABLE 24
MAXIMUM DIURNAL WIND SPEEDS (MPH)

Season	Level (M)	1973-1974	1979-1980
Summer	10	4.0	4.1
Summer	120	11.0	11.3
Winter	10	5.0	5.7
Winter	122	13.0	12.7

The median wind speeds extracted from Figure 20 at the 50 percent probability level are 1.1 M/S, 1.7 M/S and 1.4 M/S at the 10 meter level for the summer season, winter season, and annual basis, respectively. At the 122 meter level, these values are 3.4 M/S, 4.4 M/S and 3.9 M/S on the summer, winter and annual basis, respectively. These values bracket those presented by Kaplin and Laznow (1972) for the IP3 Tower. Corrected for exposure elevation no significant change would be expected between the two sets of values.

The variation of winds during the 1979-1980 season are consistent with data obtained during the 1973-1974 operational period. There is no reason to expect any significant variations with respect to the meteorology as used in FSAR 2.

3.2.4.5 Wind Velocities and Atmospheric Stability

3.2.4.5.1 Joint Frequency Distribution of Wind Direction and Stability

Stability categorizations as referenced in this study are in accordance with NRC Pasquill Tables as derived from local temperature change with elevation. Except as noted, actual temperature measured gradients have been converted to °C/100M directly from temperature difference values (°F) per difference between sensor height levels.

Tables 25, 26 and 27 show the summary frequency distributions for the 10 meter level of wind direction and stability categories for the 1979-1980 data collection period. The tables show the annual, summer season and winter season summaries respectively.

TABLE 25
ANNUAL SUMMARY OF WIND DIRECTION
PERCENT FREQUENCY DISTRIBUTION AS A FUNCTION
OF STABILITY - 10M LEVEL
(JANUARY 1, 1979 - DECEMBER 31, 1980)

Wind Direction	Stability Class A	B	C	D	E	F	G
N	1.28	0.36	0.48	3.39	2.67	0.50	0.09
NNE	1.76	0.40	0.46	3.15	3.33	0.80	0.17
NE	0.63	0.35	0.58	4.22	4.66	2.12	0.40
ENE	0.06	0.07	0.17	1.59	2.61	1.84	0.43
E	0.01	0.03	0.03	0.64	1.49	0.59	0.11
ESE	0.01	0.01	0.01	0.27	0.73	0.21	0.04
SE	0.03	0.01	0.02	0.23	0.67	0.26	0.02
SSE	0.09	0.03	0.04	0.45	1.04	0.31	0.05
S	2.04	0.25	0.29	1.74	3.39	0.76	0.11
SSW	2.58	0.51	0.38	2.14	5.04	0.72	0.05
SW	1.16	0.33	0.35	1.89	3.03	0.51	0.03
WSW	0.49	0.17	0.16	0.96	1.44	0.39	0.02
W	0.56	0.22	0.17	1.40	1.64	0.43	0.06
WNW	0.47	0.15	0.26	1.64	1.49	0.21	0.03
NW	0.70	0.31	0.32	2.36	1.85	0.10	0.01
NNW	0.80	0.40	0.49	3.26	1.60	0.17	0.04
CALM	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MISSING	0.12	0.05	0.03	0.21	0.51	0.15	0.02
TOTAL %	12.80	3.66	4.23	29.56	37.17	10.08	1.69
NO. OF HOURS	2244	641	742	5183	6519	1768	297

TABLE 26
SUMMARY OF WIND DIRECTION PERCENT FREQUENCY
DISTRIBUTION AS A FUNCTION OF STABILITY
SUMMER SEASON - 10M LEVEL
(MAY 1, 1979, 80 - OCTOBER 31, 1979, 80)

Wind Direction	Stability Class						
	A	B	C	D	E	F	G
N	1.68	0.26	0.37	1.25	2.06	0.57	0.07
NNE	2.65	0.42	0.43	2.90	2.41	1.01	0.18
NE	0.58	0.31	0.46	3.46	4.44	3.17	0.35
ENE	0.11	0.10	0.24	1.38	2.66	2.62	0.39
E	0.02	0.07	0.01	0.57	1.57	0.61	0.05
ESE	0.01	0.01	0.00	0.31	1.01	0.36	0.06
SE	0.05	0.02	0.01	0.17	0.84	0.40	0.02
SSE	0.15	0.06	0.05	0.50	1.07	0.40	0.08
S	3.32	0.36	0.43	2.47	3.58	0.85	0.05
SSW	4.10	0.75	0.59	2.93	5.70	0.85	0.01
SW	1.84	0.49	0.48	2.23	3.03	0.51	0.05
WSW	0.87	0.20	0.18	0.94	1.05	0.34	0.00
W	0.88	0.28	0.19	1.38	1.42	0.34	0.07
WNW	0.80	0.09	0.25	0.94	1.03	0.15	0.05
NW	1.05	0.19	0.17	0.84	0.63	0.10	0.02
NNW	0.78	0.19	0.24	0.97	0.74	0.20	0.02
CALM	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MISSING	0.22	0.06	0.01	0.31	0.68	0.22	0.03
TOTAL %	19.11	3.86	4.11	23.54	33.92	12.69	1.48
NO. OF HOURS	1687	341	363	2078	2994	1120	131

TABLE 27
SUMMARY OF WIND DIRECTION PERCENT FREQUENCY
DISTRIBUTION AS A FUNCTION OF STABILITY
WINTER SEASON - 10M LEVEL
(NOVEMBER 1, 1979, 80 - APRIL 30, 1979, 80)

Wind Direction	Stability Class A	B	C	D	E	F	G
N	0.87	0.46	0.60	5.56	3.28	0.44	0.11
NNE	0.85	0.38	0.49	3.41	4.26	0.59	0.16
NE	0.86	0.40	0.69	4.99	4.88	1.06	0.45
ENE	0.01	0.05	0.10	1.79	2.56	1.06	0.48
E	0.00	0.00	0.06	0.72	1.40	0.56	0.18
ESE	0.00	0.01	0.01	0.23	0.45	0.06	0.02
SE	0.02	0.00	0.02	0.29	0.49	0.11	0.01
SSE	0.02	0.01	0.03	0.40	1.01	0.23	0.02
S	0.75	0.13	0.14	1.01	3.19	0.68	0.17
SSW	1.04	0.28	0.17	1.34	4.37	0.59	0.08
SW	0.48	0.16	0.22	1.55	3.03	0.51	0.02
WSW	0.10	0.13	0.14	0.99	1.84	0.45	0.03
W	0.24	0.15	0.14	1.42	1.86	0.52	0.06
WNW	0.13	0.22	0.28	2.34	1.95	0.28	0.02
NW	0.34	0.42	0.47	3.90	3.09	0.10	0.00
NNW	0.83	0.62	0.75	5.58	2.47	0.14	0.06
CALM	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MISSING	0.02	0.03	0.05	0.11	0.33	0.09	0.01
TOTAL %	6.39	3.44	4.35	35.65	40.47	7.44	1.91
NO. OF HOURS	557	300	379	3105	3525	648	161

There are distinctive seasonal biases that coincide with variations in wind direction occurrence frequencies. It will be seen that these biases are consistent with variations in stability and wind speed on diurnal basis.

3.2.4.5.2 Frequency of Occurrence of Stability Categories

Table 28 shows a summary of historical comparison of percent occurrence of stability categories between the various reporting periods for the IP3 Tower and of the 122M Tower (IP4) for 1973/74. (Based on concurrent wind speed and temperature gradients). The former gradients were based on temperature differences from the 30M and 2M levels while the latter were based on differential measurements between the 60M and 10M levels.

On an annual basis there is generally good agreement between the results for the 122M Tower and the IP3 Tower composite year with temperature correction (FSAR 3, Supplement 13, 16).

The variation in percentages at the stability extreme A and G are most probably related to the lower gradient base level of measurement on the IP3 Tower - 2 meters. One would expect higher or lower temperatures closer to the ground with less accuracy in the thermal adjustment factor in these extreme ranges.

Table 29 shows a similar comparison for the 122 Meter Meteorological Tower for the 1973-1974 data collection period and the 1979-80 data collection period. These results are based on current wind speed data for the tower levels as noted. The 122M is shown based on two gradient differences: 122-10M and 122-60M. The percent occurrences of stability categories are sharply defined functions of season and, for the upper level, the vertical defined functions of season and, for the upper level, the vertical temperature gradient. This is apparent in both data sets.

There are seasonal differences in the two data sets particularly in the A and G stability category extremes at the 122M level, <u>however</u>, is noted that the percent occurrences in the 1973-1974 data set are based on only one or less than ten observations where these percentage differentials are most extreme. Where more data points are available in each stability category as for the lower gradient level (61-10M), there is generally good agreement.

TABLE 28
HISTORICAL COMPARISONS OF PERCENT OCCURRENCE OF STABILITY

Temperature Gradient (M)	Stability Class A	B	C	D	E	F	G	No. of Observ.
Summer (1974)								
61-10	21.44	5.46	4.37	27.92	30.21	9.28	1.31	2747
1973 (IP3)*	25.52	2.62	3.64	17.38	26.81	13.39	10.63	2935
Winter (1973/74)								
61-10	4.00	1.92	2.13	23.93	53.24	12.53	2.25	4797
1973 (IP3)*	21.49	3.52	3.74	23.29	23.76	14.24	9.96	4229
Annual (1973/74)								
61-10	10.35	3.21	2.94	25.38	44.86	11.35	1.91	7544
1970/72 (IP3)[1]	6.42	2.55	2.23	31.19	38.75	11.25	3.16	8366
1970 (IP3)*	21.68	2.20	3.39	33.35	24.75	9.01	5.62	NA
1971 (IP3)*	19.17	2.75	2.97	22.79	30.87	11.69	9.75	NA
1970/72 (IP3)[1]*	15.52	1.74	2.82	28.38	25.42	12.68	9.03	8366
1973 (IP3)**	23.14	3.16	3.70	20.87	25.02	13.89	10.23	NA

* Concurrent basis

[1] Composite year with temperature correction - concurrent basis (FSAR 3)

1* Composite year concurrent basis (FSAR 3)

** March-December only concurrent basis

NA Not Available

NOTE: Gradient for IP3 Tower: 30-2 M

TABLE 29
COMPARISON OF PERCENT OCCURRENCE OF STABILITY
ON 122 METER TOWER

Date	Wind Freq LVL (M)	Stability Class A	B	C	D	E	F	G	No. of Observ	Temperature Gradient(M)
Summer										
1974	10	21.44	5.47	4.37	27.92	30.21	9.28	1.31	2747	61 - 10
1979/80	10	19.34	3.93	4.22	23.96	34.35	12.73	1.48	8557	60 - 10
1974	122	0.51	0.66	2.15	47.40	41.54	7.72	0.04*	2747	122 - 10
1979/80	122	4.54	5.50	5.81	42.84	34.95	6.23	0.14**	7838	122 - 10
1974	122	0.04*	0.04*	0.11**	20.13	74.01	5.42	0.25**	2747	122 - 61
1979/80	122	0.17**	0.42	1.49	68.09	26.72	2.82	0.29	7838	122 - 60
Winter										
1973/74	10	4.00	1.92	2.13	23.93	53.24	12.53	2.25	4797	61 - 10
1979/80	10	6.44	3.47	4.37	35.79	40.55	7.46	1.92	8648	60 - 10
1973/74	122	3.17	1.70	1.63	41.46	48.86	3.09	0.08**	4797	122 - 10
1979/80	122	0.59	1.18	2.78	56.07	34.75	4.29	0.31	8594	122 - 10
1973/74	122	0.02*	0.31	1.19	41.94	49.59	6.82	0.13**	4797	122 - 61
1979/80	122	0.28	0.14	0.37	71.89	25.35	1.84	0.13	8594	122 - 60
Annual										
1973/74	10	10.35	3.21	2.94	25.38	44.86	11.35	1.91	7544	61 - 10
1979/80	10	12.86	3.70	4.30	29.90	37.47	10.08	1.70	17205	60 - 10
1973/74	122	2.63	1.33	1.82	43.62	46.20	4.77	0.07	7544	122 - 10
1979/80	122	2.48	3.24	4.23	49.76	34.84	5.22	0.23	16432	122 -10
1973/74	122	0.03	0.08	0.80	34.00	58.48	6.31	0.17	7544	122 - 61
1979/80	122	0.23	0.27	0.91	70.08	26.00	2.31	0.21	16432	122 - 60

It may be inferred that, except as stated for the reasons noted, the percent frequency of stability classes with the existing tower system is representative and consistent with data referenced in FSAR 2.

* Single observations
** Less than ten observations

3.2.4.5.3 Average Wind Speed and Diurnal Variation as a Function of Stability Categories

Tables 30, 31, and 32 show the average wind speed and number of observations as functions of time of day and stability category for the summer and winter seasons of the combined 1979 and 1980 data collection period.

The results are derived from valid wind speeds measured at 10M relative to the temperature difference 60 - 10M and 122M wind speeds based on the temperature difference between 122-10M and 122-60M. The latter gradient was generated by subtraction of gradient levels:

(122-60) = (122-10) - (60-10)

These tables indicate a distinctive diurnal pattern to the stability. During the summer season at the 10M level for all practical purposes G stability does not occur between 0700 to 1900 EST and F stability does not occur between 0900 and 1400. During the nocturnal hours between 1900 to 0600, for all practical purposes A, B, and C stability categories do not appear. Stability Category A appears from 0700 to 1800 EST and is the dominant gradient between 0900 and 1600 EST. Out of 2,855 observations during this time interval, the percent frequency of occurrences were 52.9 for A, 8.1 for B, 8.4 for C, 24.2 for D, 6.1 for E, 0.2 for F, and 0.04 for G.

In the winter season at 10M, the A, B, and C stability categories do not appear during the nocturnal hours from 1900 to 0600 (with random singular exceptions). D is the dominant day time stability category and E is the dominant nighttime category.

Somewhat similar patterns are found with the upper level gradients based on the 122-10M and 122-60M temperature gradients. Between these latter two gradients

TABLE 30
Diurnal Variation of Stability Class and Wind Speed
(concurrent data)

TABLE 31
Diurnal Variation of Stability Class and Wind Speed
(concurrent data)

TABLE 32
Diurnal Variation of Stability Class and Wind Speed
(concurrent data)

TABLE 33
COMPARISONS OF AVERAGE WIND SPEEDS (MPH)
AS A FUNCTION OF STABILITY

Year/ Season	Anemom LVL	Stability Class A	B	C	D	E	F	G	Temperature Gradient (M)
Summer									
1974	10M	4.2	4.4	4.0	3.8	2.7	2.3	2.6	60 - 10
1979/80	10M	4.0	3.6	3.5	3.7	2.7	2.1	2.2	60 - 10
1974	122M	4.3**	14.3	12.3	9.5	7.7	4.5	4.5*	122 - 10
1979/80	122M	11.2	10.4	9.8	10.0	7.6	4.8	4.3**	122 - 10
1974	122M	3.5*	49.0*	3.8**	10.6	8.2	4.4	2.6**	122 - 60
1979/80	122M	9.3**	12.6	12.1	10.0	6.4	4.3	4.0	122 - 60
Winter									
1973/74	10M	4.8	5.2	4.8	6.1	5.0	2.4	2.3	60 - 10
1979/80	10M	5.9	6.4	6.0	5.9	4.0	2.2	2.8	60 - 10
1973/74	122M	15.8	11.5	10.1	13.5	9.0	5.7	3.6**	122 - 10
1979/80	122M	13.9	12.4	13.9	12.9	8.6	5.6	8.6	122 - 10
1973/74	122M	16.0*	15.0	13.9	13.3	9.7	6.0	4.7**	122 - 60
1979/80	122M	19.9	21.0	20.4	12.3	7.8	7.2	6.3**	122 - 60

for the same data base the number of occurrences of A, B, and C stability categories in both summer and winter seasons are substantially reduced and become almost random when based on the 122-60M gradient. The obvious implication is that temperature gradient extremes are controlled by the surface level. This is consistent with Kaplin, et. al., 1974.

At the upper levels, for the summer season, F stability has a distinct diurnal function. It rarely occurs during the daytime from 0800 to 2000 EST. The distribution of G stability during the summer season, while a diurnal function, is clearly biased to the early morning hours. It occurs more frequently with relation to the 122-60M gradient than the 122-10M gradient. These factors are consistent with a nocturnal cool air surface drainage flow. This routine drainage flow does not exist during the winter season, and the occurrence frequencies, while still diurnal, are clearly related to the local surface air temperatures.

It is noted that during the winter seasons, drainage flow patterns are not routine occurrences. They can occur, however, during periods of weak pressure gradients. They are dependent on the horizontal and vertical temperature gradients that develop between the land (snow covered or bare ground) as well as the Hudson River (free water or ice bound).

The average wind speeds as a function of stability category are shown in Table 33 for the 1973-1974 data collection period and the 1979-1980 data period. As noted, there

* Single observations
** Less than 15 observations

are some apparent anomalies with respect to the 122 meter level wind speeds. These are probably induced by the few data points available in 1973-1974 rather than a reality. Where the total number of occurrences were in a more reliable range, at the 10 meter and the 122 meter levels, there was good agreement between average wind speeds.

Based on these data, it is concluded that within the range of normal climatological variations, there are no significant changes in the local meteorological parameters on a seasonal and annual basis. The existing meteorological data are consistent with data referenced in FSAR 2.

4.0 SUMMARY

4.1 METERОROLOGY

4.1.1 General

The meteorology of the Indian Point site and its environs has been thoroughly studied over the span of years. For the past nine years the source of on-site meteorology has been the 122 Meter Meteorological Tower that became fully operative as of October 1, 1973. This tower is located at latitude: 41° 15′ 55″ N and longitude 73° 57′ 08″ W (N38 + 31.453 and E22 + 49.473 on the Indian Point Grid).

A review of data and literature has revealed that the original Coordinates above were based on pre-1983 topographical maps that used North American Datum 1927 (NAD27) for its basis. The geodetic gurus revised the standards in the 1980s, and in the United States the USGS adopted the North American Datum 1983 (NAD83) model of the Earth's curvature, and the international community adopted WGS84 (World Geodetic System 1984) the following year, which is essentially the same model. WGS84 is the default map datum built into all GPS receivers, and is also the basis for most electronic maps including Google, MapQuest, Microsoft, Bing, etc. Also, depending upon the GPS unit or mapping system used, the numbers vary. The latitude and longitude coordinates for the met tower were only used to provide location information to the FAA when tower lights were out and the FAA no longer requests latitude and longitude information. Based on this information, the above coordinates should not be used to locate the primary tower.

Meteorological data from the 122 Meter Tower have, in previous studies and in this report, have been compared, in so far as possible, to those meteorological data, which were the data base for the FSAR 2 Report.

4.1.2 122 Meter Meteorological Tower System

The 122 Meter Tower and support systems as presently comprised, maintained, and operated are in compliance with the meteorological measurement programs included in Regulatory Guides 1.23 and 1.97 and the criteria set forth in NUREG-0654, -0696, and -0737.

The system is outlined in Figure 4. It consists of an instrumented 122 Meter Tower. The critical sensors are for winds at the 10, 60, and 122 meter levels; ambient temperature and dew point at the 10 meter level and temperature difference between the 60-10 meter and 122-10 meter levels. In addition, a precipitation gage is located within the tower complex. All sensor signals are carried to a trailer, which houses:

- Signal Conditioners
- Analog Recorders
- Data Acquisition System - Magnetic Tape
- Terminal Printer
- LED Satellite Displays for Control Rooms 2 and 3
- Telephone Modems
- Dedicated Telephone Lines
- Air Conditioning Systems

All systems are operated on primary AC voltage. A backup diesel generator within the complex provides for the automatic transfer of power if the primary source is cut off.

Appropriate meteorological data are transmitted from the Meteorological Trailer to:

- Reactor Control Rooms 2 (CON-EDISON) and 3 (PASNY)
- MIDAS and ARAC Computers

The Emergency Control Center in addition to the computer systems and interrogation systems receives wind data from backup wind sensors.

The status of the backup wind system and the MIDAS computer may be assessed by remote telephone interrogation.

4.1.3 Local Meteorological Characteristics

All earlier studies and the data evaluated and included in this report indicates that the most important characteristic of the Indian Point area is the prevalence of winds from the north and south sectors. These winds are induced by meso-scale factors: terrain channeling at all times and drainage flow and land-sea circulations during periods of weak synoptic-cyclonic scale pressure gradient field.

At all wind levels there are distinctive diurnal variation patterns to local winds as well as to the local winds in addition to the local atmospheric stability as determined by vertical temperature gradients related to Pasquill stability categories. Unstable A, B, and C categories are dominant daytime occurrences. Stable F and G categories are nocturnal occurrences.

Because of the dominance of meso-scale factors in the Indian Point and lower Hudson Avenue Valley environs, persistent straight line flow of air from Indian Point is impossible. Paths of movement of air parcels are best generated by the use of local data on a real time basis. Recirculation of air parcels within a time frame of eight consecutive hours is a likely event. Within ten miles of Indian Point there are three zones, which indicated the probability of convergence and divergence of local surface air streams:

- Peekskill Bay
- Haverstraw Bay
- Tappan Zee

4.1.4 Conclusion

From the evaluation of previous studies and the recent data years January 1, 1979 - December 31, 1980, it has been concluded that the meteorological data being collected at the 122 Meter Meteorological Tower are representative of the Indian Point site and

are consistent with the original and expanded meteorological data basis of FSAR for Unit No. 2. All deviations of data at any given time (not otherwise specifically assigned to measurement techniques, methodologies, and, evaluation procedural changes to comply with existing Regulatory Guides) can be assigned to normal regional climatological variations in any given year on, at least, the synoptic-cyclonic meteorological scale.

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NOTE: This information is classified as Historical Information

APPENDIX 2B

INDIAN POINT FSAR
UPDATE

REVISED

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16 April 1982

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INDIAN POINT FSAR UPDATE

INTRODUCTION

This report is intended as an update and synthesis of previous geologic reports on the area surrounding Con-Edison's Indian Point nuclear facilities. The report reflects current thinking on the geology, structure, tectonic history, neotectonics and recent seismicity in the region. Main sources of information include Ratcliffe's (1976) final report on the Ramapo fault system, the Dames and Moore Geotechnical Investigation of the Ramapo Fault (1977), and the recent literature on the subject of the geology of the Manhattan and Reading Prongs.

Con Edison's Indian Point power plants are located in Buchanan, New York, on the east bank of the Hudson River. The site is situated in the central portion of the Peekskill Quadrangle.

Physiography

The rocks in the vicinity of the Indian Point generating stations belong to three geologic provinces, the Hudson Highlands, the Manhattan Prong and the Newark Basin (Figure 1). Rocks that outcrop within the provinces range in age from Precambrian through Triassic (Jurassic?).

The landscape consists of northeast trending ridges and rather broad swampy valleys. Ridges are supported by bedrock and tend to follow prominent generally northeast, structural trends. Valley walls tend to be steep, the result of modification by Pleistocene glaciation. Elevations in the area reach a maximum of 1000 feet, and range from 50 to 300 feet above sea level in low lying areas.

General Geology and Tectonics

The eastern third of the North American continent has been the site of episodic tectonism since Precambrian time (see Table1). Paleozoic aged tectonism has molded a broad geologically varying zone known as the Appalachian orogen. The core of the orogen is marked by intrusive rocks modified by ductile and brittle deformation and regional metamorphism. The Indian Point site lies within the Manhattan Prong of the Appalachian Mountains.

The earliest recognized event in the area occurred in Precambrian time, and is known as the Grenville Orogeny. The Grenville orogeny, dated at 1.1 b.y., produced brittle and ductile deformation accompanied by regional granulite facies metamorphism and intrusive activity. The deformation and metamorphism affected the rocks of the Reading Prong and the Precambrian rocks of the Manhattan Prong. The Grenville events are not tectonically or temporarily related to the development of the Appalachian Orogen, which began in the latest Precambrian.

The earliest tectonic activity in the Appalachian Orogen probably involved latest Precambrian continental rifting and associated intrusive activity. The opening of the Proto-Atlantic Ocean (Iapetus) set the stage for the development of the Appalachian geosyncline. The geosyncline received sediments from earliest Precambrian through the mid-Ordovician time. The Taconic orogeny occurred in Mid-Ordovician time, and

resulted in extensive thrust faulting, folding, metamorphism and intrusion in the northern Appalachians. The Taconic orogeny, generally interpreted as a continent-island arc collision was very intense in the Manhattan Prong region, and produced most of the structure evident in the current map pattern.

The Acadian orogeny (Devovian), possibly a continent-continent collision, was the next pulse of orogenic activity. The Acadian orogeny caused considerable deformation, metamorphism and intrusion in New England, but was not as intense as the Taconic orogeny in the Manhattan Prong.

The rocks of the Hudson Highlands (see Figure 1), an extension of the Reading Prong in New York State, consist of Precambrian gneisses and granites of Grenville (1.1 b.y.) age. The Manhattan Prong is underlain by Precambrian basement. An unconformity separates Cambro-Ordovician aged metasedimentary rocks from Precambrian rocks. The Newark Basin is filled with Triassic (Jurassic?) arkosic sediments diabase intrusives and basaltic flows.

Geology of the Hudson Highlands

The Hudson Highlands outcrop in a northeast (040°) trending belt, approximately 10-miles wide, north, northwest and west of the Indian Point site (Figure 1). Four major rock types are present in the vicinity of Dunderburg Mountain, across the Hudson River from Indian Point. They are quartzo-feldspathic ± calc-silicate hornblende gneiss; migmatitic quartzo-feldspathic biotite ± gamet gneiss; calc-silicate bearing quartzite; and gneissic hornblende granite. Granite probably intruded the gneisses during Precambrian time.

Heleneck and Mose (1978) mapping in Highlands rocks near Lake Carmel, New York, recognize a mappable sequence of five rock units consisting of, gray migmatitic quartzo-feldspathic gneiss; amphibolite hornblende gneiss; leuco-granite gneiss and amphibolite; layered quartzo-feldspathic gneiss; and interlayered feldspathic quartzite and amphiboite. Highland rocks represent a sequence of Precambrian aged mio- and eugeosynclinal deposits, that have undergone a complex sequence of metamorphism and deformation. The rocks typically yield Rb/Sr ages of 1.1 billion years, the time of Grenville regional metamorphism. Mineralogic and textural evidence indicates that the rocks were metamorphosed to granulite facies, and multiply deformed during the Grenville orogeny. Recrystallization from granulite toemphibolite facies in Highland rocks near Lake Carmel accompanied folding during the Taconic orogeny (mid-Ordovician). Evidence of Taconic recrystallization in other areas of the Highlands remains equivocal. The Highlands are separated from the rocks of the Manhattan Prong and the Newark Basin by a complex fault system known as the Ramapo Fault Zone.

Geology of the Manhattan Prong

The Manhattan Prong is a sequence of highly deformed metamorphic rocks, trending north-northeast, from New York City through Westchester County and western Fairfield County, Connecticut. The prong is bounded on the east by Cameron's Line, a complicated structure possibly representing a suture between two crustal blocks. On the west, the prong is bounded by the Newark Basin border fault and the Hudson River.

The stratigraphy of the Manhattan Prong has long been the subject of controversy and frequent revision, however, most recent workers recognize five formations within the prong. In order of decreasing age they are the Fordham Gneiss, the Yonkers-Pound

Ridge Granite, the Lowerre Quartzite, the Inwood Marble and the Manhattan Schist (see Table 2). The Fordham and Yonkers formations are Precambrian in age, and are separated from the Cambro-Ordovician aged Lowerre, Inwood and Manhattan formations by an angular unconformity. The relative ages of the Fordham and Yonkers formations are not known with absolute certainty. The Fordham is generally considered at least Grenville in age, and the Yonkers latest Precambrian.

Hall's (1968) detailed subdivision of the rocks of the Manhattan Prong near White Plains, New York, served as a basis for more recent workers. Correlations of the White Plains stratigraphy to other parts of the prong are tenuous due to the complex structural and metamorphic history of the area. Difficulties in correlation are compounded by the possibility of changes in original sedimentary facies.

The Fordham was divided into five members by Hall. They are:

Fordham A - Brown weathering garnet biotite quartzo-feldspathic gneiss.

Fordham B - Gray garnet biotite quartz feldspar gneiss interlayered with amphibolite.

Fordham C - Gray biotite hornblende quartzo-feldspathic gneiss with some amphibolite.

Fordham D - Rusty weathering sillimanite-garnet biotite quartzo-feldspathic gneiss.

Fordham E - Silliceous biotite-quartz plagioclase gneiss.

Most of the Fordham rocks probably represent metamorphosed eugeosynclinal deposits, interbedded with mafic volcanics. The Fordham formation was deformed and metamorphosed to granulite facies during the Grenville orogeny. Mineralogic and structural evidence indicates that the Fordham was recrystallized and deformed during Plaeozoic orogenesis.

The Yonkers Granite is thought to represent a metamorphosed rhyolite, emplaced during the opening of the Proto-Atlantic in late Precambrian time.

The assignment of formation status to the Lowerre, has been the subject of debate for nearly 100 years. It was first named and described by Merril in 1896, but many workers in the 20th century preferred to consider the Lowerre as part of the Fordham. In addition, the unconformity between the Cambro-Ordovician rocks and the Fordham, has not been recognized by all workers in the prong. The Lowerre is a relatively thin (40-ft. thickness), discontinuous unit representing an arkosic sandstone. The discontinuity of the unit is probably the result of deposition on an irregular Precambrian aged erosional surface. The Lowerre consists of quartz, with considerable amounts of potassium feldspar and minor biotite. The Lowerre is always observed in the same stratigraphic position, at the base of the Cambro-Ordovician aged cover rocks, overlying and truncating various members of the Fordham.

The Inwood Marble, consisting of dolomite and calcite marble interlayered with calc-silicate schists, overlies the Lowerre. Hall has divided the Inwood into five members, that lens in and out. In map pattern, the Inwood does not appear to be continuous, the result of tectonic thinning of fairly ductile marble during deformation. The Inwood

represents deposition on a carbonate bank, widespread in the Appalachian orogen during the late Cambrian and early Ordovician.

In the White Plains area, Hall recognizes three mappable members of the Manhattan, 'A', 'B', and 'C' (see Table 2). Manhattan 'A' (basal Manhattan) is a fissile sillimanite garnet biotite schist, interlayered with marble and calc-silicate schist. The Manhattan 'A' may be a transitional facies between carbonate and clastic sedimentation. It is recognized by Ratcliffe (1976) near the Cortlandt complex, and by Brock (1977) north of White Plains. Manhattan 'B' is a discontinuous amphibolite and Manhattan 'C' is a brown weathering, garnet muscovite biotite schitose gneiss. The Manhattan Formation was originally deposited in a miogeosyncline, and represents pelites, mafic volcanics and greywackes. The Manhattan Prong was metamorphosed, deformed and intruded during two major orogenic episodes, the Taconic (late Ordovician) and the Acadian (Devonian). A late Acadian metamorphic and deformational event can be recognized in some locations within the prong (Brock and Mose 1979). Mose and Hall (1979) infer a mid-Ordovician unconformity within the New York City group based on structural and isotopic evidence.

Brock (1977) has worked out a detailed sequence of events for the Manhattan Prong near Croton Falls, New York (see Table 3). The rocks of the prong were metamorphosed to K-feldspar sillimanite grade (upper amphibolite facies) at the peak of the Taconic orogeny. At this time the rocks underwent intense deformation, reflecting the effects of four distinct fold events during the orogeny. Taconic aged recrystallization affected the Precambrian rocks of the Manhattan Prong, destroying most Grenville aged metamorphic and structural features. Granulite facies mineralogy and textures survive as relicts within the Fordham, but are not present in the Cambro-Ordovician rocks, supporting the inferred unconformity between Fordham and younger rocks.

During Silurian time, deformation eased, but the prong was intruded by the Croton Falls and Cortlandt mafic complexes. The Acadian orogeny (Devonian) produced another set of folds (F_5), metamorphism of kyanite-staurolite (mid-amphibolite facies) grade, and the intrusion of the Peekskill Granite. The "final" Paleozoic metamorphic and deformational event occurred late in the Acadian Orogeny or during the Mississippian, causing local retrograde metamorphism (muscovite grade) and folding (F_6) (Brock, 1977). The "final" orogenic event is seen locally as tight isoclinal folds. Late metamorphism is evidenced by recrystallization on undeformed joint faces.

The ductile deformation occurred coevally with brittle deformation along the border fault and within the Manhattan Prong. The relationship of Precambrian, Paleozoic and post Paleozoic aged faulting will be discussed in a following section.

One of the significant problems involving rocks of the Manhattan Prong is correlation on a regional scale (see Table 2). The Fordham Formation is often correlated with the Precambrian Highlands gneisses. Some workers have tried tracing the Highlands across the boundary fault, comparing structure and metamorphic details with Fordham rocks. Correlation is tenuous since the Grenville age yielded by the Highlands and Fordham rocks, is a metamorphic age, not a time of deposition. Correlation of the rest of the New York City Group with rocks of the surrounding region is based on similarities in lithology, structural position, radiometric age determinations and fossil evidence. The Lowerre is considered the metamorphosed equivalent of the Poughquag Sandstone. The Inwood is correlated with the Wappinger Limestone Group, and the Manhattan with the Annsville Phyllite and Hudson River Shale. Metamorphism increases from chlorite grade near the Hudson River, to K-feldspar-sillimanite grade near the Connecticut border.

The Geology of the Newark Basin

The third geologic province in the area is the Newark-Gettysburg Basin. The basin extends 140-miles from York County, Pennsylvania, to Rockland County, New York (Figure 1). The basin, a down dropped crustal block, formed during Mesozoic time. Deposition was continuous from the late triassic through the upper Jurassic (Dames and Moore, 1977). Intrusion of the Palisades sill apparently occurred during deposition of sediments in latest Triassic-earliest Jurassic. The extrusion of the Watchung basalt flows followed later in the Jurassic. Rocks of the Newark series are in contact with the crystalline rocks of both the Manhattan and Reading Prongs, but the nature of the contact varies. At the northeastern edge of the basin, Triassic sediments unconformably lie over the Highland rocks, while the northeastern edge of the basin is in fault with the rocks of the Highlands.

The Newark Group is divided into four formations, the Hammer Creek Conglomerate, the Stockton Arkose, the Lockatong Argillite, and the Brunswick Shale and Sandstone. Deposits of conglomerate and sedimentary breccia lie at the edges of the basin, reflecting proximity to the uplifted Precambrian and Paleozoic rocks that are the sources of the Triassic aged sediments.

The boundary fault between the Newark series and older crystalline rocks is the Ramapo fault. Movement along the fault and subsidence of the basin, concurrent with sedimentation, produced the half-graben configuration of the basin. The rocks within the basin are not greatly deformed, displaying broad open folds of uncertain origin, gentle dips of strata, and minor faults with small offsets.

History of Brittle Deformation

A series of north-northeast trending faults pass through the area surrounding the Indian Point sites. The faults, some of which have been episodically active since the Precambrian time are collectively known as the Ramapo fault system. The system is composed of a number of parallel to sub-parallel branches and draws its name from the Ramapo fault, the boundary between the Reading Prong and the Newark Basin.

Ratcliffe (1976) mapped the faults in the vicinity of the Indian Point site, and interpreted a chronologic sequence of fault movements. Ratcliffe classified faults utilizing radiometric ages, cross-cutting lithologic relationships, and textural evidence. Dames and Moore (1977) utilize Ratcliffe's conclusions, and present evidence for timing fault movements based on geothermometry of fluid inclusions in calcite. More recently, Nelson (1980) and others have examined the stratigraphy and pollen remains in swamps and sag ponds along the Ramapo, seeking evidence of Post-Pleistocene faulting in the area. In addition, Aggarwal and Sykes (1978), Yang and Aggarwal (1981) Dames and Moore (1977), and Woodward-Cylde Consultants (Quarterly Reports, Jan 1977 - Jan 1982) have studied the recent seismicity in the region, solving for magnitude and location of earthquake epicenters.

The earliest documented movement along the Ramapo fault system is Grenville age (Ratcliffe 1976). Textural evidence seen in the Canopus Pluton indicates that movement along the Canopus Hollow fault (north of Peekskill) was synchronous with emplacement of the pluton. Flow structures and mylonitization displayed within the pluton indicate crystallization during shearing. Drag folds and the overall shape of the pluton suggest right lateral strike-slip motion. The Canopus Pluton, a diorite-monzontie,

has been radiometrically dated at 1150 m.y. (Rb/Sr), thus providing a minimum age for movement along the fault.

The Lake Peekskill fault is defined by a shear zone in the Precambrian gneisses that has not affected the Annsville Phyllite (Ordovician). The fact that the Annsville has not been deformed, places a limit on the last motion along the fault. Ratcliffe (1976) states that both the Canopus Hollow and Lake Peekskill faults were not reactivated during Paleozoic time, however, in a more recent article (Ratcliffe 1980) he suggests that movement as recent as Triassic has taken place within the Canopus Fault Zone.

Dames and Moore (1977) disagree with Ratcliffe's 1976 opinion, citing as evidence a sheared inlier of Poughquag Quartzite near Canopus Lake. The shear zone is considered by Dames and Moore to reflect thrust faulting along a northeast trending fault, sub-parallel to the Canopus Hollow fault. This implies post-Precambrian reactivation along the Canopus Hollow Fault. An additional strike-slip shear zone was mapped by Dames and Moore in Highland rocks, near the southwest corner of Canopus Lake, along the strike of the Canopus Hollow fault. This shear is considered additional evidence for reactivation of the Canopus Hollow fault in Paleozoic time. It is important to note that local activity occurring along part of a fault does not require movement along the entire length of a fault. Furthermore, the shear zone that displaces the Poughquag is not necessarily an extension of the Canopus shear zone, and may in fact be related to Paleozoic aged folding. Thus, Paleozoic aged movement along the Canopus Hollow fault is not required in the vicinity of Indian Point.

A number of faults of Paleozoic age separate the Manhattan Prong from the Hudson Highlands. Most prominent are the Thiells fault, the Annsville fault, the Peekskill fault and the Croton Falls fault. The Peekskill and Croton Falls faults outcrop on the east bank of the Hudson River, and generally trend east-west. The Thiells fault, outcropping on the west bank of the Hudson, and the Annsville fault on the east bank trend northeast. The Ramapo fault extends northeast from Peapack, New Jersey separating the Newark Basin from the Reading Prong. At Ladentown, it splays into two branches, trending 020° and 060°, respectively. The 060° branch connects with the Thiells fault, and the more northerly trending branch extends into the Highlands, through Tomkins Cove, New York.

The Peekskill, Croton Falls, Thiells and Annsville faults are primarily Paleozoic in age. The faults are marked by mylonite and ultra-mylonite, displaying retrograde chlorite grade, green schist facies mineral assemblages. Movement along the faults is generally right-lateral-strike-slip. Mid-Ordovician minimum ages of movement are inferred from cross-cutting relationships with dikes related to the Rosetown Pluton (mid-Ordovician), and radiometric ages of undeformed biotites from within shear zones (Ratcliffe, 1976). A lower Devonian K-Ar age of 396 m.y. places the most recent probable movement along the Roa Hook branch of the fault squarely within the Acadian orogeny. Similar data is available for the Thiells fault.

Younger faults can be distinguished from Paleozoic aged and older faults (Ratcliffe, 1980) by their different mineralization, and cataclastic textures. Younger faults are characterized by open work breccias, clay gouge, platy fracture and deeply incised fault scarps. Older faults display healed breccia, semi-ductile mylonite shear zones, and higher temperature minerals that reflect the general pattern of Paleozic aged regional metamorphism.

Reactivation and development of new faults occurred during Mesozoic time (Ratcliffe, 1980). Deep seated zones of weakness in crystalline basement were utilized in the

development of the Triassic basin, particularly the Ramapo-Cheesecote and Mott Farm Road faults (Ratcliffe, 1976). Structural evidence indicates that normal faulting was dominant during mesozoic time, with the latest activity along the Mott Farm Road branch of the Ramapo, dated at 163 m.y. by K-Ar methods (Ratcliffe, 1976). Late north-south vertical strike-slip faults with both left-lateral and right-lateral movements are present in the vicinity of Indian Point. The relationship of these faults to the Ramapo is uncertain, although the faults are probably Mesozoic in age (Ratcliffe, 1976; Dames & Moore, 1977).

Detailed work (Ratcliffe, 1976) shows that north-south faults at Tomkins Cove across the river from Indian Point are the youngest in the area. Mineralogy and textures found in the young, Tomkins Cove faults bear a strong resemblance to faults that have been radiometrically dated as Mesozoic. In addition, the time of last movement along the faults is constrained by the lack of fault related deformation in overlying Pleistocene sediments (Ratcliffe, 1976, 1980; Dames and Moore, 1977). A group of faults located at the Indian Point site was mapped in detail by Dames and Moore (1977). Displacement along the faults is not significant, no more than a few feet. The faults are filled with undeformed euhedral calcite crystals, many of which contain fluid inclusions. Temperature equilibrium studies on the fluid inclusions indicate average formation temperatures of 160°C. Dames and Moore (1978), infer a depth of formation, by applying the geologically conservative geothermal gradient of 50°C/km. This yields a temperature of 150°C at 3 km.

The amount of time necessary to expose rocks that form at a depth of 3 km is a function of denudation rates. A minimum of 45 m.y. is required to remove 3 km of material, if the rather rapid denudation rate of 15,000 yrs/meter is applied (Dames and Moore, 1978). This calculation sets another constraint on the possible minimum age of last movement on the faults. The growth of calcite in the fault zones has been attributed to circulating hydrothermal fluids related to Mesozoic igneous activity (Dames and Moore, 1978), suggesting a time of last movement in the Mesozoic.

Radiometric age determination of undeformed minerals that have grown within fault zones (Ratcliffe, 1976) and the lack of fault related deformation of Pleistocene deposits and surface features (Dames and Moore, 1977); Ratcliffe 1976, 1980), provide the best evidence that the faults in the Indian Point area have not moved in the last two million years. Data from recent drill cores that intercepted the Ramapo fault plane, show that the dip of the structure is highly variable. The cores, taken at four locations along the fault, indicate that the dip is consistently to the southeast, ranging from 45° through 70° (Ratcliffe, 1980). Textural evidence observed in the cores, indicate that the dominant latest motion in the fault has been right oblique normal faulting (Ratcliffe, 1980).

Recent Seismicity

In the last twenty years, the catalogue of instrumentally recorded seismic events in the northeast has grown tremendously. Locally, this is the result of a dense network of seismic stations, situated in the area around Indian Point, that has been operated since 1975. Data collection by regional seismic stations has continued in the same area since 1970 with a reported detection threshold of about magnitude 2 mb (Lg). Seismic networks have provided a basis for accurately determining the location, magnitude, and in some case focal mechanism solution for many small magnitude seismic events in the area of the power plant and the Ramapo fault zone. This recent seismicity is not markedly dissimilar from the historical seismicity reported for the region. The composite data set does not define or suggest a structural association of earthquakes, however, a

regional overview does suggest a higher level of activity in the northern New Jersey, southeastern New York area than that of the surrounding areas.

A number of hypotheses have been proposed to explain the observed pattern of seismicity. Current seismicity in the northeastern United States has been attributed to: a proposed stress system in which the maximum compressive stress trends to the northwest (Yang and Aggarwal, 1981); proximity to relatively young igneous bodies (McKeown, 1978); the response of the crust to glacial unloading (Stein and others, 1979); and, in the immediate region about the site, proposed reactivation of pre-existing fault zones based on a spatial correlation with surface traces of faults exposed within the region (Aggarwal and Sykes, 1978).

Earthquakes occurring near Indian Point have been characterized as shallow focus (<10 km) and low magnitude (1.0-3.0) (Aggarwal and Sykes, 1978). Focal mechanism solutions reported for earthquakes near the Ramapo fault or the margins of the Triassic basin indicate thrust movement on faults that parallel the dominant structural grain in the exposed bedrock (Figure 2) (Aggarwal and Sykes, 1978; Yang and Aggarwal, 1981). The stress field required for this interpretation, must be compressional and oriented to the northwest (Yang and Aggarwal, 1981). Whereas some of the seismic activity in southern New York may be related to northeast trending structures, a number of other trends, transversely oriented with respect to the dominant structures are present (Ratcliffe, 1976; Pomeroy et al, 1976; Blackford and Statton, 1978; Quarterly Report for the Indian Point Seismic Monitoring Network, November 1979 through January 1980) (see Figure 2). Thompson and Bebel (1979) describe northeast and northwest trends of epicenters in the coastal plain area of New Jersey, Delaware and Pennsylvania.

Many studies have attempted to quantify the stress regimes operating in the vicinity of the Ramapo fault. Dames and Moore (1977) determined the near surface stress by in-site measurements. While these results are variable, a fairly consistent northeast to eastwest trend for the horizontal component of compression was determined. This stress direction is transverse to that suggested by others (Aggarwal & Sykes, 1978) who base their interpretations on reported focal mechanism solutions. It is, however, in general agreement with regional stresses inferred from measurements and observations made throughout the northeastern United States (Sbar and Sykes, 1973).

An examination of the distribution of earthquakes in the vicinity of Indian Point indicates that not all earthquakes in the region can be attributed to northeast trending faults. A sequence of earthquakes occurred near Annsville, New York, from 17 January to 23 January 1980. A composite focal mechanism solution was constructed using data recorded by the Indian Point Seismic Monitoring Network. The solution indicates thrust faulting along one of two possible planes, oriented N2°W 29°E or N16°W 62°W (Quarterly Report for the Indian Point Seismic Monitoring Network, November 1979 - January 1980). This trend is obliquely oriented to the dominant structural fabric in the region, and requires a compressive stress field oriented east-west to northeast-southwest.

Low level microseismicity existing in the region is evidence that crustal adjustments are continuing in response to regional stresses. No evidence exists at the surface or in drill cores of the fault zones (in particular the Ramapo fault zone), that suggest any contemporary movement along faults exposed at the surface since the major period of activity during Mesozoic time. In fact geologic data obtained from cores of the Ramapo fault zone (Ratcliffe, 1980) show evidence of normal faulting as the last movement, which is consistent with the Mesozoic faulting regime and inconsistent with the thrust mechanism proposed by Aggarwal and Sykes (1978). To date, no satisfactory stress

regime has been proposed that adequately accommodates the observed pattern of low level seismicity, regional stress measurement data and those stresses inferred from recently reported focal mechanism solutions.

CONCLUSION

Low level microseismicity in the region is evidence that crustal adjustments are continuing in response to regional stresses. Detailed field investigations (e.g., Ratcliffe, 1976, 1980; Dames and Moore, 1977) have been conducted in the immediate vicinity of Indian Point, and along the major faults in the region. To date, no evidence has been found in the rocks exposed at the surface or sediments overlying fault traces or in cores obtained in the vicinity of Indian Point, that might support a conclusion that displacement has occurred along major fault systems within the New York Highlands, the Ramapo or its associated branches during Quaternary time (the last 1.5 m.y.). In the vicinity of Indian Point, evidence that no displacement has occurred in the last 65 m.y. (since the Mesozoic) along specific major structures has been observed.

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GLOSSARY

amphibole - A complex chain silicate mineral rich in iron and magnesium.

amphibolite - A metamorphic rock whose main components are amphibole and plagioclase feldspar

amphibolite facies - Rocks formed at moderate temperature and pressure conditions during regional metamorphism.

angular unconformity - An unconformity recognizable by the deposition of sediments over deformed rocks.

argillite - A compact mudstone, generally not laminated and not fissile.

arkose - A feldspar rich, generally coarse grained, sandstone derived from continental rocks.

breccia - A generally coarse grained rock composed of angular or broken fragments of rock, which may be formed tectonically in a fault zone, or by sedimentary processes.

brittle deformation - A term used to describe faulting and fracturing of rocks.

calc-silicate - A descriptive term applied to minerals or rocks consisting of calcium bearing silicates, such as diopside.

chlorite - A green iron-magnesium rich platy mineral.

chlorite grade metamorphism - Low-grade regional metamorphism indicated by the first appearance of chlorite in rocks of appropriate composition.

dike - An igneous intrusion that cuts across planar features of a rock.

disconformity - A break in the time-stratigraphic record separating two sequences of rock, both of which are bedded parallel to the unconformity.

ductile deformation - Occurs where rocks fold or flow when subjected to a stress field.

eugeosyncline - A geosyncline or basin in which vulcanism is associated with clastic sedimentation.

euhedral - A crystal bounded by well developed crystal faces.

facies - A set of conditions that specify the environment of formation of rocks (metamorphic or sedimentary).

geosyncline - A long linear basin, characterized by subsidence coincidental with sedimentation.

geothermal gradient - The relationship of temperature to depth (pressure) in the earth’s crust.

gneiss - A metamorphic rock formed by regional metamorphism, generally high grade.

granulite facies - Rocks formed at very high temperatures and pressures during regional metamorphism.

intrusion - The emplacement of an igneous body in a pre-existing rock.

isocinal folds - A fold in which the limbs are parallel.

mafic - A term used to describe dark rocks or minerals containing large amounts of magnesium or iron.

marble - A metamorphic rock consisting primarily of calcite or dolomite.

metamorphic grade - Rocks of any composition that have been metamorphosed under a specific range of temperature and pressure conditions.

metasediment - A metamorphosed sedimentary rock.

migmatite - A mixed rock composed of metamorphic material containing segregation of igneous material formed by injection or in-situ partial melting.

miogeosyncline - A geosyncline lacking volcanic deposits, commonly located adjacent to continental margins.

neotectonics - Post-Miocene structural history of the earth's crust.

orogen - A region that has been subjected to orogeny.

orogeny - The development of structures, metamorphism and igneous activity relating to mountain building.

pelite - A sedimentary or metamorphic rock rich in aluminum.

quartzite - A metamorphic or sedimentary rock consisting mainly of quartz.

retrograde metamorphism - Recrystallization of metamorphic rocks at conditions that are lower grade than those at which the rock was originally metamorphosed.

schist - A well foliated metamorphic rock that easily separates into flakes or slabs due to an abundance of platy minerals.

sedimentary facies - An restricted area within a litho-stratigraphic unit representing a particular depositional environment.

sill - An igneous intrusion that parallels the layering of the country rock.

tectonic - Pertaining to the forces that cause crustal deformation.

throw – The vertical component of fault motion.

unconformity - A primary feature representing erosion or non-deposition, resulting in a break in the stratigraphic sequence.

TABLE 1
GEOLOGICAL TIME SCALE

TABLE 2
PROPOSED CORRELATION OF THE STRATIGRAPHIC SUBDIVISIONS IN THE MANHATTAN PRONG WITH ROCKS IN ADJACENT AREAS

TABLE 3
GEOLOGIC HISTORY IN THE CROTON FALLS AREA
(after Brock & Mose, 1979)

FIGURES

Figure No.	**Title**
Figure 1	Geological Map, Southeastern New York (after Brock & Mose, 1979)
Figure 2	Seismicity of Southeastern New York and New Jersey (after Dames & Moore, 1977)