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AN EVALUATION TO DEMONSTRATE THE COMPLIANCE OF THE INDIAN POINT REACTORS WITH THE DESIGN OBJECTIVES OF 10 CFR PART 50, APPENDIX I

VOLUME I — MAIN REPORT

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Consolidated Edison Company
of New York, Inc.
and
Power Authority of the State of New York

February, 1977

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In addition, it is concluded in this study that the Indian Point reactors not only comply with the numerical guidance on design objectives as set forth in Appendix I, but also comply with the more stringent criteria set forth in the NRC Staff's previously proposed Appendix I (RM 50-2).

Based on the results of this evaluation, existing radwaste systems are sufficient to assure releases are "as low as is reasonably achievable" and no radwaste modifications or augments are required.

D. MAYER

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Introduction

Appendix I to 10CFR50 (Reference 33) provides numerical guidance on design objectives for light-water-cooled nuclear power reactors to meet the requirements of 10CFR 50.34a that radioactive material in effluents released to unrestricted areas be kept "as low as is reasonably achievable" (ALARA - formerly "as low as practicable" - ALAP). Section III of Appendix I requires that conformity with the numerical guidance on design objectives "be demonstrated by calculational procedures based upon models and data such that the actual exposure of an individual through appropriate pathways is unlikely to be substantially underestimated, all uncertainties being considered together." It is the intent of this report to demonstrate such conformity, and describe the methods, assumptions, models and other information used in arriving at this assessment. First, a discussion of parameters assumed in arriving at estimates of radioactive releases will be presented, followed by a description of assumptions and models used for estimating doses from such releases of radioactive materials.

History

With the publication in the Federal Register on December 3, 1970 of sections 50.34a and 50.36a in Part 50, the Atomic Energy Commission provided qualitative (but not numerical) guidance for determining when the requirement that operating and design objectives of power reactors maintain levels of radioactive materials in effluents 'as low as practicable' would be satisfied.

A proposed Appendix I to 10CFR 50 was published for public comment on June 9, 1971, which provided numerical guidance for design objectives and technical specification requirements for limiting conditions of operation to assure that the 'ALAP' concept of 10CFR50.34a and 10CFR50.36a would be met. Public rulemaking hearings on the proposed Appendix I (Reference 34) were initiated on January 20, 1972, and suspended in May of 1972 pending preparation of an Environmental Impact Statement to satisfy the National Environmental Policy Act of 1969. The final version of this Environmental Statement was issued in July 1973 (WASH - 1258, Ref. 14), whereupon public hearings were resumed in November 1973. This evidentiary hearing was concluded on December 6, 1973, after generation of thousands of pages of hearing transcripts and written testimony and exhibits.

The concluding statement of the position of the Regulatory Staff (RM 50-2)[1] was issued on February 20, 1974; oral arguments were heard by the AEC on June 6, 1974. After careful consideration of the record of the hearings and the views of the participants, the decision of the Nuclear Regulatory Commission was announced on April 30, 1975. The resultant Appendix I was published in the Federal Register on May 5, 1975.

One principal difference between the Staff's proposed Appendix I & the one adopted by the Commission on April 30, 1975 includes the deletion of limits on concentrations or quantities of radioactive

1. Hereafter in this report, reference to "proposed Appendix I" refers to the Regulatory Staff's position as set forth in RM-50-2 (Ref. 35). References to "Appendix I" apply to the Appendix I published by the Commission on May 5, 1975.

materials released. Rather, the Commission recognized that such limitations over and above overall exposure limits would be unwarranted and unnecessary; accordingly, the Appendix I limits adopted are concerned only with radiation dose limits.

A second major difference between the proposed regulation and the enacted Appendix I involves the criterion adopted that the doses to the public be limited on a per reactor basis rather than for all reactors at a site. The Commission recognized that the grouping of light-water-cooled nuclear power reactors on well chosen sites would be beneficial to the public interest.

Finally, although recognizing that an unambiguous choice of a specific dollar value for the monetary worth of a man-rem reduction in population dose could not be established on the basis of the hearing record, a conservative value of $1000 per man rem or man thyroid rem was adopted for the purposes of cost-benefit consideration of the necessity of installation of rad waste augments to effect a reduction in population dose. It is the intent of the Commission to require rad waste augments in all cases where the limits on maximum doses to individuals cannot be satisfied. Additional augments would be required when, and only when, the worth of each such augment (as determined by the $1000 per man rem figure) equals or exceeds the annualized cost of its installation, maintenance, and operation.

Table I presents a brief summary and comparison of the requirements of the proposed Appendix I and the Appendix I adopted by the Commission.

Discussion

A. Source Terms

The average quantity of radioactive material released to the environment from a nuclear power reactor during normal operation is called the 'source term'; this is the amount of radioactive material used in calculating the radiological environmental impact of routine plant operation. Source terms include releases of radioactivity in both liquid and gaseous form.

Estimates of source terms require consideration of the generation, process, transport and release mechanisms which affect plant effluents. Many parameters which have an effect on source terms apply on a generic basis to all PWRs and were based on operating experience (e.g. failed fuel percentages, primary to secondary leak rate, etc.) Appropriate plant specific design features were also considered in this evaluation where source terms were affected.

1. Gaseous

Release of radioactive materials in gaseous form from normal reactor operation arise from several principal sources:

a) Waste gas processing systems
b) Steam generator blowdown systems
c) Condenser air ejector
d) Containment purges and/or pressure reliefs

e) Auxiliary Building (Primary Auxiliary Bldg. I.P. 2&3, Chemical Systems and Nuclear Service Bldgs., I.P.1) and turbine building ventilation exhaust.

f) Secondary system steam leakage.

(These sources will be further discussed below).

Other sources, such as atmospheric steam dumps and fuel storage building ventilation are negligible and were therefore not considered. Gaseous releases of interest include the noble gases, radioactive material in particulate form, radioiodine, tritium (H-3), and carbon -14 (C-14).

During reactor operation, isotopes of Xenon, Krypton and Iodine are produced in the fission process, and following fission, may diffuse out of the fuel into the pellet-clad gap.

If the clad of any fuel rods should lose its integrity, the gap activity of that rod could be released to the reactor coolant. In general, clad failure to some degree is a prerequisite for release of fission products (other than tritium) to the reactor coolant and, ultimately, the environment.

Primary to secondary tube leakage can result in releases via several secondary side pathways, and is in fact a prerequisite for gaseous releases from the secondary side of the plant. By far the most significant of these releases occurs via the condenser air ejector. Noble gases in reactor coolant leaked to the secondary system are all essentially transported out of the steam generator in the steam phase; when the steam is condensed in the condenser, these gases are removed with other non-condensibles and vented to atmosphere. Unlike noble gases, the iodines exhibit an affinity for the liquid phase in both the steam generator and the condenser. Partition Factors (i.e., the ratio of the concentration of a nuclide in the gas phase to the concentration in the liquid phase) of 0.01 and .0075 were assumed for iodines in the steam generator and condenser, respectively.

Other secondary side gaseous release pathways include discharges from the Blowdown Flash Tank (BFT) vent and secondary side leakage, which was considered to consist entirely of vapor (i.e., either steam or liquid flashing to steam).

One of the most significant sources of releases arises from the leakage of reactor coolant into the containment; periodic pressure relief of the containment and purging of containment releases this activity to the atmosphere. It was assumed, based on utility operating experience, that 1%/day of the reactor coolant noble gas inventory and 0.001%/day of the reactor coolant iodine inventory leaked into containment.

Finally, sources from auxiliary building ventilation exhaust were estimated based on 160 lb./day of leakage into the auxiliary building and a partition factor of 0.0075 for radioiodine.

The waste gas processing systems are designed to collect, concentrate, store, and discharge fission gases removed from primary water. These gases are collected as a result of two principal processes: the displacement of cover gas from various radioactive liquid containing tanks in the plant, and stripping of gases from reactor coolant during either normal operation (continuous) or in preparation for cold shutdown. These gases are routed to a header, compressed, and collected in storage tanks for radioactive decay prior to release.

I. Plant Design Features to Reduce Releases

a. I.P. 2&3

Releases of radioiodine and radioparticulates are minimized through the use of filters in the principal gaseous release flow paths; noble gas releases are minimized primarily through holdup for radioactive decay of short-lived (half life $<$ 8 days) noble gases. Purging of the containment atmosphere (assumed to occur four times per year) is normally preceded by internal recirculation for 16 hours (at a flow rate of 16,000 SCFM) through roughing filters, High Efficiency Particulate Absolute (HEPA) filters, and a charcoal absorber. Roughing & HEPA filters are effective in particulate removal, and charcoal filters in iodine removal. All containment releases (either purges or pressure reliefs) pass through roughing, HEPA, and charcoal filters prior to being released to the environment.

PAB ventilation exhaust (including ventilation from the blowdown tank area and liquid holdup tanks area) is normally vented through roughing and HEPA filters, with the additional capability for automatic diversion of ventilation flow through charcoal filters upon indication of high gross activity in the PAB discharge.

Fuel Storage Building (FSB) ventilation exhaust likewise normally passes through roughing and HEPA filters. Technical Specifications also require the operation of FSB charcoal filters during handling of spent fuel to minimize releases in the event of a fuel handling mishap.

Gases collected by the Waste Gas Processing System (i.e. cover gases and continuously stripped gases) are compressed and routed to the four 150 psig 525 $ft.^3$ large gas decay tanks, where a minimum 45 day decay period normally elapses before release. Gases stripped from reactor coolant during shutdown degassing are normally compressed and routed to the six 150 psig, 40 $ft.^3$ small gas decay tanks where they may be stored for a similar decay period.

Half lives of the noble gas isotopes of interest range from 32 seconds (Kr-90) to 10.7 yr (Kr-85), as shown in Table VIII. For a 45 day holdup period, Kr-85, Xe-131m, and Xe-133 would be the only noble gas istopes expected to be released in any significant quantity ($>10^{-4}$ Ci). Radioiodine releases from gas decay tanks would likewise not be of any significance.

Should operation of the Secondary Boiler Blowdown Purification System become necessary due to primary to secondary tube leakage, gaseous radioiodine releases may be further minimized (if Unit 1 is operational) by diversion of the BFT vent exhaust to the Unit 1 condenser via the condenser flash tank. Since iodines have a strong affinity for the liquid phase, they remain (for the most part) in the condensed liquid and do not escape as a gas.

b. Indian Point 1.

All major gaseous releases from Unit 1 are made as elevated releases via the plant vent atop the superheater stack. Such elevated releases generally result in more favorable atmospheric dilution and thus lower potential offsite doses. In addition, releases from all gas storage tanks pass through an absolute filter prior to release.

To maximize gas storage tank capacity in Unit 1, a hydrogen re-combiner system is installed, which was designed to oxidize the hydrogen used as cover gas in various liquid tanks, thereby minimizing the volume of gas that must be stored and disposed of.

Pressure relieving of the Unit 1 containment is only necessary about once every 10 days (for about 30 minutes) as opposed to twice daily (for 1-2 hours) of Indian Point 2&3. Unit 1 is also purged when shut down, as at Unit 2&3. Gaseous releases from the I.P.1 containment are therefore not as significant a source of release as for I.P. 2&3.

2. <u>Liquid</u>

Releases of radioactive materials in liquid form during normal reactor operation also originate from several principal sources:

a) Processed water generated from the boron recovery system (i.e. shim bleed) which is discharged to the environment.

b) Waste processed through the liquid waste disposal system.

c) Discharged steam generator blowdown.

d) Detergent and chemical wastes.

e) Turbine building drains

Liquid releases of interest include the release of fission products, tritium, and activation products. These sources are further described below.

The generation of liquid source terms from a power reactor involves, in addition to the factors described above for gaseous source terms, consideration of reactor coolant cleanup flow rates, decontamination factors [1.] of equipment installed in these cleanup trains, and reduction of activity levels from leakage of primary coolant. In addition, liquid source terms will depend on activities and quantitites of liquid waste (including blowdown) processed through the waste treatment systems (rad waste system or SBBPS)[2] and the decontamination factors realized in the treatment processes. For purposes of this evaluation, only 'normal' flow paths were assumed; Table V lists the DF's assumed for equipment considered to be normally used in the radwaste, shim bleed, and blowdown purification systems.

Purification

In order to maintain reactor coolant activity and solids levels at acceptable concentrations, a side stream of reactor coolant ('letdown' or 'primary blowdown') is taken from the reactor

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1. Decontamination Factor (DF) is defined as the ratio of the initial concentration of a nuclide in a stream to the final concentration of that nuclide in the stream following treatment by a given process.

2. SBBPS - Secondary Boiler Blowdown Purification System.

coolant system at a flow rate of about 75gpm, and passed through mixed bed demineralizers after being reduced in pressure and temperature. Cation bed demineralizers may also be used in series with the mixed bed demineralizers to control cesium activities levels should this be necessary. An average flow of 7gpm (on an annual basis) was assumed to pass through these cation demineralizers.

As the fuel cycle progresses, it becomes necessary to process reactor coolant to remove boron to compensate for core burn-up reactivity effects. During load follow type operation, reduction of boron concentration will also be required to compensate for the negative reactivity effect of Xenon poisoning following a reduction in reactor power. Additional dilution will be necessary for a period of time at the new power level until Xenon equilibrium is reached. Boron dilution and recovery is accomplished in Units 2&3 by passing the required portion of the letdown flow through the boric acid evaporator, which reduces the boron and solids concentration in the distillate. This distillate, now reduced in boron concentration, may be passed through a demineralizer to further reduce boron concentrations, and then recycled to the reactor coolant system or released.

The boron concentrate from the evaporator bottom may either be reused or disposed of as solid waste.

Unit 1 has no capability for boric acid recovery; primary blowdown is normally returned to the clean water storage tanks for reuse, or if dilution is needed, a portion may be processed through the waste evaporator as waste with clean makeup provided to the primary coolant system. Primary blowdown processed through the liquid waste evaporator is normally discharged. At low boron concentrations, boric acid demineralizers may be used to remove boron in lieu of the waste evaporator pathway.

Liquid Waste Disposal

The Liquid Waste Disposal system is designed to receive, store, and process all radioactive liquid wastes to reduce levels of radioactivity prior to release to the environment. Letdown purification and secondary blowdown treatment systems are considered separately and will not be reconsidered here.

The Liquid Waste Disposal system processes aerated wastes from the equipment, floor, laboratory and sampling drains, valve leakoffs, the containment sump, and miscellaneous sources of dirty, non-reusable waste. In general, these wastes are collected in waste holdup or collection tanks for decay of short lived isotopes and processed through a waste evaporator. The resultant distillate is collected in a waste distillate tank where it is monitored, sampled, analyzed, and released if acceptable.

Secondary Blowdown

In the event of a primary to secondary tube leak, it is possible to treat the blowdown of any Indian Point unit via interties to the Unit 1 Secondary Boiler Blowdown Purification System (SBBPS).

After passing through a Blowdown Flash Tank, the contaminated blowdown condensate is cooled, filtered, and processed through demineralizers prior to release to the environment. The flashed steam may be either released to atmosphere or condensed in the Unit 1 condenser (if operating) and returned to the feed-water system.

Detergent Wastes

Detergent wastes from laundry operations, equipment decontamination solutions, and personnel decontamination showers are normally released without treatment because of their low activity levels. An additional 0.06 Ci/yr of appropriate radionuclide distribution was added to the liquid source term to account for these releases.

Turbine Building Floor Drains

Releases from leakage of secondary coolant into the turbine building were computed assuming 7200 gpd of leakage at main steam activity and no treatment.

Anticipated Operational Occurrences

The calculated source term was increased by 0.15 Ci/yr per reactor using the same isotopic distribution as the calculated source term to account for anticipated operational occurrences (component failure, procedural error, etc.). This value is based on U. S. reactor operating experience between January 1973 and June 1975.

B. Radiation Doses

Calculations of radiation doses to man as a result of operation of the Indian Point plants involves consideration of the source term (both liquid and gaseous), site meterology and hydrology, land usage in the area, and population distribution and location. Radiation doses to both the whole body and various organs from all major air and water related pathways were considered in this evaluation, using the basic models described in NRC Regulatory Guide 1.109. In addition, annual population integrated thyroid and whole body does were computed for the population within a 50 mile radius of the site.

1. Doses from Gaseous Releases

- Meteorology -

The atmospheric transport and diffusion model used in the evaluation of potential radiation doses to the public resulting from gaseous releases is the straight line airflow model, presented by Sagendorf. (Ref. 27) Releases were treated as ground level releases, with credit taken for building wake as applicable. Values of σ_y and σ_z were defined by on-site measurements of temperature differential, which determines the atmospheric stability classes of Reg. Guide 1.23. These measurements were taken from the on-site 400' meteorological tower; wind data were taken at the 33' elevation and temperature differentials between the 200' and 33' levels. Data recovery for the two years of data used (1974-1975) was 94.6% and 96.2% respectively. Calms and variable winds were assigned to the lowest windspeed class and to wind directions in proportion to the directional distribution at the lowest windspeed within an atmospheric stability class. Comparison of these meteorological data with the previous data in the Indian Point area shows that these data are representative of long term conditions at the Indian Point site. The program of meteorological monitoring and data acquistion is in accordance with Regulatory Guide 1.23.

Air flow patterns at Indian Point are significantly influenced by surrounding topographic features; the proximity of the Hudson River and the alignment of the valley ridges in a northeast-southwest direction create a channeling effect for the air along the river valley during light geostrophic conditions. The valley wind is diurnal in nature, with a distinct upvalley airflow predominant during unstable (daytime) hours and a downvalley flow predominant during stable (nighttime) hours.

During periods of predominantly moderate to strong pressure gradients wind directions are similar to those observed on open terrain.

<u>Pathways Considered</u>

Radiation doses from releases of radioactive material in gaseous form were considered to occur through the following pathways:

a) Immersion in a semi-infinite cloud of noble gases. Gamma and beta doses in air and doses to the skin and whole body of an individual were computed for this pathway.

b) Inhalation of tritium, C-14, radioiodine and radio-particulates.

c) Ingestion of radioiodines, radio particulates, tritium, and C-14 from locally produced vegetables and meat.

d) Ingestion of radioiodine, radio particulates, tritium, and C-14 via the cow-milk pathway.

e) Direct exposure to activity deposited on the ground.

These pathways and their associated models are further described below.

The semi-infinite cloud model for estimating immersion doses assumes that cloud dimensions are large compared to the range of the radiation under consideration; as a consequence, an energy equilibrium (i.e., the rate of energy absorption per unit volume equals the rate of energy release per unit volume) exists.

Doses from gamma radiation will be overestimated to some degree by this model due to the fact that cloud size will not, in general, be large compared to gamma ray range. The model used computes total body dose from external radiation at a depth of 5 cm into the body and the skin dose at a depth of .007cm of tissue. Regulatory Guide 1.109 details equations used for this model and the dose factors used in these equations. In accordance with the guidelines of Table I of this Regulatory Guide, only noble gases are considered in the evaluation of immersion doses.

Doses to the total body and principal organs resulting from inhalation of tritium, Carbon-14, radioiodine and radioparticulates were evaluated for each age group (adult, teen, child and infant) and for each radionuclide in the source term. In general, iodine inhalation thyroid doses were found to be the most significant of those considered. Inhalation doses were evaluated at or near the nearest residence in critical sectors, conservatively assuming 24 hour occupation at that location.

The concentration of radioactive material in vegetation results from deposition onto the plant foliage and from uptake by the vegetation of activity initially deposited on the ground.

Concentrations of radionuclides in vegetation resulting from deposition onto the plant foliage or the ground were computed for all radioparticulates, and for that fraction of the iodine released (0.5) considered to be elemental. Concentrations of carbon-14 in vegetation were calculated by assuming that the ratio of C-14 to natural carbon in vegetation is the same as the ratio of C-14 to natural carbon in the atmosphere surrounding the vegetation. Tritium concentrations in vegetation were also calculated by assuming a relationship between vegetation concentration and air concentration of tritium (eq. C-9 of Reg. Guide 1.109). The value of the absolute humidity used was based on an assumption of 65% relative humidity and the water vapor capacity of air at $60^{o}F$ (5.7 grains/ft^3 - Ref. 25).

Relative deposition rates of radioparticulates and elemental iodine per unit area were computed using the equations presented in the Draft NRC computer code XOQDOQ (Ref. 26) for ground level releases. These equations are based on the curves presented in Reg. Guide 1.111.

For the milk and meat ingestion pathways, concentrations of radionuclides in these foodstuffs are dependent on the amount and contamination levels of the feed or forage consumed by the animal. It was conservatively assumed that meat and milk producing animals in the Indian Point area were on open pasture for six months of the year, although the use of stored feeds is much more prevalent than this would indicate. Concentrations of radionuclides in vegetation, milk, and meat were all calculated in accordance with Reg Guide 1.109.

Radionuclides deposited onto the ground surface will result in doses to the total body and skin from direct exposure to the contaminated ground. For purposes of this study, the approximate average deposition over the reactor life was considered by evaluating this accumulation at the mid point of plant operating life (approximately 15 years).

Doses from inhalation, ground deposition, immersion and ingestion were calculated at appropriate locations using the food ingestion rates and dose factors presented in Reg. Guide 1.109. A shielding and occupancy factor of 0.7 was applied to doses from immersion and ground deposition.

Table VII details the locations relative to Unit 3 of the nearest cow (and residence) for each of the 16 cardinal compass point locations. It is not anticipated that additional land will be converted to pasture use for milch animal grazing because of the high degree of commercial, industrial, and residential land usage in the area. Factors such as the limited degree of land availability, the high economic value of the land, and the high population density in the Indian Point area entered into this assessment.

No goats or other milk or meat producing animals are located within a five mile radius of the site.

2. Doses from Liquid Releases

Hydrology and Usage[2]

The Indian Point Reactors are situated on the eastern bank of the Hudson River some 42 miles north (mile point 42) of Battery Park in New York City. The Hudson River is a combination coastal-plain estuary and river, properly referred to as the Hudson River Estuary. The water of the Hudson is affected by tidal oscillation from the mouth in New York Harbor north to Troy where further upstream tidal influence is blocked by the Federal Dam. Flow in the lower Hudson (i.e., the Hudson south of Troy) is dominated by tidal currents rather than the fresh water discharge. Average monthly fresh water discharge at the mouth of the Hudson varies from 8,000 to 50,000 CFS with a yearly average of 19,700 CFS.

Table IX shows mean monthly fresh water discharge flows as measured at the USGS gauging station at Green's Island for the years 1947-1965 and 1969-1970. The ratio of freshwater flow near the mouth of the Hudson to freshwater flow at Green's island averages about 1.55; due to the limited drainage basin area between Indian Point and the Battery, it is estimated that the flow at Indian Point should exceed that at Green's Island by a factor of 1.5.

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2. Discussion based on NYU Institute of Environmental Medicine Progress Report, Vol. II, "The Fate of Gamma-Emitting Radionuclides Released into the Hudson River Estuary and an Evaluation of their Environmental Significance", M.E. Wrenn and J.W. Lentsch.

Tidal flows in the Indian Point area are about 100,000-150,000 CFS. Over an average tidal cycle of 12.5 hours, the net flow is in the downstream direction and essentially consists of the net freshwater discharge, since the net tidal flow over such a cycle is zero. Dilution by the minimum monthly average non tidal flow (8000 CFS) was assumed for computing population doses. ALARA doses were computed assuming dilution by a factor of 5.

Presently, the Hudson River is used principally for industrial purposes, and is a major transportation artery for freighter and barge traffic to upstate New York and the St. Lawrence Seaway.

Agricultural utilization of the Hudson River (i.e. for irrigation purposes or animal watering) is precluded in the Indian Point area because of the general unsuitability of the river for these purposes.

Use of the Hudson for water supply purposes is also precluded south of Chelsea (mile point 65) which is the nearest point of potable water supply.

Some 30 parks and public beaches are located between Croton Point (mile 31) and Manhattan. Sewage, oil, and industrial pollution make this area largely unsuited for swimming, although it was conservatively assumed that 1% of the people in a 50 mile radius swim one hour per day for three months a year in the Hudson. Most commerical fishing in the Hudson River has recently been banned due to the presence of certain industrial pollutants. However, fish consumption population doses were estimated assuming the 1968 commercial catch of 340,000 pounds and a sportfish catch of 200,000 pounds, although reliable sportfish data is not presently available.

Other usage of the Hudson River is primarily limited to pleasure boating and shoreline recreational activities.

Pathways Considered

Since agricultural utilization of the Hudson is non existent or extremely limited, the radiological impact on man via the irrigated food or animal watering pathways is non existent and was not considered in further detail. Radionuclide concentrations in the Chelsea water supply have been calculated[3] to be a factor of at least 500 lower than in the water in the Indian Point area. Exposures from ingestion of drinking water are therefore negligible and were not considered in further detail.

Radiation exposures from releases of radioactive material in liquid effluents were considered to occur through the following pathways:

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3. M.E. Wrenn and J.W. Lentsch, Op. Cit. P. 566

a) ingestion of aquatic foods (fish and invertebrates)

b) exposure at shoreline locations from sediment deposits of radioactive materials.

c) immersion by swimming in the Hudson.

d) recreational boating on the Hudson River.

These pathways and their associated models are further described below.

Ingestion of fish is the principal mechanism for exposure via the aquatic food pathway. Other aquatic foods, such as shellfish, were considered although their significance is essentially limited to the ingestion of crabs which are harvested and consumed in limited numbers by the local population. Aquatic plant and seaweed ingestion, although found in other estuaries, was not considered since the Hudson River is not a source of such food.

The concentrations of radionuclides in aquatic foods are directly related to the concentrations of these nuclides in water. The ratio between the concentrations of radioactive materials in aquatic organisms and in water is given by the 'Bioaccumulation Factor'; these are tabulated for the various radioisotopes for various organisms of interest in Table A-8 of Regulatory Guide 1.109. These factors represent the number of picocuries (pci) per kilogram of flesh (or vegetation) per pci per liter of water.

For purposes of determining the appropriate Bioaccumulation Factors for use in this evaluation, the Indian Point units were considered as located on a freshwater site. In reality, water at Indian Point is never completely fresh. Observed average chlorosites at Indian Point have ranged as high as 2.5 g/l, or about 13% sea water and 87% fresh water. Because of the variable magnitude of fresh water runoff and tidal influx, the chemical features of the Hudson vary considerably both with time and along its length. Qualitative or quantitative evaluation of the behavior of radionuclides in such a system is thus a complex task which cannot be adequately described by the simplified model employed for this evaluation.

According to the NRC models employed in this study, ALARA doses via the fish ingestion pathway were found to account for more than 90% of the total dose received by the hypothetical maximum exposed individual. In addition, the isotopes CS-134 and CS-137 contributed more than 90% of the dose received from fish ingestion. Studies conducted by the New York University Institute of Environmental Medicine (Ref. 16) indicate that the behavior of cesium in the Hudson is indeed a complex phenomenon, and that fish ingestion is not nearly as significant a source of exposure as this study would indicate.

The NYU study shows that Cesium concentrations in fish are regulated at a relatively constant value independent of the concentrations of Cs in water, and that Bioaccumulation Factors are thus inversely proportional to the water concentration of Cs. This explains the lower Bioaccumulation Factor for Cesium reported by numerous investigators for salt water as opposed to freshwater fish because of the higher stable Cesium content of sea water. The NYU report also states that water at Indian Point has a (disolved) Cesium concentration which is much higher than would be expected from simple mixing between sea water and fresh water, and postulates that these higher concentrations result from leaching of Cesium from bottom sediment by saline water.

Use of the Bioaccumulation Factors of Regulatory Guide 1.109 for a freshwater site will thus substantially overestimate fish ingestion doses because no account is taken of the phenomena just discussed. However, radiocesium concentrations in fish may still be estimated through the use of a Bioaccumulation Factor, provided that this factor is determined for the body or water of interest rather than on the general basis of a fresh or salt water body. This factor has been estimated (Ref. Table IX-5 of Reference 16) to be about 150 for the flesh of indigenous fish caught in the Indian Point area. In contrast, the Cesium freshwater Bioaccumulation Factor presented by Regulatory Guide 1.109

for fish (and assumed in this evaluation) is 2000. Fish ingestion doses are, therefore, overestimated by this evaluation by an order of magnitude or more.

A second conservatism inherent in the NRC model concerns the location (at a point near the discharge canal) at which the concentrations in the river of the discharged radiocesium (and thus the concentrations in fish) are evaluated. Use of this model implies that these fish have been grown directly in such a location prior to their being caught and adds about a factor of five in additional conservatism. In Volume 1 of the Final Environmenal Statement on Radiation Standard 40CFR190 (Reference 31) the EPA, in discussing the assumption of "discharge canal" fish, states that such situations, although perhaps theoretically possible, have not been observed and are not anticipated to actually occur.

Although fish ingestion doses from Indian Point releases are well within Appendix I design objectives, use of site specific and realistic assumptions regarding this pathway would reduce estimates of these doses by between one and two orders of magnitude.

Intake of aquatic foods results in an internal exposure to various organs of man as a result of deposition of radioactivity in that organ.

This deposition of radioactivity continues to deliver a dose to that organ at a rate proportional to the activity remaining in the organ at any time. Removal of this radiological burden is accomplished by the mechanisms of radioactive decay and biological removal, i.e., the removal of the nuclide by the organ's own metabolic processes.

Because of the different chemical natures of the various radio-isotopes released and the complexity of the body's chemistry, some isotopes have affinities for certain organs and deliver the bulk of their dosage to that organ. Two well known examples are the attraction of iodine to the thyroid and strontium to the bone.

Dose factors for internal exposure of ingested radionuclides are given in Tables A-3 through A-6 of Regulatory Guide 1.109. These dose factors are based on models developed by the International Commission on Radiological Protection (ICRP), which assumes an "effective" decay energy from a nuclide located at the center of a spherical organ of an appropriate effective radius.

Reactor produced radionuclides can deposit in sediment in the river, particularly in shallow, protected environments (e.g. coves), giving rise to an additional exposure pathway. Calculations of doses were performed by treating the sediment deposits as an effective surface planar source and considering the fraction of the dose received from this source at the shoreline location.

Doses to an individual from swimming (water immersion) and boating were computed using equation 7 (page F-27) of Volume 2 of Wash 12?? "Final Environmental Statement concerning Proposed Rule Making Action: Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion 'As Low as Practicable' for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents".

3. Population Doses

Annual integrated population doses (i.e. the summation of the dose received by all individuals within 50 miles of the plant) were calculated for the principal exposure pathways (both airborne and water related) described above. Population fractions of 0.66 for adult, 0.14 for teens, and 0.20 for children were assumed for this evaluation.

Gaseous

For purposes of evaluating annual population integrated total body (man-rem) and thyroid (man-thyroid rem) doses, the 50 mile region around the plant was divided into 16 sectors centered on the cardinal compass points and subdivided into 12 radial segments as shown in Figure 3. Atmospheric dispersion factors (X/Q) and relative depositions (D/Q) were evaluated at the midpoint of each subregion thus defined.

The annual population integrated total body dose from noble gases and total body and thyroid inhalation doses from iodines, particulates, C-14 and H-3 were evaluated by summing the products of the individual doses (either total body or thyroid, as appropriate) in each subregion and the population in that subregion. A shielding and occupancy factor of 0.5 was applied to noble gas immersion doses in accordance with Reg Guide 1.109. Population data used were obtained by linear interpolation of the 1970-2010 population data in Tables 2.4-1.B and 2.4-1-C of the I.P.3 FSAR.

In addition, population integrated whole body doses from external exposure to surface deposition of radioactive effluent were estimated in a similar manner, including the use of a 0.5 shielding factor.

Liquid

Annual total body and thyroid population doses from liquid discharges of radioactive materials were evaluated for ingestion of aquatic foods, and for swimming, boating, and shoreline recreational activities. Population doses from consumption of aquatic food products were evaluated using the total sport and commercial harvests of the relevant food products from the Hudson. It was assumed that sport harvests were consumed by the 50 mile population. Commercial harvests were considered as part of the total U.S. harvest with average concentrations reduced proportionally.

Recreational activity (swimming, boating, and shoreline usage) population doses were evaluated with appropriate recreational usage for each activity and age group considered.

4. Summary of Evaluation of Maximum Individual (ALARA) Doses

Gaseous

Gamma and Beta radiation doses in air from noble gas releases at Indian Point are presented in Table X1. These air doses were evaluated, as required, at the nearest offsite location that could be occupied during plant operation.

a. <u>Indian Point Unit 1</u>

Table XII summarizes by age group and pathway the maximum doses from Indian Point Unit 1 gaseous releases to the total body and principal organs calculated in this evaluation. This table shows that adults are the critical age group with maximum computed doses of 0.630 mr/yr to the total body, 0.548 mr/yr to the skin, and 0.259 mr/yr to the thyroid. Such a "maximum exposed" adult would reside at a location 730 meters east of Indian Point Unit 3, would consume vegetation from the garden located in this area and obtain his milk and meat supplies from the dairy located 7 miles SSW of Indian Point Unit 3.

b. <u>Indian Point Unit 2 or 3</u>

Table XIII presents, for Indian Point Unit 2 or 3 gaseous releases, the same type of information as Table XII. Table XIII shows that adults are again the critical age group for all doses except those to the thyroid, for which children are the critical age group. Total Body doses of 0.183 mr/yr and Skin doses of 0.163 mr/yr were estimated for the adult, and a thyroid dose of 1.71 mr/yr to the child. These individuals would reside at, and obtain their foodstuffs from, the same locations specified for Table XII.

<u>Liquid</u>

a. <u>Indian Point Unit 1</u>

Table XIV shows the liquid pathway doses to the total body and critical organ (liver) of the maximum individual computed for

Indian Point Unit 1 liquid releases. Liver and Total Body doses of 0.468 mr/yr and 0.349 mr/yr respectively are indicated by this table.

b. Indian Point Unit 2 or 3

Table XV tabulates similar information for exposures arising from Indian Point Unit 2 or Unit 3 liquid releases. Again, adults are the maximum exposed age group and maximum expected doses of 0.868 mr/yr and 0.654 mr/yr to the liver and total body are shown.

5. Summary of Evaluation of Population Integrated Doses

Integrated population doses from gaseous releases to the total body (in man-rem) and to the thyroid (man-thyroid-rem) are illustrated in Table XVI for the different pathways evaluated. Table XVII illustrates total population doses from all pathways for effluent releases in liquid form. Operation of all three units would thus result in estimated total population doses of 4.87 man-rem (total body) and 0.62 man-rem (thyroid) from liquid discharges and 49.34 man-rem (total body) and 111.7 man-rem (thyroid) from discharges in gaseous form.

6. Comparison of Requirements of Appendix I and RM-50-2 and Indian Point Radiological Consequence Evaluation

Table XVIII compares the annual design objectives of Appendix I and the staff's Proposed Appendix I (RM 50-2) with the doses calculated by this evaluation. Inspection of this table shows that, without exception, the design objectives of Appendix I are satisfied by each of these units. In fact, Table XVIII also shows that the generally more stringent design objectives of RM 50-2 are met by all the Indian Point units. (Although not shown on this table, RM 50-2 activity limits on liquid releases (5 Ci/reactor) and gaseous I-131 releases (1Ci/reactor) are also satisfied.)

C. Cost Benefit Evaluation

By letter dated February 18, 1976, the USNRC indicated that they were planning to conduct a cost-benefit evaluation on a generic basis for plants whose construction permit applications were filed prior to 1/2/71. By letter dated June 3, 1976, the NRC Staff stated that this generic evaluation could be applied to the Indian Point facilities, provided that the information requested in their February 18, 1976 letter was supplied. Since this evaluation, together with information previously submitted to the NRC, provides all the information requested in the February 18, 1976 letter, no cost benefit evaluation is required.

Perspective

As can be seen from this evaluation, releases of radioactive material in liquid and gaseous effluents from the Indian Point Reactors do indeed meet the criterion of "As Low as Reasonably Achievable" as set forth in Appendix I. The purpose of this section is to place these releases (and their consequent radiation doses) in proper perspective with regard to other sources of radioactivity, both natural and man-made.

Natural 'background radiation' represents by far the largest single source of radiation exposure to man; this source of exposure originates from two principal components, cosmic radiation, and the radiation from natural radioactive materials in soil, water, and building materials, etc.

Natural radioactive materials in the environment are of two general classes, primordial and cosmogenic. Primordial radionuclides consist primarily of isotopes of the heavy elements and belong to the three radioactive series headed by U-238, U-235, and Th-232. Others include Rb-87 and K-40; the abundance of potassium in the earth is so great that K-40 alone contributes about one third of natural background radiation's dose to man.

Cosmogenic radionuclides are produced by the interaction of cosmic nucleons with atoms in both the atmosphere and the earth. Major contributors to exposure of man include C-14, H-3 and Na-22, although very little of natural background radiation is attributable to the cosmogenic radionuclides ($<$1mr/yr).

Cosmic radiation doses arise primarily from the incidence of cosmic nucleons incident on the earth's atmosphere, generating secondary particles which produce ionization in ground level air and consequent doses.

Cosmic rays are responsible for some 30-50% of all background radiation exposure to man.

The actual dose received from background radiation varies greatly with location; background levels in the Indian Point area are typically some 125 mrem/yr. In contrast, radiation exposures from natural sources in Denver, Colorado are close to 200 mr/yr. Appendix I limits doses from liquid effluents of a reactor to 3 mr/yr and from gaseous effluents to 5 mr/year to the maximum exposed individual, levels which are a very small fraction of normal background levels and are normally indistinguishable from variations in background. The average dose to an individual living within 50 miles of the Indian Point plant is of the order of .005mr/yr, a very small quantity especially when considered in view of radiation doses received from other, less controlled, manmade radiation sources. For example, it has been estimated (Ref. 19 and 28) that the average U.S. individual receives about 4 mr/yr as a result of weapons test fallout and another 20 mr/yr or more from diagnostic dental and medical x-rays. The US Environmental Protection Agency has even estimated that the population averaged dose from watching television is about 0.1 mr/yr, about 20 times higher than the average dose resulting from nuclear power plant operation.

It has been estimated by the US Public Health Service (USPHS) that improved x-ray techniques, including a reduction in unnecessary or repetitive examinations, could reduce the average individual dose from medical x-rays by as much as 30 per cent, or an average of at least 6 mr/yr per person. Such sources of exposure, which contribute about four orders of magnitude more radiation dose than that originating from a nuclear reactor, are not subject to nearly as stringent regulatory controls as are nuclear plant emissions.

Although the biological effects of radiation on man are better known than those of perhaps any other pollutant, it is not possible to state unequivocally that any given dose of radiation is absolutely "safe". However, the effects on man of low radiation doses (especially at the levels expected from routine plant emissions), if they occur at all, occur so infrequently that they have not been detected by either experimental or epidemiological studies. Radiation standards have traditionally been set by using the linear, non-threshold hypothesis, which assumes a linear dose-effect relationship at all dose levels and that there is no threshold of radiation dose below which harmful effects do not occur. In view of present knowledge of radiation effects, this assumption is apparently conservative, particularly with regard to somatic effects of radiation, since the capacity of a cell for recovery from biological insult is neglected.

In view of the fact that average individual radiation doses from reactor effluents are less than .01% of radiation doses normally received by man from normal sources (man-made and natural) the biological effect of nuclear reactor effluents on man is negligible.

Even for the hypothetical "maximum exposed" individual, possible radiation levels which could be experienced (i.e., Appendix I design objectives) as a result of normal nuclear plant operation are not a cause for concern in view of the lack of evidence of any deleterious effects at the exposure levels of concern. Appendix I assures that releases from nuclear power plants are well below the levels of significant environmental or human health effects.

Tools

As with most complex, lengthy, and/or repetitive calculations, a number of computer codes were used to assist in this evaluation. The purpose of this section is to describe these codes and their usage.

A. Source Terms

Calculations of releases of radioactive materials in gaseous and liquid effluents were performed using the NRC PWR-GALE Code, a full description of which may be found in Nureg-0017 (Ref. 12). The GALE code actually consists of two separate codes, one which treats liquid source terms, and another for gaseous source terms.

The PWR-GALE liquid code utilizes several calculational sub-routines from the Oak Ridge National Laboratory (ORNL) code ORIGEN (Ref. 29) to process nuclear data library information and considers the transport, process, and release mechanisms that result in radioactive discharges. Appropriate adjustments to reactor and secondary coolant concentrations are made for plants whose design parameters are outside the ranges considered in the 'reference' PWR (see NUREG-0017) addressed by GALE. The radionuclide concentrations in primary and secondary coolant, and the adjustment factors utilized for effecting adjustments in these concentrations, are based on values and methods proposed by the draft standard of the ANS 18.1 working group.

Releases of tritium via both the liquid and gaseous pathways are computed by GALE on the basis of 0.4 ci/yr per MWt, assuming zircaloy fuel-clad material, with liquid tritium releases based on the total volume of liquid released. The remainder of the calculated tritium releases are considered to occur as gaseous releases. In view of the estimated ten-fold higher diffusion rate of tritium through stainless steel fuel cladding (e.g. I.P.1) as opposed to zircaloy cladding (Ref. 17) a value of 2.5 ci/MWt total tritium release was assumed for IP 1 (720 ci liquid; 320 ci gaseous.)

Particulate releases (prior to treatment) from all reactors, regardless of power level, are given in Table X. These releases are reduced by the GALE code according to the plant specific filtration capability on each of the release sources (containment, auxiliary bldg., or waste gas system).

The particulate and tritium release rates calculated by the GALE code are based on average measured or reported releases from several operating plants in the U.S.

Releases of other nuclides in liquid or gaseous effluents are determined by considering the nuclide concentrations in the various waste streams and reducing or adjusting them according to the plant specific design parameters and methods used for control of these wastes (e.g. demineralizers, hold-up tanks, evaporators, filters, etc.)

Appendix A presents the results of the source term calculations performed by GALE for discharge in vapor form (I.P.1, and I.P. 2 or 3) and in liquid form (I.P. 1, and I.P. 2 or 3).

B. Radiological Impact

As for the case of source term calculations, separate computer programs were used for the assessment of radiological impact from liquid releases and gaseous releases. Dose estimates from liquid effluents were made using the NRC code LADTAP, which calculates doses to the total body and significant organs via all principal water related pathways (viz., ingestion of different aquatic foods, drinking water, and recreational activities) in accordance with the guidance of Reg. Guide 1.109. LADTAP can be used to compute doses to the maximum individual and at other selected locations of interest. In addition, population integrated total body and thyroid doses are computed (in man rem and man thyroid rem, respectively) utilizing the site specific estimated usages of each pathway by the surrounding populace.

Appendix B presents the results of the (liquid) radiological impact assessment performed with the assistance of LADTAP. The source terms generated by the PWR-GALE liquid code were used as the nuclide input to LADTAP. It should be noted that for purposes of this evaluation, the Tech. Spec. minimum service water flow (100,000 gpm) was assumed for dilution rather than the full circulating water flow.

Radiation exposures from gaseous effluents were estimated using the code APPXITIS, which is an in house code written by the Nuclear Engineering Sub-Section. Using the models presented in Reg. Guide 1.109, doses from noble gas immersion, inhalation of radionuclides, ingestion of contaminated vegetation, milk, and meat, and ground plane deposition of radioisotopes are calculated at all locations of interest and for each age group by this code. Atmospheric dispersion factors (X/Q) are computed in APPXITIS assuming the straight line airflow (Sagendorf) model and utilizing the NRC sub-routine POLYN to compute σ_y and σ_z. Actual 1974 and 1975 (composite) measured joint frequencies of windspeed, Pasquill category, and wind direction were used to generate annual average values of X/Q for use in dose computations.

Concentrations of nuclides on the ground and in vegetation were estimated by consideration of the relative deposition of these nuclides from the release plume; values of relative deposition were found by utilization of measured joint frequency data and a numerical approximation to the curves presented in Regulatory Guide 1.111 for a ground level release.

APPXITIS also computes population integrated thyroid and total body doses from each pathway except terrestrial food product ingestion.

Appendix C contains the results of the (gaseous) radiological impact assessment performed with the assistance of APPXITIS.

Conclusion

In addition to meeting the criteria of Appendix I to 10CFR50 for determining when releases of radioactive materials from nuclear power reactors are "as low as reasonably achievable", this evaluation has shown that the Indian Point Reactors meet the more stringent guidelines of the staff's proposed Appendix I (RM 50-2). Estimated radioactive discharges from any or all of the Indian Point units are well within these guides and thus are indeed "ALARA". It is, therefore, concluded that no modifications to or augments of the various radwaste systems at any of the Indian Point reactors will be required or could be cost effective in reducing integrated population doses.

TABLE 1

ANNUAL DESIGN OBJECTIVES

COMPARISON OF APPENDIX I (MAY 5, 1975) and

THE STAFF'S PROPOSED APPENDIX I (RM 50-2, FEBRUARY 1974)

			APPENDIX I	RM 50-2
Sec II.A	Liquid Effluents	(Total Body)	3 MREM/Reactor	5 MREM/SITE (Total body or any organ)
		(Any Organ)	10 MREM/Reactor	5 Ci/Reactor(1)
Sec II.B.1	Gaseous Effluents	(Air Dose)	10 MRAD γ/Reactor	10 MRAD γ/Site
		(Air Dose)	20 MRAD β/Reactor	20 MRAD β/Site
OR				
Sec II.B.2	Gaseous Effluents(2)	(Total Body)	5 MREM/Reactor	5 MREM/Site
		(Skin)	15 MREM/Reactor	15 MREM/Site
Sec II.C	Iodine and Particulates	(Any Organ)	15 MREM/Reactor	15 MREM/Site
				1 Ci/Reactor I-131

(1) Excluding Tritium and dissolved noble gases.

(2) Higher quantities may be permitted if assured that doses to any individual in an unrestricted area will be less than these values.

TABLE II

Principal Assumptions Used in Generating Source Terms, Indian Point 2 or 3

Reactor Power	3216 MWt
Plant Factor	0.8*
Failed Fuel	0.12%*
Reactor Coolant System	
Mass	511,300#
Shim Bleed (Boron Recovery)	10 gpm
Total Letdown Flow	75 gpm
Letdown Cation Demineralizer Flow	7 gpm
Primary/Secondary Leak Rate	100#/day*
Leakage to PAB	160#/day*
Primary Coolant Volume	11,500 ft^3
Number of System Degassings	2/year
Secondary Coolant System	
Number of Steam Generators	4
Mass of Steam/generator	4800#
Mass of liquid/generator	82,000#
Total Secondary Coolant Mass	3.7×10^6#
Blowdown Rate	25,000#/hr
Total Steam Flow	13.9×10^6/hr
Containment	
Free Volume	$2.61 \times 10^6 ft^3$
Purges (Hi-Vol)	4/year
Continuous Low-Volume Purge Rate	150 cfm**
Kidney Filter Flow Rate	16,000 cfm
Internal Recirculation Cleanup Time	16 hours
Iodine Partition Coefficients (gas/liquid)*	
Primary Coolant	
Leakage to Containment	0.1
Leakage to Auxiliary Building	.0001
Secondary Coolant	
Steam Generator	0.01
Air Ejector	0.15
Turbine Building, leakage	1.0

* Values are NRC recommendations based on industry operating experience

** Value based on continuous low volume equivalent of actual pressure relief flows

TABLE III

Principle Assumptions Used in Generating
Source Terms, Indian Point 1.

Reactor Power	615 MWt
Plant Factor	0.8
Failed Fuel	0.12%
Reactor Coolant System	
Mass	233,000 lb.
Boron Dilution Flow	1gpm
Total Letdown Flow	75gpm
Cation Demineralizer Flow	7gpm
Primary/Secondary Leak Rate	100 lb./day
Leakage to auxiliary buildings	160 lb./day
Number of System degassings	2/yr.
Secondary Coolant System	
No. of Steam generators	4
Mass of steam/generator	2100 lb.
Mass of liquid/generator	32,000 lb.
Mass of secondary coolant	2.5x106 lb.
Blowdown rate	15,000 lb./hr.
Total Steam Flow	2.2x106 lb./hr.
Containment	
Free Volume	1.5x106ft3
Purges (Hi-vol.)	4/yr.
Low volume purge rate	30 CFM**
No kidney filter	
Iodine Partition Coefficients (gas/liquid)*	

* Same as Table II.

** Based on estimate of continuous low volume equivalent of pressure relief flows

TABLE IV

I.P2&3 Radioactive Waste Processing Flow Parameters

Shim Bleed Wastes*	
Boron Recycle @100%PCA	14,400gpd
Equipment Drains @80%PCA	200gpd
Release Fraction	0.1
Clean Wastes**	
Laboratory Drains and Waste Water (@10%PCA)	450gpd
Sample Drains (@10%PCA)	50gpd
Release Fraction	1.0
Dirty Wastes**	
Containment building sump (@80%PCA)	40gpd
Auxiliary Building Floor Drain (@10%PCA)	200gpd
Miscellaneous Sources (@1%PCA)	760gpd
Release Fraction	1.0
Blowdown	
Flow Rate	25,000#/Hr
Fraction Treated	1.0
Fraction Released	1.0

* Processed through Boron Recovery System
** Processed through Waste Disposal System

TABLE V

Decontamination Factors I.P.1,2&3 Purification And Waste Disposal Systems*

Demineralizers

	Iodines	Cs,Rb	Others
Mixed Bed (Letdown)	10	2	10
Cation	1	10	10
Anion Bed	100	1	1
Mixed Bed (Blowdown)	100	10	100

Evaporators

Radwaste	10^3	10^4	10^4
Boric Acid Recovery	10^2	10^3	10^3

* These values are NRC recommended values based on a generic review in the nuclear industry by Oak Ridge National Laboratory (ORNL)

TABLE VI

I.P 1* Radioactive Waste Processing Flow Parameters

Shim Bleed Wastes**	
Boron Dilution @100% PCA***	1440gpd
Clean Wastes	
Valve Leakoff @100%PCA	1.5gpd
Primary Relief @100%PCA	.3gpd
Laboratory Drains @30%PCA	400gpd
Equipment Drains @1%PCA	140gpd
Dirty Wastes	
Containment Sump @10%PCA	240gpd
Auxiliary Bldg. Floor Drains @1%PCA (include cask wash water and spent fuel pool cleanup, etc.)	300gpd
Miscellaneous Sources @1%PCA	300gpd

* Flow Rates based in part on Table I, page 80, IP-1 FHSR, Exhibit K-5A11

**Considered as processed through mixed bed demineralizer and liquid waste evaporator.

***Percent coolant activity

TABLE VII

Sector	Distance* to Nearest Milk Cow (miles)	Distance* Nearest Point of Site Boundary (meters)	Distance to* Nearest Residence (meters)
N	16	River	1950
NNW	10	River	1740
NW	13	River	1830
WNW	7	River	1830
W	7	River	1890
WSW	7	River	2135
SW	None Detected	350	2745
SSW	7	380	1525
S	7	580	1280
SSE	None Detected	595	1220
SE	7	580	1100
ESE	7	580	1070
E	7	625	730
ENE	10	760	1370
NE	7	790	1525
NNE	7	River	3050

Sector	Distance** to Nearest Garden (meters)
N	5280
NNW	1760
NW	None
WNW	None
W	2080
WSW	1920
SW	2560
SSW	1600
S	1760
SSE	1120
SE	1600
ESE	1280
E	800
ENE	1520
NE	2560
NNE	3040

* Measured from Indian Point 3
** Measured from Indian Point 1 Stack

TABLE VIII

HALF LIVES OF NOBLE GAS ISOTOPES

Isotope	Half Life*
Kr-83m	1.86 hours
Kr-85	10.7 years
Kr-85m	4.4 hours
Kr-87	76 minutes
Kr-88	2.8 hours
Kr-89	3.2 minutes
Kr-90	32.3 seconds
Xe-131m	12.0 days
Xe-133	5.27 days
Xe-133m	2.3 days
Xe-135m	15.7 minutes
Xe-135	9.2 hours
Xe-137	3.8 minutes
Xe-138	14.2 minutes

* From Reference No. 32.

Table IX

Mean Monthly Freshwater Discharges at Greens Island from 1947-1965, and during the 1969 and 1970 Water Years.

CFS

	Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept	Water Year (Avg)
1947-1965 Mean	6430	10300	13100	14300	14600	23300	30600	16300	8710	5070	4900	5020	12700
1969-1970 Mean	5020	14400	13700	9950	14100	16300	40100	17700	8200	5700	5020	5130	12900

TABLE X

PARTICULATE RELEASE RATE FOR GASEOUS EFFLUENTS

(Ci/yr per Reactor)

NUCLIDE	CONTAINMENT BUILDING	AUXILIARY BUILDING	WASTE GAS PROCESSING SYSTEM
Co-60	0.034	0.027	0.007
Co-58	0.075	0.060	0.015
Fe-59	0.0075	0.006	0.0015
Mn-54	0.022	0.018	0.0045
Cs-137	0.038	0.030	0.0075
Cs-134	0.022	0.018	0.0045
Sr-90	0.0003	0.0002	0.00006
Sr-89	0.0017	0.0013	0.00033

Table XI

γ and β- Air Doses from Indian Point Noble Gas Releases

Noble Gases

Air Doses*

IP1 β - air = 0.44 millirad
γ - air = 0.15 millirad

IP2 or 3 β - air = 3.43 millirad
γ - air = 1.15 millirad

* Evaluated at 350 meters SW of Indian Point Unit No. 3

TABLE XII

IP1 - Summary of Radiological Effects From Gaseous Effluents

Age Group - Adults

Pathway	Total Body	Skin	Thyroid	Bone
Noble Gas Immersion	6.94×10^{-3}	2.08×10^{-2}	-	-
Inhalation	9.71×10^{-2}	-	1.23×10^{-1}	2.21×10^{-2}
Deposition	4.49×10^{-1}	5.27×10^{-1}	-	-
Milk Ingestion	1.03×10^{-2}	-	1.27×10^{-2}	1.90×10^{-2}
Meat Ingestion	5.30×10^{-3}	-	5.13×10^{-3}	1.57×10^{-2}
Veg. Ingestion	6.15×10^{-2}	-	1.18×10^{-1}	1.06×10^{-1}
TOTALS	6.30×10^{-1}	5.48×10^{-1}	2.59×10^{-1}	1.63×10^{-1}

Age Group-Teens

Pathway	Total Body (mr/yr)	Skin (mr/yr)	Thyroid (mr/yr)	Bone (mr/yr)
Noble Gas Immersion	6.94×10^{-3}	2.08×10^{-2}	-	-
Inhalation	5.43×10^{-2}	-	7.79×10^{-2}	6.01×10^{-3}
Deposition	4.49×10^{-1}	5.27×10^{-1}	-	-
Milk Ingestion	1.26×10^{-2}	-	1.76×10^{-2}	9.45×10^{-3}
Meat Ingestion	3.46×10^{-3}	-	3.42×10^{-3}	2.63×10^{-3}
Veg. Ingestion	3.82×10^{-2}	-	8.57×10^{-2}	3.36×10^{-2}
TOTALS	5.65×10^{-1}	5.48×10^{-1}	1.85×10^{-1}	5.17×10^{-2}

Age Group - Children

Pathway	Total Body (mr/yr)	Skin (mr/yr)	Thyroid (mr/yr)	Bone (mr/yr)
Noble Gas Immersion	6.94×10^{-3}	2.08×10^{-2}	-	-
Inhalation	5.55×10^{-2}	-	8.86×10^{-2}	9.32×10^{-3}
Deposition	4.49×10^{-1}	5.27×10^{-1}	-	-
Milk Ingestion	2.31×10^{-2}	-	3.60×10^{-2}	2.29×10^{-2}
Meat Ingestion	5.76×10^{-3}	-	5.81×10^{-3}	4.94×10^{-3}
Veg. Ingestion	5.07×10^{-2}	-	1.29×10^{-1}	5.60×10^{-2}
TOTALS	5.91×10^{-1}	5.48×10^{-1}	2.59×10^{-1}	9.32×10^{-2}

Age Group - Infants

Pathway	Total Body (mr/yr)	Skin (mr/yr)	Thyroid (mr/yr)	Bone (mr/yr)
Noble Gas Immersion	6.94×10^{-3}	2.08×10^{-2}	-	-
Inhalation	6.04×10^{-2}	-	1.18×10^{-1}	1.38×10^{-2}
Deposition	4.49×10^{-1}	5.27×10^{-1}	-	-
Milk Ingestion	4.28×10^{-2}	-	7.63×10^{-2}	4.81×10^{-2}
Meat Ingestion	-	-	-	-
Veg. Ingestion	-	-	-	-
TOTALS	5.59×10^{-1}	5.48×10^{-1}	1.94×10^{-1}	6.19×10^{-2}

TABLE XIII

IP 2 or 3 SUMMARY OF RADIOLOGICAL EFFECTS GASEOUS EFFLUENTS

Age Group - Adults

Pathway	Total Body (mr/yr)	Skin (mr/yr)	Thyroid (mr/yr)	Bone (mr/yr)
Noble Gas Immersion	5.08×10^{-2}	1.54×10^{-1}	-	-
Inhalation	7.36×10^{-2}	-	4.31×10^{-1}	1.58×10^{-2}
Deposition	8.04×10^{-3}	9.48×10^{-3}	-	-
Milk Ingestion	6.93×10^{-3}	-	6.62×10^{-2}	1.70×10^{-2}
Meat Ingestion	4.55×10^{-3}	-	6.68×10^{-3}	1.55×10^{-2}
Veg. Ingestion	3.95×10^{-2}	-	9.38×10^{-1}	8.72×10^{-2}
TOTALS	1.83×10^{-1}	1.63×10^{-1}	1.44	1.36×10^{-1}

Age Groups - Teens

Pathway	Total Body (mr/yr)	Skin (mr/yr)	Thyroid (mr/yr)	Bone (mr/yr)
Noble Gas Immersion	5.08×10^{-2}	1.54×10^{-1}	-	-
Inhalation	4.19×10^{-2}	-	3.41×10^{-1}	3.42×10^{-3}
Deposition	8.04×10^{-3}	9.48×10^{-3}	-	-
Milk Ingestion	9.48×10^{-3}	-	9.86×10^{-2}	6.05×10^{-3}
Meat Ingestion	3.11×10^{-3}	-	4.57×10^{-3}	2.43×10^{-3}
Veg. Ingestion	2.71×10^{-2}	-	7.15×10^{-1}	1.68 x 10 [illegible]
TOTALS	1.40×10^{-1}	1.63×10^{-1}	1.16	2.87 x 10 [illegible]

Age Group - Children

Pathway	Total Body (mr/yr)	Skin (mr/yr)	Thyroid (mr/yr)	Bone (mr/yr)
Noble Gas Immersion	5.08×10^{-2}	1.54×10^{-1}	-	-
Inhalation	4.42×10^{-2}	-	4.40×10^{-1}	5.38×10^{-3}
Deposition	8.04×10^{-3}	9.48×10^{-3}	-	-
Milk Ingestion	2.02×10^{-2}	-	1.96×10^{-1}	1.49×10^{-2}
Meat Ingestion	5.41×10^{-3}	-	7.62×10^{-3}	4.59×10^{-3}
Veg. Ingestion	4.26×10^{-2}	-	1.07	3.10×10^{-2}
TOTALS	1.71×10^{-1}	1.63×10^{-1}	1.71	5.59×10^{-2}

TABLE XIII

IP 2 or 3 SUMMARY OF RADIOLOGICAL EFFECTS
GASEOUS EFFLUENTS

(Continued)

Age Group - Infants

Pathway	Total Body (mr/yr)	Skin (mr/yr)	Thyroid (mr/yr)	Bone (mr/yr)
Noble Gas Immersion	5.08×10^{-2}	1.54×10^{-1}	-	-
Inhalation	4.90×10^{-2}	-	7.26×10^{-1}	8.03×10^{-3}
Deposition	8.04×10^{-3}	9.48×10^{-3}	-	-
Milk Ingestion	3.95×10^{-2}	-	4.65×10^{-1}	3.18×10^{-2}
Meat Ingestion	-	-	-	-
Veg. Ingestion	-	-	-	-
TOTALS	1.47×10^{-1}	1.63×10^{-1}	1.19	3.98×10^{-2}

TABLE XIV

Summary of Radiological Effects
Liquid Effluents

IP 1 Liquid Pathway Doses to Maximum Individual

Pathway	Max. Organ(1) Dose (Liver), mr/yr	Max. Total(1) Body Dose. mr/yr
Fish	4.57×10^{-1}	3.41×10^{-1}
Invertebrate	1.01×10^{-2}	6.70×10^{-3}
Shoreline	1.17×10^{-3}	1.17×10^{-3}
Swimming	2.09×10^{-5}	2.09×10^{-5}
Boating	2.09×10^{-5}	2.09×10^{-5}
Totals	4.68×10^{-1}	3.49×10^{-1}

(1) Adult is critical age group for both total body and organ dose. (Total from all pathways.)

TABLE XV

Summary of Radiological Effects
Liquid Effluents

IP 2 or 3 Liquid Pathway Doses to Maximum Individual

Pathway	Max. Organ[(1)] Dose (Liver), mr	Max. Total[(1)] Body Dose, mr
Fish	8.49×10^{-1}	6.40×10^{-1}
Invertebrate	1.75×10^{-2}	1.23×10^{-2}
Shoreline	1.90×10^{-3}	1.90×10^{-3}
Swimming	3.98×20^{-5}	3.98×10^{-5}
Boating	3.98×10^{-5}	3.98×10^{-5}
Total	8.68×10^{-1}	6.54×10^{-1}

1. Adult is critical age group for both total body and maximum organ dose. (Total from all pathways.)

99.8% of total

99.7%

TABLE XVI

Summary of Radiological Effects
Population Integrated Doses via Gaseous Pathways*

Pathway	Population Dose IP 1 - man-rem/yr	Population Dose IP2 or 3 - man-rem/yr
Noble Gas Immersion		
a) Total Body	0.583	4.27
Inhalation		
a) Total Body	9.74	7.44
b) Thyroid	12.9	49.4
Ground Deposition		
a) Total Body	15.06	2.69×10^{-1}
Totals		
a) Thyroid	12.9	49.4
b) Total Body	25.38	11.98

* Based on projected 1990 fifty mile population.

TABLE XVII

SUMMARY OF RADIOLOGICAL EFFECTS
POPULATION INTEGRATED DOSES VIA LIQUID PATHWAYS

Pathway	Population Dose IP 1 - man-rem/yr	Population Dose IP2 or 3 man-rem/yr
All		
a) Total Body	1.03	1.92
b) Thyroid	1.07×10^{-1}	2.55×10^{-1}

TABLE XVIII

COMPARISON OF RADIOLOGICAL EVALUATION RESULTS WITH DESIGN OBJECTIVES OF APPENDIX I AND RM 50-2

Release Form & Type Exposure	IP 1 (mr/yr)	IP 2 (mr/yr)	IP 3 (mr/yr)	Total All Units (mr/yr/site)	Design Objectives Appendix I (mr/yr/reactor)	Design Objectives RM 50-2 (mr/yr/site)
1. Liquids						
a. Total Body	0.349	0.654	0.654	1.66	3.0	5.0
b. Max.Organ	0.468	0.868	0.868	2.20	10.0	5.0
2. Gaseous						
a. Air Dose-γ	0.15	1.15	1.15	2.45	10	10
b. air Dose-β	0.44	3.43	3.43	7.30	20	20
c. Total Body	0.63	0.18	0.18	0.99	5	5
d. Skin	0.55	0.16	0.16	0.87	15	15
e. Thyroid *	0.26	1.71	1.71	3.68	15	15

* Iodines and particulates

AVERAGE CHI OVER Q BY SECTOR NAME AT MID POINT OF EACH RADIAL SEGMENT

DOWNWIND DISTANCE METERS	N	NNE	NE	ENE	E	ESE	SE	SSE
600.0	0.131E-04	0.126E-04	0.937E-05	0.513E-05	0.475E-05	0.316E-05	0.388E-05	0.399E-05
1200.0	0.458E-05	0.439E-05	0.328E-05	0.179E-05	0.167E-05	0.111E-05	0.136E-05	0.142E-05
2400.0	0.165E-05	0.157E-05	0.117E-05	0.642E-06	0.605E-06	0.400E-06	0.485E-06	0.506E-06
4000.0	0.780E-06	0.743E-06	0.551E-06	0.304E-06	0.288E-06	0.189E-06	0.228E-06	0.237E-06
5600.0	0.476E-06	0.452E-06	0.335E-06	0.185E-06	0.176E-06	0.115E-06	0.138E-06	0.143E-06
7200.0	0.329E-06	0.313E-06	0.231E-06	0.128E-06	0.122E-06	0.793E-07	0.955E-07	0.986E-07
12000.0	0.157E-06	0.149E-06	0.109E-06	0.611E-07	0.580E-07	0.376E-07	0.450E-07	0.462E-07
20000.0	0.776E-07	0.733E-07	0.539E-07	0.302E-07	0.288E-07	0.185E-07	0.221E-07	0.226E-07
28000.0	0.499E-07	0.471E-07	0.345E-07	0.195E-07	0.186E-07	0.119E-07	0.142E-07	0.144E-07
40000.0	0.312E-07	0.295E-07	0.215E-07	0.122E-07	0.117E-07	0.743E-08	0.866E-08	0.896E-08
56000.0	0.201E-07	0.189E-07	0.138E-07	0.768E-08	0.752E-08	0.477E-08	0.570E-08	0.572E-08
72000.0	0.145E-07	0.136E-07	0.992E-08	0.560E-08	0.542E-08	0.343E-08	0.410E-08	0.410E-08

AVERAGE CHI OVER Q BY SECTOR NAME AT OTHER SELECTED LOCATIONS

DOWNWIND DISTANCE METERS	N	NNE	NE	ENE	E	ESE	SE	SSE
730.0	0.970E-05	0.934E-05	0.695E-05	0.380E-05	0.352E-05	0.235E-05	0.289E-05	0.298E-05
1070.0	0.543E-05	0.521E-05	0.389E-05	0.213E-05	0.198E-05	0.132E-05	0.162E-05	0.168E-05
1100.0	0.521E-05	0.500E-05	0.373E-05	0.204E-05	0.190E-05	0.127E-05	0.156E-05	0.162E-05
1220.0	0.447E-05	0.429E-05	0.320E-05	0.175E-05	0.163E-05	0.109E-05	0.133E-05	0.139E-05
1280.0	0.416E-05	0.399E-05	0.298E-05	0.163E-05	0.152E-05	0.101E-05	0.124E-05	0.129E-05
1370.0	0.376E-05	0.360E-05	0.269E-05	0.147E-05	0.138E-05	0.915E-06	0.112E-05	0.117E-05
1525.0	0.321E-05	0.307E-05	0.229E-05	0.125E-05	0.117E-05	0.780E-06	0.951E-06	0.993E-06
1740.0	0.264E-05	0.252E-05	0.188E-05	0.103E-05	0.967E-06	0.641E-06	0.780E-06	0.816E-06

INDIAN P[illegible] AREA-AVERAGE XOVERQ BY SECTOR AS FUNCTION OF D[illegible]NCE FROM PLANT

TABLE 19 (Page 2 of 4)

DOWNWIND DISTANCE METERS — AVERAGE CHI OVER Q BY SECTOR NAME AT MID POINT OF EACH RADIAL SEGMENT

DOWNWIND DISTANCE METERS	SECTOR NAME							
	N	NNE	NE	ENE	E	ESE	SE	SSE
600.0	0.131E-04	0.126E-04	0.937E-05	0.513E-05	0.475E-05	0.316E-05	0.388E-05	0.399E-05
1200.0	0.458E-05	0.439E-05	0.328E-05	0.179E-05	0.167E-05	0.111E-05	0.136E-05	0.142E-05
2400.0	0.165E-05	0.157E-05	0.117E-05	0.642E-06	0.605E-06	0.400E-06	0.485E-06	0.506E-06
4000.0	0.780E-06	0.743E-06	0.551E-06	0.304E-06	0.288E-06	0.189E-06	0.228E-06	0.237E-06
5600.0	0.476E-06	0.452E-06	0.335E-06	0.185E-06	0.176E-06	0.115E-06	0.138E-06	0.143E-06
7200.0	0.329E-06	0.313E-06	0.231E-06	0.128E-06	0.122E-06	0.793E-07	0.955E-07	0.986E-07
12000.0	0.157E-06	0.149E-06	0.109E-06	0.611E-07	0.580E-07	0.376E-07	0.450E-07	0.462E-07
20000.0	0.776E-07	0.733E-07	0.538E-07	0.302E-07	0.288E-07	0.185E-07	0.221E-07	0.226E-07
28000.0	0.499E-07	0.471E-07	0.345E-07	0.195E-07	0.186E-07	0.119E-07	0.142E-07	0.146E-07
40000.0	0.312E-07	0.295E-07	0.215E-07	0.122E-07	0.117E-07	0.743E-08	0.886E-08	0.896E-08
56000.0	0.201E-07	0.189E-07	0.138E-07	0.788E-08	0.752E-08	0.477E-08	0.570E-08	0.572E-08
72000.0	0.145E-07	0.136E-07	0.992E-08	0.568E-08	0.542E-08	0.343E-08	0.410E-08	0.410E-08

AVERAGE CHI OVER Q BY SECTOR NAME AT OTHER SELECTED LOCATIONS

1830.0	0.245E-05	0.234E-05	0.175E-05	0.955E-06	0.898E-06	0.595E-06	0.723E-06	0.757E-06
1890.0	0.234E-05	0.223E-05	0.167E-05	0.911E-06	0.857E-06	0.568E-06	0.690E-06	0.721E-06
1950.0	0.223E-05	0.213E-05	0.159E-05	0.870E-06	0.818E-06	0.542E-06	0.658E-06	0.689E-06
2135.0	0.195E-05	0.187E-05	0.139E-05	0.762E-06	0.717E-06	0.474E-06	0.576E-06	0.602E-06
2745.0	0.135E-05	0.129E-05	0.961E-06	0.528E-06	0.498E-06	0.328E-06	0.398E-06	0.415E-06
3050.0	0.116E-05	0.111E-05	0.823E-06	0.452E-06	0.427E-06	0.281E-06	0.341E-06	0.355E-06
5280.0	0.519E-06	0.493E-06	0.365E-06	0.202E-06	0.191E-06	0.125E-06	0.151E-06	0.157E-06
11200.0	0.173E-06	0.164E-06	0.121E-06	0.675E-07	0.641E-07	0.415E-07	0.498E-07	0.512E-07

TABLE 19 (Page 3 of 4)

DOWNWIND DISTANCE METERS

AVERAGE CHI OVER Q BY SECTOR NAME AT MID POINT OF EACH RADIAL SEGMENT

SECTOR NAME

DOWNWIND DISTANCE METERS	S	SSW	SW	WSW	W	WNW	NW	NNW
600.0	0.830E-05	0.134E-04	0.208E-04	0.105E-04	0.527E-05	0.245E-05	0.292E-05	0.406E-05
1200.0	0.268E-05	0.461E-05	0.722E-05	0.370E-05	0.188E-05	0.861E-06	0.103E-05	0.143E-05
2400.0	0.103E-05	0.167E-05	0.266E-05	0.136E-05	0.687E-06	0.310E-06	0.371E-06	0.515E-06
4000.0	0.491E-06	0.801E-06	0.129E-05	0.652E-06	0.327E-06	0.148E-06	0.176E-06	0.245E-06
5600.0	0.300E-06	0.492E-06	0.801E-06	0.402E-06	0.200E-06	0.907E-07	0.108E-06	0.149E-06
7200.0	0.208E-06	0.343E-06	0.561E-06	0.280E-06	0.139E-06	0.626E-07	0.746E-07	0.104E-06
12000.0	0.998E-07	0.166E-06	0.275E-06	0.136E-06	0.664E-07	0.299E-07	0.357E-07	0.494E-07
20000.0	0.495E-07	0.828E-07	0.139E-06	0.680E-07	0.330E-07	0.148E-07	0.177E-07	0.244E-07
28000.0	0.319E-07	0.535E-07	0.901E-07	0.440E-07	0.213E-07	0.954E-08	0.114E-07	0.157E-07
40000.0	0.201E-07	0.337E-07	0.570E-07	0.278E-07	0.134E-07	0.598E-08	0.713E-08	0.985E-08
56000.0	0.130E-07	0.218E-07	0.370E-07	0.180E-07	0.861E-08	0.366E-08	0.459E-08	0.634E-08
72000.0	0.937E-08	0.158E-07	0.268E-07	0.130E-07	0.621E-08	0.278E-08	0.331E-08	0.457E-08

AVERAGE CHI OVER Q BY SECTOR NAME AT OTHER SELECTED LOCATIONS

730.0	0.613E-05	0.981E-05	0.152E-04	0.773E-05	0.392E-05	0.187E-05	0.216E-05	0.301E-05
1070.0	0.342E-05	0.546E-05	0.852E-05	0.436E-05	0.222E-05	0.102E-05	0.122E-05	0.169E-05
1100.0	0.328E-05	0.525E-05	0.818E-05	0.419E-05	0.214E-05	0.979E-06	0.117E-05	0.162E-05
1220.0	0.281E-05	0.450E-05	0.705E-05	0.361E-05	0.184E-05	0.840E-06	0.100E-05	0.139E-05
1260.0	0.261E-05	0.419E-05	0.657E-05	0.337E-05	0.171E-05	0.782E-06	0.933E-06	0.130E-05
1370.0	0.236E-05	0.379E-05	0.596E-05	0.305E-05	0.155E-05	0.707E-06	0.844E-06	0.117E-05
1525.0	0.201E-05	0.323E-05	0.510E-05	0.261E-05	0.133E-05	0.603E-06	0.720E-06	0.100E-05
1740.0	0.165E-05	0.266E-05	0.421E-05	0.215E-05	0.109E-05	0.496E-06	0.593E-06	0.824E-06

INDIAN . REA-AVERAGE XOVERQ BY SECTOR AS FUNCTION OF ANCE FROM PLANT

AVERAGE CHI OVER Q BY SECTOR NAME AT MID POINT OF EACH RADIAL SEGMENT

DOWNWIND DISTANCE -METERS	S	SSW	SW	WSW	W	WNW	NW	NNW
600.0	0.830E-05	0.134E-04	0.208E-04	0.105E-04	0.527E-05	0.245E-05	0.292E-05	0.406E-05
1200.0	0.288E-05	0.461E-05	0.722E-05	0.370E-05	0.188E-05	0.861E-06	0.103E-05	0.143E-05
2400.0	0.103E-05	0.167E-05	0.266E-05	0.136E-05	0.687E-06	0.310E-06	0.371E-06	0.515E-06
4000.0	0.491E-06	0.801E-06	0.129E-05	0.652E-06	0.327E-06	0.148E-06	0.176E-06	0.245E-06
5600.0	0.300E-06	0.492E-06	0.801E-06	0.402E-06	0.200E-06	0.902E-07	0.108E-06	0.149E-06
7200.0	0.208E-06	0.343E-06	0.561E-06	0.280E-06	0.139E-06	0.626E-07	0.746E-07	0.104E-06
12000.0	0.998E-07	0.166E-06	0.275E-06	0.136E-06	0.664E-07	0.299E-07	0.357E-07	0.494E-07
20000.0	0.495E-07	0.828E-07	0.139E-06	0.680E-07	0.330E-07	0.148E-07	0.177E-07	0.244E-07
28000.0	0.319E-07	0.535E-07	0.901E-07	0.440E-07	0.213E-07	0.954E-08	0.114E-07	0.157E-07
40000.0	0.201E-07	0.337E-07	0.570E-07	0.278E-07	0.134E-07	0.598E-08	0.713E-08	0.985E-08
56000.0	0.130E-07	0.218E-07	0.370E-07	0.180E-07	0.861E-08	0.386E-08	0.459E-08	0.634E-08
72000.0	0.937E-08	0.158E-07	0.268E-07	0.130E-07	0.621E-08	0.278E-08	0.331E-08	0.457E-08

AVERAGE CHI OVER Q BY SECTOR NAME AT OTHER SELECTED LOCATIONS

1830.0	0.153E-05	0.247E-05	0.391E-05	0.200E-05	0.102E-05	0.460E-06	0.550E-06	0.765E-06
1890.0	0.146E-05	0.236E-05	0.374E-05	0.191E-05	0.971E-06	0.439E-06	0.525E-06	0.730E-06
1950.0	0.139E-05	0.225E-05	0.358E-05	0.183E-05	0.928E-06	0.420E-06	0.502E-06	0.697E-06
2135.0	0.122E-05	0.198E-05	0.314E-05	0.161E-05	0.813E-06	0.368E-06	0.440E-06	0.611E-06
2745.0	0.849E-06	0.138E-05	0.220E-05	0.112E-05	0.565E-06	0.256E-06	0.305E-06	0.424E-06
3050.0	0.729E-06	0.118E-05	0.190E-05	0.963E-06	0.485E-06	0.219E-06	0.262E-06	0.364E-06
5280.0	0.327E-06	0.536E-06	0.871E-06	0.437E-06	0.218E-06	0.984E-07	0.117E-06	0.163E-06
11200.0	0.110E-06	0.183E-06	0.303E-06	0.150E-06	0.733E-07	0.330E-07	0.394E-07	0.545E-07

RELATIVE DEPOSITION PER UNIT AREA (M**-2) AT FIXED POINTS BY DOWNWIND SECTORS

DIRECTION FROM SITE	DISTANCES IN METERS 400.0	800.0	1200.0	1600.0	2400.0	3200.0	4000.0	4800.0	5600.0	6400.0	7200.0
S	4.731E-08	1.601E-08	8.222E-09	5.049E-09	2.518E-09	1.527E-09	1.033E-09	7.483E-10	5.690E-10	4.483E-10	3.629E-10
SSW	7.336E-08	2.482E-08	1.275E-08	7.830E-09	3.904E-09	2.368E-09	1.601E-09	1.160E-09	8.824E-10	6.952E-10	5.628E-10
SW	8.323E-08	2.816E-08	1.447E-08	8.884E-09	4.429E-09	2.687E-09	1.817E-09	1.317E-09	1.001E-09	7.888E-10	6.386E-10
WSW	3.817E-08	1.291E-08	6.633E-09	4.074E-09	2.031E-09	1.232E-09	8.331E-10	6.037E-10	4.591E-10	3.617E-10	2.928E-10
W	1.639E-08	5.545E-09	2.848E-09	1.749E-09	8.721E-10	5.290E-10	3.577E-10	2.592E-10	1.971E-10	1.553E-10	1.257E-10
WNW	7.353E-09	2.488E-09	1.278E-09	7.848E-10	3.913E-10	2.374E-10	1.605E-10	1.163E-10	8.845E-11	6.968E-11	5.642E-11
NW	8.544E-09	2.891E-09	1.485E-09	9.119E-10	4.547E-10	2.758E-10	1.865E-10	1.351E-10	1.028E-10	8.097E-11	6.555E-11
NNW	1.348E-08	4.562E-09	2.343E-09	1.439E-09	7.174E-10	4.352E-10	2.942E-10	2.132E-10	1.622E-10	1.278E-10	1.034E-10
N	5.228E-08	1.769E-08	9.086E-09	5.580E-09	2.782E-09	1.688E-09	1.141E-09	8.269E-10	6.288E-10	4.954E-10	4.011E-10
NNE	5.806E-08	1.964E-08	1.009E-08	6.196E-09	3.090E-09	1.874E-09	1.267E-09	9.183E-10	6.983E-10	5.502E-10	4.454E-10
NE	4.317E-08	1.461E-08	7.504E-09	4.608E-09	2.298E-09	1.394E-09	9.424E-10	6.829E-10	5.193E-10	4.091E-10	3.312E-10
ENE	2.052E-08	6.943E-09	3.566E-09	2.190E-09	1.092E-09	6.624E-10	4.479E-10	3.246E-10	2.468E-10	1.945E-10	1.574E-10
E	2.237E-08	7.571E-09	3.889E-09	2.388E-09	1.191E-09	7.223E-10	4.884E-10	3.539E-10	2.691E-10	2.120E-10	1.717E-10
ESE	2.223E-08	7.524E-09	3.864E-09	2.373E-09	1.183E-09	7.178E-10	4.853E-10	3.517E-10	2.674E-10	2.107E-10	1.706E-10
SE	3.848E-08	1.302E-08	6.688E-09	4.107E-09	2.048E-09	1.242E-09	8.399E-10	6.087E-10	4.629E-10	3.647E-10	2.952E-10
SSE	3.918E-08	1.326E-08	6.810E-09	4.182E-09	2.085E-09	1.265E-09	8.552E-10	6.198E-10	4.713E-10	3.713E-10	3.006E-10

RELATIVE DEPOSITION PER UNIT AREA (M**-2) AT FIXED POINTS BY DOWNWIND SECTORS

DIRECTION FROM SITE	DISTANCES IN METERS 8000.0	12000.0	16000.0	24000.0	32000.0	40000.0	48000.0	56000.0	64000.0	72000.0	80000.0
S	3.002E-10	1.470E-10	9.223E-11	4.664E-11	2.824E-11	1.894E-11	1.357E-11	1.019E-11	7.926E-12	6.332E-12	5.169E-12
SSW	4.656E-10	2.279E-10	1.430E-10	7.232E-11	4.379E-11	2.936E-11	2.105E-11	1.581E-11	1.229E-11	9.819E-12	8.016E-12
SW	5.282E-10	2.585E-10	1.623E-10	8.206E-11	4.968E-11	3.332E-11	2.388E-11	1.793E-11	1.395E-11	1.114E-11	9.095E-12
WSW	2.422E-10	1.186E-10	7.441E-11	3.763E-11	2.278E-11	1.528E-11	1.095E-11	8.223E-12	6.395E-12	5.109E-12	4.170E-12
W	1.040E-10	5.091E-11	3.195E-11	1.616E-11	9.781E-12	6.560E-12	4.701E-12	3.531E-12	2.746E-12	2.193E-12	1.791E-12
WNW	4.667E-11	2.284E-11	1.434E-11	7.249E-12	4.389E-12	2.943E-12	2.110E-12	1.584E-12	1.232E-12	9.843E-13	8.035E-13
NW	5.422E-11	2.654E-11	1.666E-11	8.423E-12	5.100E-12	3.420E-12	2.451E-12	1.841E-12	1.431E-12	1.144E-12	9.336E-13
NNW	8.556E-11	4.188E-11	2.628E-11	1.329E-11	8.047E-12	5.396E-12	3.868E-12	2.905E-12	2.259E-12	1.804E-12	1.473E-12
N	3.318E-10	1.624E-10	1.019E-10	5.154E-11	3.120E-11	2.093E-11	1.500E-11	1.126E-11	8.759E-12	6.998E-12	5.712E-12
NNE	3.685E-10	1.803E-10	1.132E-10	5.724E-11	3.465E-11	2.324E-11	1.666E-11	1.251E-11	9.727E-12	7.771E-12	6.344E-12
NE	2.740E-10	1.341E-10	8.418E-11	4.256E-11	2.577E-11	1.728E-11	1.239E-11	9.302E-12	7.234E-12	5.779E-12	4.718E-12
ENE	1.302E-10	6.374E-11	4.001E-11	2.023E-11	1.225E-11	8.214E-12	5.887E-12	4.421E-12	3.438E-12	2.747E-12	2.242E-12
E	1.420E-10	6.951E-11	4.362E-11	2.206E-11	1.336E-11	8.957E-12	6.419E-12	4.821E-12	3.749E-12	2.995E-12	2.445E-12
ESE	1.411E-10	6.907E-11	4.335E-11	2.192E-11	1.327E-11	8.900E-12	6.379E-12	4.791E-12	3.725E-12	2.976E-12	2.430E-12
SE	2.442E-10	1.195E-10	7.503E-11	3.794E-11	2.297E-11	1.540E-11	1.104E-11	8.291E-12	6.448E-12	5.151E-12	4.205E-12
SSE	2.487E-10	1.217E-10	7.639E-11	3.863E-11	2.339E-11	1.568E-11	1.124E-11	8.442E-12	6.565E-12	5.245E-12	4.281E-12

RELATIVE DEPOSITION PER UNIT AREA (M**-2) AT FIXED POINTS BY DOWNWIND SECTORS

DIRECTION FROM SITE	730.0	1070.0	1100.0	1220.0	1280.0	1370.0	1525.0	1740.0
	DISTANCES IN METERS							
S	1.855E-08	9.971E-09	9.519E-09	7.996E-09	7.373E-09	6.572E-09	5.479E-09	4.376E-09
SSW	2.877E-08	1.546E-08	1.476E-08	1.240E-08	1.143E-08	1.019E-08	8.496E-09	6.785E-09
SW	3.264E-08	1.754E-08	1.675E-08	1.407E-08	1.297E-08	1.156E-08	9.640E-09	7.699E-09
WSW	1.497E-08	8.045E-09	7.680E-09	6.451E-09	5.949E-09	5.303E-09	4.421E-09	3.530E-09
W	6.426E-09	3.454E-09	3.297E-09	2.770E-09	2.554E-09	2.277E-09	1.898E-09	1.516E-09
WNW	2.884E-09	1.550E-09	1.480E-09	1.243E-09	1.146E-09	1.022E-09	8.517E-10	6.802E-10
NW	3.350E-09	1.801E-09	1.719E-09	1.444E-09	1.332E-09	1.187E-09	9.896E-10	7.903E-10
NNW	5.286E-09	2.842E-09	2.713E-09	2.279E-09	2.101E-09	1.873E-09	1.561E-09	1.247E-09
N	2.050E-08	1.102E-08	1.052E-08	8.836E-09	8.148E-09	7.263E-09	6.055E-09	4.836E-09
NNE	2.277E-08	1.224E-08	1.168E-08	9.813E-09	9.049E-09	8.066E-09	6.724E-09	5.370E-09
NE	1.693E-08	9.100E-09	8.687E-09	7.297E-09	6.729E-09	5.998E-09	5.001E-09	3.994E-09
ENE	8.046E-09	4.325E-09	4.129E-09	3.468E-09	3.198E-09	2.851E-09	2.377E-09	1.898E-09
E	8.774E-09	4.716E-09	4.502E-09	3.782E-09	3.487E-09	3.109E-09	2.592E-09	2.070E-09
ESE	8.719E-09	4.687E-09	4.474E-09	3.758E-09	3.466E-09	3.089E-09	2.575E-09	2.057E-09
SE	1.509E-08	8.111E-09	7.743E-09	6.504E-09	5.998E-09	5.346E-09	4.457E-09	3.560E-09
SSE	1.537E-08	8.259E-09	7.884E-09	6.623E-09	6.107E-09	5.444E-09	4.538E-09	3.624E-09

RELATIVE DEPOSITION PER UNITAREA(M**-2) BY DOWNWIND SECTORS

SEGMENT BOUNDARIES IN MILES

DIRECTION FROM SITE	.25-.5	.5-1	1-2	2-3	3-4	4-5	5-10	10-15	15-20	20-30	30-40	40-50
S	2.644E-08	8.542E-09	2.640E-09	1.051E-09	5.742E-10	3.650E-10	1.567E-10	4.191E-11	3.612E-11	1.927E-11	1.029E-11	6.374E-12
SSW	4.100E-08	1.325E-08	4.094E-09	1.629E-09	8.905E-10	5.660E-10	2.430E-10	6.498E-11	5.602E-11	2.988E-11	1.596E-11	9.883E-12
SW	4.652E-08	1.503E-08	4.645E-09	1.849E-09	1.010E-09	6.422E-10	2.757E-10	7.373E-11	6.356E-11	3.390E-11	1.811E-11	1.121E-11
WSW	2.133E-08	6.892E-09	2.130E-09	8.477E-10	4.633E-10	2.945E-10	1.264E-10	3.381E-11	2.914E-11	1.555E-11	8.306E-12	5.142E-12
W	9.159E-09	2.959E-09	9.145E-10	3.640E-10	1.989E-10	1.264E-10	5.428E-11	1.452E-11	1.251E-11	6.675E-12	3.566E-12	2.208E-12
WNW	4.110E-09	1.328E-09	4.103E-10	1.633E-10	8.926E-11	5.674E-11	2.436E-11	6.514E-12	5.615E-12	2.995E-12	1.600E-12	9.907E-13
NW	4.775E-09	1.543E-09	4.768E-10	1.898E-10	1.037E-10	6.592E-11	2.830E-11	7.569E-12	6.524E-12	3.480E-12	1.859E-12	1.151E-12
NNW	7.535E-09	2.434E-09	7.523E-10	2.994E-10	1.636E-10	1.040E-10	4.465E-11	1.194E-11	1.029E-11	5.492E-12	2.934E-12	1.816E-12
N	2.922E-08	9.440E-09	2.917E-09	1.161E-09	6.346E-10	4.034E-10	1.732E-10	4.631E-11	3.992E-11	2.130E-11	1.138E-11	7.043E-12
NNE	3.245E-08	1.048E-08	3.240E-09	1.289E-09	7.047E-10	4.479E-10	1.923E-10	5.143E-11	4.433E-11	2.365E-11	1.263E-11	7.822E-12
NE	2.413E-08	7.796E-09	2.409E-09	9.589E-10	5.241E-10	3.331E-10	1.430E-10	3.825E-11	3.297E-11	1.759E-11	9.395E-12	5.817E-12
ENE	1.147E-08	3.705E-09	1.145E-09	4.557E-10	2.491E-10	1.583E-10	6.797E-11	1.818E-11	1.567E-11	8.359E-12	4.465E-12	2.765E-12
E	1.251E-08	4.040E-09	1.249E-09	4.970E-10	2.716E-10	1.726E-10	7.411E-11	1.982E-11	1.709E-11	9.115E-12	4.869E-12	3.015E-12
ESE	1.243E-08	4.015E-09	1.241E-09	4.939E-10	2.699E-10	1.716E-10	7.365E-11	1.970E-11	1.698E-11	9.058E-12	4.839E-12	2.996E-12
SE	2.151E-08	6.948E-09	2.147E-09	8.547E-10	4.671E-10	2.969E-10	1.275E-10	3.409E-11	2.938E-11	1.568E-11	8.374E-12	5.185E-12
SSE	2.190E-08	7.075E-09	2.187E-09	8.703E-10	4.756E-10	3.023E-10	1.298E-10	3.471E-11	2.992E-11	1.596E-11	8.527E-12	5.279E-12

RELATIVE DEPOSITION PER UNIT AREA (M**-2) AT FIXED POINTS BY DOWNWIND SECTORS

DIRECTION FROM SITE	DISTANCES IN METERS 1830.0	1890.0	1950.0	2135.0	2745.0	3050.0	5280.0	11200.0
S	4.014E-09	3.798E-09	3.600E-09	3.081E-09	1.995E-09	1.661E-09	6.318E-10	1.640E-10
SSW	6.225E-09	5.890E-09	5.583E-09	4.777E-09	3.093E-09	2.575E-09	9.798E-10	2.542E-10
SW	7.063E-09	6.683E-09	6.334E-09	5.420E-09	3.510E-09	2.922E-09	1.112E-09	2.885E-10
WSW	3.239E-09	3.064E-09	2.905E-09	2.486E-09	1.609E-09	1.340E-09	5.098E-10	1.323E-10
W	1.391E-09	1.316E-09	1.247E-09	1.067E-09	6.910E-10	5.752E-10	2.189E-10	5.680E-11
WNW	6.240E-10	5.904E-10	5.596E-10	4.789E-10	3.101E-10	2.581E-10	9.821E-11	2.548E-11
NW	7.250E-10	6.860E-10	6.502E-10	5.564E-10	3.603E-10	2.999F-10	1.141E-10	2.961E-11
NNW	1.144E-09	1.082E-09	1.026E-09	8.779E-10	5.684E-10	4.732E-10	1.801E-10	4.672E-11
N	4.436E-09	4.197E-09	3.978E-09	3.404E-09	2.204E-09	1.835E-09	6.982E-10	1.812E-10
NNE	4.926E-09	4.661E-09	4.418E-09	3.781E-09	2.440E-09	2.038E-09	7.754E-10	2.012E-10
NE	3.663E-09	3.467E-09	3.286E-09	2.812E-09	1.821E-09	1.515E-09	5.766E-10	1.496E-10
ENE	1.741E-09	1.649E-09	1.562E-09	1.336E-09	8.652E-10	7.203E-10	2.741E-10	7.112E-11
E	1.899E-09	1.797E-09	1.703E-09	1.457E-09	9.435E-10	7.854E-10	2.988E-10	7.755E-11
ESE	1.887E-09	1.785E-09	1.692E-09	1.448E-09	9.376E-10	7.805E-10	2.970E-10	7.706E-11
SE	3.265E-09	3.090E-09	2.929E-09	2.506E-09	1.623E-09	1.351E-09	5.140E-10	1.334E-10
SSE	3.325E-09	3.146E-09	2.982E-09	2.552E-09	1.652E-09	1.375E-09	5.233E-10	1.358E-10

RELATIVE DEPOSITION PER UNITAREA(M**-2) BY DOWNWIND SECTORS

SEGMENT BOUNDARIES IN MILES

DIRECTION FROM SITE	.25-.5	.5-1	1-2	2-3	3-4	4-5	5-10	10-15	15-20	20-30	30-40	40-50
S	2.644E-08	8.542E-09	2.640E-09	1.051E-09	5.742E-10	3.650E-10	1.567E-10	4.191E-11	3.612E-11	1.927E-11	1.029E-11	6.374E-12
SSW	4.100E-08	1.325E-08	4.094E-09	1.629E-09	8.905E-10	5.660E-10	2.430E-10	6.498E-11	5.602E-11	2.988E-11	1.596E-11	9.883E-12
SW	4.652E-08	1.503E-08	4.645E-09	1.849E-09	1.010E-09	6.422E-10	2.757E-10	7.373E-11	6.356E-11	3.390E-11	1.811E-11	1.121E-11
WSW	2.133E-08	6.892E-09	2.130E-09	8.477E-10	4.633E-10	2.945E-10	1.264E-10	3.381E-11	2.914E-11	1.555E-11	8.306E-12	5.142E-12
W	9.159E-09	2.959E-09	9.145E-10	3.640E-10	1.989E-10	1.264E-10	5.428E-11	1.452E-11	1.251E-11	6.675E-12	3.566E-12	2.208E-12
WNW	4.110E-09	1.328E-09	4.103E-10	1.633E-10	8.926E-11	5.674E-11	2.436E-11	6.514E-12	5.615E-12	2.995E-12	1.600E-12	9.907E-13
NW	4.775E-09	1.543E-09	4.768E-10	1.898E-10	1.037E-10	6.592E-11	2.830E-11	7.569E-12	6.524E-12	3.480E-12	1.859E-12	1.151E-12
NNW	7.535E-09	2.434E-09	7.523E-10	2.994E-10	1.636E-10	1.040E-10	4.465E-11	1.194E-11	1.029E-11	5.492E-12	2.934E-12	1.816E-12
N	2.922E-08	9.440E-09	2.917E-09	1.161E-09	6.346E-10	4.034E-10	1.732E-10	4.631E-11	3.992E-11	2.130E-11	1.138E-11	7.043E-12
NNE	3.245E-08	1.048E-08	3.240E-09	1.289E-09	7.047E-10	4.479E-10	1.923E-10	5.143E-11	4.433E-11	2.365E-11	1.263E-11	7.822E-12
NE	2.413E-08	7.796E-09	2.409E-09	9.589E-10	5.241E-10	3.331E-10	1.430E-10	3.825E-11	3.297E-11	1.759E-11	9.395E-12	5.817E-12
ENE	1.147E-08	3.705E-09	1.145E-09	4.557E-10	2.491E-10	1.583E-10	6.797E-11	1.818E-11	1.567E-11	8.359E-12	4.465E-12	2.765E-12
E	1.251E-08	4.040E-09	1.249E-09	4.970E-10	2.716E-10	1.726E-10	7.411E-11	1.982E-11	1.709E-11	9.115E-12	4.869E-12	3.015E-12
ESE	1.243E-08	4.015E-09	1.241E-09	4.939E-10	2.699E-10	1.716E-10	7.365E-11	1.970E-11	1.698E-11	9.058E-12	4.839E-12	2.996E-12
SE	2.151E-08	6.948E-09	2.147E-09	8.547E-10	4.671E-10	2.969E-10	1.275E-10	3.409E-11	2.938E-11	1.568E-11	8.374E-12	5.185E-12
SSE	2.190E-08	7.075E-09	2.187E-09	8.703E-10	4.756E-10	3.023E-10	1.298E-10	3.471E-11	2.992E-11	1.596E-11	8.527E-12	5.279E-12

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