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EVALUATION OF MULTIPLE EMISSION POINT FACILITIES

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Introduction

Since 1962, the State of New York has regulated the use of byproduct, source and special nuclear material under Section 274b agreement between New York State (NYS) and the Nuclear Regulatory Commission (NRC then the Atomic Energy Commission). In 1970, the NYS Department of Environmental Conservation (NYSDEC) assumed responsibilty for the environmental aspects of the state's regulatory program. Pursuant to their authority, NYSDEC issues permits for the release of radioactive material to the air and water. The NYSDEC regulations regarding these releases are contained in 6 NYCRR Part 380. A licensee who discharges radioactive materials must comply with the release concentrations and limits stated on Section 380.9 and obtain a permit pursuant to Article 17, Water Pollution Control or Article 19, Air Pollution Control of Environmental Conservation unless discharges are to a sanitary sewer. Specific permit conditions are identified in Section 380.3.

The radionuclide concentrations identified in Section 380.9 are equivalent to 10 CFR 20 Appendix B values. To determine compliance, annual average concentrations, as measured at the point of discharge, are compared to the maximum permissible concentrations for air and water in Section 380.9. It is conservatively assumed that these concentrations are available for inhalation or ingestion by a member of the general public. The concentration limits provided in 10 CFR 20 Appendix B , and also in 6 NYCRR Part 380.9, were developed with the intent of limiting the annual dose of an individual who was continuously exposed for 50 years to a radioactive material to 500 mrem/yr at the end of the exposure period. For most radioactive materials this also corresponded to an annual dose limit of 500 mrem/year. Neither 10 CFR 20 nor 6 NYCRR 380 address the question of how to evaluate regulatory compliance of licensees with multiple effluent release points. Historically, a licensee has been judged in compliance if the effluent concentrations at each release point were less than the concentration limits specified in the appropriate NRC or NYSDEC regulations. Since each release point could be releasing radioactivity at concentrations which are within the limits set forth in Section 380.9, the question arises as to whether, when viewed collectively, the total effluent release from a facility could conceivable exceed the dose limits set forth in 6 NYCRR Part 380 Sections 380.4 and 380.5. The New York State regulations also require that effluent discharge practices be consistant with the as low as reasonably achievable (ALARA) philosophy. An additional area of concern was whether effluent discharges that were at the maximum concentrations constituted implementation of the ALARA concept.

These concerns of NYSDEC were brought to the attention of the NRC and the decision was made to fund a preliminary review of the questions by an independent outside agency. The initial request for proposal was distributed in September 1985. Finally contract authorization was received in March 1986.

Definition of Scope

The major objective of this contract was to provide 3 person-months of consulting time to the NRC and NYSDEC in an effort to initiate a program which would assist the NYSDEC in determining if broad-based licensed facilities with multiple emission points were in compliance with 6 NYCRR Part 380. Under this contract BNL would evaluate a multiple emission point facility, identified by the NYSDEC, as a case study. The review would be a nonbinding evaluation of the facility in an effort to determine likely dispersion characteristics, compliance with release limits specified in 6 NYCRR Part 380, and implementation of the ALARA philosophy regarding effluent release practices. From the data collected at the test facility, guidance as to areas of future investigation and the impact of new federal regulations were to be developed.

Phase One - Investigation of the Facility

A. Development of Criteria

The NYSDEC identified the University of Rochester, Strong Memorial Medical Center and Riverside Campus as the site for the case study. The University of Rochester is located in upstate New York, approximately 2 miles southeast of the local airport, three miles southwest of the city of Rochester, and within 5 miles southeast of lake Ontario. The University has a broad-based license with authorization to use over 55 radionuclides in the course of educational, research, and medical applications. There are 171 potential effluent release points distributed throughout the campus and medical center. All release points at this facility can be characterized as roof top vents. Figure 1 is an aerial photograph of the Strong Memorial Medical Center. The key potential release points have been identified on this figure at their location on the building by their laboratory exhaust hood numbers. Figure 2 is a diagram of the buildings located on the Riverside Campus. Figure 3 is a floor plan of the medical center while Figures 4 thru 14 show typical roof top vents as they currently exist at the Strong Memorial Medical Center and at Hutcheson Hall, the location of nearly all the release points at the Riverside Campus.

Once the location for the case study was identified, members from NYSDEC and BNL developed a plan to review the facility for compliance with 6 NYCRR Part 380, implementation of ALARA on effluent emission practices and identification of methods which would allow NYSDEC to evaluate other multi-release point facilities in a similar manner. The plan called for the review and identification of the following parameters:

* locate and identify effluent release points where the potential for airborne releases from the facility is the greatest;
* develop a source inventory;
* identify radionuclides that are likely to be emitted;
* estimate the effluent release rates (uCi/s) and effluent release concentrations (uCi/cc) from major release points;
* identify the radionuclide removal systems used in the exhaust air streams at the facility;
* obtain climatological information about the site;
* determine the location of the critical population for the airborne effluent pathway; and
* identify the method used to estimate the release fraction.

B. Investigation Report

1. Determination of Release Fraction

The first problem that was addressed was determining potential release fractions. Since virtually all the radioactive material used at this facility is in a liquid form, the decision was made to concentrate the effort on radioactive material which could readily become volatile. For purposes of this report, the only radioactive materials that have the potential to become airborne and released as an effluent are Iodine-125 and Iodine-131. A literature search on the volatility of radioactive iodine used in pharmaceuticals provided very little information. The best reference comes from a paper that Dr. C.C. Chamberlain presented at a Health Physics conference in 1984 (CH84). In the Chamberlain report, a range of volatile release fractions from 0.005 to 0.012 is reported as typical for operations at a medical institution.

Information obtained from discussions with NRC inspectors and hospital health physics personnel (MO86,SG86,HA86) indicate that iodine is volatile and that most of the releases occur when the septum is breached and the activity in the air gap of the bottle is released. Furthermore, the potential for effluent release is significantly reduced by ensuring that iodine transfers are conducted in fume hoods that have charcoal filtration of the effluent. At these facilities, the health physics staff routinely conduct charcoal filter efficiency tests to determine the fraction of iodine that is absorbed by the filtration system. Filters that fail to pass removal efficiency criteria are removed. Consequently, there is essentially no release of iodine from facilites that employ charcoal filtration systems.

The University of Rochester does not routinely employ charcoal filtration on hoods that are used for work with iodine. Two of the major use hoods, 1-5531 and AC-23, have hood insert devices (Figure 15) that the researchers and pharmacist use for iodinations. The devices fit inside the existing chemical hood and have an additional blower that exhausts the air from the insert through a charcoal filter before discharging the air to the building air removal system. The devices were installed to reduce the local workers' exposure to iodine. The charcoal filters are changed periodically but there is no formal change procedure and no filter efficiency records on these systems. Airborne effluent monitoring is not performed at this facility. Due to lack of facility specific data and effluent control devices, the upper release fraction of 0.012, as reported in the Chamberlain paper, has been used as the fraction of iodine released.

2. Identification of Source Term, Major Release Points and Critical Population

A site visit, conducted from July 9 to July 11, 1986, was used to obtain information concerning the potential source terms, effluent release points, site geometry, effluent emission control systems, and the location of critical populations. During the site visit, the radiation safety officer, Mr. Winborn D. Gregory, devoted a substantial effort to providing the review team with all the material that was requested. In order to define the potential source term, a list of radioactive materials, sorted by hood number and purchased between July 1985 and June 1986, was supplied to the team. The list was assumed to be reasonably representative of any given year's purchases based on comparison of several year's data on purchases made by the University. The isotopic inventory at each potential effluent release point, along with the hood flow rate, the mechanical controls to limit effluent releases, and the relative importance of the potential release point are summarized in Table 1. The hood flow rates were originally obtained from the Industrial Hygiene group as linear flow rates across the open face of the fume hood that was located inside a laboratory. The conversion of this measurement to an estimated volumetric flow rate was accomplished by multiplying the linear flow rate by the open face area of the hood enclosure that resulted in a linear flow rate of 125 lfpm. The relative importance rating is based on the amount of Iodine-125 that was available in the laboratory for potential release to the environment. Iodine was chosen as the element of concern based on knowledge of potential volatility, the chemical form of the other radionuclides, the intended use of the pharmaceuticals and the results of the personnel monitoring program. Iodine-125 was selected as the key radionuclide because of the number of locations that used the radioactive material without any filtration and the total activity used by the University.

The two major locations that use Iodine-131 have also been included in the analysis. Only the laboratory locations that had an Iodine-125 inventory greater than 1.4 percent (15 mCi) of the total University inventory were prioritized. This method resulted in the identification of 18 locations that account for 90% of the total release potential. Column 4 of Table 1 indicates the type of filtration that was used on each hood. As stated earlier, only two hoods used charcoal filters. All hoods did have particulate roughing filters similar to those found on home furnaces. Because there was no program to verify the efficiency of the charcoal filters, no credit was taken when the source term and air concentration projections were made.

The 18 priority locations and the total I-125 inventory have been summarized in Table 2. Table 3 provides potential source term and effluent air concentrations at the 18 release points. These values are highly speculative since neither the University of Rochester personnel nor the audit team members conducted air sampling at the suspect locations. The data, therefore, clearly represent a worst-case estimate and should be used only to determine if further investigative effort is required. The effluent release rate data and concentration data represent potential releases during the 8-hour day where research and medical procedures would likely occur. The use of the 2000-hour work year was chosen because of two major considerations. First, the literature, discussions with hospital health physicists, and representatives from the pharmaceutical companies indicate that iodine releases are most likely to occur when the user first penetrates the septum of a newly received product. The amount of discharge depends, to a great extent on the technique used to open the bottle. There is virtually no airborne releases following dilution or application of the pharmaceutical to the intended use. Second, interviews with the personnel at the University of Rochester (Appendix A) indicate that their work is generally confined to an 8 a.m. to 5 p.m. workday. Restricting the release period to 2000 hours also defines that the adult breathing rate that one would use in dosimetric calculations would be 9.6 cubic meters.

Table 4 identifies the 55 radionuclides that were purchased and used at the University of Rochester over the last year. This last table confirms the diverse nature of the work conducted at this facility and also serves to confirm the choice of Iodine as the most likely source of airborne effluent emissions.

In addition to determining the potential laboratories where effluent emissions may be significant, it was important to identify the physical release point on the roof of the building in order to determine the type of atmospheric dispersion that could be used to model potential off-site impacts of these facilities. Figures 4 thru 14 indicate the methods employed to vent material to the atmosphere from various laboratory hoods. These photographs concentrate on the 18 areas identified as potentially significant release points and have been labeled by building. In order to determine the location of a laboratory within the building complex, one must understand the building numbering system. Each laboratory identification number is composed of three parts: the first digit represents the level of the laboratory (floor number); the second two digits defines the building; and the third two digits defines the location of the laboratory within the building. While these photographs do not uniquely identify a specific effluent release point, they do serve to indicate that the release points are all roof top and not elevated.

The use of roof top instead of elevated stack release points along with other parameters such as building height and location of fresh air intake ports significantly impacts the determination of the critical population. From our site visit, two distinctly different groups of people could be considered the critical population: the non-radiation worker who is downwind of the effluent release point and members of the public who reside near the facility.

The non-radiation worker has the potential for exposure because the air intake ports are located on the sides of the building near the roof (Figures 6,8,16). Pollutants that are discharged at roof top level have the potential to flow directly into the air intake ports of the adjacent building or curl around the top and be pulled down into the air handling system. The closest members of the public who reside downwind are shown in Figures 17 and 18. These buildings are at an appreciable distance from the discharge points and as such are not likely to result in elevated exposures. Figure 19 is a graphic presentation of the discharge from one release point on S building and shows how the plume slowly migrates towards the other buildings in the medical complex.

C. Identification of ALARA Practices for Effluent Releases

Effluent releases at large multi-release point facilities can and do occur. The magnitude of the releases should be both planned and monitored. It would appear prudent to have as part of any ALARA program on effluent releases some or all of the following activities:

* program to evaluate the need to have monitoring at a potential release point;
* effluent monitoring at the release points;
* charcoal filtration in hoods where iodine work could result in significant releases to the environment;
* efficiency testing program where charcoal filters are employed;
* a bioassay program for both the direct workers and the incidentally exposed individuals at the facility; and
* an environmental safety review committee that would review changes in the design of the building or changes in the workload and assess the impact of these changes on the environment.

It is clearly recognized that not all potential release points actually have any radioactive impact on the environment. Thus it is essential to initially determine the effluent release potential of each effluent discharge point. Once a discharge point has been identified it should be monitored to determine the extent of effluent release. With this information, the environmental engineers can make an ALARA assessment as to whether additional filtration and the type, if necessary, is required.

This facility currently does not perform any effluent monitoring to confirm actual effluent release concentrations and release rates. The facility could actually have a zero release potential but it has not demonstrated this. The standard estimation of concentration technique using conservative assumptions has been adequate for determining compliance with NYSDEC 6NYCRR Part 380 and 10CFR Part 20 in the past. However, as regulations change, the use of conservative assumptions may no longer provide adequate information regarding the magnitude of the facility's impact of the environment. The facility does have a good bioassay program. The frequency of monitoring and the records are clearly adequate to determine the magnitude of Iodine-125 intakes by the worker for dosimetric purposes.

D. Compliance with the Current 6 NYCRR Part 380

As part of the case study review, this facility was to be evaluated for compliance with 6 NYCRR Part 380 regulations. The data in Table 3 summarizes the release rates and effluent concentrations at the release point for Iodine-125 and Iodine-131. The notes at the bottom of the table provide the appropriate Part 380 radiation concentration guide limit for both isotopes adjusted for the 2000 hour emission period. If the initial assumption that 0.012 of the inventory is released during the course of the year and the only method of determining compliance is comparison of effluent release concentrations to the radiation concentration guides, then there are four effluent release points that exceed the radiation concentration limits: G-6416, B-8515, 3-8106 and 1-5531. However, one must recall that the primary standard in all radiation regulations is dose and not concentrations. Consequently, unless someone actually breathes the effluent release concentrations for 2000 hours the above is no more than a conservative technique to determine if further evaluation is required. The next logical step would be to confirm these calculations with measurements of the effluent concentrations. Because this was not part of the contract and the facility had no effluent data, the best one can conclude is that more effort is needed in this area.

Phase Two - Review of the Meteorological Parameters

During the site inspection, Mr. Robert Wilson, Chief Environmental Health and Safety at the University of Rochester, supplied the team with a copy of the local meteorological data for the period 1960 to 1970 that was used on the University's Atomic Energy Project. The diagram, presented as Figure 20, indicates that the predominent wind direction was from the WSW at a wind speed of 15.3 MPH. The 1985 climatological data for the Rochester area was also obtained from the Nation Weather Service. The 1985 data, presented in Figure 21 and Tables 5 thru 12, are not significantly different from the data already presented.

The high frequency of .61 reported for neutral cases for the 1985 Rochester wind distribution can be attributed to the method used by the National Climatic Center (NCC) to calculate stability. The STAR program used by NCC employs the Pasquill stability classification as adapted by Turner for computer use [Turner]. Raynor and Hayes [1978] have shown that the STAR program attributes a much larger percentage of neutral cases than expected. The STAR program uses date, time of day, geographical location, total sky cover, ceiling height and wind speed to compute a stability class. All hours with sky cover less than 7000 feet are assigned neutral lapse rates but could actually be unstable during the day or stable during the night.

Upon review of the facility photographs, the building dynamics of the medical center and the local climatology, the BNL meteorological staff concluded that there would be no realistic way to model the dispersion of effluent pollutants without concurrent model verification measurements. Tracer sources could either be the radioactive material under study if the distribution of sources is sufficiently well characterized or inert tracers. The problems with modeling the dispersion were severalfold. First, the various heights of each building coupled with the roof level release and the close proximity of the fresh air intake ports makes the projection of plume dispersion difficult.

Our meteorological staff believes the following quotations from Meroney and Hanna et. al. explain the problems. Conventional diffusion models "contain the implicit assumptions that the flow field has straight parallel streamlines, modest velocity gradients and distributions of turbulent energy and length scales which result from surface features that remain unchanged over long distances. Near buildings the flow field becomes highly complex. Curved streamlines, sharp velocity discontinuities and non-homogeneous turbulence disperse effluents in a complicated manner uniquely related to source configuration and building geometry.

The behavior of gases emitted from stacks or vents after discharge to the atmosphere can be divided into three distinct phases. The first phase of a plume lifetime is determined by the specific properties of the discharge, i.e. the source location and its shape relative to surrounding objects. The second phase begins when excess momentum and buoyancy have been diluted to small values and the disturbance of the air mass enclosing the gases is governed by turbulence and velocity perturbations generated by objects such as buildings in the vicinity. Finally plume dimensions reach such a size that only atmospheric scale motions disperse the effluents; dispersal of all plumes of such size is identical irrespective of initial conditions." [Meroney]

"For building clusters or out-of-the-ordinary building shapes, wind-tunnel and/or field tests are necessary for a realistic assessment of a site." [Hanna et. al.]

If the medical complex consisted of a single building that was separated from other structures then conventional analysis could have been used. However, the presence of multiple buildings that were constructed with elevations that range from 30 to 118 feet above ground level and that have courtyards between buildings adds wind patterns that would not be predicted by conventional modeling techniques. A further complication is the definition of the critical population. Since this appears to be the typical medical center employee, the problem is to define the micrometeorological conditions that would permit the effluent release to enter a number of different buildings from a multitude of intakes. Again, this type of problem is better solved thru empirical observations and measurements.

In order to make some estimate of the air concentrations that are potentially available to the general public, the following simplifications have been made. First, the conservative estimate of the release point will be given by co-location of the emission points. For this study, the location was chosen to be the center of the medical complex. Second, the source term should be estimated by summation of the release rates from all effluent release locations. Third, the air concentration that a person, working in the medical center, might inhale is the product of the release rate and the average air intake rate of the medical center. This assumption does not account for the individual who spends substantial time either in the courtyards or on the roof. Finally, the dilution of the effluent emissions from the release point to the nearest residence complex, Goler House, located approximately 1200 feet NNE from the center of the medical complex is calculated as shown in Appendix B using the formula given in Hanna (HA82) for plumes entrained in building cavities. Using these assumptions concerning the dispersion characteristics of the facility, the potential air concentration was calculated for each of the critical populations. For the medical center worker, the average I-125 and I-131 air concentrations in the complex during the normal eight hour work day would be 1.5E-5 and 5.1E-5 uCi/m3 respectively. This would correspond to an annual thyroid dose of 164 mrem and a committed effective dose equivalent of 4.97 mrem. For the person who resided or worked in Goler House during the period of release, the average air concentrations of I-125 and I-131 would be 1.37E-7 and 4.62E-7 uCi/m3. This would correspond to an annual thyroid dose of 1.5 mrem and a committed effective dose equivalent of 0.045 mrem. Based on current regulatory philosophy, these exposures would not be of regulatory concern.

One should also note at this point that the effective use of charcoal filtration would have a significant impact on these projected doses. If this facility had conducted filter efficiency tests on the installed systems and demonstrated a 99% removal efficiency for hood I-5531 and AC-23, then the I-125 air concentration would have been reduced by 15% and the I-131 air concentration reduced by 98%. These reductions in effluent source terms would have reduced the dose by approximately 80%.

Phase Three - Review of Current, Suggested and Proposed Regulations and Guidance

A. Current and Proposed Regulations

The present 6 NYCRR Part 380 and 10 CFR Part 20 were developed based on the technical guidance provided by the NCRP and ICRP in the middle 1950's. These regulations stipulate that the dose to the maximum exposed individual should not exceed 500 mrem in any year from either internal or external sources of exposure. The air and water concentration limits reported in these documents were derived from mathematical models that limited the dose rate in the fiftieth year from continuous exposure to a pollutant to 500 mrem. As stated earlier, for most radionuclides used in medical and research applications this also corresponded to an annual dose rate of 500 mrem per year. In the current regulations, there is no requirement or mechanism to integrate the internal and external dose received.

The proposed 10 CFR Part 20 incorporates the most recent metabolic models for radionuclide uptake by both the inhalation and ingestion pathways. Other major features of the regulations are the addition of internal and external dose, the incorporation of the ICRP-26 weighting factors for committed effective dose equivalent, the elimination of the 5(N-18) cumulative dose limit, the provision for mandated ALARA programs and specified "de minimis" levels. For the general public, the annual dose equivalent to the maximum individual remains at 500 mrem but reference levels for non-specific members of the public have been set at 100 mrem per year from all pathways (i.e. inhalation, ingestion and direct exposure). The proposed Appendix B Table 2 and the exposure limits as specified in Sub Part D of the regulation however reference a 50 mrem per year limit. This adds a level of confusion to the document since the licensee is supposed to be able to demonstrate compliance with the 500 mrem per year limit by assuring that the general public is not exposed to reference levels of 100 mrem. Unfortunately these reference levels are based on annual doses of 50 not 100 mrem. Fortunately the proposed 10 CFR Part 20 is still in the draft stage and is likely to have these inconsistencies removed prior to publication of the final regulations.

Of more immediate importance than the proposed 10 CFR Part 20 is the existing 40 CFR 61 subpart I NESHAP regulations which applies to airborne emissions from facilities licensed by the Nuclear Regulatory Commission that was recently promulgated by the EPA. Under this rule, the maximum dose to the off-site resident is 25 mrem resulting from airborne effluent releases. This dose limit forces regulators to abandon the old conservative approaches to the assessment of dose to the general public by simple relationships between effluent concentrations and regulatory suggested concentrations. Compliance with the limit of 25 mrem per year at the site boundary limit can now only be determined by modeling the dispersion of effluent releases and environmental measurements where instrument sensitivity is adequate. The NESHAPS regulations require the use of AIRDOSE-EPA as the approved model. Since it is unlikely that each New York State licensee will have the expertise and hardware required to demonstrate compliance, it may be necessary for the state to take licensee data and run the model for the licensee.

The new NCRP Commentary #3 on "Screening Techniques for Determining Compliance with Environmental Standards" (NCRP 86) is a reasonable approach to addressing the question of regulatory compliance for effluent emissions. In this appraoch, one proceeds through three structured data collection and analysis protocols in order to determine compliance. The first level is the simplest requiring the individual to know only three pieces of data: the facility release rate for a specific radionuclide, the flow rate of the effluent release point and the applicable reference concentration. By multipling the product of the flow and release rates by 0.25, one obtains the value which is to be compared to the applicable environmental standard. If the concentration is less than the standard, no further action is required. If the concentration exceeds the reference value then one proceeds to the next evaluation technique. The second level of screening is more complicated and requires knowledge of the local meteorology, location of the general public, the stack height, calculation of building wake effect and pollutant dispersion. The third level requires all of the above information plus requires that the user estimate the contamination of the water and food products and direct exposure from plume passage. This approach allows the user to use a complex analysis when required to demonstrate compliance with environmental standards while tolerating a less strict approach for effluent release points that have little or no environmental impact. This system seems appropriate for use in demonstrating regulatory compliance.

Conclusions of the Study

There are several generalizations that can be made as result of this case study which should help the NYSDEC in developing a plan to inspect multi-release point facilities for compliance with environmental regulations. First, since ALARA is a concept that has been built into both existing and proposed regulations, the facility should have a formalized procedure for the evaluation of facility operations, research, construction and building modifications that addresses the issue of environmental impact. The procedure could consist of a review by a group or individual with the responsibilty for making the assessments and measurements required to determine the necessity of effluent control equipment and population dose.

Second, the NYSDEC regulations will need to be revised to reflect the existance of the NESHAPs regulations and the changes made to 10 CFR Part 20. The most confusing issue is most likely to be the dual regulation on airborne emissions. The best guidance that can be given here is to be consistant with the dosimetric regulations.

Third, the use of a generic approach to evaluating compliance with the environmental standards, such as outlined in the NCRP Commentary #3, is essentrial to uniform regulation. Since the NCRP has already published this protocol, it would seem prudent for the NYSDEC to standardize determination of compliance around this document.

Finally, the accuracy in the determination of the fraction of the source term available for release and the meteorological dispersion will control the estimate of compliance or lack there of with environmental regulations. The need to have records of effluent release measurements is critical to this assessment. If one can demonstrate that there is no release potential from a given operation or source, then there will be no need for meteorological information and/or environmental monitoring data. If a real release potential exists then further assessment of environmental impact may be necessary in order to demonstrate compliance.

Future Investigations

As stated in the previous section, the micro-meteorology that occurs at building releases points needs further evauation. Since this is probably a site specific problem, it may not be feasible to evaluate this problem generically. However, it may be reasonable to identify several multi-release point facilities and conduct studies at each location to determine if a general solution is possible. A second area which was poorly defined in this study was the availability of information concerning the fraction of the source term that is actually released. In this report, a value of 1.2% was assumed, based on the data reported by one health physicist. It would seem in the best interest of both the NRC and NYSDEC to expand this database for as many radionuclides as possible but clearly for the radioisotopes with large clinical and research applications. This could be accomplished by both an investigative questionnaire and site specific sampling. There appears to be data in the field, but it would take time and effort to generate a response and validate information obtained.

A final area of concern is the need to conduct environmental monitoring around the multi-release point facilities in order to confirm the level of releases. In this report, there was no allocation for either environmental or effluent monitoring. Consequently, the estimates of effluent releases and environmental impact were based on several simplifying assumptions. In lieu of supporting an intensive meteorological or release fraction study, some thought might be given to conducting environmental surveillance at several sites in an effort to corrolate projected and/or monitored effluent releases with environmental monitoring data.

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Appendix A

List of Persons on the University of Rochester Staff Interviewed

Name

Winborne Gregory
Jean Kalwas
Tom Kohler
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Appendix B

Dose Calculation Methodology

This section describes the models and assumptions used to compute the whole body and thyroid doses that are possible as a result of routine airborne effluent releases from the Univeristy of Rochester. The dose to two critical population subgroups were examined: the resident of Goler House and the non-radiation worker in the Strong Memorial Medical Center.

I. General Assumption

The following assumptions have been made for use in the evaluation of the potential dose for both critical subgroups:

a. The most conservative estimate of effluent release parameters occurs through colocation of all release points;

b. Releases occur only during the period 8 am to 5 pm from Monday to Friday;

c. The breathing rate for the adult male is 9.6 m^3 per work day;

d. The dose conversion factors for I-125 are 2.4E-2 and 8.1E-1 rem per microCurie Intake for committed effective and organ dose equivalent;

e. The dose conversion factor for I-131 are 3.2E-2 and 1.10 rem per microCurie Intake for committed effective and organ dose equivalent;

f. The person who works or resides at either the Medical Center or Goler House is present for 2000 hours per year

g. The volatile fraction of iodine represents 0.012 of the total activity present;

h. No credit was taken for the use of charcoal filters in laboratory hoods I-5531 and AC-23;

i. The Iodine-125 source term is 1.56E-3 uCi/s and the Iodine-131 source term is 5.28E-3 uCi/s.

II. Specific Assumptions for Goler House

a. The distance from the release point to Goler House in 370 meters (1200 ft.)

b. The roof cavity of the complex extends a distance of approximately 50 meters.

c. All source material released is dispersed into the environment without reduction in the source term by the medical center air intake systems.

d. Diffusion and air concentration can be calculated using the following equation:

$$X = \frac{Q}{(\pi \sigma_y \sigma_z + C\ W\ H)\ u}$$

where x = centerline air concentration, uCi/m^3

σ_y = 10 meter, for a source to receptor distance of 0.4 KM

σ_z = 5 meter, for a source to receptor distance of 0.4 KM

W = 120 meter, length of complex

H = 9 to 36 meter, height of buildings in the complex

C = empirical constant with a range of 0.5 to 2.0

Q = release rate, uCi/s.

Reference HA82

III. Specific Assumptions for Worker at Strong Memorial Medical Center

a. The total discharge from all fume hoods in the medical school is 218000 cubic feet per minute (CFM).

b. The smallest ventillation make-up intake rate is 10000 cfm.

c. Comfort ventilation is modulated between 20% and 100% outside air with the assumed average value of 50%.

IV. Dose Estimate for Resident at Goler House

For Goler House, a range of potential air concentrations was computed because of the difference in building height using a colocated average annual I-125 release rate of 1.56E-3uCi/s and I-131 rate of 5.28E-3 uCi/s.

I-125

$$X_{High} = \frac{1.564E\text{-}3\ uCi/s}{2.73E\text{+}3\ \ m3/s} = 5.74E\text{-}7\ \frac{uCi}{m3}$$

$$X_{ave.} = \frac{1.564E-3\ uCi/s}{1.14\ E+4\ m3/s} = 1.37E-7\ \frac{uCi}{m3}$$

$$X_{Low} = \frac{1.564E-3}{3.45\ E4\ \ m3/s} = 4.53E-8\ \frac{uCi}{m3}$$

I-131

$$X_{High} = \frac{5.28E-3\ uCi/s}{2.73E+3\ m3/s} = 1.94E-6\ uCi/m^3$$

$$X_{ave.} = \frac{5.28E-3\ uCi/s}{1.14E+4\ m3/s} = 4.62E-7\ uCi/m^3$$

$$X_{Low} = \frac{5.28E-3\ uCi/s}{3.45E+4\ m3/s} = 1.53E-7\ uCi/m^3$$

The organ and whole body radiation dose resulting from exposure to these air concentrations can be described by the following equations:

$$H_T = DCF \quad BR \quad T \quad X$$

$$H_{wb} = W_T H_T$$

where:

H_{wb} = committed effective dose equivalent, rem

H_T = committed dose equivalent for the tissue or organ of interest, rem

BR = Breathing rate, m^3/day

T = exposure period, days (250 work days per year)

X = air concentration, uCi/m^3

W_T = weighting factor

The dose to this hypothetical individual in Goler House are summarized in Table B-1.

V. Dose Extimate for Non Radiation Worker at the Strong Memorial Medical Center

Because the physical size of the hospital complex is so large (approximately 4.5 million gross square feet) it is unreasonable to colocate all sources and then assume that the total effluent release funnel into one air intake (simple mass balance indicates that the total discharge rate to the environment can be 22 times the smallest air intake rate). The most reasonable approach would be to colocate the release points and then use the total building air intake rate as a source of dilution. This apporach was used in the dose assessment. The release rates, breathing rates, and duration of exposure period are the same as the values used in Section IV of Appendix B.

The air concentration that would be present in the medical center if effluent release material were drawn into the building via the ventillation system was calculated using the following equation:

$$X_{max} = (Q/AI)$$

where: X = concentration, uCi/m^3

Q = effluent release rate, uCi/s

AI = Air intake, m^3/s

For I-125, the air concentration would be:

$$X_{ave.} = \frac{1.56E{-}3 \text{ uCi/s}}{102.9 \text{ m3/s}} \qquad = 1.502E{-}5 \text{ uCi/m}^3$$

For I-131, the air concentration would be:

$$X_{ave.} = \frac{5.28E{-}3 \text{ uCi/s}}{102.9} \qquad = 5.132E{-}5$$

The thyroid dose and the committed effective dose equivalent are summarized in Table B-2 and were calculated by the method outlined in Section IV of Appendix B.

Table B-1

Thyroid and Whole Body Dose Equivalent of the Maximum Individual at Goler House

Nuclide	Air Concentration uCi/m^3	Thyroid Dose mrem	Committed Effective Dose Equivalent mrem
I-125	5.74E-7	1.12	0.034
	1.37E-7	0.27	0.008
	4.53E-8	0.09	0.003
I-131	1.94E-6	5.12	0.154
	4.62E-7	1.22	0.037
	1.53E-7	0.40	0.012

Maximum Thyroid Dose = 6.24 mrem
Maximum Whole Body Committed Effective Dose Equivalent = 0.188 mrem

Table B-2

Thyroid and Whole Body Dose Equivalent for the Non-Radiation Worker

Nuclide	Air Concentration uCi/m^3	Thyroid Dose mrem	Committed Effective Dose Equivalent mrem
I-125	1.5E-5	29	0.87
I-131	5.1E-5	135	4.1

Total Thyroid dose = 164 mrem
Total Whole Body Committed Effective Dose Equivalent = 4.97 mrem

Table 1
1985 Radionuclide Inventory and Storage Information

Hood Number	Hood Flow Rate CFM	Isotopes Used	Total Activity mCi	Filtration Y/N		Relative Importance
1-4110	534	C-14	1.000	N		0
		H-3	1.000			
		I-125	0.610			
		P-32	18.000			
		S-35	25.000			
1-4121	750	I-125	0.450	N		0
		P-32	5.000			
		S-35	8.250			
1-4123	602	H-3	1.000	N		0
1-4148	658	H-3	5.00	N		0
		Cr-51	34.00			
1-5333	*	H-3	0.002	N		0
		I-125	0.007			
1-5337	*	I-125	0.013	N		0
		Co-57	0.001			
1-5527	365	I-125	5.000	N		0
1-5531	365	I-125	30.005	Y	Charcoal	11
		I-131	3088.675			
		P-32	15.000			
		Co-57	20.129			
		Cr-51	2.100			
		Ga-67	534.000			
		In-111	41.500			
		Xe-133	3320.000			
		Mo-99	146,245.000			
		Tl-201	526.000			
1-6713	333	H-3	150.00	N		0
1-6925	387	H-3	5.000	N		0
		Cr-51	42.000			
1-7544	833	P-32	7.000	N		0
1-8814	833	P-32	25.000	N		0
		Hg-203	5.00			

Table 1
1985 Radionuclide Inventory and Storage Information

Hood Number	Hood Flow Rate CFM	Isotopes Used	Total Activity mCi	Filtration Y/N	Relative Importance
1-9045	458	H-3	0.250	N	0
2-4115	890	H-3	2.000	N	0
		I-125	1.800		
		P-32	36.250		
		S-35	1.250		
2-4148	750	H-3	7.000	N	0
		I-125	0.200		
		S-35	10.000		
2-4151	*	P-32	1.750	N	0
		S-35	8.000		
2-4332	583	I-125	70.000	N	5
2-5110	660	I-125	0.500	N	0
		Ce-141	0.500		
		Cr-51	0.500		
		Sc-46	0.500		
		Sr-85	0.500		
2-5205	*	C-14	53.784	N	0
2-5343	*	I-125	0.020	N	0
		S-35	1.000		
2-5434	312	P-32	4.750	N	0
		S-35	1.000		
2-5706	409	H-3	16.950	N	0
		I-125	3.000		
		P-32	152.00		
		S-35	0.500		
		Ca-45	4.000		
2-6515	417	C-14	0.250	N	0
2-6713	639	H-3	25.250	N	0
		S-35	5.000		
		Cr-51	55.000		
2-6835	309	C-14	0.400	N	0
		H-3	2.000		
		I-125	2.000		
		P-32	0.500		

Table 1
1985 Radionuclide Inventory and Storage Information

Hood Number	Hood Flow Rate CFM	Isotopes Used	Total Activity mCi	Filtration Y/N	Relative Importance
		S-35	2.000		
		Ca-45	2.000		
		Cl-36	1.500		
		Rb-86	5.000		
2-6931	*	H-3	15.000	N	0
		Cr-51	15.000		
		Se-75	0.500		
3-4118	515	C-14	1.410	N	0
		H-3	5.000		
		I-125	5.01		
		S-35	85.000		
3-5110	906	H-3	22.000	N	0
		S-35	55.000		
3-5115	435	C-14	0.001	N	0
		H-3	0.250		
		S-35	9.000		
		Cr-51	26.000		
3-5116	580	I-125	4.000	N	0
		S-35	1.000		
3-5146	667	P-32	10.500	N	0
3-5432	295	C-14	0.250	N	0
		H-3	35.000		
		I-125	0.004		
		S-35	140.000		
3-5506	583	P-32	0.500	N	0
3-5512	700	C-14	1.000	N	0
		P-32	5.000		
3-5517	833	C-14	14.515	N	0
		H-3	1.250		
		I-125	6.000		
		P-32	94.250		
		S-35	12.000		
3-5529	*	H-3	0.265	N	0
		I-125	0.747		

Table 1
1985 Radionuclide Inventory and Storage Information

Hood Number	Hood Flow Rate CFM	Isotopes Used	Total Activity mCi	Filtration Y/N	Relative Importance
3-5750	625	C-14	0.001	N	0
		P-32	0.250		
3-6108	770	H-3	4.000	N	0
		I-125	0.013		
3-6115	591	I-125	51.000	N	7
		I-131	80.000		
3-6134	578	C-14	0.500	N	0
3-6137	577	H-3	0.047	N	0
		I-125	0.091		
3-6329	583	H-3	0.004	N	0
3-6338	*	I-125	0.001	N	0
3-6417	500	C-14	0.050	N	0
		H-3	20.000		
		P-32	50.000		
		S-35	45.000		
3-6515	1060	Ca-45	8.000	N	0
		Na-22	0.500		
3-6715	397	Ca-45	1.000	N	0
3-6823	123	C-14	0.450	N	0
		Cl-36	0.500		
3-6952	*	C-14	5.250	N	0
		H-3	7.250		
		I-125	0.001		
3-7210	1000	C-14	0.055	N	0
		I-125	0.500		
		S-35	75.000		
3-7221	***	I-125	25.000	N	14
		Fe-59	2.000		
3-7238	658	S-35	5.000	N	0
3-7518	542	P-32	20.500	N	0
		S-35	0.750		

Table 1
1985 Radionuclide Inventory and Storage Information

Hood Number	Hood Flow Rate CFM	Isotopes Used	Total Activity mCi	Filtration Y/N	Relative Importance
3-7524	667	P-32	6.500	N	0
		S-35	1.750		
3-7531	700	P-32	3.750	N	0
		S-35	8.000		
3-7533	656	H-3	5.000	N	0
		P-32	9.500		
3-7537	1458	I-125	30.000	N	12
		P-32	34.750		
3-7544	*	C-14	0.150	N	0
		H-3	2.000		
		P-32	53.000		
		S-35	7.500		
3-8106	433	I-125	95.100	N	3
3-8117	366	C-14	0.650	N	0
3-8128	***	H-3	5.000	N	18
		I-125	15.000		
3-8162	500	C-14	0.300	N	0
		H-3	0.051		
		P-32	21.000		
		Na-22	0.200		
3-8546	729	H-3	31.000	N	0
		P-32	2.250		
		S-35	2.250		
3-8552	1162	H-3	111.000	N	0
		P-32	7.500		
3-8560	*	H-3	0.500	N	0
		P-32	24.500		
3-7531	700	S-35	0.500	N	0
4-4123	938	H-3	25.000	N	0
		Cr-51	19.000		
4-4148	750	H-3	15.000	N	0
		S-35	5.000		

Table 1
1985 Radionuclide Inventory and Storage Information

Hood Number	Hood Flow Rate CFM	Isotopes Used	Total Activity mCi	Filtration Y/N	Relative Importance
4-4444	469	I-125	50.000	N	8
4-4451	625	H-3	4.000	N	13
		I-125	25.010		
		P-32	478.000		
4-5109	938	C-14	0.050	N	0
		H-3	30.000		
		I-125	5.100		
		Cl-36	0.500		
4-5148	938	C-14	5.000	N	0
		H-3	15.000		
		I-125	10.100		
4-5210	938	I-125	0.250	N	0
4-5236	938	C-14	0.550	N	0
		H-3	2.000		
		I-125	0.770		
4-5318	*	C-14	0.250	N	0
4-5506	1224	C-14	1.500	N	0
		H-3	1.000		
4-6108	458	C-14	0.621	N	0
		H-3	43.000		
		I-125	1.250		
		P-32	0.250		
		Na-22	0.200		
4-6109	*	C-14	2.050	N	0
		H-3	1.750		
4-6114	833	H-3	0.250	N	0
4-6115	458	C-14	0.550	N	0
		H-3	36.250		
		I-125	0.001		
		S-35	1.00		
4-6137	833	S-35	2.000	N	0

Table 1
1985 Radionuclide Inventory and Storage Information

Hood Number	Hood Flow Rate CFM	Isotopes Used	Total Activity mCi	Filtration Y/N	Relative Importance
4-6142	*	C-14	0.500	N	0
		H-3	1.000		
		I-125	0.250		
4-6409	425	K-42	40.000	N	0
		Cl-36	0.100		
4-6529	1516	C-14	0.251	N	0
		H-3	0.050		
		S-35	2.000		
4-6713	500	P-32	1.400	N	0
4-6731	509	C-14	0.360	N	0
4-6835	305	C-14	0.050	N	0
		H-3	0.500		
		Hg-203	14.000		
4-6951	1032	C-14	0.052	N	0
		I-125	0.413		
4-7430	1000	H-3	4.000	N	0
4-7521	625	H-3	3.250	N	10
		I-125	35.700		
		S-35	5.250		
		Cl-36	0.100		
4-7546	*	P-32	0.500	N	0
4-7558	625	C-14	0.100	N	0
		H-3	3.260		
		I-125	0.802		
		P-32	1.000		
		Ca-45	2.000		
4-8523	625	I-125	0.026	N	0
4-8528	*	C-14	0.100	N	0
		P-32	2.000		
4-8548	673	H-3	0.250	N	0
		I-125	0.100		

Table 1
1985 Radionuclide Inventory and Storage Information

Hood Number	Hood Flow Rate CFM	Isotopes Used	Total Activity mCi	Filtration Y/N	Relative Importance
4-8550	625	H-3	2.000	N	0
		Hg-203	2.000		
4-8564	417	H-3	1.250	N	0
		I-125	10.000		
		P-32	274.500		
		S-35	1.000		
4-8850	750	C-14	0.001	N	0
		H-3	17.000		
5-5322	1506	I-125	0.060	N	0
5-5344	1642	C-14	0.500	N	0
		H-3	3.000		
		I-125	0.172		
5-5527	1500	C-14	0.050	N	0
5-5708	687	I-125	20.000	N	16
5-5751	1345	P-32	0.750	N	0
		S-35	0.500		
5-6526	417	H-3	4.000	N	0
5-6715	833	I-125	1.000	N	0
5-6823	667	H-3	17.000	N	0
		P-32	7.500		
		S-35	2.250		
5-6915	667	H-3	1.010	N	0
		P-32	23.000		
5-7224	1123	I-125	55.000	N	6
		P-32	0.500		
5-7238	1430	I-125	21.000	N	15
5-7413	*	H-3	5.250	N	0
		S-35	11.500		
5-7517	500	P-32	1.750	N	0

Table 1
1985 Radionuclide Inventory and Storage Information

Hood Number	Hood Flow Rate CFM	Isotopes Used	Total Activity mCi	Filtration Y/N	Relative Importance
5-7543	687	C-14	0.350	N	17
		H-3	0.250		
		I-125	15.100		
		S-3	6.000		
5-7552	1074	C-14	0.100	N	0
		I-125	0.245		
		Cd-109	0.100		
		Co-57	0.020		
5-7572	1066	H-3	0.250	N	0
		I-125	14.000		
5-7577	*	I-125	5.000	N	0
5-8108	1000	P-32	3.500	N	0
5-8153	1000	H-3	0.252	N	0
		I-125	0.401		
		P-32	7.250		
		S-35	11.500		
5-8522	310	C-14	0.001	N	0
		H-3	15.000		
5-8527	*	I-125	0.100	N	0
		P-32	0.250		
5-8834	773	C-14	1.000	N	0
6-6523	*	I-131	2.000	N	0
6-6728	451	H-3	0.010	N	0
		I-125	0.009		
		Ce-141	7.000		
		Cr-51	7.000		
		Nb-95	7.000		
		Ru-103	7.000		
		Sc-46	6.000		
		Sn-113	6.000		
		Sc-46	1.000		
6-6807	586	C-14	0.010	N	0
		P-32	15.000		
6-7539	725	I-125	10.000	N	0

Table 1
1985 Radionuclide Inventory and Storage Information

Hood Number	Hood Flow Rate CFM	Isotopes Used	Total Activity mCi	Filtration Y/N		Relative Importance
6-8520	*	H-3	10.000	N		0
6-8540	725	I-125	2.00	N		0
6-8552	750	H-3	6.250	N		0
		I-125	0.210			
		Ca-45	10.000			
6-8818	*	H-3	0.001	N		0
		I-125	0.150			
		P-32	18.500			
		S-35	9.500			
		Fe-55	2.000			
AA-215	450	H-3	17.000	N		0
AB-238	*	H-3	0.002	N		0
		I-125	0.018			
AB-242	*	H-3	0.500	N		0
		P-32	0.500			
AB-305	437	Cd-109	2.500	N		0
		Cd-115m	0.000			
		Mn-54	1.000			
AC-23	945	H-3	0.001	Y	Charcoal	2
		I-125	120.026			
AC-35	520	P-32	1.750	N		0
		S-35	12.000			
AC-116	500	C-14	0.001	N		0
		S-35	5.000			
B-5729	293	Sr-90	5.000	N		0
B-6618	333	H-3	1.000	N		0
B-7520	1033	C-14	0.250	N		0
		H-3	1.000			
		P-32	1.500			
		S-35	1.500			

Table 1
1985 Radionuclide Inventory and Storage Information

Hood Number	Hood Flow Rate CFM	Isotopes Used	Total Activity mCi	Filtration Y/N	Relative Importance
B-7668	805	H-3	7.000	N	0
		S-35	4.500		
B-8515	500	I-125	80.000	N	4
		P-32	6.000		
		Cr-51	6.000	N	0
BL-210	*	Fe-55	0.025	N	0
CH3C24	*	C-14	0.200	N	0
		H-3	1.250		
		I-125	0.010		
CH3C26	833	H-3	12.000	N	0
CYCLOT	*	Ru-106	0.005	N	0
G-3123	365	P-32	45.000	N	0
		Ir-192	1.000		
G-3124	*	Ir-192	299.195	N	0
G-3127	*	Ir-192	2.000	N	0
		I-131	1.000		
G-5321	274	H-3	6.505	N	0
		I-125	0.010		
		S-35	10.000		
		Ca-45	2.000		
G-6415	456	H-3	3.000	N	0
		Cr-51	9.000		
		Se-75	2.500		
G-6416	**	I-125	160.000	N	1
		P-32	14.000		
		Cr-51	16.000		
G-6517	781	H-3	3.500	N	9
		I-125	40.732		
		P-32	28.250		
G-6526	500	H-3	0.250	N	0
		I-125	5.000		
		P-32	48.000		

Table 1
1985 Radionuclide Inventory and Storage Information

Hood Number	Hood Flow Rate CFM	Isotopes Used	Total Activity mCi	Filtration Y/N	Relative Importance
HH-301	625	I-125	0.200	N	0
		P-32	15.000		
HH-303	917	C-14	0.001	N	0
		P-32	20.750		
		S-35	9.750		
HH-304	451	P-32	4.250	N	0
		S-35	1.500		
HH-311	833	H-3	7.750	N	0
		P-32	6.250		
		S-35	1.000		
HH-315	1000	P-32	3.000	N	0
HH-331	525	H-3	2.250	N	0
		I-125	0.200		
		P-32	101.250		
		S-35	5.000		
HH-334	872	P-32	20.000	N	0
HH-336	525	C-14	0.001	N	0
		P-32	7.250		
		S-35	25.000		
HH-337	*	H-3	2.000	N	0
		P-32	17.000		
		S-35	1.000		
HH-338	395	C-14	0.053	N	0
		H-3	5.000		
		P-32	18.000		
		S-35	7.000		
HH-340	525	C-14	0.050	N	0
		H-3	5.000		
		P-32	0.750		
		S-35	1.250		
HH-425	328	C-14	0.250	N	0
	847	H-3	7.900		
		I-125	0.250		
		P-32	42.000		
		S-35	1.750		

Table 1
1985 Radionuclide Inventory and Storage Information

Hood Number	Hood Flow Rate CFM	Isotopes Used	Total Activity mCi	Filtration Y/N	Relative Importance
HH-455	875	H-3	500.000	N	0
HH-480	446	H-3	57.000	N	0
		P-32	25.750		
		S-35	14.000		
HH-B31	*	P-32	9.100	N	0
LLE112	1250	H-3	129.500	N	0
		Na-24	21.430		
NRSL	1250	Ta-182	0.019	N	0
PS-124	546	H-3	32.000	N	0
RR-305	1133	C-14	1.750	N	0
		H-3	18.250		
		P-32	2.750		
		S-35	8.500		
		Cl-36	0.100		

* Hood flow rate not available
** Sterile hood no outlet. Flow rates in adjacent hoods are 250 CFM in hood G-6454 and 333 CFM in hood G-6456.
*** Sterile hood, no outlet.

Table 2

Release Points Representing 90% of Total I-125 Inventory

Laboratory Number	I-125 mCi
1-5531	30.000
2-4332	70.000
3-6115	51.000
3-7221	25.000
3-7537	30.000
3-8106	95.100
3-8128	15.000
4-4444	50.000
4-4451	25.010
4-7521	35.700
5-5708	20.000
5-7224	55.000
5-7238	21.000
5-7543	15.100
AC-23	120.026
B-8515	80.000
G-6416	160.000
G-6517	40.732

Table 3

Projected Effluent Release Rates and Concentrations During 2000 Hour Work Year

	Lab No.	Inventory mCi	Projected Release Rate uCi/s	Projected Effluent Concentration uCi/cc
I-125				
	1-5531	30.005	5.00E-5	2.90E-10
	2-4332	70.000	1.17E-4	4.24E-10
	3-6115	51.000	8.50E-5	3.05E-10
	3-7221*	25.000	4.17E-5	8.83E-11
	3-7537	30.000	5.00E-5	7.27E-11
	3-8106	95.100	1.58E-4	7.76E-10
	3-8128*	15.000	2.50E-5	1.45E-10
	4-4444	50.000	8.33E-5	3.76E-10
	4-4451	25.010	4.17E-5	1.41E-10
	4-7521	35.700	5.95E-5	2.02E-10
	5-5708	20.000	3.33E-5	1.03E-10
	5-7224	55.000	9.17E-5	1.73E-10
	5-7238	21.000	3.50E-5	5.19E-11
	5-7543	15.100	2.52E-5	7.76E-11
	AC-23	120.026	2.00E-4	4.49E-10
	B-6515	80.000	1.33E-4	5.65E-10
	G-6416*	160.000	2.67E-4	2.26E-9
	G-6517	40.732	6.79E-5	1.25E-10
I-131				
	1-5531	3088.675	5.15E-3	2.99E-8
	1-6115	80.000	1.33E-4	4.78E-10

* Flow rate from adjacent hood used for the release concentration estimates

Note:
1. No credit taken for charcoal filtration system used on hoods 1-5531 and AC-23.
2. All release rates and effluent concentrations were calculated using a volatilized fraction of 0.012.
3. 10 CFR 20 Table 1 MPC air concentration which would yield 500 mrem/yr for I-125 is 5E-10 uCi/cc and for I-131 is 9E-10 uCi/cc.

Table 4

Summary of Radionuclides Used at the University of Rochester

Radionuclide	Radionuclide	Radionuclide	Radionuclide
H-3	Fe-59	Ag-110m	Hg-197
C-14	Cu-64	In-111	Au-198
Na-22	Zn-65	Sn-113	Tl-201
Na-24	Ga-67	Cd-115	Hg-203
P-32	Se-75	Cd-115m	Pb-203
S-35	Br-82	I-123	Ra-226
Cl-36	Sr-85	I-125	U-232
Ca-45	Kr-85	I-131	U-233
Sc-46	Rb-86	Xe-133	U-235
Ca-47	Sr-90	Cs-137	U-238
Sc-47	Mo-99	Ce-141	
Cr-51	Tc-99	Gd-153	Total: 55
Mn-54	Tc-99m	Tb-160	
Fe-55	Ru-103	Yt-169	
Co-57	Cd-109	Hf-181	

Table 5

Summary of Rochester 1985 Annual
Wind Distribution

Rochester New York Station Number: 4768 Latitude=43.117 Longitude=77.667

1985 Annual Wind Distribution

Most Prevalent Direction WSW Average WSW Wind Speed 10.2 knots

Direction	Frequency
360.00	0.0315
22.50	0.0261
45.00	0.0384
67.50	0.0353
90.00	0.0566
112.50	0.0271
135.00	0.0256
157.50	0.0406
180.00	0.1192
202.50	0.1134
225.00	0.1157
247.50	0.1299
270.00	0.1144
292.50	0.0608
315.00	0.0409
337.50	0.0243

Average wind speed 7.5 knots

Speed knots	Frequency
0 to 3	0.1345
> 3 to 6	0.3375
> 6 to 10	0.3105
>10 to 16	0.1810
>16 to 21	0.0301
> 21	0.0063

Total Relative Frequency of Calms = .0656

	Frequency
Extremely Unstable	0.0041
Unstable	0.0408
Slightly Unstable	0.0945
Neutral	0.6103
Slightly Stable	0.0939
Stable	0.1068
Extremely Stable	0.0496

Table 6

Rochester 1985 Frequency Distribution for
Extremely Unstable Cases

Rochester New York Station Number: 4768 Latitude=43.117 Longitude=77.667

1985 Annual Wind Distribution

Frequency Distribution of Cases That Are Extremely Unstable
Fractional Occurrence= 0.0041

Wind Speed (knots)	less than					
Direction	3.0	6.0	10.0	16.0	21.0	> 21.0
360.00	0.0001	0.0003				
22.50						
45.00	0.0001	0.0006				
67.50						
90.00						
112.50	0.0000	0.0002				
135.00	0.0002	0.0001				
157.50	0.0003	0.0002				
180.00	0.0001	0.0003				
202.50	0.0002	0.0001				
225.00	0.0000	0.0001				
247.50	0.0000	0.0001				
270.00	0.0000	0.0002				
292.50	0.0001	0.0005				
315.00						
337.50	0.0002	0.0001				

Entries of .0000 indicate non zero numbers less than .00005,
Zero is denoted by blank

Table 7

Rochester 1985 Frequency Distribution for
Unstable Cases

Rochester New York Station Number: 4768 Latitude=43.117 Longitude=77.667

1985 Annual Wind Distribution

Frequency Distribution of Cases That Are Unstable
Fractional Occurrence= 0.0408

Wind Speed (knots)	less than 3.0	6.0	10.0	16.0	21.0	> 21.0
Direction						
360.00	0.0003	0.0017	0.0017			
22.50	0.0003	0.0008	0.0003			
45.00	0.0003	0.0017	0.0006			
67.50	0.0004	0.0005	0.0003			
90.00	0.0004	0.0008	0.0002			
112.50	0.0005	0.0005				
135.00	0.0006	0.0007	0.0001			
157.50	0.0009	0.0011	0.0005			
180.00	0.0003	0.0015	0.0023			
202.50	0.0010	0.0022	0.0014			
225.00	0.0010	0.0009	0.0010			
247.50	0.0008	0.0015	0.0010			
270.00	0.0009	0.0013	0.0008			
292.50	0.0005	0.0013	0.0014			
315.00	0.0005	0.0011	0.0009			
337.50	0.0000	0.0007	0.0011			

Entries of .0000 indicate non zero numbers less than .00005,
Zero is denoted by blank

Table 8

Rochester 1985 Frequency Distribution for Slightly Unstable Cases

Rochester New York Station Number: 4768 Latitude=43.117 Longitude=77.667

1985 Annual Wind Distribution

Frequency Distribution of Cases That Are Slightly Unstable
Fractional Occurrence= 0.0945

Wind Speed (knots)	less than 3.0	6.0	10.0	16.0	21.0	> 21.0
Direction						
360.00	0.0003	0.0017	0.0030	0.0002	0.0001	
22.50	0.0002	0.0005	0.0037	0.0006	0.0001	
45.00	0.0002	0.0009	0.0033	0.0003	0.0001	
67.50	0.0000	0.0002	0.0011	0.0001	0.0001	
90.00	0.0004	0.0016	0.0017			
112.50	0.0002	0.0010	0.0009	0.0001		
135.00	0.0007	0.0005	0.0006	0.0001		
157.50	0.0004	0.0016	0.0014	0.0006		
180.00	0.0013	0.0039	0.0079	0.0009		
202.50	0.0010	0.0027	0.0052	0.0008	0.0001	
225.00	0.0010	0.0030	0.0058	0.0010	0.0002	
247.50	0.0003	0.0011	0.0044	0.0013	0.0005	0.0001
270.00	0.0004	0.0013	0.0033	0.0018	0.0002	
292.50	0.0003	0.0017	0.0021	0.0007	0.0005	
315.00	0.0003	0.0016	0.0037	0.0009		
337.50	0.0002	0.0002	0.0037	0.0006		

Entries of .0000 indicate non zero numbers less than .00005,
Zero is denoted by blank

Table 9

Rochester 1985 Frequency Distribution for
Slightly Stable Cases

Rochester New York Station Number: 4768 Latitude=43.117 Longitude=77.667

1985 Annual Wind Distribution

Frequency Distribution of Cases That Are Slightly Stable
Fractional Occurrence= 0.0939

Wind Speed (knots) / Direction	less than 3.0	6.0	10.0	16.0	21.0	> 21.0
360.00		0.0007	0.0003			
22.50		0.0003	0.0016			
45.00		0.0025	0.0015			
67.50		0.0031	0.0008			
90.00		0.0037	0.0016			
112.50		0.0017	0.0007			
135.00		0.0026	0.0003			
157.50		0.0041	0.0009			
180.00		0.0102	0.0033			
202.50		0.0074	0.0047			
225.00		0.0065	0.0050			
247.50		0.0039	0.0071			
270.00		0.0042	0.0034			
292.50		0.0018	0.0048			
315.00		0.0019	0.0014			
337.50		0.0015	0.0002			

Entries of .0000 indicate non zero numbers less than .00005,
Zero is denoted by blank

Table 10

Rochester 1985 Frequency Distribution for
Neutral Cases

Rochester New York Station Number: 4768 Latitude=43.117 Longitude=77.667

1985 Annual Wind Distribution

Frequency Distribution of Cases That Are Neutral
Fractional Occurrence= 0.6103

Wind Speed (knots)	less than 3.0	6.0	10.0	16.0	21.0	> 21.0
Direction						
360.00	0.0015	0.0056	0.0078	0.0034	0.0001	
22.50	0.0006	0.0033	0.0067	0.0046	0.0007	
45.00	0.0015	0.0059	0.0083	0.0065	0.0009	
67.50	0.0024	0.0078	0.0090	0.0055	0.0003	
90.00	0.0044	0.0174	0.0128	0.0043		
112.50	0.0021	0.0081	0.0060	0.0018		
135.00	0.0020	0.0058	0.0043	0.0011		
157.50	0.0032	0.0081	0.0067	0.0033	0.0002	
180.00	0.0057	0.0177	0.0249	0.0144	0.0011	
202.50	0.0037	0.0193	0.0232	0.0095	0.0008	
225.00	0.0045	0.0135	0.0191	0.0185	0.0043	0.0013
247.50	0.0030	0.0122	0.0293	0.0344	0.0095	0.0034
270.00	0.0031	0.0119	0.0238	0.0384	0.0065	0.0015
292.50	0.0024	0.0077	0.0103	0.0168	0.0030	
315.00	0.0016	0.0070	0.0090	0.0059	0.0006	
337.50	0.0010	0.0035	0.0060	0.0025	0.0001	

Entries of .0000 indicate non zero numbers less than .00005,
Zero is denoted by blank

Table 11

Rochester 1985 Frequency Distribution for
Stable Cases

Rochester New York Station Number: 4768 Latitude=43.117 Longitude=77.667

1985 Annual Wind Distribution

Frequency Distribution of Cases That Are Stable
Fractional Occurrence= 0.1068

Wind Speed (knots) / Direction	less than 3.0	6.0	10.0	16.0	21.0	> 21.0
360.00	0.0004	0.0014				
22.50	0.0005	0.0008				
45.00	0.0010	0.0009				
67.50	0.0006	0.0016				
90.00	0.0024	0.0034				
112.50	0.0010	0.0005				
135.00	0.0017	0.0022				
157.50	0.0012	0.0032				
180.00	0.0040	0.0113				
202.50	0.0038	0.0182				
225.00	0.0032	0.0159				
247.50	0.0018	0.0096				
270.00	0.0015	0.0065				
292.50	0.0006	0.0037				
315.00	0.0005	0.0019				
337.50	0.0004	0.0009				

Entries of .0000 indicate non zero numbers less than .00005,
Zero is denoted by blank

Table 12

Rochester 1985 Frequency Distribution for
Extremely Stable Cases

Rochester New York Station Number: 4768 Latitude=43.117 Longitude=77.667

1985 Annual Wind Distribution

Frequency Distribution of Cases That Are Extremely Stable
Fractional Occurrence= 0.0496

Wind Speed (knots)	less than 3.0	6.0	10.0	16.0	21.0	> 21.0
Direction						
360.00	0.0008					
22.50	0.0006					
45.00	0.0011					
67.50	0.0014					
90.00	0.0014					
112.50	0.0017					
135.00	0.0020					
157.50	0.0025					
180.00	0.0081					
202.50	0.0081					
225.00	0.0098					
247.50	0.0045					
270.00	0.0034					
292.50	0.0008					
315.00	0.0020					
337.50	0.0014					

Entries of .0000 indicate non zero numbers less than .00005,
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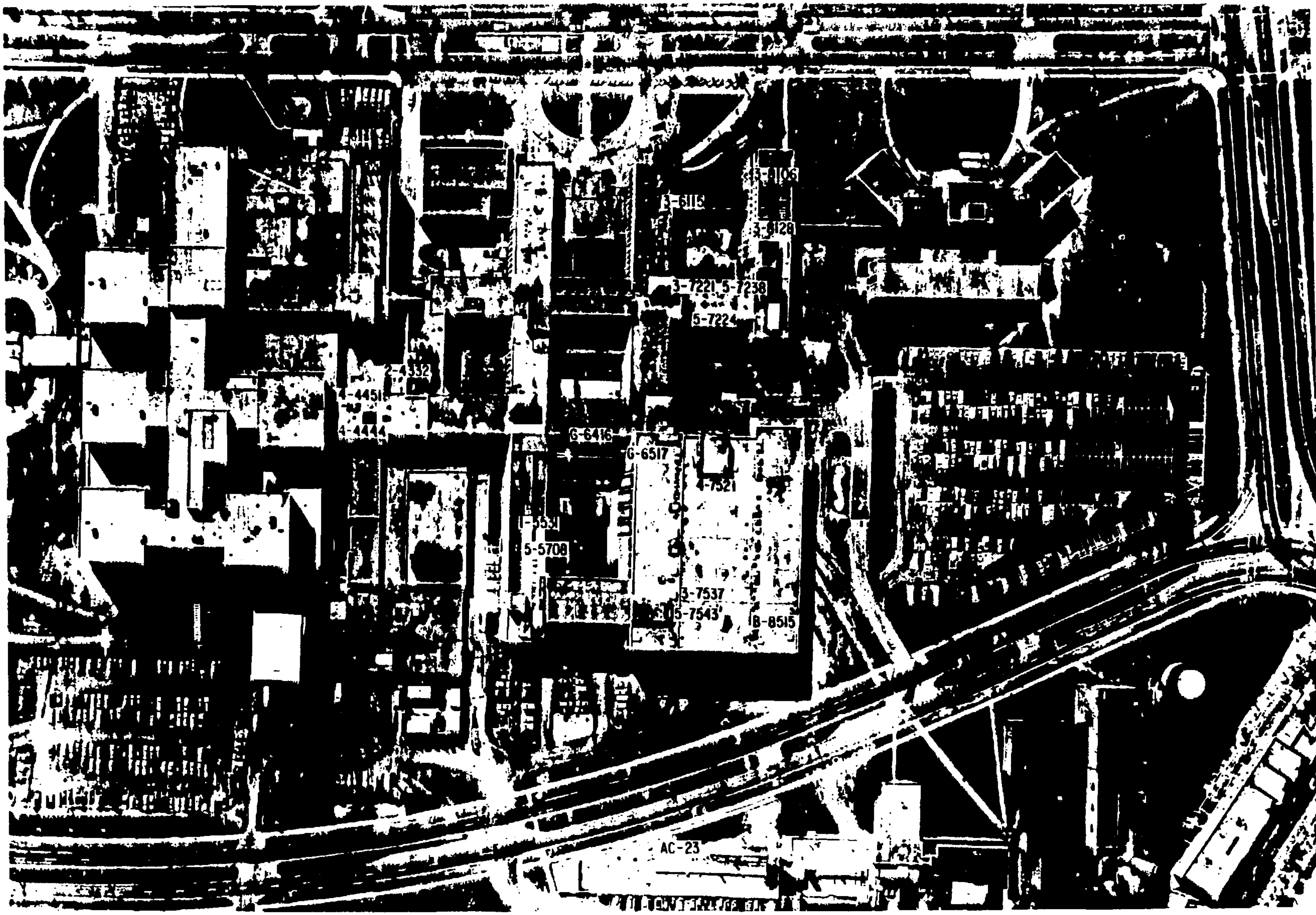

Figure 1 Aerial Photograph - University of Rochester Strong Memorial Hospital - Major Effluent Release Points Identified

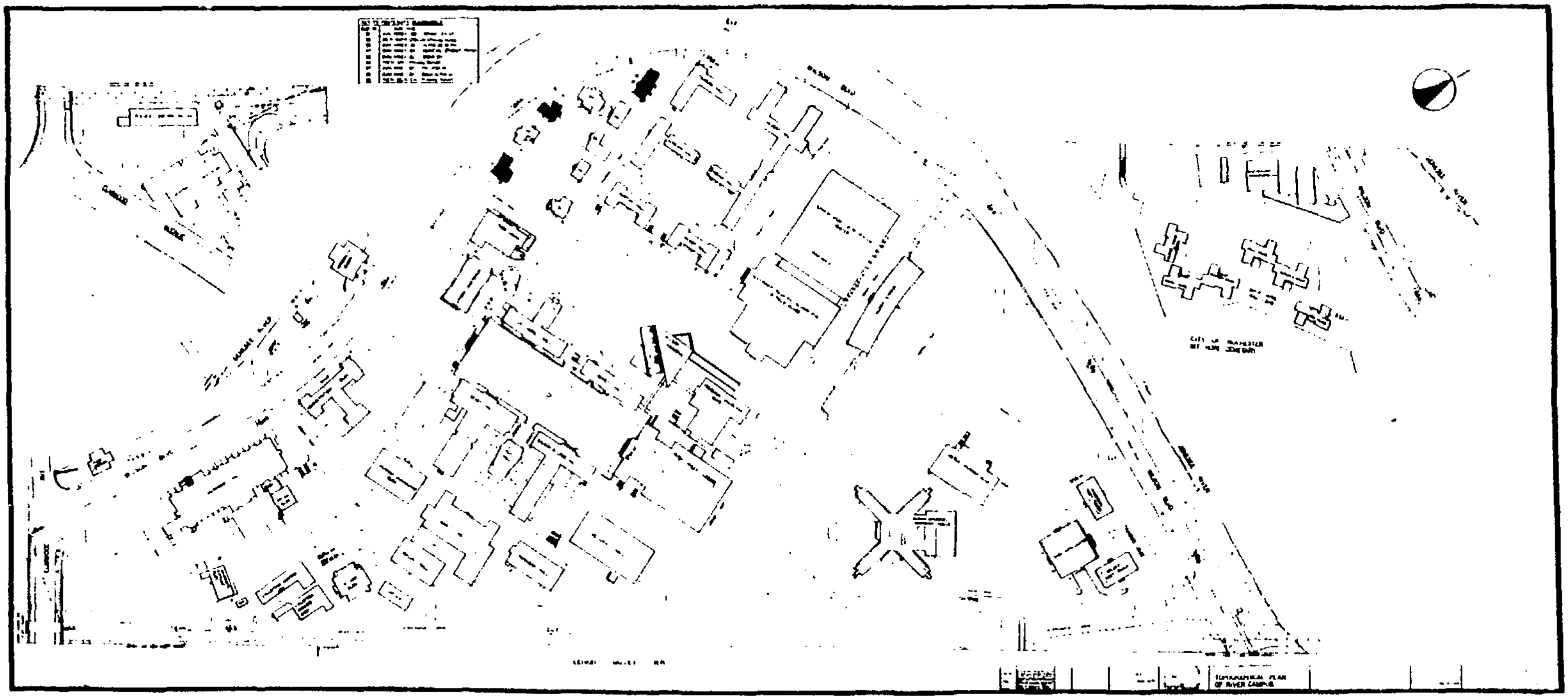

Figure 2 University of Rochester - River Campus

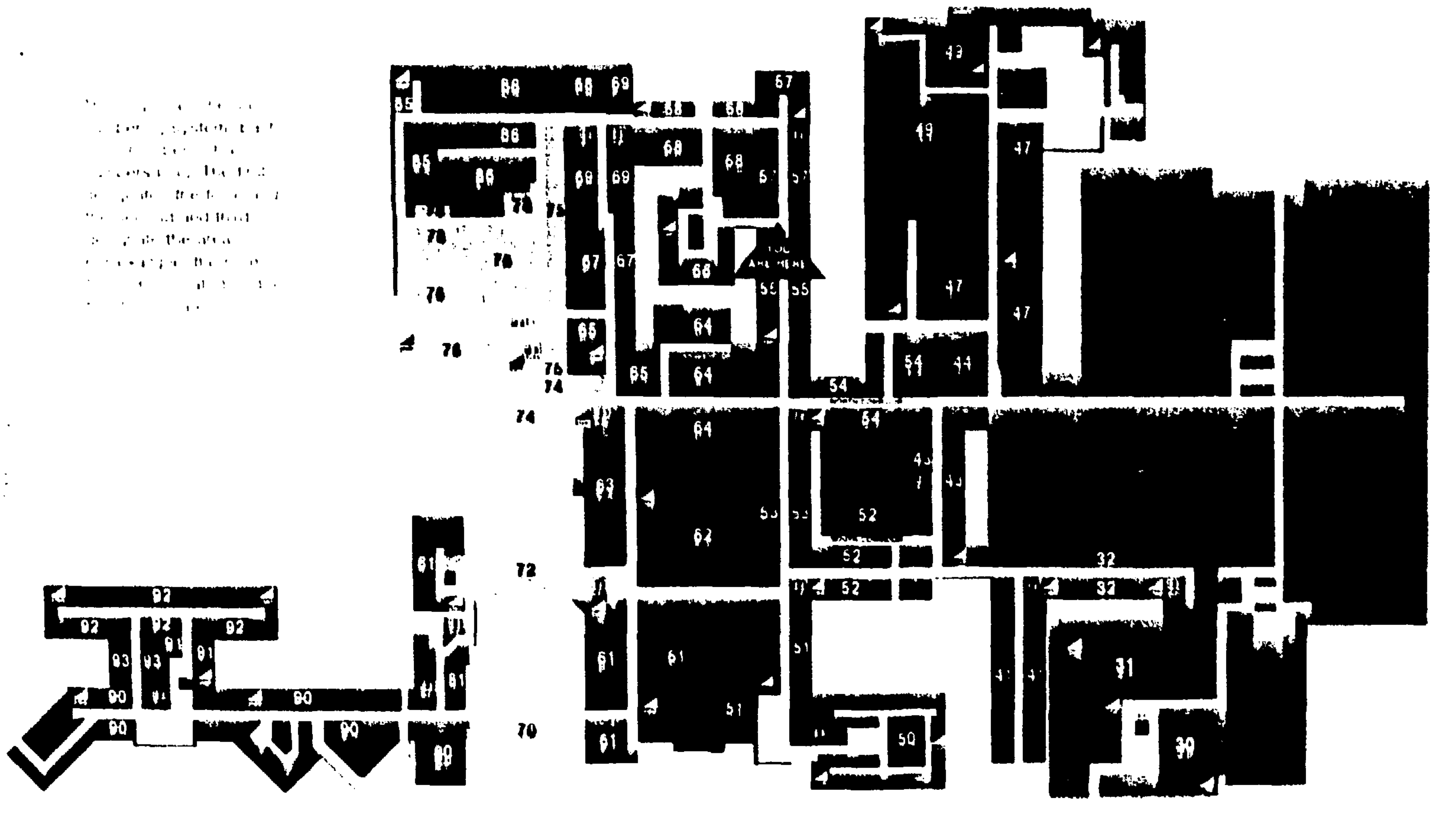

Figure 3 Floor Plan of Strong Memorial Hospital

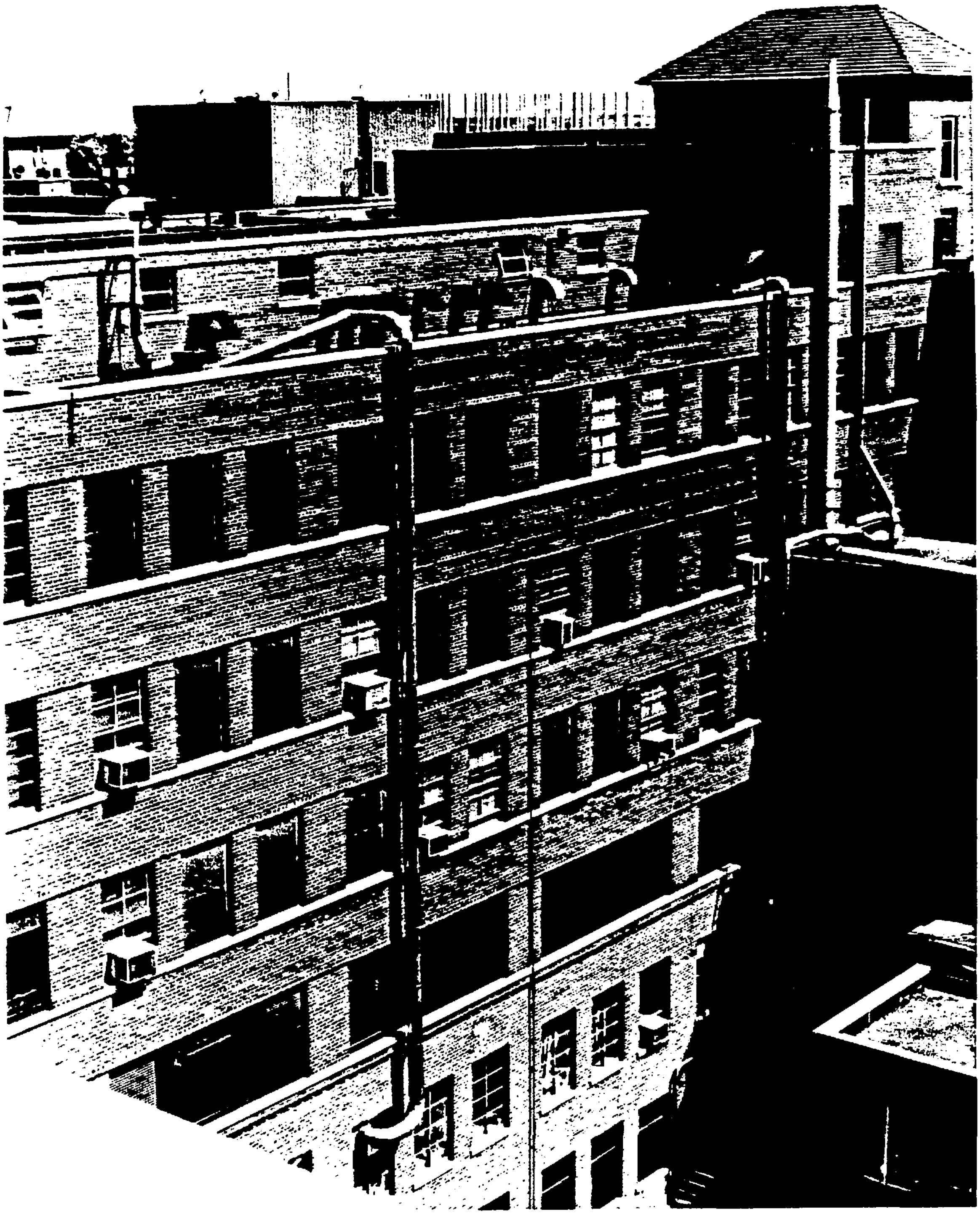

Figure 4 Effluent Release Points on Bldg. 55

Figure 5 Effluent Release Points on Bldg. 57

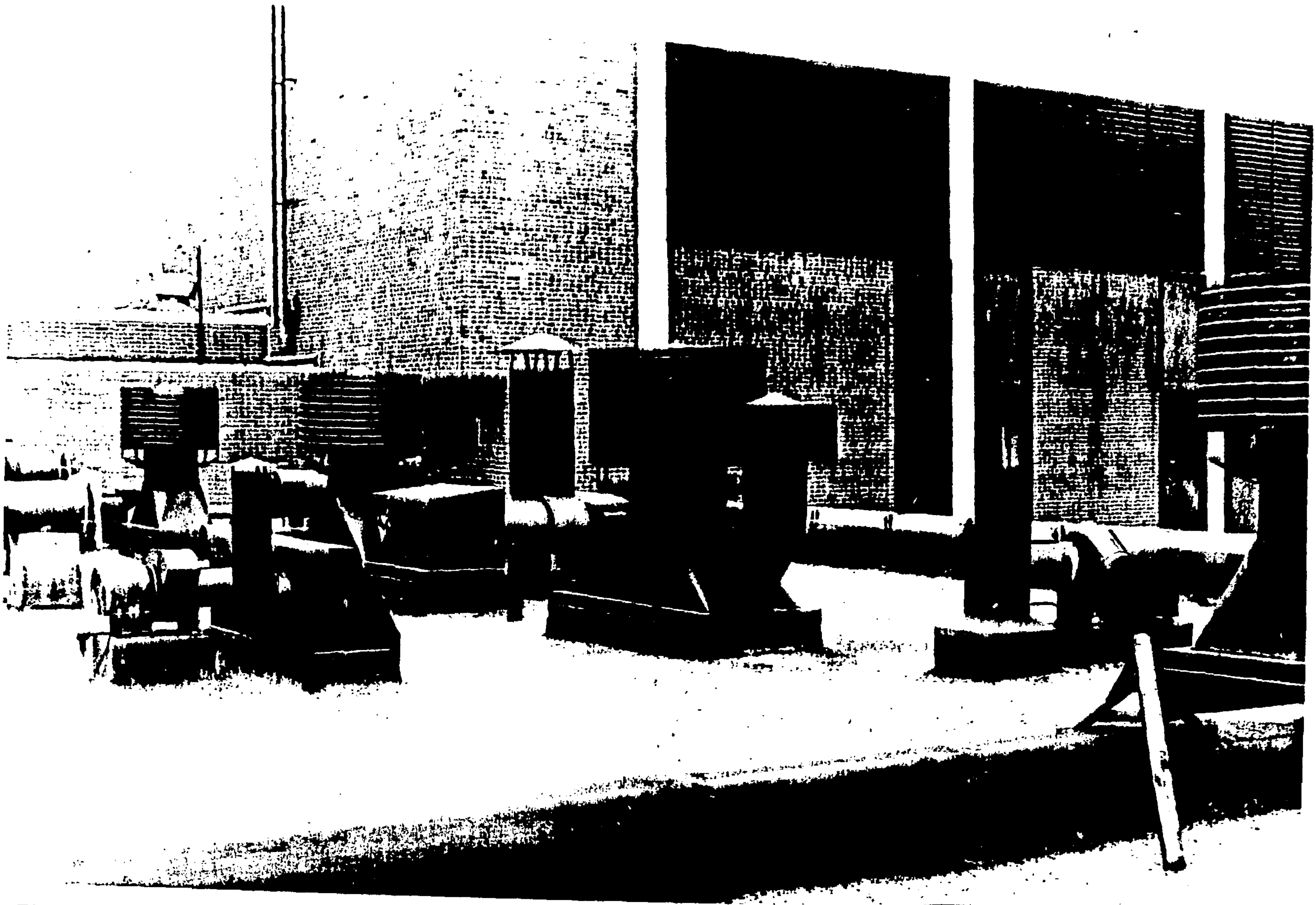

Figure 6 Effluent Release Points on Bldg. 64

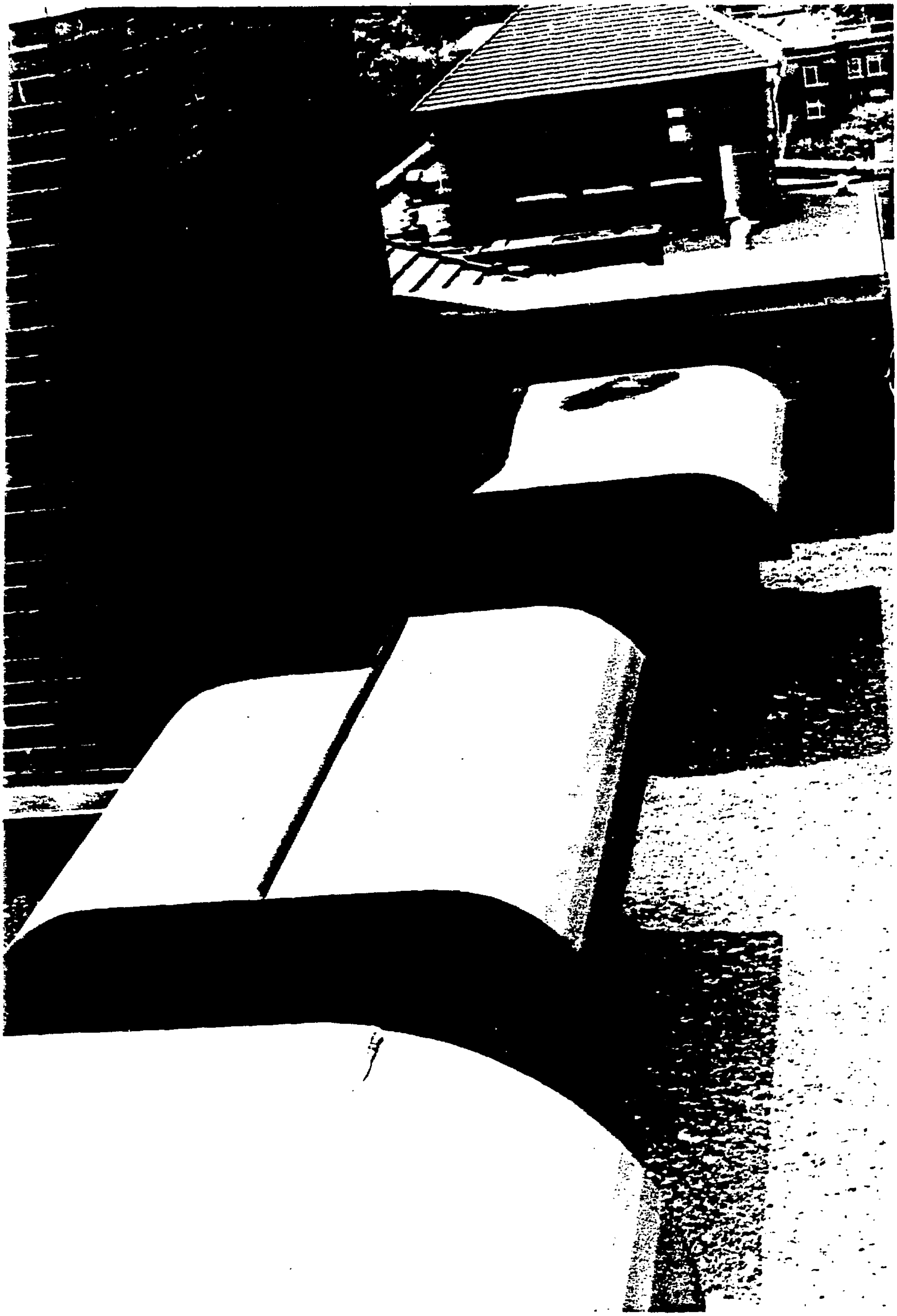

Figure 7 Effluent Release Points on Bldg. 65

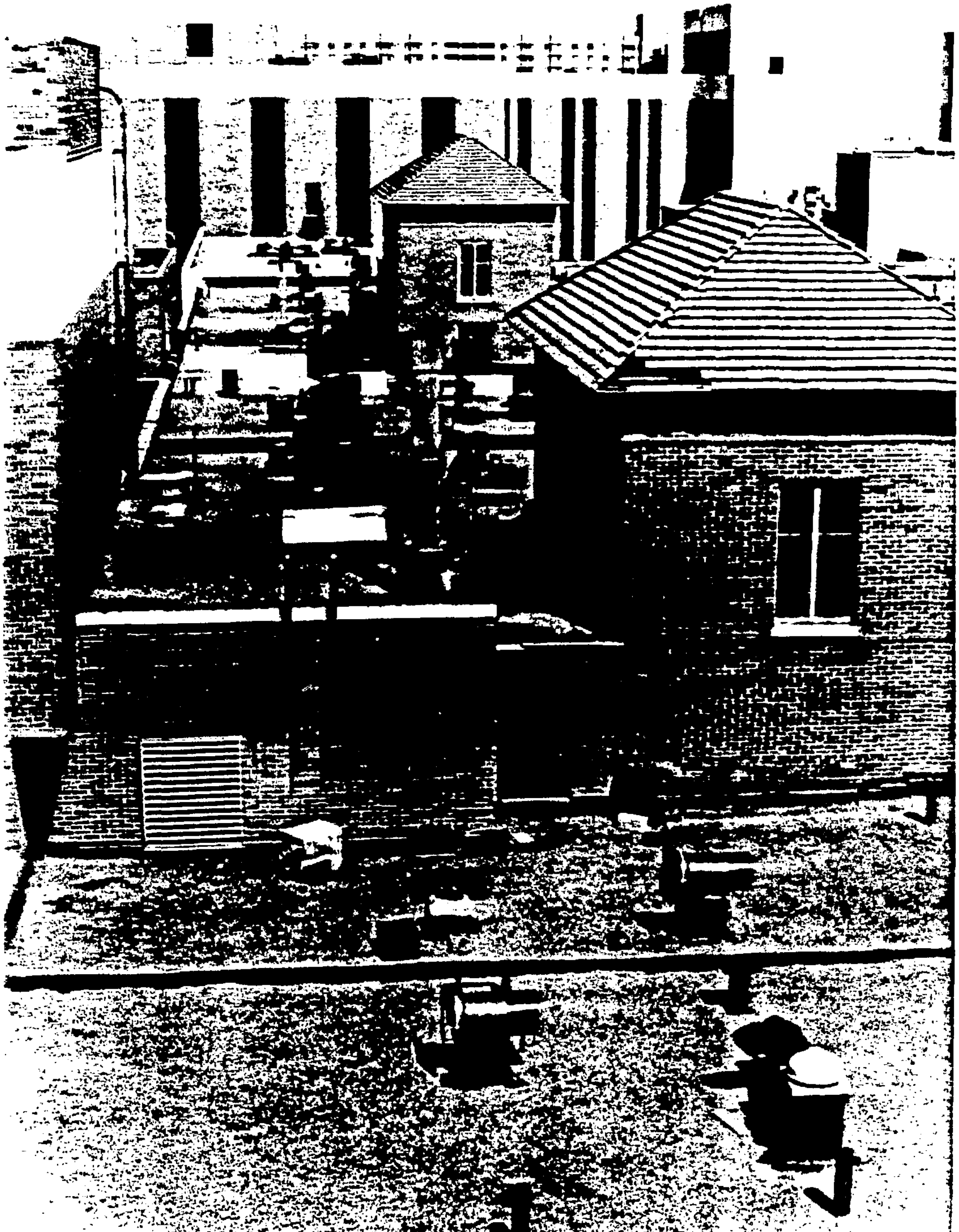

Figure 8 Effluent Release Points atop North Corridor

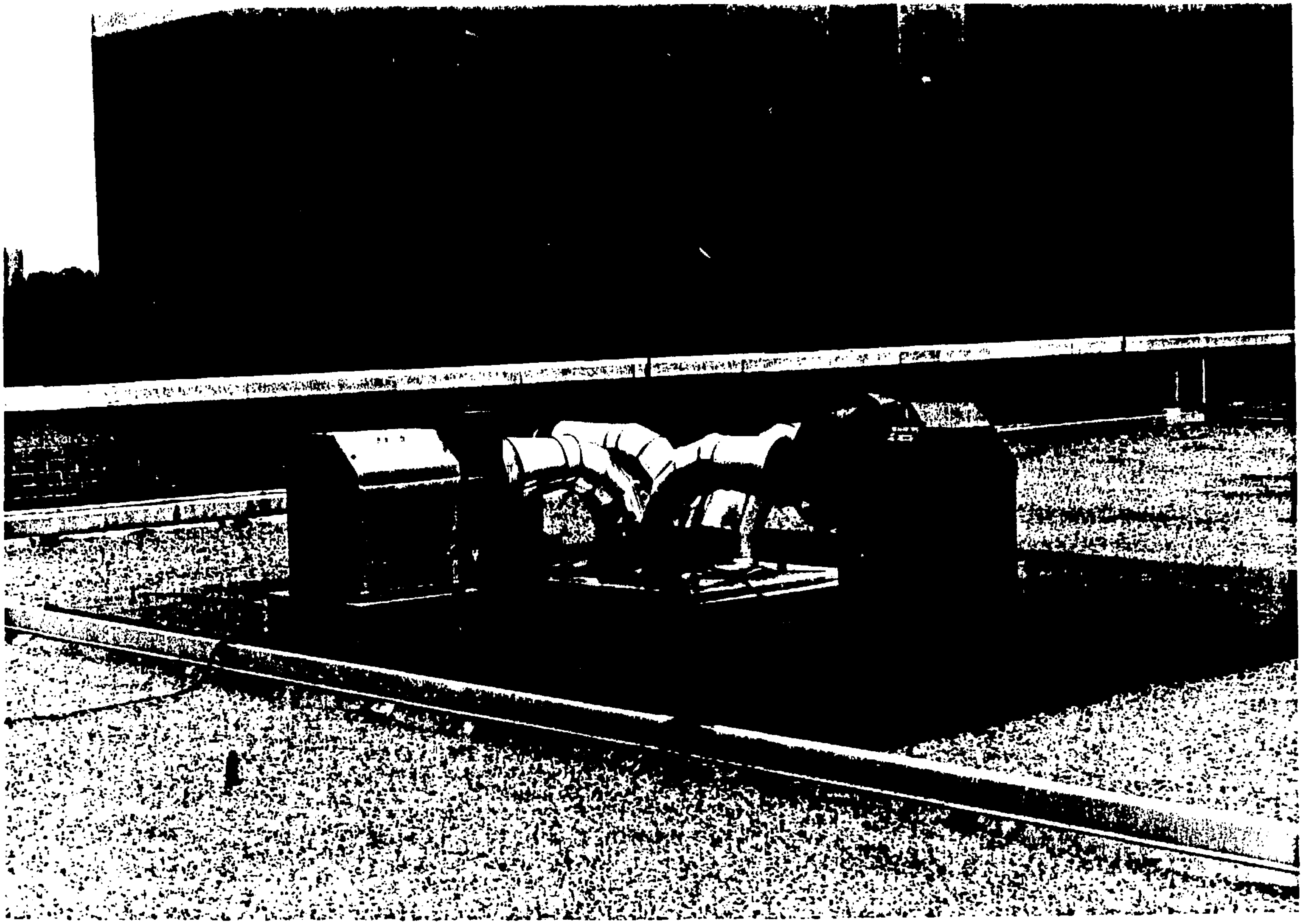

Figure 9 Effluent Release Point on Bldg. 44, Vent 4-4444

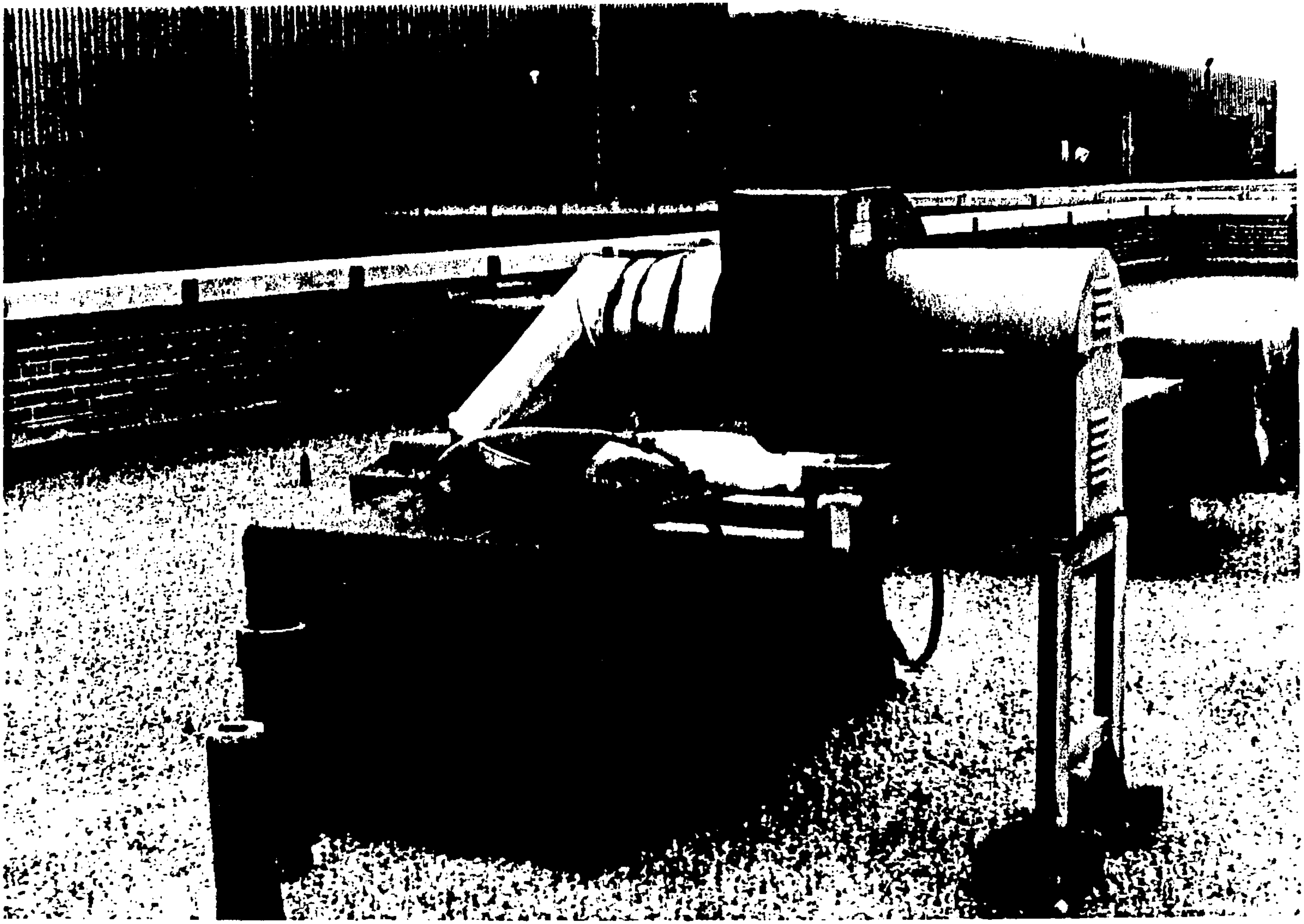

Figure 10 Effluent Release Point on Bldg. 43 - Hood 4332

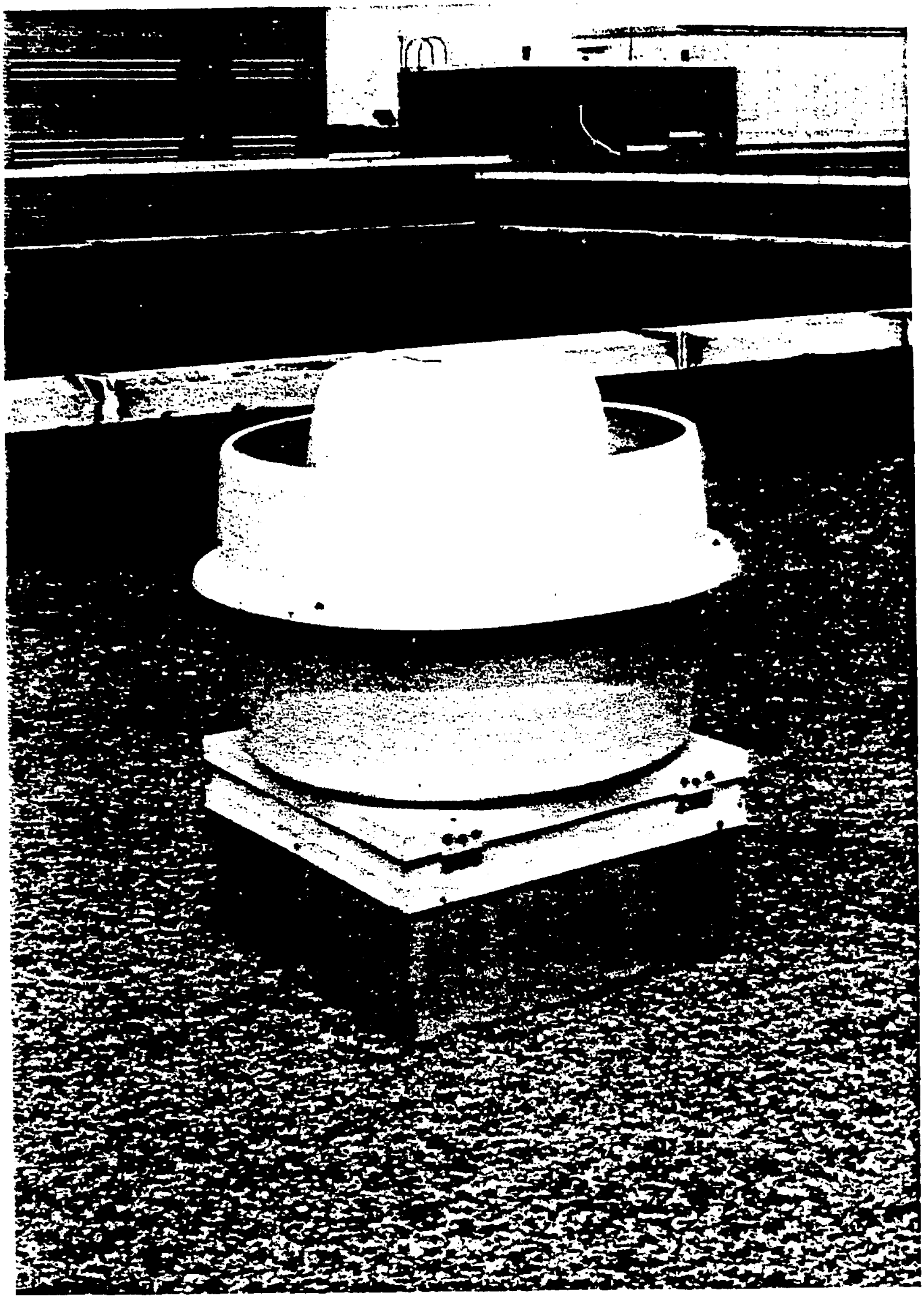

Figure 11 Effluent Release Point on Bldg. 61 - Hood 3- 6115

Figure 12 Effluent Release Points on Bldg. 72

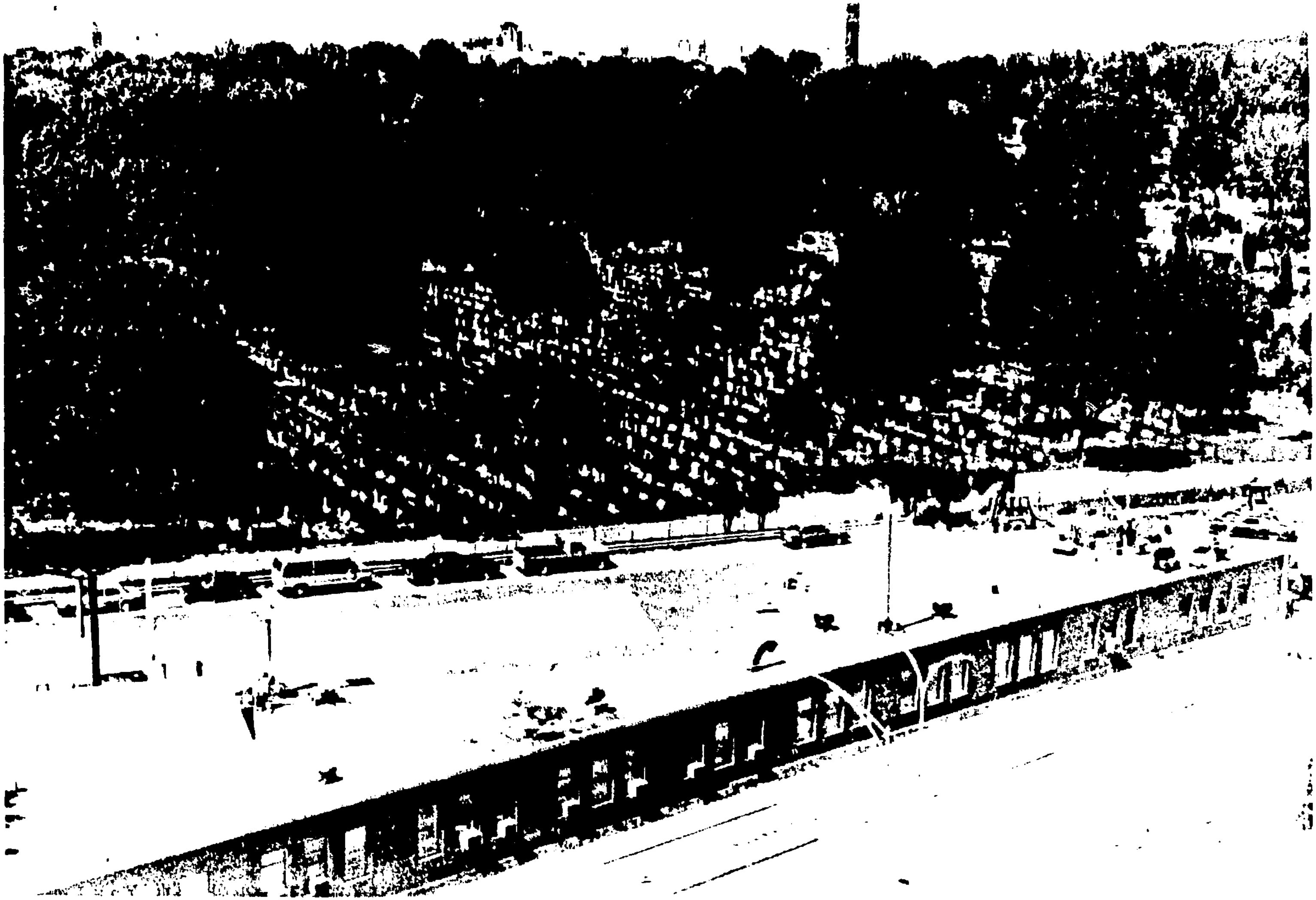

Figure 13 Effluent Release Points on Bldg. Ac/ Hood AC-23

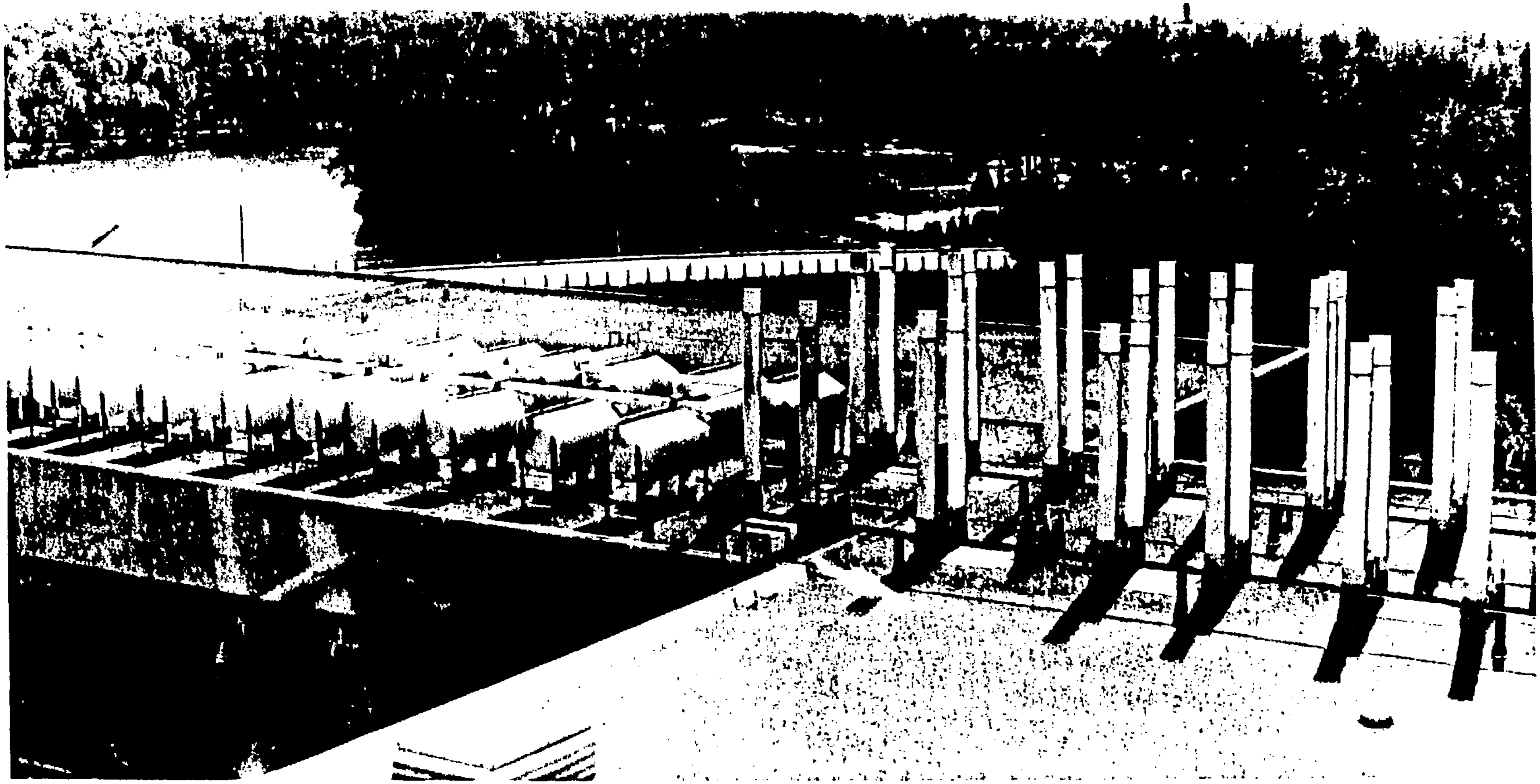

Figure 14 Effluent Release Points on Hutcheson Hall

Figure 15 Charcoal Filter Insert for Hood # AC-23

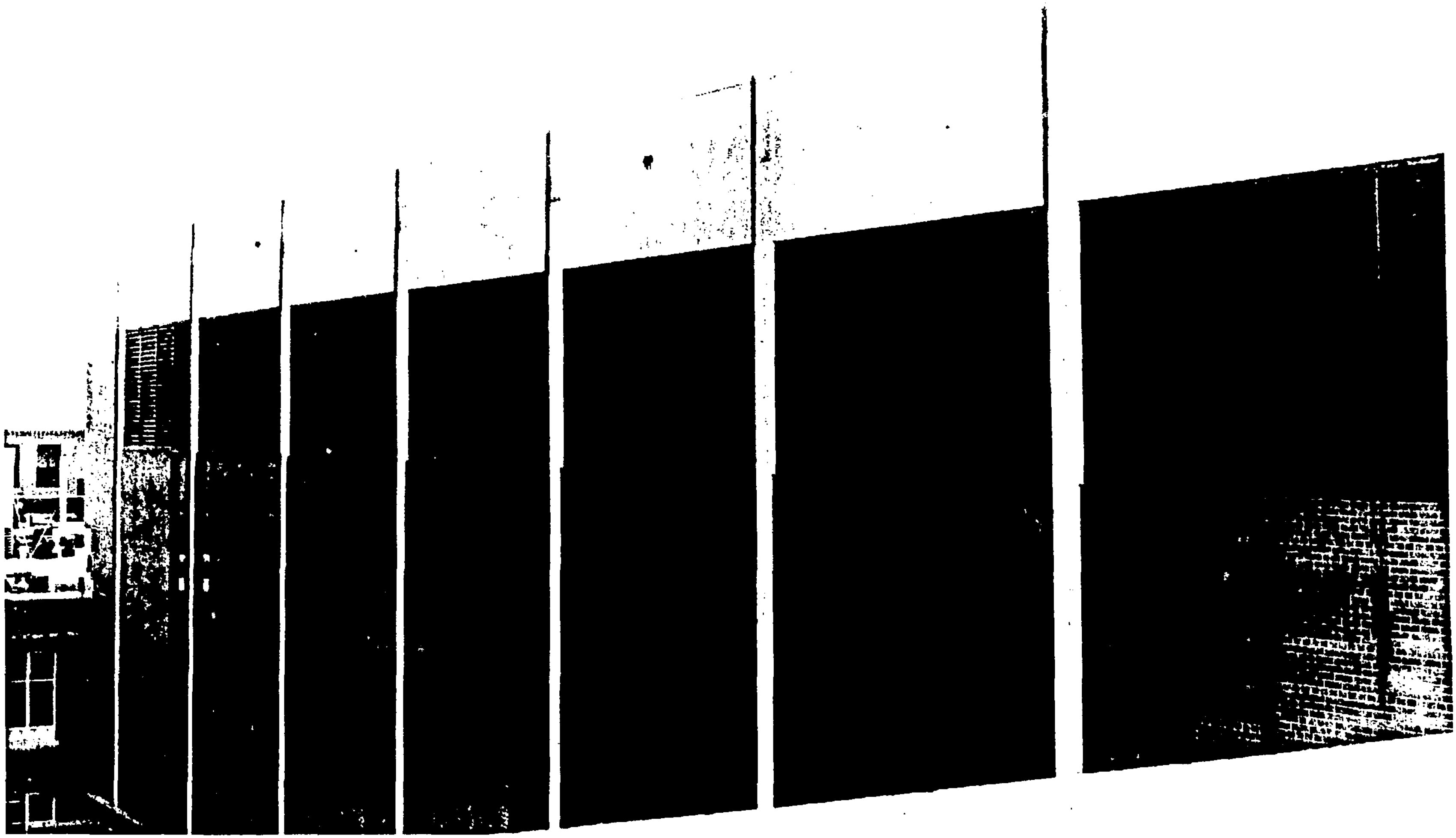

Figure 16 Air Intake for Hospital Buildings

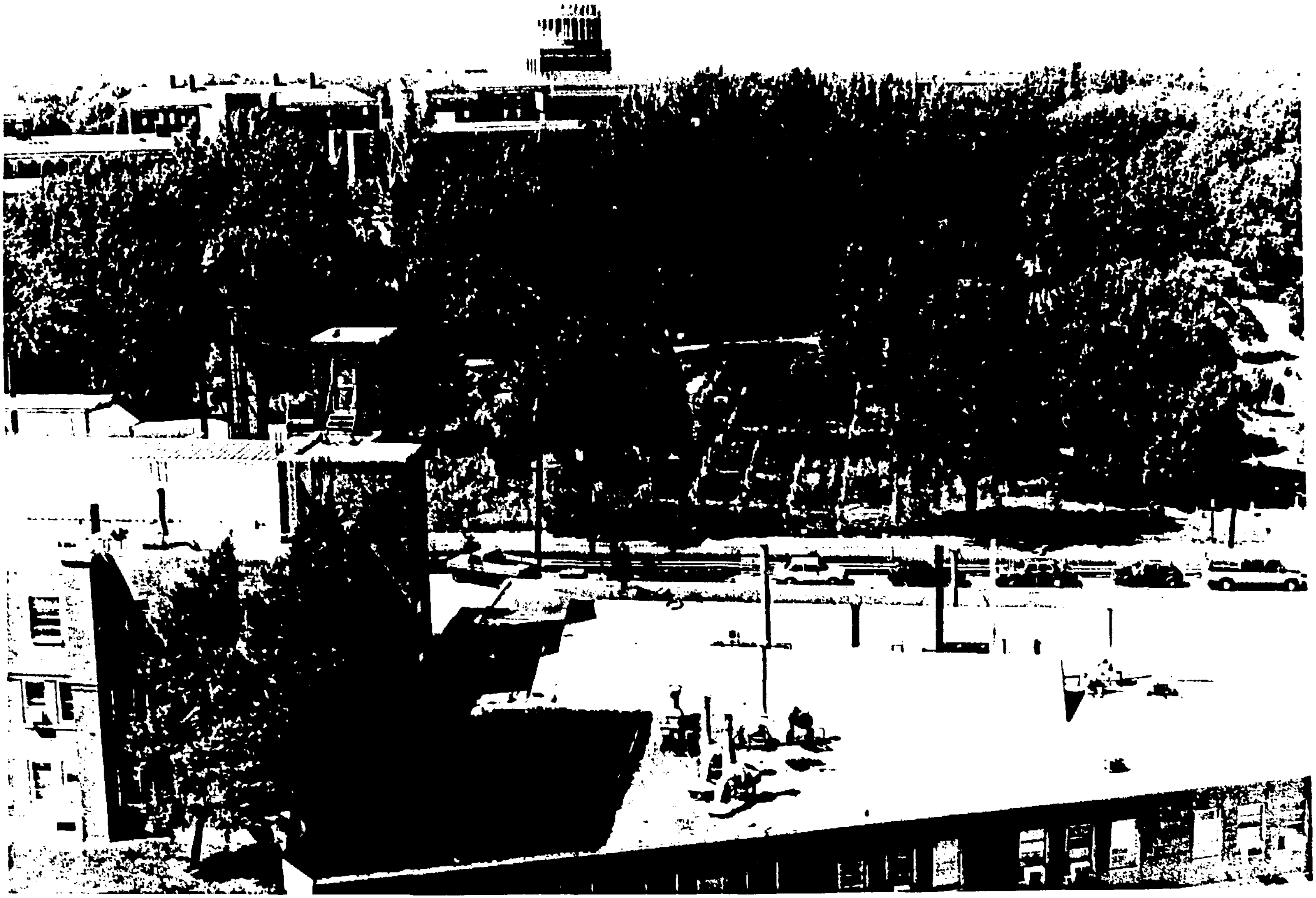

Figure 17 Predominant Downwind Land Use

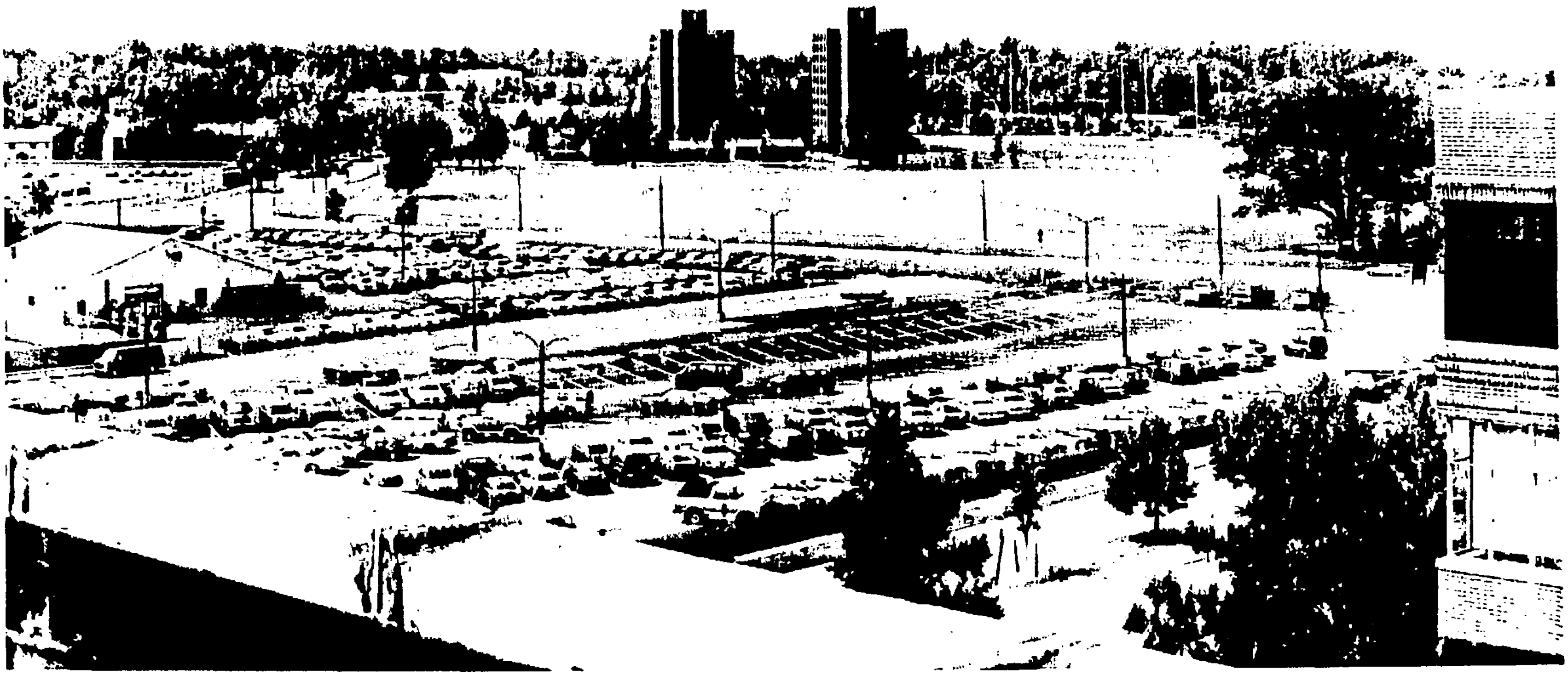

Figure 18 Graduate Student Residence Towers

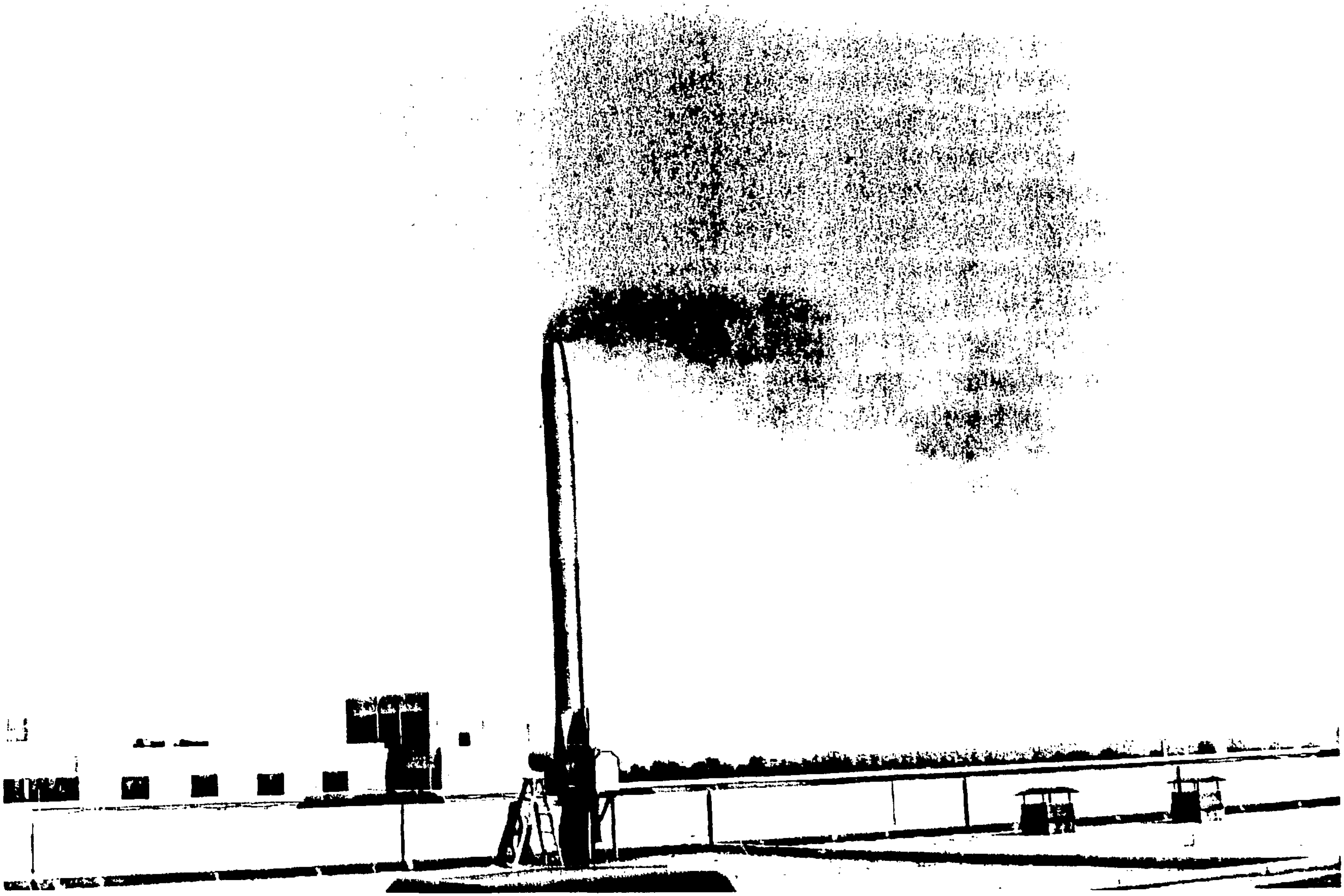

Figure 19 S-wing Animal Incinerator and Typical Atmospheric Dispersion

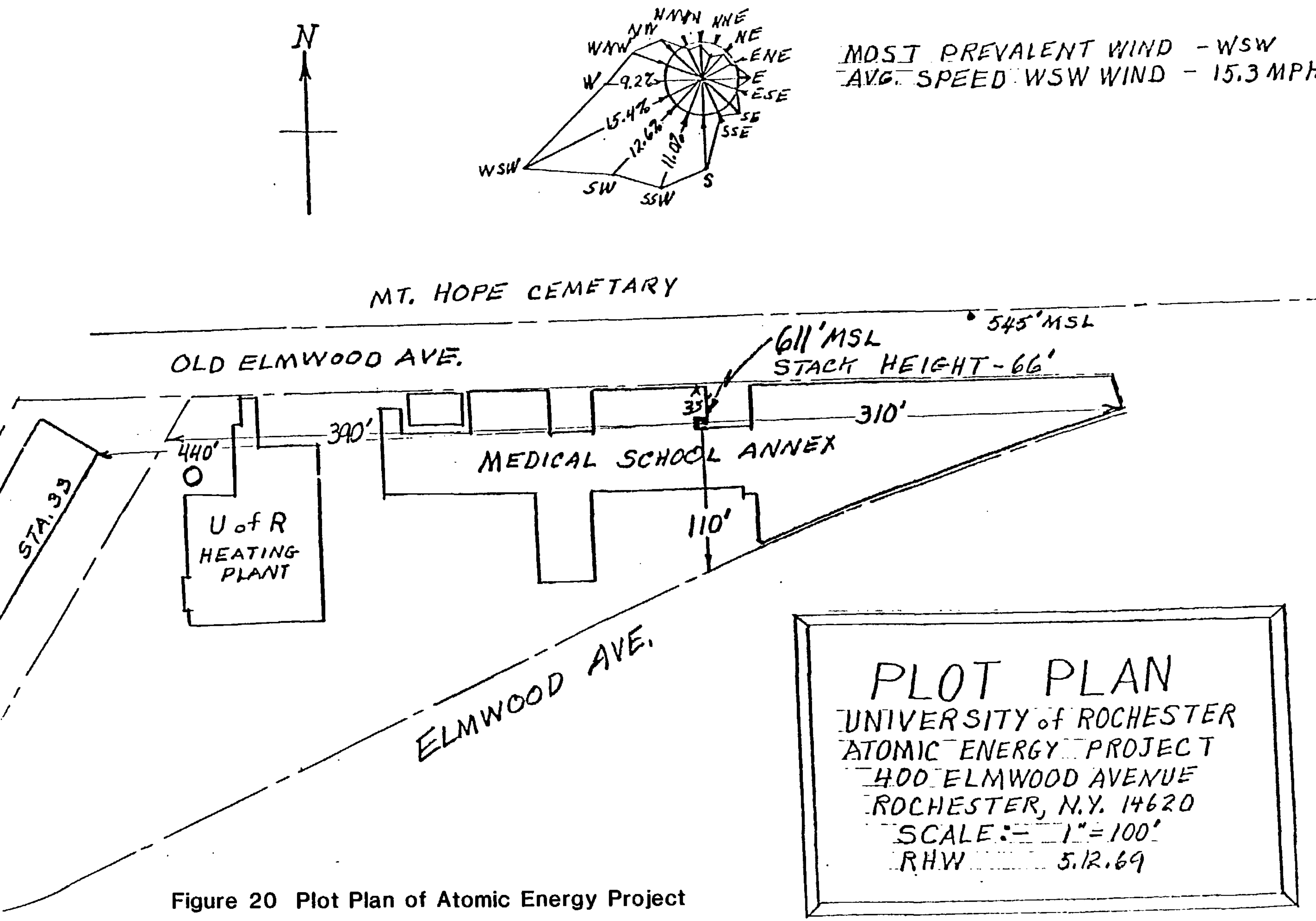

Figure 20 Plot Plan of Atomic Energy Project

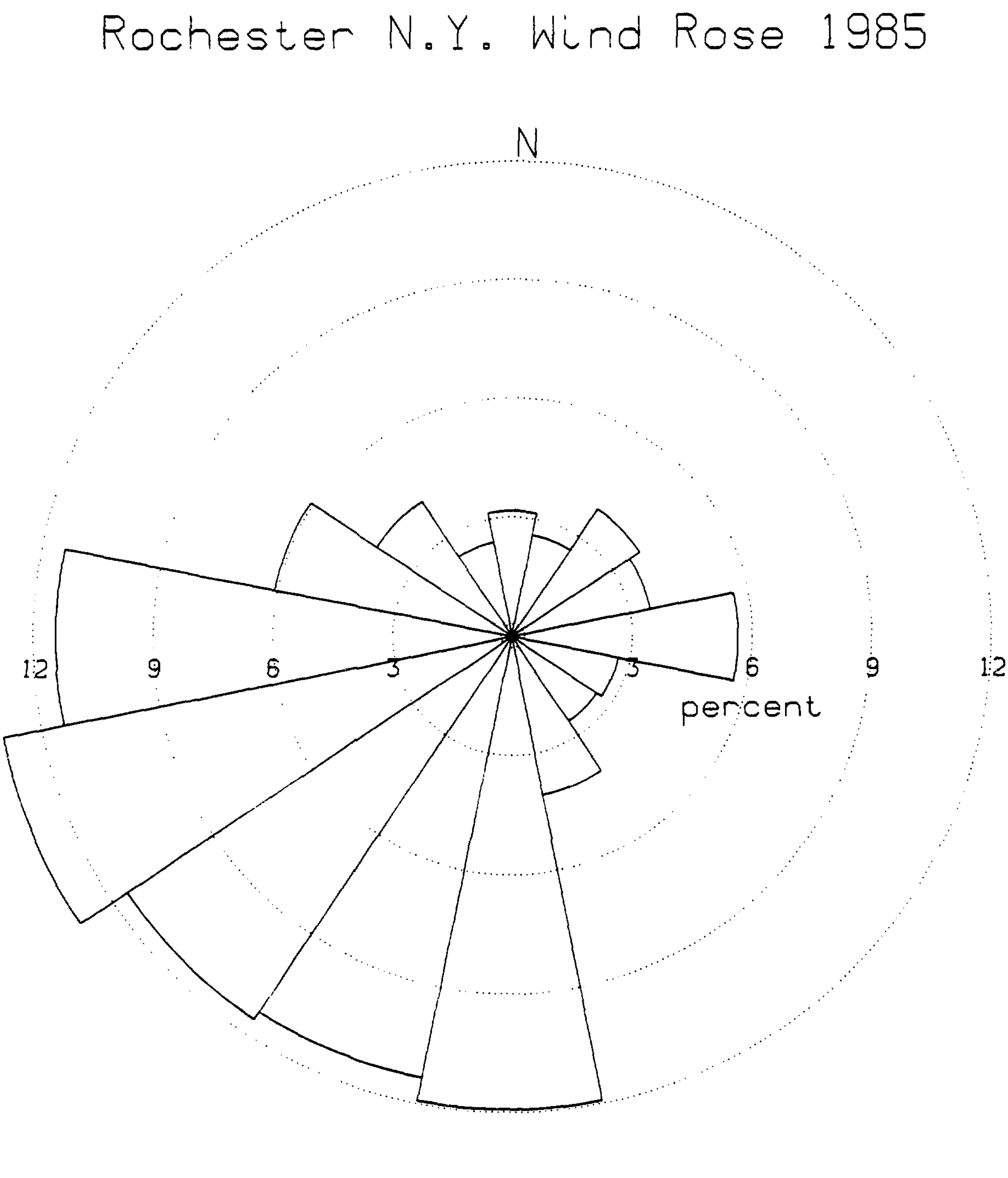

Figure 21 1985 Wind Rose for University of Rochester