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SITE

2.1 SUMMARY AND CONCLUSIONS

The characteristics of the site and the site surroundings have been investigated to establish bases for storm, flood and earthquake protection criteria and to evaluate the requirements for control of routine and accidental releases of radioactive liquids and gases to the environment. Field programs to investigate geology, hydrology and seismology were performed and meteorological observations on-site began in August 1968. A radiological environmental study to establish the normal radiation background for the area began in September 1969.

The site is in east central Wisconsin on the west shore of Lake Michigan about 30 miles ESE of Green Bay and about 90 miles NNE of Milwaukee. The plant is situated in a productive dairy farming and vegetable canning region. Since these products are for human consumption, the environmental monitoring program includes milk and food crop samples, as well as air and lake environment samples.

The region around the site is sparsely populated, and it is industrialized to the south in Two Rivers and Manitowoc and to the west in the Fox River Valley, with the low population zone extending out to 2 miles.

The site is well ventilated and is not subject to severe persistent inversions. While tornadoes occur in the region, none have been reported that affected the lakeshore site directly. High winds (about 90 mph) from storms can be expected once in one hundred years.

Lake Michigan is the source of plant service and cooling water. Low-level liquid wastes are discharged after treatment to the lake through the condenser circulating water discharge under carefully controlled and monitored conditions. The maximum concentration at the circulating water outlet is below the permissible limits of 10 CFR 20. Additional dilution of any releases from the site occurs before the water reaches the nearest current public water supply drawn from Lake Michigan, which is 11.5 miles away.

The possibility of accidentally contaminating off-site well water supplies is remote due to the relatively impervious nature of the soils and the slope of the ground water table to the lake. Surface waters on the site flow directly to Lake Michigan either through the storm sewer system or via three small creeks, which drain the site. The plant potable water supply is sampled periodically as a check for radioactivity.

Soil and subsurface layers have a high clay content, which inhibits percolation and drainage to Lake Michigan. Flooding due to rainfall and snowmelt has been investigated and is not a problem at the site. Site grade is such that changing water levels in Lake Michigan will not flood the site.

Upper glacial till or underlying lake deposits on the site appear to provide a suitable foundation for plant structures. The site is free of any known seismic disturbances. A horizontal ground acceleration at the site of 0.06 of gravity combined with a vertical acceleration of 0.04 of gravity was used for the earthquake design criteria based on a report by Dames and Moore, the consultants retained to perform the site geological, seismological and groundwater hydrological investigations (see Appendix A).

A recognized authoritative consultant performed analysis of all environmental data.

2.2 LOCATION

The site is in the Town[1] of Carlton in the southeast corner of Kewaunee County, Wisconsin, on the west shore of Lake Michigan. The city of Green Bay is about 27 miles WNW of the site. Milwaukee is about 90 miles to the SSW. It is located at longitude 87° 32.1'W and latitude 44° 20.6'N, and is shown in Figure 2.2-1. The closest distance to the international boundary between Canada and the United States is approximately 200 miles northeast of the site.

The site as shown on Figure 2.2-2 is all owned by DEK except for the highways and one cemetery site (1.13 acres) located on the highway north of the plant. Total acreage owned as plant site is 907.57 acres.

The cemetery site is owned by and will remain in the ownership of the Town of Carlton with perpetual care provided by the Town. There are no dwellings or public buildings on the cemetery site.

1. Wisconsin townships are referred to as Town of....

Figure 2.2-1 General Location Map

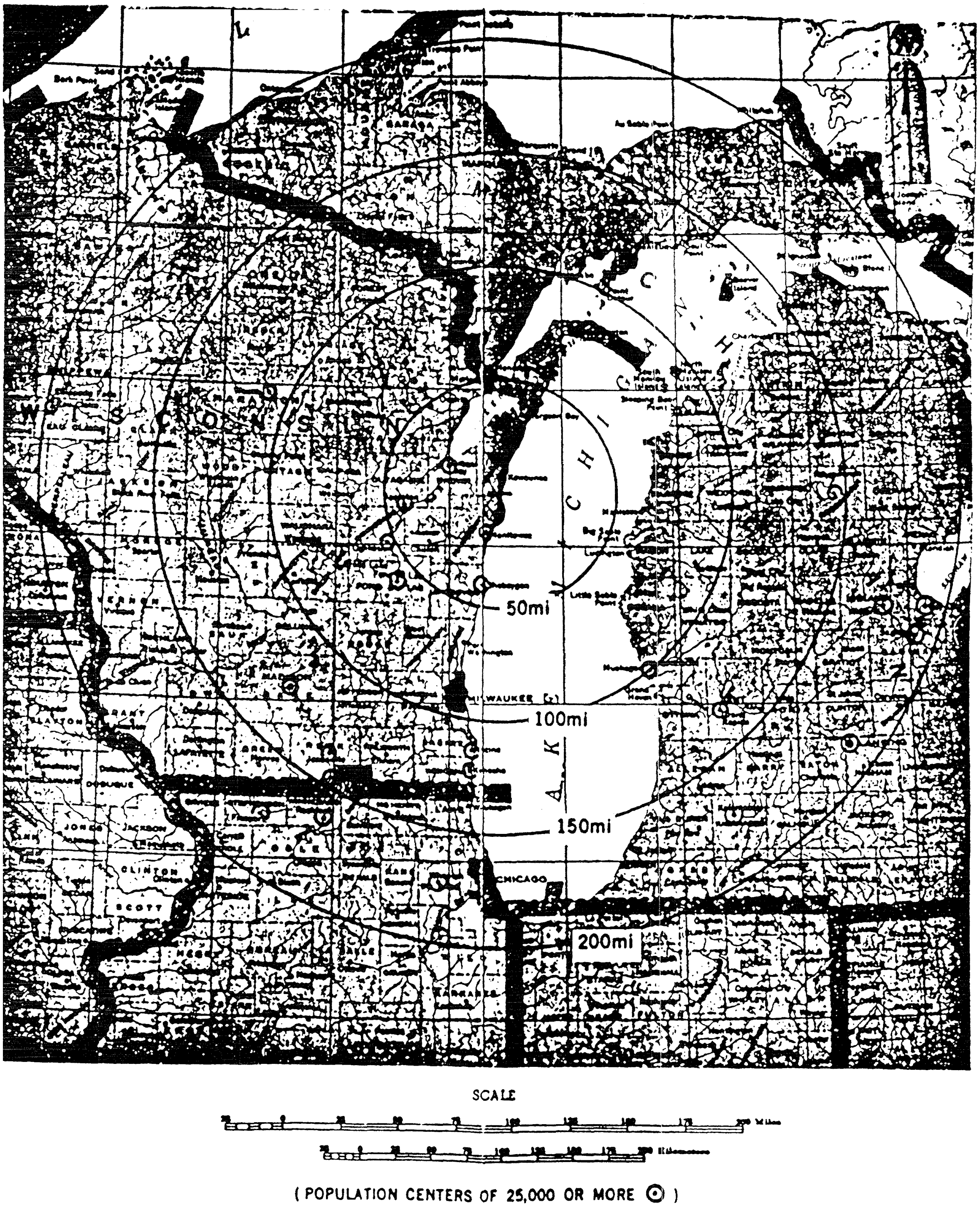
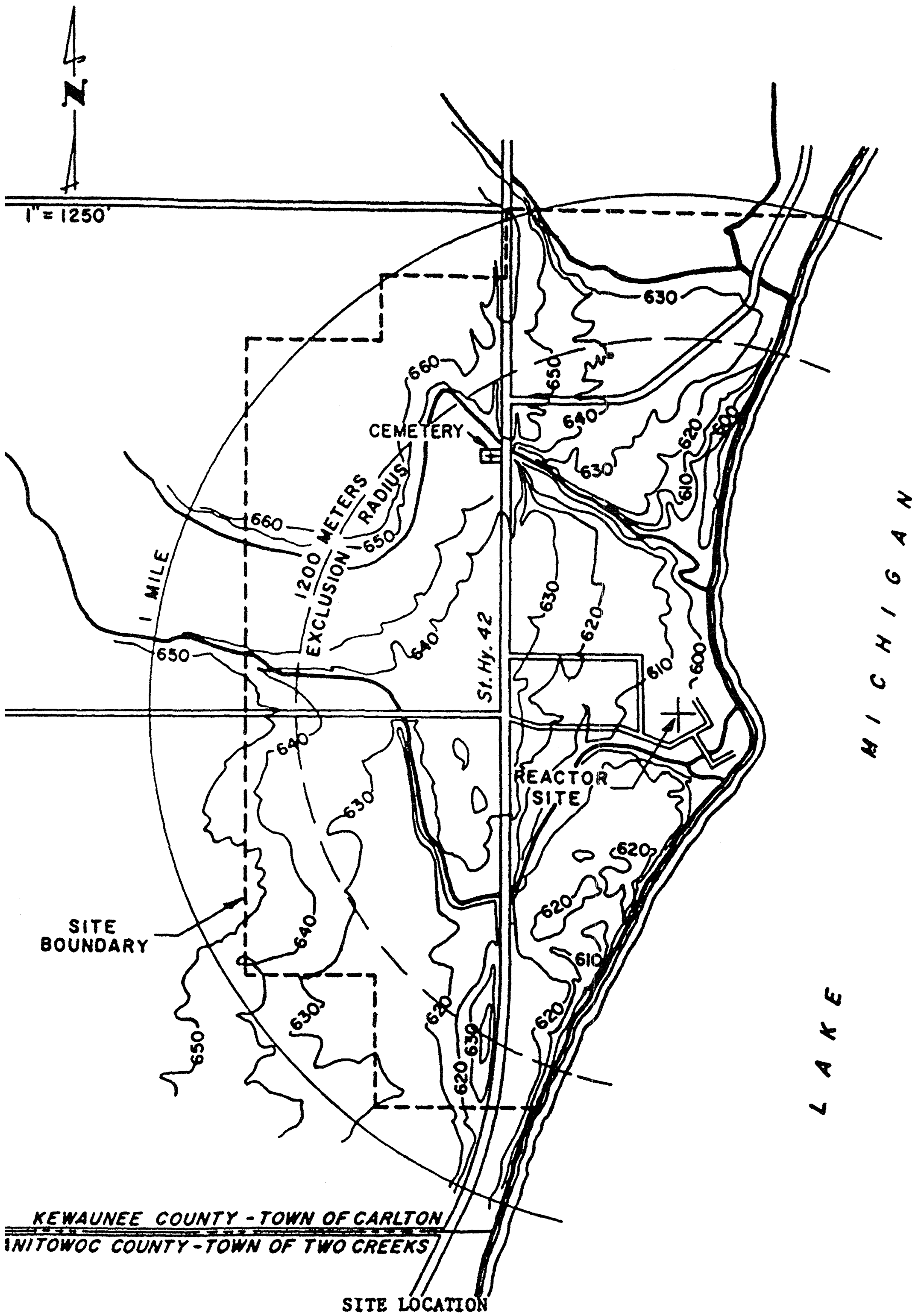


Figure 2.2-2 Site Location



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2.3 TOPOGRAPHY

Figure 2.3-1 shows the general topography of the region within a 50-mile radius of the site. Figure 2.3-2 is an aerial photograph showing the site boundaries and details of the site.

Overall ground surface at the site is gently rolling to flat, with elevations varying from 10 to 100 feet above the level of Lake Michigan (577 feet, based on the International Great Lakes Datum, IGLD, 1955). The land surface slopes gradually toward the lake from the higher glacial moraine areas west of the site.

The major surface drainage features are three creeks, which pass through the site. One creek discharges into the lake about l000 feet south of the center of the site. A second creek discharges about 600 feet north of the center of the site. The third creek discharges into the lake approximately 100 feet from the northern boundary of the site. Natural site drainage is poor due to the high clay content of the soil combined with the pockmarked surface.

At the northern and southern edges of the site, bluffs face the Lake Michigan shore; near the center of the site, the land slopes to a sandy beach.

Figure 2.3-1
General Topography

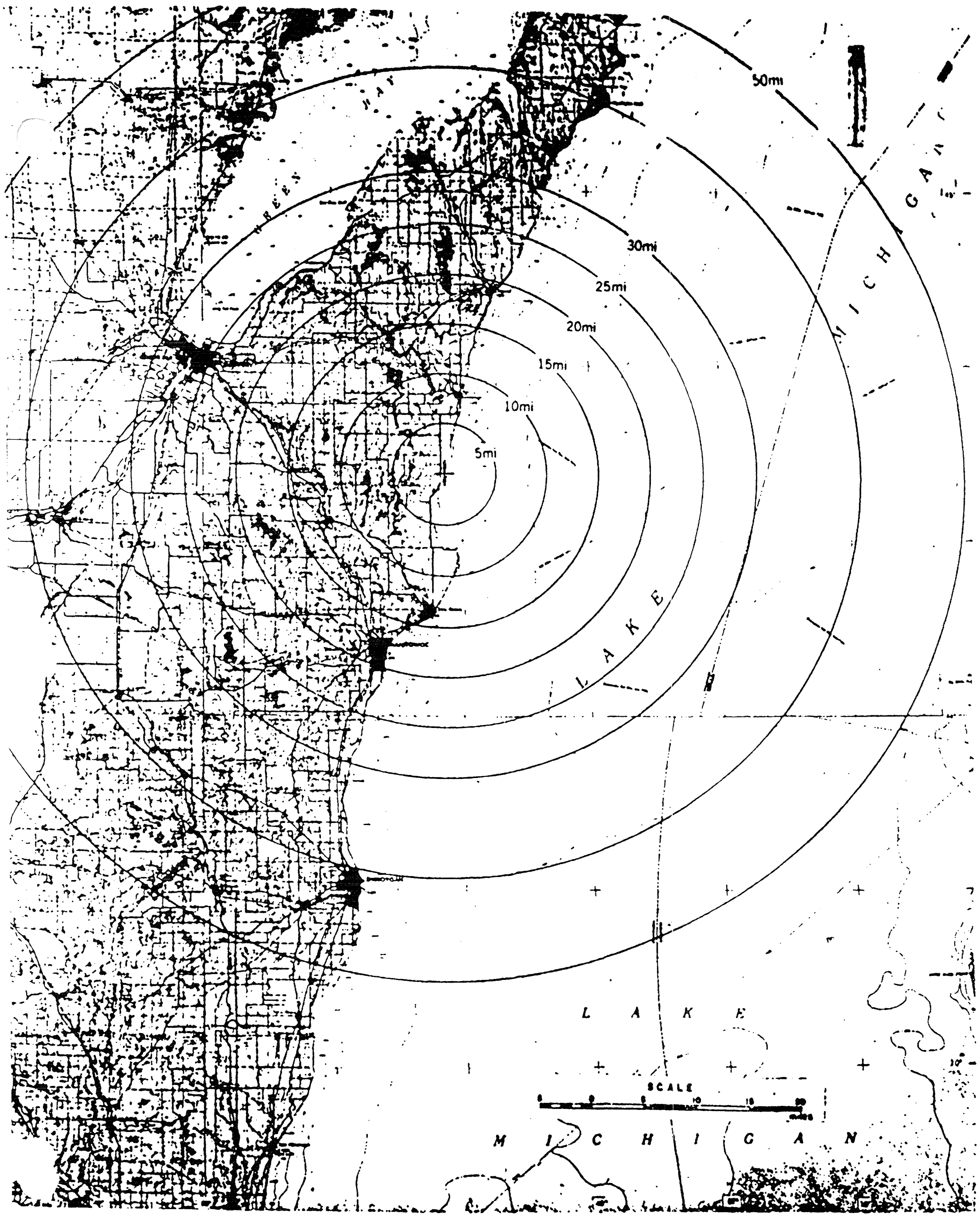
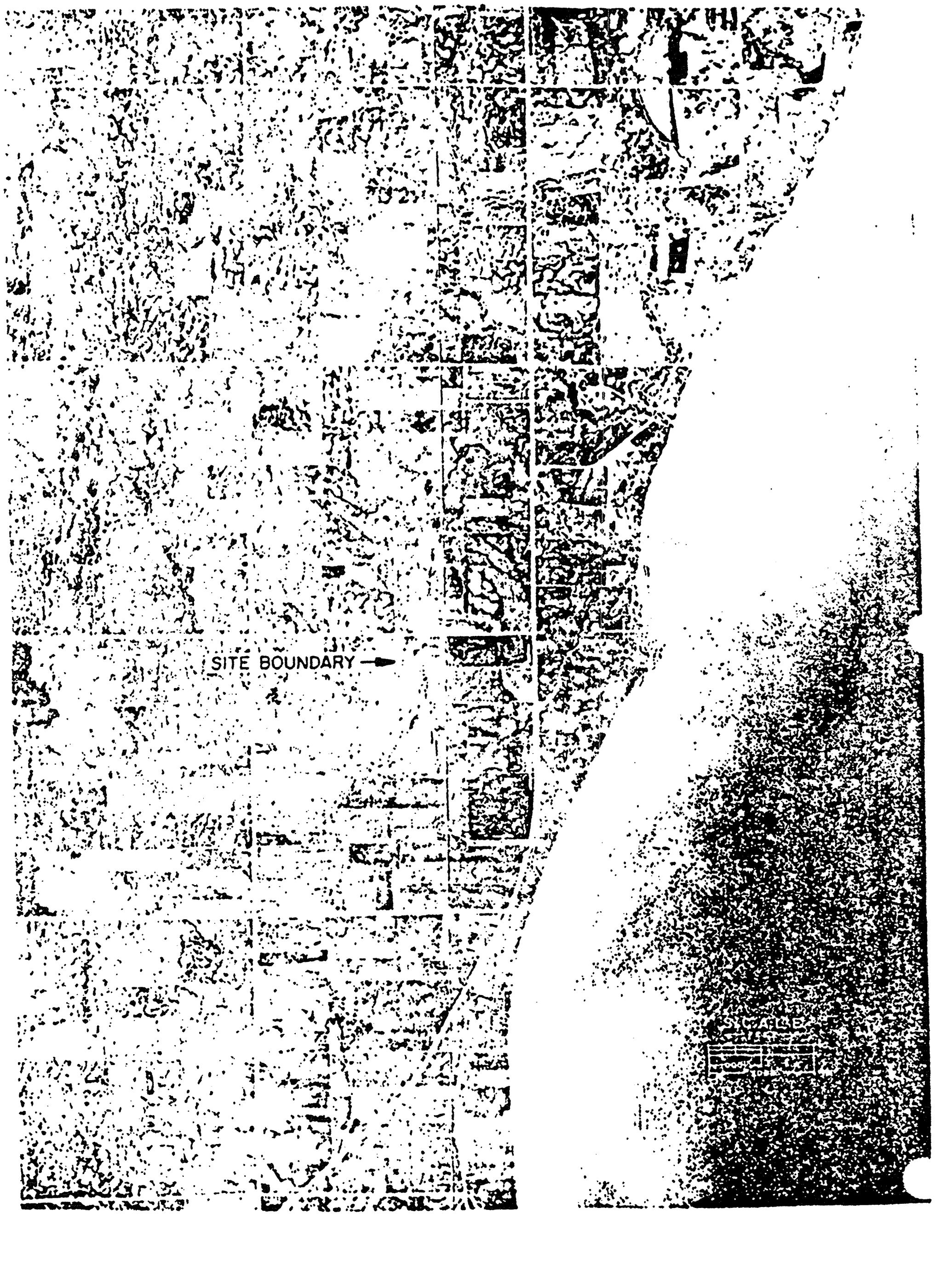


Figure 2.3-2
Aerial Photograph of Site



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2.4 POPULATION

Refer to the KPS Emergency Plan and the Radiological Environmental Monitoring Manual (REMM) for current population information.

Figure 2.2-1 shows population centers of over 25,000 people within a 200-mile radius of the site. The nearest population centers of 25,000 or more (according to the 1980 Census) are Manitowoc (17-1/2 miles SSW of the site) with 32,547; Green Bay (27 miles WNW of the site) with 87,899; Appleton (43 miles west of the site) with 59,032; and Sheboygan (42 miles SSW of the site) with 48,085. There are no other population centers greater than 25,000 people that lie within 50 miles of the site. Two Rivers (13 miles south of the site), with a 1980 population of 13,354, is projected to grow to 21,700 by 2010. Therefore, for the purposes of this report the low population distance is 2 miles. Milwaukee, with a 1980 population of 636,210, lies 90 miles SSW of the site.

Figure 2.4-1 shows the 1970 and projected (2010) population distribution in 10 of 16 directional sectors centered on the site within 1, 2, 3, 4 and 5 mile radii. Figure 2.4-2 shows similar information for 5, 10, 20, 30, 40 and 50 miles.

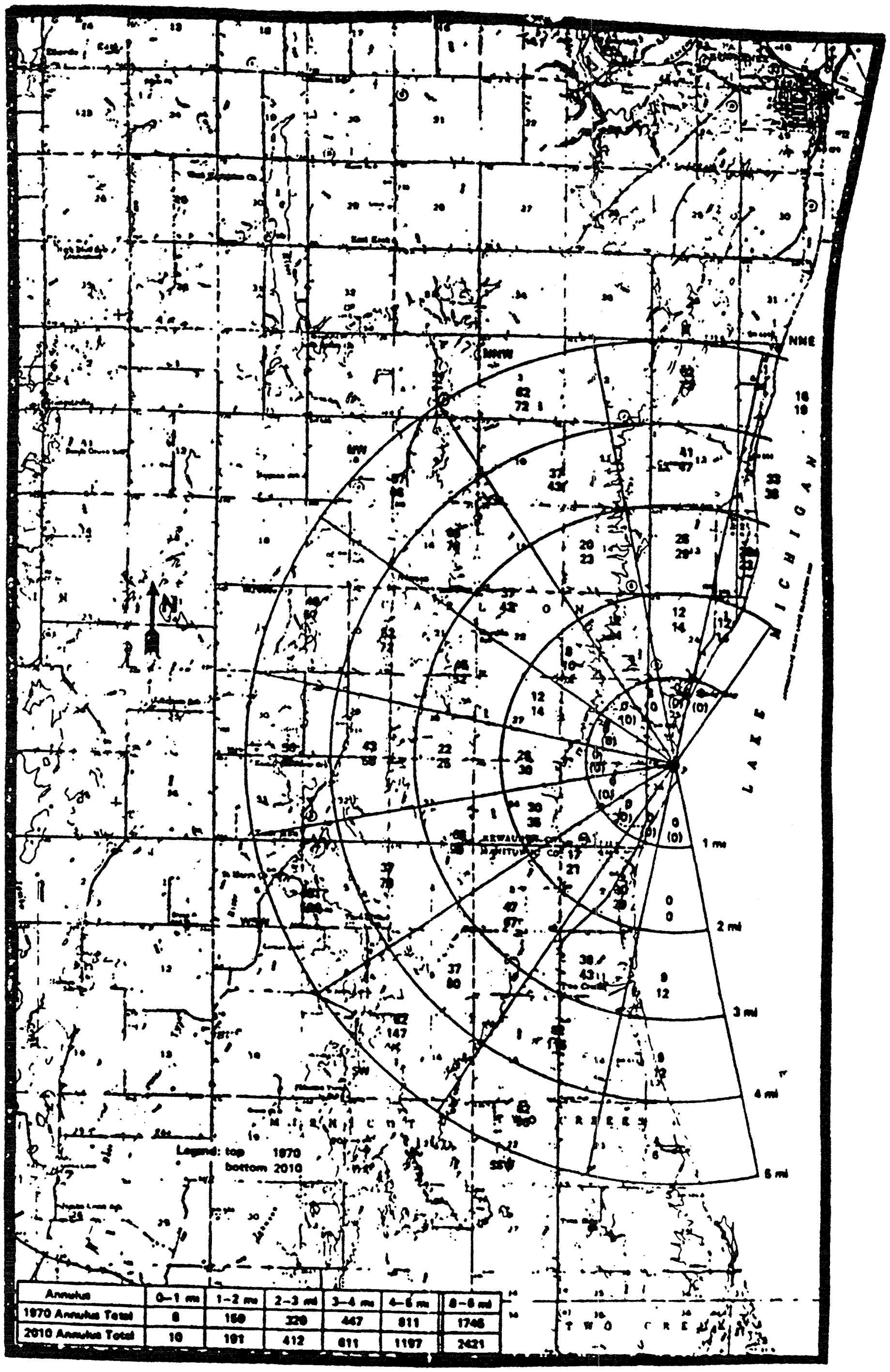
The population estimates within 5-mile radius of the site (Figure 2.4-1) were based on a house count taken from aerial photographs and multiplying by a residence factor. The population shown within the 0-1 mile radius is the anticipated population that will live outside the site boundary but within one mile of the reactor when the plant becomes operational. The nearest offsite residence is at least 1300 meters (0.8 mile) from the reactor.

Population projections to the year 2010 were made for each census tract of each county on the basis of its individual growth rate during the last decade. A geometric projection of this nature will yield higher results if smaller units (townships, cities) are considered individually rather than in-groups (whole counties). Only growth rates during the period between 1970 and 1980 were used because it is felt this period provides the best indication of future trends. Growth rates prior to this decade would not reflect the significantly reduced birth rate or significantly increased non-metropolitan growth rate being experienced by the country as a whole since 1960. Differences between this survey and the earlier one include the removal of Sheboygan City from within the 40-mile radius, use of different growth rates based on new data, and the implementation of the slightly more conservative method of projection.

Seasonal population variations due to summertime cottage occupants in the vicinity of the site is minimal. At the present time these cottages are limited to the SSE and north sectors along the lakeshore. There are currently less than 12 part-time residences within 5 miles NNE of the site and one cottage within 5 miles south of the site. Projection of these summertime residents to 2010 is difficult. One estimate would increase the number by 100% to a total of 104 people. Additionally, in Point Beach State Forest, 140 campsites are located 8 to 11 miles south of the site. Therefore, their presence at the shore is more representative of a shift in location within the area covered than it is of a net increase in population.

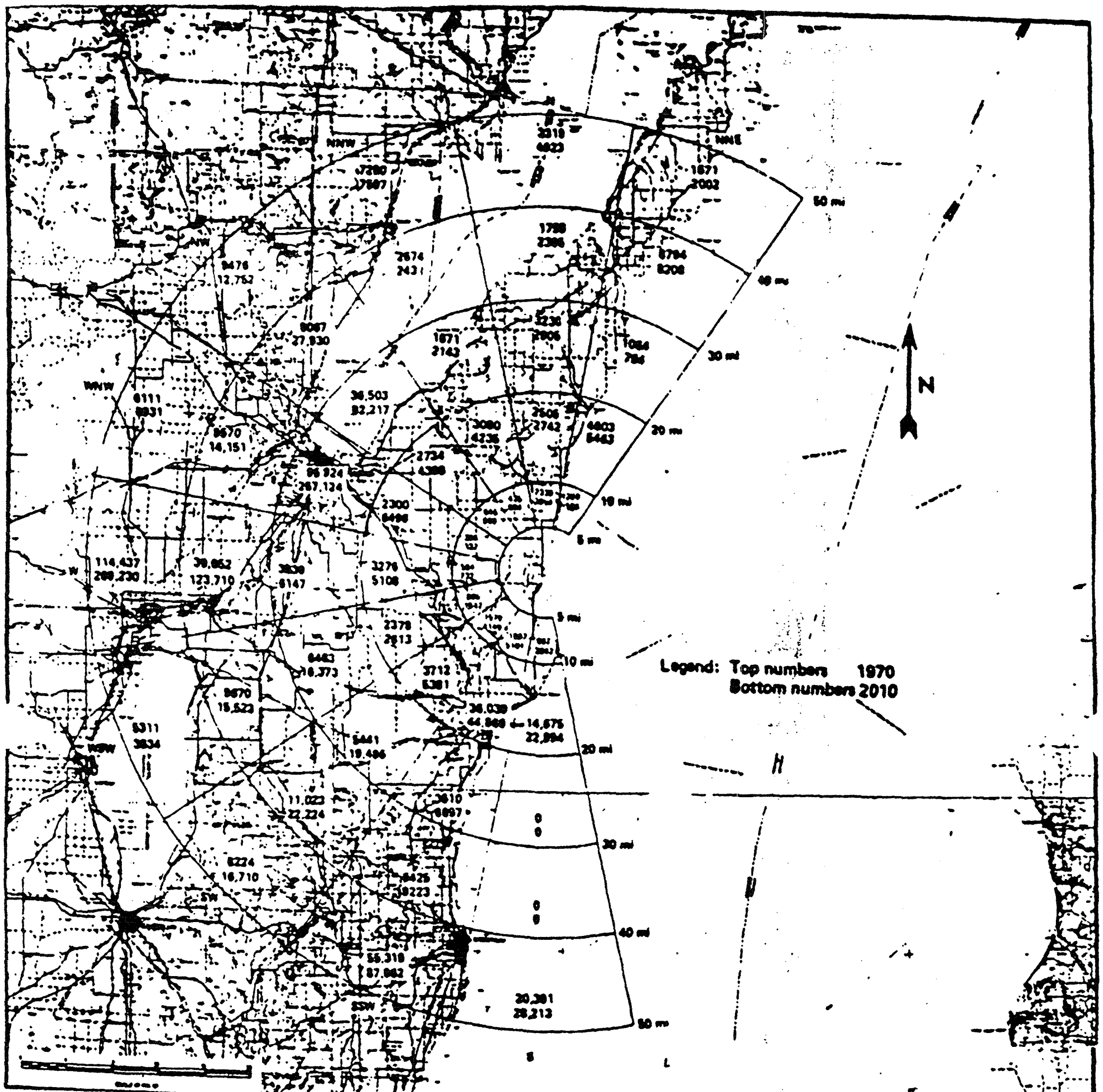
A review of the 1980 census shows there is no significant departure from the projected population figures within the 5-mile radius of the plant.

Figure 2.4-1 Kewaunee Nuclear Power Plant
Population Distribution, 0-5 Miles, 1970 and 2010



Annulus	0–1 mi	1–2 mi	2–3 mi	3–4 mi	4–5 mi	0–5 mi
1970 Annulus Total	8	150	320	467	811	1746
2010 Annulus Total	10	191	412	611	1197	2421

Figure 2.4-2 Kewaunee Nuclear Power Plant
Population Distribution, 5-50 Miles, 1970 and 2010



Annulus	5-10 mi	10-20 mi	20-30 mi	30-40 mi	40-50 mi	5-50 mi
1970 Annulus Total	11,014	75,302	157,745	98,633	231,539	574,233
2010 Annulus Total	21,140	104,191	405,886	225,795	441,854	1,198,866

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2.5 LAND USE

Refer to the KPS REMM for current land use survey information.

2.5.1 Regional Land Use

Kewaunee County, where the site is located and the adjacent counties of Manitowoc, Brown, Calumet and Sheboygan are predominantly rural. Agriculture accounts for approximately 90 percent of the total county acreage with individual farms ranging in average size from 110 to 124 acres. Dairy products and livestock account for approximately 85 percent of the counties' farm production with field crops and vegetables accounting for most of the remainder. The principal crops are grain, corn, silage corn, oats, barley, hay, potatoes, green peas, lima beans, snap beans, beets, cabbage, sweet corn, cucumbers and cranberries. Within a 20-mile radius of the site there are 11 dairy plants in Manitowoc County and 4 dairy plants in Kewaunee County. The Point Beach Nuclear Plant site is located approximately 4.5 miles south of the site.

At the time of plant licensing there were five hospitals located within 20 miles of the plant. In 1997 there were three hospitals: one at Kewaunee (currently closed), 8 miles north; one at Two Rivers, 13 miles south; and one at Manitowoc, 17½ miles south. The only airport within 20 miles of the Kewaunee site is the Manitowoc Airport located approximately 20 miles south. A suitable site approximately 9 to 19 miles northwest of the site for a future airport between Kewaunee and Algoma was once under consideration.

Representative industries in a 20-mile radius of the site have been examined, and aside from the dairy plants noted above, there are no sensitive industries in the vicinity.

2.5.2 Local Land Use

The region within a 5-mile radius of the site is devoted almost exclusively to agriculture. Within the townships of Carlton and Two Creeks, to a radius of 2 miles from the site, there are approximately 650 milk cows. Some beef cattle are raised 2 miles south of the site. Cows are on pasture from early June to late September or early October. During the winter, cows are fed on locally produced hay and silage. Of the milk produced in this area, about 25 percent is consumed as fluid milk and 50 percent is converted to cheese, with the remainder being used in making butter and other by-products.

Originally, there were 12 residences and 1 school within the site boundary. These residences and the school have been purchased, vacated, and removed. No buildings within 1200 meters of the reactor have been occupied since the plant became operational. The closest occupied residence off-site is at least 0.8 mile from the plant.

The Kewaunee School District has consolidated all schools. All school buildings located within a radius of 6 miles have been abandoned.

The Point Beach Nuclear Plant is currently owned by Wisconsin Electric and Power Company (WEPC) at a site located 4.5 miles south of the Kewaunee Plant.

2.6 HYDROLOGY

2.6.1 Summary

The plant's circulating water is drawn from Lake Michigan. All radioactive liquid wastes generated at the plant are collected, treated and monitored in accordance with 10 CFR 20 so that release concentrations at the circulating water discharge are maintained ALARA. The nearest potable water intake is 11½ miles north at the Rostok Plant intake near Kewaunee. Circulating water released from the plant is diluted by a factor of approximately 60 by the time the water flow reaches the Rostok intake, assuming an average lake current flow of 0.35 ft/sec. This dilution factor is calculated according to Equation 2.6.-5 in Section 2.6.4.

As mentioned above, normal operation of the plant results in releases ALARA at the point of discharge, consequently, normal operation results in insignificant drinking water radioactivity content at the nearest point of such use. The Point Beach Nuclear Plant wastes, which are also discharged to the lake ALARA, produce a concentration of less than 2E-9 µCi/cc at the Rostok Plant water intake. Consequently, the normal effluent to the lake waters from both plants simultaneously is more than adequately diluted at the water intake near Kewaunee.

2.6.2 General Lake Hydrology

The normal water level in Lake Michigan is approximately 577.0 feet, based upon the IGLD 1955. The maximum-recorded water level was 582.3 feet in 1986 and the minimum recorded level was 575.4 feet in 1964. At the time IGLD 1955 was established, it was recognized that this common datum would have to be periodically revised due to isostatic rebound, sometimes referred to as crustal movement. Isostatic rebound is the gradual rising or "bouncing back" of the earth's crust from the weight of the glaciers that covered the Great Lakes-St. Lawrence River region during the last ice age. This movement is very gradual and has been occurring since the retreat of the glaciers.

The IGLD was revised to the 1985 standard (IGLD, 1985) when the standard was issued (1992). This new standard affects the reporting of water levels in Lake Michigan. The U.S. Army Corps of Engineers has established a delta of 0.7 feet between the older standard (1955) and the newer standard (1985) due to this rebound effect. Due to the simultaneous movement of the water and landmass, there is no difference in the vertical position of the Kewaunee plant in relation to Lake Michigan. The difference exists in the currently reported water levels in relation to historic values. This is a result of the benchmark elevation changes due to adjustments for crustal movement, more accurate measurement of elevation differences, a new reference zero point location, and an expanded geodetic network. The zero point for IGLD 1985 is at Rimouski, Quebec.

Current, Tides, Waves and Littoral Drift (Reference 1)

On the west side of Lake Michigan, the surface current is largely parallel to the shore and nearly 22° to the right of the prevailing wind. The predominant current direction near the western shore during the period of greatest stratification is in the northerly direction. However, temporary reversals of the general trend may take place (Reference 2).

Current velocity was measured (Reference 3) at 20-minute intervals from August to October, 2-miles off the coast of Sheboygan. The measurements were taken from the surface of the lake down to a depth of 30 feet. The observed persistence patterns for different current velocities are shown in Table 2.6-1. It is fairly certain that this pattern does not differ greatly during the other months of the year.

Tides on Lake Michigan created by the attraction of the moon and sun are insignificant. The total range of oscillation does not exceed 2 inches. However, squalls may raise the surface of the lake by several feet. Deep-water wave heights in the general vicinity of the site due to storms or seiches, and the expected frequency, are shown in Table 2.6-2. Waves are responsible for most of the littoral drift on Lake Michigan. The predominant drift appears to be to the north.

Waves are potentially damaging to the shore structures from impact and run-up. Shore stability is well established as evidenced by the stable location of the shoreline over the long period of time that records are available. Historical publications making reference to the lake commerce at the site occupied by the Kewaunee plant, old photographs, and reports by old-time residents in the area indicate that the shoreline has not changed significantly over the last sixty years. The most recent occurrence of shore erosion was during construction of the plant in 1969. Wave erosion during a severe storm undercut the bank at the promontory protruding into the lake at the southeast end of the site. The damage was repaired and the bank was stabilized with large riprap, which also serves to protect the circulating water discharge.

The shore protection fronting the plant consists of riprap starting at the lake bottom at about Elevation 575.0 feet, a layer of riprap, consisting of face stones about 1500 pounds to 3 tons each, is laid on the ground rock fill (a mixture of 50 pounds to 150 pounds graded rock and pit run gravel) at a slope of 2.0 horizontal to 1.0 vertical and extends up to a 5-foot-wide promenade at Elevation 586.0 feet.

From the shore side of the promenade a layer of riprap consisting of face stones about 500 pounds each is laid at a slope of 1.5 horizontal to 1.0 vertical on the pit run gravel fill and extends up to the edge of the bank.

Specific gravity of the riprap is about 2.4 with a 2.3 minimum. All riprap stones have a 2 percent maximum absorption, as per AASHO T-85 with a maximum abrasion loss of 45 percent.

In addition to the continuous riprap along the shoreline, riprap protection is also installed on both sides of sheet-pile walls of the discharge structure and in the overflow canal immediately in front of the screenhouse forebay.

At Kewaunee, the circulating water screenhouse-forebay structure is the plant structure nearest to the shoreline and is the structure most likely to be affected by waves. The screenhouse-forebay structure is located 180 feet from the normal shoreline. Waves cannot impact directly on the structure. It is possible for wave run-up to reach the screenhouse-forebay structure on occasion. Wave run-up that reaches the screenhouse-forebay structure will have negligible effect and will neither endanger the structure nor adversely affect the operation of the circulating water system. Any water that reaches the screenhouse-forebay structure will spill harmlessly into the screenhouse-forebay through the forebay overflow weir.

Computations of maximum wave run-up are based on information from the Office of the Chief of Engineers (Reference 4). Wave height data given in Table 2.6-2 were used to establish maximum expected run-up and frequencies of occurrence. The run-up at the Kewaunee site is that for a protective beach, which in this case is the submerged and unsubmerged terrain extending from the plant into the lake. The beach is characterized by a rather uniform 1 percent slope. For maximum run-up there is a “significant wave” height which can be related to the deepwater waves summarized in this section. In general, waves remain intact until bottom influences near shore cause them to break. A wave’s energy is transmitted relatively undiminished until it breaks. Upon breaking, energy is rapidly dissipated on the unsubmerged beach.

The squall produced storm surge and resulting probable maximum water level was determined with a modified analysis technique described in Reference 4. This resulted in a maximum surge height of 1.9 feet, produced by the combined effects of wind and pressure. Based upon the study by the Corps of Engineers (Reference 20), the result is considered satisfactory. As previously stated, the maximum recorded lake level in the vicinity of the Kewaunee site is 582.3 feet. This figure in combination with the 1.9 foot storm surge results in a probable-maximum water level of 584.2 feet, resulting from probable-maximum meteorological events coincident with maximum lake level. However, since most severe storms occur during the winter months and highest lake levels usually occur during the summer months; the probability of maximum level and maximum storm surge occurring simultaneously is relatively small, and therefore, the analysis is considered to be conservative.

The Atomic Energy Commission (AEC) independently calculated the probable maximum seiche lake level for Kewaunee to be 589.9 feet (see Reference 21). To accommodate this higher water level the Kewaunee screenhouse was modified during original construction. These modifications included:

1. two bulkhead type doors on exterior access doors to the screenhouse,
2. screenhouse floor covers and manholes to be bolted down,

3. low interior bulkheads, [screen wash discharge shaft, south wall screenhouse]
4. gasketed traveling water screen covers to be sealed and strengthened, and
5. a ramp (top of ramp at elevation 586'-4") across the access tunnel to prevent seepage water from reaching the diesel generator room.

These modifications were considered adequate by the AEC to protect against adverse effects to safety-related equipment.

The seiche produced probable-maximum water level is a relatively fast transient, in the order of 30 minutes or less. The controlled seepage into the screenhouse at the 586-foot elevation is directed to the circulating water pump elevation for disposal or storage.

At the Kewaunee site, the “significant deep water wave” is 22.5 feet high and will probably have a period of 11.4 seconds. The wave will break in 28.1 feet of water, which occurs approximately 2000 feet from the shoreline at high water. The resulting maximum run-up, for maximum size waves attendant to probable maximum lake level, is at an elevation of 585.4 feet. The top elevation of the wall nearest the lake is 582.5 feet. This is the crest of the forebay overflow (shown in Figure 10.2-10). The top of the non-overflow section of the screenhouse-forebay is at an elevation of 592.5 feet. These wave run-up computations show that on rare occasions some waves may reach the lakeward wall of the screenhouse-forebay structure. The depth of the water reaching the wall will be minimal and will not contain sufficient energy to cause any structural damage. That part of the wave reaching the lakeward wall will spill harmlessly into the circulating water forebay. No part of the wave will overtop the non-overflow part of the wall.

Investigations were made of the structures that could be possibly affected by the dynamic loads caused by high lake levels. The bottom elevation of the discharge channel is 572.0 feet. Thus, the maximum water depth in the discharge channel is 11.8 feet. Based on the breaking wave theory described in Reference 4, the maximum non-breaking wave that can enter the channel is 9.22 feet, disregarding height limitations imposed by lake bottom topography. By applying the Sainflow method for wave forces due to non-breaking waves described in the same reference, the calculated maximum wave force acting on the discharge structures such as concrete wall and sheet piling, is about 15 psi which is well within the capability of these structures.

Regarding the wave force on the screenhouse structure, the maximum waves, which can penetrate into the forebay, are much lower because of shallow water depth in the overflow channel. The maximum non-breaking wave height reaching the forebay is only 1.90 feet. The calculated dynamic force is less than 1.0 psi, which is well below the force, which this structure can absorb.

The discharge structure, intake crib and screenhouse have been designed for the dynamic forces caused by the probable maximum lake level conditions or conditions which exceed the maximum lake level conditions.

These structures are discussed in greater detail below.

2.6.2.1 Discharge Structure

The major element of the discharge structure subject to the effects of high water is the sheet pile wall forming the afterbay. The condition determining the design of the sheet piling was the construction condition, which is as follows:

1. Computed back fill (Moist Granular Sand) behind sheets to elevation 582 feet and opposite side excavated to elevation 564 feet. This produced a cantilevered sheet pile design, which was the critical condition.

Since the elevation of the top of the sheets varied from 586.5 feet to 577 feet, it was determined that dynamic forces due to wave action after completion of construction would not be as severe as the construction condition. Dynamic forces due to the maximum lake level condition was not considered during the construction condition because the entire discharge construction work was protected by a cofferdam.

The concrete work of the discharge structure was designed for the following dynamic loading.

1. Ice pressure of 10-kpf thrust due to expansion of an 18-inch thick sheet of ice. This loading was applied to the east side of the structure and is based on information in Vol. 112 ASCE Transactions 1947, Thrust Exerted by Expanding Ice Sheet by E. Rose, utilizing the following assumptions:
   a. Ice Thickness - 18 inches
   b. Solar Energy Considered
   c. Rate of Air Temperature Rise - 10°F Per Hour
   d. Complete Lateral Restraint of Ice Sheet Exists
2. Baffle pier walkway was designed for an uplift pressure of 200 psf due to surge.
3. Baffle wall was designed for a uniformly applied horizontal load of 70 psf due to surge.

2.6.2.2 Screenhouse

The relative location of the screenhouse with respect to the shoreline eliminated the necessity for applying dynamic load conditions due to probable maximum lake level conditions. Where applicable, the maximum static high water level conditions were considered throughout the design of the screenhouse.

2.6.2.3 Intake Crib

The intake crib top is about 20 feet below still water level during the probable maximum water level. Therefore, there is no possibility that wave dynamic forces will endanger this structure.

Pack ice, in the form of frozen spray and ice floes, has been reported to a height of 20 feet at the shore by local residents. No measurements of the extent or depth of the pack ice have been made, and no official observations or records have been kept by any agency to verify the reports of local residents. The extent of the pack ice was established by interviewing land owners bordering the site from which it was determined that the maximum offshore extent of pack ice ranges between approximately 800 feet to 950 feet. It is shown in Table 2.6-2 that 17-foot waves may be expected on Lake Michigan once each ten years. If such waves occurred towards the shore at a time of ice break-up on the lake (a very remote possibility), it is conceivable that there would be some ice pile-up on the shore. Experience at three plants of the Wisconsin Electric Power Company on Lake Michigan has shown that no significant problems have arisen from icing as a result of design features incorporated in these plants. The Kewaunee Plant design incorporates features to insure a continuous supply of cooling water.

2.6.2.4 Lake Temperatures and Effect of Warm Water Discharges

The temperature stratification and circulation patterns of water in Lake Michigan have very distinct characteristics, as follows:

At the beginning of March, a warming trend starts in the lake water and at the end of May all of the water in the lake has reached approximately 40°F, which is the temperature of maximum water density. Until the temperature reaches this point, the surface water is colder than the deeper water in the lake. The colder surface water, which remains at approximately 34°F, is lighter than the 40°F deeper water. This layer of colder water circulates on the surface of the warmer deep water, reaching depths of 25 to 30 feet from the surface.

When all the water in the lake reaches approximately 40°F, the thermocline layer disappears and thorough mixing of the water in the lake takes place. However, when the ambient air temperature warms up the surface water, a thermocline layer is formed again at depths of 30 to 50 feet from the surface.

This occurs from May to July and at this time parts of the water in the lake reach 65°F to 70°F. Consequently, the warmer and lighter surface water circulates above the denser and relatively stagnant 40°F water at the bottom of the lake. This condition continues until a cooling trend starts in September, reaching a peak about the last part of January, at which time the water in the lake again reaches an overall temperature of 40°F. At this time, mixing of the waters in the lake takes place until a colder and lighter layer of surface water starts to build up. Seasonal lake temperatures are given by Church (Reference 5 and Reference 6).

The circulating water intake is a submerged crib-type intake located in approximately 15 feet of water. A thermocline does not exist in the vicinity of the intake since it is located at depths greater than the intake structure. Summertime water temperatures are generally above the thermocline. Historical data for lake water temperatures applied to the Kewaunee site were taken from the city of Green Bay's Rostok intake located near Kewaunee, at approximately 50-foot water depth. The water temperatures at the Rostok intake are generally above the thermocline.

The circulating water discharge facility is an onshore structure discharging at the shoreline and designed for minimum impact on the lake environment. The discharge at the shore edge is from a 40-foot wide channel, 5 feet deep (at normal lake level). Design outlet velocities range from a minimum 2.5-fps to 4.7-fps. The discharge structure provides the termination for the circulating water discharge pipe, a transition from the 120-inch pipe to the open discharge bay, and the outlet to the lake. The discharge bay (or afterbay) receives the discharge circulating water from the submerged pipe transition outlet. At the upstream end, the floor of the discharge bay rises as the sides widen. The downstream portion of the discharge bay is a rectangular channel, 40 feet wide. The discharge bay is normally 5 feet deep but may range from a minimum of 3.4 feet at lowest lake level to 9.9 feet at highest lake level. With two pumps in operation, the discharge is 420,000 gpm but on occasion may be 220,000 gpm with one circulating water pump operating. The discharge flows into the shallow beach area, and generally tends to stratify at the surface. Flow disperses away from the discharge point mixing with the cooler substrata, as water depths become greater. Surface water temperatures will decrease as distance from the plant increases. This apparent cooling is the combined effect of mixing and heat loss to the air. At approximately 1 mile from the plant, surface water temperature returns to within one degree of the lake temperature.

2.6.3 General Site Hydrology

2.6.3.1 Rainfall

Lake Michigan and Lake Huron are considered a unity from the standpoint of drainage and water level since these two lakes are connected. The drainage basin for these two lakes comprises 115,700 square miles and has an average annual rainfall of about 31 inches. The average and maximum precipitation recorded at various locations on the Wisconsin Shore of Lake Michigan is given in Table 2.6-3.

2.6.3.2 Floods

There are no large rivers or streams in the vicinity of the site. The major part of the site is 20 feet or more above the normal lake level, and there is no record that it was flooded by the lake at anytime.

The small stream directly south of the plant is one of several drainage channels lying in the immediate vicinity of the plant, that drain storm water from a high ridge located some 7000 feet west. The close proximity of these drainage channels and their associated drainage areas relieves the total maximum floodwater flow to the plant drainage channel.

The maximum probable rainfall may be determined from the one-hundred-year hourly rainfall intensity of 2.5 inches as shown in the "Rainfall Frequency Atlas of The United States", Technical Paper No. 40, U.S. Weather Bureau, which compares favorably with the greatest hourly rainfall shown in the Weather Bureau records for Green Bay, Wisconsin. (Total record available at time of license application was 10 years.)

The maximum hourly rainfall intensity falls on the area drained by the plant channel which is centered between two other channels; one lying immediately north of the plant area and one immediately south. The drainage area is pie-shaped, with its nose at the westerly high ridge, and its base at the Lake Michigan shoreline. The total area is not more than 640 acres.

The drainage channel has an effective length of 1 mile and averages 30 feet in width. The channel only flows during heavy rains. The side contours of the ditch are such that a depth of 4 feet of water can be carried through the plant area without overflowing.

In considering the maximum probable runoff, the rational method was used and was then related to the interval of time, starting from the onset of the period of precipitation for the runoff from the most remote portion of the drainage area. This time interval, when related to a maximum hourly rainfall intensity, results in a rainfall equivalent of 1.75 inches per hour. (From Rouse "Engineering Hydraulics," Chapter IV, Hydrology.)

Thus, using the rational method, the peak run to the drainage channel is 336 CFS. The peak flow that the drainage ditch can handle, without overflowing, is 466.53 CFS. It was concluded that no flooding of the plant could occur from the probable maximum flood flow.

Based on the improbability of flooding from rain and the height of the safety equipment above the maximum lake water level (585.5 feet), it was concluded that flooding is not a problem. Any safety equipment that is located below ground level is further protected by plastic sheeting associated with the concrete construction.

Flooding of the service water pumps, circulating water pump room, and plant access tunnel is not probable. These are shown in Figure 10.2-10. The maximum probable water levels that can occur in the open forebay under the most adverse weather conditions either from pump-trip upsurge (585.5 feet) or from maximum wave run-up (585.4 feet) are below the floor level (586.0 feet) of the service water pump room and access tunnel. The only flood water access to the circulating pump room is from this floor level. Hence, none of these areas are subject to flooding.

A review and re-evaluation of external flooding was performed in response to Generic Letter GL 88-20, Individual Plant External Events (IPEEE) for Severe Accident Vulnerabilities and resolution of generic issue GI-103, Design for Probable Maximum Precipitation (PMP). Using a revised PMP of 16.5 inches per hour, it was concluded that the site continued to have adequate design capability to handle the 100-year hourly rain intensity, which historical experience has not challenged (Reference 26).

2.6.3.3 Ground Water

Observations of surface drainage and water levels at the site borings indicate that the static ground water level inland from the lake ranges from 10 to 25 feet below the ground surface. The water table at the site generally slopes to the east, indicating a migration of ground water in that direction. At the base of the bluffs, ground water levels are controlled by the elevation of Lake Michigan.

The regional movement of ground water is from west to east. Therefore it is unlikely that discharge into the aquifers at the site would affect any municipal well fields. Fluctuations in the level of Lake Michigan are not of sufficient magnitude to affect the direction of ground water movement. Heavy pumpage from the glacial drift or the Niagara dolomite aquifers in the vicinity of the site would reverse the direction of ground water movement for a distance of only a few hundred yards.

Because of the clay composition of the glacial drift, it is not likely that appreciable amounts of any surface discharge from the plant would seep into the ground. Most of the effluent would flow into Lake Michigan.

The principal water-bearing formations underlying the site are the glacial drift and Niagara dolomite aquifers, which are described in detail in Appendix A.

Potable Water Sources

Lake Michigan is used as the source of potable water supplies in the vicinity of the site for the cities of Two Rivers (13 miles south) and Green Bay (intake at Rostok 11.5 miles north). No other potable water uses are recorded within 50 miles of the site along the lakeshore. All public water supplies drawn from Lake Michigan are treated in purification plants with steps consisting of chemical addition of alum, activated carbon, mechanical mixing, flocculation, sedimentation, filtration and disinfection. The nearest surface waters used for drinking, other than Lake Michigan, are the Fox River at a point 43 miles west and Lake Winnebago 40 miles west of the site.

Ground water provides the remaining population with potable supplies. Public ground water supplies within a 20-mile radius of the site are listed in Table 2.6-4. Additional wells for private use are in existence throughout the rural region.

The sole users of ground water to be found within the general area of the plant are farm residences. No public water supplies, nor any surface water users, are to be found within this area.

However, those users relative to the plant, as shown in Figure 2.6-1, are only those rural wells located in the south half of Sections 23 and 24, in the west half of Sections 26 and 35, and the south half of Section 36 (all in T22N).

No public record of these wells has been made. It is known, however, that about half of the wells within the general plant area use ground water found in a glacial drift that lies about 100 feet below ground level. This drift consists of clayey soils inter-bedded with water bearing sand and gravel out washes. These out washes are irregular and are not continuous at the plant site. The wells that draw from this glacial drift are typically 6 inches in diameter and 100 feet deep.

Each well typically produces about 17 gallons per minute. There are a total of 18 wells that relate to the plant site, of which only 17 are ground water users; therefore, water usage from ground water sources is (18 ÷ 2) x 17, or 153 gallons per minute, and 220,320 gallons per day.

Fishing (Reference 7)

Commercial fishing in Lake Michigan has decreased in the last twenty-five years due to proliferation of the sea lamprey, causing a reduction in lake trout and an increase in less desirable rougher species of fish. Alewives, chubs and yellow perch accounted for 89 percent of the 1968 production from Lake Michigan. Efforts are being made by various organizations to reduce the sea lamprey population and increase the abundance of edible fish.

Fishing is practiced generally throughout the lake. Fishing depths are greater than 12 fathoms (72 feet). These depth restrictions place the fishing grounds at least 5 miles offshore. Inshore fishing is licensed occasionally when alewives (a shad-like food fish) are schooling in along the shore. This fish is used mostly for fertilizer and fishmeal manufacture.

Fishing in Lake Winnebago (40 miles west of the site) is confined primarily to rough species; most of which go to mink ranchers in the area for use as animal food.

Sport fishing is one of Wisconsin’s prime tourist attractions. It may be considered as existing throughout the state and along all shoreline areas of the lake. Brown, rainbow, lake trout, chinook and coho salmon accounted for 95 percent of the sport fishing catch in 1980.

2.6.4 Dilution and Diffusion in Lake Michigan

Water from Lake Michigan is used extensively for municipal and domestic water supplies. As described in Chapter 11, all radioactive liquid wastes generated at the plant are collected and treated for possible reuse and monitored before being discharged from the site. All liquid waste is released consistent with KPS ALARA commitment before it reaches the nearest water supply intake. The nearest municipal and domestic water intakes are located at Rostok and Two Rivers (approximately 11.5 miles north and 13 miles south of the site, respectively).

Radioactivity discharged to the plant circulating water can occur in two modes. The first is the normal controlled release of small amounts of activated corrosion products and fission products into the circulating water stream. The second, conceivable only as a result of an operating error or equipment failure, may be regarded as a short-term release before the waste release is shut off.

Computational models for evaluating the dilution of both types of radioactive releases are discussed below.

Short Term Release

A number of diffusion relationships have been derived to describe diffusion in large bodies of water. A widely used relationship is that derived by Okubo and Pritchard (Reference 8):

$$S(r,t) = \frac{M}{\pi D (Pt)^2} \exp - \frac{(\mathrm{r}^2)}{(Pt^2)} \tag{2.6.-1}$$

Where:

S(r,t)= concentration as a function of time and distance,

$$\frac{\mu ci}{cc}$$

M = total activity release, μCi

D = depth of mixing layer, cm

P = diffusion velocity, cm/sec

r = distance downstream from release point at which S is determined, cm

t = time after start of release, sec

Experimental measurements in Lake Ontario for the Ginna Nuclear Station resulted in estimates of the diffusion velocity ranging from 0.2 to 2 cm/sec.

Based on studies of Lake Michigan currents and water masses (Reference 1) it was determined that the mixing depth of the lake is 25 to 50 feet, depending on the time of the year.

For the purposes of this analysis, it was assumed that:

P = 0.5 cm/sec

D = 10^3 cm

Furthermore, since the conditions of most interest are those that will transport the radioactive material along the shore rather than into the open reaches of the lake, the equation for concentration is multiplied by a factor of 2. This factor accounts for the restricted diffusion in the direction of the shore.

The peak concentration at any given time can be assumed to exist at the center (origin) of the drifting plume and is a function of time only:

$$S_{peak} = \frac{2M}{\pi D(Pt)^2} \quad (2.6.-2)$$

The velocity of the current and its persistence at various speeds has been discussed previously (Section 2.6.2). An average velocity calculated from these values is approximately 0.35 ft/sec. The peak concentration as a function of distance from the site, assuming this average current velocity, is given in Table 2.6-5.

As required by 10 CFR 20, the annual average concentrations of unknown radionuclides in unrestricted areas must not exceed 2E-9 $\mu Ci/cm^3$. It may be seen that short-period release of radioactivity at the site will be diluted at the nearest municipal water intake (11.5 miles) to a peak concentration of 8.54E-14 $\mu Ci/cm^3$ per µCi of activity released. Furthermore, it should be noted that the above concentration would be a transient value and not the average concentration, which would enter the water intake.

2.6.4.1 Normal Release

From the relationship used in the previous section for diffusion of an instantaneous release, it is possible to obtain an expression for the concentration from a continuous release as follows:

$$S(y, r) = \frac{2Q}{2\sqrt{\pi}PDr} \exp\text{-}\frac{(y^2)}{(Pt)^2} \quad (2.6.-3)$$

Where:

S(y,r) = Concentration as a function of cross plume and distance,

$$\frac{\mu Ci}{cm^3}$$

Q = Release rate, Ci/sec

P = Diffusion velocity, cm/sec

r = The distance downstream from release point at which S is determined, cm

D = Depth of mixing, cm

y = Cross plume point at which S is determined, cm

t = Plume travel time to reach distance r with average current velocity, sec

At a given distance r, the concentration S equals zero initially (t=0), but eventually a saturation condition is reached, corresponding to a maximum condition S_{max}, which will exist as long as the radioactive material is released at a constant rate. Under these conditions, S_{max} is a function of distance only. The maximum concentration occurs at the centerline of the plume and, thus:

$$S_{max} = \frac{Q}{\sqrt{\pi} PDr} \qquad (2.6.\text{-}4)$$

The maximum concentrations per unit activity release for various distances are shown in Table 2.6-6.

The dilution factor DF (y,r) is given by

$$DF(y, r) = \frac{A}{S(y, r)} = \frac{\sqrt{\pi} PDr}{V} \qquad (2.6.\text{-}5)$$

Where:

Q = AV

V = Discharge volume in cc/sec

A = Activity concentration μCi/cc

Using equation (5), it is calculated that a continuous discharge of radioactivity from the plant would be diluted by a factor of approximately 60 by the time the flow reached the nearest municipal drinking water intake, based on a 420,000 gpm circulating water flow.

The effluent from the Point Beach Nuclear Plant (4.5 miles south of the site) has not created any significant problems. Although lake flow is normally in the direction from the Point Beach site toward the Kewaunee site, the concentration of any radioactivity in the effluent from the Point Beach Plant will be diluted by a factor of 35 by the time the effluent reaches the Kewaunee Plant intake, based on a discharge flow from the Point Beach plant of 300,000 gpm.

Table 2.6-1
Persistence of Currents in Lake Michigan

Current Velocity (ft/sec)	Persistence (% of time)
0 - 0.5	68
0.6 - 0.7	10
0.8 - 0.9	12
1.0 or higher	10

Table 2.6-2
Wave Heights and Frequency

	Wave height in feet	
Frequency	Full Year	Ice-Free Period
Once each month	6	6
Once each 6 months	9.5	7
Once each year	11	8
Once each 2 years	12.5	9
Once each 5 years	15	11
Once each 10 years	17	12
Once each 25 years	17.7	13.6
Once each 500 years	23.5	18.0

Table 2.6-3
Precipitation [a]

Location	Ten Year Average (1971-1980)	Max Annual	Year	Min Annual	Year
Kenosha	32.92	46.12	1972	25.07	1975
Milwaukee	33.39	40.74	1978	26.45	1971
Port Washington	30.24	37.34	1978	21.51	1976
Manitowoc	30.25	36.08	1978	25.20	1976
Two Rivers	30.20	34.67	1973	24.81	1976
Kewaunee	30.35	34.69	1977	21.68	1976
Green Bay	29.36	35.47	1975	17.85	1976

a. Data obtained from Wisconsin State Climatologist and the National Oceanic and Atmospheric Administration

Table 2.6-4
Municipal Ground-Water Supplies

Place	1990 Population	Well Depth Feet	Air Miles and Direction From Proposed Site
Denmark	3968	309-456	15 Miles West
Kewaunee	6254	187-700	8 Miles North
Luxemburg	5191	431-495	16 Miles Northwest
Mishicot	3315	80	9 Miles Southwest
Whitelaw	1489	495	19 Miles Southwest
Algoma	5387	475-1334	19 Miles North

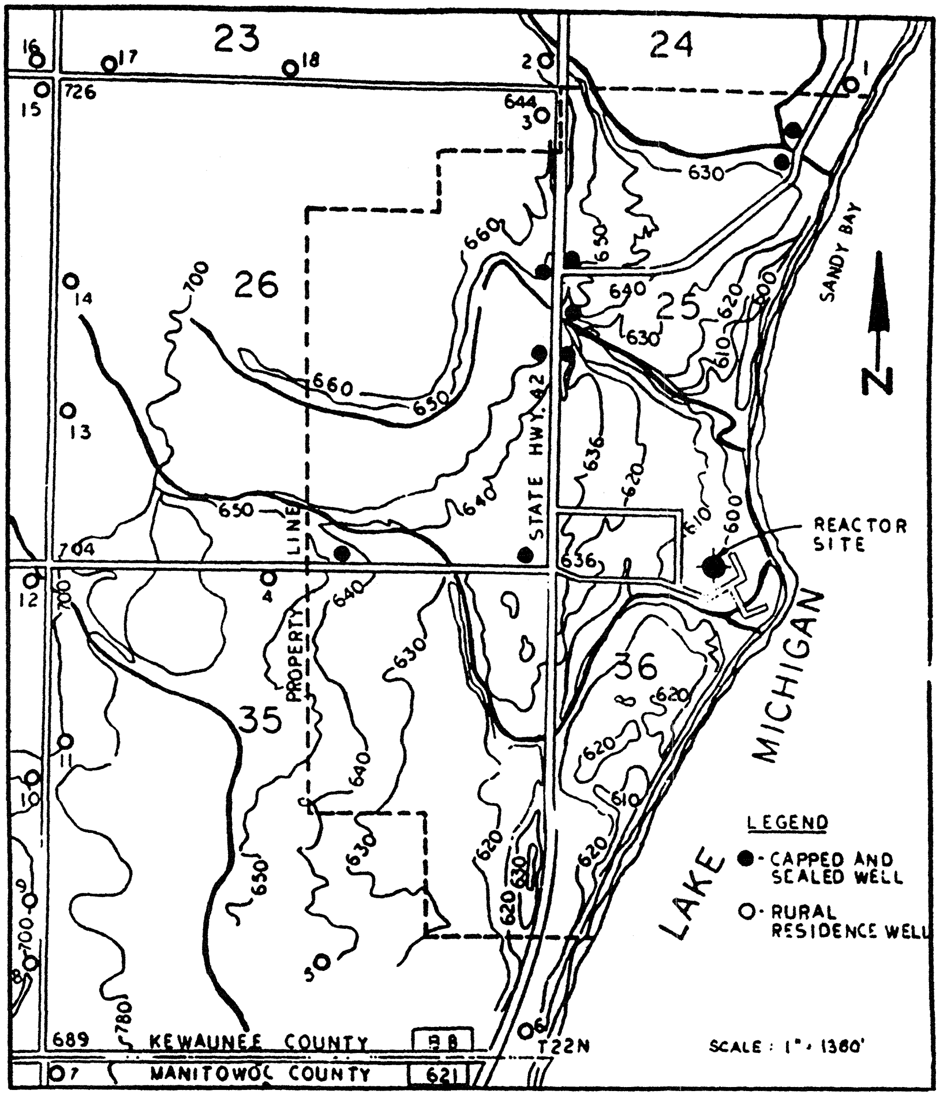
Table 2.6-5
Dilution From Short-Term Release

Distance, Miles	Travel Time, Hours	Peak Concentration per Unit Release Speak/M, µCi/cm^3 per µCi
1	4.2	1.11E-11
5	21	4.45E-13
10	42	1.11E-13
11.5	48	8.54E-14
15	63	4.95E-14
20	84	2.76E-14
25	105	1.78E-14

Table 2.6-6
Continuous Release Dilution Factors

Distance from Site, Miles	Maximum Concentration per unit release S_{max}/Q, μCi/cm^3 per μCi/sec
1	0.71E-8
5	1.41E-9
10	0.71E-9
11.5	0.62E-9
15	0.47E-9
20	3.53E-10
25	2.83E-10

Figure 2.6-1 Critical Well Locations



2.7 METEOROLOGY

Refer to the KPS Off-Site Dose Calculation Manual (ODCM) and supporting documents for current meteorological data and other related information.

2.7.1 Meteorological Program

Meteorology in the region of the site has been evaluated to provide a basis for determination of annual average waste gas release limits, estimates of exposure from potential accidents and design criteria for storm protection. The meteorology section in this USAR is based on nineteen months of site data from August 1968 through February 1970. Site data are continually being recorded. The meteorological data acquisition system was upgraded in 1982 in response to the NRC criteria for emergency preparedness discussed primarily in NUREG 0654 (Appendix 2), Regulatory Guide 1.23 (proposed revision 1), Regulatory Guide 1.97, and NUREG 0737, Supplement 1.

The primary meteorological tower is located 1200 ft. from the center of containment at 202° and is instrumented at the 10-meter and 60-meter elevation. The meteorological parameters measured at the primary tower include:

- 60 & 10 meter wind speed
- 60 & 10 meter wind direction
- 10 meter ambient temperature
- Differential temperature
- 10 meter $\sigma\theta$

A backup tower is located in close proximity to the primary tower and is available to provide the following meteorological information:

- 10 meter wind speed
- 10 meter wind direction
- 10 meter $\sigma\theta$
- 10 meter ambient temperature

There is analog readout for the meteorological data in the basement of the Technical Support Center (TSC) and digital inputs to the plant process control computer.

Power is available to the primary tower from either the transmission system on highway 42 or from MCC 1-46C which is capable of being fed by the TSC diesel generator. The backup tower is supplied entirely from the transmission lines on Highway 42.

Site meteorological data were used as input to a CDC 6600 computer. WINDVANE, a code developed by NUS, operates on this data to determine significant meteorological statistics and distributions for further analysis. Summary pages of WINDVANE output for reported Kewaunee data are on file and available as reference material.

Data recovery during this nineteen-month period, August 1968 through February 1970, was approximately 90 percent. Periods of missing data did not result in any data bias and were generally of short duration except for March 24, 1969 to April 24, 1969 when the facility was inoperative due to storm damage.

Stability in this report is classified into categories proposed by Pasquill (Reference 9) and Turner for a system based on wind direction range or wind variance formulated by Slade (Reference 10).

In assessing the meteorology of a nuclear reactor site the purpose is to ascertain the dilution capacity of the atmosphere in cases of radioactive releases. Wind direction and speed are obvious factors since the direction determines the trajectory of the material, and the speed is a measure of the flow into which the contaminant is diluted. However, wind turbulence expands the plume about its centerline. It is actually wind turbulence that progressively spreads the plume (both vertically and horizontally) as it is transported from its source, resulting in a conical configuration.

Stability characterizes the capability of the atmosphere to return to equilibrium or its original state after being disturbed. A stable atmosphere is quiescent and an unstable one is quite variable. The vertical rate of change of temperature (lapse rate) is frequently used to define stability by those interested in air parcels subjected to buoyancy forces. However, in considering releases from the Kewaunee Plant, buoyancy is not an important factor, and it is more conclusive to examine the disturbances of the mean wind direction.

The stability classes proposed by Pasquill range from “A,” the most unstable, to “F,” stable. Wind direction variance or standard deviation, which is determined by the Wind Variance Computer on a real-time basis, can be used to classify data in the various categories. It is also possible to infer the standard deviation by dividing the range of wind directions by a constant, usually 6.0 for fifteen-minute periods. Table 2.7-1 describes the various stability categories. An additional category “G” has been added to facilitate a more complete classification system.

A low degree of wind turbulence and consequently relatively unfavorable diffusion conditions can be expected for stable conditions. Conversely, during periods of instability, a high degree of wind turbulence associated with favorable dilution conditions can be expected.

2.7.2 Descriptive Meteorology

The climate of the site region is basically continental and influenced by the general storms which move eastward along the northern tier of the United States and by those which move northeastward from the southwestern part of the country to the Great Lakes. The climate is modified by Lake Michigan. Climatic characteristics are illustrated in Figure 2.7-1 which shows average and extreme temperatures, precipitation and extreme winds for forty years of USWB record (1930-1969) at Kewaunee and Manitowoc, Wisconsin. Rainfall averages about 28 inches per year, with 55 percent falling in the months of May through September. Maximum rainfall during twenty-four hours was 6 inches in September 1964. Snowfall averages about 45 inches per year, with a maximum of 15 inches in twenty-four hours in January 1967.

According to the compilation by Thom (Reference 11) extreme winds at the 30-foot elevation, as illustrated in Figure 2.7-1, are not expected to exceed 54 mph with a recurrence interval of once in two years, and 90 mph with a one hundred-year recurrence interval. (The extreme-mile wind speed is defined as the highest 1-mile passage of wind for a given length of time.)

2.7.2.1 Tornadoes

Wisconsin lies to the northeast of the principal tornado belt in the United States. During the ten-year period 1960-1969, 161 tornadoes were reported in the state. Only six of these tornadoes occurred in Brown, Door, Kewaunee, or Manitowoc Counties. During the period 1916-1969, only one tornado caused injury to people or major property damage within these four counties. This one occurred in Green Bay, 27 miles WNW of the site, on May 10, 1959, at 8:50p.m. Three persons were injured and property damage ranged from $500,000 to $5,000,000. The tornado path was 6 miles long and 600 yards wide. The region north of Sheboygan, along the Lake Michigan coast, appears to be relatively free of tornadoes. Approximately six tornadoes occurred in the Green Bay-Kewaunee area on April 22, 1970. Damages were estimated at approximately $500,000 and four to five people were injured.

Tornadoes appear to advance from the west with most of the tracks from the southwest to northeast. Maximum occurrence during the year is in May, with 90 percent reported in May through September. According to statistical methods proposed by Thom, (Reference 12) the probability of a tornado striking a point within a given area may be estimated as follows:

$$P = \frac{\bar{z}\bar{t}}{A}$$

P is the mean probability per year, $\bar{z}$ is the mean tornado path area, $\bar{t}$ is the mean number of tornadoes per year in area A. The value of $\bar{t}$ is 16.7 for Wisconsin and 1.2 for the four counties surrounding the Kewaunee site, if the April 22, 1970 tornadoes are included. The average path length and width for tornadoes occurring in the state are 7 miles and 200 yards, respectively, and yield a value of $\bar{z}$ equal to 0.80 square mile. Using a value of A equivalent to the total area of Brown, Door, Kewaunee, and Manitowoc counties yields:

$P = 4.86E\text{-}4\ year^{-1}$

An equivalent value of 2.45E-4 year-^{1} is obtained using data based on the entire state.

At a 95 percent confidence interval Thom's formula becomes:

$$P' = P\left[1 \pm \frac{1.96}{(N)^{.5}}\right]$$

N is the total number of tornadoes in the area of concern during the ten years of record, 1960-1969 (the tornadoes of April 1970 are also included for conservatism).

The 95 percent confidence limits in the four counties around the site are 7.65E-4/yr and 2.09E-4/yr. The mean recurrence interval, $R = 1/P_\rho$, is 2060 years, and at these confidence limits, the recurrence intervals $R = 1/P_\rho$, range between 1310 and 4770 years. The danger from tornadoes is therefore very slight.

Damage caused by tornadoes results from three principal effects:

1. The dynamic forces resulting from the high velocity vortex winds;
2. The bursting forces caused by differential static pressure resulting from the sharp pressure reduction in the immediate vicinity of a tornado funnel;
3. The impact of missiles generated by (1) and (2) above.

The most widely accepted values of wind speed in a tornado appear to be about 300 mph (Reference 13, Reference 14 and Reference 15) or less for a very severe tornado at the peak of its intensity. Some sources mention values as high as 500-600 mph, (Reference 13 and Reference 16) but these estimates appear to be based on indirect observations of phenomena such as straws driven into trees, etc., and are not regarded as authoritative.

The highest directly observed wind velocities were derived from motion pictures of debris in the Dallas Tornado of April 2, 1957 (Reference 14). These velocities ranged up to 170 mph tangential and 150 mph upward, resulting in a maximum wind vector of 227 mph. If higher velocities were present, they must have been very localized and not typical of the average wind on large bodies and structures.

The design wind speed of 300 mph with a forward progression of 60 mph is about 36 percent greater than that of the Dallas tornado and is thought to be conservative in view of the Kewaunee plant location. The greatest pressure drop associated with a tornado yet recorded was equivalent to a bursting pressure of approximately 3-psi (Reference 13). This measurement, however, is highly questionable and not regarded as authoritative. The greatest measured pressure drops have been on the order of 1.5 psi. For the Dallas tornado mentioned above, a maximum pressure drop of about 0.9 psi was determined from calculations (Reference 17).

The structural design criteria used to assure adequate design to accommodate the most severe storm conditions are discussed in Appendix B.

2.7.2.2 Ice Storms

Ice storms are infrequent in this region of Wisconsin. Wisconsin Public Service Corporation had transmission lines in this area, one of which was a line from Green Bay to Kewaunee to Sturgeon Bay. Six outages due to ice storms occurred on this line between 1940 and 1956, ranging in duration from 22 minutes to 2.5 hours. The line was rebuilt in 1956 with improved conductors. Only one outage occurred due to ice storms between 1956 and plant licensing.

2.7.2.3 Wind Direction and Speed

The distribution of wind direction frequencies is important in these analyses. Winds from certain directions may transport contaminant releases to uninhabited areas, as with offshore winds at this site, or conversely for onshore winds to populated areas. Figure 2.7-2 illustrates the distribution of onshore and offshore winds. Onshore winds are winds that blow from the lake toward the land and are defined at the Kewaunee location as north-northeast through south. Offshore winds blow from the land toward the lake from south-southwest through north.

It is significant that offshore winds (blowing toward Lake Michigan) occur over 60 percent of the time on an annual basis.

Onshore winds occur most frequently during the spring and summer. The maximum occurrence of offshore winds is during the autumn and winter. These are typical conditions associated with a lake-breeze effect. Due to the temperature lag of Lake Michigan, land temperatures are warmer than the lake during spring and summer and colder during autumn and winter. During spring and summer a circulation results when air is heated from below by the land, rises, and is replaced by air over the lake flowing toward the land. A reversal occurs during the autumn and winter; air ascends over the warmer lake surface and is replaced by air flowing from the land. Actually this offshore lake-breeze wind can occur nocturnally during the summer but is usually quite weak. Onshore lake breezes normally only penetrate a mile inland.

The seasonal and annual distributions of wind direction are presented in Figure 2.7-2. The percentage of occurrence (in percent of the total number of observations in the period) for each of 16 directions is represented by the length of the bars on the wind rose.

Winds occur mainly from the western (180° through 360°) half of the compass (74.26 percent) annually. The distribution is quite similar to data presented in the Point Beach USAR (Reference 18). There appears to be no significant channeling effects or predominant directions although there is a low frequency of easterly component winds. Easterly winds, usually associated with local onshore winds at this site, flow against the large-scale gradient flow and consequently are diminished in frequency of occurrence and speed.

Seasonally, there are some variations in the distribution of wind directions. Spring is characterized by a maximum occurrence of north-northeast and northeast winds. Winds predominate from the southwest quadrant (48.69 percent) during the summer season. Autumn reflects a change from a summer southerly flow to a winter northerly one with 57.38 percent of the winds occurring between south and west-northwest. The majority of winds (60.01 percent) occur in the northwest quadrant during the winter.

Atmospheric dilution is inversely proportional to the average wind speed. The seasonal and annual wind speed averages based onsite data for Kewaunee are:

Average Wind Speed (mph)

Spring	Summer	Autumn	Winter	Annual
9.2	10.9	14.7	15.4	12.6

The 12.6-mph annual average wind speed at Kewaunee is significantly higher than the 6.0-mph Milwaukee annual average. This can be attributed to the higher elevation of the site wind instrumentation compared to the low-level sensors at Milwaukee, and also to the more exposed location of the Kewaunee site (adjacent to Lake Michigan on one side and surrounded on the other sides by relatively smooth rural terrain). The site wind instrumentation used in this study was at 180-feet, currently this instrumentation is on a new tower at 60-meters. Therefore, low-level winds at Kewaunee would be higher than the low-level Milwaukee value but somewhat lower than the reported 180-foot value. The variation of wind speed with height, however, would not be great at Kewaunee for levels of interest. In fact, the use of the 180-foot level is considered conservative since the increase of wind speed with height may be more than compensated for by the decrease in turbulence, and atmospheric dilution conditions would be comparable. Also of interest is the frequency of calms as presented in Table 2.7-2. The annual occurrence of calms is only 1.02 percent versus 2.6 percent for Milwaukee and 3.5 percent for Point Beach data. Point Beach data were manually reduced, a procedure that can result in over-estimation of calm conditions. The use of a computer unit to reduce data on a real-time basis, as was done at Kewaunee, enables a more representative estimate of actual meteorological conditions and averages. The maximum occurrence of calms (1.28 percent) at Kewaunee is during the spring; the minimum (0.85 percent) is during the winter. These percentages are quite low, and persistent periods of calm do not appear to pose a problem at the site. The NRC has reviewed local and regional weather data and concluded that KNPP should be categorized as an Extremely Severe Weather Group 2 plant and as such, should not expect winds in excess of 125 mph. Therefore,

station blackout due to severe straight-line winds is not expected to be observed at the Kewaunee plant site (see Reference 22).

2.7.2.4 Wind Direction Persistence

Wind persistence is extremely important when considering possible doses from a radioactivity release. Wind persistence is continuous flow from a given direction or range of directions. Figure 2.7-3 shows the probability of occurrence, based on site data, of wind flow persistence in a 222° direction range, greater than time period “t.” There is only a 5 percent chance of continuous persistence periods greater than eleven hours and only a 1 percent chance of periods greater than eighteen hours.

The maximum persistence episodes recorded during nineteen months of Kewaunee site data were twenty-five hours occurring in February and again in October. Wind turbulence was low during the two periods but was compensated for by high average wind speeds of 16.0 and 19.4 mph, respectively. In general, persistence periods at Kewaunee are associated with quite high winds and relatively low turbulence.

Episodes of maximum wind direction persistence in 222° sectors are presented in Figure 2.7-4. The distribution of these maximum persistence cases is rather uniform. No persistence greater than five hours associated with calm conditions has been observed for the nineteen-month period of record.

2.7.2.5 Atmospheric Stability

Atmospheric stability is important in describing the diffusion capacity of the atmosphere. Atmospheric stability, as used in this report, refers to the degree of wind turbulence rather than the vertical thermal structure of the atmosphere. Stable conditions are associated with low turbulence and poor atmospheric diffusion capacity. Unstable conditions are associated with high turbulence and favorable diffusion characteristics.

The frequency of occurrence of various stability categories for Kewaunee as observed on site and at Milwaukee is presented in Table 2.7-3. In general, Kewaunee data have a greater frequency of stable conditions and higher wind speeds than the Milwaukee data. The differences in stability distributions can be attributed to the manner of stability categories used in each case, and the differences in wind speeds to the higher sensor elevation and more exposed location of the Kewaunee site. Comparisons of average dilution factors (X/Q) for Kewaunee and Milwaukee are discussed in Section 2.7.3.

Stable categories (E-G) occur 82.74 percent of the time at Kewaunee while neutral conditions (D) predominate at Milwaukee (65.3 percent). However, the classification of stability for Kewaunee differs from that used for Milwaukee. Milwaukee data consisted of observations made by the Weather Bureau and were classified as to stability according to factors such as time of day, cloud cover, solar angle, etc., following a system proposed by Turner (Reference 19).

Kewaunee data acquired onsite were classified in stability categories according to the degree of wind direction variance. It should be noticed that stable categories are associated with high wind speeds (14 mph) at Kewaunee versus 5 mph at Milwaukee for Class “F.”

The seasonal and annual distributions of atmospheric stability at Kewaunee are shown in Table 2.7-4. Winter is the season of greatest stability, and spring has the maximum occurrence of unstable conditions.

The seasonal and average stability distributions by direction (in percent of total observations for the period) are presented in Table 2.7-5 for Kewaunee. The outline of the configuration represents the wind direction frequency.

The stability distribution for each of the directions is also plotted.

The seasonal and annual distribution of atmospheric stability for onshore and offshore winds is indicated in Table 2.7-5 and Table 2.7-6, respectively. The percentages represent frequency of occurrence based only on onshore winds for Table 2.7-5 and offshore winds for Table 2.7-6.

Onshore and offshore winds have quite similar stability distributions. Winter is the season for the maximum occurrence of stable conditions (90.74 percent for onshore and 94.13 percent for offshore winds). The maximum occurrence of unstable conditions is 5.86 percent during the spring for onshore winds and 7.28 percent during the summer for offshore winds. The annual distribution of stability for onshore winds and offshore winds is also quite comparable.

2.7.3 Atmospheric Dilution

Annual average atmospheric dilution factors (X/Q) were determined for the Kewaunee Nuclear Plant site. Figure 2.7-6 shows the distribution of X/Q in seconds per cubic meter based on Kewaunee tower data. The results represent the sector-average concentrations from equation (1) below, which is the standard Pasquill-Gifford diffusion equation for a ground-level release:

$$\chi/Q = \frac{8\sqrt{2}}{\pi^2} \sum_{i=1}^{n} \frac{F_{2i}f_i}{\sigma_{z_{\bar{u}x}}} \qquad (2.7\text{-}1)$$

Where:

X = Concentration, units per cubic meter

Q = Source strength, units per second

$\bar{u}$ = Mean wind speed, meters per second

σ_y = Vertical dispersion parameter, meters

i = Pasquill stability categories (AG) with numerical values (17)

n = Number of stability classes (seven, from AG)

F_i = Fraction of time stability condition "i" exists

f_i = Fraction of time that winds occur from the sector of interest for stability "i"

x = Distance downwind, meters

Dilution factors can be considered as relative concentrations, i.e., concentration relative to the source strength. The configuration of X/Q isopleths reflect the annual distribution of wind direction, wind speed and atmospheric stability. The highest value of X/Q at the site boundary is 1.2E-6 sec/m³ and is located to the north of the containment structure. The dilution factor at the nearest off-site habitation located 1300 meters to the west of the containment is 5.6E-7 sec/m³. These dilution factors are comparable to the respective values of 1.1E-6 sec/m³ and 3.7E-7 sec/m³ based on earlier evaluations. Somewhat higher X/Q values based on site data can be attributed to the greater effect of the increase in the frequency of stable conditions rather than the increase in wind speed, as compared to Milwaukee data.

2.7.4 Hypothetical Accident Meteorology

NOTE: The dose discussion below was developed during design and construction in support of plant licensing. As such, it is considered historical and is not intended to be revised or updated. Updated dose analyses are provided in Chapter 14.

Nineteen months of onsite meteorological data have enabled a re-evaluation of the hypothetical accident model previously based on an analysis of Milwaukee Weather Bureau data. Analysis of Kewaunee site data enables a more realistic model to be formulated. A hypothetical accident is postulated to determine concentrations and doses that might occur in the event of a radioactivity release. A basic input is the meteorological conditions, which determine the diffusion capability of the atmosphere. The meteorological conditions proposed for a hypothetical accident are presented in Table 2.7-7 for Kewaunee. Analysis of the hypothetical accident situation is based on meteorological conditions, which are more unfavorable than those normally experienced. For example, ground releases are considered, and very stable meteorological conditions are assumed. In Table 2.7-7, the quantity F_i is the fraction of the time stability category "i" occurs, and f_i is the fraction that winds occur from the sector of interest for stability "i", as discussed in Section 2.7.3. To summarize, F_i and f_i are quantitative best estimates based on data collected of the frequency of occurrence of the meteorology conditions assumed for the accident. Invariant wind conditions refer to winds that do not vary in direction; sector average conditions occur when winds prevail within a 22-1/2° sector as used for this model.

The accident conditions postulated were determined on a quantitative statistical basis. The frequency of occurrence of each stability class was calculated for various wind speed ranges. These meteorological conditions were ranked in order of the magnitude of their associated (X/Q) values and are presented in Figure 2.7-7 with the frequency of occurrence of these conditions. Using the Regulatory Staff fifth percentile criterion to assess the 0-2 hour accident period, atmospheric diffusion conditions associated with stability class "F" and 1.5 m/sec winds are justified.

Dilution factors (X/Q) were calculated using Equation 2.7-1 below for invariant winds and Equation 2.7-1 of Section 2.7.3 for sector averages. These equations are used to calculate relative diffusion based on meteorological factors corrected to account for the additional initial diffusion resulting from the building wake effect.

$$\frac{\chi}{Q} = \frac{1}{(\pi\sigma_y\sigma_z + cA)\bar{u}} \qquad (2.7\text{-}1)$$

X = Concentration, units per cubic meter

Q = Source strength, units per second

$\bar{u}$ = Mean wind speed, meters per second

$\sigma_y\sigma_z$ = Lateral and vertical dispersion parameter, meters

c = Building shape factor, dimensionless (0.5)

A = Smallest cross sectional area of the containment structure, square meters (1600 m^2).

The diffusion is assumed to be Gaussian, i.e., horizontal and vertical distributions perpendicular to the plumb centerline have Gaussian properties. The lateral and vertical dispersion parameters are calculated using the methods of Pasquill (Reference 9).

A graph depicting dilution factors based on the meteorological model for a hypothetical accident is presented in Figure 2.7-8, with discrete data given in Table 2.7-8. Doses estimated for the conditions of a hypothetical accident release using this model are well below 10 CFR 100 guidelines.

Table 2.7-1
σ_θ Stability Categories

Stability Type	Range of Standard Deviation (in degrees)	Turbulence Type
A = Extremely Unstable	$\sigma_\theta > 22.5$	
B = Unstable	$22.5 > \sigma_\theta \geq 17.5$	High Atmospheric Turbulence
C = Slightly Unstable	$17.5 > \sigma_\theta \geq 12.5$	
D = Neutral	$12.5 > \sigma_\theta \geq 7.5$	Moderate Atmospheric Turbulence
E = Slightly Stable	$7.5 > \sigma_\theta \geq 3.8$	
F = Stable	$3.8 > \sigma_\theta \geq 1.3$	Low Atmospheric Turbulence
G = Extremely Stable	$\sigma_\theta < 1.3$	

Table 2.7-2
Wind Distribution (%)(Kewaunee Site Data)

	Onshore (NNE-S)	Offshore (SSW-N)	Calm
Spring	49.15	49.57	1.28
Summer	40.56	58.39	1.05
Autumn	34.47	64.48	1.05
Winter	20.36	78.79	0.85
Annual	36.14	62.81	1.02

Table 2.7-3
Stability and Wind Speed Distribution

	Frequency of Occurrence (%)		Mean Wind Speed (mph)	
Stability Category	*Kewaunee	**Milwaukee	Kewaunee	Milwaukee
A - high unstable	1.2	0.1	10.0	4.3
B - unstable	1.3	2.9	6.0	6.6
C - slightly unstable	2.6	9.8	8.6	9.2
D - neutral	12.2	65.3	10.9	13.2
E - slightly stable	32.3	9.9	13.1	8.3
F - stable	37.1	7.8	14.3	5.0
G - extremely stable	13.3	4.6	14.0	1.8

* Stability based on $\sigma\theta$ classification
** Stability inferred from solar insolation and wind speed as proposed by Turner.

Table 2.7-4
Atmospheric Stability (%)

	Unstable (A-C)	Neutral (D)	Stable (E-G)
Spring	6.70	16.20	77.09
Summer	5.89	14.78	79.32
Autumn	5.19	12.97	81.85
Winter	2.60	4.72	92.69
Annual	5.10	12.17	82.74

Table 2.7-5
Stability with Onshore NNE-S Winds (%)

	Unstable	Neutral	Stable
Spring	5.86	15.05	79.10
Summer	3.47	10.59	85.93
Autumn	3.74	7.91	88.34
Winter	4.20	5.06	90.74
Annual	4.32	9.65	86.03

Table 2.7-6
Stability with Offshore SSW-N Winds (%)

	Unstable	Neutral	Stable
Spring	7.06	17.77	75.17
Summer	7.28	17.93	74.79
Autumn	5.14	15.89	78.98
Winter	1.74	4.13	94.13
Annual	5.30	13.93	80.77

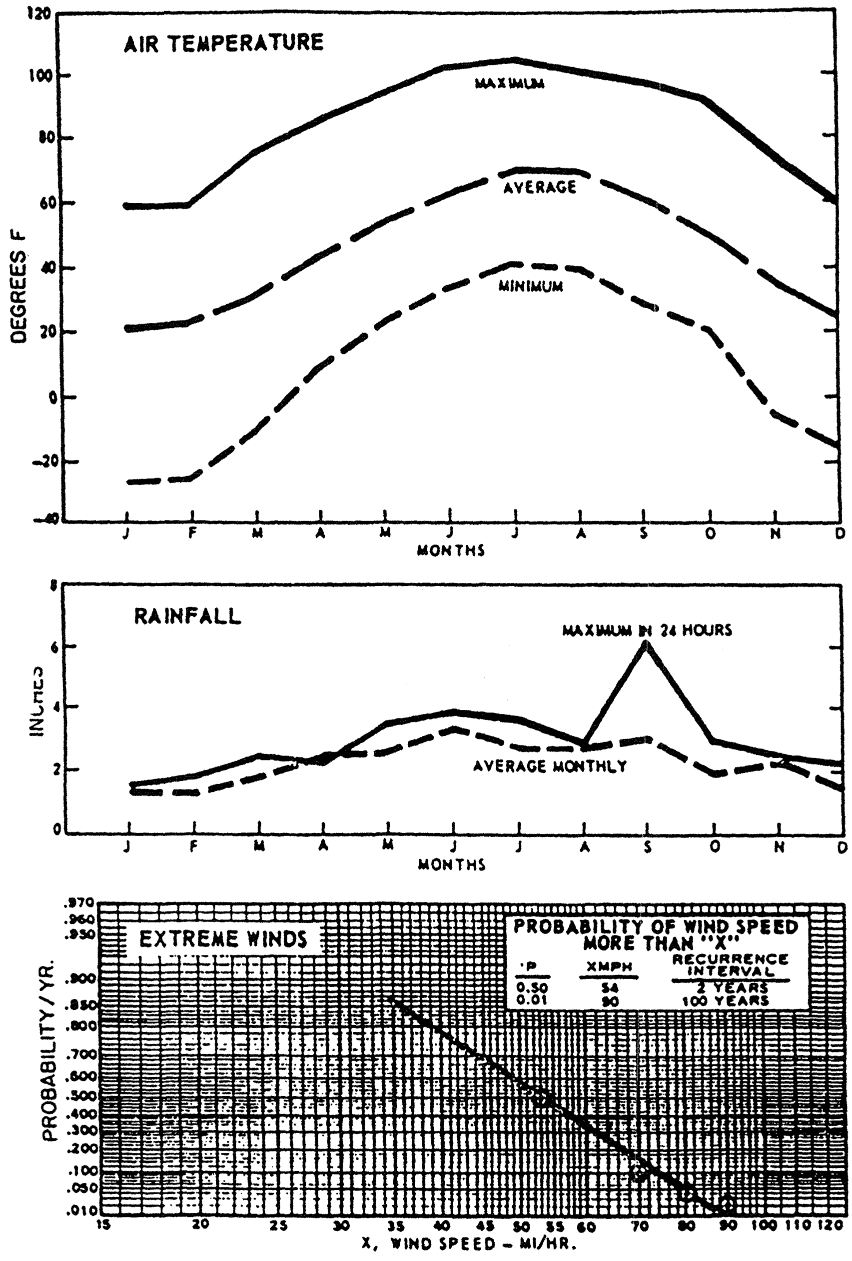
Table 2.7-7
Meteorological Model - Hypothetical Accident

Time period	Stability Class	Wind Speed (meters/sec)	F_i	f_i	Wind Conditions
0-2 hours	F	1.5	1.0	1.0	Invariant
2-24 hours	F	3.0	1.0	1.0	Sect. Avg.
1-2 days	E	4.0	0.5	1.0	Sect. Avg.
	F	4.0	0.5	1.0	Sect. Avg.
2-30 days	D	4.0	0.1	0.2	Sect. Avg.
	E	5.0	0.4	0.2	Sect. Avg.
	F	5.0	0.4	0.2	Sect. Avg.
	G	5.0	0.1	0.2	Sect. Avg.

Table 2.7-8
Site Dispersion Factors (χ/Q sec/m^3)

Distance meters	0-2 hours	2-24 hours	1-2 days	2-30 days
400	5.682E^{-4}	2.351E^{-4}	1.439E^{-4}	2.572E^{-5}
700	3.809E^{-4}	8.958E^{-5}	5.421E^{-5}	9.642E^{-6}
1000	2.724E^{-4}	4.907E^{-5}	2.921E^{-5}	5.217E^{-6}
1200	2.232E^{-4}	3.617E^{-5}	2.162E^{-5}	3.882E^{-6}
1609	1.568E^{-4}	2.214E^{-5}	1.331E^{-5}	2.412E-6
2000	1.182E^{-4}	1.539E^{-5}	9.229E^{-6}	1.696E^{-6}
4000	4.950E^{-5}	5.291E^{-6}	3.138E^{-6}	5.786E^{-7}
4800	3.977E^{-5}	4.100E^{-6}	2.427E^{-6}	4.473E^{-7}
7000	2.510E^{-5}	2.419E^{-6}	1.425E^{-6}	2.627E^{-7}
10,000	1.616E^{-5}	1.472E^{-6}	8.544E^{-7}	1.575E^{-7}
16,000	9.459E^{-6}	7.863E^{-7}	4.532E^{-7}	8.344E^{-8}
20,000	7.326E^{-6}	5.838E^{-7}	3.354E^{-7}	6.173E^{-8}
40,000	3.308E^{-6}	2.385E^{-7}	1.354E^{-7}	2.522E^{-8}

Figure 2.7-1 Climate of Kewaunee Site Region



* BASED ON DATA FROM KEWAUNEE AND MANITOWOC 1930 – 1969

Figure 2.7-2 Kewaunee Nuclear Power Plant Site
Average Wind Direction Roses (% Occurrence of Total Observations)

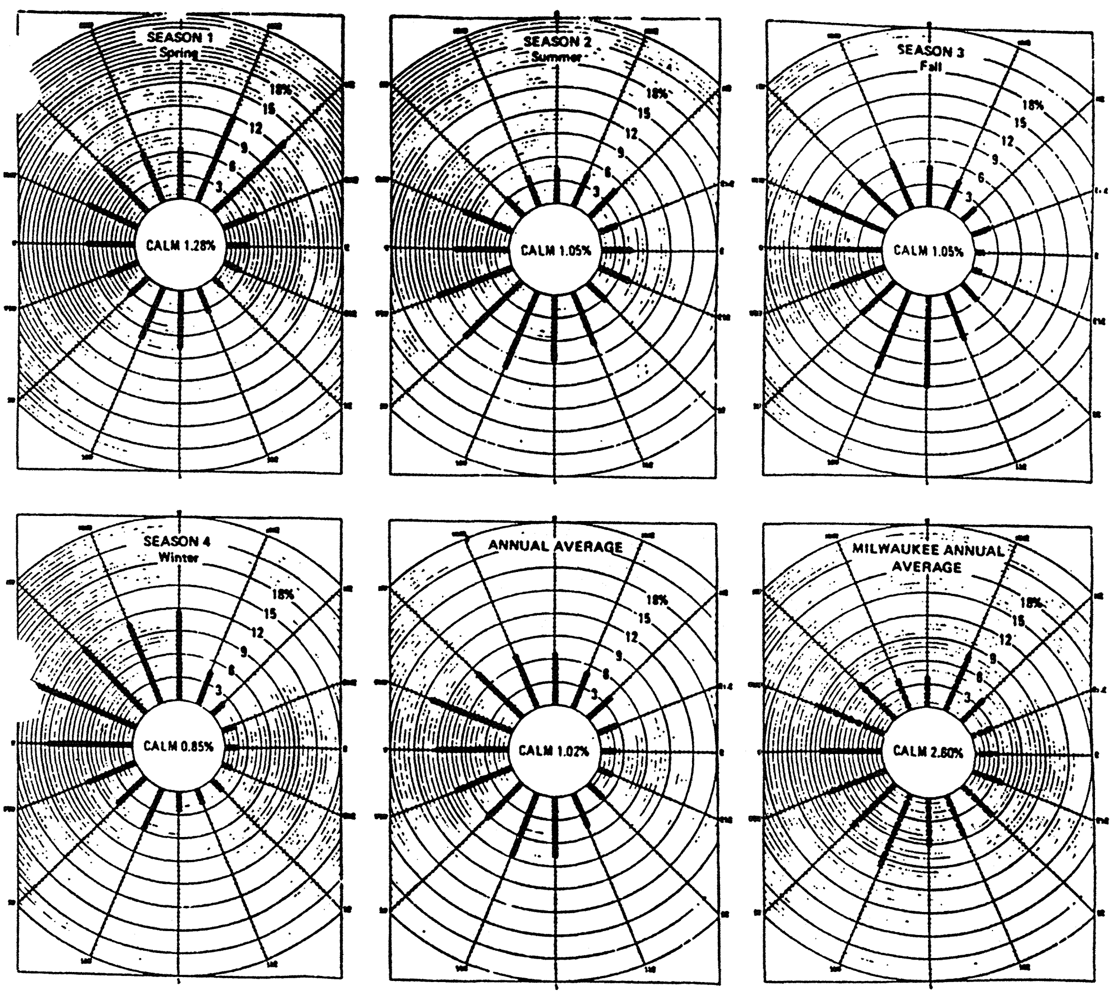


Figure 2.7-3 Kewaunee Wind Direction Persistence

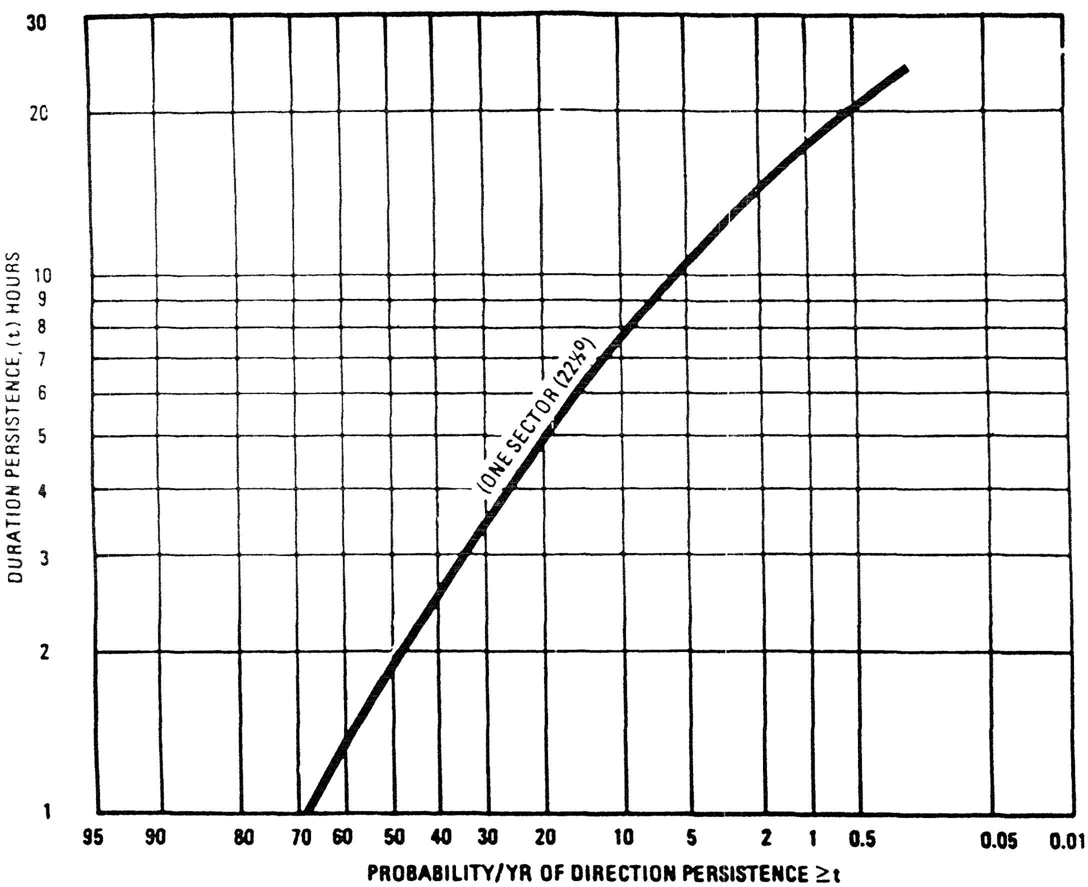
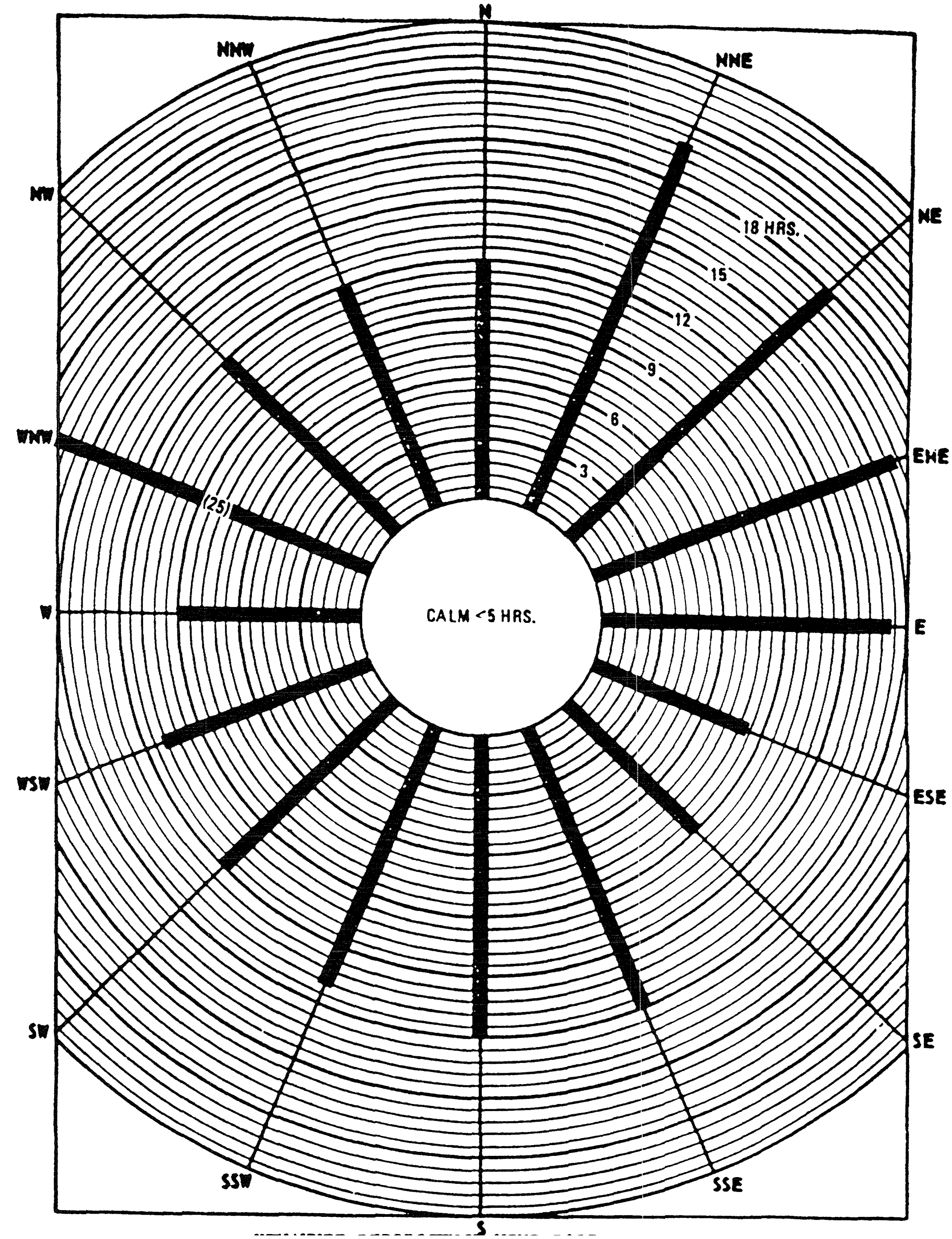


Figure 2.7-4 Kewaunee Persistence Wind Rose
(Max. No. of Hrs. Wind Blows in Each Direction)



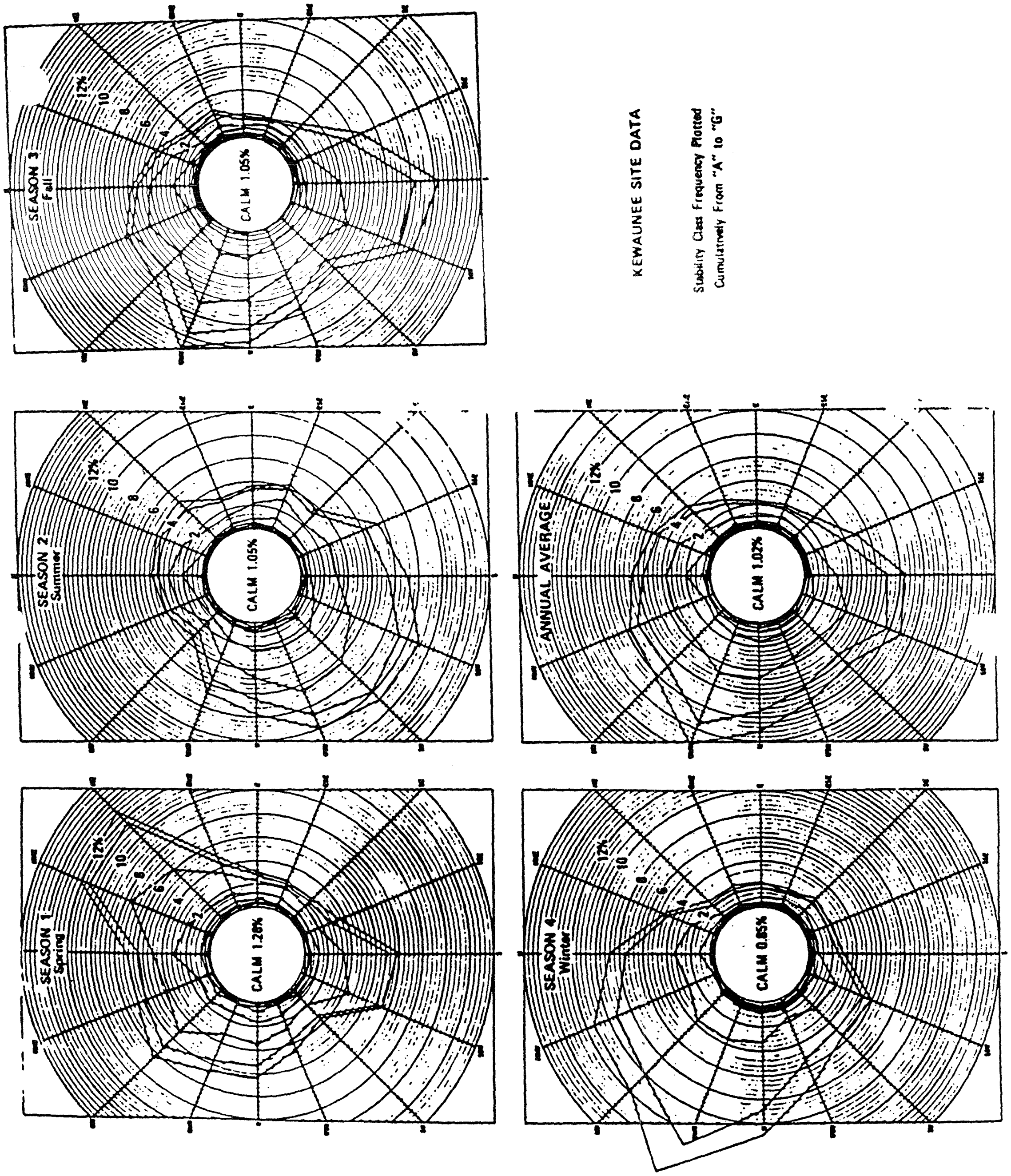


Figure 2.7-5 Stability Class Distribution in Percent of Total Observed

Figure 2.7-6 Annual Average Dispersion Isopleths

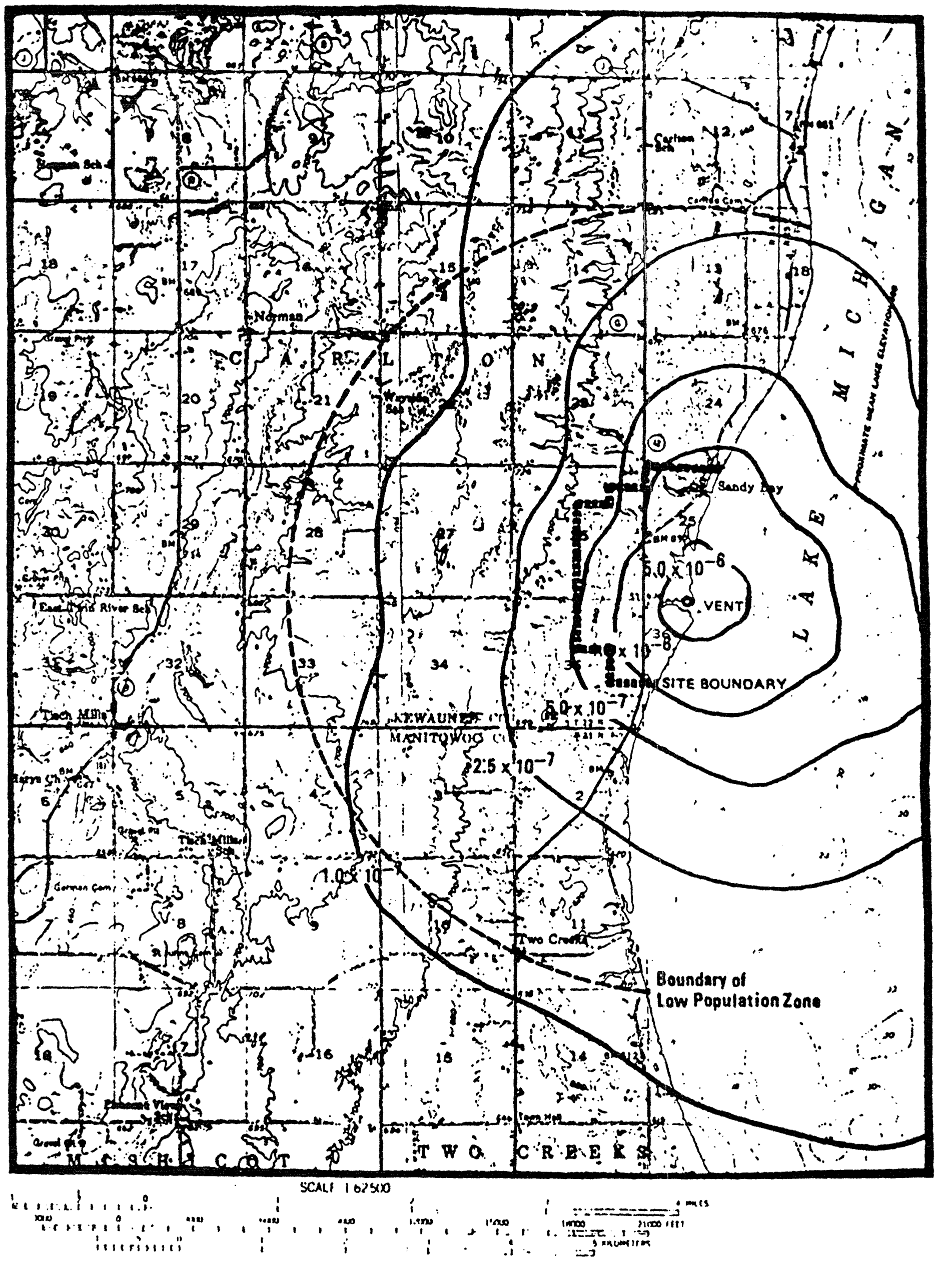


Figure 2.7-7 Two Hour Accident Meteorology

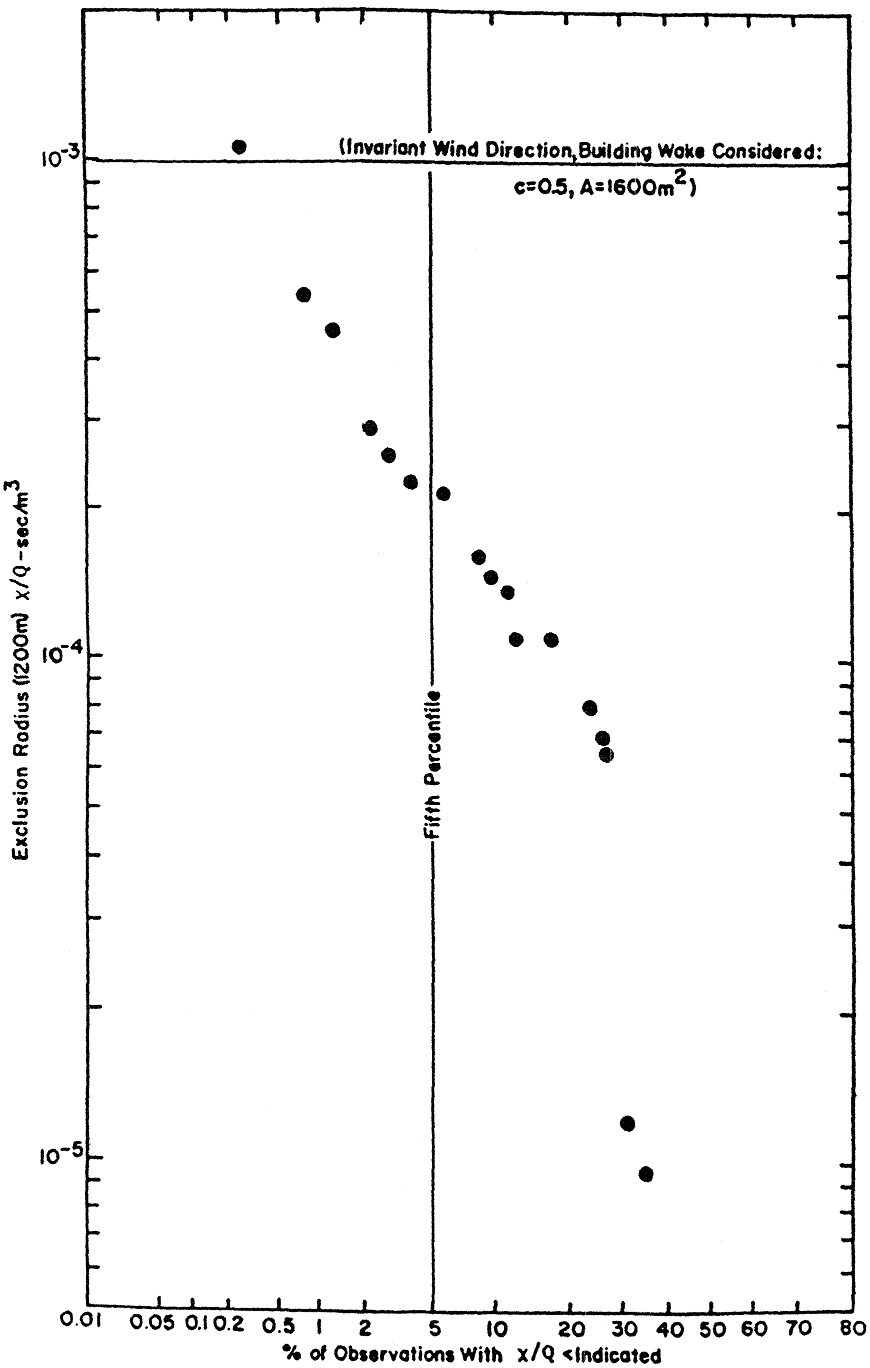
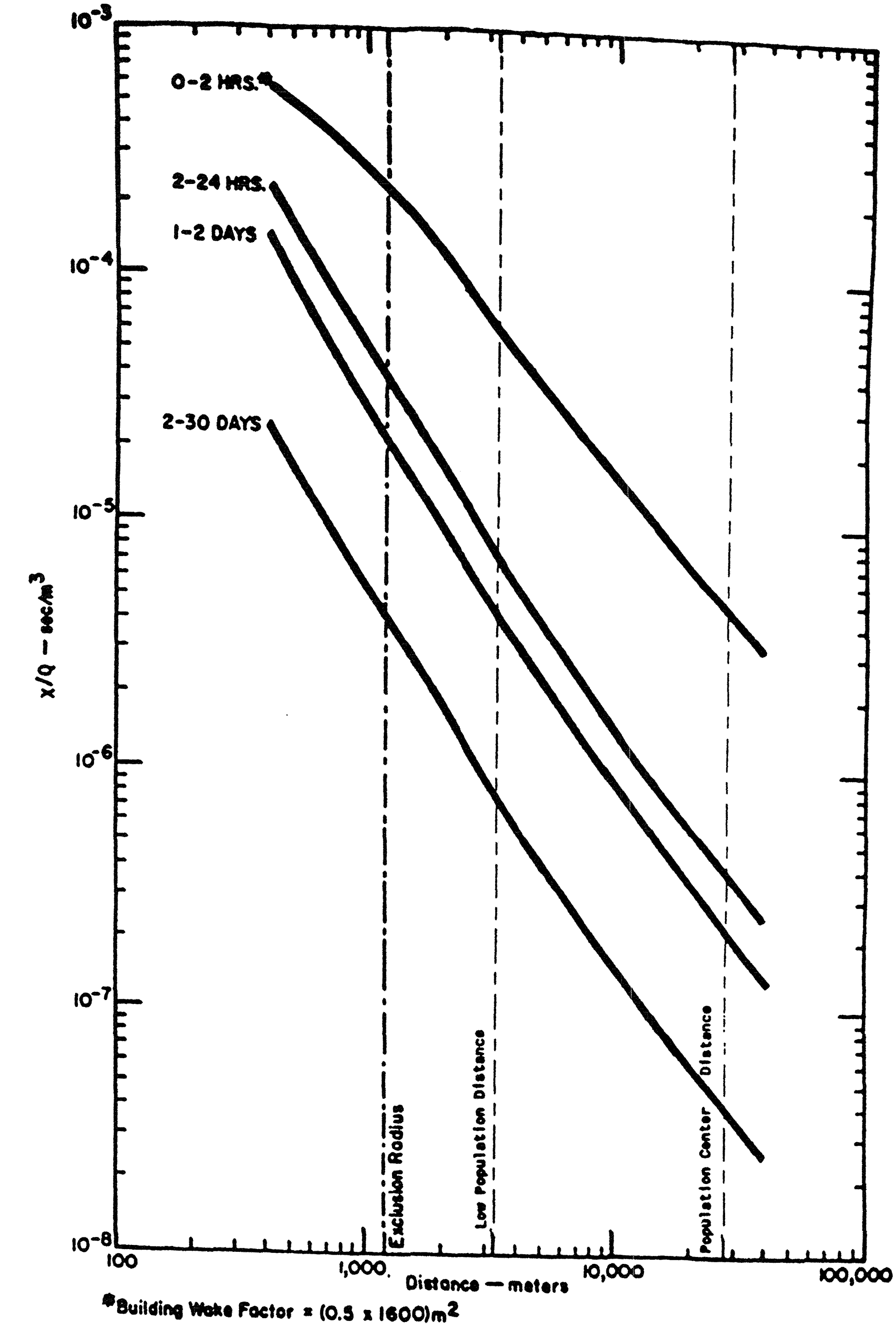


Figure 2.7-8 Kewaunee Accident Model



2.8 ENVIRONMENTAL RADIOACTIVITY PROGRAM

A pre-operational environmental radiological monitoring program was started at the Kewaunee site in September, 1969. Over four years of background data was available before plant startup. From this information it was possible to detect and evaluate changes resulting from plant operation.

The radiological effluent surveillance program was removed from Chapter 7 and Chapter 8 of the Kewaunee Nuclear Power Plant Technical Specifications, and is detailed in the ODCM.

The REMM defines the program for sampling the environment and determining the radiological effects of plant operation on the environment in areas up to and beyond the site boundary.

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2.9 GEOLOGY

A geological program involving a regional geological survey, borings and other tests at the site was completed to provide information needed to assess foundation conditions, seismic activity and ground water conditions. An investigation done by Dames and Moore is reported in detail in Appendix A.

Findings concerning ground water and seismology are described in Section 2.6.3, Section 2.10, and in Appendix A.

A further comprehensive program of subsurface explorations and laboratory testing at the plant site were made by Soils Testing Services of Wisconsin. Professor Ralph B. Peck of the University of Illinois was retained to analyze the resultant explorations and tests to ascertain a detailed stratigraphy of the glacial deposits, as described in Appendix A, and to evaluate the foundation conditions.

The results of the foundation studies are described in Appendix E and indicate that the site will provide adequate foundation for plant structures, with an ultimate bearing capacity of 9 tons per square foot for spread or mat foundations.

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2.10 SEISMOLOGY

The region within 100 miles of the site has experienced only minor-recorded earthquake activity during the last 175 to 200 years. The earthquake history is summarized in Table 2.10-1.

Additional studies have been made to evaluate the site for dynamic response criteria and to establish the design earthquake. These studies indicate that structures built on sound foundation materials at the site will not experience ground accelerations in excess of 0.06 of gravity. Results of the seismological investigation performed by Dames and Moore are reported in Appendix A.

Appendix A states that the power plant should be designed for a ground motion of 5 percent of gravity for the design earthquake, and 10 percent of gravity for the maximum credible earthquake. These values are outdate, as Plate 8-A of Appendix A correctly specifies the maximum horizontal design earthquake of 6 percent of gravity, and Plate 8-B specifies the maximum credible earthquake as 12 percent of gravity. Appendix A states that the power plant should be designed for a ground motion of 5 percent of gravity. Appendix A is an essentially verbatim copy of a report (Reference 23) provided by Dames & Moore in 1967, and should be considered historical information. Plate 8-A and Plate 8-B were revised in 1968. For additional information see Reference 24 and Reference 25.

Table 2.10-1
Regional Earthquake Occurrences

Date	Intensity (Modified Mercalli)	Locality	Epicenter Location N. Lat	Epicenter Location W. Long	Sq. Miles
Aug. 20, 1804	VI Felt in Wisconsin	Ft. Dearborn, Illinois	42.0	87.8	30,000
Aug. 31, 1886	IV Felt in Milwaukee	Charleston, S. Carolina	32.9	80.0	2,000,000
May 26, 1906	VIII Mine Collapse Probably not felt in Wisconsin	Keweenaw Peninsula, Michigan	47.3	88.4	1000
May 26, 1909	VII III at Kewaunee VI at Kenosha	N.E. Illinois	42.5	89.0	500,000
Jan. 2, 1912	VI I at Kewaunee	N.E. Illinois	41.5	88.5	40,000
Apr. 9, 1917	VI II at Madison	E. Missouri	38.1	90.6	200,000
Oct. 18, 1931	II	Madison, WI	NA	NA	NA
Dec. 6, 1933	IV	Stoughton to Putland, WI	NA	NA	NA
Nov. 1, 1935	VI Felt in Wisconsin	Timiskaming, Canada	46.8	79.1	1,000,000
Nov. 23, 1939	V III at Janesville, Wisconsin	S. Illinois	NA	NA	NA
Feb. 9, 1943	II	Thunder Mt., Marinette, Co., WI	NA	NA	NA
May 6, 1947	V	S.E. Wisc.			
Aug. 9, 1947	VI	S. Central MI	42.0	85.0	50,000
July 19, 1956	IV	Oostburg, WI Along Lakeshore	NA	NA	NA

Table 2.10-1
Regional Earthquake Occurrences

Date	Intensity (Modified Mercalli)	Locality	Epicenter Location		Sq. Miles
			N. Lat	W. Long	
Oct. 13, 1956	IV	Milwaukee -Racine, WI	NA	NA	NA
Nov. 9, 1968	VII	Southern IL	38.0	88.5	NA

NA - Not Available

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