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THORIUM RESIDUALS IN WEST CHICAGO, ILLINOIS

by

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Division of Environmental Impact Studies

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THORIUM RESIDUALS IN WEST CHICAGO, ILLINOIS

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Abstract

Lindsay and Company began operation of its West Chicago, Illinois, plant in 1931, processing thorium ores for thorium and rare earths. From that time until normal operations ceased in 1973, thorium residuals from the operation found their way offsite to Reed-Keppler City Park, the West Chicago Sewage Treatment Plant, and numerous other locations about the city and its environs. The present study located and identified such thorium residuals in the West Chicago area, a total of 75 epicenters having been found in addition to deposits at Reed-Keppler Park, the sewage-treatment plant, and down Kress Creek and the DuPage River. Deposits proved to be almost exclusively the dense, gray, insoluble particles of thorium-ore tailings from the process, which have been historically stored in two large piles in the site waste area. Epicenter locations and associated radiological parameters are given for the 75 locations, along with quantitative descriptions of the larger collections of material at the park, at the sewage-treatment plant, and on the banks of Kress Creek and the DuPage River. Not one of the areas of thorium residuals located outside security fences was found to violate the requirements of 10 CFR 20.

INTRODUCTION

GENERAL

In 1931 Lindsay and Company (which became Lindsay Light and Chemical Company in 1935) commenced operation of its West Chicago, Illinois, plant. This plant processed thorium ores, chiefly monazite, originally to extract thorium for gas mantles. In later years the rare-earth elements contained became of more value, and operation shifted so that the thorium component of the ore became more of a waste and less of a product. In the 1930s and 1940s some of these waste tailings were used in a landfill operation in an unimproved area of what is now Reed-Keppler Park, a public park in northern West Chicago. During that time waste material found its way out of the factory site and into various public and private areas around West Chicago. These included the watershed down Kress Creek into the DuPage River, the present West Chicago

Sewage Treatment Plant, and numerous other places about the city. The waste material so transported was almost exclusively thorium-ore residue from the chemical-extraction processes, a very dense, usually gray to white material, containing about 2%-6% thorium, along with its radioactive-decay products, but only relatively small amounts of uranium and associated uranium daughters. In 1973 all normal operations at the site had ceased, and the current owner, Kerr-McGee Corporation, applied to delicense and decommission the factory and its waste site. This activity began in 1974. The overwhelming bulk of radioactive material was contained in two large open piles in the waste area to the south of the factory, and it became a matter of concern to locate thorium residuals offsite, to control them as needed, and to plan for their eventual removal. The first phase was to secure the relatively large amount of material present in the unimproved area of the park (the "spoil area") and the much smaller amount on the east side of the tennis courts nearby. The latter was exhumed to the spoil area in July 1976, and the entire area was enclosed with a security fence in the spring of 1977. Once that was done, it became our task to locate and quantify the remaining thorium residuals in the West Chicago area.

THE EXTERNAL NATURAL-RADIATION BACKGROUND IN THE WEST CHICAGO AREA

The external natural-radiation background in this area varies from 12 to 36 μR/hr, with about 95% of the values ranging between 14 and 25 μR/hr. This includes both cosmic and terrestrial components. The lower values are generally found over roadways, where shielding is effected by the roadbed. The higher values are generally found over open grassy fields, especially if they have been fertilized with phosphate fertilizers, as is often the case in this area. The highest values are obtained over these same fields in the early morning, whenever meteorological inversion occurs in such a way as to trap natural-soil radon close to the earth surface. The distribution of values was such that values in excess of 20 μR/hr near roadways, or in excess of 25 μR/hr on open fields, were taken as presumptive evidence of the presence of thorium residuals. Such areas were further investigated by spectrometry to determine the presence of excess thorium, if any.

NATURAL RADIOACTIVITY IN THE WEST CHICAGO AREA

These values are relatively high for Illinois as a consequence of several factors. The soil in the West Chicago area is considerably higher in uranium, thorium, and their daughters than many other soils in Illinois. Phosphate fertilization has been common in the past and both the originally fertilized fields, and adjacent fields subject to runoff, have had their uranium-daughter content increased as a consequence. In addition, the city wells of West Chicago, and a number of other wells in the area, tap water from deep sandstone aquifers notable for their high natural radioactivity. As these waters were brought to the surface over the years, and evaporated, they left behind them a notable residue of radioactivity.

THE FACTORY AND WASTE AREA

The primary source of excess thorium is the pair of large tailings piles in the waste area to the south of the factory. This material is so dense, and so thoroughly concreted by weathering, that we were unable to find any evidence of it having been transported offsite by atmospheric dispersion. However, a good deal of the material in waste pond No. 1 had been of a much more easily airborne nature, and some of this was detected in areas immediately adjacent to the site. In the process of transporting material about the city, between the factory and the waste area, and to such sites as Reed-Keppler Park, other thorium-bearing material found its way from the site into various parts of the city. In such cases the transport was purely mechanical. Additionally, the open nature of the piles of thorium-bearing waste made them particularly subject to runoff, especially during heavy rains. Such material, along with factory waste, found its way into the storm sewer along one edge of the property, across the fields, and down into the Kress Creek watershed. The material is so dense, and so insoluble, that it was transported purely as grains of sand-like material, and these grains were found and identified down along the watershed. These grains move by placer action, and their deposition is characteristic of placer movement, as has been noted in similar situations.[1] We were able to map material transported in this way all down the creek, and then, sparingly, along the DuPage River as far south as Warrenville. However, movement by this method is very slow, and in the 47 years since the beginning of plant operation the overwhelming bulk of material carried by this process had moved only about a third of the way down the creek to the river. A foot-by-foot survey was made of both banks of the creek from above the storm-sewer entrance to the junction with the DuPage River. Below that point, material was so sparsely deposited that only a general survey was made, and only outstanding deposits were identified and confirmed.

REED-KEPPLER PARK AND THE WEST CHICAGO SANITARY TREATMENT PLANT

During the first two decades of plant operation the excellent mechanical properties of the thorium-bearing residue commended its use as landfill in the area. There was no recognition of any potential hazard associated with it, and it was used as landfill at the edge of what was to become Reed-Keppler Park and, to a lesser extent, at the present waste-treatment plant. A minor deposit at the park, east of and adjacent to the present tennis courts, was exhumed in July 1976 and consolidated with the larger amount in the spoil area, next to which a sanitary landfill is in operation. In early 1977 a security fence was installed around the spoil area. The fence was placed at the 0.2-mrad/hr isodose line.

Because of uncertainty as to just what parts of the park had been filled, and at what time, we performed a foot-by-foot survey of the entire park. To date no thorium residuals have been found outside of what little remains below the present tennis courts, the spoil area behind the fence, and some minor areas in the sanitary landfill.

At the waste-treatment plant the bulk of the material is contained in two relatively circumscribed regions. The possibility existed that thorium residuals had found their way into the sewage system by way of the combined sewer system of West Chicago. However, to date we have been unable to identify any thorium exiting from the treatment plant, either in its effluent or in its sludge. A report that its sludge was contaminated by thorium from the site proved to be untrue. The sludge was, in fact, somewhat abnormally radioactive. However, quantitative spectrometry showed that this was simply the result of concentration of the naturally quite radioactive West Chicago well water in the sludge-drying ponds.

WEST CHICAGO AND ENVIRONS

Partly through the normal traffic associated with plant operations, but more notably through the traffic associated with use of thorium residue as landfill, small deposits can be found in many parts of the city and its environs. Overwhelmingly, these lie in an area connecting the factory and waste area on the south with Reed-Keppler Park on the north. In order to identify and quantify these, we performed a street-by-street survey with instrumented vehicles and, where appropriate, on foot. In addition, clues were obtained by extensive conversations with residents, with employees of the City of West Chicago and of the Lindsay Chemical Company, and with contractors and landfill operators in the area. Some residual deposits were also discovered by deduction, e.g. if small spills seemed to constitute a probable truck route, it could be deduced that a final deposit could probably be found at the end of the route so defined.

This process was also greatly aided by an Aerial Radiological Monitoring Survey (ARMS) flyover that was completed in September 1977. Although the flyover could not identify with certainty small local deposits of thorium residuals, it clearly outlined areas of suspicion, and aided greatly in reducing the area requiring intensive scanning by vehicle or on foot. It also provided an excellent basis for determining the contours and levels of X and gamma radiation emanating from the three major sources: the factory and waste site, Reed-Keppler Park, and the sanitary treatment plant. This radiation is referred to as "skyshine" because it contains both direct and scattered components.

METHODS AND OBSERVATIONS

STUDY AREA

The study area chosen was defined on the DuPage County grid system. It extended from 4S000 on the south to 4N000 on the north, a distance of eight miles, and from 28W000 on the east to 32W000 on the west, a distance of four miles, for a total area of 32 mi^2. The study period began in March 1976 and extended through May 1978. Places are identified by street name and address, using the West Chicago numbering system within the city limits and the county numbering system outside. Addresses do not necessarily correspond to a residence, because in many cases locations were in unused fields, alleys, and the like. But they do represent an absolute location on either the West Chicago or county grid system. The study area, and its numbering, is shown in Figure 1. Because they are subjects of a separate action, the factory, the

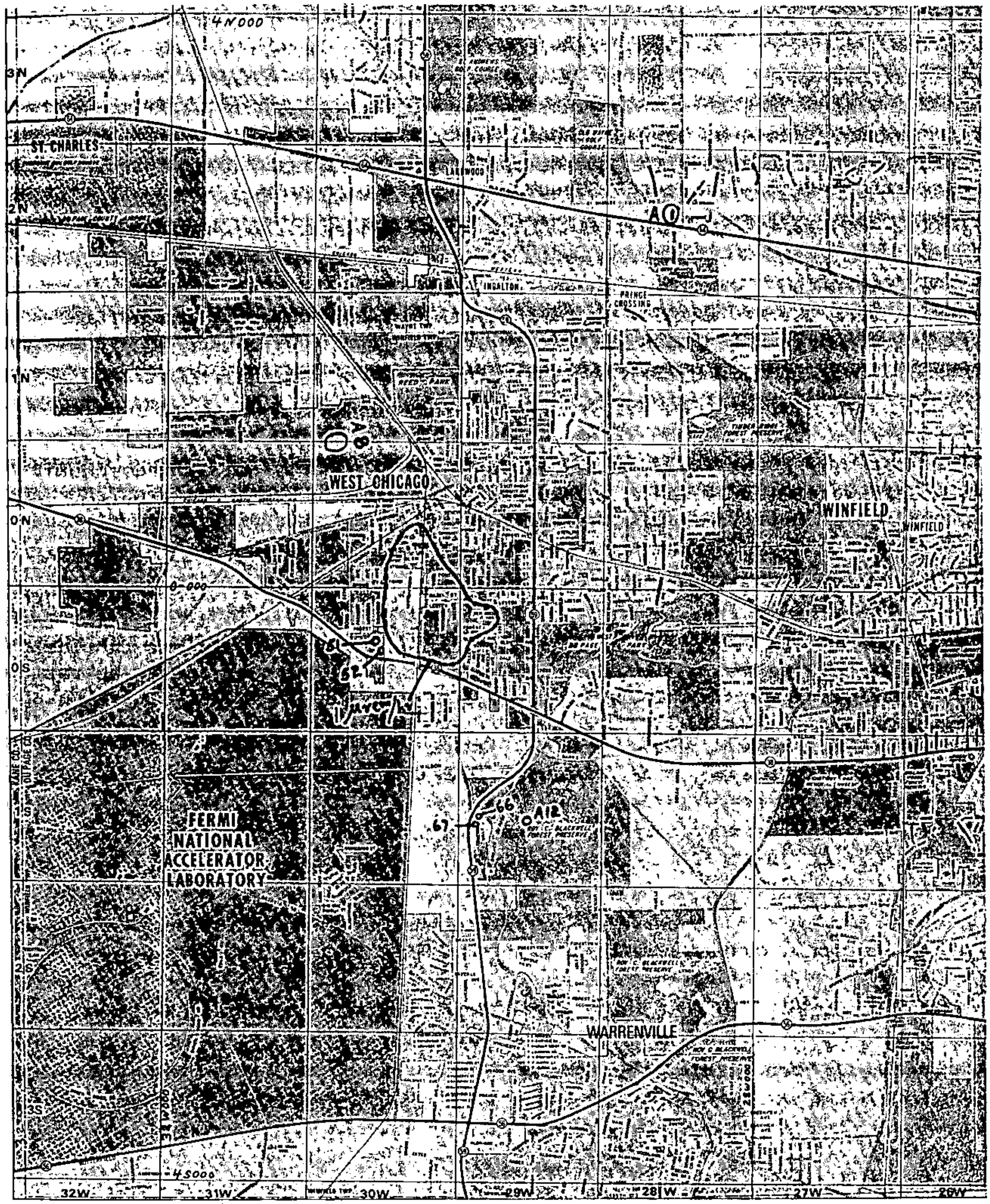

Fig. 1. The Study Area.

waste area, and the right-of-way connecting them have been excluded from this study.

THE ARMS FLYOVER

This survey was completed by October 1977, and the results are being issued as a separate report.[2] Thus, only salient features are covered here. Two radiation-field maps were produced. The first was a map of the total terrestrial fields in the area. This showed that the natural background in this area contributed by the terrestrial component varied by a factor of about six, i.e. about 2-13 μR/hr. The second was a map intended to delineate areas of excess thorium. This was produced by extracting the ratio of counts observed from the thorium daughter ^{208}Tl at 2614 keV to those from natural-soil ^{40}K at 1462 keV. Areas with ratios higher than those found in areas known to be free of excess thorium were presented in the form of excess-exposure-rate contours.

On the latter map the factory and waste areas, the fenced area at Reed-Keppler Park, and the sewage-treatment plant were clearly delineated. Their epicenters were clearly and accurately located, and successive exposure contours were clearly evident out to the point where exposure contours matched those of the surrounding natural terrestrial background. But, in addition, some 17 additional areas were noted that were otherwise not detectable, or at least not clearly so, on the general-exposure presentation. Also in evidence was a collection of fields associated with deposits along Kress Creek and into the DuPage River. The detached areas did not necessarily represent thorium residuals from the plant site, because they were simply areas where the ratio was higher than statistical expectation. However, they certainly represented areas of suspicion, and each of these was investigated further on the ground. In addition to these separated and delineated areas, an additional group of areas was identified from distortions in the contours associated with Kress Creek, the plant site, and Reed-Keppler Park. Thus, if there had been no thorium-bearing areas beyond a single epicenter in each of these areas, the surrounding field-gradient contours would have been perfectly symmetrical. This was the case around the sewage-treatment plant, for example. On the other hand, at Reed-Keppler Park a distortion was observed in the outermost contour, and this later proved to be due to thorium-residual area No. 49. Similar distorted contours along Kress Creek were identified with thorium-residual area Nos. 15 through 22 in the Joy Street subdivision, through which Kress Creek flows. These detached contours, and contour distortions, served to focus the efforts of the ground survey, and at least one thorium-residual epicenter was located to correspond to each of these flyover field indications with the exception of three. These three are indicated as A1, A8, and A12 on Figure 1. In spite of repeated, and intensive, ground surveys these three areas have failed to indicate any evidence of thorium residual.

In spite of its extraordinary utility, the aerial survey proved to have several limitations for this study. For example, the airborne instruments are at an altitude of 500 feet. Thus, the softer X-ray and gamma-ray components are filtered out by the air intervening between the ground and the instruments. This shielding is equivalent to about 18 cm of water and, although corrections can be made, the corrections themselves depend on a knowledge of the spectrum at the surface. As a consequence we have found that the total exposure rate determined by flyover is generally less than that determined for the same point on the ground. At the same time, a relatively small source on the ground creates a three-dimensional dose contour that produces the effect of viewing an inverted cone. In consequence, exposure-rate contours determined from the air are noticeably broader than the same contours observed on the ground. This results from essentially a cylindrical projection, from 500 feet, of exposure contours that have a more conical relationship. In addition, exposure contours determined on the ground include side-scatter from buildings, trees, and the like, whereas the sources themselves are shielded from direct aerial observation by these very same obstructions.

The wide field of view from the air, although permitting the extraordinary utility inherent in this method, also occasions some further limitations. The exposure rate determined by aerial survey is generally based on the source size being of the order of a thousand feet in diameter or more. To the extent that the source is smaller than that, the exposure rate will be higher. For this particular study, aerial-survey exposure rates were calculated for various hypothetical diameters down to 200 feet.[2] Although this was of some help in reconciling ground and air results, the fact was that many of the sources were very much smaller than 200 feet in diameter, and some of the most notable epicenters were only of the order of a few inches on a side. As a consequence the exposure rate measured on the ground was very much higher than what might have been deduced from the aerial results. Also, the aerial detectors report a kind of vector summation of photons arriving from various directions. In the case of relatively uniform fields, or of very intense single-point sources, this does not effect the reported location of the field or source. This was notably the case for the large natural-background fields delineated on the total-exposure-rate map, and for the relatively intense point sources represented by the sewage-treatment plant, the pile at Reed-Keppler Park, and the two piles in the factory waste area. However, between this vectorial effect and the side shielding provided by local ground contour and buildings, the location of multiple point sources was almost necessarily subject to considerable distortion. The peculiar mixture of small thorium-residual sources in all sorts of locations, and grouped in what must be called bizarre patterns at best, produced considerable displacement between the finally determined location of the epicenter on the ground and the apparent location as shown on the excess-thorium map. This displacement was often of the order of several hundred feet, and in at least one case three separate point sources on the ground gave rise to a single detached contour about midway between them. Finally, the use of ^{40}K as a reference for the determination of excess thorium meant that this method was necessarily subject to local soil-potassium content. The three detached contours for which we were unable to find corresponding thorium epicenters were all located in the center of broad fields whose potassium content, on spectrometric examination, proved to be relatively low. Thus it is quite possible that these three areas actually represent areas of potassium depletion rather than of excess thorium.

SURVEY METHODS

A battery of sodium-iodide crystals made up the primary instrumentation for detection of thorium-residual areas. Two-by-two-, three-by-three-, and four-by-four-inch high-resolution crystals were used in conjunction with a portable six-channel analyzer for onfoot surveys. A large eight-by-eight scintillator and a pair of high-resolution four-by-four scintillators, arranged in coincidence, tandem, or anticoincidence, were employed with multichannel analyzers for vehicular surveys. For the majority of vehicular surveys a large van was used that permitted the location of these scintillators at heights of 0.5, 1.0, and 3.0 m above the ground. For many off-the-road areas where it was difficult or impossible to manage this larger vehicle, especially in mud or snow, a small personal automobile was utilized instead. These scintillators served both to detect thorium-residual areas at a distance and to determine their spectrum once found. In addition, samples were taken with coring instruments and returned to Argonne National Laboratory for quantitative spectrometry using high-resolution GeLi detectors. Exposure rates and dose rates were both determined with ion chambers calibrated against NBS and New Brunswick Laboratory (NBL) standards. Exposure rates were taken in free air, whereas dose rates were taken at the standard one-meter gonadal position in a human phantom carried along in the van for that purpose. All instruments were periodically calibrated against NBS or NBL standards.

OBSERVATIONS

Thorium-residual areas proved to be of several types. In all cases but one, however, the material bearing the thorium proved to be the dense, granular material characteristic of the tailings piles in the factory waste area. Although this was by no means always evident on gross examination, it always proved to be the case on subsequent microscopic and radioautographic examination of samples. The sole exception was the material at the rear of 189 Washington Street, a one-time thorium laboratory. Much of this material appeared to be attached firmly to grains of the local soil, and probably represented material that had once been soluble, but had been precipitated by soil action.

The material along Kress Creek and the DuPage River was almost a classic example of placer deposition. No excess soluble thorium was ever detected in the waters of either the creek or the river. But thorium deposits were found on the bottom and along the banks in what appeared, at first, to be a most erratic manner. In fact, the heavier deposits proved to be associated with rapid changes of stream velocity or direction, in the manner characteristic of placer deposition. Considering the high density and extremely insoluble nature of the material, this was precisely what might have been expected.

The most common areas found on land were very clearly the result of material bouncing or jiggling from trucks in the process of transport. There would be a small intense epicenter, almost invariably at the side of a road, and quite commonly at a corner. Surrounding this would be a larger area of much-reduced activity which was clearly the result of weathering and of disturbance of the original epicenter by subsequent traffic. This was, by all odds, the most common type of area found on land.

Another fairly common type of area was characterized by a relatively uniform distribution of thorium in fertile black soil, generally forming part of a lawn or garden, and quite sharply delineated. In this case there might be one or several epicenters, but the difference in activity between epicenter and surrounding soil was only of the order of a factor of three or four. Our best guess for this type of area was that it was formed when soil was delivered by a truck that had previously been used to carry thorium-bearing material. Trucks are seldom scrubbed out between loads of fill, and the residuum from one load would tend to mix into the next one. This was consistent with the fact that the material found in these locations contained the invariant thorium-waste particles, but at an overall concentration of the order of 1%. Thus, this relatively constant dilution by a factor of the order of 100 suggested some such mechanism as that described above.

A few areas were found in which thorium waste had obviously been used as fill. These were generally beneath driveways, sidewalks, and garage foundations or floors. Although epicenters existed, probably as a result of the way in which the fill had been loaded, the distribution of material was relatively uniform and relatively sharply demarcated. However, these very same areas were often accompanied by truck-spill areas of the sort described above. In fact, we came to associate truck-spill areas along roadways with a path of delivery, and continued to search that path until we almost invariably found the fill area at its terminus. Some other types of areas were also noted, but these will be discussed below along with the special considerations that they raised.

RESULTS

To date, 75 thorium-residual areas have been identified and quantified, and these are described in Table 1. The table gives the area by number, the map figure on which it may be located, its address locator, and a short description of its type and setting (see Figs. 2 through 6). Also given is the maximum exposure rate determined on the surface at the epicenter. This is given for reasons of convenience in later relocating the epicenter, and bears only an indirect relationship to the dose rate. The dose rate at one meter above the epicenter is given in the next column. The total surface area covered by detectable residual is given in the following column. In general this is much larger than the area of the epicenter itself; the majority of epicenters were typically of the order of 1-2 ft^2.

Occupancy factors were determined by observation of these areas over a period of two years and by conversations with local residents, officials, and police. Without exception, epicenters were outdoors, so that prolonged occupancy was inhibited simply by the relatively high fraction of inclement weather in this area. In addition, epicenters where maximum dose rate occurred were generally quite small, of the order of one or two feet square. Thus, in order to remain within that field it would be necessary to remain fixed, and that required a situation where sitting was possible. For most of these epicenters not only was sitting impossible, but essentially standing as well. Many of them were at the edge or near the center of active roadways, and represented quite hazardous locations from the standpoint of traffic. Many others were clearly inhospitable, and anyone attempting to stand there any

Table 1. Thorium-Residual Areas in West Chicago, and Characteristics[a]

Area No.	Map Fig	Locator	Description	Max Surface Exposure (μR/hr)	Max Dose Rate (μrem/hr)	Residual Surface (ft^2)	Effective Occupancy (hr/yr)	Max Annual Dose (mrem)
1	2	849 Weyrauch	Center of gravel roadway	1 200	400	15	10	4.0E+00
2	2	710-847 Weyrauch	Multiple epicenters along gravel road	500	300	15 000	50	1.5E+01
3	2	Weyrauch & Brown	SE corner, edge of gravel roadway	300	200	80	10	2.0E+00
4	2	Weyrauch & Brown	Lawns on all 4 corners	50	30	2 000	200	6.0E+00
5	2	800 Weyrauch	Grassy field along N K-M fence	70	50	70 000	50	2.5E+00
6	2	Factory & Blair	Black gravel parking lot	3 500	900	400	20	1.8E+01
7	2	625 Factory	Center of gravel alley	400	200	300	30	6.0E+00
8	2	575 Wood	Entrance to gravel alley	100	30	70	30	9.0E-01
9	2	Joliet & Forest	NE corner, N along E side of Joliet	30	20	120	10	2.0E-01
10	2	Joliet & Forest	Opposite Forest, along W side of Joliet	30	15	300	10	1.5E-01
11	2	Joliet & Hazel	Lawn on SE corner	50	20	60	30	6.0E-01
12	2	Joliet & Hazel	NW corner, W along N side of Hazel	50	25	200	10	2.5E-01
13	2	Joliet & Lester	SW corner, both sides	30	15	140	10	1.5E-01
14	4	Hazel & Bishop	Rear lawn of Jr. High School	20	9	200	50	4.5E-01
15	3	0S551 Joliet	Construction-equipment area	10	4	20 000	500	2.0E+00
16	3	0S551 Joliet	E third of S driveway into equipment area	120	110	2 400	20	2.2E+00
17	3	1556 Joliet	Lawn, W half	50	17	200	50	8.5E-01
18	3	55 Joy	Front lawn, at NW corner of house	300	200	50	50	1.0E+01
19	3	35 Joy	Driveway	50	20	100	20	4.0E-01
20	3	Melolane & Joy	Center of blacktop roadway, & all corners	20	8	600	20	1.6E-01
21	3	478 Melolane	Front lawn, N half	100	40	45	50	2.0E+00
22	3	May & Gunness	Lawn on SW corner	15	4	100	50	2.0E-01
23	5	29W281 Lester	N edge of gravel roadway	50	12	20	10	1.2E-01
24	5	0N125 Lester	Center of gravel roadway	25	7	60	10	7.0E-02
25	5	28W739 Lester	S edge of gravel roadway	45	10	30	20	2.0E-01
26	5	Sunset & Forest	S half of block, both sides gravel roadway	50	35	1 200	50	1.8E+00
27	5	29W054 Blair	N edge of blacktop roadway	25	17	400	10	1.7E-01
28	5	Blair & Prince Crs.	Edge of blacktop, SW corner	15	8	400	10	8.0E-02
29	5	320 Easton	Driveway, sidewalk, & part of lawn to S	300	70	200	30	2.1E+00
30	2	454 Church	E side, gravel alley, at rear	500	55	25	20	1.1E+00
31	2	Pearl at George	S edge gravel roadway	500	200	70	10	2.0E+00
32	2	461 Ann	W edge gravel alley, rear of house	400	180	55	20	3.6E+00
33	2	323 Ann	Garage foundation & alley wall	250	200	100	50	1.0E+01
34	2	323 Ann	Across alley from above	50	30	200	20	6.0E-01
35	2	271 Ann	Alley at rear of house	50	25	300	20	5.0E-01
36	6	121 Sophia	Front lawn, cellar wall, part sidelawns	200	100	200	100	1.0E+01
37	6	189 Washington	Loading-dock area	150	100	20	200	2.0E+01
38	6	189 Washington	Below raised tank at rear of yard	200	100	8	20	2.0E+00
39	6	189 Washington	Rear loading yard	50	40	6 000	200	8.0E+00
40	6	201 Washington	Rear yard, beneath largest tree	200	70	10	20	1.4E+00
41	6	207 Washington	Rear driveway & nearby lawn	200	100	40	20	2.0E+00
42	6	207 Washington	Front & side yard	50	30	800	30	9.0E-01
43	6	Washington & Fremont	Brick roadway, just W of light	15	8	1 000	20	1.6E-01
44	6	Geneva Iron Works	Scrapyard at end McConnell	80	60	250	30	1.8E+00
45	6	Geneva Iron Works	Scrapyard, below extension York	80	60	300	30	1.8E+00
46	6	160 York	Rear yard at NW corner	50	15	30	10	1.5E-01
47	6	213 Main	Alley at rear of building	500	100	2	10	1.0E+00
48	6	Fremont & York	Lawn at NW corner	100	50	60	30	1.5E+00
49	6	NW end Fremont	E sidewalk, Elmwood to National	200	60	3 500	100	6.0E+00
50	6	536 Fremont	Gravel edge of roadway	25	15	500	20	3.0E-01
51	1	603 Roosevelt	Scrapyard, NW brick pile	25	20	200	20	4.0E-01
52	1	603 Roosevelt	Scrapyard, center brick pile	15	9	300	20	1.8E-01
53	2	Blair & Sherman	NE corner	400	200	20	20	4.0E+00
54	2	318 Blair	Driveway & sidewalk at edge of road	100	45	20	20	9.0E-01
55	4	Barber & Stimmel	Garage at rear, & alleyway	200	70	400	50	3.5E+00
56	2	180 Blair	Alley at rear	50	20	3	10	2.0E-01
57	2	150 Blair	Alleyway, north half	25	8	300	20	1.6E-01
58	4	215 Stimmel	Alley & 2 garages	300	50	400	50	2.5E+00
59	4	205-231 Parker	Gravel edge of roadway	15	6	1 200	30	1.8E-01
60	4	236 Parker	Central third of driveway	100	45	180	20	9.0E-01
61	4	149 Spencer	N half of alleyway	11	7	250	20	1.4E-01
62	2	S end Allen	NE corner of Allen & alley	16	10	50	10	1.0E-01
63	2	180 Spencer	S end of alleyway	18	15	50	10	1.5E-01
64	4	904 Gates	Gravel edge of roadway	25	18	70	20	3.6E-01
65	4	908 Gates	Rear lawn	20	12	140	30	3.6E-01
66	1	1S261 Edgewood	Mailbox at gravel edge of roadway	11	4	7	20	8.0E-02
67	1	1S310 Edgewood	Newspaper box at gravel edge of roadway	9	4	15	20	8.0E-02
68	2	675 Factory	W end of alley	100	50	100	30	1.5E+00
69	2	575 Weyrauch	E side, alley entrance	25	17	30	10	1.7E-01
70	2	575 Factory	Multiple epicenters along alley	80	50	200	30	1.5E+00
71	2	525 Factory	Multiple epicenters along alley	70	40	300	30	1.2E+00
72	2	Factory & Ann	W & S edges of parking lot on SE corner	100	55	200	10	5.5E-01
73	2	525 Sherman	Alley entrance	25	15	40	20	3.0E-01
74	4	215 Brown	Alley at rear	50	20	225	10	2.0E-01
75	2	500-700 Factory	E side, lawns & lots, multiple	40	20	2 000	200	4.0E+00

[a] *External natural-radiation background in West Chicago is 12-36 μR/hr (95% of values range from 14-25 μR/hr).*

.cs[a]

Max Annual Dose (mrem)
4.0E+00
1.5E+01
2.0E+00
6.0E+00
2.5E+00
1.8E+01
6.0E+00
9.0E-01
2.0E-01
1.5E-01
6.0E-01
2.5E-01
1.5E-01
4.5E-01
2.0E+00
2.2E+00
8.5E-01
1.0E+01
4.0E-01
1.6E-01
2.0E+00
2.0E-01
1.2E-01
7.0E-02
2.0E-01
1.8E+00
1.7E-01
8.0E-02
2.1E+00
1.1E+00
2.0E+00
3.6E+00
1.0E+01
6.0E-01
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1.4E+00
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4.0E+00

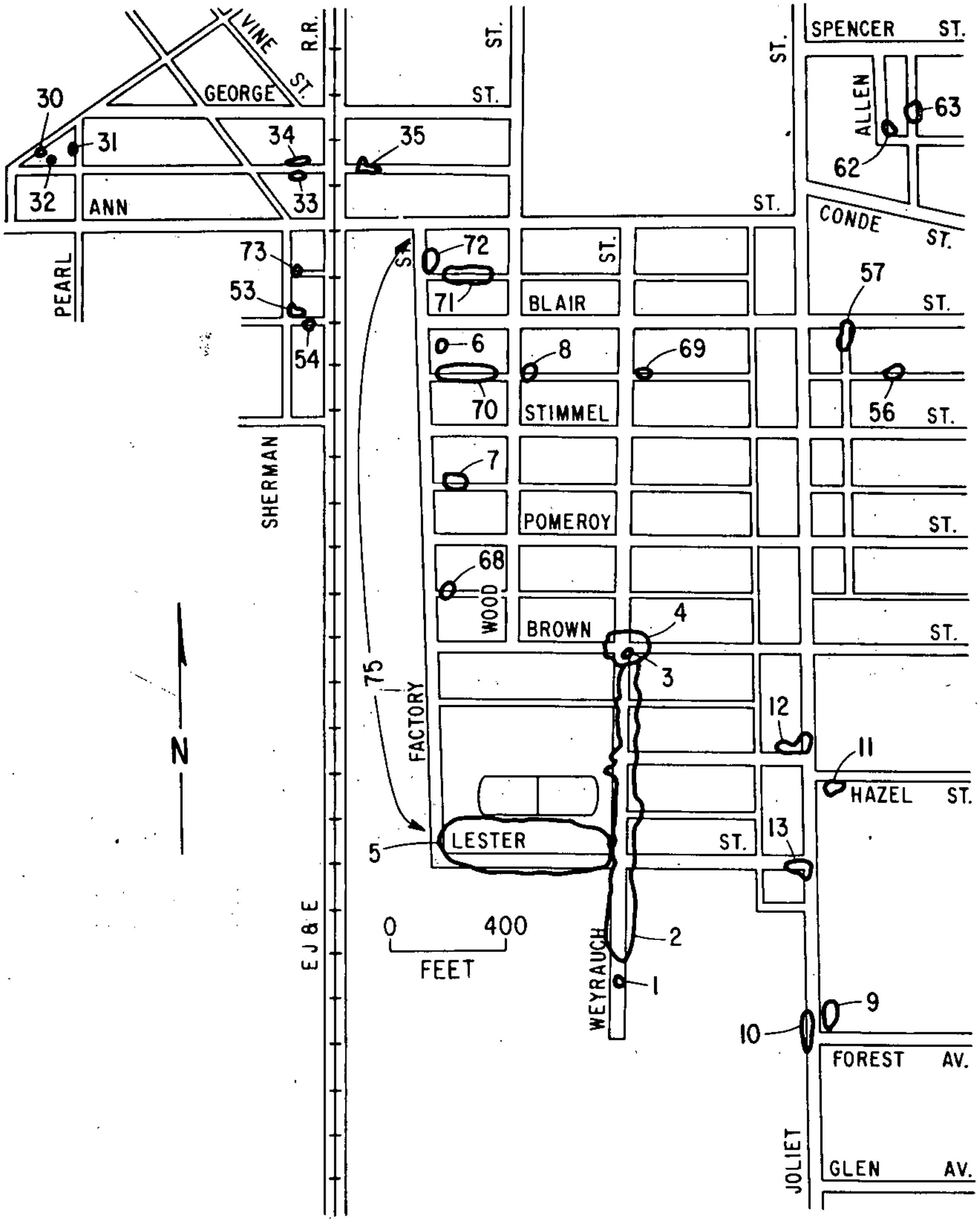


Fig. 2. Thorium-Residual Area Map.

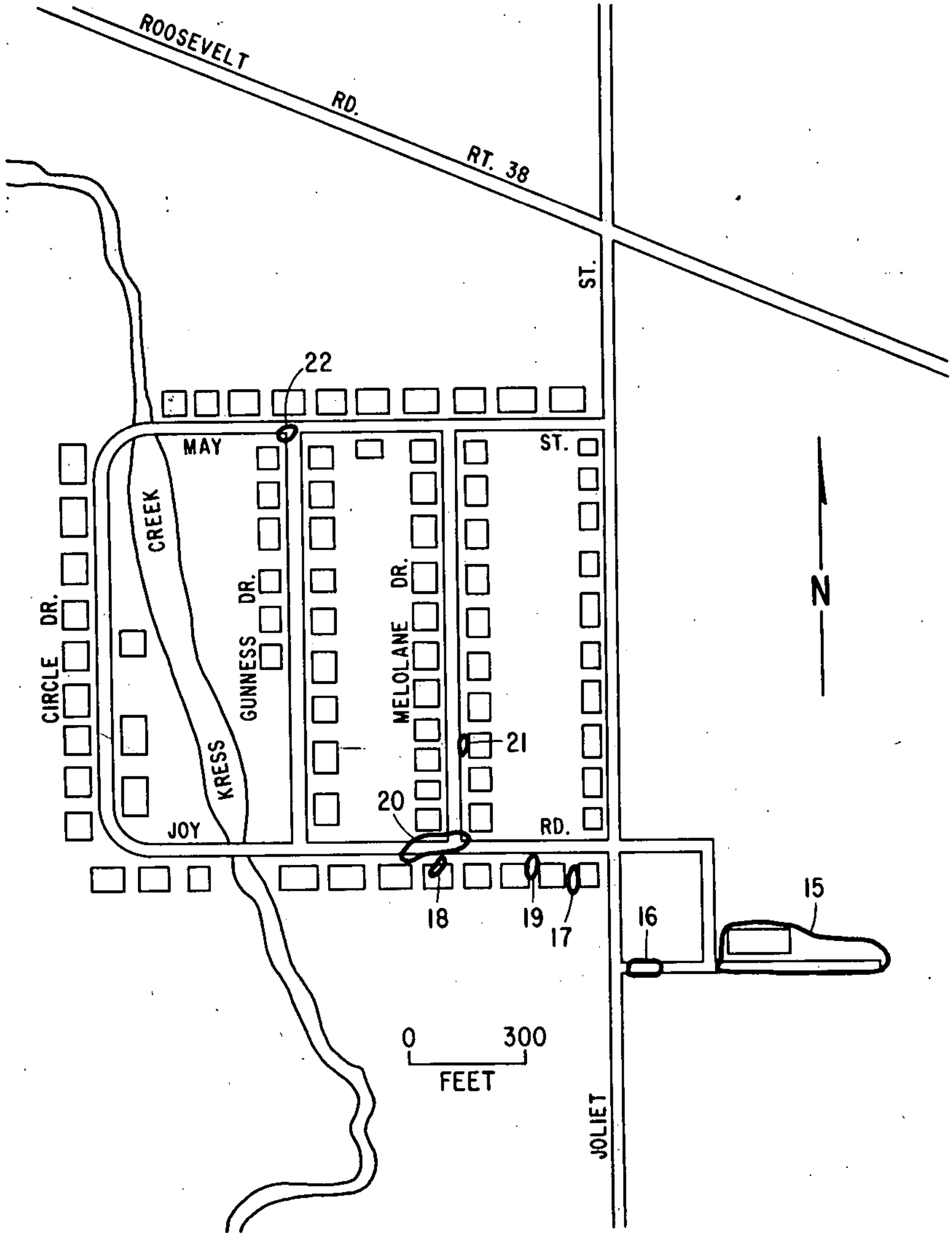


Fig. 3. Thorium-Residual Area Map.

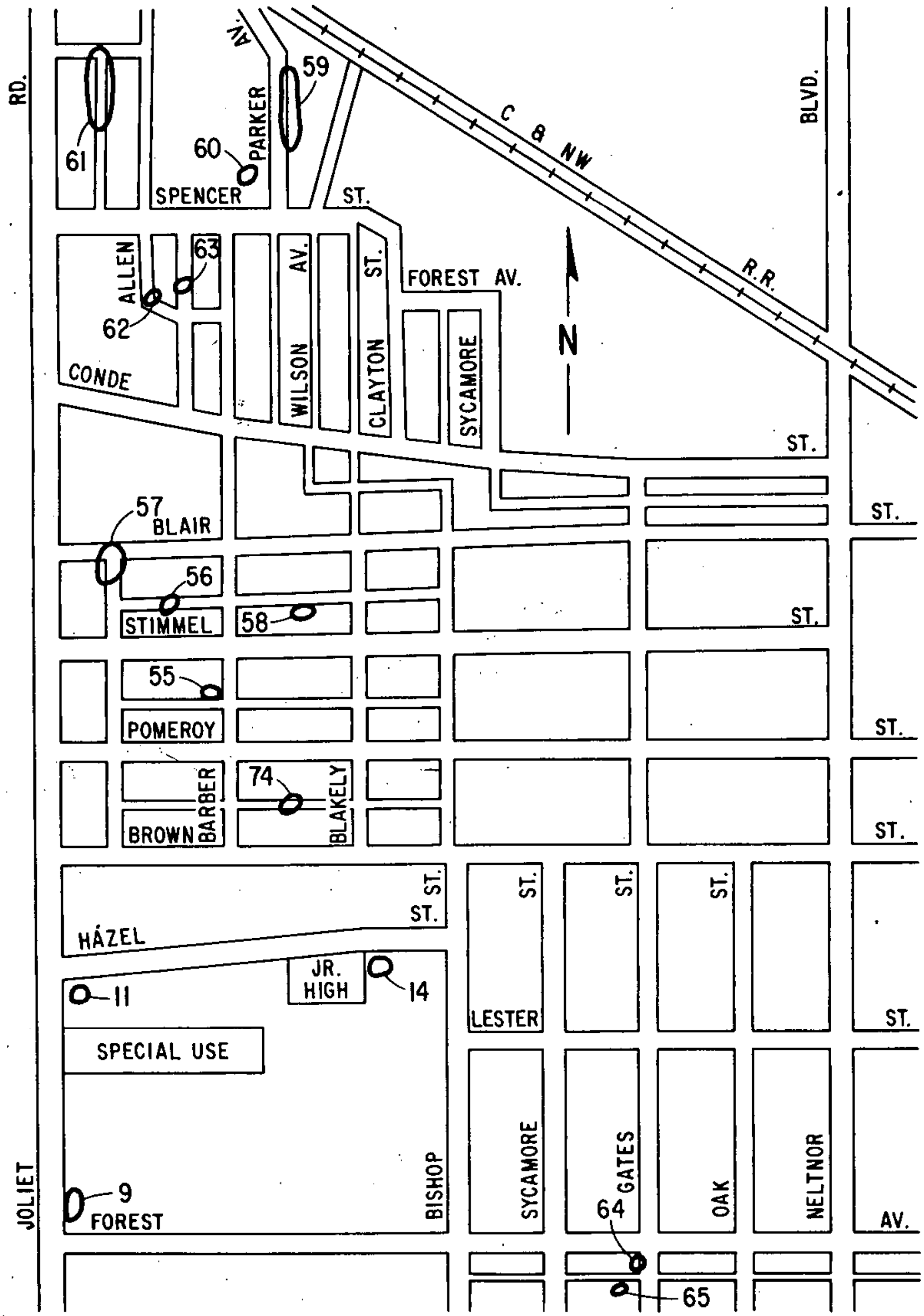


Fig. 4. Thorium-Residual Area Map.

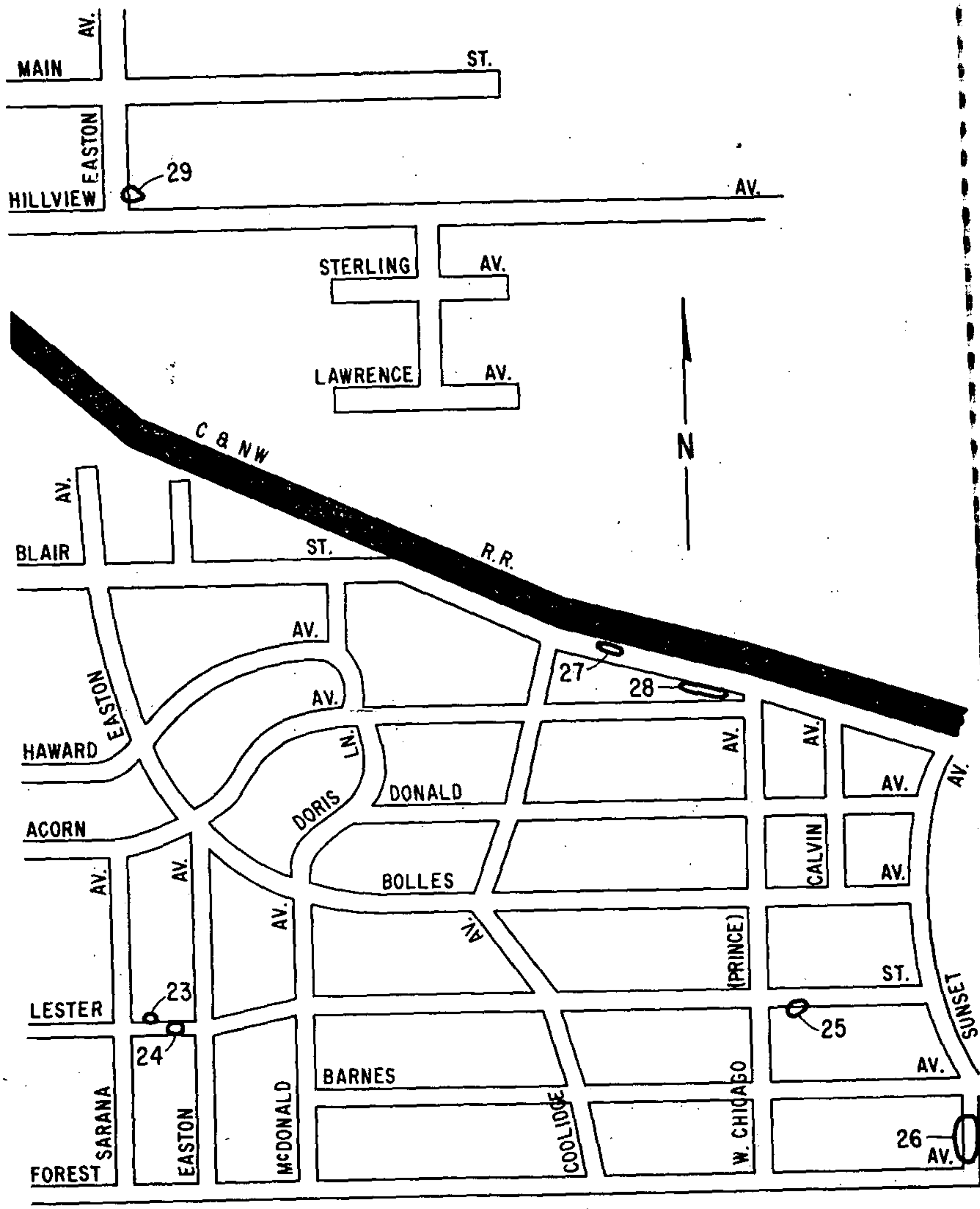


Fig. 5. Thorium-Residual Area Map.

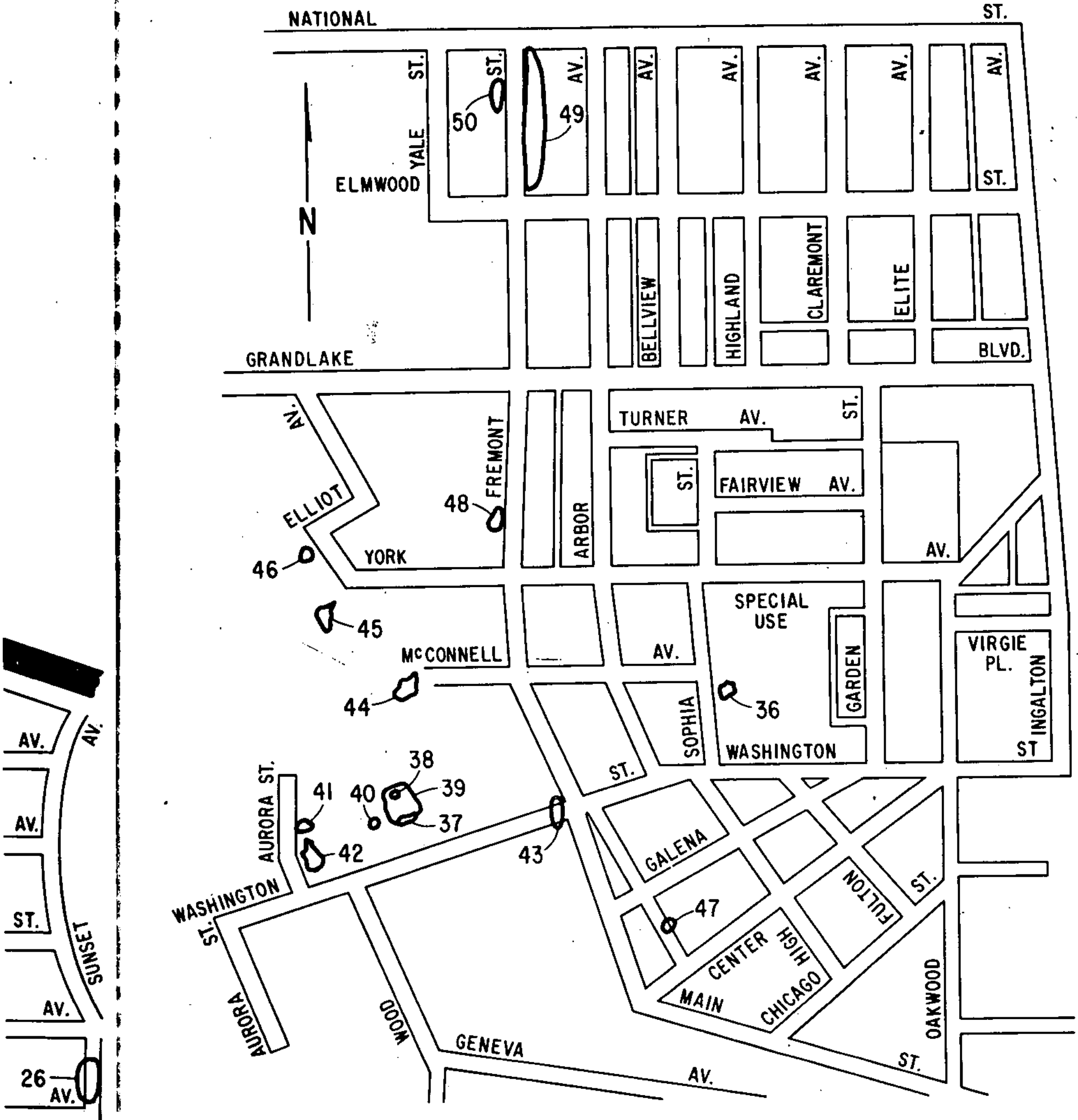


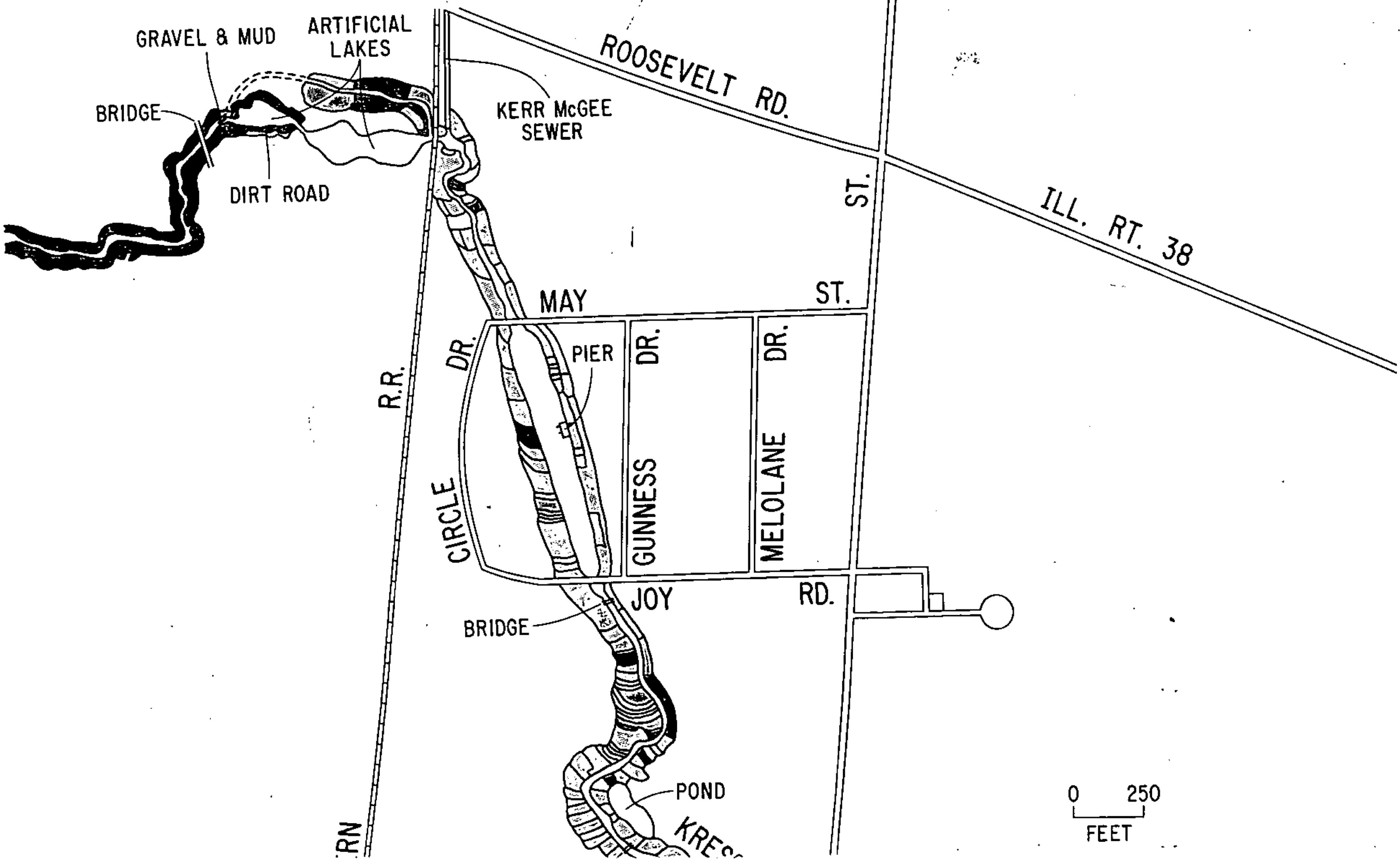
Fig. 6. Thorium-Residual Area Map.

length of time would call sufficient unwelcome attention to himself that the local police would probably be called to remove him. Nonetheless, we assign a minimum value of 10 occupancy hours per year even to such areas. At the other extreme, area Nos. 15, 37, and 39 were work areas and were fairly ofte occupied by workers in the course of their occupation. Area Nos. 4, 36, and 75 were lawns and gardens of a sort experiencing some recreational occupancy and area No. 49 is a fairly busy sidewalk. In between these extremes variou local factors either promoted or inhibited occupancy, and these are reflecte by the values given. In the last column the maximum annual dose is given in millirem. This is simply the product of the maximum dose rate and the effec tive occupancy. The corresponding areas are outlined on Figures 2 through 6 and the outlines there given are those corresponding to the total area conta ing detectable thorium residuals. The epicenters are much too small to actu show, but the outlined areas are drawn so that the epicenter is roughly at t center of the outline.

KRESS CREEK AND THE DUPAGE RIVER

As noted above we were easily able to detect the fact that material had over the years, moved down the storm sewer and railroad ditch, from the main factory and waste area, into Kress Creek. That the material was moving by placer action was also evident on detailed visual and microscopic examinatio of the storm sewer, the railroad ditch, and the creek itself. Thorium is first found at the point where the storm sewer joins the creek just south of Roosevelt Road along the Elgin, Joliet, and Eastern (EJ&E) railroad tracks. From that point on, it is found all along both banks with characteristic placer deposition as the creek goes through open oldfield, the Joy Street subdivision, through farm fields below that, under the combined bridge at Joliet and Wilson Streets, through another abandoned oldfield, underneath Route 59, behind the Edgewood Walk subdivision, and into the DuPage River. From that point on, downstream deposits are much less frequent than they are on the creekbanks. Indeed, at least 80% of the total activity along both these waterways is deposited in the first third of the distance along Kress Creek. This is typical of placer action in that placer transport occurs erratically, and though small amounts can be moved considerable distances, t bulk of material moves very slowly. In this case, over some 47 years, the great bulk of the material entering the creek has moved less than one mile downstream.

The results of a foot-by-foot survey along these waterways is shown in Figure 7. Dose rates along the banks range from purely background to as muc as 150 μrem/hr at one meter above ground. Along the DuPage River deposits a considerably more dilute, and the few deposits found downriver of Figure 7 generally represented dose rates of the order of 25 μrem/hr at one meter abo ground. Upriver of the junction of Kress Creek we were unable to find any indication of excess thorium, even though the sewage-treatment plant empties into the DuPage River up at the junction of Roosevelt Road. We have often sampled the effluent of the sewage-treatment plant, and although there is considerable thorium within the fenced boundary of the plant, we have never been able to detect any excess in the effluent. By the same token, the failure to find any excess thorium deposits along the DuPage River between t


GRAVEL & MUD
ARTIFICIAL LAKES
BRIDGE
DIRT ROAD
KERR McGEE SEWER
ROOSEVELT RD.
ILL. RT. 38
ST.
MAY
ST.
R.R.
DR.
PIER
DR.
DR.
CIRCLE
GUNNESS
MELOLANE
JOY
RD.
BRIDGE
POND
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FEET

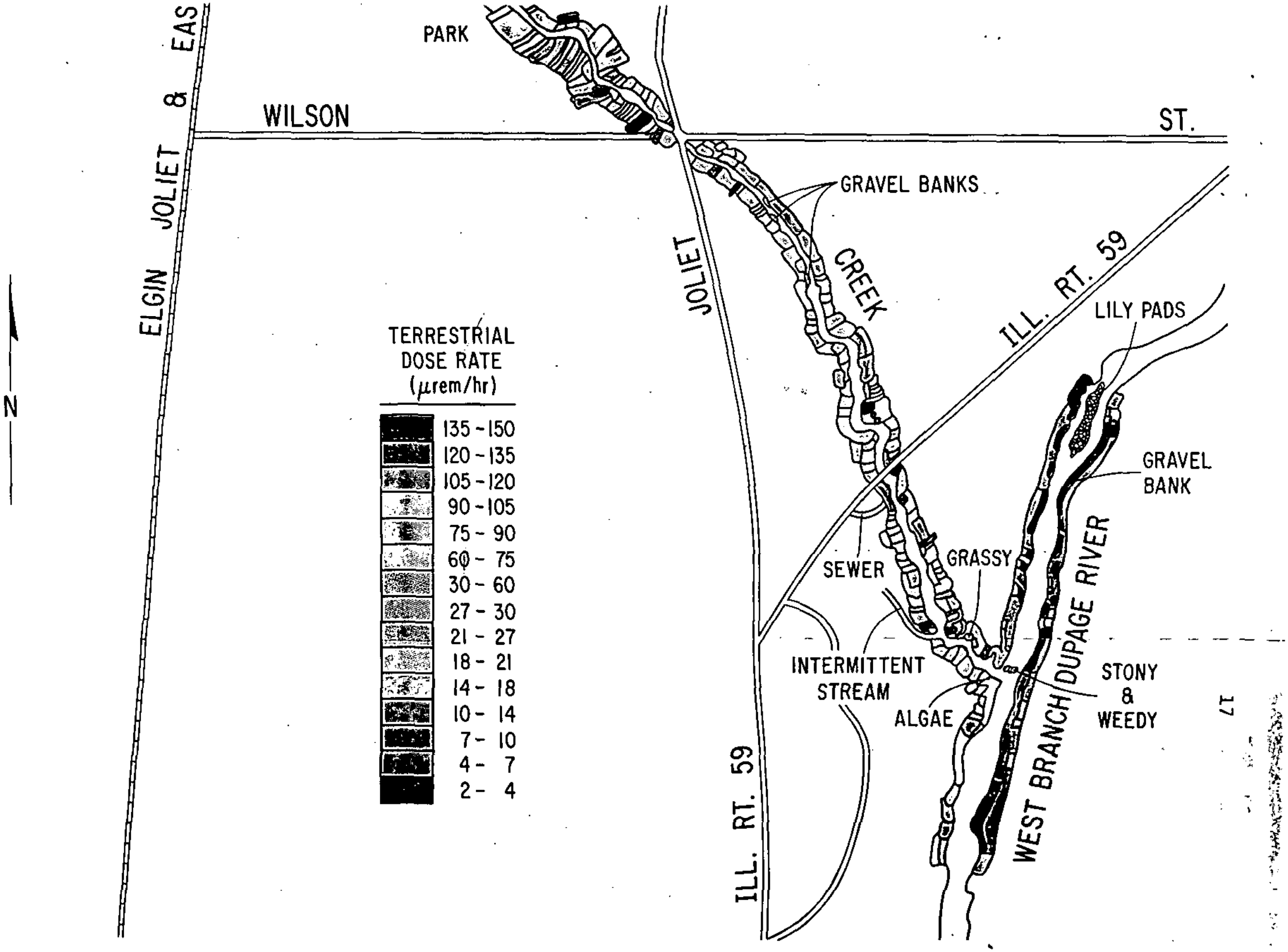

Fig. 7. Dose Rates Along the Banks of Kress Creek and the DuPage River.

sewage-treatment-plant effluent and Kress Creek strongly suggests that the present effluent condition extends back into history, and that excess thorium has never found its way through the treatment plant and into the river.

REED-KEPPLER PARK

In mid-1976 it was discovered that thorium residuals had been used as landfill at Reed-Keppler Park. Subsequent to USNRC Office of Inspection and Enforcement Investigation Report Number 76-01 (20 August 1976), thorium-bearing soil was moved from underneath the tennis courts to the spoil area bordering the landfill that lies on the west edge of the park proper. This was accomplished, and a security fence was completed around the residuals, on 28 February 1977. The center of the residual pile is located at 41°53'36" N Lat. and 88°12'30" W Long. The park proper covers 80 acres; the DuPage County Airport is 2.5 miles northwest, the closest edge of the Fermi National Accelerator Laboratory 1.5 miles southwest, and the nearest approach of the DuPage River 1.7 miles northeast. Figure 8 shows the pertinent area of the park, with a 100-foot grid that we erected for surveying purposes. Figure 9 shows the topography of that part of the park, which we produced using standard surveying methods. Figure 10 is an overlay of the latter figure on the former one. The fenced area has one of the highest elevations in the park and it drains directly into a gully to its immediate west, in the present landfill operation. Then the entire park, gully and all, drain to the northwest into a slough and lake. These are bordered on their northern and western edges by mounds, the northern one carrying a branch of the railroad. A number of monitoring wells were drilled into the fenced area, and we sampled these periodically. In addition, we sampled water and soil outside the fenced area, down along the gully, and into the slough and lake. Despite the fact that some of the material within the fenced area came to rest only in early 1977, which might be expected to promote runoff and leaching, we have been unable to find any evidence of soluble material leached out of these thorium residuals into the local groundwater or soil. A certain amount of runoff has occurred from the pile itself down into the gully in much the same manner in which heavy rains have caused similar runoff from the waste area into Kress Creek. However, in this case, the quantities are very much smaller than those involved from the waste area. Relative excess-radiation-field strength is shown in Figure 11, in units of microrem per hour multiplied by 10 (i.e. 50 = 5 μrem/hr, 10 000 = 1000 μrem/hr). The general terrestrial background in this area is 4-9 μrem/hr. Figure 12 shows the radiation-field overlay on Figure 8. In fact, these plots contain all the anomalous radioactivity that we were able to find in the entire park. All the rest of the park was surveyed both by vehicle and on foot, but nothing suggestive of excess thorium was found. Table 2 gives the various characteristics of the area enclosed by the radiation-field isopleths and an estimate of the volume of thorium-bearing material lying beneath these areas. The estimate was based on core samples taken throughout the park. In addition to these, we have located a few minor spills along the roadway running on the west side of the fenced area, through the landfill, and over to the maintenance building.

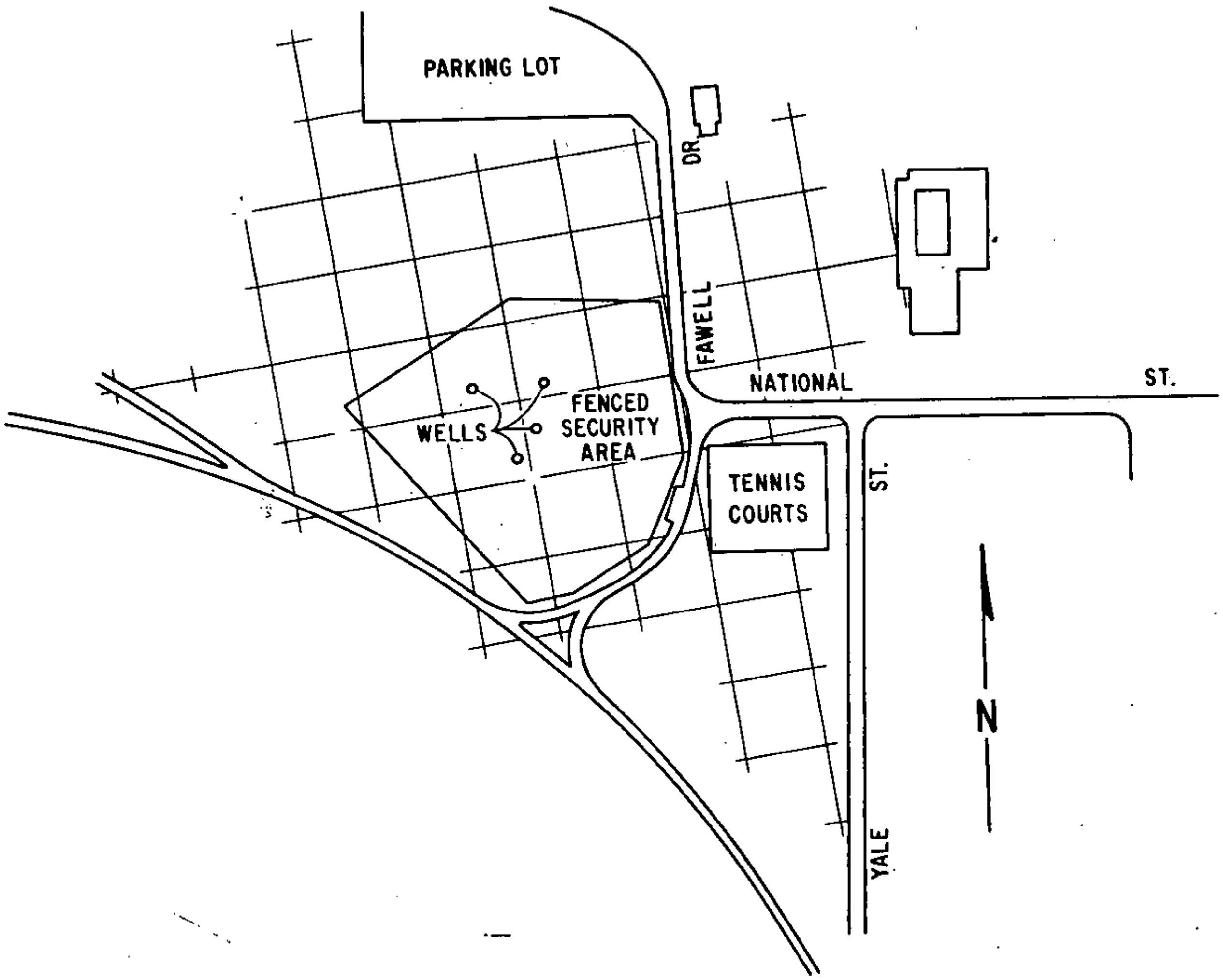

Fig. 8. Land-Surveyor's Grid and Plot Plan of Reed-Keppler Park.

Cores taken within the fenced area showed no anomalous radioactivity below 756 feet MSL. Values below that level were in the range of 0.5-3.0 pCi/g for both ^{232}Th and ^{226}Ra, values typical of the soil in this region. The greater bulk of the anomalous radioactivity lies above 760 feet MSL. However, above that level the material is extremely heterogeneous, and soil concentrations ranging from 3 pCi/g to 40 000 pCi/g of ^{232}Th were found within a few centimeters of one another.

Outside the fenced area, small patches of radioactive soil ranging from 5-50 pCi/g of ^{232}Th were found. These were almost exclusively along the roadway from the northeast corner of the fenced area around to the landfill area on its west side (Fig. 10). Even these patches were only 5-15 cm deep,

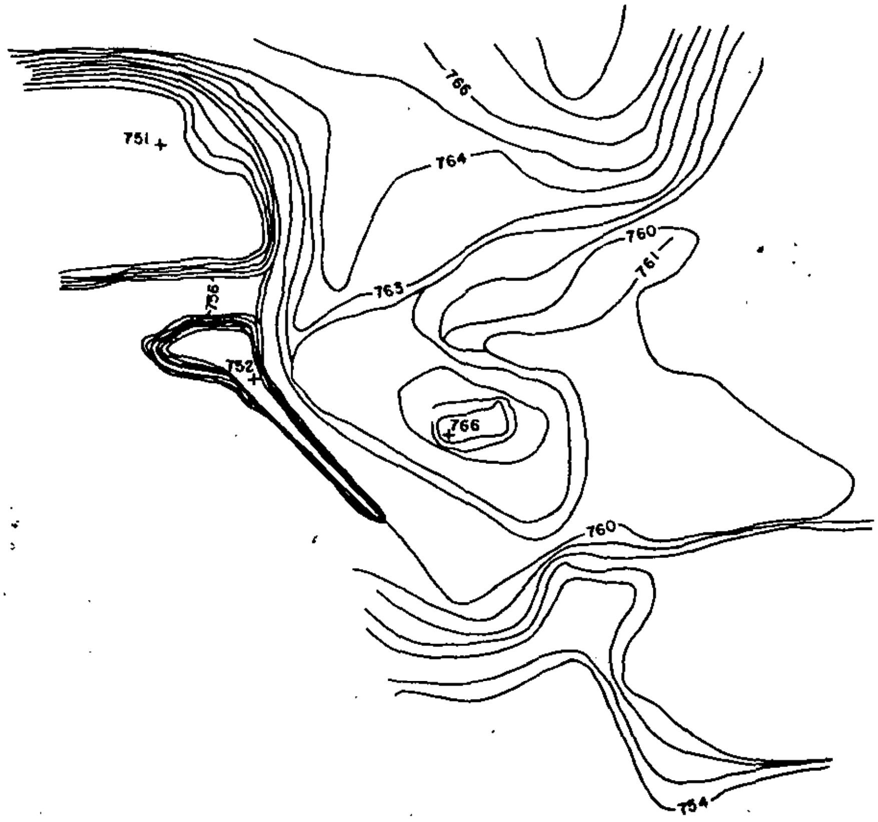

Fig. 9. Topography of Reed-Keppler Park (ft MSL).

and cores taken outside the fence showed no anomalous radioactivity below 15 cm within the 5-μrem/hr contour (Fig. 12), and no anomalous soil radioactivity at all outside this contour.

Both ground and surface waters from the fenced area necessarily drain into the small gully just to the west of the fence (Fig. 10), and from there into the slough and lake just northwest of the park. Water from these three bodies was sampled weekly, and no anomalous radioactivity was found in the lake or adjacent slough. In the small gully just below the fence, sediment levels ranged from 5-50 pCi/g of ^{232}Th and 2-10 pCi/g of ^{226}Ra, depending on the season and the occurrence of recent rainfall. Dissolved activity in the same slough was more variable, and ran from background levels to reasonably high levels as a function of rain and season, e.g. 0.5-15 pCi/L of ^{226}Ra or ^{228}Ra, and 0.2-1.5 pCi/L of ^{232}Th or ^{228}Th.

Long-lived, airborne, particulate radioactivity was sampled several time a month at the fence line, both upwind and downwind of the main residual pile The values obtained were well within typical backgrounds for the area; none

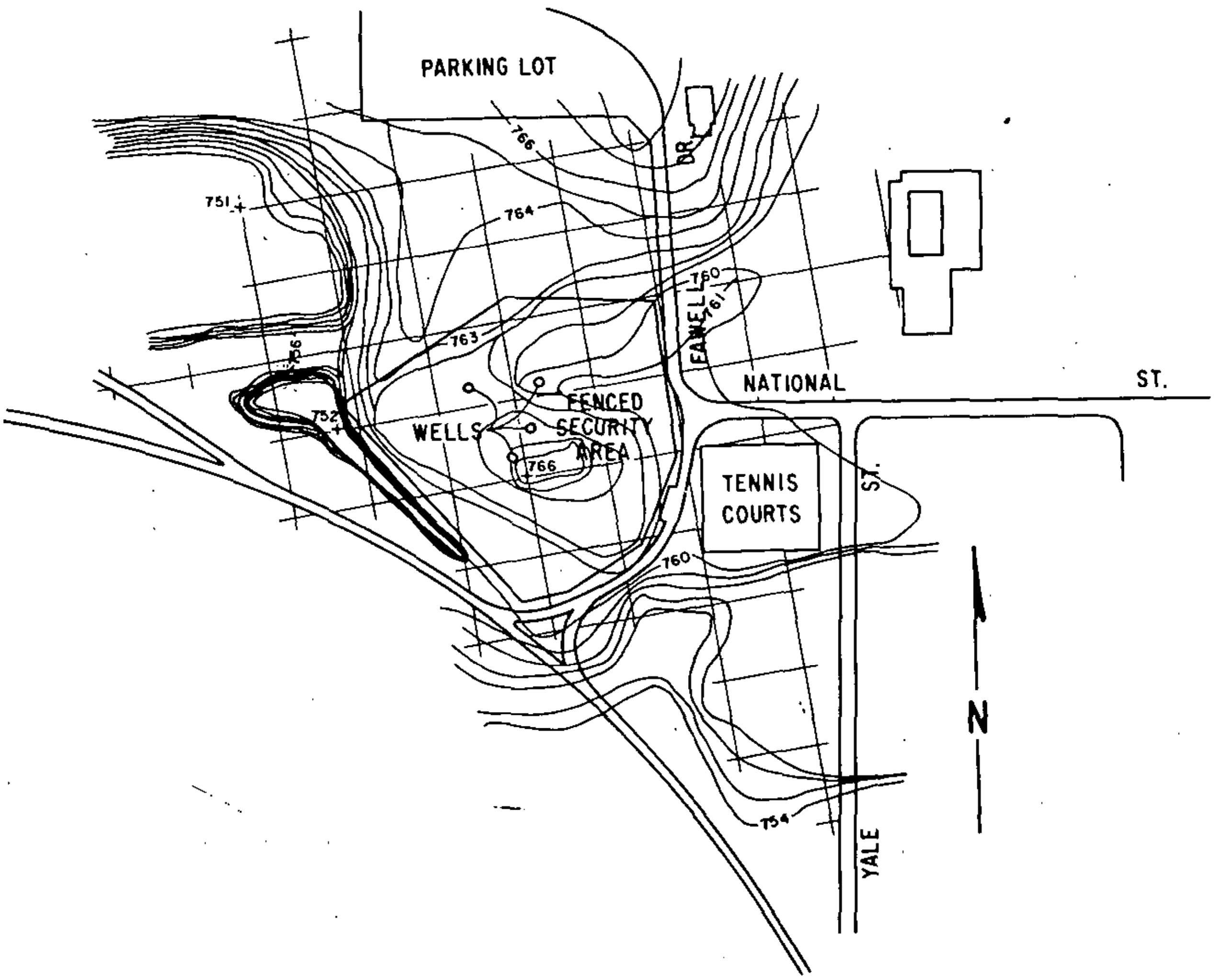

Fig. 10. Reed-Keppler Park Topography (ft MSL) and Surveyor's Grid.

exceeded 0.01 pCi/m^3 of gross alpha, and none gave downwind-to-upwind ratios indicative of significant release from the residual pile. However, ^{220}Rn and ^{222}Rn values were consistently elevated at the downwind fence line relative to the upwind fence line. Under conditions of extreme inversion and very low windspeed, downwind values of 30 nCi/m^3 of ^{222}Rn and 4 nCi/m^3 of ^{220}Rn have been observed, i.e. about ten times the simultaneous upwind or background values. However, the annual average ratio was only about 1.5. Radon concentrations dropped rapidly with distance from the fence line, and excess concentrations were never detected at the nearest residences, e.g. the homes on Yale and National Streets.

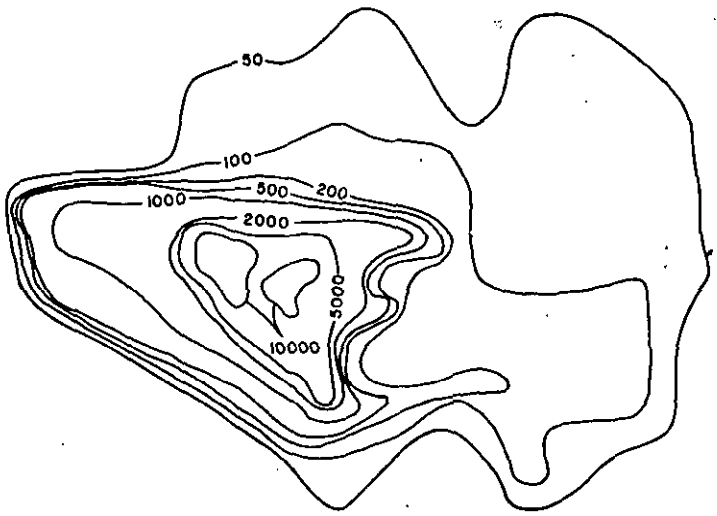

Fig. 11. Isopleths of Relative Radioactivity in Reed-Keppler Park (10^1 μrem/hr).

SANITARY TREATMENT PLANT

There are only three thorium-bearing areas here, and no more were found despite repeated foot and vehicular surveys. The major area has been staked off and extends all across the north end of the two northernmost sludge ponds. It extends from a large oak tree on the west to the last metal stake on the east. It contains four epicenters with maximum dose rates of 250-400 μrem/hr. The rest of the field averages about 100 μrem/hr. The entire area covers about 2000 ft^2. In this case, the source is largely below the surface and seems to be something of the order of 1-2 yd^3 of thorium tailings, partly filling an old buried Imhof tank. The second area is just to the south of the analytical laboratory, with its epicenter exactly eight feet east of the rear door of a concrete-block storage shed. The epicenter has a maximum dose rate of 750 μrem/hr, but in this case it appears to have been largely a drop, or small fill, because the dose rate drops off sharply. At the north side of the building and over past a very large filter drum the dose rate runs about 150 μrem/hr, and over the rest of this 500-ft^2 field the average is about 50 μrem/hr. This storage shed sits on a hill along with a large brick tank, and at the foot of that hill there is a gentle flat field running down to the large southern aeration pond. The half acre of field right at the foot of this hill, and running almost to the water's edge, has no detectable epicenter, but shows a quite uniform dose rate of 20-25 μrem/hr. This field appears to be the result of spill from up at the top of the hill being dropped to the bottom, and then graded out as the land was graded to form a lawn. All three of these areas lie outside the normal work area and are more in the nature of storage or reserve areas. As a consequence occupancy is quite low, and although we assigned 100 hr/yr to each area, this is probably a gross overesti-

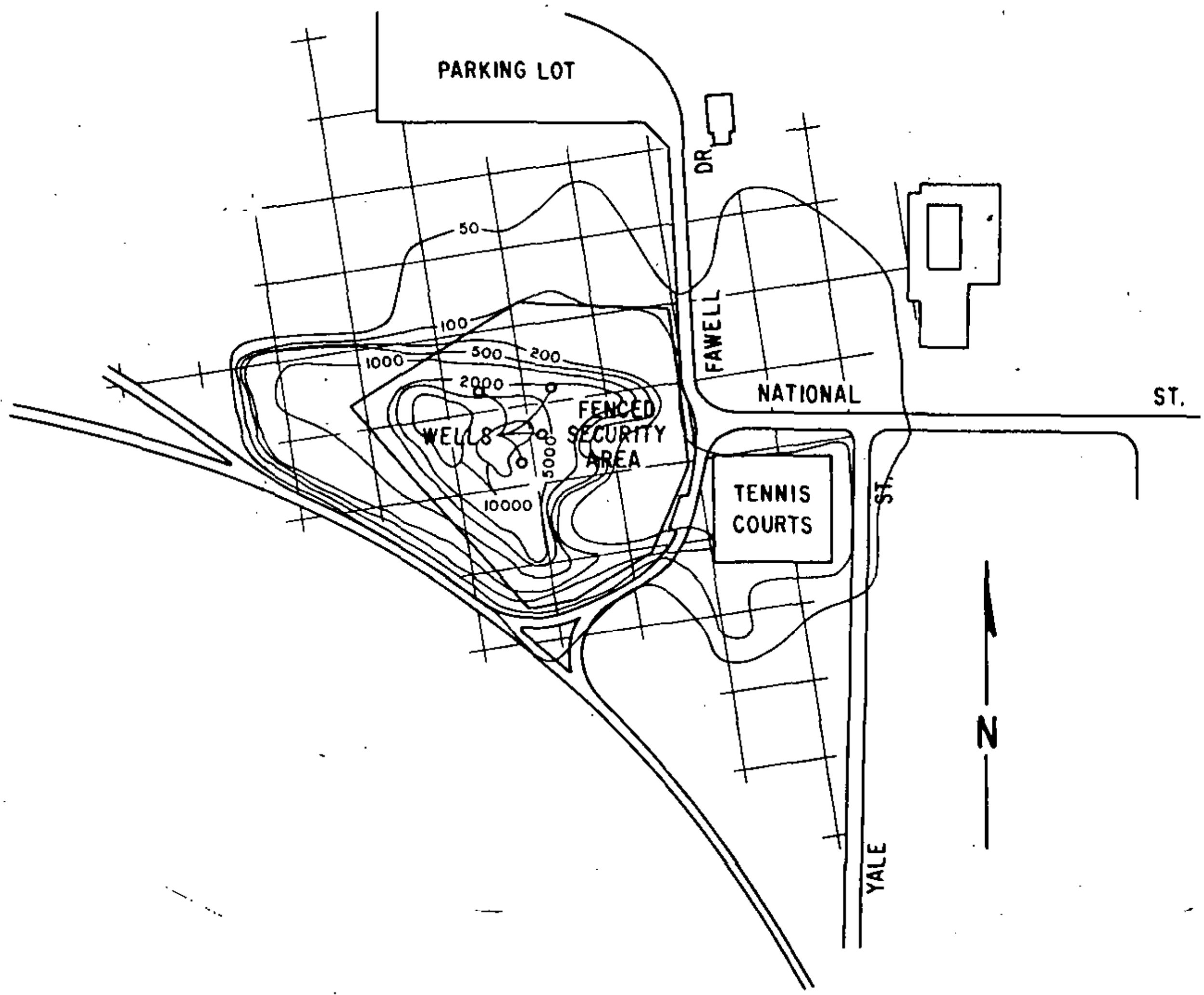

Fig. 12. Isopleths of Relative Radioactivity (10^1 μrem/hr) and Surveyor's Grid in Reed-Keppler Park.

mate. This is especially so inasmuch as the epicenters are of the order of 12 or 15 inches on a side, and standing over them would be more in the nature of an athletic feat than an occupation. In any case, this leads to annual dose values of 75, 40, and 2.5 mrem respectively. There is no public occupancy, partly because the public is excluded, and partly because a sanitary treatment plant can hardly be regarded as an "attractive nuisance". Dose contours are quite narrowly confined to the three areas, and there is no discernable dose from excess thorium beyond the fence.

Table 2. Volume of Radioactive Material for Consideration in Reed-Keppler Park

Relative Radiation Field Strength[a]	*Perimeter (ft)*	*Area* (ft^2)	*Area Between Isopleths* (ft^2)	*Volume* (yd^3)	*Volume Between Isopleths* (yd^3)
≥ 10 000	500	8 333	8 333	3 342	3 342
≥ 5 000	700	29 111	20 778	11 677	8 335
≥ 2 000	860	44 889	15 778	18 005	6 328
≥ 1 000	1 250	77 667	32 778	31 153	13 148
≥ 500	1 440	111 333	44 666	44 657	13 504
≥ 200	1 790	132 778	21 445	50 884	6 227
≥ 100	2 100	229 222	96 444	78 889	28 005
≥ 50	2 640	405 222	176 000	132 602	53 713
			405 222		132 602

[a] *As shown in Figures 11 and 12.*

SKYSHINE AND POPULATION DOSE

"Skyshine" is a term used to include the total radiation received at one point from a source at another, and includes both direct and scattered components. In the case of the sewage-treatment plant, as noted above, there is no discernable skyshine beyond the fence, so there is no public exposure from this source. In the case of Reed-Keppler Park the 5-μrem/hr thorium excess-dose contour is shown in Figure 12. Below 5 μrem/hr it proved difficult to discern excess thorium dose from the natural background, the park being a large grassy field and having the relatively high natural-background characteristic of such fields in this area. However, the excess dose beyond the 5-μrem/hr contour certainly was found to drop very rapidly, and was certainly no more than 1 μrem/hr at its highest point on the park boundary, the corner of National and Yale Streets. The overwhelming bulk of park usage lies outside the 5-μrem/hr contour; there is a very small amount within it, and virtually none at all at higher contours. This is partly a consequence of the fact that the higher contours are associated with an area that is not really park at all, but sanitary landfill. It is neither attractive nor really kept open for public use. Considering maximum feasible park occupancy, occupational occupancy at the landfill, and the residences along National and Yale Streets, it was still impossible to discern a total population dose in excess of 0.2 manrem/yr from the present thorium-residual situation in Reed-Keppler Park.

The situation around the factory site and waste area is somewhat different. There are essentially two primary sources here, the factory itself, and the two large tailings piles in the waste area. Thus, the dose-rate contour about this area is necessarily asymmetric. The 20-μrem/hr (170-mrem/yr) contour is shown on Figure 13. It contains, at most, four or five residences. The 1-μrem/hr excess-dose contour is shown in Figure 1. This is given because it is the level of confusion below which it is impossible to detect any difference above natural background. This contour contains several hundred residences, as well as the regular transients represented by the shopping area to the south, the Pioneer School to the west, and the Gary and West Chicago Junior High Schools to the east. From contours such as these, combined with surveys of the present resident and transient populations, we obtained a maximum value for the annual population dose of 20 manrem/yr.

CONCLUSIONS

A glance at the epicenter maps indicates that the thorium-residual areas in West Chicago are widely scattered. Nonetheless, and interesting as the situation may be, there is no hazard to the public health and safety. As things stand at present there are no areas that exceed the limits of 10 CFR 20 inasmuch as the three major areas of thorium residual are contained within security fences, and the remaining areas are too small and of too low a dose rate to be of serious concern. Thus, no epicenter exceeds the limit of 2 mrem in any one hour. The only epicenter that could conceivably exceed the limit of 100 mrem in one week, No. 6, is about 15 inches on a side and located in the entranceway to a little-used parking lot. It is not even remotely reasonable that anyone could spend the required 110 hours located rigidly above this spot for one week. And, as a glance at Table 1 shows, there are no epicenters that even remotely approach the limit of 0.5 rem/yr. The total population dose from all sources is certainly less than 30 manrem/yr, and this can be contrasted with the roughly 2000 manrem/yr obtained by the population of this area from the natural-radiation background. Even so, the situation does constitute a public nuisance of some magnitude and, although no regulatory action is mandated, some action to relieve the nuisance is probably in order.

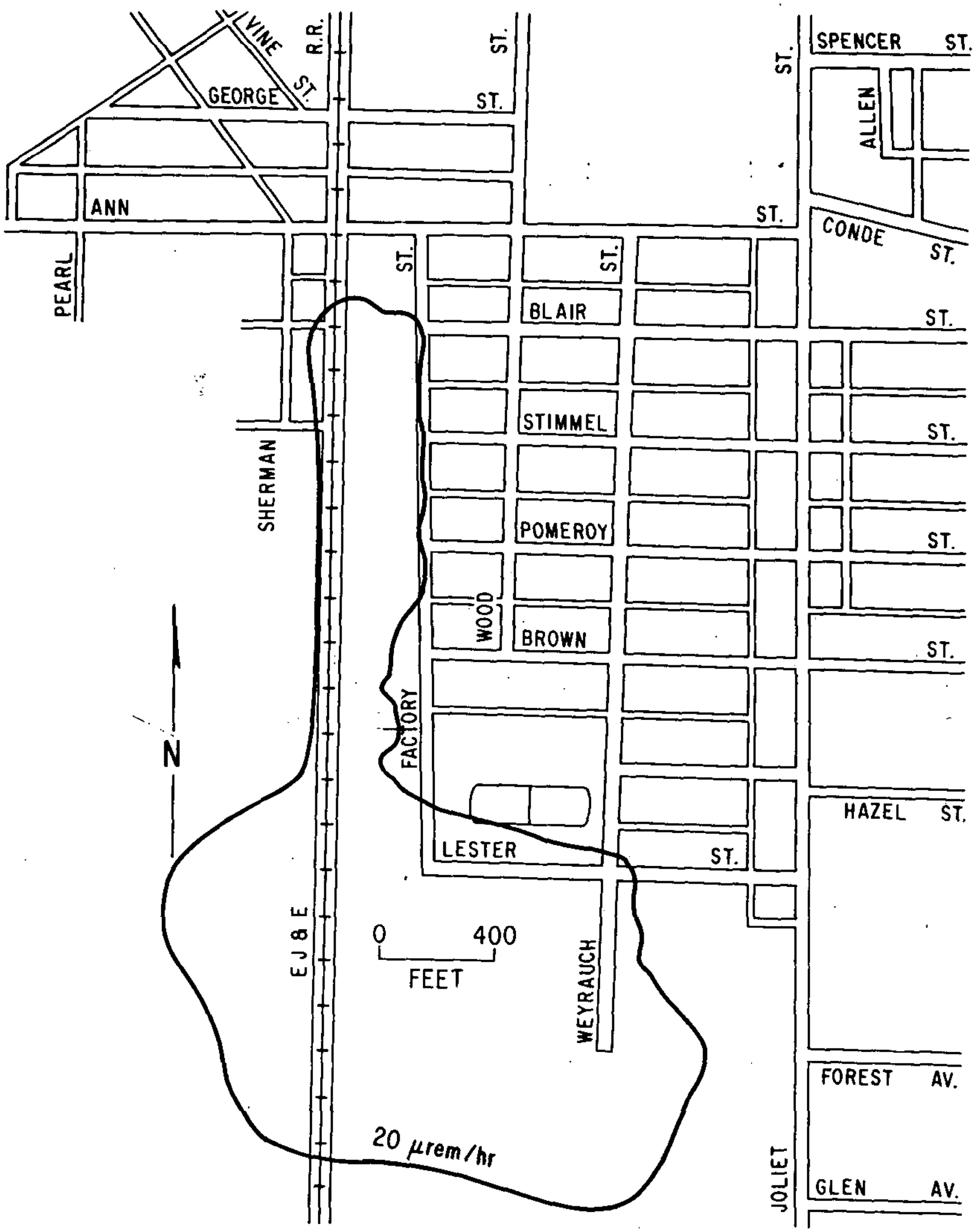

Fig. 13. Dose-Rate Contour Around the Factory Site and Waste Area.

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1. "Phase II-Title I, Engineering Assessment of Inactive Uranium Mill Tailings, Lowman Site, Lowman, Idaho." Ford, Bacon and Davis Utah, Inc., Report GJT-17, prepared for USDOE, December 1977.

2. P. K. Boyns, W. Frankhauser, T. J. Hendricks, and R. Shippman. "Aerial Radiological Survey of West Chicago, Illinois." Edgerton, Germeshausen and Grier, Report EGG-1183-1730, in preparation.

APPENDIX

ADDITIONAL THORIUM-RESIDUAL AREAS

Area No. 76

Scrap area at 31W241 Geneva Road, 0.8 mile SW of area A8 (Fig. 1). Maximum surface exposure rate of 800 μR/hr, dose rate of 200 μrem/hr, residual surface of 10 000 ft^2, effective occupancy of 50 hr/yr, and maximum annual dose of 10 mrem.

Area No. 77

Lawn and driveway at 1N070 Kress Avenue, 1.2 miles W of area A8 (Fig. 1). Maximum surface exposure rate of 200 μR/hr, dose rate of 60 μrem/hr, residual surface of 200 ft^2, effective occupancy of 100 hr/yr, and maximum annual dose of 6 mrem.