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ENVIRONMENTAL MONITORING AT LOVE CANAL

Volume I

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ABSTRACT

During the summer and fall of 1980 the U.S. Environmental Protection Agency (EPA) conducted a comprehensive multimedia environmental monitoring program in the vicinity of the inactive hazardous wastes landfill known as Love Canal, located in Niagara Falls, New York. As a result of a presidential state of emergency order issued on May 21, 1980, EPA was instructed to assess the extent and degree of environmental contamination that was directly attributable to the migration of substances from Love Canal into the occupied, residential area around the former canal defined by: Bergholtz Creek on the north; 102nd Street on the east and 103rd Street on the southeast; Buffalo Avenue on the south; and 93rd Street on the west. The area closest to the former canal, currently owned by the State of New York and containing the unoccupied so-called ring 1 and ring 2 houses, was excluded from the emergency declaration order.

The studies conducted at Love Canal by EPA included a major hydrogeologic investigation, and the collection and analysis of approximately 6,000 environmental samples consisting of water, soil, sediment, air, and biota. An extensive quality assurance/quality control program was applied to all phases of the analytical work to document the precision and accuracy of the monitoring data. Strict chain-of-custody procedures were also employed to assure the integrity of the monitoring data.

The EPA multimedia environmental monitoring data revealed a limited pattern of environmental contamination in the area immediately adjacent to Love Canal, probably caused by localized and highly selective migration of toxic substances from the former canal to the vicinity of certain ring 1 residences. The data also revealed that contamination that had probably migrated from Love Canal was present in those storm sewer lines that originated near the former canal, and was present in area creeks and rivers (primarily in the sediment) at locations near to and downstream from the outfalls of those storm sewers.

Apart from these findings, the monitoring data revealed no clear evidence of environmental contamination in the area encompassed by the emergency declaration order that was directly attributable to the migration of substances from Love Canal. The data also provided no evidence, outside of ring 1, supporting the

hypothesis that swales preferentially transported contaminants from the former canal into the surrounding neighborhood. Furthermore, the data revealed that the barrier drain system surrounding the landfill was effectively intercepting substances migrating laterally from Love Canal and was drawing near-surface ground water back to the drains for collection and subsequent treatment.

In addition to the report presented in this Volume, two other Volumes have been prepared to document the Love Canal study. Volume II consists of a complete enumeration of all validated field samples collected at Love Canal and Volume III consists of a collection of statistical tabulations of the validated Love Canal monitoring data.

CHAPTER 1
OVERVIEW

On May 21, 1980 President Carter issued an order declaring that a state of emergency existed in the area of Niagara Falls, New York known as Love Canal (Figure 1). This order was issued out of concern that toxic chemical wastes, which had been buried in a once partially excavated and now filled canal, were contaminating the adjacent residential areas and were subjecting residents to increased health risks. As a result of this order, the United States Environmental Protection Agency (EPA) was directed to design and conduct a comprehensive environmental monitoring program at Love Canal that would: (1) determine the current extent and degree of chemical contamination in the area defined by the emergency declaration order (Figure 2); (2) assess the short-term and long-term implications of ground-water contamination in the general vicinity of Love Canal; and (3) provide an assessment of the relative environmental quality of the Love Canal emergency declaration area.

The emergency declaration order of May 21, 1980 affected approximately 800 families residing in the horseshoe shaped area in Figure 2 labeled "DECLARATION AREA." In Figure 3, the outer boundary of the Declaration Area is defined by Bergholtz Creek on the north, 102nd Street and 103rd Street on the east and southeast (respectively), Buffalo Avenue on the south, and 93rd Street on the west. It should be noted that the emergency declaration order of May 21, 1980 excluded the area in Figure 2 labeled "CANAL AREA."

In this report, the Canal Area is the area bordered on the north by Colvin Boulevard, 100th Street on the east, Frontier Avenue on the south, and (approximately) 97th Street on the west. The Canal Area contains the residences located on both sides of 97th and 99th Streets. In 1978 the State of New York (NYS) acquired all but 2 of the 238 houses in the Canal Area (including a few houses on the north side of Colvin Boulevard), restricted virtually the entire Canal Area from public access by means of a guarded 8-foot high cyclone fence, and closed the public elementary school on 99th Street. The houses in the Canal Area consist of the so-called "ring 1" and "ring 2" houses. Those 99 houses whose backyards adjoin the inactive landfill have been referred

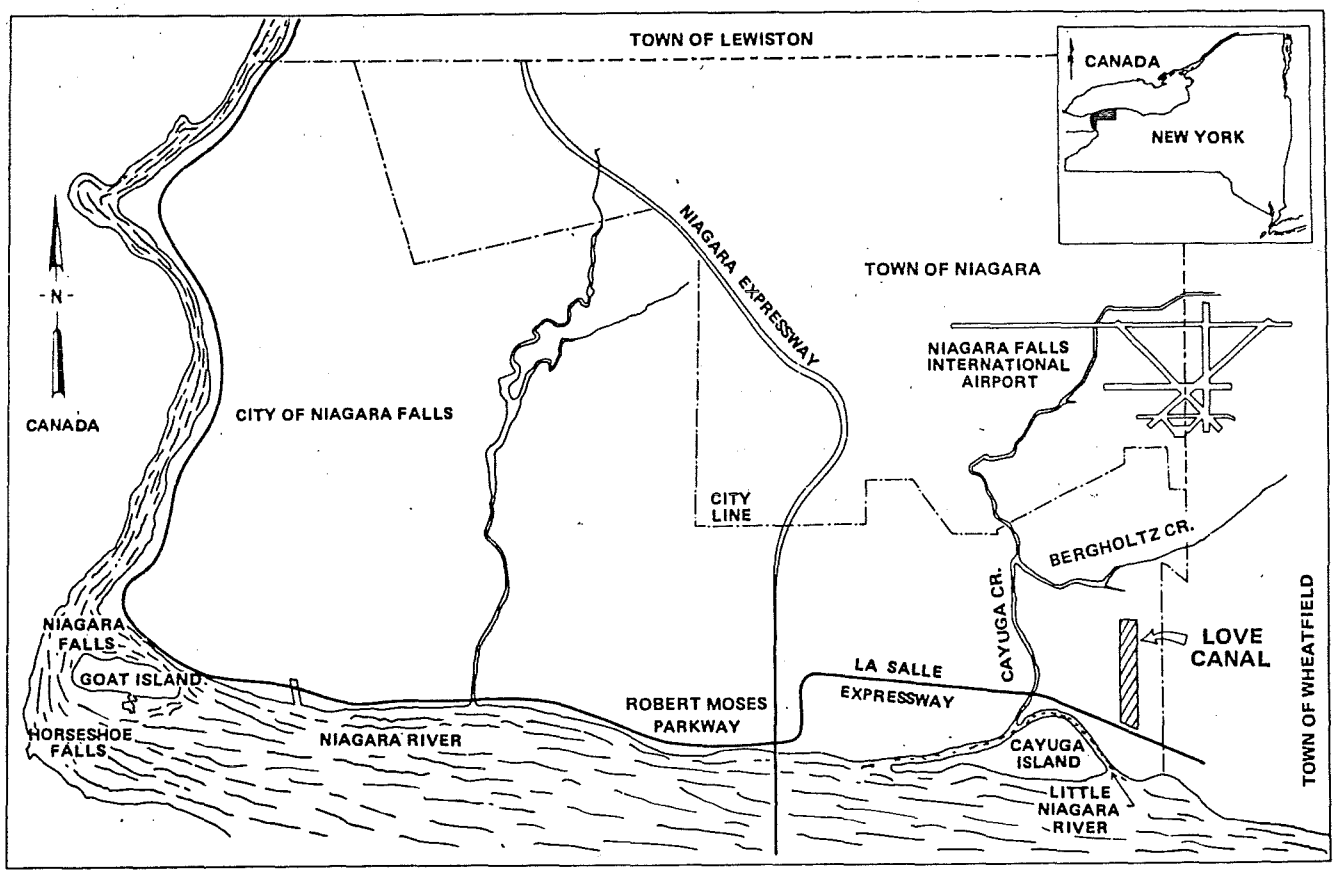

Figure 1. General Site Location Map.

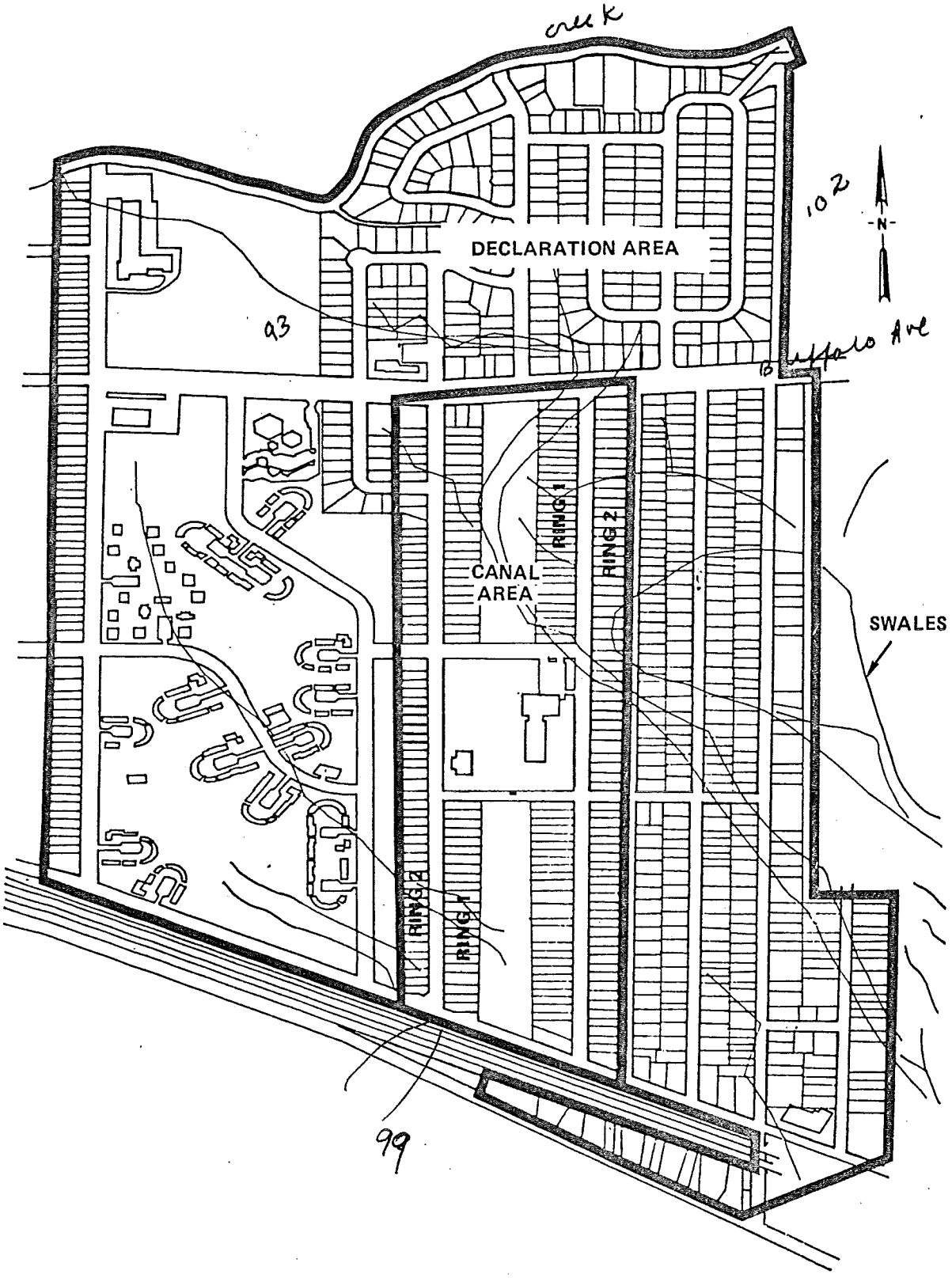

Figure 2. The General Love Canal Study Area.

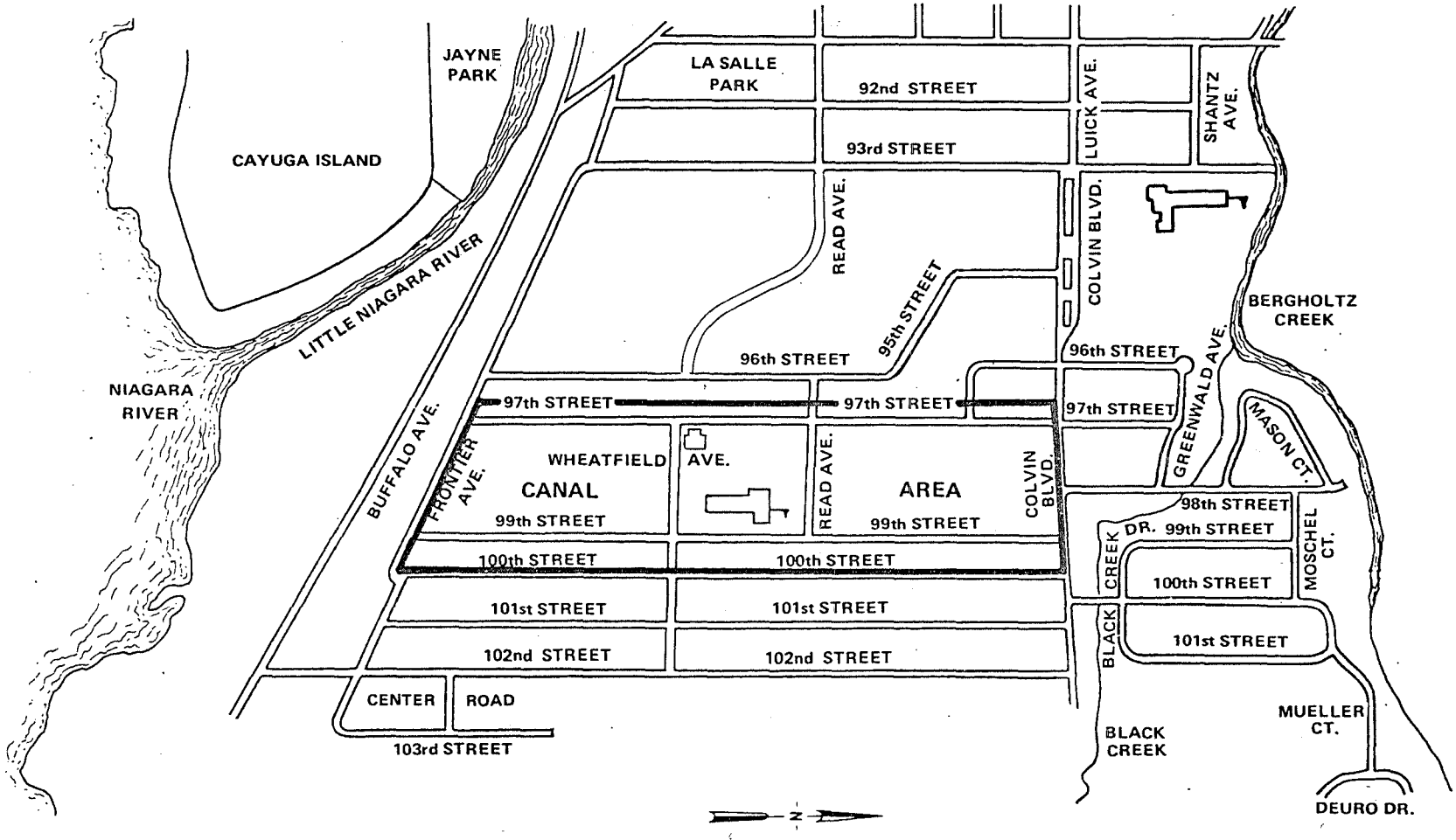

Figure 3. Detail of the General Love Canal Study Area.

to as ring 1 houses, while the houses on the east side of 99th Street, on the west side of 97th Street, and immediately opposite the landfill on the north side of Colvin Boulevard were referred to as ring 2 houses. (See Figure 2). The former canal was located in the area encircled by the ring 1 houses and at one time was approximately 3,000 feet long, 80 feet wide, and has been estimated to have been from 15 to 30 feet deep.

The 800 families residing in the Declaration Area lived within approximately 1,500 feet of the former dump site. Of these 800 families, approximately 550 lived in single-family dwellings (located mainly to the north and east of the Canal Area), 200 lived in a multiple-family complex of apartment buildings known as the La Salle Development (located to the west of the Canal Area), and 50 lived in a cluster of senior citizen garden apartments (also located to the west of the Canal Area). [As part of the emergency declaration order, all persons residing in the Declaration Area were eligible for temporary relocation, at U.S. government expense, for a period of up to 1 year while environmental monitoring was conducted. Approximately 300 families (or an eligible member of a family) took part in the temporary relocation program. The temporary relocation program was managed and funded by the Federal Emergency Management Agency.]

On October 1, 1980 President Carter and Governor Carey of New York signed an agreement providing $20 million for the voluntary permanent relocation of all residents living in the Love Canal Declaration Area. An agency of the State of New York, the Love Canal Area Revitalization Agency (LCARA), was established to manage the permanent relocation program and to plan for future use of the acquired properties. As of May 1, 1982 LCARA records revealed that approximately 570 families had been permanently relocated out of the Love Canal Declaration Area.

The EPA Love Canal final report consists of this Volume and two companion Volumes. This Volume contains a description of the design of the monitoring studies, the results of the investigations, a summary of the major findings, and conclusions and recommendations. Volume II consists of a complete listing of the analytical results obtained from all validated field samples collected at Love Canal. Volume III contains a set of statistical tabulations that summarize the Love Canal monitoring data according to various geographical areas of interests, and thus characterizes the extent and degree of environmental contamination in the Love Canal Declaration Area. Other documentation is also available that describes in detail certain aspects of the EPA Love Canal monitoring program which are only briefly reported here. This documentation has been prepared under contract, and is available to the public through the National Technical Information Service (NTIS). The material consists of: (1) an extensive four volume set of sampling and analytical protocols and quality assurance procedures entitled Quality Assurance Plan, Love Canal Study, LC-1-619-026, by GCA Corporation; (2) a report entitled

Love Canal Monitoring Program, GCA QA/QC Summary Report, by GCA Corporation; (3) a report entitled Geophysical Investigation Results, Love Canal, New York, by Technos, Inc.; (4) a report entitled The Ground-Water Monitoring Program at Love Canal, by JRB Associates; and (5) a report entitled Final Report on Ground Water Flow Modeling Study of the Love Canal Area, New York, by Geotrans, Inc.

1.1 THE EPA MONITORING PROGRAM

The EPA multimedia environmental monitoring program at Love Canal was designed and conducted under the direction of the Office of Research and Development, through its Office of Monitoring Systems and Quality Assurance (OMSQA). Contract costs for the project were $5.4 million. GCA Corporation of Bedford, Massachusetts was the prime management contractor. A total of 18 subcontractors were involved in sample collection and analytical laboratory work.

Field sampling activities were started at Love Canal on August 8, 1980 and were concluded on October 31, 1980. During that time period, more than 6,000 field samples were collected and subsequently analyzed for a large number of substances known (or suspected) to have been deposited in the inactive hazardous wastes landfill. The analyses performed on the samples collected at Love Canal resulted in the compilation of approximately 150,000 individual measurements of environmental contamination levels in the general Love Canal area. A comprehensive quality assurance/ quality control (QA/QC) program, involving the analysis of 5,743 QA/QC samples, was applied to all phases of the analytical work performed during the project to document the precision and accuracy of the analytical results. Detailed reports describing the QA/QC programs are included as Appendixes C through E of this Volume. The integrity of the data was assured through the use of strict chain-of-custody procedures that fully documented the collection, transportation, analysis, and reporting of each Love Canal sample.

1.1.1 Selection of Sampling Sites

The selection of sampling locations was designed to accomplish three objectives: first, to monitor the Declaration Area using a statistically valid sampling design so that estimates of characteristic environmental concentrations of contaminants could be obtained; second, to locate and trace pathways of chemicals that had migrated from the former canal; and third, to obtain multimedia environmental measurements for the purpose of validating the presence of suspected transport pathways. In order to achieve these objectives, the following guidelines were used for site selection purposes.

1. Written permission of the property owner/occupant had to be obtained prior to initiating sampling activities at any site.

2. Simple random sampling of sites was to be employed to obtain representative coverage of the entire Love Canal Declaration Area.

3. Suspected transport pathways (based on information obtained from prior investigations conducted at Love Canal) were to be sampled as close to the former canal as was possible, and followed away from the former canal as far as was feasible. This sampling was performed in order to ascertain if contamination in the Declaration Area was directly attributable to Love Canal.

   Pathways sampled included:

   a. swales--former low-lying soil features in the vicinity of Love Canal that surface-water runoff once preferentially followed. The locations of known former swales in the general Love Canal area are identified in Figure 2.

   b. wet areas--residential areas where standing surface water once tended to accumulate (the NYS wet/dry designation was used for classification purposes).

   c. sand lenses--sandy deposits in soils through which ground water could readily move.

   d. buried utilities--storm and sanitary sewers that were located in close proximity to the canal.

   e. other pathways--information obtained from local residents directed sampling activities to numerous areas of suspected chemical migration.

4. Creeks and rivers in the general vicinity of Love Canal (particularly near storm sewer outfalls in Black Creek and the Niagara River) were to be sampled to determine the extent and degree of contamination in those waters resulting from the discharge of contaminated water and sediment from storm sewer lines, or from other (unknown) sources.

5. Multimedia measurements were to be conducted at selected sampling sites.

6. Control sampling sites were to be selected such that they were physically similar to Declaration Area sites, except that they were to be sufficiently distant from the former canal so as to be free from potential contamination related directly to Love Canal, and not be located near any other known hazardous waste landfill areas. Control sites were selected throughout the greater Niagara Falls area, and on Grand Island (located south of Niagara Falls). See Table B-1 in Appendix B for more detailed information on the location of control sites.

7. Indoor air monitoring was to be performed only in unoccupied residences in order to reduce the potentially confounding influence of airborne contaminants that might be present due to habitation activities.

1.1.2 Samples Collected

A total of 6,853 field samples were collected by EPA during the Love Canal monitoring program. Of these samples 6,193 were analyzed and 5,708 were validated through application of an extensive QA/QC program, which involved the analysis of an additional 5,743 QA/QC samples. In total, the validated Love Canal data base contains the results from analyses performed on 11,451 samples (field samples plus QA/QC samples). Table 1 reports the number of field samples collected, analyzed, and validated according to each environmental medium sampled.

TABLE 1. SUMMARY OF LOVE CANAL FIELD SAMPLES

Medium	Samples Collected	Samples Analyzed	Samples Validated	Percent Rejected by QA/QC	Percent Other†	Percent Validated
Water	2,687	2,457	2,065	14.6	8.5	76.9
Soil	1,315	1,156	1,132	0.7	13.2	86.1
Sediment	290	266	259	2.4	8.3	89.3
Air	2,089	2,024	1,967	2.6	3.2	94.2
Biota	472	293	285	1.5	38.1	60.4
Totals	6,853	6,193	5,708	6.8	9.9	83.3

†Includes samples that were damaged, lost, not reported, etc.
Note: Percentages are based on the number of samples collected.

The Declaration Area was subdivided into 10 sampling areas that facilitated the use of statistical estimates of typical environmental concentration levels of substances monitored throughout various sections of the general Love Canal area. Sampling areas were defined (as feasible) according to those natural and manmade physical features of the Declaration Area that might be related to chemical migration pathways. Consequently, the likelihood was increased of more readily permitting the potential identification of chemical concentration gradients of substances that had migrated from the former canal. Typical physical boundaries of the sampling areas included: (1) streets, whose buried utilities (such as storm sewer lines) might serve as barriers to, or interceptors of, the subsurface migration of chemicals, and whose curb drains would serve as barriers to or collectors of overland flow; and (2) creeks, which serve as

natural recharge/discharge boundaries to the shallow ground-water system in the area. Within each of the 10 sampling areas, sites were both intentionally selected to maximize the probability of detecting transport pathways (for example, purposely locating sampling sites in former swales, sand lenses, and wet areas), and randomly selected to provide a statistically representative sample of residences. The fenced Canal Area compound was also sampled, and was identified as sampling area 11. Figure 4 depicts graphically the boundaries of sampling areas 1 through 11.

In addition to the 11 geographical sampling areas just described, a number of other sites outside the Declaration Area were sampled and, for convenience, have been grouped according to sampling area designations (even though they do not necessarily refer to physically contiguous geographical areas). For example, sampling area 97 consisted of those sites located outside the boundary of the Declaration Area that were sampled at the explicit request of area residents. Sampling area 97 sites were not considered control sites. Another sampling area, referred to as 98, consisted of sites (including one site in the Declaration Area) that were intentionally selected for a special ambient-air monitoring study to determine transport patterns and background levels of airborne pollutants. Finally, sampling area 99 consisted of those sites explicitly selected as control sites for each environmental medium sampled, and those sites that were explicitly selected as control sites for comprehensive multimedia sampling. Due to the distance of sampling area 99 sites from the Declaration and Canal Areas, they are often not displayed in subsequent figures identifying medium-specific sampling locations.

Both the number of sites sampled and the number of samples collected in each sampling area varied according to the environmental medium sampled. Air was the only medium for which there was an explicit attempt to sample an equal number of sites in each sampling area. For all other media, the intensity of sampling in a sampling area was a function of distance from the former canal (that is, sampling intensity decreased with distance), availability of the medium for sampling purposes (for example, the sampling of sump water was contingent on the presence of a sump in a residence), and the appropriateness of the sampling area approach for the medium sampled. As an illustration of this last point, note that the sampling area approach to characterizing bedrock ground-water quality was rejected as inappropriate because bedrock ground-water movement was recognized as obviously not constrained by street boundaries.

1.1.3 Statistical Analysis of the Data

In order to perform statistical analyses on the monitoring data, the data were aggregated (by medium and sample source) according to Declaration Area (sampling areas 1 through 10), Control Area (sampling area 99), and Canal Area (sampling area 11).

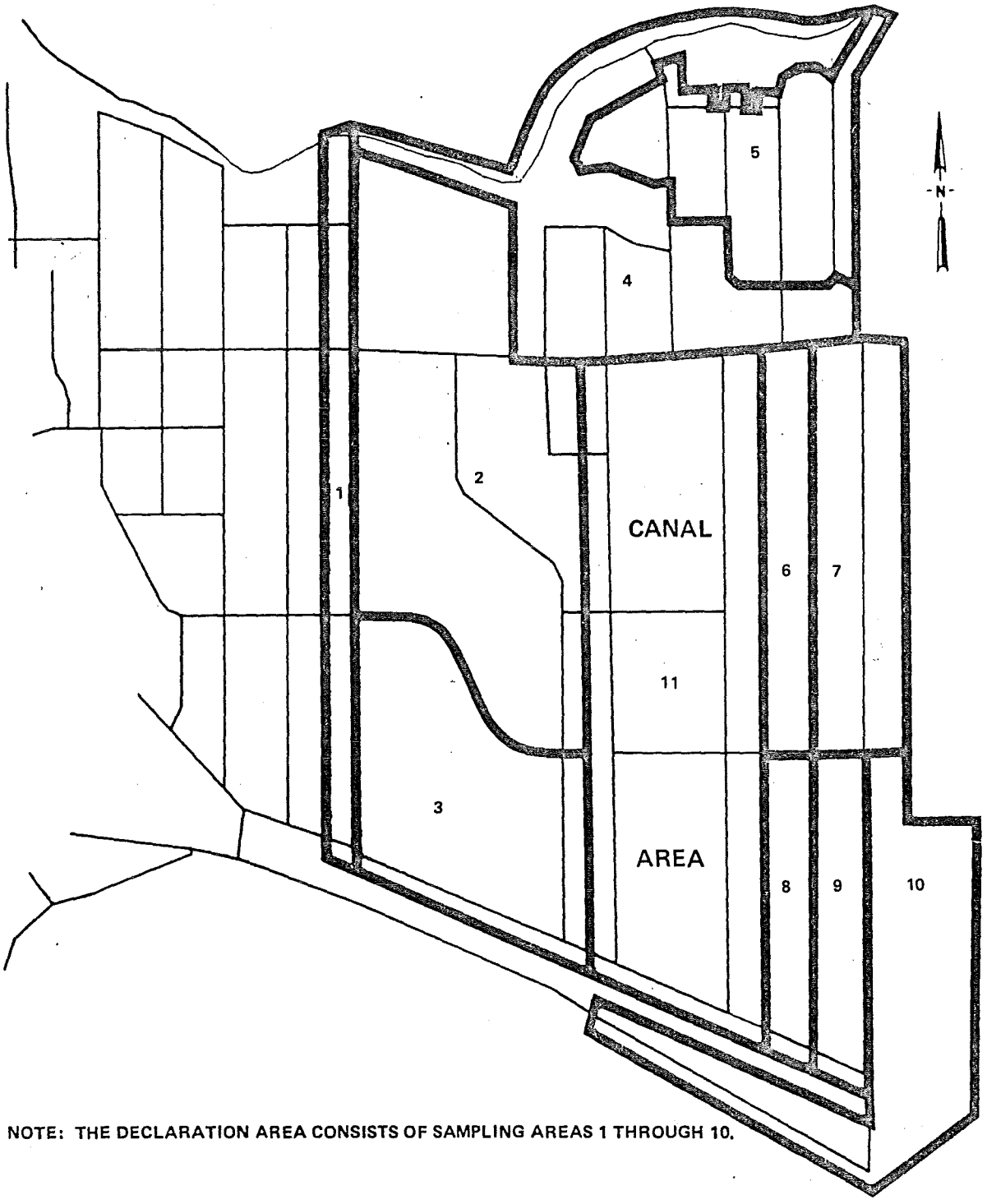

Figure 4. Sampling Areas.

The statistical tabulations and analyses performed on the aggregated monitoring data (presented in Volume III) consisted of substance-by-substance comparisons of frequencies of detections and median concentration levels observed in each of the three data aggregating units (that is, Declaration, Control, and Canal Areas).

The extent of environmental contamination in an area of interest (for example, the Declaration Area) was defined as the percentage of times a substance was identified as present at a "trace" or greater concentration level in the field samples analyzed and validated. A difference of percentages test, using Fisher's exact test to compute probability values, was used to determine if statistically significant differences in the extent of chemical contamination existed between the three aggregating units. (See, for example, Y. M. M. Bishop, S. E. Fienberg, and P. W. Holland, Discrete Multivariate Analysis, M. I. T. Press, 1975, 364). The degree of environmental contamination in an area of interest was defined as the median concentration of all field sample measurements for a substance in the aggregating unit of interest. A difference of medians test, using Fisher's exact test to compute probability values, was used to determine if statistically significant differences in the degree of chemical contamination levels existed between the Declaration, Control, and Canal Areas. (See, for example, A. M. Mood, F. A. Graybill, and D. C. Boes, Introduction to the Theory of Statistics, McGraw-Hill, 1974, 521).

Other statistical procedures used to summarize the vast amount of data collected at Love Canal by EPA and presented in Volume III consisted of grouping the data into frequency distributions, with intervals defined according to the concentration levels observed; computing various percentiles of interest; reporting finite (quantified) minimum and maximum observed concentrations; and computing the mean (arithmetic average) value of the observed finite concentrations.

The statistical criteria used to aid in a determination of the presence of Love Canal-related environmental contamination in the Declaration Area were designed to achieve three objectives: (1) test the validity of the postulated process of contaminant movement from the former canal into the Canal Area, and from the Canal Area into the Declaration Area; (2) safeguard the public health by establishing a requirement of using only lenient statistical evidence (that provides a margin of safety) to assess the extent and degree of contamination in the Declaration Area; and (3) obtain acceptably high power in the statistical tests employed that might otherwise have been affected adversely (in certain instances) by the relatively small number of control sites samples that could be collected during the short sampling time period available for conducting this study.

1.1.4 Substances Monitored

Due to time and budgetary constraints, the EPA monitoring program at Love Canal was intentionally directed at the identification of a finite number of chemicals in each sample collected. In order to increase the efficacy of this approach, efforts were devoted to developing lists of targeted substances that would be routinely monitored in each specific sample type collected at Love Canal. To this end, the following activities were conducted: (1) samples of air and leachate were collected by EPA directly at the former canal prior to the initiation of field sampling activities and were analyzed comprehensively; (2) the results from previous environmental monitoring studies conducted at Love Canal by the State of New York and EPA were reviewed; and (3) records submitted by the former owner of the site, Hooker Chemical and Plastics Corporation (concerning the 21,800 tons of chemical wastes buried in the landfill) were examined. These efforts permitted EPA to identify those substances that were most abundant in the source, prevalent in the environment, and of toxicological significance. The end result was the construction of 2 lists of targeted substances; a list of approximately 150 substances for water/soil/sediment/biota samples; and a list of 50 substances for air samples. The specific substances monitored at Love Canal are listed in Tables A-1 and A-2 in Appendix A of this Volume.

The EPA monitoring program conducted at Love Canal represents a directed, comprehensive effort in environmental monitoring at a hazardous wastes site. Due to the large number of environmental samples analyzed and the large number of targeted substances monitored, it is unlikely that significant amounts of contaminants that had migrated from Love Canal would have been undetected. Furthermore, the intentional inclusion of specific substances on the target list that were known to be present in Love Canal, and which (due to their physical and chemical properties) might also serve as effective and efficient indicators of subsurface migration of leachate, was designed to permit a determination and assessment of chemical migration from the source.

The EPA monitoring program at Love Canal also included the following two features. First, analytical subcontractors were required to analyze each field sample for all targeted substances, and were also required to identify the next 20 most abundant substances found in the sample. Second, EPA conducted an audit of the results obtained by analytical subcontractors, in order to determine the accuracy of substance identifications and completeness of substance identifications in those field samples analyzed by the subcontractors. The results of the audit, reported in Appendix F of this Volume, provided additional confirmation of the validity of the analytical chemistry data presented in this report.

1.1.5 Sampling Procedures and Sites Sampled

A total of 174 ground-water monitoring wells were installed by EPA at Love Canal and at control sites. Samples of ground water were obtained from 136 of the monitoring wells. The remaining 38 wells were either dry or the sample results were rejected by the data validation and QA/QC process.

Two separate ground-water systems exist in the Love Canal area and were monitored individually. A shallow overburden system was often encountered, usually at a depth of less than 20 feet below the land surface. Wells installed to monitor the shallow system were referred to as "A Wells." Ground-water samples collected from a total of 79 A Wells are included in the validated data base. The major aquifer present in the Love Canal area is located in the underlying Lockport Dolomite bedrock, a unit that was encountered typically at a depth of approximately 40 feet below the land surface. The major water bearing zone of the dolomite was found to occupy approximately the top 20 feet of the unit. The bedrock aquifer was sampled separately through the installation of bedrock wells, referred to as "B Wells." Ground-water samples collected from a total of 57 B Wells are included in the validated data base. Most sites sampled had both A and B Wells installed.

A large number of other water samples were collected at Love Canal. These included: (1) residential drinking water (including both raw and finished water samples collected from the Niagara Falls Drinking Water Treatment Plant); (2) sanitary sewer water; (3) storm sewer water; (4) sump water; and (5) surface water from area creeks and rivers (sites in or near to the Declaration Area were usually located in proximity to storm sewer outfalls). A full enumeration of the number of water sampling sites that are represented in the validated data base is given in Table 2.

A total of 171 soil sampling sites are represented in the validated data base. The procedure used for collecting soil samples was designed to maximize the probability of detecting the subsurface migration of chemicals through soils. Because it was not possible to stipulate the soil depth at which leachate might move laterally from Love Canal, and/or percolate downwards through soils, the more permeable top 6 feet of soil was sampled. At each soil sampling site a total of 7 soil cores, each 6 feet long and 1 3/8 inches in diameter, were collected following a pattern (typically a circular shape) that was representative of the physical area sampled. Two of the seven soil cores were analyzed for the presence of targeted "volatile" compounds. The remaining five soil cores were composited and analyzed for additional targeted substances. A full enumeration of the number of soil sampling sites that are represented in the validated data base is given in Table 2.

TABLE 2. A SUMMARY OF LOVE CANAL SITES SAMPLED AND REPRESENTED IN THE VALIDATED DATA BASE

	Sampling Areas						Grand Total
	1-10	11	99	Sub-Total	97	98	
Water							
Drinking	31	3	5	39	5	--	44
Ground: A Wells	49	19	11	79	--	--	79
B Wells	29	13	15	57	--	--	57
Sanitary sewer	1	0	0	1	--	--	1
Storm sewer	22	3	1	26	2	--	28
Sump	33	13	1	47	7	--	54
Surface	4	--	5	9	10	--	19
Soil	112	24	9	145	28	--	171
Sediment							
Sanitary sewer	1	0	0	1	--	--	1
Storm sewer	18	4	1	23	1	--	24
Stream	4	--	5	9	9	--	18
Sump	--	3	--	3	--	--	3
Air							
Basement	9	1	0	10	--	--	10
Living	55	6	4	65	--	--	65
Outside	8	1	0	9	--	--	9
Transport study	--	--	--	--	--	5	5
Occupied/ Unoccupied study	3	0	0	3	4	--	7
Sump/Basement-Air study	0	9	0	9	--	--	9
Biota							
Crayfish	1	--	1	2	--	--	2
Dog hair	20	--	15	35	--	--	35
Maple leaves	14	6	11	31	--	--	31
Mice	5	2	2	9	--	--	9
Oatmeal	12	2	4	18	--	--	18
Potatoes	11	2	3	16	--	--	16
Worms	4	2	3	9	--	--	9

Note: Dashes signify not applicable

Sediment samples were collected from a number of different sources during the Love Canal monitoring program. Sediment samples were collected from area creeks and rivers, in conjunction with the collection of surface-water samples. As was noted earlier, sites in or near to the Declaration Area were usually located in proximity to storm sewer outfalls. In addition, sediment samples were collected, as available, from the following sources: (1) sanitary sewers; (2) storm sewers; (3) sumps; and (4) from the on-site Leachate Treatment Facility located adjacent to the former canal on 97th Street. A full enumeration of the number of sediment sampling sites that are represented in the validated data base is given in Table 2.

In addition to the organic and inorganic chemicals routinely determined in water/soil/sediment samples, EPA conducted a monitoring program to define and quantify the radionuclides present in the general Love Canal area. Those radionuclides analyzed for by EPA included all gamma-emitting radionuclides and, in drinking water samples, tritium.

Air monitoring at Love Canal was conducted in 65 continuously unoccupied residences. In each of these residences, living area air was monitored by means of collecting integrated 12-hour samples using the sorbents TENAX and polyurethane foam (PFOAM). A maximum of 13 daytime (6 a.m. to 6 p.m.) air sampling campaigns were conducted in each of these residences throughout the duration of the monitoring program. In addition to the normal daytime sampling campaigns, 3 nighttime campaigns (also of 12 hours duration) were conducted in some of these same residences. Each sampling area contained from four to eight living area air monitoring sites.

In 9 of the 65 air monitoring sites, basement air and outdoor (ambient) air were also monitored using the sorbents TENAX and PFOAM. In addition, outdoor sampling sites were monitored with high-volume (HIVOL) particulate samplers, which were started simultaneously with the TENAX and PFOAM samplers, and were operated for 24-hour periods. Air samples from basement and outdoor locations were collected in synchronization with the 13 regularly conducted living area air sampling campaigns.

Residences in which multiple air sampling locations were established were referred to as "base" residences. At each base residence, efforts were made to sample all environmental media and usually included indoor and outdoor air, ground water from both A and B Wells, drinking water, sump water, soil, and foodstuff introduced to the residence as part of the limited biological monitoring program conducted at Love Canal. All sampling areas immediately adjacent to the former canal contained one base residence. Due to limited availability of appropriate locations and residential structures, it was not possible to secure a

control site that satisfied the requirements established to designate it a base residence.

Three special air monitoring research studies were also conducted at Love Canal. These studies involved an investigation of the airborne transportation of pollutants in the Niagara Falls area, the effects of domiciliary occupancy on indoor air pollution levels, and an examination of the interrelationship between contaminant concentration levels in basement sumps and basement air.

An enumeration of the number of air monitoring sites that are represented in the validated data base is given in Table 2.

A limited biological sampling program was conducted by EPA at Love Canal for the purpose of investigating the use of local biological systems to monitor the biological availability and biological accumulation of substances found in appropriate environmental media. The biota program involved the collection and analysis of a limited number of samples, including: (1) crayfish (40 composite samples); (2) domestic dog hair; (3) silver maple leaves; (4) field mice (100 samples); and (5) common earthworms (30 samples); as well as (6) purposely introducing foodstuff (oatmeal and potatoes) into the basements of base residences to determine their potential for accumulation of volatile organic compounds. The biological monitoring program was intentionally not directed at attempting to determine health or ecological effects of toxic chemicals in biota. A full enumeration of the number of biota sampling sites (approximately commensurate with the number of samples except for crayfish, mice, and earthworms) that are represented in the validated data base is given in Table 2.

1.1.6 Limitations

Even though EPA conducted a major sampling effort at Love Canal, resulting in the acquisition of a considerable amount of environmental monitoring data, it is acknowledged that the project was conceived, initiated, and conducted under severe budgetary and time constraints. It was recognized, however, that the critical nature of the problem at Love Canal, involving a large number of nearby residents, meant that the monitoring program conducted by EPA had to be initiated quickly, be thorough, and of high quality. Consequently, a number of decisions were made by EPA, concerning the design and conduct of the monitoring studies, that have potential influence on the interpretation of the study findings.

First, due to the size of the geographical area involved, a statistical survey design was formulated to determine the extent and degree of environmental contamination in the Declaration Area that was directly and incrementally attributable to the migration of toxic substances from Love Canal. Thus, for each environmental

medium monitored, a sampling design with an appropriate sampling frame was employed for site selection. In all media, the sampling design used combined aspects of both purposive selection (for example, intentionally locating some sampling sites to maximize the probability of detecting chemicals that had migrated from Love Canal), and simple random sampling. Whenever possible, sampling sites were stratified according to geographical areas that were defined by natural or manmade physical boundaries, in order to facilitate the identification of potential spatial variability in contamination levels in the Declaration Area.

Second, a finite (but large) list of targeted substances was identified for monitoring in each environmental medium sampled.

Third, because a state of emergency existed at Love Canal, a 3-month time constraint (as opposed to 6 months, 1 year, or longer) was imposed on sampling. While this time frame limited the scope of the investigation, it still provided substantial information regarding potential environmental contamination hazards in the Declaration Area resulting directly from Love Canal.

Fourth, all routine living area air monitoring residences had to be unoccupied continuously throughout the study period, in order to control for the potentially confounding effects of household activities on indoor air pollution levels. By repetitively monitoring air, a 3-month time series of data was obtained that incorporated the potential for detecting temporal trends (for example, trends due to changes in temperature, humidity, precipitation, and wind direction) in concentration levels, and were sampled repetitively.

Fifth, all EPA sampling activities at Love Canal were dependent on the cooperation and willingness of area residents (and state and local authorities) to grant EPA written permission to sample on their property. In recognition of the importance of the EPA monitoring program to each individual, a high rate of cooperation (in excess of 90 percent) was generally displayed by Declaration Area residents.

Partially due to these factors, the ability to use the findings of the EPA monitoring program to predict future weather-influenced conditions at Love Canal may be limited. In similar fashion, the statistical limitations and uncertainties associated with all sampling designs (in contrast to a complete census involving environmental monitoring at all residences), are acknowledged. Consequently, any attempt to infer prior conditions in the Declaration Area (such as air pollution levels) from the current environmental monitoring data is risky and has not been performed.

1.2 RESULTS

The EPA ground-water monitoring program revealed no evidence of contamination attributable to Love Canal in the bedrock aquifer and only very localized contamination in the shallow system. In general, evidence of contaminated ground water that was directly attributable to the migration of substances from the former canal was found only in a few shallow system A Wells located immediately adjacent to Love Canal in the residential lots of some ring 1 houses. Clear evidence of ground-water contamination directly attributable to Love Canal was not found outside of the area around ring 1 houses or in the Declaration Area.

On the basis of tests conducted in monitoring wells, and a ground-water flow model constructed specifically according to hydrogeologic conditions encountered at Love Canal, it was determined that the barrier drain system (the Leachate Collection System) was functioning effectively. The barrier drain system was installed completely around Love Canal by the City of Niagara Falls and the State of New York in 1978 and 1979, as a containment remedy designed to halt the lateral migration of chemicals through the soil. In addition, a clay cap was placed on the landfill. The EPA findings suggested that the barrier drains were operating to intercept chemicals which might be migrating laterally from the former canal, to lower the hydraulic head in the former canal (preventing a so-called "bathtub overflow" effect), and to move nearby ground water towards the drains for collection and subsequent treatment. As a result of the drawback influence of the barrier drains, which extend approximately 1,700 feet in the more permeable sandy soils and 180 feet in the less permeable clays found in the area, nearly all nearby shallow system contamination should be recovered (assuming no additional attenuation of contaminants) that resulted from the prior migration of contaminants out of Love Canal.

The soil monitoring program yielded results that were consistent with the ground-water monitoring findings. In particular, clear evidence of soil contamination attributable to Love Canal was found only in the yards of a relatively few ring 1 houses, and tended to coincide with those sampling sites where contamination was also found in shallow system A Wells. The soil findings suggested that the consistent multimedia pattern of environmental contamination observed at certain ring 1 locations was due to the presence of local, highly heterogeneous soil conditions that permitted the relatively more rapid migration of contaminants from Love Canal to those locations. In particular, soil contamination directly attributable to the migration of contaminants from Love Canal was found to be confined to ring 1, and was associated with the discrete presence of sandy soil (for example, in the form of a sand lens), and with the relative abundance of more permeable fill materials (for example, filled swales). No evidence of soil contamination outside of ring 1 was found in

support of the hypothesis that swales served as preferential routes of chemical migration from Love Canal. Furthermore, no patterns of soil contamination were found outside of ring 1, and no clear evidence of soil contamination was found in the Declaration Area, that could be directly attributed to the migration of contaminants from Love Canal.

Evidence of contamination in sump water and sump sediment samples was found in relatively few ring 1 houses. The ring 1 sites at which sump contamination was found tended to coincide with, or be located near to, those sites where contamination was found in shallow system A Wells and in soil samples. These sites were located mainly south of Wheatfield Avenue and on the 97th Street (west) side of Love Canal. Relatively high levels of contaminants were found in the few ring 1 sumps that contained an amount of sediment adequate for separate sampling and analysis purposes. No pattern of sump contamination was found outside of ring 1 houses, and no clear evidence of sump contamination was found in the Declaration Area that could be directly attributed to the migration of contaminants from Love Canal.

Samples of storm sewer water and sediment revealed that highly contaminated sediment and contaminated water were traceable from the Canal Area to local outfalls, and that approximate concentration gradients (for certain compounds) corresponding to storm-water flow directions existed. Because of the remedial actions taken at the site (and based on the findings of the hydrogeologic program), it is likely that only residual (that is, prior to remedial construction) contamination was found in the storm sewer lines. Furthermore, it is possible that the contamination found in the storm sewer lines near Love Canal resulted from the following: (1) infiltration of the storm sewer laterals on Read and Wheatfield Avenues that were connected (respectively) to the northward and southward flowing storm sewer lines on 97th Street, and the storm sewer lateral on Wheatfield Avenue that was connected to the southward flowing storm sewer line on 99th Street; (2) historical (that is, prior to remedial construction) overland flow of contaminated surface water and sediment that would have been collected by curb drains on all streets immediately adjacent to or crossing the former canal; (3) a catch basin and drain that was located near the former canal in the backyard of houses at 949-953 97th Street, and which emptied into the 97th Street northward flowing storm sewer line; and (4) by the discharge of contaminated water and sediment that was taken-up by the no longer operating sump pumps located in the basements of certain ring 1 houses, and discharged into the 97th and 99th Streets storm sewer lines.

Because of the relatively low solubility in water of many of the organic compounds monitored, and the continuing flow of water through the storm sewer lines, the concentration levels of organic compounds detected in storm sewer sediment samples were generally higher (due to certain organic compounds being more readily sorbed on sediment particles) than corresponding concentrations in storm sewer water samples. It should also be noted that sediment samples could not be collected at all storm sewer sites sampled, and that sediment tended to be more readily available for collection at storm sewer line junctions and turning points.

Surface-water samples and sediment samples collected from Love Canal area creeks and rivers revealed highly contaminated sediment and contaminated water in the general vicinity of those storm sewer outfall locations that were fed by lines connecting to the 97th and 99th Streets storm sewers. In particular, the sediment samples collected in Black Creek near the 96th Street storm sewer outfall revealed that high levels of toxic organic compounds were present, as did sediment samples collected in the Niagara River near the 102nd Street storm sewer outfall. Due to the close proximity of the 102nd Street landfill to water and sediment sampling sites in the Niagara River, it was not possible to unequivocally identify the source(s) of contaminated Niagara River sediment near the 102nd Street outfall.

The air monitoring program results were consistent with the findings obtained from monitoring other environmental media. In essence, indoor air contamination levels were elevated in a few ring 1 houses, namely those houses where other media monitoring efforts (for example, the special sump/basement air monitoring study) also identified the presence of contaminants that had migrated from Love Canal. Outside of the relatively few ring 1 houses so affected, no pattern of regular (living area) indoor, or basement air contamination was observed. Furthermore, no clear evidence of air pollution was found in the Declaration Area that could be directly attributed to contamination emanating from Love Canal.

The three special air monitoring research studies conducted at Love Canal provided limited evidence of the following results. First, airborne contaminants detected indoors were also detected in the outside ambient air, and may have been transported from upwind sources. Second, activities associated with domiciliary occupancy suggested that such activities could potentially increase indoor air pollution levels. And third, highly contaminated sumps (which were found in only a limited number of ring 1 residences) could serve as potential contributing sources of high levels of indoor air pollution.

Analyses of drinking water samples revealed that the drinking water sampled satisfied existing EPA drinking water quality standards. Furthermore, no drinking water samples collected in Declaration or Canal Area residences revealed the presence of contamination that was directly attributable to Love Canal.

The results of monitoring for radioactive contaminants in water/soil/sediment samples revealed that only normal background radioactivity was present in the Declaration Area and in the Canal Area. Analyses conducted indicated that the predominant gamma-emitting radionuclides observed were naturally occurring radionuclides such as radium-226 and the so-called daughter products of its radioactive decay. Water samples analyzed revealed that no gamma-emitting radionuclides were present above background levels, and drinking water concentrations of tritium were well below the EPA drinking water standard. Soil and sediment samples analyzed revealed the presence of only low levels of naturally occurring radionuclides such as potassium-40 and the daughter products of radium-226 and thorium-232, and low concentrations of cesium-137 comparable to worldwide fallout levels.

The limited biological monitoring program provided results that were consistent with the findings obtained from environmental monitoring activities. In general, no evidence of either biological availability or biological accumulation of environmental contaminants was observed among the species sampled in the Declaration Area that could be attributed directly to environmental contaminants that had migrated from Love Canal.

Finally, the results of a special monitoring program for the highly toxic compound 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD), revealed evidence of limited environmental contamination in the general Love Canal area. In particular, it was determined that 2,3,7,8-TCDD was present: (1) in the untreated leachate sampled at the Leachate Treatment Facility (but was not detected in the treated effluent); (2) in the sumps of certain ring 1 residences (sumps that also contained high concentrations of numerous other chlorinated organic compounds); and (3) in sediment samples collected from certain storm sewers that originated near the former canal, and in sediment samples collected from local creeks and the Niagara River near the outfalls of those storm sewers (sediments that also contained high concentrations of numerous other chlorinated organic compounds). These results for 2,3,7,8-TCDD at Love Canal both confirmed and extended the findings reported publicly in 1980 by NYS.

1.3 CONCLUSIONS

The results of the EPA multimedia environmental monitoring program conducted at Love Canal during the summer and fall of 1980 revealed a limited pattern of environmental contamination

restricted mainly to the immediate vicinity of the inactive hazardous wastes landfill. The data suggested that localized and highly selective migration of toxic chemicals through soils had contaminated a few ring 1 houses located mainly south of Wheatfield Avenue. The data also revealed that substantial residual contamination was present in those local storm sewer lines originating near the former canal, and was also present in the surface water and sediment of area creeks and rivers at locations that were near to and downstream from the outfalls of those storm sewer lines.

Apart from these findings, the Declaration Area exhibited no clear evidence of Love Canal-related contamination in any environmental medium monitored. Also, in all media monitored, the data revealed that the occurrence and concentration levels of monitored substances observed in the Declaration Area could not be attributed in a consistent fashion to the migration of contaminants from Love Canal. The data also provided no evidence supporting the hypothesis that (outside of ring 1) swales may have served as preferential routes for chemicals to migrate from the former canal. Finally, the data suggested that the barrier drain system surrounding the landfill was operating effectively to intercept the lateral migration of contaminants from Love Canal, and was also drawing near-surface ground water back to the drains for collection and decontamination at the onsite Leachate Treatment Facility.

The patterns of environmental contamination discovered at Love Canal, that could be attributed directly to the migration of contaminants from Love Canal, were found to be consistent with the geology of the site. Because of the naturally occurring clayey soils in the general Love Canal area, the rapid and distant migration of substantial amounts of contaminants from the former canal to surrounding residences is highly unlikely. Migration of contaminants from Love Canal was found to have occurred over relatively short distances, probably through selective soil pathways consisting of more permeable materials, and was confined to ring 1 of the Canal Area. Even though the transport of contaminants was greater in the more permeable soils, the random deposition and apparent discontinuity of these soils made it highly doubtful that much contamination outside of ring 1 had occurred by ground-water transport.