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Damage Assessment Studies Following the NEPCO 140 Oil Spill on the St. Lawrence River

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December 1979

DAMAGE ASSESSMENT STUDIES FOLLOWING THE NEPCO 140 OIL SPILL ON THE ST. LAWRENCE RIVER

by

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DISCLAIMER

FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory-Cincinnati (IERL-Ci) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

This report examines the impacts to both the economy and the natural resources of the St. Lawrence River after a major spill of No. 6 oil in the Thousand Islands Region. The study will be of interest to all those interested in cleaning up oil spills in inland and coastal waters. Further information may be obtained through the Resource Extraction and Handling Division, Oil and Hazardous Materials Spills Branch, Edison, New Jersey.

David G. Stephan
Director
Industrial Environmental Research Laboratory
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ABSTRACT

The primary objective of the two-and-one-half-year research effort reported here was to determine the environmental and economic impacts of the NEPCO 140 oil spill. This spill occurred in the freshwater environment of the St. Lawrence River on June 23, 1976.

The cleanup operation, which cost about 8.6 million dollars, was reviewed to compare it to the priority cleanup scheme prepared by a private consultant at the request of EPA. In addition, field surveys of residual hydrocarbons were undertaken in the fall and spring following the spill to determine the effects of time and the elements on these residuals.

Upon completion of a short background discussion on petroleum in the environment and a description of the study area, information is provided regarding the diversity and abundance of wildlife in the study area. This information was derived through extensive field survey and is compared to information from areas outside the influence of the spill. This is followed by a discussion of polynuclear aromatic hydrocarbons (based on two years of sampling), and their impacts on the various components of the environment.

The economic impacts of the spill are summarized in terms of direct economic impact experienced by both residential and commercial property owners as well as other classes of riparian property owners. Data were gathered primarily through a mail survey of property owners and review of documents such as insurance claims and cleanup contractors' records.

This report is submitted in fulfillment of Grant No. R805031-01-0 by the St. Lawrence-Eastern Ontario Commission under the sponsorship of the Industrial Environmental Research Laboratory of the United States Environmental Protection Agency. This report covers the period September 24, 1976 to March 31, 1979 and work was completed May 31, 1979.

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ACKNOWLEDGMENTS

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Mr. Glen Owen, Ontario Ministry of the Environment.

We also wish to extend our appreciation to several field associates and clean-up contractors.

The help and advice given by Louis Molinini, Gollob Analytical Service, went beyond the requirements of materials analysis, and we are grateful.

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Without the interest and dedication of graduate students participating in this research, the field data could not have been obtained. Thanks go to David M. Phillips (fish), Patricia Longabucco (waterfowl and birds), Lewis M. Smith (muskrats), Elizabeth A. McGrath (frogs), and Peter J. Petokas (turtles).

SECTION 1

INTRODUCTION

THE SPILL

The Tank Barge NEPCO 140 being pushed by the Tug EILEEN "C" enroute from Murray Bay, Canada, to Oswego, New York, with a cargo of 17.1 million liters (4.5 million gallons) of No. 6 industrial fuel oil grounded on Wellesley Island in the American Narrows section of the St. Lawrence River on June 23, 1976, at about 1:30 a.m. Upon notifying the U.S. Coast Guard (USCG) that the ship was spilling oil, the crew was directed to proceed to anchor off light 217 near Mason Point. This is an approximate distance of 10 kilometers (6 miles).

An estimated 1,167,000 liters (307,070 gallons) of oil were reported lost before operations to secure the discharge were completed (U.S. Dept. of Transportation, 1977). The movement and impact of this oil is discussed in the following chapters.

THE NATURE OF THE RIVER

The St. Lawrence River is the outlet of the Great Lakes, and as such it carries the water runoff from a large part of the North American Continent. It flows in a northeasterly direction from the northeastern end of Lake Ontario, and it empties into the Atlantic Ocean via the Gulf of St. Lawrence. The upstream 195 km (120 mi) of the River forms the International boundary between Canada and the United States, Tibbetts Point to St. Regis (Figure 1). The remaining lower reaches of the River are entirely within Canada.

The St. Lawrence River has been used for commercial shipping since the early days of settlement in North America. In 1954, the St. Lawrence Seaway Development Corporation was established, and the new Seaway was opened to 8.2-m (27-ft) draft vessels in 1959. Approximately 6,000 ships move through the channel carrying about 55 million metric tons each year. Oil of various types is an important commodity moved through this waterway. Approximately 2.25 million metric tons were transported in 1977 (U.S. Department of Transportation, 1978).

The International section of the River can be subdivided into three segments. The 77-km (48-mi) segment from Lake Ontario to Chippewa Point is broad and contains numerous islands (The Thousand Islands Region). The shipping channel weaves its way through this segment, sometimes in narrow but deep passages. The second segment of 42 km (26 mi), beginning at Chippewa

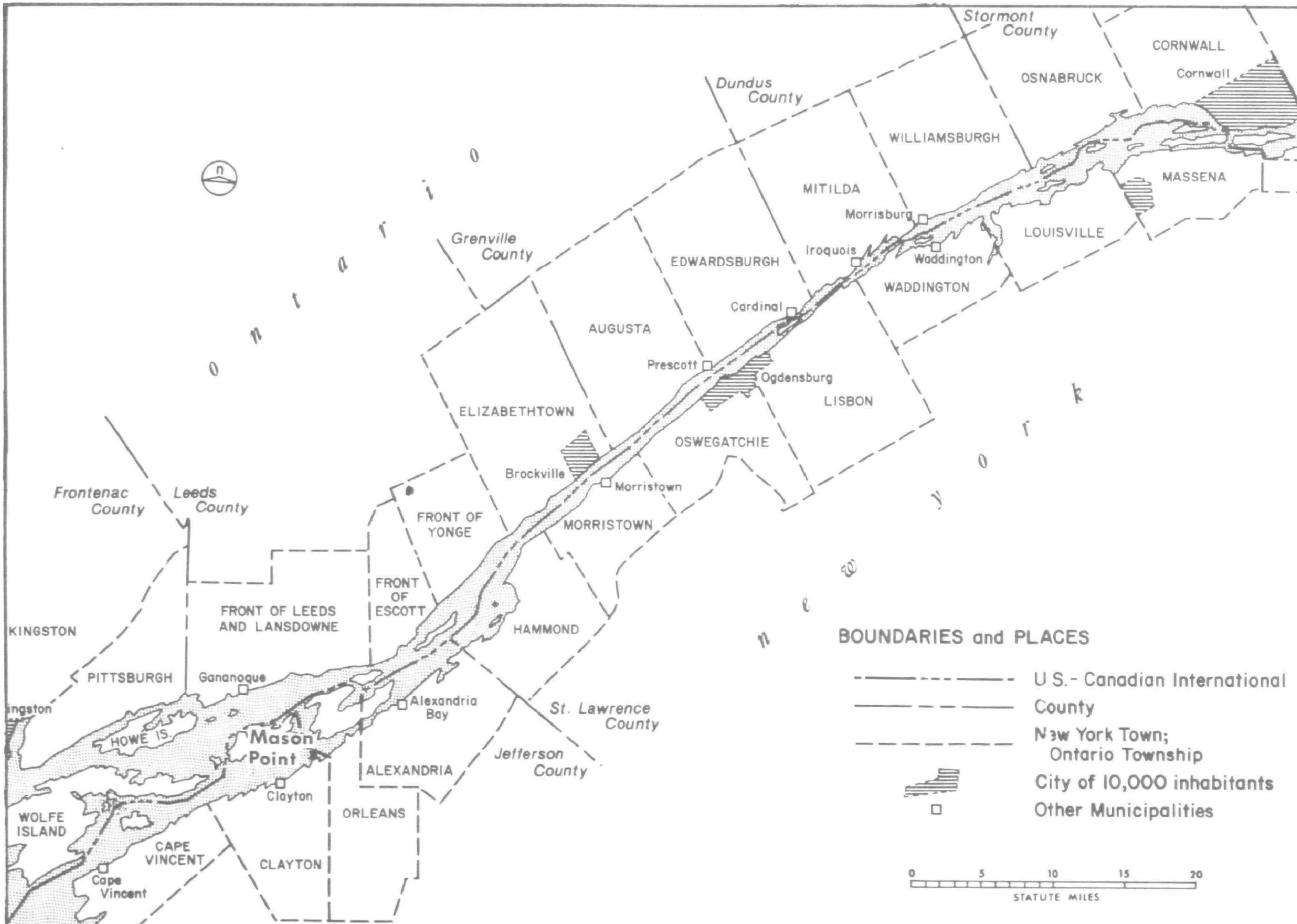

Figure 1. The International Segment of the St. Lawrence River.

Point and ending at Chimney Point, is relatively straight, free of islands, and uniform in width. The third segment of 74 km (46 mi) is that portion most influenced by the water control structure and dug channels leading to the International boundary. Because of the distinctiveness of these three segments, the dynamics of water flow is different for each.

June water levels at the beginning of the River at Kingston, Ontario and Cape Vincent, New York were within the normal range for the period of 1966 through 1972. The water was high in 1973 and 1974, normal in 1975, and high in 1976 when the spill occurred. The level at the outlet to Lake Ontario on June 23 for the past 6 years is given in Table 1, based on the 1955 International Great Lakes Datum, along with cubic feet per second flow rates. These flow rates are influenced both by the level of Lake Ontario and the rate of discharge at the downstream control structure.

TABLE 1. JUNE WATER LEVELS AND FLOW RATES OF THE ST. LAWRENCE RIVER[a]

Year	Relative Level[b]	Elevation[c] (Feet)	Flow (cfs)
1973	High	247.65	350,000
1974	High	247.35	330,000
1975	Normal	245.90	310,000
1976	High	247.15	350,000
1977	Low-Normal	244.90	260,000
1978	Normal-High	246.15	305,000

[a] Data based on weekly reports of U.S. Corps of Engineers Buffalo office on Lake Ontario.

[b] The mean of all June levels is 245.50 feet based on the 1955 International Great Lakes datum.

[c] Elevation represents a composite of Kingston and Cape Vincent data, which varies slightly.

The high water and the swift current in the narrow channel between Wellesley Island and the mainland carried the oil downstream at a rapid rate. Once past Wellesley Island, the water course widens with many small islands and large bays.

Two large bays and several smaller bays exist in the Thousand Islands Region of the River, downstream from Alexandria Bay village. The two major bays are Goose Bay and Chippewa Bay. These bays are elongate in a direction parallel to the main river and separated from it by rock formations. The ends of each bay contain the mouths of inflowing creeks, some of which are wide and slow moving. Extensive cattail[1] marshes exist in these bays, particularly in association with the mouths and lower reaches of the creeks. In general, the bays are shallow throughout, with submerged vegetation in most locations.

The movement of water, and thus the spilled oil, into these bays is influenced by the flow-through characteristics of each bay. The opening to each bay is subjected to the prevailing westerly winds, which can move surface waters into it. Goose Bay has but one principal opening, whereas Chippewa Bay has two major openings. The drainage areas and the associated inflows from the creeks into Goose Bay are much less than those for Chippewa Bay. Because Chippewa Bay has this greater creek flow and a definite flow-through characteristic, it probably received more oil and had it move more quickly to the downstream end than Goose Bay.

Along the United States portion of the shoreline, there are 2,164 seasonal residences and 321 permanent residences between the west edge of the town of Clayton and the east edge of the town of Massena (see Table 2). In addition to the residences, there is a large number of commercial establishments, primarily in the upper end of the river. Most of these support the tourism/recreation industry that is considered the mainstay of the local economy. Primary among these are marinas, restaurants, motels and other service-oriented enterprises.

TABLE 2. RESIDENTIAL RIPARIAN PROPERTIES IN IMPACT AREA

Town	Number of Residences	
	Permanent	Seasonal
Clayton	43	500
Orleans	22	300
Alexandria	57	484
Hammond	12	286
Morristown	30	251
Oswegatchie	35	194
Ogdensburg (City)	27	3
Lisbon	18	18
Waddington	2	0
Louisville	35	126
Massena	40	2
Total	321	2,164

[1]Scientific names are given in Appendix A.

The natural resources of the river area are the catalyst that has generated the growth and development of the recreation/tourism industry. The quality of the water combined with the scenic beauty of the area are primary. However, the fishery, (primarily black bass, northern pike and muskie) provide the activity visitors participate in. The area incorporates those areas required for all phases of the fish life cycle. Included are extensive wetlands. These also provide habitat for water fowl and other mammals and amphibians. The diversity of the area includes Ironsides Island, which is a major rookery for blue herons and is owned by the Nature Conservancy.

GENESIS OF THE STUDY

Immediately following the spill, confusion existed as to what the impact of such a large spill would be in a riverine environment. Little if any documentation could be found to answer the question posed by both laypersons and scientists.

Realizing the lack of data that existed regarding the St. Lawrence River, the Joint Response Team (JRT)[2] initiated efforts to obtain funding for a research effort to address these questions. At the same time, the St. Lawrence-Eastern Ontario Commission developed a scope of work in conjunction with several agency and institution representatives.

The U.S. Environmental Protection Agency (EPA), a member of the Joint Response Team and a recipient of the scope of work prepared by the Commission, realized the paucity of data regarding oil spill impacts in a non-marine environment. Quickly they funded the scope of work prepared by the Commission, but they modified it to address the additional questions raised by EPA and the JRT.

The damage assessment study was funded for a 2-year period at $207,807. The primary objectives were:

1) To review the clean-up operation conducted using the "sensitivity scheme" developed by URS Research Company following the June 23, 1976, oil spill.

2) To determine the effect of the spilled oil on small mammals, waterfowl, and aquatic and wetland resources.

3) To determine the levels of petroleum hydrocarbons within the affected ecosystems to determine the extent of contaminations and bioaccumulation from this spill.

4) To determine the economic impact of the oil spill.

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[2]The JRT consists of representatives of certain agencies of the United States and Canada. This team acts in an advisory capacity to the on-scene commander in event of a spill.

5) To relate the findings of objectives 1 through 4 to the development of a decision making document incorporating all findings and conclusions.

Section 2 addresses objective 1, and Sections 3 through 5 address objectives 2 through 4, respectively. The last chapter summarizes the findings of the studies. The conclusions and recommendations set forth will assist those agencies and individuals who are:

1) Involved in transporting hazardous materials,

2) Developing contingency plans regarding spills of hazardous materials, and

3) Responsible for cleanup of spills.

It should be noted at this point that a Steering Committee was created early in the study to provide guidance in conducting the study. Agencies participating are listed in Table 3. Through this mechanism it was possible to obtain the knowledge and views of those individuals experienced in dealing with all aspects of hazardous material handling and transportation.

TABLE 3. AGENCIES REPRESENTED ON THE STUDY STEERING COMMITTEE

Canadian

Coast Guard
Ontario Ministry of the Environment
Environment Canada

United States

Coast Guard
Fish and Wildlife Service
Department of Transportation
St. Lawrence Seaway Development Corp.
NYS Dept. of Environmental Conservation
Environmental Protection Agency

SECTION 2

CONCLUSIONS AND RECOMMENDATIONS

This chapter relates the findings and conclusions of this study to those problems and issues that relate to the transport of hazardous materials in a riverine environment. Addressed primarily are those issues regarding the clean-up of spills if they occur during transport.

CLEANUP PROCESS

The review of the URS report (URS, 1976) regarding a "sensitivity scheme" resulted in the conclusion that such an effort would be most useful if accomplished before a spill. Documentation in graphic form of the sensitive areas along a waterway would be of assistance to the on-scene commander of a cleanup. Such data would not diminish the role of the Response Team but would shift the time of its major effort from during a spill to before a spill.

The scheme provided by URS is useful but incomplete, as the areas cleaned before the 27th day after the spill and the area at the downstream end of the impacted area plus certain islands were not included. Thus without revision, the usefulness of this report is limited.

It is recommended that efforts to identify "sensitive" areas be continued through programs such as Operation Preparedness, the Commission's coastal management program, and by other agencies working in the area. It is further recommended that the St. Lawrence Seaway Development Corporation and the U.S. Coast Guard utilize this information when undertaking action in the event of future spills.

Two field surveys of the area revealed that the visible residual oil weathered slowly. Few physical changes appeared to occur over the winter following the cleanup. However, the residual appeared to be less visible with the death of old and the growth of new vegetation. These processes seemed to mask the presence of the residual except in areas of rock where the vegetative cover did not exist. Here the residual remained more visible.

Based on this information, it is suggested that in areas where visual residual would be undesirable,cleanup would have to be more extensive with less reliance on nature's assistance. If such residual is acceptable nature can be relied upon to make it less visible with the passage of a few growing seasons.

The visibility of residuals is increased through the fluctuation of water levels. Field observations in the spring and early summer of 1978 indicated that the high water level at that time covered some of the residual. This resulted in small but highly visible areas of sheen on the water surface.

FISH AND WILDLIFE

The data gathered from this two-year study indicate that the fish and wildlife communities in the impacted bays and marshes are recovering from the extensive losses that occurred at the time of the spill and the period immediately following.

The immediate impact of the spill on the fish and wildlife was known to be extensive. The welfare of some species such as the great blue heron was endangered. The production of many other species was threatened. Although the reproductive season for most species was over, the success of rearing the young in these impacted marshes was questionable. The cleanup process brought continued human activity to the bays and marshes which undoubtedly was a major disturbance factor to the remaining fish and wildlife residents.

It should be kept in mind that these results relate to a Bunker C oil spill that occurred in mid-summer of a year when water levels and the flow rate were higher than normal and that was followed by a thorough cleanup. A different oil, a different time of year, a lower water level or a less thorough cleanup could have led to different results.

It was difficult to isolate and quantify specific long term effects of the oil spill on fish and wildlife under these circumstances. The lack of prior data became more important as the ecological differences between the seemingly similar study areas became better understood.

The data suggest that losses went beyond the initial direct mortality of individuals, and that reproduction and survival was reduced for some species. As an example, the number of young yellow perch increased greatly in 1978 on the heavily oiled areas, following two years of low production or survival. At the same time, both the golden shiner and spottail shiner were still low in the heavily oiled areas in 1978. These species may be more sensitive to the oil and may require a longer period for recovery.

The number of fish species remained about the same in all study areas, with the pumpkinseed being a dominant species. No changes in its populations could be definitely attributed to the oil spill. The young of all fish species were influenced by the distribution of submerged vegetation.

Adult waterfowl increased in numbers in 1978 in the heavily oiled areas, but their production of young remained the same as the previous year. Success of breeding pairs to produce broods declined in the heavily oiled areas and increased in the unoiled areas. The high water of 1978 may have reduced suitable nesting sites or placed them close to the upland where predators were common.

No relationship could be found between the abundance of oil and populations of muskrats, songbirds or reptiles.

It is not known how long the oil residuals will remain in the marshes and influence fish and wildlife populations. An oil spill catastrophy compares in its ecological effects withthose of natural catastrophies such as fire and flood. In each, the losses are great and the recovery is slow. However, fish and wildlife can overcome these adversities. The question becomes one of evaluating the loss of a resource to the using public and the local economy for a period of one to several years.

Areas important to the fish and wildlife resource, such as bays and marshes that serve as breeding and nursery areas, should receive high priority in any developed response plan.

POLYNUCLEAR AROMATIC HYDROCARBONS

The data from this study clearly established the presence of Polynuclear Aromatic Hydrocarbons (PAH) in the marshes of the St. Lawrence River. They also indicate a movement from the bottom sediments (mud) into the cattail plants and to a more limited extent into the fish and wildlife. However, since PAH was found in unoiled areas, other sources must exist. The separation of PAHs derived from the oil spill and finally entering the fish and wildlife could not be done in a quantitative manner. Other factors that compounded the data include 1) the uneven distribution of PAHs in a given marsh, 2) the reintroduction of stranded oil at each high water period, 3) the movement of young animals in their feeding activities, and 4) the reliability of analytical procedures.

Some oil was still detectable in the impacted marshes and therefore the component PAHs were present in the mud. There was considerable uptake and accumulation of PAH in the cattail roots. The amounts could generally be associated with the level of oil impact. However, it must be kept in mind that the moderately and heavily impacted areas were quite thoroughly cleaned, whereas the slightly oiled areas were not. This action may have reduced the difference between the extremes.

There is a need to utilize greater cleanup procedures in preparing the extracts from the samples, particularly when animal tissues are involved. Although High Pressure Liquid Chromatography (HPLC) is an effective technique, other methods should be used to verify the results and determine if false positive peaks are occurring. This is important in this study to help determine if the reported presence of naphthalene and biphenyl is true, and if the other PAHs are exaggerated in their amounts.

Some of the individual PAHs were almost seasonal in their presence in cattail roots as determined by HPLC. Naphthalene, which was not found in the oil and was scarce in the mud, was present in the cattail roots during the summer period. Biphenyl, which was lost from the oil early and was rarely found in the mud, was most abundant in the cattail roots during the winter period, although found during the summer in some areas. It seems evident that the plants are accumulating some PAHs in marsh ecosystems, whether derived from oil or not. Most individual PAHs occurred in a sporadic fashion in the mud and cattail roots, although at times in large amounts. The exception was Benzo (a) Pyrene which was almost universally present in mud and cattail roots.

PAH was found to be much lower and more irregular in fish and wildlife species. Only young pumpkinseed data gave an apparent relationship between PAH and the degree of oiling. PAH was greater but more uniform in young yellow perch. This again suggests other sources besides oil. Benzo (a) Pyrene was fairly rare in fish and wildlife. Although young ducklings and young muskrat tissues contained some large amounts of PAHs,these were irregular in their occurrence and were largely naphthalene and biphenyl as determined by HPLC.

There was no evidence of plant mortaility resulting from the oil or its PAH. Cattail growth increased along the heavily impacted edges the year following the spill. These cattail plants did not flower. Growth and flowering was normal the second year. This one-year response may have been a reaction to nutrients contained in the oil, or it could have been a response to the cutting of the plants along the edge during the cleanup.

It became apparent during the study that there is a great need to gain a better understanding of the normal growth and reproduction of plants and animals in these marsh environments. There is need to study the distribution of PAHs in the river proper, the bays, marshes, creeks and small ditches. Experimentation to determine the effects of PAH on specific species of plants and animals are needed. Field areas most sensitive and most susceptable to oil spills should be monitored on a continual basis so that the effect of any future spill in the River can be accurately evaluated.

ECONOMIC IMPACT

Residential

Impacts to residential property owners were primarily losses of recreation days and costs incurred in cleaning their shoreline and boats. Since these impacts were numerous and frequently dispersed, little could be done from a preventive point of view to eliminate the impact after a spill occurs. In order to reduce the impact it is recommended that an educational effort be undertaken to advise the property owners about low cost efforts they could undertake in the event of a spill. Further, a review of the river and its characteristics with respect to the location of concentrations of residential properties may allow identification of areas where containment devices may be implemented in a cost effective manner. It is recommended that both of these actions be undertaken.

Commercial/Industrial

Data gathered through the economic impact survey were limited in some areas due to the lack of response. In general the severe impacts that were expected to occur did not. There were immediate cancellantions of reservations and minor losses of employment in the tourism/recreation sector. However these were short term. Some losses were compensated for by the increased demands of the labor force involved in the clean-up operation.

The distribution of the impact was throughout the impacted area. In many cases it was not a physical impact to the particular establishment that caused the problem but the impact to the natural resources of the river that made it a less desirable place to recreate. Due to this it is recommended that efforts be undertaken to refine the contingency plan so that the information required to ensure the optional containment procedures is readily available to the on-scene commander. Following this and based upon a pre established "sensitivity scheme" cleanup should be undertaken quickly in order to prevent the press from reporting an "end to the recreation season."

Other Riparian Properties

No impacts were reported by power producers or operators of public or private water supplies. Delays were experienced in Seaway shipping which resulted in an estimated $171,448 increase in operating costs for the vessels involved.

State Parks

Impacts at state parks occurred in the form of physical impacts and deprivation of use due to the physical impacts. Attendance data substantiate this as attendance was 18.1 percent less in the two weeks following the spill than during the comparable time the preceeding year. Overall attendance was 5.1 percent less in the impacted area as compared to a 1.6 percent decrease state wide.

From attendance data it appears that there was a shift in attendance and thus the economic impact. From a state or national point of view the impact was very small. However from a local point of view it could be significant.

Other Sources

Insurance claims reflect that 13.3 percent of the U.S. riparian owners filed a claim. This indicates again that the impact was widespread. Since the claimants are widely dispersed it is difficult to prevent all impacts. Contingency planning could determine from an economic and engineering point of view those places where oil containment devices are cost effective.

Analyses of cleanup cost reflect that cleanup is a labor intensive operation. A large portion of the labor force was from the spill area. Wages tended to be higher than those of service-oriented employees. Equipment costs were also a significant portion of the cleanup costs. Data was not available to derive an estimate of what portion of this was rented or purchased through local agents.

The expenditure of $8.6 million in the impact area has to result in positive economic impacts. In terms of labor employment and wages it is estimated it exceeded the losses incurred in the recreation/tourism sector. Total impact was not determined due to the lack of adequate data.

CONCLUDING REMARKS

The study concluded that there were impacts to both the economy and the natural resources of the St. Lawrence River. The reported data explores these impacts and attempts to define the magnitude and incidence of these, given the contraints of both time and money.

Overall, the study indicated that the impacts were high in the short term, a few weeks or months. The economy appeared to recover following this without suffering long term impact. The natural resource base suffered severe short term impacts. The longer term impacts were largely overcome in two years.

Both short and long term impacts on the natural resource base have definite influence on the economy of the study area. The longer these impacts continue, the greater the total influence on the economy.

SECTION 3

CLEANUP OPERATIONS

INTRODUCTION

Shortly after the oil spill occurred the United States Environmental Protection Agency contracted with URS Research Company "to conduct an environmental assessment of the spill and to make recommendations for future cleanup action" (URS, 1976).[1] The purpose of the effort was to provide the Regional Response Team and On-Scene Commander with information with respect to environmental priorities of future cleanup efforts. This assessment began on July 19, 1976. Discussed below is a summary of the findings and methodology set forth in this report along with a summary of the chronology of the actual cleanup operation.

These two sections provide the background information necessary to allow a comparison to be made between the priority of cleanup recommended by URS and that which actually took place. This comparison is undertaken to fulfill the terms of Task A as set forth in the Detailed Work Schedule for Grant Agreement R-805031-01-1 between United States Environmental Protection Agency and the Commission.

SUMMARY OF URS REPORT 7505-4000

The methodology developed and used was first to delineate the areas within the impacted area that were contaminated. Areas "cleaned" and "not yet cleaned" were distinguished. Second, a composite graphic entitled "Spill Area Sensitivity" was developed. Three levels of sensitivity were presented on this composite. Levels of sensitivity were based on a combination of natural and human amenities. The three levels were:

S-1 - Denoted areas of highest social and/or natural productivity. Such areas included emergent cattail marshlands, game refuges and reserves, and highly used and demanded public lands.

S-2 - Pertained to areas of medium productivity. Areas falling in the S-2 classification included private lands having direct access to the St. Lawrence River waterfront as indicated by the presence of private docks and

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[1]Number in ( ) refer to references listed on pages 154 - 158.

launching ramps. Also included were private harbors and piers and any other access areas of restricted use. The S-2 system was infrequently used when dealing with the natural systems within the spill impact area. In general the aquatic systems were either of a highly productive marsh type (S-1) or minimally productive areas (S-3) such as rock/water interface.

S-3 - Applied to those areas of lowest productivity. These included low-intensity use natural areas, industrial river frontage, and all other areas on the river where human use was restricted.

The determination of the priority of cleanup that should be followed was accomplished by comparing the cleaned up/not yet cleaned up areas with the area's sensitivity as described above. The determination of priority graphically displayed was limited to areas not yet cleaned up.

The priority levels developed by URS are reflected in Figures 3-12. The P-1 classification denotes areas of highest cleanup priority and includes sensitivity S-1 sites as well as oil pockets which could potentially contaminate unaffected or cleaned up sites downstream. The latter could not be shown graphically. The P-2 classification denotes a lower cleanup priority. The P-2 areas include all "not yet cleaned up" S-2 areas and "cleaned up" S-1 areas. "Cleaned up" S-1 areas should undergo a reconnaissance followed by any necessary action to prevent recontamination of these highly sensitive areas. Areas classed as P-3 have the lowest cleanup priority.

In reviewing the URS Report the following limitations with respect to comparison between the proposed and actual cleanup were noted. First in significance is the fact that the URS Report did not extend downstream past Sparrowhawk Point in the Town of Lisbon (see Figure 1). Second, many islands that were contaminated were not included in the analyses and thus not included in the sensitivity scheme. Among the islands not included were Ironside, Clouds Rest, Watch, St. Margarettes, Jug, Atlantis, Wyanoke, Manzanti, Schrooner, Birch, Resort and East Mary's. In addition, but of lesser significance, Alexandria Bay area was not included since it was "cleaned up" prior to the URS study.

CHRONOLOGY OF CLEAN-UP OPERATIONS

Background

Immediately after the spill, efforts were concentrated on containment of the oil and removal of that found floating or contained in larger pools. Extensive effort was also given to the cleanup of the Alexandria Bay area and final cleanup was completed by July 4(+12).[2] Additional efforts were given to protecting such areas as Wilson Hill Wildlife Management Area, Chippewa Bay, and other sensitive areas (see Figures 3-12).

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[2]Number in brackets preceded by a + refers to the days that elapsed after the oil spill. Figure 2 relates these to calendar days.

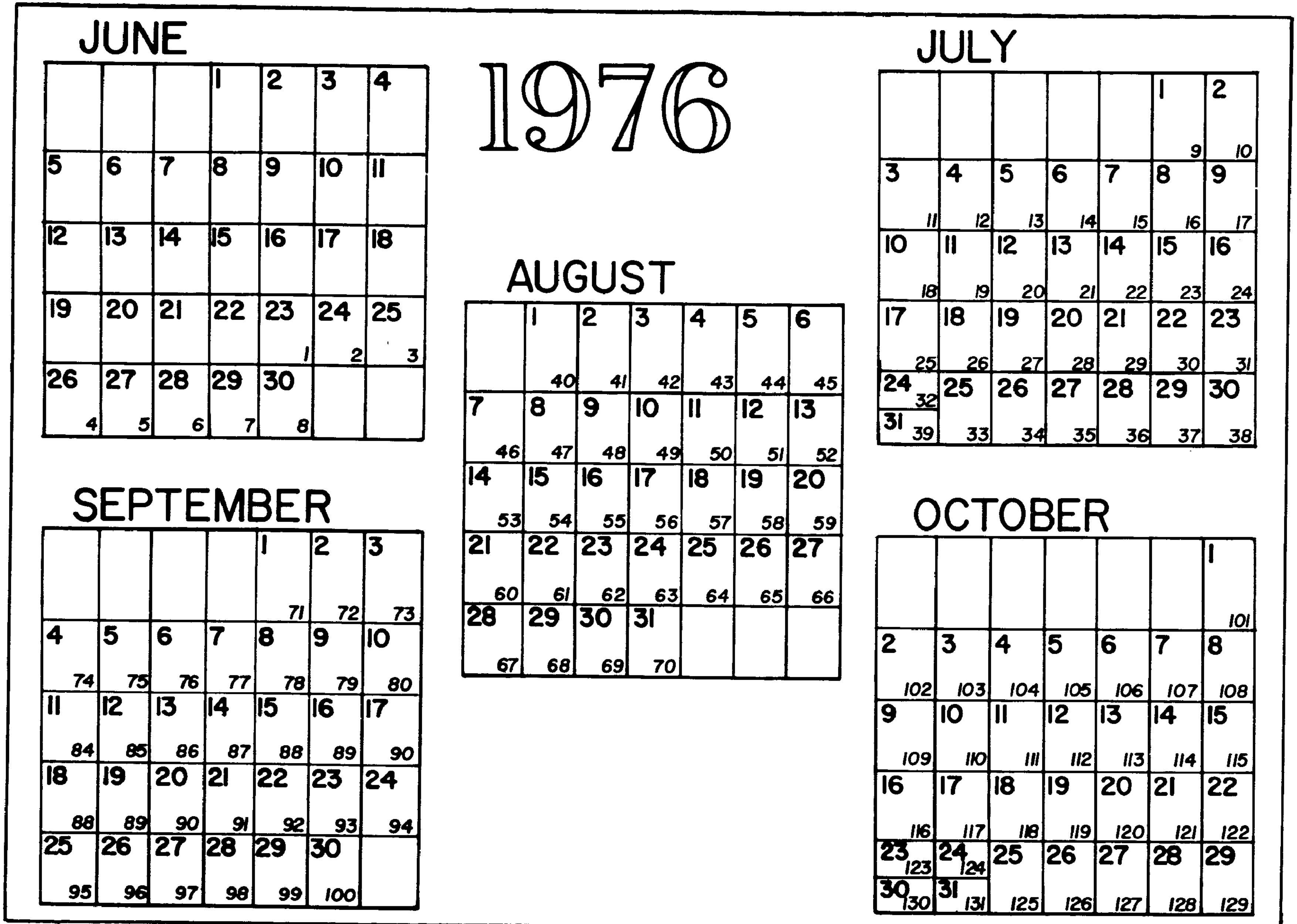

Figure 2. Calendar Days Related to Time Elapsed after June 23, 1976 Oil Spill

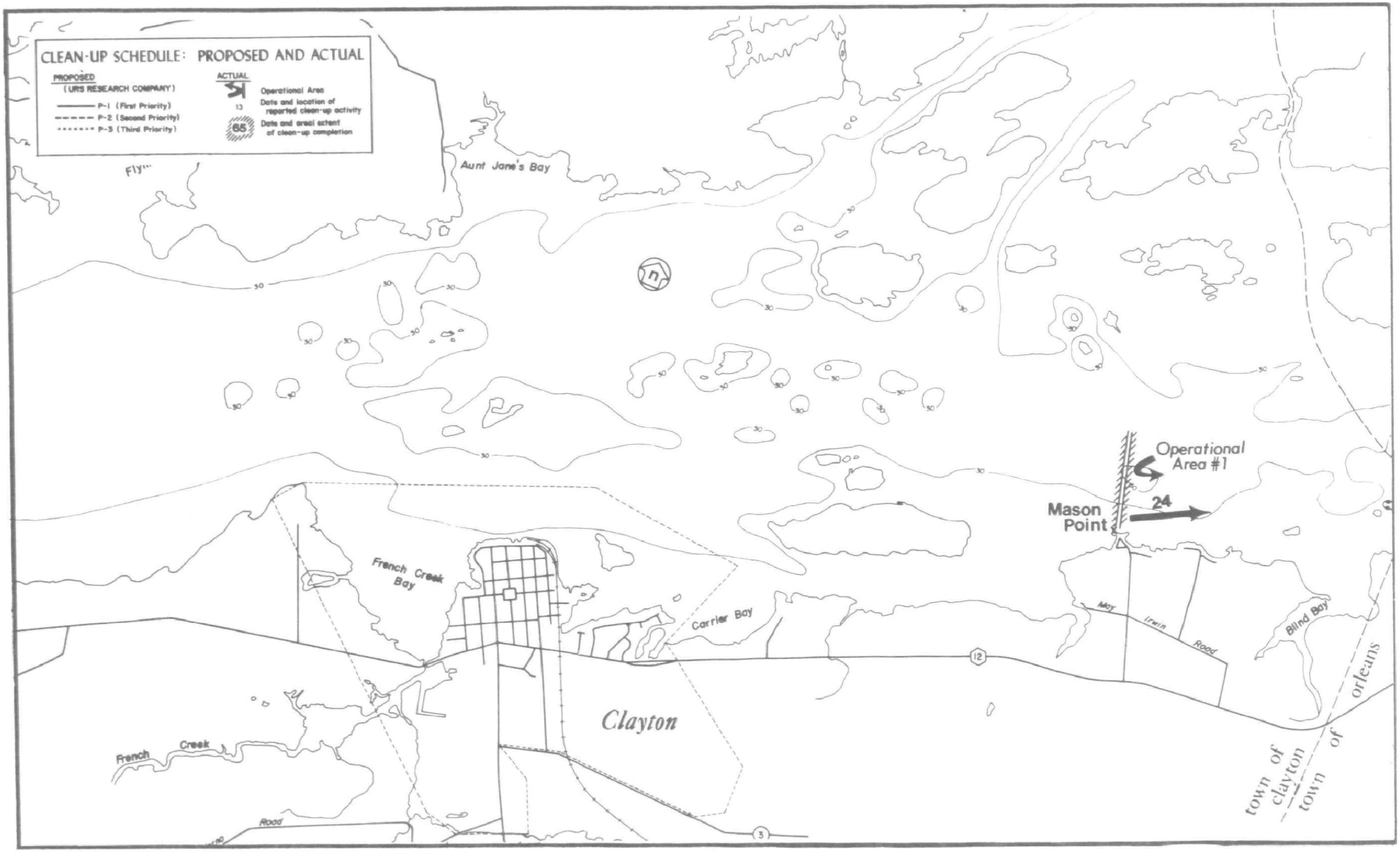

Figure 3. Chronology of Cleanup: River Section 1

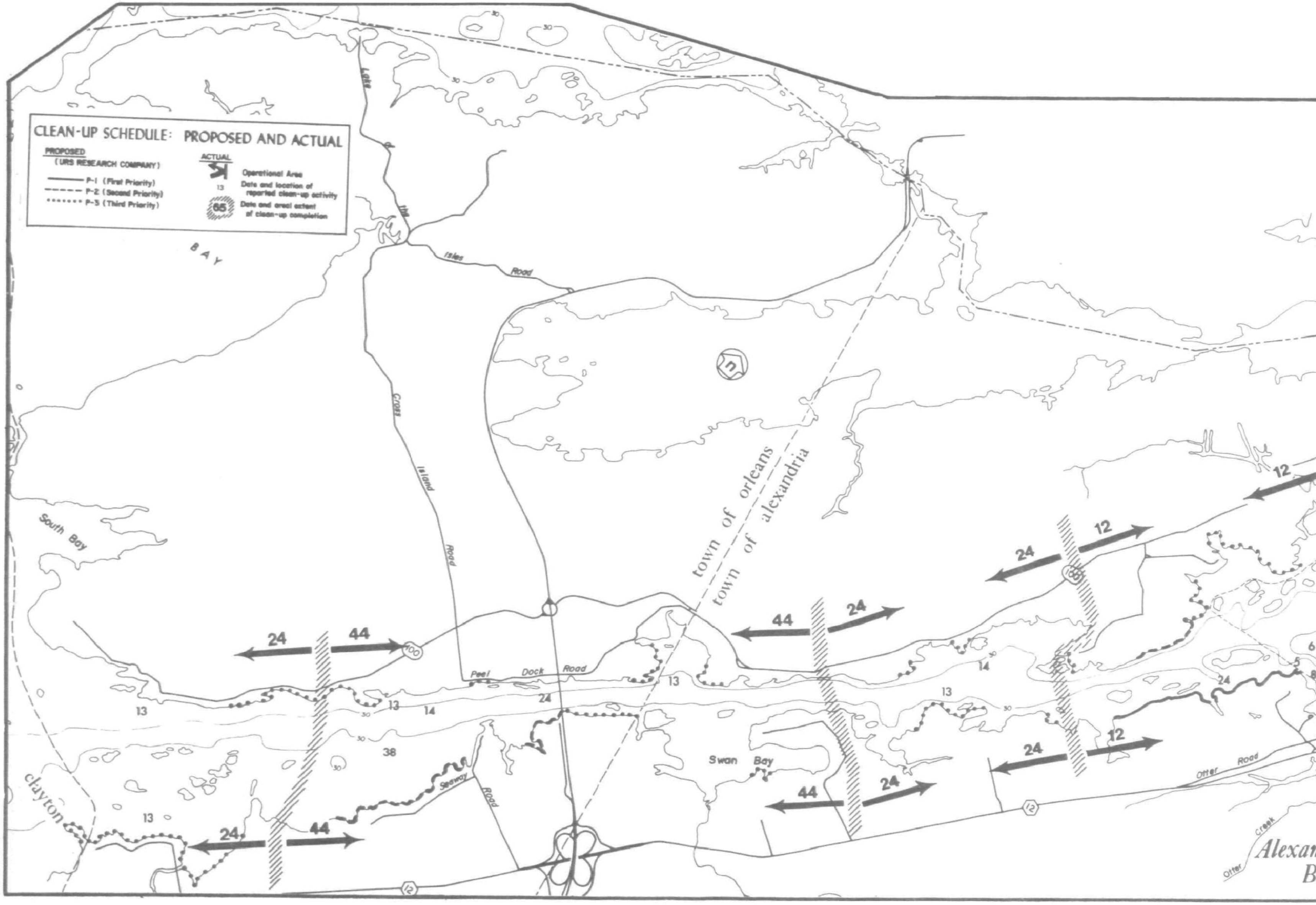

Figure 4. Chronology of Cleanup: River Section 2

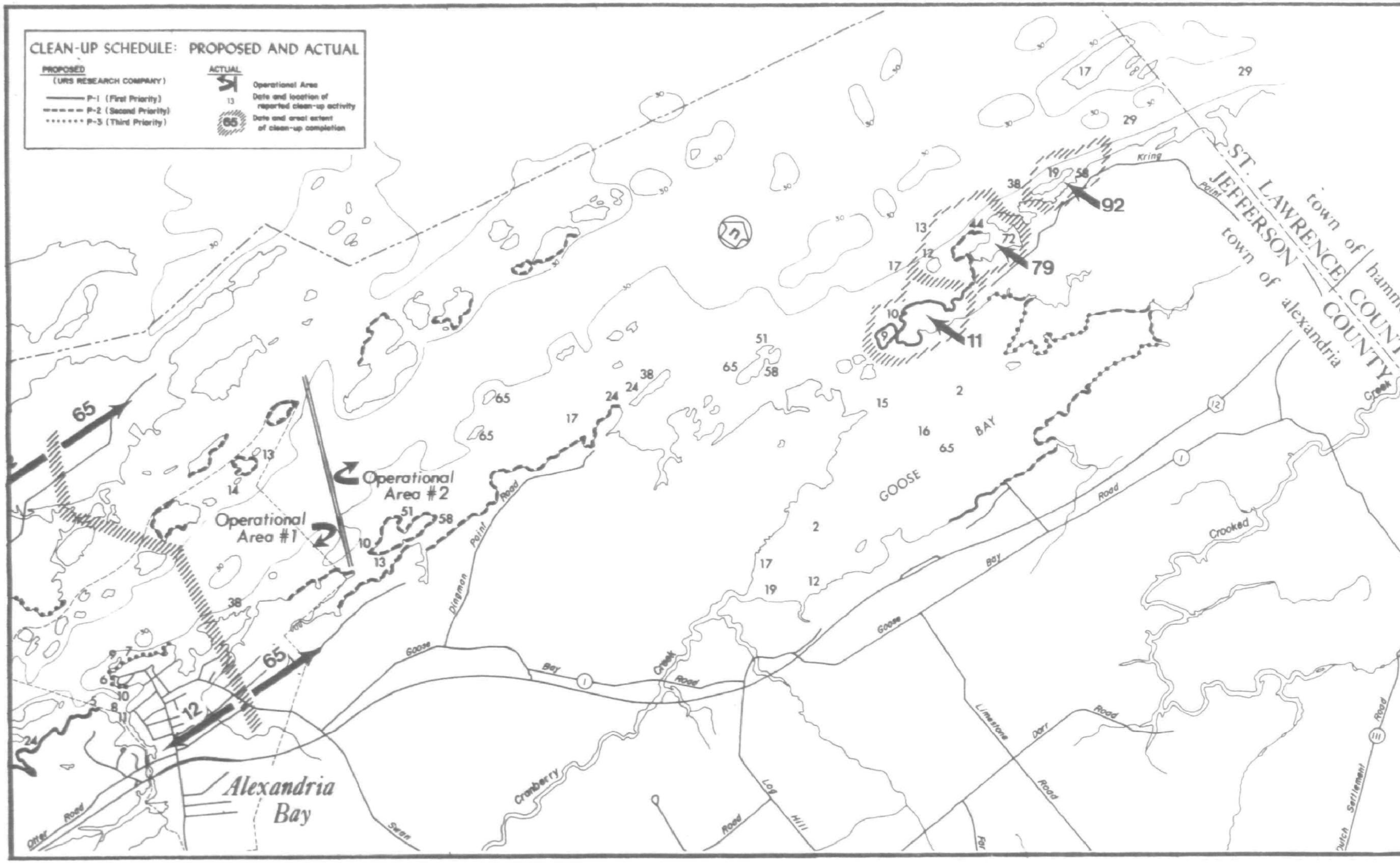

Figure 5. Chronology of Cleanup: River Section 3

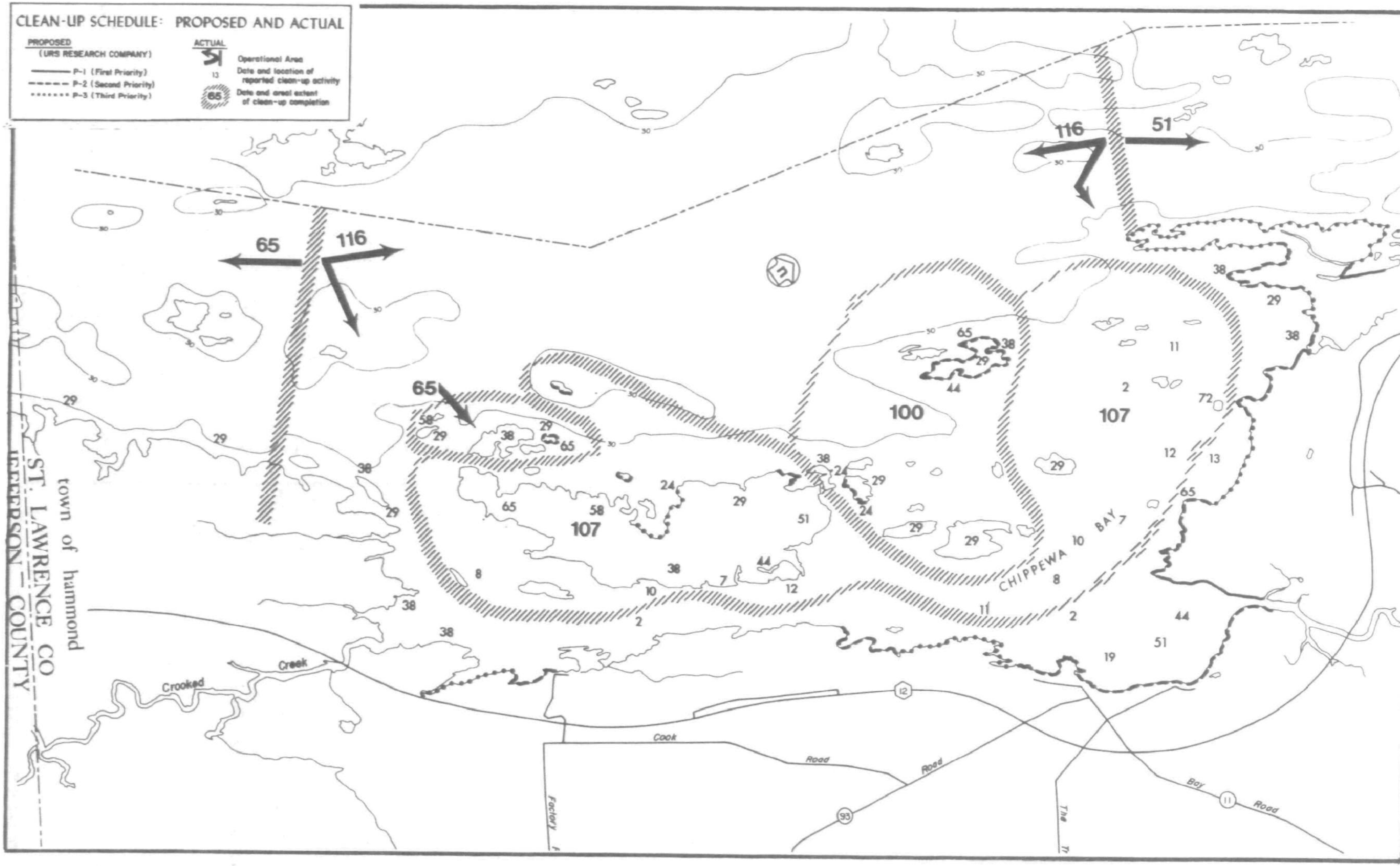

Figure 6. Chronology of Cleanup: River Section 4

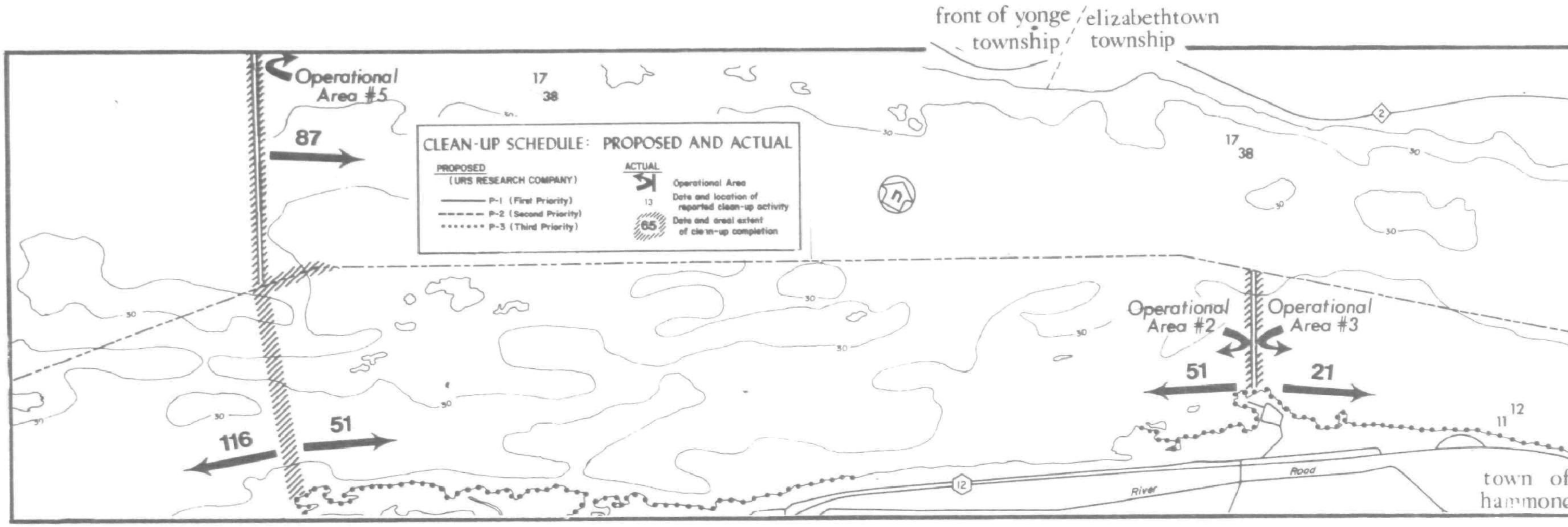

Figure 7. Chronology of Cleanup: River Section 5

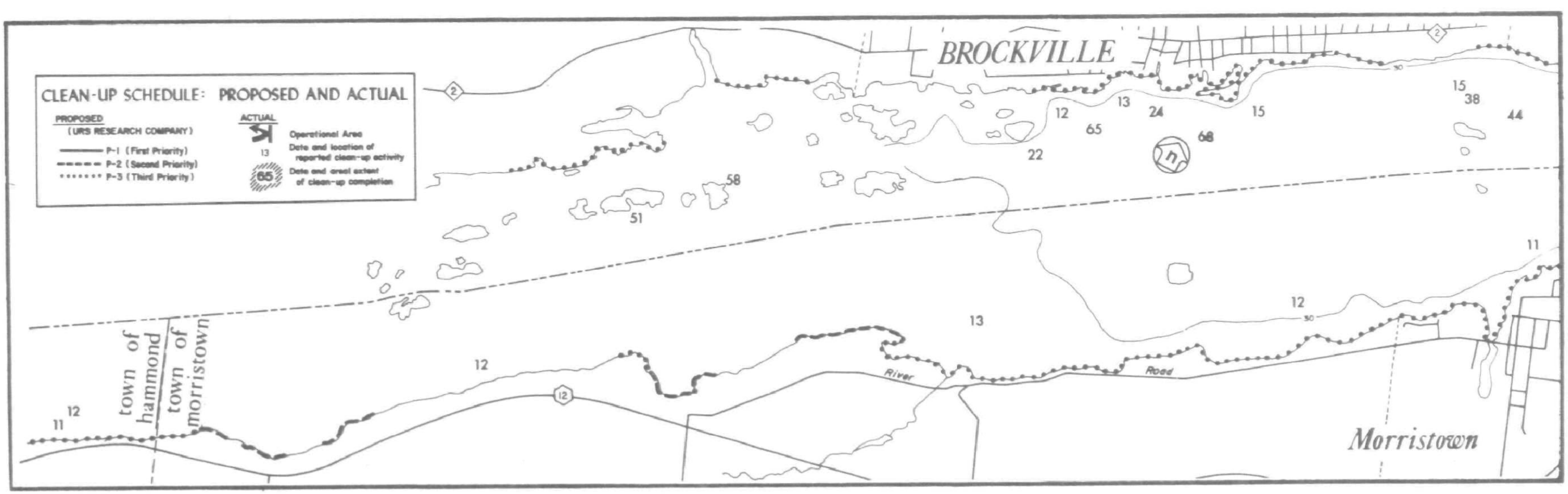

Figure 8. Chronology of Cleanup: River Section 6

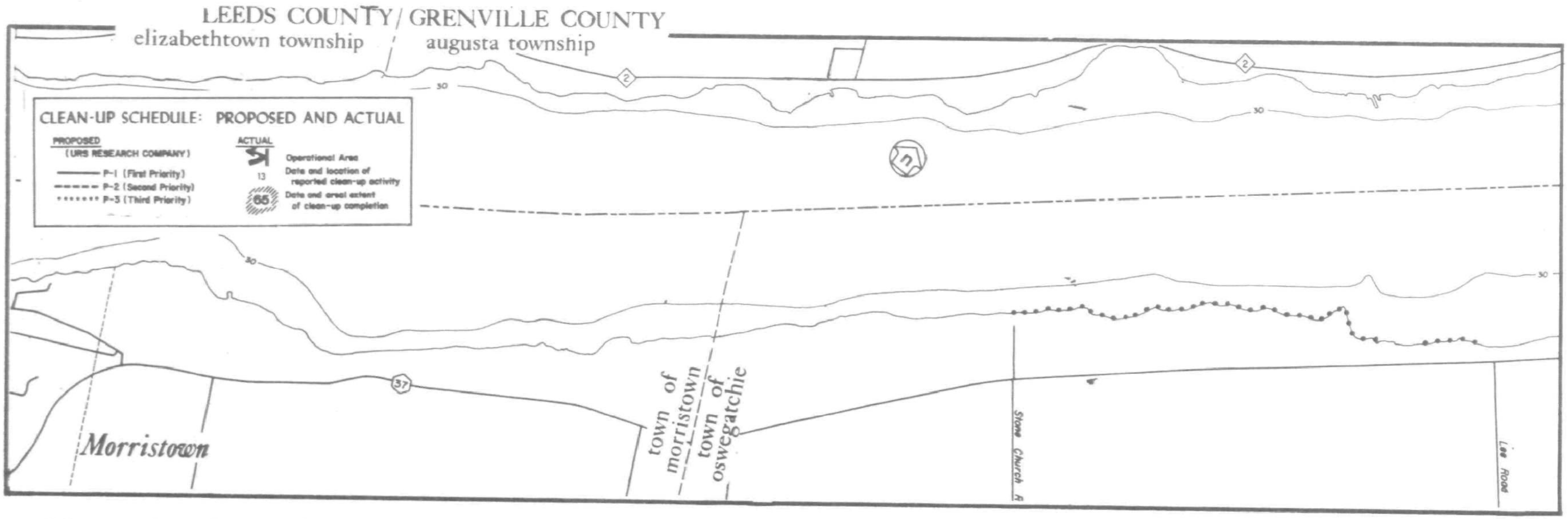

Figure 9. Chronology of Cleanup: River Section 7

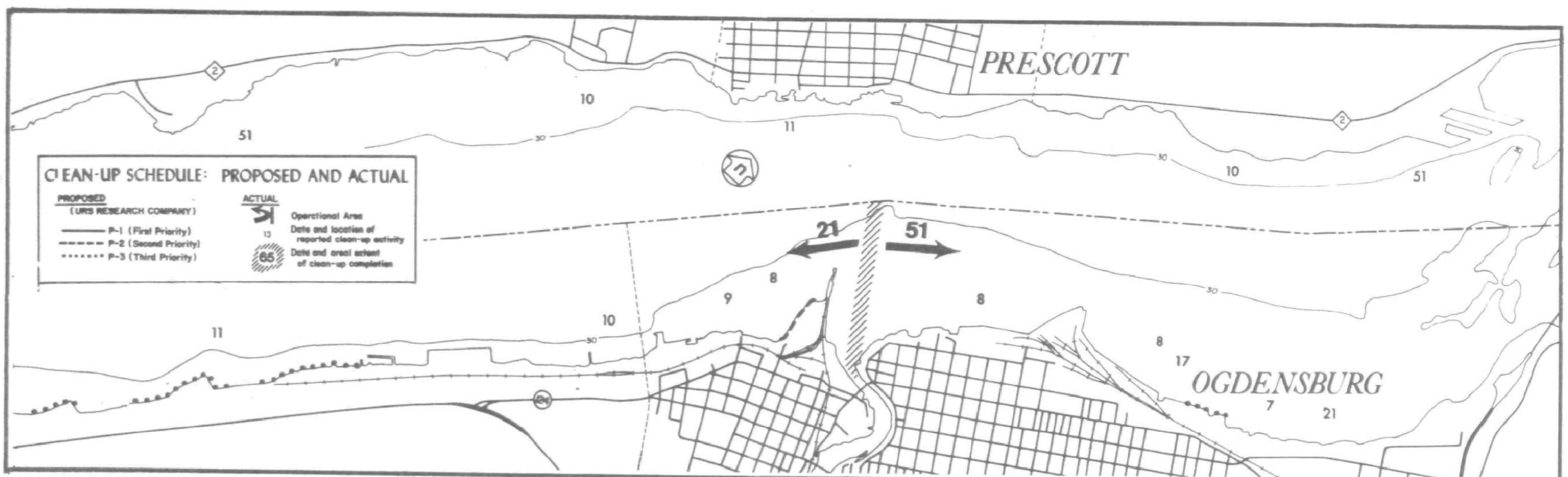

Figure 10. Chronology of Cleanup: River Section 8

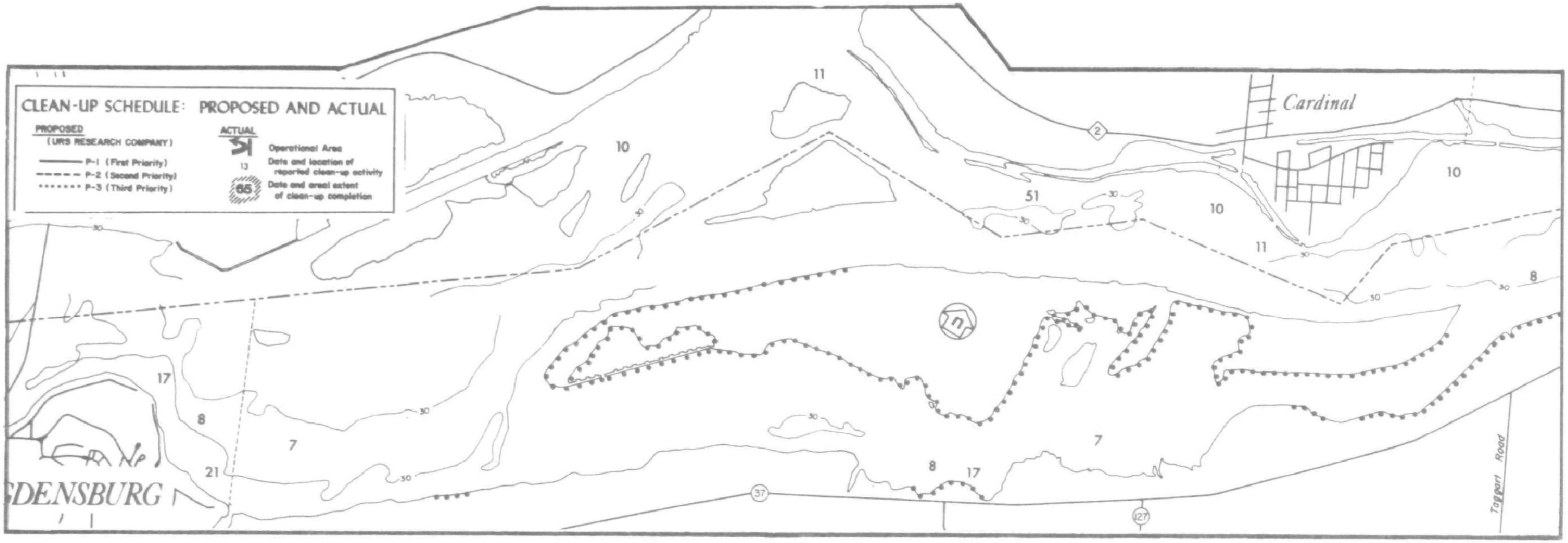

Figure 11. Chronology of Cleanup: River Section 9

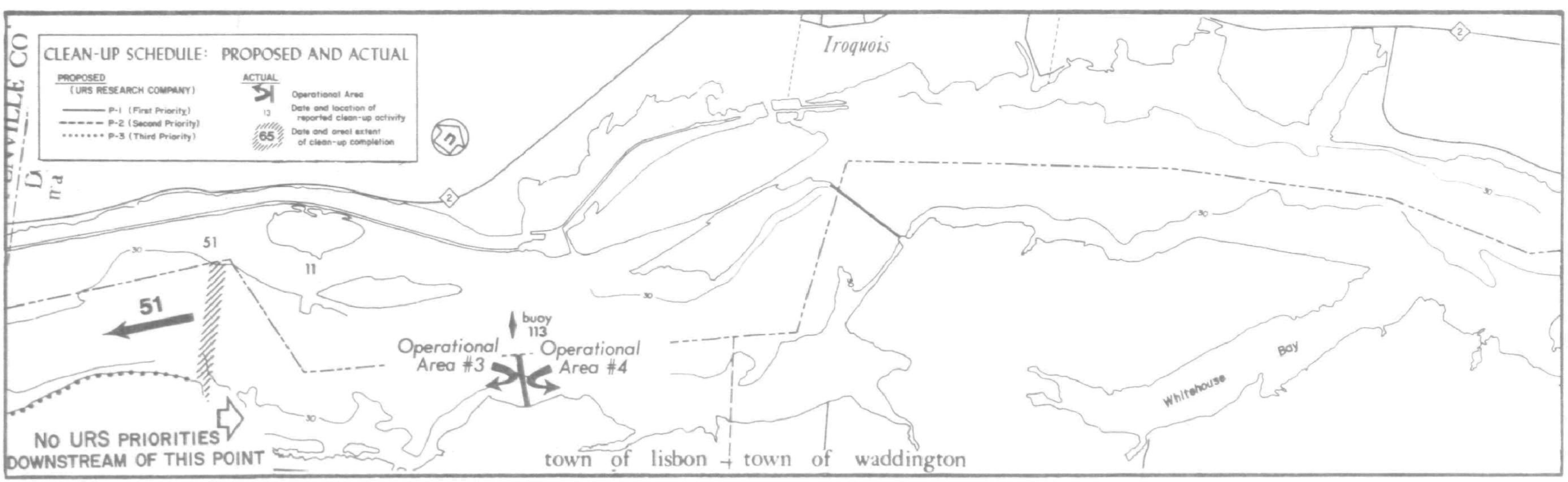

Figure 12. Chronology of Cleanup: River Section 10

The URS study was initiated on July 14(+22) and completed July 19(+27). No priority of cleanup was assigned to areas cleaned up before the initiation of this assessment. Thus the emphasis of this section will be on those areas where cleanup efforts occurred after July 19 or 27 days after the spill.

The cleanup effort was allocated among several contractors, each working a specific reach of the River. Figure 13 reflects the reaches assigned by the On-Scene Commander, and Table 4 reflects those contractors working in each reach.

TABLE 4. OPERATIONAL AREAS ASSIGNED TO CLEANUP CONTRACTORS

Operational Areas		
No.	Description	Contractor
1	Mason Point to Goose Bay	Sealand Restoration Inc.
2	Goose Bay to Oak Point	Coastal Services
3	Oak Point to Bouy 113	Marine Pollution Control Company
4	Bouy 113 to American Locks	New England Pollution Control Company[a]
5	Canadian Shoreline	Canadian Coast Guard

[a]Sub-contractor to St. Lawrence Seaway Development Corporation up to 30 July 1976. Designated prime contractor at that time upon withdrawal of the Corporation.

Financial considerations necessitated a cutback in operations, and Coastal Services and Marine Pollution Control Company were released on August 12, 1976(+51). At that point, Sealand Restoration Inc. was assigned to finish all remaining work up river from Bouy 113. New England Pollution Control Company was released on September 10(+80) and the Canadian Coast Guard on September 17(+87). The cleanup was terminated on October 22, 1976 (+122).

The chronological deployment of manpower and equipment is reflected in Figures 4-12. Dates of completion of cleanup in various areas are also shown. In addition, the priority scheme set forth in the URS Report is portrayed on the same figure.

The following is a comparison of the priority scheme and the actual cleanup. The approach used first reviews the entire impacted area and second, each of the five operational areas assigned to subcontractors.

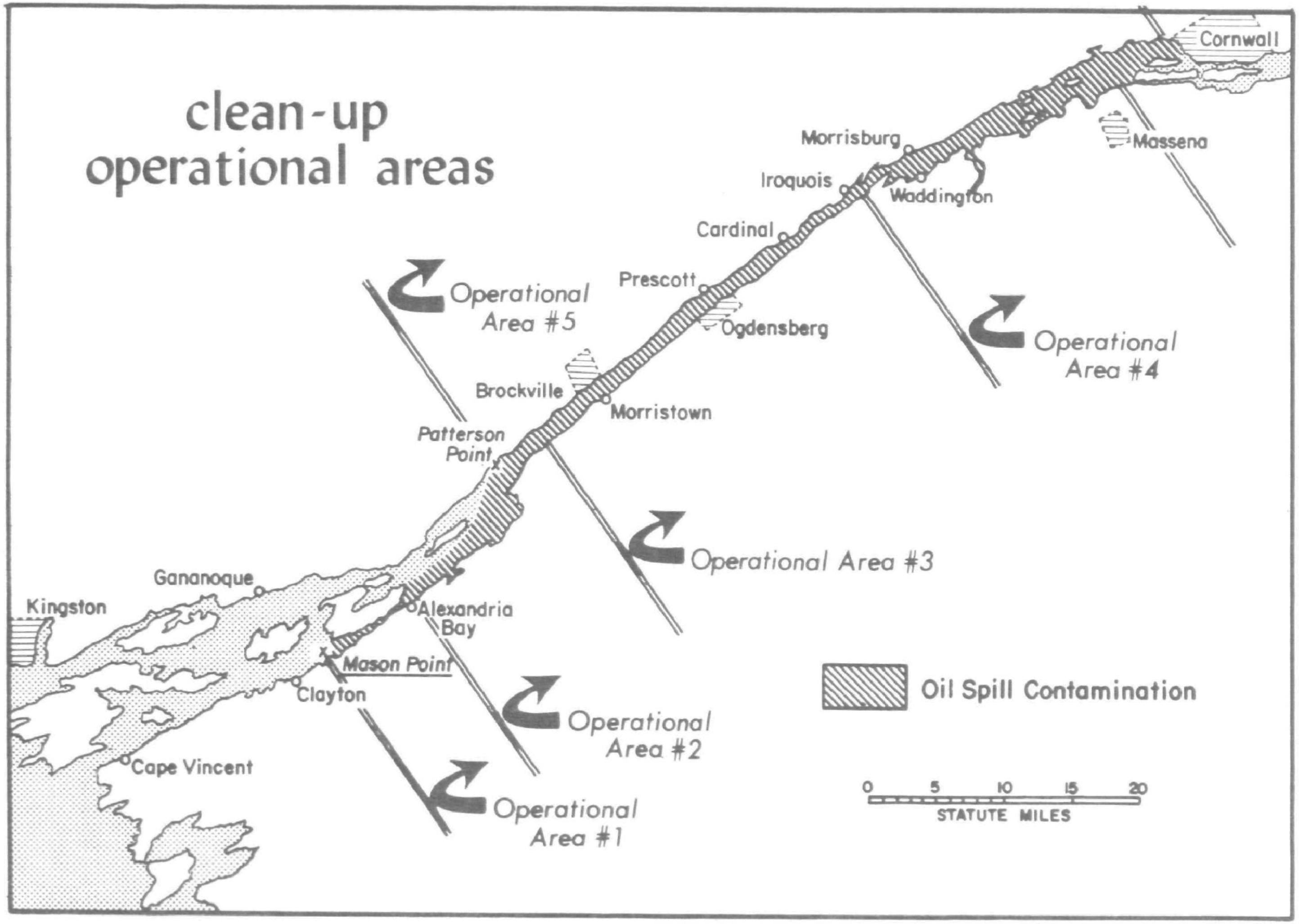

Figure 13. Cleanup Operational Areas

Overview of Impact Areas

As reflected in Figure 5, the area around the Village of Alexandria Bay was the first to be classified "cleaned up." This was accomplished on July 4. The second area reported cleaned was the entire stretch from Oak Point to Ogdensburg which was considered cleaned up on July 13. Small sections at Fishers Landing and Point Vivian were completed on July 16 and at Collins Landing on August 5. The area from Ogdensburg to Bouy 113 was completed on August 16. Downstream areas from Alexandria Bay to Watch Island were completed by August 26 with the exception of Morgan Island and part of Goose Bay. Cleanup efforts on the remainder of the shoreline continued throughout the rest of the cleanup period which ended October 22.

Included in those areas that were completed last are portions of Goose Bay and Chippewa Bay and many of the islands in these bays. As can be seen in Figures 5-6, work was started early in the cleanup period and continued throughout in these areas. However, primarily due to the complexity of the task in these areas, completion of cleanup occurred toward the end of the cleanup period. This will be discussed in greater detail under the following section, Operational Areas.

Operational Areas

The five operational areas will be examined in order starting from the upstream end of the study area and proceeding downstream. Efforts will be made to relate the actual cleanup in specific areas to the priorities set forth by URS in their report.

Operational Area 1 - (Mason Point to Goose Bay)

Within this area there were two shoreline stretches classed as priority one (P-1). They both were upstream of the Village of Alexandria Bay and included Keewaydin State Park and the Edgewood Park area (see Figures 3-5).

Priority two areas (P-2) included Grass Point State Park, upstream portions of Collins Landing, and Anthony Point on the mainland plus a small portion of Wellesley Island upstream from Alexandria Bay. Four islands downstream of Alexandria Bay - Steamboat, Manhattan, Harbor and Maple - were partially or totally classed as P-2.

Several small stretches of both the mainland and Wellesley Island were classed as P-3 areas. These are depicted on Figures 4 and 5.

Within operational area 1 the only areas classed P-1 were considered cleaned up on day 12. The next section termed cleaned up was completed on day 24 and included only P-3 areas. This area was around Point Vivian. The area around Collins Landing was termed cleaned up on day 44. It included two P-2 stretches. The remainder of the area in operational area 1 classed as P-2 was not cleaned up until day 65.

It should be noted that the date reported when cleanup was completed is for a stretch of shoreline. The dates cleanup was completed at specific points within that stretch were not available. Since many stretches of shoreline contained more than one priority classification it is not always possible to determine at what time a given priority-classed stretch of shoreline was actually cleaned up. However, when an entire area was of one priority such as the reach downstream of Alexandria Bay that was completed on day 65 a comparison with other areas can be made. Although the area downstream of Alexandria Bay with P-2 areas was not reported cleaned up earlier than other areas of P-3 priority, references to cleanup efforts indicate that all P-2 areas were being cleaned on day 13.

In summary, in Operational Area 1 the P-1 areas were cleaned early. Some of the P-2 areas were not cleaned until after some of the P-3 areas were completed.[3]

Operational Area 2 - (Goose Bay to Oak Point)

Within this area, six stretches were classed as P-1. They included the settlement of Goose Bay, Kring Point State Park, Outlet of Chippewa Creek into Goose Bay, Allen's Point, Outlet of Sheepshead Creek into Goose Bay and part of Blind Bay.

Extensive areas classed as P-2 and P-3 exist in the area. They are reflected on Figures 5-7.

A portion of Goose Bay was considered cleaned up on day 16. Since there was one P-1 location in this stretch it is logical to assume this was the one cleaned at that time. The area from Chippewa Point to Oak Point was cleaned by day 61. This was all classed as P-3 except a portion of Blind Bay which was classed P-1.

Kring Point State Park, classed P-1, was cleaned up by day 11. The areas downstream from operational area 1 to Watch Island outside Goose Bay proper was reported cleaned on day 65. This area included several stretches classed P-2. Morgan Island, classed P-2, is in this stretch and was not cleaned up until day 79.

Cleanup of the interiors of Goose and Chippewa Bays required an extensive effort that continued over a period of 64 days and 115 days respectively. References to cleanup efforts are made starting with day 2 in both bays and terminating with day 65 in Goose Bay and day 116 in Chippewa Bay.

Operational Area 3 - (Oak Point to Bouy 113)

Within this operational area there were no class P-1 areas identified. Five P-2 areas were located between Oak Point and Morristown. P-3 stretches were identified throughout the area.

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[3]It should be noted that the Alexandria Bay area which was cleaned up immediately would have been classed as S-1 due to its high level of "social productivity." The extensive effort expended there was due to this and not its environmental sensitivity.

The entire area from Oak Point to Ogdensburg was reported cleaned up by day 21. The area from Ogdensburg to Bouy 113 was reported cleaned up by day 51. Reference was made to work being done on day 8 and day 17 in this area also. Within the operational area the stretch with P-2 areas was completed before the stretch with P-3 areas.

Operational Area 4 - (Bouy 113 to American Locks)

This area was not assessed by URS.

Operational Area 5 - (Canadian Shoreline)

This area was not assessed by URS.

Summary

The strategy implemented by the On-Scene Commander of assigning specific areas to various contractors allowed a cleanup effort to be exerted throughout the entire impacted area. This was an important consideration in maintaining public support regarding the cleanup effort. In terms of placing emphasis on areas based upon their priority class as identified by URS, this strategy was not entirely compatible.

Within each operational area the priority system was generally followed. Between operational areas it appears that it was not as closely followed. For example, all the P-3 areas in operational area 3 (Ogdensburg to Bouy 113) were cleaned up before the P-2 areas on the Cedar Islands, Morgan Island and other P-2 areas at the upstream end of operational area 2 (Goose Bay to Oak Point). More effort (both manpower and equipment) was expended in operational area 2 than in operational area 3 due to the assignment of contractors and decisions on their expenditure levels. However, this increased effort was not sufficient to overcome the differences in effort required to clean up operational area 2, with its extensive wetlands in Goose and Chippewa Bays, compared to operational area 3 where few wetlands exist. The cleanup efforts were not able to follow the priority designation set forth in the URS Report completely, because it was impossible to allocate manpower and equipment among operational areas in the exact ratio of the efforts that would be required.

In summary it is not possible to tell how closely the URS priority system was followed since stretches classed P-1 were reported finished at the same time as stretches classed P-2 or P-3. References to the deployment of men and equipment do indicate that the effort was continuous over the entire operational area (see Figure 3).

Allocations of manpower and equipment appear to have been made based on perceived sensitivity of an area to ecological and economic impact, modified by public pressures. These pressures basically required that an effort be made throughout the entire impacted area immediately.

Examples of the criteria used and decisions resulting in determining actual cleanup priorities are reflected in Toxin Sitreps.[4] In these messages the following references were made to cleanup priorities:

26 June 1976 - Highest priority will be given Wilson Hill Wildlife Area as situation dictates.

7 July 1976 - Cleanup crews working to relieve sensitive areas first.

9 July 1976 - Special emphasis being placed on Stracham Island (gull rookery) and public beach areas.

22 October 1976 - Completed cleanup of that oil which the OSC[5] determined was necessary to minimize and/or mitigate damage to the public health and welfare, including fish, shellfish, wildlife, and public and private property shoreline and beaches. Some oil, which can generally be characterized as a stain and which is neither reasonable nor practical to remove will be left to degrade naturally.

In the Joint Response Team/National Response Team messages the following references were made to priority of cleanup:

23 June 1976 - Although many affected local areas have received the attention of the joint effort, Alexandria Bay, Goose Bay, Chippewa Bay and the Wilson Hill Wildlife Management Area were and remain focal points of major interest and effort.

23 July 1976 - There was general agreement among the National Response Team, Joint Response Team, and On-Scene Commander that since the emergency had passed and the situation had stabilized, the level of effort could be gradually and systematically reduced while continuing to expeditiously clean up environmentally sensitive areas such as marshes and high contact areas including beaches, boat houses, and the other seriously contaminated waterfront properties.

12 August 1976 - The following three recommendations were set forth:

1. that the following specified areas of high ecological sensitivity receive first priority for cleanup:

a. Oak Island
b. Northeast Chippewa Bay
c. Croil Island
d. Bradford Island
e. Nichols Island
f. Long Sault Island
g. Long Sault Parkway
h. Brockville Narrows

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[4]Toxin Sitreps were messages sent by the Commander, Ninth Coast Guard District, to advise the addressees of the status of the pollution incident.

[5]On-Scene Commander.

2. That high human contact areas of Chippewa Bay, Brockville Narrows and other areas as identified receive the next lower level of priority.

3. Little justification exists for cleanup of localities such as low human contact areas, industrial river frontage and low natural use areas, and the On-Scene Commander should continue to make careful determinations so related possible sources of recontamination, of course, are not included.

2 August 1976 - Prudent management of the pollution fund demands that the level of effort for this incident be reduced to practical limits. Para 2.E. of Ref (E) is apparently being interpreted that every drop of oil must be cleaned up. Language of this para (i.e. . . . removal may be considered complete...) is discretionary, not mandatory and should be interpreted to mean that the OSC should make pragmatic judgements concerning cleanup priorities. The NRT[6] agreed that the order of priorities for this incident should be:

A. Floating oil, oil in marshlands, heavy accumulations that could migrate to and recontaminate cleaned areas. Based on observations and briefings, NRT concluded that there were not many such areas remaining.

B. Oil in areas which experience high human contact such as beaches, docks, piers, boat houses and developed property frontage. Once the heavy accumulations have been removed from these areas, the remaining effort is principally for aesthetics and can be done over a long period of time. The rock cleaning operations should be curtailed and restricted to only those properties where people contact is probable. In all cases the cleanup should not leave a property in better condition than it was before the spill, such as reconditioning or replacing dilapidated docks merely to remove the oil. Low human contact shorelines that are merely oil stained should not ordinarily be cleaned even if these shorelines are in developed areas.

CONCLUDING REMARKS

It appears that the cleanup efforts were directed generally according to priorities derived from the URS report.[7] These were modified to the extent required by the strategy of segmenting the area into five operational areas and by the extent of public pressures.

In addition, it should be pointed out that 22 percent (27 of 122 days) of actual cleanup time had elapsed prior to completion of the URS Research Corporation report. It is surmised that during this period a large portion of the cleanup effort was spent on what would have been classed as P-1 areas. Since the report was not completed and no priorities were assigned

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[6]National Response Team.

[7]This is not to infer that the priorities determined by URS were followed. It is possible that those responsible for the cleanup established their own priorities separately and by coincidence the two sets of priorities were similar.

to areas cleaned up during this period, it is impossible to compare actual cleanup efforts to the priority scheme without missing some efforts directed at some of the most sensitive areas.

SECTION 4

FIELD SURVEY

Efforts were undertaken to determine the effects of time and the elements on residual hydrocarbons. Included were field surveys of the impacted area in the Fall of 1976 and again in the Spring of 1977. Comparisons of the residual oil observed during these surveys permits this evaluation.

PROCEDURES

The initial effort in carrying out the field survey was an attempt to review the shoreline from the water using either a flatbottom boat with a small outboard motor or a canoe. However, due to the decrease in the water level (about 2 to 3 feet) between June 23 and mid-September, it became readily apparent that access to many areas was not possible. This was true in the majority of the ecologically sensitive areas such as wetlands due to their gradually sloping shorelines. This problem was further compounded by the presence of weed growth that occurred during the latter portion of the summer season.

Attempts were made to conduct the survey by walking the shoreline. This was found to be satisfactory on most of the mainland shoreline except where bluffs and extensive wetlands were encountered. Survey of the islands was conducted primarily by boat. However, some portions of the larger islands were surveyed by walking. In wetland areas access was gained either by small boat, walking or canoe.

The visual findings of the survey were recorded on "Description of Residual Contaminants" forms (see Appendix B). National Oceanic and Atmospheric Administration (NOAA) hydrologic charts and New York State Department of Transportation planimetric maps were used to record observations. In order that comparisons could be made between the fall and spring surveys, specific sites were identified and "Description of Residual Contaminants" forms were completed. During the fall field survey 89 of these forms were completed for specific points. Another 195 forms provide descriptions of residual contaminants found over various segments surveyed. During the spring field survey 70 of these forms were completed for specific points. Another 130 forms provide descriptions of residual contaminants found over various segments surveyed. These observations are summarized and discussed below.

PROBLEMS ENCOUNTERED

Three major problems were encountered in conducting the fall field survey. The first, access, is described above and was almost totally overcome by adopting various modes of transportation to the local conditions.

The second problem was the weather encountered during the survey period. Early heavy snowfall combined with early ice formation periodically delayed and, finally on December 3, 1976, caused the termination of the survey. (Palm, 1977)

The third problem relates to depiction of survey results and the presentation of those results in this report. In conducting the survey, a wide range of residuals was encountered. They varied from light traces and almost unnoticeable spots of oil to heavy pockets and coatings. In order to display and discuss the residuals, three categories were defined. They are described in the next section. However, it should be kept in mind that within these categories there is extreme variation in the amount of residual contaminants.

ANALYSES OF FINDINGS

Discussed below is a general overview of the findings and a town-by-town summary of the two field surveys.

General Overview

A total of 279.04 km (173.39 mi) of shoreline was field surveyed in the fall prior to ice formation.[1] Of these kilometers, 132.79 km (82.51 mi) or 47.6 percent were found to be contaminated to varying degrees. A total of 389.38 km (241.95 mi) of shoreline was field surveyed in the Spring of 1977. Contamination of varying degrees was found on 141.41 km (87.87 mi) or 32.3 percent of the shoreline surveyed. The contaminated areas were classified as follows:

Scattered Oil

Areas described by this term contained oil mixed with vegetation or other debris observable without disturbing the vegetation or debris. The vegetation or debris was either contaminated in place or contaminated elsewhere but deposited at its observed location by winds or currents. Also included are areas where the shore had been contaminated, but the residuals were evidenced in forms other than bands or pockets as described below.

Bands of Oil

Areas described by this term consisted of primarily hard surfaced shore features, either natural or man-made, that were discolored and/or coated with oil.

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[1]Numbers in ( ) indicate U.S. equivalent units.

Pockets of Oil

Areas described by this term were those where residual oil was trapped in pockets or pools of water as the water levels fell subsequent to the oil spill. Generally these areas were less than 270 square meters (3,000 square feet) in area with oil .3 to 5 cm (1/8 to 2 inches) thick.

An overview of the findings of the field surveys is presented in Table 5. Also reflected in this table, of the 279.04 km (173.39 mi) surveyed in the fall, 198.74 km (123.49 mi) were surveyed by walking the shoreline and 80.31 km (49.90 mi) were surveyed from a boat. In the spring these distances were 169.37 km (105.24 mi) and 220.01 km (136.71 mi) respectively.

Most of the area surveyed from a boat was in the Thousand Islands area (Hammond, Alexandria, Orleans, Clayton). The lower islands were not surveyed in the fall due to the onset of winter. However, they were surveyed in the spring.

The survey teams reported that there were residual contaminants along 132.64 km (82.42 mi) of the surveyed area in the fall. This was 47.6 percent of the area surveyed. Of this, 89.27 km (55.47 mi) were classed as having "scattered oil"; 40.52 km (25.18 mi) as having "bands of oil"; and 2.99 km (1.86 mi) as having "pockets of oil." The incidence of residual contaminants increased going downstream from the spill area until the lower extremity of the study area was reached. In particular, Clayton and Orleans at the upper end and Massena and Louisville at the lower end of the impacted area had less than 20 percent of the surveyed area classified as having "residual contaminants." The towns between ranged from 28.5 percent in Alexandria to 95.5 percent in Morristown.

In the Spring, residual contaminants were reported along 141.41 km (87.87 mi) of the surveyed area. This was 32.3 percent of the area surveyed. Of this, 214.18 km (77.16 mi) were classed as "scattered oil"; 15.68 km (9.74 mi) as "bands of oil"; and 1.56 km (0.97 mi) as "pockets of oil."

Of the additional 110.34 km (68.56 mi) surveyed in the Spring that were not covered in the Fall, only an additional 8.77 km (5.45 mi) were reported as contaminated. This is 7.9 percent as compared to 47.6 percent for the autumn survey.

Analysis by Town

A brief summary of the findings of the field surveys is given below for each town that experienced oil contamination. The summaries start with the town farthest upstream that was impacted, the Town of Clayton, and progress downstream to the Town of Massena.

Town of Clayton - (Section 1, Figures 14 and 28)

Fall - Only 0.42 km (0.26 mi) of shoreline in the Town of Clayton were surveyed. Of these, 0.13 km (0.08 mi) (30.7 percent) were found to have

Table 5 Shoreline Surveyed and Extent of Residual Contaminants

	Massena	Louisville	Waddington	Lisbon	Oswegatchie	Morristown	Hammond	Alexandria	Orleans	Clayton	Total
SHORELINE SURVEYED											
Miles by Walking											
Fall 1976	22.98	20.05	16.34	11.48	14.35	4.63	10.02	19.52	3.97	0.15	123.49
Spring 1977	16.38	17.57	13.19	12.38	14.75	5.57	4.38	17.20	3.67	0.15	105.24
	-6.60	-2.48	-3.15	+0.90	+0.40	+.94	-5.64	-2.32	-0.30	0	-18.25
KM By Walking											
Fall 1976	36.98	32.27	26.30	18.48	23.09	7.45	16.13	31.41	6.39	0.24	198.74
Spring 1977	26.36	28.28	21.23	19.92	23.74	8.96	7.05	27.68	5.91	0.24	169.37
	-10.62	-3.99	-5.07	+1.44	+0.65	+1.51	-9.08	-3.73	-0.48	0	-29.37
% of Shoreline Surveyed By Walking											
Fall 1976	100.0	100.0	100.0	100.0	100.0	100.0	33.2	43.9	46.3	57.7	71.2
Spring 1977	48.2	58.7	63.5	52.1	100.0	49.2	11.5	31.6	30.0	5.6	43.5
Miles by Boat											
Fall 1976	0	0	0	0	0	0	20.19	24.99	4.61	0.11	49.90
Spring 1977	17.57	12.38	7.57	11.38	0	5.75	33.75	37.20	8.57	2.54	136.71
	+17.57	+12.38	+7.57	+11.38	0	+5.75	+13.56	+12.21	+3.96	+2.43	+86.81
KM By Boat											
Fall 1976	0	0	0	0	0	0	32.49	40.22	7.42	0.18	80.31
Spring 1977	28.28	19.92	12.18	18.31	0	9.25	54.32	59.87	13.79	4.09	220.01
	+28.28	+19.92	+12.18	+18.31	0	+9.25	+21.83	+19.65	+6.37	+3.91	+139.70
% of Shoreline Surveyed by Boat											
Fall 1976	0	0	0	0	0	0	66.8	56.1	53.7	42.3	28.8
Spring 1977	51.8	41.3	36.5	47.9	0	50.8	88.5	68.40	70.0	94.4	56.5
Total Miles											
Fall 1976	22.98	20.05	16.34	11.48	14.35	4.63	30.21	44.51	8.58	0.26	173.39
Spring 1977	33.95	29.95	20.76	23.76	14.75	11.32	38.13	54.40	12.24	2.69	241.95
	+10.97	+9.90	+4.42	+12.28	+0.40	+6.69	+7.92	+9.89	+3.66	+2.43	+68.56
Total KM											
Fall 1976	36.98	32.27	26.30	18.48	23.09	7.45	48.62	71.63	13.81	0.42	279.05
Spring 1977	54.64	48.20	33.41	38.24	23.74	18.22	61.36	87.55	19.70	4.33	389.39
	+17.66	+15.93	+7.11	+19.76	-0.65	+10.77	+12.74	+15.92	+5.89	+3.91	+110.34
EXTENT OF RESIDUAL CONTAMINATION											
Miles of Scattered Oil											
Fall 1976	4.39	2.68	12.67	6.17	10.75	4.42	8.61	5.60	0.09	0	55.38
Spring 1977	5.38	5.00	8.38	13.57	13.19	5.38	9.38	16.38	0.50	0	77.16
	+.99	+2.32	-4.29	+7.40	+2.44	+0.96	+0.77	+10.78	+0.41	0	+21.78
KM of Scattered Oil											
Fall 1976	7.07	4.31	20.39	9.93	17.30	7.11	13.86	9.01	0.14	0	89.12
Spring 1977	8.66	8.05	13.49	21.84	21.23	8.66	15.10	26.36	0.80	0	124.19
	+1.59	+3.74	-6.90	+11.91	+3.93	+1.55	+1.24	+17.35	+ 0.66	0	+35.07
% of Surveyed Shoreline Contaminated by Scattered Oil											
Fall 1976	19.1	13.4	78.1	53.7	74.9	95.5	28.5	12.6	a	0	32.0
Spring 1977	15.8	16.7	40.4	57.1	89.4	47.5	24.6	30.1	4.0	0	31.9
Miles of Bands of Oil											
Fall 1976	0	0	0.64	1.38	0.07	0	11.95	10.96	0.10	0.08	25.18
Spring 1977	0	0	0	0	0	0.15	6.75	2.76	0	0.08	9.74
	0	0	-0.64	-1.38	-0.07	+0.15	-5.20	-8.20	-0.10	0	-15.44

Table 5 Shoreline Surveyed and Extent of Residual Contaminants (continued)

	Massena	Louisville	Waddington	Lisbon	Oswegatchie	Morristown	Hammond	Alexandria	Orleans	Clayton	Total
KM of Bands of Oil											
Fall 1976	0	0	1.03	2.22	0.11	0	19.23	17.64	0.16	0.13	40.52
Spring 1977	0	0	0	0	0	0.24	10.86	4.44	0	0.13	15.67
	0	0	-1.03	-2.22	-0.11	+0.24	-8.37	-13.20	-0.16	0	-24.85
% of Surveyed Shoreline Contaminated By Bands of Oil											
Fall 1976	0	0	3.9	12.0	0.4	0	39.6	24.6	1.2	30.7	14.5
Spring 1977	0	0	0	0	0	1.3	17.7	5.1	0	2.9	0.4
Miles of Pockets of Oil											
Fall 1976	0	0	0	0	0	0	1.30	0.56	0	0	1.86
Spring 1977	0	0	0	0	0	0	0.52	0.45	0	0	0.97
	0	0	0	0	0	0	-0.78	-0.11	0	0	-0.89
KM of Pockets of Oil											
Fall 1976	0	0	0	0	0	0	2.09	0.90	0	0	2.99
Spring 1977	0	0	0	0	0	0	0.84	0.72	0	0	1.56
	0	0	0	0	0	0	-1.25	-0.18	0	0	-1.43
% of Surveyed Shoreline Contaminated By Pockets of Oil											
Fall 1976	0	0	0	0	0	0	4.3	1.3	0	0	1.1
Spring 1977	0	0	0	0	0	0	1.7	0.83	0	0	a
Total Miles											
Fall 1976	4.39	2.68	13.31	7.55	10.82	4.42	21.86	17.12	0.19	0.08	82.42
Spring 1977	5.38	5.00	8.38	13.57	13.19	5.53	16.65	19.59	0.50	0.08	87.87
	+.99	+2.32	-4.93	+6.02	+2.37	+1.11	-5.21	+2.47	+0.31	0	+5.45
Total KM											
Fall 1976	7.07	4.31	21.42	12.15	17.41	7.11	35.18	27.55	0.30	0.13	132.63
Spring 1977	8.66	8.05	13.49	21.84	21.23	8.90	26.80	31.52	0.80	0.13	141.42
	+1.59	+3.74	-7.93	+9.69	+3.82	+1.79	-8.38	+3.97	+0.50	0	+ 8.79
Total % of Surveyed Shoreline Contaminated											
Fall 1976	19.1	13.4	82.0	65.7	75.3	95.5	72.4	38.5	1.2	30.7	47.6
Spring 1977	15.8	16.7	40.4	57.1	89.4	48.8	44.0	36.0	4.0	2.9	32.3

[a]Less than 0.1 percent.

residual contaminants. These were in the form of bands of oil located at the extreme downstream portion of the Town.

Spring - A total of 3.52 km (2.19 mi) was surveyed. Again only 0.13 km (0.08 mi) were found to have residual contaminants. These were in the form of bands of oil.

Town of Orleans - (Section 1, Figures 14 and 28)

Fall - Of the 13.81 km (8.58 mi) surveyed in the Town of Orleans 6.39 km (3.97 mi) were surveyed by walking and 7.42 km (4.61 mi) by boat. Little evidence of residual contamination was found, with only 0.16 km (0.1 mi) classed as "bands of oil" and 0.14 km (0.09 mi) as "scattered oil."

Spring - An additional 5.89 km (3.66 mi) were surveyed with an additional 0.50 km (0.31 mi) being classed as having residual contaminants. All 0.80 km (0.50 mi) of contaminated shoreline were classed as "bands of oil."

Town of Alexandria - (Sections 2 and 3, Figures 15, 16, 29, and 30)

Fall - The largest number of miles surveyed in any of the impacted towns was completed in the Town of Alexandria. This totaled 71.63 km (44.51 mi) with 31.41 km (19.52 mi) completed by walking and 40.22 km (24.99 mi) completed by boat. Visual residual contaminants were found on 27.55 km (17.12 mi) of the shoreline (38.5 percent of the total surveyed). Of these, 9.01 km (5.60 mi) were classed as "scattered oil"; 17.64 km (10.96 mi) as "bands of oil"; and 0.90 km (0.56 mi) as "pockets of oil." Most of the residual contaminants were found on the mainland shoreline with very little found on Wellesley Island and a few of the islands upstream of the Village of Alexandria Bay. Most of Goose Bay was surveyed and residual contaminants classed as "scattered oil" were found in the downstream portion of the bay.

Spring - An additional 15.92 km (9.89 mi) were surveyed with an additional 3.98 km (2.47 mi) classed as having residual contaminants. Thirteen and two tenths km (8.2 mi) fewer miles were classed as "bands of oil" and 13.20 km (10.78 mi) were classed as "scattered oil."

Town of Hammond - (Section 4, 5 and 6, Figures 17, 18, 19, 31, 32 and 33)

Fall - A total of 48.62 km (30.21 mi) of shoreline in the Town of Hammond was surveyed with 32.49 km (20.19 mi) covered by boat and 16.13 km (10.02 mi) by walking. Of this mileage, 13.86 km (8.61 mi) were classed as "scattered oil"; 19.23 km (11.95 mi) as "bands of oil"; and 2.09 km (1.30 mi) as "pockets of oil." A stretch downstream of Chippewa Bay did not have visible residual contaminants present. However, in the Chippewa Bay area, both the mainland shoreline and the island shoreline were almost completely classed as having visible residual contaminants present. Pockets of oil were found primarily at the lower end of Chippewa Bay. Most of the islands, except Oak which was not fully surveyed, were classed as "bands of oil.' The area upstream from Chippewa Bay to the Town of Alexandria line was primarily classed as "scattered oil."

Spring - An additional 12.75 km (7.92 mi) were surveyed with a total of 8.38 km (5.21 mi) having residual contaminants. This reduced from 72.4 to 44.0 the percent of surveyed shoreline that was classed as contaminated.

Town of Morristown - (Sections 6 and 7, Figures 19, 20, 33 and 34)

Fall - Of the 7.45 km (4.63 mi) surveyed by walking, 7.11 km (4.42 mi) were classed as "scattered oil." The survey of the shoreline of the Town of Morristown was limited to access points between the Village of Morristown and the Town of Hammond line.[2] At most survey points, ten of fourteen, scattered oil was found. Of the other four, three were just downstream of the Town of Hammond line. It could be expected that the intervening shoreline also was contaminated to the same degree.

Spring - An additional 10.77 km (6.69 mi) were surveyed and an additional 1.79 km (1.11 mi) were contaminated. Scattered oil was found in the portion of the shoreline upstream of the Village of Morristown between those isolated points surveyed in the Fall.

Town of Oswegatchie[3] - (Sections 7, 8 and 9, Figures 20, 21, 22, 34, 35 and 36)

Fall - Of the 23.09 km (14.35 mi) surveyed in the Town of Oswegatchie, 17.30 km (10.75 mi) were classed as "scattered oil" and 0.11 km (0.07 mi) as "bands of oil." Residual contaminants were not observed at the mouth of the Oswegatchie River nor for a stretch of mainland shoreline downstream of the Port facilities. The small area where bands of oil were observed was near the base of the Ogdensburg-Prescott Bridge.

Spring - Only 0.64 additional km (0.40 mi) were surveyed. However, 3.81 additional km (2.37 mi) of shoreline were classed as contaminated. The majority of the additional contamination occurred along the downstream portion of the City of Ogdensburg's shoreline.

Town of Lisbon (Section 9 and 10, Figures 22, 23, 36 and 37)

Fall - The survey parties walked 18.48 km (11.48 mi) of the shoreline in the Town of Lisbon and classed 9.93 km (6.17 mi) of the shoreline as "scattered oil" and 2.22 km (1.38 mi) as "bands of oil." The bands of oil were observed in the Red Mills area while most of the rest of the Town's shoreline had scattered oil. The area was the only extensive area classed as not having residual contaminants.

Spring - An additional 19.76 km (12.28 mi) were surveyed with an additional 9.69 km (6.02 mi) classed as having residual contaminants. The majority of these additional miles were on Gallop Island where the head and north shore were classed as scattered oil."

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[2]The onset of winter precluded surveying the remainder of the shoreline by boat.

[3]The Town of Oswegatchie description includes the City of Ogdensburg.

Town of Waddington - (Sections 11 and 12, Figures 24, 25, 38 and 39)

Fall - A total of 26.30 km (16.34 mi) of shoreline were surveyed in the Town of Waddington by walking. Classed as "scattered oil" were 20.54 km (12.76 mi). A small portion, 1.03 km (0.64 mi) were classed as "bands of oil." White House Bay was the only significant area surveyed where residual contaminants were not observed. The area where bands of oil were observed was on Leishman Point.

Spring - An additional 7.11 km (4.42 mi) of shoreline were surveyed. A net decrease of 7.93 km (4.93 mi) of shoreline classed as contaminated occurred. The majority of the decrease occurred just below the Village of Waddington.

Town of Louisville - (Sections 12, 13 and 14, Figures 25, 26, 27, 39, 40 and 41)

Fall - A total of 32.27 km (20.05 mi) of shoreline were surveyed in the Town of Louisville by walking. Of this, 4.31 km (2.68 mi) were classed as "scattered oil." The primary area where residuals were found was on the north side of Wilson Hill Island. A few short segments were found in other areas of the Town.

Spring - An additional 15.93 km (9.90 mi) of shoreline were surveyed. An additional 3.73 km (2.32 mi) were classed as "scattered oil." The majority of this was on the islands which were not surveyed in the Fall due to weather.

Town of Massena - (Sections 13 and 14, Figures 26, 27, 40 and 41)

Fall - All 36.98 km (22.98 mi) surveyed in the Town of Massena were surveyed by walking the shoreline. Of the area surveyed, 7.07 km (4.39 mi) were classed as "scattered oil." The primary areas where the residual contaminants were observable were on the north shore of Barnhart Island immediately upstream of the Moses-Saunders Power Dam and at the head of Long Sault Island. Other small areas were scattered along the mainland shoreline.

Spring - An additional 17.65 km (10.97 mi) were surveyed with an additional 1.59 km (0.99 mi) of contaminated shoreline recorded. Again additional contaminated shoreline was found on the islands not previously surveyed.

Comparison of Survey Findings

The Spring survey covered 110.34 km (68.56 mi) more shoreline than the Fall survey. A total of 29.37 km (18.25 mi) less of shoreline were surveyed by walking while a total of 139.71 km (86.81 mi) more were surveyed by boat. Much of the additional shoreline surveyed was on islands in the downstream portions of the impact area which were not surveyed in the Fall due to weather conditions.

The extent of residuals observed varied between the two surveys. An

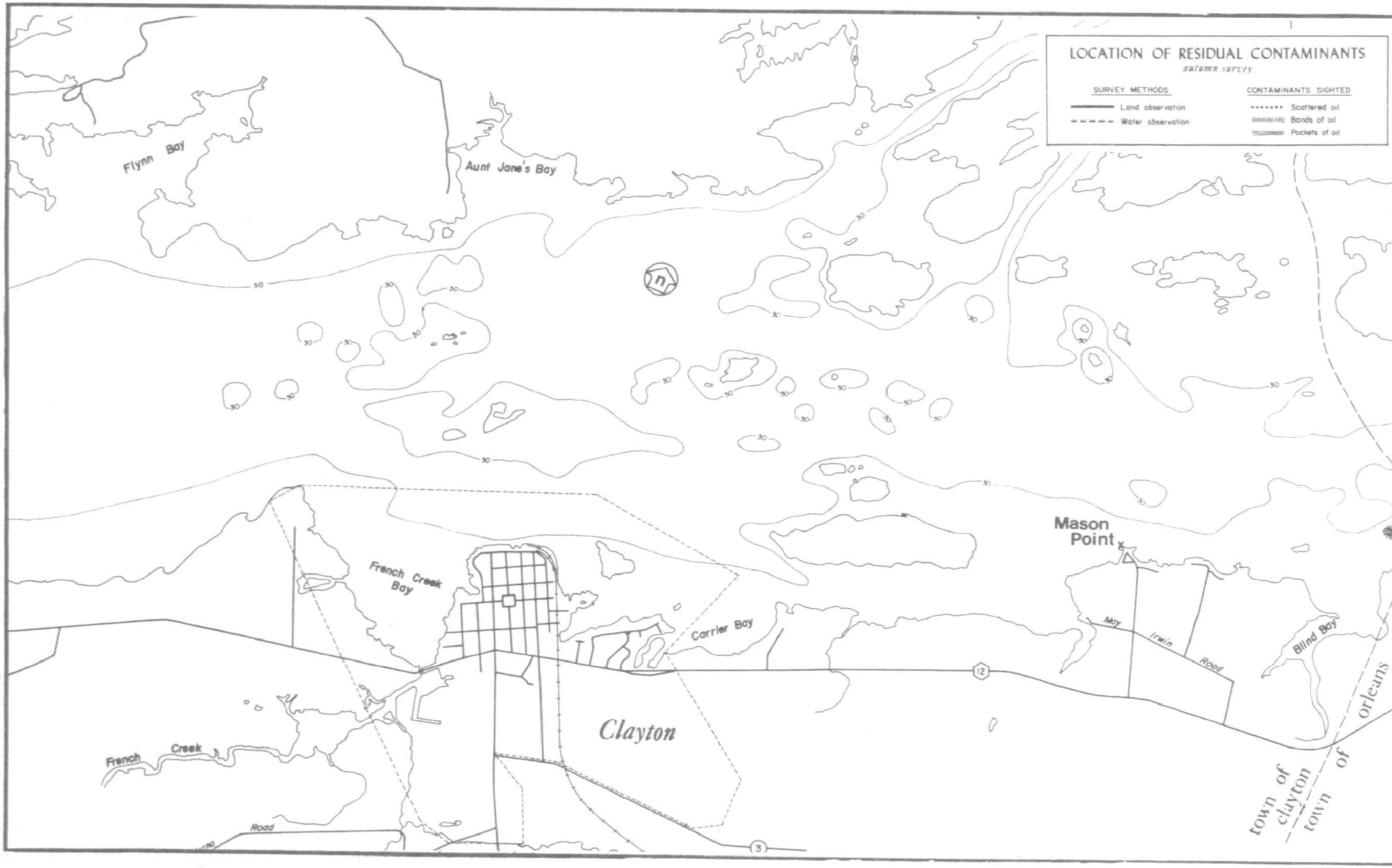

Figure 14. Section 1, Autumn Survey, 1976.

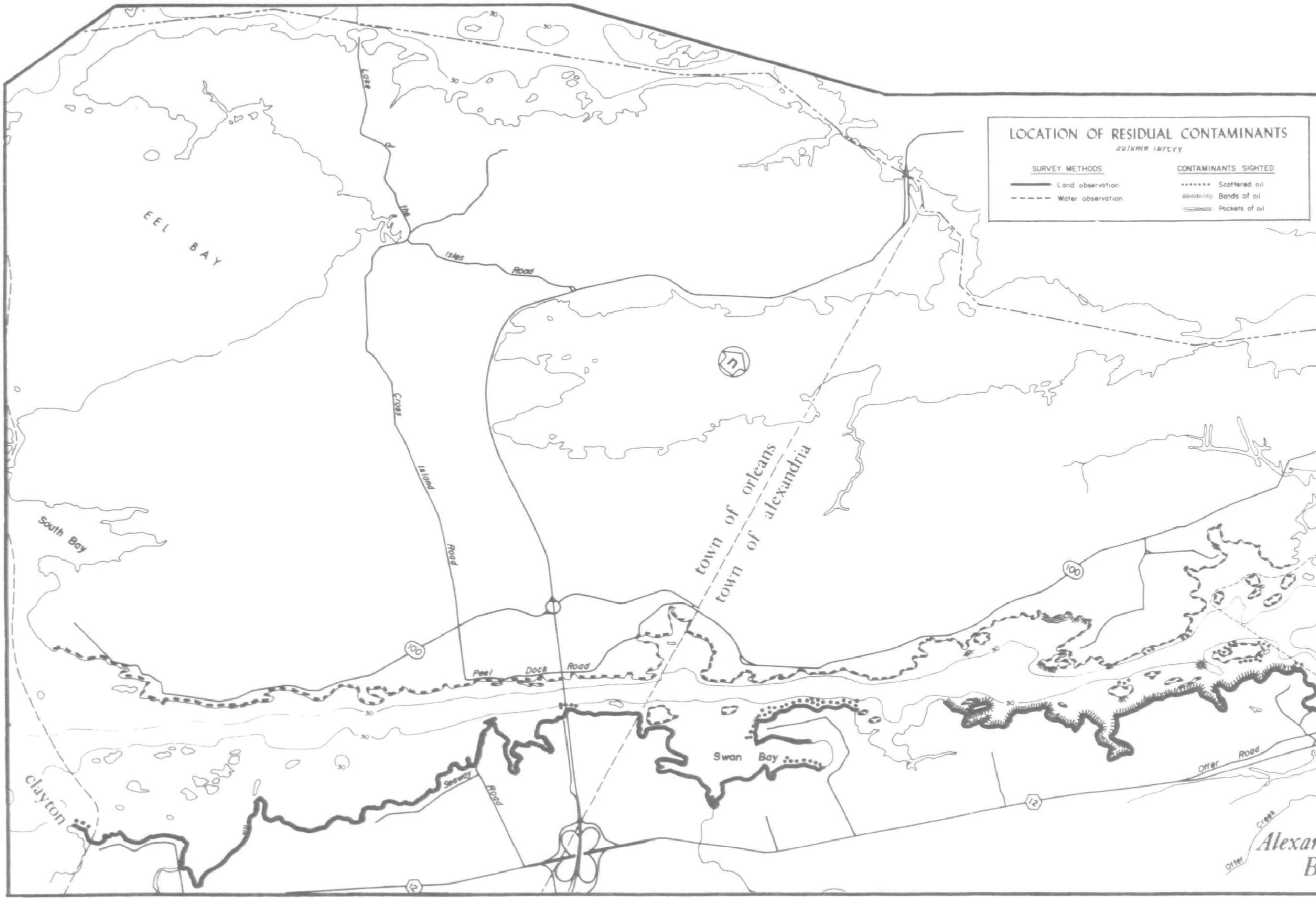

Figure 15. Section 2, Autumn Survey, 1976.

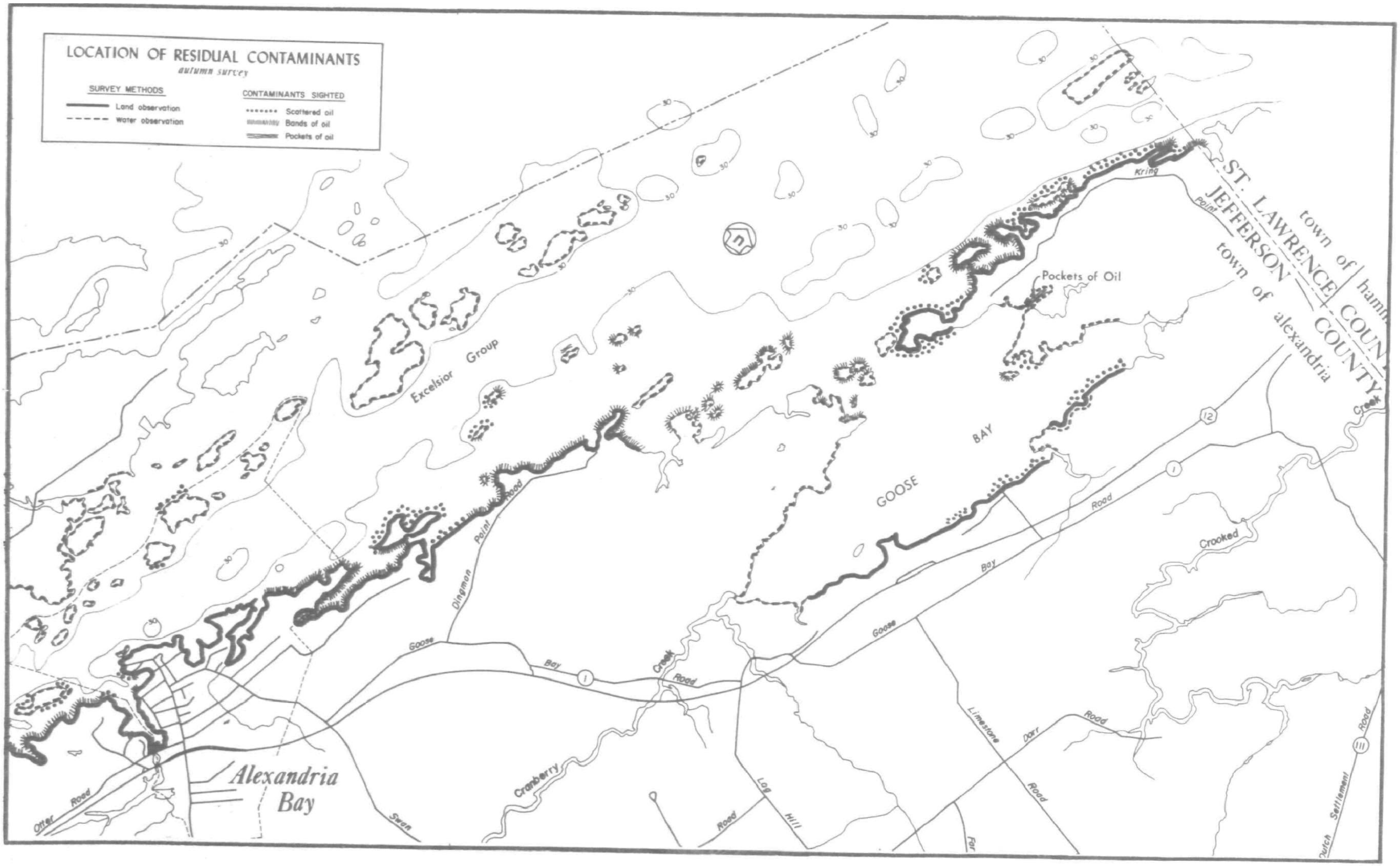

Figure 16. Section 3, Autumn Survey, 1976.

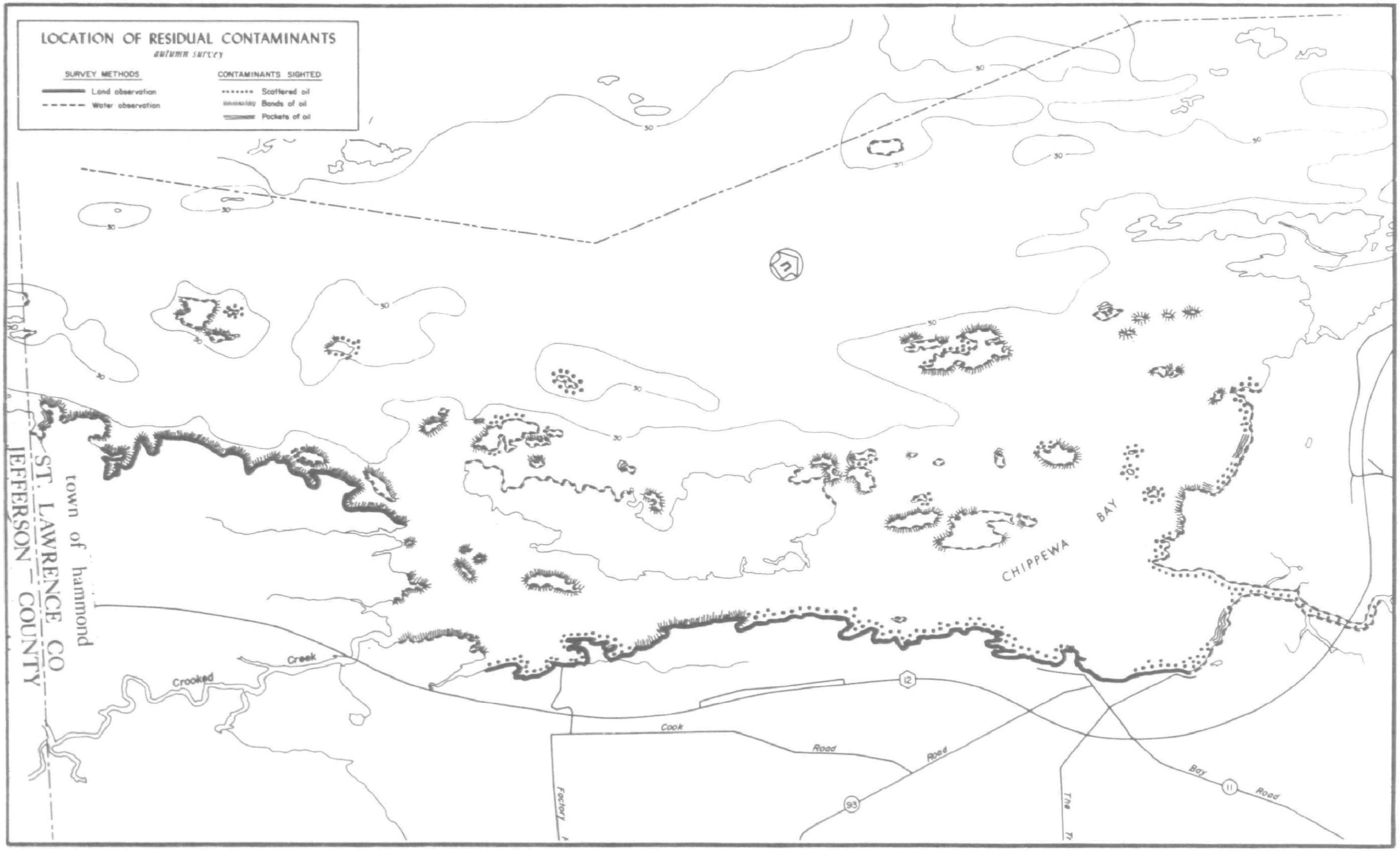

Figure 17. Section 4, Autumn Survey, 1976.

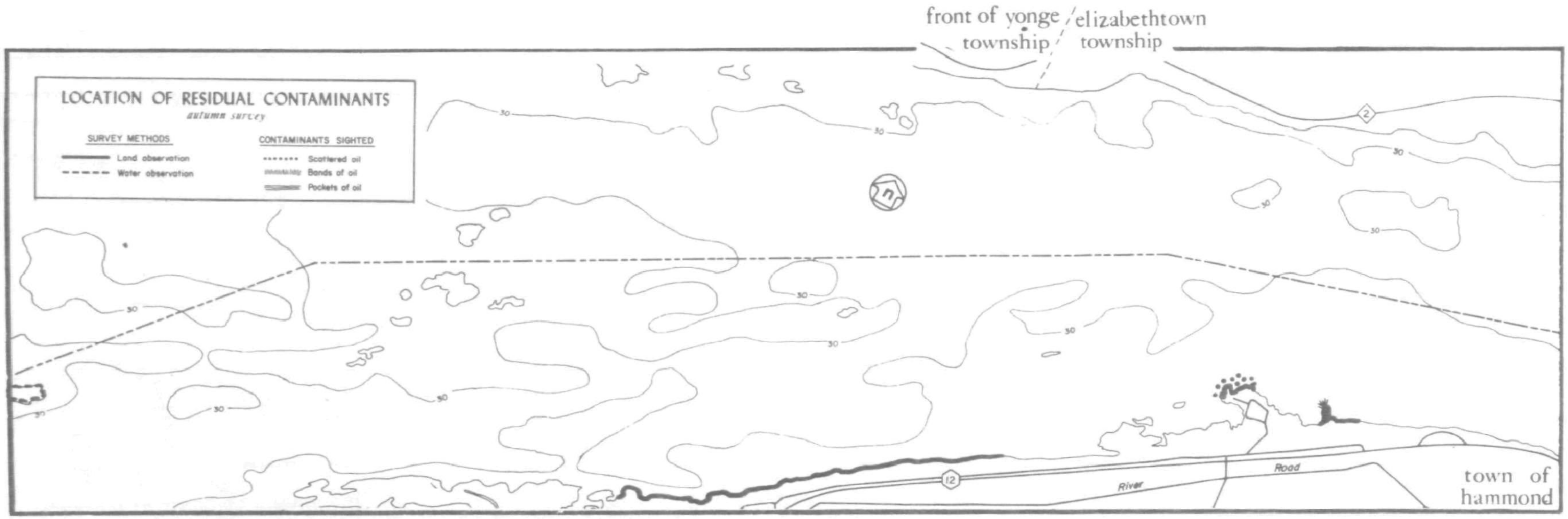

Figure 18. Section 5, Autumn Survey, 1976.

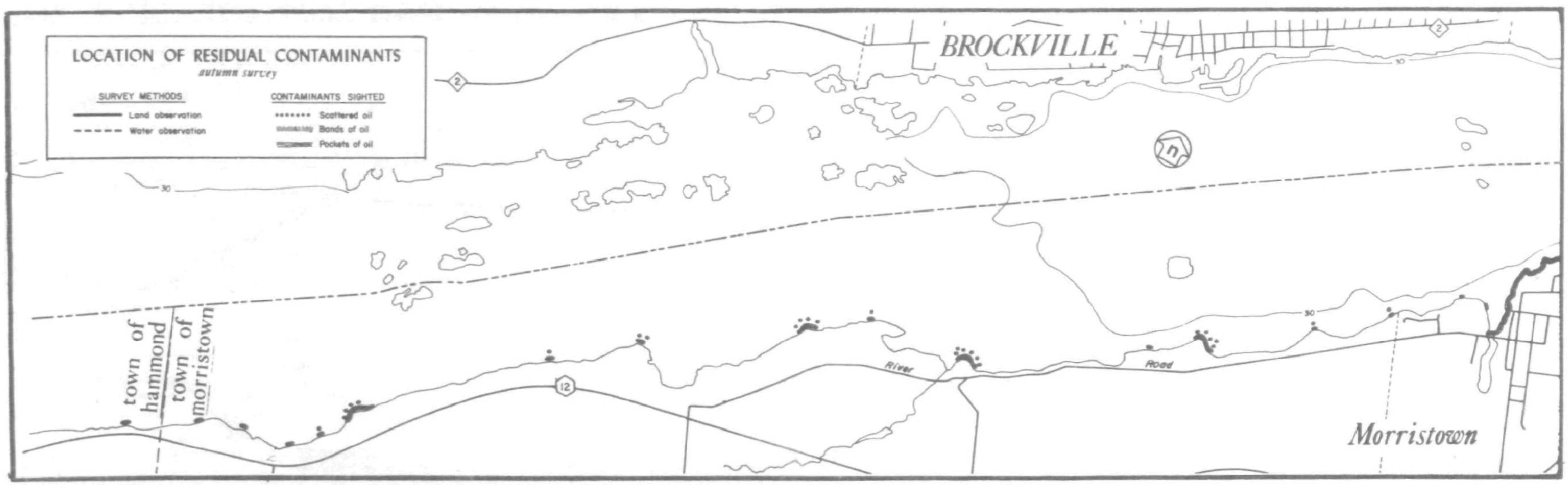

Figure 19. Section 6, Autumn Survey, 1976.

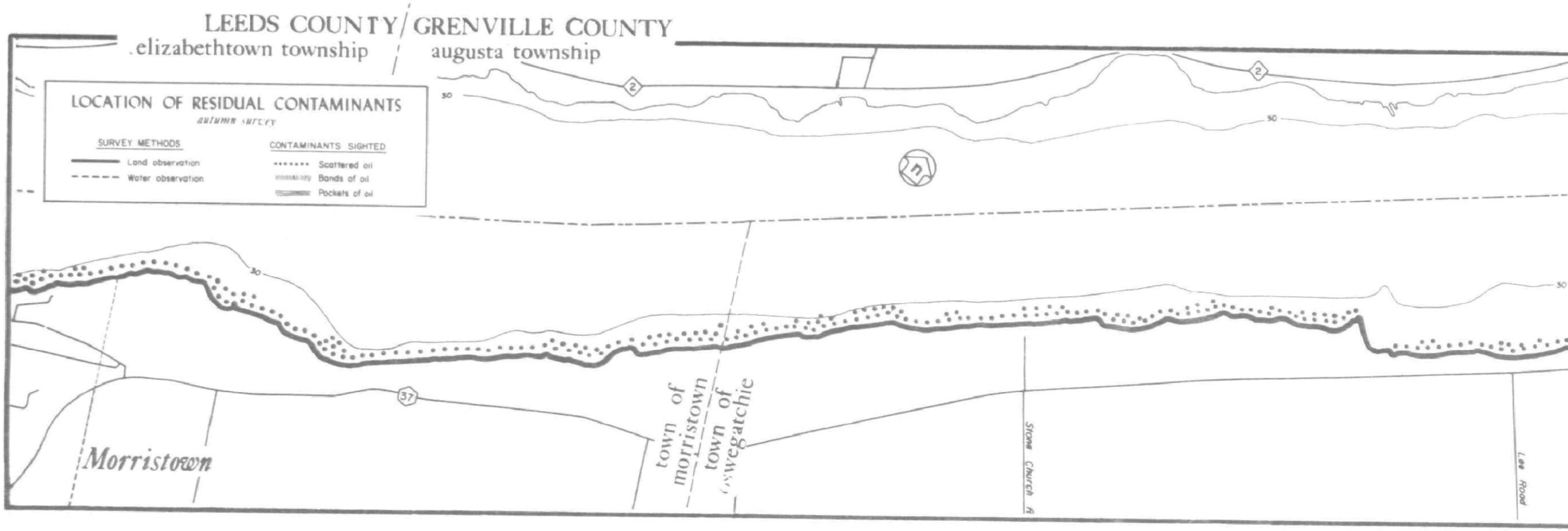

Figure 20. Section 7, Autumn Survey, 1976.

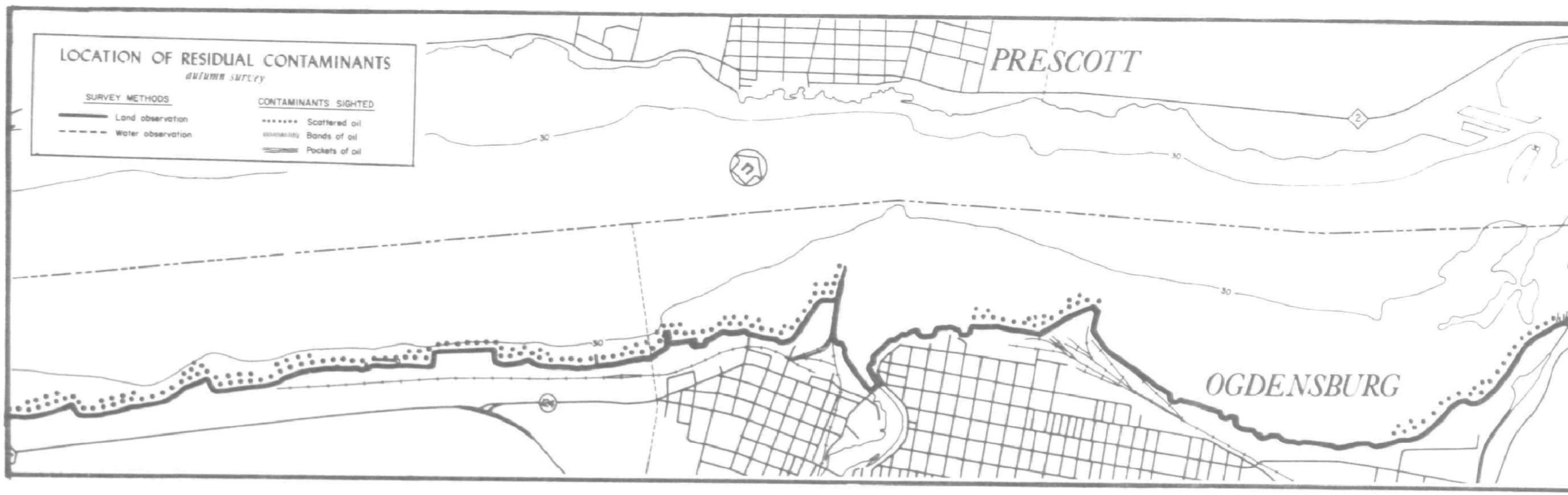

Figure 21. Section 8, Autumn Survey, 1976.

Figure 22. Section 9, Autumn Survey, 1976.

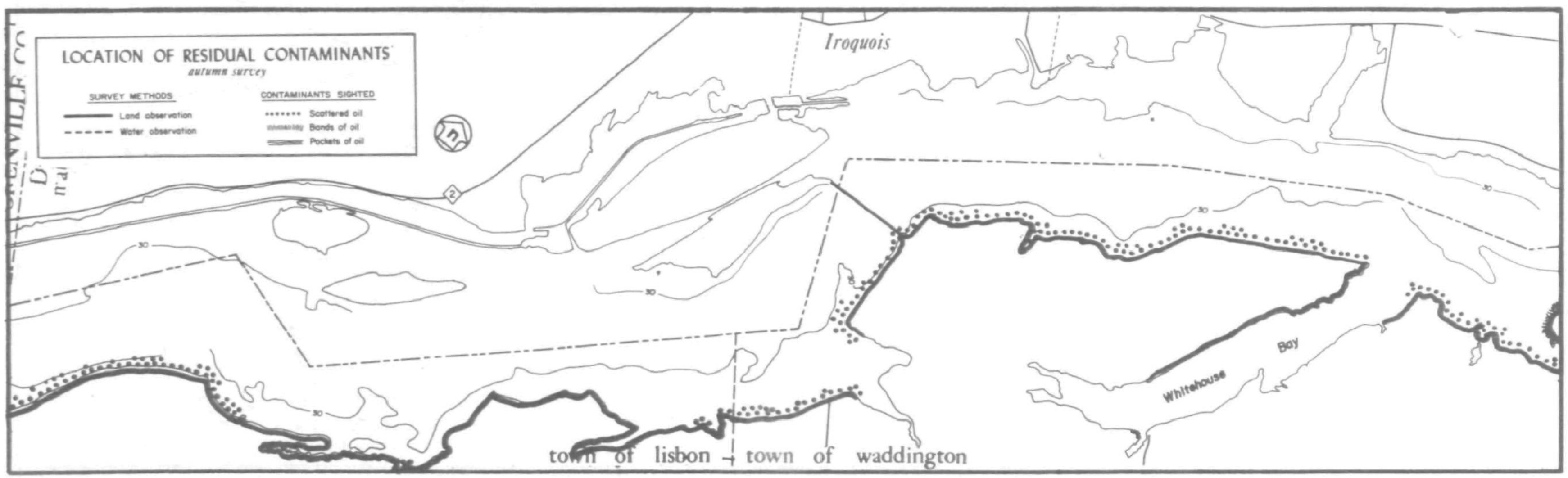

Figure 23. Section 10, Autumn Survey, 1976.

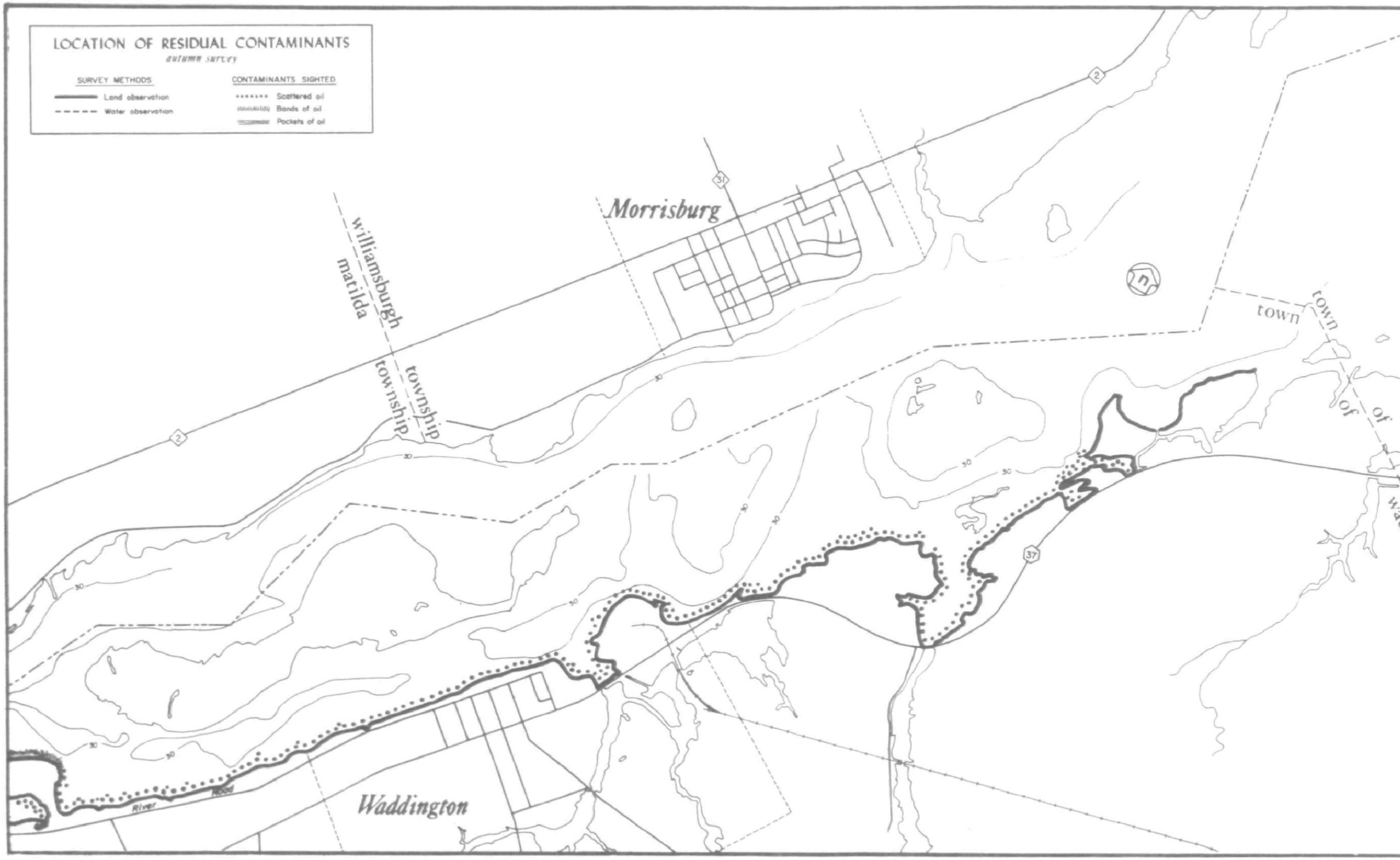

Figure 24. Section 11, Autumn Survey, 1976.

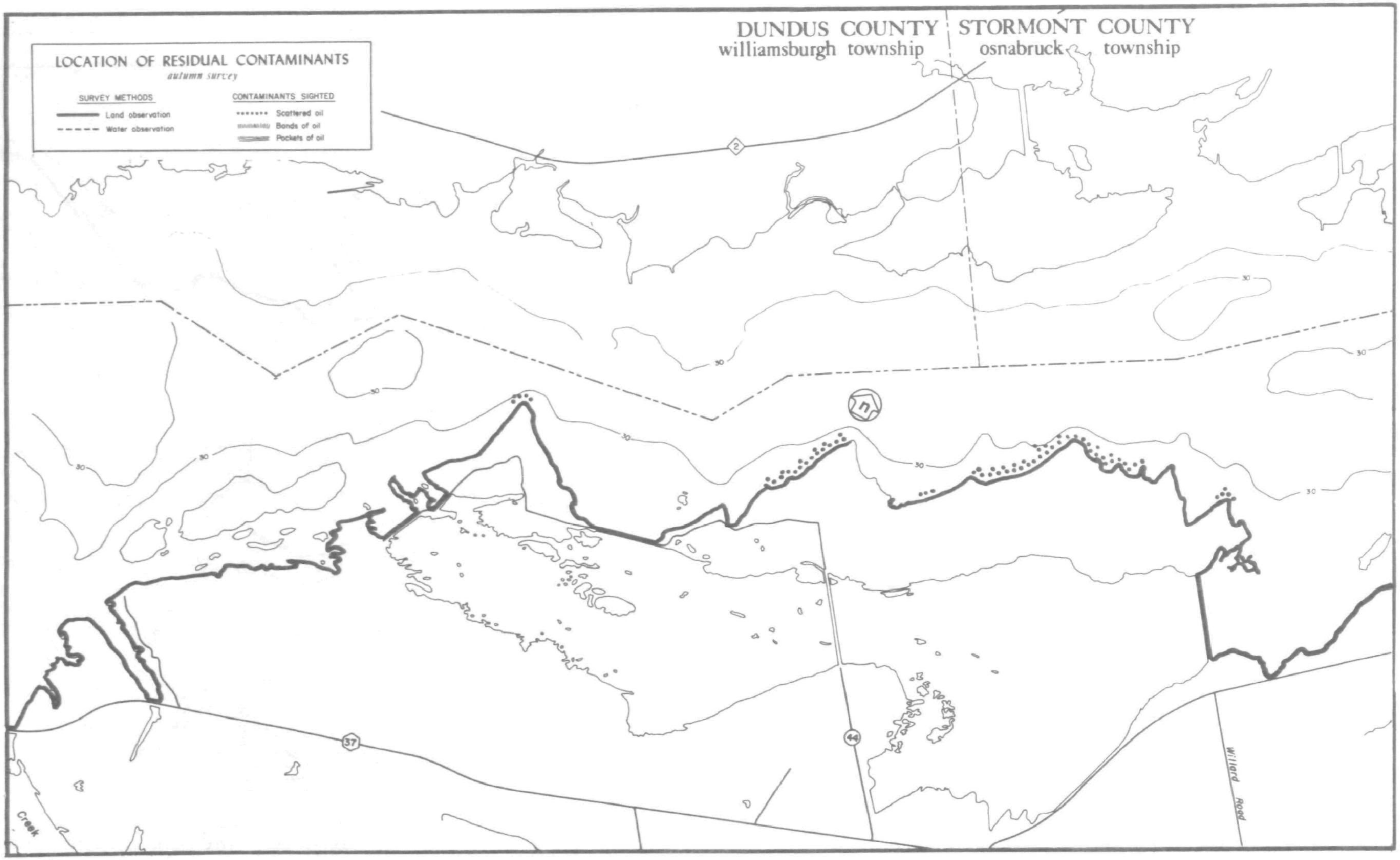

Figure 25. Section 12, Autumn Survey, 1976.

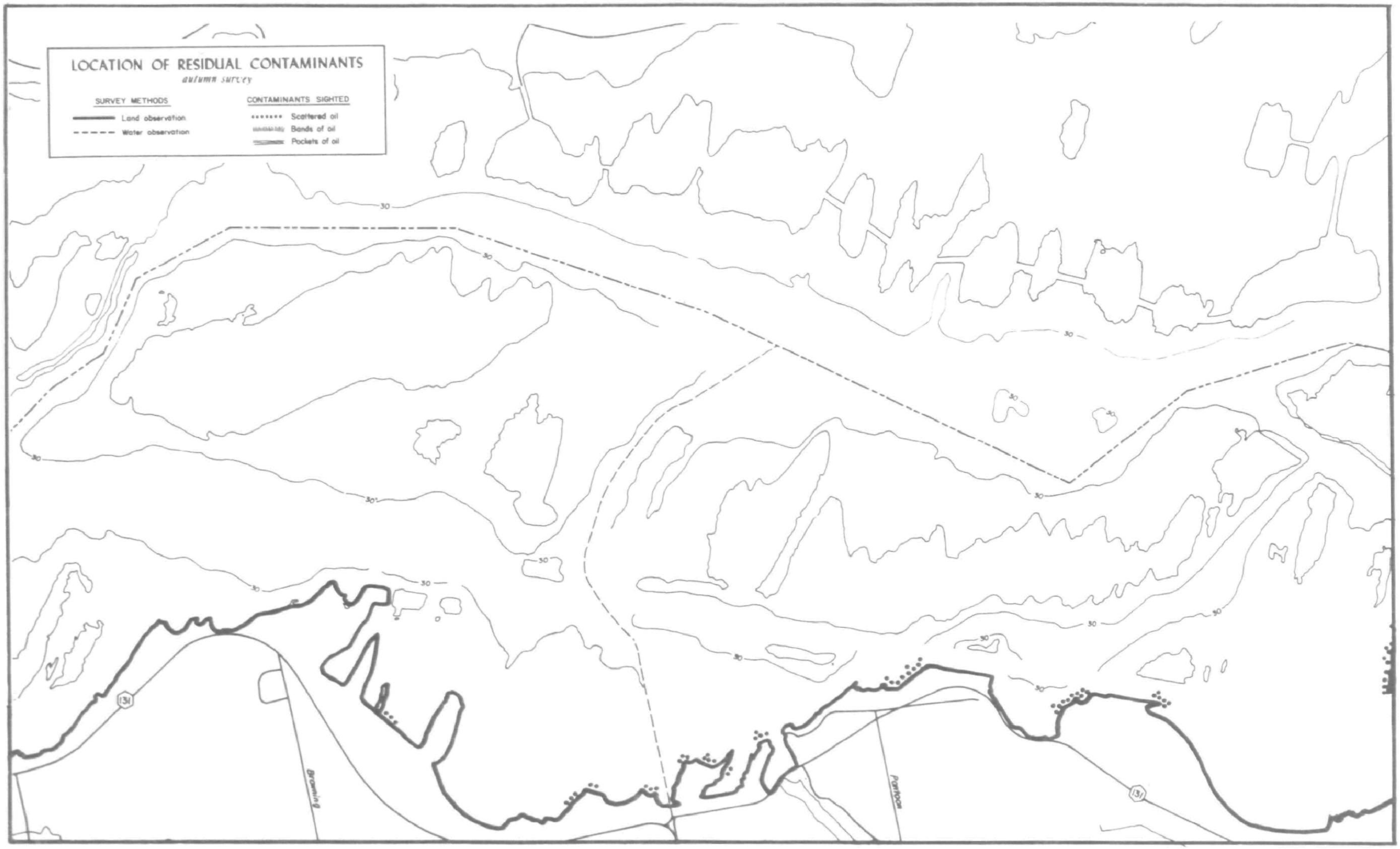

Figure 26. Section 13, Autumn Survey, 1976.

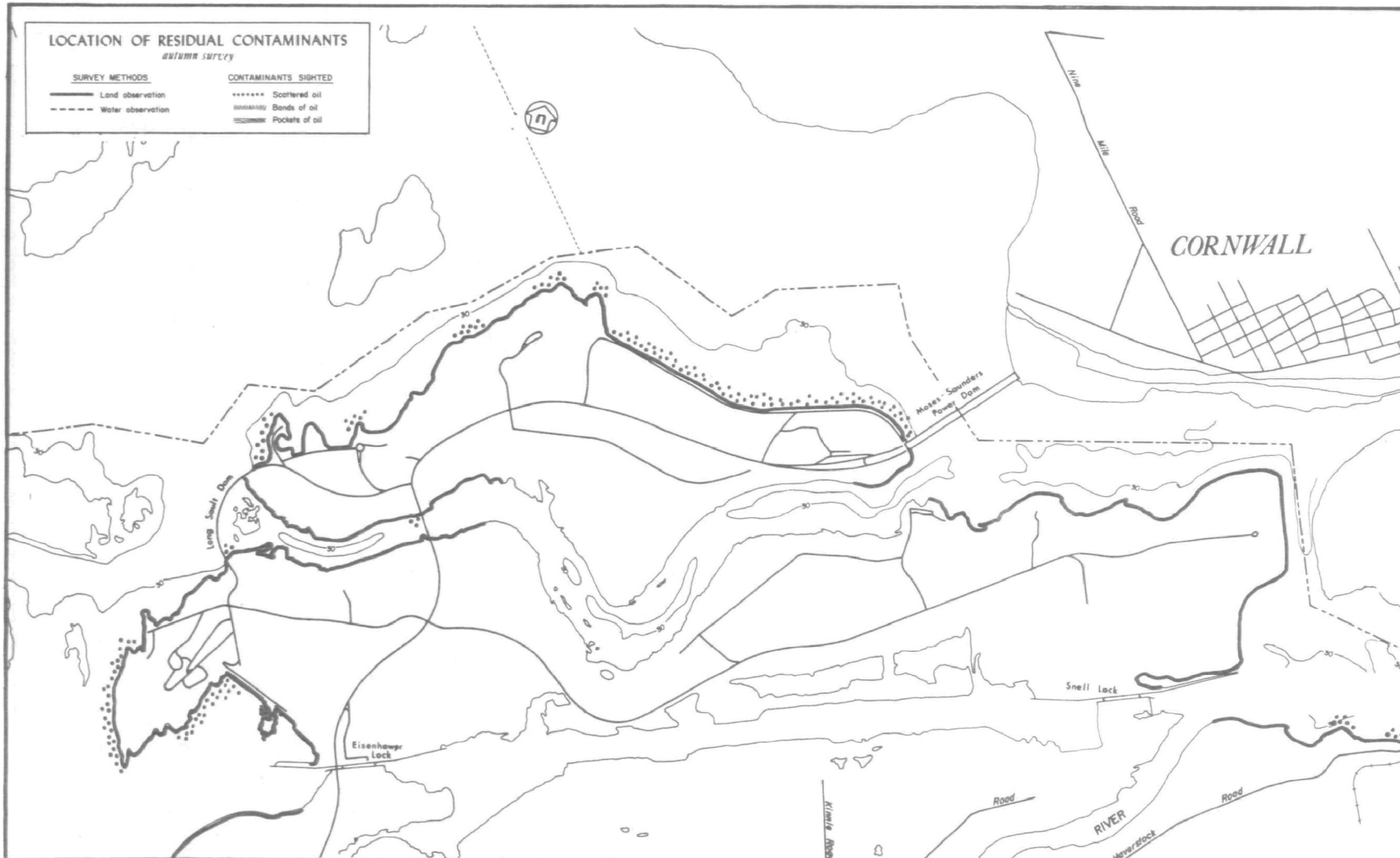

Figure 27. Section 14, Autumn Survey, 1976.

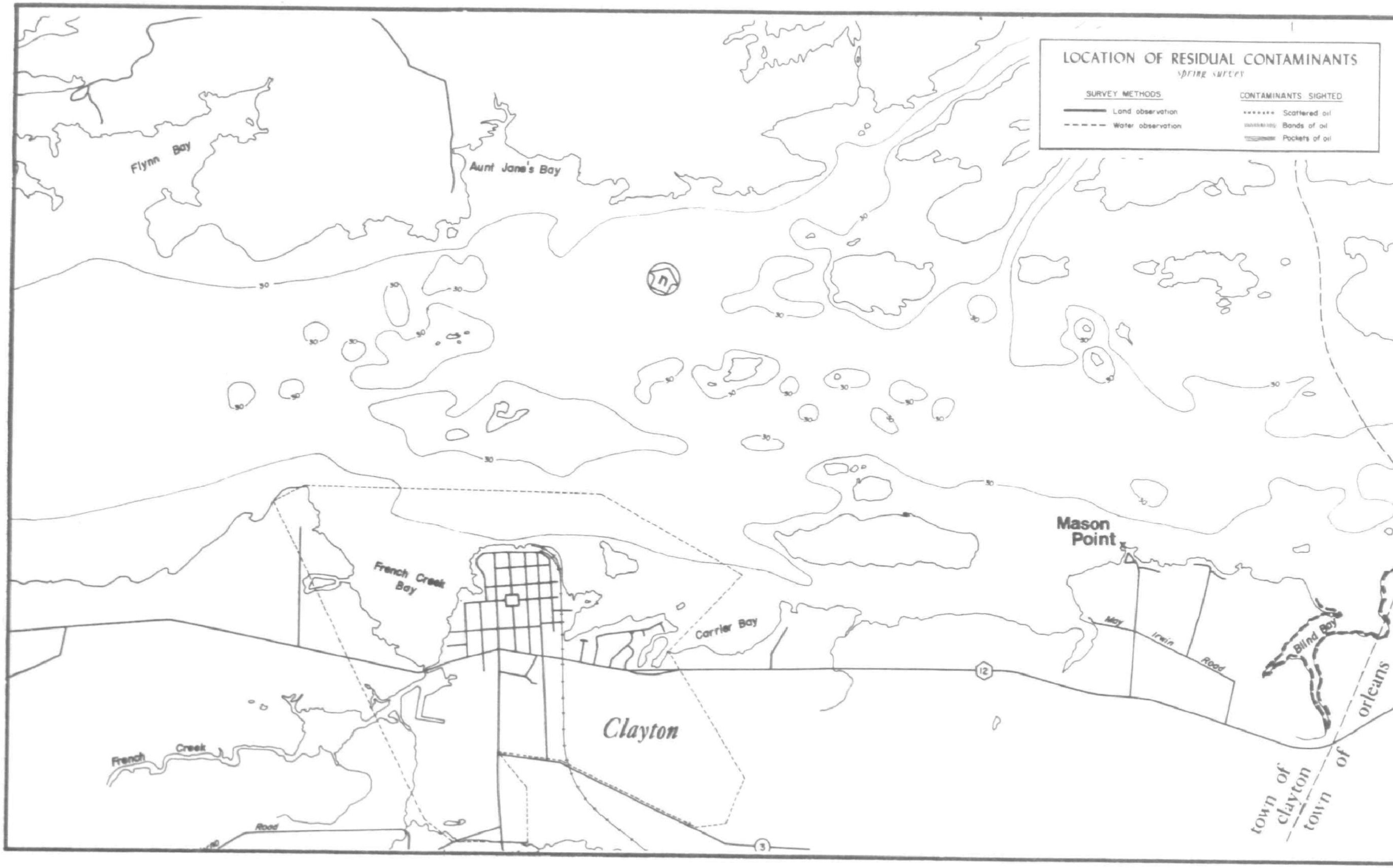

Figure 28. Section 1, Spring Survey, 1977.

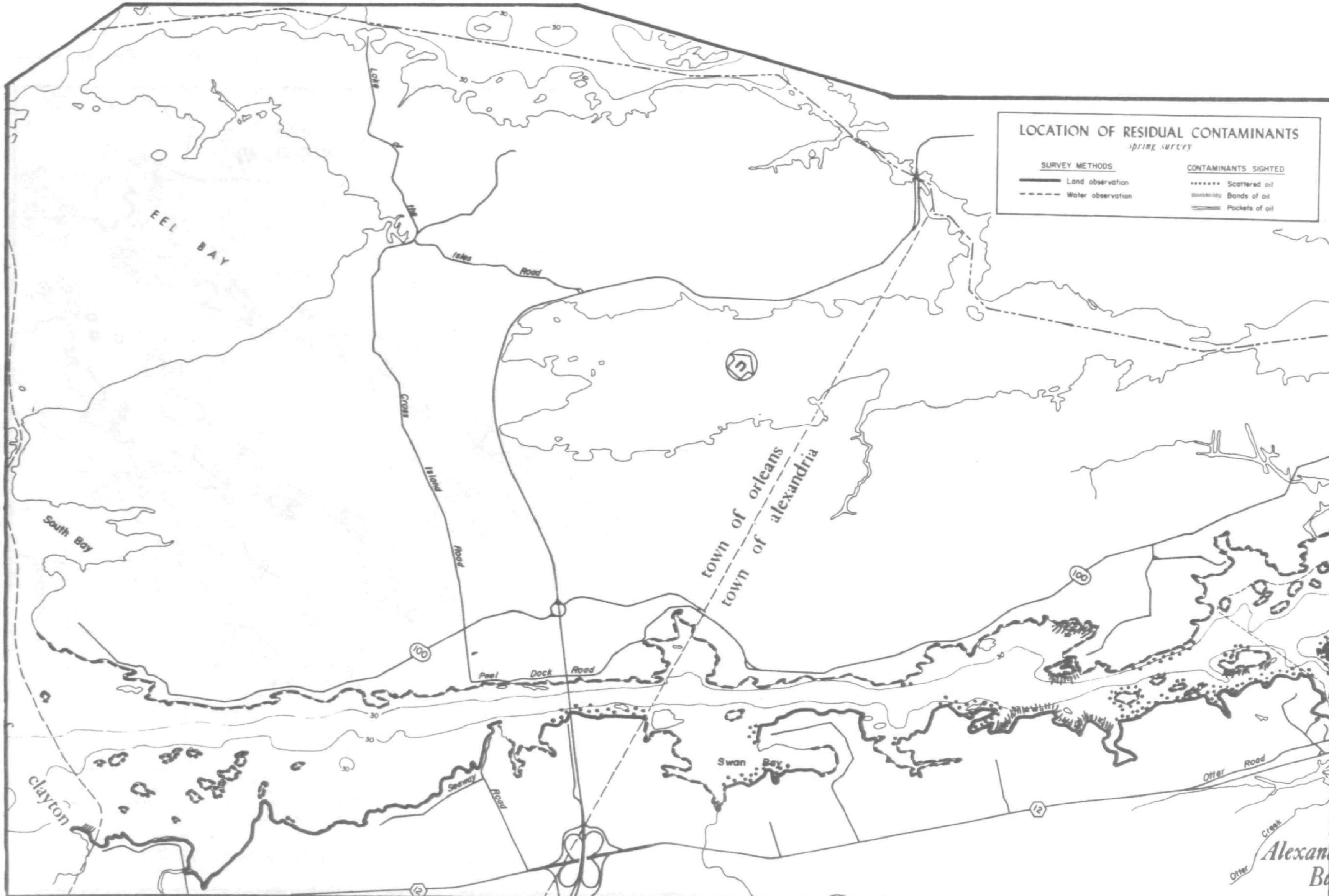

Figure 29. Section 2, Spring Survey, 1977.

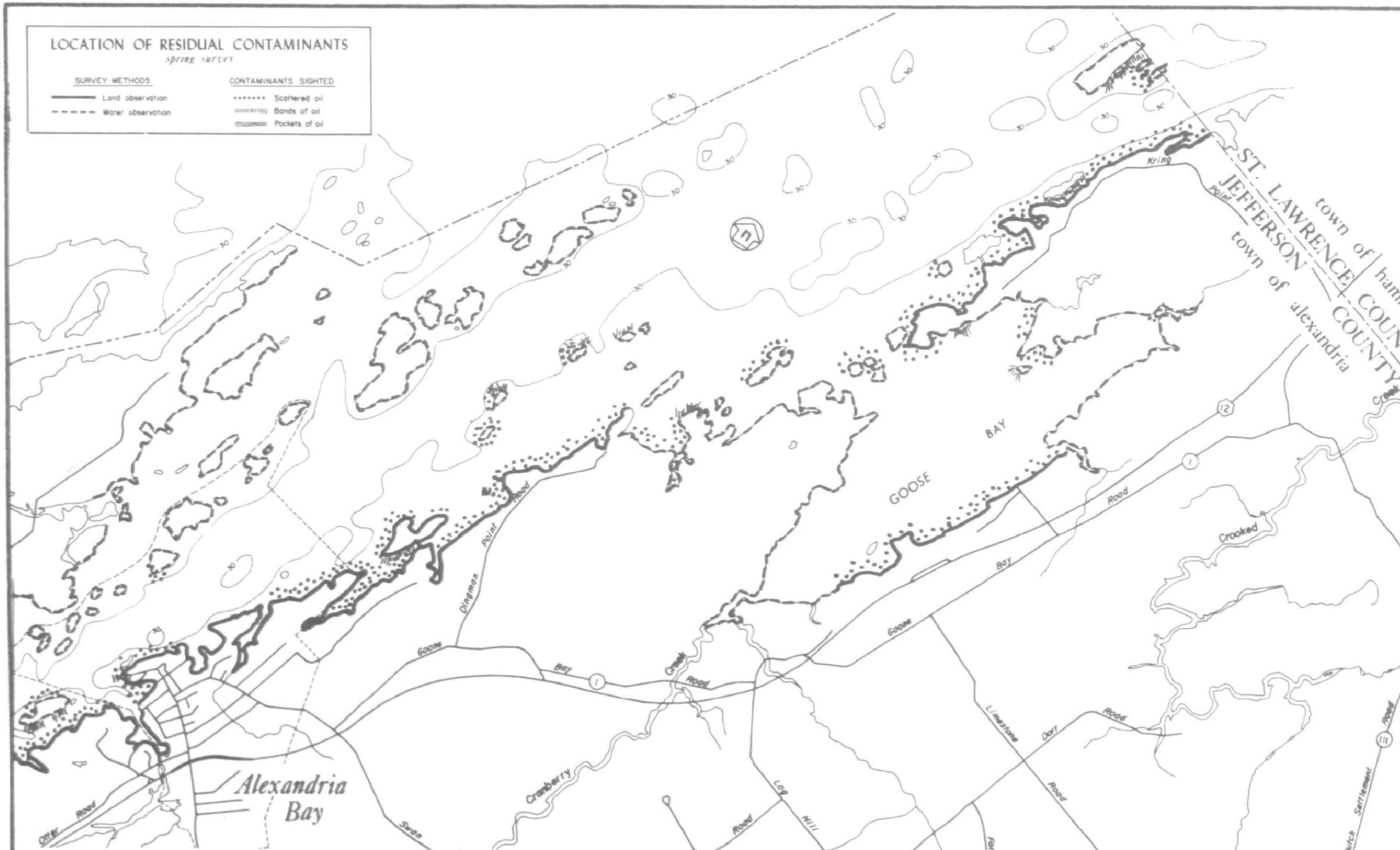

Figure 30. Section 3, Spring Survey, 1977.

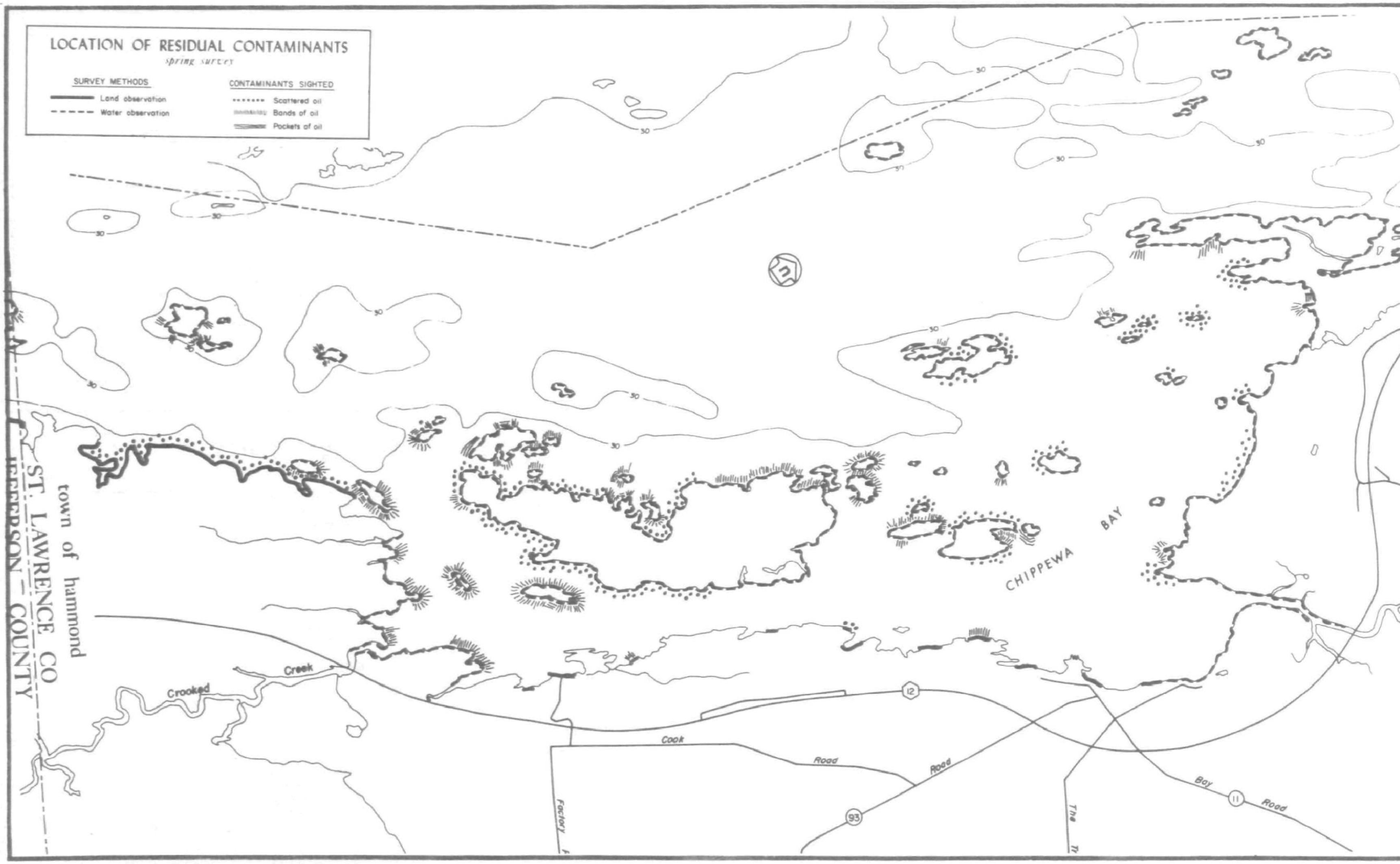

Figure 31. Section 4, Spring Survey, 1977.

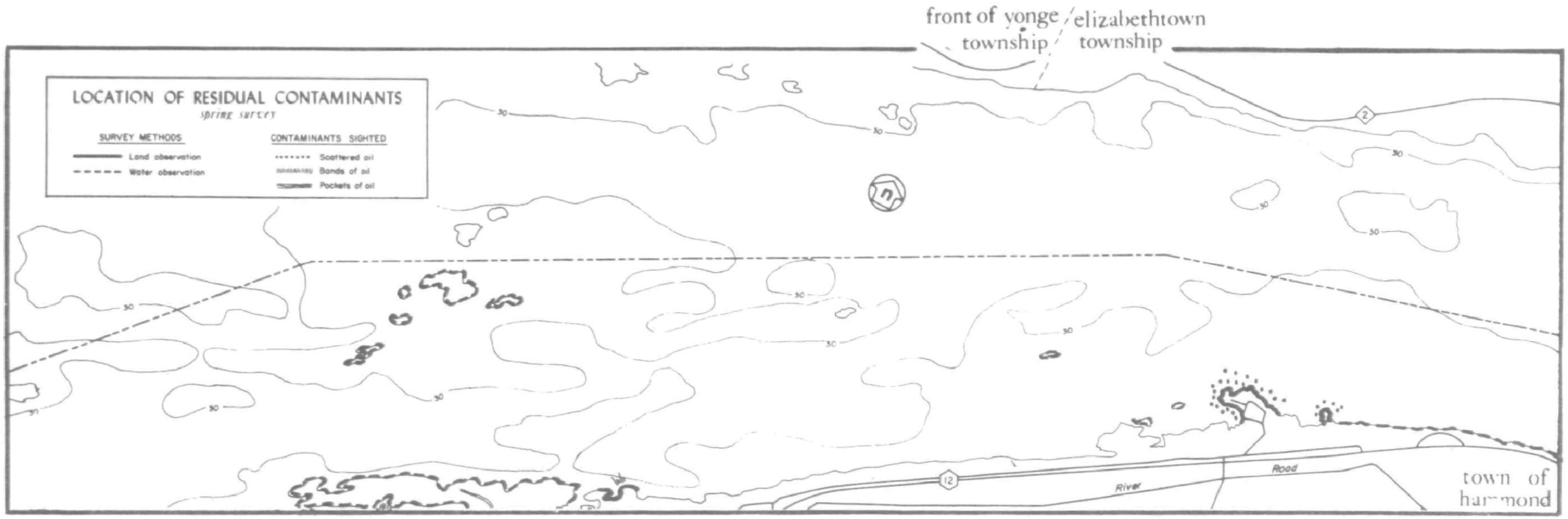

Figure 32. Section 5, Spring Survey, 1977.

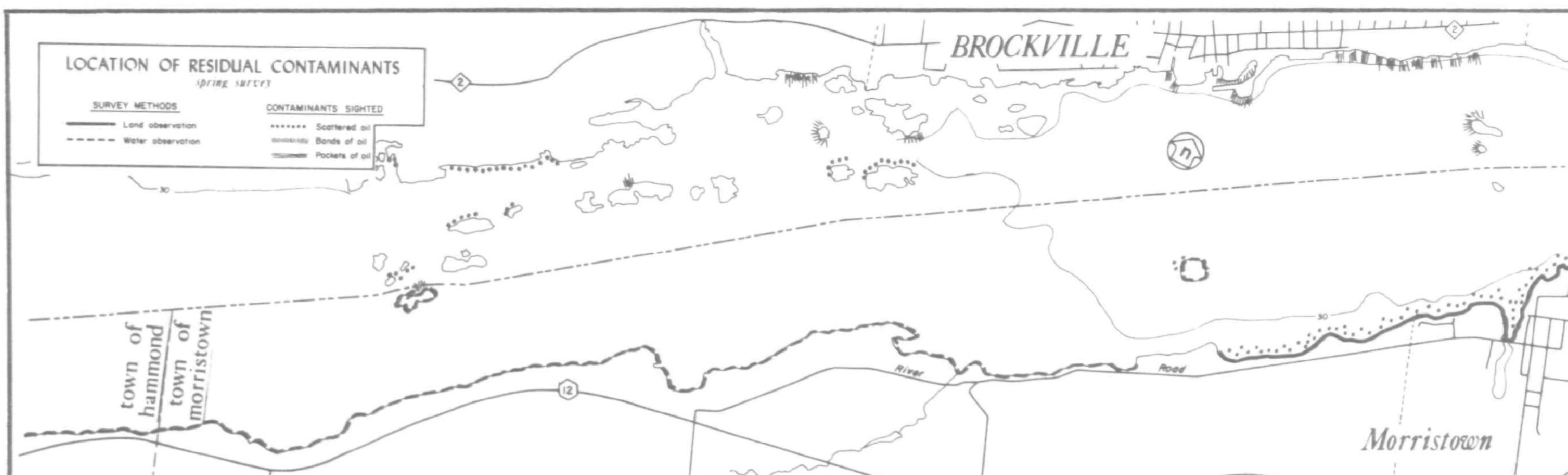

Figure 33. Section 6, Spring Survey, 1977.

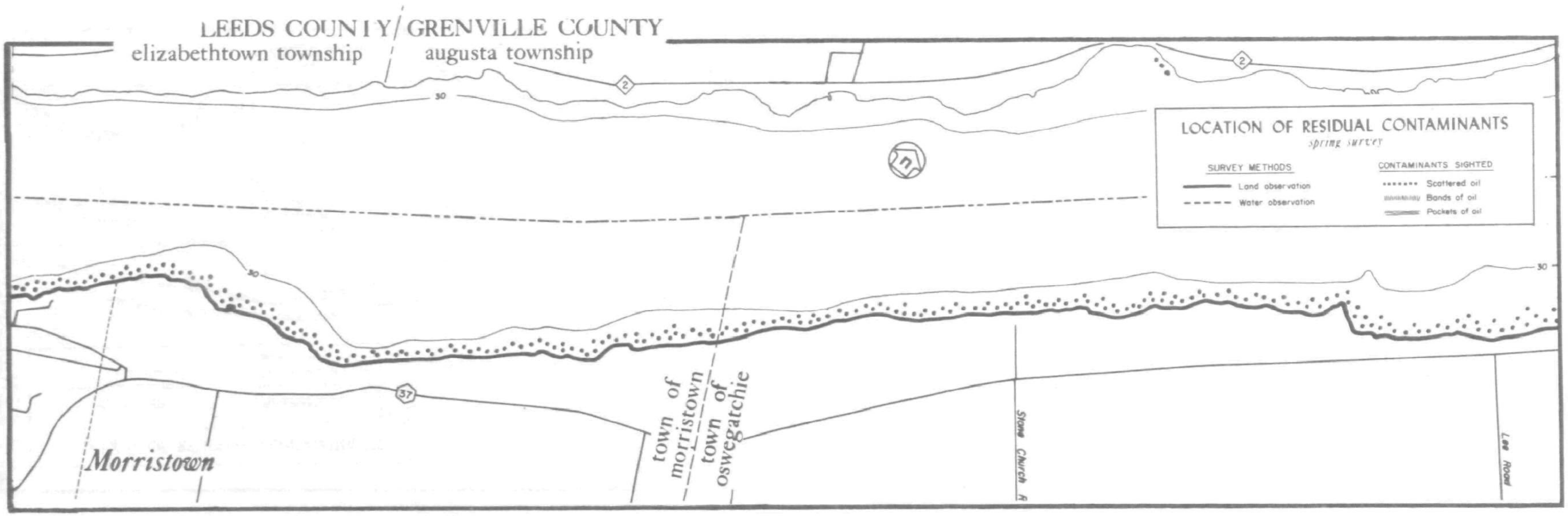

Figure 34. Section 7, Spring Survey, 1977.

Figure 35. Section 8, Spring Survey, 1977

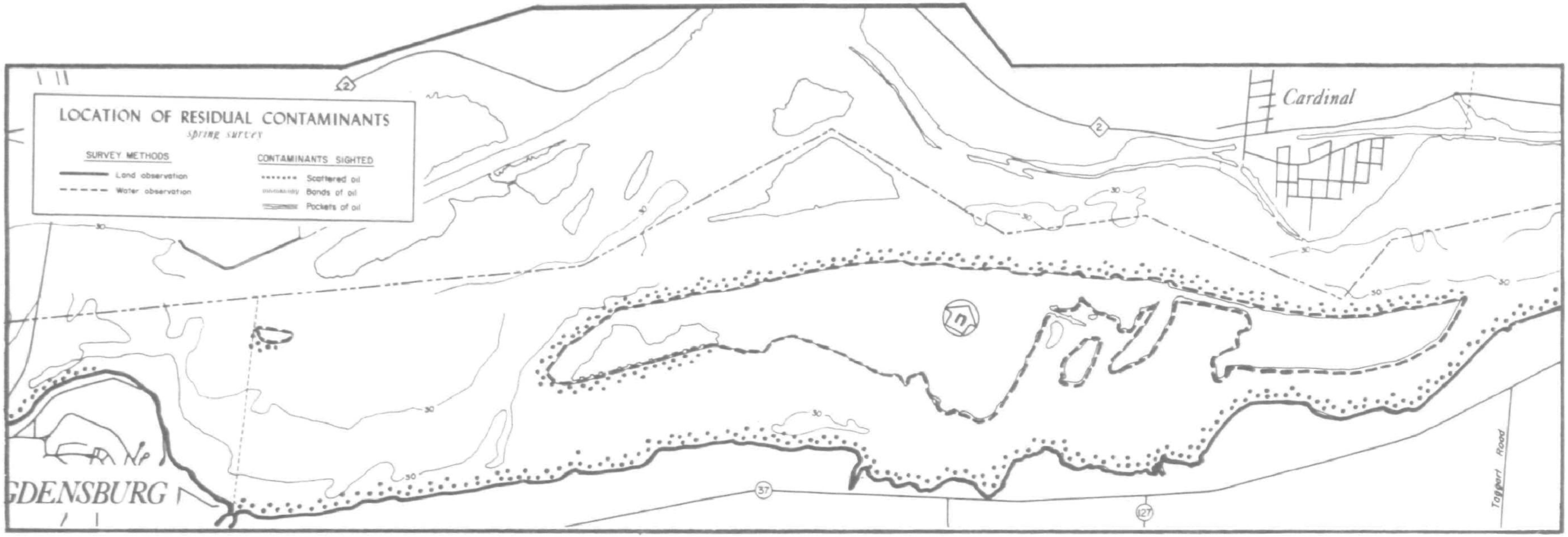

Figure 36. Section 9, Spring Survey, 1977.

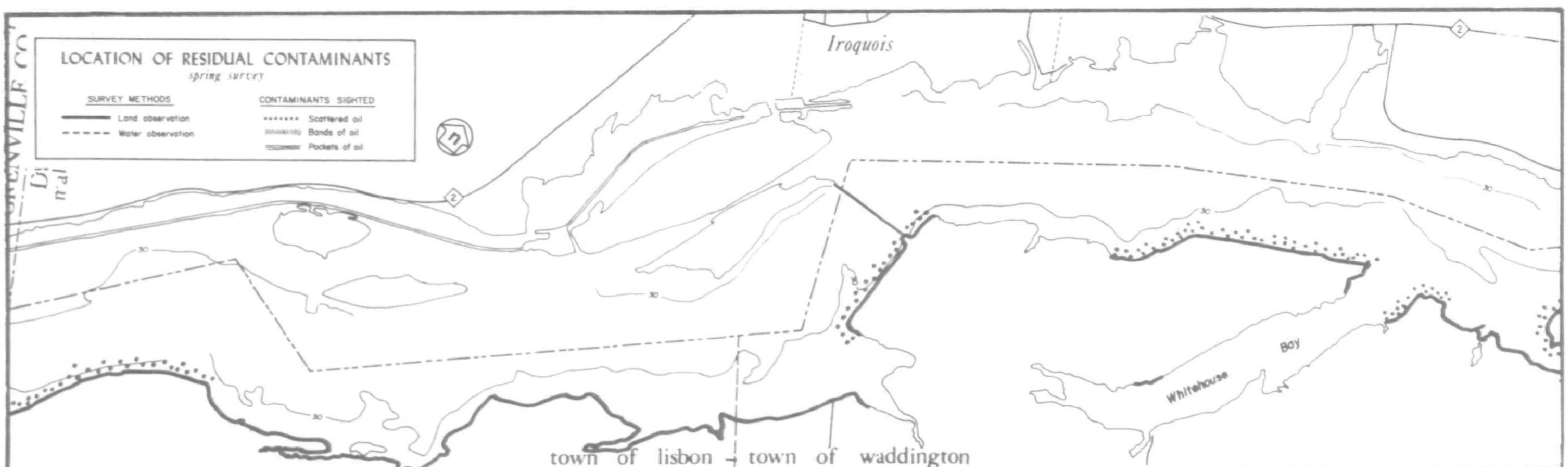

Figure 37. Section 10, Spring Survey, 1977.

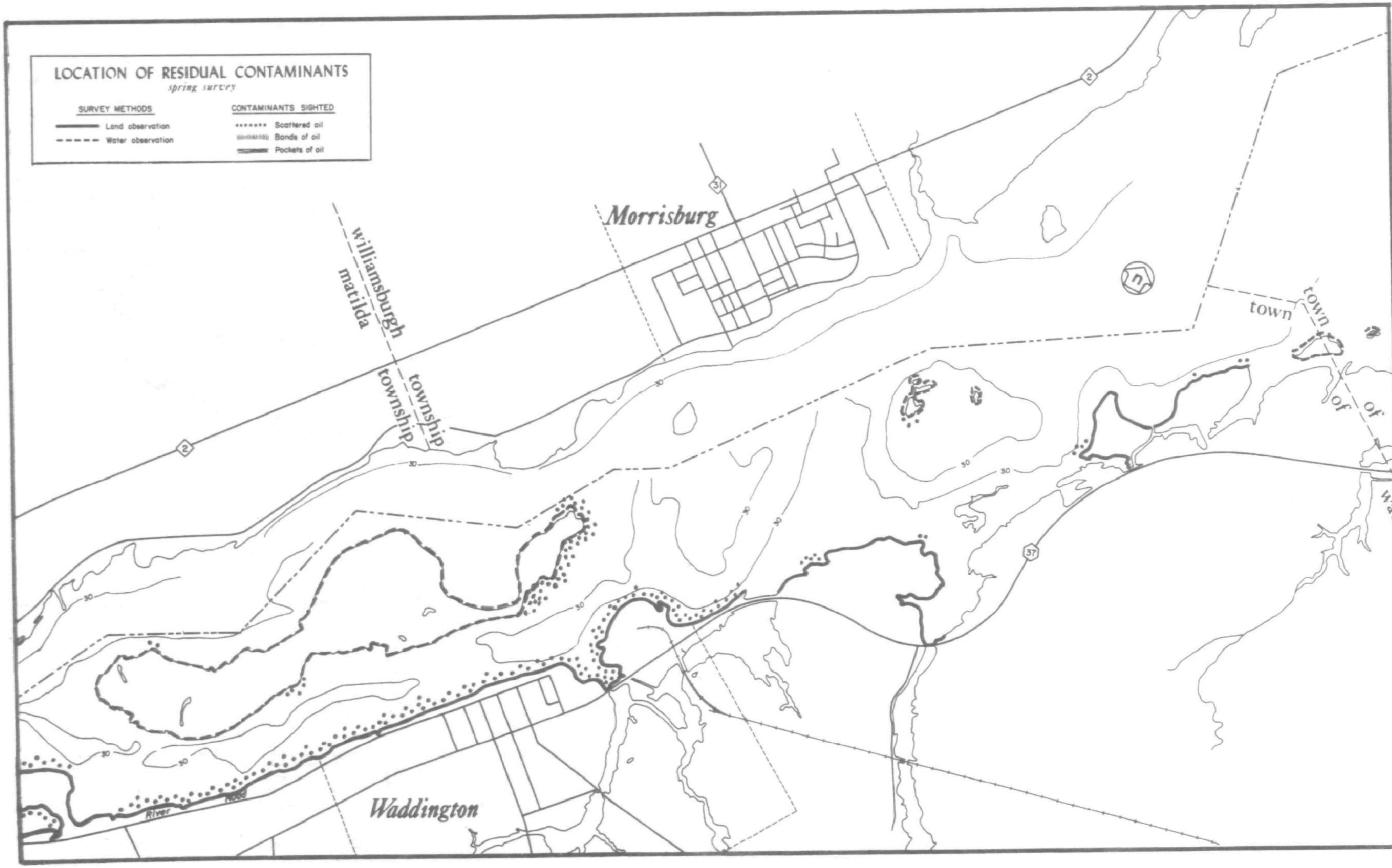

Figure 38. Section 11, Spring Survey, 1977.

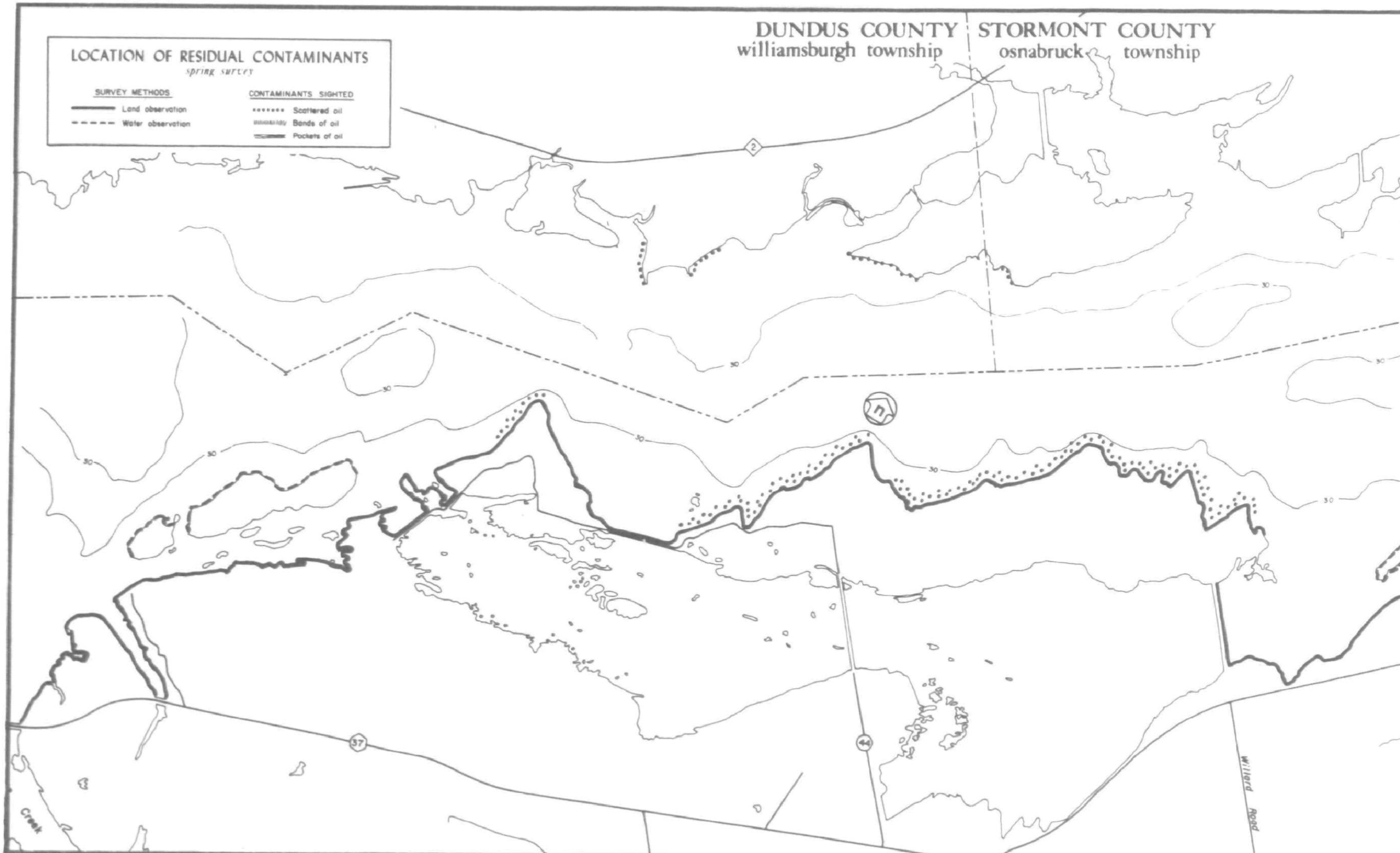

Figure 39. Section 12, Spring Survey, 1977.

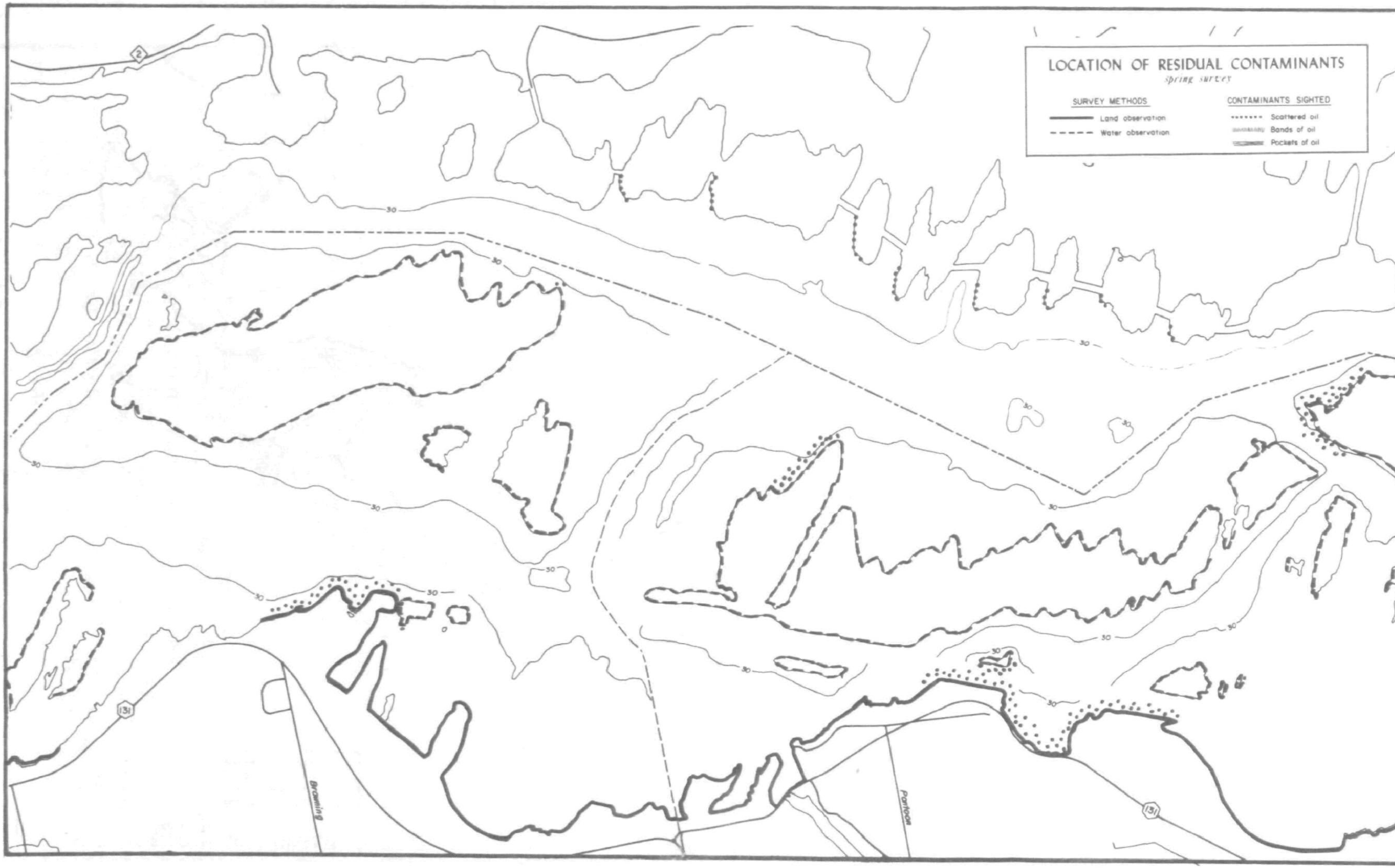

Figure 40. Section 13, Spring Survey, 1977.

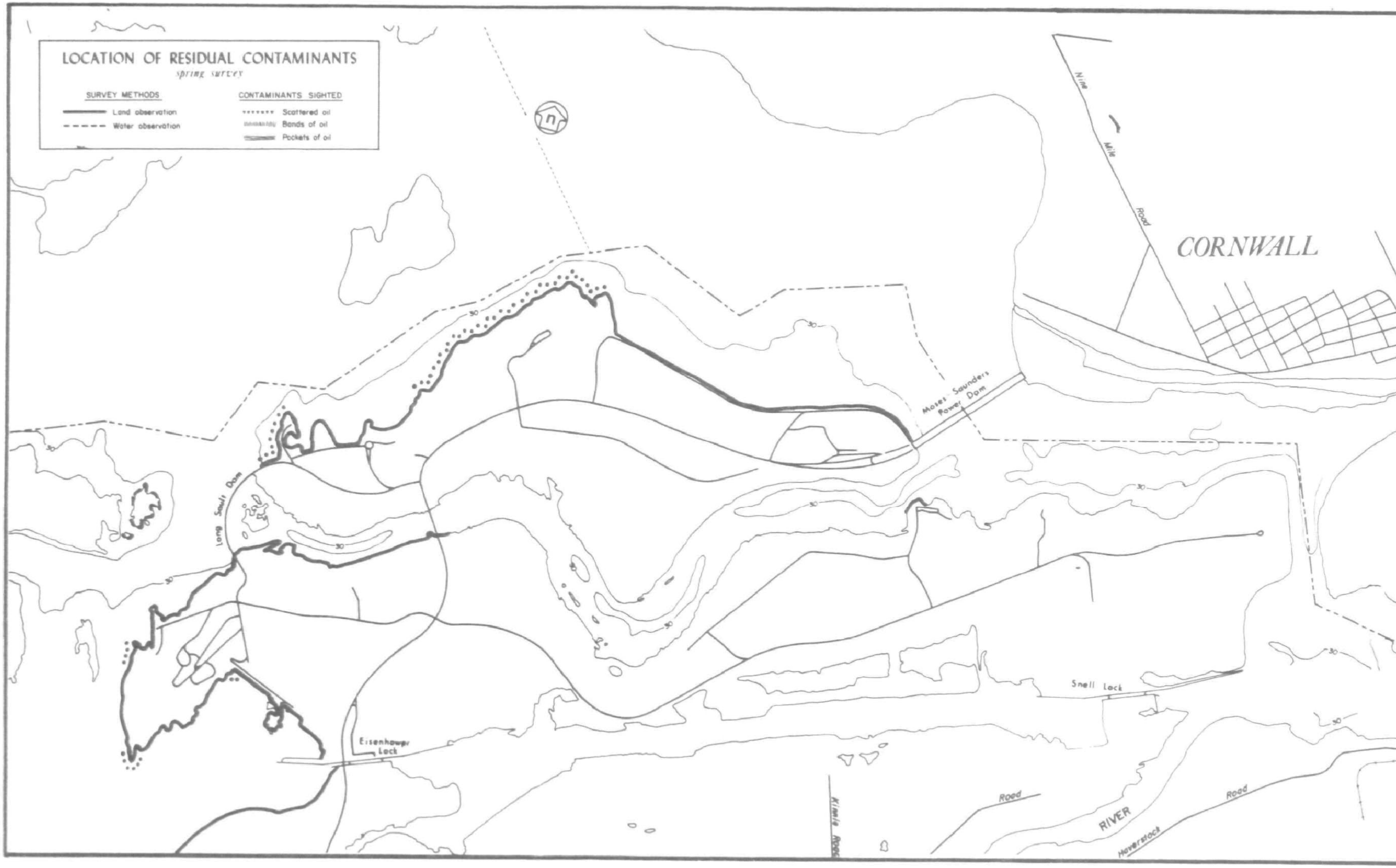

Figure 41. Section 14, Spring Survey, 1977.

increase of 35.05 km (21.78 mi) of scattered oil was observed in the Spring as compared to the Fall, while there was a decrease of 24.85 km (15.44 mi) of bands of oil. The extent of pockets of oil decreased from 2.99 km (1.86 mi) in the Fall to 1.56 km (0.97 mi) in the Spring. Over all, 8.77 km (5.45 mi) more were classed as contaminated in the Spring than in the Fall. In terms of the area surveyed, there was a decrease from 47.6 percent to 32.3 percent that was contaminated in the Spring as compared to the Fall.

The Towns of Hammond and Alexandria accounted for 21.57 km (13.40 mi) of the 24.85 km (15.44 mi) decrease in shoreline classed as "bands of oil." As is indicated in Figures 15, 16, 29 and 30 for the Town of Alexandria, and 17, 18, 31 and 32 for the Town of Hammond. Extensive areas classed as "bands of oil" in the Fall were classed as "scattered oil" in the Spring. The majority of the remainder of the additional shoreline that was classed as "scattered oil" was on islands not previously surveyed.

Observations of specific points on the shoreline indicated that the primary changes that occurred between the two surveys were as follows:

"Bands of Oil"--Hardening of the residual and a decrease in reflectiveness; no observed reduction in thickness or width; little, if any, scouring or sloughing off of the residual; less visible due to the decrease in reflectiveness; and little evidence of running or dripping of the bands.

"Scattered Oil"--Reduction in quantity that is visible due to covering up by dead vegetation; some relocation caused by movement of material (vegetation, debris, etc.) that the oil is trapped in; hardening of the residual and a decrease in reflectiveness where it is on solid objects; evidence of transport as small amounts were found submerged at water levels below those of the day of the spill; and vegetation growing through and around the scattered residual.

"Pockets of Oil"--Reduced visibility as old vegetation covered them and new vegetation grew around and through these pockets; and reducton in viscosity.

Table 6 sets forth a comparison of residuals between the fall and spring survey for a limited number of sites. The description of residual is generalized based upon the detail provided on the survey forms and is presented to reflect general changes that occurred.

Summary Appraisal

The major observation of the Spring survey was that the residual appeared to be less visible than during the previous Fall. This was reflected in the reported observations for specific sites and from the classification of the shoreline. For example, several areas where the residual was classed as "bands of oil" in the Fall were classed as "scattered oil" in the Spring. In other areas where scattered oil was found in the Fall, no residual was reported in the Spring. Again, fewer miles of pockets of oil were found in the Spring than in the Fall.

TABLE 6. RESIDUAL CONTAMINANTS COMPARISON

Location[a]	Residual Fall 1976	 Spring 1977
Seawall at Grass Point State Park	2.54 cm (1 in) by 24.38 m (80 ft) band	band--scattered
Rocks at Snow Bay (inhabited section)	scattered--prevalent	scattered
Swan Bay (inhabited section)	scattered	scattered--very little
Rocks at Edgewood Resort	scattered	scattered--very little
Hutchinson's Boat Work docks	bands	bands--scattered
Village Water Department rocks	scattered	scattered
Iroquois Island Bridge Abutment	band	band
Goose Bay Inn docks and cribs	scattered--prevalent	scattered
Turkey Point rocks	band	band--less prevalent
Kring Point (rocks in small cove)	band on rocks	band on rocks
Cloud's Rest Island	band	band
Cottage area near Lumsley cottage and downstream	scattered	little oil--no oil at one cottage but new breakwall had been constructed
Augsbury Oil and Acco	large quantity	large quantity
Ogdensburg Bridge	prevalent	slight decrease
Upstream of Red Mills (inhabited section)	continuous band	band--prevalent
Red Mills rocks	prevalent	slight decrease

[a]Details of location are available on the Description of Residual Contaminants Form.

This decrease in visibility was more noticeable in areas where the shoreline was vegetated. In these areas, dead vegetation covered or partially covered the residual and in many areas new growth screened the residual from view. It was observed that vegetation grew through the scattered oil and pockets of oil in many cases.[4]

However, it should be noted that close observation revealed there was little change in the quantity of residual in the Spring as compared to the Fall. The degree of visibility was reduced during that period but not the amount of residual.

From field observations it appears that the effect of the elements was minimal for the period between the spill and the Spring survey. As noted, little, if any, evidence of the oil becoming viscous enough to cause it to "run" was noted. The water levels during this period did not reach the height of the water on June 23, 1976, the day of the spill. During the Spring survey they were 0.61 m (2 ft) to 0.76 m (2.5 ft) below this level. Thus, opportunity for ice scour was limited. Observations at the heads of islands and other places where scour was expected to occur did not reflect any great amount of scouring.

In summary, the three significant effects of time and the elements that were observed were 1) the hardening of the residual caused primarily by the loss of more volatile residuals, 2) a decrease in visibility due primarily to the dying of vegetation and the growth of new which provided screening and covering or partial covering of the residual, and 3) substantial amounts of residual were not removed by ice scouring due to the lower water levels.

Canadian Survey[5]

During the period from May 9 to May 12, 1977, approximately 32.18 km (20 mi) of shoreline in Canada were surveyed. Included was the mainland shoreline between Lily Bay and the dike at Cornwall. This was surveyed by walking at selected spots. The islands and the mainland between Myers and McNair Islands were surveyed by boat and in some areas by walking.

Described below is a summary of the findings of that survey. It is presented by map section.

Section 6--Brockville Narrows (Figure 33)--Stovin Island, Royal Island and Prince Alfred Island were the most heavily contaminated. Bands of oil up to 3.81 cm (1.5 in) thick and 0.61 m (2 ft) wide covered the heads of

[4]The impact of the residual on vegetation will be discussed in more detail in the section dealing with environmental impacts.

[5]The survey was conducted by Clarence Muisiner, Robert Michen and John Allen of Ontario Ministry of the Environment; Thomas Walton of Parks Canada; and Janet Heuhn of the Department of Fisheries and the Environment, Environment Canada.

Royal and Alfred Islands and a bay on Stoven Island. Other areas had scattered oil or bands of oil 5.08 cm (2 in) wide; 13.84 km (8.6 mi) of the shore were surveyed and 1.29 km (0.8 mi) were found to have residual contaminants.

Section 6--Town of Brockville (Figure 33)--The municipal dock at Brockville had wide bands of oil stains. Narrow bands of oil and stains were observed on rocky shoreline and private docks. Six and twenty-eight hundredths km (3.9 mi) of shore were surveyed, with 1.77 km (1.1 mi) being classed as having residual contaminants present.

Section 7--Mainland (Figure 34)--Scattered oil was found at Brockville Chemicals. One mile was surveyed, with 0.13 km (.08mi) being found contaminated.

Section 8--Prescott (Figure 35)--No residual contaminant was observed in the 2.41 km (1.5 mi) surveyed.

Section 9-12--Prescott to Crysler Memorial Park (Figure 36-39)--No residual contaminant was observed in the area.

Section 12--Crysler Memorial Park (Figure 39)--Two and forty one hundredths km (1.5 mi) were surveyed with 1.93 km (1.2 mi) being classed as contaminated by scattered oil. The shoreine in this section consists of sto y beaches and minor vegetation.

Section 13--Woodland Islands (Figure 40)--The upstream sides of the islands of Long Sault were contaminated with scattered oil along 1.77 km (1.1 mi) of the 2.41 km (1.5 mi) surveyed.

Section 14--Long Sault (Figure 41)--Scattered oil was found in isolated places. At the Cornwall Municipal Park oil patches were observed on the bottom in 15.24 cm (6 in) to 0.46 m (1.5 ft) of water. Of the 2.09 km (1.3 mi) of shore surveyed, 0.80 km (0.5 mi) were classed as having residual contaminants.

The Canadian shoreline was surveyed only in the spring of 1977. Thus, comparisons between survey periods can not be made. The data relating to the Canadian survey is included to reflect that the problems related to oil spills are truly international in nature, thus requiring cooperative action by parties on both shores of the River. Secondly, it is set forth to reflect that even though extensive efforts were undertaken by the Canadian Ministry of Transport to clean up the Canadian shoreline, contaminants were not totally removed. This is similar to the situation on the United States shoreline.

SECTION 5

BACKGROUND TO ENVIRONMENTAL STUDIES

PETROLEUM IN THE ENVIRONMENT

Natural Seeps

The introduction of large amounts of petroleum hydrocarbons into the environment has led to great concern about their potential effects on plants and animals, natural communities, and man. It is realized that there are natural seeps and that these have a long history of occurrence in coastal marine and inland wetland environments. The communities of living organisms in these environments have adjusted, if not become specially adapted, to chronic levels of oil input. Since petroleum has its origin in living organisms, it cannot be regarded strictly as a foreign substance.

The amount of petroleum hydrocarbons being introduced by natural seeps is difficult to estimate. Wilson et al. (1973) places the amount at somewhere between 200,000 and 1,000,000 metric tons per year in marine environments with a "best" estimate at 600,000 metric tons per year. Koons and Monaghan (1976) confirm this estimate. Grossling (1976) suggests that natural seeps on land could be four times as great as those off shore. It has been further estimated that natural seeps have totalled 50 to 100 times the volume that currently exists in the earth's reservoirs (Nat. Acad. Sci. 1975). Therefore, we need not regard petroleum hydrocarbons as new environmental additives. However, like the other natural components of our environments, there must be a limit to the amount that can be tolerated by a healthy natural community. Even oxygen, carbon dioxide, and sodium chloride can become toxic while existing in still rather small amounts. Our concern then is to know the response of organisms and communities to sudden and massive introductions of petroleum hydrocarbons, as occur at the time of a major oil spill.

Means of Introduction

There are several means by which petroleum in its various forms becomes introduced into the environment. As explained by the National Academy of Sciences (1975) for marine environments, this includes all activities beginning with production, refining and transportation, and ending with use. Even for transportation the means are numerous. Major spills resulting from tanker accidents vary from year to year depending on their frequence and the amounts and kinds of oil involved. The extensive and highly publicized spills, such as the Torrey Canyon, Argo Merchant, and Amoco Cadiz have generally occurred in coastal marine environments.

The effects of freshwater spills are limited in part by the tonnage of the tankers capable of navigation in rivers and lakes. However, the spilled oil may be highly concentrated in the impacted areas, and the effects may be long lasting.

The Nature of Petroleum

Petroleum is a highly complex mixture of thousands of hydrocarbons that vary with the source, refinery product, and time. Therefore, every tanker load is different as is every spill in its physical and chemical characteristics.

Major groups of hydrocarbons are the aliphatics, alicyclics, and aromatics. The aliphatic hydrocarbons are largely the saturated alkanes or paraffins. The alicyclic hydrocarbons are largely the saturated cycloalkanes and unsaturated olefins. The aromatic hydrocarbons are largely unsaturated mono-, di-, and polynuclear aromatics. In addition, there are numerous non-hydrocarbons in petroleum. These include compounds which may contain nitrogen, sulfur, oxygen, (NSO), and various metals.

The products of petroleum refining range from natural gas, gasoline, kerosene, No. 2 fuel oil, lubricating oils, Bunker C (No. 6) fuel oil to asphalts. Bunker C fuel oil is one of the heaviest distillate fractions of petroleum. As reported by the National Academy of Sciences (1975), it has an average specific gravity near 1.00, a viscosity of 1,000 centipoises at $38^{o}C$, and a pour point of $21^{o}C$. Most of its hydrocarbon components are C_{30} or higher. On the average, it contains about 15 percent paraffins, 45 percent naphthenes, 25 percent aromatics, and 15 percent polar NSO's.

Transformation Processes

Crude petroleum and petroleum products begin transformation immediately upon entering the environment. These changes involve physical, chemical, and biological processes. In general, these processes include evaporation, spreading, emulsification, solution, photochemical oxidation, tar lump formation, sedimentation, microbial degradation, and consumption by organisms (Nat. Acad. Sci. 1975).

Bunker C oil generally spreads slowly, loses less than 10 percent by evaporation, loses other light weight aromatic hydrocarbons and polar NSO's into solution and partially emulsifies in heavy waves or surf action. It undergoes some photochemical oxidation, is broken down by some microorganisms, and is consumed by others. Tar lumps containing some NSO compounds and poly-nuclear aromatics are frequently formed. Bunker C oil may combine with various suspended particulate material and settle to the bottom as small droplets.

Specific information on the fate of Bunker C oil is not available, since it would be different for each spill. One of the better long-range studies involving Bunker C oil is that associated with the grounding of the Arrow in Chedabucto Bay, Nova Scotia (Vandermeulen 1977).

Polynuclear Aromatic Hydrocarbons

Polynuclear (or polycyclic) aromatic hydrocarbons (PAH) are multi-ring compounds found in many substances including petroleum. They contain two or more benzene rings, unsaturated and arranged in various configurations. In general, they are comparatively stable. Some, such as benzo (a) pyrene, have been determined to be carcinogenic.

PAHs are found in plant and animal tissues, in soils and sediments, and in fossil fuels. Blumer (1976) has given us his views on their formation and distribution. Most PAHs appear to be found where organic compounds are subjected to high temperatures. However, extreme high temperatures are not necessary. In petroleum they are formed in sediments at temperatures of 100^{o} to 150^{o} Celsius over long periods of time. The specific temperature helps to determine the type of PAHs being formed and also the substitution of alkylated rings. In petroleum where PAHs are formed under low temperatures, the amount of alkylated PAHs exceeds the unsubstituted carbon rings. In soil the unsubstituted carbon rings are most abundant, indicating their formation at higher temperatures. PAHs in air which is polluted with emissions from high temperature furnaces have even fewer substituted carbon rings.

Blumer and Youngblood (1975) theorize that PAH found in soils and sediments originated from forest and prairie fires and then became universally distributed by world-wide patterns of air circulation. With an increase in the rate of incomplete combustion of fossil fuels, the amount of PAH entering the environment has increased greatly. Oil spills have become an acute additional source of PAH in localized areas.

It has been suggested that plants may have the ability to form PAHs (Borneff et al. 1968). However, specific determinations have not been made to date. The metabolism of PAHs by some organic functions has been studied by Philpot et al. (1976). The functioning of metabolic activity in the carcinogenicity of some PAHs has been investigated by Gibson (1976).

Bunker C Oil From NEPCO #140

The Bunker C fuel oil (No. 6) spilled from the barge NEPCO #140 was analyzed by E. W. Saybolt and Co., Inc. as a routine procedure for all oil shipments. Table 7 lists the tests and results for that particular load of oil, as taken on June 27, 1976, at the Niagara Mohawk terminal in Oswego, NY.

A sample of the oil was also taken by the U.S. Coast Guard and fingerprinted by gas chromatography. Their chromatogram is included here (Figure 42).

The U.S. Coast Guard provided a sample of the oil which was then analysed for polynuclear aromatic hydrocarbons using high pressure liquid chromatography. The results of this analysis will be included in a later section of this report.

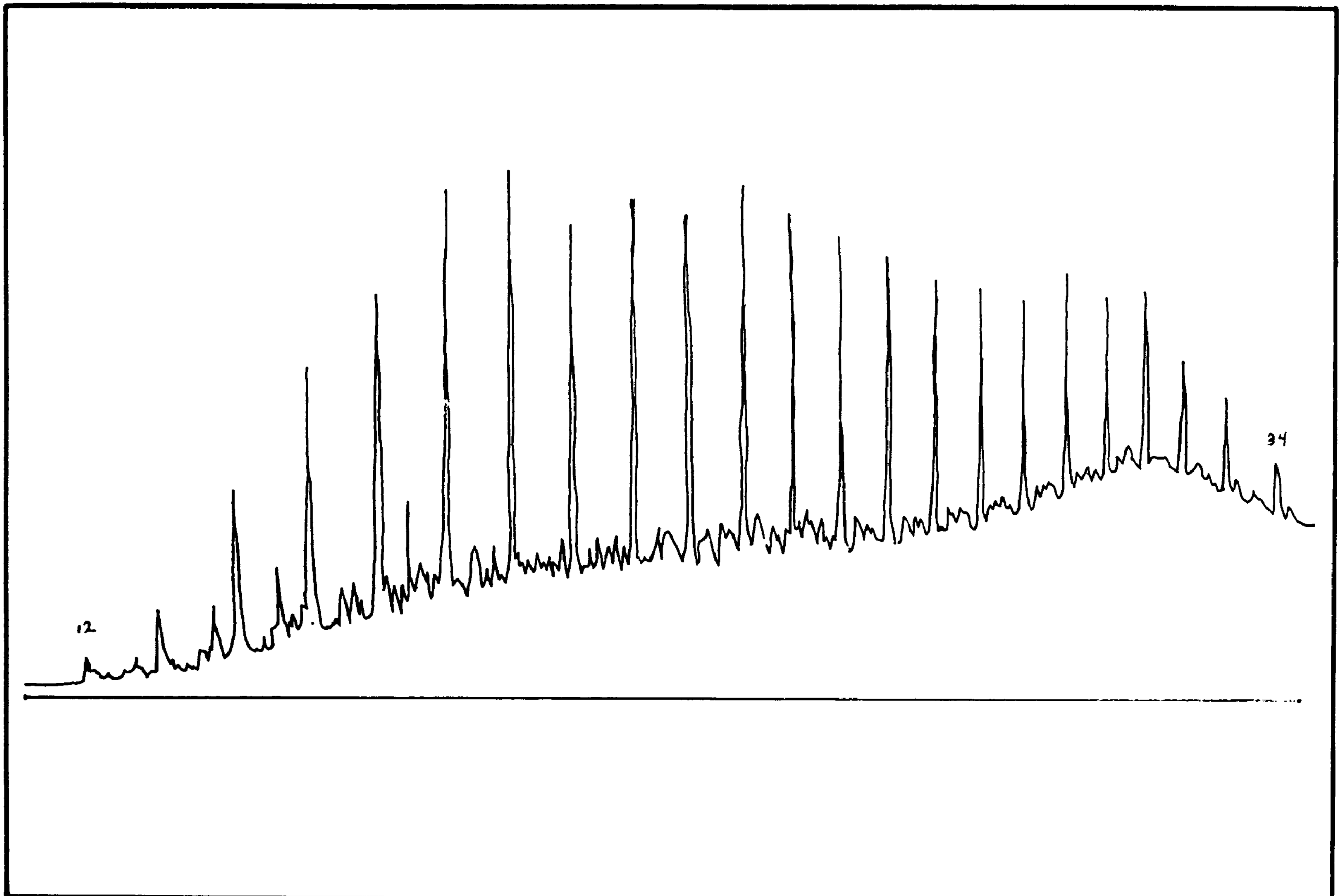

Figure 42. Gas Chromatogram of Bunker C Oil From NEPCO #140 Made By U.S. Coast Guard C_{12}-C_{34}.

TABLE 7. SAYBOLT TEST RESULTS OF NEPCO 140 OIL SAMPLE

Tests	Results
Gravity, API at 60°F	13.5 g/ml
Flash, PM CC	168°F
Visc, SF at 122°F	269 sec.
Pour, Point, ASTM	30°F
Carbon Res., Con.	12.4%
Sulfur, ASTM	2.40%
Water and Sediment	0.2%
Sediment, Extraction	0.03%
Water Distillation	Trace
B.T.U. Per Pound	18375
B.T.U. Per Gallon	149333
Ash	0.07%
Vanadium	390 PPM
Sodium	14 PPM

Source: Data provided by E. W. Saybolt and Co., Inc.

THE STUDY AREA

The St. Lawrence River marshes have received very little biological study. A recent preliminary study (Geis 1977) further emphasized the lack of baseline data. There were no specific data available on fish and wildlife for the impacted bays and marshes. Since prior data were not available, a system of comparing seemingly similar marshes was designed.

Seven study areas were selected to include a replication of slightly, moderately and heavily oiled marshes in each of the two major bays, and also to include a control area upstream from the spill site. Additional control or sample sites were added for particular function or emphasis.

Goose Bay

Goose Bay is about 4 km (2.5 mi) long, 1.6 km (1 mi) wide, elliptical in shape, and has one basic channel to the River. It has extensive cattail marshes at each end as well as near the River where an old channel has filled. The Bay is shallow and almost entirely occupied with submerged vegetation. Its channel is located about 8 km (5 mi) downstream from the initial grounding or 16 km (10 mi) from the point of anchorage of the NEPCO #140.

Point Marguerite Marsh--

This is the heavily oiled marsh in the Goose Bay complex (Figure 43). It occupies a depression that begins near the River proper and extends

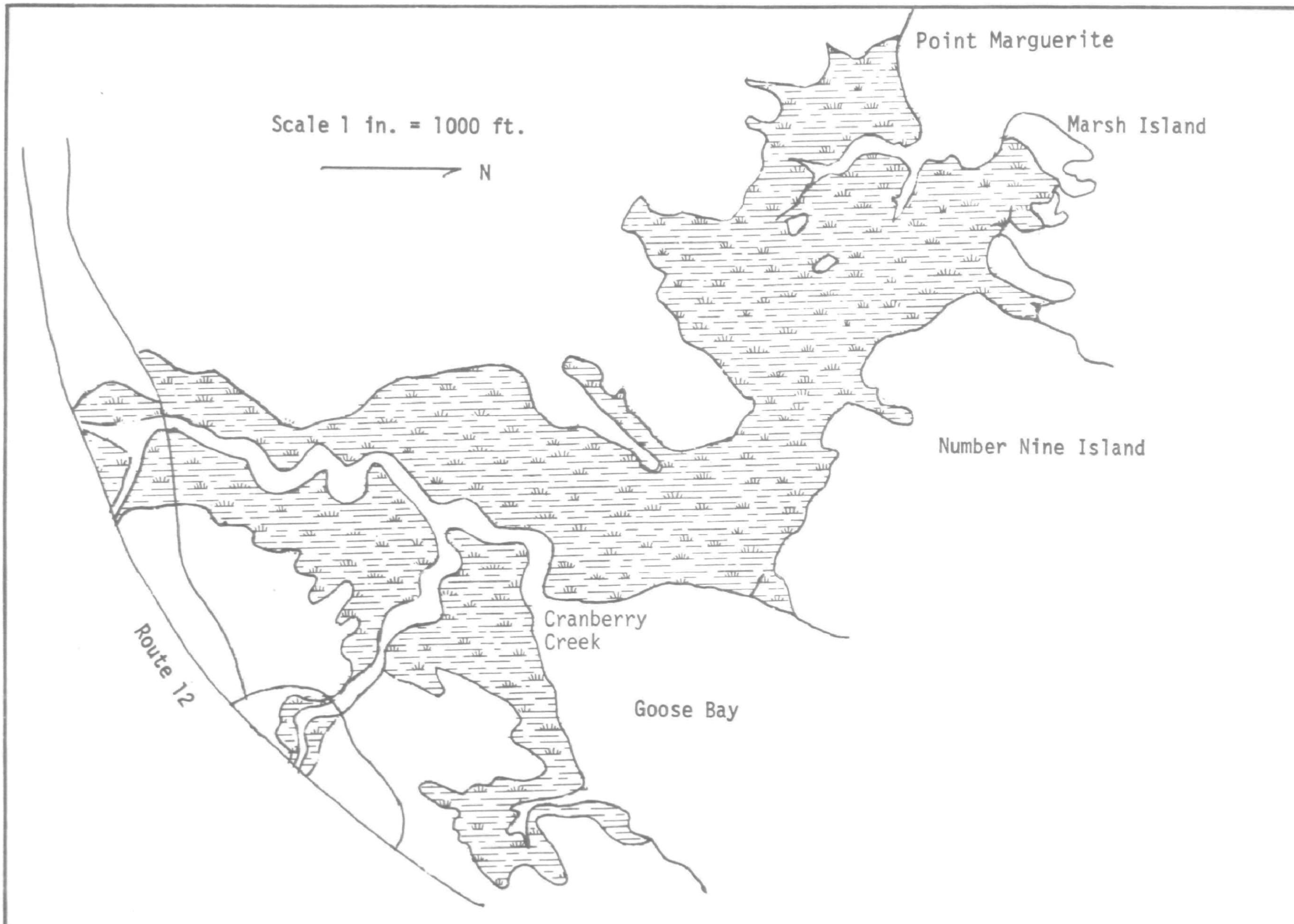

Figure 43. Point Marguerite and Cranberry Creek marshes.

toward the southwest end of the Bay and the mouth of Cranberry Creek. If the water were somewhat higher, it could become a second channel into the Bay. There is an embayment of about 10 ha (25 ac) before the marsh which contains a heavy growth of submerged vegetation, including sago pondweed, water celery and pond lilies. An opening exists in the center of the marsh edge. This extends into the marsh and branches to form several subunits.

The placing of booms across the River and between islands of the Excelsior Group introduced additional oil into the area. The small inlets permitted the oil to move back into the marsh. The area of the extent of maximum oil penetration of the marsh may have been 15 ha (38 ac). It is a mixture of emergent plant species with cattail being dominant. Some European frogbit exists along the edge of the marsh. The bottom substrate in the marsh and in front of it is rather firm with the cattail solidly fastened to it. One can wade through the marsh on rather firm footing amongst the emergent plants.

Hereafter this study area will be referred to as Marguerite.

Kring Point Marshes--

There are two marshes at the downstream end of Goose Bay which were moderately oiled (Figure 44). The one nearest to the State Park is about 8 ha (20 ac) in size and the other is about 14 ha (35 ac) in size. Single channels enter into each marsh but are often clogged with submerged vegetation, mud, floating debris, and extraneous materials of unknown origin. Submerged vegetation is abundant in front of the marsh with limited amounts of European frogbit at the edge. The marsh vegetation is dominated by cattail.

The oil was driven into the area by the prevailing winds after entering the Bay. The boom across the entrance was often opened to permit boats to pass.

There is a zone of deep muck at the edge of the cattail zone which makes walking difficult for the first several meters.

Hereafter this study area will be referred to as Kring.

Cranberry Creek Marsh--

An extensive cattail marsh exists at the mouth of the creek and extends along the creek for some distance (Figure 43). This marsh was slightly oiled when a shift in the wind direction occurred for a brief period. The marsh to the crossing point of Route 12 approximates 40 ha (100 ac).

The entire southwest end of the Bay is very shallow, and so submerged vegetation is common including coontail, sago pondweed, water celery and pond lilies. However, the creek is rather deep and wide and the bottom at the marsh edge is very soft. This marsh seems not to be solidly fastened to the substrate. The cattail sod appears to float on a layer of thin mud,

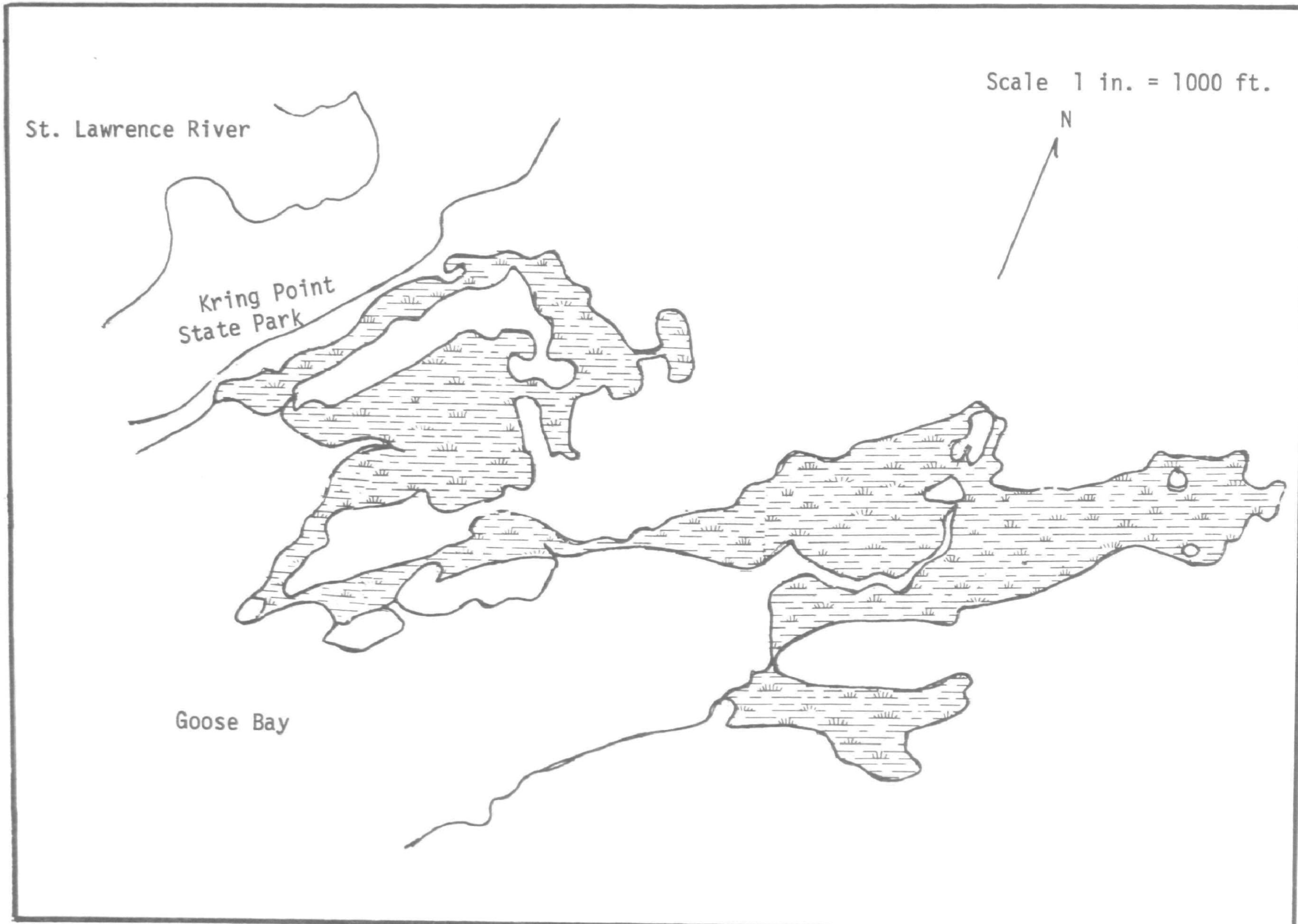

Figure 44. Kring Point Marshes

with a considerable amount of European frogbit at the edge. This results in an appearance of a high marsh easy to walk in. However, walking is hazardous since the mat can be broken through.

Hereafter this study area will be referred to as Cranberry.

Chippewa Bay

Chippewa Bay is about 7 km (4.2 mi) long and in places nearly 1.5 km (0.6 mi) wide, with one large island and several small ones that create two major openings to the River. Like Goose Bay, there are extensive cattail marshes at each end, primarily, but not entirely, associated with the mouths of large creeks. The Bay is shallow and supports submerged vegetation throughout. The upstream opening to the Bay is located about 13.5 km (8 mi) downstream from the initial grounding or 22 km (13 mi) from the point of anchorage of the NEPCO #140.

Sheepshead Point Marshes--

Two marshes, separated by Little Chippewa Point, were heavily oiled (Figure 45). They are near the downstream lip (Chippewa Point) of the Bay where much material floating downstream and driven to the shore by the prevailing winds is trapped. Because of this washing effect the shore zone is very shallow and the bottom is sandy with little, if any, submerged vegetation. The zone of cattail growth is very narrow, perhaps 15 meters. In that distance the marsh exists in a water depth of about 30 cm to land about 50 cm above water, depending on the water level of the River.

The two marshes are referred to as Sheepshead North and Sheepshead South. The North marsh exists at the end of a narrow rocksided embayment. The cattail marsh changes to a reed-sedge growth on land, flooded only during high water periods. A causeway crosses the area about 100 meters back from the water which separates it from the marshes associated with Blind Bay. The cattail marsh in this area total about 0.5 ha (1 ac) with three-quarters of it above water.

The South marsh extends southeast of Sheepshead Point proper in a narrow fringe about 0.5 km (0.3 mi) long. Behind the cattail zone is a rather open area strewn with debris washed ashore by high spring waves before the cattails developed. This gives way to herbaceous and shrub growth. About 1 ha (2.5 ac) of cattails are in the area studied.

Hereafter this study area will be referred to as Sheepshead.

Chippewa Creek Marsh--

This is a large marsh at the mouth of Chippewa Creek which was moderately oiled (Figure 46). A boom was placed across the mouth of the creek which concentrated the impact at the outer edge. However, the study involved the marsh along the creek and side channels for a distance of over 500 meters. This created a study area of over 40 ha (100 ac).

This marsh is also impacted by the prevailing wind. However, unlike Sheepshead, there is no sandy shoreline. The edge of the marsh is abrupt.

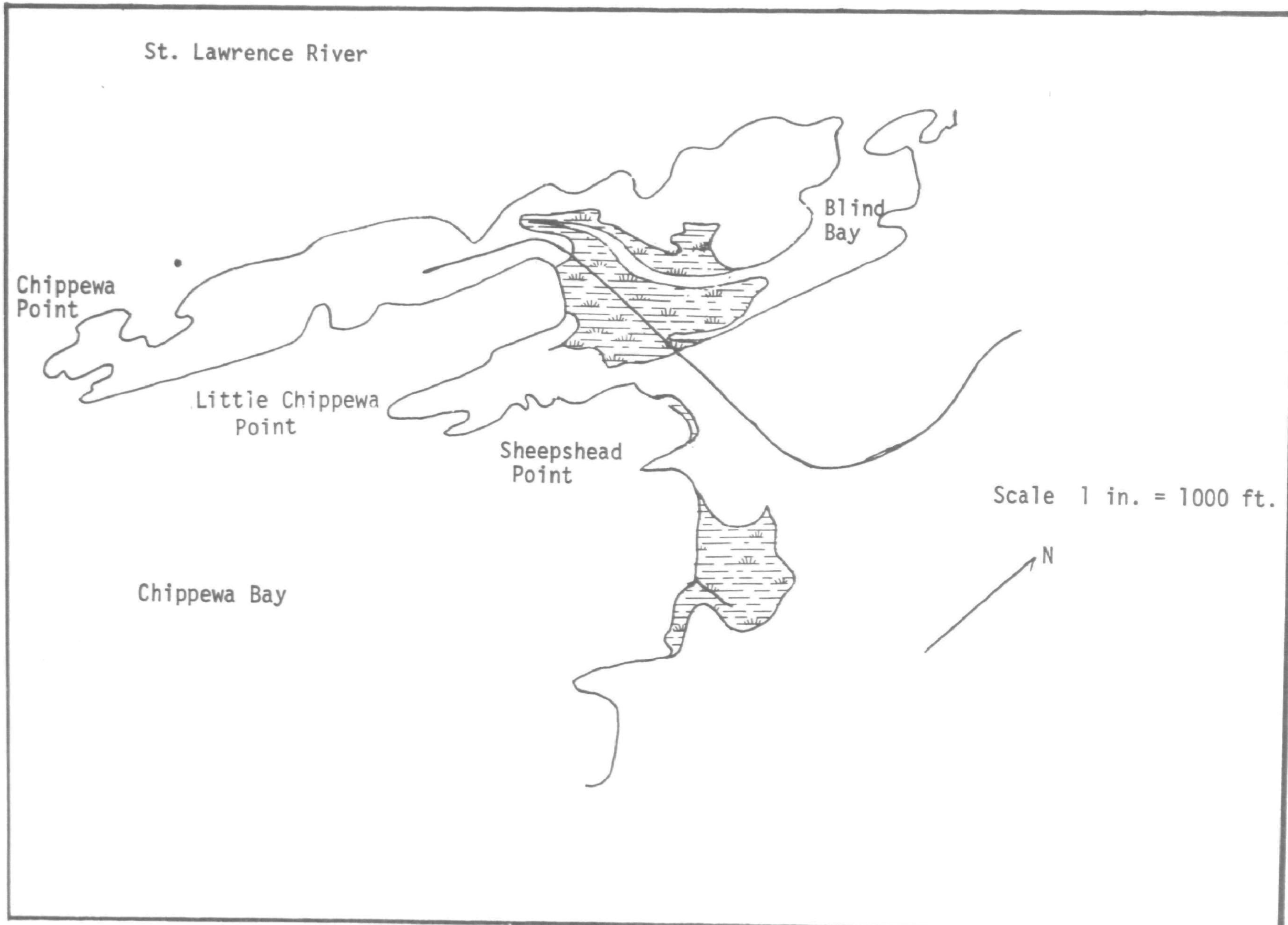

Figure 45. Sheepshead Point Marshes.

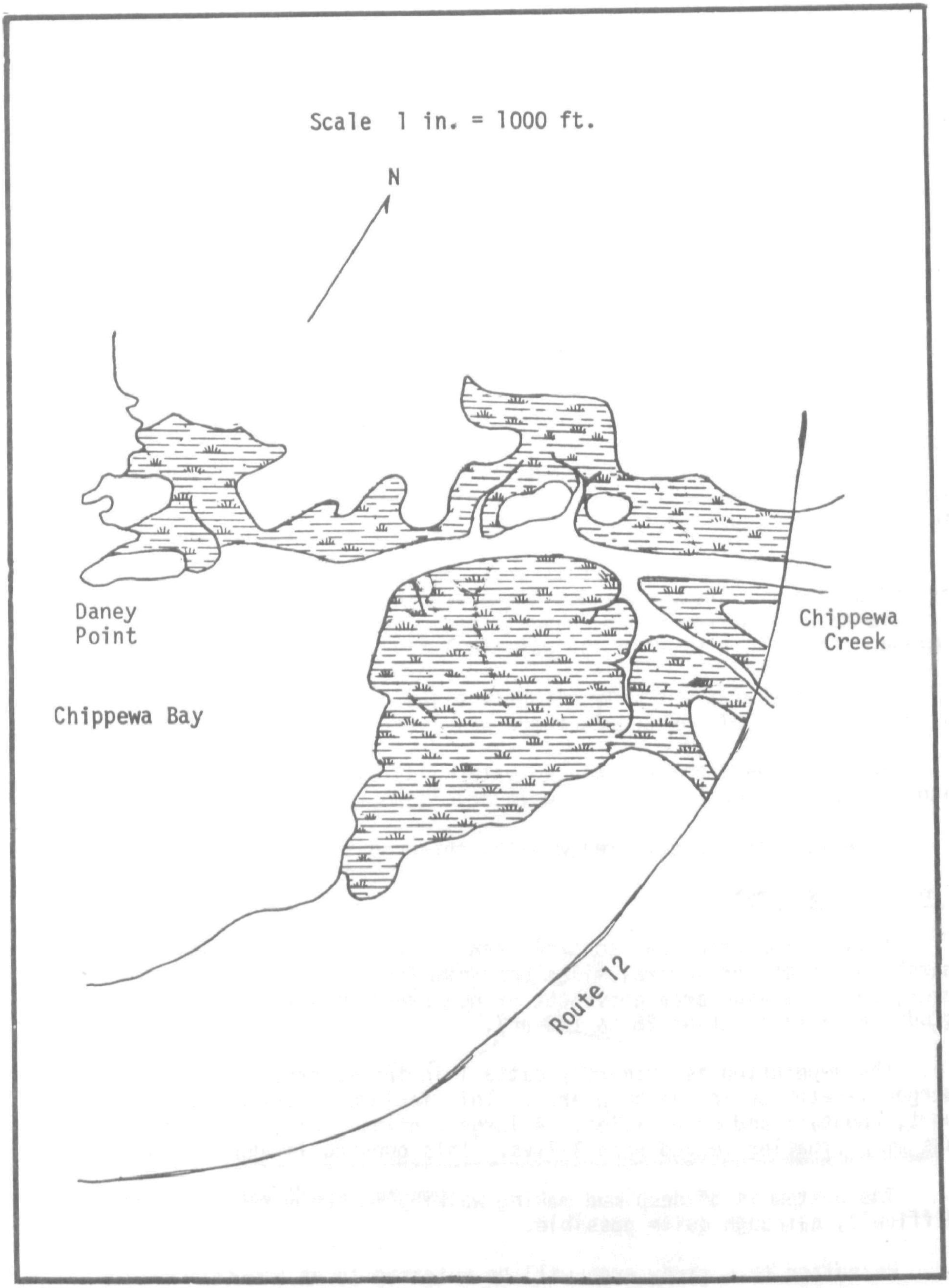

Figure 46. Chippewa Creek Marshes.

In many places one can stand at the water's edge before a platform of cattail roots which may be just above or below the water level. Much of the marsh can be walked through without great difficulty. It is attached solidly to the substrate, unlike the equally large marsh at Cranberry Creek which tends to be a floating mat.

There are several small channels or inlets where lesser amounts of oil moved after passing the boom.

Submerged vegetation includes stonewart, water celery, sago pondweed, waterweed, flexible niad, and pond lilies. European frogbit is common along the edge.

Hereafter this study area will be referred to as Chippewa.

Crooked Creek Marshes--

There are two groups of marshes in this area (Figure 47). There is a rather well-defined marsh at the mouth of the Creek, similar in many ways, but smaller than that at the mouth of Chippewa Creek. The cattail zone extends several miles upstream, but the area at the mouth below Route 12 totals no more than 5 ha (7.5 ac).

Adjacent to and west of this area are two small marshes, on either side of Indian Point. These marshes, of approximately 5 ha (7.5 ac) each, are associated with narrow water channels each draining a small area of wooded upland. These were used in the waterfowl study.

The entire area was only slightly oiled. Although a boom was placed across the mouth of the Creek, there was little need for it.

Submerged vegetation included waterweed, water celery, bladderwort, and coontail. Some European frogbit occurred along the edges.

Hereafter this study area will be referred to as Crooked.

French Creek Marsh

This is the principal control area for the project (Figure 48). The marsh continues for several miles upstream from the River at Clayton. However, only the wide area above the French Creek Marina was used in this study, an area of about 28 ha (70 ac).

The vegetation is primarily cattail in the marshes with extensive submerged vegetation in the open area. This includes water milfoil, bladderwort, coontail and pond lilies. A large central open area exists which also has many floating leaved pond lilies. This opening is about 20 ha (50 ac).

The bottom is of deep mud making walking in the marsh somewhat difficult, although quite possible.

Hereafter this study area will be referred to as French.

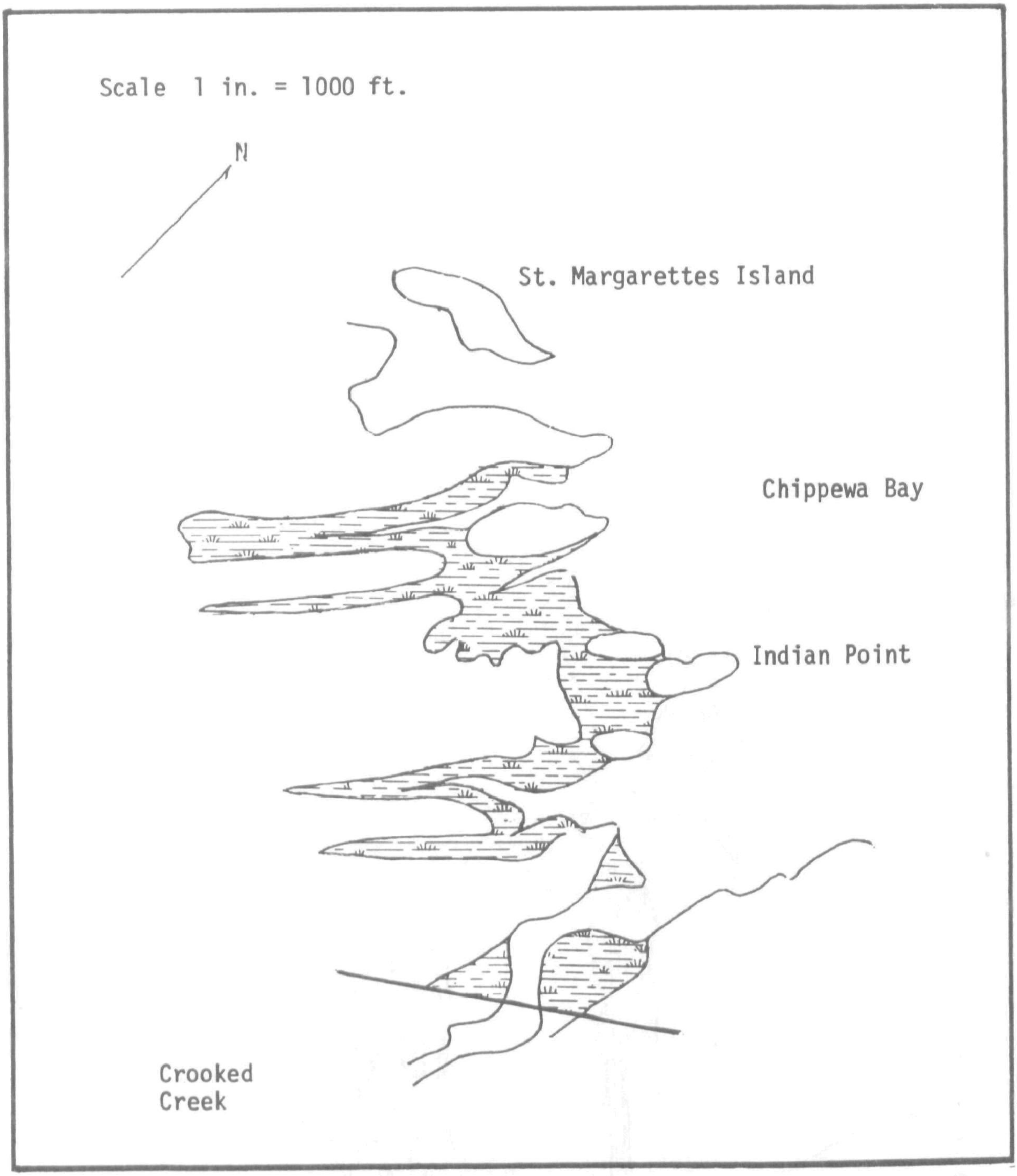

Figure 47. Crooked Creek marshes.

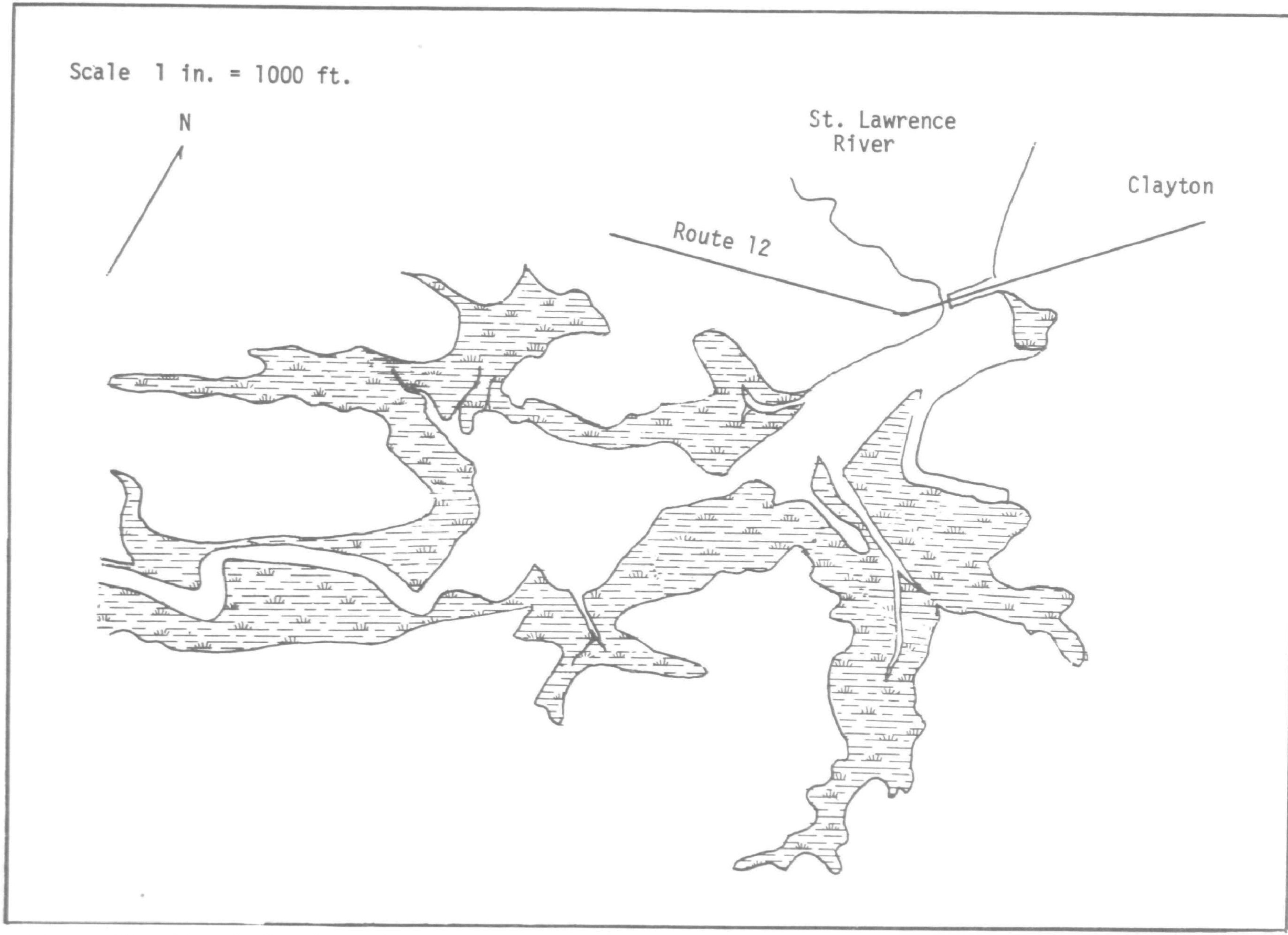

Figure 48. French Creek marshes.

Canadian Marshes

Two Canadian marshes were visited with a Canadian biologist for the purpose of securing samples. One was a very small remnant of a cattail marsh in Church Bay, downstream from the effluent of a DuPont plant. This marsh was about to disappear with the rebuilding of Route 2 along the shore.

The other marsh was a rather large cattail community in a channel behind Spencer Island and downstream from the Ogdensburg-Prescott Bridge.

Other Control Areas

The French Creek control area, although satisfactory in most respects, still had two disadvantages. First, there was a considerable amount of motor boat traffic in the Creek and so an unknown amount of oil may have entered the environment from boats. Second, it did not receive any water from the River and therefore had not developed a background of oil or other contaminants similar to the other study areas. There was a need to know what this background of petroleum compounds might be.

A remnant of a marsh was found along the River shore between Clayton and Cape Vincent where background samples could be taken.

A small marsh of about 1 ha (2.5 ac) with a 0.2 ha (0.5 ac) opening in its middle was used as a control where no oil could possibly have entered it. It was north of Rt. 26 about 0.75 km (0.5 mi) south of Alexandria Bay village. A duck brood also used this location.

SECTION 6

THE WILDLIFE COMMUNITY

GENERAL

Emphasis was placed on the fish and waterfowl populations as specified in the proposal. However, the wildlife community is made up of a wide variety of animal groups closely related in many ecological ways. Although time and personnel did not permit thorough studies of other groups, some lesser studies were made, and incidental observations were recorded. These included a count of songbirds, a productivity study of muskrats, a survey of amphibians and reptiles, and experiments on the effects of oil on frog tadpoles.

Some adult fish have been found capable of avoiding petroleum compounds while others can not (Shelford 1917, Summerfelt and Lewis 1967). There are indications that some fish may utilize oiled invertebrates as food since they are easier to catch (Blackman and Mackie 1974). On the other hand, the oil may reduce the feeding response of some fish (Korn et al. 1976). Most of the research on the effect of oil on eggs, larvae and juvenile fish has been done under laboratory experimental conditions (Kuhnhold 1970).

Previous investigations involving oil and waterfowl have indicated incompacitation and/or death from loss of buoyancy and insulation due to physical contamination of feathers (Hartung 1965, McEwan and Koelink 1973), embryonic mortality resulting from possible contamination of eggs by oiled hens (Albers 1977, Szaro and Albers 1977, Szaro and Albers 1978), and toxication when oil or oiled foods were ingested (Hartung 1964, Hartung and Hunt 1966, Snyder et al. 1973). Many of these studies were conducted in the laboratory using experimental administration of various types and concentrations of oil, although a few compared results with those from wild birds oiled by an actual spill.

This study began after early mortaliities due to the oiling of feathers and toxication from ingesting the oil were past. Since most of the eggs had hatched before the spill occurred, the loss of embryos could have been minor. However, in spite of a thorough cleaning of the environment, it can be assumed that contact with residual oil components would continue in the marshes for some time, perhaps years.

This study investigates the effect of Bunker C oil on fish and waterfowl in a freshwater marsh environment under natural conditions for which no prior data exist.

FISH DIVERSITY AND ABUNDANCE[1]

Materials and Methods

Fish were sampled through the use of several types of nets and traps. These included minnow traps, gill nets of various mesh sizes, a South Dakota trap net and a modified Alaskan trap net. The gill nets were 1.83 m (6 ft) deep and 7.62 m (25 ft) long. Mesh sizes included 1.27, 2.54, 3.81 and 5.08 cm (1/2, 1, 1-1/2 and 2 in). The square mesh on the South Dakota trap net was 1.27 cm (1/2 in). It had a 15.24 m (50 ft) leader and 7.62 m (25 ft) wings. The square mesh on the modified Alaskan trap net was 0.63 cm (1/4 in). It had a 22.86 m (75 ft) leader and 10.67 m (35 ft) wings.

In 1977 the minnow traps, gill nets and South Dakota trap net were set as they became available in the arrangement shown in Figure 49 at each of the seven sites. The nets were fished for 8-12 hours and then moved. Each area was fished uniformly during the season. All fish were identified, measured and marked before releasing.

A different sampling design was used in 1978. This was to obtain more data from fewer sites, from which better estimates of some species' populations could be calculated. It also was designed to optimize the use of available manpower and equipment. The design concentrated on French, Cranberry, Chippewa and Marguerite. Each of these four areas had moderate to heavy submerged vegetation in front of the marsh edge. Because of the higher water levels in 1978 it was possible to set the nets closer to the marsh edge. It also was believed that the modified Alaskan trap net provided a more representative sample of the younger fish.

Sheepshead was not used because of the general lack of submerged vegetation and the difficulty in setting nets in this exposed site. Kring was not used because of the presence of a thick crust that covered the surface of the shallow water. Crooked was omitted as a slightly oiled area in favor of Cranberry since the latter was more similar to the other three sites. The minnow traps, the South Dakota and the modified Alaskan trap nets were set (Fig. 50) for two days at each of the four sites and then moved. Six series of samples were completed by early August. The positioning of the nets at the four sites used in 1978 are shown in Figures 51, 52, 53, and 54.

In addition to the identification, measurement and marking of the fish, they were also weighed and a representative sample of scales was taken. A system of fin clipping was used to separate the trapping periods. Impressions of the scales were placed on acetate slides through the use of an Ann Arbor roll press. The slides were then projected for reading in a Tri-Simplex Bausch and Lomb projector.

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[1]Based on data secured by David M. Phillips and assistants.

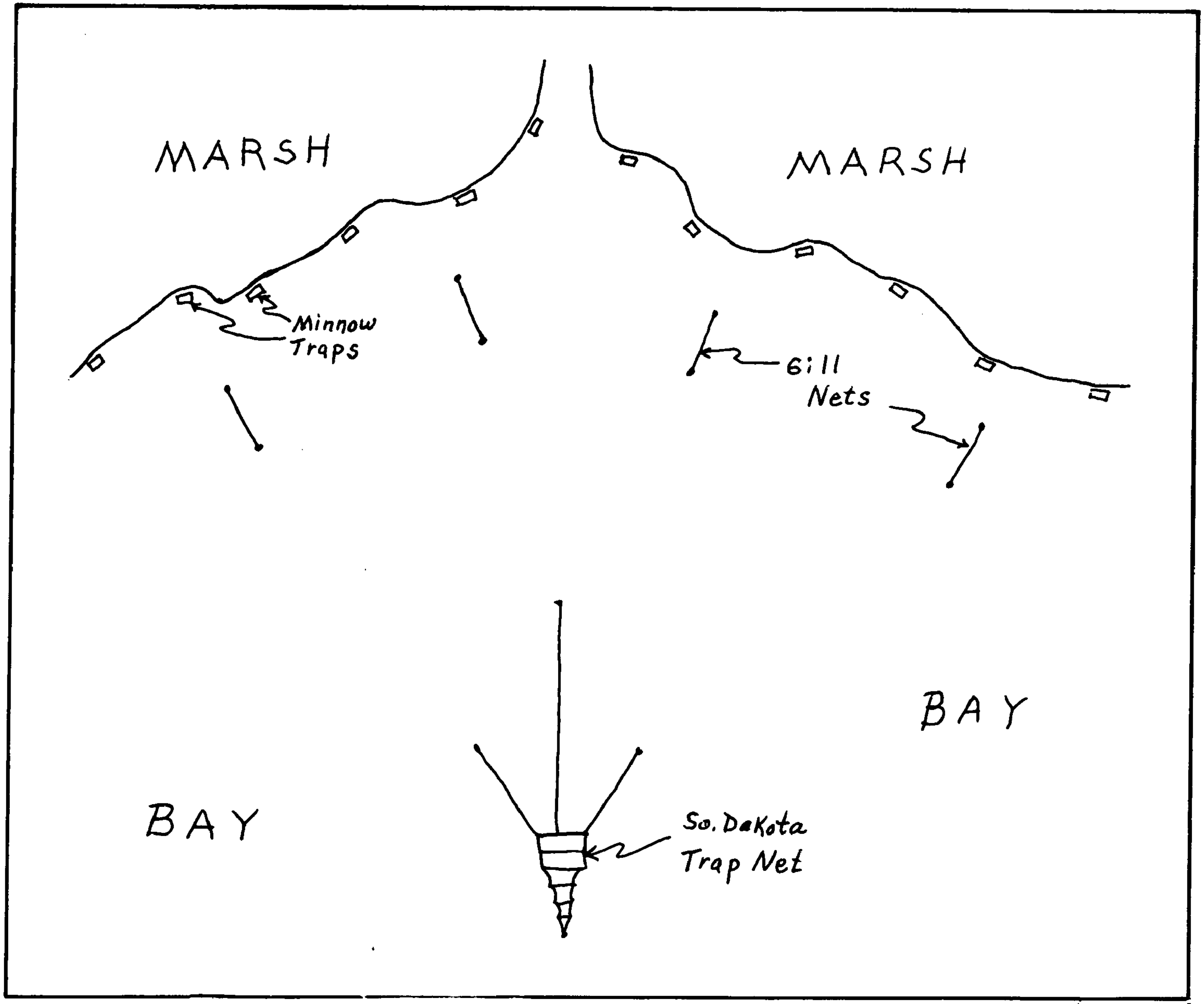

Figure 49. 1977 Arrangements of Fish Nets.

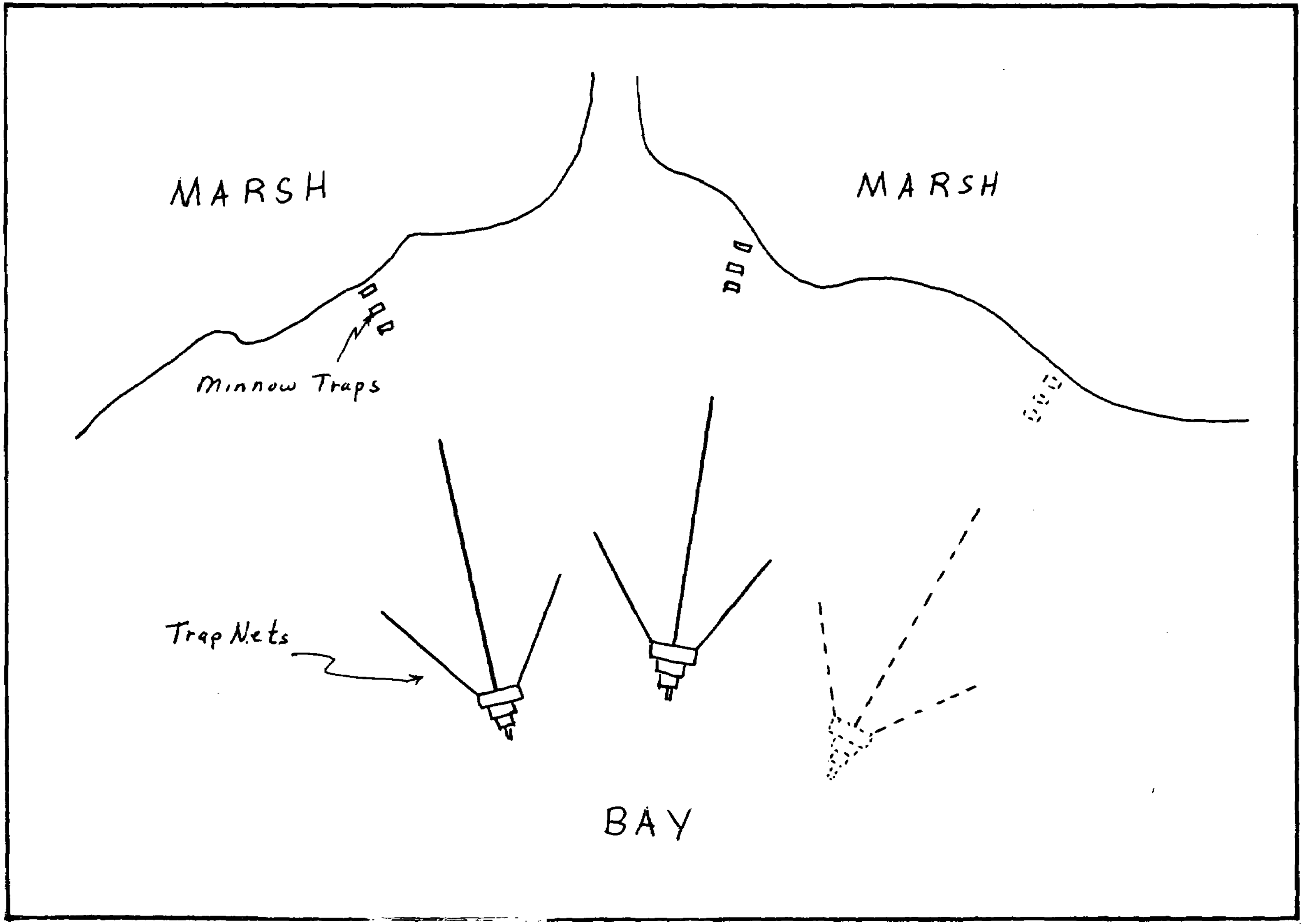

Figure 50. 1978 Arrangement of Fish Nets. NOTE: The two trap nets and six minnow traps were rotated through the three stations during the six sampling periods.

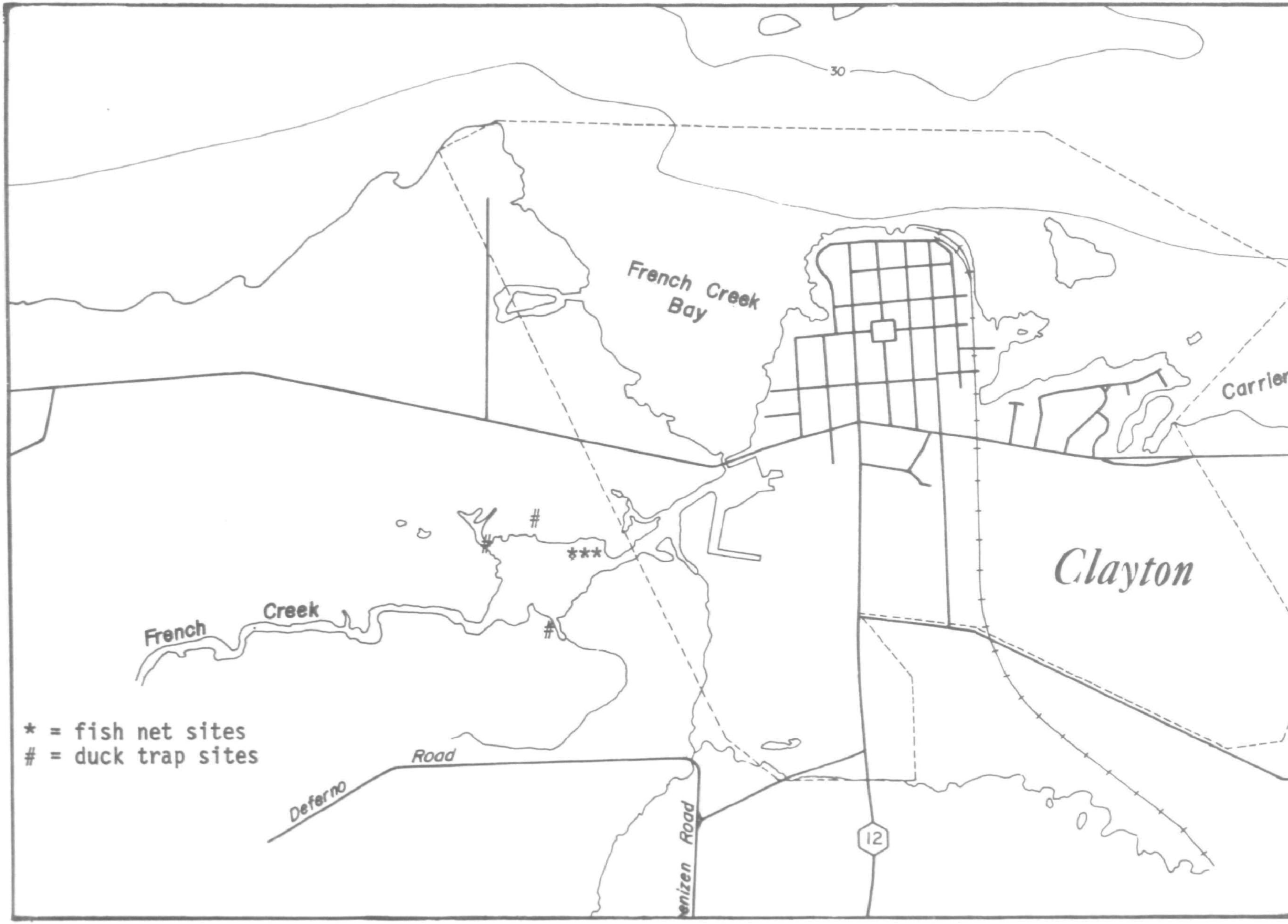

Figure 51. Positioning of nets and traps at French Creek marsh.

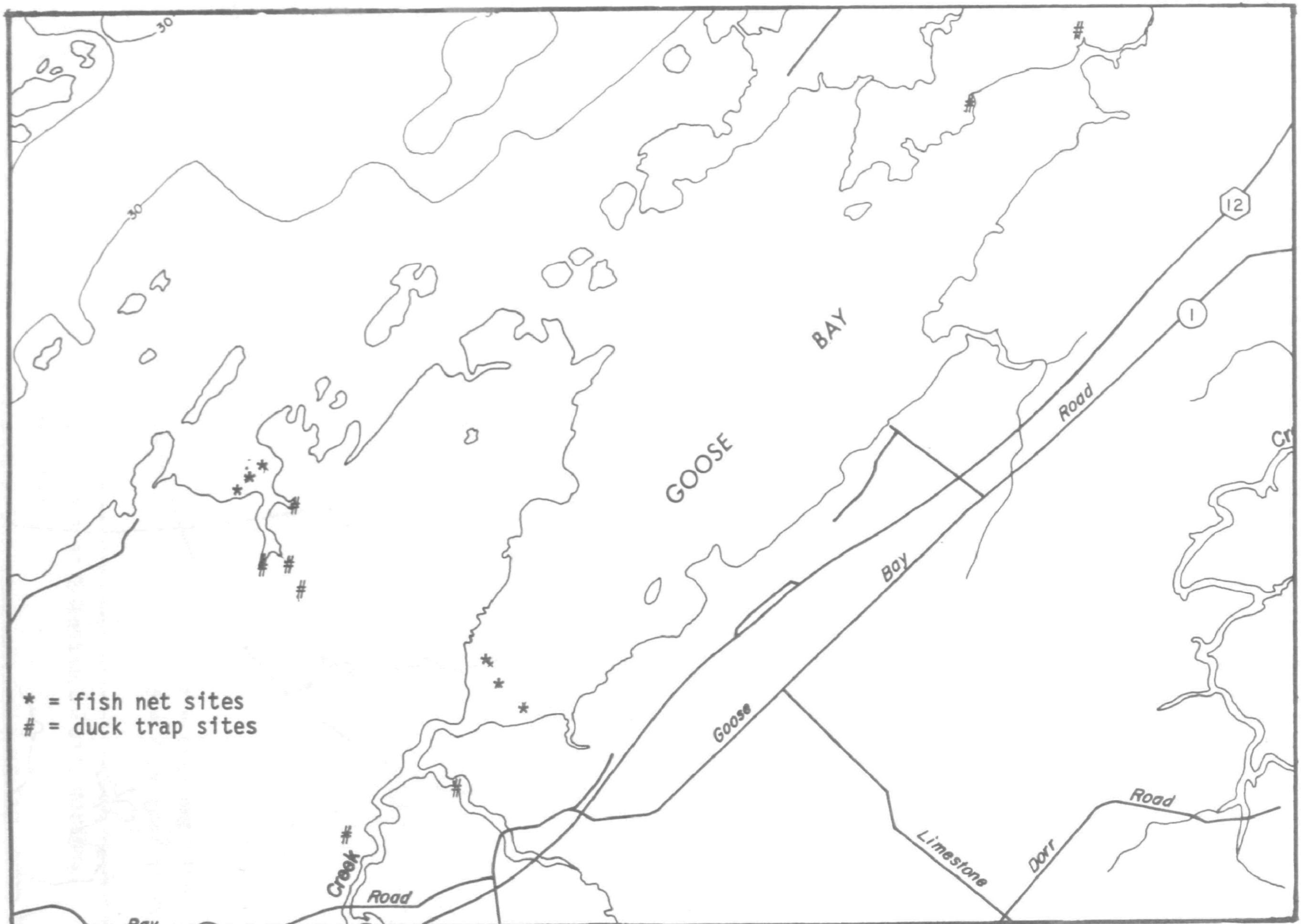

Figure 52. Positioning of nets and traps at Point Marguerite marsh, Cranberry Creek marsh and Kring Point marsh.

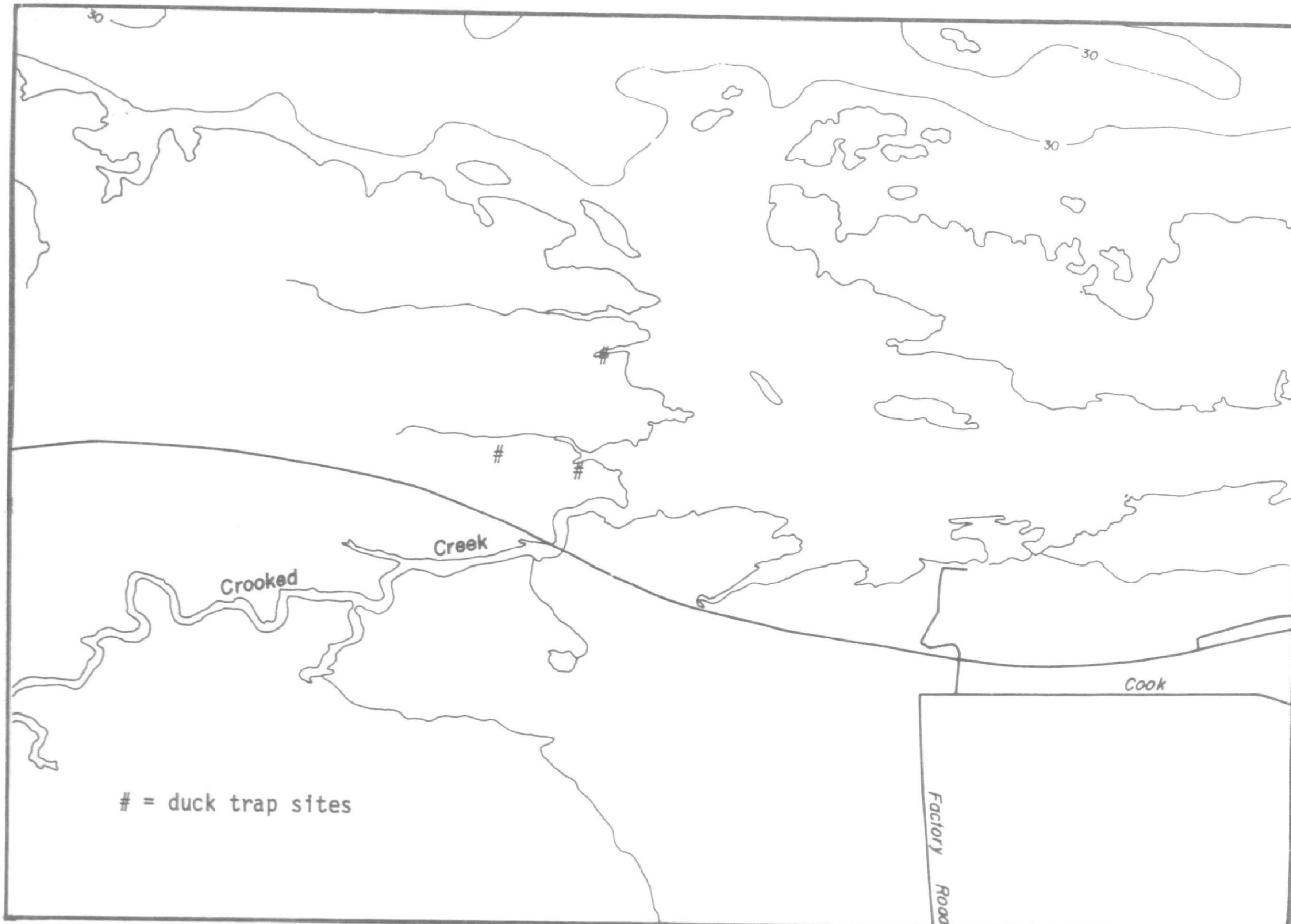

Figure 53. Positioning of nets and traps at Crooked Creek marshes.

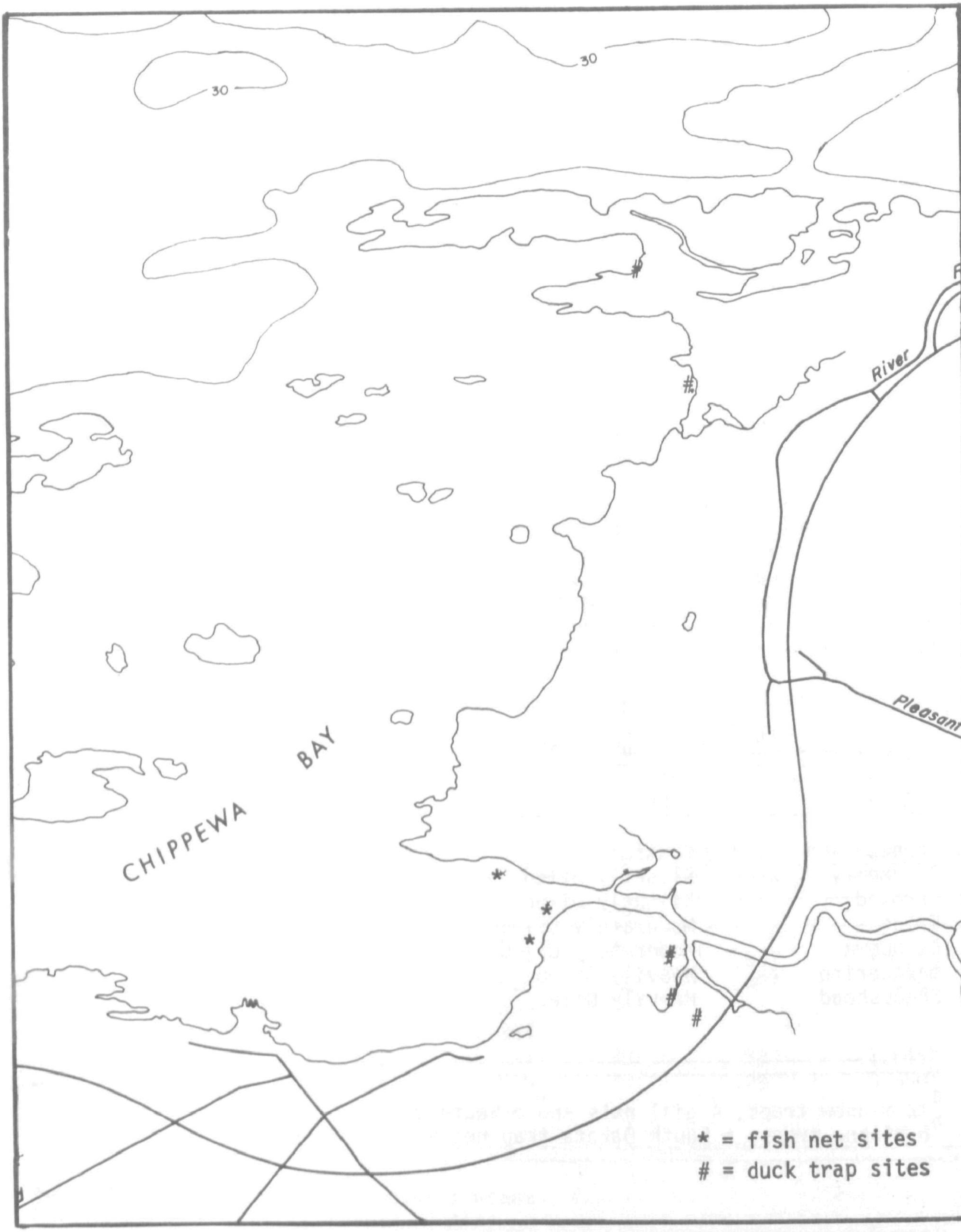

Figure 54. Positioning of nets and traps at Sheepshead Point marshes, and Chippewa Creek marshes.

Results

Over 20,000 fish were handled in the two years of the study, 3,728 in 1977 and 17,479 in 1978 (Table 8). The increase in the catch for 1978 reflects an increase in the use of trap nets and the longer fishing period. However, the average catch of the South Dakota trap net did increase from about 80 per day in 1977 to about 150 per day in 1978. Since the areas were uniformly sampled within each study year, comparative magnifications of the catches between the two years are of interest. French, the control area, increased six times; Cranberry, the slightly oiled area, increased five times; Chippewa, the moderately oiled area, increased four times; and Marguerite, the heavily oiled area, increased fifteen times. However, the large figure for Marguerite reflects a massive catch of young yellow perch[2] in that area during late summer of 1978. Excluding these young yellow perch, the increase would have been about four times, the same as for Chippewa. In this case it could suggest that the fish populations were more rapidly increasing in the unoiled or slightly oiled areas in contrast to the moderately or heavily oiled areas.

There does not appear to be any correlation between the numbers caught in 1977 in the gill and trap nets and the degree of oil impact. However, the minnow trap data (Table 9) suggest that the heavily oiled areas may have had reduced populations of young fish. The 1977 data also suggest that the number of young fish caught may have been influenced by the relative abundance of submerged vegetation. However, the numbers of young fish caught were not sufficient to test that theory statistically.

TABLE 8. FISH CATCH - ST. LAWRENCE RIVER MARSHES

Area	Condition	Numbers Caught 1977[a]	Numbers Caught 1978[b]
French	Control	616	3,989
Cranberry	Slightly Oiled	589	2,863
Crooked	Slightly Oiled	471	
Kring	Moderately Oiled	505	
Chippewa	Moderately Oiled	686	2,595
Marguerite	Heavily Oiled	520	8,032
Sheepshead	Heavily Oiled	341	
		3,728	17,479

[a] 12 minnow traps, 4 gill nets and a South Dakota trap net.
[b] 6 minnow traps, a South Dakota trap net and a modified Alaskan trap net.

[2] Fish scientific names are given in association with Table 12.

TABLE 9. CATCH IN MINNOW TRAPS, 1977

Area	Condition	Catch	Submerged Vegetation
French	Control	164	Abundant
Cranberry	Slightly Oiled	201	Abundant
Crooked	Slightly Oiled	125	Common
Kring	Moderately Oiled	143	Common
Chippewa	Moderately Oiled	232	Very Abundant
Marguerite	Heavily Oiled	58	Abundant
Sheepshead	Heavily Oiled	26	Scarce
		949	

Table 10 lists the species diversity of the fish catch for both years. The numbers of species obtained from each study area were not significantly different for either 1977 or 1978. However, when the species diversity indices were calculated, a significant difference was found for Sheepshead in 1977. This was due to a greater evenness in the distribution of individuals among the various species present. Primarily, this reflected a distinctly lower population of the still dominant pumpkinseeds in this heavily oiled area. This was attributed to the ecological differences of this area.

In 1978 each of the four sampled areas had significantly different diversity indices at the 95% confidence level. Marguerite, the heavily oiled representative, had the lowest index with French and Cranberry nearly twice as great. However, Chippewa had the greatest diversity index of all due to its having the greatest number of species (S) and the most even distribution (J') among the species.

TABLE 10. FISH SPECIES DIVERSITIES - ST. LAWRENCE RIVER MARSHES

Area	1977			1978		
	S[a]	J'[b]	H'[c]	S	J'	H'
French	15	.606	1.641	17	.542	1.535[d]
Cranberry	16	.563	1.560	15	.497	1.346[d]
Crooked	16	.598	1.659			
Kring	13	.539	1.383			
Chippewa	19	.608	1.791	23	.589	1.845[d]
Marguertie	13	.634	1.626	19	.292	0.858[d]
Sheepshead	16	.730	2.023[d]			

[a]S = Richness = number of species present
[b]J'= Evenness = H'/H_{Max} (Pielou 1966)
[c]H'= Diversity = $-\sum_{i=1}^{S} p_i \log p_i$ (Mac Arthur and Mac Arthur 1961)
[d]Significant at the 95% confidence level

There was an increase of species at three of the four areas in 1978. The greater catches of smaller fish included a few new ones that were not captured in 1977. The capture of the more scarce species also tended to reduce the evenness values. Species caught in 1977 were taken again in 1978 at the same sites.

Table 11 breaks down the 1978 fish species diversity data for each of the six sampling periods. Close examination of changes in the diversity indices for each area as the season progresses is of interest. In comparing the more heavily oiled areas, Chippewa and Marguerite, it is seen that they are rather similar during May and June. The index for Marguerite begins to decrease in early July and declines at a rapid rate into August. Chippewa at the same time continues with similar indices until August, when it declines somewhat. The catches were of the same general size range for the two areas, increasing as time passed. However, the abrupt increase in numbers taken (young yellow perch) in Marguerite during the last of July and early August did not occur in Chippewa.

Both French and Cranberry started out in May with somewhat low indices but after that remained rather uniform until August when French declined and Cranberry increased. Other than in August, Cranberry maintained a lower index than French. The changes that occurred in August seemed to once again reflect changes in evenness of distribution at that time. French had an increase in pumpkinseed whereas Cranberry had a decrease in pumpkinseed.

It should be kept in mind that the pumkinseed was the most abundant adult species in all the areas. Therefore, it still remains as a dominant species even after experiencing a decline. Differences in pumpkinseed numbers in late summer were associated with changes in numbers of the smaller individuals. The larger fish were caught in greater numbers during the early part of the season. It is suspected that these fish move into deeper water as the water levels decline, the submerged vegetation increases, and the water becomes warmer. Similar movements have been frequently reported by others.

It is believed that the 1978 catch for the four study areas is a good representation of the fish community in each for comparative purposes, since the sampling procedure was uniform throughout the season. If there were any groups not adequately represented, it would be the older individuals of the larger sized species, (such as northern pike) inasmuch as they were not readily taken in the trap nets. Nevertheless, the data for the four areas are considered comparable.

The total catch by species and area is presented in Table 12 for 1978. Twelve species were common to all four areas. All other species are shared by two or three of the areas, except longnose gar which was found only in Chippewa and white perch which was found only in French. The data show a considerable similarity in species composition for the four areas, in spite of significant differences in the diversity indices. The differences are caused by changes in the evenness component for the more dominant species.

TABLE 11. CHANGES IN FISH SPECIES DIVERSITY - 1978

Sampling Period		French	Cranberry	Chippewa	Marguerite
1 May 23 to May 31	No.	376	591	174	128
	S	11	9	10	7
	J'	0.501	0.368	0.669	0.744
	H'	1.202	0.809	1.540	1.449
2 June 5 to June 12	No.	312	779	270	94
	S	11	10	12	11
	J'	0.641	0.482	0.656	0.709
	H'	1.537	1.111	1.631	1.700
3 June 20 to June 28	No.	475	383	254	469
	S	11	9	10	13
	J'	0.642	0.549	0.640	0.559
	H'	1.540	1.206	1.473	1.433
4 July 5 to July 13	No.	1,095	557	537	427
	S	17	9	15	11
	J'	0.578	0.624	0.577	0.506
	H'	1.636	1.371	1.562	1.214
5 July 20 to July 28	No.	541	427	710	2,601
	S	12	11	14	14
	J'	0.612	0.571	0.633	0.254
	H'	1.520	1.370	1.670	0.671
6 Aug. 2 to Aug. 10	No.	1,218	120	650	4,316
	S	11	11	16	13
	J'	0.368	0.710	0.492	0.173
	H'	0.884	1.701	1.364	0.445
Total	No.	3,989	2,863	2,595	8,032
	S	17	15	23	19
	J'	0.542	0.497	0.589	0.292
	H'	1.535	1.346	1.845	0.858

TABLE 12. SPECIES OF FISH CAUGHT IN EACH STUDY AREA, 1978
RANKED BY NUMBERS CAPTURED

French[a]			Cranberry			Chippewa			Marguerite		
Rank	Species	No.	Rank	Species	No.	Rank	Species	No.	Rank	Species	No.
1	Pumpkinseed (*Lepomis gibbosus*)	2215	1	Pumpkinseed (*Lepomis gibbosus*)	1823	1	Pumpkinseed (*Lepomis gibbosus*)	989	1	Yellow perch (*Perca flavescens*)	6155
2	Largemouth bass (*Micropterus salmoides*)	621	2	Blue gill (*Lepomis macrochirus*)	300	2	Yellow perch (*Perca flavescens*)	638	2	Pumpkinseed (*Lepomis gibbosus*)	1170
3	Golden shiner (*Notemigonus crysoleucas*)	373	3	Black crappie (*Pomoxis nigromaculatus*)	199	3	Blue gill (*Lepomis macrochirus*)	239	3	Largemouth bass (*Micropterus salmoides*)	238
4	Black crappie (*Pomoxis nigromaculatus*)	224	4	Yellow bullhead (*Ictalurus natalis*)	166	4	Largemouth bass (*Micropterus salmoides*)	172	4	Rock bass (*Ambloplites rupestris*)	194
5	Brown bullhead (*Ictalurus nebulosus*)	151	5	Largemouth bass (*Micropterus salmoides*)	150	5	Unknown	166	5	Black crappie (*Pomoxis nigromaculatus*)	91
6	Yellow perch (*Perca flavescens*)	111	6	Golden shiner (*Notemigonus crysoleucas*)	112	6	Black crappie (*Pomoxis nigromaculatus*)	162	6	Blue gill (*Lepomis macrochirus*)	64
7	Spottail shiner (*Notropis hudsonius*)	110	7	Brown bullhead (*Ictalurus nebulosus*)	44	7	Rock bass (*Ambloplites rupestris*)	89	7	Brown bullhead (*Ictalurus nebulosus*)	37
8	Blue gill (*Lepomis macrochirus*)	75	8	Rock bass (*Ambloplites rupestris*)	24	8	Brown bullhead (*Ictalurus nebulosus*)	46	8	Golden shiner (*Notemigonus crysoleucas*)	34
9	Rock bass (*Ambloplites rupestris*)	53	9	Spottail shiner (*Notropis hudsonius*)	19	9	Golden shiner (*Notemigonus crysoleucas*)	36	9	Bowfin (*Amia calva*)	20
10	Gizzard shad (*Dorosoma cepedianum*)	26	10	Bowfin (*Amia calva*)	17	10	Bowfin (*Amia calva*)	10	10	Yellow bullhead (*Ictalurus natalis*)	6
11	Bowfin (*Amia calva*)	15	11	Central mudminnow (*Umbra limi*)	4	11	Gizzard shad (*Dorosoma cepedianum*)	10	11	American eel (*Anguilla rostrata*)	6
12	American eel (*Anguilla rostrata*)	5	12	Northern pike (*Esox lucius*)	2	12	Northern pike (*Esox lucius*)	8	12	White sucker (*Catostomas commersoni*)	5
13	Northern pike (*Esox lucius*)	4	13	Banded killifish (*Fundulus diaphanus*)	1	13	Spottail shiner (*Notropis hudsonius*)	5	13	Grass pickerel (*Essox americanus vermiculatus*)	5
14	Carp (*Cyprinus carpio*)	2	14	American eel (*Anguilla rostrata*)	1	14	White sucker (*Catostomas commersoni*)	5	14	Northern pike (*Esox lucius*)	2
15	Yellow bullhead (*Ictalurus natalis*)	2	15	Smallmouth bass (*Micropterus dolomieui*)	1	15	American eel (*Anguilla rostrata*)	5	15	Banded killifish (*Fundulus diaphanus*)	1
16	Banded killifish (*Fundulus diaphanus*)	1				16	Longnose gar (*Lepisosteus osseus*)	4	16	Smallmouth bass (*Micropterus dolomieui*)	1
17	White perch (*Morone americana*)	1				17	Yellow bullhead (*Ictalurus natalis*)	3	17	Unknown	1
						18	Grass pickerel (*Essox americanus vermiculatus*)	2	18	Spottail shiner (*Notropis hudsonius*)	1
						19	Central mudminnow (*Umbra limi*)	2	19	Central mudminnow (*Umbra limi*)	1
						20	Alewife (*Alosa pseudoharengus*)	1			
						21	Carp (*Cyprinus carpio*)	1			
						22	Smallmouth bass (*Micropterus dolomieui*)	1			
						23	Banded killifish (*Fundulus diaphanus*)	1			

[a]Species common to all four areas.

The golden shiner and the spottail shiner were found to increase in numbers and rank as the degree of oiling decreased (Fig. 55). The abundance of this species possibly could be associated with the abundance of yellow perch, since their numbers were inverse to each other. Several interspecific relationships, such as predation and competition, could be involved. However, the complexities of the fish food webs and the lack of prior data makes speculation on such associations uncertain.

Age data for yellow perch and largemouth bass are given in Tables 13 and 14. It was intended that pumpkinseed be treated in the same manner. However, the great variation in lengths for each age class reduced the data's accuracy and hence usefulness. This variation within an age class was reported by Scott and Crossman (1973). Therefore, age class distributions for the populations of pumpkinseed were not calculated.

The age distribution for yellow perch (Table 13) shows an increase in young-of-the-year age class (0+) that seems positively correlated to the increase in degree of oil impact. Percentages of the total catch in each age class were calculated (Fig. 56). The increase in percentage of the total catch in the 0+ age class strengthens the correlation.

TABLE 13. AGE DISTRIBUTION OF YELLOW PERCH
May 23 to August 10, 1978
Age-Year-Class

Area	0+ (1978)		1+ (1977)		2+ (1976)		3+ and older (1975 and older)		Total	
French	4	4%	31	28%	8	7%	68	61%	111	100%
Cranberry	64	38%	38	23%	10	6%	54	33%	166	100%
Chippewa	468	69%	48	7%	10	2%	142	22%	638	100%
Marguerite	5303	96%	69	1%	32	1%	116	2%	5520	100%

The reason for the increase in the 0+ age class can only be speculated upon at this time. It is possible that the yellow perch population is only now recovering from great losses which occurred during the spill. It also is possible that with an increase in the abundance of golden shiner and spottail shiner, which may have been reduced by the spill, there was an increase in the food supply for the yellow perch. In addition, it may be possible that with a reduction in predatory species of older ages the survival of yellow perch was greater. And then again, it is entirely possible that this was due to factors that had no relationship to the spill.

Pumpkinseed was the most abundant species in all areas except Marguerite, where it ranked second. Yellow perch was most abundant in Marguerite and progressively declined in rank and abundance to its lowest level in French (Fig. 55).

Largemouth bass was in the top five species everywhere, but most abundant in French. Rock bass, black crappie, bluegill and brown bullhead were all in the top ten for all areas. None of these species showed any trend that could be associated with the oil. Rock bass was most abundant in Marguerite, black crappie and bluegill in Cranberry and brown bullhead in French.

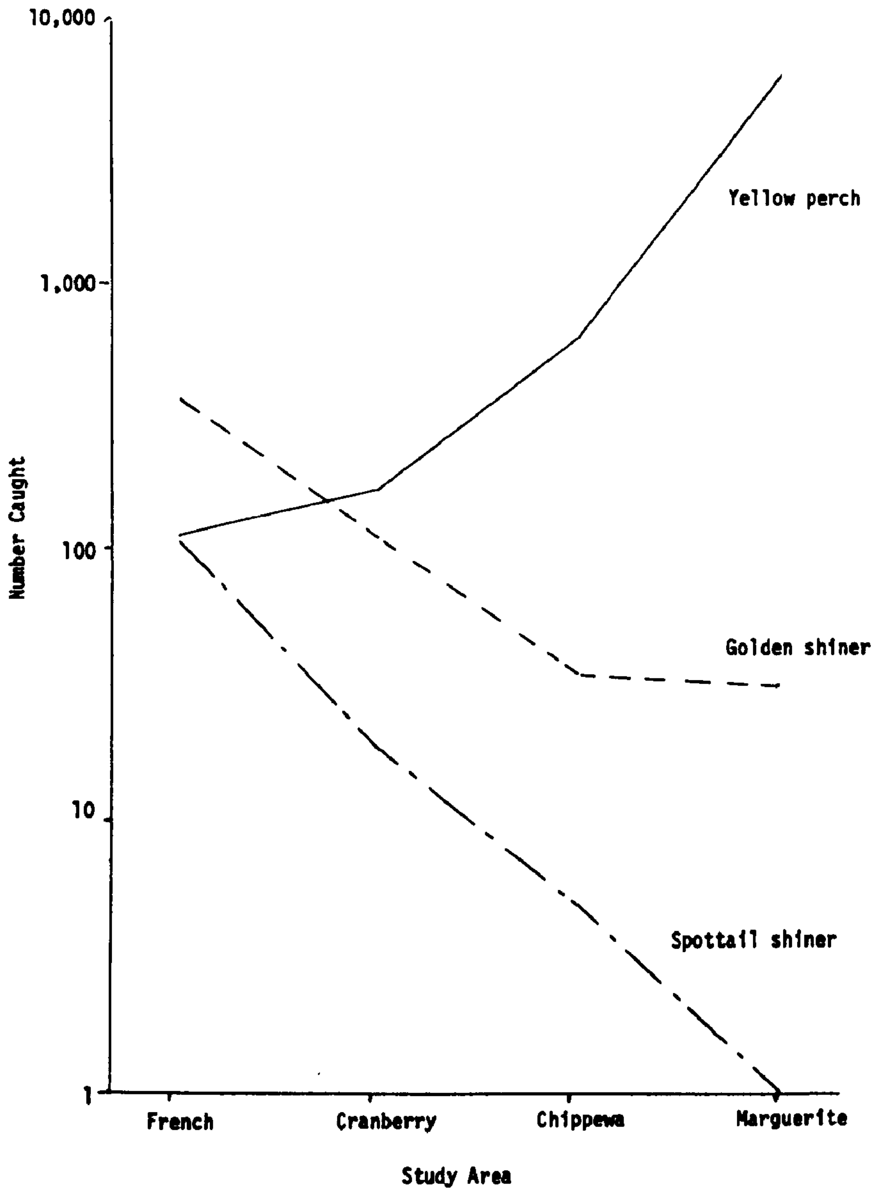

Figure 55. Comparative catches of yellow perch, golden shiner and spottail shiner.

Populations of yellow perch were significantly different from those of pumpkinseed for all areas. In this case Marguerite seemed to have the largest population and Cranberry the smallest.

Discussion

Several potential effects of oil spills on fish have been given by various researchers. These include direct mortality, mortality of eggs and larvae, destruction of breeding sites and loss of normal food source.

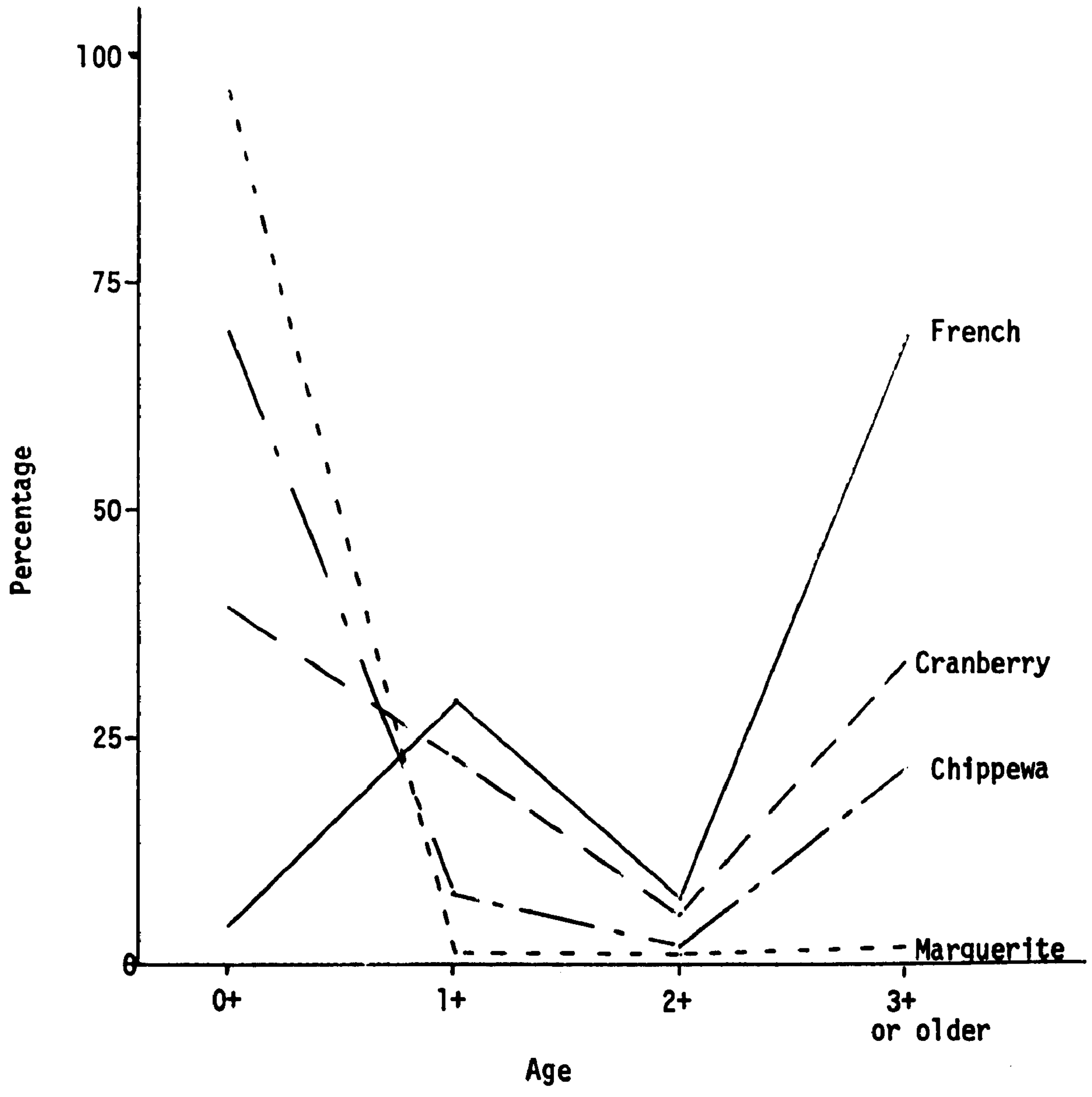

Figure 56. Percentage of total catch of yellow perch in each age class.

TABLE 14. AGE DISTRIBUTION OF LARGEMOUTH BASS
May 23 to August 10, 1978[a]

Area	0+ (1978)		1+ (1977)		2+ (1976)		3+ and older (1975 and older)		Total	
French	530	97%	2	1%	1	0%	14	2%	547	100%
Cranberry	149	96%	0	0%	3	2%	4	2%	156	100%
Chippewa	167	87%	0	0%	0	0%	24	13%	191	100%
Marguerite	222	97%	2	1%	0	0%	4	2%	228	100%

Age-Year-Class

[a]Bass older than young of the year seemed not to be sampled reliably by the trap nets.

In examining the older age classes of yellow perch, one finds a decline in percentages with increased oil impaction. This suggests the possibility that young yellow perch were reduced by the oil in 1976, started to recover in the lesser oiled areas in 1977, and are coming back strong in the heavily oiled areas in 1978. The low level of production in 1978 at French cannot be explained. Further data from these and other impacted areas are needed to verify the suggestion.

Largemouth bass occurred in smaller numbers than yellow perch. The 1977 data suggested a relationship between the young-of-the-year bass and the degree of oil impaction (Alexander et al. 1978). The greatest production of young was recorded in the unoiled areas. However, the data were meager and the suggestion of relationship was not found in the larger body of data for 1978 (Table 14).

The percentage of the catch of largemouth bass for the four areas in the 0+ age class was quite uniform. It showed a proportionate level of production on all areas. However, the older age classes were not represented adequately in the samples because of the nature of the trap nets used.

Population estimates for yellow perch and pumpkinseed were calculated by the Schnabel method (Table 15) based on limited returns of markable fish (1+ and older). The calculated population limits at the 95% level of confidence are very broad because of the low numbers of recaptures.

The estimates indicate that there were very large populations of pumpkinseed in all areas, with the largest population in French and the smallest in Chippewa. Without having prior data to compare with these figures, it is difficult to interpret their meaning.

This study investigates the effect of Bunker C oil on fish in a freshwater marsh environment under natural conditions for which no prior data exist.

The sampling procedures for 1977 and 1978 were different as were the time periods. This caused a considerable increase in the catch for 1978, although the populations were considered to be comparable. However, the increase in sample size did appear to be greater for the unoiled areas, except for Marguerite which experienced an increase in yellow perch catch at the end of the season.

There were no significant differences in species diversity among the four areas in 1977. However, with a greater data base in 1978, all four areas were significantly different from each other. Since the numbers of species were about equal for each area, the evenness component had the greatest influence on the diversity index. Changes in the level of production of young seemed to be an important factor. Because of this, along with behavioral characteristics and size variation among the several species of fish present, the utility of species diversity indices in measuring the effect of oil spills on fish communities in these marshes may be questioned.

TABLE 15. FISH POPULATION ESTIMATES,[a] 1978

Area	Yellow Perch	Pumpkinseed
French	684 364 $\leq$ N $\leq$ 5,540	333,142 139,682 $\leq$ N $\leq$ 863,185
Cranberry	661 309 $\leq$ N $\leq$ 5,020	120,781 73,053 $\leq$ N $\leq$ 348,407
Chippewa	1,423 790 $\leq$ N $\leq$ 7,127	68,067 31,392 $\leq$ N $\leq$ 517,063
Marguerite	1,879 1,879 $\leq$ N $\leq$ 11,619	164,481 68,938 $\leq$ N $\leq$ 426,185

[a]Estimates calculated by Schnabel method (Ricker 1975). Based on fish one year and older (all markable fish).

The catch of yellow perch increased in direct relation to the increased level of oil. In contrast the golden shiner and the spottail shiner decreased in relation to the increased level of oil. There may be some interspecific relationship such as predation operating here. Similar inverse relationships have been found between the alewife and the yellow perch in Lake Michigan (Wells 1977), although the specific interaction of the two species was not known.

The species composition in all four areas was similar with most species occurring everywhere. Pumpkinseed and yellow perch were dominant throughout the season, followed by largemouth bass, bluegill, black crappie, golden shiner, rock bass and brown bullhead.

The age distribution for yellow perch suggests an increase in the production of young in 1978 on the heavily oiled areas after possible low production since the oil spill. There are many complex factors other than oil that could have caused this. However, the timing of the shift in age classes is worthy of further study.

A drop in largemouth bass production was suspected in 1977. However, if it did occur, there appeared to be a rather uniform production in all areas in 1978.

No definite population trends that could be related to the oil were found for pumpkinseed in 1978. Pumpkinseed had its highest population at French in contrast to yellow perch which had its highest population at Marguerite. Whether these differences in population size and age distribution can be attributed to the oil is uncertain. Disturbances of other types that could have caused these changes are quite possible.

This study investigated the potential effects of oil on fish such as reductions in populations, destruction of habitat and loss of food sources. In spite of not having baseline data for these areas, there were indications that the oil spill did have its impact on the fish communities. However, this impact was difficult to isolate and quantify since it was only one of several factors that were affecting the fish community at that time.

WATERFOWL DIVERSITY AND ABUNDANCE[3]

Methods and Materials

Data on waterfowl for the various study areas were gathered by using two methods. These were trapping and visual observations.

Funnel duck traps (Fig. 57) were constructed and two were placed at each area as they became available in 1977. Each trap was 1.83 x 1.83 x 1.22 m high (6 x 6 x 4 ft), made of 2.5 x 5.1 cm (1 x 2 in) wire mesh with a floor and roof of nylon netting. The latter material prevented serious injury to the birds. The traps were prebaited before setting and kept baited with cracked corn during their operation.

Site selection was based on the availability of water depth suitable for duck feeding activity (approx. 0.3 m). Consideration also was given to type of substrates that would hold the corn used as bait at its surface. Trap sites were distributed so that the resulting data would be representative of the duck population using the total marsh. Whenever possible, sites were selected that would minimize both human and predator interference.

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[3]Based on data secured by Patricia Longabucco and assistants.

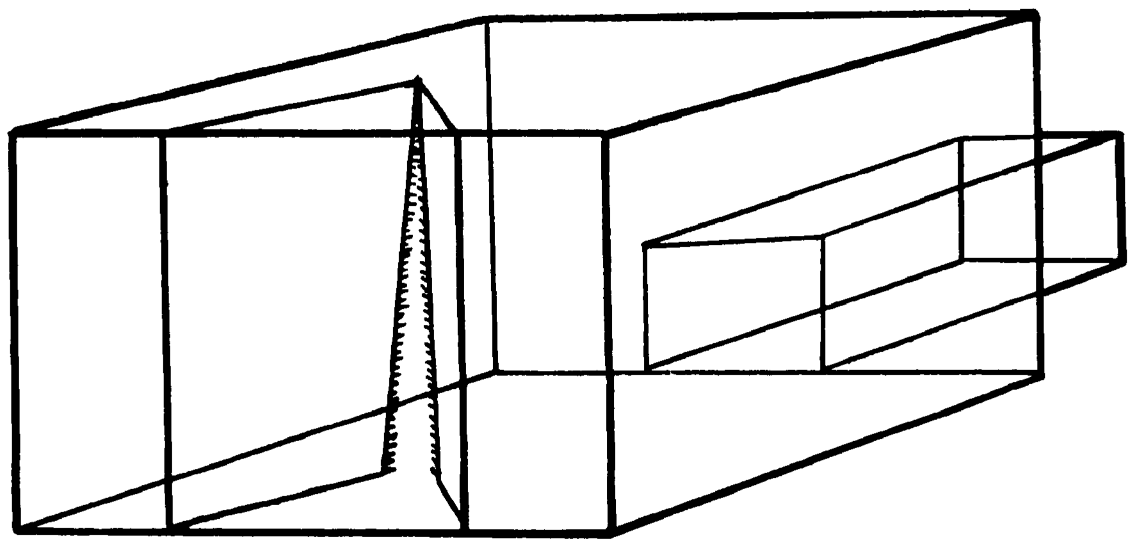

Figure 57. Sketch of funnel duck trap.

Ducks and other large marsh birds that were captured were driven into a holding cage attached to the rear of the trap. This facilitated catching the birds for study. The ducks were marked with plastic nasal saddles, the color and number on the saddles having been assigned by the U.S. Fish and Wildlife Service for each species (Fig. 58). This made easier the identification of birds at a distance and also was useful in the recognition of broods accompanying a marked hen. Each bird was sexed and aged. The age class of juveniles was determined according to a system developed by Gollop and Marshall (1954).

The time required to travel between the seven areas and operate the traps proved greater than expected. Therefore, all areas were not trapped at all times in 1977. In 1978 the number of areas was reduced to four by eliminating three areas where trapping was considered unsuccessful. At least three traps were used at each of the four areas in 1978. They were kept in near continuous operation from the time the broods hatched until early August when population shifts began.

The locations of the duck traps for each year are shown in Figures 51, 52, 53 and 54.

The number and species observed, plus sex and age whenever possible, were recorded each time a study area was visited. Observations were made along a standardized route used in reaching the trap sites. These observations taken from a canoe were combined with those taken from the motor boat used to enter the marsh. Although two persons were needed to handle boats and trapping equipment, the observations were recorded by a single person, and in most cases by the same individual throughout the two-year period.

There were some differences between the observation data for 1977 and 1978. In 1977 there was no record kept of days when ducks were not seen (zero-duck days). In 1978 zero-duck days were included. The observations for 1977 were taken largely during July and August since the time spent in constructing duck traps in the spring of 1977 precluded the taking of many duck observations until late June. In contrast, observations began in mid-May for 1978. Therefore for 1977, the data on breeding pairs and brood production were incomplete. Estimates may be high for 1977 since they could

Figure 58. Sketch of nasal saddle on mallard duck.

have included juveniles that were congregating in the marshes or otherwise moving. The 1978 observations not only began earlier but were concentrated in four areas instead of seven. Phenologically the 1978 season was about two weeks later than in 1977.

Results

Three times as many observations of ducks were recorded in 1978 as in 1977 for the same four study areas, as shown in Table 16. This was largely due to an increase in the number of times each area was visited. However, when the zero-duck days were subtracted from the 1978 data to make a better comparison between the two years, there were no significant differences for any area except Marguerite. This area experienced a 60% increase in 1978 for the average number of ducks recorded per day (5/da in 1977 and 8+/da in 1978). French had the largest number recorded per day (about 12/da); and because of the large number of ducks there, the number of zero-duck days was very low. Crooked and Chippewa were both low in ducks recorded (about 5/da), but Crooked had many more zero-duck days than Chippewa, the latter being about the same as Marguerite.

There were differences noted in the species composition for each study area, as well as some shifts from 1977 to 1978.

The two dominant duck species in French were mallard and blue-winged teal. There appeared to be a decrease in mallards between the two years and a considerable increase in blue-winged teal. High water at the beginning of the 1978 season may have caused this since some of the suitable mallard nesting sites were flooded. The number of teal may have been magnified by their tendency to congregate early. Many of those seen or trapped were flying juveniles possibly from adjacent areas. The teal may not have actually increased in 1978. Wood duck remained low both years due to a lack of nesting cavities.

Wood duck and mallard were the principal species in Crooked; the former increased and the latter remained the same in 1978.

Observations of mallard and black duck were reduced at Chippewa in 1978. At the same time blue-winged teal and wood duck increased. Mallards may have lost nesting sites due to the high water, as could be the case for black ducks.

Observations more than doubled for mallards in 1978 at Marguerite, whereas wood duck increased slightly and blue-winged teal remained the same.

There were differences also within each species in their choice of sites, as reflected by their population levels.

Wood ducks were most abundant in Chippewa and least abundant in French. On the other hand, mallards were most abundant in French and least abundant in Chippewa and Crooked. Blue-winged teal were also most abundant in French but least abundant in Crooked. Taken as a whole, mallard was the most abundant species, and was found everywhere. Wood ducks were widely distributed, even though much reduced in French. Blue-winged teal observations were numerous only because of the large number seen in French. The blue-winged teal observed per visit at French was the largest number for any species anywhere in 1978.

The number of ducks observed per unit of area was about the same for all study areas in 1977 (Table 16). However, in 1978 many more duck observations were recorded for each area per hectare. French and Marguerite had equally high densities with Crooked and Chippewa somewhat lower. Although the marshes are considerably different in their ecological characteristics they are believed to be about equal in their use by ducks per unit of area.

The waterfowl diversity indices given in Table 17 were based on observational counts for each year. Late spring migrants were excluded but summer transients were included. Only small differences exist in the species seen each year at a particular area.

The highest index for 1977 occurred at Sheepshead where both richness and evenness were high. In contrast the lowest index for 1977 occurred at French where both richness and evenness were low.

Species diversity indices for the four areas studied in both years were somewhat lower for 1978 than 1977, except at French. In 1978 the highest index was found at Marguerite due to an increase in the number of species seen. The lowest index was again at French although there had been an increase in both richness and evenness.

In general, there was a greater species diversity index for the heavily and moderately oiled areas in contrast to the unoiled or slightly oiled areas. However, this difference was not found to be statistically significant at the 95% level. Differences in the distribution of waterfowl species could be explained by inherent differences in the marsh environments.

Waterfowl trapping was not considered successful at three study areas in 1977, although the birds were regularly observed at these locations. The ducks did not respond to bait at Cranberry. At Kring the surface crust that developed at the marsh edge congested the channels and prevented the operation of funnel traps. The exposure to the wind at Sheepshead either collapsed the traps or filled their funnels with debris. Because of these features, only four areas were trapped in 1978.

A total of 138 ducks was captured in 1977 as given in Table 18. Unoiled French was the last area to have the duck traps installed, but it still gave the greatest trapping success per trap day, due largely to the congregation of juvenile ducks at that time. However, Marguerite, which had been heavily oiled, gave about the same level of success. Chippewa and Crooked were less successful but equal.

A total of only 77 ducks was captured in 1978 (Table 19) in spite of a doubling of the trap days. Trapping was started earlier in the season with more traps per site. However, the increase in human activity in the areas may have influenced the trapping success. Also from the standpoint of

TABLE 16. WATERFOWL OBSERVED 1977 and 1978 - ST. LAWRENCE RIVER MARSHES

Area	Year	Obs. Days	Zero Duck Days	Wood Duck		Mallard		Blue-winged Teal		Green-winged Teal		Black Duck		Other Identified		Un-identified		Total		
				No.	Av/Da	No.	Av/Da	No.	Av/Da	No.	Av/Da	No.	Av/Da	No.	Av/Da	No.	Av/Da	No.	Av/Da	No/Ha
French	1977	13[1]		2	0.15	128	9.85	22	1.69									152	11.69	5.63
	1978	38[2]		11	0.29	221	5.82	234	6.16					1[4]	0.03	11	0.29	478	12.58	
	1978	42[3]	4	11	0.26	221	5.26	234	5.57					1	0.02	11	0.26	478	11.38	17.70
Crooked	1977	10		10	1.00	26	2.60	1	0.10			7	0.70			7	0.70	51	5.10	4.22
	1978	28		62	2.21	82	2.93	6	0.21			1	0.04					151	5.39	
	1978	51	23	62	1.22	82	1.61	6	0.12			1	0.02					151	2.96	12.47
Chippewa	1977	17		39	2.29	48	2.82	1	0.06	1	0.06	9	0.53					98	5.76	5.08
	1978	32		87	2.72	58	1.81	19	0.59			2	0.06			9	0.28	175	5.47	
	1978	49	17	87	1.78	58	1.18	19	0.39			2	0.04			9	0.18	175	3.57	10.86
Marguerite	1977	16		15	0.94	34	2.13	20	1.25			1	0.06			10	0.63	80	5.00	5.35
	1978	32		45	1.41	163	5.09	37	1.16	6	0.19	1	0.03	5[5]	0.16	6	0.19	263	8.22	
	1978	48	16	45	0.94	163	3.40	37	0.77	6	0.13	1	0.02	5	0.10	6	0.13	263	5.48	17.63
Total	1977	56		66	1.18	236	4.21	44	0.79	1	0.02	17	0.30			17	0.30	381	6.80	
	1978	130		205	1.58	524	4.03	296	2.28	6	0.05	4	0.03	6	0.05	26	0.20	1067	8.21	
	1978	190	60	205	1.08	524	2.76	296	1.56	6	0.03	4	0.02	6	0.03	26	0.14	1067	5.62	

[1] Zero-duck days not recorded
[2] Zero duck days not included
[3] Zero duck days included
[4] Redhead
[5] Pintail

TABLE 17. WATERFOWL SPECIES DIVERSITY - ST. LAWRENCE RIVER MARSHES

Area	1977 S[a]	1977 J'[b]	1977 H'[c]	1978 S	1978 J'	1978 H'
French	3	.438	.482	5	.519	.835
Cranberry	4	.663	.919			
Crooked	4	.740	1.026	4	.619	.858
Kring	2	.845	.586			
Chippewa	6	.618	1.107	4	.727	1.007
Marguerite	4	.793	1.100	6	.591	1.059
Sheepshead	6	.817	1.463			

[a] S = Richness = Number of species present
[b] J'= Evenness = H'_s/H_{Max} (Pielou 1966)
[c] H'= Diversity= $-\sum_{i=1}^{S}$ pi log pi (MacArthur and MacArthur 1961)

capture per trap-day, it may be possible that three traps would catch no more ducks than two traps (or even one) in these sites where the ducks can move throughout the entire study area. However, the higher water levels at the beginning of 1978 forced the placing of traps in less than ideal locations. This also meant that the traps were closer to the upland and raccoons became a greater problem than in 1977. Even snapping turtles occasionally occupied the traps. For some reason adult ducks were difficult to capture at all sites.

More of the marshes were flooded in 1978 which gave the ducks greater areas to feed in and therefore did not limit their movements to the vicinity of the traps. Natural foods may have been more abundant in 1978.

Hens with their broods were captured in 1977, though rarely in 1978. At the time trapping began in 1977, hens were regularly seen with their broods. In 1978 trapping began as soon as the first broods were seen. The earlier trapping in 1978 may have created a wariness in the adult birds. Still at some trap locations ducks were regularly flushed while feeding on the cracked corn outside of the traps.

The collection of trapping data stopped somewhat earlier in 1978 than it did in 1977 in order that the report could be completed on schedule. This meant that the congregating juveniles did not enter into the sample, except in French Creek where some early-maturing blue-winged teal occurred in greater numbers.

The number of breeding pairs of waterfowl by species was determined for each of the four principal study areas for 1977 and 1978 (Table 20). In 1977 there was a similar number of breeding pairs at the beginning of the season in each area. However, in 1978 there were increases in all areas, even a doubling in French and Marguerite. Some of these increases reflect the earlier field work which gave a better determination of the correct

TABLE 18. WATERFOWL CAPTURE, 1977, ST. LAWRENCE RIVER MARSHES

Area	Wood Duck	Mallard	Blue-winged Teal	Black Duck	Total	Trap Days	Birds per trap day
French	5/3[d]	13/3	12/3	1/0	31/9 = 40	44	0.91
Cranberry	0/2	2/0	0/0	0/0	2/2 = 4	37	0.11
Crooked	7/8	6/2	4/0	0/0	17/10= 27	52	0.52
Kring[a]	1/0	0/0	0/0	0/0	1/0 = 1	33	0.03
Chippewa[b]	9/5	3/0	6/0	3/0	21/5 = 26	52	0.50
Marguerite	7/7	11/3	10/1	0/0	28/11= 39	54	0.72
Sheepshead[c]	9/9	1/0	0/0	0/0	1/0 = 1	50	0.02
Totals	29/25	36/8	32/4	4/0	101/37=	322	0.57
	54	44	36	4	138		

[a]Encrusted surface layer due to pollution.
[b]Most extensive submerged vegetation.
[c]Least amount of submerged vegetation.
[d]Juvenile/adults.

TABLE 19. WATERFOWL CAPTURE, 1978, ST. LAWRENCE RIVER MARSHES

Area	Condition	Wood Duck	Mallard	Blue-winged Teal	Total	Trap Days	Birds per trap day
French	Control	0/0	4/0	14/0	18/0 = 18	111	0.162
Crooked	Slightly oiled	14/1	0/0	0/0	14/1 = 15	100	0.150
Chippewa	Moderately oiled	7/1	5/1	8/0	20/2 = 22	101	0.218
Marguerite	Heavily oiled	15/0	7/0	0/0	22/0 = 22	124	0.253
Total		36/2	16/1	22/0	74/3 = 77	436	0.176
		38	17	22	77		

TABLE 20. WATERFOWL PAIRS, 1977 and 1978 - ST. LAWRENCE RIVER MARSHES

Area	Year	Wood Duck		Mallard		Blue-winged Teal		Green-winged Teal		Black Duck		Total	
		No.	ha/pr	No.	ha/pr	No.	ha/pr	No.	ha/pr	No.	ha/pr	No.	ha/pr
French (27.1 ha)	1977	*		5	5.4	1	27.1	0		0		6+	4.5
	1978	1	27.1	9	3.0	2	13.5	0		0		12	2.3
Crooked (12.1 ha)	1977	3	4.0	4	3.0	0		0		0		7	1.7
	1978	3	4.0	5	2.4	0		0		0		8	1.5
Chippewa (16.2 ha)	1977	2	8.1	3	5.4	1	16.2	0		1	16.2	7	2.3
	1978	5	3.2	3	5.4	2	8.1	0		0		10	1.6
Marguerite (14.9 ha)	1977	2	7.5	3	4.9	2	7.5	0		0		7	2.1
	1978	6	2.5	5	2.9	2	7.5	1	14.9	0		14	1.1
Total	1977	7+		15		4		0		1		27+	
	1978	15		23		6		1		0		45	

*Insufficient data to determine.

numbers. Because there were considerable differences in the size of each area, densities were calculated on the basis of hectares (2.5 acres) per pair.

The highest density of breeding pairs for all species was found in Marguerite with Crooked second, both in 1978. Crooked also had the highest density in 1977. The lowest density was found in French in both 1977 and 1978.

When the data for breeding pairs were examined for each separate species mallards had the greatest densities overall for each year. They were most dense in Crooked for both 1977 and 1978, whereas they were least dense in French and Chippewa in 1977 and in Chippewa in 1978.

The second most dense species was the wood duck which was most dense in Crooked in 1977 and in Marguerite in 1978. Its lowest densities were in French for both 1977 and 1978.

Blue-winged teal were most dense in Marguerite for both years and least dense in French for both years, of those areas having the species.

The number of pairs in each area did not always agree with the overall frequency of observations made of ducks during the two years. Whereas the greatest number of observations per day were recorded for French, this area had the lowest densities of pairs each year. Crooked, on the other hand, gave some close correlation between numbers observed per day and breeding pair densities. One factor that influenced this relationship had to be the differences in the sizes of the study areas.

The breeding pairs of waterfowl in an area are the first factor that shapes the level of production for that area. Table 21 gives the number of broods encountered in the field during the study. These are broods that could be identified as being separate from others or could be determined by trapping records.

Marguerite had the greatest density of broods each year, although it was essentially the same as that at Crooked in 1977 and at Chippewa in 1978. The lowest densities were found at French.

The average brood size at hatching for each species as given by Bellrose (1976) was used to calculate total potential production. A maximum of 75 ducklings could have been hatched at Marguerite in 1977. This high production was equalled or exceeded in 1978. Chippewa also experienced a slight increase in production from 1977 to 1978, in this case primarily due to an increase in wood duck broods. At the same time, Crooked experienced a definite decline in production, due to decrease in successful mallard nests. High water flooded some of the suitable nesting habitat for mallards in this area. Although insufficient data were obtained in 1977 for French, it was assumed to be about the same as in 1978, which was low with most of the production being mallards.

TABLE 21. WATERFOWL BROODS, 1977 and 1978 - ST. LAWRENCE RIVER MARSHES

Area	Year	No.	ha/brood	No.	ha/brood	No.	ha/brood	No.	ha/brood	No.	ha/brood	No.	ha/brood
French (27.1 ha)	1977	*		2	13.5	*		0		0		2+ (17+)**	13.5
	1978	1	27.1	5-6	5.4-4.5	1	27.1	0		0		7-8 (61-70)	3.9-3.4
Crooked (12.1 ha)	1977	3	4.1	3-4	4.1-3.0	0		0		0		6-7 (58-67)	2.0-1.7
	1978	2	6.0	1	12.1	0		0		0		3 (30)	4.0
Chippewa (16.2 ha)	1977	1-2	16.2-8.1	3	5.4	1	16.2	0		1	16.2	5-6 (52-63)	3.2-2.7
	1978	4-5	4.1-3.2	1	16.2	2	8.1	0		0		7-8 (69-80)	2.3-2.0
Marguerite (14.9 ha)	1977	3	4.9	3	4.9	1-2	14.9-7.4	0		0		7-8 (67-75)	2.1-1.9
	1978	4-6	3.7-2.5	2	7.4	1	14.9	0		0		7-9 (69-91)	2.1-1.7
Total	1977	7-8 (77-88)		11-12 (92-101)		2-3 (17-25+)		0		1 (8)		20-23 (194-222)	
	1978	11-14 (121-154)		9-10 (76-84)		4 (34)		0		0		24-28 (230-271)	

*Insufficient data to determine
**Number of individuals produced at hatching

Taken as a whole, it was determined that duck production in the St. Lawrence River marshes increased slightly in 1978.

Discussion

Every attempt was made to measure the characteristics of the duck populations one and two years after the spill. Diversity of species and their relative abundance were investigated. In addition, the numbers of breeding pairs and their success in producing young were studied.

There were no significant differences in species diversity among the areas impacted with oil of varying amounts. The availability of suitable nesting sites was a strong factor in dictating the presence of the different species. French, the control area, had the lowest species diversity each of the two years because of this, in spite of its large size and lack of oil.

The species, when analysed separately, indicate that each resides where its natural niche is available and not crowded.

In 1977 the number of ducks observed per visit was much lower in the oiled areas than in the control, although it appeared that all areas were good duck habitats. Marguerite, the most heavily oiled area, had the fewest recorded observations of ducks in 1977, one year after the spill. In 1978 Marguerite experienced the greatest increase in ducks recorded. Whether this can be attributed to a recovery to some former level after two years is unknown due to the lack of prior data. The possibility cannot be ignored.

Careful observation of the ducks in each marsh gave a good indication of the breeding pairs using the areas during the nesting season. All areas had an increase in breeding pairs between 1977 and 1978, with the greatest increase occurring at Marguerite and French (about double). The increase at Chippewa was greater than at Crooked.

If there are any features of these various duck populations that would have potential meaning in respect to level of oiling, it would seem that it should be the breeding duck pairs and broods per unit of area.

The production of young ducklings in 1977 was greatest at Marguerite followed by Crooked, Chippewa and French. In 1978 Marguerite repeated with about the same number of ducklings but was equalled at Chippewa and French, with Crooked being the least productive. French had the greatest increase because of its low production in 1977. Chippewa had a slight increase, Marguerite remained the same, and Crooked declined.

It is perhaps most important to compare the success of breeding pairs to produce young.

In general 1978 was a poorer year for producing ducklings, possibly because of the high water. The success of breeding pairs to produce broods declined from 80% in 1977 to 50% in 1978. Success at Crooked declined 60%, Marguerite declined 47%, Chippewa declined 5%, whereas French increased 76%.

It is of interest to compare the most heavily oiled area (Marguerite) with the control area (French). Marguerite had the greatest increase in ducks recorded per visit, although French had the largest actual number. Marguerite and French were the same in their increase of breeding pairs, although Marguerite had the greatest number per unit of area. French had the greater increase in production, although the two were about equal in 1978. Success of breeding pairs to nest and produce young declined at Marguerite and increased at French.

In summary, the most heavily oiled area experienced a large increase in ducks and breeding pairs but the production remained the same. At the same time the control area experienced a slight increase in ducks, a large increase in breeding pairs and a great increase in production. The fact that the heavily oiled area had the increase in ducks and breeding pairs but did experience the production increase that was experienced at most other locations may suggest that this was the effect of the oil. However, the density of a brood per 2 ha may be the carrying capacity of the St. Lawrence River marshes for broods, since some other areas were approaching that density but none exceeded it. It seems clear that in the absence of pre-spill data, more data are needed over a longer period of time before one can evaluate duck production changes in these marshes and determine whether such changes can be attributed to the spill.

OTHER WILDLIFE STUDIES

Amphibians and Reptiles[4]

No formal study was planned for the amphibians and reptiles since reliable indices of abundance are not available for this group. However, data were gathered whenever possible. A recent survey of the amphibians and reptiles had been conducted along the River including many of the same marshes (Alexander 1976). Therefore, a basic understanding of this group's distribution was in hand.

Little if any apparent differences in frog populations were observed among the seven study areas either in 1977 or 1978. A general progression of frog activity was observed along the marsh front during the season. Bullfrogs were predominant prior to July 1st. Green frogs existed along with the bullfrogs during the month of July. About August 1st the leopard frogs replaced the bullfrogs and coexisted with the green frogs throughout August. All frogs became scarce at the marsh edge by the end of August.

Few snakes were seen at the marsh edges except where rocks were exposed above the water. Only water snakes were seen at these sites.

Turtles were found at all seven sites. Because of their secrecy, they had to be trapped to determine the species present. Snapping turtles and painted turtles were the two universally present species. However, snapping turtles were scarce and painted turtles were infrequent in the Sheepshead

[4]Based on data secured by Peter J. Petokas and Elizabeth A. McGrath.

area. The rock ledges along the sides of Sheepshead North and along the north shore of Chippewa were the only locations where map turtles were found. Blanding's turtles and stinkpots, although present at most sites, were found in their usual low numbers and no differences could be attributable to the oil.

An intensive study of turtles was conducted in the Cranberry Creek area in 1977 (Petokas 1979). Since this area was slightly, if at all, impacted by oil and since the study was conducted in the marshes of the Creek proper, this study of turtle population furnishes an excellent baseline study for the River with emphasis on the two primary species, the snapping turtle and the midland painted turtle.

It would appear that the amphibians with their soft glandular skin should be very sensitive to oil in the environment. Therefore, a new and associated study was started in 1978. The bullfrog was selected for the study, although other species of frogs were used at times. The study was made possible by a fellowship sponsored jointly by the American Petroleum Institute and the National Wildlife Federation.

Tadpoles (larvae) of the bullfrog are being exposed in the laboratory to varying concentrations of Bunker C oil (No. 6 fuel oil) for a period of 96 hours. This experimental work will continue as long as bullfrog tadpoles can be obtained this fall.

Preliminary results indicate that tadpoles in advanced stages when exposed to the oil in concentrations exceeding 1% have a 75% mortality rate within 24 hours, and all die before the end of 96 hours. Tadpoles in early developmental stages are more tolerant of the oil than tadpoles in late developmental stages.

Tadpoles exposed to 1% or higher concentrations of oil are observed leaving their normal position at the bottom of the tanks and appearing at or near the surface within four hours. They develop a "bulging" appearance. Through autopsies, it is found that the lungs are over-inflated. This causes them to rise to the surface where direct exposure to the oil increases and some oil is ingested. The oil also is found in their digestive tracts.

Bunker C and most other oils float on the surface of the water where adult amphibians spend most of their time while in water. The young (tadpoles) on the contrary spend most of this time near the bottom. However, now it is known that the oil components in the water column cause stressful reactions in the tadpoles, they rise to the surface where direct oiling adds its impact. The next step will be to determine the impact of oil on the adult frogs.

Birds[5]

Bird counts were not made in 1977 although the species present in each area were recorded. Time-area counts were made in 1978. The bird species

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[5] Based on data secured by Patricia Longabucco.

shown in Table 22 are those that were recorded during the actual counts. It is known that other species were present in the marshes such as the Virginia rail, sora, green heron and belted kingfisher. At the edges of the marshes where the uplands begin other species such as the woodcock, red-tailed hawk, yellow warbler and grackle were seen on occasion. Some of the more open water species such as the herring gull, ring-billed gull, common tern and common loon were seen in the vicinity of the marshes. The great blue heron, bank swallow, tree swallow, rough-winged swallow and barn swallow came to feed in or adjacent to the marshes. Turkey vultures and ospreys were occasionally seen above the marshes. Several migrating waterfowl were seen in the spring, including lesser scaup, bufflehead, canvasback and Canada goose. The resident waterfowl species are included in the calculations of species diversity given in Table 23.

The redwing blackbird was the most abundant species recorded in the count, ranging from one to three pairs per hectare. The greatest densities occurred in French and Marguerite with the lowest in Chippewa. The long-billed marsh wren was abundant only in French were many nests with eggs were found. The swamp sparrow was also abundant in French.

Gallinules were common everywhere but were very abundant in Marguerite. American and least bitterns were present in all marshes. Black tern were common in Marguerite where eight pairs nested with considerable success. A few had been seen there in 1977 with one successful nest. In 1978, 16 young were seen in mid-summer. Why this marsh was the only one having pairs cannot be explained.

There were no significant differences in the four areas for their bird species diversity as given in Table 23. Marguerite was high and Chippewa was low. It does not appear that the bird life in the marshes can be related to the degree of oiling. The differences in the habitat and the availability of food seem dominant in determining the make-up of the bird community.

Muskrats[6]

Since muskrats were the primary mammalian herbivore living in these marshes and since any effects of the Bunker C fuel oil on the vegetation should be reflected in the herbivore population, an attempt was made in 1977 to sample the muskrat populations. A trapping period of three nights was used for each of the seven study sites. This was done in late July and early August.

At Marguerite, Cranberry and Kring 50 small (5" x 5" x 16") and 25 medium (7" x 7" x 20") Tomahawk live traps were used. At the other sites only 25 small and 25 medium traps were used. The traps were set at intervals of about 15 meters along the marsh edge wherever runs or other signs were observed. They were all baited with fresh pieces of apple and carrot. The results are given in Table 24.

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[6]Based on data secured by Lewis M. Smith.

TABLE 22. BIRD COUNTS, 1978 - ST. LAWRENCE RIVER MARSHES

Species	French		Crooked		Chippewa		Marguerite	
	No. Pairs	Pairs/ha	No. Pairs	Pairs/ha	No. Pairs	Pairs/ha	No. Pairs	Pairs/ha
Redwing Blackbird	74[a]	2.73	21	1.74	68	0.99	35	2.36
Long-billed Marsh Wren	35[b]	1.29	0	0	10	0.15	5	0.34
Swamp Sparrow	12[b]	0.44	1	0.08	8	0.12	0	0
Gallinule	6	0.22	3	0.25	2	0.03	7	0.47
American Bittern	3	0.11	0	0	5	0.07	2	0.14
Least Bittern	4	0.15	2	0.17	9	0.13	4	0.27
Black Tern	0	0	0	0	0	0	8	0.54
Harrier	1	0.04	0	0	0	0	0	0
Snipe	0	0	0	0	0	0	1	0.07

[a]Number of Redwing Blackbird pairs determined by averaging the number of males and females counted.
[b]Number of singing males used rather than number of pairs.

TABLE 23. BIRD SPECIES DIVERSITY, INCLUDING WATERFOWL, 1978 ST. LAWRENCE RIVER MARSHES

	Richness S	Evenness J'	Diversity H'	Individuals
French	10	0.736	1.695	364
Crooked	8	0.695	1.445	79
Chippewa	10	0.731	1.682	274
Marguerite	13	0.742	1.902	178

TABLE 24. MUSKRATS CAPTURED 1977 - ST. LAWRENCE RIVER MARSHES

	No. traps	No. muskrats	No./100 trap-nights
French	50	3	2.0
Cranberry	75	7	3.1
Crooked	50	0	0.0
Kring	75	13	5.8
Chippewa	50	4	2.7
Marguerite	75	3	1.3
Sheepshead	50	10	6.7

Based on this limited sample there appears to be no clear relationship between the catch of muskrats and the degree of oil impact. Since all marshes appeared to be productive and all muskrats handled were healthy and vigorous, the sampling was considered inadequate in 1977 and the results inconclusive.

A more thorough investigation of the Goose Bay complex was begun early in the 1978 season. Muskrats were live-trapped at the Cranberry, Kring and Marguerite study areas beginning in mid-May. A total of 150 small and medium live traps were used, 50 at each area. Trapping was simultaneous at all three areas. However, an encrusted mat that developed in the Kring area forced the elimination of that area from the study after a few days.

Data on litters were obtained by opening houses while the young were still in the nest. These were marked by toe clipping. However, this activity was successful only in Marguerite where the muskrat houses were accessible. In Cranberry, which was a floating mat, the houses were not to be found anywhere near the edge where they could be reached by canoe or by wading.

The live trapping, tagging and release program involved in each cycle eight days of tagging, followed by eight days of rest and finally eight days of recapture. The first such cycle began May 23 and ended on June 15. The second cycle began August 10 and ended September 1. All muskrats captured were tagged in both ears with numbered size 1 monel fingerling tags.

The results of this study to date are given in Table 25. It would appear that muskrats exist in much greater density in Marguerite than in Cranberry. Although Cranberry may actually have a greater productivity for cattail, the floating nature of the marsh seemed to have prevented it from being fully utilized by the muskrats. The houses were remote and isolated and there appeared to be but one litter produced in Cranberry in contrast to three litters in Marguerite. It seems that the heavily oiled Marguerite marsh was as productive of muskrats as could be expected two years after the spill. Undoubtedly influenced by the higher density of muskrats in Marguerite and the greater linearity of the creek in Cranberry, the ranging movements of the muskrats in Cranberry were far greater than in Marguerite.

TABLE 25. MUSKRAT TRAPPING DATA - ST. LAWRENCE RIVER MARSHES

	Marguerite		Cranberry	
	Initial Period	Final Period	Initial Period	Final Period
Trap nights	800	1600	800	1600
Number caught	41	64	11	53
Catch/100 trap nights	5.1	4.0	1.4	3.3
Houses examined	15	23	3	5
Houses with litters	7	9	0	0
Kits marked at houses	30	46	0	0
Population estimate	84	154	a	253
68% limits	$42 \leq N \leq 126$	$87 \leq N \leq 221$	a	$82 \leq N \leq 424$
Population density	78.5/A	90.6/A	a	68.4/A
Sex Ratios (M:F)	1.6:1	1.8:1	3.1:1	3.8:1
Age Ratios (Y:A)	1.5:1	2.4:1	1:1	1.1:1
Average young/litter	4.3	4.6	b	b

[a]No recaptures to use as basis for calculation.
[b]No litters examined due to inaccessibility of breeding houses.

CONCLUDING DISCUSSION

The impact of the 1976 spill of Bunker C oil on the fish and wildlife of the St. Lawrence River marshes was studied in 1977 and 1978. No prior data for the fish and wildlife were available. Areas with varying degrees of oil impact but having similar ecological characteristics were selected for study and comparison to control areas. It was found later that these areas were all somewhat different from each other in size, substrate, surroundings, winds, submerged vegetation, pollutants, water movement, and other factors. Nature does not replicate itself in an exact manner. These differences in the areas had their effects on the data collected during the study.

The long history of shipping on the St. Lawrence River includes a few smaller spills along with chronic introduction of petroleum products from ships, motor boats and industrial equipment. A background of petroleum hydrocarbons must exist in the River and its associated marshes. How uniform this background of hydrocarbons is in the marshes is unknown, but it is suspected to vary greatly depending upon movements of the water carrying the compounds and the movement of bottom sediments by currents and wave action.

It would appear from the data gathered during the two-year study that the fish and wildlife communities in these marshes are recovering from the extensive losses that occurred at the time of the spill. This is based on the fact that the fundamental ecological differences among the areas studied seem to have greater influence on the fish and wildlife community than influences which could be attributed to the oil spill. This in no way means that there were not important and probably long term effects of the oil on the fish and wildlife. Some of these effects are noted in the discussion of the fish study and the waterfowl study.

It should be kept in mind that these results relate only to this particular spill. The oil was Bunker C, the time was mid-summer after many reproductive processes were over, the water was higher than normal and the cleanup was as thorough as possible. A lighter oil, a different time of year, a lower water level or a less extensive cleanup could have changed the results considerably. Even so, we do not know just how much is still left in the environment, how long it will stay there, or how many more such spills the marsh biota can tolerate.

It is believed that the age structure of the more dominant fish species such as yellow perch and pumpkinseed along with selected other species such as the largemouth bass should be monitored to further establish the characteristics of these species over the next few years.

It is also believed that the collection of data on density of breeding pairs of waterfowl and their success in producing young should be continued in order to clarify the comparative productivity of these marshes.

The danger from future spills is still great, in spite of the favorable report on this one. A survey of sensitive areas should be made throughout the length of the International section of the River. A plan to protect them through appropriate immediate response should be developed.

SECTION 7

POLYNUCLEAR AROMATIC HYDROCARBONS

GENERAL

Several petroleum hydrocarbons were known or suspected to have entered the food webs in marine communities. Some studies have been conducted to determine this movement, using crude or refined oils while others have used specific petroleum hydrocarbons. The subjects of uptake, accumulation and transformation have been reviewed recently by the National Academy of Sciences (1975, p. 58-67), Teal (1977) and Varanasi and Malins (1977). Much work has been done in the laboratory under controlled conditions. Anderson (1975) reported on his work with clams, oysters and grass shrimp. Stainken (1977) worked with the soft-shelled clam. Lee (1975, 1977) studied copepods, amphipods and other marine zooplankters as they metabolized some aromatic hydrocarbons. Stegeman and Teal (1973) observed the uptake of various hydrocarbons from No. 2 fuel oil by oysters and related this to the fat content of the organisms. Clark et al. (1974) studied the uptake of outboard motor effluents by oysters and clams.

Few studies have been conducted under field conditions. Conover (1971) found that zooplankton utilized and accumulated Bunker C oil after the wreck of the Arrow. Clark et al. (1973) found that some algae and crustaceans utilized the fuel oil from the wreck of the General M. C. Meigs. Blumer et al. (1970) studied the levels of hydrocarbons in oysters and scallops following the spill of No. 2 fuel oil from the barge Florida.

No attempt is made here to review the work done by others. The reader is referred to the excellent reviews mentioned above. Most petroleum hydrocarbons studied to date have been the water soluble fractions that could be extracted by filter feeders. The alkanes, paraffins and some naphthalenes have been the leading hydrocarbons studied. It is recognized that greater emphasis should be placed on polynuclear aromatic hydrocarbons (PAHs), particularly since some of these are known carcinogens. The importance of this group of hydrocarbons is emphasized by the series of annual International Symposia on Polynuclear Aromatic Hydrocarbons held at Battelle's Columbus Laboratories. Papers presented cover the measurement, chemistry, metabolism and carcinogenesis of PAHs. Benzo (a) pyrene has received much attention as have other PAHs and their simple and multialkylated associates.

The present study attempts to document the presence of polynuclear aromatic hydrocarbons in the substrate, vegetation and animal tissues of marsh communities impacted with Bunker C fuel oil from the barge NEPCO #140.

MATERIALS AND METHODS

Samples were taken of bottom mud and selected components of the biological communities at the various study sites for PAH analysis. The analyses were performed by Gollob Analytical Service using high pressure liquid chromatography (HPLC).

Samples were collected and placed in glass jars with aluminum foil covering beneath the screw-top lids. All instruments and containers were washed with cyclohexane. The samples were then frozen and shipped by air to the laboratory.

At the laboratory the samples were homogenized, weighed and Soxhlet extracted for 8 hours in 250 ml of spectroanalysed cyclohexane. The solvent was then removed at room temperature under a stream of dry nitrogen. A measured quantity of acetonitrile was added to each sample and then they were placed in an ultrasonic bath for approximately 2 minutes. They were then filtered. In some cases it was necessary to centrifuge a sample before filtration. All samples were brought to volume in a 5 ml volumetric flask, mixed, and an aliquot (100 ul) was injected into the high pressure liquid chromatograph.

The instrument was a Waters model ALC 202 liquid chromatograph equipped with a 30 cm x 4 mm i.d. - Muro-Bondopak C_{18} column. The mobile phase was water and methanol using a gradient from 60% to 100% methanol in 20 minutes. The flow rate was 1.2 ml per minute. The detector was a Schoeffel-variable, and the wavelength used was 290 nm (ultraviolet). There were times when the nature of the sample required some changes in the gradient and the flow rate.

Retention times between 2 and 14 minutes were usually recorded, although there were times when the flow was continued for 30 minutes or more. The instrument was calibrated using a PAH standard including known amounts of naphthalene, biphenyl, phenanthrene, anthracene, fluoranthene, 2-3 benzanthacene, chrysene, pyrene, and benzo (a) pyrene. The amounts of these and any unknowns were calculated and expressed in parts per billion (ppb) by weight.

This procedure was selected in the belief that it would give quantitative data for specific PAHs. Early samples of mud and cattail roots gave encouraging results for the method. However, when later data for animal tissues were analysed for final interpretation, some uncertainties about the procedure developed. To resolve these,the extracts of several samples were sent to the Residue Analysis and Methods Investigation Branch of the Food and Drug Administration. Their evaluation indicated that there was need for greater cleanup procedure if false positives were to be avoided. An attempt was made to substitute gas-liquid chromatography (GLC) but false positives were still obtained. A third method was then tried by the FDA laboratory, this being ultra violet-visible analysis (UV-Vis). This was considered more reliable although the 2-ring PAHs were lost by the procedure.

The basic results given in this report are founded on the HPLC analysis described above. Additional comments will be made on the GLC and UV-Vis data wherever appropriate. The possibility of false positives appearing in the data should be kept in mind.

THE SAMPLING PERIODS

Five sampling periods were used in the study. These included a limited sample in the late fall of 1976 before the project was funded, followed by some winter samples taken at all seven study areas, and a repeat of this in late spring at high water. Only bottom sediments ("mud") and cattail rhizomes and shoots ("roots") were taken at these times. These were considered important since it was recognized that this could be one of the major avenues of PAH entry into the food webs of the marsh ecosystems. Further, the frequent sampling during the first year would show changes in concentrations if they were found to exist. No animal life was sampled because of its near absence in late fall and winter and because the spring populations were entirely adults having unknown exposure to the oil. One adult muskrat obtained from a trapper at the mouth of Crooked Creek gave no results for PAH.

The August 1977 sampling was more extensive. It included mud and cattail roots at the warmest time of the year and also the young (or their tissues) of a variety of animal life. This was the first opportunity to sample young individuals that had been produced and had spent all their short life in the immediate vicinity of the impacted marsh. Their high rate of tissue formation would give a greater indication of accumulation of PAH, if it occurred. Adults that had greater mobility were not sampled.

Problems with obtaining representative samples were evident. The bottom sediments at the edge of the marshes contained much light-weight partially-decomposed plant material. This material moved about readily in response to currents and wave action. It was difficult and often impossible to get mud from amongst the cattail roots since this was a near-solid mat of root hairs. An attempt was made to get a mixture of the dead organic sediments and the inorganic substrate in each such sample. Five samples of mud were taken at Marguerite in August 1977 as a test of variability. Benzo (a) Pyrene, the principal PAH found varied from 0 to 4,650 ppb. The sample having no benzo (a) pyrene was the only one to have traces of other PAHs. Since this was heavily oiled and had been thoroughly cleaned by personnel cutting the cattail, there were many footprint depressions which could have caused uneven distribution of oil in the sediments.

Winter sampling required the drilling of holes through 75 cm (30 in) of ice with a power auger. Extra care had to be taken to avoid contamination of the sample. The selection of specific sample sites was difficult because of the snow and ice. In addition, the mud and roots were sometimes in the frozen zone, with unfrozen mud located several meters away from the edge. At Sheepshead both frozen and unfrozen mud were sampled and tested. The frozen sample taken close to the cattail contained nearly three times the PAH that was present in the more silty sample farther away. The frozen cattail roots taken at Sheepshead had lower PAH than expected. The difficulty of selecting appropriate sample sites and the low water conditions in winter could have introduced some sampling error.

The spring 1977 samples were taken under what were thought to be rather ideal conditions. PAH levels were generally higher but more variable. Whether the high spring waters caused some uneven redistribution of oil from depressions that had been above the water level since the preceeding summer could not be determined, but was suspected.

The summer 1977 data were also quite variable. However, they were extremely important because of the inclusion of young animal life. Two sites in Canada and two additional control areas were included during this period.

In 1978 only late July samples were taken. This avoided the uncertainties of locating proper winter sampling stations and the problems of the redistribution of small quantities of oil during the spring high water period. The spring 1978 water levels were higher than those for 1977 and some tar lumps that had been stranded since the spill were seen floating in the marshes. Frequent small oil sheen areas were seen in the marshes during the early summer of 1978. The taking of a summer sample did permit once again a look at the PAH content of young animals.

RESULTS

A total of 197 samples was analysed for polynuclear aromatic hydrocarbons (PAHs) between the fall of 1976 and the summer of 1978. The distribution of these samples is given in Table 26.

The PAHs used as standards in the chromatograph were purchased by the laboratory as pure chemicals. Since PAHs in petroleum include many substituted alkylated rings (Blumer 1976), the precision of the chromatogram peaks from petroleum PAHs cannot be as accurate as that from purchased standards. The column was standardized after about every three samples to avoid changes due to "loading" on the column. Therefore, an appropriate zone on the chromatograph was determined for each PAH and its isomers. In general, any peak that occurred within 0.5 minutes on either side of the standard was considered an isomer of the PAH. This left four groups of peaks not included. These corresponded to those eluting prior to naphthalene or after benzo (a) pyrene, and two areas of unknowns--all of which were classed as phthalate esters or hydrocarbon oils, not PAHs). A few of the PAH zones were too close to accurately separate, and so were combined.

The PAH regions on the chromatograms that were separated are-

Naphthalene	Fluoranthene/2, 3 Benzanthracene
Biphenyl	Chrysene/Pyrene
Phenanthrene/Anthracene	Benzo (a) Pyrene

Three samples of oil were analysed during the study. These included a sample that had been collected by the U.S. Coast Guard, a one-year-old sample from an oil pool in Sheepshead North, and a two-year-old sample of tar lumps from Chippewa. The oil pool found in 1977 could not be relocated in 1978. Whether it degraded or floated away in the high water of the spring is unknown. The analyses of the three samples taken are given in Table 27.

TABLE 26. SAMPLES TAKEN FOR PAH ANALYSIS - ST. LAWRENCE RIVER MARSHES

Sample Type	Date						Total
	11/76	2/77	4/77	5/77	8/77	7/78	
Oil			1		1	1	3
Mud	3	8		9	16	9	45
Cattail Roots	3	7		7	12	9	38
Cattail Tops					2		2
Young Fish					23	8	31
Tadpole					1		1
Turtle-liver						2	2
Turtle-muscle						2	2
Turtle-fat						2	2
Duckling-skin					6	5	11
Duckling-fat					6	2	8
Duckling-liver					6	5	11
Duckling-muscle					6	5	11
Duckling-brain						4	4
Muskrat-carcass			1				1
Muskrat-fat					3		3
Muskrat-liver					7	2	9
Muskrat-muscle					6	2	8
Muskrat-kidney					1		1
Muskrat-brain					1		1
Muskrat-skin					1	2	3
	6	15	2	16	98	60	197

The lack of naphthalene in the original oil agrees with Pancirov (1974) who analysed a Bunker C oil. However, he found methylnaphthalene and very small amounts of other PAHs.

By the time the oil had weathered for one year, all of the lighter PAHs had disappeared. This resulted in the increased concentration of others such as pyrene/chrysene. However, benzo (a) pyrene underwent considerable reduction.

After two years of being stranded above water, the tar lumps were further degraded or otherwise changed.

TABLE 27. ANALYSIS OF BUNKER C OIL FROM NEPCO #140

PAH	Original Oil 1976[a]	Oil Pool 1977[a]	Tar Lumps 1978[b]
Naphthalene	ND[c]		
Biphenyl	6750		
Phenanthrene	75		400
Anthracene	ND		
Unidentified	310		
Fluoranthene/2,3 Benzanthracene	ND	1000	590
Pyrene/Chrysene	260	3100	1600
Unidentified	40	68	
Benzo (a) Pyrene	25	12	150
Unidentified	15	30	160

[a] Amounts in parts per million by weight.
[b] Amounts in parts per billion by weight.
[c] ND = Non detectable.

Mud and Cattail Roots

A primary route for PAH to enter the food webs would be through the soils or sediments and the plant roots, as mentioned earlier. These were the first and most regularly sampled materials. Therefore, the results of their analyses will be considered separately.

A total of 45 samples of "mud" and 38 samples of cattail "roots" were taken.

Tables 28 and 29 give data in parts per billion by weight for the five sampling periods and the various areas where taken. The quantities are the total for the six PAH regions named above on the chromatograms.

Only three areas could be sampled in late fall (November) of 1976 because of ice conditions. Crooked served as the control, being only slightly oiled. Although the sample of mud from Marguerite contained no PAH, the later samples indicated the presence of considerable amounts of PAH in this heavily oiled area. Further, the data definitely showed that there was a concentration of PAH in the cattail roots.

The February 1977 data came from the seven basic areas. The samples from French, the control, contained the highest levels of PAH. Sampling errors may be involved in this "blind" sampling through the ice. However, there was a rather uniform increase in concentration from mud to cattail roots.

TABLE 28. TOTAL PAH IN MUD SAMPLES - ST. LAWRENCE RIVER MARSHES (ppb by weight)

Site	Sampling Date 11/76	2/77	5/77	8/77	7/78
French		1930	150	775	200
Cranberry		38	530	370	565
Crooked	32	150	25	550	360
Kring		50	710	710	3705
Chippewa		20	150	60	140
Marguerite	0	80	180	1929[a]	70
Sheepshead S	2180	85	b	95	355
Sheepshead N				1445	27970
Church Bay				2570	
Spencer Island				1400	
Rt. 26				1815	470
Cape Vincent				30	

[a]Average of five samples.
[b]Not determined by laboratory--too concentrated.

TABLE 29. TOTAL PAH IN CATTAIL ROOTS - ST. LAWRENCE RIVER MARSHES (ppb by weight)

Site	Sampling Date 11/76	2/77	5/77	8/77	7/78
French		16,300	415	17,100	3,400
Cranberry		2,375	2,600	855	7,400
Crooked	1,012	4,840	2,800	18,000	4,020
Kring		380	15,985	1,100	4,150
Chippewa		1,950	1,400	400	2,180
Marguerite	2,900	3,600	900	16,860	10,265
Sheepshead S	3,905	560	17,300	5,190	1,070
Sheepshead N				3,840	8,130
Church Bay				4,150	
Spencer Island				20,300	
Rt. 26				15,540	800
Cape Vincent				6,690	

The May 1977 samples, although taken at carefully selected representative locations, still resulted in some irregularities. There did appear to be some relationship between the level of oiling and PAH in the cattail roots. However, the mud gave few trends. The magnitude of PAH quantities remained about the same as in earlier samples.

The August 1977 samples included new sampling areas, some in Canada, others as new controls. The data from the mud samples indicated heavy loads of PAH at Marguerite, Sheepshead North, Church Bay (below a Canadian Dupont factory) and Spencer Island,also in Canada. Unexpectedly, the Route 26 marsh, which was a new control isolated from the River, had about as much PAH as Marguerite. In contrast the sample of mud from the River above the spill was very low in PAH. The cattail roots from French, Crooked, Marguerite, Spencer Island and Route 26 marshes were all high in PAH. Where all the PAH came from at French, Crooked and Route 26 is uncertain. These areas had considerably more agricultural activities around them than the other areas. The PAH quantities again were generally higher for cattail roots than for mud.

The mid-summer 1978 data were sporadic with no detectable trends. Marguerite had the lowest quantity of PAH in the mud and the highest in the cattail roots. There appeared to be some average reductions in PAH, particularly in mud. However, the largest quantity ever taken in mud came from Sheepshead North.

Cattail tops were sampled only in August 1977 at Chippewa. This was done because it had been noted that where the oil impacted the most, the cattail growth was considerably more (about 0.5 m additional height) and that flowering did not occur there. A sample was taken at the edge where the increased growth was found and another inland where growth was normal. The only PAHs found were in the biphenyl region totaling 33,000 ppb at the impacted edge and 136,000 ppb inland.

It was necessary to breakdown these PAH values to their PAH components in order to gain a better understanding of their meaning. Naphthalene was present largely in cattail roots in the summer periods, with basically none in the mud. This is of interest since naphthalene was not reported in the original oil. The highest concentration was in August 1977 for Crooked which had 18,000 ppb.

Biphenyl on the other hand was most common in the cattail roots during winter and spring. French had 16,000 ppb in February and Kring and Sheepshead South had 15,000 and 16,000 ppb respectively in May. However, Marguerite did have moderate levels in the summer.

There was no phenanthrene/anthracene in the mud. It was most abundant in the cattail roots in summer. Highest concentrations were found in Marguerite and Route 26 marsh during the summer of 1977, when 15,000 ppb were found in each.

There also was not much fluoranthene/2, 3 benzanthracene in either mud or cattail roots. Highest amount was 440 ppb found in Marguerite cattail roots in the fall of 1976.

Chrysene/Pyrene was the only PAH that occurred in larger amounts in the mud than in the cattail roots. Its highest quantity was found in Sheepshead North in the summer of 1978.

Benzo (a) Pyrene is the PAH most regularly found in the mud and cattail roots (Table 30). These data also are the most useful in correlating the degree of oil impaction to PAH presence. Realizing that there is a problem of selecting an average or typical place to sample in each marsh, the data still indicate that there is 1) an increase in BaP with increased oil impaction, and 2) a definite accumulation in the cattail roots. These tendencies held best for the fall of 1976 and the winter of 1977. However, they weakened in the early summer of 1977 when high water may have reintroduced some of the stranded oil. The values for May 1977 are generally higher but more uneven. It is at this time that plant growth might have been diluting any concentrations in the roots. However samples of cattail tops taken in August contained no BaP.

The samples taken in August 1977 had about the same level of BaP in the mud but there was a general decline in the cattail roots, except at Kring and Marguerite where the effect of BaP may have been more lasting. Although it was found in Route 26 mud, none was found in the cattail roots. There was a particularly high level at Church Bay, with mud (2300 ppb) exceeding cattail roots (1900 ppb). At Spencer Island both cattail roots and mud were equal at 1400 ppb--about the same as Marguerite.

The July 1978 samples indicated a complete collapse of all trends. Only Kring had high values (3,400 and 3,000 ppb). Whether this indicates the effect of the very high spring water levels and flow, or the fact that BaP was degrading is unknown.

Fish and Aquatic

The uptake of PAH by aquatic or semi-aquatic animal life in a marsh should be influenced by its presence in the water or plant food materials. Since there is a rather rapid exchange of water in this riverine environment, it is assumed that the most common source would be the plants. However, many of these animals are carnivorous or omnivorous in their feeding habits. Many feed upon aquatic invertebrates which themselves may be carnivores or herbivores. Those that are herbivores may be feeding upon phytoplankton.

It was impossible to sample the needed quantities of every member of these complex communities. In analysing fish and wildlife, the question became one of whether PAH reached these organisms, whatever the pathway.

A total of 31 samples of young fish were analysed for PAH, including five species. The total PAH found is given by species and area in Table 31. It was not possible to collect young of every species in every area, although such an attempt was made while conducting the field studies. Based on total PAH, trends that could be related to the oil spill were seen only for the pumpkinseed in 1977. Therefore, they were sampled again in 1978 along with yellow perch, another dominant fish species. The pumpkinseed data for 1978 showed the same trend as in 1977. The yellow perch data gave higher levels of PAH than the pumpkinseed, but any correlation to the presence of oil was not as definite. Largemouth bass of the four-inch class had much less PAH than the two-inch class. This had been suspected.

TABLE 30. BENZO (A) PYRENE - ST. LAWRENCE RIVER MARSHES
(ppb by weight)

Site	11/76 Mud	11/76 Cattail	2/77 Mud	2/77 Cattail	5/77 Mud	5/77 Cattail	8/77 Mud	8/77 Cattail	7/78 Mud	7/78 Cattail
French			40	300	150	415	670	100	200	0
Cranberry			38	405	530	2600	370	115	530	0
Crooked	25	200	150	540	25	2800	500	0	10	20
Kring			50	380	710	130	710	1100	3400	3000
Chippewa			20	420	150	1400	60	0	140	260
Marguerite	0	2200	80	1500	180	220	1484	1500	0	650
Sheepshead S	2000	3000	85	560	--	1300	0	90	85	400
Sheepshead N							1300	340	1900	200
Route 26							1700	0	470	100
Clayton							0	160		
Church Bay							2300	1900		
Spencer Island							1400	1400		

TABLE 31. PAH IN YOUNG FISH - ST. LAWRENCE RIVER MARSHES
(ppb by weight)

Fish	Year	Site: French	Cranberry	Chippewa	Marguerite	Sheepshead North	Sheepshead South
Pumpkinseed	1977	0	630	2,160	4,780		
Pumpkinseed	1978	2,580	1,397	5,354	6,452		
Bullhead	1977	12,170	0	9,845		1,890	4,020
Largemouth Bass (small)	1977	2,270	0		2,030		
Largemouth Bass (medium)	1977	0	585		575		
Golden Shiner	1977	5,770	2,285	17,090	6,000	29,310	
Yellow Perch	1977		2,800	12,520	360		
Yellow Perch	1978	8,826	16,035	15,590	14,760		

Of the various PAHs in fish, the phenanthrene/anthracene group was found to contribute substantially to the trend in the pumpkinseed. Chrysene/Pyrene also added to this trend in lesser amounts.

In general naphthalene and biphenyl were frequent but showed few, if any, trends. Naphthalene seemed to be relatively abundant in the yellow perch and golden shiner from all areas. Biphenyl was abundant only in the yellow perch.

Benzo (a) Pyrene was found only occasionally in fish and then in very low amounts. The other PAHs were low and scattered.

Extracts of five fish samples were analysed by GLC with little change except the loss of naphthalene and biphenyl. UV-Vis gave reduced amounts of pyrene but did find some phenanthrene. There was no relationship to the degree of oiling.

It would appear that fish may be deriving some of their PAHs from other sources than the oil.

Only one tadpole was sent in for analysis. This came from Marguerite and contained 81,000 ppb of biphenyl.

Snapping turtles were collected in 1978 from Cranberry and Marguerite. Liver, fat and muscle tissues were analysed. Biphenyl was found in the liver (26,000 ppb) and fat (40,000 ppb) from Cranberry. Nothing was found in the tissues from Marguerite. It had been expected that a scavenger like the snapping turtle would concentrate some of these compounds, particularly in its fat.

Wildlife

Ducks and muskrats were considered the appropriate representatives of the birds and mammals found in these marshes. Tissues of 11 ducklings and 9 muskrats were analysed, totalling 45 samples from ducklings and 24 samples from muskrats.

In 1977 the duckling tissues analysed were skin, fat, liver with gall bladder and breast muscle. Some of the 1978 analyses included brains. Most of the tissues came from mallards and wood ducks. One blue-winged teal was analysed. The results of these analyses are included in Table 32.

It is difficult to determine differences in the species because of the variations that are seen between tissues, years and areas. It appears that the wood duck may have the larger concentration of PAH. However, some of the exceptional quantities are found in the mallard, such as the 3,497,500 ppb measured in fat from Sheepshead. The feeding habits of each individual bird may have great influence here.

Most of the PAHs found in ducklings were in the regions of naphthalene and biphenyl. On the average they were more abundant in the heavily oiled areas

TABLE 32. PAH IN DUCKLINGS - ST. LAWRENCE RIVER MARSHES
(ppb by weight)

Area	Species	Year	Tissue				
			Skin	Fat	Liver	Muscle	Brain
French	Mallard and Wood	1977	551,400	5,400	8,040	1,805	
	Teal	1978	3,200		0	11,000	0
Cranberry	Mallard	1977	8,500	195,100	55,670	253,130	
Crooked	Wood	1977	38,000	252,700	2,800	2,135	
	Mallard	1978	230	0	9,300	1,600	
Chippewa	Wood	1977	6,400	38,000	2,960	0	
	Wood	1978	2,650	800		0	2,000
Marguerite	Wood	1977	72,670	0	5,920	101,800	
	Mallard	1978	6,550	13,700	380	1,000	0
	Wood	1978	22,800		21,200	3,000	1,200
Sheepshead S.	Mallard	1977	500,000	3,497,500	3,030	6,200	

than in the slightly oiled areas. It was not possible to arrange the different tissues in order to reflect the presence of oil.

Extracts of six duck samples were analysed by GLC which showed no naphthalene or biphenyl but did show pyrene and benzo (a) pyrene although this was not related to oil concentration. UV-Vis gave fewer and smaller amounts for these PAHs.

Fat was a difficult tissue to find in young growing wildlife and this was particularly true for the muskrat. Liver and muscle were the primary tissues studied. Other tissues tested at least once were skin, kidney and brain. Table 33 gives the results of these analyses for total PAH.

Some trends that could be associated with the oil were seen in the 1977 data and these were strengthened when Marguerite was specifically contrasted to Cranberry. The contents of skin were about the same, but liver and muscle had many times more PAH in Marguerite than in Cranberry. As with ducklings, most of the PAHs were in the areas of naphthalene and biphenyl. Both of these were quite common in Marguerite cattail roots during the summer period.

Extracts of two muskrat samples were analysed by GLC which produced no naphthalene or biphenyl but pyrene and benzo (a) pyrene were present in both extracts in near equal amounts. UV-Vis gave small amounts for only pyrene.

The presence of PAHs in ducklings and muskrats does not lead to any firm conclusions about their relationship to the oil spill.

Concluding Discussion

The determination of uptake, movement and accumulation of polynuclear aromatic hydrocarbons (PAHs) by biota in the marsh ecosystems of the St. Lawrence River that have flowthrough characteristics was difficult. This was because -

1. there was found to be a considerable variation in the samples of similar materials taken at a given time in a particular marsh.

2. there was a reintroduction of stranded oil whenever water levels increased.

3. there was considerable movement of even the young animals, associated with their feeding activities.

4. there were no accepted standard methods of analysis available that had been thoroughly tested.

Based on the experience gained in this study, the fall season is probably the best time to sample the bottom sediments and plant roots. This is because -

TABLE 33. PAH IN YOUNG MUSKRATS - ST. LAWRENCE RIVER MARSHES
(ppb by weight)

Area	Year	Tissue					
		Liver	Muscle	Fat	Skin	Kidney	Brain
French	1977	1,020[a]	2,584	966,800			
Cranberry	1978	597	2,613		3,000		
Kring	1977	2,460	7,790				
Chippewa	1977	345	3,500				
Marguerite	1977	1,100[a]	0	45,000			
	1978	73,970	35,090		2,600		
Sheepshead No.	1977	58,000	1,900		0	8,200	7,500
Sheepshead So.	1977	575	630	626,000			

[a]One adult liver also analysed having 76,690 ppb PAH.

1. it gives the maximum time after the high water of spring and prior to the freeze up.

2. most of the living plant materials are located in the roots and underwater shoots at that time.

3. the selection of sampling sites can be made with greater ease.

4. other activities on and along the River are much reduced.

5. tributary streams are low and should carry less new material into the marshes.

Animals, however, are full grown by fall and are highly mobile. Therefore, they still must be sampled in later summer while they are actively feeding within the area being studied. Late summer also gives them the maximum time to accumulate materials while growing.

This two-year study followed the introduction of Bunker C oil into marsh environments. A thorough cleanup of the oil followed the spill. The removal of contaminated vegetation was a time consuming task, one that should have given time for various transformation processes to have had their effect. It seems safe to assume that some components of the oil, including PAHs, remained in the ecosystems after completion of the cleanup, although unevenly distributed.

What happened to them? Were any PAHs present in the mud and, if so, were they taken up by the cattail plants? It seems clear there was a considerable amount of PAH that had entered the marsh and its sediments. It would also appear that these materials were being taken up by the cattail roots. Since PAH was also present in the control areas, the presence of other sources complicates the results.

There are some strong suggestions that there was an increase in PAH in the mud that can be associated with an increase in the level of oil impact. This association also seems to exist for the cattail plants. However, it must be kept in mind that the moderately and heavily impacted areas were quite thoroughly cleaned, whereas many, if not most, of the slightly oiled areas were not. This may have reduced the difference between the two extremes.

Some of the individual PAHs were quite seasonal in their occurrence. This suggests the role of plants in accumulating and later releasing this material back into the environment. Many other PAHs occurred in sporadic although sometimes large amounts in the bottom mud and cattail roots. However, benzo (a) pyrene was almost universally present in mud and roots, although not usually in high amounts.

PAH in fish and wildlife was much lower and more irregular than in the sediments or cattail roots. Only young pumpkinseed showed an apparent correlation with the degree of oiling. Although yellow perch had more PAH than the pumpkinseed, there was no trend in the data. It was also found that young largemouth bass contained more PAH than older individuals of the same species. The principal PAHs in pumpkinseed that could be related to the oil were phenanthrene/anthracene and chrysene/pyrene.

Common, and sometimes abundant, PAHs in fish and wildlife were naphthalene and biphenyl, as reported by HPLC. These had been fairly common in cattail roots but not in the mud. Benzo (a) Pyrene which had been the most regular constituent in mud and cattail, was fairly rare in all fish and wildlife.

For the duckling, it was difficult to determine which tissue was most useful in relating PAH to the impact of oil. However, in the muskrat, it appeared that liver and muscle might possibly be used in this manner. Fat was often not available for testing since little was deposited in these rapidly growing young animals.

It should be kept in mind that the cleanup procedure may not have been adequate to prevent false positives, such as the high values for naphthalene and biphenyl shown in the HPLC analysis. GLC showed little improvement except for the loss of these two PAHs. The characteristics of UV-Vis analysis eliminate the 2-ring PAHs from the analysis. However, all HPLC results seem high, indicating a need for further refinement of the cleanup and analysis procedures if PAH evaluation is to become accurate, particularly from animal tissues.

The data clearly establish the presence of PAH in the marshes of the St. Lawrence River. They also indicate a movement from the mud into the cattail and also to a more limited extent into the fish and wildlife. However, the data from such an open ended system include the effects of all sources of PAH, not oil alone. Therefore the exact relationship of the PAH found in fish and wildlife to the degree of impact of Bunker C oil cannot be specifically isolated in a quantitative manner.

Field studies, including the sampling of components of marsh communities, are needed to better understand the practical application of the results of laboratory experiments. Field sampling determines the presence of petroleum components, their duration in an open-ended system and their physical and chemical changes. However, it is important that similar data be available for a period prior to the introduction of oil. Other sources of PAH to the environment should be known, if possible.

Field studies should provide for a continuous monitoring of the environment through which shipping moves. If laboratory experiments can determine the limits of tolerance of various organisms to the several PAHs, the monitoring process can give warning of critical conditions. Such monitoring may be limited to bottom sediments, the water column and plant materials.

SECTION 8

ECONOMIC IMPACT

INTRODUCTION

Efforts in this portion of the report are directed toward setting forth the net impact of the oil spill on the economy of the impact area. This net takes into consideration both shifts in costs and benefits (incidence) between various sectors of the economy and the size of these shifts (magnitude). Determination of both factors, magnitude and incidence, is required to evaluate the economic impact.

In order to derive this impact each sector was examined as a separate entity. Upon completion of this examination the separate sectoral impacts were totaled to derive the net economic impact. Discussed below, by sector, are the impacts determined to have occurred following the June 23, 1976 oil spill.

DIRECT IMPACT

Survey Results

The findings of the survey of riparian owners and operators of commercial enterprise in the area are detailed below. The methodology used in conducting the survey is summarized in Appendix C.

Residential--

Due to differences in duration of use of residential property, two classes were defined. Those properties that are used as permanent residences were differentiated from those that were used as seasonal residences. Due to the level of use it was expected that the impact of the oil spill would be different for each class of residential property.

Permanent--The distribution of the 213 United States and 246 Canadian permanent home owners is reflected in Table 34. Of these 155 U.S. or 72.8 percent and 209 Canadian or 85.0 percent returned the survey form.[1] Overall 79.3 percent of the permanent residence property owners responded.

Analyses of the returned questionnaires reflect that of the 148 U.S. owners who responded to this question, 32.4 percent, and of the 197 Canadian,

[1]Each of the 364 respondents provided enough information to permit analyses of his questionnaire.

TABLE 34. DISTRIBUTION OF ECONOMIC IMPACT QUESTIONNAIRES

Area/ Property Type	Number of Contacts	Number of Responses	Percent Response
United States	1,084	736	67.9
Permanent			
Orleans	14	10	71.4
Alexandria	37	24	64.9
Hammond	7	7	100
Morristown	23	19	82.6
Oswegatchie	29	23	79.3
Ogdensburg	26	19	73.1
Lisbon	14	10	71.4
Waddington	2	0	0
Louisville	30	23	76.7
Massena	31	20	64.5
Total	213	155	72.8
Seasonal			
Orleans	79	70	88.6
Alexandria	74	60	81.1
Hammond	123	112	91.1
Morristown	90	71	78.9
Oswegatchie	56	47	83.9
Louisville	75	66	88.0
Total	497	426	85.7
Commercial			
Fishing Guides	24	8	33.3
Commercial	350	147	42.0
Total	374	155	41.4
Canada	388	319	82.2
Permanent	246	209	85.0
Seasonal	135	107	79.3
Commercial	7	3	42.2
Total Surveyed	1,472	1,055	71.7

42.6 percent indicated they incurred a cost in clean-up efforts after the June 23 spill.[2] The costs reported were either in terms of dollars or hours of labor expended.

U.S. owners reported a total of 432 hours of labor and $7,588 expended in cleanup efforts. The Canadian owners reported 881 hours and $2,246. This totals 1313 hours and $9,834. These expenses were primarily incurred in efforts to remove oil from boats, docks and from the shoreline.

A total of 60 of the 281 respondents[3] indicated they filed insurance claims following the spill. The total amount of the claims was $86,562 with $82,400 submitted by U.S. property owners and $4,162 by Canadian property owners.

Table 35 reflects the degree to which water related recreational activities were disrupted by the spill. Reflected is the fact that 1930 people lost 15,611 recreation days following the spill.

TABLE 35. RECREATIONAL ACTIVITY IMPACT ON PERMANENT RESIDENCE OWNERS AND THEIR FAMILIES

Activity	Number of Persons Unable To Participate	Estimated Total Recreation Days Lost
Swimming	735	2,517
Boating	586	10,234
Fishing	302	1,605
Water Skiing	225	929
Other	82	326
Total	1,930	15,611

Ninety-three of the 321 respondents, or 30.5 percent, reported inconveniences other than loss of recreation following the spill. The major ones reported were the presence of smells and repeated tracking of oil into the home by children and pets.

Data regarding the impact of the spill on prices of homes for sale during or after the spill were not sufficient to allow analysis. Of the 341 respondents only 3 had their homes for sale during the period.

[2] Since the Canadian survey was limited to that portion of the St. Lawrence River where impact was known to have occurred it was expected that the percentage would exceed the U.S. where the entire area downstream of the spill was surveyed.

[3] Respondents refers to those persons answering the specific question being addressed in the text. This number varies by question.

In terms of other impacts not covered by the questionnaire the following were mentioned: damage to natural environment; effect on wildlife and impact on business. The latter is covered under the following sections of this chapter.

Total impact to permanent residents is summarized in Table 37. It totals to $168,542 plus an indeterminate amount caused by inconvenience.

Seasonal--Table 37 reflects the distribution of the location of seasonal residences whose owners were surveyed. Overall 84.3 percent or 533 of 632, responded. Of these 426 were U.S. Owners and 107 Canadian owners.

When asked if any costs were incurred in clean-up efforts 247 of 281, or 87.9 percent, of the respondents indicated they were. The distribution was 205 of 208 in the U.S. and 39 of 76 in Canada.

Expenditures reported included 3,067 hours of labor and $25,186 by U.S. owners and 647 hours of labor and $2,274 by Canadian owners. This totals 3,714 hours of labor and $27,410. These expenses were primarily incurred in efforts to clean boats and docks and to replace boat lines on boats.

Of the 293 U.S. respondents, 131 filed insurance claims totaling $405,301. Of the Canadian respondents, 11 of 102 filed claims totaling $1,856. Overall 142 of 395, or 35.9 percent, filed claims that totaled $407,157.

It was reported that 113 of the 415 respondents did not use their seasonal homes due to the oil spill for a period of time subsequent to the spill. The distribution was 103 of 312 U.S. owners and 10 of 103 Canadian owners or 27.2 percent of the total. Respondents indicated that there were 20,407 days of use lost by 4,507 family members in the U.S. and 1,414 days of use lost by 411 family members in Canada. This amounts to 21,821 days of recreation lost by 4,918 people.

As with permanent home sales, adequate data were not available to quantify the effect of the oil spill on the saleability or price of seasonal homes along the river. The limited data obtained indicate that of the 10 houses for sale which were not sold, the reason given by the owner in 7 cases was the effect of the oil spill. This reflects what those owners perceived as the reason but is not sufficient to statistically verify it as the cause of homes not selling.

The impact of the oil spill on recreation activities of seasonal property owners and their families is reflected in Table 36. Overall, 4,918 people lost 21,821 recreation days following the spill.

When asked if any inconveniences, other than those discussed above, resulted from the oil spill, 175 indicated they did. This accounted for 56.6 percent of the respondents. The major inconveniences reported were the presence of smells, inability to travel to and from the mainland, effect on water supplies and children getting into the oil.

TABLE 36. RECREATIONAL ACTIVITY IMPACT ON SEASONAL RESIDENCE OWNERS AND THEIR FAMILIES

Activity	Number of Persons Unable to Participate	Estimated Total Recreation Days Lost
Swimming	1,392	6,276
Boating	1,446	5,196
Fishing	900	5,254
Water Skiing	934	3,748
Other	246	1,347
Total	4,918	21,821

A summary of the impacts to seasonal residences is also shown in Table 37. The total dollar impact reported was $68,326 plus inconvenience to 175 people.

Commercial/Industrial Properties--

In order to determine the impact of the oil spill on this sector of the economy a series of questionnaires were developed. Similar questions were asked but were oriented specifically toward each type of enterprise that was felt to have a potential for suffering impact. This included not only those enterprises immediately adjacent to the River but also those inland and dependent upon business generated by persons recreating on the River. Included were guide boats, tour boats, marinas, hotels and motels, restaurants, bait and tackle shops, private campgrounds, and gasoline stations.

Guide Boats--There were 24 fishing guides identified and contacted in the impact area. However only 8 responded to the economic impact questionnaire.

When asked to compare the number of parties guided and the length of the season in 1975 and 1976 no significant differences overall were noted. An average of 1.56 parties per week in 1975 as compared to 1.61 in 1976 were reported. Four guides reported no differences while the other four felt there were differences. Two of these felt the cool rainy summer was responsible while one felt the oil spill impacted business.

When the question was asked regarding the number of parties guided during the period June 10-June 23 and June 23-July 7 1975 and 1976 no significant changes were reported. Based upon these limited data it appears as if there was not a significant economic impact on the fishing guides in the area.

Tour Boats--Six tour boat operators were contacted with four responding. The data they provided indicated that there was a slight increase in tour passengers in 1976 compared to 1975. However, data were not provided, as requested, to indicate if there was any change in the number of passengers in the period immediately after the oil spill.

TABLE 37. SUMMARY OF RESIDENTIAL IMPACTS

Type of Impact	Residential Property Owners								Total Residentials
	Permanent				Seasonal				
	United States		Canada		United States		Canada		
	Hours[a]	Value	Hours[a]	Value	Hours[a]	Value	Hours[a]	Value	
Clean-up Costs									
Self Supplied Labor	432	1,728	881	3,524	3,067	12,268	647	2,588	
Cost of Item		7,588		2,246		25,186		2,274	
Purchased Total		$9,316		$5,770		$37,454		$4,862	57,202
	United States		Canada		United States		Canada		
	Days	Value			Days	Value			
Recreation Days Lost[b]	15,611	$153,456			21,821	$214,500			367,956
	United States		Canada		United States		Canada		
Other Income	93 Indeterminate				175 Indeterminate				268 People
Total	$168,542 plus inconvenience to 93 people				$68,326 plus inconvenience to 175 people				$452,158 plus inconvenience to 268 people

[a]These hours reflect the amount of hours of labor the respondent or his family expended. A rate of $4.00 an hour was used to convert the hours reported to dollars. This rate is commensurate with the rate paid to persons working on the clean-up.

[b]A value of $9.83 per day is used to derive a value for recreation days lost. This is based upon data provided regarding expenditures reported in Characteristics, Perceptions and Attitudes of Resource Users in the St. Lawrence-Eastern Ontario Commission's Service Area. St. Lawrence-Eastern Ontario Commission, 1978.

Marinas--Fifteen marinas in the impacted area were surveyed. Responses were received from four. Sales of gas, oil and other supplies decreased between the 1975 and 1976 tourist season (June 15-Sept. 15) from $62,720 to $52,771 or 15.9 percent. All of the respondents had boat launching facilities at their marinas. They reported a slight increase in the number of launches that occurred between the 1975 and the 1976 season. This increase was about 7 percent.

When the operators were asked what they felt was the reason for the differences in sales between 1975 and 1976 two indicated the oil spill and two the cool rainy summer. One operator also indicated that his plan for expansion was delayed due to the impact of the oil spill.

It should be noted that the data reported were from a limited number of operators. Even these reported only a small portion of the data requested. Thus, as indicated before, quantitative analyses are not possible.

Hotels and Motels--To determine the impact of the oil spill on this class 170 operators were contacted. Of these, 78 or 45.9 percent responded. The respondents indicated that their occupancy rate averaged 80.5 percent in 1975 and 71.0 percent in 1976 during the tourist season. The primary reasons cited for this difference and the number of respondents giving those reasons were: oil spill impacts, 18: cool rainy weather, 8; and state of the economy, 4. Eight other operators indicated that the oil spill and the state of the economy were the second most significant reasons for the difference. Twenty-eight operators indicated no difference between the two seasons.

Overall the average percentage of businesses that were dependent on tourists and recreation was 74.9 percent for those operators who responded. They indicated that the average rate per person per night was $10.55. Rates ranged from $6.33 to $13.62.

When asked if they had planned to physically enlarge, modify or change their establishment during the 1976 year 12 responded in the affirmative and 51 in the negative. Of the 12, five completed their plans and five cancelled or postponed them. Three of the five who postponed or cancelled their plans sighted the impact of the oil spill as the reason for their action.

Occupancy during the period June 24-July 7, 1976 was reported to be 62.8 percent. During the same period in 1975 the occupancy rate was 74.0 percent. During the period June 10-June 23, 1976 the rate was 64.8 percent and in 1975 for the same period it was 61.5 percent. This reflects that the 1976 season had a higher occupancy rate immediately prior to the oil spill than the same period the previous year, followed by a rapid decline to a level below that of the previous year immediately after the oil spill.

Respondents reported a total of 240 cancellations with the oil spill given as the reason. This was for the 30 establishments reporting cancellations. An additional 32 operators did not report any cancellations. Based on the average rate these cancellations reduced revenue by $2,532.

Ten establishments provided 472 nights of lodging to personnel working on the cleanup of the spilled oil. Another 51 establishments did not provide such lodging on an extended basis. Based on the average rate these 472 nights of lodging increased revenue $4,980.

In obtaining data relative to employment changes brought about by the spill, operators reported they hired 3 additional people for a total of ten weeks additional employment while 10 others were laid off for a total of 24 weeks employment. Twenty employees had their hours of employment reduced for an average of ten hours per week for four weeks. Their average wage was $2.83 per hour. It was also reported that four employees' working hours were increased a total of 44 hours per week for eight weeks. Their average wage was $2.75 per hour. In addition six employees had their number of working days reduced while none were reported to have their number of working days increased.

Restaurants--A total of 82 restaurant operators were contacted with only 10 responding. Gross receipts for these operators were reported to increase from $114,365 in 1975 to $142,430 in 1976. Three operators indicated the oil spill decreased their receipts while two indicated the Olympics increased their receipts.

When asked if they had plans to physically enlarge, modify or change their establishment during the 1976 tourist year, four indicated they had. Of these four, three cancelled their plans.

Gross receipts for the period June 24-July 7, 1975 were reported as $3,909 while they were $2,661 for the period June 10-June 23, 1975. In 1976 for the same periods they were $9,447 and $5,569 respectively. As is reflected they followed the same trend in both years. After the spill they increased similar to the previous year but were higher in magnitude in 1976. Again it should be noted that no data were provided by the respondents relative to employment. The data provided and described above is of limited nature and not sufficient to allow detailed quantitative analyses.

Bait and Tackle Shops--Only one of the four bait and tackle shop operators provided information in response to the survey. In general the data reflected an increase in sales in 1976 over 1975. Also an increase in sales was recorded in both years for the period June 23-July 7 as compared to June 10-June 23. No data were provided regarding impacts on employment.

Private Campsites--Forty-two private campground operators were identified and contacted. Thirty-two responded. They indicated that the overall occupany rate for 1975 was 86.3 percent while it was 77.5 percent for the 1976 tourist season. The primary reason provided by four respondents for the change was the oil spill while four others felt it was the cool rainy summer.

The average charge per campsite per day was reported as $4.64. This covered 914 campsites. All four of the respondents who had plans to physically enlarge, modify or change the operation of their establishment carried out their plans.

Data on occupancy rates reflect that in 1976 occupancy during the June 24-July 7 period was 74.3 percent while during the June 10-June 23 period it was 69.5 percent. This is similar to 1975 rates which were 82.4 percent and 74.1 percent for the respective periods. These figures are also consistent with the overall occupancy rates for the two years. Insufficient data were reported relative to the employment impacts to allow analyses.

Gasoline Stations--Sixteen of 32 gasoline station operators responded. They reported an increase in total volume from 697,142 gallons in 1975 to 716,869 gallons in 1976. Three operators indicated the reason for the change was the oil spill. Two of these sold greater amounts in 1976 than 1975 while one sold less. On the other hand an operator indicated his volume changed due to the cool rainy summer.

In both 1975 and 1976 a larger volume was sold during the period of June 24-July 7 than the period June 10-June 23. For 1975 the sales were 82,834 and 59,034 gallons respectively and in 1976 they were 97,412 and 76,807 gallons.

As with other types of establishments adequate data werenot provided that would allow analyses of the impact on employment.

Other Commercial--In addition to the above described categories, there were other riparian commercial property owners that had the potential of being impacted by the spill. Twenty-one of these were contacted with 13 being in the United States and 8 in Canada. An additional 10 Canadian property owners could not be contacted by mail or phone.

No impacts were reported by the United States property owners. Included were oil companies, realty companies and bridge and port authorities. All Canadian property owners except one also reported no impact. The exception reported inconvenience to customers, many ruined clothes and the continuing presence of oil residuals. However, no dollar value was attached to these.

OTHER RIPARIAN PROPERTIES

Efforts were undertaken to determine if other than the above described users of the St. Lawrence River waters or riparian property owners were impacted. The extent of the impact to operators of water supply systems, transportation, power production and users of state parks is discussed below.

Water Supply Systems

It was expected that those systems using the St. Lawrence River as a source for municipal water supply would be impacted by the presence of the spilled oil. Contact with municipal officials indicated that no systems were forced to change their mode of operation. However, planning for the use of alternative sources was actively pursued. This did not, however, result in any identifiable costs.

Transportation

Since the St. Lawrence Seaway is a major transportation system, it was expected that the oil spill would have a disruptive effect on the operation of the system. Contact with the St. Lawrence Seaway Development Corporation verified this as they provided the following data.

A total of 42 ships were delayed as a result of the spill (see Table 38). The total delay of 393.3 hours increased transit costs an estimated $171,448. The rates used to determine this are set forth in Table 39.

Power Production

Representatives of the power producers on the St. Lawrence River reported that there were no negative impacts in terms of costs or losses of production due to the spill. Flows were not reduced and thus no reduction in generated power occurred. Maintenance in excess of normal was not experienced either.

TABLE 38. INCREASES IN OPERATING COSTS DUE TO SHIP DELAYS[a]

Class	Number of Ships	Total Length of Delay (Hours)	Operating Costs Per Hours (1976)[b]	Cost of Delay
2	12	107.1	$324	$ 34,700.
3	3	10.5	380	3,990.
4	3	39.7	446	17,706.
5	7	81.9	465	38,084.
6	2	145.9	490	4,018.
7	15	393.3	500	72,950.
Total	42[a]			$171,448.

[a]Does not include 9 ships or tugs of less than 400 feet in length.
[b]See Table 39 for cost determination.

State Parks

Impacts to state parks occurred in the form of physical impact and deprivation of use due to the physical impacts. The physical impacts and the costs associated with removal of the spilled oil are discussed later in this section.

The parks impacted were Keewaydin, Kring Point, Jacques Cartier, Cedar Island, Coles Creek and Robert Moses. Attempts were undertaken to determine the man days of recreation activity that were lost due to the spill. Adequate data upon which to base a statistical analysis were not readily

TABLE 39. HOURLY OPERATING COSTS FOR LAKE VESSELS

Class	Length	Hourly Operating Costs ($) 1967	Hourly Operating Costs ($) 1971	Average Increase Per Year (%) 1967-1971	Hourly Operating Costs ($)[a] 1976
2	400-499	140	205	11.63	324
3	500-549	155	233	12.60	380
4	550-599	165	271	12.90[b]	446
5	600-649	215	305	10.48	465
6	650-699	230	324	10.23	490
7	700-730	260	345	9.00[c]	500

[a]Derived by inflating 1971 costs by the average yearly increases between 1971 and 1976.

[b]Adjusted downward since the estimated rate of 16.05% results in an hourly rate for this class that is greater than for the next larger size class.

[c]Adjusted upward since the estimated rate of 8.18% results in an hourly rate for this class that is less than that for the next smaller size class.

Source: 1967 and 1971 hourly operating costs are from Table E-13 of Regulation of Great Lakes Water Levels, Appendix E, International Great Lakes Levels Board, 7 December 1973.

available. Analyses of the data reflected that park attendance decreased 3.5 percent in 1976 as compared to 1975. Statewide the decrease was 1.6 percent.[4] In the time of two weeks before the spill to two weeks after the attendance decreased 18.1 percent as is reflected in Table 40. The decrease was larger above the spill than below it.

Analysis of park concession revenue reflects an increase both in the area above and below the spill. The increase above the spill was 6.4 percent as compared to that below the spill of 0.7 percent (see Table 41).

Factors such as weather, pollution problems, economic recession, the Summer Olympics and others influenced the number of park users. Comparison within the area below the spill site indicates that there was a redistribution of park users. Those sustaining a high impact from the spill, Keewaydin, Kring Point and Jacques Cartier, experienced the greatest decrease while Robert Moses, which was not significantly impacted, reported an increase in users.

Expenditures by campers in the area were reported to be $4.38 per person per day (Palm). It is estimated that the difference in the area average attendance and the reported attendance below the spill at Keewaydin, Kring Point, Jacques Cartier resulted in about 20,100 fewer people at these parks. Their estimated expenditure would have been $88,000.

In the Robert Moses area there were about 17,900 more users than there would have been if attendance there had been equal to the average for the area. This increased attendance resulted in an estimated $78,400 increase in expenditure in the Robert Moses area.

The above analyses are based upon the hypothesis that the decrease in use of parks physically impacted by the spill were increases experienced at Robert Moses State Park. This has not and at this point can not be substantiated.

Table 42 summarizes the above discussed impacts to other riparian properties.

Other Sources

Insurance Claims--

Following the oil spill numerous claims were filed with the insuror of the NEPCO 140. The amounts claimed can be used as a proxy to damages sustained by those who filed them. It must be held in mind though that the dollar amount of damages claimed is not an exacting measure of damages sustained. With this in mind details of both settled and unsettled claims will be discussed below.

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[4] If Long Island, New York City and Taconic park systems are excluded park attendance decreased 0.2 percent between 1975 and 1976.

TABLE 40. PARK ATTENDANCE

Above Oil Spill	1975	1976	% Change
Southwick Beach[a]	12,477	8,618	-30.9
Westcott Beach[a]	43,545	27,539	-36.8
Long Point[a]	4,733	4,648	- 1.8
Cedar Point[a]	16,087	12,801	-20.4
Total	76,842	53,606	-30.2
Below Oil Spill			
Grass Point[a]	6,720	4,895	-27.2
Wellesley Island[b]	207,190	179,078	-13.6
Keewaydin[b]	35,045	18,865	-46.2
Kring Point[a]	12,069	7,418	-38.5
Jacques Cartier[b]	44,254	30,838	-30.3
Robert Moses[a]	49,064	58,350	18.9
Total	354,342	299,444	-15.5
TOTALS	431,184	353,050	-18.1

[a]Daily totals (6-12 through 7-7 for 1975, 6-10 through 7-5 for 1976).
[b]Monthly totals (June, July, August, and September 75-76).

TABLE 41. REVENUE FROM PARK CONCESSIONS*

Above Oil Spill	1975	1976	% Change
Southwick Beach	$ 2,046.64	$ 2,974.62	45.3
Westcott Beach	2,068.44	1,982.55	- 4.2
Long Point	371.50	476.00	28.1
Cedar Point	19,584.33	20,185.89	3.1
Total	$24,070.91	$25,619.06	6.4
Below Oil Spill			
Grass Point	$ 5,474.73	$ 5,296.77	- 3.3
Wellesley Island	12,550.62	13,827.03	10.2
Keewaydin	2,214.07	1,101.55	-50.2
Kring Point	2,565.40	2,660.26	3.7
Jacques Cartier	379.63	390.46	2.9
Robert Moses	627.97	697.28	11.0
Total	$23,812.42	$23,973.35	6.4
TOTALS	$47,883.33	$49,592.41	3.6

*June through September.

TABLE 42. SUMMARY OF OTHER SECTOR IMPACTS

Sector	Type of Impact: Positive	Negative
Municipal Water Systems	None Reported	None Reported
Transportation	None Reported	42 ships delayed for 393.3 hours at an increased operating cost of $171,448.
Power Production	None Reported	None Reported
State Parks	Increase at Robert Moses	Decrease at Kring Point, Jacques Cartier and Keewaydin

Settled Claims--A total of 543 claims amounting to $81,470.42 filed by individuals have been settled. Table 43 provides details on the geographic distribution of these claimants. As can be seen the largest number of claimants were from the towns of Alexandria, Hammond and Louisville. Table 44 reflects these numbers as percentages of the total number of riparian properties in each town.

It should also be noted that the policy regarding insurance settlements was to settle small claims as soon as possible. Thus the average settlement of $150.04 does not include the larger claims which are currently mostly unsettled.

In addition the State of New York filed a claim for $10,363,800. Of this $9,010,000 was duplication of the federal government's claim for an identical amount to cover its costs of clean up; $63,000 for contravention to water quality standards (Econ Law 71-1941); $1,220,000 for contravention of purity (Econ Law 17-0501); $10,800 for discharge of material injurious to fish life; and $40,000 for loss of use of state parks and public lands. A settlement of $75,000 was agreed upon to cover $15,000 spent by the State in cleanup, $45,000 for salaries and expenses of regular state employees, and $15,000 for statutory penalities.

Unsettled Claims--A total of 174 claims amounting to $26,005,351.63 are unsettled (See Table 45). These claims are currently under litigation. In all cases except four, property damage is the sole or one of the reasons given as the basis for the claim.[5] Due to the limited extent of the information filed it was not feasible to determine the geographic distribution of the claimants.

[5] A basis for the claim was not specified in four cases.

TABLE 43. NUMBER AND AMOUNT OF SETTLED INSURANCE CLAIMS[a]

	Number of Claimants	Percent of Claims	Settlement($)	Average Claim($)	Percent of Total Settlement
Orleans	46	8.5	7,354.73	159.88	9.0
Clayton	20	3.7	2,665.27	133.26	3.3
Alexandria	202	37.1	39,066.69	193.40	48.0
Hammond	96	17.7	18,917.24	197.05	23.1
Morristown	19	3.5	2,821.83	148.52	3.5
Oswegatchie	9	1.7	2,043.74	227.08	2.5
Ogdensburg	4	.7	597.36	149.34	.7
Lisbon	2	.4	296.00	148.00	.4
Waddington	0	--	0	0	--
Louisville	118	21.7	2,950.00	25.00	3.6
Massena	1	.2	228.00	228.00	.3
Total U.S.	517		76,940.86	148.82	
Brockville	26	4.8	4,529.56	174.21	5.6
Grand Total	543	100	81,470.42	150.04	100

[a]Includes 543 of 1533 claims for which addresses could be determined. Total claims were $208,172.33 or $137.78 per claim.

Source: Listing filed by Kernan and Kernan with U.S. District Court, Northern District of New York on December 30, 1976.

TABLE 44. DISTRIBUTION OF SETTLED INSURANCE CLAIMS

Town	No. of Riparian Property Owners	No. of Claimants	Percent of Riparian Owners
Orleans	435	46	10.6
Clayton	886	20	2.3
Alexandria	771	202	26.2
Hammond	387	96	24.8
Morristown	358	19	7.4
Oswegatchie	267	9	3.4
Ogdensburg	66	4	6.1
Lisbon	44	2	4.5
Waddington	370	0	0
Louisville	185	118	63.8
Massena	111	1	0.9
Total	3,830	517	13.3

TABLE 45. NUMBER AND AMOUNTS OF UNSETTLED INSURANCE CLAIMS

Nature of Claim	Number of Claims	Amount Claimed($)	Average Claimed($)
Property damage	161	3,024,479.30	18,785.59
Property damage, invasion of privacy and mental anquish	1	7,500.00	7,500.00
Property damage and privative damage	1	290,000.00	290,000.00
Property, punitive and statutory damages	4	1,300,000.00	325,000.00
Property damage, statutory liability and natural resources and wildlife damage	1	21,000,000.00	21,000,000.00
Property and punitive damages	1	175,000.00	175,000.00
Property damage and credit against limitation fund	1	208,172.33	208,172.33
Not stated in claim	4	200.00	50.00
Total	174	26,005,351.63	149,456.04

Source: Listing of claims provided by Healy and Baillie, counsel for Oswego Barge Corporation.

Included in the unsettled claims is a $21,000,000 suit by the U.S. government. A portion of this (about$8.5 million) is to cover the actual costs incurred in cleaning up the spill. A suit of $25,000 was brought by the Nature Conservancy and the Central New York Chapter of the Nature Conservancy to cover damages to Ironsides Island and to the blue heron population residing there.[6] Other claims were filed by marina and resort operators and owners of seasonal and permanent homes in the impacted area.

Employment--

The net impact on employment is the summation of the impact on employment in the commercial establishments that are dependent upon the tourism

[6]Ironside Island is an island in the St. Lawrence River owned by the Nature Conservancy. It is the site of an extensive blue heron rookery.

and recreation trade and the employment generated through efforts to clean-up the oil. The former is derived primarily from the mail survey conducted. The latter from information provided by the clean-up contractors. It should be kept in mind that not only is the level of employment but also the distribution of employment important in this analysis.

Decreases

The decreases in employment were discussed earlier in this section. They are summarized below in Table 46. As is evident few respondents provided the requested data regarding the employment impact of the oil spill. Thus, little can be stated regarding employment changes in the service-oriented tourism/recreation sector of the economy. The hotel/motel section of that sector experienced an estimated decrease in employment equivalent to 70 work weeks as a result of the spill.

TABLE 46. EMPLOYMENT DECREASES

Type of Business	Reported Decrease	Percent Response	Adjusted Decrease
Guide Boats	No Data Obtained	--	--
Tour Boats	No Data Obtained	--	--
Marinas	No Data Obtained	--	--
Hotels/Motels	32 weeks	45.9	70 weeks
Restaurants	No Data Reported	--	--
Bait and Tackle Shops	No Data Reported	--	--
Private Campsites	No Data Reported	--	--
Gasoline Stations	No Data Reported	--	--

Source: Economic impact mail survey conducted by the St. Lawrence-Eastern Ontario Commission, 1977.

Increases

Employment increases due to the oil spill were created by the labor intensive operation of cleanup. Data provided by cleanup contractors indicated that the typical person employed was young with about one half coming from the local area. Table 47 reflects the place of residence of these employees.

Employees were categorized into three general groups. They were supervisors, foremen, equipment and machine operators/laborers. The starting hourly rates were approximately $8.00, $6.00, and $5.00 respectively. Table

TABLE 47. RESIDENCE OF CLEANUP EMPLOYEES

Home Address		Number of Employees
Clayton		81
Alexandria Bay		16
Watertown		17
DePauville		6
Remainder of Jefferson County		18
St. Lawrence County		279
Remainder of New York State		46
Out of State		432
	Total	895

48 reflects the number of employees throughout the cleanup period. A total of 22,220 days of employment was completed. This amounted to an expenditure of $2,492,952 for labor.[7]

As stated earlier the average age of the employee was young. This averaged 22 years for temporary help; 25 for permanent help and 28 for supervisors.

CLEANUP COSTS

The dollar amount of the cleanup discussed here is that amount paid by the United States Coast Guard to cleanup contractors. This amounted to $8,650,242 (see Table 49).

Based on contractors' data, labor and equipment costs were the largest components of these costs. They amounted to 36 and 31 percent respectively.

Efforts to determine the cost of cleanup per unit length of shoreline for various types of shoreline were unsuccessful. The data, in the form of a billing to the USCG, were not in a form that would allow this.

[7] Per personal conversations with representatives of major clean-up contractors.

TABLE 48. NUMBER OF PERSONS EMPLOYED

Date (1976)	Supervisors	Foremen	Operators/Laborers	Total
6/23	6	17	104	127
24	7	19	116	142
25	8	20	109	137
26	9	21	164	194
27	9	21	154	184
28	16	27	223	266
29	17	28	316	361
30	19	37	328	384
7/1	20	41	344	405
2	20	47	389	456
3	21	47	418	486
4	19	49	437	505
5	19	50	438	507
6	21	48	441	510
7	20	48	450	518
8	21	46	454	521
9	22	47	443	512
10	21	44	454	519
11	4	13	137	154
12	20	46	449	515
13	22	45	441	508
14	21	46	447	514
15	21	47	443	511
16	21	47	445	513
17	5	10	58	73
18	2	4	25	31
19	18	44	407	469
20	20	44	390	454
21	20	44	395	459
22	20	44	390	454
23	15	45	388	448
24	5	10	42	57
25	5	4	30	39
26	17	44	392	453
27	17	44	354	415
28	18	43	363	424
29	17	43	378	438
30	14	43	367	424
31	4	11	63	78
8/1	2	7	41	50
2	16	44	384	444
3	17	43	385	445
4	16	44	397	457
5	15	39	334	388
6	12	33	313	358
7	3	11	19	33

TABLE 48. NUMBER OF PERSONS EMPLOYED
(Continued)

Date (1976)	Supervisors	Foremen	Operators/Laborers	Total
8	2	3	15	20
9	10	32	120	162
10	12	32	284	328
11	12	32	259	303
12	11	27	253	291
13	9	25	200	234
14	5	5	31	41
15	2	3	18	23
16	8	24	197	229
17	8	24	207	239
18	9	25	225	259
19	9	25	222	256
20	9	24	215	248
21	5	6	19	30
22	2	6	21	29
23	7	20	212	239
24	7	23	217	247
25	6	23	208	237
26	6	23	219	248
27	6	23	215	244
28	4	7	16	27
29	2	3	14	19
30	6	20	193	219
31	4	19	191	214
9/1	6	21	192	219
2	5	21	183	209
3	5	21	181	207
4	2	4	13	19
5	2	2	13	17
6	2	3	12	17
7	5	18	179	202
8	5	14	118	137
9	6	18	134	158
10	6	17	122	145
11	4	4	9	17
12	1	4	12	17
13	6	15	109	130
Total Man-days	898	2,215	19,107	22,220

TABLE 49. CLEANUP COSTS

Contractor	Amount Paid
New England Pollution Control Company	$ 325,116
Marine Pollution Control Company	529,659
Coastal Services, Inc.	3,023,612
Sealand Restoration	3,348,838
McAllister	51,150
St. Lawrence Seaway Development Corporation	518,696
Canadian Ministry of Transport	843,171
	$8,650,242

Source: U.S. Coast Guard, 9th District, Cleveland.

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APPENDIX A. SCIENTIFIC NAMES

Fish

Listed after Table 6.

Amphibians[1]

Bullfrog	*Rana catesbeiana*
Green Frog	*Rana clamitans*
Leopard Frog	*Rana pipiens*

Reptiles[1]

Snapping Turtle	*Chelydra serpentina*
Stinkpot	*Sternotherus odoratus*
Map Turtle	*Graptemys geographica*
Painted Turtle	*Chrysemys picta marginata*
Blanding's Turtle	*Emydoidia blandingi*
Water Snake	*Natrix sipedon*

Birds[2]

Common Loon	*Gavia immer*
Great Blue Heron	*Ardea herodias*
Green Heron	*Butorides striatus*
Great Egret	*Casmerodius albus*
American Bittern	*Botaurus lentiginosus*
Least Bittern	*Ixobrychus exilis*
Canada Goose	*Branta canadensis*
Mallard	*Anas platyrhynchos*
Black Duck	*Anas rubripes*
Pintail	*Anas acuta*
Blue-winged Teal	*Anas discors*
Green-winged Teal	*Anas crecca*
Wood Duck	*Aix sponsa*
Canvasback	*Aythya valisineria*
Redhead	*Aythya americana*
Lesser Scaup	*Aythya affinis*
Bufflehead	*Bucephala albeola*
Turkey Vulture	*Cathartes aura*
Red-tailed Hawk	*Buteo jamaicensis*

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[1] Scientific names of Amphibians and Reptiles from Conant (1975).
[2] Scientific names of Birds from Bull and Farrand (1977).

Birds (continued)

Harrier	*Circus cyaneus*
Osprey	*Pandion haliaetus*
Virginia Rail	*Rallus limicola*
Common Gallinule	*Gallinula chloropus*
Sora	*Porzana carolina*
Common Snipe	*Capella gallinago*
Woodcock	*Philohela minor*
Black Tern	*Chlidonias nigra*
Common Tern	*Sterna hirundo*
Herring Gull	*Larus argentatus*
Ring-billed Gull	*Larus delawarensis*
Belted Kingfisher	*Megaceryle alcyon*
Tree Swallow	*Iridoprocne bicolor*
Bank Swallow	*Riparia riparia*
Barn Swallow	*Hirundo rustica*
Rough-winged Swallow	*Stelgidopteryx ruficollis*
Long-billed Marsh Wren	*Cistothorus palustris*
Yellow Warbler	*Dendroica petechia*
Red-winged Blackbird	*Agelaius phoeniceus*
Grackle	*Quiscalus quiscala*
Swamp Sparrow	*Melospiza georgiana*

Mammals[3]

Muskrat	*Ondatra zibethicus*

Plants[4]

Stonewart	*Chara vulgaris*
Cattail	*Typha spp*
Sago Pondweed	*Patamogeton pectinatus*
Flexible niad	*Najas flexilis*
Water weed	*Elodea canadensis*
Water Celery	*Vallisneria americana*
European Frogbit	*Hydrocharis morsus-ranae*
Coontail	*Ceratophyllum demersum*
Pond Lilies	*Nuphar* sp. and *Nymphaea* sp.
Water milfoil	*Myriophyllum* sp.
Bladderwort	*Utricularia vulgaris*

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[3] Scientific name from Miller and Kellogg (1955).
[4] Scientific names from Fernald (1950).

APPENDIX B. DESCRIPTION OF RESIDUAL CONTAMINANTS JUNE 23, 1976 OIL SPILL

Date:______________________________

Location Description

Map Location Symbol______________________

Type Shoreform/Structure__________________

Type Vegetation Affected__________________

Residual Description

Band: width_________ length_________ thickness________

Coating: area covered____x_____ thickness_____________

Globs: area covered__________ thickness_____________

floating or submerged________ estimate of quantity_______

Comments:____

APPENDIX C. ECONOMIC IMPACT QUESTIONNAIRE

The following procedures were followed in conducting the mail survey.

Residential Properties

All seasonal and permanent residential properties in the impact area in the United States were identified from current tax rolls. Each owner was contacted as follows:

Attempt 1 - A letter, questionnaire and return envelope were mailed.

Attempt 2 - Five days after Attempt 1, a reminder post card was mailed.

Attempt 3 - Ten working days after Attempt 2, a reminder letter, questionnaire, and return envelope were mailed.

Attempt 4 - Ten working days after Attempt 3, a letter, questionnaire and return envelope were mailed.

A listing of Canadian owners was provided by Environment Canada personnel.

Commercial Properties

All U.S. commercial properties in the towns bordering the St. Lawrence River were identified from tax rolls, Chamber of Commerce contacts, telephone directories, and other sources. Environment Canada personnel provided a listing of Canadian properties. The contact schedule for residential property owners was followed.

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/7-79-256	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Damage Assessment Studies Following the NEPCO 140 Oil Spill On the St. Lawrence River		5. REPORT DATE December 1979 issuing date 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Daniel J. Palm & M.M. Alexander, D.M. Phillips & P. Longabucco		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS St. Lawrence-Eastern Ontario Commission Watertown, NY 13601 and Suny College of Environmental Science and Forestry Syracuse, NY 13210		10. PROGRAM ELEMENT NO. INE 623 11. CONTRACT/GRANT NO. R805031.01.0
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15. SUPPLEMENTARY NOTES

16. ABSTRACT The primary objective of this two-and-one half year research effort was to determine the environmental and economic impacts of the NEPCO 140 oil spill. This spill occurred in the freshwater environment of the St. Lawrence River on June 23, 1976.

The cleanup operation, which cost about 8.6 million dollars, was reviewed to compare it to the priority cleanup scheme prepared by a private consultant at the request of EPA. In addition, field surveys of residual hydrocarbons were undertaken in the fall and spring following the spill to determine the effects of time and the elements on these residuals.

Upon completion of a short background discussion on petroleum in the environment and a description of the study area, information is provided regarding the diversity and abundance of wildlife in the study area. This information was derived through extensive field survey and is compared to information from areas outside the influence of the spill. This is followed by a discussion of polynuclear aromatic hydrocarbons (based on two years of sampling), and their impacts on the various components of the environment.

The economic impacts of the spill are summarized in terms of direct economic impact experienced by both residential and commercial property owners as well as other classes of riparian property owners. Data were gathered primarily through a mail survey of property owners and review of documents such as insurance claims and cleanup contractors' records.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Oil Recovery Assessments Environmental Surveys Wildlife Economic Analysis	NEPCO 140 Damage Assessment Studies Oil Spill Polynuclear Aromatic Hydrocarbons Wildlife Impacts Economic Impacts	

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