



## Urban Spill Management Planning in the Greater Toronto Area

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**Abstract.** One of the major water pollution sources in the Greater Toronto area is land spills. Land spills are defined to be originated from industrial and municipal lands and are different from tanker spills in oceans. Land spills affect air, water, soil and their associated terrestrial and aquatic species. In 1988, the Province of Ontario established a Spill Action Centre (SAC) to document land spill records. In cooperation of SAC, Ryerson University's researchers have compiled a geocoded land spill database for the Greater Toronto area and conducted a series of research projects to facilitate spill management planning. This paper overviews the research projects which include the statistical and spatial analysis of spill characteristics, development of a spill management planning framework, and evaluation of spill management options.

*Keywords:* land spills, statistical and spatial characteristics, geographic information system, spill prevention, spill control systems.

### 1. Introduction

One of the major water pollution sources in the Greater Toronto area (GTA) is land spills. Land spills are defined to be originated from industrial and municipal lands and are different from tanker spills in oceans. Between 1998 and 2000, there were 2475 oil spills (estimated 830,600 L) and 1584 chemical spills (estimated 1,125,000 L) in Toronto, Richmond Hill, Markham, and Vaughan (major municipalities in GTA). The primary causes of spills were human error and/or equipment failure (Li and McAteer 2000). It has been well documented that spills affect air, water, soil and their associated terrestrial and aquatic species (Tagatz 1961; Hutchinson et al. 1974; Postgate 1979; McKinley et al. 1982; Rogerson et al. 1982; Zeikus 1983; Shales et al. 1989). The GTA is the economic engine of Canada and the associated commercial and industrial activities are the result of our industrial-based economy. With the support from federal, provincial, and municipal governments, the redevelopment of the Toronto waterfront is considered to be a major infrastructure construction and rehabilitation project in Canada. Recognizing these opportunities and the Toronto's watershed restoration targets and priorities, the Government of Canada's Great Lakes Sustainability Fund, the Toronto and Region Conservation Authority, the City of Toronto, the Town of Richmond Hill, and the Ministry of Environment's Spills Action Centre (SAC) sponsored a series of research studies to evaluate spill characteristics and management options.

This paper overviews the research study findings on land spill management in the GTA. The following sections describe the compilation of spill database, the statistical analysis of spill event characteristics, the spatial analysis of spill locations, and evaluation of spill management options.

### 2. Land Spills

#### 2.1 Land spill database

The oil and chemical spill records in the GTA were provided by SAC and the attributes include date, municipality,

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owner name, municipal address where a spill occurs, type, estimated volume, source, sector, reason, cause, and impact. These records were evaluated for consistency (e.g. spill event volumes, cause, reason). For each spill record, the associated municipal address was checked for spelling and postal codes before geo-coding (i.e. assignment of longitude and latitude). Additional attributes such as locations (e.g., parking lot, gas stations, roads, etc.), road types (e.g. local, collector, arterial, highway), and chemical classes (e.g. cancer class, chemical family) were added to the spill database. The updated data were eventually developed into a Microsoft ACCESS database and linked to ArcGIS. The following subsections describe the statistical analysis of oil spills and the spatial analysis of chemical spills in the City of Toronto. Similar analyses of oil and chemical spills were also conducted for other municipalities in the GTA (Li 2002a, 2002b, 2002c, 2002d, 2002e; Li 2003)

## 2.2 Statistical analysis of oil and chemical spill characteristics in the City of Toronto

As indicated in Table 1, the annual number of oil spills in Toronto (which impact on water) fluctuates from 99 to 191 while the annual oil spill volume varies between 12,460 to 122,800 L from 1988 to 2000 (Li, 2002a). On the average, the average annual number of oil spills is about 148 and the average spill event volume is about 332 L. However, the range of oil spill event volume can vary between almost minimal to 85,500 L. As a result, information such as average spill event volume may not be useful for sizing spill control systems.

**Table 1** Annual statistics of oil spills which impact on water in Toronto (Li, 2002a)

Year	# Of Spill	Total Spill Volume (L)	Average Spill Event Volume (L)	Max Spill Event Volume (L)	Min Spill Event Volume (L)
88	155	104000	671	50000	0.5
89	149	122798	824	65000	0.5
90	129	30000	233	6750	0.25
91	144	36327	252	11700	0.5
92	148	118200	799	85500	0.25
93	178	18394	103	2000	0.5
94	119	14115	119	1380	0.5
95	191	56516	296	40000	0.5
96	160	17168	107	7000	0.1
97	164	12460	76	1125	0.5
98	143	34905	244	12500	0.5
99	99	26100	264	16500	0.15
2000	72	20975	291	7000	0.5
Average	148	49249	332		
Total:	1851	611958			

Five major oil spill locations are observed: roads, service stations, parking areas, storage depots, parking, and hydro related facilities. The largest spill event volume and total volume are observed at storage depots, service stations, roads and parking areas and their characteristics are listed below.

### Service Stations

Many service stations are located at arterial roads while others can be found at collector and local roads. A typical gas station has 4 to 6 valves allowing gasoline from a fuel tank truck to transfer into an underground storage tank through a pipe. The spill data reveal that if not properly sealed, the valve may overflow. This is the major cause of spills and these spills may result in water contamination. A leaky underground storage tank is the main reason for soil contamination. New design guidelines suggest that underground tanks be double walled to prevent fuel leak. Gasoline (87,450 L) and diesel fuel (10,260 L) are the primary types of oil spills.

### Storage Depots

Storage depots are commonly used to store gasoline and diesel fuel. The size may vary from thousand liters to million liters depending on its purpose and location. Petroleum companies may own several huge fuel tanks at their storage depots. These tank fields are typically located at less urbanized areas. Small factories have small storage depots which store hydraulic oil and fuel. Overall, gasoline is the major oil spills at these locations (67,443 L) and these spills usually occur in tank fields owned by petroleum companies.

### Roads

Roads have the largest number of occurrences (645 water contaminated spills). It is necessary to examine different types of roads and the seasons of occurrence. Oil spills occur frequently on local roads. They are primarily caused by small vehicles, resulting in a small quantity. In terms of spill event volume, obviously, highways, arterial and collector roads are the types of roads frequently used by fuel trucks, which make them susceptible to fuel spills (especially diesel fuel). Summer is the busiest spill season as the number of running trucks increases on each type of roads. Large amount of spilled oil enters the sewers and only a few spills cause soil contamination by off-road vehicles.

Percentile values of oil spill event volumes which impact on water across the city are shown in Table 2. The largest frequency and volume of oil spills are diesel fuel and gasoline. The primary reasons of oil spills are related to human errors and equipment failure. About two-thirds of the oil spills in Toronto were cleaned up after their occurrence.

**Table 2** Percentile event volumes of oil spills in Toronto (Li 2002a)

Location	95%	90%	85%	80%	75%	Total # of Spills
Road	500	375	225	200	150	523
Service Station	250	110	80	50	45	383
Parking Lots	800	450	250	200	150	246
Storage Depot	1500	900	455	329	225	237
Hydro related facilities	360	200	136	125	100	165

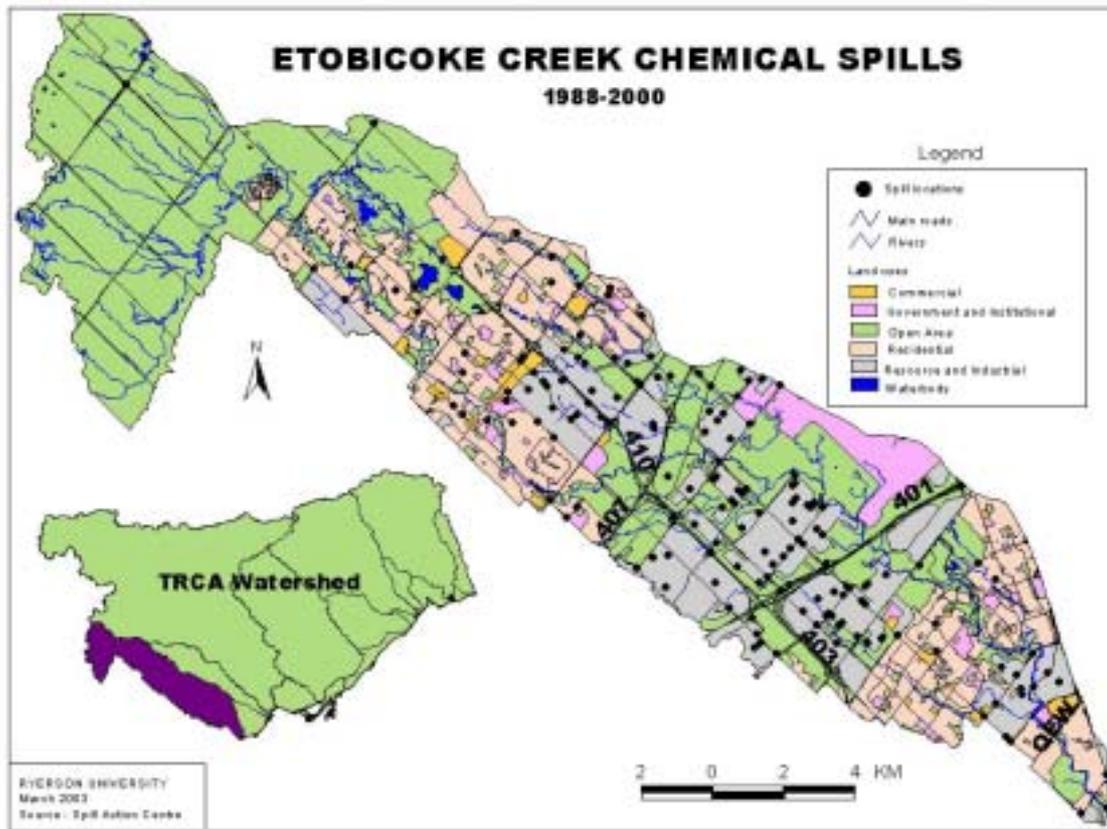
In the City of Toronto, the frequency of chemical spills reaches the highest in 1997 and at summer months. Among all these spills, Ethylene Glycol (Antifreeze), used motor oil, smoke, waste oil, and oily water are the more frequent chemical types. In terms of volume, natural gas, CFC and refrigerant are the largest while waste oil and oil water are the second largest. Most of the chemical spills are originated from industrial plants, motor vehicles, transportation vehicles, and storage facilities. However, chemical spills at pipelines, storage facilities, motor vehicles, and industrial plants have the largest volume. Chemical, transportation, and general manufacturing sectors have frequent spills while petroleum sector produces the largest spill volume.

Chemical spills which escape to atmosphere are frequent and are very large in volume. Parking areas, storm sewers, roads, and water bodies are also frequent spill locations. Water pollution (e.g., watercourses, surface and ground water) and soil contamination are the most frequency impacts of chemical spills while the largest chemical spill volumes are associated with air pollution. Container and pipe line leaks are the primary causes of chemical spills while the pipeline leak results in the largest chemical spill volume.

### 2.3 Spatial analysis of chemical spills in the Etobicoke Creek watershed in GTA

The Etobicoke Creek watershed drains a total area of 211 square kilometers and flows 60 kilometers into Lake Ontario (Li, 2003). There are three distinct branches: the Main Branch, Little Etobicoke Creek, and Spring Creek. It encompasses four municipalities: Caledon, Brampton, Mississauga, and Toronto. Spill data from 1988 to 2000 for Toronto, Mississauga, Brampton, and Caledon are compiled from the Ontario Spill Action Centre's (SAC) spill records. In order to identify the location of spills in the watershed, addresses of spills are geocoded. Geocoding is a process where a municipal address is converted into longitude and latitude. By overlaying the watershed boundary with spill locations, the spills within the Etobicoke Creek watershed were then extracted out. Spills were then divided into two groups for spatial and statistical analysis: (1) spills which caused water impacts (water-impact spills); and (2) spills which caused soil impacts (soil-impact spills). Fig. 1 shows the spatial distribution of chemical spills which caused water impacts in the Etobicoke Creek Watershed. It is noted that most of the spills are located in industrial areas of Cities of Brampton and Mississauga.

Chemical spill characteristics were analyzed in terms of frequency, volume, and cause. The most frequent water-impact chemical spills are Ethylene Glycol (anti-freeze), waste oil, and paints while the largest chemical spill is alcohol, used motor oil. The most frequent soil-impact chemical spills are paints, waste oil, solvent, alcohol, while the largest soil-impact oil spill is alcohol. The primary cause of chemical spills is container leaks. Analyses of chemical spills on soil can also be found in Li (2003).



**Figure 1** Spatial distribution of chemical spills in the Etobicoke Creek watershed (1988-2000)

### 3. Land Spill Management Planning Frameworks

In order to manage land spills, there is a need to develop planning frameworks for both industries and municipalities. A comprehensive spill management planning framework for petroleum industries has been developed at Ryerson University and demonstrated in Trinidad (Tang, 2005). It consists of a characterization of oil spills, an identification of oil spill prevention, control and clean-up options, as well as an economic evaluation of spill impacts and management options (Fig. 2). Each component of the oil spill management framework is illustrated in the recommended sequence in which they should be considered. The oil spill characterization step identifies the trends and factors that influence oil spill events, which translates into the mobilization of appropriate oil spill prevention measures such as the development of a suitability matrix to identify preferred prevention measures to target specific oil pollution sources. Other areas of oil spill prevention should include oil spill contingency planning, ISO 14001 certification and adherence to applicable environmental laws. Given the fact that with or without preventative measures, many oil spills are accidental in nature, oil spill controls are necessary to contain the spilled oil into a predefined area, in order to prevent it from flowing into and contaminating adjacent environments. Oil spill clean-up measures are mobilized next, to reduce or eliminate harmful environmental impacts to the surface, subsurface and water environments. Unfortunately, cleaning a contaminated site does not always return the environment to its former ecological integrity, instead, remediation measures are required to rehabilitate the natural environment affected by oil pollution. Lastly, it is important to examine the cumulative cost of oil spills, which include the clean-up cost and compensation paid to external parties for damage to their property. Knowledge of the cumulative oil spill expenditure is an important consideration, and especially useful when encouraging polluters to develop comprehensive spill management plans. This framework can be applied to other industries in a similar manner.

A spill management planning framework has also been developed for municipalities (Li, 2002c, 2002d, 2002e). It consists of the following three parts:

### Oil spill prevention

Municipalities should adopt sewer use by-laws (e.g. Toronto sewer use by-law) which regulate industrial discharges to the sewers and require industries to prepare pollution prevention plans. Most of the Toronto's spills entered municipal sewers before reaching rivers and lakes. In order to address the spill problems effectively, the former Metro Council adopted Clause no. 21(n) of Report No. 4 which addressed pollution prevention initiatives around regulating wastes being discharged into sewer system. The City of Toronto is probably one of the first municipalities in Canada to incorporate Pollution Prevention (P2) Planning requirements into its new sewer use by-law. Industries are required to carry out pollution prevention planning. To assist industries to comply with the P2 planning requirements, the Canadian Centre for Pollution Prevention (C2P2), formed in 1992 by Environment Canada, will serve as an information and training centre for pollution prevention strategies. This cooperation between Environment Canada and Toronto is facilitated through a 50% subsidy from the Federal Government's Great Lakes 2000 Clean-Up Fund. The new Toronto's Sewer Use By-law No. 457-2000 has been incorporated into the Municipal Code, Chapter 681, Article I, which requires Pollution Prevention Planning by industries discharging subject pollutants. Chapter 681-9 stipulates that the person responsible or the person having the charge, management, and control of the spill immediately notify the Commissioner and provide any information with regard to the spill. The person shall do everything reasonably possible to contain the spill, protect the health and safety of citizens, minimize damage to property, protect the environment, clean up the spill and contaminated residue and restore the affected area to its condition prior to the spill. The person shall provide a detailed report on the spill to the Commissioner within 5 days after the spill. Industries at whose premises a spill has occurred have to submit an updated plan and plan summary to the Commissioner within 30 days of the spill. Chapter 681-10 stipulates that every owner or operator of a restaurant, commercial, industrial or institutional premises, take all necessary measures to prevent oil and grease, motor oil and lubricating grease, and sediment from entering the drain or sewer. Additionally, the owner or operator shall install, operate and properly maintain a grease interceptor or oil interceptor in any piping system at its premises that connects directly or indirectly to a sewer.

Additionally, municipalities should coordinate with provincial and federal agencies and industrial associations to promote spill education and training. In this study, human error and equipment failure are found to be the primary reasons of oil spills. Thus, employee training and preventive maintenance should be emphasized in training programs of spill prone sectors (e.g., petroleum and transportation). Last but not least, spill prevention should also be promoted to residents in older residential areas and institutions where heating oil is still used.

### Individual Site Controls

For the control of oil spills at individual sites, containment structures and oil/water interceptors should be used. However, sizing of these devices is not currently based upon spill characteristics. For instance, the Canadian Petroleum Product Association has developed a draft code of practice and recommended that the sizing of oil interceptors be equal to the largest on-site pumping rate over one minute. Table 2 shows the locations of oil spills in Toronto and their spill volumes. These percentile values enable designers of oil capturing devices to assess the risk of their designs at different locations.

### Downstream Outfall Controls

Installation of large spill control devices may be required at spill prone sewer outfalls to prevent spilled oil from discharging directly to watercourses. Another control option is to retrofit stormwater ponds which are likely to receive oil spills. The procedure to identify outfall control options is listed below:

- Overlay oil spills (which impact surface water) with existing sewer systems and stormwater ponds;
- Identify stormwater ponds which are likely to receive these spills;
- Identify spill prone sewer outfalls which discharge directly to water bodies; and
- Identify public lands, in the vicinity of these spill prone outfalls, which may provide space for the construction of spill control facilities.

Figs. 3 and 4 illustrate the application of GIS in identification of stormwater pond retrofit and spill control devices.

## **4. Spill Management Options**

Spill management options for industries are typically divided into non-structural and structural options. Non-structural options are spill preventive measures such as improved employee training, good operation practices, preventive maintenance, and emergency response. In regards to non-structural changes, employees could be re-trained in the use and maintenance of the physical mechanisms, in order to reduce or prevent future spills events. Concepts of environmental integrity could be also instilled in the values of not only management staff but also field and operations staff, to foster improved environmental performance. Thereby simple mistakes can be fixed, such as

valves left open or closed when they shouldn't, or failure to recognize that the stuffing box rubbers require replacements when worn down. The volume capacity of storage or temporary holding tanks requires a better monitoring system to ensure tanks do not exceed their capacities. If it does occur, containment systems should be implemented at all storage tanks whether temporary, transitory or long-term, as it was observed in the field, that not all storage systems were outfitted with appropriate oil spill containment/trap systems.

Structural options for industries are spill control devices such as containment walls, surface water ponds, oil/water separators, and oil backup systems. Containment systems are built structures usually around or near fixed operations such as tanks and wells. They serve to capture spill oil for easy recovery, to ensure spilled oil is not lost and to protect the immediate environment from oil contamination by containing the spill in a confined area. Proper drainage must be provided to drain rainfall and trap the spills. The captured oil is then removed either physically or by mechanical means. Oil/water separators are devices which intercept spilled oil along the drainage systems and are based on the relative density of oil and water (Li, 2000a). Oil backup systems are devices which stop the spilled oil from leaving the drainage system by mechanical shut-off valves (Truong, 2002). Sizing of structural spill control measures are typically based either by arbitrary volume or the maximum spill volume that is affordable. In order to properly size spill control measures, statistical properties of spill event volume should be considered (Li, 1998).

## 5. Conclusions and Recommendations

From the land spill research studies in the Greater Toronto area, it can be concluded that

- Compilation of a geocoded spill database is necessary in order to facilitate the development of spill management plans.
- Analysis of the statistical and spatial characteristics of spills will provide the information to identify the extent of the problems and the potential locations where management measures should be implemented.
- A spill management planning framework which emphasizes spill prevention, control measures, and emergency response should be used in the development of spill management plans.

Although land spills occur frequently in both developed and developing countries, they are not considered to be important by many jurisdictions. However, the cumulative volume of spills can be significant. For instance, given the 6.84 million litres spilled in the Golden Horseshoe (including the Greater Toronto area) between 1988 and 1997, only 3 million litres are on record as having been cleaned up. In all, then, some 3.84 million litres of petroleum products escaped into the environment (Li and McAteer, 2000). This is an average of 1050 L per day. Where the environmental impact is assessed, (5267 of 9956 records, or only 53% of the reported spill events), the data reveals that soil contamination occurs in 55% of the cases, and watercourse pollution in 31%. It is clear that more research is needed in order to management land spills effectively.

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# OIL SPILL MANAGEMENT PLANNING FRAMEWORK

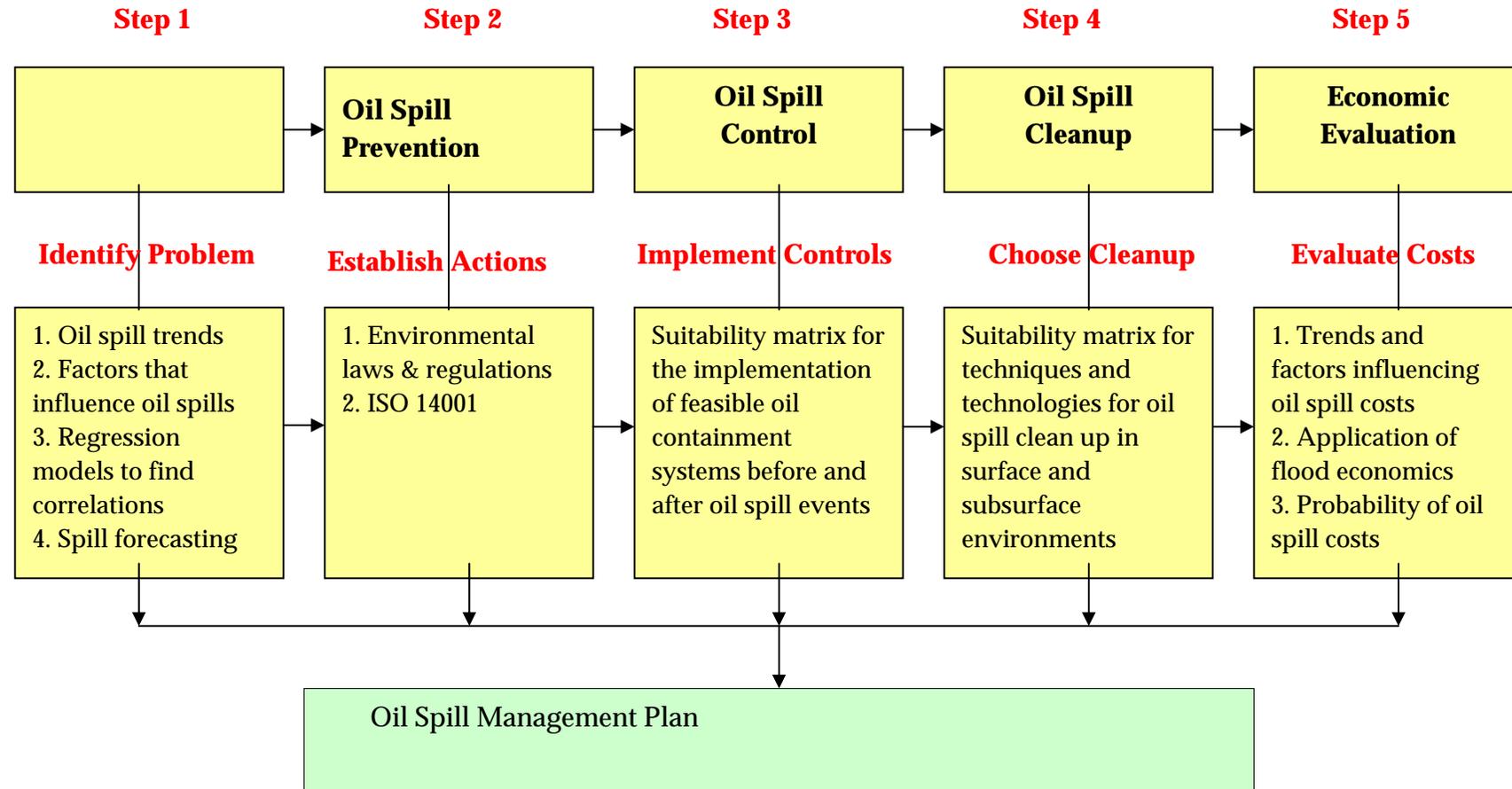


Figure 2 An oil spill management framework (Tang, 2005)

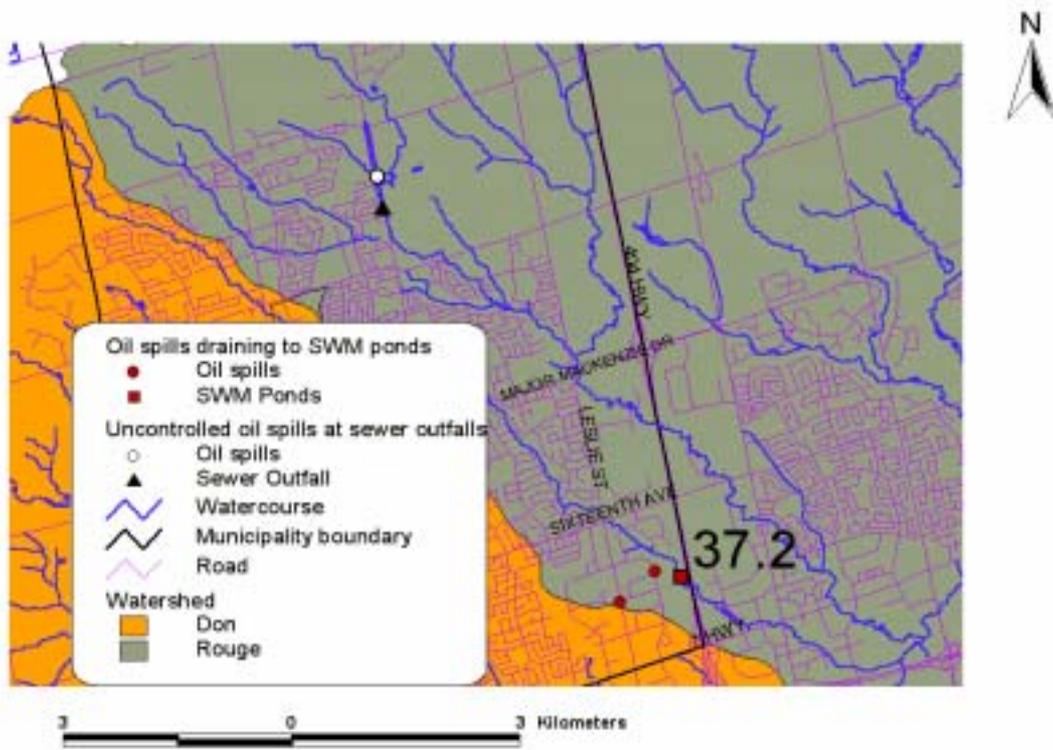


Figure 3 Mapping of spills and stormwater management pond locations

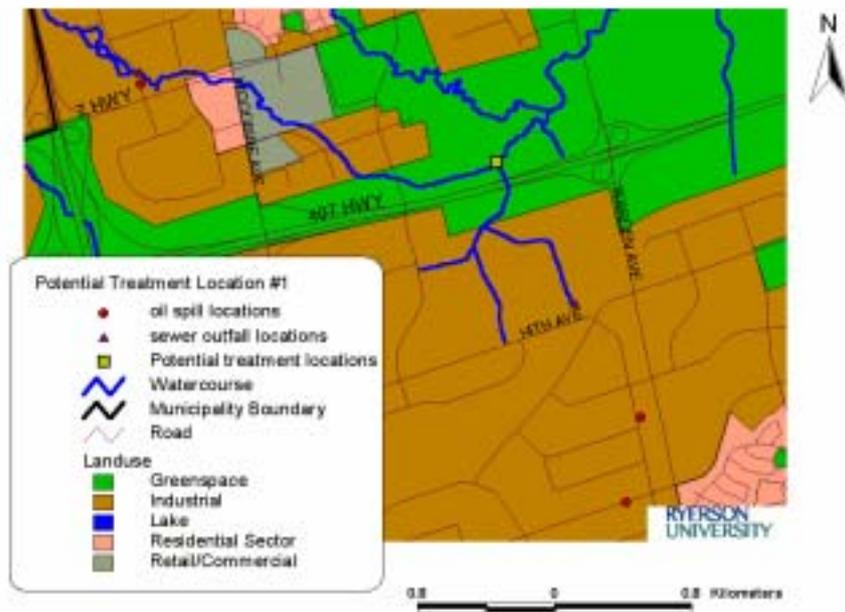


Figure 4 Potential locations of new spill control devices in the Rouge River watershed (Li, 2002)

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