Chapter 3
Public Water Supplies and THM Monitoring Program

3.1 *Characteristics of Public Water Supplies*

There are two types of water sources used to meet the public water demand throughout Newfoundland and Labrador. These sources are:

1) Surface water
2) Groundwater

As shown in Figure 3.1, it is estimated that approximately 85% of all provincial public water supply systems use surface water, while the remaining 15% use groundwater. The data reported in Figure 3.2 indicates that 312 of the total 772 communities meet their demand through surface-based water supply systems, 38 communities rely on groundwater-based systems and the remaining 422 unserviced communities rely on privately-owned systems which are comprised of dug and drilled wells. Approximately 71% of the total population meets its municipal water demand through surface water and the remaining 29% through groundwater. This report deals mainly with THM levels in surface-based water supply systems, as the available data indicate that groundwater is generally low in natural organic matter and consequently THM levels.

Surface water consists mainly of lakes, ponds, rivers and streams. Figure 3.3 presents data for each region of the province on various types of surface water sources, used for drinking purposes. There are a total of 329 surface water supplies throughout the province with approximately 313 in active use. Among surface water sources, ponds and reservoirs are the common source of public water supplies. Appendix A (Tables 1, 2 and 3) provides details on water supply sources for each community.

3.2 *THM Formation Potential*

As discussed in Section 2.2, there are numerous factors that affect the formation of THMs in public water supplies. Both natural and human factors influence the quality of a water source and consequently the THM formation potential. This section outlines these factors and their impact on THM formation potential.

3.2.1 *Natural Factors*

The natural characteristics of a surface water source and characteristics of its watershed surrounding area greatly influence water quality, including the potential formation of THMs. Among the natural factors hydrology, topography, geology, soil, vegetation, and climate are considered as key parameters to influence the water quality.

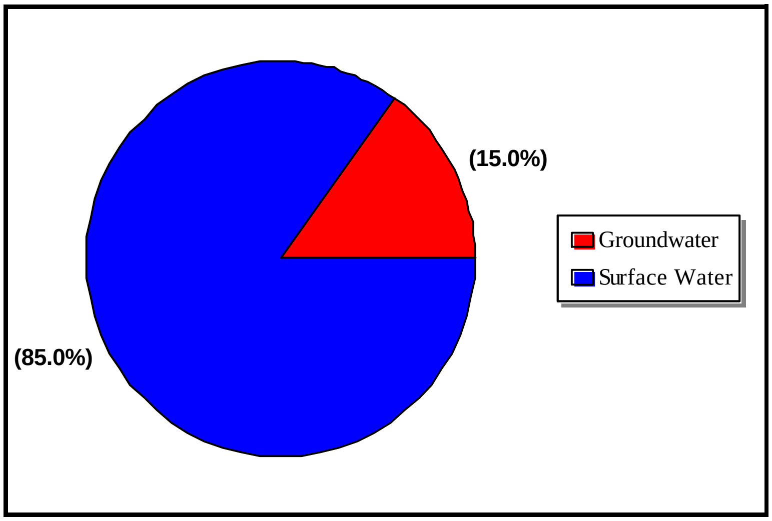

Figure 3.1: Sources of Public Water Supply Systems in Newfoundland and Labrador

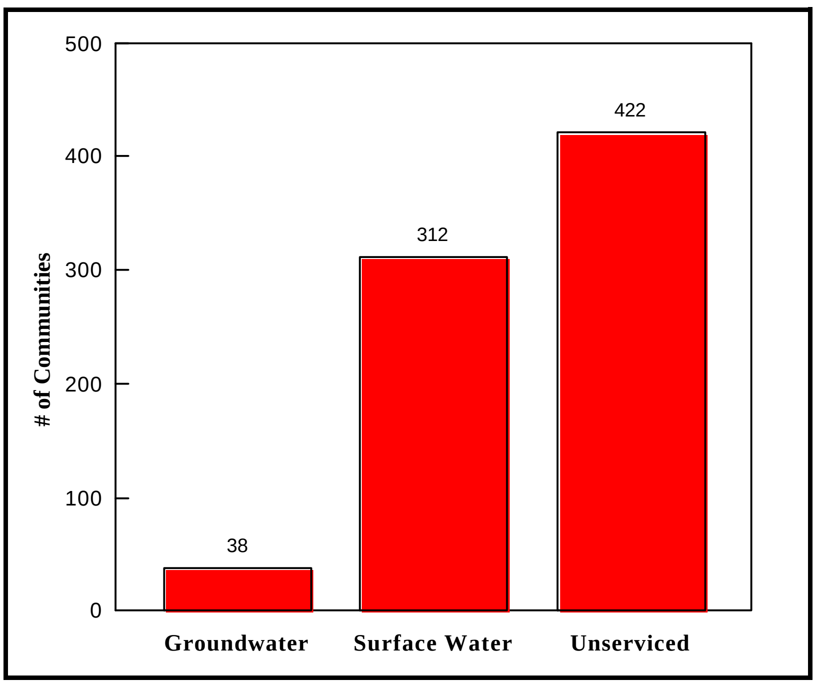

Figure 3.2: Communities Serviced by Surface and Groundwater Sources

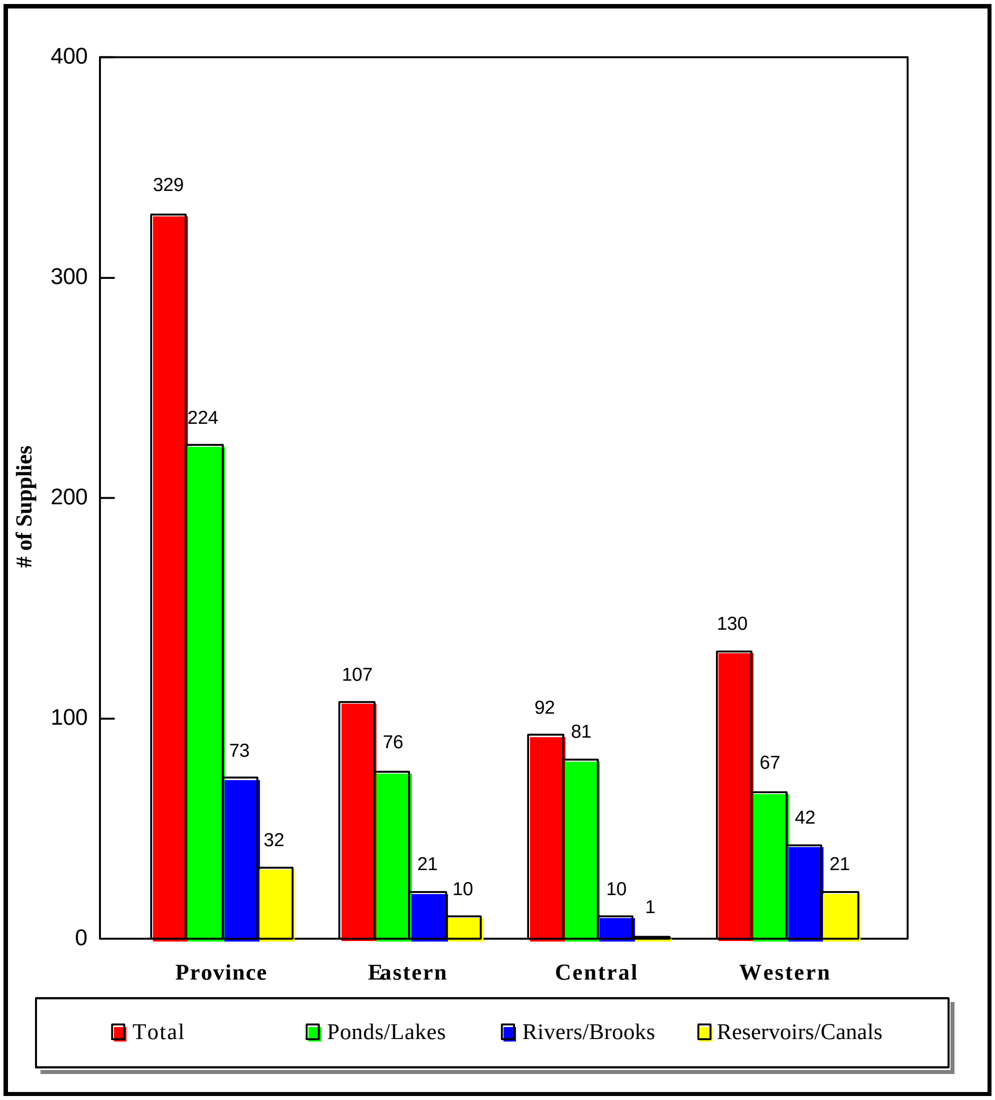

Figure 3.3: Types of Surface Water Sources in the Province

3.2.2 *Human Factors*

Human factors affecting water quality are generally associated with the type and level of development activities being undertaken within the catchment of a water body. The presence of human activity in a public water supply area is considered as a potential risk to water quality impairment. In addition, human activity may increase the THM formation potential of the public water supply, due to the disturbance to the natural watershed setting and surface run-off pattern. For this reason, it is important to consider the level of human activities within public water supply areas of the province. Table 3.1 presents general land use and potential pollutant analysis matrix which provides additional details on different types of pollutants associated with each land use activity. Overall, both natural and human factors influence the quality of source water.

3.2.3 *THM Formation Potential Ranking*

The methodology for assessing the THM formation potential of each public water source was based on an analysis of the correlation between the average measured THM levels of tap water, and the average DOC and colour levels of raw water for municipal water supplies with the available data. It must be recognised however that the actual level of THM formed can be a complex function of DOC and colour levels as well as other factors. In particular, the literature indicates that chlorine dosage, water temperature and residence time in a water supply distribution system can be additional significant factors in determining the actual level of THMs formed.

An analysis of the average DOC values and colour values reported for the water supplies listed in Appendix B and the average THM values for each community listed in Appendix F indicates the following:

(a) Most of the "low" THM levels (defined as less than 75 µg/L relative to the Guidelines for Canadian Drinking Water Quality of 100 µg/L) occurred when DOC was less than 4.5 mg/L and colour was less than 80 True Colour Unit (TCU). For DOC values greater than 4.5 mg/L, the data indicated that "low" THM levels were also possible when colour was between 60 and 100 TCU.

(b) Most of the "high" THM levels (defined as greater than 150 µg/L relative to the Guidelines for Canadian Drinking Water Quality of 100 µg/L) occurred when either (i) DOC was between 5 and 7 mg/L and colour was between 30 and 50 TCU or (ii) DOC was greater than 7mg/L and colour was greater than 100 TCU.

(c) Most of the "medium" THM levels (defined as between 75 µg/L and 150 µg/L) occurred for the remaining combinations of DOC and colour values.

Table 3.1: Land Use and Potential Pollutant Analysis Matrix

Land Use Sources	Turbidity Sediment	pH	Nitrogen/ Phosphorous	Algae	Viruses/ Parasites	Bacteria	Trihalo-methane Precursors	Pesticides	Other Synthetic Organic Chemicals (SOCs)	Volatile Organic Chemicals (VOCs)	Heavy Metals	Iron/ Manganese
Cropland runoff	X		X	X	X	X	X	X			X	X
Dairies/feedlots	X		X	X	X	X	X					
Grazing	X		X	X	X	X	X					
Recreation					X	X						
Forest Management	X		X	X		X	X	X				X
Roads	X		X	X			X					X
Mining	X	X									X	X
Industrial discharge	X	X	X	X		X	X	X	X	X	X	X
Wastewater discharge	X	X	X	X	X	X	X	X	X	X	X	X
Septic tanks		X	X	X	X	X	X	X				
Urbanization	X	X	X	X	X	X	X	X	X	X	X	X
Hazardous materials								X	X	X	X	X
Acid rain		X										

A graph of the relationship between the three (3) classes of THM level (low, medium, high) and the levels of DOC and colour is provided in Appendix B. The complex relationship between measured THM, DOC and colour reinforces the fact that THM formation is a complex process with possible lower as well as upper threshold values for each of the causative factors. The relationship was used to assess the THM formation potential of each municipal water source, however, the results must be viewed only in light of the assumptions made. The THM formation potential for each of the 258 water sources for which DOC and colour data were available is given in Appendix B.

Figure 3.4 presents the results of the assessment of the THM formation potential of the 258 public water supply sources for which DOC and colour data were available. The results assume that all the 258 public water supplies will be provided with the minimum mandatory level of water treatment, i.e., chlorination. At the provincial level, 144 water supply sources are classified as having "low" THM formation potential, while 69 have "medium" potential and 45 have "high" THM formation potential. This analysis indicates that about 50% of the surface drinking water sources throughout Newfoundland are "naturally" predisposed to have "medium" to "high" THM formation potential.

3.3 *Water Treatment Practices*

The method by which the source water is treated greatly influences the formation of THMs in public water supplies. Raw water from natural sources requires treatment prior to its use for drinking purposes. Water supplies may contain pathogenic organisms, suspended particles, dissolved chemical substances, unpleasant tastes and odours and mineral impurities. It is, therefore, important to provide a certain level of treatment to all public water supplies. The level of treatment depends upon the source water characteristics.

The most common types of water treatment practices used in the province include:

1) Chlorination
2) Conventional Water Treatment Plants
3) Non-Conventional Water Treatment Practices

3.3.1 *Chlorination*

Chlorination is the most widely used method of water treatment throughout the province, and in many cases it is the only method of water treatment. As discussed in Section 2.1, chlorine is added to water to inactivate pathogenic organisms and to protect the distribution system from microbial growth. Chlorination is also found to be useful in the removal of colour, iron and sulphur compounds. However, the removal efficiency is limited to a certain level.

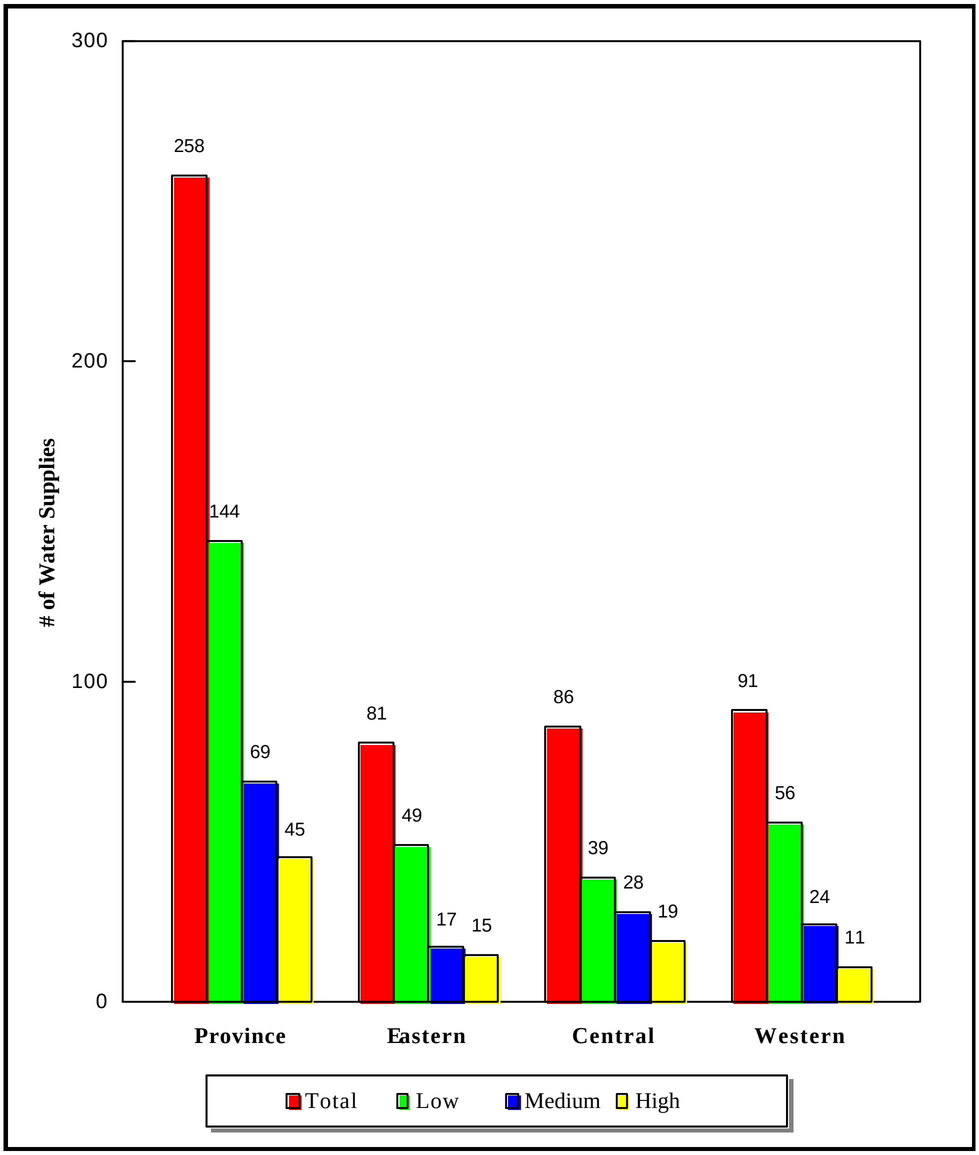

Figure 3.4: THM Formation Potential Ranking of Surface Water Supplies in the Province

As shown in Figure 3.5, based on the analysis of the available data, it is reported that there are about 283 chlorination facilities in the province. Of these facilities, about 116 are gas-based chlorination and about 167 are liquid-based chlorination. It is estimated that liquid chlorination systems are far cheaper than gas chlorination systems, and thus are used more extensively for small size communities in the province. Table 3.2 presents data on the average capital and annual operation cost for different types of chlorination facilities. The comparative low-cost of chlorination facilities relative to other disinfection methods, as well as the reliability and simple handling, make chlorination the most popular method of water disinfection in this province.

3.3.2 *Conventional Water Treatment Plants*

There are 11 conventional water treatment plants in the province. These plants provide water to about 124,543 people which is about 23% of the total population. In the majority of cases, treatment plants were commissioned to improve source water quality for larger centers.

The major features of each of the eleven treatment facilities are presented in Table 3.3. A brief description of each facility is as follows:

Clarenville - This plant consists of two clarification/coagulation tanks, four rapid gravity anthracite and sand filters, a pre and post-chlorination system, a hydrated lime injector unit and a multi-unit pumping system.

Channel Port-aux-Basques - In this plant lime, alum and polymer are initially added and are mixed in a rapid mixing tank where water impurities are coagulated into small flocs. After the mixing tank, water flows into a “pulsator clarifier” where flocs are collected into “sludge blanket”. The sludge is bled from the clarifier into a sewer line to the sludge pond where settling takes place before backwash water runs into a natural water course. The clarified water passes through a gravity sand filter tank before being collected in a clear water well ready for distribution by gravity.

Churchill Falls - This plant includes a simple slow sand filtration unit followed by chlorination.

Deer Lake - This plant is a package type based on membrane filtration technology “thread type water filtration unit” along with disinfection.

Dunville - This plant consists of dual media rapid sand filtration with ozone as the primary disinfectant. The plant has provisions for pH adjustment and chlorination to maintain residual chlorine.

Grand Falls-Windsor - This plant consists of screening, chemical feed coagulation, multi-media rapid filtration and chlorination.

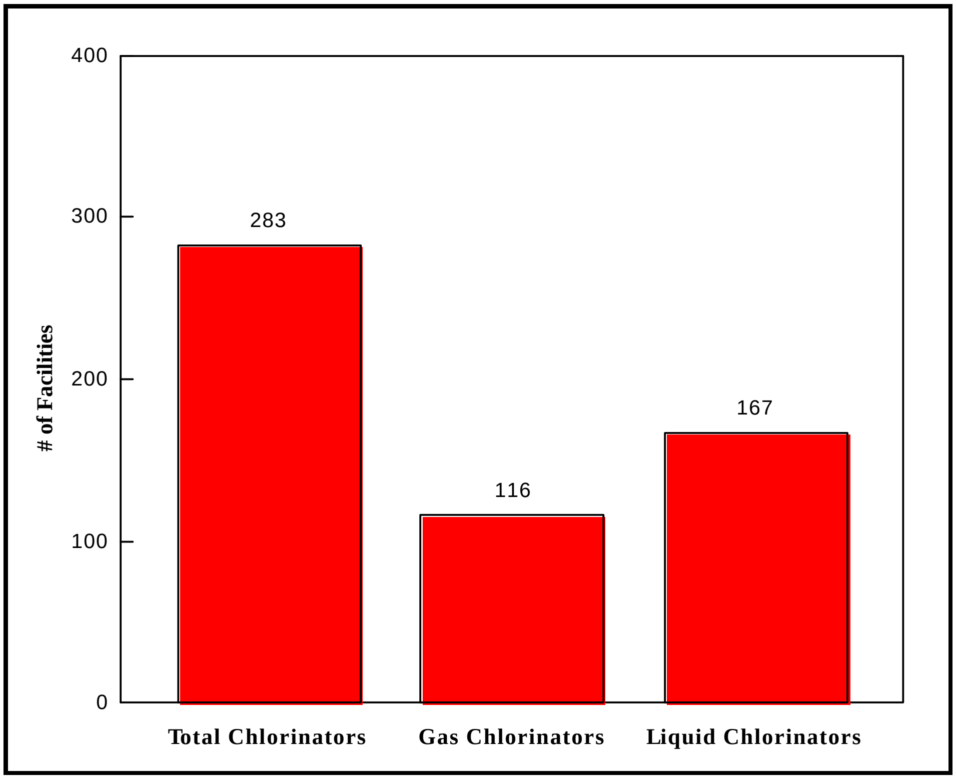

Figure 3.5: Chlorination Facilities throughout Newfoundland and Labrador

Table 3.2: Capital and Operational Costs of Chlorination Systems

Chlorination System	Average Capital Cost ($)	Capital Cost - Range ($)	Annual Average Operating Cost * ($)
Gas Chlorination	50,000	40,000 - 60,000	10,000
Hypochlorination	10,000	7,500 - 15,000	3,000
* Operator's Salary is not included			

Table 3.3: Conventional Water Treatment Plants in Newfoundland and Labrador

Community	Population Served	Design Flow (cubic metres per day)	Storage (litres)	Treatment Features	Year Commissioned	Capital Cost ($)	Annual Operation and Management ($)
Clarenville	3,700	6,385	264,000	dual media rapid sand filtration (anthracite, sand), Cl disinfection, Al sulphate	1969	500,000	400,000
Channel Port-aux-Basques	5,243	10,000	200,000	dual media filter (anthracite, sand), Cl disinfection, hydro lime, Al sulphate	1988	6 million	200,000
Churchill Falls	704	1,600	0	3 pressure vessels-slow sand, Cl disinfection	1969	100,000	10,000[a]
Deer Lake	5,222	-	-	-	1998	800,000	-
Dunville	1,200	1,362	0	Cl & ozone disinfection, soda ash, hydro lime	1991	1.4 million	30,000
Grand Falls-Windsor	18,200	35,000	5,270,000	multi-media filter (anthracite, stratified sand and stratified gravel, Cl disinfection, lime treatment, Al sulphate	1996	8 million	300,000
Happy Valley-Goose Bay	8,655	4,000	225	reactor pressure (Greensand, $KMnO_4$), Cl disinfection, Al sulphate	1999	4 million	-
Lumsden	653	1,090	950,000	dual media rapid sand filter (anthracite, stratified sand), Cl disinfection, Al sulphate	1972[b]	165,000	40,000
Musgrave Harbour	1,386	2,180	510,000	dual media rapid sand filter (anthracite, sand 300mm)	1998	3 million	-
Ramea	1,080	1,080	0	dual media (anthracite and silica sand), hydro lime, Cl disinfection	1999	1.1 million	130,000
St. John's Metro	78,500	110,000	58,900	dual media rapid sand filter (anthracite 560mm, sand 250mm), Cl & Chloramine (ammonia) disinfection, hydro lime	1978	15 million	3 million

Note:
a - power charges not included
b - mechanical parts replaced in 1993

Happy Valley-Goose Bay - This plant includes treatment features of chlorination, filtration and coagulation.

Lumsden - This plant is a package Neptune Microfloc "Aquarius" type. The package plant consists of chemical feed with flocculation, settling chamber, high rate filter beds, clear water storage and associated piping controls.

Musgrave Harbour - This plant consists of a dual media rapid filtration with other features of coagulation and chlorination.

Ramea - This plant is a reverse osmosis filtration plant.

St. John's (Bay Bulls Big Pond) - In this plant, raw water flows by gravity from intake into the wet well where it passes through one of two self-cleaning water screens. Water is then pumped into the ozone contact chamber. Following ozonation, lime is added to raise the pH for corrosion control purposes. As the water leaves the ozone contact chambers, it flows towards one of six rapid gravity anthracite and sand filters. Prior to filtration, a coagulant is added to assist the filtration process. The filtered water then flows into one of two clear water wells. As the water enters these wells, it receives a small dosage of chlorine to maintain its disinfection. In addition, a small amount of ammonia is added to stabilize chlorine residual in the treated water to prepare it for the long journey through transmission and distribution systems.

3.3.3 *Non-conventional Water Treatment Practices*

In addition to the communities listed in the previous section, other communities throughout the province have also had various types of water quality problems. Due to constraints, mainly lack of financial resources, these communities could not pursue the option of a conventional water treatment plant. However, other low cost options, mainly infiltration galleries and rock berms, were used to address the water quality problems of these communities.

Infiltration galleries are considered to be effective in reducing turbidity, suspended organic loading and possibly dissolved organic carbon. Typical construction of an infiltration gallery involves building a dam across a stream to form a natural pool and installation of perforated pipes in a bed of graded gravel or other filter media. Infiltration galleries and rock berms represent the low end of alternative technology to improve source water quality.

Table 3.4 provides the details of water supply systems in the province with some form of infiltration gallery or rock berm. A brief description of each setup is given below.

Table 3.4: Non-conventional Water Treatment Methods

Community	Population	Water Treatment Method	Capital Cost ($)	Year	Comments
Bird Cove	425	Infiltration Gallery	185,000	1995	- to provide cost effective means of reducing suspended materials
Northern Arm	422	Infiltration Gallery	70,000	1997	- to provide cost effective means of reducing suspended materials
Botwood	3613	Infiltration Gallery	1.2 million	1993	- to control *Giardia* problem; no outbreaks since installation of gallery
Twillingate	2954	Infiltration Gallery	450,000	1999	- to address poor water quality problems
King's Point	845	Rock Berm	-	-	-
Brighton	272	Rock Berm	50,000	1998	-
Port Saunders	876	Rock Berm	10,000	1990	- to reduce the amount of mud and silt being drawn into the distribution system
George's Brook	400	Water Intake Gallery	2,300	1998	- to reduce turbidity in water supply
Pynn's Brook	88	Water Intake Gallery	3,000	1989	- to reduce turbidity in water supply
Green Island Cove	216	Water Intake Gallery	6,000	1981	- to reduce turbidity in water supply

Bird Cove - This system consists of a low dam to provide about 0.5 metre of water above the stream bed and four 150mm diameter Johnson screen intakes in a two layers of filter bed with specified gradation.

Botwood - This system consists of four 250mm diameter stainless steel screens and connecting pipes, a precast concrete control weir, a gravel filter bed, a geotextile membrane and a rock filler reno mattress.

Northern Arm - This system consists of a 100 metre long and 2 metre high dam, two 150mm diameter stainless steel pipes with well screens in a multi-media filter bed.

Port Saunders - This system consists of a semicircular rock berm around the screened intake.

Twillingate - This system consists of four 250mm diameter stainless steel screens and connecting pipes, a dam to maintain adequate water level and four layers multi-media filter bed.

The communities of Brighton, King's Point, Pynn's Brook, George's Brook and Green Island Brook also have some form of infiltration galleries.

The intake galleries at Northern Arm and Twillingate have been provided with multi-media filter (including anthracite). The effectiveness of these two systems for the removal of colour and DOC and subsequent reduction in THM formation is under investigation. If the results of the assessment are favourable, then multi-media infiltration gallery could be considered as one of the low cost options for THM reduction.

Whether the form of water treatment is simple chlorination, conventional or non-conventional methods, the majority of public water supplies in the province use chlorine at some point throughout the treatment process. It is essential to note that the addition of chlorine to a natural surface water source with high colour and DOC values, will increase the potential for THM formation.

3.4 *THM Monitoring Program in Newfoundland and Labrador*

Regular THM monitoring of the provincial public water supplies officially began in April 1996. Prior to this, periodic THM sampling was undertaken as a part of site-specific complaints about THMs and federal initiatives for national or regional surveys of THM levels. The sampling sites under federal initiatives were selected on a random basis, and only limited number of samples were collected from each selected site. Most of the pre-1996 THM data for provincial public water supplies was collected under a federal initiative relating to "Toxic Chemicals Survey in Atlantic Canada". Since 1996, the THM Monitoring Program has been an evolving process which has been growing on an annual basis. The total number of annual samples collected under this program have increased from 206 in 1996 to 945 in 1999.

The monitoring program is carried out as a joint cost-shared or partnership program between provincial and municipal governments. Under the partnership arrangement, the provincial government is responsible for the sampling and data management costs while the analysis cost of samples is paid by the participating municipalities.

As a part of the joint THM monitoring program, in the months of January or February, letters are sent to each community with a surface-based public water supply soliciting its participation in the THM Monitoring Program for the upcoming year. Each community is given an opportunity to choose the number of water samples to be collected and analyzed annually. Communities are encouraged to participate in seasonal sampling (spring; summer; fall; winter) in order to account for seasonal variation and to be able to compare the available results with the national guidelines. In order to have information on THM levels along the distribution system, three sampling sites (beginning, middle and end) are recommended for each water supply system. However, if this is not possible, communities are still encouraged to participate to any possible extent. A sample copy of the 2000 letter and form is included in Appendix C.

3.4.1 *Sampling*

From the beginning of the program in April 1996 to the present time, three staff members of the Water Resources Management Division have been responsible for THM sampling. These staff members are based in St. John's, Grand Falls and Corner Brook offices of the division. St. John's staff is responsible to sample all supplies in the eastern region, Grand Falls staff for central region and Corner Brook staff for western region and Labrador.

All THM sampling is carried out according to protocols as approved by USEPA and Health Canada. A copy of sampling protocol is included in Appendix D. Each sampling staff carries the following:

- field sheets
- 20 mL glass vials pre-treated with sodium thiosulphate
- chlorine test kit
- thermometer
- cooler
- ice packs

Field sheets are prepared for each collected THM sample. The field sheet contains space to record all pertinent information such as community, sample location, date, time, water temperature, free chlorine and remarks. A copy of the blank field sheet is included in Appendix D.

At each sampling site, the tap water is allowed to run for approximately 4-5 minutes. This ensures that the water being tested has not been stagnant in the water distribution pipes. After the water has been running, the temperature of the water is taken and recorded on the field sheet.

Secondly, a simple test utilizing a chlorine kit to determine the free or total chlorine in the water, is carried out. The procedures for testing free and total chlorine vary slightly, however, in general a powder is added to a small amount of water which reacts with the chlorine in the water. This reaction leads to a colour change which is then used as a comparison to quantify the amount of free or total chlorine present in the water. These numbers are also recorded on the field sheets. Finally, the actual THM sampling is carried out. The water is turned down to a gentle flow rate and the pre-treated vial is filled completely leaving no head space. The purpose of the sodium thiosulphate already present in the vial is to prevent further formation of THMs during the storage and shipping of the samples. When the vial is completely filled, it is tightly capped and labeled immediately. Samples for THM analysis are collected in duplicate due to the fragility of glass vials during the storage and shipment process.

3.4.2 *Storage and Shipment*

After the samples are collected, they are stored in coolers with ice packs at approximately 4°C. The samples are shipped to the laboratory for analysis as soon as possible, usually within one working day from the time of sampling. Upon arrival at the laboratory, samples are kept in a cold storage room at a controlled temperature until they are analyzed.

3.4.3 *Laboratory Analysis of THM Samples*

Trihalomethanes in water samples are measured by solid phase micro-extraction/capillary column gas chromatography/mass spectrometry (SPME/GC/MS). The water sample is extracted onto a SPME fiber. The desorbed material from the fiber is analysed using GC/MS. The trihalomethane concentration in the water sample is determined from the following equation:

$$\textbf{Concentration}_{(\mu g/L)} = \mathbf{M}_{(ng)} / \mathbf{V}_{(mL)}$$

where: $\mathbf{M}_{(ng)}$ is the mass of the respective trihalomethane in ng.
$\mathbf{V}_{(mL)}$ is the total volume of the sample

For quality assurance and control purposes, the following protocols are followed on a daily basis:

- A procedural blank is performed daily using deionized water. Results are rejected if the blank is greater than the detection limit.
- A standard reference material is analysed (in duplicate) with each run. ERA THM Reference 3221 is used. The concentration of reference material is determined from the calibration curve and results are rejected if the concentration does not fall within Performance Acceptance Limits.

- A duplicate analysis is performed at least once in every ten samples. Results are rejected (and analysis is repeated) if two numbers vary by greater than 20%.

A copy of the complete analytical protocol is included in Appendix D.

3.5 *Monitoring Status*

The THM monitoring has been an evolving program. More and more communities have chosen to regularly sample their drinking water for THM levels. According to the available data, there are a total of 313 active public surface water supplies in the province servicing approximately 312 communities. As shown in Figure 3.6, to date, 207 of 313 active surface water supplies are involved in the THM monitoring program, while 106 surface water supplies remain uninvolved in the program.

3.6 *Data Management and Dissemination*

All of the THM results for all water supplies across the province are stored in one provincial THM database. This database is designed to input and retrieve all THM data in a user friendly manner. The THM database was created using Microsoft Access™ and Visual Basic™. It has the following two main functions:

1) Data Input
2) Data Retrieval

The data input function is designed to simplify the task of inputting large amounts of data collected as a part of the THM Monitoring Program. The data input process is comprised of a number of interactive forms/screens. The first form/screen provides space to input information about the region, community name, sample location, date collected, lab where analysis was performed and site number. The second form/screen provides space for the amount of chloroform, dibromochloromethane, bromodichloromethane and bromoform, whose sum provides the total THM found in the drinking water sample. The final form/screen provides space for any additional information including free chlorine, total chlorine and temperature of the tap water as well as DOC, pH, colour and temperature of the source water. A printout of each screen is included in Appendix E.

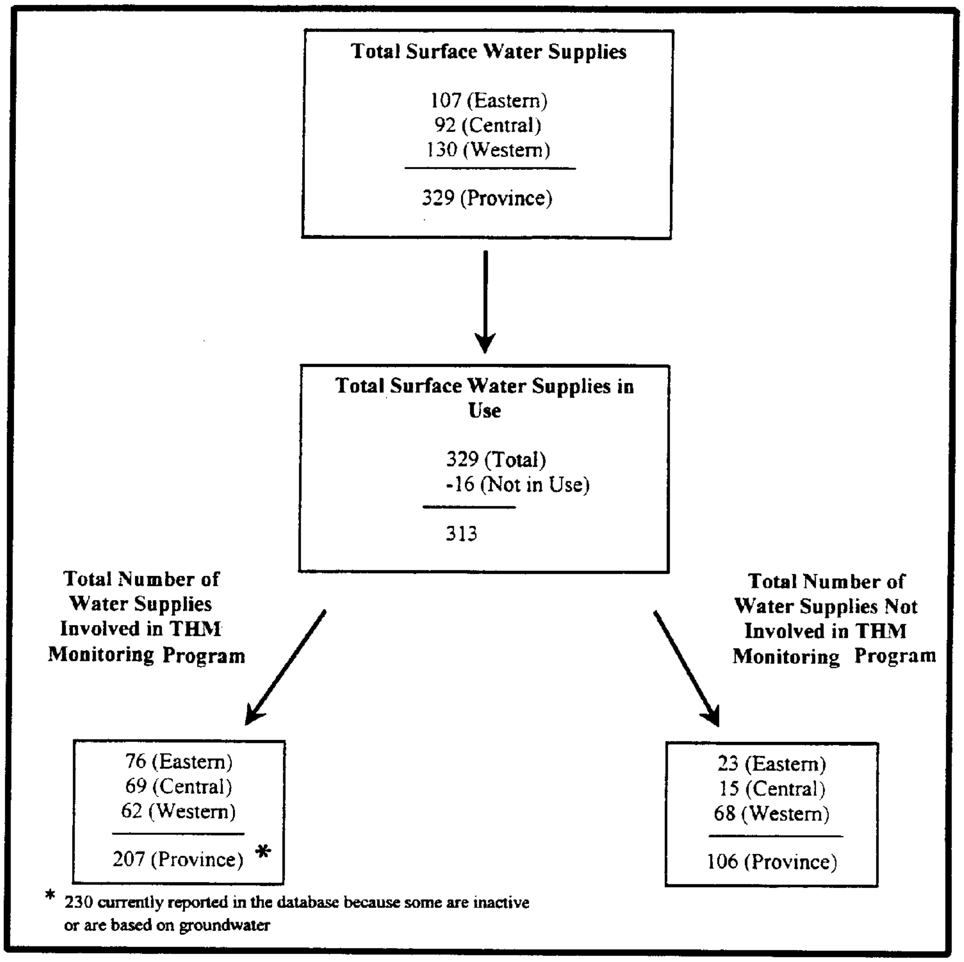

Figure 3.6: Status of THM Monitoring Program

The data retrieval function allows the user to sort the THM results primarily by community and secondarily by date. As a result, it is possible to print a report for each community which provides all the THM results for that particular community through the years since sampling first began. A printout of a sample community report is included in Appendix E.

The THM database management software is continually evolving and additional changes will be made to improve the usefulness of the software.

The THM data is disseminated annually at the beginning of the new year (January/February) after the sampling and analysis from the previous year is complete. Each community is provided with an annual report clearly stating the total THMs for each sampling event and the running annual average wherever applicable, along with a brief technical interpretation. Along with these annual reports, the Water Resources Management Division of the Department of Environment and Labour offers its technical assistance to explain the results and possible measures for reducing THM levels if desired or requested by any community.

The municipalities are advised to disseminate the drinking water quality data (THM and other contaminant information) to the residents of the community by displaying the annual data report on a public notice board or any other appropriate means.

The Water Resources Management Division of the Department of Environment and Labour maintains a THM web page which includes highlights of THM monitoring results. This web page is updated on a regular basis as appropriate. The web page can be visited at http://www.gov.nf.ca/env/Env/waterres/Surfacewater/THM/THM.asp**.**

It should be noted that the Department of Environment and Labour is responsible for monitoring the physical and chemical aspects of drinking water quality while the Government Service Center is responsible for the monitoring of microbial water quality.