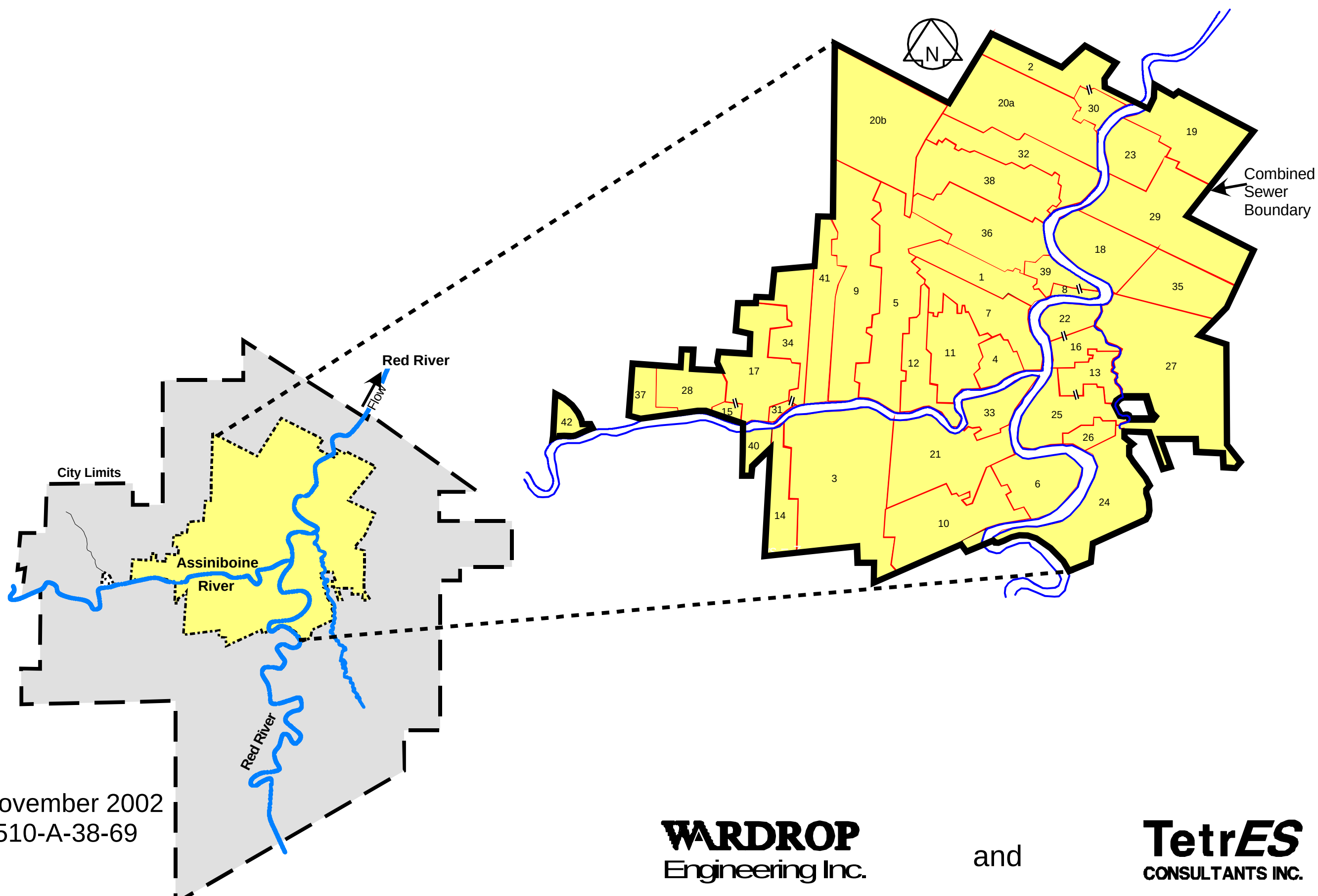
Winnipeg

Embrace the Spirit • Vivez l'esprit

City of Winnipeg
Water and Waste Department

Combined Sewer Overflow Management Study

FINAL REPORT



November 2002
0510-A-38-69

WARDROP Engineering Inc. and TetrES CONSULTANTS INC.

In Association With:

CH2M Hill Canada and **EMA Services Inc.**

Certification

This report was prepared by Wardrop Engineering Inc., and Tetr*ES* Consultants Inc., under the direction of a professional engineer registered in the Province of Manitoba. It is intended solely for the use of the City of Winnipeg, Manitoba, for which it was prepared, and for the purposes and within the limitations stated in the report.

Both firms are authorized to provide consulting engineering services in the Province of Manitoba as shown below.

APEGM
Certificate of Authorization
No. 195
Expires April 30, 2003
signature
Nov 14/02
date

APEGM
Certificate of Authorization
No. 254
Expires April 30/03
signature
Nov 14/02
date

PROVINCE OF MANITOBA
G. REMPEL
REGISTERED ENGINEER
Nov 14/02

Third Party Disclaimer

The report, which is reported in the following pages, has been prepared in response to a specific request for services from the City of Winnipeg Water and Waste Department to whom it is addressed. The report is not for the use of, nor is it intended to be relied upon, by any person, firm or corporation other than the City of Winnipeg Water and Waste Department, to whom it is addressed. Wardrop Engineering Inc. and Tetr*ES* Consultants Inc. deny any liability whatsoever to other parties who may obtain access to this report for damages or injury suffered by such third parties arising from use of this report by them without the express prior written authority of Wardrop Engineering Inc., Tetr*ES* Consultants Inc. and the City of Winnipeg Water and Waste Department, who have commissioned this report.

ACKNOWLEDGEMENTS

The Study Team acknowledges, with sincere appreciation, the contribution of many individuals and agencies consulted in the course of the CSO Management Study. The Study Team especially acknowledges the assistance of the City of Winnipeg Project Management Committee and the Advisory Committee.

The main participants in the consulting team, and their affiliations during the study, are listed below:

Wardrop Engineering Inc./Tetr*ES* Consultants Inc.
in Association with CH2M Canada Limited and EMA Services Limited

G. Rempel, P. Eng. (Tetr*ES*), Project Manager
R. Gladding, P. Eng. (Wardrop), Assistant Project Manager (Phase 1 to Phase 3)
N. Szoke, P. Eng./L. Chambers, P. Eng. (Wardrop), Assistant Project Manager (Phase 4)
D. Morgan, Ph.D., P. Eng. (Tetr*ES*), Control Alternatives and Modelling
J.M. McKernan, M.E.S., M.Sc. (Tetr*ES*), Illness Risk
G. Steiss, C.E.T. (Wardrop), Infrastructure and Hydraulic Modelling
S. Quigley, P. Eng. (Wardrop), Control Alternatives
R. Rempel, P. Eng. (Tetr*ES*), Runoff Modelling, Floatables
G. Mohr, P. Eng. (Tetr*ES*), Hydraulic Modelling
D. Dagg, M.Sc. (Tetr*ES*), Public
M. Sweet, B.Sc. (Tetr*ES*), Public
M. Parente, P. Eng. (CH2M Canada Limited), Control Alternatives
M. Yue, P. Eng. (CH2M Canada Limited), Wastewater Treatment
R. Skrentner, P.E. (EMA), Real Time Control and SCADA
L. Thompson, P. Eng. (CH2M Canada Limited), Flow Monitoring

Specialist Advisors

G. Zukovs, P. Eng., Control Alternatives
D.Weatherbe, P. Eng., Regulatory Trends
P. Moffa, P.E., Control Alternatives

External Advisors

W. Schilling, Ph.D., Real Time Control
C. Rowney, Ph.D., P. Eng., Modelling, Regulatory Trends
N. Wheatley, Regulatory Trends

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF FIGURES

List of Figures (cont'd)

LIST OF TABLES

1. INTRODUCTION

The City of Winnipeg's Water and Waste Department has completed a comprehensive planning study of its combined sewer system in terms of the effects of combined sewer overflows on river water quality and related river uses. The Combined Sewer Overflow (CSO) Management Study involved several years of study activity.

This important planning study will help to define the next generation of water pollution control for the City. The study will assist in the development of long-term environmental policies in relation to the Red and Assiniboine rivers and could result in a substantive long-term commitment of financial resources.

CSOs are a major public and environmental policy issue. Exploring the best ways to deal with CSOs raises many issues and presents many choices. These include technical choices on how best to modify the old combined sewer system, the extent of practicable CSO Control, and value judgements on acceptable levels of protection of the rivers. The options could be costly, and the benefits are difficult to quantify. In forming positions on these important public policy issues, it is important that the City, the public, and the regulatory agencies be provided with comprehensive information to facilitate an informed decision-making process.

1.1 COMBINED SEWER OVERFLOWS

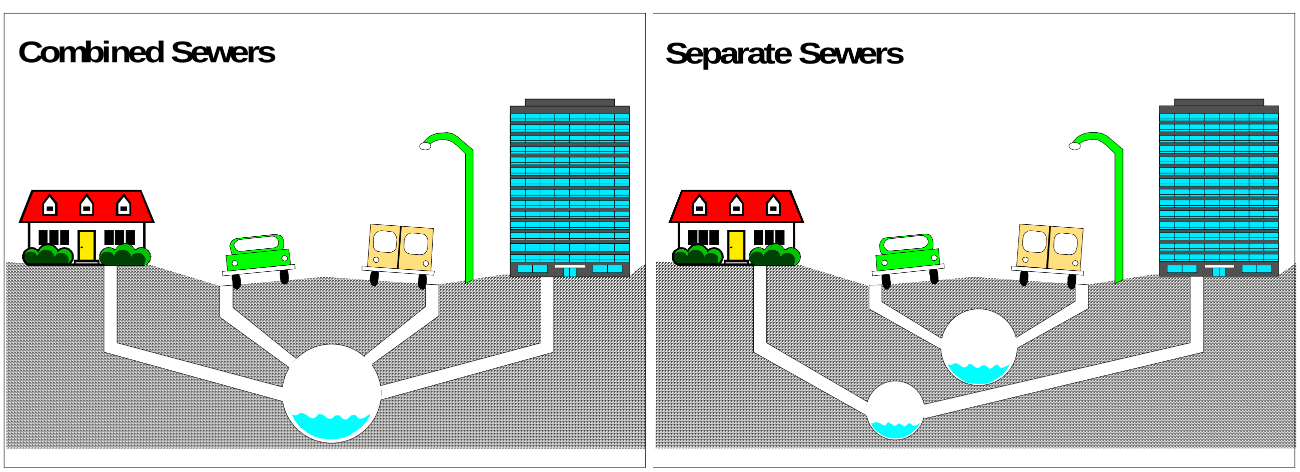
In the older areas of Winnipeg, single-pipe, combined sewers carry both wastewater and stormwater runoff, as shown on Figure 1-1. The combined sewers were originally built as individual systems or sewer districts, with each district having one or more outfall sewers discharging directly to the river. When sewage treatment was implemented, interceptor sewers were built to convey the wastewater to the treatment plants instead of discharging to the river. During dry weather, all wastewater in the sewers is conveyed to the treatment plants for processing before being discharged to the rivers. However, during rainfall and snowmelt, the amount of surface runoff entering the combined sewers is greater than the hydraulic capacity of the interceptor sewer system and the processing capacity of the wastewater treatment plants.

When this combination of stormwater and sewage exceeds the interceptor sewer capacity, the combined sewage overflows directly into the rivers.

In newer areas of the City, a two-pipe, separate sewer system conveys domestic wastewater and stormwater, as shown in Figure 1-1. In these areas, under virtually all weather conditions, wastewater always goes to the treatment plant for treatment prior to discharging into the rivers.

Combined sewers were built in Winnipeg between 1880 and 1960. They service about 40% of the population, and originally covered an area of about 10,500 hectares (35% of the developed area). Combined sewers are not unique to Winnipeg. About 1,000 communities in North America have combined sewers.

Combined sewers typically overflow a dilute mixture of runoff and wastewater about 18 times per year, on city-wide average, during the recreational season (May to September). The amount of raw wastewater discharged by these combined sewer overflows (CSOs) is approximately 1% of the total wastewater generated in the City on an annual basis. This overflow contains untreated domestic, commercial and industrial wastewater, diluted by stormwater. The overflows result in higher levels of pollutants entering the rivers than would be found in stormwater alone. In addition to this wastewater component, combined sewers also convey the floating material and debris from street runoff which, in a separate system, are discharged by separate land drainage sewers.



City of Winnipeg Sewer Systems
Figure 1-1

1.2 THE CSO MANAGEMENT STUDY

The City of Winnipeg Terms of Reference noted that the "*primary objective of the project is to establish a cost effective prioritized implementation plan for remedial works based on an assessment of costs and benefits of practicable alternatives*". This was to be achieved by:

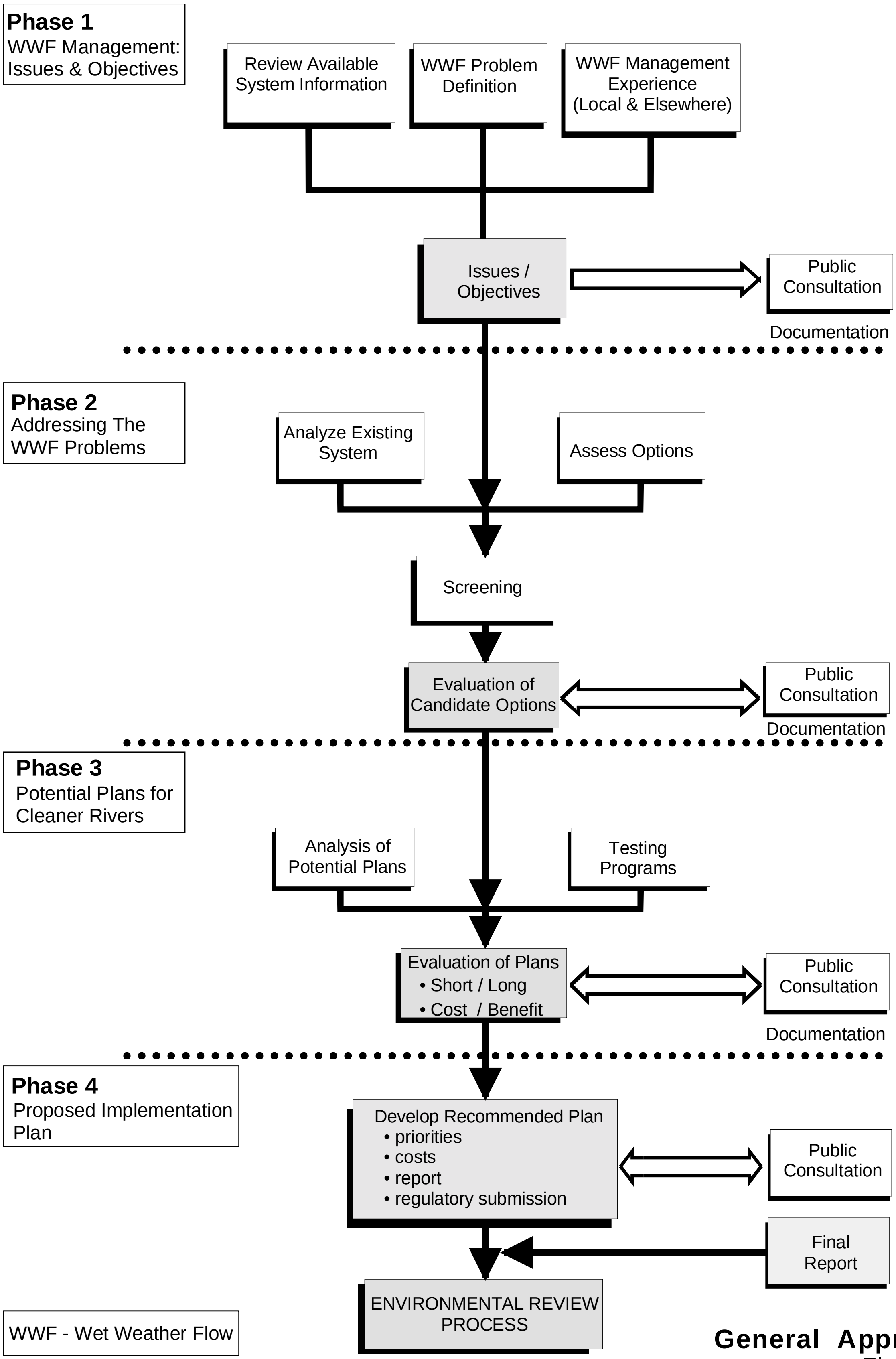
- developing an understanding of the effects of CSOs on river quality and river use;
- developing comparative cost and benefit information; and
- providing relevant information to enable informed value-judgements by policymakers and the public.

The implementation strategy, and the supporting assessments, analyses, and documentation, will be used by the City, after consultation with the public, to develop and substantiate its proposed program in the ongoing regulatory review process.

1.2.1 <u>Study Process</u>

The study was conducted in 4 phases, as shown in Figure 1-2. In addition to the technical studies, it was intended that experience elsewhere on CSO control would be drawn on, together with the input from public consultation. The process would involve a progressive distillation of knowledge and the development of the means of addressing the CSO problem in Winnipeg, eventually resulting in the selection of a recommended approach to CSO control.

Phase 1, was an introductory phase, and comprised a review of the available local information on CSOs, including their effects on river quality. It also developed a framework for technical evaluation, and a program for communication of study issues and results to the interested public and stakeholders.



General Approach
Figure 1-2

Phase 2 was entitled "Addressing the Wet Weather Flow (WWF) Problem". This phase comprised the development of data-gathering programs and computer simulation models (system hydrology, sewer hydraulics and river water quality dynamics under dry and wet weather). Dry weather flow issues were addressed. A wide-range of CSO control options was reviewed, including assessing the ability to handle wet weather flows (WWF) and analyses of structurally-intensive options. The costs and benefits of a blanket application of control options, that is, a single technology applied across the whole of the combined sewer area, were estimated. A comparison of such an application of the options was made. The intent was to determine those technologies which would be carried forward for more detailed assessment in Phase 3. Public consultation was begun and an Advisory committee of external individuals was established.

Phase 3 comprised an in-depth analysis of the options developed in Phase 2, including optimizing the existing system, and defined alternative CSO control plans consisting of combinations of these technologies. The impacts of the various scenarios on the existing infrastructure (interceptors and Water Pollution Control Centres) were assessed. These investigations resulted in a comparison of the performance, costs and benefits of the different control plans. Public consultation and dialogue with the Advisory Committee continued during this Phase.

Phase 4 comprised the final documentation of the study and the development of the preferred approach to CSO control. It included the preparation of an Illness Risk Report; the updating of the wet weather discharge perspective; refinement of the financial analyses of potential plans and ongoing discussions with the Advisory Committee and Manitoba Conservation.

At the end of each of the first three phases, the Study Team prepared Technical Memoranda (TMs) reporting on the results of the investigations. These TMs were distributed to all members of the Study Team, including the special advisors, for review of the documentation and subsequent discussion at a Workshop. The results of each of these workshops were, in turn, summarized in a TM. Suggestions for follow-up, elaboration or refinement were carried forward into the subsequent phase.

The study highlights are summarized on Table 1-1.

TABLE 1-1

STUDY HIGHLIGHTS

PHASE	ACTIVITY	REMARKS
1	**Problem Definition**	Introductory phase – review of all available information on local CSOs, including effects on rivers.
2	**Coarse Screening of Options**	The beginning of the site-specific analysis of the Winnipeg situation, development of data-gathering programs and computer simulation models.
	Interceptor	Hydraulic conditions modelled using XP-SWMM computer software
	CSO Hydrographs	XP-SWMM Software used to develop hydrographs on a city-wide basis.
	River Quality	Applied US EPA dynamic routing model (DYNHYD), along with the steady-state model (HEC2) to define hydraulic characteristics and travel times of the rivers. Detailed hydraulic information from DYNHYD was used to set up a cascading-pool description with the US EPA WASP model. WASP software was then used to simulate river quality under dry and wet weather conditions.
	Control Options	The application of broad spectrum of options, uniformly across all CS districts, was undertaken to obtain an order-of-magnitude indication of their effectiveness and cost.
	In-Line Storage	Identified as having the potential to improve river quality under dry and wet weather conditions.
	Diversion Structures	An inspection was undertaken to determine the structural condition of all CSO diversion structures in the City.
	Monitoring Program	A program was established to determine the reaction of the North East and North West interceptors to rainfall. - needed to determine capacity of main interceptor to dewater stored combined sewage.
	Public Consultation	Established external Advisory Committee as recommended by the CEC to monitor and comment on work in progress, comprised provincial, federal and municipal representatives, also began public consultation.
3	**Refinement of Options**	Comprised a more in-depth analysis of the options developed in Phase 2.
	Modelling And Recommended Program	A Paradox-based planning level model linked the land use/ runoff, the interceptor, the regional system/control alternatives and receiving stream models. The integrated model framework made it possible to assess number and volume of overflows, compliance with water quality objectives and illness risk. The model assessed the impacts of runoff and controls for 43 CS districts over a 36 year period, using 39 combinations of control alternatives. The end product allowed for definition of effects, operability and cost of an array of options and thus arrive at a final recommended control program.

Table 1-1 (cont'd)

PHASE	ACTIVITY	REMARKS
	Pilot Projects	
	1	Assessment of High Rate Treatment: tested effectiveness of Retention Treatment Basins (RTB) and Vortex Solid Separators (VSS) in treating CSOs.
	2	Demonstration of In-Line Storage – Clifton District: proposed to test motorized gate and inflatable dam. Used dynamic modelling (XP-SWMM) to establish operating parameters which would permit use of in-line storage without jeopardy level of basement flood protection. Project shelved as a result of siting complications.
	3	Demonstration of In-Line Storage – Hart District: moved through testing of motorized gate (because of concerns about reliability) to a finger weir structure (fail-safe). Program was shelved because cost of the weir option was considerably more expensive than the gate and the level of investment was considered premature.
	Public Consultation	Dialogue with Advisory Committee continued as well as general public consultation.
4	**Development of Potential Program**	Comprised the refinement of the potential program and the writing of the final report.
	Preferred Approach	Preferred approach was further developed so that it could be implemented over time with a stipulated annual expenditure. This activity included ongoing consultation with the regulators.

1.2.2 Final Report

This document presents an overview of the investigations and methodologies used during the course of the study, the findings of the investigations, the definition of a potential, illustrative program and the related conclusions and recommendations reached. The intent of this document is to provide the City Administration and City Council with sufficient background and understanding to enable them to formulate a river water quality management strategy for wet weather conditions.

Under the conventional decision-making process, the City would provide a proposal on CSO control to the Clean Environment Commission (CEC), who would hold public hearings to establish wet weather river water quality objectives. Manitoba Conservation[*] would be a key

[*] At the outset of the study, **Manitoba Environment** was the provincial agency responsible for regulation of the environment. During the course of the study these responsibilities were vested in **Manitoba Conservation.** The latter has been used throughout this report.

participant in these public hearings and would prepare their response. After the hearings, the CEC would make recommendations to the Minister of Conservation who, in turn, would issue an Order to the City, with specific compliance objectives. As discussed later, it is possible that the City and the Province may agree on an approach that would not require hearings.

1.3 STUDY DOCUMENTATION

In keeping with the phased approach to the study, there has been a progressive documentation of the study results. The documentation has been done through a series of technical memoranda and technical appendices, as shown in Table 1-2. In addition, a number of documents have been produced specifically to aid in the public consultation process.

The supporting TMs and appendices are intended for the technical readership. This final report presents a comprehensive synthesis of the study activities and results, while the Executive Summary (bound separately) discusses the main policy issues, the major study findings and the potential, illustrative program and the related recommendations.

References to the appropriate background TMs are provided (in italics) at the beginning of each section, or sub-section, as appropriate.

TABLE 1-2

STUDY DOCUMENTATION

Executive Summary

Technical Report
- Appendix # 1 "Illness Risk Report"

Technical Memoranda:

Phase 1
1 – Problem Definition
1 – Infrastructure
3 – Treatment
4 – Receiving Stream
5 – Control Alternatives
6 – Experience Elsewhere
7 – Technical Framework
8 – Public Presentation
9 – Phase 1 Workshop

Phase 2
1 – Problem Definition & Appendices
2 – Infrastructure and Treatment
3 – Control Alternatives and Experience Elsewhere & Appendices
4 – Receiving Stream & Appendices
5 – Public Communication
6 – Potential CSO Management Strategies
7 – Phase 2 Workshop

Phase 3
1 – Control Alternatives
2 – Public Communications
3 – Phase 3 Workshop
Appendices:
Appendix # 1 – Cost Estimates
Appendix # 2 – Alternatives, Site Investigation and Evaluation
Appendix # 3 – Treatability
Appendix # 4 – NEWPCC Impacts
Appendix # 5a – Infrastructure Modelling
Appendix # 5b – NE/NW Monitoring
Appendix # 6 – Floatables
Appendix # 7 – Assiniboine river Fecal Coliform Survey
Appendix # 8 – Ammonia Impacts
Appendix # 9 – Sonar Surveys Health Risk Study

Public Reports:

Phase 1 – Report
Phase 2 – Report & Study Update
Phase 3 – Study Update
Phase 4 – Letter of Endorsement from Advisory Committee

2. REGULATORY BACKGROUND TO THE STUDY

In 1987, the Provincial government promulgated the *Manitoba Environment Act*. With the passage of the *Act*, responsibility for protection of river water quality within the City was transferred from the City to the Province, under the administration of the Manitoba Department of Environment (now Manitoba Conservation).

During the time the City had responsibility for protection of the surface waters within its jurisdiction, the City developed its own pollution control program, with broad guidelines acceptable to both jurisdictions. This program included implementation of wastewater treatment in the 1930s (North End Water Pollution Control Centre [NEWPCC]). The system was progressively upgraded to a secondary level of treatment for all dry weather flows at the three existing treatment facilities. The program over this entire duration was defined, initiated and funded exclusively by the City of Winnipeg.

Prior to the *Manitoba Environment Act*, the City had undertaken a number of studies on water quality issues related to both dry and wet weather issues. The City has long recognized that CSOs represent an environmental issue with regard to stewardship of the river water quality. In its long-term water pollution control strategy, the City gave first priority to providing “state-of-the-art” secondary treatment to all dry weather flow. Having accomplished this goal, the next challenge was to address the intermittent wet weather sources of pollution, including CSOs. Following from these studies, the City was planning to undertake a major CSO planning study.

2.1 MANITOBA ENVIRONMENT ACT

Under the new *Environment Act*, the Province of Manitoba was given greater regulatory responsibilities for the management of surface water quality within the City, including the CSO issue. The *Act* provides that all proposed and existing developments having environmental impacts are subject to licencing. In 1989, the Minister of Conservation instructed the Clean Environment Commission (CEC) to hold public hearings and to provide a report with recommendations concerning water quality objectives for the Red and Assiniboine rivers, within and downstream of the City of Winnipeg, for the protection of beneficial uses of the rivers. This classification of the rivers was to be followed by further hearings into the licencing of the City of Winnipeg's three wastewater treatment facilities.

2.2 CEC CLASSIFICATION HEARINGS

In accordance with the above Ministerial Directive, the CEC hearings were held in late 1991 and early 1992. Both the City and Manitoba Conservation provided submissions to the CEC, along with numerous public and other government submissions. The CEC report (CEC 1992) contained 14 recommendations, including the types of beneficial uses, such as recreation, that should be protected during dry weather flow (DWF). The CEC proposed that classification of the rivers "***during wet weather flows should be postponed until site-specific research can provide adequate information for informed decision making***." With respect to CSOs, the CEC concluded that there was insufficient site-specific information to advocate a requirement that all CSOs be regulated or that the combined sewers be separated. Consequently, it recommended that site-specific studies be undertaken, to determine water quality impacts and to formulate remedial measures for potential CSO control (CEC 1992). Follow-up CEC Hearings were to be held "*within six months of the completion of the study to determine the implementation schedule for fecal coliform objectives*".

2.3 CITY OF WINNIPEG RESPONSE

The City readily accepted the CEC recommendation to complete a CSO study. Section 1.1, "Plan Winnipeg…Towards 2010", included a statement of principle to maintain and enhance the potential of the City's rivers as community assets. The document includes a specific initiative addressing the development of a CSO Management Plan to mitigate, in a cost-effective manner, the effects of CSOs on the rivers. The City expanded the scope of the study, as defined by the CEC, to address the full range of impacts on river quality including land drainage and upstream sources as well as CSOs. It also required a review of the potential integration of CSO controls into other related infrastructure programs, such as basement flooding relief, and CS renewals.

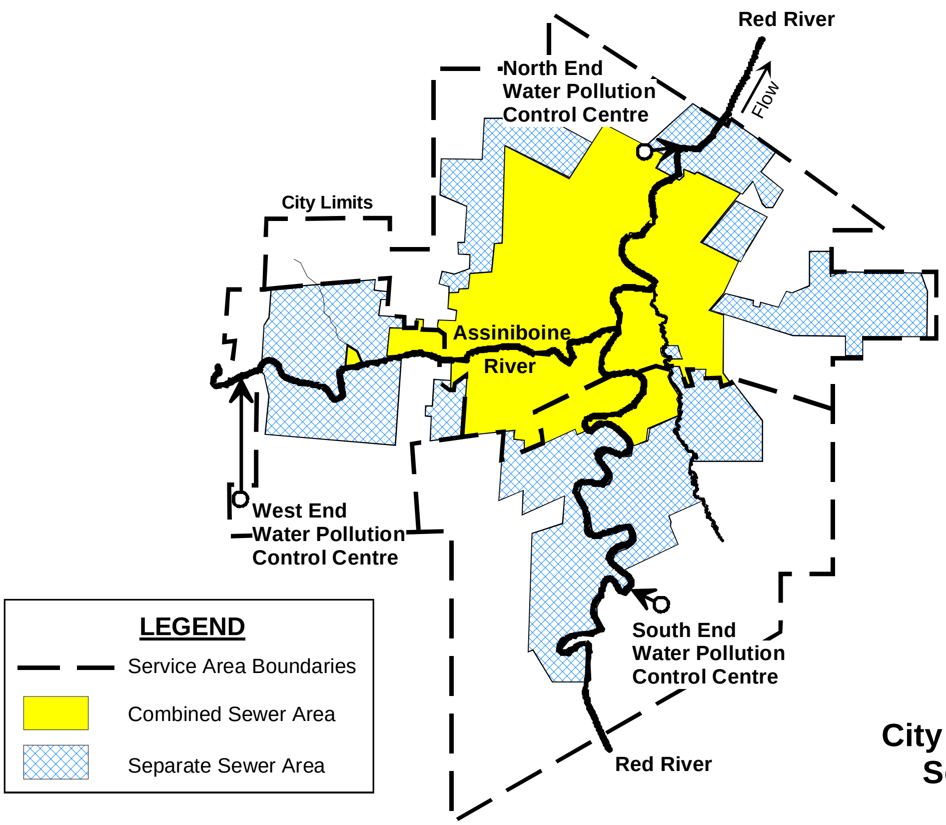
3. WINNIPEG WASTEWATER COLLECTION & TREATMENT

Background TM: Phase 2, TM #2

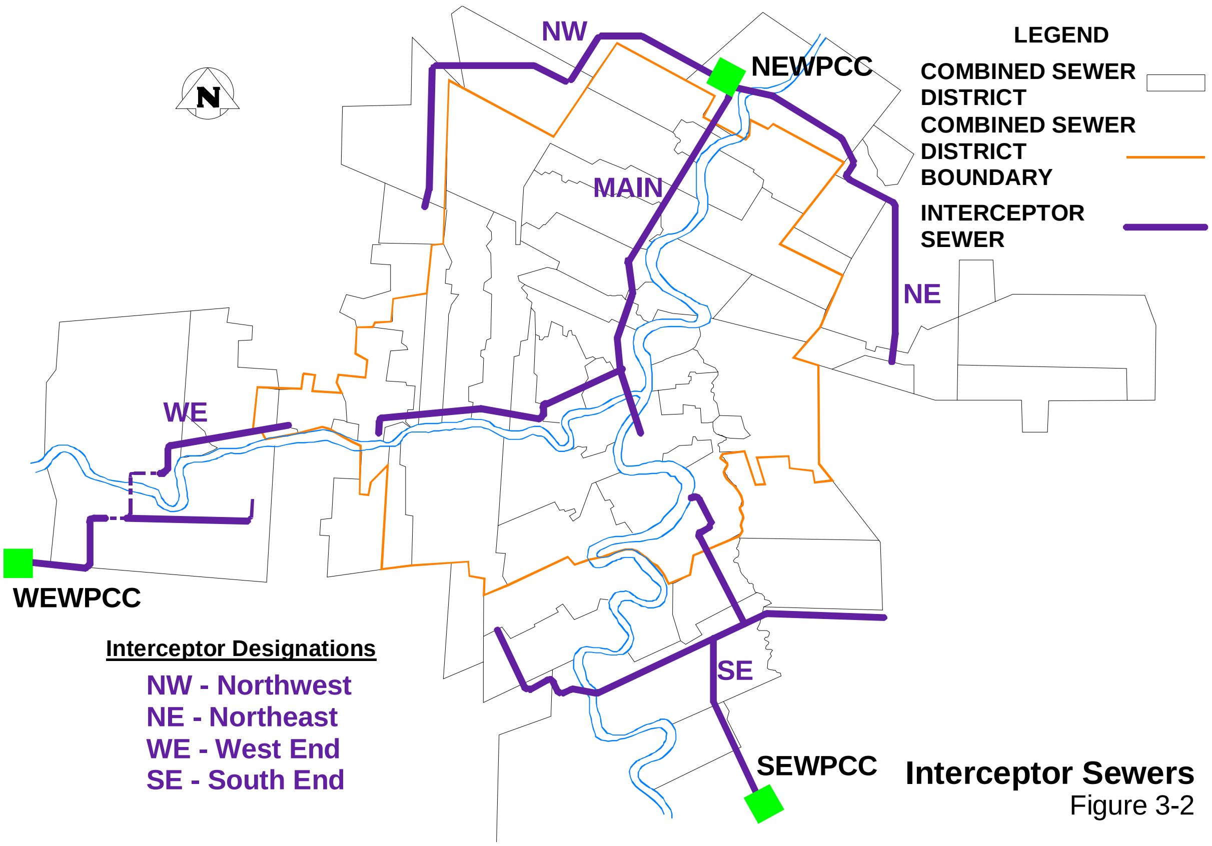
In order to evaluate potential control options, it is necessary to understand how the existing infrastructure operates, especially during wet weather conditions. A description of the main components of the wastewater infrastructure follows.

3.1 SEWERAGE SYSTEM

Wastewater in the City of Winnipeg is collected, and conveyed to the Water Pollution Control Centres (WPCCs), through three types of sewer systems, namely, combined, sanitary, and interceptor sewers. The combined and sanitary sewers collect wastewater from the source and convey it to the interceptor sewer system. The interceptor sewers in turn, collect the wastewater from the individual sewer districts and convey it to the WPCCs. The service area boundaries and the WPCCs are shown on Figure 3-1. The interceptors are shown on Figure 3-2.



City of Winnipeg Service Areas
Figure 3-1

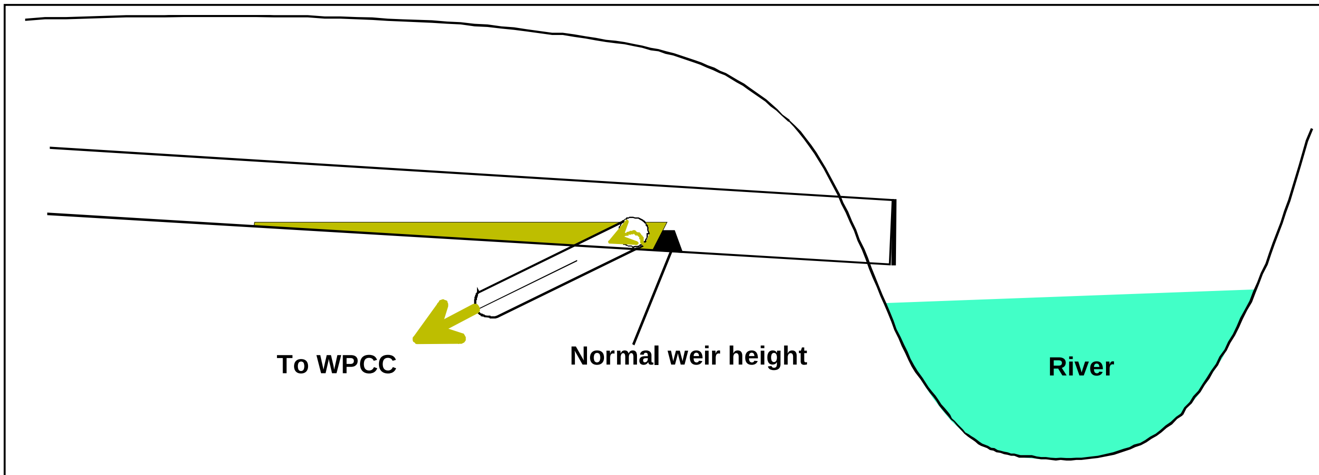


Interceptor Sewers
Figure 3-2

3.1.1 Combined Sewers

Combined sewer systems were installed in Winnipeg, as in most other major North American cities, up to 1960. The original purpose of the combined trunk sewers was to convey the wastewater/runoff flows away from the development and discharge directly to the rivers. Forty-three combined sewer districts were established, each with an outfall sewer to the river.

In the 1930s, interceptor sewers were built, along with associated diversion weirs and pumping stations, to intercept the wastewater discharging into the rivers and to convey the wastewater to the newly constructed North End Water Pollution Control Centre (NEWPCC). The diversion arrangement is illustrated in Figure 3-3. The system was designed to convey about 2.75 times dry weather flow (DWF), thus including a nominal amount of wet weather flow (WWF), to the treatment plant. (The 2.75 interception factor was consistent with general practice at the time and is above typical peak DWFs of about 2 x DWF). During dry weather all flow is conveyed to the treatment plants. During the majority of wet weather events, the flows in the combined trunk sewers greatly exceed the capacity of the interceptor sewers and the excess overflows to the rivers. Such overflows occur, on average, about 18 times during a typical recreation season (May 1 to September 30), although the numbers range from 7 to 30 for the individual districts.



Combined Sewer Diversion
Figure 3-3

The CSO districts have a history of basement flooding during intense summer storms. The City has initiated basement flood relief (BFR) programs to alleviate this problem, which have resulted in the installation of relief piping, catchbasin inlet restrictors and separation of sewers in selected areas. In 1999, the 43 combined sewer districts have a total of 72 combined sewer outfalls to the rivers, including relief pipes. Selective separation for the purpose of basement flooding protection has reduced the total combined sewer area to about 8,700 ha.

3.1.2 <u>Separate Sewers</u>

Since 1960, all new developments in the City of Winnipeg have been serviced by a two-pipe system, one for wastewater (separate sanitary sewers) and one for stormwater (land drainage sewers, LDS). Overland stormwater runoff is channelled, via catchbasins, into the LDS system and is then conveyed, either directly to the rivers or local surface water courses, or indirectly through stormwater retention basins (SRBs).

The sanitary sewers collect domestic, commercial and industrial wastewater and convey it, via the interceptor system, for treatment at the WPCCs. Under DWF conditions, all wastewater is conveyed to the plants. Under WWF conditions, extraneous stormwater flows can enter the system through foundation drains, infiltration, direct inflow and, in extreme cases, can cause sanitary sewer overflows (SSOs).

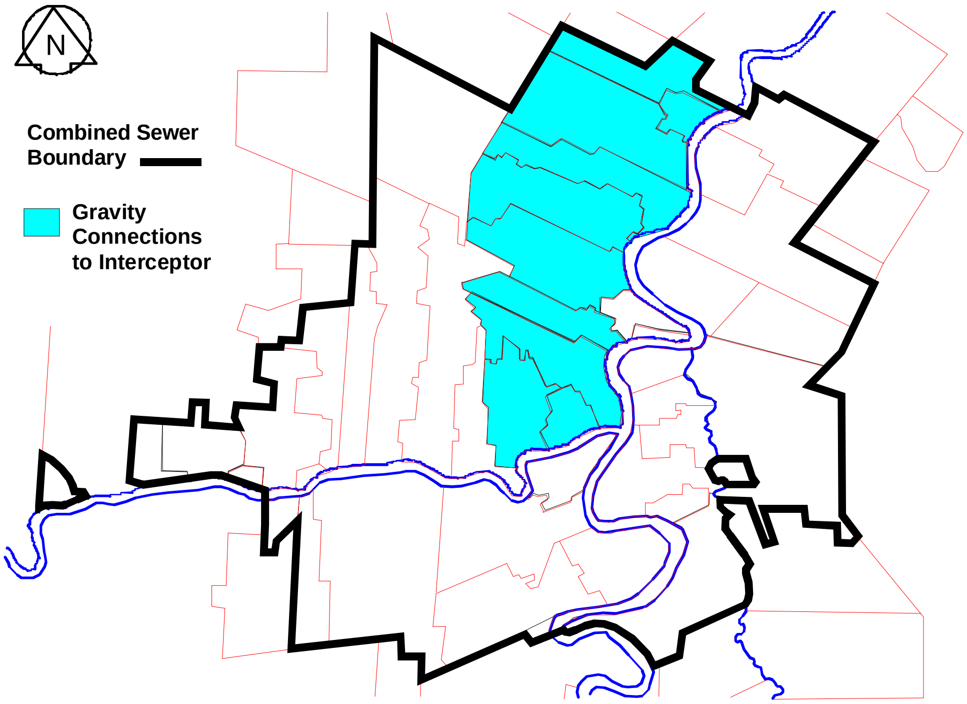
3.1.3 Interceptor Sewers

The interceptor sewers convey the wastewater and combined sewage from the individual sewer districts to the WPCCs. There are five major interceptor sewer systems in the City (see Figure 3-2). The Main, Northeast and Northwest Interceptor systems are tributary to the NEWPCC. The SEWPCC and WEWPCC each have a tributary interceptor system.

Main/NE/NW Interceptors

The Main Interceptor serves the older part of the City and receives flows from combined sewer districts only. It conveys diverted flows from 34 of the 43 combined sewer districts (approximately 7,750 of the current 8,700 hectares of sewers served by the combined sewer systems). The Interceptor has capacity to convey all diverted flows from minor storm events (typically 5 to 10 per year). For larger storm events, potential overflows can occur at the combined sewer districts which discharge to the river by gravity (e.g., St. John's, Polson, etc.) and at other points at the upstream end of the system.

- Most of the flow diversions to the Main Interceptor are pumped. Ten of the districts are sufficiently high, in elevation, that the flows could be diverted by gravity (Figure 3-4). There is a wide variation in interception rates (from 1.3 to 26 x average DWF) for the individual districts. This variation from the original design of 2.75 x DWF has resulted from modifications to the diversion facilities.



Districts with Gravity Connections to the Interceptor
Figure 3-4

- Hydraulic analysis of the Main Interceptor system (including the NEWPCC) indicated that there is sufficient capacity to convey up to 5 times DWF on an area-wide basis. This indicates potential for enhanced WWF operations (through extensive upgrades to the district diversion facilities) of the interceptor system.

- Due to the importance of the Main Interceptor as the backbone of the City's central collector system, visual spot inspections were carried out to provide a preliminary estimate of its structural condition. Based on the limited inspection, the structural condition of the Main Interceptor, in spite of its age (over 60 years), is surprisingly good (Wardrop/Tetr*ES* 1995).

The Northeast (NE) Interceptor conveys wastewater flows from the North Kildonan and Transcona areas. The Northwest (NW) Interceptor conveys wastewater from the Brooklands and Maples areas. Both interceptors are relatively new and serve separate sewered areas.

<u>SE/WE Interceptors</u>

The south-end (SE) and west-end (WE) interceptor sewer systems are also shown on Figure 3-2. These interceptors convey flows from primarily separate sewer districts, however, the SE and WE interceptors also receive diverted combined sewer flows from 4 and 3 districts, respectively.

The SE interceptor conveys separate wastewater flows from the Fort Garry, St. Norbert, St. Vital and St. Boniface areas, as well as combined sewage from Cockburn/Calrossie, Baltimore, Major and Metcalfe Districts.

The WE interceptor conveys separate wastewater flows from the St. James and Charleswood areas and combined sewage from Woodhaven, Moorgate and Strathmillan Districts.

Although serving essentially separate areas, both the WE and SE interceptor systems are subject to extraneous WWF from foundation drains or inflow from manholes, infiltration, etc. Further investigations into this situation have been recommended in Section 11.

3.2 WATER POLLUTION CONTROL CENTRES (WPCCs)

As indicated on Figure 3-1, the City's sewerage system is serviced by three water pollution control centres, namely, the North End Water Pollution Control Centre (NEWPCC), the South End Water Pollution Control Centre (SEWPCC), and the West End Water Pollution Control Centre (WEWPCC). Since the installation of the first plant in the mid-1930s (the NEWPCC), the City of Winnipeg has continuously increased and upgraded their treatment capacity to the present time. Currently, the City's DWFs receive state-of-the-art secondary treatment (biological activated sludge) prior to discharge to the Red and Assiniboine Rivers. Plant capacities are summarized in Table 3-1.

TABLE 3-1

WPCC DESIGN CAPACITIES

Treatment	ADWF ML/d	PDWF ML/d	Factor x ADWF	PWWF ML/d	Factor x ADWF
NEWPCC					
Primary	302	600	2.0	825	2.75
Secondary	302	600*	2.0	600*	2.0
SEWPCC					
Primary	58	200	1.7	176	3.0
Secondary	58	200	1.7	100	1.7
WEWPCC					
Primary	32	54	1.7	112	3.5
Secondary	32	54	1.7	54	1.7

ADWF = Average Dry Weather Flow
PDWF = Peak Dry Weather Flow
PWWF = Peak Wet Weather Flow
ML/d = Megalitres per day

*currently restricted to 400 ML/d

During spring runoff and following heavy rainfalls, flows may exceed the hydraulic capacity of the secondary treatment process. These excess flows receive primary treatment only and are blended with treated secondary effluent before being discharged to the river.

3.3 ONGOING RELATED PROGRAMS

3.3.1 <u>WPCC Effluent Disinfection</u>

Until recently, the treated effluents from the three WPCCs were not disinfected before discharge to the rivers. The City has undertaken a program of implementing disinfection of these effluents. At the SEWPCC, disinfection facilities using ultra-violet light (UV) went on-stream in July of 1999. Disinfection of the NEWPCC has been included in the City's Five Year Capital Budget program but the technology has not yet been selected. In the case of the WEWPCC, treated effluent is discharged through the existing lagoons prior to discharging to the river, resulting in compliance with fecal coliform limits without disinfection.

3.3.2 Basement Flooding Relief

Beginning in the 1960s, the City implemented a program designed to increase the sewer system hydraulic capacity, and hence reduce the frequency of basement flooding in those districts where such flooding occurred frequently. The program included: replacement of some smaller sewers; selective separation where economically feasible, and construction of relief sewers, often paralleling inadequate trunk sewers. The City has spent more than $200 Million to date, with another $110 Million budgeted for future investment. There is considerable potential in integration of future basement flood relief and potential CSO control measures.

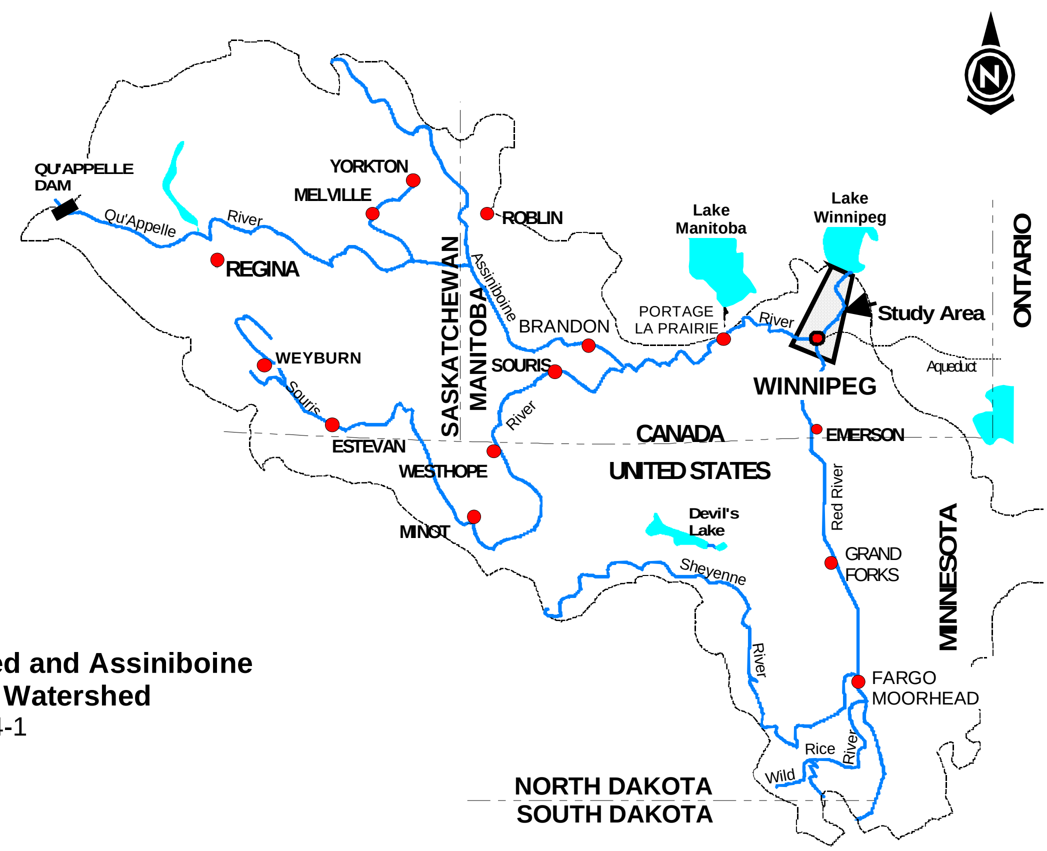
3.3.3 Sewer Renewal

Many of the City of Winnipeg's combined sewers were constructed in the early 1900s. As with other North American cities, the City has become concerned with the condition of these aging sewers and the need to rehabilitate them. The City is currently investigating the extent of deterioration in the sewer systems and implementing appropriate methods to maintain their continuing operation. The current financial plan includes budget provisions for about $8 million per year for combined sewer rehabilitation.

4. RIVER USES AND COMBINED SEWER OVERFLOW IMPACTS

Background TMs: Phase 2, TM #4: Phase 3 TM #4

The Red and Assiniboine Rivers drain a large watershed, including prairie regions of southern Manitoba, southeastern Saskatchewan, North Dakota, northern South Dakota, and northwestern Minnesota (Figure 4-1). The total drainage area exceeds 270,000 km^2 (Wardrop and Tetr*ES* 1991). Much of the tributary area has an extensive drainage network. The rivers cross intensively-used agricultural lands. Many cities, towns, and agricultural operations discharge into the rivers before they reach Winnipeg. The rivers naturally carry large volumes of suspended sediments.

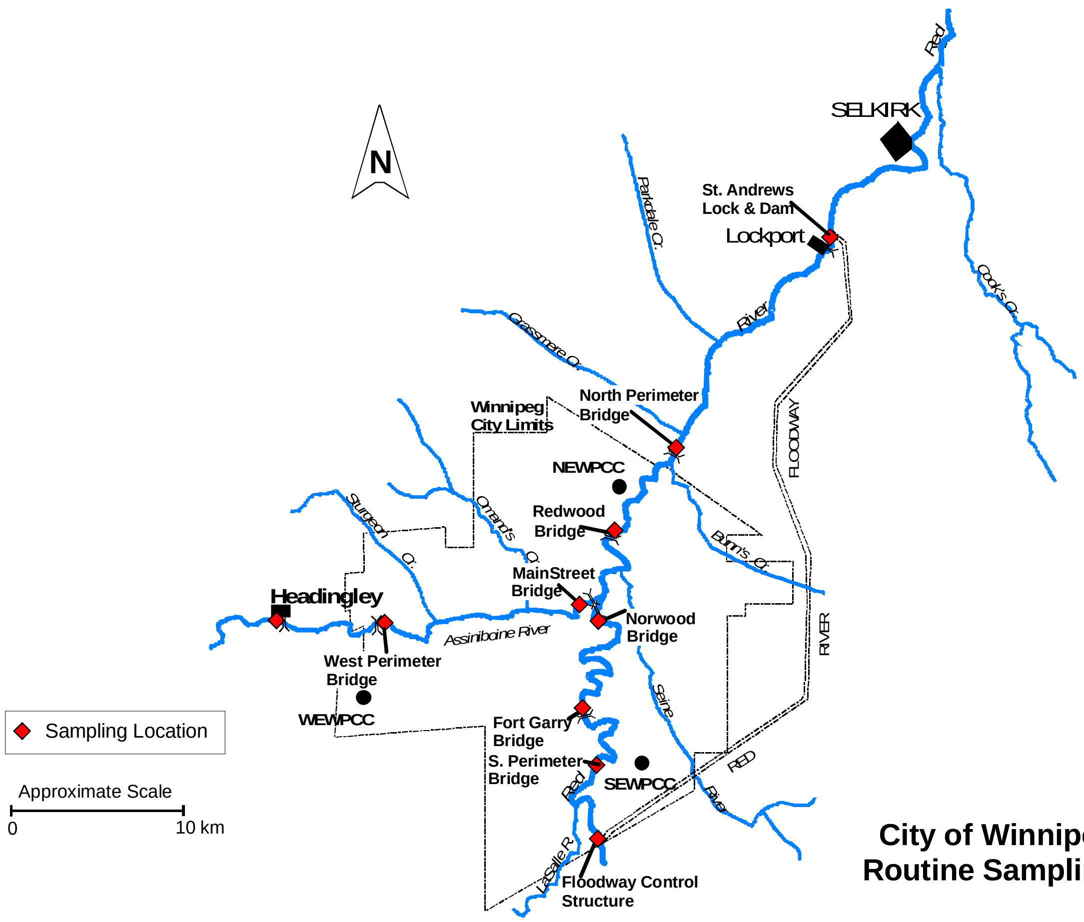


The Red and Assiniboine Rivers Watershed
Figure 4-1

4.1 WATER QUALITY IN THE RIVERS

The water quality of the Red and Assiniboine Rivers has been monitored extensively by the City of Winnipeg for many years. Since 1977, the City has conducted bi-weekly monitoring of key water quality parameters in the Red and Assiniboine Rivers year-round, at eleven bridges throughout the study area (Figure 4-2). The Province of Manitoba also monitors water quality upstream and downstream of the City of Winnipeg.

The City has also conducted numerous specific monitoring programs which have provided data relevant to the CSO study.



City of Winnipeg Bi-Weekly Routine Sampling Locations
Figure 4-2

4.1.1 Manitoba Surface Water Quality Objectives

The Province has set Manitoba Surface Water Quality Objectives (MSWQO) which define the minimum levels of quality which will protect specific beneficial uses of surface waters (Williamson 1988a). Compliance with the objectives is intended to protect aquatic life, designated river uses, and public health, to an adequate degree of safety. Over eighty substances are listed in the objectives, which cover six classes of use. Several narrative requirements are also noted, such as avoiding the discharge of sewage-related material. Wastewater assimilation is recognized as a beneficial use of surface water in the MSWQO but no special requirements are indicated.

Manitoba Conservation is proposing amendments to these objectives (Williamson 2001), however, these are not expected to change the objectives for wet weather conditions.

After the 1991/92 hearings, the Clean Environment Commission (CEC) recommended, and Manitoba Conservation accepted these recommendations, that river uses be protected for the local rivers as shown in Table 4-1 (CEC 1992). One of the major water quality issues identified by the CEC was fecal coliform levels in the rivers due to urban discharges.

TABLE 4-1

**CEC RECOMMENDATIONS: RIVER USES TO BE PROTECTED
(DRY WEATHER CONDITIONS)**

RIVER USE CLASSIFICATION	RED RIVER	ASSINIBOINE RIVER
Aquatic life and wildlife	√	√
Recreation a) primary	√	
b) secondary	√	√
Agricultural (Irrigation & livestock watering)	√	√
Industrial Consumption	√	√
Raw water for domestic consumption	√	√

In the case of CSOs, it is necessary to review the rivers uses, the MSWQO for these uses, and consider how CSOs and other dry and wet weather discharges affect the use or the compliance with the relevant numerical objectives. The next section will discuss the various classes of uses and the associated water quality issues.

4.2 RIVER USES

The Red and Assiniboine Rivers support a number of natural and human activities within and downstream of Winnipeg. These activities can be affected by the rivers' water quality.

The following is a brief overview of the individual classes of river use along with the related water quality issues, particularly as they are affected by CSOs.

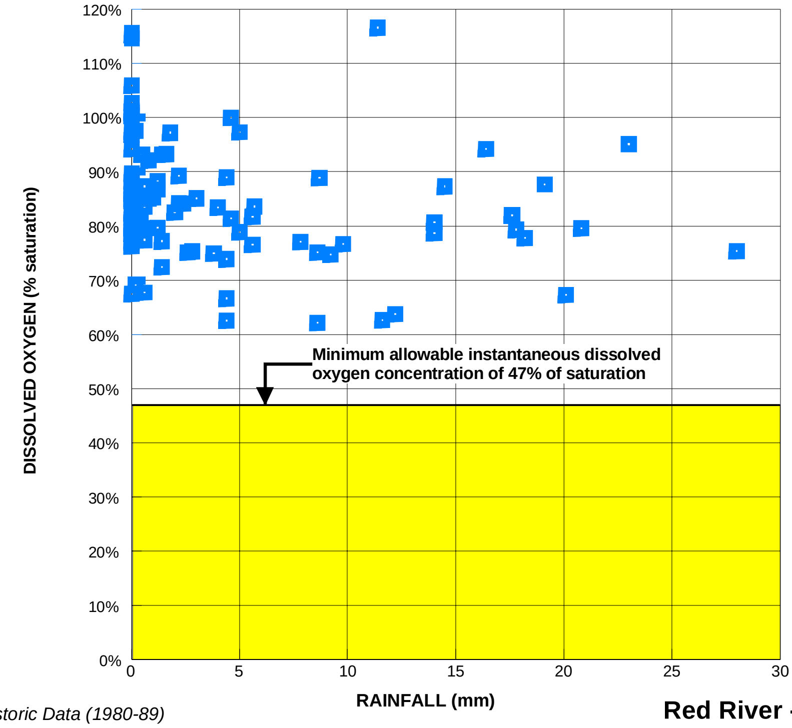
4.2.1 Habitat for Fish and Other Aquatic Life

In their natural state, rivers support aquatic plants and animals. Generally, conditions that support a healthy fish population indicate good conditions for other aquatic life. The Red River represents a highly-valued sports fishery. In 1998, over 1,600 master-angler awards were given for 11 species of fish caught in the Red River.

Discharging treated and untreated wastewater can change conditions in the rivers and affect their ability to support aquatic life. The MSWQO set desired minimum or maximum levels for substances related to wastewater that can affect fish populations. Dissolved oxygen and ammonia content are two of the most important criteria.

Dissolved Oxygen

Dissolved Oxygen (DO) is a very important parameter for protecting aquatic life. DO levels in the Rivers within the study area have been shown to be well above the minimum concentrations in the Objectives. DO has been shown, through monitoring and water quality modelling, to be relatively unaffected by WWF for current and projected future conditions (see Figure 4-3 which shows the DO levels in the river in the heart of the Winnipeg urban area, at the Redwood Bridge after a range of rainfall and CSO events). DO levels were found to exhibit a depression of about 1 mg/L in response to significant CSO events. The depression does not threaten levels required to sustain a healthy aquatic life. Accordingly, DO is not a CSO issue.



Source: COW Historic Data (1980-89)

Red River - Redwood Bridge
Wet Weather Dissolved Oxygen Levels
Figure 4-3

Ammonia

Ammonia can be toxic to aquatic life, depending on the concentration and the organisms and their life stage. Most of the ammonia entering the rivers through the City of Winnipeg is from treated wastewater effluent discharges. CSOs are not a significant factor in ammonia levels in the rivers. In response to a CEC recommendation, studies are currently being undertaken on the impact of ammonia on local aquatic life. These studies are independent of the CSO Management Study and focus on DWF effects, i.e., the WPCC effluents.

Persistent Toxic Substances

Toxic substances are a rural and urban land drainage issue rather than a CSO issue, i.e., if the combined sewer system was separated, the same toxic substances would be discharged into the rivers via the land drainage sewers. Monitoring done to date indicates that persistent toxic substances in the Rivers are not a significant issue at this time with respect to compliance with objectives.

Suspended Solids

The local rivers carry large volumes of suspended sediments giving them their characteristic murky brown appearance ("typical prairie rivers"). These natural characteristics limit water contact activities such as swimming. Because of their episodic nature, CS discharges only add solids to the rivers during and following rainstorms, and during snowmelt. The bulk of this loading would reach the rivers through land drainage sewers even if the system was totally separate. Sediments are not considered an important issue for the CSO study. The typical suspended solids in the Rivers exceed the guidelines for aquatic life due to natural conditions and are elevated somewhat during runoff events. Suspended solids from CSO's are not considered to be an important issue for aquatic life in the urban setting since an abundant and diverse aquatic life exists.

4.2.2 Recreation

More than any other use, water-related recreation exposes the largest number of people to the rivers. Under the MSWQO, such recreation in divided into primary and secondary uses. Primary recreation involves activities in the water, like swimming and waterskiing, where immersion in the water is probable. Secondary recreation covers activities like fishing, boating, hunting, camping and hiking, where immersion in the water is incidental or accidental.

Primary Recreation

MSWQOs have been developed for turbidity levels for primary recreational use (i.e., involving likely immersion). The rationale for this objective is based on the need for water clarity for situations where swimmers are in distress. These turbidity levels are frequently exceeded in the Red River. Swimming activities are limited because of the unattractiveness of the rivers' natural muddy appearance. The steep and muddy banks are unappealing to swimmers and, in addition to providing no beach access, pose safety hazards. Waterskiing and jetskiing comprise more frequent usage of the river than swimming.

Secondary Recreation

Secondary recreation is much more extensive, with power-boating being the most popular. Estimates range between 11,000 and 70,000 boaters on the rivers, with about 60% thought to be regular river users who moor their boats at private docks or marinas. Power-boating is most common between the Floodway entrance control structure, in St. Norbert, and Selkirk. Several commercial river cruise boats ply the rivers regularly. Canoeing is estimated to involve between 200 and 1,600 users annually. About 200 competitive rowers also use the river as a club activity.

The parameter of greatest concern for recreational use of the rivers (primary recreation especially) is microbiological, represented by the fecal coliform indicator organism as an indicator of risk to human health, since present concentrations frequently exceed the objectives. This issue is very relevant to both dry and wet weather flow management. The provincial numerical objectives call for fecal coliform concentrations to be less than 200 fecal coliform per 100 mL (fc/100 mL) for primary and secondary recreation, respectively.

During dry weather

During dry weather, elevated fecal coliform levels in the rivers may originate from:

- sources upstream of the City, which occasionally result in fecal coliform levels above the MSWQO recreational limits;
- treated effluent (undisinfected) from the WPCCs*, which may cause instream levels to exceed the MSWQO for recreation; and
- dry weather overflows (DWO), which result from illegal or faulty sewer connections or occasional operational emergencies.

---

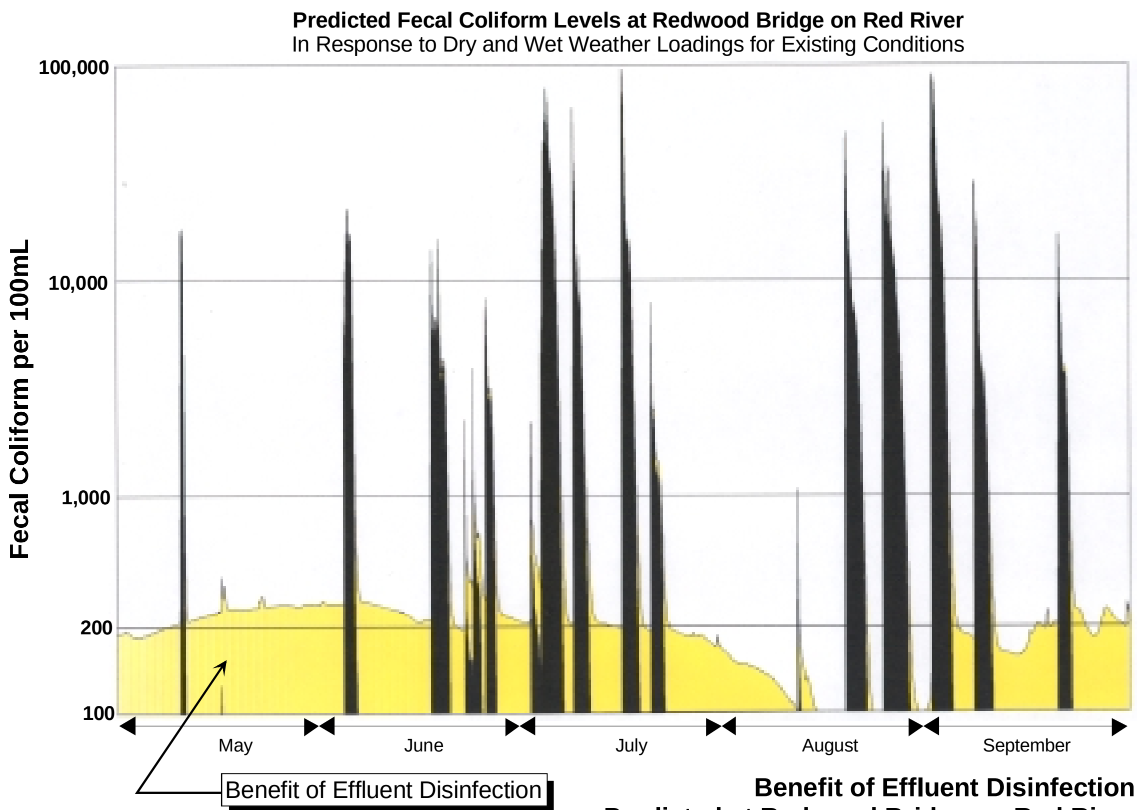
* The City has begun a program to disinfect WPCC effluents to meet the CEC recommendation that the rivers be protected for recreation during dry weather conditions.

During wet weather

During wet weather, there are five major sources of fecal coliform discharge from the City of Winnipeg into the rivers, namely:

1) interceptor sewer overflows;
2) combined sewer overflows (CSOs);
3) land drainage sewer (LDS) discharges;
4) sanitary sewer overflows (SSOs); and
5) WWPC effluent (including bypasses of secondary treatment process).

During wet weather, all five sources affect river water quality. Combined sewer overflows contribute the most fecal coliforms. Overflows generate high levels of transient fecal coliform, creating fecal coliform "spikes" in the rivers which often greatly exceed the MSWQO for recreation, as shown by Figure 4-4, which shows Red River concentrations in a typical summer period at the Redwood Bridge. Natural die-off causes the elevated coliform levels to return to normal in about three to four days, depending on river temperature, sunlight and other factors.



Benefit of Effluent Disinfection
Predicted at Redwood Bridge on Red River
Figure 4-4

Disinfection of WPCC effluents will improve the quality of river water during dry weather conditions. It is anticipated that WPCC disinfection will result in general compliance with the primary recreation objective (elimination of the yellow area on the figure) during dry weather conditions. However, such disinfection will have little or no effect on the spikes of fecal coliform from CSOs, LDSs and sources upstream of Winnipeg.

The CEC recommended that classification for these uses during wet weather flows should be postponed until additional research can provide adequate information for informed decision-making.

4.2.3 Irrigation

The CEC recommended that both the Red and Assiniboine rivers be protected for the use of the water for irrigation or agricultural consumption (greenhouse and/or field crop irrigation) during dry weather conditions. Manitoba Conservation has microbiological guidelines for these uses. The numerical objectives are 1,000 fc/100 mL, except in cases where contact with the irrigation water by field staff is probable, where 200 fc/100 mL will apply. There are about 40 greenhouse operations in the Winnipeg vicinity; most do not use the river due to restricted access to the rivers due to development. While some seven operations use the river periodically, all but one of these operations are located where CSOs would not affect their withdrawals.

4.2.4 Domestic and Industrial Consumption

The CEC ruled that the Red and Assiniboine Rivers should be protected as a source of raw water for domestic and industrial consumption. These recommendations would not require action by the City of Winnipeg with respect to CSO control, as no guidelines are provided for industrial use. Any use of the river water for potable drinking water purposes would require complete treatment even if no CSOs existed (CEC 1992).

4.2.5 General Requirements

Aesthetics

The MSWQO contain some general qualitative requirements for surface water quality. All surface waters should be free of constituents attributable to sewage, industrial, agricultural and other land use practices. The aesthetic quality of the rivers is affected by City of Winnipeg WWF discharges, particularly CSOs, and to a lesser extent, LDSs. Options for CSO control for aesthetic considerations were thus examined in this study.

Nutrients

The MSWQO also discusses nutrients. Nitrogen, phosphorus, carbon and other trace elements should be limited to the extent necessary to prevent the nuisance growth and reproduction of aquatic plants, fungi or bacteria.

CSO discharges play a minor role in the seasonal and annual contribution of nitrogen and phosphorus load to the rivers. On an annual basis, the CSO loading amount is less than 10% of the load contributed by treatment plant effluents and land drainage. On a single-event basis, the CSO load is approximately 30% of the total contribution of the event.

An analysis was made of the nutrient loading on the Lake Winnipeg south basin in order to place the City of Winnipeg contribution into context. The conclusion reached was that nutrient loadings from wet weather sources are not considered a significant CSO issue. The results are documented in Section 7.5.3.

4.3 SUMMARY OF WATER QUALITY ISSUES

A summary of the key water quality issues is shown in Table 4-2.

TABLE 4-2

RIVER WATER QUALITY ISSUES AND CSOs IN WINNIPEG

RIVER USE	CSO ISSUE
Aesthetics	Floating debris attributable to wastewater
Environmental regulation/policy/public perception	Overflow of untreated wastewater
Recreation	Microbiological (public health)
Greenhouse, irrigation	Microbiological (public health)

The key issues with respect to water quality and CSOs are microbiological quality (fecal coliforms are used as indicator bacteria and a measure of contamination), aesthetics (floatables), and regulatory compliance.

Sediment loading and persistent substances such as metals and pesticides are not considered major issues related to CSOs. CSO volumes under various CSO control options can provide a suitable surrogate for these parameters to the extent that their reduction is of interest.

5. TECHNICAL APPROACH

Background TM: Phase 3 TM #1, Section 3

Characterization of the CSO situation requires careful consideration of the effects of WWF on the receiving streams and its potential impairment of beneficial river uses.

The purpose of the CSO management strategy study is to provide information to assist the regulatory authorities, the City of Winnipeg, and the residents in choosing an appropriate balance between costs and benefits of potential control strategies. The implementation plan which is selected must be practicable, affordable and must address the priorities of the Winnipeg taxpayers.

This section provides an overview of the Technical Approach used to develop the options, and the potential implementation plans, along with a methodology for evaluating these options.

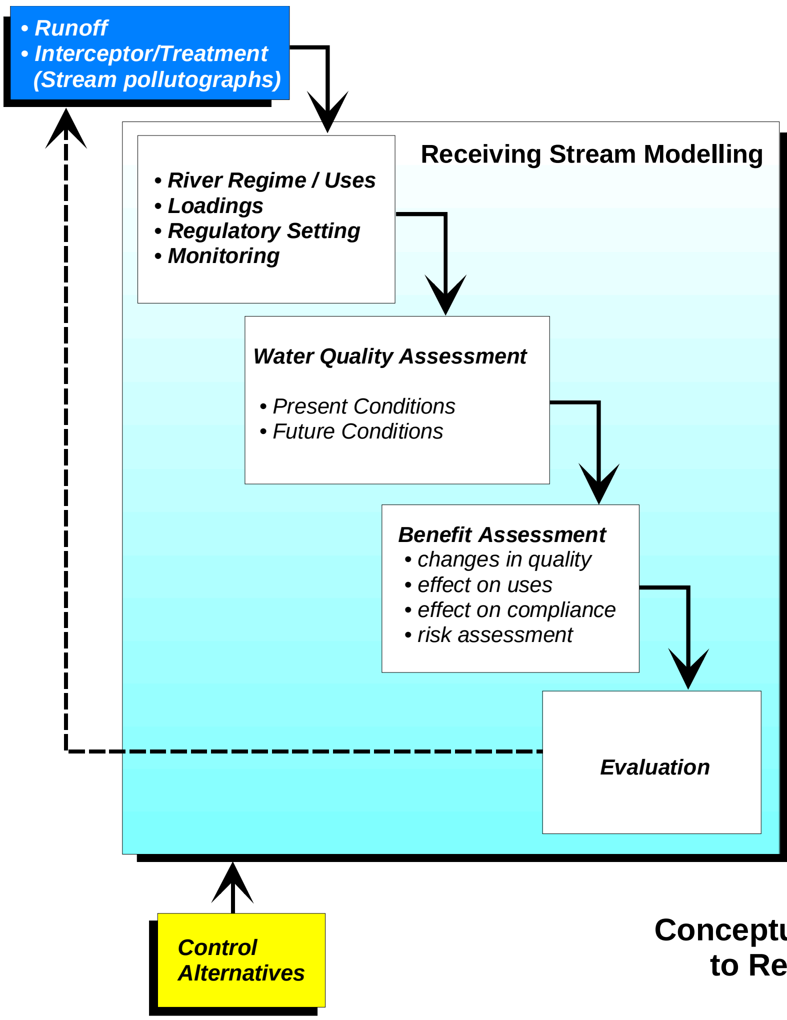
5.1 APPROACH

For the current study, it was necessary to review the available CSO abatement technologies and to evaluate them for their particular application to the specific combined sewer areas in Winnipeg. Factors considered included regulatory compliance, reduction in illness risk from use of the rivers, improvements in aesthetics, feasibility, complexity, proven experience, costs, land requirements, and environmental and public acceptance considerations.

In order to characterize the Winnipeg situation under current conditions and for combinations of possible control alternatives, extensive numerical modelling of the receiving stream under existing DWF and WWF conditions was carried out. Figure 5-1 illustrates the general approach taken. The objectives of the receiving stream modelling were:

- to provide the policymakers and the public with information about how WWF, particularly CSOs, affect the existing water quality;
- to determine the way in which control options would improve the water quality; and

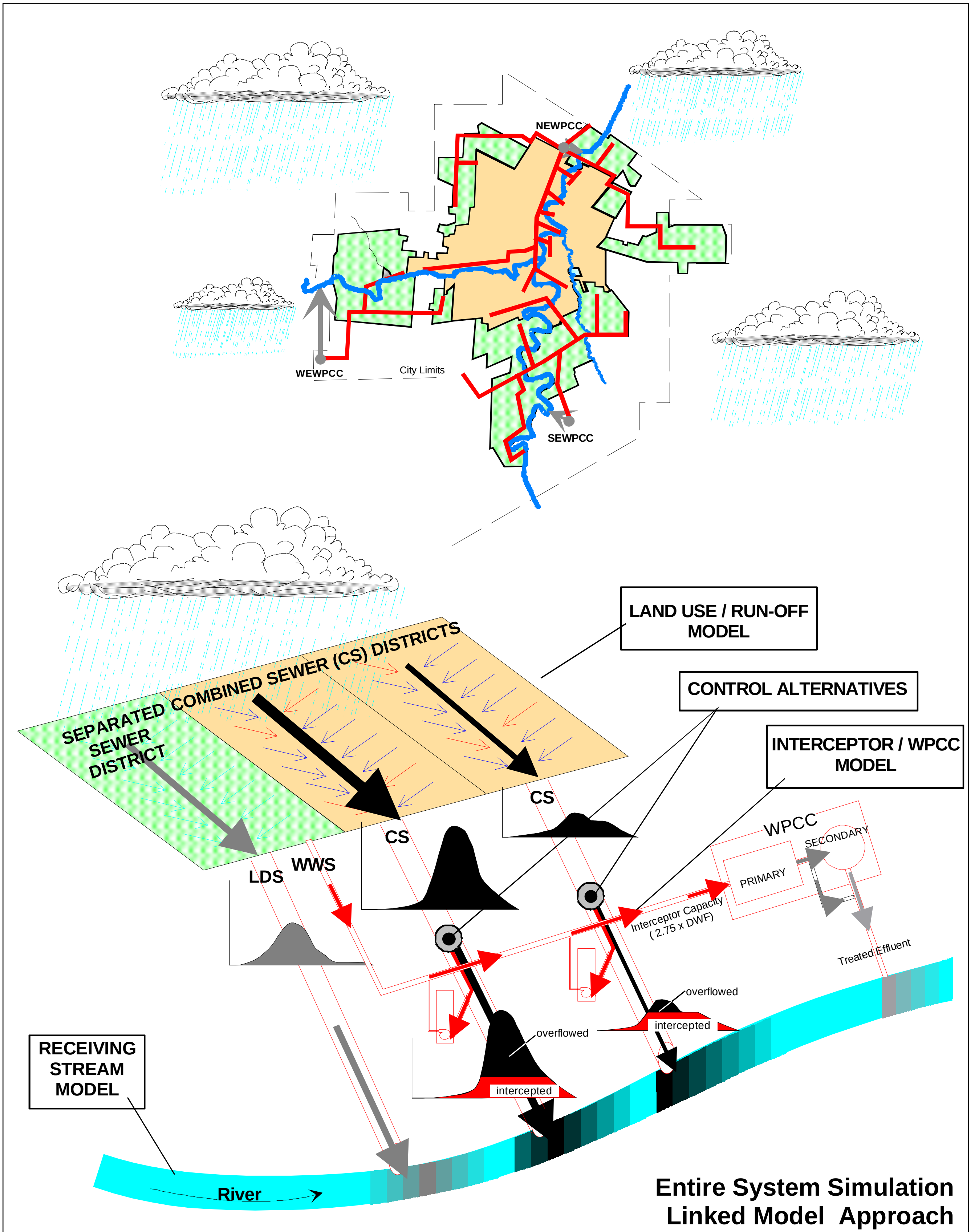
- to predict the associated changes in beneficial use of the rivers.



Conceptual Overview of Approach to Receiving Stream Modelling
Figure 5-1

A single computer model of adequate sophistication to achieve these objectives was not found to exist. Therefore, it was necessary to develop a technical framework which integrated a series of models to simulate system behaviour. A series of linked integrated mathematical computer models was used to simulate system hydrology, pollution loads, conveyance hydraulics and control options. This technical framework was presented in several technical forums and for scientific comment and review (e.g., WEF Annual Conference, Dallas 1996; Effluent Impact Modelling Workshop, Winnipeg, 2001).

A description of the integrated modelling approach follows.



Entire System Simulation Linked Model Approach
Figure 5-2

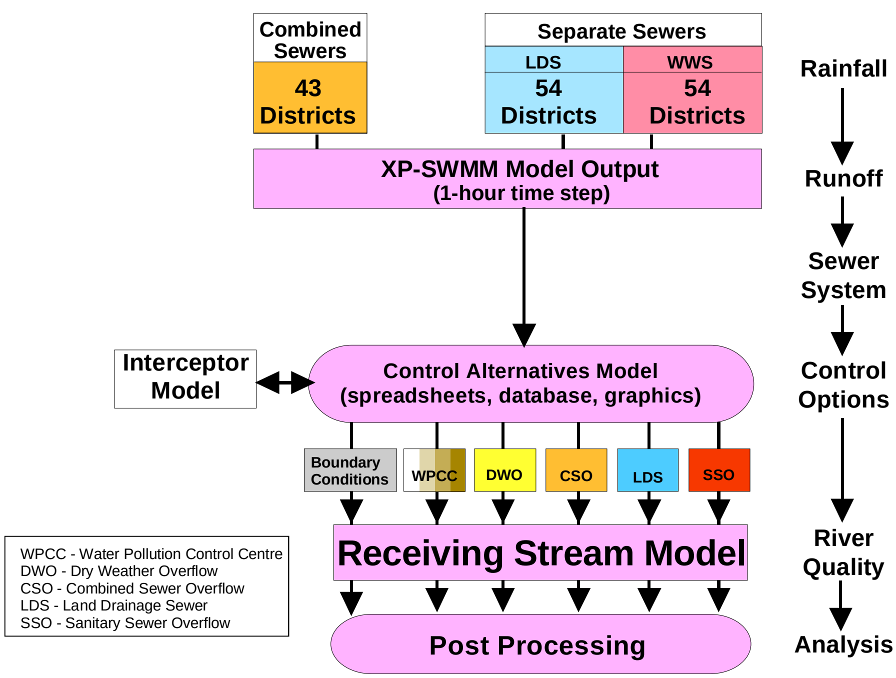
5.1.1 Integrated Modelling Approach

Conceptually the regional model was divided into four major sub-models (Figure 5-2):

- urban land use/runoff model;
- interceptor model;
- regional system/control alternatives model; and
- receiving stream model.

After careful review of the available spectrum of computer-based models, a modelling framework was developed to assist in the logical flow of data between the linked models, as shown in Figure 5-3. The choice of models was done in collaboration with specialists with experience in a broad cross-section of North American and European studies on CSO control strategies. Integration of the four major sub-models provided the required system evaluation of CSO impacts on water quality. Several quality checks were built into the technical framework to ensure that model simulations were sufficiently accurate for planning level analyses.

The models were used to understand the existing conditions in the rivers and the relevant contributions of different dry and wet weather sources. The models were used to test various CSO control strategies and their predicted effects on water quality. The integrated model



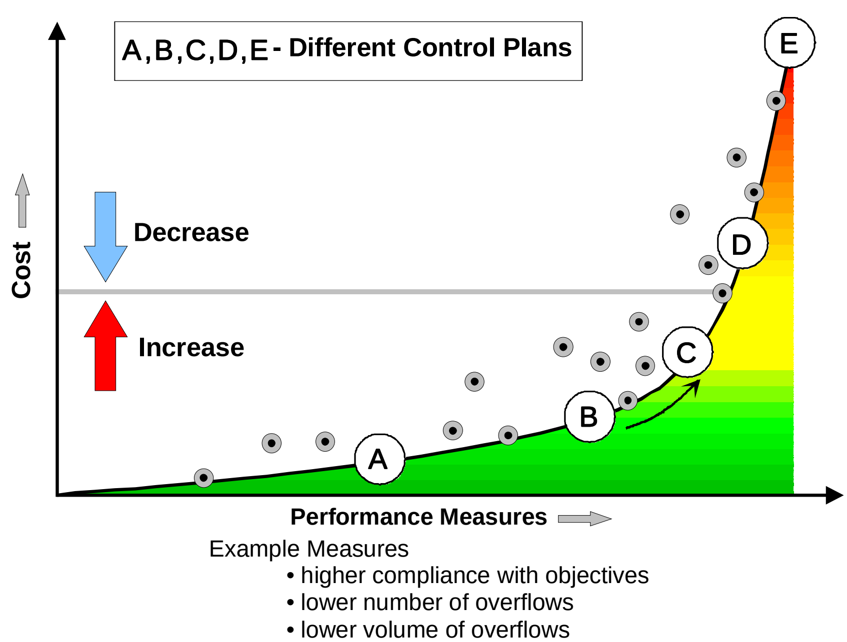
Data Management - Linked Model System
Figure 5-3

framework made it possible to assess various performance measures, such as:

- number and volume of overflows;
  - statistics for each combined sewer district and the City-wide average were estimated.
- compliance with water-quality objectives
  - the continuous water-quality model is able to estimate compliance with MWSQO at various locations in the river.
- illness risk
  - using the estimations of fecal coliform densities from the model for various control scenarios, the estimates of river use (i.e., numbers of people swimming, waterskiing, etc.), can be used to provide an estimate of the illness risk, as measured by the incidents of related gastrointestinal illness, using epidemiological equations.

5.1.2 <u>Application to CSO Control Planning</u>

The study considered a range of CSO control alternatives. Using the integrated models, the characteristics of the alternatives could be evaluated in terms of various performance measures such as compliance with water quality objectives, number of overflows, and volume of capture of overflows. The modelling results were used to develop "trade-off" curves, as illustrated in Figure 5-4, to assist in the evaluation of potential control strategies, as discussed in Section 9.



Illustrative Cost/Benefit Curve
for Performance Measures
Figure 5-4

5.2 PERFORMANCE MEASURES

Background TM: Phase 3, TM #1, Section 3

In choosing the most appropriate control plan, one of the most important considerations is the level of performance achieved by the different control measures. In this context, it is useful to consider the overall goals of the City in terms of developing CSO control strategies.

The key product of the CSO management strategy for the City of Winnipeg is the establishment of "a cost-effective, prioritized implementation plan for remedial works, based on assessment of costs and benefits of practicable alternatives"*. The following objectives of the City provide context to achieving this final product:

1. provide protection for the beneficial uses of the Red and Assiniboine Rivers, including the aquatic ecosystems of the rivers;
2. respond to the reasonable expectations of the public and stakeholders;
3. respond to the provincial surface water quality objectives for the Red and Assiniboine Rivers;
4. consider the prevailing environmental practices and policies in terms of CSO control in Canada and the USA; and
5. ensure that any remedial work implemented will not increase risk to basement flooding.

The goal of the study was to develop a range of alternative control plans which would address the above objectives, along with their costs, benefits, practicability, affordability and cost-effectiveness. The study program was designed to communicate this information to policymakers and interested publics and help facilitate informed judgements and decision-making.

A review of experience elsewhere with regard to control policy, performance measures or control indicators was undertaken. It was found that there was little specific guidance from regulatory agencies or from experience elsewhere regarding the means by which the relative

---

* Combined Sewer Overflow Management Strategy, Terms of Reference.

effectiveness of different control measures should be gauged. This deficiency was due partly to complexities involved in measuring the performance of different CSO control measures, such as the inherent variability of wet weather flows, the difficulty of measuring wet weather impacts on the stream, etc. The prevailing practice is to adopt general objectives to site-specific control indicators relevant to the local conditions.

A number of sources were explored in terms of evolving CSO control guidance or policy. These included the CSO Control Policy developed by the Environmental Protection Agency (EPA) of the USA, other Canadian provincial policies, the Association of Metropolitan Sewerage Agencies (AMSA), and relevant CSO policies in Europe.

The EPA has been a leader in developing CSO policy. Many agencies have patterned their policies using the EPA approach as a guideline. The EPA advocates that a long-term CSO control program be developed, sufficient to meet the state water quality standards. It defines target levels of control, i.e., 4 overflows per year on average (with a maximum 6 overflows) or a capture of 85% of the combined sewage (or treatment equivalent to primary treatment) during an event. These levels of control are presumed to meet water quality goals.

The various approaches were used to develop performance objectives for the purpose of evaluating different control strategies for the City of Winnipeg.

5.2.1 Manitoba Experience

Given its importance for the regulation of the control of Winnipeg CSOs, the current regulatory guidance in Manitoba is discussed below.

Province of Manitoba

Manitoba has no special policies relating to CSOs at this time, except that the discharge of untreated sewage is not allowed in the MSWQO. Two other communities, Brandon and Selkirk, have Combined Sewer Systems. These systems are much smaller than the Winnipeg system. In the case of Winnipeg, the CEC has directed that wet weather water quality objectives for the Red and Assiniboine rivers, within and downstream of Winnipeg, be reviewed.

In reviewing specific objectives for a watershed, particularly when the existing water quality is impaired and affecting either a present or future water use, the Province recommends an evaluation (Williamson 1988). This evaluation is guided by the following general questions:

1. Which water uses are being impaired?
2. What are the water quality variables causing the impairment?
3. To what extent do human activities contribute to the impairment?
4. What level of control is required to ameliorate the water quality exceedances?
5. Do control technologies actually exist in order to achieve the level of reclamation necessary?
6. Does the cost of achieving the water quality improvement bear a reasonable relationship to the benefits associated with attaining the water use?

Depending upon the result of this evaluation, surface water quality objectives could be recommended for the area under consideration such that the existing impaired water quality would be accepted. Alternatively, objectives could be recommended that would provide the basis for a plan that would improve water quality to the level necessary to protect the affected water use.

The current study, focussed on microbiological water quality as affected by CSOs and allowed for input from the general public, scientific, and other stakeholders, as recommended by the CEC. The results of the study will be reviewed by the City, the public and the regulatory agencies, and a course of action will be defined. This is consistent with the Manitoba process.

5.2.2 Illness Risk

Fecal coliform densities in the rivers are a major CSO issue. Fecal coliform guidelines exist in the MSWQO for the purpose of protecting human health. Many attempts have been made to correlate fecal coliform densities in surface waters to cases of gastrointestinal disease in humans. The fundamental basis for quantification of illness risks from river uses is the science of epidemiology, which attempts to define the relationship among:

- pathogen densities at the point of human contact;

- the extent of exposure (usually the infective dose(s) and the amount ingested); and
- the disease attributed to the exposure.

In this particular case, the interest is in relationships between a river user and exposure to an infective dose of pathogens in the river water. In general, relationships between the above factors are usually expressed in the form of regression equations or "models" of the dose-response (D-R) relationship.

Epidemiological research on the question of recreational use of surface waters has resulted in publication of some practical D-R models relevant to the present study. The D-R models used in most of the recreation-illness risk modelling completed to date have been for indicator organisms, mostly fecal coliform. These models predict illness-risk rates (i.e., gastrointestinal illness (GI) cases/1,000 immersions) for various densities of indicator bacteria (usually fecal coliform or *E. coli*). For this study, three D-R models were used to estimate the health risk for river users under baseline conditions and various CSO control scenarios as discussed in Section 7.7 and in the attached Appendix 1.

5.2.3 <u>Proposed Measures of Performance for Winnipeg</u>

Potential CSO performance measures were proposed with due consideration of the overall goals of the CSO study, water-quality issues, guidelines for surface water quality, and experience elsewhere. These measures were intended to characterize the strengths and weaknesses of the different control alternatives. Applying these measures will assist in the understanding of the options and their evaluation, and will provide a basis for making judgements. The performance measures for end-of-pipe and receiving streams are summarized in Table 5-1.

The range of control plans began with assessment of the existing baseline situation and included various levels of incremental control, such as optimizing the use of infrastructure, adding storage, etc., and proceeded to an assessment of the complete separation of the existing combined sewer system. In the identification of potential control plans, the EPA "benchmarks" (4 CSOs or 85% volumetric control), zero overflows and compliance with Manitoba Objectives, were used to define candidate control plans.

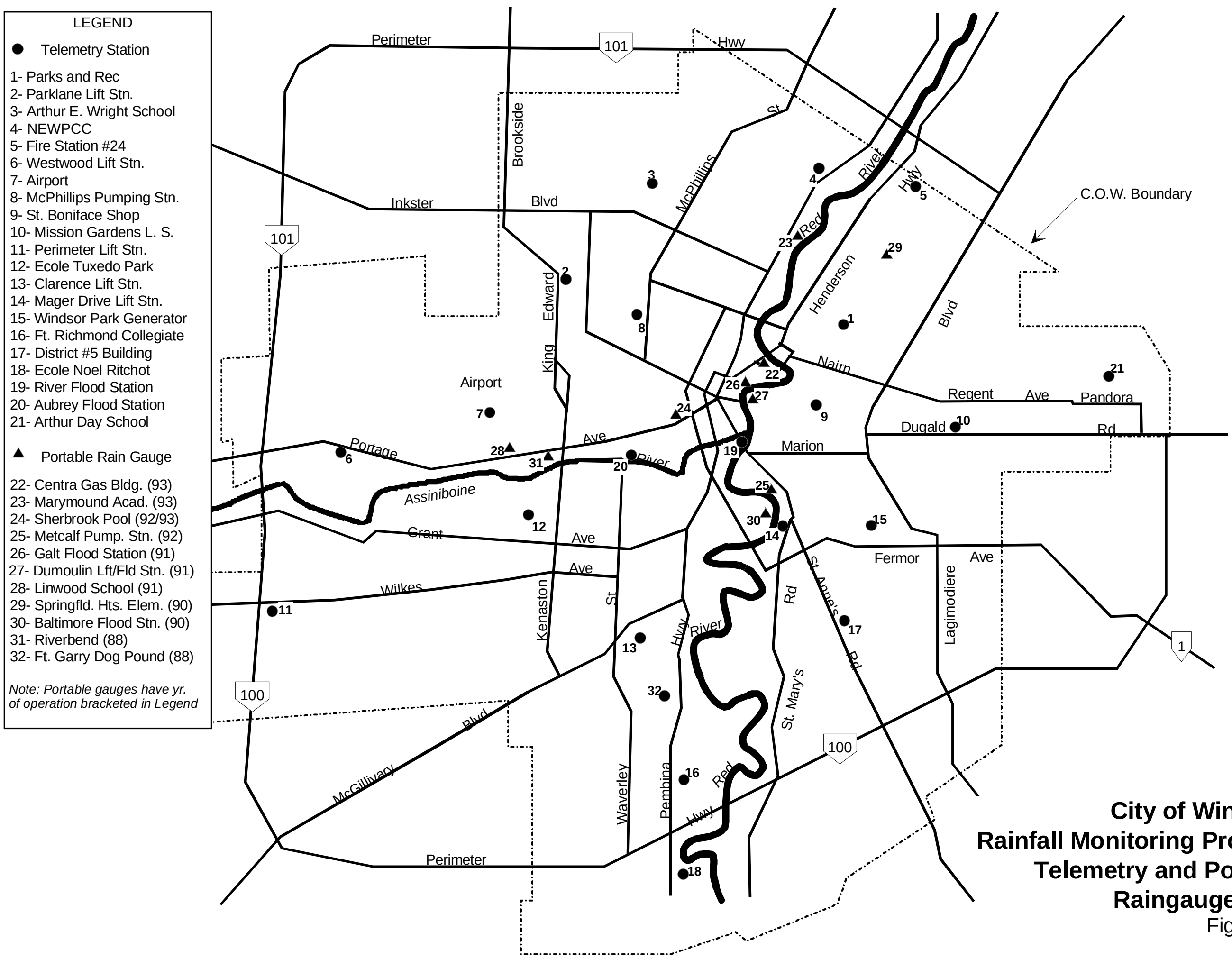
TABLE 5-1

CSO CONTROL PERFORMANCE MEASURES

		CONTROL INDICATOR	REMARKS
1.0		**"End-of-Pipe" Measures**	
	1.1	Number of CSOs	- provide numbers for: (a) existing baseline performance, (b) plans that will optimize the existing system, and (c) develop incremental plans that reduce CSOs to benchmarks of about 4/year and about 0/year.
	1.2	Volume of CSOs	- estimate the volume capture of the existing baseline system and incremental improvements as above.
2.0		**Receiving Stream Measures**	
	2.1	Duration of Compliance with Direct Contact Fecal Coliform Guidelines	- consider number of hours of compliance with 200 fc/100 mL guidelines at different locations during the recreation season for different plans.
	2.2	Duration of Compliance with Secondary Recreation Fecal Coliform Guidelines	- consider number of hours of compliance with 1000 fc/100 mL guidelines at different locations during the recreation season for different plans.
	2.3	Human Illness Risk	- estimate disease, as predicted by dose-response models using fc densities and river use, for different locations and control plans as a partial measure of health risk.
	2.4	Pollutant Loading	- estimate the mass-loading of nutrients, metals, TSS, from the CSOs for different plans (volume of CSO will be used to provide this information).
	2.5	Aesthetics	- use the number and volume of CSOs as an indicator for aesthetic performance.
	2.6	Protection of Sensitive Reaches of Winnipeg rivers	- the location of Combined Sewer outfalls relative to sensitive river uses will be considered.
	2.7	Protection of Aquatic Life in Winnipeg rivers	- the DO resources in the Winnipeg rivers are ample; ammonia from CSOs are not expected to be toxic to fish. Volume of capture of CSOs will serve as a measure for ammonia control.

5.3 RAINFALL

A main objective of this study was to gain an understanding of the response of the CS system to rainfall. In this regard, the City of Winnipeg has acquired a considerable database. The City has established a network of 21 permanent rain gauges (Figure 5-5), read by a telemetry system. The system has developed a reliable database from 1990 to the present. These data are supplemented by data from the Atmospheric Environment Service (AES) meteorological station at the Winnipeg Airport. The latter have been collected continuously since 1960.



City of Winnipeg
Rainfall Monitoring Program
Telemetry and Portable
Raingauge Sites
Figure 5-5

5.3.1 Areal Distribution

Comparisons were made between the AES Airport Station and all available City of Winnipeg network gauges to analyze rainfall distribution. It was found that the areal distribution (temporal and spatial patterns) of an individual rainfall event was highly variable between stations but annual and longer term rainfall records at the various stations compared quite favourably. The data indicated that any given station in the City would likely experience a similar number of rainfall events and total rainfall over a long period (i.e., the long-term data from any one of the stations is likely to provide a good representation of rainfall patterns for the urban area) even though there will be variation for any single event. Since the Winnipeg Airport had the longer available record of rainfall events, it was considered to provide the best long-term statistical representation of rainfall for planning level runoff modelling for the City of Winnipeg.

5.4 EVALUATION PERIOD

A “representative year” approach was considered appropriate for the assessment of existing conditions as a first-level screening of alternatives. This approach comprised the use of a single year which had typical rainfall (total rainfall and typical distribution) and river flow, would be representative of a longer period of record for rainfall and river flow. The use of the representative year is a reasonable approach (EPA guidance) and has been used in other Canadian cities, e.g., St. Catherines. Using this approach, the range of options was narrowed and the longer period of record was used to evaluate a shorter list of selected scenarios. From a review of Atmospheric Environment Services rainfall records (at the Winnipeg International Airport since 1960), 1992 was determined to be the best representative year.

A comparison was also made, for the 35-year period of record of the volumes of rainfall for each year, and the volumes of runoff from the existing system. The results of the analysis showed that the long-term rainfall average was equivalent to that for 1992. However, when compared to the volumes of runoff from the districts (as modelled by XP-SWMM runoff block), the 1992 runoff is about 75% of the long-term average. This comparison illustrates that rainfall depth does not directly correspond to runoff volume on an annual basis. The intensity and duration of the individual rainfall event, as well as antecedent conditions, are of primary importance to the volume of runoff from previous areas, i.e., rainfall must exceed the infiltration capacity of the soil for runoff to occur.

Accordingly, control plans, were evaluated on the basis of a long-term period of record.

6. PUBLIC CONSULTATION

Background TMs: Phase 2, TM #5; Phase 3, TM #2

Public participation in the CSO Management Study is warranted from the standpoint of City policy as well as through the direction of the Clean Environment Commission (CEC 1992).

The City has established policy guidelines for citizen participation in public works projects. The policy outlines criteria for projects where public participation is warranted. These criteria include :

- projects which have key strategic importance in the City's long-term plans;
- projects where the City is seeking public input, awareness and support for a project;
- projects which already have a history of public involvement; and
- projects where a requirement exists for *Environment Act* approvals.

The potential CSO program meets these criteria. Specifically, the potential costs involved in CSO control are very large. The City will want to confirm public support for such a control program, as it has for its river quality protection programs in the past. There has been a history of public involvement in river water-quality management projects. There will be requirements for acceptance of the CSO control program by Manitoba Conservation.

The CEC, in delivering its report on the water quality objectives for the Red and Assiniboine rivers in June 1992, recommended that an advisory or steering committee be established during implementation of the study and that members of the scientific community should be invited to collaborate in the study design. Thus, the CEC gave some specific direction in terms of consultation with certain publics.

For this study, public involvement was expanded from the CEC directive to accomplish the following:

- develop public awareness of how CSOs occur and their impact on river water quality;
- enable the public to have a better understanding of the CSO control planning process;
- help determine and define the public's judgements on issues and priorities;

- promote an understanding among the “stakeholders” of the trade-offs involved in CSO control options, and
- demonstrate to Manitoba Conservation that the City has made reasonable efforts to inform the various publics and to obtain meaningful feedback from these publics.

6.1 PROGRAM

Obtaining input from the public on such a complex study is difficult and an iterative, sustained process was used. The major challenge in obtaining meaningful feedback regarding the public’s opinion is to gain the public’s attention towards the major issues of a planning study.

The public communication plan was based on the tenet that the public must be informed before they can be asked to provide opinions. The consultation process emphasized improving public awareness on the general CSO issues. As the study progressed, the emphasis changed to requesting feedback and opinions on choices. In Phases 1 and 2, the emphasis was on public awareness of the existing conditions. For Phase 3, the focus shifted to:

- explaining the effects of alternative control strategies on different water quality goals; and
- obtaining public opinion on choices available for improved CSO management.

During each phase of the Study, the study results were provided to the public in a format designed to be both objective and comprehensive.

The information will be discussed in the following categories of activities:

- general public; and
- Advisory Committee.

6.2 GENERAL PUBLIC

A number of different methods and venues were used to communicate with the public on the CSO study, as discussed below.

6.2.1 Public Meetings/Events

- **Open House**

  A public event was developed to raise public awareness of the initiation of the CSO Study and to provide an understanding of the existing system and CSO issues. An Open House with information in a "storyboard" format, along with a Poster Contest, was held on October 1 and 2, 1994 (Saturday and Sunday from 10:00 a.m. to 4:00 p.m.) at The Forks Pavilion.

- **Mall Displays**

  In 1995, a CSO display was located at the Grant Park shopping mall and at the Polo Park shopping mall. The display comprised a working physical model of the CS system and a storyboard presentation. A handout addressing CSOs and River Quality, was developed and distributed to the public during the events. The handouts included a short questionnaire which the attendees were asked to fill out.

- **Family Fish Festival**

  The City provided an information display regarding CSOs and river quality at the Family Fish Festival, in June 1995, held at The Forks and sponsored by the Mid-Canada Marine Dealers Association.

- **Urban Rivers and Creeks Stewardship Workshop**

  In June 1995, The International Coalition (TIC) coordinated a summer workshop, as part of an Urban Rivers and Creeks Stewardship Project to promote stewardship on Winnipeg Rivers and Creeks. The City provided a presentation on the CSO Management Study and other river quality issues.

- **Mid-Canada Boat Show**

  The CSO Study Team participated in the Mid-Canada Boat Show held at the Convention Centre in the spring of 1996 and 1997. Information display panels as well as the Combined Sewer Overflow Model were utilized at the booth. Handouts were also distributed at the events.

- **Home Expressions**

  The CSO Study Team set up a display booth at Home Expressions Show each spring from 1996 through 2000. Handouts were distributed at these events.

- **Earth Day Trade Show**

  The CSO Study Team attended the Earth Day Trade Show held on April 21, 1997 outdoors (under a tent) at The Forks. The display booth and working model were utilized for the exhibit.

- **Public Works Week**

  The CSO Study Team set up a display booth at the Convention Centre, as one part of the City's participation in the Public Works Week (May 1999 and 2000) displays. The displays comprised updated panels and the CSO model. Handouts were distributed at these events.

In general, while the interest of those attending these events appeared to be fairly high with respect to the CSO displays, the mail-back response was quite low.

6.2.2 Special Interest Groups

The aforementioned approach was aimed at informing the general public and determining their concerns with regard to the effects of CSOs on river quality. The following contacts below involved more community groups that showed an interest in river quality, also with the aim of informing and gaining feedback.

- **Manitoba Eco-Networks**

  Manitoba Eco-Networks (an umbrella group for over 40 environmental organizations) was contacted and provided the names of groups in Winnipeg interested in river water quality issues. Representatives from these groups were contacted and asked to attend a meeting regarding the City's project.

  On May 10, 1995, a meeting was held at the Centre Cultural Franco-Manitobain. Members of the CSO Study Team provided the attendees with a short presentation on the CSO Management Study and its status to date and handed out copies of the Phase 1 report.

  On the afternoon of June 12, 1996, a similar meeting was held at the Centre Culturel Franco-Manitobain with various Eco-Network groups.

- **Urban Fishing Committee**

  The Urban Fishing Committee consists of members of the Mid-Canada Marine Dealers Association, Manitoba Wildlife Federation, Fish Futures, City of Winnipeg Parks and Recreation and Water and Waste Departments, Travel Manitoba, and Fisheries and Oceans. A presentation of the CSO Study was made to the Committee during one of their regularly scheduled monthly meetings on June 27, 1996. Feedback was invited.

- **Rotary Club of Winnipeg**

  On April 23, 1997, the Study Team gave a presentation on the Combined Sewer Overflow Management Study to the Rotary Club of Winnipeg, (Club No. 35). The 1997 Update brochure was made available to the Rotary members.

- **River User Groups**

  On June 10, 1996, an afternoon meeting was held at the Franco-Manitobain Culturel Centre with various groups who utilize the river for recreational activities, e.g., yacht clubs. A total of 14 organizations were contacted, and 7 groups were represented at the meeting.

- **TIC Conference**

  The City of Winnipeg was invited to present a brief overview of the CSO Study at the annual summit conference of The International Coalition (a group involved with water management issues associated with the Red River Basin) held November 13-15, 1996 in Winnipeg. The City of Winnipeg also reserved space at the conference to display the CSO exhibit and model. Brochures used in past public events were offered at the conference.

6.2.3 Reports for Public Use

A number of reports were specifically prepared for the public audience to facilitate understanding and discussion of CSO issues. These included:

- CSO Management Strategy Phase 1 Report, September 1994; and
- Phase 2 Report, May 1996.

These reports were distributed to all members of the committees and groups contacted during the study, (i.e., the Advisory Committee, the scientific community group and the interested environmental groups) and all individuals requesting further information during public events. To date, reports have been distributed to approximately 30 committee and group members and 40 city residents. The reports are also available through the City of Winnipeg and were placed in the public libraries.

As well, a series of Study Updates (mainly for the Mid-Canada Boat Shows and Home Expressions Shows) were developed and distributed at the public events. All of these reports were intended to summarize the study results in non-technical terms for public disclosure and discussion.

6.2.4 Media Coverage

- **Study Announcement and Newspaper Articles**

The Study Team completed several articles for community newsletters and other publications in Phase 3. Combined sewer overflow articles have been published in:

- Fisherman's Gazette, June 3, 1996;
- Real Estate News, September 6, 1996;
- Civic Pulse, September 1996 Issue;
- The International Coalition Summer Newsletter, October 1996; and
- Western Canada Water and Wastewater Association's "The Bulletin", December 1996 Issue.

A media interview (September 1996) regarding Combined Sewers and the CSO Management Strategy Study was provided to Winnipeg's Shaw Cable Company, which was aired periodically on their public interest channel.

The purpose of the written articles was to inform people in Winnipeg and the Red River Valley of CSO discharges associated with the City of Winnipeg sewer system and the City's initiatives to study the river quality impacts and evaluate possible control options. Each article provided the reader with the latest CSO study information.

- **On-Line Publishing**

The City of Winnipeg features a brochure regarding the City's CSO Study on their Internet home page (**www.city.winnipeg.mb.ca/waterandwaste/combnd_sewrs_and_rvrs_qlty.stm**). The CSO information is offered as a link on the Water and Waste Department portion of the City of Winnipeg Web Site.

6.2.5 Scientific Community

As noted in the Introduction, the CEC recommended that an advisory or steering committee be established and that members of the scientific community be invited to collaborate in the design of the study. The Advisory Committee is discussed later, in Section 6.3; the latter is discussed below.

- **Local Scientists**

  After completion of the Phase 2 public report, a meeting was held to develop a list of individuals from the scientific and academic community that might be interested in participating in the study. Approximately 30 people, whose expertise included engineering, biology (plankton nutrient recycling, fish ecology, toxicology, riverine macro-invertebrates, and ecological microbiology), economics, and community health, were contacted to explain the study and request their input in the project. The comments received were constructive and were addressed. Specific comments are discussed in Phase 3 Technical Memorandum No. 2.

  The CSO Study Team conducted a presentation to a scientific meeting regarding CSO Phase 2 results. The meeting was held at the DFO Freshwater Institute on April 11, 1996. The presentation was attended by approximately 60-70 people.

- **Technical Presentations**

  A series of technical papers providing information regarding the City of Winnipeg CSO Study have been presented throughout North America, at internationally-recognized conferences and technical seminars. These were intended to present the Winnipeg study results and receive constructive feedback and peer review. These include:

  - **Urban Effects on Water Quality in the Red River and Related Uses**
    - presented at the Water Environment Federation (WEFTEC) Specialty Conference on Wet Weather Flows, Quebec City, PQ, June 15-19, 1996.

- **The City of Winnipeg's Combined Sewer Management Study and the Partnering Process**
  - presented at the Water Environment Association of Ontario (WEAO) Conference, Toronto, ON, April 1996; and
  - presented at the Western Canada Water and Wastewater Association Conference, Regina, SK, September 1996.

- **Application of Linked Models to Develop Combined Sewer Overflow Control Plans**
  - presented at the Canadian Society for Hydrological Sciences, Winnipeg, MB, May 28, 1996; and
  - presented at the Water Environment Federation (WEFTEC) Conference, Dallas, TX, October 7-9, 1996.

- **Preparing for Informed Decision-Making**
  - presented at the Western Canada Water and Wastewater Association Conference, Winnipeg, MB, November 1997.

- **In-Line Storage With and Without Real Time Control**
  - presented at Advances in Urban Wet Weather Pollution Reduction, Cleveland Ohio, June 1998.

- **Winnipeg's Floatable Capture and Quantification Program**
  - presented at Advances in Urban Wet Weather Pollution Reduction, Cleveland Ohio, June 1998.

- **Urban Wet Weather Case Study, Winnipeg, Manitoba**
  - presented at "Winning the Challenge of Urban Wet Weather" Workshop, Cleveland, Ohio, June 1998.

- **Effluent Impact Modelling Workshop**
  - held in Winnipeg, Manitoba, November 5 & 6, 2001.

The feedback from these papers has been positive and has confirmed that "state-of-the-art" methods, technology, and analysis are being used in the Winnipeg CSO Study.

6.2.6 Contact Database

As part of the public communication program, a database was used to schedule and record communications between the Study Team and interested residents, special interest groups, the scientific community, etc. The information was used to aid in the distribution of study-related material to interested persons. The number of individual residents/groups in the database grew to approximately 1,850.

6.2.7 Surveys

Two questions were asked in the questionnaire distributed during public events and were recorded in the database. The questions are as follows:

- Which river use is most important to you?
- How much more are you willing to pay on your annual sewer bill to control combined sewer overflows?

The survey is not statistically sound, since the people solicited would already have had an interest in the City's rivers. Even so it does provide a general indication of the opinion of the people responding to the survey.

Of the 1,472 responses received, 1,132 answered the second question. The responses indicated that the majority (913 responses) would be willing to pay more on their annual sewer bill to control combined sewer overflows. The largest response (404) was in the $26-$50/year category. The next largest response (265) was in the $1-$25/year category. The majority of people think that all river uses are important. Individually, only 16 respondents chose swimming/waterskiing as the most important river use and the majority of the 16 respondents were willing to pay an additional $26-50 for this river use. 48 people cited the river's appearance as the most important use and the majority of the 48 were willing to pay either $1-25 (13 responses) or $26-50 (17) more per year for this use. 106 people cited aquatic life as the most important river use and the majority in this group are willing to pay either $1-25 (28) or $26-50 (38) more per year to protect this use.

6.2.8 Summary

The following points summarize, generally and subjectively, the responses received from the public and interest groups over the duration of the water-quality issue:

- CSOs are not an urgent public water-quality issue but people tend to support additional control;
- people value the environment and river water quality and they are apparently willing to pay for improved quality; and
- people's understanding of the CS system seems to be increasing.

6.3 ADVISORY COMMITTEE

An external Advisory Committee was formed in the fall of 1994. The Committee's responsibilities include providing advice (from an external perspective) to the CSO Study Team as the study progressed, and reporting to the CEC upon completion of the study. Its members were selected to represent a cross-section of major stakeholders from whom the City would receive ongoing feedback. The Committee met regularly on approximately a quarterly basis. The member list as of August 2000 is provided below.

- Chris Leach, Manitoba Housing (Chair);
- Charles Conyette, Manitoba Conservation;
- Art Derksen, Natural Resources;
- Cheryl (Nielson) Heming, City of Winnipeg, Parks and Recreation Department;
- Dr. Sande Harlos, Deputy Medical Officer, Winnipeg Regional Health Authority;
- Randy Borsa, Town of Selkirk;
- Drew Bodaly, Fisheries and Oceans;
- Dr. Jim Popplow, Manitoba Health (until February 1998);
- Dr. Margaret Fast, Medical Health Officer, Winnipeg Regional Heath Authority;
- Darwin Donachuck, Natural Resources; and
- Gary Swanson, Natural Resources.

An agenda was developed by the Study Team prior to each meeting and distributed through the Advisory Committee chair to the members. The common agenda items for each meeting included:

- technical progress on control alternatives;
- public communication updates; and
- overall schedule.

The Advisory Committee has met on 15 different occasions.

The Advisory Committee is expected to provide a report to the Clean Environment Commission and/or Manitoba Conservation at the end of the study. The Committee has provided an Interim Report (Advisory Committee 1998) to the CSO Study Team. The comments contained in the report were discussed with the Committee. The feedback from the Advisory Committee was incorporated into this final report, particularly on the health risk discussions in Sections 5.3.2 and 7.7. In addition, the Committee Chairman sent a letter to the City, in September 2002, accepting the Report.

6.4 ONGOING CONSULTATION

As discussed in Sections 10 and 11, keeping the public informed on the follow-up activities with regard to implementation of a CSO control program will continue to be an important and vital part of the program.

7. CURRENT CONDITIONS

The performance of the existing system provides a context for assessing the relative performance of potential CSO controls.

7.1 EVALUATION OF PERFORMANCE

The performance of the existing system was evaluated by simulation of the long-term actual record of rainfall for Winnipeg, as measured at the Winnipeg International Airport. The Runoff Model and Interceptor/Control Model were used to quantify the total runoff, the portion of combined sewage diverted to the WPCCs, and the portion which could overflow to the rivers.

The evaluation of existing performance considered the following factors:

- dry weather overflow;
- existing interception rates;
- number and volume of overflows;
- pollutant loadings (% capture of combined sewage);
- compliance with fecal coliform objectives; and
- illness risk.

Each factor is discussed in the following sections.

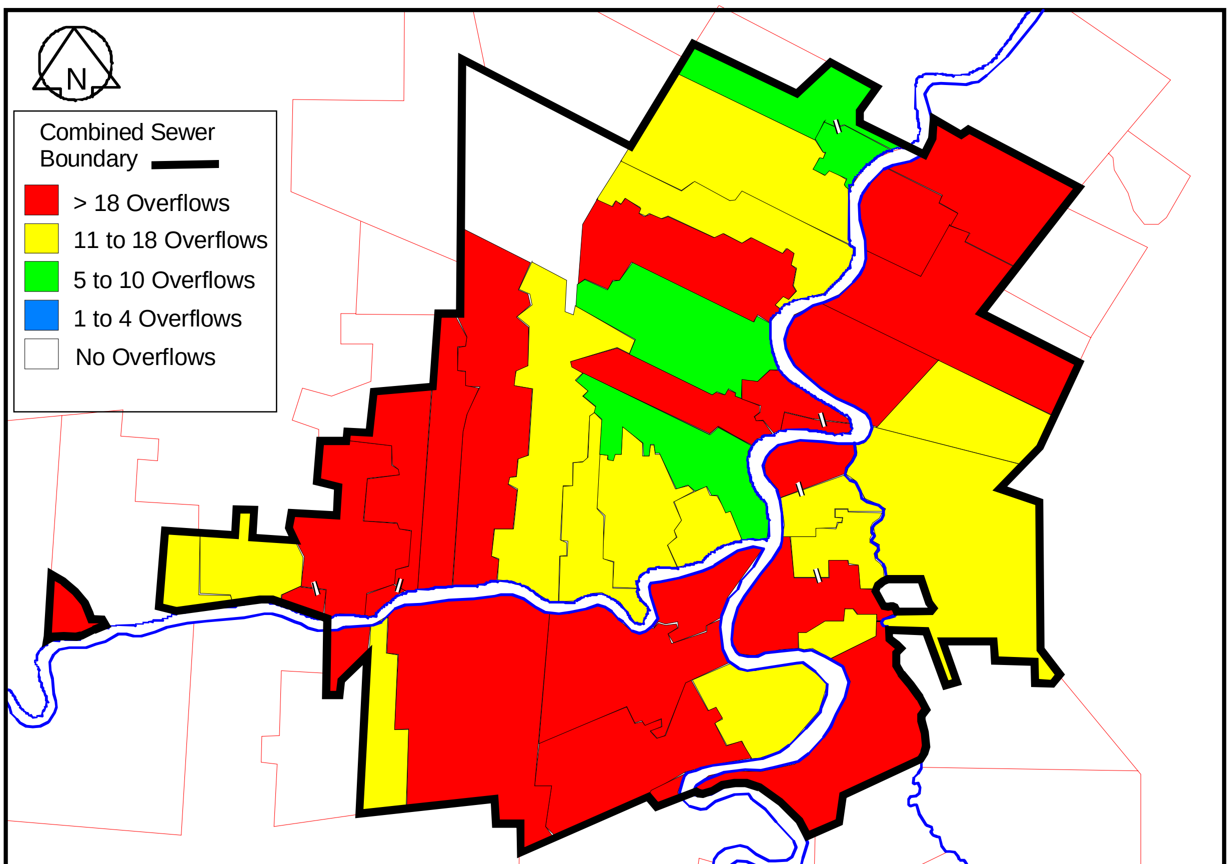
7.2 DRY WEATHER OVERFLOWS

The first priority in CSO control is to ensure that no overflows occur during dry weather. During the course of investigations of the existing system, it was discovered that some periodic dry weather overflows (DWOs) were occurring. City of Winnipeg staff routinely inspect these occurrences, identify the cause and correct the problem. The DWOs identified in the study have since been corrected by the City.

7.3 NUMBER AND VOLUME OF OVERFLOWS

Background TM: Phase 3, TM #1, Section 6

On average, over a long-term period of record, about 18 overflows of combined sewage occur per district during the recreation season (May 1 to September 30). In a typical year, about 7,000,000 m^3 of runoff is generated in the combined sewer area. In a combined system, this urban runoff is mixed with domestic and commercial/industrial wastewater. Over a long-term period, about 32% of this combined sewage is captured for treatment, i.e., does not overflow to the rivers. The long-term performance of the various districts, with respect to average number of overflows, is illustrated in Figure 7-1.



Average Annual Overflows ~ 17.5
Range: 6.5 - 30

Existing Conditions - Long-Term Performance
Figure 7-1

A comparison of the individual performance of the 43 combined sewer districts results in the following observations:

- overflow can occur in some districts from very modest runoffs, i.e., 2 to 3 mm/hour;
- the number of CSOs per year in the individual districts ranges from 7 to 30/year;
  - the small numbers generally relate to those districts with uncontrolled gravity connections to the interceptor;
- on an annual basis, the amount of sewage lost to the river during these events is relatively small, i.e., about 1% of the annual sewage generated is lost during WWF events;
- average duration of CSO is 5 to 6 hours.

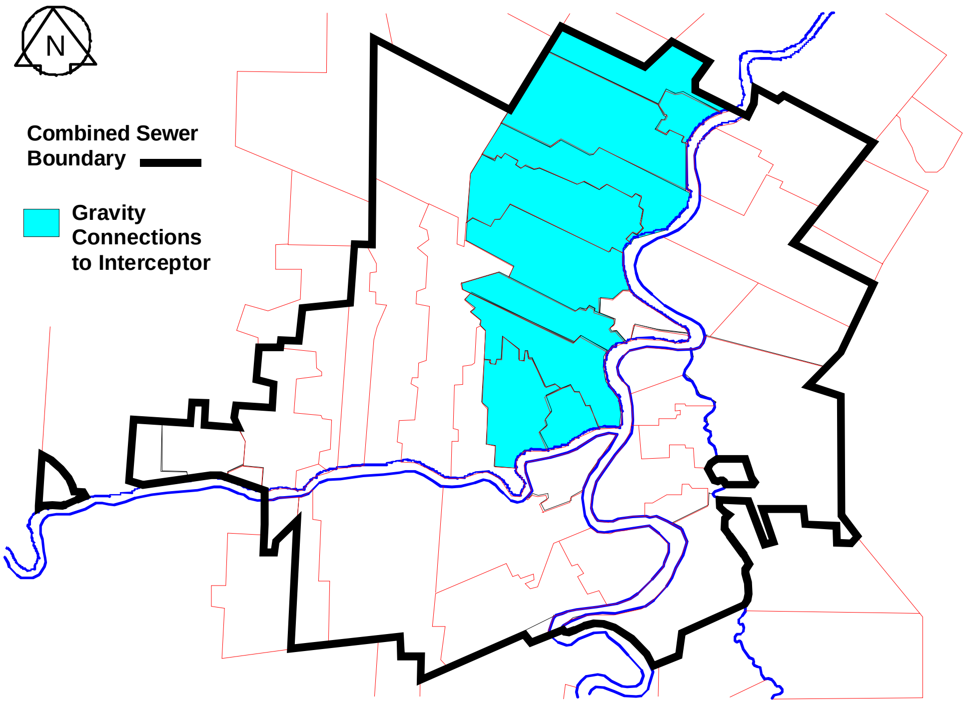
The existing performance is well short of the U.S. EPA expectation of 4 to 6 CSOs per year or 85% capture of combined wastewater.

7.4 EXISTING INTERCEPTION RATES

Background TM: Phase 2, TM #2

The combined sewer system was designed to intercept about 2.75 times DWF during rainfall events. The average interception rate is actually about 4.2 times DWF. On average, the system capture exceeds the design intent but the interception rates for individual districts vary widely across some 43 CS districts.

Most of the combined sewage is intercepted at the low end of the combined sewer trunk system and pumped into the interceptor sewers. The exception comprises the 10 districts, shown on Figure 7-2, whose combined sewer trunks are sufficiently high in elevation that the flows can be diverted directly into the interceptor by gravity. As a result of the removal of the old control devices (to restrict the diversion) in these districts, the intercepted flows are significantly greater than the intended 2.75 x DWF. Accordingly, these districts contribute more than their intended share of the capacity of the Main Interceptor during WWF. The result is that overflows to the rivers in the upper reaches of the interceptor system are greater than intended in frequency and volume. This observation indicates that any future CSO control program should begin by gaining control of the intercepted flows and replacing these overflow control devices with a suitable and reliable flow control device, allowing appropriate allocation of the Main Interceptor's capacity. This modification will optimize the volume of wastewater diverted to treatment during wet weather and hence minimize interceptor overflows.



Districts with Gravity Connections to the Interceptor
Figure 7-2

7.5 POLLUTANT LOADINGS TO THE RIVERS

Background TM: Phase 2, TM #1

This section will discuss loadings to the rivers from CSOs in relation to discharges to the rivers from other sources.

7.5.1 Dry Weather Loadings

The major dry weather wastewater discharges to the rivers in the Winnipeg urban area are the treated effluents from the three Water Pollution Control Centres (WPCC). The City of Winnipeg has directed significant attention in its pollution control programs towards establishing best practicable secondary treatment of all continuous dry-weather wastewater flows.

The DWF is measured at each of the three WPCCs. Quality characteristics of the final effluent from these pollution control centres are monitored regularly to assess plant performances and discharge loadings to the rivers. Quality characteristics of the plant effluent that are of most relevance to the river quality assessment are listed in Table 7-1, and demonstrate an ability to produce a high-quality secondary process effluent.

TABLE 7-1

REPRESENTATIVE WPCC FINAL EFFLUENT QUALITY CHARACTERISTICS - ANNUAL AVERAGES PRIOR TO DISINFECTION

	*CBOD5 (mg/L)	**SS (mg/L)	AMMONIA (mgN/L)	NITRATE (mgN/L)	TOTAL PHOSPORUS (mgP/L)	FECAL COLIFORM (per 100 mL)
NEWPCC	9	21	27.3	1	3.5	100,000
WEWPCC	10	25	11.1	2	4.2	160,000
SEWPCC	7	14	13.8	4.4	4.3	5,000

* CBOD5 is the total Carbonaceous Biochemical Oxygen Demand after a 5-day period.

** SS is Suspended Solids

7.5.2 Wet Weather Loadings

Background TM: Phase 2, TM #1, Section 2

The concept of using Event Mean Concentrations (EMCs), i.e., the storm event load, or mass, divided by the storm event runoff volume has been used in many other CSO studies (e.g., Hamilton, Ontario, and Chattanooga, Tennessee) and was considered appropriate for application in the Winnipeg studies. The EMCs have been found to be typically log-normal in distribution, not only for CSOs, but also for stormwater runoff, rural runoff and treatment plant effluent (WEF 1989). The Nationwide Urban Runoff Program (NURP), reported on the results of test data from about 2,300 separate storm events on 81 sites in 22 different cities. These data showed, based on extensive statistical analysis, that EMCs could be used for overall stream loadings as they were essentially uncorrelated with runoff volume (U.S. EPA 1983). These data analyses were based on a range of water quality parameters (metals, nutrients, solids). While fecal coliform were not in this group, there is little reason to believe this parameter would exhibit different characteristics.

The finding of no significant linear correlation between EMCs (i.e., the typical quality of the CSO) and runoff volumes is important in that it means that it is not likely that the size of storms for different monitored events will have biased the EMCs. Further, it indicates that refinement of methods to account for precipitation and runoff characteristics, antecedent conditions, etc. are not warranted, particularly for planning level studies.

Accordingly, the EMCs were applied to the dry and wet weather hydrographs to estimate loadings to the river for the various contaminants. EMC's for CSO CBOD5 and suspended solids average 110 mg/L and 845 mg/L, respectively. These EMCs were based on the results of local sampling programs. The EMCs for Fecal Coliforms used for the modelling of City of Winnipeg discharges to the Rivers are provided in Table 7-2.

TABLE 7-2

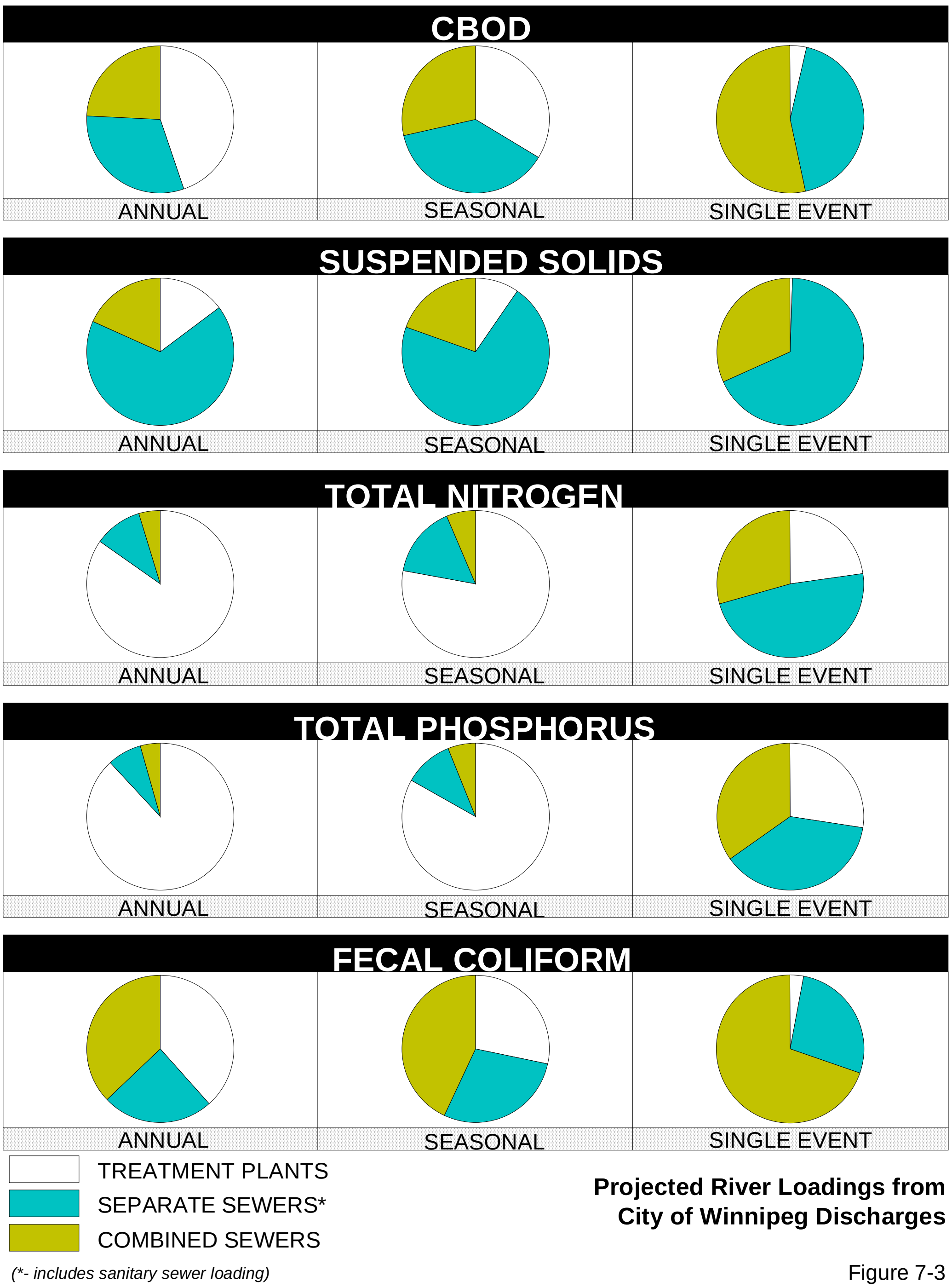
EMCs FOR FECAL COLIFORM CONCENTRATIONS FOR WINNIPEG SYSTEM

	SOURCE	ORGANISMS/100 mL
WPCCs	DWF PDWF PWWF	200,000 200,000 2,400,000
LAND DRAINAGE	DIRECT PONDS	40,000 20,000
CSO		2,400,000
SSO		10,000,000
INTERCEPTORS	CSO SSO	2,400,000 10,000,000

Source: Phase 2, TM #1, Table 2-6

7.5.3 Total Loadings

Loadings to the rivers for current conditions were estimated by combining concentrations for the specific water quality parameter and discharge volumes on an annual and seasonal basis. The results of these estimates are shown on Figure 7-3.



Projected River Loadings from City of Winnipeg Discharges

Figure 7-3

These estimates indicate that volumes for WPCC and LDS discharges tend to dominate annual total volumes discharged to the rivers. Although CSOs are still significant volumes (about 5% annually), the sanitary sewer overflows (SSOs) and interceptor overflow volumes are insignificant in comparison. River loadings were reviewed for 1996 conditions, both with and without disinfection (as discussed later in this section).

Some observations on the perspective of CSO and total loadings to the rivers from City of Winnipeg discharges are:

- The $CBOD_5$ loading on the Rivers are about equal from WPCCs, CSOs, and land drainage on an annual basis. A large single rainfall event might be expected to exert a large BOD load and possibly cause dissolved oxygen suppression in the river, however, as discussed earlier in Section 4.2.1, actual monitoring data indicate that oxygen suppression appears to be about 1 mg/L from large runoff events and does not result in non-compliance levels.

- Nitrogen and phosphorus loadings to the rivers are dominated by WPCC discharges on an annual and seasonal basis. Potential nutrient impacts therefore relate to these loadings and CSO loadings are not significant for these parameters.

- The major loading of total suspended solids to the rivers (over and above that already carried by the rivers) for current and future conditions originates from urban runoff, especially land drainage discharges. The seasonal total suspended solids loadings from land drainage are significantly greater than the annual loading from all WPCCs.

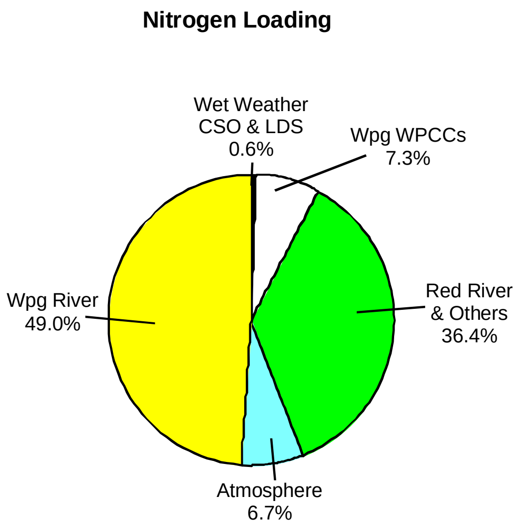
- The “historical” fecal coliform loadings to the river mainly originate from the WPCC effluent discharges (undisinfected) and combined sewer overflows and land drainage. Treated effluents from WPCCs are the major source of fecal coliforms to the rivers under dry weather conditions. Fecal coliform levels from combined sewer discharges and land drainage during the following wet weather events completely dominate the influence of WPCC discharges in the short-term. It should be pointed out these transient fecal coliform peaks typically “die-off” in the stream in about 3 to 4 days, because the river environment is not conducive to their survival. Accordingly, mass loading analysis for annual or seasonal discharges are not representative of transient stream conditions for fecal coliforms and are useful for comparative purposes only. Consequently, the short-term impacts of fecal coliforms from CSOs and LDS on river water-quality runoff are more important than annual loadings.

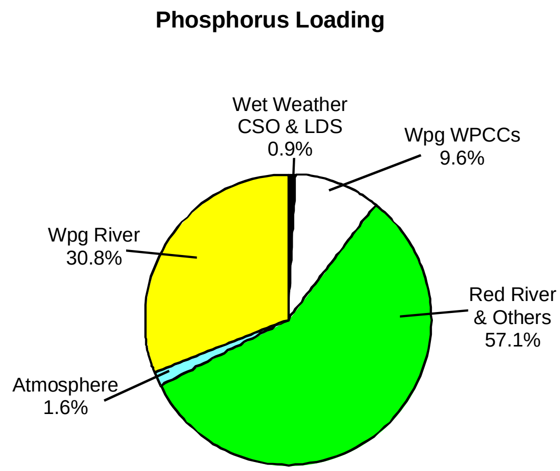
- WPCCs are the major factors that influence river water quality **during dry weather conditions**.

- Discharges from land drainage and combined sewers are major factors in influencing surface water quality **on a wet weather basis**. Combined sewer overflows and land drainage are peak loading events that occur only during a rainstorm. Loading of $CBOD_5$, total nitrogen, total phosphorus, and fecal coliforms from combined sewer overflows and land drainage during these events completely dominate the normal dry weather discharges to the rivers.

- Wet weather discharges from land drainage and combined sewers can temporarily impact physical characteristics (i.e., turbidity, suspended solids, grease and oils, floatables...) and microbial characteristics (i.e. fecal coliform). The aesthetic impact of these wet weather discharges can give the impression that the rivers are "polluted".

- The results of the analysis of the nutrient loading on the Lake Winnipeg south basin is given in Figure 7-4. The analysis determined that the total City of Winnipeg contribution to the basin is in the order of 8%, nitrogen and 10%, phosphorus, of the total nutrient loading on an annual basis. Of this contribution, 1% of each constituent is attributable to wet weather sources from Winnipeg, both land drainage and CSOs. As noted in Section 4.2.5, nutrient loadings from the latter sources are not considered a significant issue. It should be noted that the City of Winnipeg loads have been defined from two decades of data. Loads from other sources, such as atmosphere and upstream runoff, are more uncertain and variable. The specific sources, such as agriculture, industry, or natural runoff, have not been determined. Any future management plan would require greater knowledge of all sources.





Loadings on Lake Winnipeg South Basin
Figure 7-4

In summary, wet weather discharges from combined sewer overflows and land drainage are peak loading events that most significantly impact on fecal coliform concentrations and aesthetics on a single event basis. These discharges are significant factors in elevating the average fecal coliform densities in the rivers. The river flow also strongly influences instream concentrations of fecal coliform and the extent of impact downstream of outfalls. Discharges from the treatment plants are the most significant factor influencing nitrogen and phosphorus concentrations on an annual and seasonal basis.

7.6 FECAL COLIFORM COMPLIANCE

Background TM: Phase 3, TM #1

The impact of CSOs on the levels of fecal coliform in the river is a key factor from a regulatory perspective. As noted, the DWF classification for the Red River is primary recreation (i.e., an objective of 200 fc/100 mL), and an objective of 1,000 fc/1,000 mL applies to the Assiniboine River for secondary recreation.

Understanding the existing conditions is essential for evaluation purposes. A calibrated river model was used to assess the water quality response of the rivers under dry and wet weather loadings for existing conditions. The statistical compliance and actual responses to WWF at various locations under present conditions over time were later used to estimate the benefits arising from various control technologies.

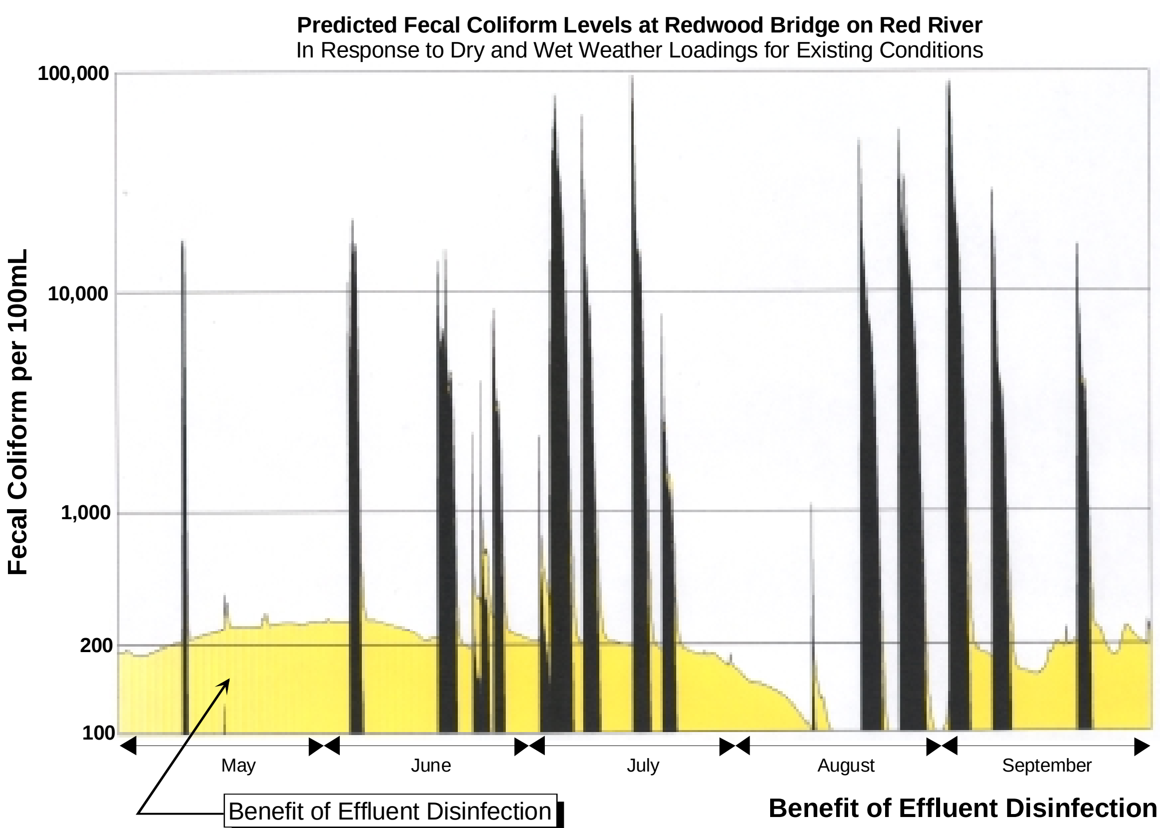
The City has adopted a program of implementing dry weather disinfection of the WPCC effluents in their financial plan. In July 1999, disinfection of the SEWPCC effluent (by ultra-violet disinfection) was operational. Capital programs allow for disinfection at the NEWPCC by the year 2005. The current performance of the WEWPCC lagoons, in reducing effluent to concentrations to within compliance limits, may obviate the need for effluent disinfection. The existing conditions of fecal coliform profiles were therefore modelled without WPCC disinfection. The future conditions, with WPCC effluent disinfection, were also modelled.

Loadings, due to growth of the City, will not deviate significantly from current loadings under future conditions. Specifically, the main growth in the City of Winnipeg will occur in the areas serviced by the SEWPCC and WEWPCC plants. The vast majority of these areas are serviced by separate sewer systems. Most of the new LDS systems will also include storm retention basins and will not significantly increase the wet weather loadings. These basins have proven to be effective in reducing fecal coliform levels and other pollutants. The NEWPCC service area will experience little growth and no further increases in combined sewers.

Based on the foregoing, the conditions with WPCC effluent disinfection will be representative of average future conditions and will be the base condition from which to assess the benefits of WWF control alternatives.

For conditions during and after the wet weather event, a detailed examination is required. Figure 7-5 illustrates the water quality response during both dry and wet weather conditions as predicted by the model at the Redwood Bridge location over the full 1992 recreation season. The figure illustrates the conditions with and without effluent disinfection at the SEWPCC. This illustration is useful in describing water quality dynamics under dry and wet weather conditions. Prior to the rainfall (and without disinfection) fecal coliform concentrations remain at about 250 fc/100 mL. These densities are influenced by the continuous undisinfected discharge from the upstream wastewater treatment plants, i.e., SEWPCC and WEWPCC (or <100 fc/100 mL if disinfection is in place). Immediately following a significant rainfall, the fecal coliform concentrations can rise several orders of magnitude. These high coliform incidents (spikes) can last from hours to several days before the levels return to normal dry weather concentrations as the organisms die-off. This figure represents the transient effects of wet weather discharges from CSOs and LDSs.

The data as plotted on Figure 7-5 is based on hourly model outputs of predicted fecal coliform concentrations at Redwood Bridge location on the Red River for the representative year. This data was used to assess the percent compliance with MSWQO microbiological objectives at 200 and 1,000 fecal coliforms per 100 mL. This approach produces approximately 3,600 hours or equivalent data points to assess statistical compliance with the Manitoba Fecal Coliform Objectives (i.e., the sum of the hours with fecal coliforms less than 200 or 1,000 per 100 mL for the total 3,600 hours associated with the recreation season is a measure of compliance).



Benefit of Effluent Disinfection
Predicted at Redwood Bridge on Red River
Figure 7-5

The model results for WPCC effluent disinfection conditions indicate that for both rivers, substantial compliance with the MSWQO (i.e., a minimum of about 75% of the time, with the 200 fc/100 mL objectives), can be met over a recreation season. For the Assiniboine River, compliance with the 1,000 fc/100 mL secondary recreation objective is achieved about 82% of the time. During wet weather conditions, however, the predicted fecal coliform levels would exceed the MSWQO objectives during and just after the rainfall events.

7.7 ILLNESS RISK PERSPECTIVE

Background: Phase 4 Appendix #1

As part of the CSO study, a study to update the illness risk associated with recreational use of the rivers (Illness Risk Report 1999; Appendix 1) was conducted. This was intended to provide a site-specific perspective on this issue, especially as to how the illness risk might be affected by CSO control. This update was reviewed thoroughly by the Advisory Committee. The Committee was of the opinion that the update focussed on “illness” assessment, rather than a broader concept of “health” which includes community perception and feeling of wellness. The Committee agreed, however, that the CSO issue does not warrant a more comprehensive health risk assessment to explore these broader health issues. Accordingly, this section will discuss the estimates of illness rates related to beneficial uses of the river and will comment briefly on broad aspects of community health. Appendix 1 provides a more extensive discussion of the health risk issues.

Using the estimations of fecal coliform densities and river use (i.e., numbers of people swimming, waterskiing, etc.), an estimate of the incidence of gastro-intestinal illness (GI) can be developed using epidemiological (dose-response) equations developed in the U.S.A., Canada and France (GI would typically involve mild diarrhoea and is not likely reported to doctors). This analysis allows CSO controls to be put into perspective with other public health issues.

Three published dose-response (D-R) equations were considered most appropriate for quantitative illness risk estimation; two of which have been reviewed by Manitoba Conservation in the course of developing their objectives for protective criteria for public health. The equations are:

- Ferley et al. 1989 – fecal coliform model;
- Seyfried & Brown 1985 – fecal coliform model; and
- Dufour 1984 – E. coli model.

These models allow the estimation of risk rates for contracting GI from primary recreation in the Red River. They are not able to estimate skin, ear, or respiratory infections from such use.

While the D-R models and the estimated disease caseload have many weaknesses, they indicate that there is no reason to expect that a significant disease caseload exists from recreation in the Red River.

Table 7-3 illustrates the illness risk rate for river conditions without WPCC effluent disinfection, for conditions with WPCC effluent disinfection and shows the health risk for the hypothetical condition where CSOs were eliminated through sewer separation.

TABLE 7-3

ESTIMATED GI CASES FOR RECREATIONAL RIVER USE (WINNIPEG AREA)

	Seyfried & Brown (1986)	Dufour (1984)	Ferley (1989)
River Conditions Without WPCC Effluent Disinfection	173	93	84
After Dry Weather WPCC Effluent Disinfection	114	3	42
Sewer Separation	107	0	36

Source: Ferley *et al.* 1989; Seyfried and Brown 1988; Dufour 1984

Some observations follow:

- Any illness risk assessment of the impact of pathogenic organisms (for which fecal coliforms are used as indicator organisms) is an imprecise science primarily because of the limited information available on the correlation between fecal coliform densities and cases of gastrointestinal disease. The accuracy of the relationship between indicator bacteria and the presence of pathogens is uncertain and subject to considerable challenge.

- The predicted caseload of GI is very small (see Table 7-3) in the context of the overall GI caseload. A community of the size of Winnipeg can be expected to have a total of 500,000 to 1,000,000 GI cases per year (Wardrop/TetrES 1990), most of which are not reported. These cases originate from a number of sources, foodborne, travel, and waterborne. In this context, the GI caseload that could be attributed to WPCC discharges and CSOs is very low.

- The table shows a modest reduction in GI caseloads associated with WPCC effluent disinfection (40-90 cases per year).

- There is virtually no additional reduction in illness as indicated from elimination of CSOs (as illustrated by sewer separation of the entire CS system).

- The risk associated with inhalation of aerosols from irrigation was estimated and found to be very low. This assessment also applies to instances of golf course irrigation, children playing near sprinklers using river water, etc. It does not consider deliberate ingestion, i.e., drinking of river water. The illness risk assessment, undertaken as part of the CSO Study, concluded that the probable health risk associated with irrigation under current conditions is so low as to be unable to be reliably quantified. Accordingly, any benefits to irrigation from CSO control will not be measurable.

Aside from avoided disease, there are other community health considerations which could be factors in determining CSO control policy. These were explored in the risk assessment, as summarized below:

- ***Safety Considerations in Use of Rivers***
  - The use of the Red River for primary recreation has inherent risks due to the nature of the water and other competitive uses. The Red River has naturally high levels of turbidity, strong currents, relatively steep muddy banks and concealed objects. These all represent risks to the personal safety of users and are relevant to an overall community health risk assessment. The high use of the river for boating also represents a concern in terms of physical risk of injury to the waterskiiers, jetskiiers and swimmers. None of these factors would be influenced by the degree of control of CSOs.
  - Swimming has never been popular in the Red River. Manitoba Conservation does not recommend swimming in the river when turbidity levels exceed 50 NTU. The rationale is

based on the need for clarity for situations where swimmers are in distress. The turbidity levels, based on 1977-1998 turbidity data, exceed 50 NTU during the recreation season about 55% of the time at the southern edge of the City and 29% of the time at the North Perimeter bridge. These data indicate that the river is naturally not very suitable, for swimming. The elimination of CSOs would not change the clarity of the rivers for swimming.

People using surface waters for recreation recognize and implicitly accept some degree of risk when they choose such use. Their enjoyment of the experience may more than offset the above safety considerations in their judgement.

- ***Increased Use of Rivers***
  - If additional control of CSOs resulted in the increased use of the Red River for primary recreation, a small increase in disease caseload could result, i.e., if a number of users exposed to the river water increases at a given risk rate, the total disease caseload will increase. Increased use of the rivers may also result in more accidents and incidents of personal injury.
  - This increase in the health burden may be acceptable to the community. Other benefits could accrue from increased usage, such as improved public perception and community pride in the rivers, improvement in outdoor enjoyment, fitness, community well-being and perhaps some increased economic benefits. CSOs may be constraints to maximizing these potential benefits. The appropriate balancing of risk versus benefits involves the value-judgements of the community.

The illness risk assessment report concluded that:

"*CSO control will be costly and the benefits are subjective. There are many reasons to consider CSO control, including improving compliance with environmental guidelines, improvements in aesthetic and/or microbiological water quality, improving public perception and pride in the local rivers. The weight of the evidence and analysis indicates CSO control should not be considered a significant public health issue in the conventional context of avoiding disease. The extent of CSO control that is appropriate and acceptable to the community is fundamentally a public policy and a regulatory compliance issue.*" (Illness Risk Report 1999; attached Appendix 1).

The foregoing perspectives illustrate that the available ability to estimate illness risk rate is not likely to assist in the evaluation of CSO control scenarios.

8. ALTERNATIVE CONTROL PLANS

Background: Phase 3, TM# 1; Costing; Phase 3, Appendix #1

Methods for CSO control employed in other cities were reviewed for their potential application to the Winnipeg situation. The methods include source control, improvements to the existing sewer system, construction of new storage or treatment facilities, and system-wide separation of the combined sewers. The costs and the suitability of the different methods vary with the characteristics of the local situation, for example, the local rainfall/runoff characteristics, the capacity of the local sewer system and the objectives of the control plan. A range of different plans, using proven technologies, was defined which would provide specific levels of control performances. A large number of district plans are potentially possible and some screening of options was done in this process.

This section will describe:

- the approach to the definition of the plans;
- the use of the existing infrastructure (all of the possible control plans build on the existing system);
- the alternative control plans; and
- the approach to estimating their costs.

The evaluation of the performance of the alternative plans is presented in Section 9.0.

All cost estimates in this report are in 2001 dollars.

8.1 BEST MANAGEMENT PRACTICES (BMPs)

Background TM: Phase 2, TM #3

This study will assess a wide range of potential CSO controls. It is generally considered good practice, even without an intensive CSO control plan, that combined sewer systems should be operated to minimize CSOs. This includes the application of Best Management Practices (BMPs) usually non-structural or minimal structural actions (WEF 1989). In the U.S., the EPA has identified 9 activities, termed “9 Minimum Controls” that it considers should be applied in every CS system, even before a major CSO control plan is implemented.

Before considering potential control plans, the study team, drawing on its collective experience and the specialists advisors, reviewed the existing Winnipeg system to determine if typical BMP’s and the 9 minimum controls were being applied.

The 9 minimum controls include:

1. Proper operation and regular maintenance.
2. Maximum use of the collection system for storage.
3. Review and modification of pre-treatment programs.
4. Maximum flow delivery to the treatment plant(s) for treatment.
5. Prohibition of dry weather overflows.
6. Control of solids and floatables materials in CSO discharges.
7. Required inspection monitoring and reporting of CSOs.
8. Pollution prevention, including water conservation, to reduce CSO impacts.
9. Public notification of any areas affected by CSOs especially beach and recreation areas.

Table 8-1 provides a listing of the potential BMPs relevant to CSO control, correlates them to the EPA 9 minimum controls and notes the extent to which these measures have been applied in Winnipeg. As can be seen in the table, the City has implemented many of the Best Management Practices to improve the operation of the combined sewer system and to minimize CSOs.

TABLE 8-1
BEST MANAGEMENT PRACTICES
CORRELATION TO CSO CONTROL

BEST MANAGEMENT PRACTICES	EPA 9 MINIMUM CONTROLS	APPLIED IN WINNIPEG	REMARKS
NON-STRUCTURAL			
Sewer flushing	#1	√	Part of Sewer Rehabilitation Program
Catchbasin cleaning	#1	√	City has annual program, not aimed at litter capture
Street sweeping	#6	√	City has limited program
Catchbasin inlet restriction	#2	√	City has applied in some areas for flood protection (part of proposed program)
Inflow & Infiltration reduction	#2,4	√	
Overland flow attenuation	#2	√	Catchbasin restorations
Roof leader disconnection	#2	√	City had active public education program, 95% disconnected
Chemical addition	#3		
Review/implementation of by-laws	#8	√	City has comprehensive industrial waste control by-laws
Industrial runoff control	#8		
Water conservation	#8	√	City has implemented strong program
Receiving stream water quality monitoring	#7,9	√	City has long-term program in place
Public Education	#9	√	City has had campaigns for downspout disconnection, lot grading and litter control
Inspection, Monitoring, Reporting of CSOs	#7		City has FAST alarm system. System was upgraded. City currently has budgeted for installing a SCADA System
MINIMAL STRUCTURAL ALTERNATIVES			
Flow balancing between districts	#2		Not likely to be effective
Overland flow slippage	#2		Could be effective as part of BFR
Increase pervious area	#2		Little potential
Elimination of dry weather overflows	#5	√	Discussed below. Some additional effort needed (SCADA)
Hydraulic control devices	#4	√	City has devices in place but are not effective.
Interception optimization	#4		
Maximize WWF treatment at WPCCs	#4	√	Existing WPCCs are run at nominal full capacity during WWF
In-line storage	#2		

Some of these measures include the following:

- The City had implemented a FAST alarm system that alerts the Operations Department of incipient overflow at the interception point and/or troubles with pumping stations or other malfunctions in the lift station or the interception point. This system has been upgraded in recent years and is currently scheduled for replacement by a supervisory control and data acquisition system (SCADA) which will improve data acquisition and assist in reducing the number of dry weather overflows and improving current flood protection.
- The City has a successful program of educating the public on the merits of root leader disconnection. It is believed that approximately 95% of the downspouts are disconnected in combined sewer districts.
- The City has an annual program for cleaning catchbasins. Approximately 9,000 to 10,000 cleans are accomplished on an annual basis.
- The City has a street cleaning program which concentrates mostly on spring clean-up to capture much the sand that has been applied for winter ice control. The City has made an effort to reduce the amount of sand spread on the streets. About 50% of the sand is recovered from mechanical sweeping. The reductions in applied sand mean less grit is delivered to the rivers through CSOs.
- The City encourages runoff control at source through parking lot storage, catchbasin inlets, etc. and sewer system bylaws. The City has also provided public education information on control of street litter and illicit discharges to the sewer.
- The City treatment plants are operated such that they currently provide at least primary treatment to wet weather flows that are delivered to the WPCCs.
- The City monitors dry weather flows in the various districts and endeavours on this basis to assure that all DWF is captured. This is an ongoing inspection and maintenance process. The City's current program comprises a 24-hour day, 7-day a week centralized alarm, dispatch and emergency response to dry weather overflows. Dry weather overflows are promptly reported to Manitoba Conservation.
- The City has constructed sewer separation in selected districts during the course of BFR programs. This is done wherever it is economically advantageous.

It is recognized that any new control options will build on the current Best Management Practices and will also include the initiation of new BMPs.

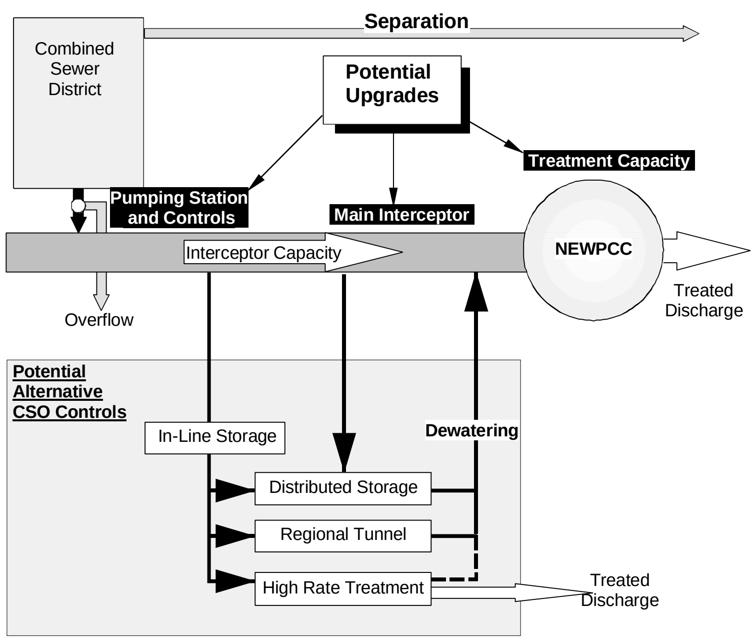
8.2 DEFINING SYSTEM UPGRADES

The existing combined sewer system consists of the following main elements:

- collection system;
- wet weather flow interception controls at each district;
- conveyance by means of interceptor sewers; and
- central treatment (WPCC).

All the control plans involve consideration of the capacity of these existing elements (see Figure 8-1). Control options include their upgrades, and/or additions of further control options including:

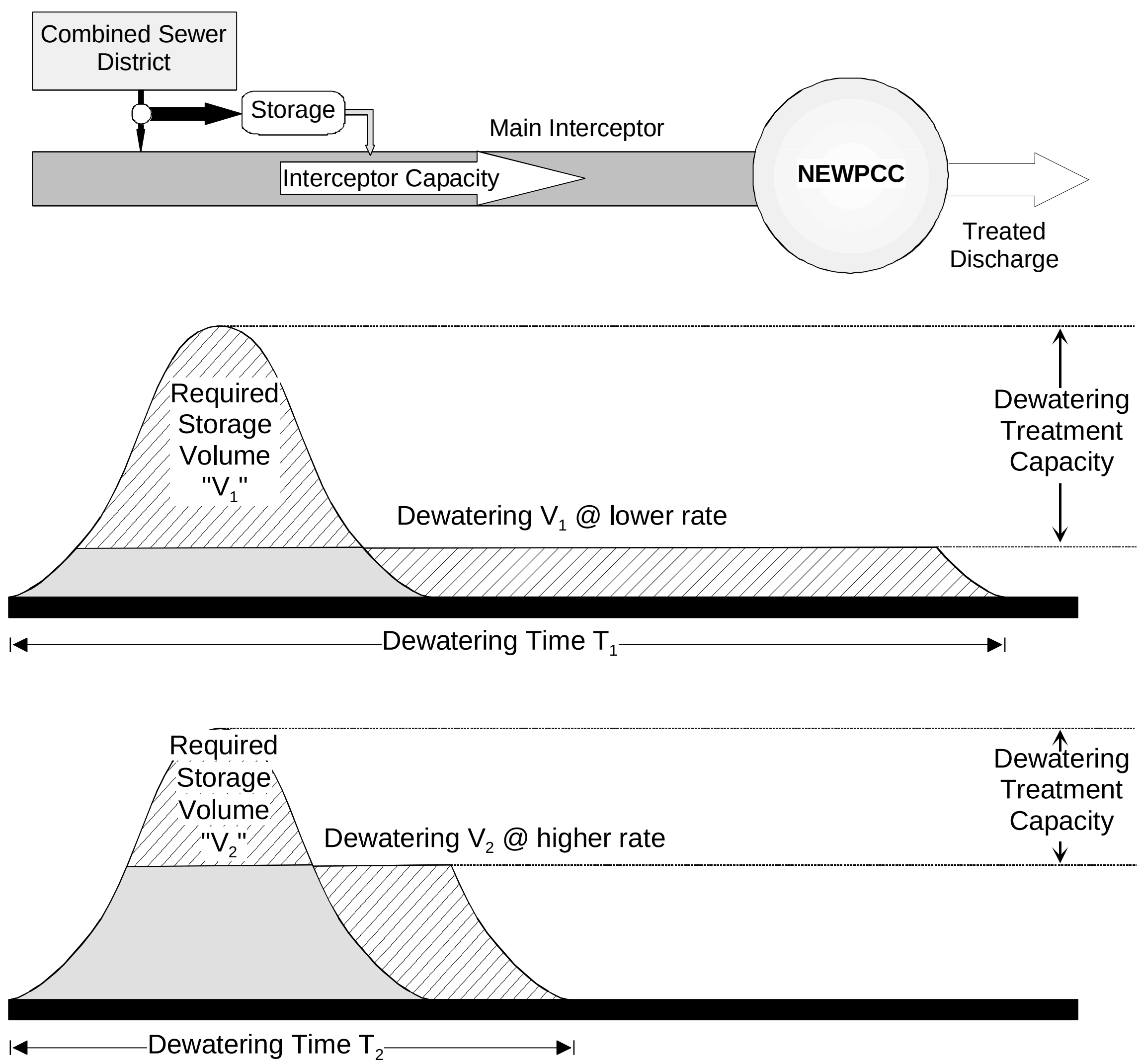
- wet weather flow interception controls;
- interceptor conveyance;
- storage (in-line, distributed off-line storage or regional storage);
- high rate treatment of CSOs at the outfall points; and
- central treatment (NEWPCC).



Potential Options for CSO Control
Figure 8-1

Since 90% of the combined sewer districts in the City of Winnipeg are tributary to the North End Water Pollution Control Centre (NEWPCC), the districts tributary to the NEWPCC dominate any solution for reduction of the CSO impacts on the rivers passing through the City.

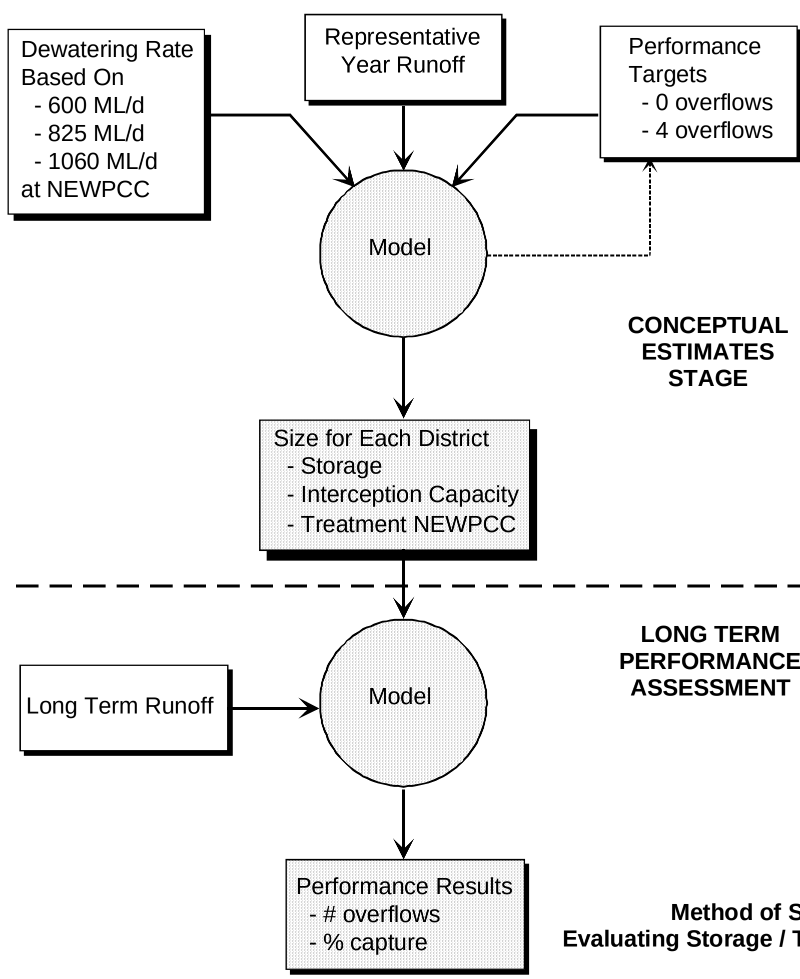
The key characteristics in each district are the rate of interception (and dewatering of storage) available and the associated amount of storage required to meet a given control target. The system-wide rate of flow available for dewatering of captured storage is equivalent to the NEWPCC treatment capacity minus the average summer dry weather flow.



Storage Requirements at Various Dewatering Rates
Figure 8-2

The number and volume of overflows occurring in any year or any district is dependent upon the interception rate and storage available in these districts. In designing to meet a performance target, say a given number of overflows, the greater the interception or dewatering rate available, the less storage volume required, as shown in Figure 8-2. For example, if wet weather flow is intercepted at rates corresponding to 825 ML/d total system wastewater flow, the volume of storage needed will be less than for a rate based on a system flow of 600 ML/d but there will be higher treatment costs associated with treating WWFs at the higher rate. Both the interception rate and storage factors are discussed below.

Figure 8-3 illustrates the steps used in defining the physical requirements for the different groups of control alternatives. Using a representative year of runoff and river flow, the models described in Section 5 were used to estimate the storage requirements for a number of different system-wide interception rates and to meet different levels of performance. This step defined the conceptual requirements for storage and upgrades to the conveyance system. The models were then used to assess the performance of the selected control alternatives for long-term rainfall records and to refine the storage/treatment requirements.



Method of Sizing and Evaluating Storage / Treatment
Figure 8-3

8.2.1 Interception/Storage Dewatering Rates

Three system-wide interception rates were considered based on various treatment capacities available at the NEWPCC. The three capacities assessed were:

- 600 ML/day – equivalent to the existing secondary treatment design capacity;
- 825 ML/day – equivalent to the existing primary treatment capacity; and
- 1,060 ML/day – equivalent to the existing total pumping capacity.

For the sewer districts tributary to the WEWPCC or the SEWPCC, the strategy was similar, i.e., limit the WWF from these districts to the existing total peak WWF treatment capacity at each of the plants.

The existing system was originally designed to intercept about 2.75 x DWF from each district. Currently, the interception rates are usually close to 2.75 x DWF for districts in which pumping is required to the interceptor. However, in many districts, the interception is by unrestricted gravity connections, resulting in interception rates much higher than 2.75 x DWF. These high interception rates thus dominate the use of the interceptor capacity.

For potential CSO control systems, the interception rate and interceptor capacity can be more systematically allocated to each district and thus make better use of the existing hydraulic capacity of the main interceptor sewer on a system-wide basis. The method used in the final analysis assumed two components to the interception rate, i.e., the dry weather flow and the runoff interception or dewatering rate. The dry weather portion will be equal to the average dry weather flow in each district. A proportion of the available total system-wide wet weather treatment rate was assigned to each district based on the proportion of runoff of each district relative to the total runoff in the combined sewer area. This will require the upgrading of control facilities at many of the districts. This approach will optimize the proportion of wastewater diverted to treatment during wet weather.

The estimated costs of the modifications needed to effect this change in interception rate is about $14 million.

8.2.2 Estimating Storage Requirements

The amount of storage required at each district was estimated, based on the amount of runoff in the district, the three interception rates described above, and the performance level required.

Two performance levels were assessed, namely, 4 overflows or zero overflows, during the recreation season for the representative year (1992).

The model(s) described in Section 5 were also used to evaluate the performance of each one of the storage/dewatering combinations, using the long-term period of record from 1960 through 1994.

The amount of storage for each district, so determined, was used in the costing of the interceptor and treatment upgrades discussed in Section 8.2.3 and 8.2.4.

8.2.3 Main Interceptor Upgrades

Background: Phase 3, TM #1, Section 4

The runoff-based interception rates will require changes to the various district diversion rates to the interceptor. For all three of the proposed dewatering rates, most of the districts which currently involve pumping of intercepted flow from the trunk sewers to the interceptors will require capacity upgrades, i.e., they can intercept more combined wastewater. Further, the 10 districts which currently discharge by gravity will require some means of controlling the rate of flow diverted to the interceptor.

The hydraulic analyses (XP-SWMM) revealed that the Main Interceptor could be overloaded by the increased flows from runoff-based interception. Modifications to the Interceptor required in order to accommodate the flows are summarized below:

- 600 ML/d scenario: some discharges from individual districts increase but do not exceed the capacity of the Main Interceptor;

- 825 ML/d scenario: the flows from almost all district/systems increase. For the most part, the Interceptor can accommodate the increases. Some additions are needed at an estimated cost of $26 Million;
- 1,060 ML/d scenario: the flows from all districts except Mission, exceed the Interceptor capacity such that it needs relief over most of its length. The additions needed have an estimated cost of $79 Million.

The estimated costs included an allowance of 20% for estimating contingencies and 20% for engineering, finance, and administration.

8.2.4 NEWPCC Upgrades

Background: Phase 3, TM #1, Section 4

The three dewatering/treatment rates have different implications to the NEWPCC treatment facilities, as summarized below:

- 600 ML/day rate
  - The entire intercepted WWF would be given secondary treatment and, in the long-term, disinfection. This plant effluent would have the least impact on the river quality.
  - The most cost-effective upgrade for this rate involved the expansion of the NEWPCC final clarifiers. The increased sludge solids would require additional primary digester capacity.
  - These modifications are estimated to cost $17M.

- 825 ML/day rate
  - Bypass of the secondary treatment process, after the rainfall event, could occur for many hours while dewatering the stored combined sewage.
  - The portion of the flow exceeding the hydraulic capacity of the secondary treatment facility (825-600 ML/d) would receive primary treatment, only, during and after the wet weather event, however, the secondary bypass could be disinfected.

  - The most effective upgrade for this treatment rate involves the provision of additional primary clarifier capacity at the NEWPCC plus additional primary digester volume.
  - These modifications are estimated to cost $40M (including disinfection).

- 1,060 ML/day rate
  - 460 ML/day (1,060-600 ML/d) would bypass the secondary plant which could be disinfected. This bypass of secondary treatment could occur for many hours while dewatering the captured stored combined sewage.
  - Significant upgrades would be required to increase the firm raw wastewater pumping capacity at the NEWPCC, the capacities of the headworks, the primary clarifiers and to provide an auxiliary effluent conduit.
  - Additional primary sludge digester volume would be required.
  - These modifications are estimated to cost $78M (including disinfection).

The above costs have been adjusted to include 20% for estimating and 20% for engineering, finance, and administration contingencies.

8.3 DEVELOPING ALTERNATIVE CONTROL PLANS

Background: Phase 3, TM #1, Section 5

A wide range of alternative control methods are possible, based on experience elsewhere. The main categories are:

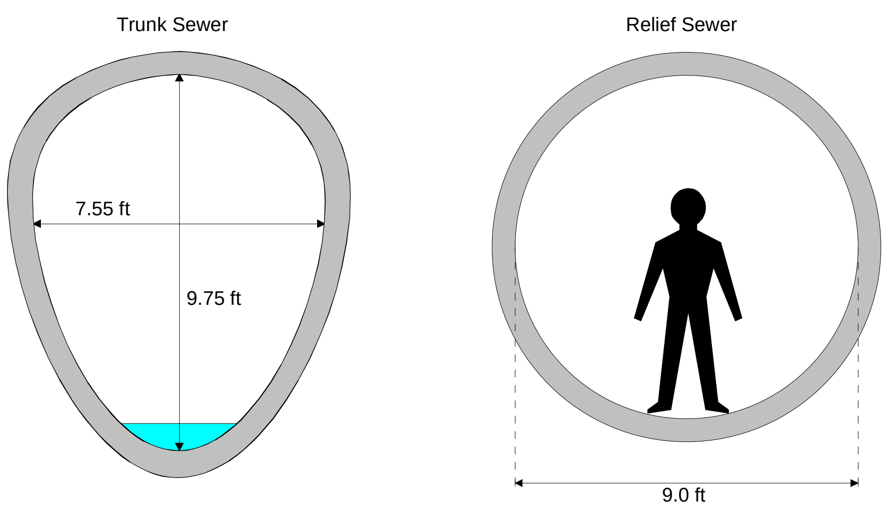
- Addition of Storage:
  - wet weather flows can be stored for subsequent treatment at the WPCC once treatment and conveyance capacity have recovered after the rainfall event. Technologies include storage in pipes (in-line storage); in off-line storage tanks; and in local and regional storage tunnels;
- high rate treatment of CSOs at the point of overflow;
- separation of combined sewers; and
- control of floatables at the point of overflow.

Alternative control plans were developed for each of these technologies to meet different performance or control targets, using the different dewatering rates, where applicable. This resulted in 39 alternative plans, which are described in Phase 3 TM No. 1. This section will describe the main characteristics of the different categories of the plans and provide illustrative examples of each type of plan.

8.3.1 <u>In-Line Storage</u>

In Winnipeg, due to the flat topography, the existing combined sewers are typically large, relatively flat in slope, and extend considerable distances from the river. The same applies for relief sewers installed for basement flood protection (see illustration Figure 8-4). These sewers only flow at a small fraction of their depth in dry weather, thus providing significant potential in-line storage.

In-line storage can be developed by construction of a flow regulator to utilize storage capacity in these existing conduits. The regulator restricts wet weather flow, causing the conduit to fill and provides storage volume. Developing in-line storage in existing conduits is typically less costly than building off-line storage, and is attractive because it provides the most effective utilization of existing facilities. The applicability of in-line storage is very site-specific, depending on existing conduit sizes and the risk of basement flooding due to an elevated hydraulic grade line.



Typical Winnipeg Combined Sewer Trunks
Figure 8-4

Due to the history of basement flooding in the combined sewer districts in Winnipeg, it is imperative that the flow control technique does not increase the risk of basement flooding.

8.3.1.1 In-Line Storage Estimates

During the course of the CSO study, the potential application of different in-line storage concepts and control technologies evolved. The following three control concepts are the most relevant to the Winnipeg situation:

- accessing existing latent storage;
- raise weirs; and
- automatic control (gates/inflatable dams, fixed weirs).

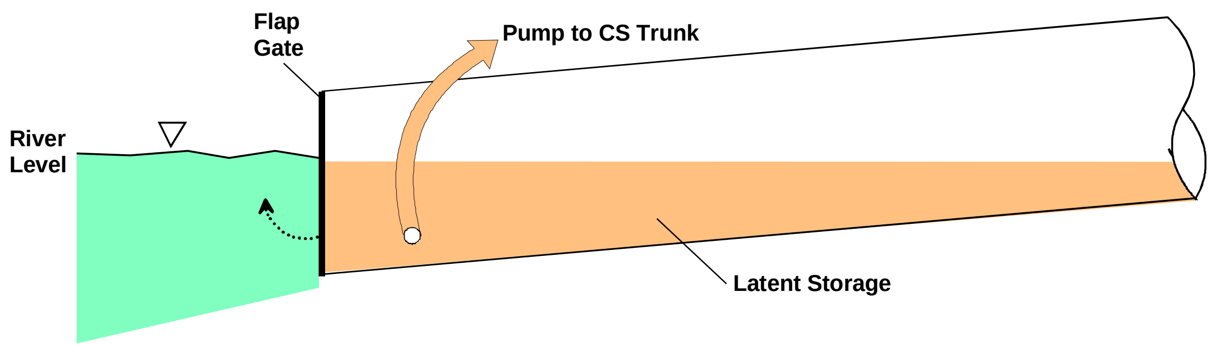
The amount of storage available from these concepts differs and therefore the effectiveness of control of CSOs will also vary.

The following discussion elaborates on these three control concepts as they relate to Winnipeg's CSO study and relevant local circumstances.

8.3.1.1.1 Latent Storage

Many of the underground combined sewer districts have existing relief sewers to achieve a design level of basement flood protection. Where such relief sewers exist, the hydraulics in both systems (combined sewers and relief piping) were synchronized such that overflow from the relief system did not occur prior to overflows from the combined sewer system.

Currently, many of the relief sewer pipes are below normal river water level (see Figure 8-5). Each relief system outfall has a flap-gate installed to prevent river water from entering the sewer system. The majority of these relief pipes do not have a dewatering system and remain partially full under normal river water level conditions. By ensuring that the flap gates will seal properly and installing a pumping station and connecting forcemain to the interceptor, this combined wastewater could be dewatered after a rainfall event. This would provide an empty pipe for storage for the next rainfall. This type of storage has been labelled “latent”. Since most of the infrastructure needed is already in place, this latent storage can be accessed at very reasonable cost.



Relief Pipe with Latent Storage Potential
Figure 8-5

The capital costs of developing this latent storage in the 17 districts with such potential was estimated to be $11.8 Million. This amount included rehabilitation of flap gates and provision of pumping capability to the interceptor, during and after rainfall events.

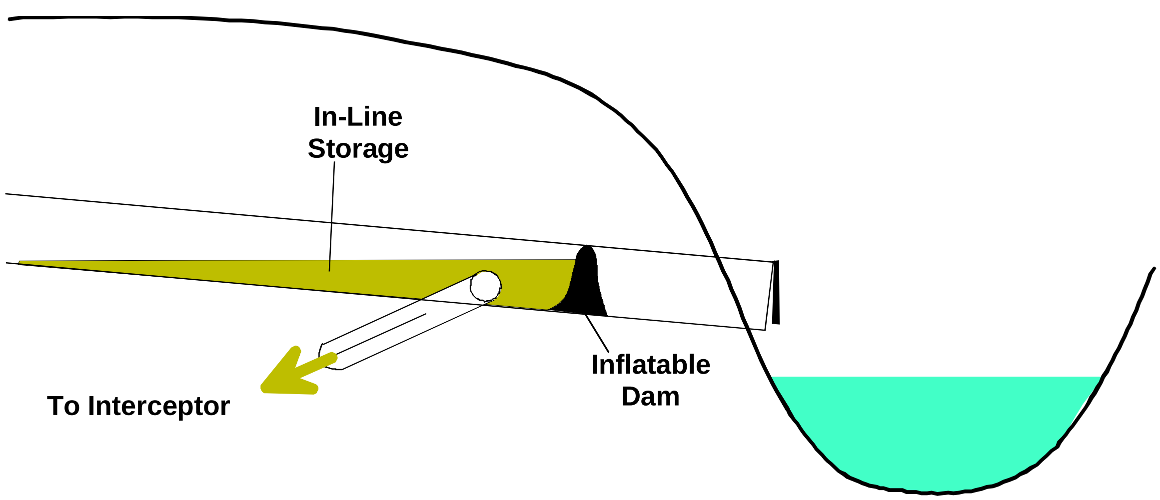
8.3.1.1.2 Raising Existing Diversion Weirs

The current diversion weir, in the CS trunks, ranges between 0.1 to 0.4 x the trunk diameter. For purposes of calculating the current in-line storage potential, a value of 0.2 of the diameter was used. It would be possible, at low cost, to increase the height of this diversion weir in all CS trunks, whose flows are currently diverted. For purposes of predicting the benefit, it was assumed that the weirs were raised to 0.4 of the trunk diameter.

The estimated capital cost for this undertaking was $1.5 Million.

8.3.1.1.3 Controlled In-Line Storage

One option under consideration is the use of an automated real-time gate system (either a sluice gate or an inflatable dam) to access available in-line storage, by temporarily holding wet weather flows (WWF) within the system during and after smaller rainfall events. Runoff from these smaller rainfall events could be stored within the combined sewer system and then dewatered during and after the storm event (see Figure 8-6). For larger storms, sensing devices would automatically open the device to allow the high flows to discharge as at present. This would achieve the goal of not interfering with the current level of basement flood protection.



In-Line Storage with Inflatable Dam
Figure 8-6

<u>Inflatable Dams</u>

An inflatable dam is a reinforced rubberized fabric device that can be inflated during wet weather to create in-system storage. When deflated, the dam collapses to take the form of the conduit in which it is installed. Inflatable dams are controlled by local or remote level sensing devices, which regulate the height of the dam to optimize in-line storage and prevent upstream basement flooding. The dam height is controlled by the air pressure in the dam. These controls can be made “fail-safe”, i.e., they will deflate under loss of power for the air supply.

Mechanically Operated Sluice Gates

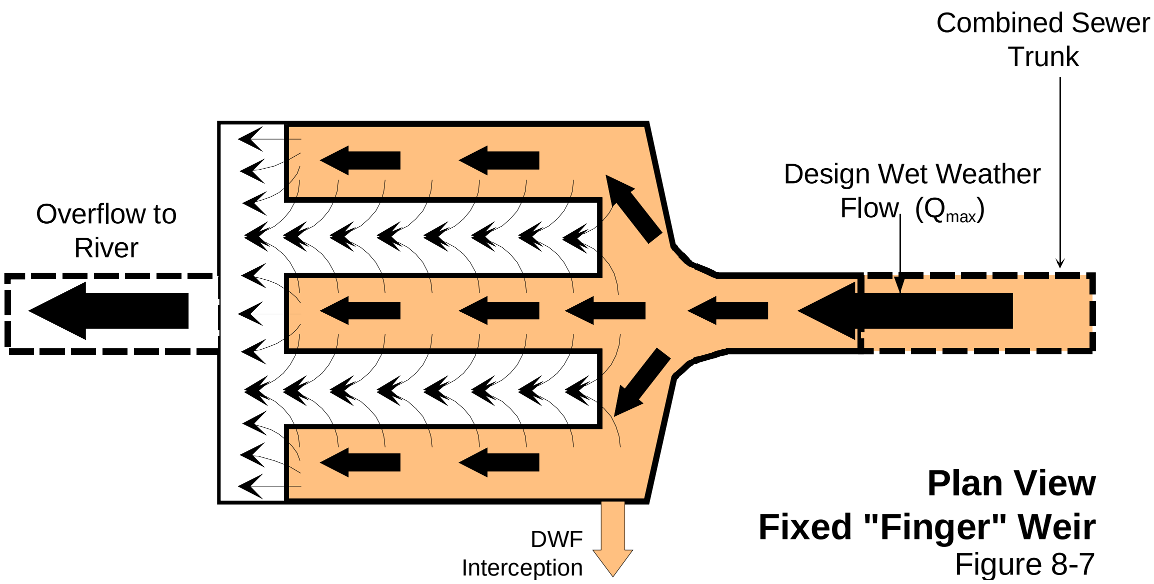
Similar to the inflatable dams, motor- or hydraulically operated gates typically respond to local or remote level sensing devices. Normally closed gates can be located on overflow pipes to prevent overflows except under conditions when upstream flooding is imminent. The level of control and general reliability of motor-operated gates make them well suited for use with real-time control systems, except that, in the case of an equipment malfunction, there is a risk of extensive basement flooding. In order to minimize basement-flooding risk associated with gate control, the following additional design safety factors were considered:

- in-system storage levels should not exceed the obvert elevation of the pipe at the location for automated control (avoids potential for air surges and/or waterhammer and reduces concerns related to structural integrity);
- inlet restriction on catchbasins should be utilized to reduce the rate of inflow into the combined sewer system such that the in-system flow hydraulics would not be worse than that generated by a one in five year “design storm”;
- the logic of gate control systems (with redundancy) would be developed to open the gate if there is a malfunction or failure in any of the water level sensing monitors;
- gates would be designed to open automatically in case of power failures or interruptions (e.g., an air-accumulator connected to a hydraulic operator or an air-drive motor); and
- utilization of the existing flood pumping stations to initiate emergency dewatering of the combined sewer system if the gate fails to open (e.g., shaft breakage or mechanical malfunction).

The inflatable rubber dam option was preferred over the sluice gate since it offers greater basement flood protection in the event of a malfunction. These devices would include the additional safety devices described above. Inflatable dams have been successfully put to similar uses in other North American cities (e.g., Cleveland, Detroit). They are significantly more costly than the sluice gate option but less costly than the fixed-weir option discussed below.

Fixed Weir Option

Given the history of basement flooding, a fail-safe fixed weir was considered as a possible control device. The fixed weir would utilize long weir lengths to minimize flow depth over the weir, and was considered both fail-safe and practicable (see Figure 8-7). A design condition of 150 mm (6 in) depth of flow over the weir to safely pass a 1 in 5 year design storm was selected. The existing hydraulic gradeline (HGL) for each sewer system under the design event would be reviewed to establish the top elevation of the weir (i.e., HGL-0.15 m).



Plan View
Fixed "Finger" Weir
Figure 8-7

A fixed finger-weir system to utilize available in-line storage has the advantage of little need for operational attention relative to the inflatable dam control system and is inherently more fail-safe. However, it is more costly to construct than the inflatable dam option and will only utilize about 80% of the in-line storage that could be achieved with the dam.

8.3.1.2 Operational Considerations for In-Line Storage

None of the in-line storage options will involve complicated operating procedures, beyond normal inspection and maintenance procedures.

There are a number of operating conditions which need to be evaluated, on a site-specific basis, for Winnipeg. These comprise:

- potential for odour generation of stored wastewater;
- potential for sediment build-up in the sewers;
- flushing of sediments during larger storms;
- impact of stored sediments on river quality during flushing events; and
- impact on NEWPCC operations.

These factors will have to be determined through pilot tests.

8.3.1.3 Performance and Costs

In-line storage calculations were performed for each of the 43 combined sewer districts to quantify the potential volume of storage available for each of the three control concepts previously discussed (i.e., latent storage, automated control and fixed weir). The results are summarized in Table 8-2, along with estimated costs. It should be noted that the volumes indicated are the total volumes available. In a few districts, the volume available is greater than that needed to achieve the desired reduction in the number of overflows, for that district. Therefore the total volume, while available, will not be used. Some districts have sufficient in-line storage available to achieve zero overflows (e.g., Aubrey), while others would experience 17 overflows, even with the use of in-line storage.

Table 8-2 shows the projected long-term average number of overflows across all districts for the recreation season.

TABLE 8-2

IN-LINE STORAGE – CAPITAL COST AND PERFORMANCE

OPTION	POTENTIAL* STORAGE VOLUMES (m^3)	ESTIMATED CAPITAL COST (DISTRICT-WIDE) ($MILLION)	PREDICTED AVERAGE NO. OF OVERFLOWS (Recreation Season)
Present Situation			17.5
Latent Storage	120,000	$11.7	12.5
Latent Storage & Raised Weirs	170,000	$13.5	10.5
"In-Line Storage":			
(1) Inflatable Dam Option	385,000	$64	6.5
(2) Fixed Weir Option	325,000	$112	7

*It is estimated that these volumes could be increased by 10% through integration with the continuing BFR program

In-line storage alone cannot provide sufficient storage across the entire system to meet the potential targets of 4 or zero overflows/recreation season.

Since the details of redundancy, security, and fail-safeness of the inflatable dam option have not been fully confirmed for the Winnipeg case, the $110 Million cost of the weir option was used for the comparison of the cost of CSO control options undertaken in Section 9. This total cost includes the $14 Million for modifying the interception/dewatering rates, as described in Section 8.2.1.

In developing the potential, illustrative approach to CSO control (Section 10), the estimated cost for in-line storage was based on the installed costs of the recommended inflatable dams (developed on the basis of the estimated supply and installation of the Bridgeston "Expan Gate" rubber dams). The use of this lower number ($64M including modifying interception rates) resulted in a more realistic projection of the costs and timing of the illustrative approach. The use of the higher number in the cost comparisons did not change the result of these comparisons since the in-line/off-line options were the most cost effective in any case.

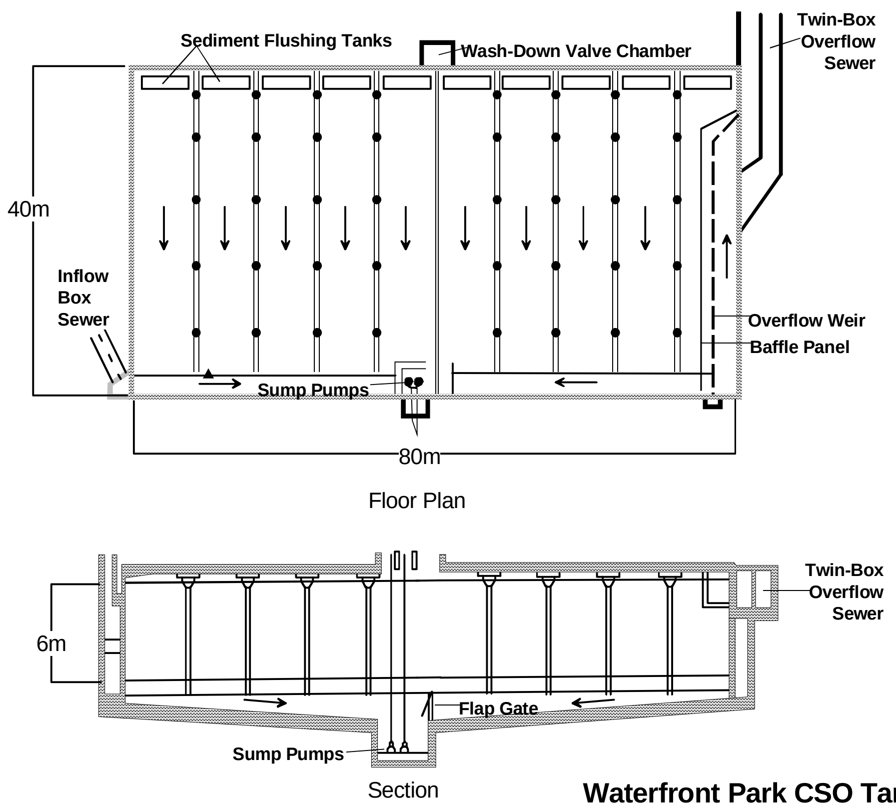
8.3.2 <u>Off-Line Storage</u>

This technology reduces overflow quantity and frequency of CSOs by storing all or a portion of diverted wet weather combined flows in off-line, near-surface tanks. Stored flows are returned to the interceptor for conveyance to the treatment plant once system capacity is available.

Storage can also be provided in large tunnels constructed well below the ground surface. Tunnels can provide large storage volumes with relatively minimal disturbance to the ground surface, which can be very beneficial in congested urban areas. Flows are introduced into the tunnels through dropshafts. Pumping facilities are usually required at the downstream ends for dewatering. Both techniques were evaluated for this study.

8.3.2.1 Near Surface Tanks

Near surface storage tanks would take the form of covered, concrete storage basins located just beneath the surface of the sites. Combined sewage would be pumped from the end of the CS trunk to the storage tank(s). After installation, the site would be restored as closely as practicable to its original condition. The adequacy of this technology has been proven elsewhere. A floor plan and section of such a storage device, as built in the City of Hamilton, Ontario, is shown in Figure 8-8.



Source: Hamilton CSO Detention Tanks Design Considerations

Waterfront Park CSO Tank; Floor Plan and Section
Figure 8-8

During the course of the Phase 3 investigations, the availability and location of public lands was investigated to determine potential locations for near surface tanks.

It was assumed that the size of the pumps needed to convey the flow to the near surface storage would be close to the predicted peak flow of the largest storm to be captured, in order to prevent any overflow from that storm.

After construction, the major potential impact of the near surface tanks on adjacent areas could be odour. Experience at storage facilities, such as at the Eastern Beaches in Toronto, has shown satisfactory odour control. Odour-scrubbing facilities had been installed at the Beaches, consisting of the use of charcoal filters. The filters have been replaced once in the last 10 years. No odour complaints have been received from the public. A second concern with regard to CS storage is flushing. The systems at the Beaches and elsewhere have included the installation of a sediment-flushing tank, which returns water for flushing purposes at the upstream end of the basin. On completion of basin dewatering, the stored water is released. This technique has proven to satisfactorily flush the floor with virtually no manpower requirements.

8.3.2.2 Local Storage Tunnels

In districts where siting of near surface storage tanks did not appear practicable, the cost of the off-line storage system was based on the use of local tunnels. The entire NEWPCC combined sewer area was divided into groups of contiguous areas wherever possible. Tunnel storage for these areas would be provided by deeper continuous tunnels parallel to the Assiniboine and Red rivers.

The group tunnels would likely be constructed at some depth, in bedrock, below the clay and till, so as to avoid mixed face tunnelling. Flows from the CS trunk or relief sewer to the storage tunnels would be by gravity. The tunnels would be emptied at the dewatering rate for the districts involved, after the abatement of runoff, or, where used, after the in-line storage had been transferred to the interceptor. Stored combined sewage in the tunnels would be pumped to the interceptor.

Dewatering rates will not generate the scouring velocities needed to re-suspend settled solids. Accordingly, each group tunnel would be provided with a flushing system designed to develop a scouring velocity.

8.3.2.3 Costing

Table 8-3 shows the costs for control options that would use in-line storage supplemented by off-line storage to meet 4 overflows per recreation season (RS). The table also shows these costs without the use of in-line storage.

TABLE 8-3

OFF-LINE STORAGE – COST SUMMARY
CAPITAL COSTS: FOUR OVERFLOWS PER RECREATION SEASON

DEWATER RATE	STORAGE VOLUME	BASE COST(1)	FLOW CONTROL COSTS(2)	IN-LINE STORAGE COSTS(3)	FLUSHING COSTS(4)	INTERCEPTOR COSTS	NEWPCC COSTS	TOTAL OPTION COSTS
ML/d	1,000 m^3	M	M	M	M	M	M	M
4 OVERFLOWS WITH USE OF IN-LINE STORAGE								
600	300	$179		$112	$18		$17	**$326**
825	220	$130		$112	$9	$26	$40	**$317**
1060	185	$100		$112	$9	$79	$78	**$378**
4 OVERFLOWS WITHOUT USE OF IN-LINE STORAGE								
600	300	$397	12		$29		$17	**$456**
825	220	$347	12		$25	$26	$40	**$451**
1060	185	$305	12		$26	$79	$78	**$501**
4 OVERFLOWS WITH USE OF IN-LINE STORAGE AND TRANSFERS								
600	300	$136		$112	$18		$17	**$283**
825	220	$112		$112	$11	$26	$40	**$301**

All costs include 20% for estimating contingencies and 20% for engineering, administration and finance
(1) includes: costs of off-line storage (tunnels and near surface tanks) plus pumping and forcemains; also includes 10% surcharge on tunnels and tanks
(2) costs for modifying to runoff-based interception rates (Section 8.2.1)
(3) includes cost of modifying interception rates
(4) costs for flushing local storage tunnels based on a concept from CG&S for Toronto (see Appendix I, Phase 3)

At 4 overflows per RS, the representative year closely approximated the long-term average. 1992 was not only selected on the basis of rainfall/runoff but also on river flow, which was average in 1992. Accordingly, the representative year was selected as the basis for evaluating CSO control for 4 overflows per year.

The base cost for tunnels comprises a 20% allowance for estimating contingencies plus a 20% allowance for engineering, finance and administration plus a 10% allowance for unforeseen soil conditions, e.g., the regional tunnel options will be in bedrock which could involve a significant surcharge; similar conditions could apply to storage tunnels and therefore were subject to the same surcharge. The base cost for off-line storage was subject to the same mark-ups. In this case, the 10% was used as an allowance for ancillaries.

For simplicity, Table 8-3 does not show the use of in-line/off-line storage for elimination of overflows.

For the greater volumes of storage involved in achieving one and zero overflows per RS, the Phase 3 investigations indicated that the off-line storage option would cost significantly more than the regional tunnel option. The regional tunnel concept is described in Section 8.3.3.

The estimated capital costs of these storage alternatives, both for the 4 overflow/RS target are summarized in Table 8-3, for the three dewatering rates. The least cost options, without district transfers, utilize the 825 ML/d and 600 ML/d storage dewatering rates and in-line storage (the estimated costs are $295 and $308 million, respectively). The lowest cost options for (4 overflows) without the use of in-line storage, are $409 Million and $435 Million for 600 ML/d and 825 ML/d withdrawal rates, respectively. Clearly, in-line storage provides a major cost advantage.

Scenarios were developed to determine the magnitude of the savings which might be realized by transferring the CS volumes from storage-deficient districts. Flows would be pumped to nearby districts with excess in-line storage volumes or to districts which had sites available for additional off-line surface storage. These costs were compared to the costs of developing tunnel storage in the storage-deficient district. Pumping and conveyance would be at the peak flow of the largest storm to be captured. Using this simplistic approach, it was only justified, economically, to transfer flows from six districts: Mission and Roland/LaVerendrye to Roland;

Syndicate/Boyle to Selkirk; and Riverbend to Clifton. The estimated costs are also provided on Table 8-3.

As can be seen from a comparison between the options, with and without district transfers, the apparent saving for district transfers are not large (about 15% for the 600 ML/d option and 5% for the 825 ML/d option). The difference might be reduced by a further optimization of the off-line storage without transfers or through real time control. In any case, it is not likely to increase. These, and similar, transfer options should be investigated as part of the detailed assessment for each district, which would take place before implementation of CSO control for the district.

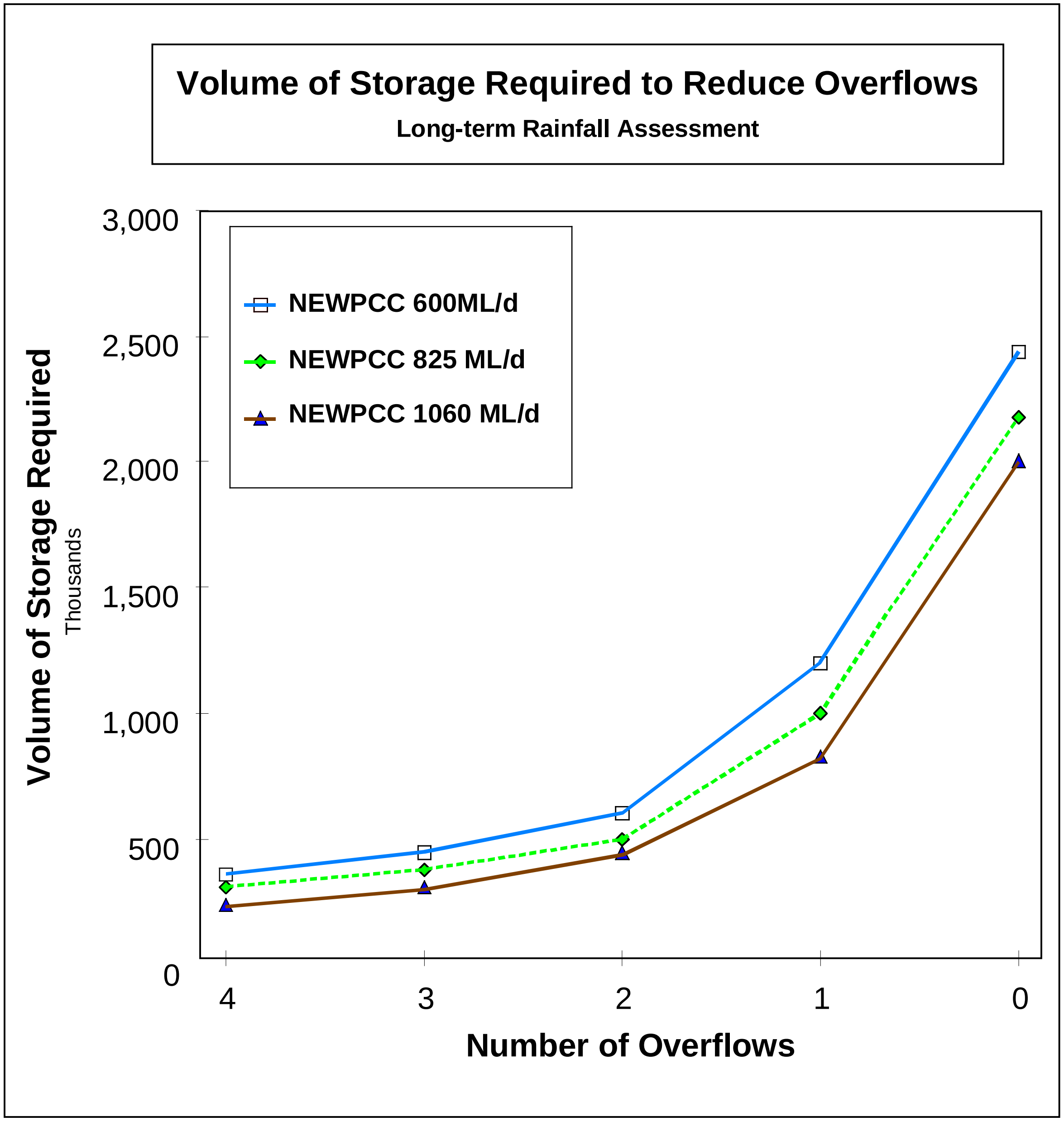
8.3.2.4 Representative Year Versus Long-Term Average

It was found that there were some discrepancies in the predicted performances of control facilities sized based on the 1992 representative year, as compared to the long-term average. For a target of four overflows per year, storage volumes based on the 1992 year provided results similar to the long-term average. However, for the performance target of zero overflows per year, the 1992-based storage results more closely approximated the required infrastructure for two overflows per year on the long-term basis. Figure 8-9 shows the results of the analysis for the required storage in order to meet the target of zero to four overflows per year on the long-term average basis.

Figure 8-9 shows that the storage volumes required to virtually eliminate overflows are much greater than for a target of 4 overflows. The figure also shows the degree to which the number of overflows must be reduced on the long-term basis in order to approach a target of 85% capture of combined sewage, for the three dewatering rates considered. The target of 85% was one of the performance measures selected for the study (Section 5.2.3) and relates to the U.S. EPA “benchmark”. Under all conditions of dewatering, 85% capture corresponds to one overflow per year.

Number of Overflows	Volume of Storage Required		
	600 ML/d	825 ML/d	1060 ML/d
4	362,000	312,000	238,000
3	450,000	375,000	312,000
2	600,000	500,000	450,000
1	**1,200,000**	**1,000,000**	**825,000**
0	**2,438,000**	**2,175,000**	**2,000,000**

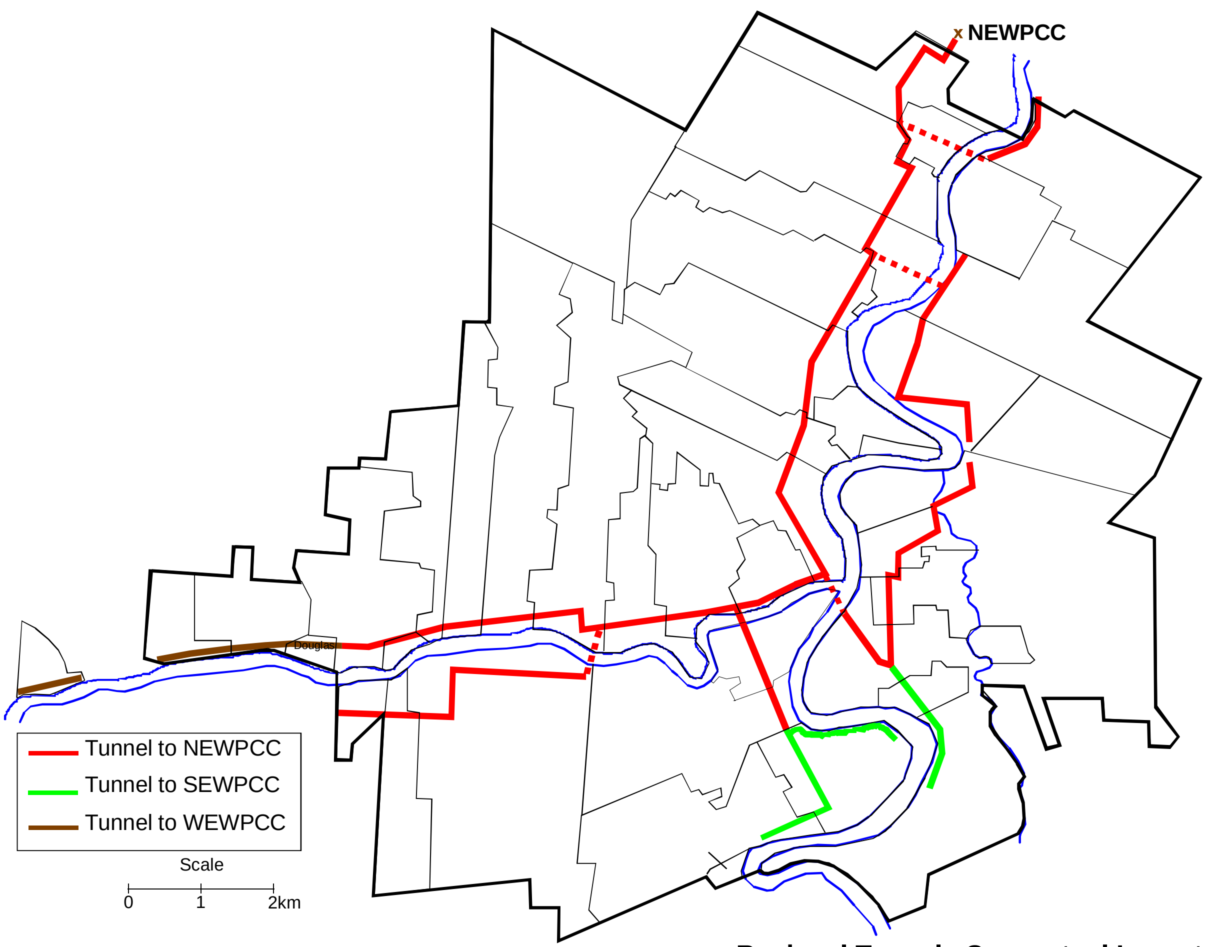
Number of Overflows	Median % Capture		
	600 ML/d	825 ML/d	1060 ML/d
4			
3			
2			
1	**84.0%**	**84.6%**	**84.7%**
0	**100%**	**100%**	**100%**



The volumes required to meet the targets of one and zero overflows per year on the long-term average basis were used to estimate the size, and hence cost, of regional tunnels which would be needed in order to achieve these results. Off-line storage options were not considered for these targets as the costs for the greater volumes of storage are much higher for off-line than for regional tunnels.

8.3.3 Regional Tunnels

Regional tunnels have been used in other cities to control CSOs, e.g., Chicago, Illinois. The regional tunnel concept is similar to the off-line storage concept. It entails the storage of excess combined sewage flows to limit the number of overflows to the river, i.e., four or zero). It differs from the off-line storage option in that the flows are conveyed by the tunnels, directly or via interconnection, to the WPCCs.



Regional Tunnels Conceptual Layout
Figure 8-10

A conceptual layout for regional tunnel systems is shown on Figure 8-10. Connection to the West End and South End WPCCs are very similar to off-line storage in that the flows are pumped from the storage tunnels. The main storage tunnel conveys flows directly to the NEWPCC for pumping. Where possible, the tunnel routes were located along road rights-of-way so as to minimize the need for property acquisition.

The volumes of storage required were identical to off-line storage volumes. The tunnel options considered the use of in-line storage; meeting targets of zero and four overflows per year; and using the three storage dewatering rates already discussed.

Operational Considerations

The profiles for the regional tunnels were set to generate self-cleaning velocity of 1 m/s at the full dewatering rate. In order to avoid mixed-face tunnelling, the regional tunnels would be located in bedrock and, because of their depth, would require a new pumping station for dewatering to the NEWPCC. Since the collector tunnels would normally be dewatered at less than a flushing rate, flushing systems would be installed. Accordingly, operation and maintenance of the regional tunnel storage system should be minimal.

Costing

The capital costs of the regional tunnels are summarized in Table 8-4 for the four overflows. The minimum size of tunnel used was 1.5 m. The costs include for flow control, in-line storage, flushing and the NEWPCC expansion/modification.

The costs for zero and one overflow were estimated on the basis that a larger tunnel would follow the same route, including length, as that for other regional options. The results are listed in Table 8-5.

TABLE 8-4

REGIONAL TUNNELS – COST SUMMARY
4 OVERFLOWS PER RECREATION SEASON: CAPITAL COSTS

DEWATER RATE	STORAGE VOLUME	BASE COST(1)	FLOW CONTROL COSTS(2)	IN-LINE STORAGE COSTS(3)	FLUSHING COSTS(4)	NEWPCC COSTS	TOTAL OPTION COSTS
ML/d	1,000 M m^3	M	M	M	M	M	M
4 OVERFLOWS WITH USE OF IN-LINE STORAGE							
600	300	$291		$112	$18	$17	**$438**
825	220	$264		$112	$16	$40	**$432**
1060	185	$264		$112	$15	$78	**$472**
4 OVERFLOWS WITHOUT USE OF IN-LINE STORAGE							
600	300	$486	$13.5		$27	$17	**$543**
825	220	$439	$13.5		$26	$40	**$518**
1060	185	$406	$15.5		$22	$78	**$520**

All costs include 20% for estimating contingencies and 20% for engineering, administration and finance
(1) includes: costs of regional tunnels plus pumping & forcemains; includes 10% surcharge
(2) costs for modifying to runoff-based interception rates
(3) includes cost of modifying interception rates (Section 8.1.2)
(4) costs for flushing local storage tunnels (based on concept from CG&S for tunnels – see Appendix 1, Phase 3)

A comparison to Table 8-2 shows that, for a target of 4 overflows, regional tunnels are more costly than building other off-line storage. Such a comparison also shows a very significant increase in cost to meet a target of zero overflows compared to 4 overflows/recreation season.

TABLE 8-5

REGIONAL TUNNELS – COST SUMMARY
0 AND 1 OVERFLOW PER RECREATION SEASON: CAPITAL COSTS

DEWATER RATE	STORAGE VOLUME	BASE COST(1)	FLOW CONTROL COSTS(2)	FLUSHING COSTS(3)	NEWPCC COSTS	TOTAL OPTION COSTS
ML/d	1,000 M m^3	M	M	M	M	M
1 OVERFLOW						
600	1.2	$894	$13.5	$54	$17	**$919**
825	1.0	$772	$13.5	$48	$40	**$873**
1060	0.12	$701	$13.5	$44	$76	**$836**
0 OVERFLOW						
600	2.4	$1198	$13.5	$76	$17	**$1304**
825	2.2	$1050	$13.5	$71	$40	**$1254**
1060	2.0	$1087	$13.5	$68	$78	**$1241**

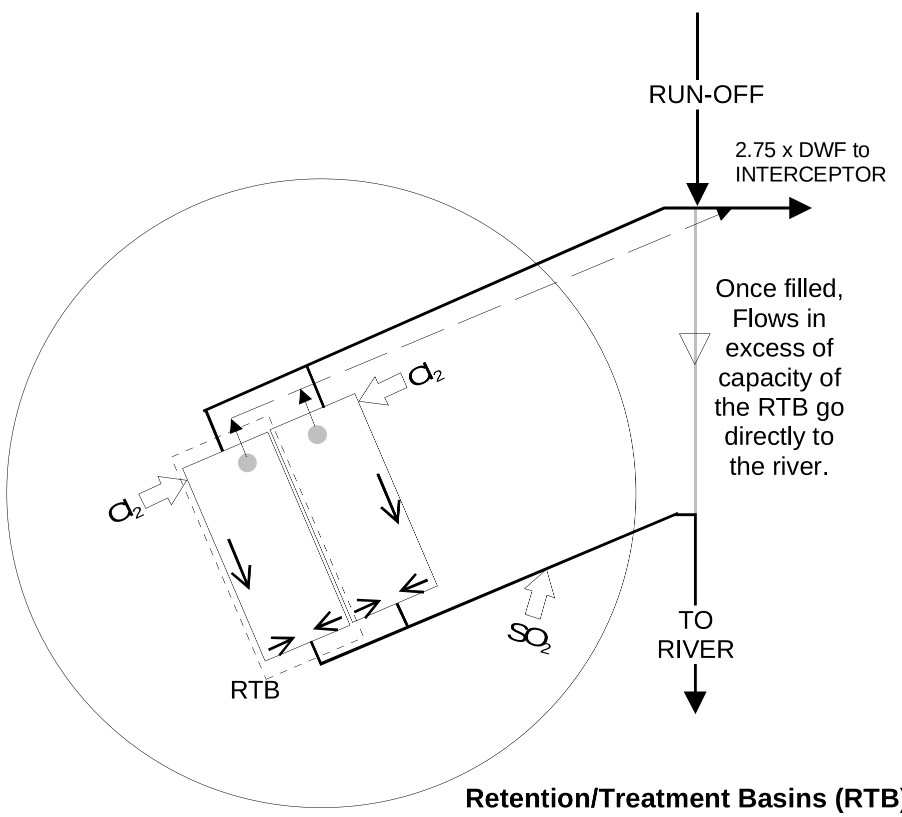
All costs include 20% for estimating contingencies and 20% for engineering, administration and finance
(1) includes: costs of regional tunnels plus pumping and forcemains
(2) costs for modifying to runoff-based interception rates
(3) costs for flushing local storage tunnels

8.3.4 High-Rate Treatment

All high-rate treatment control options consider treatment at the outlet end of the combined sewer. Two control technologies considered were; vortex solids separators (VSSs) and retention treatment basins (RTBs).

The VSSs are high-rate sedimentation devices. The prime purpose is to remove solids to the point where disinfection can achieve the MSWQO for fecal coliforms in the rivers. During the course of Phase 3, a treatability evaluation was undertaken on the Aubrey District to determine the effectiveness of the high rate treatment options on CSOs. This treatability evaluation showed that, if the Aubrey CSO is representative of Winnipeg-wide CSO characteristics, the VSS technology would be unsuitable for the Winnipeg situation. The suspended solids comprised a very high percentage of the very fine (poorly settling) material in the wastewater. This faction of the solids is considered too light for effective removal with the VSS process.

The operation of the RTB is shown schematically on Figure 8-11. The RTBs act initially as a storage basin and then as a high-rate sedimentation basin. As with the storage basins considered earlier, the volume of combined sewage up to the storage capacity of the RTB is captured, returned to the interceptor and conveyed to the treatment plant for treatment. The



Retention/Treatment Basins (RTB)
(Illustrative Only)
Figure 8-11

flow in excess of the storage capacity would pass through the RTB, acting as a sedimentation basin which would allow effective disinfection, and then discharge directly to the river (after dechlorination). If chlorination is used, it is contemplated that this would be accomplished by liquid chemicals and dechlorination would be applied. The CS flows in excess of the RTB sedimentation/disinfection capacity would be discharged directly to the river undisinfected. Capture of CS flows would be pumped from the combined sewers to the treatment facility at the rated capacity of the device.

The high-rate treatment devices would be either near-surface or above-surface facilities depending on cost and/or aesthetics. The devices would require sufficient land to accommodate them.

The high-rate devices would have similar concerns with odour as the near surface storage facilities. These can be addressed through the use of exhaust air filters. In addition, both high rate devices would entail the storage and handling of chemicals: probably sodium hypochlorite (liquid) for disinfection and sodium metabisulphite (powder or liquid) for dechlorination before discharge to the rivers. In themselves, neither the storage nor handling of these chemicals should present any serious hazards. Notwithstanding their stability, however, they will be located generally in or near residential areas. Neighbours may perceive the use of these chemicals in their area as being undesirable.

Operational Concerns

Because of the addition of chemicals, the operation of these high-rate facilities will be more complex and demanding than would be the operation of the near surface or local tunnel storage options. The difference in complexity would be reflected in more frequent, routine inspection visits and would therefore be reflected in O&M costs (see Section 8.3).

Costs

Due to the indication of the unsuitability of the VSS for Winnipeg, it was decided not to analyze the VSS future but to develop conceptual costs for the RTB only. A numerical model was developed to simulate the performance of the RTBs with an 825 ML/d storage/treatment rate to meet a target of four overflows per recreation season.

The estimated capital costs for this RTB option is $467 Million. In comparison to the costs associated with the use of in-line/off-line storage, as shown in Table 8-2, RTB's are significantly more costly.

8.3.5 Separation of Combined Sewers

Complete separation of the existing combined sewer system would involve a decision to separate land drainage and sanitary sewers on a regional basis, i.e., a conversion of the existing one pipe combined sewer system to a two pipe system. This section discusses the method of accomplishing such a retrofit separation, the costs, and associated implications.

In most cases it would be practicable to designate the existing combined sewer to act as the separate wastewater sewer and to install new land drainage sewers (LDS) to carry the stormwater runoff. A new network of storm sewers would then be constructed, in general, typically parallel to the combined sewers, to capture urban runoff. The LDSs would drain directly to the rivers or creeks.

Implementation Considerations

The construction of regional retrofit separation would involve significant costs and significant community disruption. Virtually all streets in an area served by combined sewers would be affected by separation activities. The retrofit LDS system would likely affect 70 to 80% of the remaining 8,700 hectares in the City of Winnipeg which remain served by combined sewers. A corollary benefit to retrofit separation would be the provision of basement flood protection for those districts that have not yet been provided with relief sewers (possibly 2,700 ha). For those districts with existing relief sewers, the added protection would be nominal.

Rehabilitation of the existing combined sewers would still be required since they would continue to be expected to form an integral part of the sewerage system.

Cost of Retrofit Separation

A number of studies have been done on the cost of retrofit separation in various districts in Winnipeg. This information was used to estimate system-wide costs. Numerous studies have been done in other cities which provide comparative cost information (Sacramento CA, Hartford CT, Edmonton AB). These data were used to cross-check the estimated costs of regional separation in Winnipeg.

A cost for sewer separation of $1,500 million was used for comparisons with other control options. This cost estimate is considered adequate for planning level comparisons, however, if complete separation was deemed worthy of further consideration, a Winnipeg-specific regional estimate would be required to develop a more reliable cost estimate.

By comparison, the City of Edmonton has estimated the cost of regional separation of their combined sewer area (5,000 ha) to be $1.9 Billion. Winnipeg has 8,700 ha of combined sewer area. The topography is different but this illustrates that regional separation is very costly. Further, prevailing CSO control practice shows that regional separation is rarely the most cost-effective control option.

8.3.6 Floatables

Background: Phase 2, TM #3, Section 4.5, and Phase 3, Appendix No. 6

The study considered the issue of the discharge of "floatable" materials carried by CSOs to the river. If this material is the main issue (floatables have been a major issue with respect to the beaches in New Jersey), there are devices available which can specifically address this issue, namely:

- coarse screen technologies (screen openings of 6 mm or greater);
- fine screen technologies (screen openings less than 2 to 6 mm);
- weir mounted screens; and
- end-of-pipe netting systems.

The least complicated and most cost-effective means of addressing floatables capture alone appears to be the "TrashTrap" system developed in the United States. The technology comprises large net bags and supporting infrastructure at the end of each of the combined sewer outlets. This technology could be used in specific areas where downstream floatables are a particular concern and where space consideration in the river permitted the installation of the devices. It is unlikely that this technology could be applied over the whole region.

A combination of in-system screening and end-of-pipe netting, depending on district-specific conditions, could cost between $33 million (netting) to $123 million (screening). Recent application of Department of Fisheries and Oceans (DFO) regulations could increase complexity of approvals (and the cost) of installing riverside facilities for floatables capture. The implications of this DFO involvement were not investigated in this study.

8.4 OPERATION AND MAINTENANCE COSTS

Background: Phase 3, TM #1

Operating and maintenance (O&M) costs for the types of CSO control options under consideration were found to represent a relatively small fraction of the total cost of CSO control plans, based on experience elsewhere. For comparison of the total present value costs of alternatives, the costs were estimated on the basis of the City of Winnipeg's current O&M costs for 70 small pumping stations and WPCCs. They were cross-checked through comparison with costs developed by the City of Edmonton. The costs include labour, materials and power consumption. Chemical costs were included in the capital cost estimates. The present value was based on a discount rate of 4% over 20 years.

The costs developed in the preceding portions of Section 8, for the various CSO control options, were Capital Costs, including allowances. The total estimated costs for the 39 candidate control plans, considered to be practicable means of control CSOs were developed for the study. Part of these estimates (for the most part those associated with the 600 ML/d dewatering rate) are listed in Table 8-6. It should be noted that the present value of the O&M costs represent a small fraction of the total cost (in the order of 4%).

8.5 POTENTIAL CSO MANAGEMENT STRATEGIES

The full array represents a wide range of costs and different degrees of CSO control. The implications of the potential management strategies are discussed further in Section 9.

TABLE 8-6
COST OF SELECTED OPTIONS*
(Mainly 600 ML/d dewatering)

	DEWATERING RATE @NEWPCC ML/d	REQUIRED OFF-LINE STORAGE Volume m^3	IN-LINE STORAGE OR FLOW REGULATION $M	TOTAL FACILITY CAPITAL COST $M	FLUSHING/ DISINFECTION $M	O&M COST PV $M	TOTAL COST $M
Existing Situation	825						$0
Optimizing Existing Infrastructure							
(In-Line Storage)	600		$112	$17			$129
Target of 4 Overflows/RS							
• Distributed Off-line Storage	600	300,000	$13.5	$414	$29	$21	$477
• Distributed In-line/Off-line Storage	600	102,000	$112	$196	$18	$17	$343
• Distributed In-line/Off-line Storage with Tranfers	600	80,000	$112	$153	$18	$17	$300
• Tunnel/Transport Storage	600	300,000	$13.5	$503	$27	$14	$558
• In-line with Tunnel/Transport Storage	600	102,000	$112	$308	$18	$14	$452
• Hirate Treatment (RTB)	825	160,000	$13.5	$409	$45	$32	$500
Target of 1 Overflow/RS – Long-term							
• Tunnel/Transport Storage	600	1,200,000	$13.5	$861	$54	$14	$942
Target of 0 Overflows/RS – Long-term							
• Tunnel/Transport Storage	600	2,438,000	$12	$1,212	$76	$14	$1,316
Separation							$1,500

*Complete list in Phase 3 Appendix No. 1

9. PERFORMANCE EVALUATION OF ALTERNATIVE PLANS

Background: Phase 3, TM #1, Section 6

A wide range of potential control plans was identified in Section 8 along with their respective storage/conveyance/treatment requirements and costs. These plans span the spectrum of technologies from those which maximize the use of the existing infrastructure; plans with structurally-intensive additions; and a plan for the conversion of the system to a separate system. This section discusses the comparative performance of these plans in terms of meeting a range of performance measures.

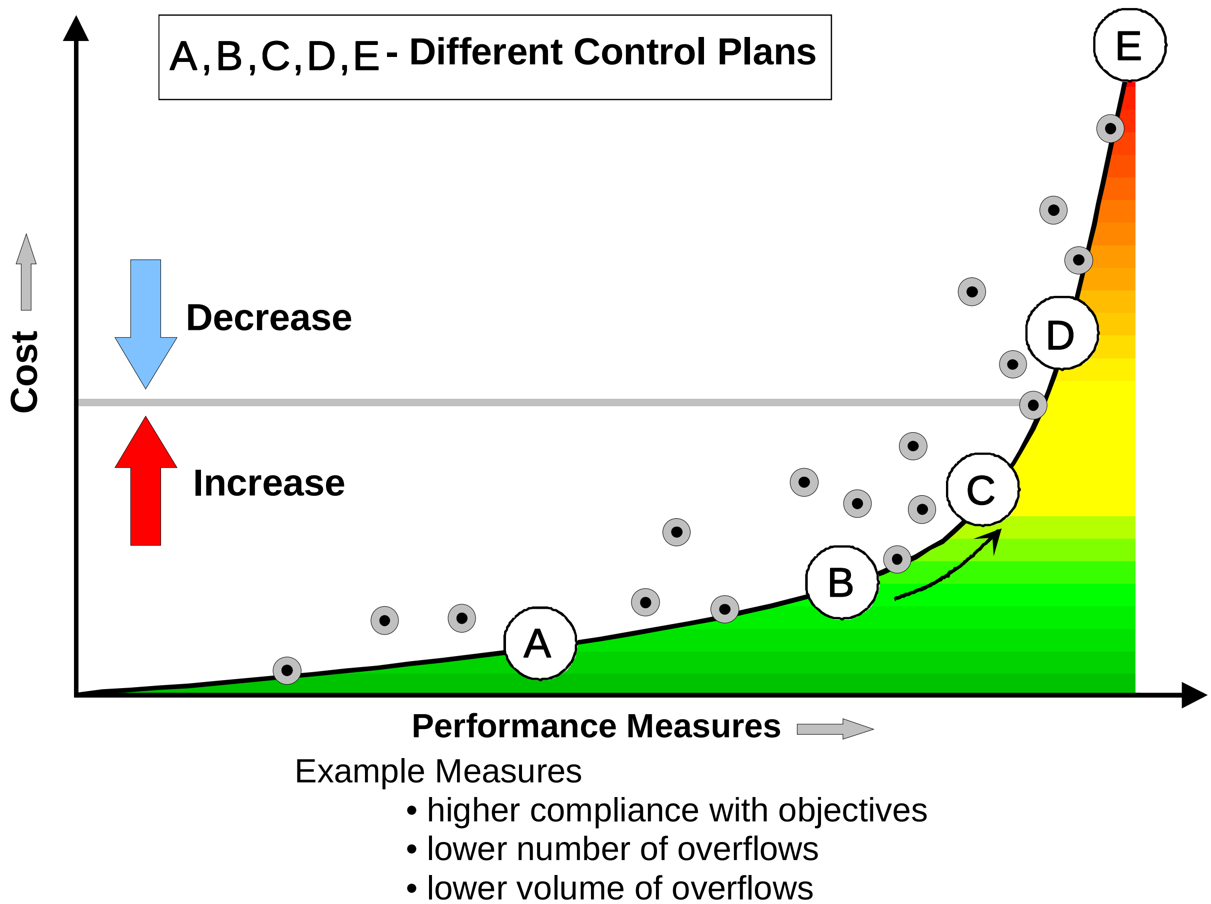
As explained in Section 5, a number of possible performance measures were selected as potential "targets" for the definition of comparative control plans. These include:

- compliance with MSWQO objectives for fecal coliform;
- optimizing existing infrastructure;
- reduction in number and volume of CSOs;
  - limiting CSOs to about 4 per year*; or
  - 85% capture of combined sewage*;
- elimination of CSOs (zero overflows per year).

*Conforming to the U.S. EPA presumptive criteria.

The intent was to present a broad range of control plans which would have different performance levels, physical characteristics and costs. This approach allows stakeholders to assess the "trade-offs" and offer opinions on the preferred action, as illustrated graphically in Figure 9-1.

The following discussion elaborates on the performance of the better control options vis-a-vis the performance measures.



Illustrative Cost/Benefit Curve for Performance Measures
Figure 9-1

9.1 COMPLIANCE WITH MSWQO FOR FECAL COLIFORM

Compliance with regulatory objectives is often considered as a proxy for an assumed environmental benefit. To the extent that is practicable, compliance with objectives is also a basic objective of any utility in its operation.

9.1.1 Existing System Compliance

The performance of the existing system provides a context for assessing the relative performance of potential CSO controls.

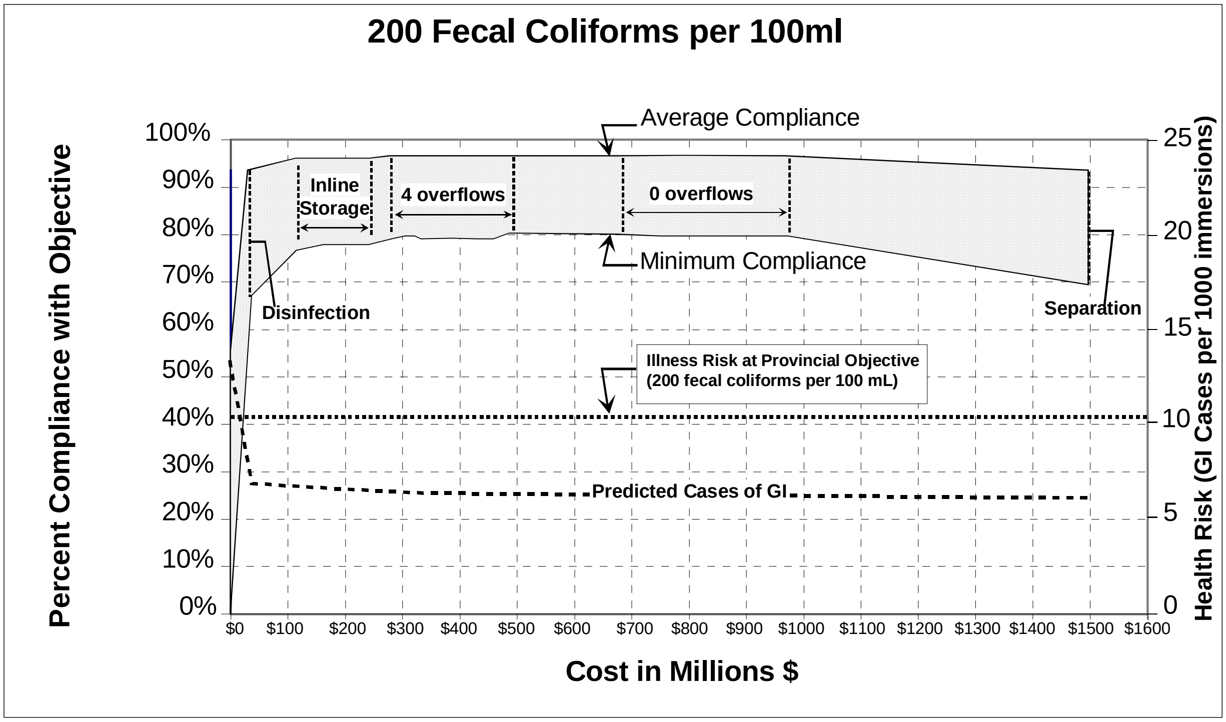
Section 7.6 discussed the fecal coliform concentrations in the river under representative conditions (prior to disinfection of SEWPCC effluent). The compliance with the primary recreation objective of 200 fc/100 mL ranged from as low as 0% of the time (for a location just downstream of the NEWPCC) to an average of about 55% for all locations on the urban river system. Compliance with the secondary recreation objective of 1,000 fc/100 mL can vary from as low as 10% of the time (again, just downstream of NEWPCC) to an average of 80% of the time at all locations. Compliance was determined based on the geometric mean of the predicted hourly concentrations of fecal coliform in the rivers at 13 monitored locations.

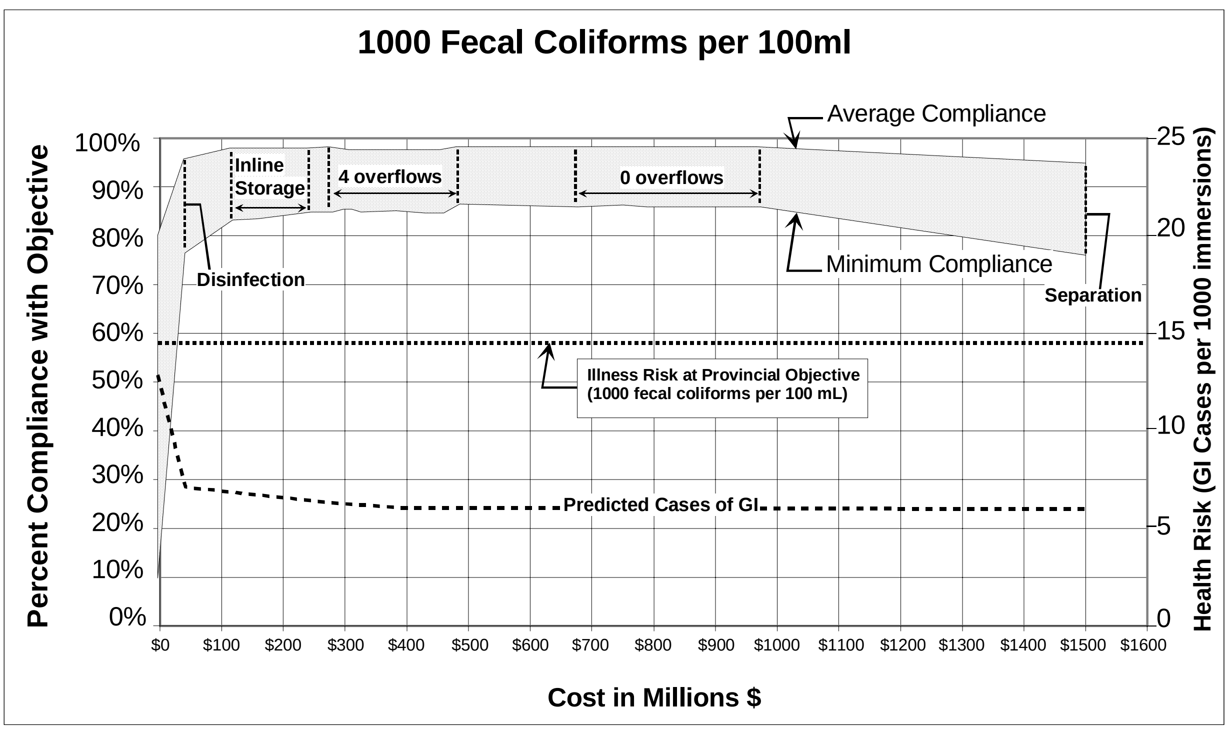
9.1.2 Effect of Planned WPCC Effluent Disinfection

With this context of prevailing conditions, the compliance with the primary and secondary recreation objectives was estimated for a range of control options, including disinfection of WPCC effluents. Compliance with fecal coliform objectives, prior to SEWPCC disinfection was often not achieved due to the dry weather impacts of the undisinfected effluents from the three WPCCs, particularly the NEWPCC. Disinfection of the SEWPCC effluent went on-stream in July 1999. The City has made budget provisions for disinfecting the NEWPCC (2004 target). Treated effluent from the WEWPCC is discharged to the River via the existing lagoons. The retention time in the latter is normally sufficient to reduce fecal coliform concentrations in the effluent to MSQWO limits.

Figure 9-2 shows that disinfection (or equivalent treatment) of all WPCC effluents will result in compliance with the primary objective (200 fc/100mL) about 65% of the time at the worst case location and an average of 95% of the time at all river monitoring locations. Likewise, the secondary recreation objective (1,000 fc/100 mL) would result in compliance 75% of the time at the worst case location, and on average above 95% of the time at all stations.

Although disinfection will significantly improve compliance with the MSWQO for fecal coliforms, this is a result of dramatic improvements in compliance under dry weather conditions, while wet weather conditions are not changed. Figure 9-3 illustrates the effects of wet weather discharges, mainly CSOs, on fecal coliform concentrations in the rivers.





Compliance with Fecal Coliform Objectives for Different Control Scenarios
Figure 9-2

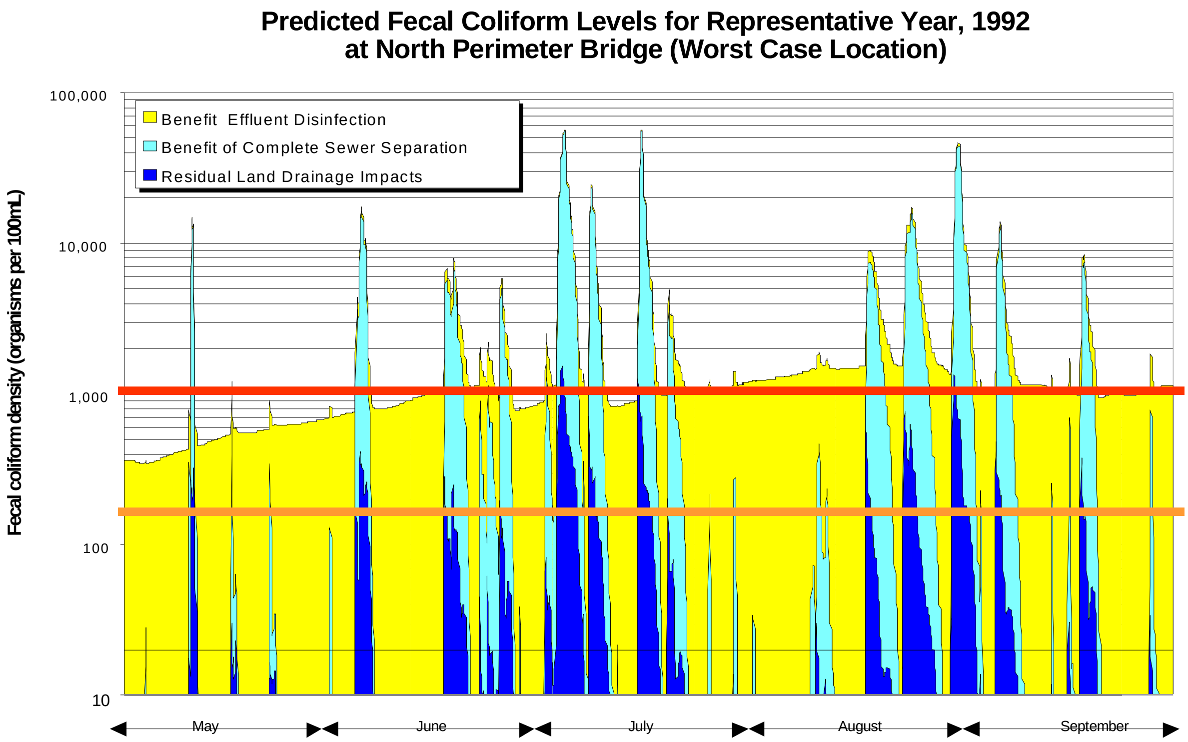


Figure 9-3

9.1.3 <u>Additional Compliance Through Various Control Options</u>

Figure 9-2 illustrates the compliance with the primary and secondary objective under specific control scenarios modelled for this study. Relative to dry weather disinfection at all plants, the increase in compliance with any wet weather control option is relatively modest in terms of improving compliance with MSQWO.

- The in-line storage option, which includes disinfection of the dry weather flows at the treatment plants, showed an average compliance, with the primary recreation objective, of about 96% at the 13 stations selected along both rivers.
  - The in-line storage option in itself results in only a slight increment in improved compliance (3-5%) compared to the planned implementing of disinfection of the WPCCs

and correcting dry weather overflows. This is because non-compliances resulting from CSOs are of relatively short duration.

- Non-compliance would still occur during those WWF events when CSOs occur. With in-line storage, this would occur about 5 to 8 times during the recreation season on an overall system basis, but some districts could overflow more frequently and would need other control measures to conform to the average system performance.

- As can be seen from Figure 9-2, other more costly control options do not raise the average compliance by more than an additional 2 or 3% over disinfection and in-line storage.

- Separation of the combined sewers would not result in an improved benefit in terms of average compliance. Separated districts discharge significant quantities of land drainage, which would cause exceedances of the fecal coliform objectives.

Wet weather events will cause exceedances of MSWQO fecal coliform objectives under any control scenario which results in an overflow to the river.

Compliance with the fecal coliform objective is not very helpful in comparing the alternative CSO control scenarios.

9.1.4 Implications of Compliance with Objectives

Most regulatory agencies, including Manitoba, do not give direction on the percent of time that compliance is required to meet their water quality objectives. Alberta Environmental Protection, however, requires that the geometric mean for primary recreation and secondary recreation be below the objective 80% and 90% of the time, respectively. Most locations on the Winnipeg rivers would meet (or be very close to meeting) such criteria after the WPCC effluents are disinfected. Some locations on the river would not comply but judicious implementation of any of the CSO control plans would meet these criterion. There would still be significant exceedances of objectives during and after wet weather events.

The rationale behind the MSWQO for fecal coliforms is protection of public health (Manitoba Conservation 1988). Figure 9-2 shows the predicted illness risk in terms of GI cases/1,000 immersions for the various control scenarios. This shows that there is virtually no change in risk associated with wet weather controls, i.e., once WPCC effluent disinfection is in place. There are many other "community health" factors that could be considered with respect to CSO control, however, in terms of reasonable differences in public disease, the CSO control scenarios are not significantly different nor particularly effective.

As stated in the Illness Risk Report, Appendix 1, "*CSOs are wet weather events and intermittently contribute pathogens to the river, many of which are fairly ubiquitous in the surface water, including the Red and Assiniboine Rivers. CSO control would reduce the concentrations of some pathogens in the rivers, during and shortly after rainstorms……….. From a public disease standpoint, the available epidemiological analyses and evidence indicates that the public health benefits of CSO control, in terms of avoided disease caseload, will not be measurable….*"

The conclusion from the above discussion is that protection of public health (implicit in compliance with the fecal coliform objectives) is not very useful in evaluating the benefits of alternative control plans because the benefits are not measurable.

9.2 REDUCTION IN NUMBER AND VOLUME OF CSOs

In the absence of significant differences in the effects of control options on regulatory compliance or illness risk, it was necessary to consider other performance measures to assess their performance. Two of the key measures used were number and volumes of CSOs. The number of overflows is considered to be the better measure of performance since it is the most identifiable to the public and the regulatory agency.

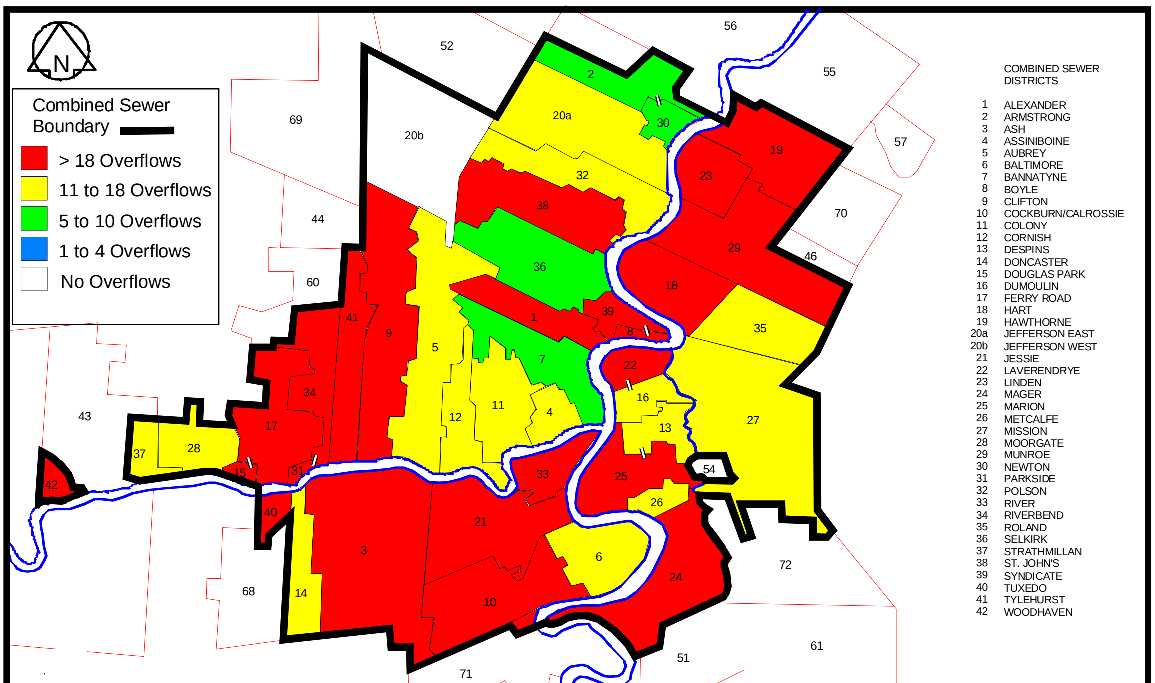
In the following discussion, the costs and performance of the various options (capital plus operation) have been included in tables, as follows:

Table 9-1 – Optimizing Existing Infrastructure
Table 9-2 – Candidate Options to Meet the Target of 4 Overflows/Recreation Season
Table 9-3 – Candidate Options to Meet the Target of Zero Overflows/Recreation Season

9.2.1 Existing System

The existing system was analyzed for the long-term rainfall record of 35 years (1960 to 1994 inclusive). This analysis showed that there are about 18 overflows per year on average across all districts. The number of overflows vary significantly from district to district. Some districts have averages as low as 7 overflows a year, while others may overflow as often as 30 times per year. The percent capture of the combined sewage volume on a City-wide basis is about 32% when assessed with the long-term record of rainfall.

Figure 9-4 indicates the range of overflows from district to district for the long term under existing conditions.



Average Annual Overflows ~ 17.5
Range: 6.5 - 30

Existing Conditions -
Long-Term Performance
Figure 9-4

9.2.2 Optimizing Existing Infrastructure

There are two types of potential storage in existing pipes: latent storage which, as discussed below, can be accessed at selective locations with minor modifications to the system and at moderate cost; and in-line storage, which involves larger costs but can be applied more widely across the CS districts.

The performance of these initial options was assessed for the 600 ML/d dewatering rate since this would ensure that the additional quantities of stored wet weather flow being dewatered to the NEWPCC after the rainfall would receive secondary treatment and hence would not increase the impact of the plant effluent on river quality. In addition, this approach would ensure that the increased wet weather flows would be disinfected, once secondary disinfection was introduced at the NEWPCC.

- Latent Storage

As discussed in Section 8.3.1.1.1 some of the existing relief sewers were constructed with their inverts below normal river levels. This provides latent storage which can be readily accessed at a moderate cost and can potentially provide 120,000 m^3 of storage. This storage volume can be readily augmented by raising the intercepting weirs in all of the existing CS trunks. Raising these weirs to about 40% of the trunk height would increase the latent storage by about 50,000 m^3. These two options could be the initial stages of any CSO control program since they will result in an early improvement in river conditions in a cost-effective manner. The costs and performance (number of overflows and volume of capture) of the two options is summarized (at the 600 ML/d dewatering rate) on Table 9-1.

TABLE 9-1

EVALUATION OF OPTIMIZING EXISTING INFRASTRUCTURE

	Dewatering Rate @ NEWPCC ML/d	Volume of Storage m^3	Total Cost $M	Long-term Median Number of Overflows	Long-term Median % Capture
Existing Situation	825	0	$0	17	32%
Optimizing Existing Infrastructure					
Latent Storage	600	120,000	$11.7	12.5	
Latent Storage plus Raised Weirs	600	170,000	$13.5	10.5	
In-line Storage	600	385,000	$129	7	52%

- In-Line Storage

In-line storage, on the basis of the use of control devices (inflatable dams, fixed weirs or automated gates) designed and operated to maintain the current level of basement flood protection, could provide 300,000 m^3 to 385,000 m^3 of in-line storage. For purposes of cost comparison, the most expensive option (fixed weir; as discussed in Section 8.3.1.1.3) was used. The costs and performance of in-line storage, for the 600 ML/d dewatering option is summarized in Table 9-1.

- Reduction in CSOs

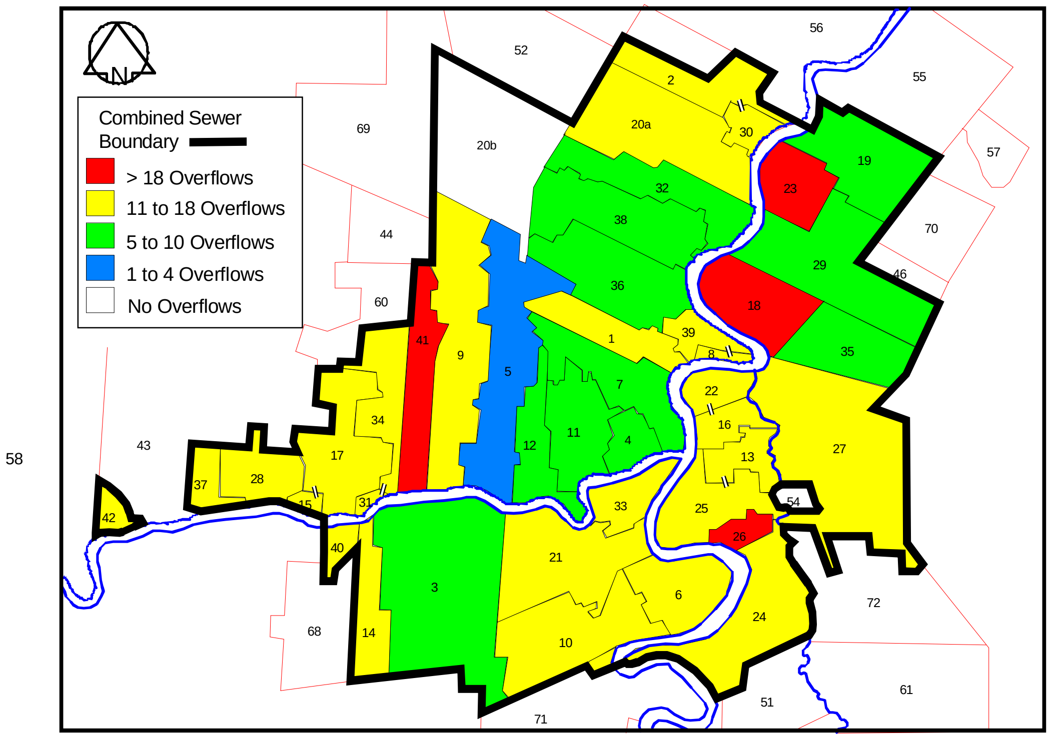
As can be seen from Table 9-1, a major reduction in the number of overflows from the use of latent storage options is achieved at a very modest cost, $11.7M for latent storage and an additional $1.8M for raising the interception weirs.

With the use of in-line storage, the range of expected overflows is reduced to between 5 and 8, on average, across all districts, depending on the control device and the dewatering rate, at a cost of about $130 M (including capital and present value of O&M costs). **This, therefore, is a very cost-effective solution relative to other control options.** The number of overflows will vary across the districts depending on the extent of available in-line storage.

The degree of capture of combined sewage is a surrogate measure of the avoided pollutant loadings to the stream, and, to some extent, aesthetic impacts. The percent capture for the long-term record, with the use of in-line storage, is about 52%.

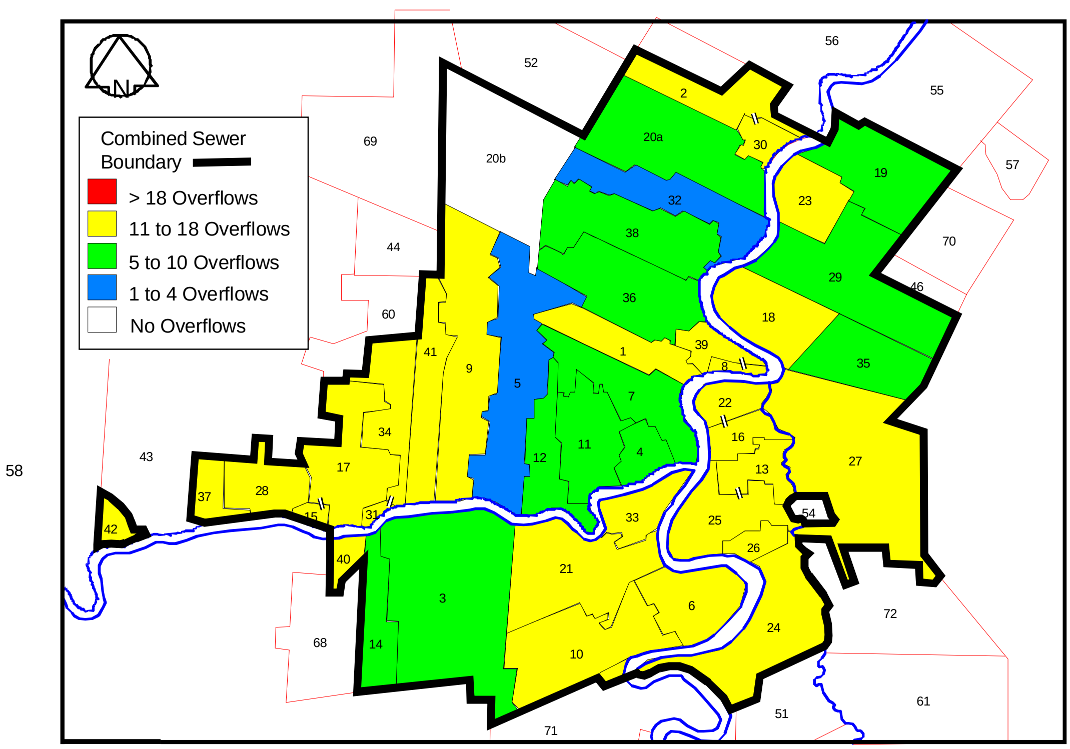
- Observations on In-Line Storage

  - As noted above, implementation of in-line storage could be staged via the development of latent storage and raising the interception weirs. The overflow frequency for each CS district, using these options, is illustrated on Figures 9-5 and 9-6 (refer to Figure 9-4 for existing overflow frequencies to assess improvements in control).



Average Annual Overflows = 12.5
Range: 3 to 22

Modified Interception Rate; Latent Storage
Figure 9-5

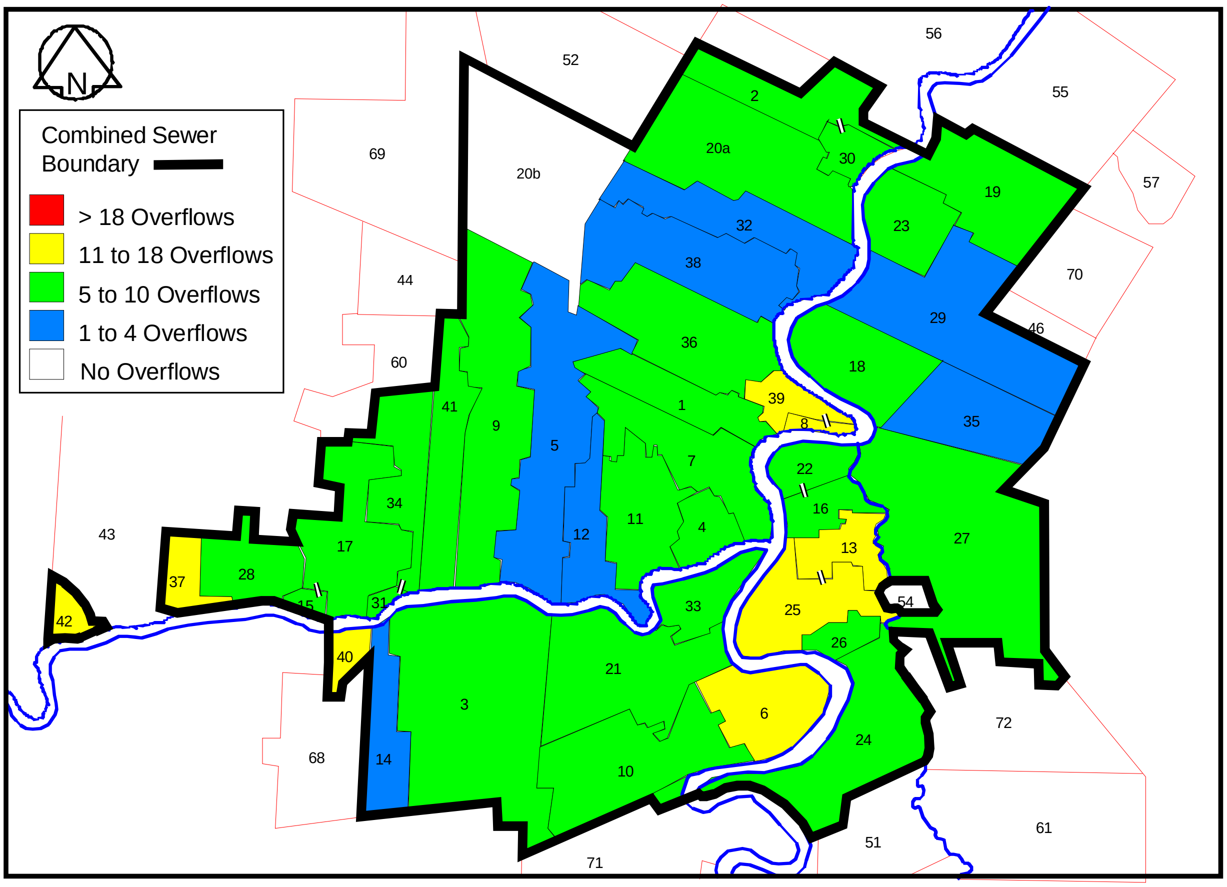


Average Annual Overflows = 10.5
Range: 2.5 to 18

Modified Interception Rate; Latent Storage Plus Raised Weirs
Figure 9-6

- In-line storage is a very cost-effective way of reducing the volume and number of overflows to the rivers at most CS districts.

- The benefit of reducing the number of overflows with in-line storage is not distributed evenly across the City. Figure 9-7 shows the distribution of overflow frequency expected from in-line storage for the storage dewatering rates of 600 ML/d over the long-term. Many of the districts have less than 4 overflows and a few could be reduced to zero overflows if their full potential of in-line storage can be realized. Five districts have overflows ranging from 11 to more than 18.



Average Annual Overflows = 7
Range: 2 to 17

Long Term; Modified Interception Rate;
In-line Storage
Figure 9-7

- The in-line storage option by itself does not provide a coherent system-wide CSO management plan. It may be necessary to add additional storage or treatment in districts without significant in-line storage, in order to reduce the number of overflows system-wide. This could be done by a number of methods, such as adding off-line storage. The performance of these options is explored in the following sections.

- It might be possible to increase the in-line storage available during the execution of basement flooding relief (BFR) programs. If relief pipes are added to the district, thereby providing an increase in in-line storage, the number of overflows may be reduced. Oversizing these relief pipes would add an extra CSO control benefit. These possibilities would have to be investigated during the design phase of each basement flood relief project in order to assess the associated costs and benefits to both BFR and CSO control.

9.2.3 Meeting 4 Overflows/ Year

Background: Phase 3 Appendix #1

Sixteen alternative control plans were identified that approximated 4 overflows during the recreation season (RS). It should be noted that the 4 overflows/RS 'target' is based on the EPA "presumption" that such control will meet water quality standards and, therefore, it is not a rigid target in itself. As noted (Section 8.2.2) the representative year (1992) was used to size control facilities for 4 overflows/RS. Under the long-term record, the performance of these facilities did not always meet the long-term 4-overflow target, as shown on Table 9-2. These data primarily comprise the results for the 600 ML/d dewatering options. The variation in the number of overflows (Table 9-2) for the long-term median (from 5 to 3½) results from the use of in-line storage, i.e., in some districts the available in-line storage is sufficient to result in zero overflows/RS.

TABLE 9-2

***EVALUATION OF CANDIDATE OPTIONS TO MEET TARGET 4 OVERFLOWS/RECREATION SEASON**

	Dewatering Rate @ NEWPCC ML/d	Required Off-line Storage Volume m^3	Total** Cost $M	Long-term Median Number of Overflows	Long-term Median % Volume Capture***
Target of 4 Overflows					
Distributed Off-line Storage	600	300,000	$427	5	54%
Distributed In-line/Off-line Storage	600	102,000	$343	4	59%
Distributed In-line/Off-line Storage with Transfers	600	80,000	$300	3½	59%
Tunnel/Transport Storage	600	300,000	$558	5	54%
In-Line with Tunnel/Transport Storage	600	102,000	$452	5	59%
High Rate Treatment (RTB)	825	160,000	$500	5	64%

* Complete list in Phase 3 Appendix No. 1
** Capital + O&M
*** The volume capture is fairly low, even with only 4 overflows/year. The EPA considers that 4 OF/yr generally corresponds to about 85% volume capture. For the prairies, a large portion of the annual rainfall is associated with a few large thunderstorms, hence the volume of capture, even with only 3 or 4 overflows, is relatively low.

These control plans involve a very significant increase in cost, relative to in-line storage, as they are structurally intensive, involving the addition of major system components and operational complexities.

- Off-Line Storage Alone

Plans using distributed off-line storage alone were sized to achieve a target of 4 overflows per RS in each of the districts for the representative year. For the long term evaluation, the estimated performance for this storage volume was about 5 on average. The 600 ML/d dewatering rate provided the best performance at the lowest estimated cost ($427M).

- In-Line and Distributed Off-Line Storage

For the distributed off-line storage combined with in-line storage, the distributed storage was sized so that the combination (i.e., in-line plus distributed storage) provided the volume necessary (according to the screening model) to reduce the number of overflows to 4 per RS for the representative year. When the long-term record was assessed, the average number of overflows in all districts was close to 4, while the percent capture was about 59%. The cost of such a plan was estimated to be $343M.

For all dewatering rates, the use of in-line storage reduced the cost by approximately $90 million and reduced the average number of overflows by about one. In-line storage thus represents a cost-effective opportunity.

- Distributed In-Line/Off-Line with District Transfers

A preliminary analysis was undertaken to test the sensitivity of replacing potential storage in selected districts with a transfer of CS flows to a nearby district where excess in-line or near surface off-line storage could be available. The opportunities were, for the most part, either impracticable (i.e., no apparent opportunities) or more expensive. Where feasible, the costs showed potential savings of 10 to 15% in total estimated costs. The multiple-transfer system may be more difficult to operate than the no-transfer option and, therefore, may not provide the full cost savings demonstrated in this early analysis.

- Tunnel Transport/Storage (Regional Tunnel)

The cost of these options was about $120 million higher than the off-line storage equivalent for the same level of performance.

- High Rate Treatment (RTBs)

A district-wide conceptual design of RTBs was done using the data from the representative year to provide treatment for all but 4 overflows per RS. With disinfection of the RTB effluent, this technology would provide similar benefits to the river in terms of fecal coliforms as the storage options. For water quality parameters other than fecal coliforms, however, the treatment provided at the NEWPCC with the storage option would be considerably more effective. The estimated cost is about $500 million, well above the costs of off-line storage options.

- Comparison of "4 Overflows per RS" Options

The use of in-line storage provides a major cost saving of about $90 million.

Of those plans using in-line storage, the most economical appear to be the ones which blend in-line and distributed off-line storage with selected transfers ($300 million). As noted earlier, however, the selected transfers will be more difficult to operate than the simpler no-transfer options. In terms of percent capture, all the options are very similar (about 60%).

Of those plans not using in-line storage, the off-line storage and high rate treatment options have an edge over the regional tunnel options, from the perspective of cost-effectiveness.

Integration of basement flooding relief to provide additional in-line storage has the potential to reduce the costs using in-line storage, while providing the same level of performance.

9.2.4 Meeting Zero Overflows/Year and 85% Capture

One of the goals of developing candidate options was to develop and cost an option which would have zero overflows in an average year, i.e., 100% capture (see Table 9-3 for these options). The long-term record was used to evaluate the zero overflow/RS. One overflow/RS for the long-term record was found to be equivalent to about 85% capture (an EPA target for the presumptive approach).

TABLE 9-3

***EVALUATION OF CANDIDATE OPTIONS TO MEET THE TARGET OF ZERO OVERFLOWS/RECREATION SEASON**

	Dewatering Rate @ NEWPCC ML/d	Required Off-line Storage Volume m^3	Total** Cost $M	Long-term Median Number of Overflows	Long-term Median % Capture
Overflow – Long-term					
Tunnel/Transport Storage	600	1,200,000	$942	1	84%
0 Overflows – Long-term					
Tunnel/Transport Storage	600	2,440,000	$1,316	0	100%
Separation			$1,500	0	100%

*Complete list in Phase 3 Appendix No. 1
** Capital + O&M

Meeting 85% Capture

One overflow per RS for the long-term record provides treatment to 85% of the combined sewage. The volume of the tunnel storage required is 1.2 million m^3, and the estimated total cost is about $940 million. There may be potential to reduce the size of the tunnel by combining with in-line storage, however, the cost saving would likely not offset the $100 million cost of in-line storage. Tank storage as an alternative to tunnel storage was considered to be more costly at these massive storage volumes, even if sites were available.

Zero overflow/RS

Transport/storage tunnels, without in-line storage, were investigated to meet a long-term performance, on average, of zero overflows and 100% capture (on average means that overflows would have occurred during large storms in half the years of record). The size (9 m diameter, 40,000 m long) of these tunnels would be massive, with a volume of about 2.5 million m^3, and an estimated cost of $1,320 million. For tunnels of this size, reducing the volume by 200,000 m^3 to 300,000 m^3 by combining with in-line storage would not save money. As with one overflow/RS, the off-line storage alternative would be more expensive.

Separation

Separation of the existing sewer system would consist of using the existing combined sewers as the separate wastewater sewer system and the construction of a new and separate land drainage sewer system. The retrofit would likely affect 70 to 80% of the 8,700 ha currently served by combined sewers. The costs are estimated to be $1,500 million. This option would eliminate CSOs.

Observations of Plans for “0” Overflows or 85% Capture for the Recreation Season

- The cost for these plans range from $940 to $1,500 million.
- For all conditions, the cost to gain an incremental reduction of from 4 to zero overflows per RS will be very high.
- The cost/benefit relationship of these marginal improvements is questionable.
- Separation would achieve 100% capture of combined sewer wastewater flow (not stormwater), and would eliminate CSOs. It is the most costly of the options considered.

9.2.5 Floatables

The capture of floatables would only be relevant if floatables (for aesthetic reasons) were the primary control issue with respect to CSOs. There is no indication that this applies on an area-wide basis to the City of Winnipeg. If this was the case, control of floatables from storm sewers (originating from street litter) would also need attention. **The cost of floatables control for the entire CS system would be in the range of $33 to $123 million**. There may be a few districts where attention could be warranted, e.g., areas of sensitive shoreline use or where there is excessive or dangerous floatables. Further monitoring would be needed to determine whether such action is necessary and practicable.

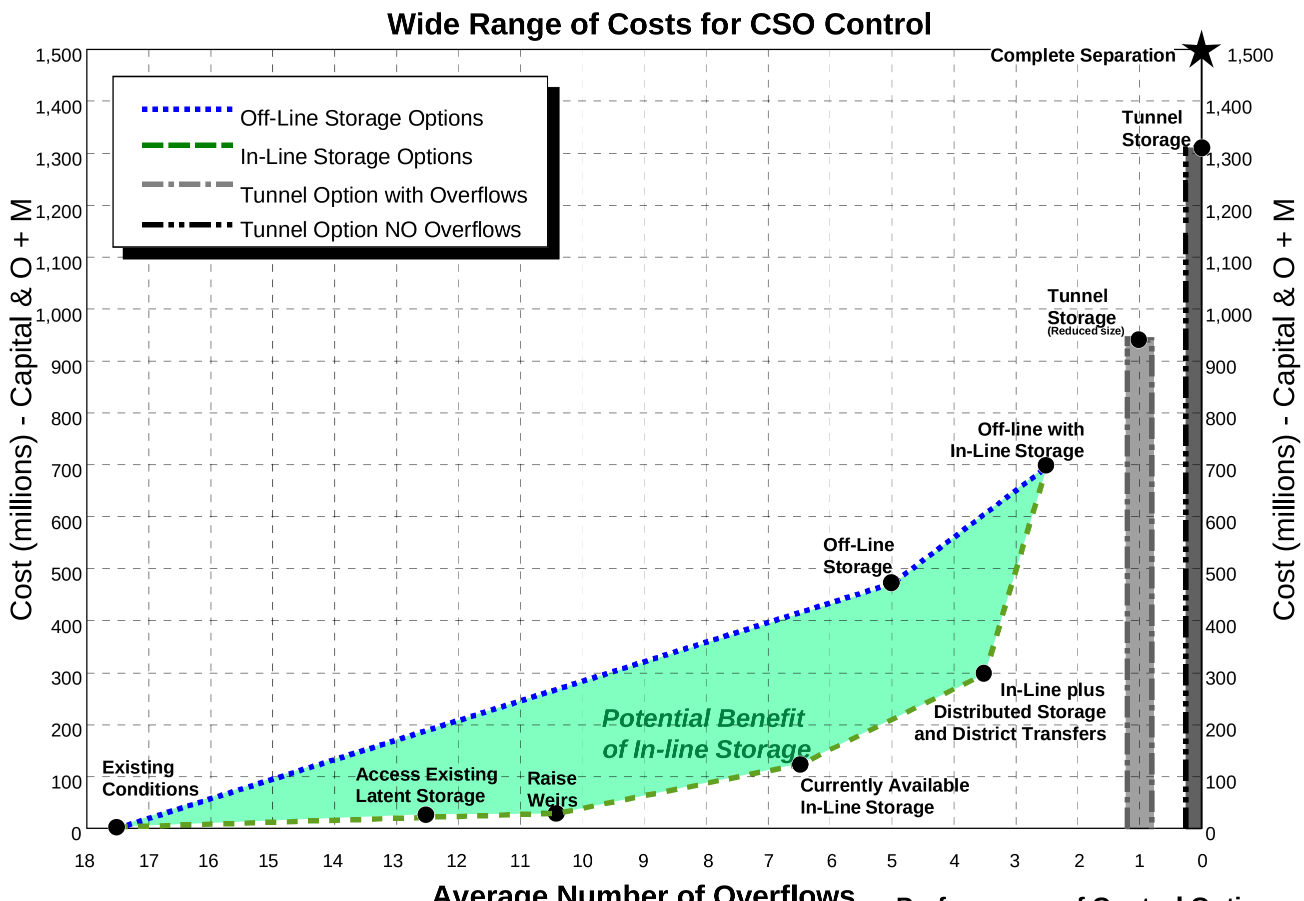
9.2.6 Real Time Control

Many CSO control systems (e.g., in Europe and the U.S.A.) use electronic systems to regulate the conveyance of wet weather flows to the treatment plant. Such "Real Time Control" (RTC) involves actively operating flow regulators in the system, by means of remotely transmitted measurements **during** the runoff process. This dynamic control in response to the actual rainfall/runoff and hydraulic conditions across the system can optimize the storage and conveyance capacities of the system.

The potential application of RTC to Winnipeg CSO control plans was the main subject of the Working Session 3-4 held in Winnipeg on January 14, 1997. The leader of this discussion was Professor Wolfgang Schilling, of Trondheim University, Norway, an international expert on RTC. In his presentation, Schilling noted that it was common in many cities that new separate developments outside of the CSO districts drained to a central facility through the CS system. Winnipeg is somewhat unique in that the main interceptor almost exclusively conveys combined wastewater from the CS districts to the NEWPCC with other separate interceptors conveying sanitary wastewater flows from the separate sewer districts. Winnipeg's combined sewer system comprises, in essence, many discrete parallel systems all connecting into one common interceptor. This characteristic allows Winnipeg to apply RTC on a local, i.e., district, basis (through dewatering stored combined sewage at a rate proportional to the runoff from each district, as discussed in Section 8.2.1). This will optimize the performance for every specific district. An area-wide RTC would refine this process and optimize the use of the interceptor capacity on the basis of system-wide conditions. For example, such a system could adjust dewatering rates from particular districts on the basis of unused capacity in the interceptor (or the treatment plant). In the Winnipeg case, this system-wide RTC would be a refinement of the proposed system. The need for, and the details of, such a system would be best studied as the implementation of a CSO control program progresses. It would not be required until control facilities were in place at most, if not all, the districts.

9.2.7 <u>Summary of Plans</u>

Figure 9-8 illustrates the wide range of controls and their performance with respect to the reduction of the number of CSOs. Costs and performance are shown for those plans that



Performance of Control Options - Number of Overflows
Figure 9-8

appear to be the most cost effective in their group. This "trade-off curve provides useful information for the process of developing judgements on the appropriate level of CSO control for Winnipeg. By inspection, it is obvious that there is a large cost/benefit advantage for in-line storage ($200 Million, on average). Other evaluation considerations are discussed in the following section.

9.3 OTHER EVALUATION CRITERIA

As well as considering the relative performance or capability of the different plans to control CSOs, it is necessary to consider other characteristics important in the evaluation of the alternative plans as follows:

- Cost - Any one of the control plans represent a massive public works program in terms of cost implications. As such, costs will be a major factor in overall programming for the City of Winnipeg.

- Cost-Effectiveness - CSO control could be considered in terms of its effectiveness in delivering benefits relative to other potential public works programs. The alternative plans could also be considered in terms of their cost-effectiveness relative to each other, e.g., the optimization of existing infrastructure through the use of in-line storage is relatively cost-effective when compared to the other structurally-intensive options.

- Environmental Benefits - The benefit from CSO control is difficult to quantify. If the frequency of compliance with objectives is considered as a surrogate measure of environmental benefit, the degree of compliance is only marginally improved with any of the CSO control plans. Control plans will, to varying degrees, reduce the number and duration of exceedances resulting from urban runoff. The benefits in terms of reduced illness risk are insignificant for all plans.

- The plans offer different degrees of improvement in reducing the number and volume of overflow. This represents less pollutant loadings to the river and less aesthetic impact and thus reflects an environmental benefit.

- Operations - Wet weather controls are operated intermittently and will add to the complexity and cost of operating the wastewater collection and treatment systems. The proposed technologies are reliable and have proven to be practicable. Considerable automation can be built into the operation.

- Constructability - Generally, all plans should be practicable for construction. Separation would by far cause the greatest disruption of the community.

- Staging - The ability to stage the work will be an important aspect of a long-term implementation plan. District-specific controls can be implemented in stages and will progressively reduce CSOs as these are installed. Separation could also be staged on a district-specific basis. Regional tunnels are less suited to deliver progressive benefits as large sections of the tunnel would need to be constructed before benefits would be realized; construction would have to start at the NEWPCC and proceed upstream.

- Flexibility is provided by the in-line storage alternatives. These alternatives could be upgraded, as required, by the addition of supplemental controls such as off-line storage or high-rate treatment. In contrast, selection of a separation plan or a regional tunnel would involve a long-term commitment and would offer little flexibility.

- Potential to Affect Basement Flooding Protection - All of the plans would be designed to maintain or improve the existing level of basement flooding protection. In-line storage, with inlet restriction devices, would offer some improved protection. Separation would have the advantage of a significant improvement in basement flooding protection, in that street runoff would be diverted from the existing combined sewer to a new storm sewer. It would also avoid the need to install additional relief piping in those districts without storm relief sewers at present (nineteen outlets and an estimated cost of about $130 million). Basement flooding protection can be provided more economically through the existing program, in combination with any of the CSO control plans.

- Public Acceptance - Public acceptance of the control plans will need to consider compatibility with land use, safety (chemicals), aesthetics of the control structures, odour potential, and community disruption. In-line storage should not interfere with existing land use except in the immediate vicinity of the fixed weir installation. No land acquisition should be required and no chemicals are involved. A regional tunnel is similar. Off-line storage will require access to public property, such as parks, schoolyards, etc. and probably some property acquisition. This would be similar for high-rate treatment. Separation would involve wide-spread disruption over a very long period of time since new storm sewers would be installed in built-up areas over the entire combined sewer area. Storage facilities will likely raise odour concerns, however, experience elsewhere indicates this is readily mitigated.

- Affordability - The question of affordability of CSO control raises a number of questions:
  - How would a plan be financed (debt-finance, pay-as-you-go, etc.)?
  - What would be the effect on wastewater bills (residential, commercial, industry)?
  - How long an implementation time period would be involved?
  - How much is the public willing to pay for the improved CSO control?

The City of Winnipeg appears to be moving to a "pay-as-you-go" system. To date, the costs of upgrades to the wastewater system have been recovered largely from the sewer bill, with some frontage-based levies. Most cities implementing CSO control programs have used long time periods for full implementation of a control plan, i.e., 25 years or longer.

- Political Acceptability - The acceptability of control plans to City decision-makers will need to be tested and will likely depend on expenditure priorities, available public funding, provincial cost-sharing benefits, and public attitude. Plan Winnipeg states that "*The City shall maintain the highest practical and cost-effective level of river water quality consistent with the natural characteristics of our rivers and in accordance with water quality objectives established for the Red and Assiniboine Rivers*."

- Regulatory Acceptability - Manitoba Conservation is responsible for advancing surface water quality objectives. CSOs are an issue with respect to compliance with microbiological objectives (fecal coliform). They are also a policy issue in that they involve discharges of raw sewage to the rivers. Manitoba Conservation will need to consider questions such as the following:
  - Should the dry weather objectives apply to wet weather conditions?
  - After WPCC disinfection, compliance during dry weather will be achieved and, overall compliance will be high (over 90% of the time). CSO control will only add slight improvements to the overall duration of compliance.
  - Should there be wet weather waivers of coliform objectives?
  - What degree of overall compliance with the coliform objective is deemed adequate (90%, 95%, 100% of the time)?

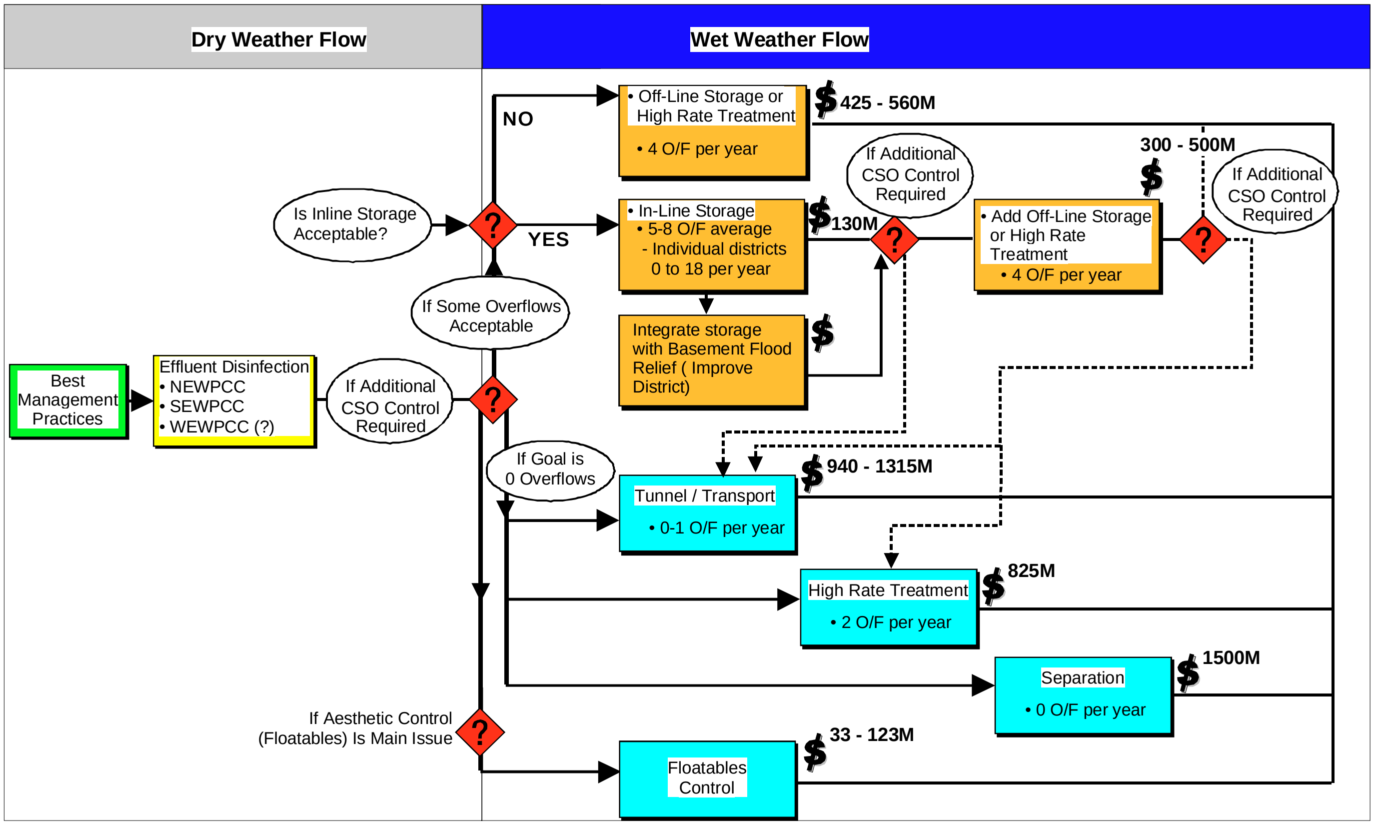
The above considerations will need to be factored into the definition of the appropriate public policy to address CSO control, as discussed in Section 11.

9.4 OVERVIEW OF CONTROL PLANS

Figure 9-9 illustrates that a number of questions arise which influence the potential identification of a preferred plan. These questions include:

- Is additional CSO control, i.e., beyond the existing system, required?
    - The existing system, once effluent disinfection at three WWPCs is in place, can meet the provincial water quality objectives (microbiological) for primary and secondary recreation for a high percentage of the time, i.e., in excess of 65% and 95%, respectively. During and shortly after runoff events, however, the CSOs do contribute significantly to the exceedance of these objectives. CSO's typically occur in response to the runoff in excess of 4 mm.

- Are some overflows per recreation season acceptable?
    - It makes a huge difference in the overall cost of CSO control if some overflows are acceptable, as compared to the virtual elimination of overflows. The U.S. EPA has stated that controlling overflows to 4 per year on average (with up to 6 allowed) is a "presumption" of adequate compliance with water quality standards. Manitoba does not provide such guidance. Figure 9-9 shows that if some overflows in this range are acceptable, control plans are possible in the cost range of $130 million to $560 million. These plans also offer significant flexibility in staging. To illustrate, in-line storage could be implemented, with CSO control integrated with ongoing basement flooding relief programs (at an approximately cost of $130 million), as a first-step control program. After evaluation, additional off-line storage or high-rate treatment could be added in the next phase, to reduce the overflows even more, to an average of 4 or possibly 1 per recreation season, if this was deemed justified. The added costs would be in the range of $170 to $810 million.



Note: Costs in millions (M), are Capital + O&M, cumulative, and are updated to 2001.

Potential CSO Management Strategies
Figure 9-9

- Is the goal to eliminate overflows?
  - If it were to be agreed that the goal is to eliminate CSOs, it must also be recognized that the costs will be in the range of $1,320 to $1,500 million. Such massive costs raise questions of affordability, benefits, willingness to pay, etc. For some options, such as tunnel storage/transport, the goal must be defined at the outset of the program. A regional tunnel plan would probably begin near the NEWPCC and would be designed for the full capture of CS flows. It would be a very long time before improvements in CSO control would be tangible from this option. High-rate treatment design requirements, including land, would have to be based on the ultimate requirement. The staging of a separation plan would probably begin with the unrelieved districts but would require careful consideration beyond this.

- Is in-line storage an acceptable and practicable technology?
    - In-line storage is a major opportunity to gain significant improvement in CSO control at the least costs. Even allowing for fail-safe operations, the use of in-line storage is the most cost-effective compared to constructing equivalent new storage or treatment. The use of in-line storage represents a savings of about $90 million when compared to an alternative of not using this storage. There are some operating concerns (odour, sedimentation, etc.) with in-line storage but testing programs can be used to determine how best to address these issues. Experience elsewhere indicated that such problems are manageable. The use of in-line storage appears to be a practical cost-effective technology for the City of Winnipeg.

- Is control of floatables a key issue?
    - If the aesthetic impacts of CSOs were a central issue, controls could be put in place for a relatively low cost, i.e., $33 to $123 million. It does not appear, from inspections of the river and from a testing program on several CS outfalls, that floatables from CSOs have a major visible impact on the Rivers. Street runoff to the rivers occurs in separate districts as well and would still occur if the combined sewers were separated. In other cities, floatables control typically is used where there is significant beach activity.

The answers to these questions are policy-related and involve public value-judgements. Figure 9-9 shows the applicability of potential plans, depending on the answers to these questions.

Many of the evaluation criteria are value-judgements and require input from sources external to the Study Team, i.e., the public, politicians, or the regulatory agencies. In considering their position, Manitoba Conservation, as a matter of policy, will also be expected to consider whether the benefits of controls justify the costs (Williamson 1988).

In the next section, a proposed approach to CSO control will be presented.

10. A POTENTIAL APPROACH TO CSO CONTROL

10.1 GENERAL CONCEPTS

The attributes of the range of potential plans, in terms of costs, control performance, and other evaluation criteria, have been described in the previous sections. The analysis has confirmed that the degree of CSO control is primarily a public and environmental policy issue. In terms of the benefits of CSO control, the following considerations apply:

- improved CSO control will result in a modest improvement in compliance with MSWQO fecal coliform numerical limits;
- CSOs are not a major public health issue in the conventional sense of avoiding disease;
- improved CSO control could contribute to the general "wellness" of the community primarily through an improved perception of river quality; and
- floatables control could help to improve river aesthetics at points of particular interest, if considered necessary.

In developing a CSO control plan, the analysis has also shown that:

- compliance with dry-weather objectives during wet-weather is not practicable, even with complete CSO control, and therefore some CSOs may have to be accepted;
- CSO control is very costly;
- dealing with wet weather discharges is a difficult policy issue for the City and for Manitoba Conservation; and
- the current trend is for cities to implement site-specific long-term CSO control programs to reduce the number and volume of CSOs.

With this perspective, this section will present a potential, illustrative CSO control program for consideration by the various parties involved in defining public policy.

10.2 SHAPING THE APPROACH

In reviewing the "trade-off" curve, as developed in Section 9, (repeated as Figure 10-1) and with due consideration of the other evaluation criteria, the study team derived the following observations:

- The modest identifiable improvements which would be realized from reaching a target of zero overflows per recreation season (RS) on average, for the long term, does not justify the additional expenditure, i.e., an increment in the range of $600 to over $1,000 million (see Section 9) when compared to plans that could control overflows to about 4 per RS. If this judgement is accepted, the more costly and inflexible plans would not be considered further and the review would focus on the plans discussed below.

- Utilization of in-line storage, i.e., the existing storage in the existing system, is the most cost-effective means of reducing CSOs. Use of in-line storage can reduce CSOs from the current 18 to about 6/RS system-wide. In-line storage has a value of greater than $100M compared to the cost of construction of this storage.
  - The development of the currently available latent storage and the potential for increasing existing in-line storage through the raising of the existing diversion weirs would be the initial step in implementation of the in-line storage program. The above procedures, in themselves, represent the most cost-effective segment of the in-line storage program, and represent optimization of existing infrastructure.
  - Figure 10-1 shows capital plus operating and maintenance costs and is based on the use of fixed weirs (for comparison purposes).
  - Installation of dynamic controls to access in-line storage has been used elsewhere and has been demonstrated to be practicable. Accordingly, a priority in any preferred program would be to build and to demonstrate the effectiveness of this option in Winnipeg (i.e., through a pilot installation in a selected CS district).
  - Based on constructability, successful operating experience elsewhere, operability, and fail-safeness, the Study Team recommends that the in-line pilot program utilize the inflatable dam as a means of control of in-line storage.

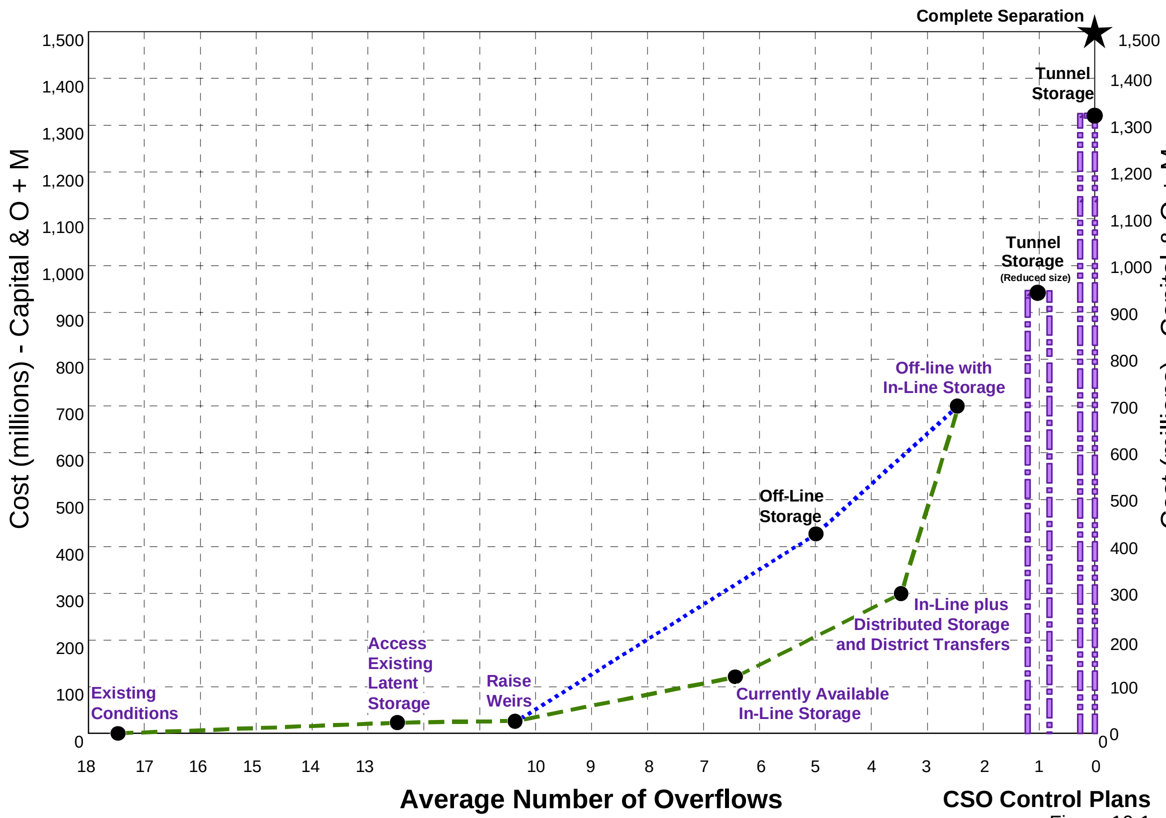


Figure 10-1

- After in-line storage is initiated across the system, the resulting reduction in overflows could be supplemented by the construction of additional CSO control facilities.

This could either be through distributed off-line storage or through a tunnel transport/storage system.

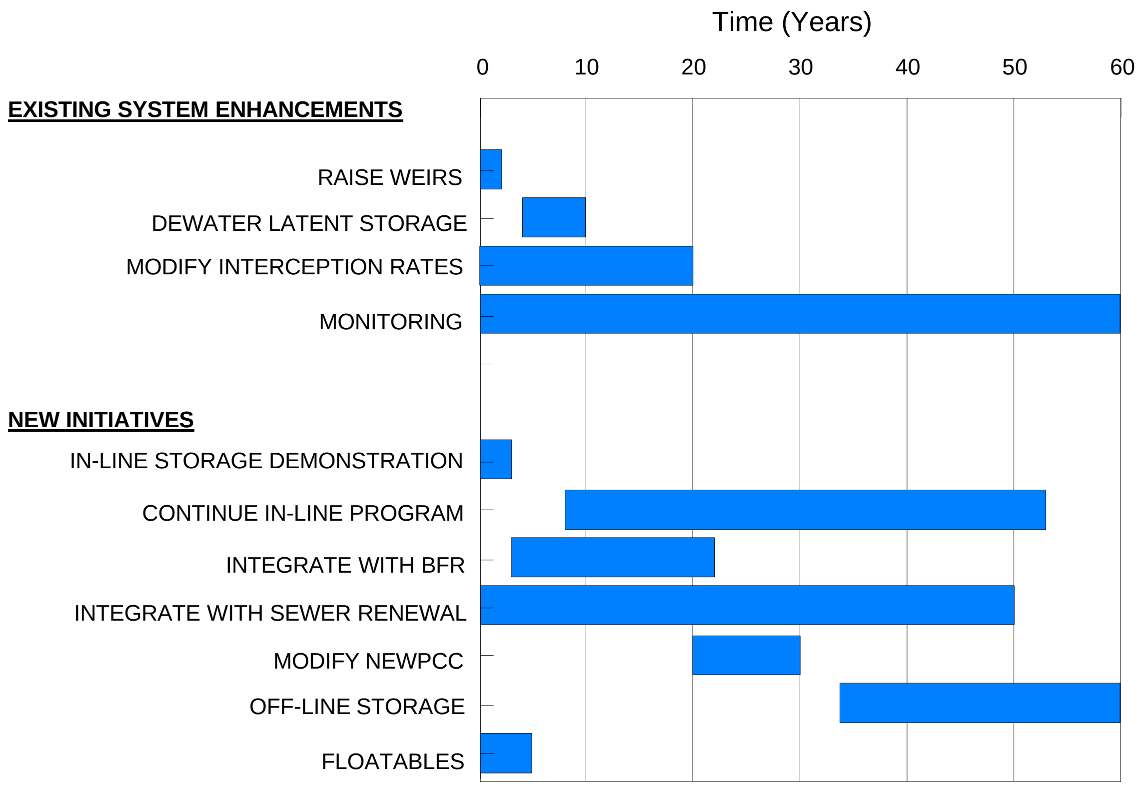
- The first step in the augmenting of the in-line storage option would be to construct off-line storage in those districts with little in-line storage capacity and higher numbers of CSOs.
- The advantage of the distributed off-line storage, over a tunnel transport/storage system, is that the districts in need of improvement, i.e., those that are currently experiencing high rates of annual overflow, could be addressed on an individual basis. The distributed off-line storage option has the advantage over the high rate treatment in that no chemicals are stored on the storage sites.

- A program incorporating in-line and off-line storage could be staged over an extended period of time and thus be rendered affordable.
  - The City of Winnipeg sewerage costs are recovered from payments on the water/sewer bill, i.e., not from the mill rate. The water/sewer bill currently includes $8 million per year as an Environmental Projects Reserve. The CSO control program could be programmed so as to be covered by these funds. This is a matter for Council decision. As such, the program could be subject to deferral or interruption should other environmental issues deemed to be of higher priority require funds from the same source. One example of the latter might be the need to nitrify the WPCC effluents, which could result from the current investigations of ammonia in the rivers and could be seen as a higher priority.

- The in-line/off-line storage program could be integrated with the current Basement Flood Relief Program, (BFR) and the newly implemented Sewer Renewal Program (SRP).
  - The City still has a significant ongoing BFR program. About $110 million in infrastructure is planned for 13 districts which have not yet received a relief program.
  - By oversizing major sewer elements in a BFR program in a particular sewer district, the amount of in-line storage could be increased, and therefore the need for supplementary off-line storage reduced. This would be economical, not only because of the reduction in off-line storage required but, because significant volumes of additional storage could be obtained through relatively moderate additional costs for increased sizes of the relief trunk sewers.
  - Alternatively, for smaller districts adjacent to the rivers, the BFR program could benefit from increased selective sewer separation within the districts.
  - Part of the costs associated with these integrated approaches could be charged to the CSO control program since these measures would reduce the volume of CSO and the cost of CSO control.
  - The City is planning to spend about $7 million per year for rehabilitating old combined sewers. This reconstruction also offers the potential for over-sizing major sewers to provide in-line storage for CSO control.

10.3 POTENTIAL (ILLUSTRATIVE) PROGRAM

Figure 10-2 provides a preliminary schedule for al illustrative program. Each component of the program and the key supporting rationale are discussed below.



Illustrative Option Schedule
Figure 10-2

A CSO control program must be practicable in terms of being delivered in an affordable schedule. Such programs are typically long-term because of the huge costs involved. In the case of Winnipeg, the potential program was conceptualized on the basis of an annual CSO expenditure of approximately $ 4.5M/year. The selection of the $4.5M/year was used for illustrative purposes only*. The annual investment could be more or less than this amount and

* The original analysis, as shown in the supporting documentation, was based on facility costs developed using $1995 and an illustrative cost of $4M/yr. In order to reflect $2001, the base estimates and annual expenditure were increased to cover the increase in CPI (11.2% cumulative).

would be arrived at through discussions between the administration, City Council, the regulatory parties and the public.

The Environmental Projects Reserve (EPR) ($8M annually) is currently being used to fund the WPCC effluent disinfection program, the study of the impacts of ammonia on aquatic life, this ongoing CSO study and implementation of its recommendations. The potential CSO control program was laid out on the basis that $4.5M/yr of the EPR would be allocated to the CSO control program. This would allow for the execution of other programs concurrently. As noted, the decision as to whether or not this is a suitable basis for funding must be decided by Council.

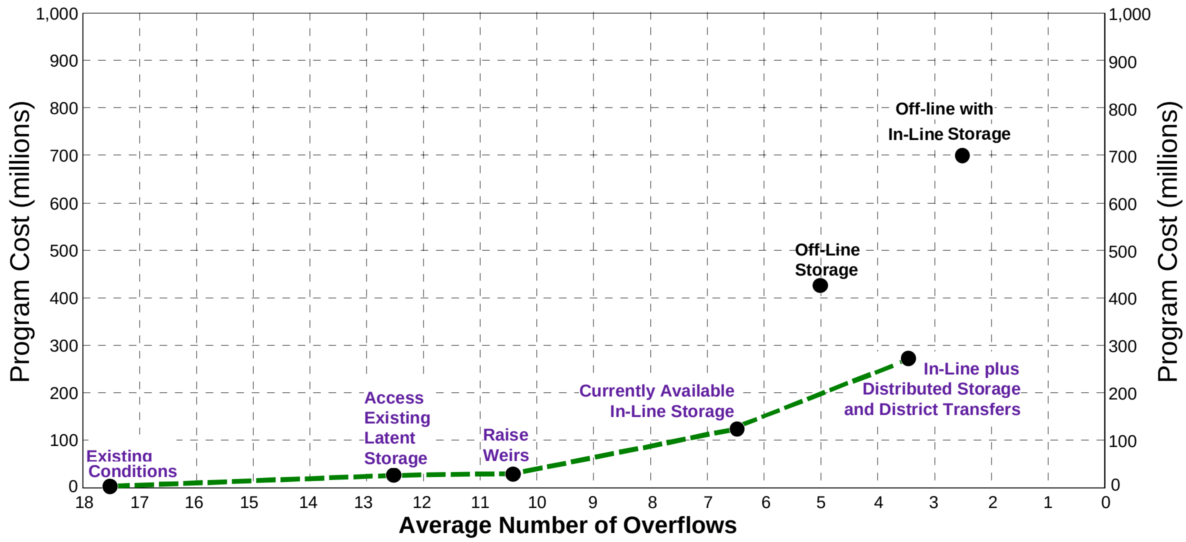
The $4.5M/year expenditure on CSO control could potentially be accommodated within the current financial plan of the utility but this would require administration and Council approval. The potential plan will be flexible in staging and annual costs.

The total estimated costs for the illustrative program, exclusive of O&M, are about $270 million and are based on the use of inflatable dams for in-line storage. The proposed program provides for significant ongoing costs for monitoring ($850K/year, including provision for Supervisory Control and Data Acquisition [SCADA]); support for the BFR program ($1.1M/year for 20 years) and support for the Sewer Renewal Program ($550K/year for 50 years).

The integration of the BFR and SRP programs with the CSO Control program is expected to provide a synergistic benefit in that the provision of storage through over-sizing of major trunk sewers is less costly than the construction of off-line storage. This benefit is estimated to be about $15 Million (a saving of $65 Million in off-line storage offset by a cost of $50 Million in additional in-line storage).

Each of the activities involved in the program was prioritized and the budgeted $4.5M/year was distributed, on the basis of the priorities established, with the result shown on Figure 10-2.

For the purposes of the illustrative option, it was assumed that in-line storage would be implemented using inflatable dams, the recommended option. The results of the program are illustrated on Figure 10-3.



Potential Long-Term CSO Control Plan
Figure 10-3

As indicated on the schedule, the activities involved in the program are divided into two aspects, namely, those activities associated with **enhancing the existing system** and **new initiatives**. The enhancement of the existing system would mainly involve relatively short term actions whereas the new initiatives continue over decades. The illustrative program would result in a reduction in the average number of overflows from 18 to about 10 in the first 20 years. All time periods would be reduced with a higher annual budget or with a further reduction in the required storage volume resulting from the synergy from integration with other programs (BFR and SRP).

The recommended control program is based on achieving a long-term target of 4 overflows per recreation season. It is also based on the use of a **600 ML/d dewatering rate to the NEWPCC**, for the following reasons:

- the 600 ML/d interception rate would mean the elimination of the WWF bypassing the secondary process. 100% of the WWF would receive secondary treatment and disinfection;
- the capital costs (based on the Distributed In-Line/Off-Line Storage option) for the 600 and 825 ML/d dewatering rate are within 3% of each other (for the 4 overflow/year option), with the 825 ML/d option being the lower; but no initial investment is required for the 600 ML/d option for Interceptor Modifications as compared to an estimated $26 Million for the 825 ML/d option. Since this would be incurred early in the program (it would be done

concurrently with the modification of interception rates), the present value of this differential strongly favours the 600 ML/d option and overrides the modest 3% differential;

- one of the objectives of this program is to learn, early in the process, the best means of controlling CSOs. In this context, there is less value-added to the 825 ML/d option since much of the early investment will be in modifying existing plant rather than installing CSO control systems.

Each of the two main categories of control activities will be described.

10.3.1 Existing System Enhancements

There are three key enhancements to the existing system:

- raise diversion weirs from current 0.2 to 0.4 of the design flow height in the trunk sewers;
- install interception and dewatering facilities in current relief pipes suitable for latent storage; and
- modify current diversion facilities so that diverted flows would be proportional to runoff, for each district.

Raising of the interception weirs would be done at the beginning of the program. This activity would provide 50,000 m^3 of additional storage across all districts and would result in a slight reduction in number of overflows. The modification should be modelled on a district-by-district basis, to confirm that this will indeed have little effect on the system hydraulics.

The actions involved in the dewatering of the districts with latent storage comprise rehabilitation of existing flap gates at the end of these outfall pipes, to ensure water-tightness. Each district would be provided with pumping facilities which would discharge the stored combined sewage to the interceptor at the assigned dewatering rate for the district. This would provide an additional 120,000 m^3 of storage from some 12 districts with significant latent storage potential.

The rationalizing of the wet weather flow diversion rates comprises modification of the existing interceptor pumping stations or pumps and providing flow control for those districts which currently discharge to the interceptor by gravity. This will ensure that the flows diverted from each district are proportional to the runoff within that district and would result in the effective use of the capacity of the Main Interceptor. The activity would begin with modification of the districts with gravity diversion, in order to restore interceptor capacity to upstream districts. When the diversion rates for the gravity districts are controlled, the program would continue with the remainder of the districts until all districts were modified.

Throughout the duration of the implementation of the CSO control program, the City should undertake a monitoring program. The program would determine changes in river quality during implementation of CSO control and changes in the quality of the wastewater (stored in-line and off-line). The general quality of the river water under dry and wet weather conditions would be monitored over the full extent of the river reaches affected by combined sewers in the City as well as downstream. Combined sewers would be monitored to determine the quality and frequency of overflow and to ensure that the desired performance of the district systems was being met. The need for sewer flushing would be assessed by monitoring sediment accumulation in the sewers and storage devices. The monitoring program would provide ongoing assessment of the effectiveness of the CSO control program and the information gathered would assist in the adjustment of the CSO program as needed to meet the objectives.

The City has budgeted for a SCADA (Supervisory Control and Data Acquisition) system to assist in the monitoring of the City's sewerage systems. This will be used, in part, as a tool in the minimizing of dry weather overflows. It will also contribute significantly to the monitoring of CSO locations, occurrence and frequency. This activity comprises a continuation of the City's policy of implementing Best Management Practices (BMPs).

10.3.2 <u>New Initiatives</u>

The new initiatives involved in the program comprise the following:

- In-Line Storage Demonstration:
  - Design, construct and implement a prototype;
- In-Line Storage Development Program:
  - once proven, implement in-line storage in existing relief pipes;

- Coordination with BFR Program to improve CSO control performance (in districts to be relieved):
    - Optimize costs through program integration;
    - oversize trunk relief sewers to reduce overflow frequency;
    - partial separation of the district to reduce CS volumes.
- Coordination with Sewer Renewal Program (SRP):
    - renewal of trunk sewers showing serious structural deterioration, in old city areas, includes cleaning; inspection and, if necessary, rehabilitation;
    - during extensive rehabilitation, trunk oversizing may be possible (increase available in-line storage).
- Floatables – an allowance has been made for installing facilities to address districts with particular problems.
- Modifying NEWPCC, as required and interceptor sewers, if required.
- Off-line storage.

Each aspect of the program is discussed below.

10.3.3 Demonstration Project

In-line storage is the key component of the proposed CSO control program. It is the most cost-effective means of reducing the number and volume of overflows into the local rivers. It has been demonstrated as being effective and reliable in other cities. It has not been demonstrated in Winnipeg. Accordingly, one of the key elements of the program would be to demonstrate the operability, effectiveness and fail-safeness of the in-line storage option.

The preferred means of control of in-line storage is the inflatable dam. The alternatives are an automated gate, which has raised valid Department concerns with regard to fail-safeness, and a fixed weir system. The latter will be more costly and, because of the hydraulics of the combined sewer trunks, is unable to store as much as the inflatable dam.

The purpose of the demonstration project would be to establish the following:

- determine whether odour is a problem and, if so, how to control it;
- confirm the reliability of the control systems;
- determine optimum level for in-line storage without affecting the existing level of basement flood protection;
- monitor sediment build-up, quality, and determine flushing requirements;
- monitor fecal coliform concentrations in the stored combined sewage to assess die-off;
- monitor ammonia concentrations in the stored combined sewage to determine nitrogen dynamics;
- establish operator comfort with inflatable dam operations;
- determine the impact of the overflows which do occur on the quality of river water during overflow.

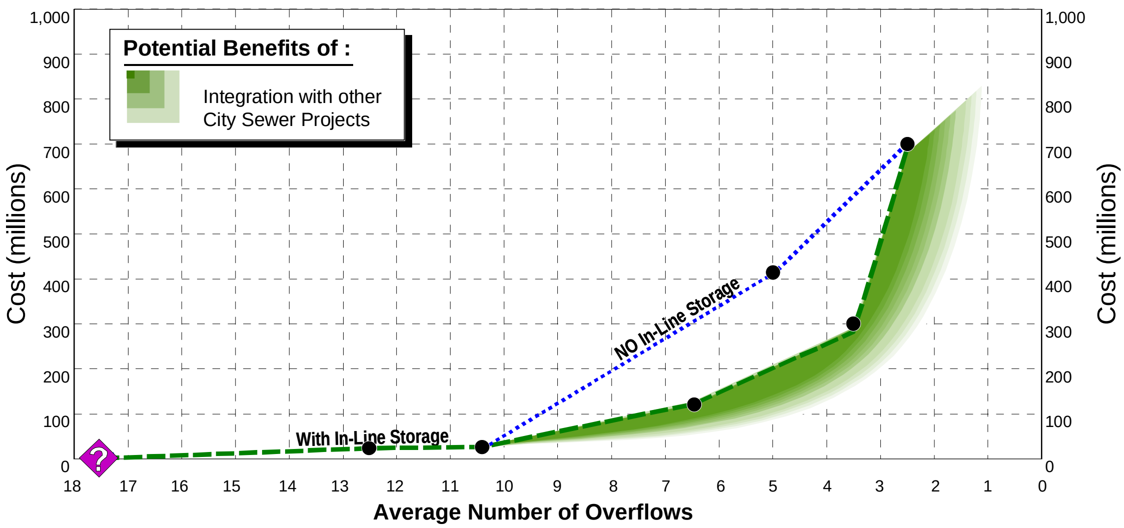
Once proven, in-line storage would be implemented in already relieved districts, both trunks and relief sewers, to access as much as possible of the 380,000 m^3 of storage available. Priorities would have to be established at the outset of the program. Matters for consideration would include: present frequency of overflows; sensitive locations (e.g., possibly The Forks); the sewer rehabilitation program.

10.3.4 <u>Integration with BFR and Sewer Renewal Programs</u>

The combined sewer overflow control program would be integrated, from the outset, with the ongoing basement flood relief (BFR) program. During the course of the development of the BFR program for any CS district, the costs of oversizing trunk relief sewers (for the purposes of in-line storage) and the costs of partial separation of the districts (in order to reduce CSO volumes) will be weighed against the cost of off-line storage. To accommodate this, the proposed CSO program allows for a $1.1 million contribution to the BFR program per year. This amount was based on 15% of the expected $7 million per year to be invested in BFR over a 19-year program.

In a similar fashion, the CSO control program would be integrated with the sewer renewal program. In this instance, the potential benefit for CSOs would be in the ability to oversize significant lengths of trunk sewer that were scheduled for replacement. There is probably less opportunity of benefit to the CSO program from this program as from the integration with the BFR program. A contribution of $550K per year for CSO control has been set aside for this possible oversizing.

Figure 10-4 illustrates the potential benefits of integration of the different sewer projects.



Potential Benefits of Integration
Figure 10-4

10.3.5 Modifications to the NEWPCC

As the program progresses there will be extended time over which peak flows will be conveyed to the NEWPCC for the dewatering of stored combined sewage. As a result, there may be a need to modify the NEWPCC infrastructure (Section 8.2.4). Two of the potential dewatering rates (825 and 1,060 ML/d) also require modification to the existing main interceptor. The least cost option, with regard to modifications to the NEWPCC and the main interceptor, is the 600 ML/d dewatering rate. The latter rate would involve upgrades to the treatment plant only (upgrade final clarifiers and digesters), at a projected estimated cost of $17 million.

It is expected that the NEWPCC will be able to sustain some increase in the duration of peak flows, caused by dewatering in-line storage. Accordingly, for the purposes of the proposed plan, the expansion has been scheduled as being some 20 to 30 years in the future.

10.3.6 Off-Line Storage

The construction of the off-line storage needed to supplement the in-line storage has been projected to start some 30 years in the future. In order to achieve the target of four overflows per RS across the system, the program could carry on for another 30 years, assuming a reduction of 20 years through the BFR and SRP programs. Whether or not this is the case depends on a number of factors. Integration with the basement flood relief program may further increase latent storage; further increase in-line storage; or further reduce the CSO volumes and, hence, frequency of overflow to an acceptable degree. Similarly, oversizing of renewed trunks could reduce the necessary volume of off-line storage. These are currently unknown benefits that could result in the need for less off-line storage. The monies budgeted for these programs would only be spent if there is a benefit. If there is no benefit, these monies would be available for CSO control. Finally, it may also prove to be economically feasible to transfer flow from some districts to potential storage in nearby districts.

In addition to all these options, the ongoing monitoring program may indicate that, sometime during the process, sufficient benefits have been achieved with respect to CSO control and protecting river water quality that further improvement is not warranted. In this case, the period of construction of off-line storage may be curtailed. Such action would need discussion with the policy-makers of the city and province at that time.

10.3.7 Floatables Control

The last activity of the program comprises floatables control. There are some outfalls which, because of the nature of floatables or because of activities downstream (for example the Alexander CS outfall or CS districts upstream of the Forks) may warrant consideration for floatables removal. An allowance of $0.4 million has been made to cover the costs of such actions.

10.4 TIMING OF THE ILLUSTRATIVE PROGRAM

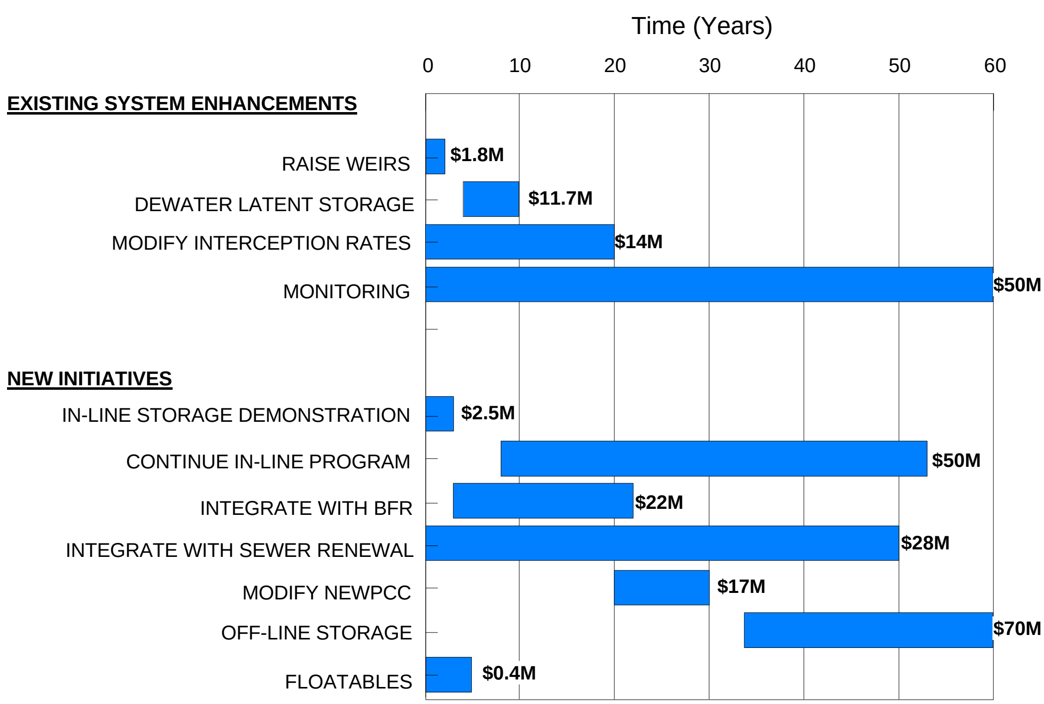
Should the City decide to implement a control program, this should begin as soon as practicable. This would:

- provide an opportunity to begin addressing CSOs into the Red and Assiniboine rivers, immediately;
- provide near-term improvements in river water quality from CSO impacts while pursuing a long-term objective; and
- benefit through immediate integration with Basement Flood Relief (BFR) and Sewer Renewal Program (SRP).

10.5 COSTS AND FINANCIAL IMPLICATIONS

10.5.1 Costs

The estimated capital costs of the various program elements (i.e., without O&M included) are shown on Figure 10-5. The following is a brief review of the basis for the costs.



Illustrative Option Costs
Figure 10-5

- Raising Weirs - this is based on an allowance of $1.8 million. The level of effort is expected to be nominal, probably comprising a reinforced concrete addition to the existing weirs with some anchorage into the walls. Hydraulic modelling would also be done to confirm the appropriate increase in height.

- Dewatering Latent Storage – this will comprise refurbishing of the existing flap gates, or providing new flap gates if needed, at an estimated cost of $50,000 - $110,000 per unit. Dewatering could be effected through a new pumping station and forcemain at an estimated cost of $560,000 per unit (both estimates include estimating allowances). The projected capital cost of this aspect of the program would be $11.7M.

- The in-line storage demonstration program was estimated to cost $2.5 million. Once the in-line storage concept was demonstrated to be satisfactory for the Winnipeg situation, integration with the BFR program would commence. It is projected that one outlet would be done per year for the duration of the remaining BFR program, i.e., 13 districts (19 outlets) over a 19-year period. The amount budgeted per year is $1.1 million.
- Implementation of in-line storage in the 34 districts already relieved would begin in year 10 and carry on to about year 54 of the program. This would also represent one district per year at $1.1 million per year. The start date is deferred to year 10 in order to fit into the annual expenditure at $4.5 million.

- The costs carried for the in-line storage facilities are based on the estimated costs of the inflatable dam supply and installation in 45 CS trunk and relief sewers. It has been assumed that the remaining 27 discharge points from the CS system will overflow at less than the 4 overflows/year target level (i.e., they are likely system relief points for storms of higher intensity) and hence will not require modification for CSO control.

- Integration with the sewer renewal program has been allowed for $550K per year. Whether or not this amount will be utilized, i.e., whether or not the potential exists for improving the CSO program through sewer rehabilitation, will be determined as the sewer renewal program is defined.

- The Phase 3 studies indicated that the NEWPCC may need modification in order to accommodate the longer duration peaks resulting from dewatering of CSO storage. The estimated capital cost is $17 million and is programmed over year 20 to 30. This would likely be done as one continuous project. Whether or not such investment will be needed can be investigated in the interim through pilot studies.

- At various stages in the program and prior to the construction of off-line storage, the City will be in the position to assess the effects of the program on improved river quality and on the reduction in the number of overflows. It is likely that off-line storage will be required in some districts which overflow frequently and do not have significant in-line storage. If all of the off-line storage required to achieve 4 overflows per RS across all districts were constructed, the total capital cost could be approximately $137 million. This program would take about 45 years.

- No specific program has been outlined for site-specific floatables capture, however, an allowance of $0.4 million has been made which may be initiated in the first 5 years of the program.

- A projection of the potential implications of the integration of the CSO control program with the BFR and SR programs is also indicated on Figure 10-5. Through activities such as sewer oversizing or selective separation, it is estimated that the target of 4 overflows per RS could be achieved some 19 years earlier than forecast (i.e., the total program could be some 60 years in duration at $4.5M per year), at an additional savings of approximately $85M for reduced off-line storage and monitoring.

The illustrative program timing and costs are summarized in Table 10-1.

TABLE 10-1

ILLUSTRATIVE APPROACH – PROGRAM SUMMARY* CAPITAL COSTS

ENHANCE EXISTING SYSTEM	**TIMING (YEAR 00 IS START)**	**10-YR PROGRAM $M**	**LONG-TERM (BEYOND 10 YRS) $M**
Raise Weirs	00-02	$1.8	
Modify Interception Points	00-29	$5.5	$8.5
Access latent Storage	03-09	$11.7	
Sub-Total		$19	
NEW INITIATIVES			
In-line Storage Demonstration	00-02	$2.5	
Sewer Renewal (oversizing)	00+	$5.5	$0.55/yr
Floatables	01-04	$0.4	
Integrate with BFR [$1.1M/yr]	02-09	$9	$13
Modify NEWPCC	11-28		$17
Continuing In-line Program	10-54		$50
Monitoring	03-09	$6	$0.85/yr
Sub-total		$23½	
Total 10 Year Program		$42½	
P.V. – without O&M		$37	
- with O&M		$38	
POSSIBLE LONG TERM			
Off-line Storage	29+		$1.7 to $4.2/yr

*developed on the basis of $4.5M/year investment, which was used for purposes of illustration

10.5.2 Impact on Rates and Utility Reserves

Depending on the means of financing, implementation of the CSO control program could impact on sewer rates and/or utility reserves. The costs of the sewer utility are recovered from customers, i.e., not mill-rate supported. The operating revenue of the sewer utility is based on water-consumption and appears on the water bill. The latter currently includes the $8M/year Environmental Projects Reserve (EPR). Two other reserves are supported by frontage rates and include the Sewer Renewal Reserve $8M/year and the Basement Flood Protection Reserve $7M/year. Implementation of the illustrative plan ($4.5M) could fit into the current program, so long as there are no exceptional demands on the EPR.

10.5.3 Nitrification

The potential for ammonia control was another major issue reviewed by the CEC. The Department initiated two major studies in this regard which are virtually complete. A potential nitrification program could involve up to $210 million in capital cost. There is limited ability to stage such control. If required at 3 plants, implementation would take place over an approximately 10-year program. If such extensive ammonia control was deemed necessary, it would impact heavily on the City's financial ability to undertake CSO control. It is likely that the CSO control program would have to be interrupted to accommodate this expenditure.

10.6 PUBLIC

As emphasized throughout this report, the extent of CSO control required essentially relates to public policy and environmental regulation.

From the outset of the study, public opinion has been recognized as a critical component of the study process. A public consultation/communication program was carried out and used to solicit public input to define study issues as well obtain public opinion. Public input is expected to be an important factor in shaping the character of the CSO control program and the intensity of its implementation. Direction on the nature of the public consultation program will be provided by City Council.

11. RECOMMENDATIONS

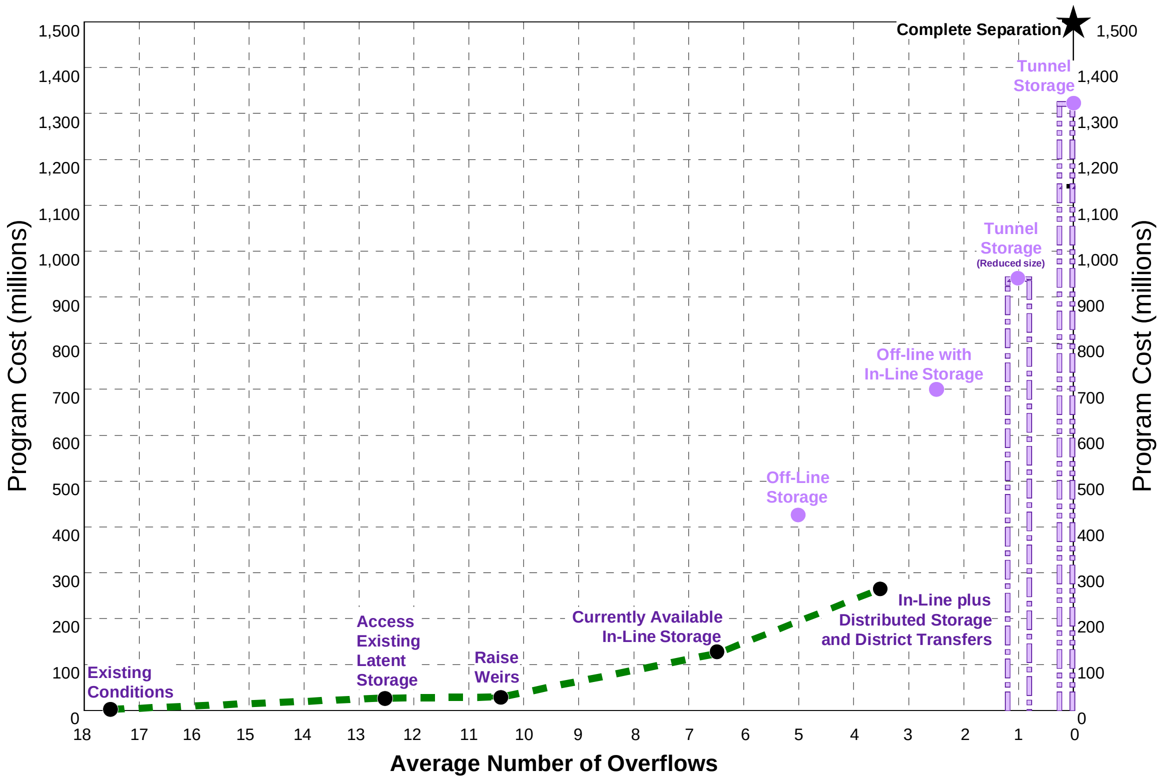
The key product of the Combined Sewer Overflow Management Study, as stated in the Terms of Reference, **is the establishment of "*a cost-effective prioritized implementation plan for remedial work based on assessment of the costs and benefits of practicable alternatives*"**. Accordingly, the study has reviewed a broad range of possible CSO control plans. This review resulted in the development of a conceptual plan (as described in Section 10) which is intended to be the focus of discussions between interested parties.

The plan is intended to be illustrative of a pragmatic long-term, affordable approach which could achieve CSO control to a level acceptable to both the City and Manitoba Conservation. The program, as developed, could be modified after review by the two parties, along with consultation with the public. The following recommendations have been developed on the premise that a CSO control program will proceed.

The recommendations also embrace a perspective that a CSO control program, because of the complexity and significant costs involved, will involve a long-term commitment. The implementation program represents an ongoing flexible process, including: monitoring of results; ongoing evaluation; dialogue with stakeholders; and adjustments as appropriate for the future delivery of the program.

11.1 DEFINING THE CONCEPTUAL CSO PROGRAM FOR WINNIPEG

The main elements of the proposed illustrative plan and the projected performance, if the program is carried through to its conclusion, are illustrated on Figure 11-1.



Proposed (Illustrative) Long-Term CSO Control Plan
Figure 11-1

Whether or not the plan continues through to the provision of 4 overflows per district per recreation season (RS) is expected to be a matter of negotiation between the City and the regulatory authorities. Since the most cost-effective options will have been fully developed relatively early in the overall program, the question will be whether or not the projected improvement in performance, i.e., to meet the 4 overflows per RS, warrants the ongoing continuation of the investment. The various components of the program, and the associated recommendations, are discussed below, along with supplementary recommendations which developed during the study.

STEP 1 – Preliminary Regulatory Discussions – The completion of the CSO Study was the initial step in the decision-making process. The next step will be preliminary informal discussions between the City and Manitoba Conservation. These discussions will be designed to elicit an approval in principle, on the part of Manitoba Conservation, to allow the City to proceed with the implementation of a CSO control program on a mutually-agreed timeframe.

These discussions will also include the impacts on schedule and budget of other programs currently under consideration by the City and the Province (e.g., Ammonia Control).

STEP 2 – Presentation to the City - On completion of the discussions with Manitoba Conservation, the CSO study recommendations, and the results of the provincial discussions, will be presented to Council. This activity would provide the opportunity for City representatives, including Council, to consider the proposed plan.

STEP 3 - Develop a Public Consultation Program – The public will have to be consulted about the proposed CSO control program at a time yet to be determined. Both the City and the Province desire public consensus and support for the program. The information to the public should describe the characteristics of the CSO issue, related water quality effects, CSO control alternatives, the proposed program, timing, expected improvements and the costs to the customer. The program should be designed to provide information and to receive feedback from the public. The program should be developed in concert with both the City and the Province.

STEP 4 – Public Consultation - The City will carry out the Public Consultation Program, including evaluation of the feedback and reporting of the results.

STEP 5 – Review With Manitoba Conservation - The City will review and reassess the program in the light of the public feedback, and discuss the results with Manitoba Conservation.

STEP 6 – Regulatory Approvals The next step will depend on the manner in which the City and the Province determine to proceed.

If the parties agree to implement a CSO control program directly, i.e., without involving the CEC hearing process, negotiations between the City and the Province will be required in order to confirm a consensus on the details and execution of the program including: timelines; cost-sharing; monitoring needed; preparation and timing of reports, and timing of the reviews of the process and effectiveness of the program. Implementation would then proceed accordingly.

If this is done, it is suggested that milestone reviews take place approximately every 5 to 10 years. It is recommended that an annual report be developed to keep the City, Manitoba

Conservation and the public informed as to the nature and effectiveness of the program. One of the central focuses of the milestone reviews would be to examine progress with particular emphasis on improvements relative to performance targets.

If the matter is placed before the CEC, City staff would prepare for and participate in public hearings to establish water-quality objectives for the rivers under wet weather conditions and hence define a CSO Control Plan. In this case, the City would present its recommended plan to the CEC. The CEC would make a report to the Minister of Environment, who would make decisions on the required CSO control program and implementation would proceed accordingly.

Step 7 - Implementation of the CSO Control Plan - Before initiating any part of a CSO Control Plan, the City will have to resolve the means by which the program will be funded, and the amount allocated to execute the program. As noted in Section 10, the preliminary assessment of budget, and the associated schedule/duration, was based on a continuation of the Environmental Project Reserve and the dedication of $4.5 million per year for the CSO program. This amount was used for illustration purposes only. Any change to this amount will directly affect the schedule and implementation of the program.

Once the available funding has been defined, the first step in the program execution would be to establish a preliminary schedule of activities, including planning and engineering design, for the near-term program. This process will entail the balancing of priorities, and allocation of available funds.

11.2 DEFINING THE NEAR-TERM PROGRAM

Once the framework of the longer-term program is in place, details of the near-term specific control program can be better defined. **It is recommended that a detailed, specific control plan be established for the 5 to 10-year timeframe, as part of the long-term vision.** Insofar as the budget permits, this would comprise a combination of optimizing existing infrastructure, and beginning the implementation of new initiatives. The prioritization will involve consideration of the existing district performance, e.g., number of overflows for the representative year (for the 4 overflows/RS option); location of the district with respect to sensitive areas (e.g., The Forks);

storage potential, whether it be latent or potential in-line storage; river use/quality; BFR plans and rehabilitation plans, and related works.

The following discussion outlines the actions which would comprise the near-term plan and which, to some extent, would likely be part of the longer-term program.

11.2.1 Optimize Existing Infrastructure

The most cost-effective means of reducing the volumes of combined sewage being discharged into the river is to develop the readily-available in-line storage (i.e., latent storage, plus the raising of combined sewer interception weirs). Since this activity comprises the first stage of increasing the volumes of wet weather flows conveyed to the Water Pollution Control Centres (WPCCs), rationalizing of the existing wet weather flow diversion facilities is recommended in the early stages of the program. **The latter involves modification of all the existing interceptor pumping stations or pumps, and providing flow controls to those districts which currently discharge to the interceptor by gravity**.

11.2.2 New Initiatives

Once latent storage has been developed, and the diversion weirs have been raised, further reduction in combined sewage overflows becomes more expensive. The study concluded that storage and in particular, the development in in-line storage, was the most cost-effective means of further reducing overflows and volumes in the City.

11.2.3 Demonstration Program

- An in-line storage demonstration project should be established as early as possible in the control program to evaluate the operability, effectiveness, and fail-safeness of the in-line storage option in Winnipeg.
- The recommended means of control of in-line storage, for the demonstration project is the inflatable dam.

11.2.4 Integration of CSO Control and Other City Sewerage Programs

Early benefits can be realized by immediate integration of the CSO control program with the existing basement flood relief and sewer renewal programs. Accordingly, it is recommended that:

- The remaining BFR studies, for districts still in need of protection against basement flooding, should include investigations into the economics of lowering relief trunks (for the purpose of increasing latent storage potential); increasing the diameter of relief trunks (for the purposes of increasing off-line storage) or selective separation of segments of the system (for the purposes of reduction of CS volumes). The additional costs of any or all of these actions should be compared to the reduction in the estimated costs for CSO control (e.g., off-line storage). The investigations should be carried out in accordance with the approach developed for the Marion/Despins BFR Program (Steiss *et al.* 2000). The generalized approach used is provided in Figure 11-2. The resulting assessment will enable the City to evaluate the economics of integration and to assess the additional costs against the appropriate budget.

Generalized Approach to Integration and Optimization Basement Flooding Relief with CSO Control

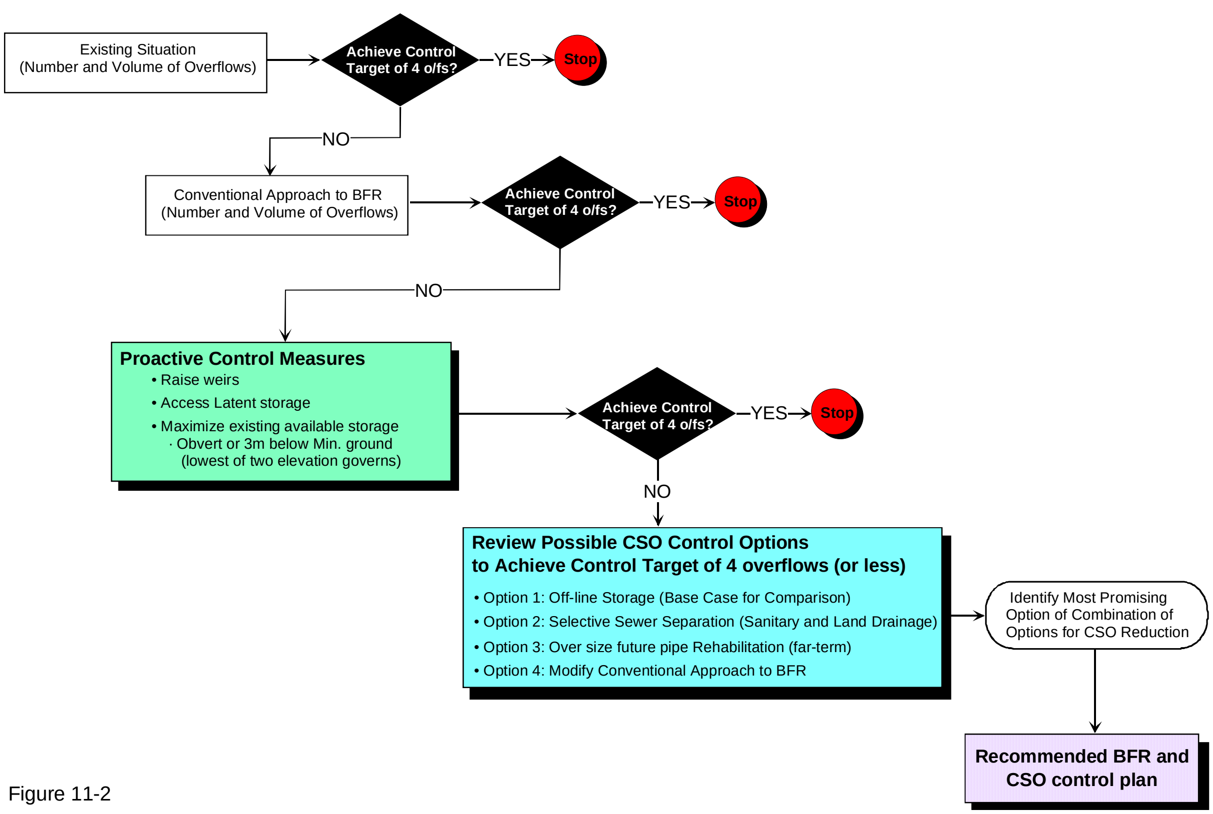


Figure 11-2

- **The possibility exists to integrate the sewer renewal and CSO programs**. If extensive lengths of a combined sewer trunk sewer need to be rehabilitated, the diameter could be increased, thereby increasing the potential for in-line storage. This possibility should be investigated before rehabilitation of major CS trunks sewers begins. In addition, the main trunk systems in the district in which a CSO control program is to be initiated should be cleaned and the need to rehabilitate the sewers should be assessed. If rehabilitation is required, this should be done before initiating the CSO program.
- In order to facilitate the scheduling of the longer-term CSO control initiatives, it would be necessary for the City to document BFR/rehabilitation program priorities.

11.3 LONG-TERM MEASURES

There are a number of recommendations associated with developing the in-line storage as elaborated in Section 10. These are outlined below:

11.3.1 Development of In-Line Storage

- Once the demonstration program has proven the viability of in-line storage as a CSO control option, the program should proceed with the development of this resource. It is recommended that the following features be incorporated into the in-line storage facilities, including the demonstration project:
  - inlet restrictions should be used in the catchbasins in the district to reduce the rate of street drainage inflow into the combined sewer system. These restrictions would be designed to limit the inflow to the runoff generated in a 1-in-5-year synthetic design storm;
  - the default position for the inflatable dam should be normally deflated. The control system will signal the dam to inflate, based on upstream water level sensors, during the start of a wet weather event. For smaller storms, the dam would remain inflated until the event is completely over and the sewer is dewatered. In the case that the water level in the sewer rises to a specified critical condition (either level or rate of rise), vis-a-vis basement flood protection, the dam will deflate and remain in this position until the upstream sensor signals the next runoff event;

- in-system storage conditions for the in-line storage should not exceed the obvert elevation of the sewer pipe at the selected location for the inflatable dam, most likely near the outlets, or the design hydraulic gradient at that point, whichever is the lower;
- the logic of the inflatable dam control system (with redundancy) will be such that the dam will deflate if there is a malfunction or failure in any of the water level sensing monitors or in case of power failure or power interruption;
- the existing flood pumping stations will be used to initiate emergency dewatering of the combined sewer system in the unlikely event that the dam fails to deflate.

11.3.2 Off-Line Storage

If further improvement in CSO control is needed (beyond in-line storage), the next most cost-effective means for additional storage is off-line, either in the form of near-surface tanks or local tunnels. The time for the commencement of the development of off-line storage will be heavily dependent on the annual budget available for the program. Available in-line storage will not reduce overflows from all CS districts uniformly. The CSO study indicated that, over the long term, the use of in-line storage would result in overflows ranging from 2 to 17, with an annual average of 7 overflows per year. Accordingly, the following recommendations are made:

- **In the long-term, off-line storage should be installed at least to the point where overflows from all districts achieve the potential average for in-line storage, i.e., 7 overflows per recreation season (RS)**. Installation of off-line storage facilities should commence in those districts with insufficient in-line storage or those districts upstream of sensitive locations.
- Preliminary investigations indicated that some limited opportunities exist for transfers of CS flows to nearby districts to take advantage of excess in-line storage or the potential for the development of near surface off-line storage. This option should be investigated during the implementation of the CSO control program for each District where additional storage is needed.
- At various stages in the program the City will be in a position to assess the effects of the programs on river quality and on the number of overflows. Before proceeding beyond the reduction of overflows to 7 per RS, the City should, through the ongoing monitoring program, determine the degree to which benefits have been achieved with respect to

protection of river water quality. Such an assessment could be used to evaluate whether or not further investment would be considered cost effective or appropriate. Such assessments would include dialogue with Manitoba Conservation.

11.3.3 Wet Weather Flows at the Water Pollution Control Centres

NEWPCC

The modifications to the NEWPCC, as discussed in Section 10, may be needed some 20 years in the future, at an estimated cost of $17 Million. It is recommended that pilot tests be run on the plant, once some of the CSO control systems are in place, to determine the extent and scope of the changes required.

In the event that there is any significant further development in the North East and North West sanitary sewer districts (tributary to the NEWPCC), the City should ensure that these developments are designed so as to limit peak wet weather flows to the current rates. At this time, it is projected that most of the City's future development will occur in areas tributary to the SEWPCC and WEWPCC, not the areas tributary to the NEWPCC. Accordingly, restricting the flows in these districts to this degree, should not be onerous. Ongoing monitoring of wastewater flows in the North East and North West interceptors is recommended.

WEWPPC AND SEWPCC

Flows in the West End and South End interceptor systems are dominated by extraneous wet weather flows (WWF) from the separate sewer districts during large rainfall and snowmelt conditions. Accordingly, these WWFs should be investigated in order to address any impacts which they may have on the WPCCs and river quality. Hydraulic models of the South End and West End interceptor systems should be developed to provide an understanding of the impact of WWFs from the separate districts on the interceptor systems and the WPCCs. With the data obtained from monitoring installations on these systems, an understanding of the system flows and the potential for overflows from the interceptor systems to the rivers, could be developed. The information could also be used as part of a program to reduce inflow/infiltration in these systems.

With specific reference to the SEWPCC it is noted that the Baltimore, Cockburn, Mager and Metcalfe combined sewer districts are currently interconnected by pumping and forcemains. The relevant merits of extending the South End interceptor system into these districts, to intercept these discharges by gravity, should be investigated. It may be that extending the interceptor system could reduce overflows into the river.

11.4 MONITORING/REPORTING

The City should undertake a monitoring/reporting program throughout the duration of the implementation of the CSO control program. The purpose of the monitoring would be to continuously assess the effectiveness of the CSO control program and, where necessary, adjust the program to meet the objectives. The monitoring would assist in:

?? determining changes in magnitude, frequency, and duration of CSOs during implementation of CSO control;

?? characterizing the quality of the stored wastewater (in-line and off-line);

?? determining if flushing of sewer or storage basins is needed to remove sediments resulting from the CSO control program;

?? providing the basis for future discussions between the City and the Province on the progress and the benefits achieved at that time. The information gathered will help the two parties to determine how the program would be continued.

The monitoring program should include for the provision, and continuous upgrading, of a SCADA system.

The progress of the implementation program should be reassessed periodically (e.g., at 5 to 10-year intervals). This milestone review would entail a report providing details of the work done and the results of the monitoring program. It is suggested that an annual “reader-friendly” report be produced for public information.

11.5 BLEND INTO THE ASSET MANAGEMENT PROGRAM

The City is in process of developing an Asset Management System. The implementation of a CSO control plan will involve installation and operation of a number of control devices, and the establishment of an ongoing monitoring program and reporting system. The purpose of the Asset Management System is to consider the timing of project capital expenditures related to annual operation and maintenance requirements, based on minimizing life-cycle costs. The CSO control program should be incorporated in the management system from its inception to maximize cost efficiencies that could be realized from integrating and coordinating capital works programs.

11.6 WET WEATHER FLOW TECHNOLOGY

The City should ensure that their senior and technical staff are informed and up-to-date on evolving technology, regulation and experience elsewhere associated with CSO control. This goal could be achieved through:

- regular attendance at relevant Water Environment Federation (WEF) Conferences;
- staying abreast of research planned and undertaken by the Water Environment Research Foundation (WERF);
- regular dialogue/discussion with other Cities undertaking CSO control programs; and
- keeping informed and up-to-date on regulatory trends across Canada and in the United States.

12. REFERENCES

Advisory Committee. 1998. CSO Study Advisory Committee, Interim Report. November 1998.

CEC. 1992. Clean Environment Commission, Report on Public Hearings; Application of Water Quality Objectives for the Watershed Classification of the Red and Assiniboine Rivers and Tributaries within and Downstream of the City of Winnipeg. June 1992.

Dufour. 1984. Canadian Journal of Public Health 75. Bacteriological Indicators of Recreational Water Quality.

Ferley *et al*. 1989. International Journal of Epidemiology: Epidemiological significance of microbiological pollution criteria for river recreational waters.

Sayfield and Brown. 1985. Department of Microbiology, Faculty of Medicine, University of Toronto. Technology Transfer Conference No. 6, December 11 & 12, 1985. Epidemiological Study of Disease Incidence and Recreational Water Quality at Selected Conservation Areas in Southern Ontario.

Steiss, G. and W. Watters. 2000. Developing a Model for Basement Flood Relief Works for the New Millenium. Stormwater and Urban Water Systems Modelling Conference. February 2000.

Wardrop and Tetr*ES*. 1991. The Red and Assiniboine Rivers Surface Water Quality Objectives, Technical Report. September 1991.

Wardrop and Tetr*ES*. 1995. Combined Sewer Overflow Management Study: Phase 2 Priority Field Inspection Report – District Diversion Structures and NEWPCC Interceptor Sewers. February 1995.

WEF. 1989. Water Environment Federation Manual of Practice FD-17 “Combined Sewer Overflow Pollution Abatement

U.S. EPA. 1983. Nationwide Urban Runoff Program, Water Planning Division, U.S. Environmental Protection Agency. December 1983.

U.S. EPA. 1995. United States Environmental Protection Agency, Combined Sewer Overflows: Guidance for Long-Term Control Plan, EPA 832-B-95-002.

Williamson, D.A. 1988. Manitoba Surface Water Quality Objectives; Water Standards and Studies section, Manitoba Department of the Environment.

Williamson, D.A. 2001. Manitoba Surface Water Quality Standards, Objectives and Guidelines, Technical Draft for Review and Comment, Manitoba Conservation.

13. GLOSSARY

ADWF	Average Dry Weather Flow
BFR	Basement Flood Relief (Program)
$CBOD_5$	Total Carbonaceous Biochemical Oxygen Demand after a 5-day period
CEC	Clean Environment Commission
CPI	Consumer Price Index
CS	Combined Sewer
CSO	Combined Sewer Overflow: an event which occurs when the flow in the combined sewer exceeds the capacity of the structure which diverts flows to the interceptor. These excess flows discharge into the receiving body and contain both wastewater and stormwater runoff.
DO	Dissolved Oxygen
D-R	Dose-response
DWF	Dry Weather Flow
DWO	Dry Weather Overflows – illicit/undesirable CS discharges during dry weather when all CS should be diverted to the interceptor
EMC	Event Mean Concentration = storm event load divided by the storm event runoff volume
fc	Fecal Coliform – bacteria associated with fecal matter from warm-blooded animals; commonly used as an indication of fecal contamination
GI	Gastrointestinal Illness
LDD	Land Drainage Discharges
LDS	Land Drainage Sewer
mg/L	milligrams per Litre
mg/L-N	milligrams per Litre as nitrogen
mg/L-P	milligrams per Litre as phosphorus
ML/day	megalitres per day = 1000's of cubic metres/day
MSWQO	Manitoba Surface Water Quality Objective

NEWPCC	North End Water Pollution Control Centre
NTU	Nephelometric Turbidity Units – a measurement of turbidity
NURP	Nationwide Urban Runoff Program
Recreation Season	May 1 to September 30
RTB	Retention Treatment Basins = a high rate storage and disinfection device
SCADA	Supervisory Control & Data Acquisition
SE	South End
SEWPCC	South End Water Pollution Control Centre
SRB	Storm-water Retention Basin
SRP	Sewer Renewal Program
SSO	Sanitary Sewer Overflow
TIC	The International Coalition – a group interested in and involved with water management issues associated with the Red River Basin
TM	Technical Memorandum
USEPA (EPA)	United States Environmental Protection Agency
UV	Ultraviolet Light
VSS	Vortex Solids Separator – high rate sedimentation device whose prime purpose is to remove solids to the point where disinfection can effectively reduce fc concentrations in CSOs
WE	West End
WEF	Water Environment Federation
WEFO	Water Environment Federation of Ontario
WEWPCC	West End Water Pollution Control Centre
WPCC	Water Pollution Control Centre
WWF	Wet Weather Flow
XP-SWMM	a proprietary version of the "Storm-Water Management Model" used in the analysis of storm-water sewerage systems

City of Winnipeg
Water and Waste Department

Combined Sewer Overflow Management Study

PHASE 4 Appendix No. 1

ILLNESS RISK ASSESSMENT

July, 2000
0510-A-38

Internal Document by:

WARDROP Engineering Inc. and TetrES CONSULTANTS INC.

In Association With:

Gore & Storrie Limited and EMA Services Inc.

TABLE OF CONTENTS

1. INTRODUCTION

The City is conducting a combined sewer overflow (CSO) study to define optimum long-term management strategies for potential controls of these overflows. In the context of this CSO study, the microbial quality of the urban reaches of the Red and Assiniboine Rivers is a relevant issue, particularly insofar as CSO's discharge dilute sewage to the rivers and thus contribute to the contamination of the rivers and related risks to human health from use of these surface waters.

As part of the overall CSO Study, the Water and Waste Department of the City authorized a study (1997 Update: Health Risk Relating to Uses of the Red and Assiniboine Rivers in Winnipeg and Downstream 1998) to provide a site-specific perspective on health risks associated with the beneficial uses of the urban reaches of the local rivers, especially as these risks might be affected by CSOs. This study was intended as an update of previous study done in 1990. The results of the study are intended to contribute to informed decision-making on potential CSO control programs as these relate to public health issues.

As part of the consultation process of the CSO study, the CSO Study Team met on several occasions with the CSO Advisory Committee, which comprises a group of resource managers, scientists, public health and public works officials.

The Advisory Committee has reviewed the various Technical Memoranda produced by the Study Team throughout the three phases of the study to date. This Advisory Committee also reviewed the draft 1997 Update Report. In November 1998, the Advisory Committee provided an Interim Report (1998) to the Study Team which provided comments on the information received to date by the Committee. The Interim Report included the Committee's comments on the health risk information provided by the Study Team.

Subsequent to the Advisory Committee's release of their Interim Report, the "Health Risk Report" was edited and discussions were held with the Committee to further clarify their comments and concerns. Their specific comments on the edited report were contained in an e-mail from Dr. Sande Harlos (dated February 18, 2000) and are provided here, in part:

> "*It was agreed that a considerable amount of investigation has been done into the modeling of the illness burden associated with CSOs and various CSO remediation*

> *options, but that a complete, "state-of-the-art" health risk assessment was never required, intended or attempted.*
>
> *The work done focussed on "illness" (specifically GI illness) rather than the more broadly defined concept of "health" usually explored in a health risk assessment (which includes issues of wellness, perceptions, etc.). Therefore, the Health Risk Assessment should use different terminology (such as Illness Risk Assessment) and be re-titled and edited to reflect the focus of what the scope of the assessment was.*
>
> *…*
>
> *While the broader health issues have not been fully described or investigated, this is true of the public health component of many public policy issues where decisions are made on the best information available. On the basis of professional judgement and common sense, the Health Team does not feel that the CSO issue warrants the resource utilization that a full Health Risk Assessment would entail to fully explore all of the broader health issues".*

In accordance with the foregoing, this report provides a discussion of the findings of the Update Report on CSO illness risk assessment, with particular consideration of the points raised by the Advisory Committee. Consistent with the suggestions of the Advisory Committee, this report has been re-titled "Illness Risk Assessment" and will provide, to the extent possible, an overview of health risks associated with the use of the local rivers, in addition to those related to CSOs, and provide a degree of public health context to the CSO control issue.

This report will discuss:

- relevant water quality regulations;
- a discussion of typical pathogens in surface waters;
- dose-response relationships as predictors of health risk associated with use of surface waters;
- use of the local rivers for recreation and irrigation (exposure to risk);
- a characterization of the risk to users in terms of disease caseloads, safety considerations; and
- an overall perspective of CSO control and community health risk.

2. RELEVANT SURFACE WATER QUALITY REGULATION

Because CSOs are known to contain pathogenic organisms, they are a concern with respect to the contamination of surface water quality, particularly as it relates to the microbiological quality of the surface water. This section will describe the relevant guidelines for the protection of human health for certain uses of the rivers.

Most regulatory agencies have objectives or guidelines for surface water quality parameters with the intent of protecting beneficial uses of the water. The objectives include microbiological guidelines relating to health risk. Because of the variety of bacteria, viruses and protozoa that may be present in surface waters, monitoring of all these organisms in an attempt to define the health risk of water use would be impractical. It is therefore common practice to monitor surface water quality for benign enteric organisms, such as "indicator bacteria", whose presence is considered to infer the presence of pathogens.

"Indicator organisms" are bacteria associated with the intestinal tract of warm-blooded mammals whose presence in surface water indicates that the water has received contamination from an intestinal or fecal origin. Fecal coliform is a commonly used indicator bacteria in surface water quality regulations.

The accuracy of the relationship between indicator bacteria and the presence of pathogens is uncertain and subject to considerable challenge.
A transition to indicators other than fecal coliform (i.e., *E. coli*, enterococci) and involving other numerical objectives is now occurring on the basis that epidemiology shows them to be *better risk predictors*. The US EPA, as of 1987, recommended the use of Escherichia coli (*E. coli*) and entorococci as measures of water quality (EPA, Fox Testimony 1998). Manitoba Environment accepts either E. coli or fecal coliform densities as equivalent indicators of water quality for the purposes of compliance with their guidelines.

<u>Primary Recreation</u>

Primary recreation includes uses where the human body may come in contact with the water to the point where water may be ingested accidentally or water may contact sensitive organs such as eyes, ears and throat (Manitoba Environment 1988). This includes uses such as swimming and waterskiing where contact with the water is an important part of the activity. In Manitoba, this recreation is usually restricted to the period May 1 to September 30.

The Clean Environment Commission (CEC) recommended in 1990 that the Red River be protected for primary recreation during dry weather conditions. The CSO study, and the related judgements on health risk, will assist in determining appropriate objectives during wet weather. The Red River is used for waterskiing, jetskiing, and limited swimming. In their Interim Report, the Advisory Committee, as discussed later, questioned whether the Red River is suitable for this use, due to safety issues (turbidity, currents, boat traffic, etc.).

A review of the literature shows that bacteriological guidelines in North America for protecting human health from recreational use of surface waters have a largely arbitrary origin. Their origin, including Manitoba guidelines, is based on protecting “natural” bathing beaches (Williamson 1988). Manitoba Conservation has defined an objective of 200 fecal coliforms/100 mL for protecting primary recreation, which is consistent with those used in many other jurisdictions. The current “standard” of 200 fc/100 mL for protecting primary recreation has been rationalized by many agencies, including Manitoba Conservation, after review of several epidemiological studies done on bathers and gastrointestinal illness, done in the early 1980s in the U.S.A. and Canada.

While some epidemiological studies support this numerical guideline, there is growing recognition of the weaknesses of water-quality indicators and specific numerical values among regulators. Manitoba Conservation recognizes that primary recreation in water meeting the fecal coliform objective does not imply a risk-free condition. The health risk at 200 fc/100 mL is estimated to be about 10 gastrointestinal illness (GI) cases/1,000 immersions (Williamson 1988).

<u>Secondary Recreation</u>

Secondary recreation involves uses such as fishing and boating where contact with the water is only incidental to the activity (Manitoba Environment 1988). The Red and Assiniboine rivers are used extensively for boating, fishing, riverbank walks, and aesthetic enjoyment. The CEC recommended that the Red and Assiniboine rivers be protected for secondary recreation during dry weather conditions.

Like some other jurisdictions, Manitoba Conservation has adopted an objective of 1,000 fecal coliforms/100 mL for protection of secondary recreation use. No epidemiological studies were found that relate health risk to secondary recreational use. The need for the numerical objectives for this use is uncertain.

Irrigation

The CEC recommended that both the Red and Assiniboine rivers be protected for the use of the water for irrigation or agricultural consumption (greenhouse and/or field crop irrigation) during dry weather conditions. There are about 40 greenhouse operations in the Winnipeg vicinity; most do not use the river due to access restrictions (development). While some seven operations use the river periodically, all but one of these operations are located where CSOs would not affect their withdrawals.

Manitoba Conservation has microbiological guidelines for the protection of the use of surface water for irrigation of greenhouse plants and field crops. The numerical objectives are 1,000 fc/100 mL except in cases where contact with the irrigation water by field staff is probable, where 200 fc/100 mL will apply. No epidemiological studies were found that were applicable to this use.

River water is also used fairly extensively for golf courses and lawn watering by individuals. No specific guidelines are in place for this use but the question of the associated health risk for this use has been raised by the Advisory Committee.

The illness risk assessment discussed in the following sections relates chiefly to the use of the rivers for recreation and irrigation.

3. APPROACH TO RISK ASSESSMENT

A typical Illness Risk Assessment is intended to estimate the adverse health effects that may be associated with exposure to a potentially-harmful substance, and to predict the likelihood that specific human populations will experience such effects at different exposure levels. For the

CSO study, the update of the available information on risk studies elsewhere on users of surface waters was intended to explore the illness rates for users of the local surface waters resulting from exposure to pathogens contributed by Winnipeg CSOs. In this study, the different exposure levels relate to the use of the local rivers, the current river quality conditions and the water quality resulting from differing levels of potential CSO control in Winnipeg.

This risk assessment was intended to use recent information to build upon prior risk assessment work related to surface water use and potential exposure to pathogens in these waters, particularly the Disinfection Evaluation (McLaren 1986) and evidence presented and debated at the CEC Hearings on River Classifications (Wardrop/Tetr*ES* 1990/91).

For this study, the approach to risk assessment followed conventional steps in risk assessment, which include:

- **identification of hazards**;
  - this activity is intended to determine if a substance could cause specific adverse health effects in human populations. For this study, the analysis reviewed the probable range of pathogens that may be present in CSOs.

- **dose-response assessment**;
- this step is intended to describe the quantitative relationship between a particular dose level (in this case a particular pathogen in the river water), and the resulting incidence of disease in humans.
  - in this study case, the dose-response reactions were based on literature review of epidemiological studies.
- **exposure assessment**;
  - this step typically involves estimating the populations exposed to the risk agent of concern. In this study, this is the population potentially exposed to pathogens in the rivers resulting from CSOs. This includes the magnitude, frequency, duration, and spatial extent of exposure from different uses by people of the river water, such as for recreation and irrigation, under current river water quality conditions and under different potential CSO control scenarios.

- **risk characterization**;
  - this step is intended to combine the findings of the preceding steps, i.e., hazard identification, dose-response, and exposure assessments. From this, the overall risk associated with this particular risk agent, in this case CSOs, can be placed in perspective with the overall population health determinants.

The following sections will discuss each of these steps with respect to illness risk and CSOs as the source of hazard. The risk characterization will discuss this perspective as well as its context in a more holistic view of river-water quality and community health.

4. ILLNESS RISK AND CSOs

The major concern with respect to illness risk and CSOs relates to disease-causing organism (pathogens) originating from CSOs. This section will discuss the range of pathogens typically found in surface waters and the range of sources.

4.1 PATHOGENS IN SURFACE WATERS

Surface waters are typically contaminated with microbiological organisms which originate from the digestive tract of warm-blooded animals. Some of these are pathogenic, or disease-causing. Users of the water, such as swimmers, may through ingestion or direct contact with the water, receive an infective dose of a pathogen. The diseases typically caused are infections of the skin, eyes, ears, nose, and throat and gastroenteritis (diarrhea). The gastroenteritis is usually fairly short-lived and most cases do not require medical attention and are not reported. In the case of irrigation, infections could also occur from inhalation of respirable aerosols.

Most waterborne pathogens are classified as viruses, bacteria, protozoa or fungi. **Bacteria** are the most common and widely distributed of life forms. In the context of risk assessment, bacteria can be both pathogenic and benign. The infectious dose to cause bacterial infection varies with different bacteria.

Viruses are obligate parasites, i.e., they need a host to survive, and they have high host specificity (Payment 1992). Little is known with precision about the occurrence, survival time and the distribution of viruses in surface waters, other than that they do not multiply in these environments but are capable of significant survival, perhaps for many months (Berg 1967, 1983; Sattar 1978; Bitton 1980). Generally, the infectious dose for viruses is much less than the infectious dose for bacteria.

Protozoa are much larger than bacteria and viruses. Protozoa survive environmental stress by secreting protective coatings ("encystment") and forming a resting stage ("cyst") which resists disinfection and aids survival and spread (U.S. EPA 1993). Protozoa normally enter the human body by ingestion of cysts. Protozoa of current and increasing regulatory and public interest include *Giardia* and *Cryptosporidium* species which can cause serious diarrhea. Many small mammals that live near water (e.g., mice, squirrels, muskrats) may be infected with *Cryptosporidium* and/or *Giardia* and may shed cysts into urban and rural area runoff (U.S. EPA 1993). Cattle are known to excrete large quantities of *Cryptosporidium*. *Cryptosporidium* and *Giardia* have become of significant interest with respect to the safety of public water supplies. These organisms are difficult to filter, due to their small size, and are resistant to disinfection chemicals, especially *Cryptosporidium*. *Cryptosporidium* and *Giardia* are likely to be found in most surface waters, especially in recreational and urbanized areas.

4.2 SOURCES OF PATHOGENS

Pathogens and indicator bacteria can be discharged into a waterbody in partially or completely treated wastewater effluents, or may enter the water via overland flow from contaminated point- and non-point-source runoff. Even in disinfected wastewater treatment plant effluent, some residual densities of pathogens may exist (e.g., *Cryptosporidium*). Once in the receiving stream, most pathogens begin to perish but a certain fraction survive for some time. Rates of die-off depend on such environmental factors as temperature and exposure to sunlight.

Health Canada (Health Canada 1995) reviewed the major sources of waterborne pathogens in surface water. The major sources appeared to be:

- effluent from wastewater treatment plants;

- CSOs;
- SSOs;
- urban land drainage sources (LDS); and
- upstream animal sources.

In the urban reaches of the Red and Assiniboine Rivers, the wastewater plant effluents are presently the largest sources of **indicator bacteria** to the rivers on an annual basis. During a rainfall event, the CSO's are the major source. With the planned disinfection of the plant effluents, indicator bacteria in the effluent, as well as other bacteria and viruses, will be greatly reduced but the resistant pathogens, such as *Cryptosporidium*, will still be present in the effluents. Some of these protozoa settle out in the treatment process but many will pass through and survive the disinfection process. Land drainage, from local and upstream sources, including animal husbandry practices, will continue to be important sources of pathogens thus, urban-source controls, such as effluent disinfection and CSO control, will not eliminate the presence of pathogens in the rivers due to contributions from both rural and urban non-point sources.

5. DOSE-RESPONSE ASSESSMENT

The fundamental basis for quantification of health risks from river uses is the science of epidemiology, which attempts to define, usually by "hindcasting" statistical techniques, the relationship among:

- pathogen densities at the point of human contact;
- the extent of exposure (usually the infective dose(s) and the number of doses ingested); and
- the disease(s) attributed to the exposure(s).

In this particular case, our interest is in relationships between a water user, say a waterskiier, contracting an infective dose of pathogens in the river water as a result of CSOs. In general, relationships between the above factors are usually expressed in the form of regression equations or "models" of the dose-response (D-R) relationship. Quantitative health-risk assessment (QRA) therefore depends on the state of the epidemiological literature, and whether pathogens (or indicators) of interest in a specific situation have been the subject of prior epidemiological research. To predict the societal disease caseload attributable for each organism, dose-response models or epidemiological relationships must exist which model the infectivity of the organism-host relationship for the pathogen or indicator of interest. As well, monitoring data on the concentrations of these specific pathogens in the waters must be available. As discussed below, there are a limited number of dose-response models and severe limitations of monitoring data on specific pathogens in surface waters.

5.1 POTENTIAL D-R MODELS

Epidemiological research on the question of recreational use of surface waters, both inland rivers (and lake beaches) and marine beaches, has resulted in publication of some practical D-R models relevant to the present study.

As previously noted, most D-R models have been created by hindcasting. This means they have been constructed from limited available data, because disease-caseload data related to recreational use of surface water are scarce, as has been noted in many epidemiological reports. Further, the diseases are usually relatively mild and of short duration and, hence, rarely reported. The lack of reported cases accounts, in substantial part, for the lack of pathogen-specific D-R models applicable to this study.

A list of 36 organisms, including bacteria, viruses, and protozoa, were identified by means of a computerized key-word search as being potential causative agents of disease from recreational (or irrigation) use of freshwater waterbodies (see Appendix 1). This list was screened, on the basis of the literature, on the health-risk significance of these 36 organisms to identify those pathogens for which a specific D-R model existed which is potentially capable of being applied to the CSO situation.

On the basis of this screening process, it was learned that D-R models have been reported for 14 of the 36 organisms (these are discussed in the Appendix).

It was clear from a review of these models that most of the new D-R models for specific pathogens have been derived by assessing disease expressions following exposure to ingestion of inoculated drinking water, i.e., their purpose was to address drinking water risk where ingestion is a given. This is very different from episodic exposure to surface waters where ingestion is not planned and where there may or may not be pathogens in the ingested water.

Some other models have more potential relevance to the Winnipeg situation (e.g., Regli *et al.* 1991; Seyfried *et al.* 1985b), but could not be applied because of the absence of relevant river-monitoring data (e.g., for rotavirus, *Giardia, Entamoeba, Staphylococcus, Streptococcus*) and because the epidemiological work needed to apply them was beyond the scope of this study.

The above limitations make it impractical to quantify risk from specific pathogens known or suspected to be present in the river water. Instead, it was determined that the most relevant D-R models for the Winnipeg situation are based on indicator bacteria, as discussed below.

5.2 DOSE-RESPONSE (D-R) MODEL SELECTION

The D-R models used in most of the recreation-health risk modelling completed to date have been for indicator organisms. These models predict illness-risk rates (i.e., GI cases/1,000 immersions) for various densities of indicator bacteria (usually fecal coliform or *E. coli*).
Three published D-R equations were considered most appropriate for quantitative risk estimation; two of which have been reviewed by Manitoba Conservation in the course of developing their objectives for protective criteria for public health. These are:

- Ferly *et al*. 1989 – fecal coliform model;
- Seyfried & Brown 1985 – fecal coliform model; and
- Dufour 1984 – E. coli model.

These models estimate risk rates for contracting GI from primary recreation in the Red River. They are not able to estimate skin, ear, or respiratory infections from such use. These shortcomings are further discussed in Section 7.

These 3 D-R equations are considered the most applicable because they are expressed in terms of unit rates of recreational use, i.e., number of immersion events, and because they focus on fecal coliforms or *E. coli*, for which data exists on their densities in the rivers. Water quality monitoring and modelling of discharges to the Red and Assiniboine Rivers have focussed to date on the fecal coliform indicator organism. Fecal coliform concentrations are often considered a reasonable surrogate for concentrations of *E. coli*.

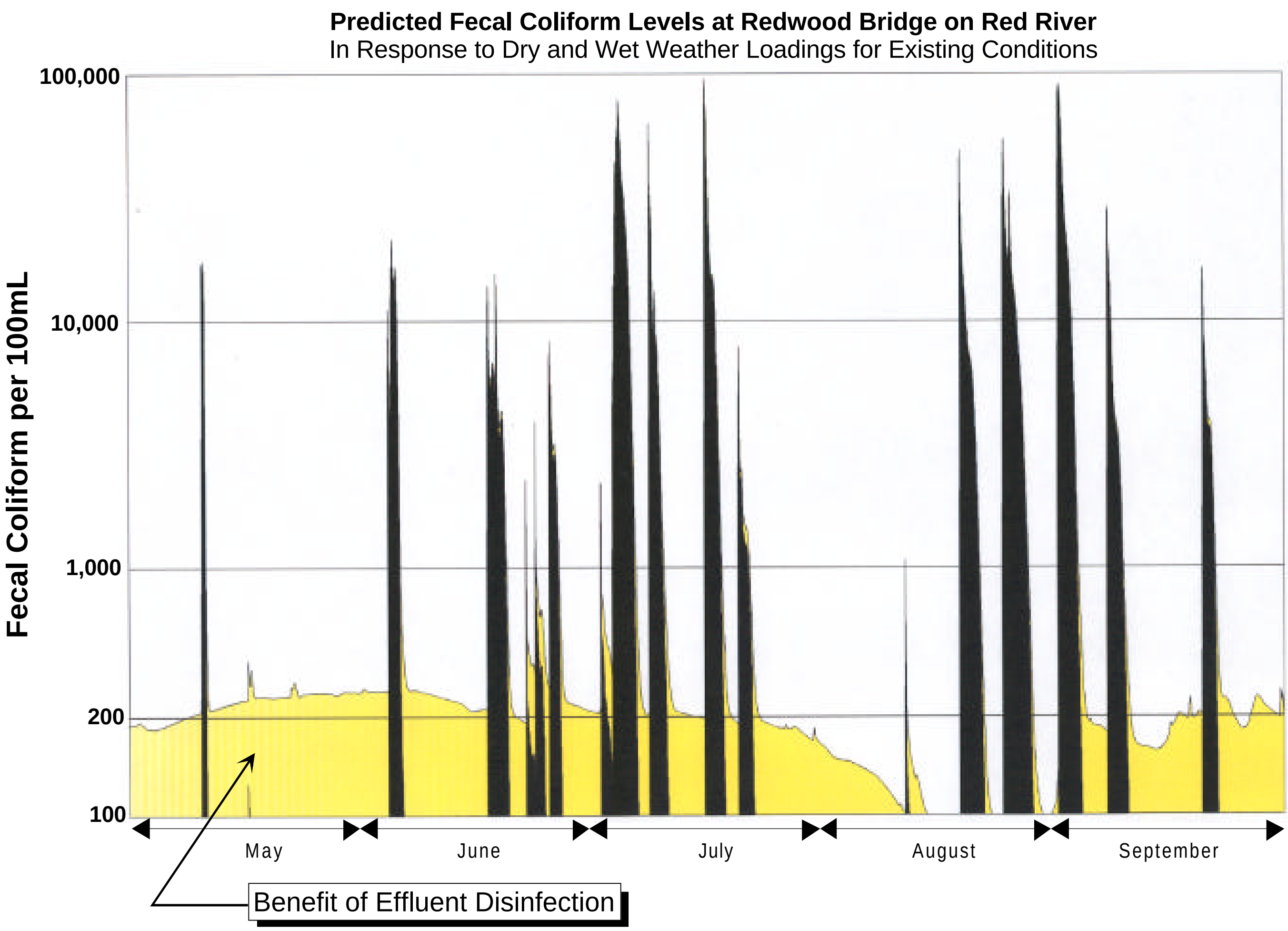
The Appendix discusses the 3 D-R models and compares the ranges in fecal coliform densities in the respective studies compared to the range of actual data on the rivers. While some extrapolation to the local situation is necessary, the studies are applicable for most of the local conditions. All 3 models were used to estimate illness-risk rates and their reduction by various pollution control options, as described in the Appendix.

The current illness risk from use of the rivers was estimated by applying these D-R models using estimates of indicator organism densities from actual data and calibrated and verified river water quality models for Winnipeg urban reaches. The potential reduction in recreational-use health-risk rates along the Red River was determined by estimating the reduction in fecal coliform levels in the river in response to specific wastewater control programs and applying the models to these reduced densities. The following sections will describe the microbial densities in the rivers and then the application of the models.

5.3 INSTREAM MICROBIAL DENSITIES

As part of the Combined Sewer Overflow Management Study (Wardrop/Tetr*ES*, ongoing), detailed river modelling was conducted in Phase 2 of this study to simulate the water quality response of the local rivers in relation to dry and wet weather urban discharges. Model simulations for the representative year 1992 were calibrated and verified with actual river data to provide a high degree of confidence in model predictions, as discussed in "Combined Sewer Overflow Management Study: PHASE 2 Technical Memorandum No. 4 Receiving Stream".

Figure 5-1 illustrates the response of the fecal coliform levels over time at the Redwood Bridge in the Red River for the representative year 1992. The Redwood Bridge area is in the middle of the areas serviced by combined sewers. The figure illustrates the temporal variation of fecal coliforms at this location and is thus also indicative of the potential temporal variation in illness risk. The peaks in the fecal coliforms are the result of the intermittent rainfall-induced



Benefit of Effluent Disinfection
Predicted at Redwood Bridge on Red River
Figure 5-1

discharges from CSO and, to a lesser extent, from land drainage sewers. It is evident that these wet weather discharges cause temporary exceedances of dry weather objectives.

These data were developed for every kilometre along the entire length of the river in the study area. This information was developed for each hourly time step in the modelling and was used to calculate the peaks and the geometric mean fecal coliform concentrations along the rivers for the full recreation season (see Appendix).

The analysis focussed on the Red River, since it is classified as suitable for primary recreation. Fecal coliform concentrations along the Red River were used in the D-R models.

Figure 5-1 illustrates the fecal coliform densities for the current situation, the future condition where all dry weather effluent discharges from Winnipeg's three wastewater treatment plants are disinfected during the recreation season, and potential complete separation of all combined sewer systems to separate sewer systems. (This represents the maximum possible CSO control, i.e., the elimination of CSOs).

Additional information on the variation of fecal coliform densities throughout the year at different locations along the rivers are described in the Appendix, however, Figure 5-1 illustrates the following points:

- Exceedances of objectives for both primary and, to a much lesser extent, secondary recreation occur in the urban reaches under present conditions.
- Dry weather effluent disinfection of WPCC effluents (in respect to reduction of fecal coliform) is noteworthy in that this action alone has the capacity to reduce existing mean levels to below the 200 fecal coliform/100 mL objective set forth in the Manitoba Surface Water Quality Objectives. Wet weather discharges, however, would still cause short-term exceedances of the objectives.
- The benefit of complete sewer separation of all combined sewer systems in Winnipeg is only marginal in terms of reduced average fecal coliform levels. This is so because, even in the absence of CSOs, land drainage would continue to contribute to exceedances of fecal coliform levels in the river; to a lesser extent than CSOs, but still sufficient to cause non-compliance with dry weather objectives after rainfall events.

5.4 ESTIMATED ILLNESS-RISK RATES

Using the geometric mean of fecal coliforms (under current and potential control scenarios) and applying the three D-R equations (discussed earlier) to the different microbial densities noted above, it is possible to calculate the corresponding illness risk rates, **in terms of GI cases**, along the Red River for the full recreation season. The illness risk rate (estimated gastrointestinal (GI) illness cases per 1,000 immersion) was estimated for the predicted fecal coliform densities associated with current and the different pollution control scenarios, as shown in Table 5-1, as follows.

TABLE 5-1

ESTIMATED ILLNESS RISK RATES* FOR RECREATIONAL RIVER USE (WINNIPEG AREA)

	Seyfried & Brown (1986)	Dufour (1984)	Ferley (1989)
Existing Conditions	19.8	10.7	9.7
Acceptable Risk Rate (200 fc/100 mL)	19	10	9.2
After Dry Weather WPCC Effluent Disinfection	13	0.3	4.9
Sewer Separation	12.3	0	4.2

*GI Cases per 1000 immersions

The predicted GI cases vary according to each D-R equation but all have the same trend and indicate that, after WPCC effluent disinfection, the additional reduction in GI risk rate associated with CSO control is predicted to be very modest.

The above is based on using the geometric means of fecal coliform densities at 1-km segments of the Red River, assuming the recreational use is distributed evenly along the river.
The average risk rate was also calibrated using the hourly values of fecal coliform at each 1-km segment, which includes the peak wet weather days and normal dry weather days. The aggregated health risk was the same as that calculated using the geometric means.

Risk rates were also estimated at Selkirk, which again showed that the disinfection of the three WPCC effluents reduces the risk rate and that complete elimination of CSOs has virtually no effect on further reduction of the illness risk rate, as indicated by GI cases.

These risk rates were next used to estimate the total incidence of GI cases arising from recreational use of the river, which depends on the extent of the exposure of humans to the pathogens in the river, i.e., the river use.

6. RIVER USE/EXPOSURE ASSESSMENT

Having described the magnitude of the risk rate along the rivers, this section will consider the river use characteristics, i.e., the numbers of people involved in recreation and irrigation, and translate the risk rate into estimated cases of GI in the community.

Detailed estimates of river use are limited, however, sufficient information exists from surveys (Wardrop/Tetr*ES* 1990/91) done in 1990 to provide guidance as to the approximate number of people engaged in the different types of river use and allow estimates of the total disease burden.

6.1 RECREATION

The Red and Assiniboine Rivers are very popular for passive enjoyment, use of riverwalks, and secondary (non-contact) recreation (boating, fishing). The use of the surface waters for primary recreation is limited in the Winnipeg and Selkirk area. Low participation in primary recreation can be attributed, in part, due to flow, clarity, muddy banks, and conflicts with other uses. About 6,400 immersions are estimated to occur as a result of primary recreation activities, mainly from waterskiing and jetskiing (see Appendix). Ingestion of river water during these activities is likely. Therefore, some risk of exposure to the river water has been implicitly accepted by individuals choosing to engage in primary recreation.

Secondary recreation is very popular in the Winnipeg and Selkirk area, with approximately 70,000 instances of participation in secondary recreation per year. While immersion is not intended during secondary recreation activity (unlike primary recreation), accidental immersion can occur. Accidental immersions due to secondary recreation are estimated to be approximately 3,500 immersions/season (see Appendix 1). As immersion is unintentional and rare in secondary recreation, river quality is not as significant a risk factor for such uses as for primary recreation.

This exposure was used to characterize the illness risk in terms of disease cases, and their potential reduction with CSO control, in Section 7.0.

6.2 IRRIGATION

In December 1992, the City of Winnipeg conducted a survey to determine the extent that river water is used as a raw water source for greenhouse operations (Wardrop/Tetr*ES* 1990/91). The survey obtained information from 40 greenhouse growers identified as being within the study area. The results were:

- Forty greenhouse growers in this region produce spring bedding plants. None of the growers produced edible crops (i.e., tomatoes, lettuce, cucumbers, etc.) for direct sale to market.

- Seven of the 40 greenhouse growers contacted indicated that they used river water for a portion of their operating season. While the majority of the greenhouse growers within the study area are located relatively close to either the Red, Assiniboine or Seine Rivers, the majority of greenhouse operations (approximately 85%) do not use the river due to access restriction (due to recently established river-front developments). There is only one irrigator located in the RM of St. Andrews, who would be potentially affected by high coliform counts as a result of wet-weather overflow conditions.

7. RISK CHARACTERIZATION

The discussion will summarize the estimated community disease caseload from exposure to pathogens in the river, safety considerations in use of the rivers, and the implications of increased river use on overall community health.

7.1 ESTIMATED DISEASE FROM USE OF RIVERS

The estimated disease, in terms of GI cases, was estimated for recreational and irrigational use of the river waters.

7.1.1 Recreation: Disease Caseload Reduction

The exposure (recreational use of the rivers in terms of immersion events) was multiplied by the unit health risk rates to estimate the GI disease caseload for current and potential future control scenarios. The results are shown in Table 7-1, as follows.

TABLE 7-1

ESTIMATED GI CASES FOR RECREATIONAL RIVER USE (WINNIPEG AREA)

	Seyfried & Brown (1986)	Dufour (1984)	Ferley (1989)
Existing Conditions	173	93	84
After Dry Weather WPCC Effluent Disinfection	114	3	42
Sewer Separation	107	0	36

The predicted caseload of GI is very small in the context of the overall GI caseload. A community of the size of Winnipeg can be expected to have a total of 500,000 to 1,000,000 GI cases per year (Wardrop/Tetr*ES* 1990). Most of these cases are not reported. They originate from a number of sources, food borne, travel, and waterborne. In this context, the GI caseload that could be attributed to CSOs is not measurable. The results show a modest reduction in GI caseloads associated with WPCC effluent disinfection (50-90 cases/yr) but almost all of the reduction is attributed to WPCC disinfection. Virtually no additional reduction or benefit from elimination of CSOs is indicated.

It should be recognized that this disease caseload relates to GI cases, based on the available D-R models which are based on ingestion of river water. It does not account for non-GI infections, such as skin rashes or ear infections, due to contact with other organisms. The available science and local data does not allow this to be estimated.

The US EPA plans to sponsor research to provide better indicators for ear, skin, and respiratory infections. At present, no reliable D-R models exist for this purpose. Discussions with a local jet-ski user group indicated that the members apparently do not experience any difference in such infections from recreation in the Red River as compared to other surface water in the province.

While the D-R models and the estimated disease case load have many weaknesses, they appear to confirm that there is no reason to expect significant disease caseload resulting from recreation in the Red River, in terms of anecdotal or reported cases. The models all indicate that elimination of CSOs should not be expected to yield measurable reductions in public health diseases.

7.1.2 Irrigation: Disease Caseload Reduction

The D-R models used for recreation cannot be used directly for estimating risk from exposure to irrigation, since they are based on ingestion of water. As discussed in the Appendix, the risk associated with inhalation of aerosols from irrigation was estimated and found to be very, very low. The above assessment also applies to instances of golf course irrigation, children playing near sprinklers using river water, etc. It does not consider deliberate ingestion, i.e., drinking of river water. The risk from such an event would be similar to immersion from primary recreation. In terms of workers contacting the water with their hands, the best protection is good personal hygiene. There is some risk from such exposure to non-potable water but the risks are too low to be quantifiable.

The study team concludes that the probable illness risk associated with irrigation under current conditions is so low as to be unable to be reliably quantified. Accordingly, any benefits to irrigation from CSO control will not be measurable.

7.2 SAFETY CONSIDERATIONS IN USE OF RIVERS

The use of the Red River for primary recreation has attendant risks due to the nature of the water and other sometimes competitive uses. The Red River has naturally high levels of turbidity, strong currents, relatively steep muddy banks and concealed objects. These all represent risks to the personal safety of recreationalists and are relevant to an overall community health risk assessment. The high use of the river for boating also represents a concern in terms of physical risk of injury to the waterskiiers, jetskiiers and swimmers. None of these factors would be influenced by the degree of control of CSOs.

Swimming has never been popular in the Red River. Manitoba Conservation does not recommend swimming in the river when turbidity levels exceed 50 NTU. The rationale is based on the need for clarity for situations where swimmers are in distress. The turbidity levels, based on 1980-89 turbidity data, exceed 50 NTU during the recreation season about 40-53% of the time at the southern edge of the City and 20-35% of the time at the North Perimeter bridge. These data indicate that the river is not very suitable, naturally, for primary recreation. The elimination of CSOs would not change the clarity of the rivers for swimming. Moreover, increased use of primary recreation (e.g., jetskiiers) would increase conflict with secondary recreation such as fishing, boating, canoeing, and bring about concerns regarding personal safety.

The local waters are an attractive recreational resource. People using surface waters for recreation recognize and implicitly accept some degree of risk when they choose such use. The enjoyment of the experience may more than offset the above safety considerations.

7.3 INCREASED USE OF RIVERS

If additional control of CSOs resulted in the increased use of the Red River for primary recreation, this could result in an increase in disease caseload, i.e., if a number of users exposed to the river water increases at a given risk rate, the total disease caseload will increase. Increased use of the rivers will also result in more accidents and incidents of personal injury.

On the other hand, this increase in the health burden may be acceptable to the community. Other benefits could accrue from increased usage, such as community pride in the rivers, improvement in outdoor enjoyment, fitness, community well-being and perhaps some increased economic benefits. CSOs may be constraints to maximizing these potential benefits. The appropriate balancing of risk vs. benefits involves the value-judgements of the community.

8. OVERALL PERSPECTIVE

CSOs are wet weather events and intermittently contribute pathogens to the river, many of which are fairly ubiquitous in the surface water, including the Red and Assiniboine Rivers. CSO control would reduce the concentrations of some pathogens in the rivers, during and shortly after rainstorms. CSO control would also improve the visual appearance of the rivers after a rainstorm, to some extent, but land drainage would still contribute street litter and contribute to temporary un-aesthetic conditions. From a public disease standpoint, the available epidemiological analyses and evidence indicates that the public health benefits of CSO control, in terms of avoided disease caseload, will not be measurable. Improved CSO control may contribute to other subjective community health benefits, such as improved public perception of the rivers, community pride, and improved quality of life.

CSO control will be costly and the benefits are subjective. There are many reasons to consider CSO control, including improving compliance with environmental guidelines, improvements in aesthetic and/or microbiological water quality, improving public perception and pride in the local rivers. The weight of the evidence and analysis indicates CSO control should not be considered a significant public health issue, in the conventional context of avoiding disease. The extent of CSO control that is appropriate and acceptable to the community is fundamentally a public policy and a regulatory compliance issue.

This risk assessment is intended to contribute to the discussion of these policy issues.

9. REFERENCES

Advisory Committee. 1998. CSO Study Advisory Committee, Interim Report.

Clean Environment Commission. 1992. Report on Public Hearings.

Dufour, A.P. 1984. Bacterial indicators of recreational water quality. Can. J. Public Health 75(1):49-56.

Ferley, J.P., D. Zmirou, F. Balducci, B. Baleux, P. Fera, G. Larbaigt, E. Jacq, B. Moissonnier, A. Blineau and J. Boudot. 1989. Epidemiological significance of microbiological pollution criteria for river recreational waters. Int. J. Epidemiol. 18(1):198-205.

Fox, J.C. 1998. Testimony to Sub-Committee on Water Resources and Environment. U.S. House of Representatives.

Health and Welfare Canada. 1992. Guidelines for Canadian Recreational Water Quality. Ministry of National Health and Welfare. ISBN 0-660-14239-2, pp. 101.

Manitoba Environment. 1988. Surface Water Quality Objectives.

McLaren Engineers. 1986. Disinfection Evaluation, City of Winnipeg Wastewater Treatment Plant Effluents.

Payment, P. 1992. “Entire Viruses in Water: An Underestimated Health Risk:. Proc. 5th National Drinking Water Conference. Winnipeg. Sept 13-15, 1992. pp. 157-163.

Regli, S. *et al*. 1991. Modelling the Risk From Giardia and Viruses in Drinking Water”. J. AWWA, pp. 76-84.

Seyfreid, P.L. and N.E. Brown. 1985. Epidemiological Study of Disease Incidence and Recreational Water Quality at Selected Conservation Areas in Southern Ontario. Department of Microbiology, Faculty of Medicine, University of Toronto. Technology Transfer Conference No. 6. Dec. 11 & 12, 1985. Toronto Hilton-Harbour Castle.

United States Environmental Protection Agency (USEPA). 1993. Preventing Waterborne Disease - A Focus of EPA’s Research. Report No. EPA/640/K-93/001. Office of Research and Development. Washington, D.C. 20 pp.

Wardrop Engineering Inc./Tetr*ES* Consultants Inc. 1998. 1997 Update: Health Risk Relating to Uses of the Red and Assiniboine Rivers in Winnipeg and Downstream.

Wardrop Engineering Inc./Tetr*ES* Consultants Inc. 1998. Red and Assiniboine Rivers Surface Water Quality Objectives.

Williamson, D.A. 1986. Rationale Document Supporting Revisions to Manitoba Surface Water Quality Objectives. Water Standards and Studies Report #86-12. Manitoba Environment and Workplace Safety and Health. July 14, 1986.

Williamson, D.A. 1988. Manitoba Surface Water Quality Objectives. A Water Standards and Studies Report. July 15, 1988.

APPENDIX 1

ILLNESS RISK ASSESSMENT

SUPPORTING INFORMATION

TABLE OF CONTENTS

INTRODUCTION

The attached information provides supporting technical information to the above report. **Additional detail is found in the "1997 Update: Health Risk Relating to Users of the Red and Assiniboine Rivers in Winnipeg and Downstream, 1998", Wardrop/Tetr*ES*.**

1. DOSE-RESPONSE MODELS

A list of 36 organisms was identified by means of a computerized key-word search as having potential to be causative agents of disease from recreational (or irrigation) use of inland (i.e., freshwater) waterbodies as shown in Table 1-1. On the basis of the abstracts and papers discussing the health-risk significance of these 36 organisms, the list of 36 organisms was screened down to those capable of Quantifiable Health Risk (QRA) Assessment for recreational water use by virtue of the existence of a specific Dose-Response (D-R) model.

On the basis of this screening process, it was learned that D-R models have been reported for 14 of the 36 organisms listed in Table 1-1. The 14 organisms are listed below:

- *Campylobacter* species (spp.) - bacteria
- *Cryptosporidium parvum* - parasite
- Echovirus (12) - virus
- *Entamoeba coli* - bacterium
- *Escherichia coli* - bacterium
- fecal coliforms - bacteria
- *Giardia lamblia* - parasite
- Poliovirus (I,III) - virus
- Rotavirus - virus
- *Salmonella* spp. - bacteria
- *Shigella* spp. - bacteria
- *Staphyloccus* spp. - bacteria
- *Streptococcus* spp. - bacteria

TABLE 1-1

MICRO-ORGANISMS RELEVANT TO RIVER-USE ILLNESS-RISK ASSESSMENT

BACTERIA

Aeromonas (hydrophila and other spp.)
Bacillus cereus
Campylobacter jejluni
Escherichia coli (non-pathogenic)
enteropathogenic *E. coli* (e.g., *E. coli* 0157:H7)
Leptospira spp.
Listeria monocytogenes
Plesiomonas shigelloides
Proteus spp.
Pseudomonas spp.
Salmonella spp. (typhosa, typi)
Shigella spp. (flexneria 2A)
Staphylococcus aureus
Streptococcus spp.
Yersinia (enterocolitica, pseudotuberculosis)
Vibrio (cholerae 01, non-01, *parahaemolyticus, vulnificus)*

PARASITES

Acanthamoeba and other free-living amoebae
Anisakis sp. and related worms
Ascaris lumbricoides and *Trichuris trichiura*
Balantidium coli
Cryptosporidium parvum
Diphyllobothrium spp.
Entamoeba histolytica
Eustrongylodes sp.
Giardia lamblia
Nanophyetus spp.
Schistosoma spp.

FUNGI

Candida albicans
Clostridium (perfringens, botulinum)

VIRUSES

Coxsackie A and B
Echovirus 12
Hepatitis (A, E)
HIV
Polio virus
Rotavirus
Norwalk agents

APPX1.TBL

The 14 reported models were considered for their direct applicability to estimating public recreation (and irrigation) river-use risk within the City of Winnipeg under a variety of river- and control-strategy scenarios, and for the downstream community of Selkirk under the same scenarios.

The review of these models showed most of the new D-R models for specific pathogens have been derived by assessing disease expressions following exposure to (i.e., ingestion of) inoculated drinking water. This is very different from episodic exposure to surface waters which may or may not have pathogens in the ingested water.

Other models having potential relevance (c.f., Regli *et al.* 1991; Seyfried *et al.* 1985b) could not be applied because of absence of relevant river-monitoring data (e.g., for rotavirus, *Giardia, Entamoeba, Staphylococcus, Streptococcus*) and because the epidemiological work needed to apply them was beyond the scope of this study.

The D-R models used in most of the recreation-health risk modelling completed to date have been for indicator organisms. These models predict illness-risk rates (i.e., GI cases/1,000 immersions) for various densities of indicator bacteria (usually fecal coliform or *E. coli*).

Three published D-R equations were considered most appropriate for quantitative risk estimation:

- Ferley *et al.* 1989 fecal coliform model;
- Seyfried & Brown 1985b fecal coliform model; and
- Dufour 1984 *E. coli* model.

These 3 D-R equations are considered the most applicable because they are expressed in terms of unit rates of recreational use and because they focus on fecal coliforms or *E. coli*, for which data exists on their densities in the rivers. Water quality monitoring and modelling of discharges to the Red and Assiniboine Rivers have focussed to date on fecal coliform indicator organism. Fecal coliform concentrations are considered a reasonable surrogate for concentrations of *E. coli* by Manitoba Environment.

Figure 1-1 shows the 3 D-R models and compares the ranges in fecal coliform densities in the respective studies compared to the range of actual data on the rivers. While some extrapolation to the local situation is necessary, the studies are applicable for most of the local conditions. All 3 models were used to estimate illness-risk rates and their reduction by various pollution control options.

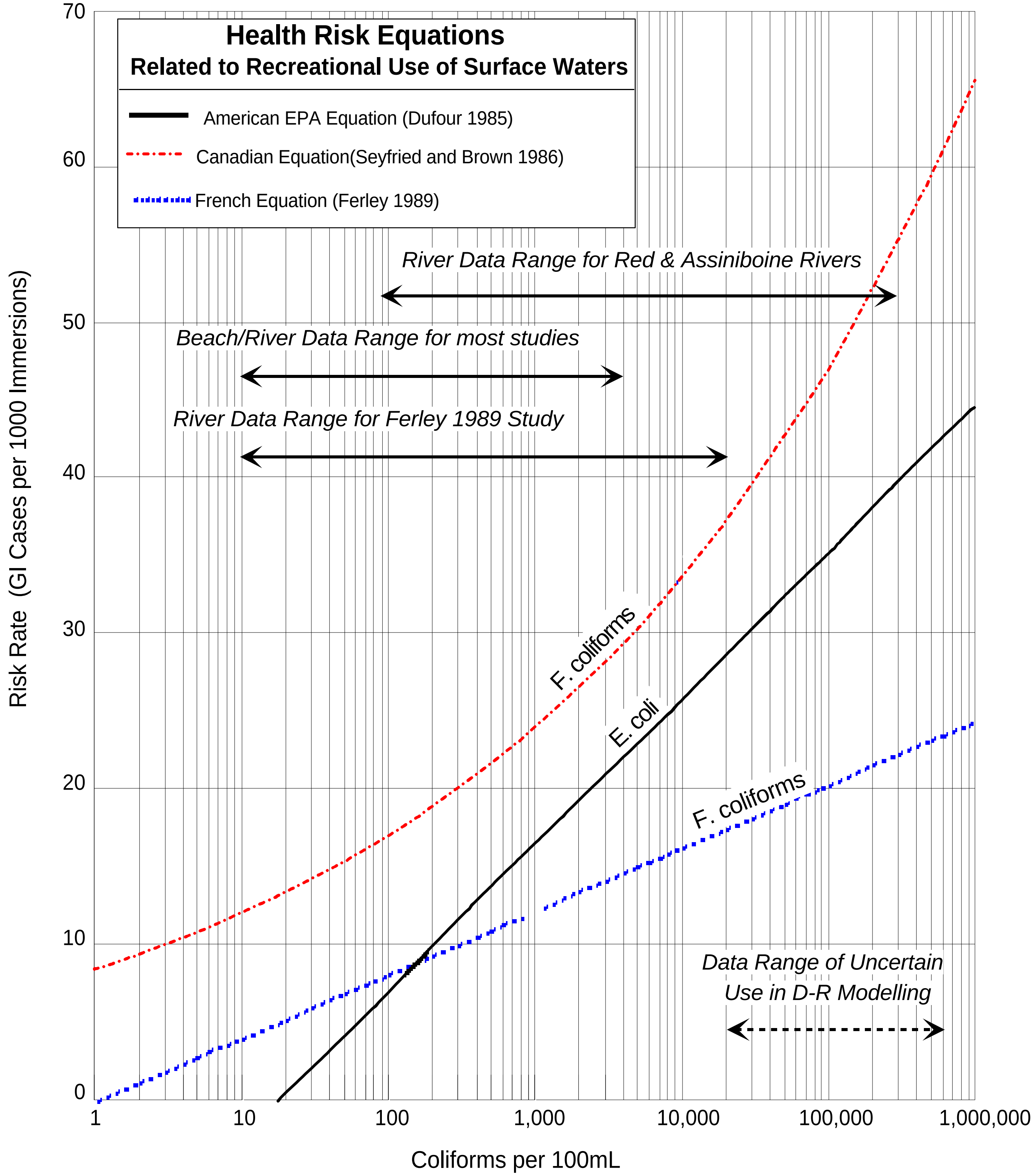
The current illness risk from use of the rivers was estimated by applying these D-R models using estimates of organism densities from actual data and calibrated and verified river water quality models for Winnipeg urban reaches. The potential reduction in recreational-use health-risk rates along the Red River was determined by estimating the reduction in fecal coliform levels in the river in response to specific wastewater control programs and applying the models to these reduced densities.

2. FECAL COLIFORM DYNAMICS, RED RIVER

As part of the Combined Sewer Overflow Management Study (Wardrop/Tetr*ES*, ongoing), detailed river modelling was conducted in Phase 2 of this study to simulate the water quality response of the local rivers in relation to dry and wet weather urban discharges. Model simulations for the representative year 1992 were calibrated and verified with actual river data to provide a high degree of confidence in model predictions, as discussed in “Combined Sewer Overflow Management Study: PHASE 2 Technical Memorandum No. 4 Receiving Stream”.

Figure 1-2 illustrates the response of the fecal coliform levels over time at the Redwood Bridge in the Red River for the representative year 1992. The figure illustrates the temporal variation of fecal coliforms at this location and is indicative of the potential temporal variation in health risk. The peaks in the fecal coliforms are the result of the intermittent rainfall-induced discharges from CSO and, to a lesser extent, from land drainage sewers.

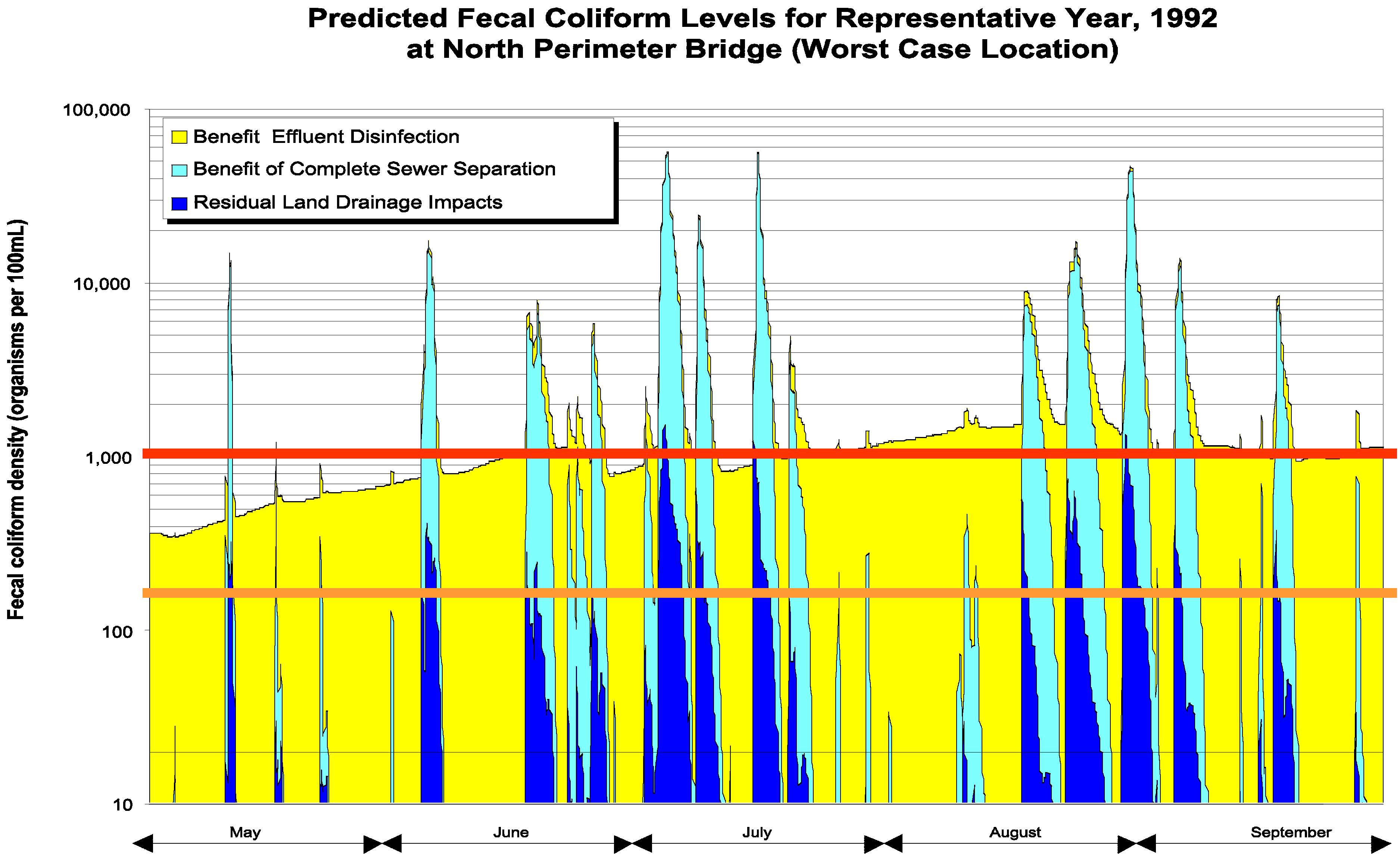
These data were developed for the entire length of the river in the study area. This information was used to calculate the geometric mean fecal coliform concentrations along the rivers, as shown in Figure 1-3, for the full recreation season.



TetrES
CONSULTANTS INC.
rskequat
s\01\0510

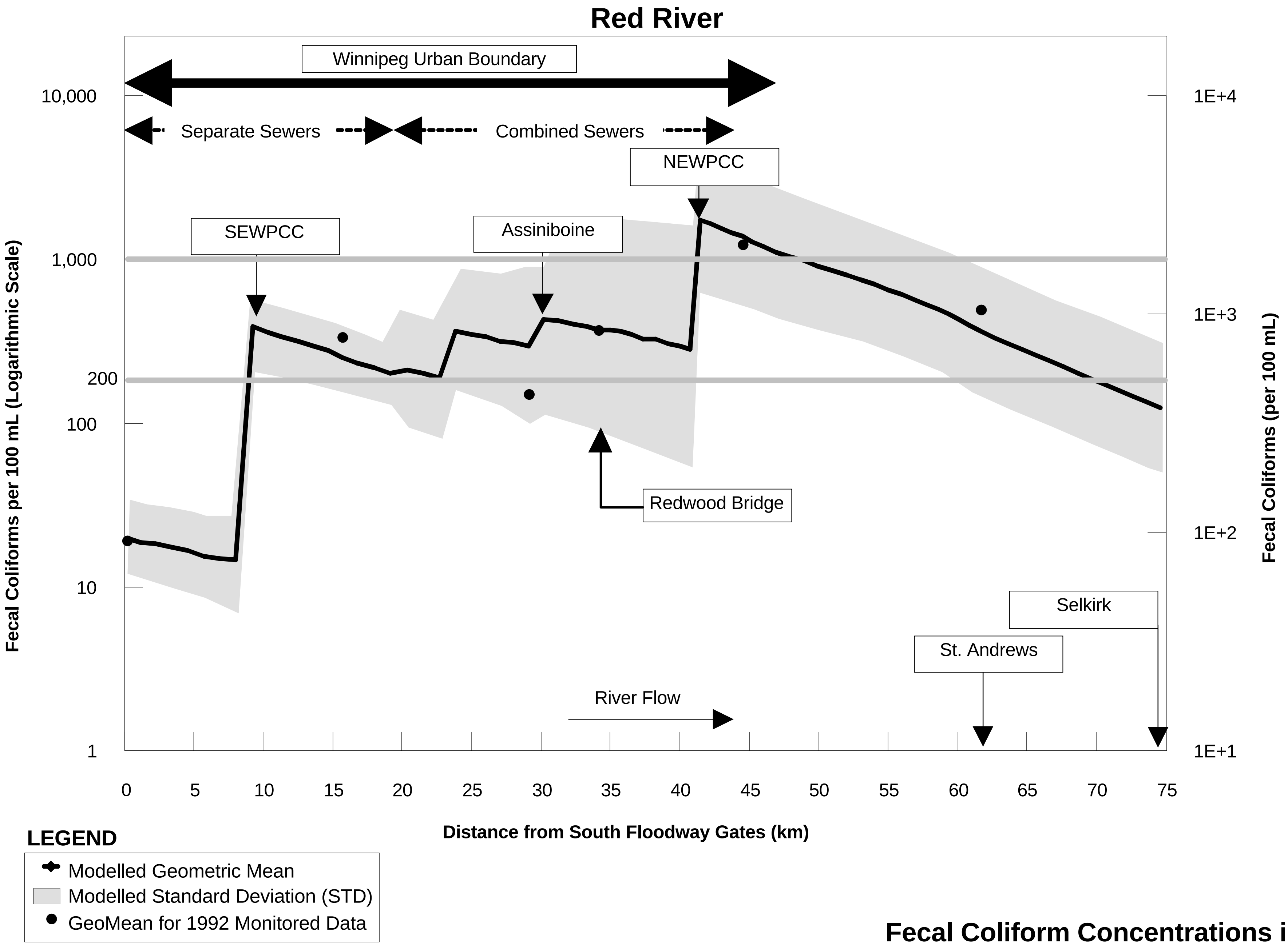
Appicability of D-R Models viz. Indicator Organism Data Distribution for Reaches of the Red and Assiniboine Rivers affected by Urban Discharges from Winnipeg

Figure 1-1



nperfc
s\01\0510\38

Figure 1-2



Fecal Coliform Concentrations in Red River (Representative Year, 1992)

Figure 1-3

redrfc
s\01\0510\38

The analysis focussed on the Red River, since it is classified as suitable for primary recreations. Fecal coliform concentrations along the Red River were used in the D-R models for the following scenarios.

1. Current conditions.

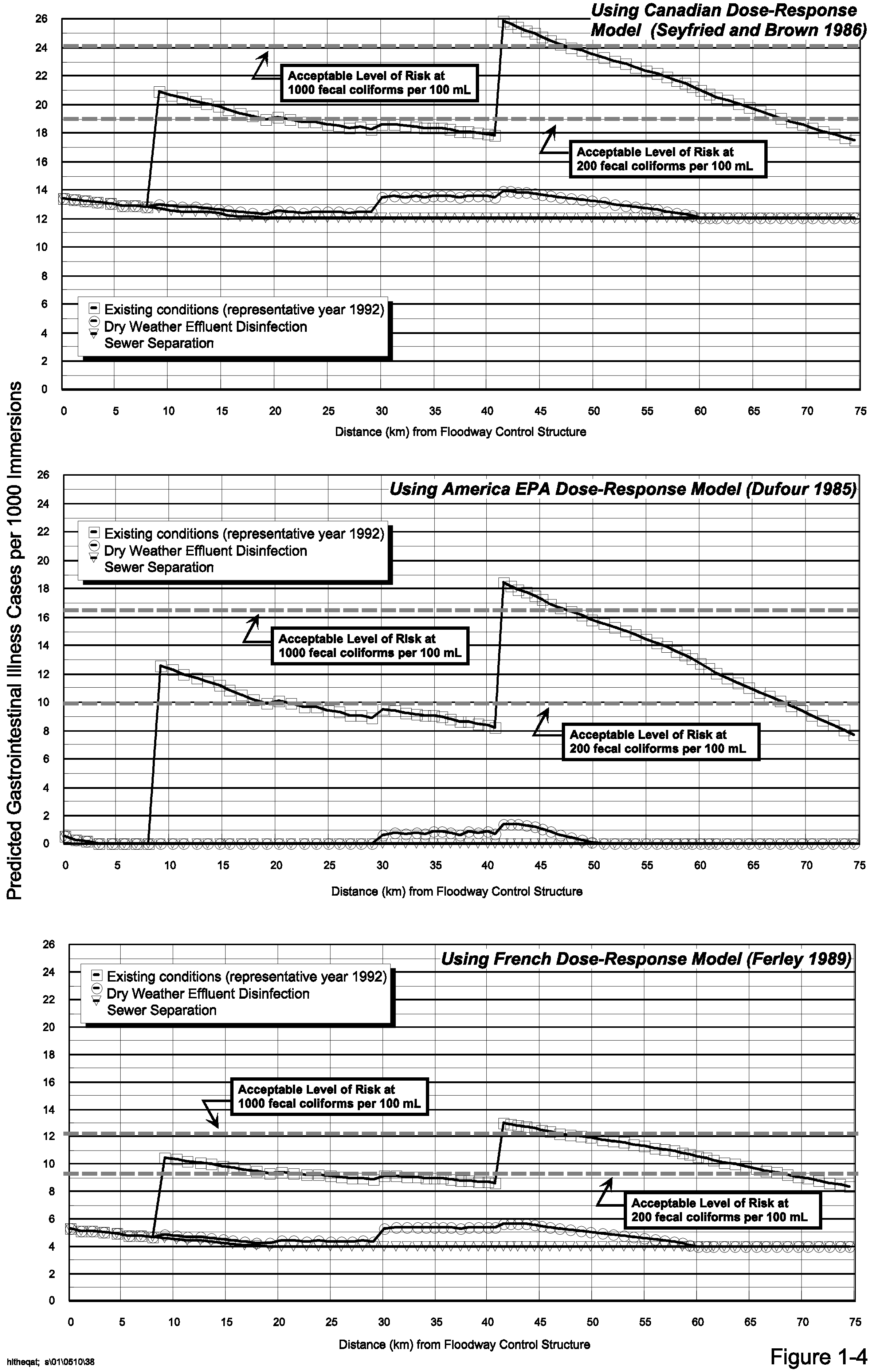
2. Effluent Disinfection - this condition represents the disinfection of all dry weather effluent discharges from Winnipeg's three wastewater treatment plants during the recreation season.

3. Complete Separation - this condition represents the conversion of all combined sewer systems to separate sewer systems (i.e., one sewer system for wastewater and another for land drainage) and the disinfection of all treated wastewater discharges (i.e., dry and wet weather effluent). This represents the maximum possible CSO control, i.e., the elimination of CSOs.

3. RISK RATES

Using the geometric mean of fecal coliforms (under current and potential control scenarios) and applying the three D-R equations to the different microbial densities, the corresponding illness risk rates along the Red River for the full recreation season were calculated. Figures 1-4 displays the illness risk rate (estimated gastrointestinal (GI) illness cases per 1,000 immersion) for the predicted fecal coliform densities associated with current and the different pollution control scenarios. The calculations were based on using the geometric means of fecal coliform densities at 1-km segments of the Red River, assuming the recreational use is distributed evenly along the river. The acceptable risk levels at the secondary recreation (1,000 fc/100 mL) and primary recreation (200 fc/100 mL) objectives are noted on each graph for the corresponding D-R equation. The predicted GI risk rates vary according to each D-R equation but all have the same trend and indicate similar results relative to the acceptable levels of risk at 1,000 and 200 fc/100 mL.

Health Risk Along Red River for Identified Pollution Control Options



hltheqat; s\01\0510\38

Figure 1-4

4. RIVER USE AND ESTIMATED GI CASELOAD

The risk rates were estimated in Section 3.0. This section will describe the nature and size of the population exposed to the risks represented by microbial concentrations in the rivers (from CSOs and other sources). The risk rates have described the magnitude of the risk rate and its spatial characteristics. This section will consider the river use characteristics, i.e., the numbers of people involved in recreation and irrigation, and translate the risk rate into estimated case of GI in the community for these uses. Detailed estimates of river use are limited, however, sufficient information exists to provide guidance as to the approximate number of people engaged in the different types of river use and allow estimates of the total disease burden.

4.1 RECREATIONAL USE

4.1.1 Exposure

A detailed river use survey was conducted in the Red and Assiniboine Surface Water Quality Objectives Study (Wardrop/Tetr*ES* 1991). The survey consisted of five sources of information, as listed below:

- anecdotal information collected in 1986 by MacLaren Engineers Inc. as part of the report titled "Disinfection Evaluation: City of Winnipeg Wastewater Treatment Plant Effluents";
- actual counts of river activity from 5 aerial surveys by the City of Winnipeg in June, July and August 1990;
- anecdotal information collected in 1990 by the Province on club activities;
- anecdotal information collected by the City of Winnipeg in 1990 from the Harbour Master;
- results gathered as part of a telephone survey conducted by the City of Winnipeg in 1990.

Since these surveys were done, the use of jet-skis appears to have increased but overall it is believed that relatively minor differences exist in current recreational river use. As such, the 1990 survey information is considered sufficiently accurate for subsequent estimates of health risk associated with ingestion of raw river water.

The surveys found that the Red and Assiniboine Rivers are very popular for passive enjoyment, use of riverwalks, and secondary (non-contact) recreation (boating, fishing). The use of the surface waters for primary recreation is limited in the Winnipeg and Selkirk area. Low participation in primary recreation can be attributed, in part, due to flow, clarity and current constraints. Ingestion of river water during these activities is likely. There were approximately 70,000 instances of participation in secondary recreation in the Winnipeg and Selkirk area. While immersion is not intended during secondary recreation activity (unlike primary recreation), accidental immersion can occur.

Using the survey of river use, the number of immersions which lead to ingestion of river water were estimated for the extent of the recreation season, May 1 to September 30 (inclusive), i.e., 153 days. This provides an estimate of the immersion events as follows:

A) Primary Recreation

- Winnipeg area = 5,814 events
- Selkirk area = 612 events

= 6,426 events

B) Secondary Recreation*****

- Winnipeg area = 2,907 events
- Selkirk area = 612 events

= 3,519 events

*4% of boating users were assumed to become immersed, based on a Red Cross Survey in 1984 on all boaters.

The total estimated number of immersions resulting in ingestion of raw river water from Winnipeg to Selkirk (inclusive) for the full recreation season is about 9,945 unique events.

This exposure was used to characterize the health risk in terms of GI disease cases, and their potential reduction with CSO control, as discussed below.

4.1.2 GI Disease Caseload Reduction

The exposure (recreational use of the rivers in terms of immersion events) were multiplied by the unit health risk rates to estimate the GI disease caseload for current and potential future control scenarios. The results are shown in Figure 1-5. The results show a modest reduction in GI caseloads associated with WPCC effluent disinfection (40-100 cases/year, depending on the D-R model used) but virtually no additional reduction or benefit from elimination of CSOs.

The predicted caseload of GI is very small in the context of the overall GI caseload. A community of the size of Winnipeg can be expected to have a total of 500,000 to 1,000,000 GI cases per year. Most of these cases are non-reportable. They originate from a number of sources, food borne, travel, and waterborne, with the largest source being waterborne. In this context, the GI caseload that could be attributed to CSOs is not measurable.

It should be recognized that this disease caseload is for GI cases, based on the available D-R models which are based on ingestion of water. It does not account for infections such as skin rashes or ear infections, due to contact with other organisms. The US EPA plans to sponsor research to provide better indicators for ear, skin, and respiratory infections. At present, no reliable D-R models exist for this purpose. Discussions with a local jet-ski user group indicated that the members apparently do not experience any difference in such infections from recreation in the Red River as compared to other surface water in the province.

4.2 IRRIGATION

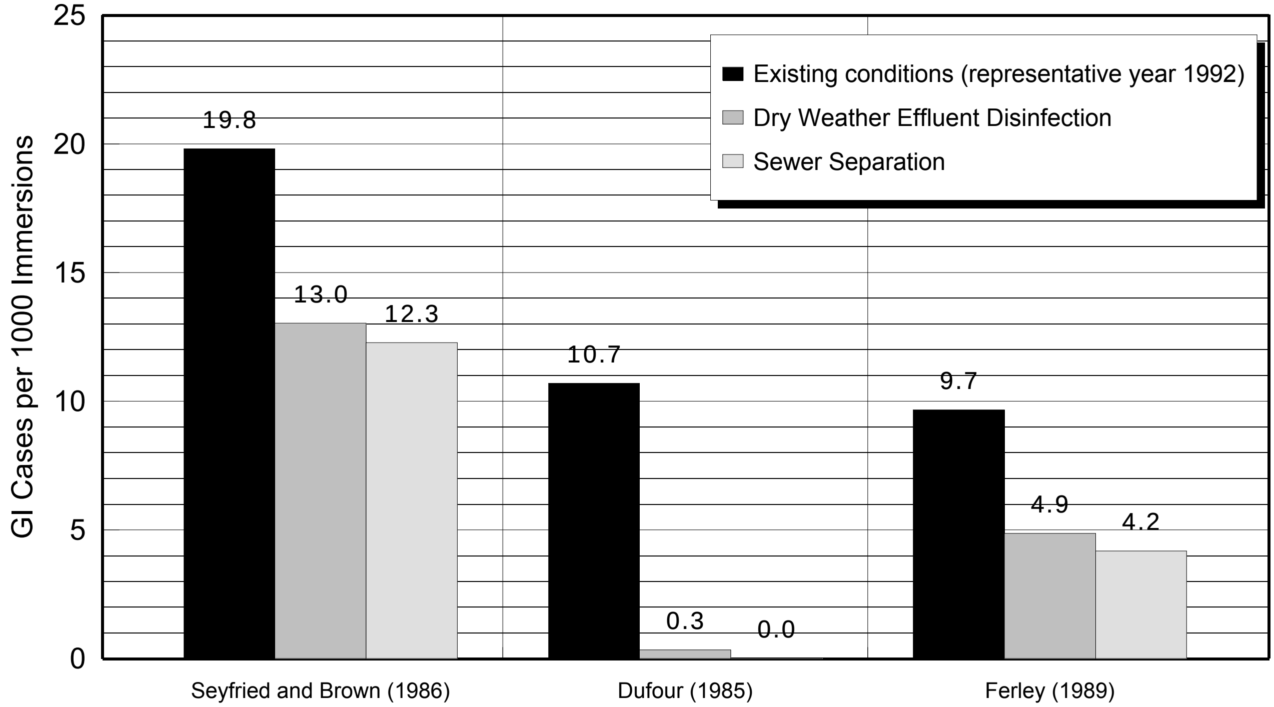
4.2.1 Exposure

In December 1992, the City of Winnipeg conducted a survey to determine the extent that river water is used as a raw water source for greenhouse operations. The survey obtained information from 40 greenhouse growers identified as being within the study area. The results were:

- Operation
  - Twenty-one of the 40 greenhouse growers in this region reported that they operate their greenhouses seasonally for approximately 5 or 6 months of the year (early February to

Estimated Health Risk Rates For Winnipeg River Use

for Indentified Pollution Control Options



Estimated Health Risk Rates For Selkirk River Use

for Indentified Pollution Control Options

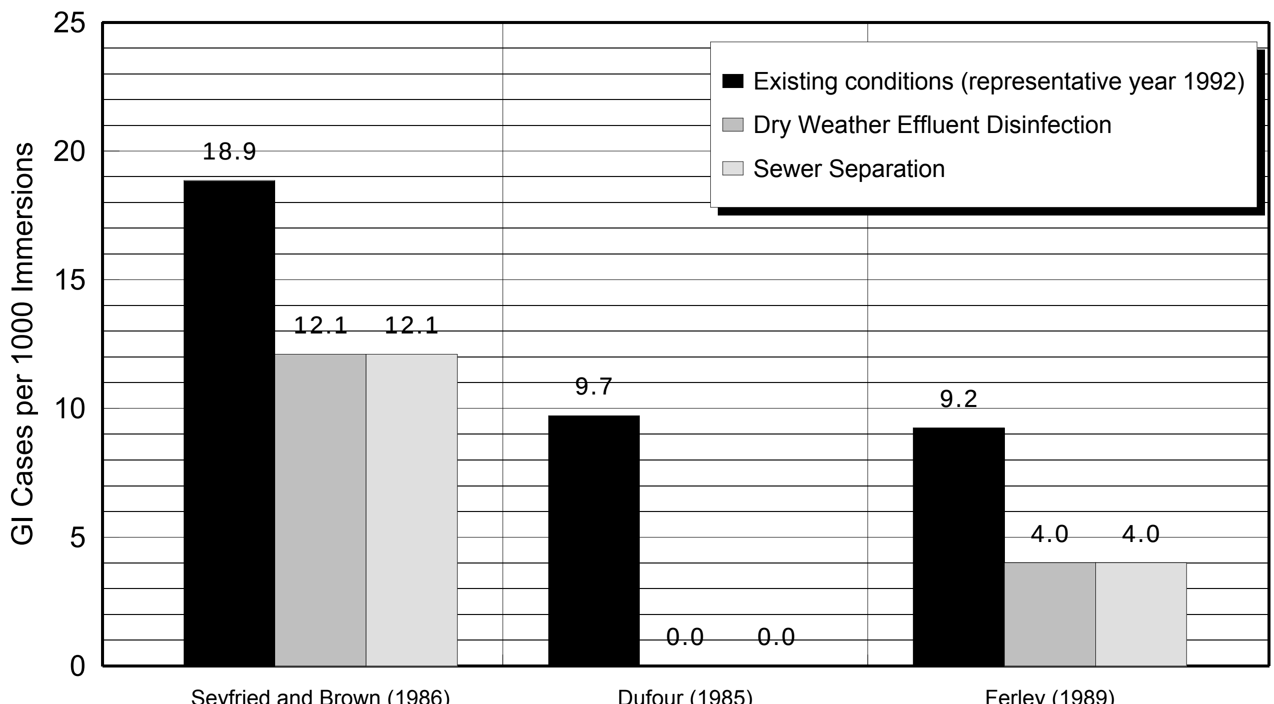


Figure 1-5

late June). All 21 growers produce bedding plants that are intended for sale in the spring season.

- The remaining 19 growers operate their greenhouse business year-round (i.e., 9 months or more). Of these year-round greenhouses, 17 of them grow bedding plants, other ornamental plants such as trees and shrubs, tropical plants and potted flowers (i.e., poinsettias and other special occasion specialties). Two of the 19 year-round operations grow a variety of field crops for agricultural research purposes.
- None of the growers surveyed were using greenhouse space for the production of edible crops (i.e., tomatoes, lettuce, cucumbers, etc.) for direct sale to market.

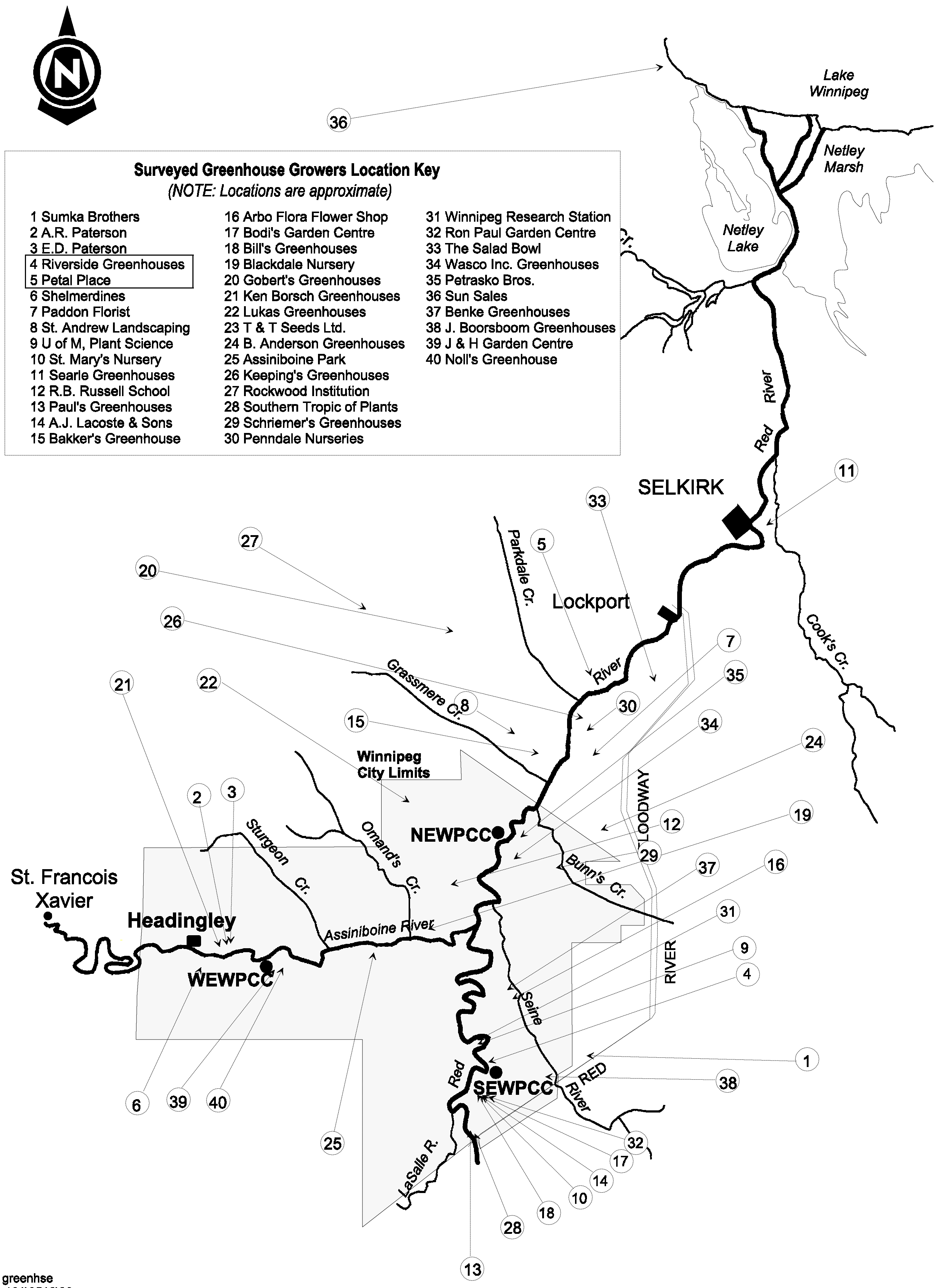
- Proximity to Rivers
  - The majority of the greenhouse growers within the study area are located relatively close to either the Red, Assiniboine or Seine Rivers. Although some of the greenhouse operators use the rivers for greenhouse irrigation, the majority of greenhouse operations (approximately 85%) do not use the river due to access restriction (due to recently established river-front developments).

- Use of River Water
  - Seven of the 40 greenhouse growers contacted indicated that they used river water for a portion of their operating season.
  - Withdrawal of irrigation water by greenhouse operators indicates an opportunistic seasonal pattern which is based on the ability to readily withdraw river water during the open water season (April to November).
  - Two of the seven operations may potentially benefit from disinfection of treated effluent from the City of Winnipeg Water Pollution Control Centre (see Figure 1-6).
  - There is only one irrigator located in the RM of St. Andrews, who would be potentially affected by high coliform counts as a result of wet-weather overflow conditions.

4.2.2 <u>GI Disease Caseload Reduction</u>

The D-R models used for recreation cannot directly be used for estimating risk from exposure to irrigation, since they are based on ingestion of water. The risk associated with irrigation was estimated by assuming a situation as described below:

Area Locations of Surveyed Greenhouse Operations



greenhse
s\01\0510\38

Figure 1-6

- the irrigator will use a spray-irrigation method which applies 1 inch of water in a day (0.025 m);
- this represents a volume of water of 250 m^3/ha applied to 1 hectare;
- approximately 0.1% of spray irrigation is vapourized (Health and Welfare Canada 1984); therefore, about 0.25 m^3 of water is in vapour above the specific hectare;
- to estimate the density of aerosol, all of the aerosol was assumed to remain in a volume 3-m high above a 1 ha base. This represents a volume of air of 30,000 m^3/ha. The aerosol density or water vapour represents about .001% of the air volume;
- it is estimated that during an 8-hour period a worker inhales 12 m^3/8 h (Conway 1982); therefore, the worker will inhale 0.1 L of aerosol or 100 mL of water vapour but highly diluted (10^{-5}) in the air;
- this is approximately equivalent to the water a recreational swimmer would ingest in one immersion event, but at greatly reduced concentrations of organisms (10^{-5}). It is estimated that the irrigation risk to the worker is much less than the equivalent of one immersion event/year from recreational use.

The estimated risk, from the above analysis is therefore, very very low. The analysis done above is inherently conservative. It assumes that a worker is continually working in the mist during the irrigation. This assumption also assumes that the entire day's aerosol is contained within a stationary volume and does not settle to the ground or disperse across a larger area. It should also be noted that water vapour in an aerosol form would allow the pathogens to be exposed to considerable ultraviolet radiation which would cause a rapid die-off of the pathogen. Therefore, the actual concentration of pathogen in the aerosol would likely not be as high as in the river water.

The study team concludes that the probable health risk associated with irrigation under current conditions is so low as to be unable to be reliably quantified. Accordingly, any benefits to irrigation from CSO control will not be measurable. This assessment also applies to instances of golf course irrigation, children playing near sprinklers using river water, etc. There is some risk from such exposure to non-potable water but the risks are too low to be quantifiable.

In terms of direct contact of the worker with river water, the best protection is to practise good personal hygiene, i.e., washing hands with soap and water.