

Preliminary Design Report

**City of Winnipeg
Water and Waste Department
Nitrification Study**

Prepared for:

City of Winnipeg
Water and Waste Department
1500 Plessis Road
Winnipeg, Manitoba R2C 5G6

Prepared by:

Earth Tech (Canada) Inc.
850 Pembina Highway
Winnipeg, Manitoba R3M 2M7
Phone: (204) 477-5381
Fax: (204) 284-2040

November 2002

Project No. 62340.00 [49919]

Table of Contents

SECTION	TITLE	PAGE NO.
TABLE OF CONTENTS		
1.0	INTRODUCTION	
1.1	Nitrification Study Background and Objective.....	1-1
1.1.1	Background.....	1-1
1.1.2	Objective.....	1-2
1.2	Purpose and Objectives of Preliminary Design Phase	1-3
2.0	FACILITY PLANNING FRAMEWORK	
2.1	Introduction.....	2-1
2.1.1	General.....	2-1
2.1.2	Planning Horizons	2-1
2.1.3	Allowances for Future Conditions	2-2
2.2	Flow and Load Projections	2-2
2.2.1	General.....	2-2
2.2.2	City of Winnipeg Projections	2-2
2.2.3	Historic Flows and Loads	2-6
2.2.4	Unit Flows	2-12
2.2.5	Unit Loads	2-15
2.2.6	Diurnal Flow Variations	2-19
2.2.7	Projected Flows and Loads	2-26
2.2.8	Synthetic Flow Distribution.....	2-28
3.0	EXPERIENCE ELSEWHERE	
3.1	Preamble	3-1
3.2	Nitrification Technology Review	3-1
3.2.1	Canada	3-1
3.2.2	USA	3-4
3.2.3	Europe.....	3-7
3.2.4	Asia	3-10
3.2.5	Australia.....	3-10
3.3	Regulatory Trends Towards Nitrification and Nutrient Removal	3-10
3.3.1	Preamble	3-10
3.3.2	Canada	3-10
3.3.3	USA	3-18
3.3.4	Europe.....	3-19
3.3.5	Asia	3-21
3.4	Regulatory Trends Towards Nitrification of WWFs & CSOs.....	3-21
3.4.1	Canada	3-21
3.4.2	USA	3-22
4.0	NITRIFICATION TECHNOLOGY REVIEW	
4.1	Preamble	4-1
4.2	Nitrification Theory	4-1
4.3	Possible Nitrification Technologies	4-2

SECTION	TITLE	PAGE NO.
5.0	NITRIFICATION/BNR TECHNOLOGY REVIEW	
5.1	Introduction.....	5-1
5.2	Biological Nitrogen Removal	5-1
5.3	Biological Nitrogen Removal Processes.....	5-2
5.4	Biological Phosphorus Removal.....	5-3
5.5	Biological Phosphorus Removal Processes	5-4
5.6	Biological Phosphorus and Nitrogen Removal Processes	5-5
5.7	Summary.....	5-6
6.0	CANDIDATE TECHNOLOGIES	
6.1	Preamble	6-1
6.2	Candidate Nitrification Technologies	6-1
6.2.1	Initial Short Listing.....	6-1
6.2.2	Preliminary Designs of Technologies.....	6-7
6.2.3	Refined Short Listing.....	6-10
6.2.4	Short Listed Technologies	6-18
6.3	Candidate BNR Technologies	6-19
6.3.1	NEWPCC and SEWPCC	6-19
6.3.2	WEWPCC	6-22

LIST OF TABLES

Table 2.1	Population Projections.....	2-3
Table 2.2	Predicted Wastewater Unit Flows (L/c/d, Average Annual).....	2-5
Table 2.3	Flow Characteristics – 1995 to 1998.....	2-7
Table 2.4	Seasonal Flows – 1995 to 1998.....	2-8
Table 2.5	Plant Loads – 1995 to 1998.....	2-10
Table 2.6	Seasonal Plant Loads – 1995 to 1998.....	2-11
Table 2.7	Ratio of Seasonal Plant Loads to Average Plant Loads	2-12
Table 2.8	Unit Flows – 1995 to 1998.....	2-13
Table 2.9	Comparison Between Actual and Conservative Unit Flows	2-14
Table 2.10	Unit Loads – 1995 to 1998	2-16
Table 2.11	Comparison Between Actual and Conservative Unit Loads	2-18
Table 2.12	NEWPCC Design Flows and Loads.....	2-26
Table 2.13	SEWPCC Design Flows and Loads	2-27
Table 2.14	WEWPCC Design Flows and Loads.....	2-28
Table 3.1	Typical NH ₃ -N and Total N Limits Specified in Selected Jurisdictions in Canada	3-23
Table 3.2	Typical NH ₃ -N and Total N Limits Specified in Selected Jurisdictions in USA	3-24
Table 3.3	Typical NH ₃ -N and Total N Limits Specified in Selected Jurisdictions in Europe.....	3-25
Table 3.4	Typical NH ₃ -N and Total N Limits Specified in Selected Jurisdictions in Asia.....	3-26
Table 3.5	Typical NH ₃ -N and Total N Limits Specified in Selected Jurisdictions in Australia ..	3-26
Table 6.1	NEWPCC – Summary of Short-Listed Ammonia Removal Options	6-8
Table 6.2	WEWPCC – Summary of Short-Listed Ammonia Removal Options.....	6-8
Table 6.3	SEWPCC – Summary of Short-Listed Ammonia Removal Options	6-9
Table 6.4	NEWPCC – Cost Estimates for Short-Listed Ammonia Removal Options	6-9
Table 6.5	SEWPCC – Cost Estimates for Short-Listed Ammonia Removal Options	6-9
Table 6.6	WEWPCC – Cost Estimates for Short-Listed Ammonia Removal Options	6-10
Table 6.7	Summary of Scoring of Alternatives.....	6-13

SECTION	TITLE	PAGE NO.
Table NE-1.1	Single Stage Nitrification at the NEWPCC	6-27
Table NE-2.1	HPO RAS Reaeration at the NEWPCC	6-32
Table NE-3.1	Second Stage Nitrifying Trickling Filters at the NEWPCC	6-36
Table NE-4.1	RAS Reaeration at the NEWPCC	6-41
Table NE-5.1	Periodic Chlorination at the NEWPCC	6-45
Table SE-1.1	Single Stage Nitrification at the SEWPCC	6-49
Table SE-2.1	RAS Reaeration at the SEWPCC	6-53
Table SE-3.1	Second Stage Nitrifying Trickling Filters at the SEWPCC	6-57
Table SE-4-1	RAS Reaeration at the SEWPCC	6-63
Table SE-5.1	Single Stage Nitrification at the SEWPCC	6-66
Table WE-1.1	Single Stage Nitrification at the WEWPCC	6-71
Table WE-2.1	Step Feed Nitrification at the WEWPCC	6-75
Table WE-4.1	CEPT with Single Stage Nitrification at the WEWPCC	6-83
Table WE-5.1	Ammonia Reduction by Chlorination at the WEWPCC	6-87
Table NEC-1.1	Centrate Biological Treatment System at the NEWPCC	6-91

LIST OF FIGURES

Figure 2.1	Diurnal Flow at NEWPCC, Dry Weather Periods, 1996	2-19
Figure 2.2	Diurnal Flow at NEWPCC, Dry Weather Periods, 1999	2-20
Figure 2.3	Diurnal Flow at NEWPCC, High Flow Periods, May 1999	2-21
Figure 2.4	Diurnal Flow Pattern at SEWPCC, Dry Period.....	2-22
Figure 2.5	Diurnal Flow Pattern at SEWPCC, Wet Period	2-23
Figure 2.6	Diurnal Flow Pattern at WEWPCC, Dry Period	2-24
Figure 2.7	Diurnal Flow Pattern at WEWPCC, Wet Period.....	2-25
Figure 5.1	Biological Nitrogen Removal Processes	5-7
Figure 5.2	Biological Phosphorus Removal Processes.....	5-8
Figure 5.3	Primary Sludge Fermenter Configurations.....	5-9
Figure 5.4	Nitrogen & Phosphorus Removal Processes	5-10
Figure 6.1	Upgrade of HPO Single Stage Nitrification Process to BNR.....	Following Page 6-20
Figure 6.2	Upgrade of HPO RAS Reaeration Nitrification Process to BNR.....	Following Figure 6.1
Figure 6.3	Upgrade of HPO Second Stage NTF Process to BNR	Following Page 6-21
Figure 6.4	Upgrade of Single Sludge Nitrification Process to BNR	Following Page 6-23
Figure 6.5	Upgrade of Step Feed Nitrification Process to BNR.....	Following Figure 6.4
Figure 6.6	Upgrade of Tertiary Lagoons to BNR.....	Following Page 6-24
Figure NE-1.1	Single Stage Nitrification at the NEWPCC	6-26
Figure NE-1.2	NEWPCC HPO Single Stage Nitrification	Following Page 6-26
Figure NE-2.1	HPO RAS Reaeration at the NEWPCC	6-31
Figure NE-2.2	NEWPCC HPO RAS Reaeration	Following Page 6-31
Figure NE-3.1	Second Stage Nitrifying Trickling Filters at the NEWPCC	6-35
Figure NE-3.2	NEWPCC Second Stage NTF	Following Page 6-35
Figure NE-4.1	RAS Reaeration at the NEWPCC	6-40
Figure NE-4.2	NEWPCC Periodic CEPT With RAS Reaeration	Following Page 6-40
Figure NE-5.1	Process Flow Schematic – NEWPCC Breakpoint Chlorination for Ammonia Removal	6-44
Figure SE-1.1	Process Flow Schematic – SEWPCC Single Stage Nitrification	6-48
Figure SE-1.2	SEWPCC Second Stage Nitrification	Following Page 6-48
Figure SE-2.1	RAS Reaeration at the SEWPCC	6-52
Figure SE-2.2	SEWPCC HPO with RAS Reaeration.....	Following Page 6-52

SECTION	TITLE	PAGE NO.
Figure SE-3.1	Second Stage Nitrifying Trickling Filters at the SEWPCC	6-57
Figure SE-3.2	SEWPCC Second Stage NTF.....	Following Page 6-57
Figure SE-4.1	RAS Reaeration at the SEWPCC	6-63
Figure SE-4.2	SEWPCC CEPT With RAS Reaeration	Following Page 6-63
Figure SE-5.1	Process Flow Schematic – SEWPCC Breakpoint Chlorination	6-66
Figure WE-1.1	Process Flow Schematic – WEWPCC Single Stage Nitrification.....	6-70
Figure WE-1.2	WEWPCC Single Stage Nitrification	Following Page 6-72
Figure WE-2.1	Process Flow Schematic – WEWPCC Step Feed	6-74
Figure WE-3.1	Ammonia Concentration in Lagoon Effluent (monthly average).....	6-79
Figure WE-4.1	Process Flow Schematic – WEWPCC CEPT/Single Stage Nitrification.....	6-82
Figure WE-5.1	Process Flow Schematic – WEWPCC Breakpoint Chlorination	6-86
Figure NEC-1.1	Centrate Biological Treatment System at the NEWPCC	6-90
Figure NEC-1.2	NEWPCC Centrate Treatment – Biox Unit	Following Page 6-90
Figure NEC-2.1	Centrate Treatment – Ammonia Stripping & Recovery at the NEWPCC	6-95
Figure NEC-2.2	NEWPCC Centrate Treatment – Ammonia Stripping Recovery	Following Page 6-95