Watershed Characterization
Ausable Bayfield Maitland Valley
Source Protection Region

Module 1

Version 1.1
March 2008

DRAFT REPORT FOR CONSIDERATION OF THE AUSABLE BAYFIELD MAITLAND VALLEY SOURCE PROTECTION COMMITTEE

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FORWARD

At the meeting of March 26, 2008, the Source Protection Committee received this report. The reader should understand that this document was written in keeping with guidelines from the province and is intended **for information only.** The document acknowledges data gaps, and recounts historical information which may no longer reflect the current situation. The document does not form part of the Assessment Report.

INTRODUCTION

The Clean Water Act, which received Royal Assent on October 19, 2006, is part of the Ontario government's plan to implement recommendations from the Walkerton Inquiry and the O'Connor Report. Justice O'Connor concluded that a multi-barrier approach was the most effective method to prevent contamination from affecting drinking water. This approach includes taking action to prevent the contamination of sources of water, using adequate water treatment and distribution systems, water testing and training of water managers.

The Clean Water Act sets out a framework to identify and assess risks to the quality and quantity of drinking water sources, and to rank these risks from those requiring immediate action, to those which require monitoring to prevent elevation to a higher risk, to those risks which are negligible. The legislation also mandates the development of a source protection plan which sets out how the risks will be addressed. The plan will be carried out through official plans and other planning or regulatory requirements. Any activity that poses a significant risk to a drinking water source may be prohibited or require a site specific risk management option.

The Watershed Characterization for the Ausable Bayfield Maitland Valley Source Protection Region is one of a set of modules that will help the local Source Protection Committee and regional working groups to prepare an Assessment Report and a source water protection plan. It is the aim of this document to compile information on the physical, sociological and economic characteristics of the Ausable Bayfield Maitland Valley watersheds. Information will be updated as knowledge and data gaps are prioritized and filled, and used for other modules. It is anticipated that a Map Book will be produced in the future to include all the maps required for the Watershed Characterization, Conceptual Water Budget, Tier 1 Water Budget and other modules, and will encompass up-to-date data.

ABBREVIATIONS AND ACRONYMS

ABCA	Ausable Bayfield Conservation Authority
ABMV	Ausable Bayfield Maitland Valley
ACLA	Ashfield Colborne Lakeshore Association
BRFU	Basin Runoff Forecasting Unit
CA	Conservation Authority
CCME	Canadian Councils of Ministers of the Environment
CURB	Clean Up Rural Beaches Program
DWSP	Drinking Water Source Protection
IPZ	Intake Protection Zone
LHPWSS	Lake Huron Primary Water Supply System
LOWESS	Logically weighted regression
MOE	(Ontario) Ministry of the Environment
MNR	(Ontario) Ministy of Natural Resources
MVCA	Maitland Valley Conservation Authority
MYLOW	My Land, Our Water Project
OMAFRA	Ontario Ministry of Agriculture, Food and Rural Affairs
PGMN	Provincial Groundwater Monitoring Network
PWQMN	Provincial Water Quality Monitoring Network
SPR	Source Protection Region
VA	Vulnerable Areas
WAT	Water Action Team (Maitland Valley)
WHPA	Wellhead Protection Area
WPSC	Water Protection Steering Committee (Huron County)

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Chapter 1

WATERSHED DESCRIPTION

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Prepared by

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1 Watershed Description

The *Watershed Description* uses existing information to summarize the watershed's fundamental natural and human-made characteristics, their status and trends. It provides context and support for future technical studies and public consultations and identifies major information gaps. The table of contents is a standard one from Ontario Ministry of the Environment and arranged by topic. Minor reorganization allows presentation by component watersheds for a more composite picture. Gaps are identified at the end of the chapter.

1.1 Overview of Source Protection Planning Region

In Part Two of the Report of the Walkerton Inquiry, Justice O'Connor recommended protection and enhancement of natural systems as one of the most effective means to protect the safety of Ontario's drinking water. He stressed the need for water protection planning to fit the functioning of the natural systems (O'Connor 2002). Since the fundamental unit for water's natural functioning is the watershed, watershed-based planning was a key recommendation. Conservation Authorities, as watershed-based jurisdictions, are well-suited to coordinate source protection planning. For optimum efficiency, the expert advisory committee on watershed-based source protection planning proposed that adjacent Conservation Authorities with similar natural functions and comparable source protection issues be grouped into a planning region (Implementation Committee 2004).

1.1.1 Drinking Water Source Protection Planning Region

The Ausable Bayfield and Maitland Valley Conservation Authorities (ABCA and MVCA) form a drinking water source protection planning region, the Ausable Bayfield Maitland Valley Source Protection Region. Their jurisdictions abut and their major rivers flow into Lake Huron. Their watersheds share common patterns of landscapes and natural systems. Their towns are small; their economies are based on agriculture, a growing and diverse manufacturing sector and Lake Huron-focused tourism.

Table 1-1 briefly outlines the watersheds and Conservation Authorities. WC Map 1-1 shows their locations. The planning region includes several independently functioning watersheds.

Table 1-1: Conservation Authorities within the Source Protection Planning Area: Basic Information

	Ausable Bayfield	**Maitland Valley**
Watersheds	Ausable, Bayfield, Parkhill, numerous small watercourses outletting to Lake Huron	Maitland (including South Maitland, Middle Maitland, Little Maitland , North Maitland and Lower Maitland), Nine Mile River and numerous short streams along Lake Huron
Brief Description	Level, fertile agricultural area. High livestock concentration. Limited upstream natural areas and extensive artificial drainage. Forested river gorges and highly significant dune ecosystem. Watershed Area = 2440 km^2 Population = 45,000 Population Density = 18.44 people/km^2	Level to rolling fertile agricultural area. Very high livestock concentration. Limited natural areas and extensive artificial drainage in the south and east. More natural area to the north. Watershed Area = 3266 km^2 Population = 60,000 Population Density = 18.37/km^2
History Outline	Ausable River Conservation Authority formed in 1946 (first Conservation Authority) to deal with serious problems of local flooding, soil erosion, water supply and water quality. 1950s projects included flood control, erosion control, land purchases and Morrison Dam construction in 1959. In the 1960s, education projects and the construction of Parkhill Dam occurred. In the 1970s, flood control, erosion control and property purchases continued. The Bayfield watershed joined in 1972 and the CA name changed accordingly. 1980s brought more focus on water quality; 1990s added funding challenges and more partnerships. Since 2000, projects have dealt with private land stewardship, species-at-risk, source water protection and groundwater.	Formed in 1951, the original jurisdiction covered only the Middle Maitland. In 1961, Maitland Valley Conservation Authority was established covering the whole Maitland watershed. In 1972, 1975, and 1976 a series of enlargements added shoreline streams and Nine Mile River. Early projects included land acquisition and flood control engineering. In the 1980s, flood warning and education were added. The 1990s brought a focus on ecosystem health and functioning. The 2000s added watershed partnerships, restoration and water quality emphases (MVCA 2003).
Vision	Clean and usable watersheds where human needs and the needs of the natural environment are balanced to ensure quality of life and biological diversity today and in the future (ABCA Conservation Strategy 1993).	Maintained essential natural processes and life-support systems, preserved biological diversity, and sustainable use of ecosystems (MVCA Conservation Strategy 1989).
Mandate	To provide leadership and management, in cooperation with the community, to maintain and enhance the watershed resources now and in the future (ABCA Conservation Strategy 1993). The Programs and Services offered by the ABCA are designed to work in partnership with the landowners, municipalities and governments (provincial and federal) in managing the soil and water resources of the watershed. Each partner plays an important role in the conservation of our natural lands and waters.	To establish and undertake a program that will promote and enhance the conservation, restoration, development and management of renewable natural resources associated with water, land and people (MVCA 1984).

1.1.2 Stakeholders and Partners

Source protection planning will use a broad scale, interdisciplinary approach to manage and protect sources of drinking water. Many partners and stakeholders will be involved in the plan development; residents will contribute to and benefit from the plan implementation. Both Conservation Authorities have a strong tradition of working closely with partners in the watershed and a wide network of interested and committed contacts. Among the partners may be:

- Municipalities – the 24 lower tier municipalities (six upper tier) in the planning region provide drinking water from wells or Lake Huron. Many also treat sewage. Local taxes pay to identify wellhead and intake protection zones. All have numerous activities (e.g., road maintenance, zoning) that affect source water protection;

- Health Units – the 6 health units in the planning region administer health promotion and disease prevention programs. Drinking water source protection is basic to their mandate. They are concerned with both drinking water and beach safety;

- Members of the public – both businesses and residents – bring valuable local knowledge and will be implementation partners in their day-to-day actions, community activities and tax contributions. Their input throughout the planning process will make the outcome relevant to their needs and will strengthen their commitment;

- Provincial ministries – the policies and programs of many ministries affect water.

- Adjacent Conservation Authorities – groundwater flows cross Conservation Authority boundaries, extending the coordination of drinking water source protection;

- Federal departments – the Federal Government funds local initiatives, typically research projects involving Conservation Authorities;

- Joint Provincial and Federal Initiatives – Lake Huron Sustainability Framework through MNR, MOE, OMAFRA, and Environment Canada to encourage and support local basin communities;

- First Nations – Kettle and Stoney Point First Nations bring the insights of generations living intimately with land and waters, as well as other First Nations with claims in the region;

- Non-Governmental Organizations – many NGOs have mandates and activities that involve water protection or that have impacts on water protection. They offer in-depth knowledge of issues, valuable liaison with residents and assistance in program implementation.

1.1.2.1 Municipalities

Municipalities are key partners in the assessment of source water protection and are members of the local Conservation Authorities. Municipalities in the planning region are listed in Table 1-2 and located on WC Map 1-1. Table 1-2 also includes key municipal contacts: the clerk and the water manager as well as the county Planning Department contact.

Table 1-2: Municipalities in the Source Water Protection Region

County	Municipalities/Townships/ Towns	Clerk/ Administrator	Planning Dep't Contact	Water/Works Manager
Huron			Scott Tousaw	
	Ashfield – Colborne – Wawanosh	Mark Becker		Bryan Van Osch
	North Huron	Kriss Snell		Ralph Campbell
	Morris/Turnberry	Nancy Michie		Berry O'Krafka
	Howick	Ronna Lee Johnson		Wray Wilson
	Goderich	Larry J. McCabe		Kenneth C. Hunter
	Central Huron	Richard Harding		Steve Gibbings
	Huron East	John R. McLachlan		Barry Mills
	Bluewater	Lori Wolfe		Ross Fisher
	South Huron	Roy Hardy		Don Giberson
Perth			David Hanly	
	North Perth	Mark Urbanski		Matt Ash
	Perth East	Glenn Schwendinger		Bud Markham
	West Perth	Will Jaques		Mike Kraemer
	Perth South	Muriel King		William Doupe
Middlesex			Steve Evans	
	Adelaide-Metcalfe	Fran Urbshott		Eldon Bryant
	Middlesex Centre	Cathy Saunders		Maureen Looby
	North Middlesex	Shirley Scott		Joe Adams
	Lucan Biddulph	Ronald J. Reymer		Steve McAuley
Lambton			Dave Posliff	
	Lambton Shores	John Byrne		Paul Turnbull
	Warwick	Don Bruder		Arnold Syer
Wellington			Gary Cousins	
	Mapleton	Patricia Sinnamon		Sandy Vallance
	Minto	Barbara L. Wilson		Norm Fisk
	Wellington North	Lorraine Heinbuch		Gary Williamson
Bruce			Chris La Forest	
	South Bruce	David Johnston		Donald Jackson
	Huron-Kinloss	Mary Rose Walden		Hugh Nicol

1.1.2.2 Health Units

Medical Officers of Health for the six counties within the source water protection planning region:

Huron: Dr. Beth Henning
Perth: Dr. Rosana Pellizzari
Middlesex: Dr. Graham Pollett
Lambton: Dr. Chris Greensmith (Acting)
Wellington: Dr. Troy Herrick
Bruce: Dr. Hazel Lynn

1.1.2.3 Interested and Engaged Stakeholders

Members of the public are essential participants in drinking water source protection planning. They bring valuable local knowledge and will be implementation partners in their day-to-day actions, community activities and tax contributions. Their input throughout the planning process will make the outcome relevant to their needs and will strengthen their commitment. Stakeholders or groups who have already participated in a watershed planning management activity, committee or rehabilitation project form an initial contact list, Table 1-3.

Table 1-3: List of Stakeholders who have provided past input

County	Business	Contact
Huron	B. M. Ross and Associates	R.R. Anderson
Huron	Maitland Engineering Ltd.	
Huron	Sid Bruinsma Excavating Ltd.	
Huron	McCann Redi-Mix	
Huron	Merner Contracting Ltd.	
Huron	George Radford Constructing Ltd.	
Huron	Vandriel Excavating Ltd.	
Bruce	Bruce-Grey-Huron-Perth-Georgian Triangle Training Board	Virginia Lambdin
Huron	Wescast Industries Inc.	Vicky Skinner
Huron	Huron Manufacturing Associations	Monica Walker-Bolton
Huron	Volvo Motor Graders Inc.	Patrick Olney
Perth	R.J. Burnside & Associates Ltd.	
Perth	Gamsby & Mannerow Ltd.	
Perth	Johnson Engineering	
Bruce	Merlin General Corporation	Rick Goodman
Lambton	Colt Engineering	
Middlesex	M.M. Dillon	Al Mitchell
Perth	Ontario Stone, Sand & Gravel Association	Carol Hochu
Huron	Environmental Geosolutions	Stephen Boles
Perth		Mervyn Erb
Perth		Laura Neubrand
Perth		Patrick Feryn
Bruce		Leslie Nichols
Bruce		Robert Helm
Bruce		Susan Gagne
Wellington		Jeff Jacques
Wellington		Matt Robillard
Lambton		Robert Wellington
Lambton		John Couwenberg
Lambton		Gabrielle Ferguson
Middlesex		Paul Cornwell
Middlesex		Rob Langford

1.1.2.4 Provincial Agencies

Partners with Provincial Government affiliations include:

- Ministry of the Environment (MOE)
- Ministry of Natural Resources (MNR)
- Ontario Ministry of Agriculture and Food (OMAFRA)
- Ministry of Municipal Affairs and Housing (MMAH)
- Ministry of Northern Development and Mining (MNDM)
- Saugeen Conservation Authority
- Grand River Conservation Authority
- St. Clair Region Conservation Authority
- Upper Thames River Conservation Authority
- Conservation Ontario
- Pinery Provincial Park
- Point Farms Provincial Park

These parnerships come both in the form of funding sources and partnerships for delivering programs. Some of the recent provincial programs or studies include:

Managed Forest Tax Incentive Program
The MNR provides a 75% reduction in property tax for forest owners who have more than 10 acres of woodlot and do not receive the farm tax on their property. Conservation Authority staff help landowners to apply for this program by compiling and approving a forest management plan.

Ontario Low Water Response
The program is to ensure provincial preparedness, assist in coordination and support local responses in the event of a drought. Each Conservation Authority has a Low Water Response Team to monitor the water levels and advise the public of voluntary and regulated measures to reduce water consumption. This program is a partnership of MOE, MNR, OMAFRA, MMAH, the Ontario Ministry of Economic Development and Trade, Conservation Ontario and the Association of Municipalities.

Provincial Surface Water Quality Monitoring Network
The program began in the 1960s and up until 1996, the MOE provided funding to the ABCA to collect samples. The program was discontinued for a brief period, and was restarted in 2000. Currently, the ABCA pays for the cost of the sampling and the MOE pays for shipping an lab costs. Eight surface water locations are sampled monthly as part of this program.

Provincial Groundwater Monitoring Network
The MOE, along with Conservation Authorities and municipalities, are partners in developing this strategy to establish an effective water management strategy.

Sinkhole Investigation Study
The MOE provided funding for the completion of this study. The focus of the Ausable Bayfield Sinkhole Investigation is to determine the locations of sinkholes in the study area, map the extent

of karst conditions throughout the region, and develop a plan that addresses potential groundwater quality concerns throughout the region.

Adjacent Conservation Authorities
The Ausable Bayfield and Maitland Valley Conservation Authorities also work in conjunction with neighbouring Conservation Authorities to deliver programs. The ABCA works in partnership with the Upper Thames River, St. Clair Region, Grand River, Long Point, Catfish Creek and Kettle Creek Conservation Authorities with the Middlesex-Oxford-Perth Clean Water Program. Similarily, the Ausable Bayfield and Maitland Valley are partners with the County of Huron in the Huron Clean Water Project.

The ABCA and and MVCA are also members of a Southwestern GIS group. This group includes the conservation authorities of Essex, St. Clair, Upper Thames River, Lower Thames River, Saugeen Valley and Grand River. In addition, the ABCA is part of a 'six CA mapping group" which uses a common internet service provider to display maps through a portal on the internet. The original intent of this group was to display regulation limits and CA propeties, and the group is now developing the ability to share drinking water source protection information through this portal with other partners and stakeholders.

The MVCA and the Saugeen Valley CA were involved in a pilot study called My Land, Our Water (MYLOW), which was developed into a report by Conservation Ontario titled Improving Access to Water Resource Information in Agricultural Watersheds.

1.1.2.5 Federal Government

The Federal Government funds local initiatives, typically research projects coordinated with Conservation Authorities. Recent local water-related projects and their contacts include:

Maitland Watershed Partnerships
In 1999, Human Resources Development Canada provided seed funding to initiate an improvement of self-reliance of organization in the Maitland watershed. This money went to provided facilitators, technical and administrative support. Two groups were formed; the Terrestiral Team, to protect and restore forest health, and Water Action Team, to protect and improve both surface water quality and quantity.

Ausable River Recovery Strategy
The Ausable River Recoverty Strategy began in 2002 to devise a plan to sustain and enhance the natural aquatic communities of the Ausable River. Historically, the river system has supported over 83 fish species, 25 species of freshwater mussel and 21 reptile species. In particular, the Ausable River is home to 14 species at risk including seven fish, four mussels, and 3 reptiles, and the strategy focuses to oversee their continued survival. This program has been funded by the Government of Canada's Habitat Stewardship Program for Species At Risk and has worked in partnership with the National Water Research Institute of Environment Canada.

Federal Fisheries Act, Section 35
The ABCA operates under a Level II Agreement with the Department of Fisheries and Oceans. ABCA Staff review projects that have the potential to create a Harmful Alteration, Disruption or

Destruction to Fish Habitat as defined under the Fisheries Act, with regard for the potential to mitigate the loss of fish habitat.

Zurich Drain Water Quality Enhancement Project
The aim of this project is to improve the water quality in the Zurich Drain through the implementation of Best Management Practices. Approaches include education, outreach, watershed stewardship and water quality monitoring. Funding for this project was received from both Environment Canada and the Ontario Trillium Foundation.

Habitat Stewardship Program
This program (under Environment Canada) provides funding to property owners for implementing activites that protect or conserve habitats for species at risk designated by the Committee on the Status of Endangered Wildlife in Canada. It supports many organizations and individuals interested in the recovery of species at risk.

1.1.2.6 First Nations

First Nation partners adjacent to the planning region and with possible interest are:
- Kettle and Stoney Point First Nation
- Walpole Island First Nation
- Chippewas of Saugeen Ojibwe First Nation

The Walpole Island First Nation (Bkejawong Territory) has made a claim along the bed of Lake Huron from their reserve at Walpole Island to north of the Maitland River. Similarly, the Chippewas of Saugeen Ojibwe First Nation have made a claim of the bed of Lake Huron that extends from their reserve in Southampton to south of the Maitland River. Neither one of these First Nations have been involved with the Ausable Bayfield or Maitland Valley Conservation Authorities.

The reserve of the Kettle Point First Nation is outside of the Source Protection Region in Forest Ontario, however, the former Stoney Point reserve is within the Region. In 1927 and 1928, the shorefront of the property was sold to non-aboriginal interests, and the Department of Defense expropriate the rest of the reserve lands to form the former Military Camp Ipperwash for training during the Second World War. Afterwards, the area became known as the Ipperwash Range and Training Area. Currently, the Stoney Point First Nation has reached an agreement with the federal government to return the expropriated lands to the First Nation and is currently in negotiation with the provincial government over the return of Ipperwash Provincial Park to the First Nation.

Kettle and Stoney Point First Nation has been involved with the Ausable Bayfield Conservation Authority. A drain assessment was undertaken in the former Camp Ipperwash, although subsequent sampling in L-Lake was unable to take place due to the potential presence of IEDs (improvised explosive devices). As well, Kettle and Stoney Point First Nation Hillside School (elementary) has participated in the SWAP (Spring Water Assessment Program) by the ABCA. This spring program teaches children about the river systems and the hazards associated with them.

1.1.2.7 Non Governmental Organizations (NGOs)

Local NGOs that may be interested in source water protection planning are listed below. The capacity each may bring is included.

Ailsa Craig Environmental Group	
Ashfield Colborne Lakefront Association:	Provides information and advocacy for groundwater quality issues and other common concerns of the lakeshore community. Has a partnership with the MVCA to take water samples in small lakeshore streams and provides a volunteer base.
Bluewater Shoreline Residents Association:	Interested in promoting water quality.
Business Improvement Associations:	Work towards improvement and betterment of communities such as the Sarnia-Lambton Business Development and the Huron Business Development Corporation.
Christian Farmers Federation of Ontario:	Chapters in Bruce, Huron, Lambton, Perth, Middlesex, Wellington Counties: Knowledge of local agricultural industry, issues and concerns.
Dairy Farmers of Ontario:	Knowledge of local dairy industry, issues and concerns.
Ducks Unlimited:	Knowledge of wetlands, habitat, hydrological roles of natural areas; project funding.
Huron Fringe Field Naturalists:	Knowledge of local natural areas and species; possible volunteer base.
Ecological Farmers Association of Ontario:	Knowledge of agricultural approaches and techniques that work with nature.
Friends of the Bayfield River:	Knowledge of local area, possible volunteer base, education and water quality focused.
Goderich Port Management:	Knowledge of port issues.
Huron Business Development Centre:	Expertise on local business opportunities.
Huron County Water Protection Steering	*Committee*: The mandate of the Committee is to bring together representatives of the various organizations, agencies and municipalities, to prioritize and recommend implementation measures to participating groups, and to coordinate activities at a broad scale, subject to the resources of the participating organizations (Huron

	County Planning and Development Department, 2005). Representatives on the *Huron County Water Protection Steering Committee* include: Huron County Council, Clerks and Treasurers Association, Local Councillors, Ausable Bayfield Conservation Authority, Maitland Valley Conservation Authority, Ministry of the Environment, Ministry of Agriculture and Food, Huron Federation of Agriculture / Christian Farmers/ Huron Farm Environmental Coalition, Huron Manufacturing Association, Huron Tourism Association, Ashfield Colborne Lakefront Association, Bluewater Shoreline Residents Association, Planning and Development Department, Drinking Water Source Protection, Lake Huron Centre for Coastal Conservation, Ontario Pork Producers, Huron Stewardship Council, B.M. Ross and Associates, and the Huron County Health Unit.
Huron Farm Environmental Coalition:	Knowledge of local agricultural concerns and capacities for Best Management Practices.
Huron County Environmental Farm Plan	A voluntary assessment that is performed by farmers to assess the strength and areas of environmental concern on their farm. Farms with a complete EFP are eligible for certain grants.
Huron County Federation of Agriculture	Farmer-led dynamic lobby to bring the wishes of farmers to the provincial government.
Huron Manufacturing Association	Promotes community support and economic growth within the manufacturing sector.
Huron Stewardship Council	Knowledge of rural stewardship issues; possible project funding; staff person coordinator.
Huron Tourism Association	A resource of business members with a desire to further tourism and promote economic growth and employment opportunities.
Lake Huron Centre for Coastal Conservation	Planning and management of shoreline zone.
Lambton Chapter of the Ontario Woodlot Association:	Knowledge of local woodlots, management techniques and income opportunities; communication link with landowners.
Lambton Wildlife Incorporated:	Knowledge of local natural areas and species; volunteer base; staff.
Lower Maitland Stewardship Group:	Members from diverse backgrounds, with an active interest in maintaining and enhancing the natural ecosystem features of the Lower Maitland River Valley.
Middle Maitland	Volunteer base to do projects within the Middle Maitland

Rejuvenation Committee	subwatershed.
Middlesex Chapter of the Ontario Woodlot Association:	Knowledge of local woodlots, management techniques and income opportunities; communication link with landowners.
Middlesex Stewardship Council:	Knowledge of rural stewardship issues; possible project funding; staff person coordinator.
Nairn Creek Project:	Example of stream rehabilitation and possible volunteer base for other local projects.
National Farmers Union:	Knowledge of farming issues. Encourages economic and social policies to maintain family farm as the primary food-producing unit in Canada.
Perth County Visitors' Association:	Promotes tourism in the area.
Perth Stewardship Council:	Knowledge of rural stewardship issues; possible project funding; staff person coordinator.
Perth-Huron Chapter of the Ontario Woodlot Association:	Knowledge of local woodlots, management techniques and income opportunities; communication link with landowners
Rural Lambton Stewardship Network:	Knowledge of rural stewardship issues; possible project funding; staff person coordinator.
Sarnia Lambton Economic Partnership:	Interested in promoting economic development and in promoting the long-term health of the community.
Sarnia Lambton Environmental Association:	Association is comprised of member industries that are committed to water quality care. Perform plant outflow and river water analyses. Sponsors "Go with the flow" program to introduce groundwater care.
Tourism Sarnia Lambton:	Promotes tourism in the area.
Waterloo-Wellington Chapter of the Ontario Woodlot Association:	Knowledge of local woodlots, management techniques and income opportunities; communication link with landowners.
Wellington Stewardship Council:	Knowledge of rural stewardship issues; possible project funding; staff person coordinator.

1.2 Geological Setting

The foundation of the planning region is a deep layer of sedimentary rock overlaid by unconsolidated material deposited by the Ice Age glaciers.

1.2.1 Bedrock Geology

The Palaeozoic sedimentary rock formations underlying the planning region are shown on WC Map 1-2 and they are approximately 1 km deep. They were deposited near the crest of the Algonquin Arch, a Precambrian ridge underlying Southwestern Ontario and separating the Michigan basin to the northwest and the Appalachian basin to the southeast. The planning region falls on the Michigan basin side. The layers that reach the bedrock surface in the region were deposited in the Silurian and Devonian ages. The Silurian is older and represented by the dolomite Bass Island Formation. Above it, the Devonian-age formations in order are the limestone Bois Blanc Formation, the limestone and dolostone Detroit River Group of the Amherstberg and Lucas Formations, the limestone Dundee Formation and the predominantly shale Hamilton Group. The bedrock tilts gently southwest from the Dundalk Dome northeast of the planning region. The tilt exposes the strata at the bedrock surface in sequence from oldest in the northeast to youngest in the southeast with occasional windows revealing the underlying stratum (Map 1-2). Water-yielding capacities rate as very good for the Bass Island unit, excellent for the Bois Blanc unit, very good for the Detroit River Group, very good for the Dundee unit, and fair for the Hamilton Group (Singer et al. 1997). The Huron Groundwater Study rates the Lucas Formation of the Detroit River Group generally highest yielding (International Water Consultants et al. 2003).

Numerous pre-glacial river valleys interrupt the gentle lake ward slope of the bedrock surface. A rise occurs near Arkona (Dillon Consulting and Golder Associates 2004a) and a valley extends from Parkhill southeast to Lake Erie (Dillon Consulting and Golder Associates 2004b). Bedrock exposures are few. Occasionally, stream courses have cut through the surficial deposits (James F. Maclaren 1977), e.g., at Rock Glen in the Ausable Gorge and in the lower Maitland. Sinkholes occur in several parts of the planning region, most notably in the upper Ausable and Bayfield watersheds (ABCA 1985; Malone 2003; International Water Consultants et al. 2003) (Map 3-7). Bedrock also surfaces in a few spots near Brussels in the Middle Maitland (International Water Consultants et al. 2003) and near Thedford in the Ausable watershed (Dillon Consulting and Golder Associates 2004a).

Documented bedrock uses (Conservation Branch 1949; Conservation Authorities Branch 1967; ABCA 1985) include:

- Building stone near Brussels;
- Bricks and tile from shale in the south (Thedford Quarry);
- Flint nodules from limestone at Stoney Point and traded by First Nations;
- Minor fossil fuel producing areas occur in the south half of the Ausable watershed (1985 Plan); and
- Rock salt and brine at Goderich (Sifto Canada, Goderich Mine) and Seaforth area; brine wells near Brussels.

1.2.2 Quaternary Geology

The overburden that covers the bedrock is unconsolidated sediments deposited during the Quaternary Period. It includes the Pleistocene (Ice Age) and Holocene (Recent) epochs. In the planning region, the glaciers of the most recent Pleistocene stage, the Wisconsian, largely obliterated effects of earlier stages and shaped today's land surface. They left a fine till base for much of the region and a loamier till in the northeast. Coarse textured ice contact stratified drift is also more common in the north. Melt waters deposited a web of glacial sand and gravel spillways, a delta under today's Hay Swamp, as well as several coarse-textured eskers. Glacial lake ancestors of Lake Huron extended across the western and southern parts of the planning region where they deposited beach sands and gravels at shorelines and clay and silt in the deeper areas. More recently, wind-blown (eolian) fine sands have formed dunes, floodplains collected alluvial sediments and organic soils developed from decomposed plant material (MVCA 2004).

The overburden thickness generally deepens to the west, exceeding 60 m in the Wyoming Moraine near Bayfield but thinning out to 20 m or less in the east with some of the shallowest near Brussels (International Water Consultants et al. 2003; MVCA 2004). The depth also decreases to less than 10 m from the Ausable gorge west through Thedford to Port Franks (Dillon and Golder 2004a).

Elma Till of silt, sandy silt and clayey silt is the oldest till in the region and surfaces in the east part of the planning region. The more recent Rannoch Till, a stonier silt to silty clay till, covers the central part. The most recent silt to silty clay St. Joseph Till covers the Rannoch Till near the shore and forms the Wyoming Moraine and shore bluffs. The more resistant Rannoch Till below helps to stabilize much of the shoreline. Fine sediments from eroded bluffs are deposited offshore; sands travel south along the shore to form beaches, dunes and bars. Sand and gravel beaches from the glacial Lake Warren parallel today's shore. Beaches from the later Lakes Nipissing and Algonquin have eroded away at the bluffs to become the sand of the Pinery dunes and beaches (ABCA 1985).

Generalized cross sections – both county-wide and in local municipal well areas - are presented in each of the county groundwater studies (Dillon Consulting and Golder Associates 2004: a,b; International Water Consultants et al. 2003; Waterloo Hydrogeologic 2003: a,b; Burnside Environmental 2001: a,b). They show confining units (low permeability silts and clays), sand and gravel units, and bedrock.

1.3 Hydrology

1.3.1 Watershed Form and Surface Hydrology

Physiography, topography and soils are interrelated factors affecting a watershed's surface hydrology. Rainfall easily infiltrates the coarse textured deposits of kame moraines, eskers and spillways and, as groundwater, steadily discharges from these units to maintain stream flows. Rainfall on clay till, both plains and moraines, however, tends to flow over the surface to generate spikes of flow during storms but little on-going base flow. The coarse textured units increase northward in the planning region, as do the base flows and incidence of cold water streams. The discussion uses a watershed-based format to make the links of physiography, topography and soils with surface hydrology. The main watersheds are Ausable River, Bayfield River, Maitland River, Nine Mile River, Shore Streams and Gullies. Physiography (Chapman and Putnam 1984) is presented on Map WC 1-3; surface hydrology features are shown on WC

Map 1-4. Table 1-4 lists some basic statistics by watershed. Further information on watershed hydrology is listed in the Conceptual Water Budget for the Ausable Bayfield Maitland Valley Source Protection Region.

Table 1-4: Basic Surface Hydrology Statistics by Watershed

	Ausable	Bayfield	Maitland	Nine Mile	Shore
Watershed Area (km^2)	1233	497	2572	243	692
Streams and quaternary codes * direct outlet to Lake Huron	Ausable*: 2FF-03 Parkhill*: 2FF-04 Little Ausable: 2FF-05 Mud Creek*: part of 2FF-02	Bayfield*: 2FF-07 Bannockburn: 2FF-08	Maitland*: 2FE-02 South Maitland: 2FE-03 Middle Maitland: 2FE-04 Little Maitland: 2FE-05	Nine Mile*: 2FD-06	Many*:2FF-06 Many*:2FE-01 Many*:2FD-07 Many*:2FD-05 Eighteen Mile*: 2FD-04
% kame, sand plains, beach, esker, spillway	kame: 0.17 sand plains: 8.06 beach: 2.35 esker: 0.00 spillway: 6.76	kame: 0.63 sand plains: 0.52 beach: 0.03 esker: 0.17 spillway: 8.74	kame: 8.79 sand plains: 0.24 beach: 0.05 esker: 0.92 spillway: 21.06	kame: 34.49 sand plains: 0.66 beach: 0.26 esker: 0.00 spillway: 2.44	kame: 0.00 sand plains:17.41 beach: 3.43 esker: 0.00 spillway: 4.05
% poorly drained soil	82.71	67.88	27.30	28.92	78.75
Main River Gradient (m/km)	Ausable: 0.90 Parkhill: 1.03 Little Ausable: 2.22	Bayfield: 2.08 Bannockburn: 2.42	Maitland: 1.61 South Maitland: 1.79 Middle Maitland: 1.13 Little Maitland: 1.49 North Maitland: 1.43	Nine Mile: 2.54	Eighteen Mile: 3.84
Main river length (km)	Ausable: 163 Parkhill: 76 Little Ausable: 39	Bayfield: 82 Bannockburn: 39	Maitland: 80 South Maitland: 57 Middle Maitland: 95 Little Maitland: 72 North Maitland: 84	Nine Mile: 56	Eighteen Mile: 30
Drainage Density (km/km^2)	1.08	0.88	1.12	1.44	1.21
Cold Water Stream Density (km/km^2)	0.08	0.22	0.29	0.46	0.17
Municipal Drain Density (km/km^2)	0.69	0.64	0.15	0.11	0.49
Main River Base Flow Index					

<u>Ausable River </u>(Figure 1-1)
The basin includes the watersheds of the Ausable River, Parkhill Creek, Mud Creek and Dune area (see Map 1-1). The total area is 1233 km^2 in the shape of a broad J. The Ausable takes its name from the shifting sands at its mouth. The Ausable River begins near Staffa and flows south to Ailsa Craig where it makes a wide arc to the west. The main tributaries include Black Creek, the Little Ausable River and Nairn Creek.

Physiography (WC Map 1-3)
The watershed is shaped by J-shaped till moraine ridges flanking plains of fine till. Glacial meltwater deposited the spillway skirting the Seaforth Moraine and formed a large outwash delta under today's Hay Swamp. Glacial lakes accumulated sand and clay plains over till and left linear beach remnants. Lake Huron eroded sand from shore bluffs to the north and deposited it to form the southern sand plain where lake winds shaped the extensive dune system that sheltered a large lagoon. Natural processes of coastal erosion and accretion continue today (Chapman and Putnam 1984; Donnelly 1994).

Topography
Ausable's till plains are almost level. The moraines are more rolling but rarely more than gently sloping. The undulating topography around Arkona supports orchards. The steepest slopes occur where streams dissect moraines, most notably the Ausable Gorge. The sand dunes of the Port Franks-Pinery area also have steep slopes, in sharp contrast to the adjoining level lagoon bed (Conservation Branch 1949).

Soils
The clay soils of the till plain and moraines are mainly Huron/Perth/Brookston series, and are high capability soils for agriculture. Imperfectly drained Perth and poorly drained Brookston dominate on more level areas; well drained Huron occurs on the moraine slopes. Soils in some spillway areas have developed on sands (Bookton, Berrien, Wauseon). The glacio-lacustrine clays extending up the river valley form the high capability Brantford/Beverly/Toledo catena. Heavy and wet Blackwell clay with thinning patches of muck sits on the old lagoon bed. The dunes are low fertility and low moisture holding Plainfield sands. Soil compaction is a common problem in the watershed. Much of the basin rates a severe water erosion risk given the soils and intensive land use. The many tile outlets and extensive channelization aggravate bank erosion (Snell and Cecile et al. 1995).

The Ausable watershed is dominated by soil group C, slow drainage, which suggests higher levels of runoff from these lands. The Old Ausable Channel area is characterized by soil group A, which has rapid drainage, although the areas south and west Port Franks are dominated by soil group D, very slow drainage (see CWB Map 6 Soils).

Surface Hydrology (WC Map 1-4)
The Ausable is 145 km long (ABCA 1985). The main stem and its major tributary, the Little Ausable, are both directed by the parallel moraines, both following the spillway pattern of their much larger post-glacial river ancestors, and both generally oriented in a J shape. Most tributaries enter from the outside of the J and tend to form short fan patterns as they flow off the moraine divide. When the Ausable finally breaches the broad Wyoming Moraine, it carves a gorge about 40 m deep, exposing fossil-bearing deposits. The river emerges first onto the sand plain of glacial Lake Warren, then down the Algonquin beach to the lagoon bed flats.

At European settlement, the river meandered northward through the lagoon flats to today's Grand Bend where, within sight of the lake, it made a "grand bend" to flow another 15 km parallel to the shore between the dunes before outletting near today's Port Franks. The sands there were unstable and shifting as was the river mouth. Picturesque small lakes that form part of the Port Franks Forested Dunes and Wetlands Complex are remnants of former channels (Donnelly 1994) and Mud Creek likely formed an Ausable tributary.

Even before forest clearance, the large volume of snowmelt and spring rains swelled the river system to much higher flows in the spring than in mid-summer. The flooding replenished the lagoon flats, which acted as a sediment trap and nourished large numbers of migratory waterfowl. By the 1870's, upstream land clearance had aggravated the natural flooding and as interest in settling and farming the lagoon flats grew, techniques to drain them and relieve flooding were sought. Between 1873 and 1875, a channel was excavated to divert the river straight through the dunes (known as 'The Cut') and to drain two of the three lagoon flats' lakes, Lake George and Lake Burwell (Donnelly 1984).

The Parkhill Creek watershed is cupped in the crook of Ausable's J and mirrors the Ausable on a smaller scale. Like the Ausable, other tributaries are predominantly from the outside of the J forming short fan patterns as they flow off the moraine divide. The main such tributary is Ptsebe Creek. The Parkhill was originally a tributary of the Ausable but after The Cut, the severed original lower Ausable channel became the lower extension of Parkhill Creek. In 1892, another constructed channel diverted Parkhill Creek straight to the lake at Grand Bend, cutting off the reach through the dunes. Today this reach, known as the Old Ausable Channel (OAC), is fed only by adjacent runoff and seepage through the sands as it flows very slowly southward into the modified Ausable outlet (Snell and Cecile et al. 1995). The OAC, no longer part of the Ausable or Parkhill rivers, is characterized by clear water and dense aquatic vegetation. Due to its lack of flow, the old river channel seems to be converting to a more pond like ecosystem that may eventually become less aquatic and more terrestrial. It has been identified as an important ecosystem in the Recovery for Species at Risk Strategy for the Ausable River (Killins 2006). Along the Old Ausable Channel, the tributaries are a set of parallel relatively straight creeks that resemble Shore Gullies and Streams crossing the same physiography.

In 1952 the Conservation Authority straightened, widened and deepened The Cut downstream west of Highway 21 to help deal with on-going flooding. The remaining lagoon, Lake Smith, was drained in the 1960s. Although these measures succeeded in reducing floods, the former lagoon area still retains some of this natural function; buildings and fields are occasionally inundated. Natural processes of ice jam flooding and unstable sands persist at the mouth (Snell and Cecile et al. 1995).

Prior to European settlement, Dr. William 'Tiger' Dunlop, Canada Company Warder of the Forest, noted there were so many streams that every farm would have one (Conservation Branch 1949). Although possibly a sales pitch, today's streams are fewer. The clay soils and level land made drain construction relatively easy and by 1949, the drainage extent had raised concerns about lowered summer flows and drying wells (Conservation Branch 1949). By 1981, municipal drains had multiplied over 10-fold (ABCA 1985) and by 1983 tile drainage was installed in approximately 60% of the watershed (Snell and Cecile et al. 1995). Response time to storms sped up, downstream flooding continued, summer base flows decreased, and upper tributaries went seasonally dry. Forest and wetland clearance aggravated all these problems (Snell and Cecile et al. 1995). Although drains can retard event runoff if they free up soil storage space, the effect is likely minimal in the Ausable's clay till soil. The efficient drainage network also contributes to water quality problems. It can move contaminants such as manure to the stream system (Wall et al. 1997); it increases sediment and nutrient loads, aggravates channel instability, raises temperatures, reduces wetland function and degrades fish habitat. Costs climb with channel maintenance. The Ausable has a history of enclosing headwater surface drains in some areas; for example, 38% of the Nairn system has been enclosed since 1960. Effects of reduced headwater functions in agricultural areas have had little study. Channel straightening can impair the capacity of headwater streams to reduce downstream nitrate concentrations; closed drains may have a similar effect (Veliz and Sadler-Richards 2005).

The wet clay soils in the Parkhill watershed encourage artificial drainage to the point where little natural watercourse remains. Between 1950 and 1979, channelizing, dredging, straightening, ditching, tiling and riparian clearing in the upper Parkhill accelerated runoff from storm events, leaving barely a trickle in the summer (ABCA 1979). A cold water stream noted in 1949 (Conservation Branch 1949) had lost that rating by 1979 (ABCA 1979) and was a possible casualty of the extensive alteration. Other consequences are destabilized streambeds and banks. Dislodged sediment and soil eroded from fields clogs ditches and rapidly collects in the Parkhill Reservoir (ABCA 1979). The 1979 report also warned of loss of wetland hydrological function if muck soils are cleared from the upper watershed.

Morrison Dam was completed in 1959 and supplied the vegetable canning company, a water taking that caused late summer quantity and quality problems downstream (ABCA 1985). A hydro-power dam above Rock Glen operated from 1908-1926 and was later removed to allow fish passage. The Parkhill Dam, built in 1969, augments low flows to aid farmers and decrease water quality problems (ABCA 1985). By 1991, 41 dams – some 19th century millponds – interrupted the Ausable and Bayfield systems, 19 located on streams with sensitive fish species (Veliz 2001).

Today's flow patterns show maximums in February to April coinciding with snow melt and heavy rains on frozen ground. Ice jams compound flood problems. A smaller flow peak occurs in November and December after fall rains. High evapotranspiration lowers summer flows (Shaus 1982). Intense thunderstorms, however, sometimes dump very high amounts of rain and cause localized summer flooding.

Mud Creek is a small stream that skirts the southwest boundary of the Ausable watershed. Its level agricultural upper basin has the extensively drained and cleared pattern of the Ausable basin. The lower watershed, however, crosses the heavily forested dune unit, much of which was Stoney Point First Nations land taken over for Canadian Forces Camp Ipperwash. The forest and natural sand filter improves water quality and volumes in the lower reaches. The creek outlets at Port Franks near 'The Cut'; the depositional shoreline is evolving and subject to flooding. Port Franks suffers increased flood risk from ice jams in both the Ausable and Mud Creek (Snell and Cecile et al. 1995).

The Ausable watershed is known to have a number of sinkholes (WC Map 3-7, Appendix D). These areas are defined as shallow semi-circular depressions where surface waters can access bedrock aquifers. Sinkholes are present in the West Perth headwater areas, and the area's stream-feeding shallow aquifers are vulnerable to contamination from surface water (Waterloo Hydrogeologic Inc. 2004). The Ausable Bayfield Conservation Authority conducted two studies in order to determine the impact of sinkholes on municipal water supplies: the Sinkhole Investigation for areas mainly within the municipalities of Huron East and West Perth, and the Sinkhole Extension Study. Sinkholes in the area were located and mapped, and two boreholes were drilled to classify the geological characteristics of a sinkhole.

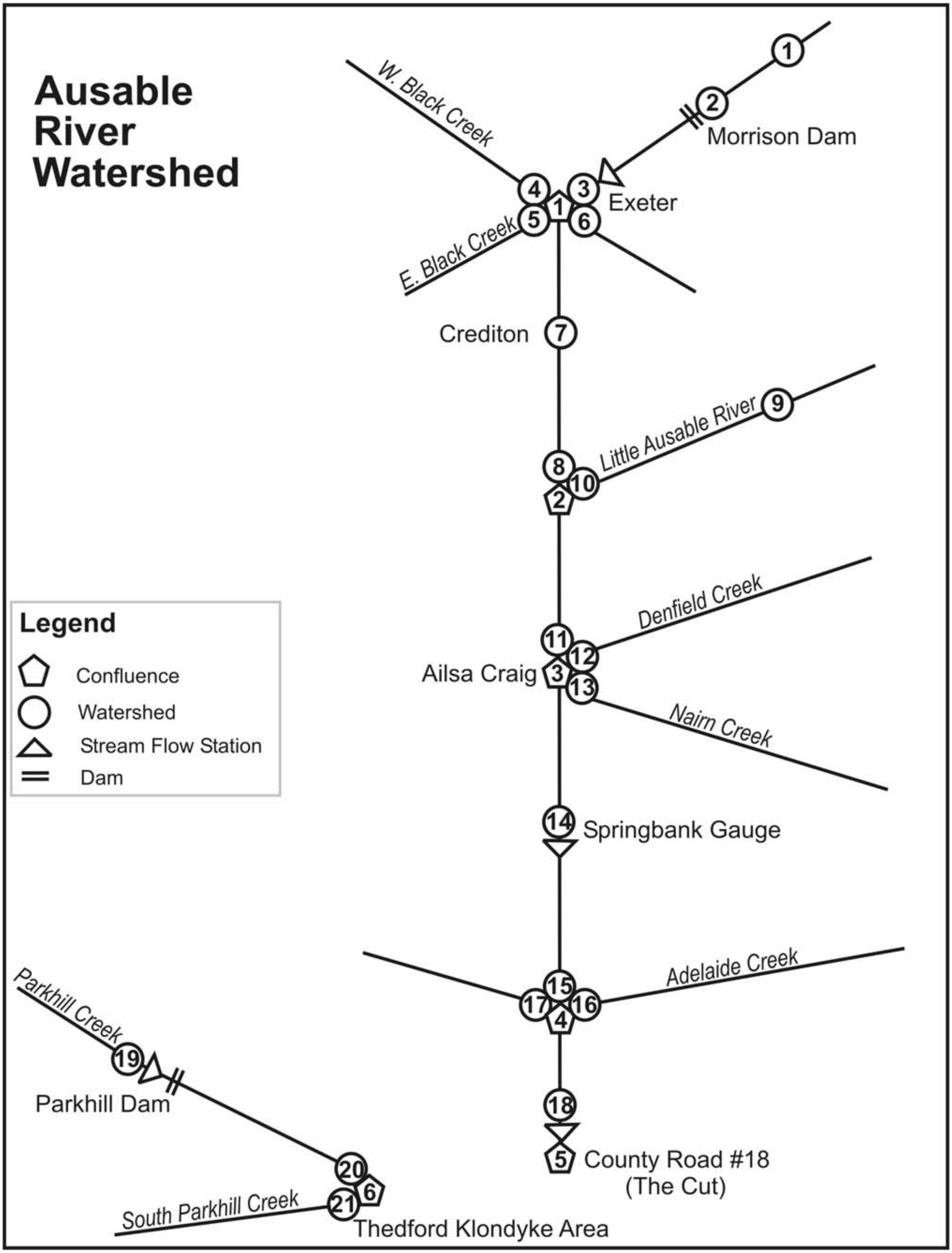

Figure 1-1: Basin Runoff Forecast Unit (BRFU) Model Schematic Representation of the Ausable River System

Bayfield (Figure 1-2)
The Bayfield watershed is 497 km^2 (Malone 2003), flowing east to west and entering Lake Huron at Bayfield. The basin has an almost rectangular shape pinched off at both the upper and lower ends.

Physiography
The Bayfield watershed crosses the same till moraines and till plain sequence as the Ausable watershed (see WC Map 1-3). It differs, however, in rising from one moraine further east, the Mitchell Moraine, and in having almost no influence of glacial Lakes Warren and Algonquin because of the watershed's very narrow shore plain extent. A major north/south spillway system splits and then flanks the Wyoming Moraine (Chapman and Putnam 1984).

Topography
Giancola (1983) described Bayfield watershed slopes as generally less than 2 % with steep slopes limited to the lower Bayfield and Bannockburn river valleys. Upstream banks have some moderate slopes as does the Trick's Creek and the kame area near Clinton.

Soils
Perth clay loam, an imperfectly drained soil on clay till, dominates much of the upper and middle portions of the watershed. On the moraines, the slight roll improves the drainage to develop well-drained Huron clay loam till soils. In the Clinton area, the till soils become siltier, developing Harriston silt loams in the well-drained areas. The kame near Clinton has some steep gravel Donnybrook soils; the spillway associated with Trick's Creek has developed well-drained Burford gravel outwash soils (Malone 2003; Snell and Cecile et al. 1995). The agricultural capability is high on most of the clay and silt till soils, slightly lower in poorly drained or more rolling areas. The sand and gravel soils – Burford, Gilford, and Donnybrook – are lower capability with limitations of low fertility and, in some cases, susceptible to drought. Alluvial soils occur in the lower Bayfield floodplain. Soil erosion likely increases in the more sloping moraine areas; the 1995 plan rates only a sub-watershed in the more rolling Wyoming Moraine as relatively high, which is a similar finding to Giancola (1983). Bonte-Gelok and Joy (1999) rate the basin 'moderate' for extent of poorly drained and imperfectly drained soils (44% in the Huron County portion).

Surface Hydrology (Map 1-4, Appendix D)
The Bayfield River is 65 km long, rising near Dublin and outletting at Bayfield with a gradient of 2.3 m/km (Malone, 2003). It contends with the same three moraines as the Ausable but skirts them northward rather than southward and is more prompt at breaching them. Despite headwaters further inland than the Ausable's, the Bayfield's more direct route results in a river less than half the length and a watershed less than half the area. The river's main tributary is the Bannockburn River; Trick's Creek, another tributary, is a cool/cold water system, which helps to maintain water quality and provides habitat for salmonids.

In the pinched-off upper Bayfield subwatershed, the Liffy, Cook and McGrath Drains meet in a glacial spillway to launch the Bayfield River. The narrow moraine basin divide directs the new river northwest until it breaks through into the east end of Bayfield valley's rectangle. From there, the general river direction is northwest across clay till plains, barely diverted by the moraine at Egmondville. Near Clinton, both the kame moraine and Wyoming till moraine block its northwest direction. The river turns to intercept and follow the major spillway south for a few kilometres before slicing westward through the Wyoming Moraine, the glacial Lake Warren beaches and coastal plain. There the lower Bayfield forms a wide, deep (as much as 50 m) and forested valley where high level terraces, old oxbows and isolated meanders resemble those in the lower Maitland (Malone 2003). Limestone outcrops are exposed in the lower reaches (George and Pfrimmer 1973). The rectangular shape of the watershed abruptly narrows to only the width of the deep river valley.

On the till plain, most streams have been converted to municipal drains. For the river and tributaries above Clinton, clearing, draining and low infiltration soils result in spring torrents and very low flows the rest of the year (George and Pfrimmer 1973). Many homes in Seaforth sit in the regional Flood Plain. Only Silver Creek and Hellgramite Creek have a permanent, though small, flow. In each case, flow possibly originates in small pockets of sand and gravel associated with eskers. The Bayfield's main flow contributions occur west of Clinton, some from the kame and Wyoming Moraine but most through the major spillway that splits the moraine. Trick's Creek is the main contributor. It flows down the spillway from the north with steady cold base flows. Bannockburn Creek originates in the Wyoming Moraine and follows the spillway northward, receiving flow from both units. Although permanent, it becomes low and weedy in the summer with most of its tributaries dry (George and Pfrimmer 1973).

At the Bayfield mouth, which is an active commercial harbour, ice jams or lake storms can cause flooding.

None of the watershed's eight dams – all private – create large reservoirs. The two ponds in Trick's Creek sub-watershed cover 6.2 ha; the remaining six total 2.8 ha. They alter flow, sedimentation patterns, temperature, and fish migration, but also offer recreation options (Malone 2003).

Tile drained land covers 49% of the watershed, a lower proportion than the more poorly drained soil found within the Ausable (Snell and Cecile et al. 1995).

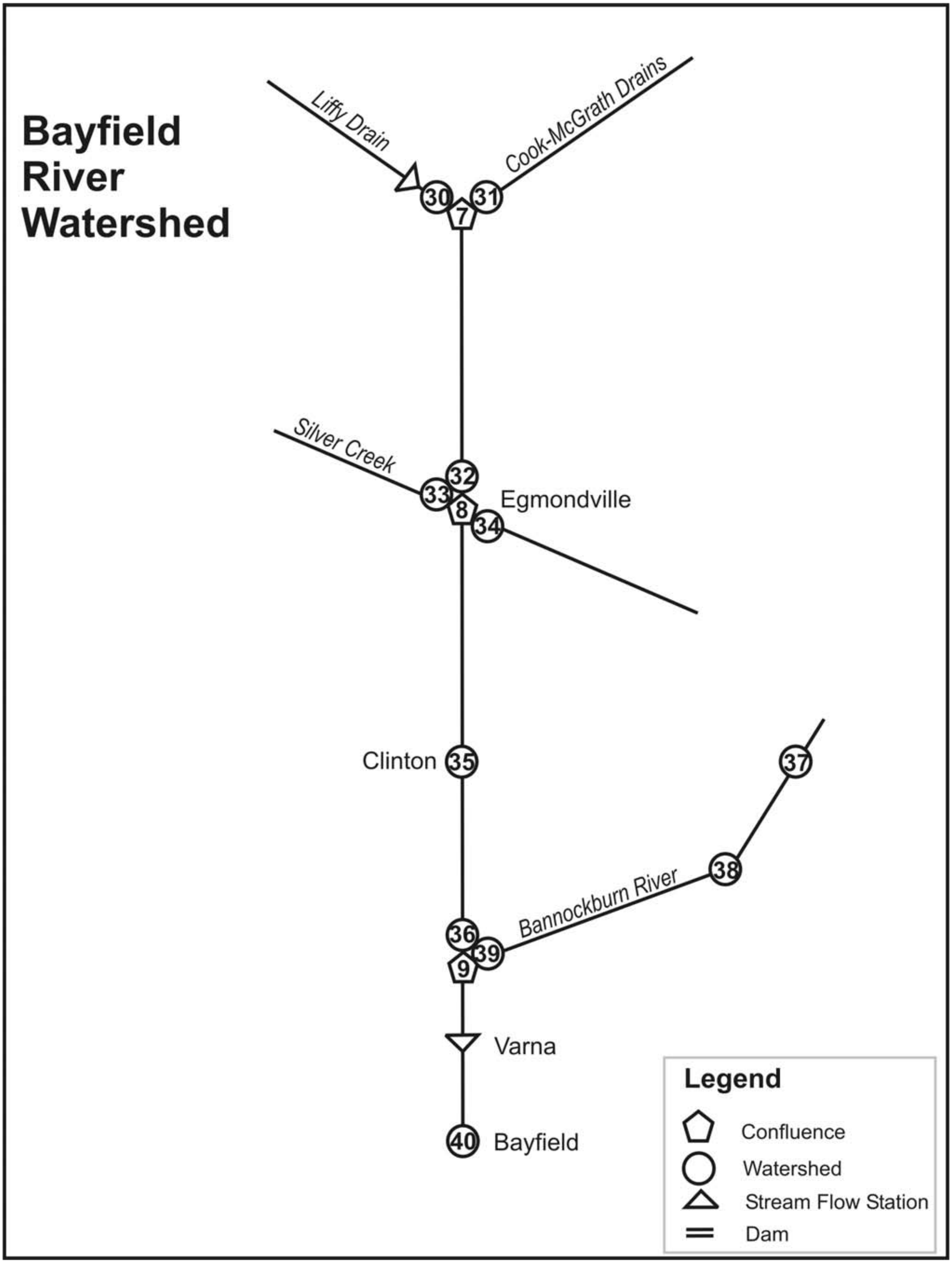

Figure 1-2: BRFU Model Schematic Representation of the Bayfield River System

Maitland (Figure 1-3)
The Maitland is 2572 km^2, the largest of the five main watershed units. It includes the South, Middle and Little Maitland River tributaries. The main stem can be divided into the North and Lower Maitland Rivers (see WC Map 1-4). The Maitland River is 150 km long and falls 235 m to Lake Huron at Goderich.

Physiography
WC Map 1-3 presents the physiography. Like the Upper Bayfield watershed, the oval shaped South Maitland basin is a clay-till plain crossed by three narrow north/south till moraines. The eastern Mitchell Moraine marks the headwater divide. The middle Lucan Moraine tapers off into a small kame ridge in the middle of the South Maitland basin. Just above its outlet, the South Maitland joins a branch of the same spillway that maintains Trick's Creek. The watershed's main distinction from the upper Bayfield is the broad band of hilly, coarse textured Wawanosh kame moraine. A large organic deposit is associated with the Hullett Marsh and several gravel eskers rise out of the clay till plains.

The main physiographic unit of the funnel-shaped Middle Maitland unit is the Teeswater drumlinized till plain. The upper reaches of the watershed flow off the Milverton Moraine onto a flat, wet, and clay-till plain with some extensive muck soils. At mid-basin an intricate spillway system interspersed with small kames is superimposed on the till plain. Several distinctive esker gravel ridges up to 15 m high cross the plain and provide valuable aggregate (Conservation Authorities Branch 1967).

The elongated Little Maitland watershed rises in the Dundalk till plain. It lies in a drumlinized till plain with a complex pattern of spillways. Two large organic soil-based wetlands bracket the valley in the lower end and two prominent eskers bisect the valley further upstream.

The North Maitland's north boundary is a series of kames and its eastern headwaters rise in the Dundalk till plain. Drumlins of the Teeswater Drumlin Field sprinkle the middle and lower watershed. The spillway pattern becomes increasingly dense down through the watershed to the point that large areas north of Wroxeter form complete spillways among the protruding drumlins. Several eskers and organic deposits occur throughout the system.

The Lower Maitland has a highly varied physiography. Upper areas include the drumlinized till plain with a network of drumlins and spillways. A broad kame band bisects the basin north-south just east of the wide Wyoming Moraine, itself bisected with the major spillway. The river outlet cuts through the shore sand plain below the Lake Warren beach (Chapman and Putnam 1984).

Topography
The topography generally increases from the relatively level till plains in the south and east to the steep kames in the north. The till moraines gently slope, the drumlins moderately slope in a rolling landscape and the kame moraines more steeply slope in an irregular pattern. Eskers have short steep sides; the valley slopes of the Lower Maitland are very high and steep. The Maitland River mouth at Goderich provides eastern Lake Huron's only deep harbour for large ships (Beecroft 1984).

Soils

Poorly drained Brookston clay dominates the soils of the level plains in the upper South and Middle Maitland watersheds. Elsewhere loamier associations and better drainage become more prevalent. Some kame soils and spillways have sandier series; eskers are gravely. Several large accumulations of organic soils occur in the basin. Bonte-Gelok and Joy (1999) measured the extent of poor and imperfect soil drainage in Huron County, rating South with the most (63%), followed in order by Middle, Little, North and Lower. Maitland soils are generally classed as high capability for agriculture. Lower ratings occur in the very wet areas, steeper slopes and stonier kames (Conservation Authorities Branch 1967). South Maitland and Lower Maitland have the worst soil erosion for the Maitland system (MVCA 1984).

Surface Hydrology

The Maitland River bends to the north and west side of the basin with the major tributaries flowing in from the southeast (see WC Map 1-4, Appendix D). The largest tributaries are the South Maitland and Middle Maitland Rivers. The South Maitland joins the Maitland downstream of Auburn. The Middle Maitland meets the main channel at Wingham immediately below the Middle Maitland's confluence with the Little Maitland.

The South Maitland River skirts the southern divide of the watershed; all its major tributaries join from the north, all flowing westward. Most cross the clay till plains; a few tributaries contribute from the kame moraine near the South Maitland outfall.

The upper South and upper Middle watersheds rate the most channel modification in MVCA (Steele et al. 1995). In the South Maitland basin, the indistinct upper river valley, extensive drainage and clearance and clay soils all contribute to flashy flows after storms and low stream levels at other times. Dikes reduce the Hullett Marsh's natural roles for filtering and flow modification. The river's runoff curve is higher than the Maitland average. The hydrology changes markedly, however, in the lower reaches, where the high percolation in the spillway and Wawanosh kame (B.M Ross no date) moderates flows. Eskers may offer some groundwater discharge to a few upper tributaries.

The wide fan of Middle Maitland headwater streams rises from the edge of the till plain that dominates the watersheds to the south and almost immediately enters the drumlinized till plain. The headwaters fall promptly to a level plain above Listowel; in the Boyle Drain even the headwaters are flat (Conservation Authorities Branch 1967). The stream valleys are indistinct in the level landscape where only eskers have any possibility for groundwater discharge. Mid-basin, the river course joins the spillway network. A few tributaries – all of which are short – enter downstream of Brussels; the major exception is the Little Maitland that joins the Middle Maitland just above its outlet at Wingham.

Flooding has long been a concern on the Middle Maitland. Reasons include: its headwaters topography of higher gradients that quickly flatten out, it receives large volumes of snow melt, rain occurson frozen ground, and that there are ice jams, extensive clearance and drainage. The close confluence of all the upstream tributaries may also be a factor. Extreme summer storms occasionally flood; the worst flood was from a freak storm in August 1883 (Department of Planning and Development 1954). Severe damage at Listowel was largely attributable to the dilapidated conduit carrying the river under the town (Department of Planning and Development 1954). A 1970 study (Crysler and Jorgensen 1970) linked agricultural drainage to Listowel's problems, given the conduit's limited capacity further restricted by sediment accumulation. The study proposed a plan for drain improvement, channel dredging, reservoir construction and conduit improvements. An 8-phase Listowel conduit project started in 1979 and opened in 1991 has prevented flooding in subsequent extreme events (MVCA Partnerships 2003). The watershed, however, still carries a substantial flood risk and recent studies recommend riparian planting and channel naturalization (MVCA 2004). Floods at Wingham result from its location at or near the confluence of the Middle, Little and North Maitland Rivers (Conservation Authorities Branch 1967).

The Middle Maitland watershed's heavy soil, extensive drainage and few coarse deposits all limit base flow. The Middle Maitland River joins the South Maitland in having the lowest base flow index of the MVCA and a higher than average runoff curve. For both metrics, the most extreme tributary is Boyle Drain (B.M. Ross no date).

Within a few kilometres of the Little Maitland River headwaters, the stream falls to the relatively level till plain and continues in a shallow spillway valley its remaining length (Conservation Authorities Branch 1967). Tributaries are well distributed. Artificial drainage is likely less extensive than in the more poorly drained South and Middle Maitland. Spillways and eskers may provide groundwater discharge. No reports of significant flooding were noted.

The North Maitland River's eastern headwaters flow across the till plain. Past Harriston, however, the main channel and most tributaries follow the spillway pattern. The north tributaries often originate from kames. Within a few kilometres, the headwater tributaries fall to the level till plain. At Harriston the valley is flat, shallow and swampy but west of the town, the river enters the Teeswater drumlin field. There the valley is deeper for 16 km with occasional banks up to 15 m high with remnants of old gravel terraces. This deeper valley has a gradient of 30 m in the next 26 km providing mill sites at Gorrie and Wroxeter. From there the valley becomes indistinct as it winds through spillways and among drumlins to Wingham (Conservation Authorities Branch 1967; B.M. Ross no date). The North Maitland's kames and spillways both discourage artificial drainage and provide steady groundwater discharge. The result is that the North Maitland River, with Nine Mile River, rates as the most pristine in the planning region. The Nine Mile's more permeable landscape results in a relatively high base flow index for the Maitland Valley region, a lower than average runoff curve (runoff potential) and a fairly high percolation rating (B.M. Ross no date).

The North Maitland watershed contains the only natural lake of any size in MVCA: Lakelet Lake is located near the north boundary and associated with the kame unit. Mid and lower North Maitland rates low channel modification for MVCA (Steele et al. 1995).

The Lower Maitland follows the major spillway through a narrow valley 8 to 30 m deep winding among drumlins and large areas of kame, then between the kame and Wyoming Moraine, before, like the Bayfield, chiselling a deep valley into the Wyoming Moraine to cross the shore sand plain. Within a few kilometres of Lake Huron, the valley is almost 50 m deep with steep banks and limestone exposed at the base (Conservation Authorities Branch 1967). The rock creates small falls and rapids that provided white water rafting as early as 1829 when Samuel Strickland enjoyed an expedition there "amazingly" (Beecroft 1984). Some elevated terraces in the lower valley are related to Lake Algonquin levels (James F. Maclaren 1977). At the mouth, ice jams or lake storms can cause flooding. High Lake Huron water levels – from both long term cycles and very brief wind-generated seiches – can influence the Maitland for 1-2 km upstream (Conservation Authorities Branch 1967).

The Lower Maitland has some major tributaries beyond the North, Middle, Little and South contributions. Blyth Brook flows in along a spillway off the drumlinized till plain and then through the kame unit. Sharpes Creek originates in the Saratoga Swamp, follows the deep spillway that splits the Wyoming Moraine and drops abruptly (30 m in the last 2 km) to the Maitland (B.M. Ross no date). Its dependable spring-fed flow powered three mills in Benmiller and is still vital to the village's tourist industry (Beecroft 1984).

By 1967, the Donnybrook gauge averaged 52% of its flow in March and April; 8% in June to September. The contrast is more extreme than average for Southwestern Ontario (Conservation Authorities Branch 1967) and later shifted slightly to 47% and 9% (B.M. Ross No date). The Lower Maitland's base flow index and percolation is rated fairly high in the planning region context (B.M. Ross no date) and artificial drainage is likely low, given the low extent of wet soils. In 2003, however, MVCA noted that since 1985, a shift to less snow and to more mid-winter melts had reduced base flow in the Maitland system (MVCA 2003).

The flooding, sand bar formation and ice created challenges for the Goderich harbour facilities to the point that in 1873 the river was diverted away from the piers (Beecroft 1984).

The 1967 Report on the Maitland system assessed no water issue (flooding, low flow, pollution, drainage, low groundwater, water supply, sedimentation, bank erosion) as extreme except for flooding at Listowel. The 1984 plan judged the worst flood damage in North Maitland (Harriston) and Middle Maitland (Listowel, Brussels). Most flooding extent has been in South Maitland, Boyle Drain of the Middle headwaters and the Middle Maitland's lower reach south of Wingham (MVCA 1984). In the 1970s, Wingham (Lowertown) sold flood plain area to the Maitland Valley Conservation Authority, but today there is not the type of funding available for Conservation Authorities to acquire land. In 1989 there were more than 600 buildings in flood susceptible areas, led by Harriston, Lucknow and Listowel, followed by Wingham, Brussels and Blyth. Harriston, Lucknow and Wingham had many undeveloped lots in flood-prone areas (MVCA 1989). In the 1990s, Listowel, one of the many centres in the Maitland where the river flows underneath the town, improved and increased its conduit's capacity to help with flooding issues.

Although there are slight changes that occur in the area designated as floodplain as new technologies become available, but the introduction of 'Generic Regulation' in May of 2006 did not change the areas designated as floodplain within the Maitland.

There are no large reservoirs in the watershed, but almost every community has a small one. Cumulatively, they offer some flood staging for minor events but little capacity for major ones. MVCA operates several old mill ponds. B.M. Ross (No date) found that in the previous 40 years, only two annual floods were not associated with snowmelt and frozen ground flooding. B.M. Ross also explained how in areas of low relief, even with drains, low level flooding can act as a form of storage and can lower peak runoff rates. The 1989 Conservation Strategy expressed concern about the extent of streams widened and deepened for outlet and about the associated loss of cleaning functions and lack of natural headwater reaches.

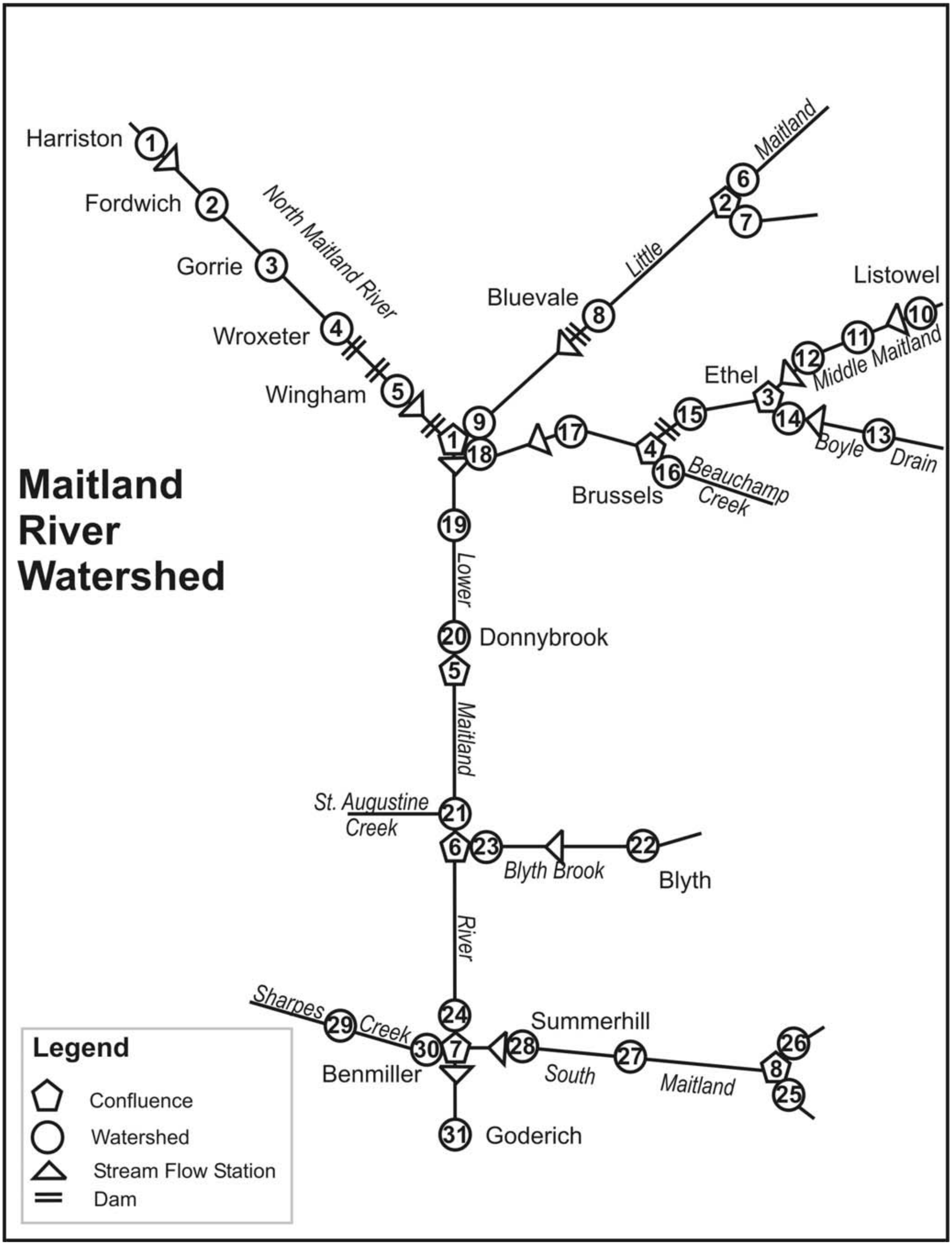

Figure 1-3: BRFU Model Schematic Representation of the Maitland River System

Nine Mile River (Figure 1-4)
The Nine Mile River watershed covers 243 km^2. It has a wide rectangular upper portion connected to the lake with a narrow "handle" that outlets into Lake Huron at Port Albert.

Physiography
The watershed headwaters are in the large Wawanosh kame moraine and much of the area is the Wyoming Moraine that abuts the kame to the west (see WC Map 1-3). This till moraine is split by the spillway that supports the major coldwater streams to the south, the closest being Sharpes Creek. The narrow lower part of the watershed crosses the glacial Lake Warren bevelled till plain below the Lake Warren beach (Chapman and Putnam 1984).

Topography
Slopes range from irregular steep areas in the kame to longer more moderate and gentle slopes on the till moraine to level topography on the bevelled till plain.

Soils
The upper watershed soils are coarse kame-associated series. Clay till series have developed on the till moraine and bevelled till plain. Sandy and gravely outwash soils occur in the spillway. The soils are generally well-drained; only 26% are poor or imperfect drainage (Bonte-Gelok and Joy, 1999). Upper Nine Mile is rated high soil erosion for MVCA (MVCA 1984 Plan).

Surface Hydrology (WC Map 1-4)
The headwaters rise in the Wawanosh kame. In Lucknow, Anderson Creek, Dickies Creek and Ackert Drain/Kinloss Creek join to form Nine Mile River and impose occasional flood damage (MVCA 1984). Below Lucknow, the river follows the spillway southwest across the Wyoming Moraine and over the glacial Lake Warren beach. There it turns west to flow straight to the shore across the bevelled till plain, carving down to lake level. The kames and spillways both discourage artificial drainage and provide steady cold groundwater discharge. The result is that the Nine Mile River rates the highest base flow index and the most pristine water quality in the planning region and supports a valuable trout fishery.

The River flows down the westward spine of the watershed; several short tributaries originate in the kame at the east divide and flow west to join the river in sequence. The Nine Mile River is rated low channel modification in the MVCA context (Steele et al. 1995).

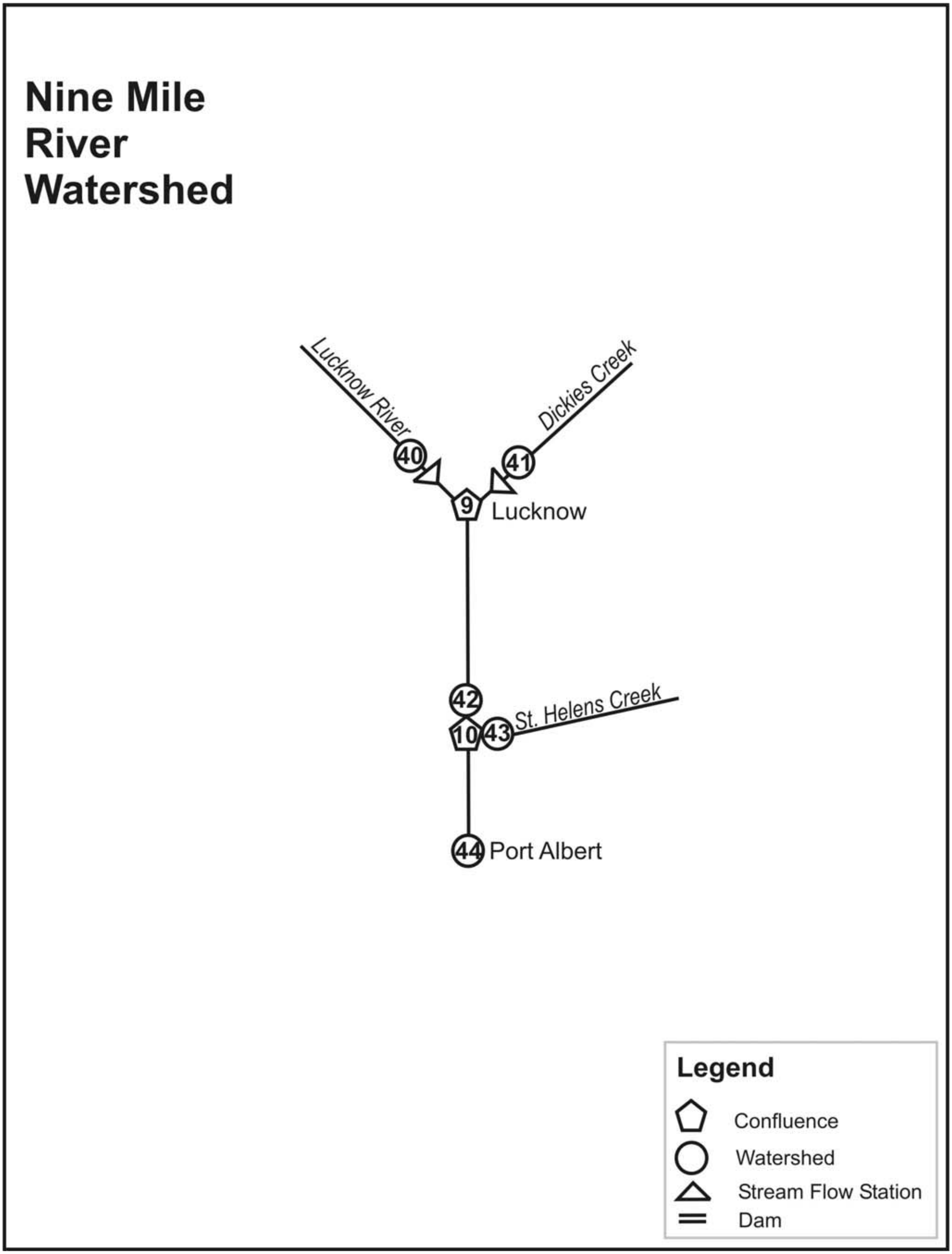

Figure 1-4: BRFU Model Schematic Representation of the Nine Mile River System

Shore Gullies and Streams

The total area of the shore gullies and stream watershed unit is 692 km^2. It includes the basins of all the short streams flowing into Lake Huron from just north of Grand Bend to Eighteen Mile River (see WC Map 1-1, Appendix D). They are numerous – the planning area has 742 streams that are greater then 10 metres flowing into Lake Huron (this number has removed channel types or pseudo nodes in its calculation). The basin of each stream tends to be narrow and most are parallel, flowing westward and carving down to lake level. The unit forms a very long narrow strip along the shore, interrupted only by the narrow outlet valleys of the larger basins.

Physiography

Headwaters originate on the west slopes of the Wyoming Moraine (see WC Map 1-3). The physiographic sequence westward to the lake is down the glacial Lake Warren beach and across Lake Warren's bevelled till plain that usually includes a narrow strip of sand plain (Chapman and Putnam 1984). As the streams approach the lake, they cut down as much as 20 m to form deep gullies to the shore.

The shore is actively eroding to form shore cliffs. Goderich breakwater to Kettle Point is a closed littoral cell for shoreline sand transport; those two extremes trap any sand from the north. Goderich to just north of Grand Bend contributes sediment to the cell's shoreline budget; Grand Bend to Kettle Point receives it. Over millennia (the pre-breakwater cell extended to Point Clark just north of the planning region) this process has eroded away the north bluffs and Lake Algonquin beach. On the other hand, in the accretion area to the south, the Algonquin Beach swings far inland behind the sand deposits and the geologically recent lagoon (see WC Map 1-3). Gully erosion of the shore streams between Goderich and Grand Bend also contributes sediment – 12% of the sand plain accretion (Snell and Cecile Environmental Research 1991).

The Goderich breakwater shortens the natural cell, reduces sand supply, thereby narrowing accretion beaches from their natural width. On-going bluff erosion is natural as these geologically young landforms evolve and is an essential supply to accretion areas and beaches. Structures like groynes that interfere with the sediment transport can have distant adverse effects (Baird and Associates 1994).

Topography

The watersheds are generally level with gently sloping headwaters off the Wyoming Moraine. The lakeshore is a very steep bluff which ranges from 20-22 metres in the north, and peaks around 28 metres around Goderich. As the gullies gouged down to lake level, they too created very steep banks.

Soils

Soils are predominantly the Huron/Perth/Brookston clay tills. Narrow strips of Burford, an outwash gravel, occurs at the Lake Warren beach line; Berrien, shallow sand over clay, marks the narrow sand plain that runs the length of the Lake Warren bevelled till plain. The clay tills are high capability soils; the Burford and Berrien have some low fertility and droughtiness limitations. The Shore Gullies and Streams unit rates high for proportion of poorly and imperfectly drained soils – 68% in the Huron County portion (Bonte-Gelok and Joy 1999). Besides the gullies themselves, the main erosion issue is the proximity of older cottages to the largely natural shoreline bluff erosion (MVCA 1989). Field erosion and compaction are also serious problems (Snell and Cecile et al. 1995).

Surface Hydrology

Samuel Strickland (circa 1830) noted the "fine spring streams" in the rolling land east of the lake (Beecroft 1984). Today they are largely agricultural drains. The streams follow the same physiographic sequence as described under Physiography above, generally flowing straight towards the shore. Few are long enough to have tributaries; Eighteen Mile River in the north has a small tributary, Boyd's Creek.

Some gullies were present at settlement as steep shore ravines stabilized under forest cover. Human activities have extended them. Land clearance, accelerated drainage, tile outlets, channel straightening and cultivation to gully edge all contributed to their growth (Conservation Branch 1949).

The short narrow streams have very short reaction times to storm events. The lack of forest cover also accentuates the sharp hydrographs. The gullies generally drain so quickly that flooding is not an issue.

Ambitious plans to dig a canal from St. Joseph to Lake Erie stalled after construction of the St. Joseph dock in 1904 (Conservation Branch 1949).

Local surface water in the nearshore of Lake Huron has suffered degradation from intensification and seasonal shoreline development (Peach 2006). Some nodes have experienced a lot of growth: Goderich, Bayfield and Grand Bend are examples. Given the movement of water currents, the effects of intensification can have impacts in areas where there is little development.

1.3.2 Climate

The planning region's mid-continent location immediately leeward of Lake Huron shapes its climate. In the Canadian context, its southern latitude favours it with a long growing season, surpassed in Ontario only by areas still further south. The lake moderates continental hot summers and cold winters. The result is a mean daily temperature of about 5.4 ^{o}C in the headwaters and 7.3 ^{o}C at the lake. North to south the gradient is less – Lucknow's mean is 6.7 ^{o}C; Dashwood's mean is 7.9 ^{o}C (Environment Canada 2005). In the Maitland, the pre-1967 frost-free period ranges from 154 days near the lake to 132 days inland (Conservation Authorities Branch 1967).

The planning region's location also contributes to precipitation levels rated among the highest in the Great Lakes basin (Water Use and Supply Project 2004). The region is in the snowbelt off the lake and receives 200 to 270 cm snow annually (Environment Canada 2005). Precipitation is 840 mm to 1050 mm distributed throughout the year (B.M. Ross No date). The lake spawns streamers of intense, linear snow squalls that extend from Lake Huron across the planning region sometimes as far as Kitchener-Waterloo.

Location also causes variation within the region. The cooling effect of Lake Huron curbs the development of thunderstorms and lowers summer rainfall in a lake shadow area extending 10 to 20 kilometres inland. In contrast, a band from Grand Bend to Listowel sees many more summer storms as onshore winds from Lakes Huron and Erie converge. Precipitation also increases on the higher Wawanosh kame. The higher precipitation watersheds of the planning region are

Nine Mile River, Middle and South Maitland Rivers, Bayfield River and North Gullies (Water Use and Supply Project 2004). Sudden spring melts accentuated by rain on frozen ground can bring significant flooding. The area has the average level of drought probability for southern Ontario (ABCA 1979; ABCA 1985; Conservation Authorities Branch 1967; B.M. Ross No date).

A number of climatological stations have been developed through the years by the conservation authorities, primarily for the purposes of local flood forecasting. Environment Canada climate records include Atmospheric Environment Service (AES) stations at Blyth, Brucefield, Cromarty, Dashwood, Exeter, Lucknow and Wroxeter. Brucefield, Cromarty and Lucknow have since been closed. The total amount of precipitation received within the study area has risen slightly over the past 50 years and is discussed further in the Conceptual Water Budget for the Ausable Bayfield Maitland Valley Source Protection Region. Appendix A lists the climate normals for AES stations from the period of 1971-2000.

In addition, there is a network of rain gauges through the region (see WC Map 1-13 Monitoring Sites, and CWB Map 2 Climatological Stations). The stations are located at Mitchell, Seaforth, Varna, Morrison Dam, Exeter, Springbank, Parkhill, Ausable Cut (Thedford), Plover Mills (Thorndale), Port Franks, Lucknow, Harriston, Wingham A, Wroxeter, Listowel, Newry (Atwood), Belgrave, Wingham B, Blyth, Summerhill, Benmiller, Fall Reserve CA and Ethel. These stations measure different variables at an hourly rate; see the inserted box in CWB Map 2. The precipitation recorded at these stations, however, is only in the form of liquid precipitation and unlike the AES stations, does not include snowfall and underestimates the total amount of precipitation. A further discussion on the subject is located in the Conceptual Water Budget.

1.3.2.1 Climatic and Meteorological Trends

Climate change is expected to bring warmer temperatures, higher evapotranspiration, lower lake levels, more flooding, low flows, more droughts, more intense storms and more erosion (Bruce et al. 2000). Already long, gentle rainfalls are yielding to shorter, more intense thunderstorms. A shorter lake ice season may increase snowfalls and expose the shore to strong winter storms. Climate change effects on water quality could include more runoff, erosion and pollution (MFX Partners 2002). Groundwater levels may gradually decrease. In southern Ontario, base flow decreases are projected to be most severe in the spring. Groundwater-linked management implications include: drilling deeper wells, designing sewage treatment plants for more extreme low flows, and promoting water conservation and efficient irrigation (Piggott et al. in press).

1.3.3 Groundwater and Hydrogeology

This section is derived from the county groundwater reports (Perth: Waterloo Hydrogeologic 2003b; Huron: International Water Consultants et al. 2003; Lambton and Middlesex: Dillon and Golder 2004: a,b; Wellington: Minto and North Wellington: Burnside 2001: a,b; Bruce: Waterloo Hydrogeologic 2003a).

Major Aquifers

Aquifers are formations that provide adequate drinking water when tapped by a well. Good aquifers can include sand, gravel and fractured limestone. Overburden aquifers are aquifers that occur in unconsolidated deposits above the bedrock. Confined overburden aquifers are protected from contamination by an overlying fine textured layer. Shallow unconfined aquifers can be associated with sand plains and spillways and, although less protected than confined aquifers, can be more productive (Dillon Consulting and Golder Associates 2004a).

The aquifer in the fractured and fissured limestone bedrock is by far the most significant drinking water aquifer in the planning region. Most area wells use the top few meters of the aquifer. The yields from units that occur in the planning region are generally among the best from bedrock in southern Ontario. Only the Hamilton Group in the extreme south fails to make that rating (Singer et al. 1997).

Overburden aquifers were tapped historically more than today and are less well documented than bedrock ones. Significant overburden aquifers in the planning region include:

- North Lambton/South Huron unconfined aquifer that exploits the beach and bay-mouth bar deposits of Lake Algonquin and Lake Nipissing as well as the more recent dunes between Grand Bend, Port Franks and Thedford. Wells are shallow, usually less than 15 m (Dillon Consulting and Golder Associates 2004a);
- The unconfined glacial Lake Warren beach sand and gravel north and south from Goderich;
- The confined to semi-confined and poorly understood Hensall aquifer;
- The Wyoming and Seaforth Moraines; and
- The kames and network of sandy outwash and spillway deposits that becomes more extensive to the north of the region.

Many smaller locally significant overburden aquifers occur throughout the area. In Lambton clays, some overburden wells acted as cisterns. They were highly susceptible to contamination and most have been replaced with municipal servicing from Lake Huron (Dillon and Golder 2004a). A number of users in the north part of the MVCA watershed, including Mennonites, often use shallow overburden wells. This can present a problem for Mennonites if a well becomes dry or contaminated, as they have no option to bore down to the bedrock.

The regional bedrock aquifer flow direction is generally from east to west. A steep hydraulic gradient east of Seaforth indicates karst features (International Water Consultants et al, 2003). A bedrock rise near Arkona directs groundwater flow northwest toward the Lake. Surface topography controls the flow in overburden aquifers (Golder 2000).

Overburden Thickness (R.74)

Overburden thickness (see WC Map 1-5) is an indicator of the bedrock aquifer's protection from contamination. The general trend is for deeper overburden to the west with the exception of the Thedford – Port Franks area. Shallow areas with little protection include the sinkholes in the Ausable and Bayfield headwaters, the Brussels area and the lower 17 km of the Maitland River.

Recharge and Discharge Areas

Groundwater flow maps indicate that the major bedrock groundwater systems originate east of the watershed. Local recharge areas include sinkhole areas in the upper Ausable and Bayfield watersheds and an area near Lucan with a very low bedrock water table. Till moraines and kames tend to have a moderate rate of recharge to the regional aquifers. Recharge in the Lambton clays is very slow; the area's freshwater aquifer at the bedrock contact is estimated to have been recharged thousands of years ago (Dillon Consulting and Golder Associates 2004a).

The Conservation Authorities used overburden and surface features to rate groundwater recharge potential rates highest in the Maitland watershed, intermediate in the Bayfield and lower in the Ausable, Nine Mile and Shore watersheds. Major exceptions to this trend are high recharge areas along the shore between Bayfield and Goderich and near Hay Swamp (Golder Associates 2000).

Discharge is strongest in the Ausable Gorge and lower Maitland. Bedrock discharge also occurs in the Port Franks area and in a bedrock trench that crosses the upper Maitland watersheds in a North/South direction. Some discharge from deep overburden takes place in the Nairn and Little Ausable sub-watersheds. Shallow overburden discharge occurs along some streams.

Because overburden discharge is often associated with spillways and kames, overburden springs are more prevalent in the northern watersheds (James F. Maclaren 1977).

1.3.4 Surface – Groundwater Interactions

Potential for infiltration depends on surface soil porosity, location in the watershed, land use, natural drainage patterns, degree of soil saturation and extent of each of depression storage, agricultural drainage and underlying impervious soils (B.M. Ross No date).

The most vulnerable aquifers are shallow unconfined ones that tend to occur in sand plains, spillways and kames – the overburden recharge areas (Golder Associates 2000). These poorly understood aquifers often influence streams but their effect on wells is unknown. Their coarser soils tend to have lower agricultural capability and more forest cover with its associated source water protection.

For bedrock aquifers, overburden depth and high clay content provide good protection across much of the planning region. Bedrock aquifer susceptibility tends to rise to the east where overburden thickness is least.

Very high susceptibility occurs in sinkholes, a feature of the Lucas Formation (International Water Consultants et al. 2003; Waterloo Hydrogeologic 2003b). Dissolution of the limestone creates a network of cavities and channels. If sediments collapse into the cavities, sinkholes form that directly link surface water with groundwater. Sinkholes occur in the Upper Ausable and Bayfield watersheds, Middle Maitland near Brussels and near the lakeshore west of Lucknow (International Water Consultants et al. 2003) and are indicated on WC Map 1-4, Appendix D. Most are less than 5 m deep and 9 m diameter; a large one in the bed of the Ausable River is 46 m wide and 122 m long (Waterloo Hydrogeologic 2003b). A detailed study in Huron East and Perth West found over 50 sinkholes draining over 800 ha. The two largest sinkholes receive water from municipal drains and transmit large amounts of water to the aquifer. Characterization of effects requires longer term monitoring (Waterloo Hydrogeologic 2004).

Groundwater flow is from north-east to south-west and is shown on WC Map 3-11. The following surface-groundwater interactions are organized by watershed.

<u>Ausable</u>
High susceptibility is noted (Snell and Cecile et al. 1995; Donnelly 1994; Paragon 1986; Schaus 1982; Waterloo Hydrogeologic 2003b, International Water Consultants et al. 2003; Dillon Consulting and Golder Associates 2004: a,b) for:

- Sinkholes in the upper Ausable watershed (Waterloo Hydrologic Inc. 2004).
- The Dunes unit and extending into the Thedford Marshes. Malfunctioning septic systems could leak into the shallow groundwater;
- A small area in the Nairn Creek headwaters;
- Near Hensall where limited confining material protects the overburden aquifer;
- The spillway associated with the Hay Swamp, while half forested, still exposes a large area to surface – groundwater interactions. A landfill and composting facility are potential contaminant sources above the cold water stream section; and
- Staffa, on a susceptible kame.

Other interactions include:

- Base flow interference from Exeter area development and groundwater use by irrigation;
- Possible effects on the Little Ausable from a landfill, gravel pit, and Exeter's well; and
- Possible effects on the Ausable temperature and flow from gravel pits near Arkona;

Exeter will soon reduce its effects when it switches its water source from groundwater to a surface water intake in Lake Huron. Parkhill rates few susceptibility concerns.

<u>Bayfield</u>

Potential interactions (Snell and Cecile et al. 1995, International Water Consultants et al. 2003; Waterloo Hydrogeologic 2003b) include:

- Sinkholes in the Upper Bannockburn, mid-basin and Clinton;
- Possible well contamination below Clinton from Clinton's STP effluent: flagged by 1980 MOE Basin Study;
- Gravel pits and development effects on Trick's Creek; the lower Bayfield has a trailer park in the floodplain and potential landfill issues; and
- Gravel pits very close to the river affecting temperature and base flows.

<u>Maitland</u>

Interactions or potential interactions (MVCA 1984 Plan; Middle Maitland Initiative 2000; James F. Maclaren 1977; Steele et al. 1995; International Water Consultants et al. 2003; Waterloo Hydrogeologic 2003b; Burnside 2001: a,b; Beecroft 1984) include:

- The highest base flow contributions appear to be associated with spillways and kames in the lower Middle and upper Lower Maitland watersheds;
- Recharge to overburden does happen but no evidence connects it to bedrock aquifers. The few areas where the piezometric elevations are below the bedrock surface and therefore possibly, though not necessarily, unconfined and subject to recharge through the overburden are in the west end of the basin – Lower and South Maitland watersheds that tend be protected by thick overburden;
- Several areas have <3 m clay at the surface, and so there is some possibility of overburden recharge – the thinner the clay, the more likely the recharge;
- Trowbridge uses a localized overburden aquifer that should be protected. Middle Maitland may be recharging the overburden aquifer south of Trowbridge;
- A number of sinkholes are draining agricultural lands and could directly link surface contamination with the bedrock;
- In the early 1960s, Middle Maitland flow volumes were half baseflow. By 1970 the baseflow proportion had declined despite increasing precipitation. Upper watershed drainage, cropping and tillage practices that discourage recharge were blamed. The

decline diminishes the system's ability to withstand drought and impacts aquatic life; a higher surface flow proportion raises sediment and pollution potential;
- The Middle Maitland River may also be interacting with the bedrock aquifer near Brussels;
- The upper North Maitland has a few vulnerable spots for surface-groundwater interactions, most along spillways and distant from any potential sources;
- Saratoga Swamp (Sharpes Creek watershed, Lower Maitland) is a discharge area for localized groundwater flow from the surrounding glacial overburden aquifers; and
- From Auburn to Goderich there are several areas where the river flows over bedrock and where either groundwater discharge or recharge may be occurring.

<u>Nine Mile</u>
Interactions or potential interactions (MVCA 1984; James F. Maclaren 1977; International Water Consultants et al. 2003; Waterloo Hydrologic 2003a) include:
- Lucknow has an overburden well that should have recharge area protection;
- High susceptibility spots for both overburden and bedrock susceptibility occur in the kame between Lucknow and Wingham;
- High base flow contributions appear to be associated with spillways and kames; and
- Recharge to overburden does happen but no evidence connects it to bedrock aquifers. In some areas the piezometric elevations are below the bedrock surface and therefore possibly, though not necessarily, unconfined and subject to recharge through the overburden. Its thick depth, however, provides protection.

<u>Shore Gullies and Streams</u>
Interactions or potential interactions (International Water Consultants et al. 2003; Waterloo Hydrologic 2003a; Donnelly 1994) include:
- Septic systems on the highly impervious clay can fail and result in beach postings. Near bluffs, contamination could seep laterally to emerge at lakeshore and gully slopes (Donnelly 1994). Some surface – groundwater interactions may also be occurring at bedrock exposures along Lake Huron (e.g., north of Goderich); and
- Recharge to overburden does happen but no evidence connects it to bedrock aquifers. In a few areas the piezometric elevations are below the bedrock surface and therefore possibly, though not necessarily, unconfined and subject to recharge through the overburden. Its thick depth, however, provides protection.

1.4 Natural Heritage

Terrestrial natural areas play important roles in source protection. They trap contaminants to cleanse surface and groundwater and are a vital link in the hydrological cycle. They also rely on clean, adequate water – generally from surface sources but sometimes from seepage areas and springs.

History
Generally across Southwestern Ontario after approximately 1850, clearance for agriculture, fuel wood, fencing and roads sharply reduced natural area extent. By the early 1900s forest cover had shrunk to below 10% of the Ausable watershed. A gradual recovery raised forest extent to 11.7% in 1947 (Conservation Branch 1949) and to 15% by 1983 (Stoll 1983). Many natural areas were doomed by their good agricultural capability. Areas remaining and recovering tend to

coincide with soils of lower agricultural capability. The Dunes, Ausable Gorge, and Hay Swamp are prominent examples. Fragmented woodlot remnants in the "back 40" create a curious pattern that often runs perpendicular to tributaries, a relic of early settlement's attempt to make roads parallel to the major rivers (Conservation Branch 1949). The shift from livestock grazing benefits woodlots; 60 years ago almost all were pastured (Conservation Branch 1949) destroying the critical lower tiers. However, seed banks may have been depleted. Reforestation with very few species and without restoring the natural pit and mound microtopography creates forests that function far below their natural counterparts for both habitat and water protection roles.

Maitland natural areas have a history similar to the Ausable's. Early settlers marvelled at the lush forests and teeming fish (Beecroft 1984). Forest exploitation for roads, railroads, timber, fuel and fence posts peaked in the late 1800s. Much of Goderich and Colborne township forests fuelled the salt works (Beecroft 1984). In 1964, the Conservation Authority's jurisdiction was 12.6% woodland and plantation, and 4.3% scrubland (Conservation Authorities Branch 1967). An assessment of forest health in 2001 found over half the forest surveyed in fair or poor condition due to a lack of large trees, lack of marking, logging damage, lack of woody debris and disturbance levels. Alien species proved less of a problem than in other parts of Southwestern Ontario (Maitland Watershed Partnerships 2001). Modest losses continue: between 1984 and 1999, 256 ha were lost – most to agricultural land, some to aggregate and development.

In 1952, the Middle Maitland was 8% forest. The central level plain had many large hardwood swamps. Extensive mixed forest swamps in the upper Boyle drain had been reduced to wet thickets by fires, grazing and clearing. Grazing was found in 62% of the forest, destroying new growth. Fire was a menace – some had been deliberately set to burn off peat (Department of Planning and Development 1954). The watershed is now 11.2% forest cover.

In the last few decades, the planning region, like many other parts of southern Ontario, has seen some gains in immature forest extent as agricultural economics forces abandonment of marginal farmland. Since high capability soils dominate the area, however, the trend is far more subdued than in central or eastern Ontario (Larsen et al. 1997).

1.4.1 Wetlands and ANSIs

Wetlands can play very important hydrological roles; they can perform flow stabilization, water quality improvement and erosion control. Beecroft (1984) cites an instance of a creek once large enough to support sawmills disappearing after cedar swamp removal. The following paragraphs outline the evaluated wetlands within each watershed of the source protection planning region, but there remain a number of unevaluated wetlands. Calculated areas and percentages of wetland are derived from natural heritage studies.

Areas of Natural and Scientific Interest (ANSIs) are also included in this section. ANSIs are described as areas (land or water) containing natural landscapes or features which possess values related to protection, natural heritage, scientific study or education (Hanna 1984). ANSIs vary in significance (provincially or locally significant); it is important to remember that wetlands and ANSIs are not mutually exclusive.

Ausable

Documented wetland extent is at 1.52% (2,604 ha): 1.28% is swamp, 0.12% is marsh and 0.12% is unevaluated. The number mainly comprises Hay Swamp (a local ANSI) and a handful of very small areas. Hay Swamp is in the Upper Ausable watershed. It plays an important role in flood moderation, aided by roads and bridges across the direction of flow. The swamp improves water quality in the critical summer period and then releases nutrients in the fall and winter (Paragon 1986).

Lake Smith, its predecessors and associated marshes were part of the flood retention function of the Lower Ausable flats and also an effective sediment trap. The flats still have some flood storage capacity but not near the pre-Cut, pre-drainage volume. Wetland removal eliminated habitat and the only marsh between Walpole Island and Arran Lakes near Southampton, which is outside the planning region (Conservation Branch 1949). Today, although abandoned by most wildlife, tundra swans and other migratory waterfowl still alight before water is pumped out for the spring planting.

The landscape potential for wetland restoration is best in the Lower Ausable flats, Hay Swamp vicinity and Parkhill watershed's wet clay tills and wet sand plains (Snell and Cecile et al. 1995).

Within the Ausable River watershed, there are a number of ANSIs. The Ausable River Valley is a 1780 ha forested area near Arkona and is significant in its seepage for cold water. It was selected as a provincially significant ANSI for its large size, relative natural condition, and excellent diversity of habitats and landform types (Brownell 1984). The ANSI crosses two physiographic regions: the Horseshoe Moraines, where the river valley has cut deep through the moraine to the underlying bedrock, and the Huron Slope near Thedford, where there are sand plain deposits (Lindsay 1981). Broad-leaved species such as beech, sugar maple, red maple, red oak, basswood, white oak and bur oak dominate, and the area is habitat for the threatened Queen Snake (Lindsay 1981) and the threatened Eastern Hog-nosed Snake (Brownell 1984). A large amount of forest in the Ausable River Valley ANSI has been disturbed for timber removal (Brownell 1984). Other provincially significant ANSIs are the Staffa Kame complex, Pinery Provincial Park and the Port Franks Dunes and Wetland Complex.

Hay Swamp, a local ANSI, is 2,150 ha of swamp forests, scrub, and plantations. It is bounded by the Wyoming moraine on the north, west and south sides, till plain to the east, and is a wide, gentle spillway. The predominant tree species includes silver maple, white elm, black ash, cottonwood, white cedar, poplar and tamarack (ABCA 1984). Dashwood, another local ANSI, is located adjacent to Hay Swamp.

Bayfield

Documented wetland extent is very small – wetlands account for 0.59% of the watershed (294 ha): 0.48% swamp, 0.01% marsh and 0.10% unevaluated. Huron groundwater study maps indicate only Trick's Creek wetland plus three other very small wetlands (International Water Consultants et al. 2003). Trick's Creek wetland lines the creek along the spillway; the wetland benefits from the spillway's groundwater discharge and buffers the stream. Bayfield's main wetland restoration potential is in the eastern headwaters and the Big Drain watershed (Snell and Cecile et al. 1995).

Two ANSIs are located within the Bayfield watershed: the Bayfield River ANSI and the Bayfield North ANSI.

The Bayfield River ANSI is 850 ha of long, narrow, river valley that follows the river for 10 km, upstream of Bayfield. The ANSI is representative of floodplain wetlands with abandoned meander channels, oxbows and floodplain terraces (Klinkenberg 1983). The Bayfield River harbours a range of vegetation including floodplain, riverbank and valley wall communities (Hanna 1984). Due to the variation exposures along the valley slopes, there exists a variety of microclimates (Crins 1983). The uplands support deciduous forest (sugar maple, american beech, green ash, black cherry, ironwood) while the slopes support some coniferous species like eastern hemlock and white cedar. Twelve vascular plants considered to be rare in Ontario have been found in this ANSI (Crins 1983). Special features to this system include a deer yard and a migratory trout and salmon run (Hanna 1984).

The Bayfield North provincially significant ANSI is comprised of 273 ha of adjoining woodlots that are bisected by concession roads: Huron County Road 13, Orchard Line and the Bayfield Concession Road (Jalava 2004). It is located north of the Town of Bayfield, in close proximity to Lake Huron. The woodlots of the ANSI contain both upland (sugar maple, beech, and ash) and lowland (cedar, red maple, basswood, and dogwood) species, but generally represent upland woods (Hanna 1984). Stream corridors and small wetlands also make up part of the ANSI and the moist rich organic soils of the bottomlands support extensive meadow marsh-woodland mosaics (Jalava 2004). The area is mostly undisturbed, but some of the woodlands have been used for fuelwood and commercial timber production (Jalava 2004). Bayfield South, another locally significant ANSI, is also located within this watershed and runs parallel to Lake Huron.

Maitland

The Maitland watershed has the greatest amount of wetland both in area and in percent of overall land. The Maitland has a wetland extent of 5.48% (14,120 ha) broken down into 4.83% swamp, 0.06% marsh, 0.03% fen, 0.22% bog and 0.34% unevaluated. Little Maitland River joins the North Maitland River with the best distribution of wetlands in the watershed. Several wetlands buffer the Little Maitland River system. Most North Maitland wetlands are associated with tributaries rather than with the river.

The Middle Maitland watershed has an intermediate number of wetlands especially in the south including some that may moderate the flow and quality problems of Beauchamp Creek.

South Maitland has no wetlands in the upper and mid basin. The lower river flows through the diked Hullett Provincial Wildlife Area. Flow moderation and filtering services were likely important given upstream concerns but the dikes limit the interactions with the river and the wetland's role. A few small wetlands are scattered through the kame unit in the basin's west end. Most are along a tributary that joins the South Maitland from the north immediately above its confluence with the Maitland; their hydrological services benefit the Lower Maitland.

In the Lower Maitland, the spillway that discharges into Sharpes Creek also contributes to Saratoga Swamp which buffers much of the creek's length. Other concentrations of wetlands occur in the upper Blyth Brook watershed and along Hopkins Creek. Hopkins Creek is part of the same spillway unit as Sharpes Creek but across the Maitland; Hopkins Creek wetlands, like Saratoga Swamp, are discharge areas and buffer the creek.

The Maitland has a number of ANSIs which together make 4,572 ha: Holmesville, Winthrop and Kinburn are all provincially significant, while the Maitland River Valley, Anient and Pollard

Tract, Blyth Area, Ethel Kame and Seaforth Esker are all locally significant. The Seaforth-West Wawanosh Moraines borders the Maitland and Bayfield River watersheds, and is provincially significant.

<u>Nine Mile River</u>
The upper area has a relatively high number of small wetlands including several buffering the river. Wetlands account for 13.54% (3,290 ha): 12.74% being swamp and 0.80% is unevaluated wetland. The Nine Mile also has 200 ha of ANSIs.

<u>Shore Gullies and Streams</u>
Like Bayfield, this watershed has a low number of wetlands. The wetland extent is 0.75% (519 ha): 0.68% is swamp and 0.07% is unevaluated. The major system is Saratoga Swamp that is at the headwaters of Boundary Creek.

The Eighteen Mile Shorecliff provincially significant ANSI of 30 ha is comprised of a 20 m high bluff that stretches 3 km along Lake Huron southward from the mouth of the Eighteen Mile River. Trembling aspen, balsam popular and cedar dominate the steep slopes with beach grass along the sand at the toe of the slopes (Hanna 1984).

1.4.2 Terrestrial

The current forest differs markedly from the original forest not only in extent but in form. Black cherry trees ten feet in diameter or hollow sycamores able to hold a dozen men in one tree base (Beecroft 1984) are long gone. Since its low point near the turn of the 20th century, the forest area is very gradually recovering as more marginal farmland is abandoned but many woodlots are immature, highly altered replacement forests (Larsen et al. 1999).

Forest diseases and pests have also taken a toll on the area's woodlots. The Hickory Bark Beetle has killed up to 80 to 90% of the trees in hickory woodlots. Recent droughts appear to have weakened the trees and increased their vulnerability while mild winters have not killed the insects' over wintering stage (ABCA 2004). The Emerald Ash Borer is an invasive species that has garnered recent headlines when it was found in the City of London in November 2006, but it has yet to come to the source water planning region. The larvae feed on the nutrient-rich cambium of the ash, which results in girdling the tree; the first signs to tell if the tree has the emerald ash borer are look at the health of the tree canopy and the presence of 'D' shaped holes in the bark. In its native system, the ash borer is not a pest as it is prey to parasitic wasps and birds. Other aggressive tree diseases and pests include the gypsy moth, beech bark disease, striped sumac leaf roller, fall webworm, bass leaf miner and European woodwasp (Tucker 2006).

WC Map 1-6, Appendix D, presents today's forest distribution.

<u>Ausable</u>
Stoll (1983) and Snell and Cecile et al. (1995) report that up to 20% of the Ausable watershed is woodland; however, recent calculations put the number at 14.5%. The Dunes unit is the major forested area. The Dune forests protect overburden recharge, stabilize the soil and support highly significant biological communities. Much of the remainder of Ausable's natural area buffers the main stem river from the extensive Hay Swamp at the headwaters to the slope protection in the Ausable Gorge. Forest also buffers the deeper part of the Parkhill valley and

lower Ptsebe Creek. Few tributaries, however, benefit from riparian woodlands; the woodlot pattern tends to be scattered and perpendicular to the streams. Exceptions are the well-buffered lower Adelaide, lower Nairn and lower Little Ausable as well as a broken woodlot corridor along Parkhill's north/south sand plain. Current calculations estimate 811,239 m of linear riverine buffer.

The 1995 Watershed Management Strategy (Snell and Cecile et al. 1995) assessed extent of vegetated dunes, riparian extent, forested potential recharge areas, wooded headwaters and wooded steep slopes to rate the forest's water protection roles. Highest role loss has occurred in the headwaters, southeast tributaries, Hobbs-MacKenzie Drain, Decker Creek and the flats. The dunes area dramatically outscores the others in retained functions, followed by Ausable Gorge and Mud Creek. Many sub-watersheds show little natural area function. The flats and the mid reach between Ailsa Craig and Exeter have the least woodland.

Source data for all open watercourses was used to calculate the amount of linear buffer in each watershed. Woodlots were buffered by 30 metres and then identified onto streams. Where these streams were inside woodlot buffers, they were considered watercourses which had a riparian zone. In the Ausable watershed, there is 811 km of linear buffer.

<u>Bayfield</u>
The forest cover is low at 10% (Snell and Cecile et al. 1995). The upper watershed is barren; much of the forest is concentrated along the lower Bayfield valley below Clinton, as well as in the valleys of Trick's and lower Bannockburn Creeks. The vegetation found within the lower valleys helps stabilize slopes, moderate flows and improve water quality. The lack of forest in the mid and upper watershed aggravates an already un-moderated and unnatural drainage system and contributes to the wide gap in water quality and quantity between the two parts of the basin.

The 1995 Watershed Management Strategy indicated a high loss of natural area function relative to the ABCA for the upper and middle Bayfield River reaches and the adjoining Silver Creek sub-watershed, as well as for the Big Drain tributary of Bannockburn Creek. The rating for quality of remaining features singles out the Lower Bayfield, which includes an ANSI and diverse forest, as clearly the best terrestrial functioning sub-watershed in the basin. Of the remaining nine sub-watersheds, seven have very little natural area function – only Trick's Creek and the Middle Bayfield indicate even moderate roles.

<u>Maitland</u>
Natural areas cover 18.9% of the Maitland; forest – natural and plantation – covers 16.5% of the watershed. Little Maitland, North Maitland and Lower Maitland subwatersheds are above the average for natural areas with 19.3%, 21.3% and 26.8% respectively, while South has the least at 12.6%. The Maitland watershed has a total length of linear buffers of 1274 km.

<u>Nine Mile River</u>
The watershed has the highest proportion of natural area in the planning region – 32.6%. Natural forest is 25.0%, plantation is 1.8% and old field is 3.8%. Most of the stream system's banks are forest lined. The Nine Mile watershed has 222 km of linear buffer.

<u>Shore Gullies and Streams</u>
Forest cover is 11.2%. The highest concentration occurs in the gully basins immediately north of Bayfield. Further north, moderate percentages extend as far as Port Albert but dwindle to less

than 10% beyond. The Gully watersheds north of Bayfield, led by Gully Creek, have good riparian cover, surficial recharge area cover, and slope protection (Snell and Cecile et al. 1995). Boundary Creek, south of Nine Mile River, has well forested headwaters associated with the Saratoga Swamp. Elsewhere, the main forest remnants occur on the narrow and shallow sand plain strip. The Shore Gullies and Streams watershed has 351 km of linear buffer. Table 1-5 presents percentages for the five watersheds within the source protection planning region determined through aerial photography from 2000.

Table 1-5: Watershed Natural Area Distribution for the Source Protection Planning Region

Watershed	Natural Area %	Natural Forest %	Plantation %	Old Field %	Distribution and Roles
Ausable	14.5%	13.6%	<0.1%	0.9%	-concentrations on Dunes unit -buffers along Ausable River from Hay Swamp to Ausable Gorge. -well buffered lower Adelaide, lower Nairn and lower Little Ausable.
Bayfield	10.8%	10.3%	<0.0%	0.5%	-very little natural area function only the Trick's Creek and Middle Bayfield subwatersheds have moderate roles. -forest concentrated along lower Bayfield valley below Clinton. -vegetation in valleys help to stabilize slopes, moderate flows and improve water quality.
Maitland	19.8%	16.9%	0.8%	2.1%	-some concentration on kames -Two large wetlands in Little Maitland subwatershed may have some flow moderation roles. -Maitland River, Blyth Brook and Sharpes Creek all well vegetated for most of their lengths
Nine Mile	32.6%	25.0%	1.8%	3.8%	-most of streams banks system are forest lined.
Gullies	13.9%	11.2%	1.2%	1.5%	-Gully subwatersheds have good riparian cover, surficial recharge are cover, and slope protection. -Boundary Creek has well forested headwaters

1.5 Aquatic Ecology

Pre-settlement rivers had more cold or cool water habitat maintained by springs and forest shade. Except for river bank erosion at meanders and gorges, complete ground cover minimized soil erosion and stream sediment. Flooding maintained the lagoon flats' marsh community.

Today, species sensitive to warm water or sediment are severely limited by land use activities, turbidity and sedimentation, increased temperatures and modified hydrology (Veliz 2001). Today's cold and warm water streams are distinguished on WC Map 1-6.

1.5.1 Fisheries

<u>Ausable</u>
Although the 1949 Report mapped a very limited extent of cold water streams and permanent flow, Veliz in 2001 reported even less cold water habitat. Although Veliz (2005) confirms 83

species – an impressive number for an agricultural watershed – most sites supported less than 10 species, a number suggesting poor water quality (Veliz 2001).

Reports of cold or cool water streams or associated species include:

- Upper part of Black Creek is cold water with resident trout (Veliz 2001) but the remainder of the creek is warm;
- Nairn Creek has sand and isolated gravel that historically supported cold water but very little is left. Veliz (2003) confirmed that low discharge and warm temperatures limit trout. Out of 115 sites studied, six were cold, five had trout but only one of those five was cold. The best trout numbers were in warm water but with gravel, cover and continuous flow;
- A small tributary north of Ailsa Craig has cold water;
- Staffa headwater flow was historically cold and is still relatively clear with a gravel bed. It helps Morrison Reservoir support rainbow trout, smallmouth bass and largemouth bass (Veliz 2001).

Migratory trout and walleye are found in the main Ausable below Ailsa Craig. The Pinery's Old Ausable Channel, although warm water, is isolated from upstream water quality concerns and has been habitat for Rainbow Trout, Yellow Perch, Northern Pike and Largemouth Bass (Schaus 1984).

Although Veliz (2001) found some good cover and substrate on the main Parkhill Creek, water quality problems limit the fisheries (Schaus 1984). The reservoir becomes stratified; the upper warm layer concentrates the nutrients from agricultural runoff and encourages algae growth. Any fisheries are warm water only.

Mud Creek is not a major fisheries stream but the small lakes - Bio, Moon and L Lakes - near Port Franks have high significance for aquatic habitat (Snell and Cecile et al. 1995). A list of fish species found in the Ausable River Basin can be found in the Fish Habitat Management Plan for the ABCA (2001).

The Ausable also supports 26 species of freshwater mussels: 23 live species and fresh shells were found for three other species. Mussels act as living filters for aquatic environments, filtering up to 40 litres a day. Water is drawn across their inhalant siphon and is then passed across their gills to consume particles such as bacteria, algae and detritus. Unused nutrients are converted and expelled and are used by aquatic plants and benthic organisms.

In 2002 the Ausable River Recovery Team, a multi-agency team, was formed to implement a recovery strategy and ensure the continued survival of species-at-risk. The team has conducted several preliminary mussel surveys over the past five years to determine mussel abundance and distribution. In 2006, seven sites along the Ausable River were surveyed (Brinsley, Little Ausable, Ailsa Craig, Nairn, Highway 81, Rock Glen and Arkona): the most prevalent species found was the Threeridge (*Amblema plicata*) (Baitz et al. 2007 unpublished). A new species, the Pimpleback (*Quadrula pustulosa*) was also found in the watershed. Out of the six species-at-risk mussels found, the Kidneyshell (*Ptychobranchus fasciolaris*) was the most predominant. The Northern Riffleshell (*Epioblasma torulosa rangiana*) is globally rare and the only two populations in Canada occur in the Ausable and Sydenham rivers (Baitz et al. 2007 unpublished).

This recently study also confirmed an isolated healthy population of Snuffbox (*Epioblasma triquetra*) at Arkona.

Bayfield

In 1973, George and Pfrimmer noted a gradual deterioration in water quality and decline of less tolerant salmonids. They blamed poor land use practices as well as domestic and industrial waste from Seaforth and Clinton. Lamprey control and introduction of Pacific Salmon by Michigan had restarted spring and fall runs of salmonids but only Trick's Creek showed any spawning success. Trick's Creek rated below-potential because of the dam and a poor fish ladder. George and Pfrimmer found good resident populations of Smallmouth Bass and Northern Pike in the lower Bayfield and Bannockburn. The status of the river above Clinton was rated "deplorable" but, with proper management and good land use practices, capable of much improvement. Problems included intermittent flows, warm temperatures, eutrophication, erosion and sedimentation. The Conservation Authority assisted in rehabilitating cold water habitat in Trick's Creek in 1982.

In 1984, Schaus reported the lower Bayfield below Trick's Creek had a cool water fishery of considerable significance, noting Smallmouth Bass and Northern Pike as resident sport fish, and migratory Rainbow Trout in the spring and fall. Most headwater areas were rated warm water with resident species including minnows, Rock Bass, Sunfish, and suckers. Some streams supported resident Rainbow and Brook Trout.

In 2001, Veliz found 34 species with little effort. In the upper Bayfield, although mostly silty-clay tills and very low base flows, a few gravely areas had some cold water and others like Silver Creek had potential after riparian improvements. In the Lower Bayfield, gravel deposits – notably Trick's Creek – generated some of best cold water habitat in ABCA. Bannockburn's sands also supported some cold water tributaries.

In 2003, Malone confirmed 34 species. Low flow, warm temperatures and eutrophication may be limiting Bannockburn Creek's capacity to support sensitive species. The lower Bayfield continued to have much better water quality than the upper watershed with higher base flows, lower temperature and more dissolved oxygen – all greatly helped by Trick's Creek's flow. Trick's Creek continues to support resident Brook and Brown Trout. A comprehensive list of fish species found in the Bayfield River Basin can be found in the Fish Habitat Management Plan for the ABCA (2005).

Maitland

A 1963 survey found 42 fish species (Conservation Authorities Branch 1967). By far the most common were: Creek Chub, Hornyhead Chub, Common Shiner and Rainbow Darter. Very common but less widely distributed were: Rock Bass, White Sucker, Blacknose Dace, Bluntnose Minnow, Johnny Darter and Brook Stickleback. Trout were found only in the North and Lower Maitland basins, the basins with the most numerous cold or cool water systems. Sharpes Creek, a Lower Maitland tributary, had the best cold water flow. The Little, Middle and South each had small reaches of cool water. The majority of streams either dry up in summer or form stagnant pools suitable only for minnows, suckers and catfish.

The MVCA 1984 Plan indicates 21 cold water streams in a pattern very similar to the 1963 survey; most streams align with spillways and a few rise in kames or moraines. Base flow patterns, however, did not fully correspond to the cold water streams. Of all of the watercourses within the Maitland watershed, 37% are cold or cool with 23% lacking trout or salmon, and 14% having either trout or salmon present. 44% of the watercourses are warm water, with 35% having no top predators and 9% with top predators. 19% of the watercourses within the Maitland are intermittent.

Nine Mile
Of all of the watercourses within the watershed, 69% are cold/cool. Of this 69%, 35% have no trout or salmon present and 34% do have trout or salmon present. Of the rest of the watercourses, 6% are warm water with no top predators, and 25% are intermittent and are dry for at least three months of the year.

Shore Gullies and Streams
One of the most vegetated gully systems, Gully Creek, has cold water habitat and supports runs of migratory salmonids. Most gullies, however, have poor aquatic habitat; their highly variable flow has problems of erosion, poor water quality and no base flow. Of all of the watercourses, 23% are cold/cool, 34% are warm water and 43% are intermittent. Of the 23% cold and cool watercourse, 16% have no trout or salmon present and 7% do, while of the 34% warm watercourses, 29% have no top predators and 5% do.

Off-shore shallow areas and shoals correspond to fish spawning areas, as does the sand deposition area offshore of the Pinery and Port Franks. Offshore fish include Rainbow, Brown and Lake Trout; Coho, Chinook, and Pink Salmon; Freshwater Cod; Lake Whitefish; Chub; Smelt; and Alewife. Near-shore waters contain Yellow Perch, Walleye, Smallmouth Bass, Northern Pike and various pan fish. Commercial fisheries depend mainly on Whitefish and Yellow Perch with licensed fishermen out of Grand Bend, Bayfield and St. Joseph. Sport fisheries focus on Yellow Perch, Rainbow Trout, Brown Trout and Chinook Salmon in Lake Huron with docking at Bayfield, Grand Bend and Port Franks (Donnelly 1994)

1.5.2 Aquatic Macroinvertebrates

Narrow tolerance ranges of certain species of aquatic macroinvertebrates make them a valuable indicator of water quality. Although neither Conservation Authority participates in the Ontario Benthos Biomonitoring Network, both collect aquatic macroinvertebrate data, often using the BioMap protocol.

In the MVCA jurisdiction, from 1994 to 1999, 141 sites have had benthic macroinvertebrates collected to be used as bioindicators of aquatic health. Quantitative samples were collected with a fixed-area T-sampler and a qualitative sample was collected by selectively picking and available habitat types.

The samples were provided to a private consultant for identification to the species level where possible. Using the BioMAP protocol, a water quality index is determined based on the sensitivity values of the species found. Sensitivity values are assigned to a substantial number of species found in this area and range from a 1 (tolerant of warm water, sediment and nutrients) to a 4 (intolerant of warm water, sediments and nutrients). BioMAP has been criticized for being more of a reflection of stream temperatures than aquatic health, and it is planned to experiment with a Family Biotic Index to compare findings.

Ausable

A 2000 study (Veliz and Jamieson 2000) of benthic macroinvertebrates found the dominant taxa were chironomids, elmid beetles and aquatic worms typical of agricultural drains that have sediment and nutrient enrichment.

In 2001, Jamieson found relatively pollution intolerant Capniidae (Stonefly) along with Chironomidae (Midge Fly) as the dominant species in several sample sites including Mud Creek. Nairn Creek had the best Family-Level Biotic Index but other indicators suggest good rather than excellent water quality.

Bayfield

A 1980 MOE Basin Study found only pollution tolerant species above Clinton. In Clinton some pollution-intolerant forms appeared. Lower Bayfield and Bannockburn Creek supported some intolerant taxa but less sensitive forms dominated. Trick's Creek offered a diverse, pollution intolerant community that indicates good water quality.

In 2000, Veliz and Jamieson found the most diverse site at Helgrammite Creek where clear water and a cobble/gravel substrate supported larvae of Mayflies and Caddisflies. Elsewhere the dominant taxa of chironomids, elmid beetles and aquatic worms were typical of agricultural drains that have sediment and nutrient enrichment. In 2001, Jamieson found Chironomidae (Midge Fly) dominant in the Bayfield at Clinton; Caenidae (Mayfly) at Bayfield and Capniidae (Stonefly) in the Bannockburn.

Since 2000, ABCA has been sampling 6 sites. In 2002, diversity was lowest for Silver Creek and highest for Helagrammite, but almost as good at the other four sites. Dominant taxa were: at the poor rated sites - Tubificidae (worms) at Liffey Drain, Hyalellidae (Side Swimmer) at Seaforth; at the fair rated sites - Chironomodidae (Midge Flies) at Silver Creek and Caenidae (Mayflies) at Bannockburn; at the good rated sites - Caenidae (Mayflies) at Varna, lower Bayfield, and Baetidae (Small Mayfly) at Helagrammite (Malone 2003).

Maitland

35% of the sites in the Maitland watershed were found to be unimpaired, with the proportion of unimpaired sites being the largest (60%) in the North Maitland (9/15). Next largest was the Lower Maitland with 42% (5/12), followed by the South Maitland with 37% (7/19), Little Maitland with 27% (4/15) and finally the Middle Maitland, where only 13% (2/16) of the sites were found to be unimpaired.

The different ratings for each of the branches are due to the varied amount of forest cover, gravel soils and landform which produce more stable flows and cooler water temperatures. The more unimpaired sites tended to the areas of higher forest cover and away from the till plain physiographic feature.

Nine Mile River

86% (6/7) of the sites in the Nine Mile watershed were found to be unimpaired due to the presence of sensitivity values of three and four for caddisfly, mayfly and stonefly insects. This watershed has cooler water temperatures, more forest cover and a more stable flow regime.

Shore Gullies and Streams

29% of the sites were unimpaired (2/7) which reflects the variable flow regime of this area and more clay soils. The streams with better ratings tended to be those ones with headwaters that touch the Wyoming Moraine. In 2001, Jamieson found Capniidae (Stonefly), a relatively pollution intolerant species, dominant in the Gully Creek site and Zurich Drain.

1.5.3 Species and Habitats at Risk

The presence of threatened or rare aquatic species can suggest unique habitat characteristics that should be considered in a source protection plan.

Ausable

The Ausable River, located on the northern fringe of the Carolinian Zone, supports unique aquatic biota and is one of the most biologically diverse basins of its size in Canada (Veliz, 2005). The aquatic community of the Ausable River includes 16 species listed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC): seven fishes, six mussels (Baitz et al. 2007 unpublished), and three aquatic reptiles. Because several of these species at risk are declining within the basin, a recovery team was formed in 2002. The Ausable River Recovery Team has conducted inventories of fish, mussels and reptiles, drafted a strategy and is now undertaking recovery actions to improve conditions for these species in the watershed (Veliz 2005).

Bayfield

Malone (2003) noted 21 rare species. Aquatic ones include Black Redhorse, Lake Chubsucker, Northern Brook Lamprey, as well as life stages of Queen Snake, Wood Turtle, Ashy Clubtail – a dragonfly, and Louisiana Waterthrush. Obligate wetland plants include: Hemlock Parsley (*Conioselinum chinense*), Beaked Spike-Rush (*Eleocharis rostellata*), and Hairy Valerian (*Valeriana edulis spp. Ciliata*).

Maitland

Natural Heritage Information Centre list of Committee on the Status of Endangered Wildlife in Canada (COSEWIC) aquatic or floodplain species found in the Maitland watershed includes: Least Bittern, Black Redhorse, Queen Snake, Wavy-rayed Lampmussel and a plant, *Arisaema dracontium* (Green Dragon). Central Stoneroller and Striped Shiner are listed but classified Not At Risk. The Maitland Valley also hosts the Wood Turtle. The Rainbow Mussel is yet to be listed under SARA, but is anticipated for 2007-2008.

Nine Mile

It is not known whether there are species at risk in the Nine Mile watershed.

Shore Gullies and Streams

For the Shorelines Gullies and Streams watershed, the American Eel and the Deepwater Sculpin have no status under SARA, but are designated by COSEWIC for future consideration for Schedule 1 listing. The Blackfin Cisco is listed as threatened under SARA, but is believed to be extinct.

Table 1-6 lists the various at-risk fish, mussels and aquatic reptiles found within the source water planning region.

Table 1-6: Species at Risk within the watersheds of the source protection planning region and their listing under SARA and SARO

Common Name	Scientific Name	Watershed	SARO	SARA
Fish				
Pugnose Shiner	*Notropis anogenus*	Ausable	END-NR	END, Schedule 1
Lake Chubsucker	*Erimyzon sucetta*	Ausable Bayfield	THR	THR, Schedule 1
Eastern Sand Darter	*Ammocrypta pellucida*	Ausable	THR	THR, Schedule 1
Black Redhorse	*Moxostoma duquesnei*	Ausable Bayfield Maitland	THR	THR, Schedule 2
Blackfin Cisco	*Coregonus nigripinnus*	Maitland	EXT	THR, Schedule 2
River Redhorse	*Moxostoma carinatum*	Ausable	SC	SC Schedule 3
Greenside Darter	*Ethostoma blennioides*	Ausable	SC	SC, Schedule 3
Bigmouth Buffalo	*Ictiobus cyprinellus*	Ausable	SC	SC, Schedule 3
Northern Brook Lamprey	*Ichthyomyzon fossor*	Bayfield	SC	SC, Schedule 3
Redside Dace	*Clinostomus elongates*	Shoreline	THR	SC, Schedule 3
American Eel	*Anguilla rostrata*	Shoreline	No status	No status, SC under COSEWIC
Deepwater Sculpin	*Myoxocephalus thompsonii*	Shoreline	THR	No status, SC under COSEWIC
Mussels				
Northern Riffleshell	*Epioblasma torulosa rangiana*	Ausable	END-NR	END, Schedule 1
Wavy-rayed Lampmussel	*Lampsilis fasciola*	Ausable, Maitland	END-NR	END, Schedule 1
Snuffbox	*Epioblasma triquetra*	Ausable	END-NR	END, Schedule 1
Kidneyshell	*Ptychobranchus fasciolaris*	Ausable	END-NR	END, Schedule 1
Rainbow mussel	*Villosa iris*	Ausable Maitland	No status	No status, END under COSEWIC
Mapleleaf	*Quadrula quadrula*	Ausable	No status	No status COSEWIC= THR

Aquatic Reptiles				
Eastern Spiny Softshell Turtle	*Apalone spinifera*	Ausable	THR	THR, Schedule 1
Queen Snake	*Regina septemvittata*	Ausable, Bayfield, Maitland	THR	THR, Schedule 1
Northern Map Turtle	*Graptemys geographica*	Ausable	SC	SC, Schedule 1
Wood Turtle	*Glyptemys insculpta*	Bayfield Maitland	END-NR	SC, Schedule 3

EXT=Extinct
END-NR=Not regulated under Ontario's Endangered Species Act (33)
END=Endangered
THR=Threatened
SC=Special Concern

1.5.4 Invasive Species

Some invasive species can affect water quality. Examples include the common carp and zebra mussel. The common carp was introduced to North America in the mid 1800s as a commercial fish. Because carp are omnivorous, they often eat the eggs and young of other fish and disturb sediment in a watercourse as they forage for food, thus disrupting the quality and clarity. The disturbance of sediment can discourage other fish from nesting in the area and can prevent aquatic vegetation from establishing which provides food to other fish.

Zebra mussels were first discovered in North America in 1988 and have since spread through the water system using the water currents during their planktonic larvae stage. Zebra mussels can affect water quality through their respiration and filtering by decreasing the amount of plankton, suspended sediments and dissolved oxygen and increasing the concentration of ammonia nitrogen and soluble phosphorous.

There is anecdotal evidence that the Round Goby has travelled as far upstream as the dam at Parkhill. The round goby is a bottom-feeding fish that is an aggressive feeder and breeder – producing more young for a longer period of time than other fish. The goby also establishes in prime habitat that is preferred by native fish. Little is known about the distribution of aquatic invasive species and is an identified data gap.

1.6 Human Characterization

Small nomadic bands may have followed caribou herds through a spruce forest landscape as long as 11,000 years ago (W. Fox in Beecroft 1984). Subsequent aboriginal use was based on hunting. By the late 1600s Chippewas settled in the area and developed a trade in flint found at Kettle Point. European settlement was deterred by Niagara Falls, the distance to the Nipissing route, poor river navigability and the Thedford Swamp. It was the Huron Road built by the Canada Company in 1828 that finally brought settlers to the area (Conservation Authorities Branch 1967; Beecroft 1984).

The relative remoteness discouraged industry and large cities while the rich soils encouraged agriculture. Agriculture remains a major economic mainstay of the community. It is only with the advent of the automobile that the tourism industry boomed (Butler and Hilts 1978) based on the allure of the Lake Huron shore. More recently, good roads and ready access to Canadian and US markets have encouraged industry beyond agricultural support and processing.

Provided documentation on human use was scant. Little of the documentation applied to the watershed boundaries of the planning region. In the following sections, Huron County data are used as most representative of the planning region (see WC Map 1-1).

1.6.1 Population Distribution

Both Conservation Authorities average 18 persons per kilometre squared in population density; a majority are rural residents. In the 2001 census, Huron County was 60% rural residents – more than any other Southwestern Ontario county (Statistics Canada 2002). Table 1-7 lists the region's towns and villages by watershed. For this table, populations were taken from a variety of sources. The 2006 Statistics Canada census did not record populations at the town or village level, but at lower-tier municipality. From this list, only Goderich has more recent population data.

Table 1-7: Population Sizes and Densities of Towns and Villages within the Ausable Bayfield Maitland Valley

Town or Village	Watershed (* main)	Location in Watershed	Population	Population Density/km^2
Hensall	Ausable	Headwaters of Black Creek	1,194 [4]	746.3 [4]
Exeter	Ausable	Upper	4,500 [1]	914.2 [4]
Lucan	Ausable	Little Ausable	2,010 [4]	1,248 [4]
Ailsa Craig	Ausable	Mid	1,000 [2]	473.3 [4]
Arkona	Ausable	Hobbs-Mackenzie Drain	464 [4]	348.9 [4]
Thedford	Ausable	Decker Creek	755 [4]	379.4 [4]
Port Franks	Ausable*, Shore Streams	Mouth of Ausable and of Mud Creek		
Grand Bend	Ausable, Parkhill, Shore Streams*	Mouth of Parkhill	995 [4]	283.5 [4]
Parkhill	Parkhill	Mid	1,700 [2]	420.1 [4]
Seaforth	Bayfield, South Maitland	Silver Creek	2,500 [1]	914.4 [4]
Clinton	Bayfield, Lower Maitland	Boundary of upper and lower	3,000 [1]	764.0 [4]
Bayfield	Bayfield, Shore Streams	Mouth	830 [5]	317.8 [4]
Listowel	Middle Maitland*, Little Maitland	Near headwaters	5905 [4]	954.0 [4]
Brussels	Middle Maitland	Mid	1,143 [4]	589.2 [4]
Wingham	Middle Maitland, North Maitland*, Lower Maitland	Confluence of Middle and North so top end of Lower	3,000 [1]	1,187.2 [4]
Palmerston	Little Maitland	Near headwaters	2518 [4]	868.3 [4]
Harriston	North Maitland	Near headwaters	2034 [4]	600.0 [4]
Blyth	Lower Maitland	On Blyth Brook	952 [3]	440.6 [4]
Goderich	Lower Maitland*, Shore Streams	Mouth	7,563[6]	956.1 [6]
Lucknow	Nine Mile	Mid	1136 [4]	576.6 [4]
Zurich	Shore Streams	Headwaters	850 [5]	924.7 [4]

[1] Dodds et al. 2005
[2] Peeters 2006
[3] Black 2006
[4] Statistics Canada 2005
[5] Municipality of Bluewater 2006
[6] Statistics Canada 2007

From 1951 to 1996, Huron County farm population decreased from 46% of the total to 18%, still much higher than the 3% proportion of farmers nationally (Huron County Planning and Development Department 2001). The recent rise in rural non-farm population results in non-farm population exceeding farm population in most townships (Bonte-Gelok and Joy 1999). The higher population growth areas have been in the south toward cities outside the basin (ABCA 1985).

Table 1-8 lists the populations divided among the lower tier muncipalities within the Ausable Bayfield Maitland Valley Source Protection Region. Altogether, there are approximately 97,000 residents of the region excluding seasonal residents. WC Map 14 illustrates the population densities throughout the region.

Table 1-8: Population within the ABMV watershed.

Municipality	Population within the ABMV watershed
BRUCE	2,590
Huron-Kinloss	2,532
South Bruce	58
HURON	54,700
Ashfield-Colborne-Wawanosh	5,163
Bluewater	6,421
Central Huron	7,138
Goderich	7,308
Howick	3,197
Huron East	8,903
Morris-Turnberry	2,946
North Huron	4,792
South Huron	8,832
LAMBTON	6,142
Lambton Shores	5,875
Warwick	267
MIDDLESEX	13,110
Adelaide Metcalfe	849
Lucan Biddulph	2,680
Middlesex Centre	3,036
North Middlesex	6,545
PERTH	15,291
North Perth	11,359
Perth East	1,016
Perth South	82
West Perth	2,834
WELLINGTON	5,647
Mapleton	411
Minto	3,606
Wellington North	1,630

Source: Based on 2006 Statistic Canada Population Census proportioned by percentage of municipal area in the Source Protection Region.

1.6.1.1 Population Projections

Starting in the mid-1990s with the expansion of urban centres and the changing responsibilities of local and provincial governments, there was a movement of municipal restructuring and merging. Between the years of 1996 to 2001, the number of municipalities within Ontario decreased by 40%. Refer to Appendix B to see how the municipalities within the source protection region were restructured since 1996. Dates of approval for Official Plans and Zoning By-Laws are also listed; some municipalities have yet to consolidate the zoning by-laws of the various townships prior to municipal restructuring. Other municipalities do not have their own official plan and use that of their county, or have official plans for urban areas and use the county's official plan for rural areas.

The following population projections were obtained from both the county official plans and from the Ministry of Finance. While the county official plans offer a local perspective on the projections, the MOE guidance used to write this document (October 2006) requires that the projections be given for the years 2006, 2011, 2016 and 2031. While some counties conform to this requirement, the projections listed by the County of Wellington do not. In addition, none of the official plans offer a population prediction for 2031. Therefore, both sets of projections have been listed here and the populations in the text differ from those listed in Table 1-9.

<u>Huron County</u>
From 1951 to 1996, Huron County grew by 11,000, averaging 0.5% per year compared to Ontario's 2% per year. Between 1996 and 2001, however, Huron County population declined by 0.9%. The Ontario government projects that Huron County will grow at a modest rate: from a population of 59,701 in 2001 to 69,000 in 2031 (Dodds et al. 2005). The population fluctuates seasonally with summer cottagers and tourists.

<u>Middlesex County</u>
In the County of Middlesex's Official Plan (2006), the population of the county is estimated at 71,631 in 2001. The Official Plan attempts to forecast the growth of the county over the next 15 years to predict the required land use and infrastructure and predicts the population to be 71,502 in 2006, 75,399 in 2011 and 78,556 in 2016 (County of Middlesex Projections 2001-2026).

<u>Lambton County</u>
From 1961 to 2001, Lambton County grew by 52,011 averaging 1.4% per year (Lambton County Planning & Development Services 2002). Between 1991 and 2001, the population of Lambton County declined by 1.53%. In 2001, Statistic Canada estimated the population size at 126,971 (Lambton County Planning & Development Services 2002) and the County predicts a growth to 142,000 by the year 2016 (Lambton County 1998).

<u>Bruce County</u>
In the 1991 census, the population of Bruce County is estimated at 64,215 individuals. In the current official plan which uses a planning period until 2016, Bruce County predicts a population growth of 21,294 to a total of 85,509 (Bruce County 1999). Most of the growth will occur in primary, secondary and hamlet communities; it does not have a large regional centre within the county.

<u>Perth County</u>

The average annual growth rate in the County for the years between 1971 and 1991 was a modest 0.6% (Perth County 1997). As a rule, the populations increased significantly in the urban centres within the county, as compared to the rural areas. Between the years 1996 to 2016, the County predicts a growth rate of 1.25% and estimates that the population will be distributed 46% within the City of Stratford and Town of St. Marys, and 54% within the rest of the county (Perth County 1997).

Wellington County

The County of Wellington has projected its population on a five year basis starting in 2002 over a twenty-year time period. The projections are based on the assumption that 82% of the growth will occur in 15 urban centres: Arthur, Mt. Forest, Clifford, Harriston, Palmerston, Drayton, Moorefield, Belwood, Elora-Salem, Fergus, Rockwood, Erin, Hillsburgh, Aberfoyle and Morriston (Wellington County 1999). The county predicts a population of 83,000 in 2002, 89,500 in 2007, 96,500 in 2012, 102,500 in 2017 and 109,000 in 2022.

Table 1-9: Population projections for counties within the Ausable Bayfield Maitland Valley Region. All projected populations are from the Ministry of Finance, 2006.

County	Population (2006)	Population (2011)	Population (2016)	Population (2031)
Huron	61,600	62,300	63,500	67,930
Middlesex*	438,050	457,670	476,870	528,630
Lambton	132,200	132,390	142,000	136,470
Bruce	67,530	69,240	71,540	78,670
Wellington*	208,170	223,240	238,100	278,870
Perth	78,160	81,050	84,040	92,340

*Note: the projections for Middlesex County include the population for the City of London and the projections for Wellington County include the population for the City of Guelph.

1.6.2 Land Use

Land use (1980s) is presented on WC Map 1-7. Agriculture dominates the planning region. Small urban areas are scattered throughout the area. Cottage development has spread along the lakeshore. Forest concentrations occur in the Dunes, Ausable Gorge, the Lower Bayfield and Maitland Valleys and the major spillway and delta unit that include the Hay Swamp, Lower Bannockburn Creek, Trick's Creek and the Saratoga Swamp. There are a number of Conservation Areas, private campgrounds, and two provincial parks: The Pinery and Point Farms. Several gravel pits occur in the major spillway unit. Stoney Point First Nation, located outside of the source protection planning region, has reclaimed Ipperwash Range and Training Area. In 1989, the Maitland was 80% agriculture, 2% urban and 18% natural (MVCA 1989).

Potential land uses are presented on WC Map 1-8 to show Official Plan zoning; currently the map is an incomplete draft.

1.6.2.1 Existing Urban Development

The planning region is predominantly rural. All towns or villages in the planning region are listed in Table 1-7 in Section 1.6.1 and shown on WC Map 1-1. These towns and villages were all considered independent municipalities prior to the municipal restructuring and amalgamation which began in 1996. The largest is Goderich with a population of 7,500. Towns are scattered throughout the region and the urban footprint (which includes any town, village, hamlet or other grouping of houses) covers 1.42% of the Ausable watershed, 1.64% of the Bayfield, 1.41% of the Maitland, 1.94% of the Nine Mile and 2.28% of the Shorelines and Gullies watershed.

In the Bayfield Ward, shoreline development in Central Huron and Varna are considered urban, although Varna is a small residential community. Clusters of development within Stanley Ward and Central Huron are categorized as rural/recreational. These areas consist of a large number of permanent and seasonal residences, campgrounds and trailer parks. Rural areas are largely situated in Central Huron east of Highway #21 and north of County Road #13.

Some urban development is atypical of the extensive impervious surfaces associated with urbanization. Subdivisions such as Southcott Pines, Huron Woods and Beach O' Pines have greatly altered the dune ecosystem but maintained enough natural cover to minimize erosion and encourage infiltration in the highly pervious sands. The density of cottage development has allowed for more efficient water servicing, but has led to increased risks due to septic system use and failures.

The community of St. Joseph is unique in that there is a mixture of land use. It is comprised of 45% farms and 35% cottages. The cottages are connected to the pipeline from Port Blake, while the farms have private wells. All properties use septic systems in this area.

Other towns and communities serviced by municipal wells as listed in Section 1.6.3.5.1.

1.6.2.2 New and Projected Urban Development

Ontario's recent Greenbelt Plan and Places to Grow Policy does not apply to the planning region. The 2005 Provincial Policy Statement directs growth to existing urban areas and protects agricultural lands by discouraging lot creation (Ontario Ministry of Municipal Affairs and Housing, 2005).

1.6.2.3 Industrial / Commercial Sectors Distribution

As agricultural employment declines, industrial and commercial sectors have grown in importance. In 2002, Huron County employment in manufacturing and construction sectors outstripped all others (Statistics Canada 2002). Most manufacturers are small. The largest product categories are food related (farm feed supplies, food products and processing) and fabricated metal. Other major manufacturing categories include wood products, furniture, printing and publishing, and equipment – industrial, commercial, electric and transportation. Industries are well distributed in towns and villages throughout the region. In Huron County, the highest numbers occur in Goderich, Wingham and Exeter (Huron Manufacturing Association 2005) Goderich continues its long history of salt mining and port transport. The top five employers for Huron County in 2003 were Wescast Industries Inc., Volvo Motor Graders, Royal Homes Ltd., Nabisco Ltd., and Northlander Industries Inc (Huron County Planning and Development Department 2003).

Tourism is a major employment sector in the planning region. Lake Huron is the main attraction. The lakeside location has generated many business and activities for visitors and cottagers. Major tourist centres are Grand Bend, Bayfield and Goderich.

1.6.2.4 Trends in Industrial and Commercial Sectors

Manufacturing is the fastest growing sector of the Huron County economy both for business start-ups and job creation and has replaced farming as the largest generator of Huron's economy. A manufacturing strategic plan has initiatives to create economic development from within the area and to attract investment from outside (Huron Manufacturing Association 2005).

Tourism and its many associated businesses are also growing (Malone 2003). Cottage prices are climbing. As the cost of gasoline rises, the area's relative proximity to major population centres such as Toronto and Detroit may increase its attraction.

These growth trends buck the slight decline in population, possibly indicating a switch of employment out of farming.

1.6.2.5 Agricultural Sector Distribution

Significantly, the Maitland watershed has the highest livestock manure production/ha (7,610 kg/ha) in Canada, 10 times the national average. The Ausable Bayfield watershed was seventh at just over 4,000 kg/ha. Manure components showed similar patterns: Maitland was highest nitrogen in Canada at 48 kg/ha, while the Ausable Bayfield was sixth with 28 kg/ha. Maitland placed second for Phosphorus at 13 kg/ha and Ausable Bayfield was seventh with 8 kg/ha. Maitland ranked third nationally for total coliform bacteria and second for fecal coliform bacteria; in each case the Ausable Bayfield was at a lower ranking (Statistics Canada 2001).

Agricultural sector distribution is presented in Table 1-9. Cultivated lands include continuous row crops, corn systems, extensive field vegetables, grain systems, hay systems, mixed systems, orchards, vineyards and tobacco systems. Pasture lands include grazing systems, pastured systems and pastured woodlots. Lands which do not fall in one of these two categories include, but are not limited to, built-up urban lands, extraction sites, recreation sites, water, woodlots, and wetlands. Land that is either cultivated or pastured can also be described as prime or marginal; the two sets of categories are not mutually exclusive. Not all land is of either prime or marginal value and can be considered 'Non Marginal or Prime'.

Table 1-10: Agricultural Sector Distribution within the Ausable Bayfield Maitland Valley

Watershed	% cultivated	% pasture	% prime	% marginal	Cattle Density	Poultry Density	Swine Density	Livestock Unit Density
Ausable	78.04	3.87	91.67	2.54	M*	L*	H*	M*
Bayfield	84.23	1.60	97.23	0.99	M*	H*	M*	M*
Maitland	78.43	2.84	88.70	2.84				
Nine Mile	68.01	4.64	65.58	9.92	L*	L*	L*	L*
Shore Streams & Gullies	82.77	1.44	97.58	0.48				

*The ratings are from Bonte-Gelok and Joy (1999) and apply to Huron County portions only.

1.6.2.6 Trends in Agriculture

In 1996, Huron County housed approximately 240,000 livestock units: 405,000 hogs, 4.5 million chickens and 165,000 cattle (Huron County Planning and Development Department 2001). These numbers mark a decline in cattle since 1971 but an increase in poultry and swine for little change in total livestock units. In the same period, improved land area decreased while un-improved areas grew (Bonte-Gelok and Joy 1999).

Between 1996 and 1999, Huron saw a further 54% increase in hogs marketed per producer. Between 1996 and 2000, 391 building permits were issued for new or expanded barns to accommodate an additional 58,000 livestock units, and hogs accounted for 72%. In 1996, every municipality still averaged adequate area to accommodate the manure. But since then, intensity of production has risen dramatically and new barns are much larger (Huron County Planning and Development Department 2001). The 1996 to 2000 building permits for new or expanded barns showed some concentration in Bayfield, Middle Maitland, Little Maitland and North Maitland watersheds, but occurred in all other areas as well. Expansion was highest in former Stanley Township, south of Bayfield. Livestock density remains highest in the Maitland watershed (Huron County Planning and Development Department 2001).

Between 1961 and 1996, the number of farms in Huron County dropped by 38% and the average farm size grew 1.5 times (Huron County Planning and Development Department 2001), but Huron still has more census farms and farmland (3,260 and 711,525 acres, respectively) than any other district or county in the province (Huron Tourism Association no date). Agricultural employment has decreased, although there is a need for skilled agricultural workers at a higher pay scale and many jobs go unfilled.

In the longer term, the dominance of mixed farms noted in the 1949 Report gave way to a major expansion of row crops (corn and soy beans) in the following 25 years in Huron County. Pasture receded to river valleys while livestock numbers and feedlots grew. The changes brought increases in artificial drainage, fertilizer use, manure production and spreading, manure spills, milkhouse wastes, cultivation to stream edges and clearing of marginal land. Rotations declined, woodland was cut and fields expanded, flash flows increased and both water and soil declined in quality (ABCA 1979; MVCA 1989).

Perth County has also had a long history in agriculture. Following a wheat midge infestation that destroyed crops in the mid 1870s, farmers turned to cooperative dairying resulting in many creameries and cheese factories. Indeed, Perth County was second only to Oxford County as the largest cheese producer in Ontario (Perth County Visitor's Association 2007). Perth County is also home to the Ontario Pork Congress and animal farming is prevalent (Perth County Visitor's Association 2007).

In Perth County, 90% of the land is classified as prime agricultural land (class 1, 2, 3). 4899 farms were recorded during the 1941 census with an average acerage of 105. At this time, pasture, cereal grains and cultivated hay formed a large part of Perth County's agricultural landscape (Hoffman 1952). The total number of farms recorded in the 1996 census was 2,832 (Perth County 2005). Currently, 30% of the labour force in Perth County is tied directly or indirectly to agriculture (Perth County Social Planning Council 2006).

1.6.2.7 Non Agricultural Rural Land Uses and Trends

The discussion focuses on land use relationships to drinking water source protection.

1.6.2.7.1 Aggregates

A 2004 Aggregate Resource Inventory Paper for Huron County notes all aggregate as sand and gravel; there is no bedrock-derived aggregate. Between 1998 and 2002, total production averaged about 2.8 million tonnes per year and the average since 1981 has been about 2.7 million tonnes per year. Most of the 169 pits are in the north and central parts of the County and associated with major spillways (e.g., Trick's Creek, Sharpes Creek, Nine Mile River) and eskers. Glacial lake beaches, sand plains and some coarser textured moraines can also provide aggregate. Goderich and Grey townships had the highest number of licensed pits in 2002. Many of the primary deposits can have potential conflicts with adjacent agriculture, wetlands, ANSIs and recreational uses (Dodds et al. 2005). The focus of exploitation on major spillways could raise concerns of potential interference with shallow overburden aquifers vital to wetlands and streams.

In the Draft Aggregate Resource Strategy Report (2005), Huron County followed the guidelines set out in the Draft Mineral Aggregate Resource Manual published by the Ministry of the Environment and performed a constraint mapping exercise. A constraint was considered of any social, economic and environmental features which may impact the ability of the mineral aggregate deposit to be extracted. Environmental constraints included, but were not limited to, areas with a 30 m buffer of a sinkhole, 120 m buffer of a locally significant wetland, 50 m of a locally significant ANSI and 50 m of a significant floodplain. Deposits with no or one constraint were recommended to be designated as Mineral Aggregates in the Municipal Official Plans. Deposits with two or three constraints are recommended not to be designated. Only deposits that are classified as primary or secondary by the Ministry of Northern Development and Mines were considered. In addition, several sterilizing features were identified, and it was recommended that deposits that were located at or adjacent to a sterilizing feature be discouraged. These features included landfills, provincially significant wetlands, provincially significant ANSIs and municipal wellhead capture zones.

Huron County's distance to markets makes it a small player on the provincial scale. Slow population growth and few new major infrastructure projects would indicate no dramatic increase in production in the short term. In the longer term, however, as resources closer to large urban markets deplete, Huron County may see a rise in production (Dodds et al. 2005).

1.6.2.7.2 Cottage Development

Over the last 60 years, a band of cottage development has spread along much of the Lake Huron shoreline. By 1993, Huron County shoreline townships had over triple the number of seasonal residents as permanent ones (Bonte-Gelok and Joy 1999). Some older areas built close to the eroding cliffs are now experiencing erosion threats from these natural processes. In some areas gullies are threatening to erode. Many cottages are also degrading water quality from malfunctioning septic systems. Many older cottages have expanded, exacerbating the erosion and septic system problems (Snell and Cecile et al. 1995).

In 1989, there were 1038 lakeshore residences with septic systems in ABCA and 1000 new single residences planned (Hocking et al. 1990). Many systems are now used well beyond their design as piped lake water supplies provide limitless volumes and conversions transform cottages into year-round residences.

Port Franks cottages suffer a number of stresses imposed by flooding made worse by ice jams, erosion – both natural and from boat wakes and sediment deposition. Some of these problems result from 'The Cut' creation; some have been made worse by upstream Ausable watershed processes of sediment loading and reduced flood retention due to land clearance, artificial drainage and marsh removal (Snell and Cecile et al. 1995). The dunes are unstable when disturbed and the lakes of the channels are sensitive and support significant plant and wildlife communities. The pressures of development including the septic systems in the porous sands are causing problems to both terrestrial and aquatic habitats.

Pressures for expansion of shore communities and cottage developments are especially severe near Grand Bend and on the coastal sand plain outside protected areas. Existing developments are serviced by the Lake Huron pipeline, and it is anticipated that the same will occur for future cottage development.

1.6.2.7.3 Forestry Operations

Conservation Authority properties undergo sustainable logging, and wood harvest is economically important for many landowners. No large-scale forestry operations exist in the area.

1.6.2.7.4 Protected Areas

The conservation lands, Crown lands, and other protected areas of the planning region are summarized in Table 1-10.

Table 1-11: Area of Conservation Lands (in hectares) within the Ausable Bayfield Maitland Valley

Watershed	Provincial Parks and Wildlife Management Areas (in ha)	CA Lands (in ha)	Other conservation Lands (Nature Conservancy, NGO Nature Reserve) (in ha)	ANSIs (in ha)
Ausable	2149	4093		7210
Bayfield	134	143		1325
Maitland	2061	1470	13	1563
Nine Mile	58	80		7915
Shore Streams & Gullies	233	135	35	410

1.6.2.7.5 Brownfields

The Ontario Ministry of the Environment (MOE) is currently compiling a list of brownfields for the province.

1.6.2.7.6 Landfills

There are a number of active and closed waste disposal sites within the source water protection planning region (WC Map 1-9).

The Waste Management Master Plan for the County of Huron (Stage 3 1997) identifies two existing landfill sites, Morris and Exeter, to have long term potential. There are 26 years of identified capacity, with a possibility of more capacity (up to 40 years) at these sites if a staged expansion program is granted by the MOE (CH2M Gore & Storrie Ltd. 1997). A potential new landfill site has been identified in Ashfield Township, but further work on this site will be postponed until the above two landfills have been optimized.

Bonte-Gelok and Joy (1999) documented waste water treatment plant lagoons and landfills for Huron County. From available data, they found little evidence of water quality issues from landfills, nor any relationship between treatment plants and water quality trends.

1.6.2.7.7 Oil and Gas

Oil, gas and brine wells are displayed on WC Map 1-10.

The following paragraph is an excerpt from the Lambton County Groundwater Study (2004):

"The two most sensitive areas where oil and gas wells are most likely to have an effect on the potable water aquifer are: a) the locations of wells where industrial wastes were historically injected into the Detroit River Group under pressure, and b) the historical oilfields, although natural factors have complemented the efforts of operators to abandon wells in the historic Devonian oilfields. The risk of migration of crude oil and sulphur water upward from the Devonian reservoirs into the potable water aquifer is considered to be relatively small. Unplugged wellbores in oil and gas wells pose the same risk as unplugged water wells, in that surface water may flow down the wellbore into the potable water aquifer. The density of wells drilled in the historical fields increases this risk."

1.6.2.7.8 Transportation

Because the area is rural and does not have a large city, most of the roads are county or local roads with the exception of four 'King's Highways.' Highway 21 begins at Highway 402 and heads north to Lake Huron, following the coast until Southampton where it then heads inland to Owen Sound. In the planning region, it connects the towns of Port Franks, Grand Bend, Bayfield, Goderich, Port Albert and Point Clark. Highway 4 runs north-south and connects Clinton on Highway 8, running through downtown London as Richmond Street, and then on to Port Stanley on the shores of Lake Erie. Highway 4 connects the towns of Clinton, Hensall, Exeter, Huron Park, Mooreville and Lucan within the planning area. Highway 8 runs northwest to southeast, connecting the towns of Goderich, Clinton, Seaforth then continuing outside of the planning area to Mitchell, Sebringville and Stratford before joining Highway 7 to Kitchener-Waterloo. Lastly, Highway 23 is a main artery through Perth County. It runs in a southwest-northeast direction beginning from Highway 7 at Elginfield, and connects the communities of Mitchell, Monkton, Listowel, Palmerston, Harriston and ends at the intersection of Highways 9 (to Walkerton) and 89 (to Mount Forest).

There are three minor airports located within the source water planning region: Centralia/Huron in Huron Park, Goderich, and Wingham. In the area there are also a number of train lines. Refer to WC Map 4-5: to see the locations of the train lines and the locations of salt storage. Transportation Issues are further discussed in Chapter 4: Existing Threats Inventory.

1.6.2.7.9 Wastewater Treatment
(WC Map 1-11)

Septic Systems
Impact on water depends on age, density, design, soil, illegal tile connections and use of lawn chemicals.

Septic system numbers for the different watersheds may be outdated. In the Ausable, Parkhill and Mud Creek areas, 4049 systems area estimated (Hocking - CURB 1989).
In the Bayfield area, 1450 are estimated, while in the Shore Streams and Gullies it is 1848 (Hocking - CURB 1989). The Bayfield area is rated as 'high density' by Bonte-Gelok and Joy (1999) and the highest density of the watersheds in Huron County goes to the Shorelines and Gullies. The Nine Mile has a low density (Bonte-Gelok and Joy 1999) and there is no information for Maitland.

Most of the documentation applied to systems built in heavy soils and was concerned with effects of malfunctioning on surface water quality. Cottages built on the shoreline sand plain, however, correspond to a major overburden recharge area and raise concerns for the shallow overburden aquifers.

The Huron County Health Unit has undertaken a septic system re-inspection program for the communities of Amberley Beach, Port Albert, Bluewater Beach, Black's Point, St. Joseph and Egmondville. The Health Unit targeted these areas because of the combination of high classification, history of sewage ponding, odour complaints, a history of poor-quality beach water for adjacent lakeshore communities; some of the communities volunteered for the program (Scharfe and the Ashfield-Colborne Lakefront Association 2005). In 2005, the Health Unit performed 174 re-inspections; 3 of systems had failed and needed to be replaced. For 2006, the number of re-inspections has exceeded the volume from 2005 and 2 systems required replacement. These numbers are conservative estimates of failures because it does not take into account the systems that failed, but could be repaired because the failure was due to a lack of maintenance. As well, the re-inspection program is currently of a voluntary nature, and landowners with known failed systems may be unwilling to contact the re-inspection program.

Stormwater Management
In addition to its regulatory role, the Conservation Authorities (CAs) are often called upon to provide support services in the review of development applications made under the Planning Act, generally being in the position as either having the required technical expertise or otherwise assuming the role as resource managers. With regard to stormwater management, the Conservation Authority generally acts in an advisory capacity to the local municipality. The Conservation Authority, generally, would encourage that suitable, effective stormwater management be implemented supporting a development proposal. The degree of stormwater management required will depend on the nature of the development proposal. Typically, change

in land use will trigger the need for stormwater management. Development can take many forms and may proceed as a proposed plan of subdivision or condominium, may proceed by way of severance, or may involve a relatively small parcel of land such as in the case of an infill situation within an existing developed area.

Stormwater management may not be a requirement of the municipality in all cases. The decision to employ stormwater management may consider issues such as: size of area to be developed, density of the proposed development (consideration for resulting change or increase in percent imperviousness), proposed use, and assessment of the sensitivity of the natural environment to the impacts from development. Generally, at the request of the municipality, a site specific assessment would be undertaken by the Conservation Authority. At the request of the planning authority, being either the municipality or county, recommendations are provided by the CA in terms of specific requirements for stormwater management. In the case of a draft plan of subdivision or condominium, these recommendations typically would take the form of recommended conditions (with regard to SWM) to be fulfilled. These recommendations are associated with the approval of the plan prior to registration.

The "ABCA Stormwater Management Policies and Technical Guidelines, Final Report" (2004) sets out policies, criteria, and targets as guides towards the application of stormwater management within the ABCA's area of jurisdiction. Similar policy documentation has been adopted within the MVCA jurisdiction.

A certain degree of flexibility may be necessary in interpreting policy documentation and arriving at the best practices or otherwise criteria associated with stormwater management which should be applied to a given development proposal and the uniqueness of the surrounding natural environment.

Although the ABCA policy documentation does speak, in part, to water quality, policy generally dictates that stormwater quality control shall be provided in accordance with the guiding document from the MOE Management Planning and Design Manual (2003).

Both the ABCA and MVCA policy documentation encourages the use of lot level controls as best practices to be incorporated as first priority measures before the use of end pipe facilities such as stormwater management ponds. Provided that soils are suitably permeable, the use of onsite controls to promote the infiltration of surface runoff is encouraged where appropriate.

A stormwater management (SWM) plan, if prepared in accordance with the requirement of the CA, will generally demonstrate to the satisfaction of the CA that:

- Storm flows (surface and piped) are safely conveyed form the site to a suitable receiver;
- There will be no increase in flood risk onsite of offsite as a result of the development;
- Post development peak flows are controlled to pre-development levels;
- Erosion and sediment control is satisfactorily addressed (during construction and following development)
- Water quality objectives as set out by the MOE guiding documentation in terms of capture of suspended sediment are met (during construction and following development);
- Impact on the natural environment is duly considered

The stormwater management (SWM) plan may, in addition, address the following issues:

- Impact on water budget
- Consideration for thermal impact on the receiving watercourse
- Dissolved oxygen levels in the receiving watercourse as related to the support of life stage of fish (it is noted, ABCA policy documentation provides a target and does not set out strict criteria to be met);
- Phosphorous loading in the receiving watercourse (ABCA policy documentation provides a target and does not set out strict criteria to be met).

Both the ABCA and MVCA endorse the concept of an integrated approach to stormwater management through the planning process. The development of Watershed Plan(s), Master Drainage Plan(s) etc. which are endorsed by a municipality and address stormwater management needs at a community scale, regional scale, or on a watershed basis are encouraged. It is recommended that such plans be recognized within municipal land use plans such as the Official Plan or a Secondary Plan.

A municipality's Official Plan or Secondary Plan may make provisions for stormwater management. In such case, stormwater management requirements might be described as a statement of policy objectives. The policy/criteria is likely to be generic in nature and may not address in detail the specific stormwater management requirements which would be associated with a specific development proposal as would typically be addressed by a detailed stormwater management report.

1.6.3 Water Uses and Values

Groundwater uses are discussed in the county and township groundwater study reports (Huron: International Water Consultants et al. 2003; Lambton and Middlesex: Dillon Consulting and Golder Associates 2004 a & b; Wellington: Minto and North Wellington: Burnside 2001 a&b; Bruce and Perth: Waterloo Hydrogeologic 2003a & b). The reports present data by township or municipality and occasionally by Conservation Authority but never for watersheds within a Conservation Authority. Units vary, e.g., cubic metres per day in some reports and per year in others. Because data cannot be readily assembled to match planning region boundaries, Huron County is used to represent the area with reference to data from other counties where possible.

Livestock is the biggest water user. Domestic wells and municipal wells are other major uses but, over a township, their volumes of use rarely rival that for livestock. Aggregate washing also needs large amounts of water.

Groundwater is judged adequate to meet the area needs today and well into the future. Huron County withdrawals are conservatively estimated to be 17% of aquifer recharge. Wellington – Minto report estimated that about 1% of the infiltrated groundwater is used. Most is returned to the watershed although to more surficial systems.

The largest water use sectors are municipal, livestock watering, and rural domestic. Lesser uses include commercial and industrial sectors and recreation (Rush 2003).

1.6.3.1 Drinking Water Sources

WC Map 1-12 locates drinking water sources in the planning region. In towns, sources tend to be municipal wells; in rural areas most sources are individual or communal wells. Most wells are bedrock wells. For example, in Huron County, more than 80% of the wells reach bedrock (International Water Consultants et al. 2003). Overburden wells are concentrated in central and west Ausable with many shallow ones also at Port Franks and Grand Bend (Dillon Consulting and Golder Associates 2004a). Some municipal surface water systems are fed by Lake Huron and service nearby rural areas. Since the 1960s, Lake Huron pipelines have spread through Lambton County to the point that most areas are supplied and well drilling has almost ceased. In Lambton County within the planning region, only Arkona had municipal groundwater and it was replaced by Lake Huron supply in 2005. Subsequently, the wells in Arkona are slated for decommissioning in 2007. In Lambton Shores, however, 30% of the population is still self-supplied (Dillon Consulting and Golder Associates 2004a). Middlesex municipalities in the planning region have no public groundwater supply but some private wells (Dillon Consulting and Golder Associates 2004b). On the other hand, all Bruce County residents in the planning region use groundwater sources (Waterloo Hydrogeologic 2003a) and so do all of Perth County and Township of Wellington North residents (Rush 2003).

In 1989-1990, Lake Huron Water Supply at Grand Bend extended a pipeline north to Bayfield encouraging many cottages to switch from seasonal to year-round. This shift sparked concerns that septic systems could fail under the extra use.

Most MVCA residents, besides those living in the Town of Goderich and some other lakeside communities, use groundwater (MFX Partners 2002). A Huron County survey in 2000 found one-third of the wells above the drinking water guideline for bacteria and 10% above the guideline for nitrate (MVCA 2003). All larger towns have supplies exceeding requirements and problems are few (James F. Maclaren 1977).

1.6.3.1.1 Municipal wells

The groundwater studies document municipal well locations, volumes, potential contaminant sources and wellhead protection areas. Municipal well locations are listed in Table 3-1 in <u>Chapter 3: Vulnerable Areas.</u>

The only municipal wells that draw water from overburden aquifers are Hensall, Exeter, Trowbridge and Lucknow. In Huron, municipal wells supply about 30% of the population including seasonal residents.

1.6.3.1.2 Communal Wells

In Huron County, public supplies taken from non-municipal wells are estimated at about 10% of the municipal supply. They occur in ten campgrounds and several small subdivisions (International Water Consultants et al. 2003).

1.6.3.1.3 Private groundwater supplies

Domestic wells are numerous. For example, in Huron County about 3,400 domestic wells supply approximately 45% of the population including seasonal residents. Well locations are mapped in the county groundwater studies (Huron: International Water Consultants et al. 2003; Lambton and Middlesex: Dillon Consulting and Golder Associates 2004 a & b; Wellington: Minto and North Wellington: Burnside 2001 a&b; Bruce and Perth: Waterloo Hydrogeologic 2003a,b). Each distinguishes depth range and bedrock wells from overburden ones. A residential shift from individual private wells to municipal wells is emerging as a trend.

Potential village field wells are further discussed in Chapter 3: Vulnerable Areas and are listed in Appendix C to that chapter.

1.6.3.1.4 Surface water intakes

Although most residents depend on groundwater, a substantial percentage uses water piped from Lake Huron. In Huron County, Lake Huron water supplies 24% of the population (International Water Consultants et al. 2003). Much of the planning region's Lambton and Middlesex areas also use Lake Huron water.

There are two intakes from Lake Huron in the planning region: the intake at Port Blake and the intake at Goderich. The intake at Port Blake (see Figure 1-5), just north of Grand Bend, services the City of London with a population of 350,000, located outside the planning region. It also supplies much of the population in the southern part of the planning region in eight muncipalities: the entire municipality of North Middlesex, the former Town of Lucan and part of the former Biddulph Township (in Lucan-Bidduph), Middlesex Centre (Denfield), the former Town of Strathroy and parts of the former Caradoc Township, Lambton Shores (most of Bosanquet Township as well as Parkhill, Thedford, Grand Bend and Port Franks), South Huron (Huron Part/Centralia, Exeter, Crediton, Dashwood) and Bluewater (the lakeshore villages from Bayfield to Kettle Point along Highway 21). Hensall will be added to this list in 2007/2008. It also serves the towns of Ilderton, Arva, Delaware, and Ballymote which are outside of the planning region. This intake services approximately 500,000 people. The plant average day flow is 145,000 m3/day while the plant maximum flow is 348,000 m3/day and the intake rated maximum is 454,000 m3/day. The depth of the pipe at the intake is eight metres, and the pipe length is 2.4 km from shore (Stantec 2007; LHPWSS 2002). Map 1-12 shows the Lake Huron Primary Water Supply pipeline through the southern area of the ABMV source protection region.

The other lake intake within the source protection planning region is located at Goderich. The water treatment facility was constructured in 1961 and upgrades occurred in 1986 and 2004. The system supplies a population of approximately 7,500 people, takes 900,000 gallons per day (~3,400 m^3/day) and has a maximum flow of 12,000 m^3/day. The depth of the pipe at the intake is seven metres, and the intake is located 520 m from shore. Unlike the Port Blake intake, the IPZ-1 of the Goderich intake does reach land and includes the mouth of the Maitland River and the Goderich sewer treatment plant outfall.

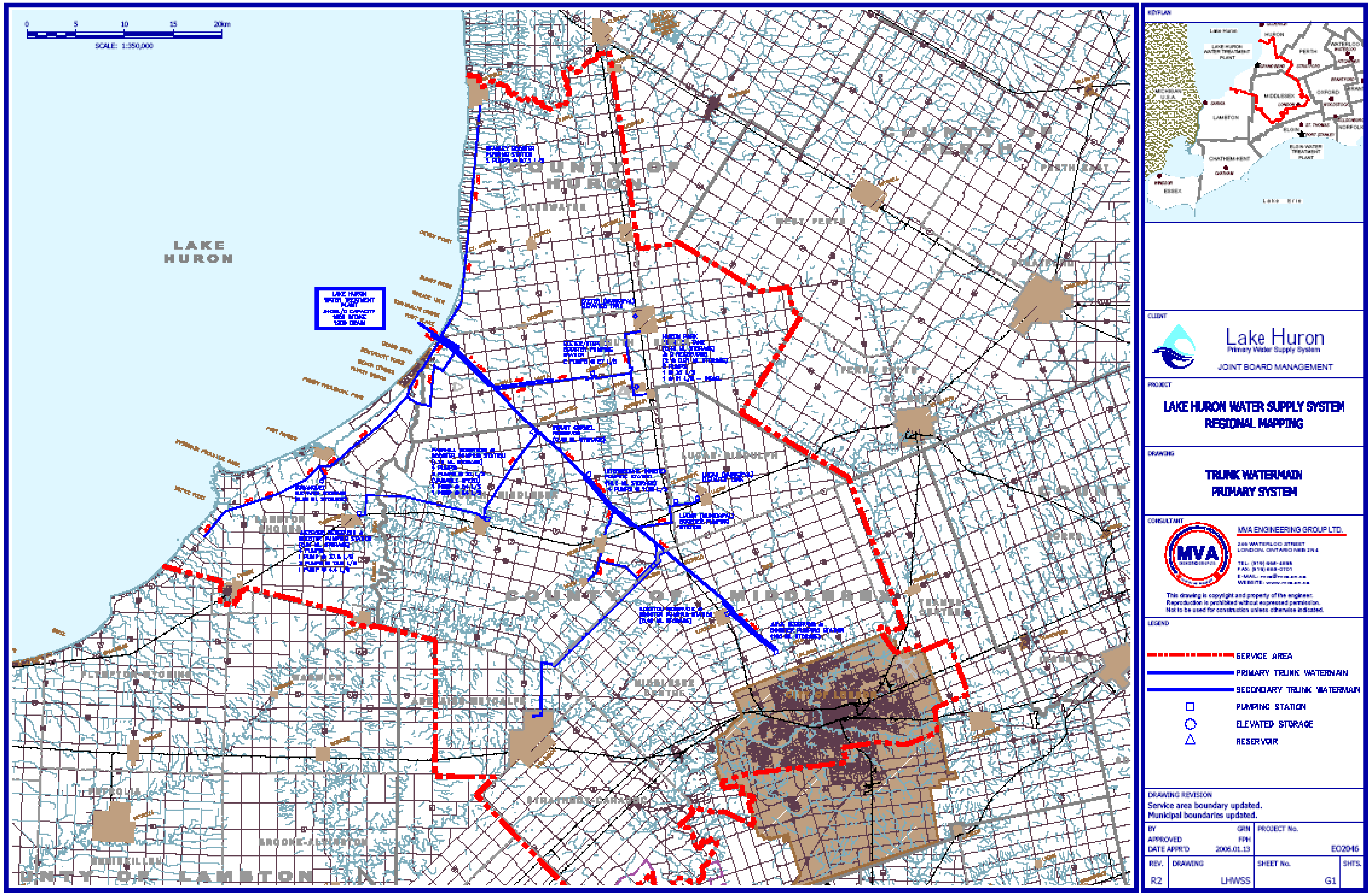

Figure 1-5: Lake Huron Water Supply Systems Map of Lake Huron pipeline serving the City of London and other areas of southwestern Ontario

1.6.3.2 Recreational Water Use

Recreation along Lake Huron is a major component of the planning region's economy and depends on good water quality for the highly popular beach use. In 1992, 750,000 people visited Pinery and Ipperwash Provincial Parks; on holiday weekends beaches are extremely busy (Hocking 1992). Point Farms Provincial Park is on the shore north of Goderich. Cottages line much of the region's shoreline and are interspersed with several private campgrounds. The larger harbours house marinas. Summer multiplies the population of the shoreline area and communities.

Inland recreational uses of water in the planning area include fishing, canoeing, and swimming. Picnic areas, campgrounds and trailer parks are associated with rivers and reservoirs (see Table 1-11, the list may not be comprehensive). Golf courses require water for irrigation. Huron County golf courses use about 240,000 m^3 of water/year (International Water Consultants et al. 2003).

Table 1-12: Trailer parks and campgrounds in the Ausable Bayfield Maitland Valley Region

Watershed	Campground/Trailer Park	Open*	Number of Sites	Sewage
Ausable	Birch Bark Tent & Trailer Park		148	Sewer outlet Dump station
	Elliott Park	Y	10 transient	No septics
	Great Canadian Hideaway	Y	215	
	Green Haven Trailer Park		130	Sewer outlets Dump station
	Harbour Side Family Trailer		170	Sewer outlets
	Klondyke Trailer Park		450	Sewer outlets Dump stations
	Pinehurst Trailer Park		193	Sewer outlets Dump station
	Pinery Provincial Park	Y	1000 campsites	Dump station Flush toilets
	Riverside Trailer Park		11	Sewer outlets Dump station
	Rock Glen Resort		200	Sewer outlets Dump station
	Rus-Ton Family Campground		242	Sewer outlets Dump station
	The Dunes Oakridge Park Ltd.		240	Dump station
Bayfield	Bluewater Golf Course and Campground	S	155 seasonal	Sewer outlets Dump station Flush toilets
	Wildwood by the River	Y	8 transient 270 permanent	Sewer outlets Flush toilets
Maitland	Auburn Riverside Retreat	S	65 transient 35 seasonal	Sewer outlets Flush toilets
	Blyth Recreation Campground	S	500 transient	No septics
	Falls Reserve Conservation	S	120 transient	Dump station

	Area		67 seasonal	Flush toilets
	Family Paradise Campground	S	55 transient 120 seasonal	Sewer outlets Dump station Flush toilets
	Pine Echo Camp	S	18 transient 145 seasonal	Sewer outlets Dump station Flush toilets
	Shelter Valley	S	28 transient 144 seasonal	Dump station
	Wawanosh Park Conservation Area	S	50 seasonal	Dump station No septics
	Wingham Trailer Park	S	30 transient 15 seasonal	Sewer outlets Dump station Flush toilets
Nine Mile	Happy Hollow	S	10 transient 90 seasonal	Sewer outlets Dump station Flush toilets
	Riverside Park	Y	10 transient 95 seasonal	
Shoreline Gullies and Streams	Birch Bark Tent and Trailer Park	S	20 transient 80 seasonal	Sewer outlets Dump station Flush toilets
	Kitchigami Family Campground	S	13 transient 77 seasonal	Sewer outlets Flush toilets
	Lake Huron Resort	S	125 transient 100 seasonal	Sewer Outlets Dump Station Flush toilets
	MacKenzie Tent and Trailer Park	S	30 transient 90 seasonal	Sewer Outlets Dump Station Flush toilets
	The Old Homestead	S	40 transient 210 seasonal	Sewer outlets Dump station Flush toilets
	Paul Bunyan Trailer Camp	Y	7 transient 375 seasonal/year round	Sewer Outlets Flush toilets
	Pine Lake Campground	Y	10 transient 429 seasonal	Sewer outlets Dump station Flush toilets
	Point Farms Provincial Park	S	216 transient	Dump Station Flush toilets
	Princess Huron Lakefront Trailer Park Resort	Y	10 transient 80 seasonal	Sewer outlets Flush toilets

Sources: Sarnia & Lambton County 2006 Travel Guide; 2006 Huron County Vacation Guide.
*S=Seasonal; Y=Year Round

Millponds, left over from the days of early settlement, are also an important part of recreation. They provide swimming areas to residents, as do decommissioned water-filled gravel pits (Rush 2003). Millponds also perform important ecological uses such as wildlife habitat, providing flow to streams in drier conditions, limiting flood control and being a source for groundwater recharge (Rush 2003).

1.6.3.3 Ecological Water Use

All ecosystems rely on water. Lake, river, stream, pond and wetland systems are particularly dependent.

Lake Huron is one of the biggest fresh water ecosystems in the world. Inland, the planning region has very little natural ponding; Lakelet Lake in North Maitland is the largest, well-buffered by forest. Several small millponds remain. Low summer stream flow prompted construction of reservoirs near Exeter and Parkhill. These lakes offer permanent habitat although their quality suffers from upstream agricultural inputs.

Groundwater from the surface overburden layer is critical to several important ecosystems. Groundwater provides cold water fish habitat, maintains wetlands, sustains base flow that supports aquatic habitat during droughts and contributes clear water to dilute pollution.

Stream habitat quality in the planning region generally improves from south to north. Physiography drives much of this trend; streams flowing through kames and spillways have much more access to the permanent and cold flows from near-surface groundwater aquifers than do streams on clay plains. Kames and spillways are also lower capability agricultural land than clay plains and support more forest, a form of natural infrastructure that protects water quality and quantity. Like forest, wetlands too are much more numerous towards the north, maintained by near-surface groundwater discharge and surface inflows. They both rely on water and protect it.

The Ausable River, located on the northern fringe of the Carolinian Zone, supports unique aquatic biota and is one of the most biologically diverse basins of its size in Canada (Veliz 2005). The aquatic community of the Ausable River includes 14 species listed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

1.6.3.4 Agricultural Water Use

Rainfall is essential to crops. For other water needs, agriculture in the planning region relies largely on groundwater and use by livestock operations is by far the greatest. Livestock operations use water for drinking, washing and cooling livestock, rinsing barns, mixing and spraying of pesticides or herbicides and for washing equipment. In Huron County's case, livestock use 4.8 million m^3 per year of which approximately 3 million m^3 is groundwater. Livestock use overshadows all others in Middlesex municipalities in the planning region. Huron County irrigation uses 1.2 million uses m^3 per year of which about 0.8 million m^3 is from groundwater. Surface water is used for irrigation in Black Creek sub-watershed near the Hay Swamp and in the Klondyke lagoon bed flats. Arkona area fruit operations require irrigation. Cattle – watering sometimes uses streams or dugouts. Streams and drains are outlets for tile drainage. Even in Lambton Shores where drinking water is largely supplied from Lake Huron and only 16% of the total water use is groundwater, groundwater provides two thirds of agriculture's water needs – largely for vegetable and fruit irrigation (Dillon Consulting and Golder Associates 2004a). Greenhouse operations can use large volumes of groundwater. Exeter has seen recent greenhouse development and associated high groundwater use.

1.6.2.5 Industrial Water Use

Among industries, aggregate washing operations and Sifto Salt in Goderich use very large volumes of water, though the vast majority of this water is returned through drainage and infiltration. Food processing plants and golf course operations can also be large users. In Huron County, industry accounts for 37% of groundwater use most of which is aggregate washing. In the Perth portion of the planning region, the largest industrial user is Campbell Soup/Horizon Poultry in Listowel. The company uses five times the Perth portion's domestic use and exceeds the area's agricultural use. The two deep wells that the company owns provide 5,996 m^3 of water per day (Rush 2003).

1.7 Watershed monitoring strategies and programs

Water monitoring sites, both current and historical, are presented by type in WC Map 1-13. Table 1-12 summarizes current long-term monitoring by Conservation Authority.

Table 1-13: Long-term watershed monitoring programs within the Ausable Bayfield and Maitland Valley Conservation Authorities

Programs	ABCA	MVCA
Provincial Water Quality Network (monthly)	- started in 1960s - funding gap: 1996-2000 - 9 sites + 3 more in 2005	- started in 1960s - funding gap: 1996-1998 - 12 sites
Provincial Groundwater Monitoring Network- levels and water quality	- started in 2003 - 14 sites: 5 bedrock & 9 overburden	- started in 2003 - 11 sites
Stream Flows	- discontinuously by federal government since 1945 - CA started in 1982 with 4 sites - flood warning model started 1986	- discontinuously by federal government since 1945 - CA started in 1981 with 12 sites - flood warning model started 1981
Other monitoring	- 9 surface water sites by CA: started in 1982	- monitors snow bi-weekly at 17 sites

Sources: Malone 2003; ABCA 1985, 2004; Waterloo Hydrogeologic 2003b; Shaus, 1982; MFX Partners 2002

Monitoring data has also been collected throughout a number of shorter term programs. In 1981, following PLUARG's (Pollution from Land Use Activities Reference Group) recognition of the importance of agriculture to water quality, a survey of all farms in ABCA identified about 30% causing potential contamination from manure handling and storage. Over the next few years, several projects studied the problem in more detail and an awareness program was launched. A target sub-watershed program provided guidance on the effectiveness of remedial measures; from 1986 to 1993 the Desjardine Drain, upstream of Grand Bend (lower Parkhill watershed), provided data on water and effects of remedial measures (Hocking 1988, 1989, 1990 (with Schottroff), 1992, 1994, 1996). This study launched CURB, Clean Up Rural Beaches program. High bacteria concentrations were periodically closing popular downstream Lake Huron beaches. From 1991 to 1996 CURB was very active. In ABCA, CURB implemented more projects per unit area than in any of the 30 CURB jurisdictions and granted over \$2.7 million on 811 project approvals. Although the bulk of the money went to manure handling improvements, repairs to domestic septic systems dominated project numbers as the importance of this contaminant source was realized. Monitoring included beaches and drains (Hocking 1988, 1989, 1990 (with Schottroff), 1992, 1994, 1996).

In the Maitland, surveys from 1986 to 1988 provided the basis for CURB plan. Modeling indicated that the three main sources of bacteria to Lake Huron beaches were faulty septic systems, winter spreading of manure and livestock access to watercourses. A target of 32% reduction in bacteria loads was set (Fuller and Foran 1989). Annual reports listed types of projects and bacterial concentrations at the beaches (e.g., Loeffler 1992). Maitland watershed had even more projects than ABCA. Like ABCA, septic systems received the most grants and manure storage the most funding but Maitland placed a higher emphasis on livestock-related projects (Loeffler 1999).

Following CURB, the next set of grants to assist Best Management Practices (BMPs) came through the Healthy Futures for Ontario program that was implemented on a CA/County basis. All programs are voluntary on the part of the landowners. It is not known how many landowners apply BMPs without grants nor the level of BMPs needed to reach target water quality levels. Grant levels have declined throughout the program.

Although County Health Units regularly monitor beaches for bacteria, their set schedule often missed the problem events (Hocking 1992, 1994, 1996). In a 1996/97 study, eight beaches and upstream drains were more intensively monitored to develop a rapid analysis method. Parkhill Reservoir exceeded the guidelines less often than any Lake Huron beach (Glaskin-Clay et al. 1996; EnviroMicrobial 1997).

Bonte-Gelok and Joy (1999) collected past water quality studies for Huron County and found them highly variable in parameters, timing and location of samples. Large amounts of historic data have been lost. Bonte-Gelok and Joy noted the number of water contaminant studies but were concerned about short spans and small extents. No comprehensive study of surface water contaminants had been done. Data were inadequate for correlations with potential contaminant causes and there was a lack of tracking of delivery from source to streams. They also questioned the small sample size that established the high estimate of faulty septic systems in the two Conservation Authorities.

Stream water quality in the planning region is dramatically worse during rain events but monitoring often misses the important but very sharp peak in concentrations. One solution is the use of aquatic macroinvertebrate indicators. Species reflect the stream's recent water quality history. Benthic monitoring began in 2000 (Malone 2003). ABCA alternates sampling headwaters and main channel stations on a bi-annual basis. Watershed report cards will use both benthic macro-invertebrates and water quality data (ABCA 2004).

Occasional short-term monitoring of water quality and aquatic biota results from events such as spills (Veliz 2005) or specific concerns. MOE's routine monthly water quality monitoring of the Maitland and Nine Mile Rivers found that concentrations of several heavy metals occasionally exceed Provincial Water Quality Objectives. A study sampling sediment, fish, crayfish and mussels, indicated the possibility of point sources in Listowel. The study also flagged PCB levels slightly above the International Joint Commission's aquatic life protection guidelines in fish at the river mouths but samples the following year fell below the guidelines (Zaranko 2001, 2003).

Golder Associates (2001) recommended sentinel well monitoring in Huron County. The 2002 results showed little seasonal variation and an annual sampling regime was recommended (Golder Associates 2003).

1.8 Water Quality

1.8.1 General Overview of Surface Water Quality

Form determines water quality and contaminant type. The upper lake location discouraged major settlement centres and the good soils encouraged agriculture – both row crops and livestock – to the point where the planning region rates the highest livestock and manure concentrations in Canada (Statistic Canada 2001). Contaminants are agricultural ones such as phosphorus, nitrates, sediment and bacteria. Pollutants associated with heavy industry are not a major problem.

Form also affects water volumes and resulting contaminant concentrations. The dominance of heavy textured soils – often poorly drained, cleared land and agricultural drains makes the whole region highly responsive to events. The main event is the spring thaw and associated rainfall. Flows peak in March and April and decline sharply the rest of the year. Smaller peaks follow storms at other seasons. Events flush high concentrations of accumulated sediments, nutrients and bacteria through the system to the lake.

Within this pattern, however, the variation in form across the region creates a north-south trend. The clay soil, poor drainage, drain density and lack of natural cover are all more prevalent in the south. Coarse-textured spillways and kames increase northward. Their lower agricultural capability encourages more natural cover and less built drainage. They support near-surface groundwater aquifers that discharge into the stream system. The result is a northward trend of increasing flows, decreasing concentrations but greater loadings. The stream water quality improves but the total amount of contaminants transported to the Lake Huron beaches increases; in effect, the travel time decreases. *E. coli* levels tend to increase downstream and at the northern beaches (Bonte-Gelok and Joy 1999; Hocking 1989).

The most productive clean cold water flow source is the major spillway splitting the Wyoming Moraine through the Bayfield, Lower Maitland and Nine Mile River watersheds. Streams through this feature (e.g., Trick's Creek, Sharpes Creek, Nine Mile River) are the most pristine of the planning region and the receiving waters of the lower Bayfield and lower Maitland Rivers benefit greatly from their input.

The form of the short shoreline gullies and streams determines their role. They represent the extreme of clay soils, drainage density and lack of natural cover in the planning region. They have additional factors. As streams carve down to lake level, gully erosion, a process encouraged by the intensive land use and tile drainage, increases sediment loads. Cottage density boosts septic system loading. The very short travel time to the shore limits in-course attenuation. Shore gullies are major contributors to shoreline contamination (Hocking 1989).

Non-agricultural sources of water contaminants can include snow dumps, landfills, food processing plants, industry, septic systems and golf courses. Although many sewage treatment plants have been upgraded, it is unknown whether older ones are causing contamination problems.

The major surface water contaminants of the planning region are:
Phosphorus: is a fertilizer which encourages algae growth. Once the algae die, they decompose, which consumes oxygen from the water. The reduced oxygen in the water can limit other aquatic organisms. Phosphorus is carried by sediment and originates from field erosion and faulty septic systems (Hocking 1989).

Nitrate: high levels can lead to blue-baby syndrome; after long exposure, adults can develop kidney and spleen problems (Statistics Canada 2001). Elevated nitrates can harm livestock and aquatic life. Nitrogen is a nutrient that encourages algae. Nitrates are highly soluble and can move into the shallow groundwater systems (MVCA 2000).

Sediment: it smothers stream life, blocking light and burying habitat. Non-point source field erosion is a major source.

Bacteria: *E. coli* does not affect stream life but is a risk to humans and livestock (MVCA 2000). Faulty septic systems and manure spreading are major sources (Hocking 1989).

Recent trends suggest phosphorus concentrations are decreasing, nitrates are rising, and fecal coliform is increasing in some areas (Bonte-Gelok and Joy 1999). In the last 20 years, Conservation Authority programs have raised farmer awareness of the issues; in 1984, many farmers were unaware of the severity of the problem (Balint 1984).

In an intensively used landscape such as the planning region, spills from agricultural and industrial operations are an on-going risk to streams and their biota.

Additional watershed-specific comments from the available reports are presented in Appendix C. Some reports are dated and many cover a limited area and time period. The most comprehensive report is the Bonte-Gelok and Joy (1999) survey of Huron County data.

1.8.2 General Overview of Groundwater Quality

The county groundwater study reports (Huron: International Water Consultants et al. 2003; Lambton and Middlesex: Dillon and Golder, 2004 a & b; Wellington: Minto and North Wellington: Burnside, 2001 a&b; Bruce and Perth: Waterloo Hydrogeologic, 2003a,b) conclude that the bedrock aquifer is generally well protected by the depth and fine texture of the overburden. Overburden wells typically have lower total dissolved solids, hardness, sodium, sulphate and iron levels but higher concentrations of dissolved organic carbon, chloride and bacteria. They also show greater occurrence of volatile organic compounds, pesticides and total petroleum hydrocarbons, although only trace to low levels. Nitrates were more likely in overburden wells but were very rarely above Ontario Drinking Water Standards (Golder 2001). The Provincial Groundwater Monitoring Network results indicate no concerns with pesticides, herbicides, fungicides, hydrocarbons or nitrate. The land use has not yet had any influence on the quality; only natural parameters like fluoride, hardness and iron are noted. Huron East is unique in adding uranium. Seaforth and Egmondville well water showed naturally elevated levels of radium-226, an element that can be removed with a water softener (Golder 2000). Singer et al. (1997) found many samples of poor natural water quality in all the bedrock units that are within the planning region. Commonly exceeded Provincial Drinking Water Objectives are total dissolved solids, sulphate and iron. The Hamilton Formation showed the highest proportion of instances for the whole set. Iron was often exceeded in all formations.

Caveats on the water quality assessments include the short data record, the lengthy residence time of contaminants in the overburden before they reach the bedrock, and the possibility of problems at private wells because of poor wellhead management (MVCA 2004). Chloride and sodium levels approach Ontario Drinking Water Standards aesthetic limit in the Thedford-Port Franks area groundwater (Dillon Consulting and Golder Associates 2004a). Areas with poorer well water quality (e.g., Stephen Township and Lambton County) are largely supplied with piped Lake Huron water. The 2002 results of sentinel well sampling program show little seasonal variation (Golder 2003).

Short circuits can directly and quickly contaminate aquifers. Access points potentially include sinkholes (see WC Map 1-5), non-commissioned wells, and rivers that have chiselled down to bedrock (e.g., lower sections of the Ausable, Bayfield and Maitland). The biggest threats of groundwater contamination are from agriculture (e.g., fertilizer or manure application near wells), road salt, landfills and hydrocarbon (fuel) storage (MVCA 2004). Depending on overburden depths and textures, improperly functioning or high density septic systems can contaminate groundwater (International Water Consultants et al. 2003).

Several township reports indicate that municipal wells could be susceptible to surface activities. All reports agree that shallow overburden aquifers – important contributors to streams and wetlands - are more sensitive than the bedrock aquifers.

1.9 Watershed Description Knowledge and Data Gaps

Stakeholders and Partners

The list of potential partners continues to grow. There are contacts for every upper and lower tier municipality, general farm organizations by county (National Farmers Union, Ontario Federation of Agriculture, and Christian Farmers Federation) and six governmental agencies (the Ministry of the Environment, Ministry of Natural Resources, Ministry of Municipal Affairs and Housing, Ontario Ministry of Agriculture, Food and Rural Affairs and the Department of Fisheries and Oceans). As well, there are stakeholders in industry, business and tourism, the local stewardship networks and other non-governmental agencies and individuals.

Groups that have had little contact in the source water planning process are the Mennonites and the Amish. There are a sizable number of communities belonging to these groups in the Maitland Valley watershed, and some within the Ausable Bayfield watershed. Traditionally, the relationship has moved one way when the CA is approached for assistance by a group or individual. The Mennonites and Amish cannot be easily classified: the individual communities range from conservative to modern. Any contact with these communities should be done through their leader, the Bishop, and should respect their views. Currently, there is an established link through these groups and their local Health Units.

While there is no First Nations reserve within the source water protection planning region there are bands in adjacent areas that have made claims on Lake Huron. These claims may impact the intake protection zones in Goderich.

There will always be temporary gaps in information when there is a municipal election or when a person leaves the contact position. Some groups are missing a contact person; this can be rectified if an individual attends an information meeting or if the organization is contacted. Some organizations may not have all of their capabilities listed, and this information may become apparent through the stakeholder process. There may also be some groups or members of the public that are unaware of the process or meetings. Hopefully these groups or individuals may find out about through public advertisements and word of mouth of upcoming meetings. The Ausable Bayfield Maitland Valley Partnership welcomes any new stakeholder.

Hydrology
There is a need to complete base-flow surveys to determine the extent of surface-groundwater interactions.

Climate and Meteorological Trends
Information is available from the AES stations, but at Conservation Authority stations only liquid precipitation is measured, thus discounting snowfall. However, the Ausable Bayfield Maitland Valley Partnership recently completed a missing-value fill-in project by comparing AES data with historical CA data. The analysis was completed using techniques described in Schroeter et al. (2000) by Schroeter and Associates.

Other stations are operated by the Ontario Weather Network (OWN) and the Ontario Ministry of Transpirations (MTO). These stations are examples of ones that are only operational for part of the year. The OTN focuses on the growing season for agricultural producers while the MTO focuses on the road conditions, particularly in the winter. The data from these stations may be available to the project at a cost, but may not be as valuable as the year round AES data. More information regarding climatological trends can be found in Chapter 3: Conceptual Water Budget.

Terrestrial
Percentage forest cover was not given as calculated by the SOLRIS (Southern Ontario Land Resource Information System) information, although this was recommended by a peer reviewer. The Ministry of Natural Resources in partnership with Ducks Unlimited developed a methodology to create a land cover layer using medium resolution satellite imagery and aerial photography. This method has been somewhat automated through SOLRIS and is now in the "full implementation phase". It was felt that in-house databases provided comparably accurate information on the percentage cover and delineation of cover types such as plantation, natural cover and old field.

Aquatic Ecology
There is comprehensive information detailing the sampling of fish in the watershed in the DFO drains database, and individual CA databases. Unfortunately, these databases have not been linked to the 5 watersheds within the source water planning region. In the future, an interface could be made between these sources of information and GIS. There is also a lack of specific information in regards to the distribution of fish species. A large portion of the Ausable and Bayfield watersheds would be described as being in the headwaters of a major system, and there has not been any work to delineate the presence of sensitive fish species in either these areas or in groundwater discharge systems. As well, the Ausable Bayfield CA has a Fish Habitat Management Plan, but no relationship to water quality has been highlighted.

Species at Risk

This fall, an internal document provided by the Department of Fisheries and Oceans and circulated among CA listed the known watercourses where species-at-risk fish and mussels were located, as well as a location (watercourses) of the species that are likely to become species at risk in 2007-2008. This information is not available to the public as yet. It is not known if any species-at-risk exist within the Nine Mile watershed. Nor is there much information as to the distribution of species-at-risk in any of the watersheds. Unlike plants, fish have the mobility to move if their habitat is no longer sufficient for them. There is some limited data on the locations of fish and mussels located in watercourses, and locations of nesting sites for turtles, but it is not conclusive that certain sites will have a specific organism. As well, the presence or lack thereof of a sensitive species has not been linked with water quality data.

Invasive Species

Little is known about the distribution of invasive species and some evidence is anecdotal. More needs to be done to identify the areas where there are invasive species, to limit their expansion and reduce their potential degradation of water quality. Information on water quality must be quantified to identify changes that have occurred since the introduction of the invasive species. This may not be achievable for the common carp since it was introduced over a hundred years ago, but there would be water quality data prior to the arrival of zebra mussels.

Human Characterization

Populations for towns and villages within the source water planning region were sought from Statistics Canada, municipal offices and from Dodds et al. 2005. Only the Village of Port Franks remains with a gap in information with respect to population size and population distribution.

Many subsections of ‘Human Characterization’ including ‘Land Use’ and ‘Water Uses and Values’ have information for Huron County, but lack information for other municipalities. Because of the location of the planning region, a large portion of the watershed is comprised of Huron County and conversely, most of Huron County lies within the Ausable Bayfield and Maitland Valley watersheds. As a result, there are a greater number of contacts and associations developed through Huron County and the information is representative of a large portion of the planning area.

Land Use

In section 1.6.2 and on WC Map 1-7, the land use depicted has its source from 1983. Recent information on land use information is a data gap.

Only recently (December 2006) has there been discussion that would allow Conservation Authorities to have access to MPAC information for the purpose of source water protection. The information has not yet been released, but this will be provided in the future. Unfortunately, at the time of writing the counties of Perth, Bruce and Wellington have not signed the agreement which would allow for the dissemination of information. Another thing to note is that zoning information from MPAC and zoning from municipalities are not necessarily the same. Municipalities can have zoning information on a paper copy or Corel Draw or in CAD which is not easily convertible into a GIS environment, and the information is not geo-referenced.

Designated growth areas and expected phasing are listed in Official Plans, but do not appear to be available in digital format.

Agricultural Sector Distribution and Trends

Locations of large agricultural operations would be a benefit to the planning process, especially if the operations are clustered. Determining what crop types are typically cultivated and if these crops are rotated would also help to understand the capacity of the watershed. Agricultural census data is needed for changes since 2000 to identify trends. The BSE crisis and new milkhouse regulations have also affected farmers and could have changed farming practices.

Trends in Industrial and Commercial Industries

The source protection planning region has experienced a shift from agriculture to manufacturing over recent years, although the pressure that this increase in manufacturing may put on drinking water and where this trend will continue or is sustainable is unknown. It would be beneficial to determine the proximity of major industrial and commercial plants to urban centres, determine the proximity of these operations to municipal and private drinking water sources and determine if they are connected to municipal sewer, or if they discharge directly into the environment.

Cottage Development

Lake Huron has been growing as a tourist attraction, and the increase in gas prices may have influenced tourists from Toronto and Detroit to choose the area. Certain areas along the shoreline have experienced greater growth than others e.g., Goderich, Grand Bend and Bayfield. What is unknown is if records have been kept, possibly with the planning departments, noting changes in watershed development as a result of the tourist industry.

Aggregate Extraction

The state of mineral and aggregate extraction is in good shape. Huron County has a wealth of sand and gravel deposits, and a number of aggregate pits, as seen on the series of maps produced for the Huron County Aggregates Study. What is not known is the state of aggregate extraction in other counties within the source protection planning region. There is no list available of historic sites and specific future sites have not been identified, although the County would focus on large deposits will few constraints.

Septic Systems

Numbers for septic systems are possibly outdated. There is no inventory of septic system locations: the responsibility of septic system permits was transferred to local municipalities in 1998. The Huron County Health Unit was able to provide figures as part of their septic system re-inspection program, but that program is voluntary. Information as to the percentage of population served by a septic system and if there are linkages when comparing urban land use to major recharge areas would be valuable.

Recreational Water Uses

Some of the information for recreation and tourism are out of date. Members of the tourism industry and the county planning departments will be contacted to provide this information. Septic systems were identified for rural trailer parks and campgrounds, but information regarding the water source and water uses would be beneficial.

Table 1-14: Data Gap Reporting for the Watershed Description Chapter of the Ausable Bayfield Maitland Valley Watershed Characterization

WC Deliverable	Data Set Name	Data Gap Problem	Comment
WC WC Map 4 Land uses as they relate to soil composition	Land Use (future)	Out of date Does not exist	Land use from 1983. Not clear what needs to be created.
2.3.5 Climatic and Meteorological Trends Written description of the evaluation and identify potential climatic predictive models.		Does not exist	
WC WC Map 7 Natural Features	Forest Cover (FRI) Wooded Area	Too sparse	Vegetated areas along stream banks do not exist, can only map forest cover.
2.5.1 Fisheries Written description that includes reference to any species found in groundwater discharge areas or headwaters of major systems, reference to portions of fisheries management plans especially referring to water quality.		Does not exist.	
WC WC Map 8 Diversity of benthos specimens in the watershed		Does not exist	No digital data.
2.5.4 Invasive species Written description of known invasive species with distribution and relation to water quality.		Does not exist	
WC WC Map 10 Existing and future land use		Not populated	Future land use not present in the desired categories. Getting information from municipalities (Official Plans).
2.7.1 Drinking Water Sources Written description that identifies inadequacies and gaps between studies requiring resolution			

1.10 References

Ausable Bayfield Conservation Authority students. 1979. Parkhill Creek Basin Study. Ausable Bayfield Conservation Authority.

Ausable Bayfield Conservation Authority. 1984. Environmentally Significant Areas of the Ausable Bayfield Conservation Authority.

Ausable Bayfield Conservation Authority. 1985. Watershed Plan.

Ausable Bayfield Conservation Authority. 2004. 2004 Annual Report.

Baird and Associates. 1994. Consideration for Shore Protection Structures.

Baitz, A., M. Veliz, and H. Brock. 2007 unpublished. Monitoring current distribution of freshwater species at risk mussels in the Ausable River, Ontario, 2006. Ausable Bayfield Conservation Authority.

Balint, D. S. and M. B. Thomas. 1983. Potential Farm Pollution from Manure Storage and Handling Systems in Watersheds of the Ausable-Bayfield Conservation Authority. Ausable Bayfield Conservation Authority.

Balint, D. S. 1984. Analysis of the Manure Management - Water Quality Program of the Ausable-Bayfield Conservation Authority. Ausable Bayfield Conservation Authority.

Beecroft, M. 1984. Windings: A History of the Lower Maitland River. Maitland Conservation Foundation, Maitland Valley Conservation Authority.

B.M. Ross and Associates Ltd. No date. Hydrology Study Technical Manual. Maitland Valley Conservation Authority.

B.M. Ross and Associates Ltd. No date. Municipality of Bluewater: Bayfield Service Area Water Supply Master Plan.

Black, B. 2006 October 31. Phone Interview: Population size of villages within the municipality. Municipality of North Huron.

Bonte-Gelok, S. and D. M. Joy. 1999. Huron County Surface Water Quality Data Study. Ausable Bayfield Conservation Authority

Bowles, J., N. Gaetz, T. Schwan, and R. Steele. 2001. Assessing Forest Health in the Maitland Watershed. Maitland Valley Conservation Authority

Brownell, V. R. 1984. A Life Science Inventory and Evaluation of the Ausable River Valley.

Bruce, J., I. Burton, H. Martin, B. Mills, and L. Mortsch. 2000. Water Sector: Vulnerability and Adaptation to Climate Change. Background paper for regional workshops. Organized by the Soil and Water Conservation Society: Ontario Chapter. Final report available at: http://www.c-ciarn.mcgill.ca/watersectro.pdf

Bruce County. 1999. County of Bruce Official Plan. http://www.brucecounty.on.ca/planning.php

Burnside Environmental. 2001a. Township of Minto: Groundwater Management and Protection Study. Ontario Ministry of the Environment.

Burnside Environmental. 2001b. Township of Wellington North: Groundwater Management and Protection Study. Ontario Ministry of the Environment.

Butler, R.W. and S.G. Hilts. 1978. Patterns of Land Use and Change on the Lake Huron Shore, Bosanquet Township, Ontario

CH2M Gore & Storrie Ltd. 1997. County of Huron Waster Management Master Plan: Stage 3 Report, Solid Water Management Master Plan Preliminary Draft.

Chapman, L.J. and D.F. Putnam. 1984. 3rd edition. Physiography of Southern Ontario. Ontario Geological Survey. Special Volume 2.

Conservation Authorities Branch. 1967. Maitland Valley Conservation Report Ontario Department of Energy and Resources Management. Toronto.

Conservation Branch. 1949. Ausable Valley Conservation Report 1949. Department of Planning and Development, Toronto.

Crins, W. J. 1983. Life Science Inventory and Vegetation Survey of the Bayfield River Area of Natural and Scientific Interest (A.N.S.I.). Ontario Ministry of Natural Resources.

Crysler, D. and Jorgensen Ltd. 1970. Water Resources Study: Upper Middle Maitland Watershed. Maitland Valley Conservation Authority.

Department of Planning and Development. 1954. Middle Maitland Conservation Report. Toronto

Dillon Consulting Ltd. And Golder Associates Ltd. 2004a. Lambton County Groundwater Study. Ontario Ministry of the Environment.
http://www.ene.gov.on.ca/envision/water/groundwater/lambton/executive_summary.htm

Dillon Consulting Ltd. And Golder Associates Ltd. 2004b. Middlesex-Elgin Groundwater Study. Ontario Ministry of the Environment.www.Thamesriver.org/Groundwater/Groundwater_study_report

Dodds, C., B. Treble and A. Vanderloo. 2005. Huron County Aggregate Strategy: A Report from the Technical Committee to the Steering Committee.

Donnelly, P. 1994 (revised 2000). Shoreline Management Plan. Ausable-Bayfield Conservation Authority.

Environment Canada, 2005. Climate Data.
http://climate.weatheroffice.ec.gc.ca/climate_normals/stnselect_e.html

Enviromicrobial Services Inc. 1997. Rapid Fecal Coliform and Escherichia coli Detection in the Recreational Waters of Lake Huron Beaches and an Inland Beach in 1997. Ausable Bayfield Conservation Authority

Foran, M. E. 1992. Comparison of Liquid Manure Spreading Practices on Tile Drain Water Quality. Ausable Bayfield Conservation Authority.

Fuller, R. and M. E. Foran. 1989. Clean Up Rural Beaches (CURB) Plan for the Lake Huron Beaches in the Maitland Valley Conservation Authority Watershed.
For Ontario Ministry of the Environment. Maitland Valley Conservation Authority.

Giancola, J.. 1983. Soil Erosion Study: Ausable River and Bayfield River Watersheds. Technical Report #3. Ausable Bayfield Conservation Authority.

Glaskin-Clay, M., J. Aldom, T. Prout, D. Ban Bakel, R. Griffiths and G. Palmateer. 1996. Rapid E. coli Test Evaluation at Eight Bathing Beaches. Ausable-Bayfield Conservation Authority.

George, Jon and Brian Pfrimmer. 1973. The Bayfield River Stream Survey. Ausable Bayfield Conservation Authority.

Golder Associates Ltd. 2000. Report on Groundwater Resource Assessment County of Huron Ontario. County of Huron, Department of Planning and Development.

Golder Associates Ltd. 2001. Groundwater Quality Assessment: Huron County Groundwater Study . County of Huron, Department of Planning and Development.

Golder Associates Ltd. 2003. 2002 Sentinel Well Monitoring Program: Huron County Groundwater Study. County of Huron, Department of Planning and Development.

Griffiths, R.. 1988. Response of Fecal Bacteria and Water Chemistry in an Agricultural Drain to Remedial Construction Activities on Livestock Farms. Ausable-Bayfield Conservation Authority.

Griffiths, R.. 1989. Response of Fecal Bacteria and Water Chemistry in the Desjardine Drain to the 1987-1988 Remedial Construction Activities on Livestock Farms. Ausable-Bayfield Conservation Authority.

Hanna R. 1984. Life Science Areas of Natural and Scientific Interest in Site District 6-2. Ministry of Natural Resources.

Hocking, D. 1988. Rural Beaches Strategy Program: Target Sub-Basin Study Report April, 1987 to March 1988. Ausable-Bayfield Conservation Authority.

Hocking, D. 1989. Rural Beaches Strategy Program: Target Sub-Basin Study Report April, 1988 to March 1989. Ausable-Bayfield Conservation Authority.

Hocking, D. 1989. Clean Up Rural Beaches (CURB) Plan for the Lake Huron Beaches in the Ausable Bayfield Watershed. For Ontario Ministry of the Environment. Ausable Bayfield Conservation Authority.

Hocking, D. and J. Schottroff. 1990. Rural Beaches Strategy Program: Target Sub-Basin Study Report April, 1990. For Ontario Ministry of the Environment. Ausable Bayfield Conservation Authority.

Hocking, D. 1992. Target Sub-basin Study Annual Report. Ausable Bayfield Conservation Authority.

Hocking, D. 1994. Ausable-Bayfield Conservation Authority CURB Program Annual Report. For Ontario Ministry of the Environment . Ausable-Bayfield Conservation Authority.

Hocking, D. 1996. Ausable-Bayfield Conservation Authority CURB Program 1991-1996 Final Annual Report. For Ontario Ministry of the Environment. Ausable-Bayfield Conservation Authority.

Hoffman, D.W. and N.R. Richards. 1952. Soil Survey of Perth County: Report No. 15 of the Ontario Soil Survey. Guelph, Ontario. http://sis.agr.gc.ca/cansis/publications/on/on15/on15_report.pdf. Accessed 18 March, 2008.

Huron County Planning and Development Department. 2001. Intensive Livestock Operations and Manure Management: Huron County Interim Control Study. Report for Discussion.

Huron County Planning and Development Department. 2005. Water Protection Steering Committee. Retrieved October 24, 2006 from http://www.huroncounty.ca/planning/pages/sproj/index.html.

Huron County Planning and Development Department. 2003. Huron County Manufacturing Factsheet.

Huron Manufacturing Association. 2005. Huron Manufacturing Directory. www.huronmanufacturing.on.ca

Huron Tourism Association. No date. Ontario's West Coast: Huron County. History of Huron County. http://www.ontarioswestcoast.ca/PAGES/INFORMATION%20PAGES/ourhistory.html

Implementation Committee. 2004. Watershed Based Source Protection: Implementation Committee Report to the Minister of the Environment. Queen's Printer for Ontario, Toronto. http://www.ene.gov.on.ca/envision/techdocs/4938e.pdf

International Water Consultants Ltd., B.M. Ross and Associates Ltd. and Waterloo Numerical Modelling Corp. 2003. County of Huron Groundwater Assessment and Municipal Wellhead Source Protection Study. Ontario Ministry of the Environment.

Jalava, J. 2004. Reconnaissance Life Science Inventory and Evaluation of the Bayfield North Area of Natural and Scientific Interest.

James F. Maclaren Ltd. 1977. Report on Preliminary Evaluation of Groundwater Hydrology for the Maitland Valley Conservation Authority.

Jamieson, E. 2001. Benthic Monitoring Program Fall 2001: Ausable Bayfield Conservation Authority.

Klinkenberg, R. 1983. An Identification and Evaluation of Life Science Candidate Nature Reserves on Site District 6-1. p. 49-50.

Killins, K. 2006. Terms of Reference: Development of a Management Plan for the Old Ausable River Watershed. Ausable Bayfield Conservation Authority.

Lake Huron Primary Water Supply System. 2002. 2nd Quarter Water Quality Report. http://www.watersupply.london.ca/Compliance_Reports/2002/LH_2002_Compliance.pdf Accessed April 28, 2008.

Lambton County. 1998. Lambton County Official Plan. http://www.lambtononline.com/uploads/945/Official_Plan_County_of_Lambton.pdf

Lambton County Planning & Services Department. 2002. County and Municipal Population: 1951 to 2001, Statistic Canada Data. http://www.lambtononline.com/uploads/965/Population_Data__1951_-_2001_Statistics_Canada.pdf

Larsen, B., J. Riley, E. Snell and H. Godschalk. 1999. The Woodland Heritage of Southern Ontario: A Study of Ecological Change, Distribution and Significance. Federation of Ontario Naturalists. Don Mills.

Lindsay, K.M. 1981. An Identification and Evaluation of Life Science Candidate Nature Reserves in Site District 7-2. p85-86.

Loeffler, A. 1992. Maitland Valley Conservation Authority Clean Up Rural Beaches Program 1991 Annual Report. For Ontario Ministry of the Environment. Maitland Valley Conservation Authority.

Loeffler, A. 1999. Strategies for development, implementation and monitoring of agricultural non-point source pollution control programs in Ontario. Ontario Ministry of the Environment.

Maitland Valley Conservation Authority. 1984. Watershed Plan.

Maitland Valley Conservation Authority. 1989. Maitland Conservation Strategy.

Maitland Valley Conservation Authority. 2003. Maitland Watershed Partnerships

Maitland Valley Conservation Authority. 2004. MVCA Municipal Groundwater Workshop Materials. CD.

Maitland Watershed Partnerships. 2001. Assessing Forest Health in the Maitland Watershed. Maitland Valley Conservation Authority.

Malone, P. 2003. Bayfield River Watershed Report. Ausable-Bayfield Conservation Authority.

MFX Partners. 2002. Maitland Watershed Partnerships. CD. Maitland Valley Conservation Authority

Middle Maitland Initiative. 2000. Water Sampling Results – 2000. Maitland Valley Conservation Authority.

Middlesex County. 2002. Middlesex County Official Plan. http://www.county.middlesex.on.ca/EconomicDevelopment/planning_COP_contents.asp

Ministry of Finance. 2006. Ontario Population Projections Update: 2005-2031. http://www.fin.gov.on.ca/english/demographics/demog06.html#sec4

Municipality of Bluewater. 2006 Oct 31. Private conversation: Population size of villages within the municipality. Municipality of Bluewater.

O'Connor, Justice D. R. 2002. Part Two Report of the Walkerton Inquiry: A Strategy for Safe Drinking Water. Ontario Ministry of the Attorney General. Queen's Printer for Ontario, Toronto. http://www.grandriver.ca/index/document.cfm?Sec=60&Sub1=2

Ontario Ministry of the Environment. 1980. Bayfield River Drainage Basin Study

Ontario Ministry of Municipal Affairs and Housing. 2005. Provincial Policy Statement. http://www.mah.gov.on.ca/userfiles/HTML/nts_1_23137_1.html

Ontario Ministry of Municipal Affairs and Housing. 2006. Summary Table. http://www.mah.gov.on.ca/userfiles/page_attachments/Library/1/2657334_flashtable.Mar.7_06.xls

Peach, G. 2006 Nov 23. Phone Interview: Hardening of Lake Huron shoreline. Lake Huron Centre for Coastal Conservation.

Perth County. 2005. County of Perth: Perth County Statistics. http://www.countyofperth.on.ca/county/main.htm

Perth County. 1997. Perth County Official Plan. http://www.countyofperth.on.ca/pdffiles/Section2.pdf

Perth County Social Planning Council. 2006. The Hidden Face of Poverty in Perth County. http://www.perthcountyspc.ca/reports/hidden_face_of_poverty.pdf Accessed March 18, 2008.

Peeters, A. 2006 October 31. Phone Interview: Population size of villages within the municipality. Municipality of North Middlesex.

Piggott, A., B. Mills and S. Moin. In press. Groundwater and climate change: impacts and adaptation in southern Ontario. Canadian Civil Engineer.

Rush, R. 2003. Maitland Valley Characterization Report. Guelph Water Management Group. http://www.uoguelph.ca/gwmg/wcp_home/Pages/M_home.htm

Ryan, T. E. 1987. Manure Management Awareness Program Summary Report 1986. Ausable Bayfield Conservation Authority.

Scharfe, P. and the Ashfield-Colborne Lakefront Association. 2005. Huron County Health Unit Septic Reinspection Program, Phase 1. http://www.northwesthuron.com/env/HCHU-2005-septic.html

Schaus, B. 1982. Water Quality and Quantity of the Ausable Bayfield Conservation Authority. Ausable Bayfield Conservation Authority

Schaus, B. 1984. Fish and Wildlife Management Inventory: Ausable Bayfield Conservation Authority. Watershed Plan Technical Report # 7. Ausable Bayfield Conservation Authority

Schaus, Barbara and Jim Giancola. 1984. Environmentally Significant Areas of the Ausable Bayfield Conservation Authority. Watershed Plan Report 2. Ausable Bayfield Conservation Authority.

Singer, S.N., C.K. Cheng and M.G. Scafe. 1997. The Hydrogeology of Southern Ontario. Volume 1. Ontario Ministry of Environment and Energy.

Snell and Cecile Environmental Research. 1991. Shoreline Management Plan: Environmental Review Component Goderich to Kettle Point. Ausable Bayfield Conservation Authority.

Snell and Cecile Environmental Research and Ausable Bayfield Conservation Authority. 1995. Ausable Bayfield Conservation Authority Watershed Management Strategy.

Stantec. 2007. Lake Huron Water Treatment Plant Intkae Protection Zone Study and Vulnerability Assessment: Draft Report.

Statistics Canada. 2001. A Geographical Profile of Manure Production in Canada

Statistics Canada. 2002. Population Counts, 2001. http://www12.statcan.ca/english/census01/products/standard/popdwell/Table-UR-D.cfm?T=1&PR=35&SR=1&S=1&O=A

Statistics Canada. 2006. 2001 Community Profiles. http://www12.statcan.ca/english/profil01/CP01/Index.cfm?Lang=E

Statistics Canada. 2007. *Goderich, Ontario* (table). *2006 Community Profiles*. 2006 Census. Statistics Canada Catalogue no. 92-591-XWE. Ottawa. Released March 13, 2007. http://www12.statcan.ca/english/census06/data/profiles/community/Index.cfm?Lang=E (accessed March 25, 2008).

Steele, R., J. Bowles and J. Fitzgibbon. 1995. Basic Health Indices. Maitland Valley Conservation Authority.

Total Approach Initiative. 2000. Water Sampling Results – 2000. Maitland Valley Conservation Authority.

Tucker, L. 2006. Forest Health-Update: Aylmer Guelph District. Ministry of Natural Resources Factsheet.

Veliz, M. and E. Jamieson. 2000. Benthic Monitoring Program Fall 2000: Ausable Bayfield Conservation Authority.

Veliz, M. 2001. Fish Habitat Management Plan. Ausable Bayfield Conservation Authority

Veliz, M. 2003. Cold Water Fish Habitat Management in the Nairn Creek Sub-Basin. Ausable Bayfield Conservation Authority

Veliz, M. 2005. Terms of Reference: Monitoring Recovery of Aquatic Life in the Ausable River After a Chlorine Spill in April 2005. Ausable Bayfield Conservation Authority

Veliz, M. and J. Sadler Richards. 2005. Enclosing Surface Drains: What's the Story? Journal of Soil and Water Conservation. May/June, 2005 pp:70A-73A.

Wall, G.J., B.A. Grant, D.J. King, N. Mclaughlin. 1997. The Effects of Livestock Manure Application Methods on Water Quality, Focusing on Nitrogen and Bacteria Transport in Soil

Water Use and Supply Project Management Team. 2004. Water Use and Supply Project for the Great Lakes Basin: Year 3 Summary April 2003 to March 2004. Canada Centre for Inland Waters, Burlington.

Waterloo Hydrogeologic Inc. 2003a Grey and Bruce Counties Groundwater Study. Ontario Ministry of the Environment. http://www.greybrucegroundwaterstudy.on.ca/study_info.htm

Waterloo Hydrogeologic Inc. 2003b. Perth County Groundwater Study. Ontario Ministry of the Environment. http://www.perthgroundwaterstudy.on.ca/

Waterloo Hydrogeologic Inc. 2004. Sinkhole Investigation for Areas Mainly within the Municipalities of Huron East and West Perth. CD. Ausable-Bayfield Conservation Authority

Wellington County. 1999. Wellington County Official Plan. http://www.county.wellington.on.ca/document_info.aspx?id=931

Zaranko Environmental Assessment Services. 2001. Biological Monitoring for Contaminants in Nine Mile and Maitland Rivers, 2000. Maitland Valley Conservation Authority

Zaranko Environmental Assessment Services. 2003. Biological Monitoring for Contaminants in Maitland and Nine Mile Rivers, 2001. Maitland Valley Conservation Authority

Appendix A: Climate Normals (1971-2000) Measures at Long-Term AES Stations in the Ausable Bayfield-Maitland Planning Region

CLIMATE STATION	CLIMATE STATISTIC	MONTH												
		JAN	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**Annual**
Blyth	**Temperature**													
(6120819)	Daily Average (°C)	-7.5	-6.7	-1.7	5.5	12.3	17.3	20.2	19.1	15.1	8.8	2.7	-3.6	**6.8**
1971-2000	Standard Deviation	3.3	3.5	2.6	2.1	2.2	1.7	1.4	1.8	1.3	1.9	1.9	3.1	**1.3**
	Daily Maximum (°C)	-4.1	-2.9	2.5	10.1	17.9	22.9	25.9	24.6	20.1	13	5.8	-0.6	**11.3**
	Daily Minimum (°C)	-10.8	-10.5	-5.9	0.8	6.7	11.7	14.5	13.6	10	4.5	-0.5	-6.5	**2.3**
	Precipitation													
	Rainfall (mm)	24.9	22.9	39.1	68.4	89.8	85.1	72.7	105.9	115.4	89.2	80.7	40	**834**
	Snowfall (cm)	102.9	55.9	33.9	13.4	0.4	0	0	0	0	3.6	40.5	99.8	**350.4**
	Precipitation (mm)	127.8	78.8	73	81.8	90.2	85.1	72.7	105.9	115.4	92.8	121.2	139.8	**1184.3**
Brucefield	**Temperature**													
(6121025)	Daily Average (°C)	-6.4	-6.3	-1	6.2	12.6	17.2	19.6	19	14.9	9	3.2	-3	**6.8**
1971-1993	Standard Deviation	2.8	2.9	2.4	1.9	2	1.5	1.1	1.2	1.1	1.8	1.4	2.6	**1.3**
	Daily Maximum (°C)	-2.6	-2	3.5	11.4	18.9	23.4	25.8	24.9	20.4	13.6	6.6	0.2	**11.3**
	Daily Minimum (°C)	-10.1	-10.6	-5.6	1.1	6.4	10.9	13.4	13	9.4	4.3	-0.3	-6.2	**2.3**
	Precipitation													
	Rainfall (mm)	21.1	23.8	51.1	69.9	76.5	70.5	77	88.6	106.4	93	85.4	41.3	**804.6**
	Snowfall (cm)	66	39.4	23.5	4.8	0.1	0	0	0	0	1.3	19.1	47.4	**201.6**
	Precipitation (mm)	87	63.2	73.4	74.7	76.6	70.5	77	88.6	106.4	94.3	104.5	88.6	**1004.8**
Cromarty	**Temperature**													
(6141919)	Daily Average (°C)	-7.3	-6.9	-1.4	5.9	12.7	17.2	19.8	18.9	14.9	8.5	2.5	-4	**6.7**
1971-1991	Standard Deviation	3	3.2	2.7	2	2.3	1.5	1.2	1.4	1.3	2.1	1.8	2.9	**2.1**
	Daily Maximum (°C)	-4	-3.1	2.6	10.6	18.4	22.9	25.8	24.6	20.1	12.9	5.5	-1	**11.3**
	Daily Minimum (°C)	-10.7	-10.7	-5.4	1.2	7	11.4	13.8	13.1	9.5	4.1	-0.7	-7	**2.1**
	Precipitation													
	Rainfall (mm)	19.6	24	53.8	66	75.4	72.2	77.4	90.1	111.4	90.7	79.2	45.6	**805.5**
	Snowfall (cm)	84	54	33.8	12.7	0.6	0	0	0	0	3.7	30.3	71.6	**290.8**
	Precipitation (mm)	103.6	78	87.5	78.8	76	72.2	77.4	90.1	111.4	94.5	109.6	117.2	**1096.3**
Dashwood	**Temperature**													
-6121969	Daily Average (°C)	-5.6	-4.9	0.1	6.7	13.3	18.3	20.5	19.7	16	9.5	3.5	-2.5	**7.9**
1976 - 2000	Standard Deviation	2.8	3.1	2.4	1.7	2.1	1.6	1.3	1.3	0.9	1.6	1.6	2.8	**1.8**
	Daily Maximum (°C)	-2.5	-1.4	4	11.1	18.6	23.5	25.7	24.7	20.8	13.6	6.5	0.4	**12.1**
	Daily Minimum (°C)	-8.7	-8.3	-3.8	2.2	7.9	12.9	15.3	14.6	11.1	5.4	0.4	-5.3	**3.6**
	Precipitation													
	Rainfall (mm)	23.1	25.3	42.4	75.2	78.5	76.8	85.5	81.9	118.8	84.1	76.4	43	**811.1**
	Snowfall (cm)	49.4	32.6	19.4	4.6	0	0	0	0	0	1.3	18.3	48.5	**174.1**
	Precipitation (mm)	72.5	57.9	61.9	79.9	78.5	76.8	85.5	81.9	118.8	85.4	94.6	91.5	**985.2**
Exeter	**Temperature**													
(6122370)	Daily Average (°C)	-6	-5.7	-0.5	6.2	12.9	18	20.4	19.5	15.3	9.1	3.1	-2.9	**7.5**
1971 - 2000	Standard Deviation	2.7	2.9	2.5	1.8	2.1	1.5	1.2	1.3	1.2	1.7	1.6	2.7	**1**

	Daily Maximum (°C)	-2.4	-1.8	3.7	11	18.6	23.6	25.8	24.7	20.5	13.6	6.5	0.4	**12**
	Daily Minimum (°C)	-9.6	-9.7	-4.7	1.3	7.2	12.3	14.9	14.1	10.1	4.6	-0.3	-6.2	**2.8**
	Precipitation													
	Rainfall (mm)	25.9	20.7	43.4	73.5	77.3	77.7	84.9	85.7	114.5	84.8	74.9	42.8	**805.8**
	Snowfall (cm)	54.5	32.2	22.5	6	0.1	0	0	0	0	1.8	17.3	48.2	**182.7**
	Precipitation (mm)	80.4	53	65.9	79.5	77.4	77.7	84.9	85.7	114.5	86.5	92.1	91	**988.5**
Ilderton Bear Creek	**Temperature**													
(6143722)	Daily Average (°C)	-6	-5.1	0.2	7	13.6	18.7	21.1	20	16.1	9.7	3.4	-2.8	**8**
1971 - 2000	Standard Deviation	2.9	2.8	2.3	1.7	2.2	1.4	1.1	1.2	1.1	1.7	1.7	2.8	**2**
	Daily Maximum (°C)	-2.4	-1.2	4.4	12	19.4	24.6	27	25.7	21.3	14.3	6.8	0.4	**12.7**
	Daily Minimum (°C)	-9.5	-8.9	-4	1.9	7.6	12.8	15.1	14.3	10.7	5.1	0	-6	**3.3**
	Precipitation													
	Rainfall (mm)	28.2	27.1	51.5	79.1	87.6	85.4	82.3	96.1	97.5	74.7	76.1	43.8	**829.4**
	Snowfall (cm)	50.6	34.4	23.4	6.2	0	0	0	0	0	2.2	17.8	51.5	**186.1**
	Precipitation (mm)	78.8	61.5	74.9	85.3	87.6	85.4	82.3	96.1	97.5	76.9	93.8	95.4	**1015.5**
Lucknow	**Temperature**													
(6124700)	Daily Average (°C)	-6.7	-6.6	-1.7	5.7	12.3	16.8	19.5	18.8	14.6	8.5	2.7	-3.4	**6.7**
1971 - 1993	Standard Deviation	2.5	2.7	2.3	1.9	2	1.5	1.2	1.3	1.1	1.8	1.4	2.4	**1**
	Daily Maximum (°C)	-2.9	-2.1	3.2	11.2	18.9	23.2	25.7	24.6	20.1	13.2	6.2	0	**11.8**
	Daily Minimum (°C)	-10.5	-10.9	-6.5	0.2	5.8	10.4	13.2	13	9	3.7	-0.8	-6.7	**1.7**
	Precipitation													
	Rainfall (mm)	15.9	15.2	38.5	64	79	82.2	69.5	99.4	109.6	94.4	79.9	34.5	**781.9**
	Snowfall (cm)	111.2	67.6	32.8	11.4	0.3	0	0	0	0	3	26	86.6	**338.9**
	Precipitation (mm)	127.1	82.8	71.3	75.5	79.3	82.2	69.5	99.4	109.6	97.3	105.9	121.1	**1120.9**
Wroxeter	**Temperature**													
(6129660)	Daily Average (°C)	Temperature data not collected												
1971 - 2000	Standard Deviation													
	Daily Maximum (°C)													
	Daily Minimum (°C)													
	Precipitation													
	Rainfall (mm)	20.4	19	38.9	59.7	86.7	85.3	77.2	99.1	99.3	77.7	68.8	34	**766.1**
	Snowfall (cm)	64.6	36.8	23.6	6.2	0	0	0	0	0	1.1	23.7	54.8	**210.8**
	Precipitation (mm)	85	55.8	62.5	65.9	86.7	85.3	77.2	99.1	99.3	78.8	92.4	88.9	**976.9**

Source: Environment Canada's World Wide Web Site. Url of this page : http://www.climate.weatheroffice.ec.gc.ca/climate_normals/

Appendix B: Municipal Restructuring of the six counties within the source protection planning region (Ontario Ministry of Municipal Affairs and Housing 2006).

COUNTY	DATE OF OFFICIAL PLAN	PARTY MUNICIPALITIES	NEW MUNICIPAL NAME	NUMBER OF MUNICIPALITIES BEFORE	NUMBER OF MUNICIPALITIES AFTER	DATE OF OFFICIAL PLAN	DATE OF ZONING BY-LAW
Bruce	1997	county restructuring: (County plus 8 lower tier mun.) St. Edmunds, Twp/Lindsay, Twp./Eastnor, Twp./Lion's Head Vg. Amalgamation	Municipality of Northern Bruce Peninsula (Name change Gazetted Jan16/99)	28	9	county	2002
		Albemarle, Twp./Amabel, Twp./Wiarton, Town/ Hepworth, Vg. Amalgamation	Town of South Bruce Peninsula (Name change Gazetted Jan16/99)			2001	
		Arran, Twp./Elderslie, Twp./Chesley, Town/Tara Vg./ Paisley, Vg. Amalgamation	Municipality of Arran-Elderslie (Name change Gazetted Jan16/99)			urban-2004 rural-county	Chesley-1982 Elderslie-1984 Paisley-1982 Tara-1981 Arran-1994
		Greenock, Twp./Brant Twp./Walkerton Town - Amalgamation	Municipality of Brockton (Name change Gazetted Jan16/99)			county	Brant-1981 Greenock-1998 Walkerton-1992
		Mildmay-Carrick, Twp./Teeswater-Culross, Twp.- Amalgamation	Municipality of South Bruce (Name change Gazetted Jan16/99)			2004	Carrick-1985 Culross-1985
		Saugeen, Twp./Southampton,Town/Port Elgin, Town - Amalgamation	Town of Saugeen Shores (Name change Gazetted Jan16/99)			2000	2000
		Huron, Twp./Kinloss, Twp./Lucknow, Vg. - Amalgamation	Township of Huron-Kinloss			1999	2006 (draft)
		Bruce, Twp./Kincardine Twp./Kincardine, Town - Amalgamation	Municipality of Kincardine (Dec 22/99)			2006	2003
Huron	1997 (draft)	Stephen, Twp/Usborne, Twp/Exeter, Twn - Amalgamation	Municipality of South Huron	3	1	2003	2006 (draft)
		Goderich, Twp/Hullett, Twp/Clinton, Town - Amalgamation	Municipality of Central Huron	3	1	2003	Clinton-1985 Hullett-1987 Goderich-1984
		Hay, Twp/Stanley, Twp/Bayfield, Village/ Hensall V./Zurich, Village - Amalgamation	Municipality of Bluewater	5	1	2005	Hay-1987 Stanley-1985 Hensall 1987 Bayfield-1991 Zurich 1988
		Ashfield, Twp/West Wawanosh, Twp/Colborne, Twp - Amalgamation	Township of Ashfield-Colborne-Wawanosh	3	1	2003	2006 (draft)

		Morris, Twp/Turnberry, Twp - Amalgamation	Municipality of Morris-Turnberry	2	1	2006 (draft)	Turnberry-1987
		Brussels, V/Grey, Twp/McKillop Twp/Seaforth, Twn/ Tuckersmith, Twp - Amalgamation	Municipality of Huron East	5	1	2003 (draft)	2006
		Wingham, Twn/Blyth, V/East Wawanosh, Twp - Amalgamation	Township of North Huron	3	1	2004	Wingham-1992 Blyth-1991 E.Wawanosh-1987
Lambton	1998	Watford, Village/Warwick, Township - Amalgamation	Township of Warwick	2	1	1999	2000
		Dawn, Township/Euphemia, Township - Amalgamation	Township of Dawn-Euphemia	2	1	county	2002
		Arkona, Village/Bosanquet, Town/Forest, Town/Grand Bend, Village/Thedford, Village - amalgamation & annexation of part of Plympton, Township/Warwick, Township	Municipality of North Lambton (Amending Order - Gazetted June 26/99) (Amending Order - Gazetted Jul 01/00 Municipality of Lambton Shores (Name change)	5	1	2001	2003
		Brooke , Township/Alvinston, Village - Amalgamation	Municipality of the Township of Brooke - Alvinston (Amending Order - Gazetted Oct 2/99)	2	1	2000	2000
		Plympton, Township/Wyoming, Village - Amalgamation	Town of Plympton-Wyoming	2	1	2001	2003
		Petrolia, Town/Enniskillen, Township - Annexation	No Change			1999	2000
		Sombra, Twp/Moore, Twp - Amalgamation	Township of St. Clair	2	1	2003	2003
Middlesex	2006	Lobo, Township/London, Township/Delaware, - Township - Amalgamation	Municipality of of Middlesex Centre	3	1	2000	2005
		Lucan, Village/Biddulph, Township Amalgamation	Township of Lucan Biddulph	2	1	2003	2005
		Strathroy, Town/Caradoc, Township - Amalgamation	Municipality of Strathroy-Caradoc	2	1	2002 (draft)	Strathroy-1977 Caradoc-1987
		McGillivray, Twp/East Williams, Twp/West Williams, Twp, Parkhill Town/Ailsa Craig, V. - Amalgamation	Municipality of North Middlesex	5	1	2004	2004
		Adelaide, Township/Metcalfe, Township - Amalgamation	Township of Adelaide Metcalfe	2	1	2003	Adelaide-1997 Metcalfe-1994
		North Dorchester, Township/West Nissouri,	Municipality of Thames Centre	2	1	2004	2006

		Township - Amalgamation					
		Ekfrid, Township/Mosa, Township/Glencoe, Village/Wardsville, Village - Amalgamation	Municipality of Southwest Middlesex	4	1	2007 (draft)	
Perth	1997	Logan, Township/Hibbert, Township/Fullarton, - Township/Mitchell, Town - Amalgamation	Township of West Perth Municipality of West Perth (name change) Effective December 20/00	15	5	1996	1999
		Wallace, Township/Elma, Township/Listowel, Town - Amalgamation	Town of North Perth			Listowel-1998 county	1999
		Mornington, Township/Ellice, Township/ North Easthope/South Easthope, Township/Milverton, - Village - Amalgamation	Township of Perth East			Milverton county	1999
		Downie, Township/Blanshard, Township - Amalgamation	Township of Perth south			county	1999
Wellington	1999	Erin, Township/Erin, Village - Amalgamation	Town of Erin	2	1	2004	2002
		Drayton, Village/Peel, Township - Amalgamation	Township of Mapleton	2	1	county	2000
		Two tier System (County plus 7 lower tier municipalities) Palmerston,Town/Harriston,Town/Minto Township/ Clifford, Village - Amalgamation	Town of Minto	21	9	county	2001
		Mount Forest, Town/Arthur, Village/Arthur, Township/ West Luther, Township/Pt of Mapleton, Township/Pt of West Garafraxa - Amalgamation	Township of Wellington North (Name change Gazetted April 17/99)			1999	2001
		Fergus, Town/Elora, Village/Pt of West Garafraxa, Township/Pt of Nichol, Township/Pt of Pilkington Township, Pt of Eramosa Twp - Amalgamation	Township of Centre Wellington			2004	Elora-1995 Fergus-1995 W. Garafaxa-1984 Eramosa-1997 Nichol-1988 Pilkington-1996
		Guelph, Township/Pt of Eramosa, Township, Pt of Puslinch, Township - Amalgamation	Township of Guelph/Eramosa			county	1999
		Mapleton, Township/Maryborough, Township, Pt of Pilkington, Twp. Pt of Nichol Twp - Amalgamation	Township of Mapleton			county	2000

Appendix C: Watershed-Specific Summary of Surface Water Quality from Available Documents

Ausable

The trend within the Ausable watershed follows the planning region's north-south pattern of poorer quality to the south (Balint 1983; Schaus 1982; Snell and Cecile et al. 1995). An exception is The Pinery's Old Ausable Channel. Engineering benefited this reach by cutting it off from the polluted river systems and restricting its inputs to clean groundwater through the sands.

Water-taking in the Ausable can exacerbate the already low flows and increase contaminant concentrations.

'The Cut' has erosion problems from boat wakes, flooding and the non-natural design. Dredging creates fisheries concerns (Snell and Cecile et al. 1995).

Shallow beaches at Ipperwash and Port Franks suffer more bacterial problems than Grand Bend and the Pinery (Glaskin-Clay et al, 1996). Lake water has less chance to mix; again form is a factor.

Bonte-Gelok and Joy (1999) studied Huron County surface water quality and rated the Ausable High for fecal coliform concentrations and loadings; Moderate for nitrate concentration and loading; High for phosphorus concentrations, Moderate for loadings. It had poor water quality compared to the northern basins.

An example of a recent spill was an April 2005 discharge of 5000 L of chlorine into the river below Exeter. Over 20,000 fish died in the 5 km affected reach (Veliz 2005).

Parkhill

Parkhill's water quality is poor (Schaus 1982; Snell and Cecile et al. 1995; Bonte-Gelok and Joy 1999). Agriculture is the main contaminant source; clay soils, poorly drained soils, agricultural drainage, faulty septic systems, erosion and manure are all contributing factors (Balint and Thomas 1983; Ryan 1987). Parkhill Reservoir has a high sedimentation rate and problems of warm temperatures, bacteria, algae, carp and turbidity (ABCA 1979). A more extensive forest cover in Ptsebe Creek's watershed benefits that tributary. But high drainage density there and in the lower Parkhill tributaries off the Lake Warren Plain, encourages contaminant delivery.

Besides agriculture, potential contamination sources include the sewage treatment plants at Parkhill and Grand Bend and a landfill on the glacial lake beach.

Studies of effects of remedial measures in Desjardine Drain showed some improvement (Griffiths 1988, 1989), sometimes masked by other inputs (Hocking 1996). Long bacterial survival and growing antibiotic resistance combine with short travel times to continue concerns at downstream beaches.

Bayfield

The upper Bayfield resembles the Ausable in form and land use and suffers similar high levels of contamination and very low summer flows. The watershed's main distinction from the Ausable is a major spillway that adds a cold, clean, permanent base flow to the lower river via Trick's Creek and, to a lesser extent, via Bannockburn Creek. The input greatly improves the water quality of the lower Bayfield water quality over that of the upper reaches but also transports contaminant loads to the shore.

Besides agriculture, potential contaminant sources include faulty septic systems, sewage treatment plants (Clinton, Seaforth, Vanastra, Huronview) and landfills on permeable bases or valley brows.

Bonte-Gelok and Joy (1999) in their ratings for Huron County rate Bayfield High for fecal coliform concentrations and loadings; High for nitrate concentrations and loadings; Moderate for phosphorus concentrations and loadings.

Maitland River

Like the Bayfield, the downstream base flow contributions, led by those from the same spillway, help moderate upstream contaminant concentrations. The Maitland differs, however, in both its greater size and its extensive network of baseflow-contributing landforms and associated natural areas.

Like the Bayfield the main contaminant sources are septic system failure and manure (MVCA 1989). Effects are excessive algae, decreased oxygen, and degraded stream habitat and health threats. Since 1966, nitrate concentrations have increased to the point of harming aquatic life, while phosphorus levels have declined slightly (MVCA 2003).

South Maitland

The upper basin's clay plain generates high sediment and nutrient loads. Diking of the Hullett wetland has reduced its role as a filter and possible low flow contributor. The downstream kame probably contributes a small amount of base flow to the lower end. Bonte-Gelok and Joy (1999) in their study of Huron County rank South Maitland 'moderate' for fecal coliform concentrations and 'low' for loadings; 'high' for nitrate concentrations and 'moderate' for loadings; 'moderate' for phosphorus concentrations and loadings. Low flows give much of the river an impaired rating for ecosystem health (MVCA 2002). MVCA has targeted the watershed for water quality improvement (MVCA 2003).

Middle Maitland

In 1954, the Middle Maitland was dismissed as a "textbook example of the effects of dumping massive quantities of untreated sewage into an inadequate stream" (Department of Planning and Development 1954). Listowel was the obvious culprit; sources were both septic systems and industry. By 1967, many problems persisted (Conservation Authorities Branch 1967). The river became a priority for improvements. Today Listowel sewage treatment is much improved. But the same agricultural issues as in southern basins apply, especially after rain events. The upper parts of the Middle Maitland have the wet clay plains and extensive drainage that encourage delivery of contaminants to the streams. On-going projects with community partners are improving the situation. Projects include riparian plantings and a constructed wetland (MVCA 2003). Phosphorus concentrations have declined over the last 3 decades but still encourage excessive algae. Nitrates have increased; all sample sites were elevated beyond the health of stream life and livestock. *E. coli* levels showed no trends but jumped sharply after storms, often exceeding swimming guidelines (Middle Maitland Initiative 2000).

Bonte-Gelok and Joy (1999) in their Huron County study rated Middle Maitland 'moderate' for fecal coliform concentrations and loadings; 'moderate' for nitrate concentrations and 'high' for loadings; and 'high' for phosphorus concentrations and loadings.

Little Maitland

Little Maitland shows the moderation effects of the spillway network and slightly lighter soils. Bonte-Gelok and Joy (1999) rate Little Maitland 'low' for fecal coliform concentrations and loadings; 'moderate' for nitrate concentrations and 'low' for loadings; and 'low' for phosphorus concentrations and loadings. MVCA has targeted the area for water quality improvement (MVCA 2003).

North Maitland

Natural conditions in the North Maitland River support good water quality and healthy aquatic ecosystems (MFX Partners 2002). Sewage treatment at upstream towns improved the urban inputs. Agricultural inputs are diluted by baseflow contributions from the spillway network and kames, lighter soils, relatively extensive natural areas. The results are a rating of 'moderate' for fecal coliform concentrations and loadings; 'low' for nitrate concentrations and loadings; and 'low' for phosphorus concentrations and loadings (Bonte-Gelok and Joy 1999). Long-term trends are steady to decreasing phosphorus levels but rising nitrate concentrations. Loads increase during rainfall events (MFX Partners 2002).

Lower Maitland

The Lower Maitland collects all the flow from the above tributaries and adds its own. The watershed's natural conditions support good water quality and healthy aquatic ecosystems (MFX Partners 2002). Blyth Brook, like the upstream contributions, carries elevated phosphorus, nitrates and *E. coli* (Total Approach Initiative, 2000). But Sharpes Creek and likely, to a smaller extent, Hopkins Creek, pour cold permanent base flow into the Lower Maitland from the same major spillway that benefits the lower Bayfield.

The outcome is improved quality in the Lower Maitland while delivering the upstream loads to the lake. Bonte-Gelok and Joy (1999) rank Lower Maitland Low for concentrations of each of fecal coliform, nitrate and phosphorus, but 'high' for all their loadings. Long-term trends are steady to decreasing phosphorus levels but rising nitrate concentrations. As elsewhere, rainfall events carry the highest loads (MFX Partners 2002).

The 1967 Report (Conservation Authorities Branch 1967) notes some salt plant effluent near the mouth.

Nine Mile

The same spillway that feeds Sharpes Creek extends into Nine Mile River. That spillway and kame headwaters contribute baseflow to the creek. Natural area buffers help keep it cool and clean. The result is Nine Mile River is in good condition, meeting both nitrate and phosphorus targets (MVCA 2003). Bonte-Gelok and Joy (1999) rate Nine Mile River's nitrates and fecal coliforms 'low' for both concentrations and loadings.

Shore Gullies and Streams

The combination of heavy clay soils, gully erosion, numbers of septic systems and lack of natural cover all contribute to high contaminant concentrations. The short length and high drainage density efficiently delivers them to the lake. Bonte-Gelok and Joy (1999) rate Gullies south of Bayfield High for each of fecal coliform concentrations, nitrate concentrations and phosphorus concentrations.

Appendix D: List of WC Maps in Accompanying Map Book

Chapter 2

WATER QUALITY

Water Quality in the Ausable Bayfield Maitland Valley
Planning Region,
Including the Nearshore of Lake Huron

Version 1.0
January 2007

Prepared by

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2 Water Quality

Water has many uses in the Ausable Bayfield Maitland Valley Planning Region (refer to WC Map 1-1) and the quality of this water is critical to the local economy. Groundwater is the drinking water source for 100,000 people, more than 837,000 livestock and more than 5,200,000 poultry. Lake Huron provides drinking water to approximately 30,000 people within the area and is exported to about 500,000 others including the City of London. In addition, Lake Huron is the major tourism attraction in the area and is valued for its prime recreational opportunities. Area rivers provide water for irrigation and support an active angling community. While the focus of this chapter is water quality as it pertains to drinking water sources, the impacts and effects on the whole system will be discussed to provide a holistic context.

In order to protect current and future uses of water for drinking water, recreation, agriculture, and the needs of the aquatic ecosystem, water should not contain contaminants which limit its use. Water quality guidelines have been developed for consumption, recreation, and for aquatic protection. Again, to provide a holistic context, where more then one guideline exists based on different uses, the most stringent or lowest value should be used to assess water quality.

The purpose of Chapter 2 is to generally document the quality of water in the Ausable Bayfield Maitland Valley Planning Region. This report can be considered a broad environmental scan of water quality conditions at select sampling sites as opposed to a detailed analysis of all water quality parameters, sources and solutions (Site specific details are provided in Appendix A). Water quality data is summarized in order to outline current water quality conditions and spatial trends. Where data makes it possible, historic trends are documented to be used in predicting future conditions and to assist in identifying potential contaminant sources. This document will be used as a guide for areas of further study and future directions.

Knowledge and data gaps will be documented which are required to better understand water quality and its sources and finally, next steps for filling these gaps will be identified.

Three major water systems will be discussed and include:

- Surface water quality of rivers and streams: Summarized by major basin which will allow the comparison of water quality conditions to the basin characteristics in Chapter 1 in order to begin the process of understanding pathways and relationships to land use and management
- Lake Huron water quality in the nearshore: The two intakes adjacent to the study are compared. As intake protection zones are to be identified in later chapters, the focus will be on water quality results.
- Groundwater quality of the major aquifers: outlined by source aquifer for each municipal system. Again this approach will help focus best management practice efforts

2.0 Background

The purpose of this section is to outline some of the general concepts of landscape scale relationships to water movement and, therefore, its quality. These concepts will be used in discussing the actual water quality results in the document, but is easier to define them here in one place instead of repeating concepts in the discussion. These are general concepts and are not meant to take precedence over the actual water quality discussion.

Water quality issues in rural-agricultural watersheds tend to result from non-point source pollution. The quality of water in these watersheds is a function of the pathway of water through the hydrologic system, the materials it comes in contact with, and the duration between the time when water comes into contact with a contaminant until its chosen use. Generally, the longer the pathway in both real physical terms or in terms of time or duration, the more chance that contaminants can be bound, filtered, diluted, or chemically or biologically stabilized.

Chapter 1 outlined the physical characteristics of the watersheds that define water movement; landform determines hydrologic function.

For water quality and quantity, four main components are used to characterize a basin:

- geology and landform
- land use and land management
- sensitive areas
- drainage modifications

Geology and Landform

The pathway that water follows in a basin is dictated by the permeability of the soil, slope of the land, geology below the soil zone, and elevation differences or varied elevation features. One specific landform in the study area that greatly modifies water movement is hummocky terrain. This landform is defined as depressional areas which have no outlet for surface water. Therefore, water is forced to infiltrate into the groundwater system and/or evaporate.

Basins can be categorized into either surface water or groundwater systems. Surface water systems are those in which the main pathway for water is runoff or overland flow from precipitation to streams and rivers. This is usually due to steep topography, less permeable soils (clay), and less permeable geology (till). In a surface water system, water is generally not infiltrated and as a result, there is a greater likelihood that contaminates will be carried and delivered to streams and rivers resulting in poorer water quality. Water quality problems can be compounded by lack of water quantity, since very little water from precipitation is stored on the landscape or in the ground. Surface water systems have warmer stream temperatures, as there is no opportunity to cool water as it moves through the ground, which further stresses the aquatic environment.

Groundwater systems generally have a pathway of water which includes infiltration into the ground. These types of basins include mostly permeable geology such as sands and gravels and, in this region, are typified by highly variable topography and steep slopes, a result of the glacial provenance of sand and gravel deposits. The high permeability materials allow water to be infiltrated, and the high relief provides a gradient for water to reappear as springs at the ground surface. As a result of this infiltration and storage of water in shallow aquifers, water quality is typically better, flows in streams are more stable, and stream temperatures are cooler in summer and warmer in winter.

Land Use and Land Management

Both water quality and quantity can be further influenced by activities occurring on the land. The major factors are the degree of vegetative cover and the presence of nutrients in the soil. The more exposed the soil, the more likely that sediment and other soil-related contaminants can be carried to streams. As such, a row cropped field is more likely to be significantly eroded by runoff then a grain or hay field. Over time, land management that changes the soil properties (i.e. compaction from farm implements) may cause it to behave more like a surface water system.

The other major factor is the presence of contaminants. The major contaminants in the area are nutrients, specifically nitrogen and phosphorus. The more nutrients that are applied or produced, the greater the likelihood they will be transported to a stream or into the groundwater, and the higher the concentrations of those nutrients will be to the receiving body.

Other major potential contaminants are pathogens from manure, improperly composted manure, and other sources. Livestock and poultry manure may contain a variety of bacteria, viruses and protozoa that are pathogenic to humans including *E. coli*, Salmonella spp., Streptococcus spp., Giardia and Cryptosporidium (Martin 2005). Good agricultural practices reduce the risk of pathogen contamination in water.

Sensitive Areas

For surface water quality, certain landscape features such as highly erodable soil, steep slopes, presence of saturated soil such as springs or high water tables, and riparian areas, are more likely to contribute sediment and nutrients to watercourses. These areas are often marginal for agricultural production and can have a disproportionably high contribution to poor water quality.

Drainage Modifications

A final major factor relates to the distance that precipitation has to travel before reaching a stream, drain, or tile. The shorter the distance, the greater the risk to water quality since there is less of an opportunity for settling or treatment of contaminants (OMAF – BMP Water Quality). Water quantity can be affected as well, as water is removed from the landscape quickly and is less likely to be infiltrated. This can reduce the available water to streams from shallow aquifers during dry periods. The greater the drainage density, the more a basin will exhibit the behaviour of surface water systems. At least seventy-five percent of the agricultural land in the till plain areas of the Ausable Bayfield Maitland Valley Planning Region has been tile drained, greatly modifying the natural drainage network (Dean and Foran 1989). Figure 2-1 is a spring aerial photograph clearly showing the quantity of tiles in agricultural fields.

Figure 2-1: Example of tile drainage density in northern Perth County.

2.0.1 Indicators

Water quality issues can be determined through appropriate indicator selection. Water quality indicators are defined as certain chemicals or organisms that can be used to monitor environmental conditions because they can:

- Represent a contamination source with their presence or lack thereof
- Assist in determining the pathway of water has taken
- Provide information which follows a guideline for determining the impacts on humans or the ecosystem
- May be related to the behaviour of chemicals or pathogens of interest, but they are easier to collect in the field or analyze in the laboratory.

At present the Provincial Water Quality Monitoring Network (PWQMN – see section 2.2.1.1 Data Collection Programs) currently has 44 indicators with the Provincial Groundwater Monitoring Network (PGMN) having between 50 and 100 indicators. For the purposes of this report, it is necessary to select a few key indicators to discuss water quality in order to develop a general understanding of major issues and pathways. The indicators selected are those that have been identified through previous investigations or by Conservation Authority staff as being issues within the partnership area for water resources.

Indicators of nutrient enrichment and erosion are most common for river monitoring in this area, including nitrate, total phosphorus and suspended sediment. Water quality of Lake Huron is a major issue, therefore, the use of fecal coliform (*E.coli*) as an indicators for the presence of harmful bacteria to humans is warranted. Most common issues for groundwater are nitrate, *E.coli* and chloride along with naturally occurring elements such as iron, fluoride, carbonates, and sodium. The new indicator for this area, copper, will be added as a measure of human impacts on water quality.

Six indicators (nitrate, total phosphorous, suspended sediment, chloride, copper, and *E. coli*), were examined in detail for this report. However, a scan of all water quality indicators for rivers that have been sampled and have a standard for comparison will be completed.

Chloride

Chloride is a water soluble and conservative element that is not typically present in natural groundwater or surface water systems in large concentrations. Approximately 0.05% of the lithosphere consists of chloride, with the greatest amount found in oceans. In freshwater systems, concentrations of chloride vary according to climate. Concentrations are typically lower (<10 mg L^{-1}) in humid areas compared to more arid regions (100 mg L^{-1}) (CCME 1999). Therefore, it is a good indicator of the impact from human activities on water quality. The largest single potential source of chloride is from the use of road salt for winter ice control, but is also derived from sewage treatment effluent, septage, animal waste and potassium chloride (potash in fertilizer).

Chloride is not considered a health hazard in the concentrations found in groundwater in Ontario; however, it imparts an undesirable taste above 250 mg L^{-1}, which has been designated as an aesthetic water quality objective for under the Ontario Drinking Water Standard. The benchmark identified in Environment Canada's Priority Assessment Report, 2001 is 250 mg L^{-1} for aquatic protection. The British Columbia government has developed a standard of 150 mg L^{-1} for the protection of aquatic species.

A potential pathway for chloride in groundwater, particularly in deeper, confined aquifers, is through cross contamination from deeper formational waters via inadequately decommissioned brine wells. Chloride concentrations are useful for determining the source of elevated concentrations, as water contaminated from salt (NaCl) should have elevated and near equal concentrations of both sodium and chloride. Sampling and analysis of chloride should always include an analysis of sodium concentrations, as elevated concentrations of chloride in groundwater, if derived from salt, may indicate coupled elevated concentrations of sodium.

Copper

Copper is a persistent element that is not typically present in natural surface water systems and therefore is a good indicator for heavy metals from human activities. The largest potential source is from sewage treatment effluent. There is an interim PWQO for copper of 1 ug L^{-1} if hardness as $CaCO_3$ is 0-20 mg L^{-1}, or 5ug L^{-1} if hardness as $CaCO_3$ greater then 20 mg L^{-1}. All historic river and stream sampling results in the area have been above 20 mg L^{-1} of $CaCO_3$ and therefore the 5ug L^{-1} guideline applies.

Nitrate

Nitrate is the most common form of nitrogen in the environment in aerobic conditions (i.e. when oxygen is present). Nitrate is the primary source of nitrogen for aquatic plants. All forms of inorganic nitrogen (nitrite and ammonia) have the potential to undergo nitrification to nitrate. In well-oxygenated systems, increasing concentrations of inorganic nitrogen increase the risk of algae blooms and eutrophication. Eutrophication is the process of reduced oxygen levels in an aquatic environment brought about due to excessive plant growth and die-off as a result of elevated nutrients (predominantly phosphorus, but also nitrogen).

There are two water quality guidelines for nitrate, both expressed as mg L^{-1} nitrogen from nitrate. The first guideline is an Ontario Drinking Water Standard (ODWS) and is set at 10 mg L^{-1} of nitrate as N. Above this level, nitrogen can preferentially bind to haemoglobin in the blood of mammals reducing the quantity of oxygen in the blood. Young children are especially susceptible to this condition, but the same effect can occur in young calves as well. The second established by the Canadian Council of Ministers of the Environment (CCME), for the protection of aquatic ecosystems is at 2.93 mg L^{-1} of nitrate as N. Above this level, nitrate can be toxic to fish and amphibian eggs.

In rural areas, potential sources of nitrogen are agricultural and lawn fertilizer, manure, septic systems, sewage treatment effluent and atmospheric deposition. Nitrate is soluble in water and therefore can easily be transported in water in overland runoff or into streams via diverted infiltrating water from tile drainage or aquifers. The fate of nitrogen in natural systems is complex, as it is utilized by all plants and is subject to many biological processes that can bind and transform nitrogen.

Nitrogen sources applied or injected into the shallow aquifers are quickly converted to the relatively inert mineral nitrate form, which is highly soluble in water and extremely persistent in the anaerobic conditions of the saturated groundwater zone. As a result of this, they are considered one of the more conclusive indicators of contamination from surface water in aquifers worldwide.

For the purposes of this study, the presence of any significant concentrations of nitrate in an aquifer can be considered an indicator of a connection with surface water, although the degree of this connection is not necessarily proportional to the concentration of nitrates.

Phosphorus

Phosphorus is often the limiting nutrient in many aquatic ecosystems for primary production (plant growth). Nutrients must be available to plants in certain proportions to be utilized; the nutrient that has the least amount available is considered the limiting nutrient.

For the report, total phosphorus (TP) will be used and includes dissolved phosphorus and forms bound to organic and inorganic material in water. An interim Provincial Water Quality Objective (PWQO) of 0.03 mg L^{-1} of total phosphorus has been established to avoid nuisance algae in streams and rivers. An objective of 0.02 mg L^{-1} is used for lakes during the ice free period to avoid nuisance algae.

The PWQO for phosphorus was not established to delimit toxicity, but rather to identify the indirect impacts of excessive phosphorus on aquatic ecosystems through oxygen imbalances. Since phosphorus is oxygen limiting, any excess in water will result in increased primary production (plants), which is usually algae (Figure 2-2). Like all plants, algae photosynthesize in the daylight which releases oxygen, and respire at night which consumes oxygen. If there is excessive algae, oxygen concentrations in the early morning can approach zero, resulting in fish kills. A second impact may occur when algae decays. Decaying algae is biologically consumed which requires oxygen, once again limiting the oxygen concentration of the water.

Phosphorus ions form ionic bonds with clay through a process called adsorption. Phosphorus therefore often moves attached to soil particles. For this reason, excess phosphorus is very closely associated with rainfall and runoff and is generally found in those areas that have higher clay content soils. Potential sources of phosphorus are from agricultural and lawn fertilizer, manure, septic systems, sewage treatment effluent and milkhouse washwater.

Phosphorus is not considered an important indicator for discussion with respect to groundwater as it typically is adsorbed to soil particles, and does not persist in infiltrating water.

Figure 2-2: Algal bloom due to excess nutrients

Suspended sediment

Suspended sediment is an indicator for the amount of soil erosion that has occurred from runoff, streambank erosion and channel processes. In addition, since some indicators (e.g. phosphorus and aluminium) are bound to soil particles, understanding sediment movement makes it possible to interpret these water quality contaminants. Higher suspended sediment concentrations often result from soils with higher clay or silt contents. Sediment can also directly impact aquatic organisms by removing benthic habitat and fish spawning habitat as interstitial spaces between cobble and gravel substrate are filled. Concentrations of carbon, nitrogen, and phosphorous on the surface or suspended sediments may be 10-100 times more concentrated than on the water column.

In Canada, many agencies recommend that suspended matter should not be added to surface water in concentrations which will change the background level by more than 10 percent. In Ontario, 30 mg L^{-1} is the minimum standard for suspended material permitted in effluent discharged to surface water. The European Inland Fisheries Advisory Committee (EIFAC 1965 In Kerr 1995) reported that there was no evidence that TSS (total suspended sediment) concentrations less than 25 mg L^{-1} have any harmful effects on fisheries. Good fisheries could be maintained in waters that contain TSS at 25 to 80 mg L^{-1}. Waters normally having suspended solids at 80 to 400 mg L^{-1} are considered unlikely to support good fisheries. Only poor fisheries are likely to be found in waters with TSS above 400 mg L^{-1}. For analysis in this report, 25 mg L^{-1} was be used as a standard for aquatic protection based on EIFAC findings.

Microbes

Two indicators for fecal contamination of water include fecal coliform and *Escherichia coli* (*E.coli*). Fecal coliform are a group of bacteria that inhabit the intestines of warm blooded animals and the presence of these bacteria in surface water indicate a potential for harmful bacteria and pathogens to humans. *E.coli* is a member of the fecal coliform group and is the current indicator bacterium.

The applicability of *E.coli* as an indicator bacterium for aquifers is somewhat more tenuous. In the anaerobic conditions of the saturated groundwater zone *E.coli* is not likely to persist for long periods. Enterococci can survive in the absence of oxygen and this bacterium, along with coliphage, are superior indicators of fecal pollution in groundwater because their survival is consistent with both bacterial and viral pathogens. In higher nutrient conditions of surface waters, however, *E.coli* can thrive and it is found in almost all surface water. The presence of *E.coli* in a well would therefore represent a direct connection between an aquifer and a surface water body. What is more likely and more commonly found, is that the presence of E.coli in a given sample is a reflection of the quality of the construction of the well, rather than aquifer conditions.

The Ontario Drinking Water Standard (ODWS) for *E.coli* is set at 0 cfu/100ml and the recreational PWQO is a geometric mean of 100 cfu/100ml of samples taken over a month. As groundwater is primarily a source of drinking water and has no obvious recreational use, the standard for discussion of the results in this report shall be 0 cfu/100ml.

Hardness

Hardness is a naturally occurring characteristic of groundwater and is a calculated quantification of the overall mineral content in water corrected to and expressed as mg L^{-1} $CaCO_3$. Hardness is useful for discussion as it is a relative indicator of the security of an aquifer. Surface water is generally not hard and if an aquifer that is typically hard is displaying a lack of hardness, this may be an indication of interaction with surface water. It should be noted that not all aquifers, as a consequence of differing source material chemistry, produce hard water, such that it is not possible to consider the security of different aquifers based solely on hardness.

Hardness is also considered a nuisance in domestic drinking water, as it leaves a residue on cooking utensils and piping. As such, an ODWS for Hardness of 100 mg L^{-1} has been established as an operational guideline for drinking systems. There is no known health problem associated with hardness.

Fluoride

Fluoride is a common, naturally occurring constituent of groundwater throughout the Ausable Bayfield Maitland Valley Planning Region, most particularly in bedrock aquifers. The level of fluoride in a particular sample is representative of the chemistry of the rocks from which it has been extracted. Fluoride continues to be a concern for a number of municipal drinking water supplies and private well owners.

Fluoride has a health related ODWS of 1.5 mg L^{-1}, but is not considered to be an issue of concern if naturally occurring below 2.5 mg L^{-1}. Fluoride in low concentrations ($\leq$ 1.5 mg L^{-1}) is considered a health benefit, and most municipal water systems fluorinate water for distribution to a concentration of ~1.0 mg L^{-1}.

Iron

Iron occurs both naturally in groundwater and as a result of contamination. Although difficult to separate the sources of iron in groundwater, it is worth considering for the purposes of this report. Caution should be used when interpreting iron analytical data, as discrete samples from one aquifer may have highly variable concentrations. Trends in iron concentrations should only be interpreted with a long record of data from a single, controlled sampling location. Elevated iron in a given sample is often a reflection of the quality of the construction of the well, rather than aquifer conditions

An aesthetic water quality objective has been established for iron at 0.3 mg L^{-1} for Ontario. Above these concentrations, iron is considered a nuisance in domestic drinking water, as it leaves an oxidized residue on household fixtures, cooking utensils, and piping.

Sodium

Sodium occurs both naturally in groundwater as well as a result of contamination from human activities, particularly the application of road salt and via cross contamination from deeper formational waters via inadequately decommissioned brine wells. Determination of the source of sodium can only be accomplished by interpreting the concentration of chloride in a sample. Water contaminated from salt (NaCl) should have elevated concentrations of both sodium and chloride.

Sodium has a health related ODWS of 200 mg L^{-1}, but is considered to be an issue of concern for hypertensive people at concentrations above 20 mg L^{-1}. For the purposes of this study, long-term sodium concentrations are important to monitor the potential impacts of road salt application, particularly in more susceptible aquifers.

2.1 Methodology

2.1.1 Surface Water

Two surface water sources in the Ausable Bayfield Maitland Valley Planning Region are rivers or streams, and Lake Huron. At present, surface drinking water supplies are only drawn from Lake Huron. Despite the fact that there is no drinking water taken from river surface water, it is considered important for the purpose of Source Protection Planning to include riverine water quality in this analysis. The major reason for including surface water is that it can directly impact current groundwater and Lake Huron drinking water sources, for example:

- At least one Lake Huron water intake is within the zone of influence from the mouth of the Maitland River (B.M. Ross and Associates Limited 2002).
- The lower portions of the Maitland River (17 km – Figure 2-3) flow across fractured bedrock where at certain times of the year surface water is entering directly into the bedrock groundwater system.
- Portions of the lower Bayfield River stop flowing in the summer as the water seeps into the river bottom to emerge further downstream, indicating a connection to the groundwater system.
- The presence of sinkholes in the area and the tendency for them to be used as an “adequate outlet” for municipal drains also allows surface water to enter the groundwater system directly.

Figure 2-3: Exposed bedrock in the Maitland River at Falls Reserve Conservation Area

River and stream water quality has been monitored in the area since 1964, both for special projects and as part of structured, long-term monitoring programs. The focus over much of this time has been on nutrients, sediment and bacteria, and more recently biological monitoring. WC Map 2-1 identifies the location of all surface water quality monitoring sites sampling, both short and long-term. In total, water quality data has been collected for varying periods of time at 266 distinct sites in the Ausable Bayfield Maitland Valley Planning Region. For the analysis of surface water quality as part of this report, the data has come from three sampling programs: The Provincial Water Quality Monitoring Network (PWQMN), The Ashfield Colborne Lakeshore Association (ACLA) sampling, and the ABCA enhanced water quality network.

2.1.1.1 Data Collection Programs

Provincial Water Quality Monitoring Network

The majority of the surface water quality data for the area has been collected through the Provincial Water Quality Monitoring Network (PWQMN). This network is a partnership between Conservation Authorities and the Ministry of the Environment (MOE) and has been operating in the area since 1964, with a short hiatus in the late 1990s. Sites are sampled from eight to twelve times a year and consist of single grab samples, typically collected in a stainless steel dipper. The parameters analyzed for this program include nutrients, basic water properties, common metals, bacteria (1970-1994) and heavy metals (since 1998). The MOE lab performs the laboratory analysis. The PWQMN sites in the ABCA watershed are also analyzed at a private lab for *Escherichia coliform* (*E.coli*) and suspended sediment in addition to the network parameters. The PWQMN is a Provincial network aimed at general trends, and as a result not all watercourses are monitored, with sites for the PWQMN are typically located on larger rivers and their main branches.

Ashfield-Colborne Lakefront Association

A second available data source is derived from the sampling of small shoreline watercourses by the Ashfield Colborne Lakefront Association (ACLA) in partnership with the MVCA and is available from 2001 to present. This sampling was initiated in order to fill the gap in water quality information for small lakeshore streams that were not monitored as part of the PWQMN or any other program due to their large number and relatively small catchments. For this program, single grab samples are collected using a stainless steel dipper every other week in the spring/summer/fall period by ACLA volunteers and analyzed for *E.coli*, nitrate and phosphorus at a private lab.

ABCA Enhanced Water Quality Monitoring

A third source of surface water quality data is the enhanced water quality network initiated by the Ausable Bayfield Conservation Authority in 2003. Like the ACLA sampling, the purpose of this sampling is to fill in water quality gaps of the PWQMN, especially for smaller watercourses. The samples are taken monthly in the ice-free period and analyzed for *E.coli*, total phosphorus, dissolved reactive phosphorus, ammonia, nitrate, nitrite, total Kjeldahl nitrogen, and suspended solids.

CURB

A fourth major data source in the area that is not utilized in preparation of this chapter, but that warrants explanation is the CURB (Clean-Up Rural Beaches) Program. The major focus of this program was bacterial contamination, especially of Lake Huron swimming beaches. Sampling occurred from 1986-1989 during development of the CURB Plan and from 1990-1994 during the CURB Plan implementation. Data from this program has not been included in this report due to the short duration of sampling, the age of the data, and the fact that most sites were situated within smaller watercourses.

Drinking Water Surveillance Program

For Lake Huron drinking water sources, indicators of water quality have been collected twice a month year-round at the intake of municipal water treatment plants in the Ontario waters of the Great Lakes since 1976. Trends in total phosphorus (TP) concentrations for 18 municipal water treatment plants have recently been evaluated (Nicholls 2001). This information is not in the perspective of nearshore Lake Huron conditions and other water quality indicators have not been documented. There are two Lake Huron water intake facilities serving the Region, the Town of Goderich intake and the Lake Huron Water Supply at Port Blake. Water samples from both plants were collected prior to any treatment with the analysis of the water samples conducted at the Ministry of the Environment laboratories.

2.1.1.2 Scan of Potential Water Quality Issues

Site Selection – Scan of Potential Water Quality Issues

Four indicators of rural non-point source water quality (nitrate, total phosphorous, suspended sediment and *E. coli*) and two indicators that reflect more common urban water quality issues (chloride and copper) were examined for spatial and temporal trends in the rivers and streams of the study area. In order to assess the presence of other water quality issues, a scan of historic data was completed.

The best source of data for less common water quality contaminants is the PWQMN. Any site that has been sampled under the PWQMN in the 2001 to 2005 time period was scanned. There have been 26 sites sampled; 22 sites are current and 4 are no longer sampled.

Scan of Potential Water Quality Issues – Data Analysis

Using the MS Access water quality database, all samples collected in 2001 to 2005 were compared to all indicators that currently have an objective. The objectives were first based on the

PWQO and the ODWS. If there was no provincial standard, the Canadian Water Quality Guidelines were referenced. Where there were two objectives for the same indicator, the lowest concentration indicator was used for the scan. No reporting was completed for an indicator with no standard.

The number of exceedances for each site for each indicator was totalled and all the exceeded values were averaged in order to develop an appreciation for the magnitude of exceedance over the standard. As a general indicator of sites of highest concern, all exceedances for all indicators were summed.

2.1.1.3 Temporal Changes

Site Selection – Temporal Changes

For temporal change determination to be useful for drinking source water protection, a long term record is needed and current data. For this reason, the CURB data will not be used as well as any other short or project specific sampling. All of the PWQMN sites ever sampled (84) will be summarized for determining trends, and augmented with data from the same site monitored more recently through the ACLA and ABCA Enhanced programs.

For Lake Huron water quality trend analysis, both the Goderich and Lake Huron Water Treatment Plant intake data will be used.

Temporal Change – Data Analysis

All of the PWQMN, ACLA and ABCA enhanced water quality data was imported into an MS Access database created to manage water quality data, graphical trends, statistics and highlighting guideline exceedances. The only filtering of the data was to replace non-detects with the actual value of the method detection limit, and indicate in a 'remarks' field as a non-detect.

Temporal changes were determined for six water quality indicators including chloride, copper, nitrate, total phosphorus, suspended sediment, and bacteria (fecal coliform and *E.coli*) and these indicator data were extracted to MS Excel. All data was attributed with a year grouping in five year blocks, starting with 1961-1965, and going to 2001-2005. All of the data was used without any filtering except for one sample. A nitrate value of 178 mg L^{-1} was removed from the Ausable River data which was measured on December 31, 1986 as the value was outside the plausible expected value for this location.

All of the water quality data was imported into Systat ver.11 (2004) and has been summarized both graphically and statistically. Graphically, a scatterplot of all samples was created with a LOWESS (locally weighted regression) smoothing line with a tension of 0.5 fit to the data. Analysis of water quality is sometimes difficult as this data may not be normally distributed or may have sporadic high and low data values ("outliers"). In the current analysis, data was examined with an exploratory procedure, LOWESS, to detect potential time series trends (SYSTAT version 11, 2004). If a specific geographic site has been sampled through different programs for the same indicator, this data was lumped. This is an exploratory approach and a formal trend analysis will be performed in the future.

The statistical summary for each five year time block included the number of samples, and the minimum, maximum, median, 25th percentile, and 75th percentile values.

2.1.1.4 Temporal Trends

For the purpose of reporting on temporal trends, six sites were selected. These sites were selected due to the length of record (greater then 5 years) and location on major river systems in the watershed. These sites are located in the downstream sections of the watersheds in order to integrate all the potential sources of the indicators for those watersheds. They also represent the six major watersheds in the area, namely: the Ausable, Bayfield, Maitland and Nine Mile Rivers, Parkhill Creek and Blyth Brook. The lakeshore gully system is not monitored and is not included in the analysis. These sites are considered sufficient to provide a general indication of water quality trends for the study area. Details of these six sites can be found in Table 2-1.

- Blyth Brook – PWQMN site from 1964-1994, 1998-2005 (site name Blyth)
- Ausable River – PWQMN site from 1980-1998, 2000-2005 (site name Thedford)
- Bayfield River – PWQMN site from 1975-1995, 2000-2005 (site name Varna)
- Maitland River – PWQMN site from 1964-1994, 1998-2005 (site name Goderich)
- Nine Mile River - PWQMN site from 1964-1994, 1998-2005 (site name Port Albert)
- Parkhill Creek – PWQMN site from 1972-1995, 2003-2005 (site name Downstream Parkhill)

Significant differences between the six sites were determined for each indicator except bacteria. All of the analysis was completed in Systat ver. 11 by first transforming the data, and second performing an ANOVA (analysis of variance). The data was transformed in order to create a more normal distribution.

The data for nitrate, chloride and residue particulate was transformed by taking the square root of the observed value. Total phosphorus and copper observed values were transformed by first multiplying the value by 1000 and taking the square root of this sum.

The ANOVA was performed with the sites as factors, and a Post hoc Tukey test applied. A difference between two sites was considered significant if the pairwise comparison of probabilities had a p-value of less than 0.05 (5% probability that the difference between sites is just a coincidence).

All of the lake intake water quality data was imported into Systat ver.11 and a scatterplot of all samples was created with a LOWESS smoothing line with a tension of 0.5 fit to the data. In the current analysis, data was examined with an exploratory procedure, LOWESS, to detect potential time series trends (SYSTAT version 11, 2004). Difference in mean concentrations for the three variables (TP, nitrate and chloride) between the two locations was determined with non-parametric Mann-Whitney U –Tests (SYSTAT version 11, 2004).

Graphs of the water quality data appear as box and whisker plots. The box length shows the central 50 per cent of the values from the 1st to the 3rd quartile or the 25th percentile to the 75th percentile. The median is indicated as the central line within the box. The whiskers and asterisks denote 1.5 and 3 times, respectively, the absolute values between the 25th percentile and the 75th percentiles. The empty circles are values that are beyond 3 times the absolute values between the 25th percentile and the 75th percentile.

2.1.1.5 Spatial Trends

Site Selection – Spatial Trends

The sites that are presently (2005) sampled and are part of long term structured monitoring program will be used. This is limited to 46 distinct sites in the tributaries draining into the southeast shore of Lake Huron (Table 2-1) from the PWQMN, the ABCA enhanced network and the ACLA sampling. The main rationale for only using these sites as opposed to all 266 sites is that many of the 266 sites are not currently sampled. Data that is 10 years old is not deemed to be beneficial. Historic sites may be useful in the future to add further refinement of issues in a particular watershed. It is important to note some locations are sampled through more than one program and are therefore in the table for each program.

Spatial Trends – Data Analysis

For spatial trends, only three indicators for rural watershed were used: nitrate, total phosphorus and bacteria (*E.coli*).

The data used for determining spatial trends was the same set for the temporal changes, with all the data screened out except for the 2001-2005 time period. This created a larger data set that reflects the water quality issues at each site more accurately. If a specific geographic site has been sampled through different programs for the same indicator, this data was lumped. The data for the 46 sites is presented in two forms: graphically and mapped.

To produce the mapping, the median concentration for nitrate and total phosphorus at each site was calculated using Systat ver.11. The geometric mean for *E. coli* was calculated in MS Excel for each site. The concentration for each site was plotted as a point and colour coded based on a classification scheme. Firstly, breakpoints were created for known guidelines or objectives. Secondly, all data for each indicator at each site was lumped and descriptive statistics calculate median, 25^{th} and 75^{th} percentiles. The values were used as a next level of breakpoint determination. Finally, if still too large a range between categories, the mid-point between breakpoints was used.

The contributing areas to each water quality monitoring site were also shaded based on the classification scheme used for the point data. Where sites were nested, the most upstream site took precedence.

For a more comprehensive comparison of concentrations between sites, statistical graphs were created. The sites were divided into three groupings. This is due in part that the scale of each watercourse, or stream order, greatly impacts water quality conditions (Vannote et al. 1981). To facilitate comparison the sites have been divided into main branch, shoreline, and headwater streams. Shoreline streams were those that empty directly into Lake Huron. Headwater sites were determined generally based on watershed size and the size of the watercourse. Generally, a stream narrower than 2 metres was considered headwater. The main branch category was by default those sites not shoreline or headwater and by far has the most variation. While specific sites are not compared, this level of organization is useful for general water quality discussion, but there was no scientific basis for the headwater and main branch groupings. A statistical comparison will be performed in the future.

The sites placed in each of the three categories are:

- Headwaters:
  - Salem Creek (NMSalem)
  - Blyth East (NMBlyth)
  - Upper Bayfield (Dublin)
  - Upper Bayfield (Silver)
  - Steenstra
  - Upper Ausable (Staffa)

- Main branches:
  - Lucknow
  - Port Albert
  - B-Line
  - Jamestown
  - NEListowel
  - Trowbridge
  - Wingham-Midd
  - Henfryn
  - Summerhill
  - Blyth
  - Zetland
  - Benmiller
  - Goderich
  - Seaforth
  - Bannockburn
  - Varna
  - Upper Parkhill
  - Lower Parhill
  - Exeter
  - Springbank
  - Thedford
  - Black
  - Nairn
  - Decker
  - Huron Park
  - Lucan

- Shoreline:
  - Boyd
  - Eighteen Mile
  - Kintail
  - Kerrys
  - Kingsbridge
  - Griffins
  - Midhuron
  - Boundary
  - Bogies
  - Allans
  - Zurich
  - Desjardine
  - Mud

For each indicator and each of the three groupings, box and whisker plots are displayed and sites are organized from north to south, and, within a watershed, from upstream to downstream. Systat ver.11 was used for the plotting (see Appendix C).

Table 2-1: Water Quality Monitoring Stations in the Ausable Bayfield Maitland Valley Region that were selected for data analysis (2006)

Watershed	Site		Years	Program	Location
Branch	Name	MOE ID or local ID			
Nine Mile River					
	Lucknow	08007600202	1964-present	PWQMN	Canning St.-Lucknow
	Port Albert	08007600102	1970-present	PWQMN/ACLA Shore	Hwy.21-Port Albert
Maitland River					
North Maitland					
	B-Line	08005603802	2004-present	PWQMN	B-Line Road, East of Wingham
	NMSalem	08005605002	2005-present	PWQMN (NM)	Salem Road, East of Cty Rd 12
Little Maitland					
	Jamestown	08005603502	1987-present	PWQMN	Conc. 1/2 Grey
Middle Maitland					
	NE Listowel	08005604302	2004-present	PWQMN (NM)	Perth Road 157, NE Listowel
	Trowbridge	08005600902	1964-present	PWQMN	Trowbridge
	Wingham	08005603902	2004-present	PWQMN	Clegg Line, 5 km S of Wingham
Middle Maitland Tributaries					
	Henfryn (Boyle Drain)	08005602002	1972-present	PWQMN	Downstream of Henfryn
	Beauchamp	08005604102	2004-present	PWQMN	St. Michaels Road, E of Cty Rd 12
South Maitland					
	Summerhill	08005603702	2004-present	PWQMN	Base Line Road, Summerhill
Lower Maitland					
	Zetland	08005600302	1964-present	PWQMN	Hwy.86-NW Wingham
	Benmiller	08005603602/C3	2003-2005	PWQMN/ACLA Shore	Benmiller Ln, Huron Cnty Rd. 1, Benmiller
	Goderich	08005600102/C3	1964-present	PWQMN/ACLA Shore	Hwy.21-Goderich
Lower Maitland Tributaries					
	Blyth East (Blyth Brook)	088005604402	2004-present	PWQMN (NM)	Martin Line, East of Blyth
	Blyth (Blyth Brook)	08005600202	1964-present	PWQMN	Currie Line, West of Blyth
Bayfield River					
Upper Bayfield					
	Dublin (Liffy Ditch)	HBLIF1	2003-present	ABCA Enhanced	Perth Rd 180 (.7 km north of Hwy 8)
	Silver Creek	08004001102	1983-present	PWQMN (NM)	Hwy 8, Seaforth
	Seaforth	08004000202	1964-present	PWQMN	Kippen Road, Egmondville
Lower Bayfield					
	Bannockburn	MBBAN1	2003-present	ABCA Enhanced	Bannockburn Wildlife Area
	Steenstra	HBSTEEN1	2003-present	ABCA Enhanced	County Rd. 13 East of County Rd 31
	Varna	08004000802	1975-present	PWQMN	Cty Rd 31, N of Varna
Parkhill Creek					
	Upstream Parkhill	MPMCGUF1	2003-present	ABCA Enhanced	McGuffin Hills Drive above Parkhill Resevoir
	Downstream Parkhill	08002201202	1972-present	PWQMN	McInnis Road, West of Parhill
Ausable River					
Main Branch					
	Staffa	08002200802	1966-1975	PWQMN	Perth Rd 180, Staffa
		HASTAF1	2003-present	ABCA Enhanced	Perth Rd 180, Staffa
	Exeter	08002201602	1975-present	PWQMN	Airport Line, Exeter
	Springbank	08002202002	2003-present	PWQMN	Springbank Dr, N of Springbank
	Thedford	08002100202	1980-present	PWQMN	Bog Line, Lambton Rd 18, NE of Thedford
Ausable Tributaries					
	Black	08002200702	1966-present	PWQMN	Airport Line, West of Hensall
	Nairn	MANAIRN1	2003-present	ABCA Enhanced	behind Nairn Cemetery downstream of confl with Bear Creek
	Decker	08002201902	2000-present	PWQMN	Gordon Rd, N of Thedford
Little Ausable					
	Huron Park	08002201402	1974-present	PWQMN (NM)	Park Rd, Usborne Twp, East of Huron Park
	Lucan	08002201002	1969-present	PWQMN	Middlesex Rd 20 (Denfield Road), West of Lucan
Shoreline Watersheds (north to south)					
	Boyd	A1	2001-present	ACLA Shore	Hwy 21 at Boyd Creek
	Eighteen Mile	A2	2001-present	ACLA Shore	Hwy 21 at Eighteen Mile River
	Kintail	A3	2001-present	ACLA Shore	Hwy 21
	Kerrys	A4	2001-present	ACLA Shore	Hwy 21 at Kerrys Creek
		08009000102	2004-present	PWQMN (NM)	Kintail Beach, 200m from Lake Huron
	Kingsbridge	A5	2001-present	ACLA Shore	Hwy 21
	Griffins	A6	2001-present	ACLA Shore	Hwy 21 at Griffins Creek
		08005604902	2005-present	PWQMN (NM)	Birch Beach Road
	Midhuron	A7	2001-present	ACLA Shore	Hwy 21
	Boundary	A9	2001-present	ACLA Shore	Hwy 21 at Boundary Creek
	Bogies	C1	2001-present	ACLA Shore	Bogies Beach Road
	Allans	C2	2001-present	ACLA Shore	Sunset Beach Road
	Zurich (Drain - Pergel Gully	GULZUR8	2003-present	ABCA Enhanced	Hwy 21 just south of Cty Rd 84
	Desjardine	HPDESJ1	2003-present	ABCA Enhanced	Kirkton Rd just off hwy 81 east of Grand Bend
	Port Franks (Mud Creek)	MMOUTER1	2003-present	ABCA Enhanced	Mud Creek crossing on Outer Drive

2.1.2 Groundwater

This section deals explicitly with the water quality of groundwater in the Ausable Bayfield Maitland Valley Source Protection Region. This was undertaken primarily as a result of the high usage of groundwater for municipal water supplies, as well as for private supplies, in the region.

Although many sources of data are available for groundwater in the area, the vast majority of that data is available for only the period after 2001. Given the extended residence times within aquifers in these aquifers (25-500 years), this period of record does not allow for any meaningful analysis of trends in groundwater quality, but rather only provides a characterization of existing conditions.

It is also important, herein, to refer to the many variables that complicate the collection and analysis of groundwater samples. In this report, efforts have been made to characterize the aquifers rather than the water systems themselves. Most sampling completed to date has focused on the end water quality coming form a well. This means that well head safety, casing integrity and plumbing are not considered. As a result, it can be difficult to discern between water quality issues that reflect the natural aquifer conditions, or those that reflect upon the infrastructure used to deliver the water to the end user (Health Canada 2005).

For the purposes of this report, groundwater chemistry analyses were assembled and grouped according to the aquifers from which they were derived and analyzed accordingly. The regionally extensive bedrock aquifers are subdivided to the formation level, as shown in WC Map 1-2. Overburden aquifers were divided based on the physiographic regions of the partnership area, and are shown in Figure 3.10 of the Conceptual Water Budget for the Ausable Bayfield & Maitland Valley region.

Where possible, wells were selected that could be assigned solely to a specific aquifer, and which have water quality considered representative for that aquifer. Within these areas, wells were identified that can be considered exclusively representative of each formation. These wells were selected firstly based on their location. Overburden wells were evaluated by examination of their drilling logs in order to determine if they captured any other aquifer. Bedrock wells were evaluated by comparing the depth they penetrate bedrock to the estimated thickness of the formation in that area in order to determine if they captured any other aquifer

A number of different sources of data were made available for this report. Comprehensive groundwater quality monitoring has been only recently (2003) initiated throughout most of the Ausable Bayfield Maitland Valley PRegion, and the data thus derived is insufficient for long-term, trend analysis. Groundwater quality data from these various sources was assembled for the purpose of providing a preliminary assessment of the issues relating to groundwater quality in the Ausable Bayfield Maitland Valley Source Protection Region.

Groundwater quality has come from three major sampling programs; Provincial Groundwater Monitoring Network, Municipal monitoring, and counties.

2.1.2.1 Provincial Groundwater Monitoring Network

The Provincial Groundwater Monitoring Network (PGMN) was initiated in 2003 by the Maitland Valley and Ausable Bayfield Conservation Authorities, in partnership with the Ontario Ministry of Environment. Areas of interest were selected based on the groundwater issues relevant to the times. Within these areas, where possible, existing wells were evaluated for long term monitoring. Where suitable existing wells were not available, new wells were drilled. These monitoring wells were then equipped with data loggers that record water levels and temperature on an hourly basis.

Sampling of wells for water quality was conducted initially in 2003 and has been performed on an annual basis according to protocols established by the Ministry of Environment. All samples were analyzed at a common, certified laboratory. Subsequent, more frequent samples were taken from wells for which parameters exceeded an Ontario Drinking Water Standard (ODWS).

The PGMN wells are the most reliable source of groundwater water quality data for the Ausable Bayfield Maitland Valley Source Protection Region. These samples were all collected using a standard, rigorous protocol designed to minimize or eliminate any contamination of samples. In addition, the samples from these wells were all analyzed for a comprehensive suite of parameters at a single lab, using standardized analytical methods, which make them ideal for comparing results between wells.

The major limitation of the PGMN data is the length of record for these analyses. The typical length of record for these samples is limited to the two years of the program's existence, and for the majority of these wells only two samples have been taken at the time of writing.

2.1.2.1 Municipal groundwater supplies

Municipal groundwater supplies represent valuable sources of groundwater quality data. Since the establishment of more rigorous sampling requirements in 2001 as part of the Provincial Safe Drinking Water Act (2002), wells servicing municipalities and large communities have been required to take regular samples of raw well water. These analyses are usually limited to those parameters identified in the pertinent regulations and do not typically include as comprehensive a suite of parameters as the PGMN. In addition, municipal data is often presented in summary, qualitative format for parameters that do not exceed drinking water standards, which makes analysis of these data impossible. Efforts are ongoing to locate the original data in order to characterize each municipal well.

Prior to 2001, the availability of data for municipal wells is extremely limited, with most wells only being regularly tested for microbiological parameters and using several different laboratories. In addition, of particular difficulty for performing comprehensive analyses, results are only available in hard copy. The availability of data prior to year 2000 is further hampered by the high turnover of staff as a result of the amalgamation of municipalities in the Ausable Bayfield Maitland Valley Source Protection Region that took place in this time period.

Data collected after 2001 are, by legislation, available to the general public for viewing in the form of reports. However, these reports tend to vary in quality between municipalities and have different reporting formats. In addition to this, samples have been analyzed using different methodologies and laboratories, thereby making comparisons between samples difficult.

Regardless of these limitations, wells which have a good length of records do provide valuable sources of information and can be used to fill holes in the monitoring strategy in the Ausable Bayfield Maitland Valley Source Protection Region. Data records, however, are not yet long enough to analyze trends within the aquifers, and are optimally used to characterize existing groundwater quality conditions.

Several groundwater quality studies have been completed in the Ausable Bayfield Maitland Valley Source Protection Region prior to the initiation of Drinking Water Source Protection efforts. The data collected from these studies is valuable for identifying potential issues in the Ausable Bayfield Maitland Valley Source Protection Region, as well as directing future monitoring efforts.

Huron County undertook a groundwater resource assessment in 1999 that identified and sampled 6 separate clusters of private wells for a comprehensive suite of analytes (Golder and Associates, 2001). Three of these clusters are centered over the regionally significant Lucas aquifer, and one cluster dedicated to the Dundee, Hensall and Seaforth aquifers. Results of this study have been included and are discussed below. As part of this project, a representative well from each cluster was identified for long term monitoring as part of the Huron County Sentinel Well program. Sampling of these wells has continued, in partnership with the Ausable Bayfield and Maitland Valley Conservation Authorities, through 2005.

The former Town of Bosanquet undertook a groundwater quality study within the North Lambton aquifer, located near and around the communities of Grand Bend and Port Franks (BM Ross 2001). The results of this report are not public but were made available for general viewing to the Ausable Bayfield Maitland Valley drinking water source protection staff and technical team. As part of this study, a comprehensive sampling program was undertaken targeting approximately 128 private wells in the area. These wells were sampled for nitrates and microbiology, with a subset of 20 representative wells sampled for a more comprehensive suite of parameters. The details of this study are discussed below.

Additional work completed recently, including the ABCA North Lambton and Sinkhole studies, have incorporated groundwater quality in their investigations. These studies sampled both private and PGMN wells in specific areas. These wells were all sampled using PGMN or equivalent protocols and were analyzed for a comprehensive suite of parameters, similar to that of the PGMN wells.

2.2 Results

2.2.1 River

2.2.1.1 Scan of data – all indicators with standards

The focus for the analysis of surface water quality data has been on past water quality issues and those that are most common in agricultural watersheds. In order to determine if there are any emerging issues, sampling data from the PWQMN for the period from 2001 to 2005 has been compared to the Provincial Water Quality Objectives, or if there are no PWQO, the Canadian Water Quality Guidelines.

There are nineteen metals in the analysis package for the PWQMN. The metals that have never exceeded the PWQO at any sites in the region are listed in Table 2-2. There are some metals in the analysis package for which there is no PWQO or CWQG to be used in determining if the concentrations are an issue. These metals area also listed in Table 2-2.

Table 2-2: Metals in the analysis package for the PWQMN with no exceedances or no guideline

Metals with no Provincial Water Quality Objective Exceedances at any site (2001-2005)	Metals Sampled without a Provincial Water Quality Objective or Canadian Water Quality Guideline
Berylium	Barium
Molybdenum	Magnesium
Nickel	Manganese
Vandium	Potassium
	Sodium
	Strontium
	Titanium

From the water quality data collected at 26 sites in the Ausable Bayfield Maitland Valley Source Protection Region, eight metals have had at least one sample exceed a published guideline in the 2001 to 2005 period. Aluminium, cadmium, chromium, cobalt, copper, iron, lead, and zinc have been found to exceed their respective published guidelines on at least one occasion.

During the process of scanning the data for values exceeding known water quality guidelines, two non-metal parameters that have not been discussed to this point were also discovered, including nitrite and pH. Table 2-3 has a listing of sites and the number of samples exceeding a known water quality guideline.

Table 2-3: Summary of all samples exceeding known PWQO or Canadian Water Quality Guidelines (2001-2005) in the Ausable Bayfield Maitland Valley Source Protection Region

Location	PWQMN ID	Watercourse	Years	Total	Aluminum		Residue Par		Cadmium		Chromium		Cobalt		Copper		Iron		Lead		Nitrite		pH (lab)		pH Field		Zinc	
				Exceedance	Count	Avg.	Count	Avg.	Count	Avg.	Count	Avg.	Count	Avg.	Count	Avg.	Count	Avg.	Count	Avg.	Count	Avg.	Count	Avg.	Count	Avg.	Count	Avg.
Gordon Rd, N of Thedford	08002201902	Decker Creek	01-05	81	34	260.2	9	57.2	3	0.659	4	1.11	6	1.29			14	464.57	2	7.14	8	0.09	1	8.58				
Bog Line, Lambton Rd 18, NE of Thedford	08002100202	Ausable River - The Cut	01-05	79	33	305.8	13	70.1	7	0.782	1	1.49	4	1.17			13	559.92	3	7.93	2	0.06	2	8.55	1	8.58		
Hwy.23 - Listowel	08005601302	Middle Maitland River	01-03	70	18	189.8	2	38.8	1	0.604	7	1.19	3	1.13	3	8.63	3	360.33	3	8.29	12	0.23	4	8.71	3	8.82	11	43.33
Trowbridge	08005600902	Middle Maitland River	01-05	68	10	128.9	2	32.1	5	0.870	8	1.62	4	1.11	1	5.12	2	382.00	7	7.32	9	0.10	10	8.59	6	8.78	4	31.98
Cty Rd 31, N of Varna	08004000802	Bayfield River	01-05	66	27	282.9	5	159.4	3	0.793	4	1.46	2	1.11	1	5.15	3	728.00	5	6.36	7	0.08	5	8.54	1	9.18	3	54.13
Springbank Dr, N of Springbank	08002202002	Ausable River	03-05	65	19	339.8	17	50.4	4	0.998	4	1.14	2	1.26			12	422.58	5	8.44			1	8.51	1	8.97		
McInnis Road, West of Parhill	08002201202	Parkhill Creek	03-05	60	20	425.9	12	45.1	1	0.954	3	1.21	1	1.18			9	552.33	6	8.66	7	0.11	1	8.54				
Hwy.21-Port Albert	08007600102	Nine Mile River	01-05	58	26	149.2	4	41.8	3	0.693	6	1.79	6	1.12			1	493.00	4	8.13			6	8.55	2	8.61		
Downst. Henfryn	08005602002	Boyle Drain	01-05	51	21	139.4	1	37.0	2	0.623			8	1.29			2	351.50	3	9.40	8	0.13	4	8.68	2	8.55		
Airport Line, West of Hensall	08002200702	Black Creek	01-05	48	16	135.6	1	38.3	6	0.802	3	1.54	1	1.13					4	7.20	14	0.20	3	8.59				
Cty Rd 5 (Greenway Drive), Tricounty Brid(	08002201802	Parkhill Creek	01-02	48	14	279.9	12	38.0			2	1.43	1	1.18			10	435.50			7	0.11	2	8.56				
1stSdRdW.-Blyth	08005600202	Blyth Brook	01-05	44	9	148.4			5	0.914	1	1.03	6	1.22	2	8.01			3	7.75	5	0.09	6	8.58	7	8.63		
Kippen Road, Egmondville	08004000202	Bayfield River	03-05	36	14	155.8	1	39.8	4	0.853	4	1.32	1	1.00					7	11.39	5	0.09						
Middlesex Rd 20 (Denfield Road), West of	08002201002	Little Ausable River	01-05	35	13	208.9	3	72.1	2	1.255	2	1.05	2	1.01			3	328.33	4	9.20	5	0.08	1	8.58				
Hwy.21-Goderich	08005600102	Lower Maitland River	01-05	34	5	102.5	1	25.5	6	1.018	1	1.43	2	1.22					7	8.74			6	8.55	5	8.64	1	21.70
Airport Line, Exeter	08002201602	Ausable River	01-05	33	11	153.8			3	0.957	2	1.08	3	1.22	1	5.55			1	8.10	6	0.09	5	8.73	1	8.89		
Conc.1/2 - Grey	08005603502	Little Maitland River	01-05	28	3	95.6			5	0.878	1	1.31	1	0.96					4	10.37	2	0.10	7	8.57	5	8.56		
E. of Ethel	08005602602	Middle Maitland River	01-03	27	7	120.5	1	44.5	5	0.677			2	1.03			1	352.00	4	6.54	6	0.12	1	8.64				
Canning St.-Lucknow	08007600202	Nine Mile River	01-05	22	6	153.3	1	26.5	5	0.796			2	1.43			1	364.00	3	12.25	1	0.07	3	8.59				
Hwy.86-NW Wingham	08005600302	Lower Maitland River	01-05	14	3	82.7			2	0.637	2	1.80	1	0.95					2	9.29			2	8.58	1	8.54	1	37.50
St. Michaels Road, E of Cty Rd 12	08005604102	Beauchamp Creek	04-05	14	5	138.8			2	0.577	1	1.30					1	313.00	2	11.43	2	0.08	1	8.53				
Base Line Road, Summerhill	08005603702	South Maitland River	04-05	13	6	138.8			1	0.630	1	1.11	1	1.05					1	5.95			2	8.52	1	8.57		
Clegg Line, 5 km S of Wingham	08005603902	Middle Maitland River	04-05	13	2	86.7			2	0.996			3	1.42					2	7.08			3	8.55	1	8.60		
Park Rd, Usborne Twp, East of Huron Parl	08002201402	Little Ausable River	04-05	11			4	122.1													6	0.08			1	8.51		
B-Line Road, East of Wingham	08005603802	North Maitland River	04-05	11					1	0.743			3	1.21					1	12.00			5	8.55	1	8.51		
Hannah Line, W of Seaforth	08004000902	Bayfield River	03-05	8	2	134.5							1	1.09							2	0.09	3	8.63				
					IPWQO 75ug/l for pH >6.5 & pH < 9.0 in a clay free sample Refer to residue		General Criteria 25 mg/l		IPWQO 0.5 ug/l for hardness as CaCO3 >100 mg/l		PWQO 1 ug/l for CrVI * results are for total Cr		PWQO 0.9 ug/l		IPWQO 5ug/l for hardness as CaCO3 >20 mg/l		PWQO 300 ug/l		IPWQO 5 ug/l for hardness as CaCO3 >80 mg/l		CWQG 60 ug/l 1987upd. 2002		PWQO 6.5 - 8.5		PWQO 6.5 - 8.5		IPWQO 20 ug/l	

Count is the number of exceedances from 2001-2005 and Avg. is an arithmetic average of only the values exceeding the PWQO. All sites and samples part of the PWQMN.

No longer current sampling site

Not all sites were sampled for the entire period. Refer to the years column

Aluminium and chromium need further explanation with respect to both the type of lab analysis and the PWQO in order to interpret the results. The PWQO for aluminium is stipulated for a clay free sample. However, the water samples taken are not filtered before analysis at the Ministry of the Environment lab and, therefore, cannot be considered clay free. The results for residue particulate have been included next to the aluminium column so that if a sample was found to greatly exceed the current PWQO for aluminium and contained high particulate, one can assume that the majority of the aluminium is contained in, or partitioned to, the solids. If, on the other hand, the PWQO was exceeded and the sample was low in suspended sediment, the results are a concern. From Table 2-3, there are instances of high aluminium concentrations without a corresponding high level of sediment at 10 locations.

Chromium is another metal where lab analysis does not conform to the PWQO. The PWQMN results are for total chromium, while the PWQO is 1 ug/l for hexavalent chromium (Cr VI) and 8.9 ug L^{-1} for trivalent chromium (Cr III). Given the fact that Chromium VI is the most toxic form of Chromium, the PWQO (adopted CWQG) for Chromium VI (i.e. 1 ug L^{-1}) will be used for interpreting total chromium results. Chromium toxicity is inversely affected by water hardness, so some leeway is warranted for harder water (>100 mg L^{-1} as $CaCO_3$). Hardness is always above 100 mg L^{-1} as $CaCO_3$ in the watershed region; therefore, this is a data gap as to the bioavailability of chromium in surface water.

Metals have not traditionally been considered an issue in the Ausable Bayfield Maitland Valley Source Protection Region, and this is the first general summary of historic data. Analyses began in 1998 in the MVCA watershed and 2000 in the ABCA watershed, when approximately 14 metals were added to the list of indicators. The distribution of sites exceeding guidelines reflects point sources, likely municipal waste water treatment plant discharge. The sites that most frequently exceeded the guidelines included the Middle Maitland downstream of Listowel, Black Creek and Decker Creek; all small watercourses receiving Wastewater Treatment Plant (WWTP) discharge.

Some water quality indicators that have exceeded their benchmarks require further study. Key metals to be examined further are aluminium, cadmium, cobalt and lead. In addition, of particular concern are the nitrite concentrations at Trowbridge and Black Creek. As well, point sources where high concentrations of iron are identified should be located.

2.2.1.2 Temporal Trends

In order to understand current water quality issues and to assist in determining potential sources of contamination, historic or temporal changes are valuable. Examining trends also allows one to extrapolate into the future to predict impacts on various uses of water.

All PWQMN sites were graphed for each indicator; only the results for the six sites are found in the body of this report and Appendix A has water quality information for all sites.

Chloride

At many stations, the long-term trend for chloride over the length of record has been to undergo a slight increase in concentration as indicated through LOWESS interpretation in Figure 2-4, and chloride concentrations are well below levels of concern. The ODWS and the British Columbia aquatic protection guideline are shown for reference. The Maitland River at Goderich has had the highest concentrations, which peaked in 1989 and since have declined. None of the sites have had any concentrations above the PWQO in the last five years. These results may reflect the more rural nature of the watershed region and the limited use of road salt. The chloride concentrations and changes over time at Goderich are more likely related to salt extraction industry modifications then to road salt. Chloride concentrations have decreased between 1965 and 1970 in Black Creek (Appendix A), which feeds into the Ausable River.

Results of the ANOVA revealed three clusters of sites with significant differences for chloride. Sites within the same cluster have no significant difference. The clusters were, from lowest to highest concentration: 1) Blyth Brook and Nine Mile River; 2) Parkhill Creek, Bayfield River and Ausable River; and 3) the Maitland River.

Other than the Middle Maitland River site at Trowbridge (Appendix A) which has a steeper increase in concentrations with some samples exceeding the British Columbia aquatic protection guideline, the concentrations of chloride are not of concern at this point and monitoring of concentrations would be an appropriate tool to ensure that chloride does not become a drinking water issue.

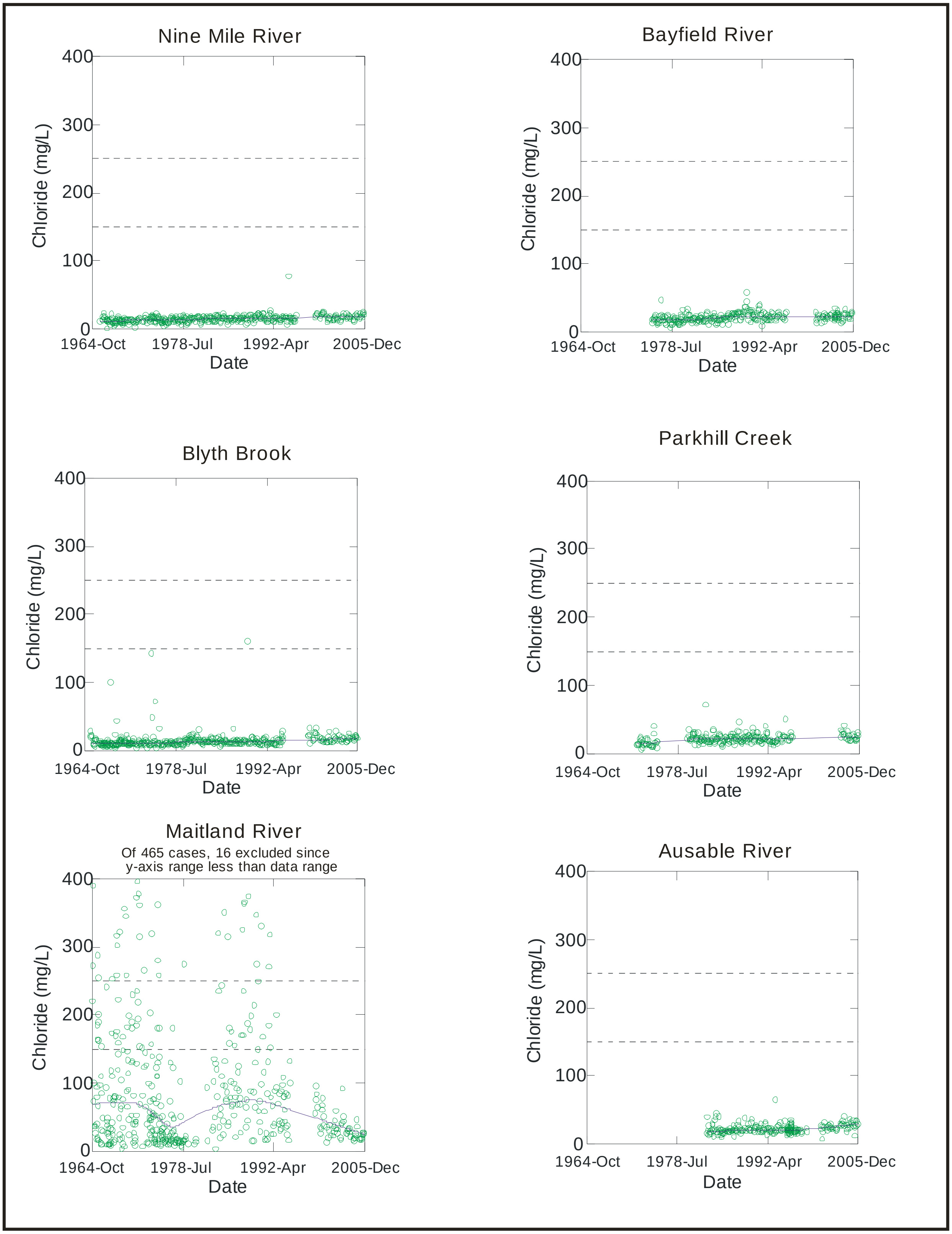


Figure 2-4: Chloride concentrations in major watercourses in the Ausable Bayfield Maitland Valley Source Protection Region, 1964-2005

Copper

Copper concentrations have declined or stayed constant over the period of record and no sites currently have concentrations above the PWQO (shown as dashed line), with significant water quality improvements at Port Albert (Nine Mile River) (Figure 2-5). These results may reflect the more rural nature of the watershed region and lower level of industrialization.

Results of the ANOVA revealed four clusters of sites with significant difference for copper; three of the clusters overlap. Sites within the same cluster have no significant difference. The relationships were, from lowest to highest concentration: **Blyth Brook**, with no significant difference from the Bayfield River; **Bayfield River**, with no significant difference from Blyth Brook or the Nine Mile River; **Nine Mile River**, with no significant difference from Parkhill Creek or the Bayfield and Maitland Rivers; **Maitland River**, with no significant difference from Parkhill Creek or the Nine Mile River; **Parkhill Creek**, with no significant difference from the Maitland and Nine Mile Rivers; and the **Ausable River**, which was significantly different from all sites.

The concentrations of copper at the other monitoring stations are not of concern at this point. Continued monitoring of copper would be an appropriate tool to ensure that copper does not become a drinking water issue.

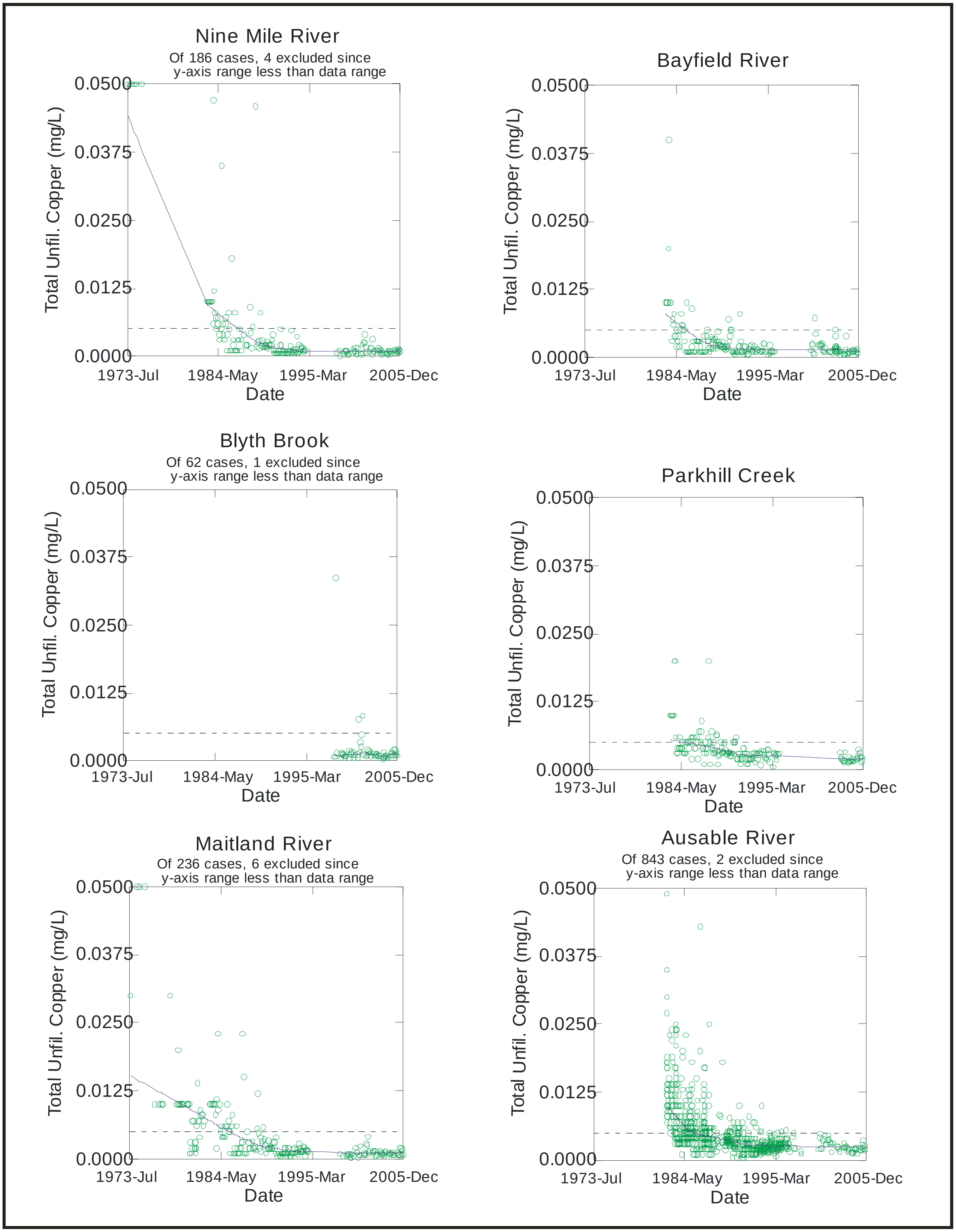


Figure 2-5: Copper concentrations in major watercourses in the Ausable Bayfield Maitland Valley Source Protection Region, 1973-2005

Nitrate

The lab method for determining nitrate concentration in water samples through the PWQMN has changed over the sampling period. The analysis used filtered reactive nitrate until 1984, unfiltered reactive nitrate until 1995, and total nitrates unfiltered reactive to present. A visual scan of the data did not indicate that these method changes influenced the general determination of trends.

Nitrate concentrations have increased at every site over the record, to the point that five of the six sites are above the aquatic protection limit more then 50% of the time (Figure 2-6). The exception is the Nine Mile River which has concentrations below this limit at both Lucknow and Port Albert. However, the Nine Mile River also experienced the increasing nitrate trend. The ODWS and the CCME aquatic protection guideline are shown for reference. The largest increase in concentration occurred between 1970 and 1985.

The increasing nitrate trend ended around 1985 in the Maitland watershed and concentrations have remained steady or even declined. The increasing trend is still occurring in the Bayfield River and Parkhill Creek, and to a lesser degree in the Ausable River.

Since all sites exhibit this trend, it indicates that there may have been a widespread adoption of a land management practice, or practices, which increased the amount of nitrate in watercourses. The nitrate trend has been level or slightly declining since 1985, possibly indicating that this practice or practices are still in use in the Maitland watershed, but not intensifying. In the Bayfield River and Parkhill Creek watersheds, this land management change may still be occurring or intensifying.

The greatest increase during this 1970-1985 time period in terms of nitrate, based on anecdotal evidence, could be related to a possible increase in the use of commercial fertilizers and the replacement of mixed farming with “cash cropping” or specialized systems. The changes that occurred over this time need to be understood in order to better define the sources of the nitrogen and should be considered a data gap.

Results of the ANOVA revealed four distinct clusters of sites with significant differences for nitrate. Sites within the same clusters have no significant difference. The clusters were, from lowest to highest concentration: 1) Maitland and Nine Mile Rivers; 2) Blyth Brook; 3) Parkhill Creek; and 4) the Bayfield and Ausable Rivers.

A considerable number of samples in the Bayfield River were above the ODWS. Even though there are no current surface water uses of the river, the impact of these concentrations on Lake Huron needs to be determined in order to asses drinking water risk for Lake Huron intakes.

One exception in the Maitland watershed is the Little Maitland PWQMN site at Palmerston (Appendix C), which, at the time sampling was discontinued in 1994, nitrate levels were in the 7 to 8 mg L^{-1} range and if the increase stayed constant, would be at the ODWS by early 2000. This site should be monitored again to determine current conditions.

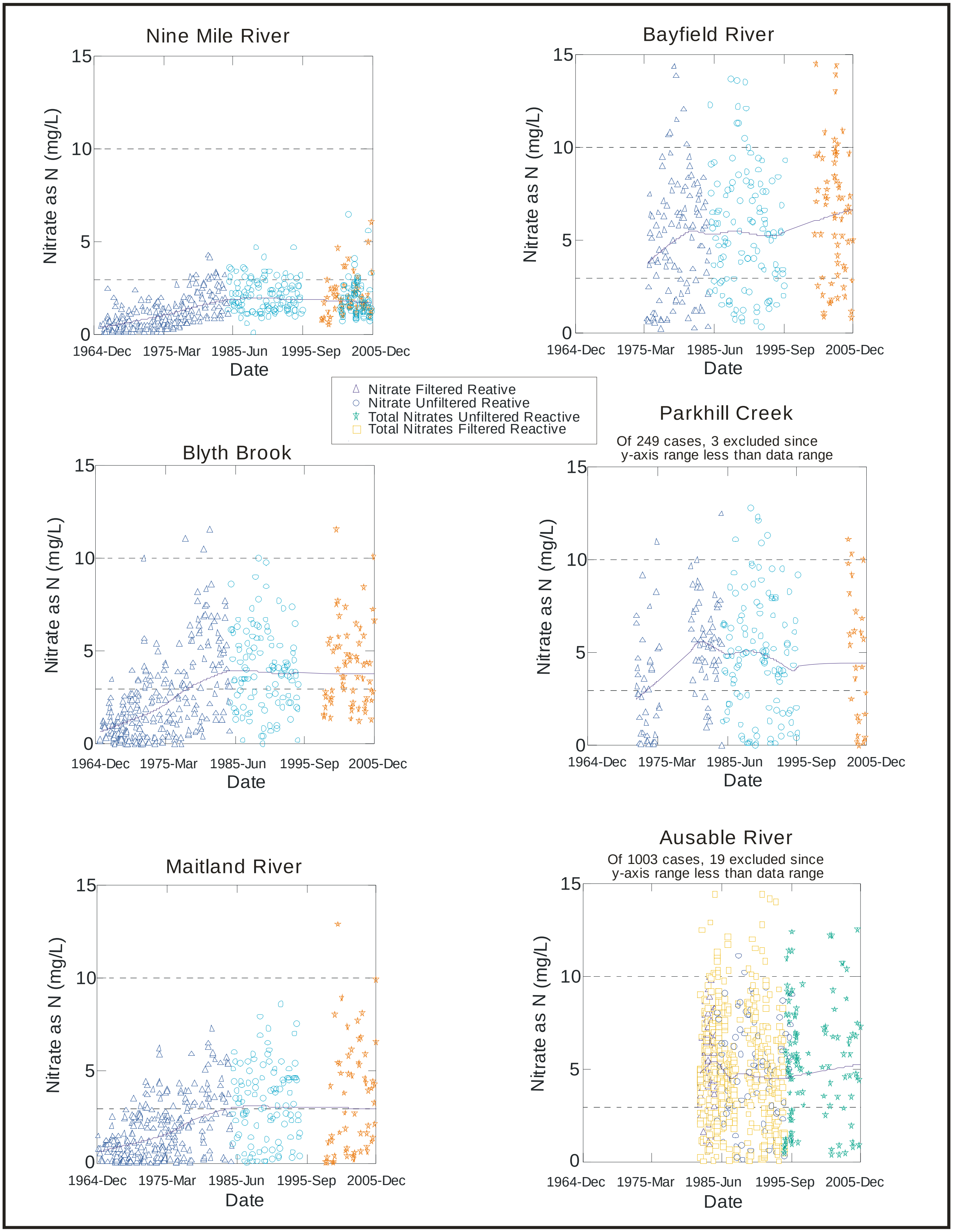


Figure 2-6: Nitrate concentrations in major watercourses in the Ausable Bayfield Maitland Valley Source Protection Region, 1964-2005

Total Phosphorus

Total phosphorus concentrations have slightly declined or remained constant over the record, but median concentrations are at or just above the PWQO (shown as a dashed line) for five of the six sites (Figure 2-7). Parkhill Creek has shown significant declines from 1985, but median concentrations remain five times the PWQO. Phosphorus enrichment is an issue in the entire watershed region.

Results of the ANOVA revealed three distinct clusters of sites with significant differences for total phosphorous. Sites within the same cluster have no significant difference. The clusters were, from lowest to highest concentration: 1) Maitland and Nine Mile Rivers; 2) Blyth Brook and Bayfield River; and 3) Parkhill Creek and Ausable River.

There have been significant improvements in some watersheds, including the Middle Maitland River at Trowbridge and Decker Creek (Appendix A). These large improvements could possibly be attributed to modifications and improvements in effluent quality at the Listowel Wastewater Treatment Plant and demonstrate the impact of an urban area on a watercourse that has lower summer flows.

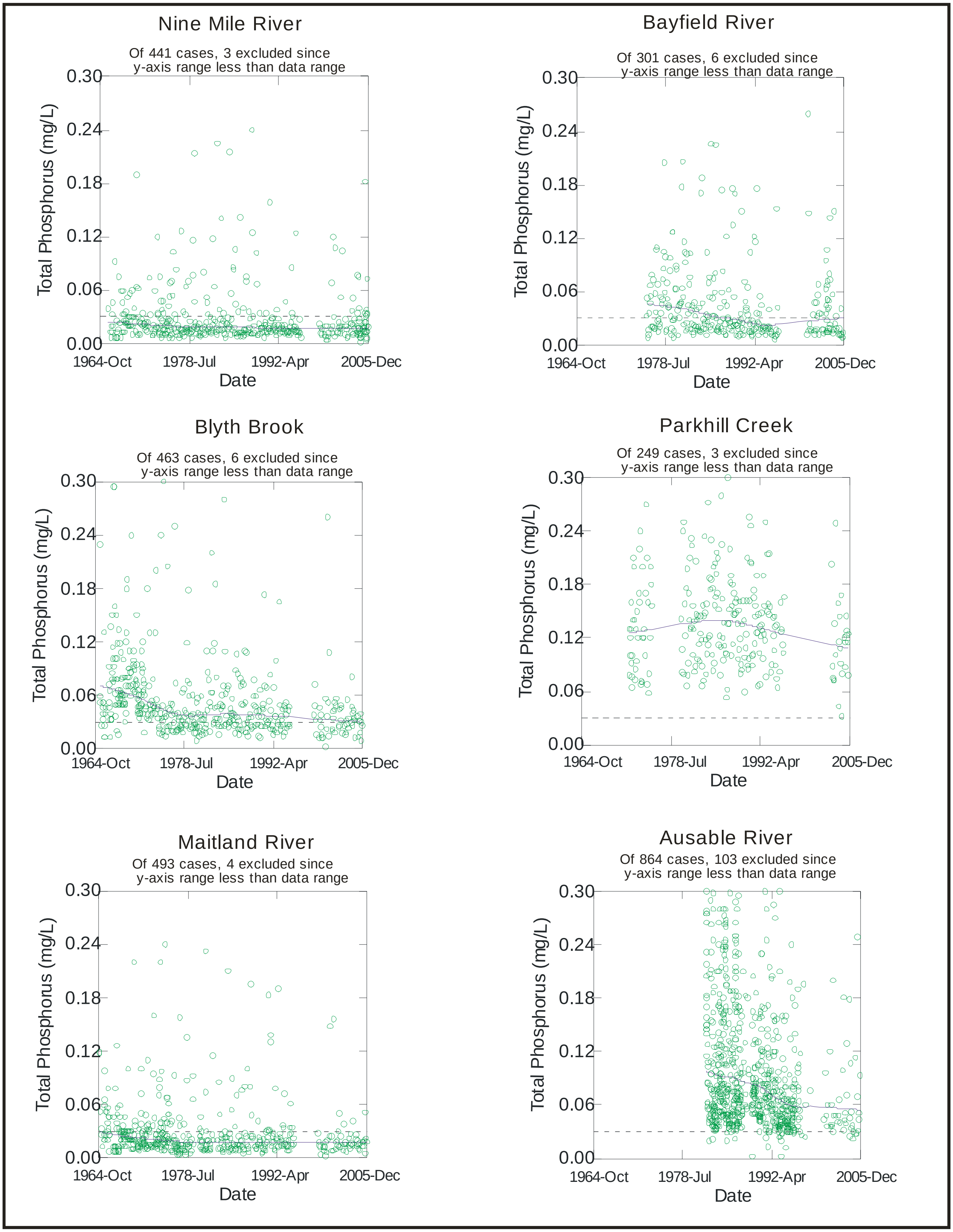


Figure 2-7: Total Phosphorus concentrations in major watercourses in the Ausable Bayfield Maitland Valley Source Protection Region, 1964-2005

Total Suspended Solids

Suspended sediment has declined or remained constant over the record for the Nine Mile River, Maitland River, Bayfield River and Blyth Brook with these sites all below the dashed line representing the aquatic protection general criteria (Figure 2-8). Improvements have occurred in the Ausable River with concentrations at or slightly above this benchmark. Suspended sediment concentrations in Parkhill Creek are above the general criteria for aquatic protection in more than half of the samples, but concentrations have declined since 1985. The shape of the trend line for Parkhill Creek is similar for both total phosphorus and sediment, indicating that they have similar mechanisms and pathways of transport. The declines in sediment loads could be attributed to various agricultural and soil erosion initiatives since the mid 1980s.

Results of the ANOVA revealed five clusters of sites with significant differences for suspended sediment. Three of the clusters overlap. Sites within the same cluster have no significant difference. The relationships were, from lowest to highest concentration: **Blyth Brook**, with no significant difference from the Bayfield and Maitland Rivers; **Maitland River**, with no significant difference from Blyth Brook or the Bayfield River; **Bayfield River**, with no significant difference from Blyth Brook or the Nine Mile and Maitland Rivers; **Nine Mile River**, with no significant difference from the Bayfield River; **Parkhill Creek**, which is significantly different from all sites; and the **Ausable River**, which is also significantly different from all sites.

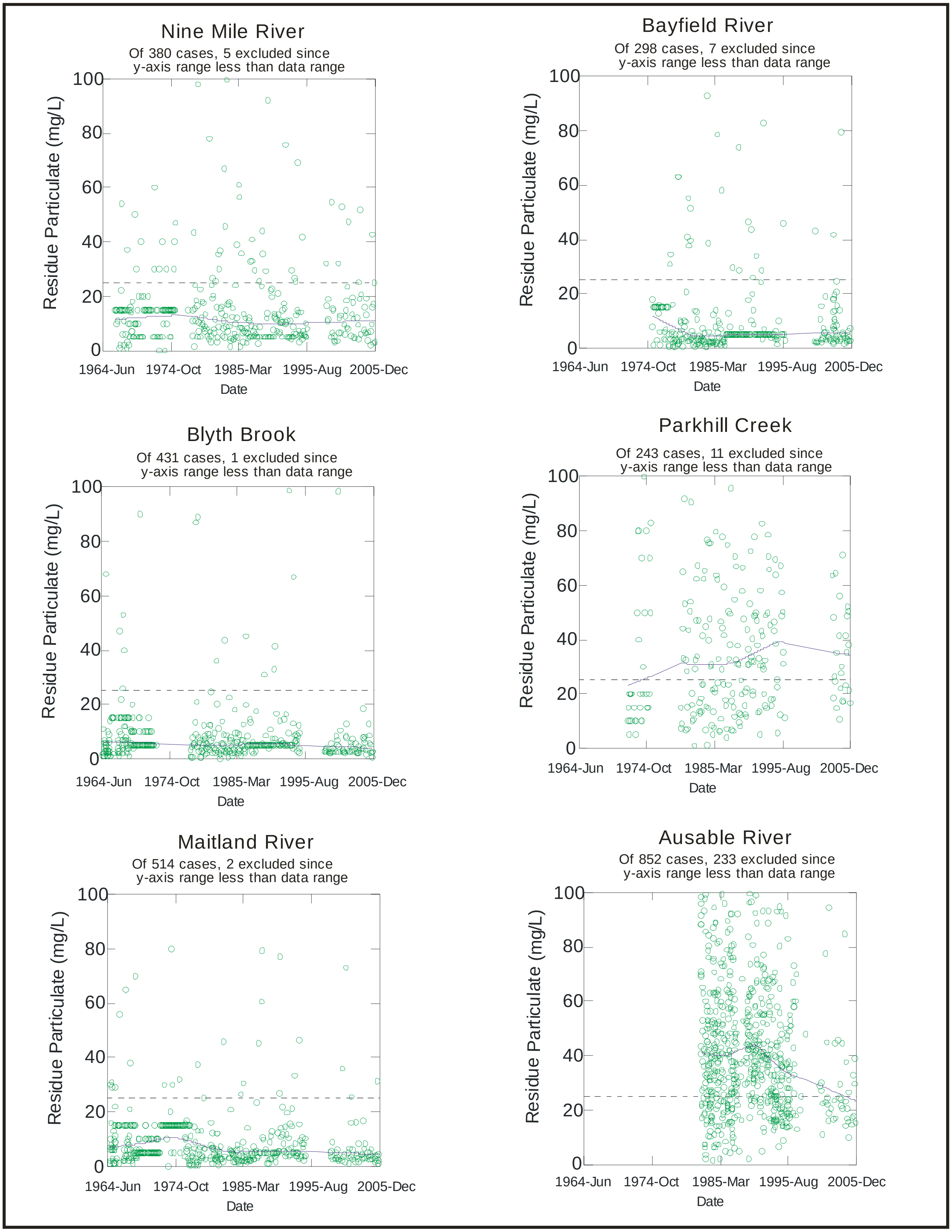


Figure 2-8: Residue Particulate concentrations in major watercourses in the Ausable Bayfield Maitland Valley Source Protection Region, 1964-2005

Bacteria

Fecal coliform were the indicator bacterium until 1995, with *E.coli* being used from 1994 to the present. The two are not directly comparable, but are sufficient to determine general trends for this analysis.

Bacteria concentrations have fluctuated, both within years and between years, but have no evident trends over the period of record for four of the six sites (Figure 2-9). The PWQO recreational guideline is shown for reference.

The Nine Mile River has an increasing trend in *E.coli* concentrations from the fecal coliform levels in the mid-nineties, but this could be due to more samples being collected since 2001 for the ACLA shoreline stream monitoring program. One other site that had a trend from the late seventies to early mid eighties was the Blyth Brook. It has been steady since that time.

Further work is required on the significance and presence of trends using methods appropriate for microbiology.

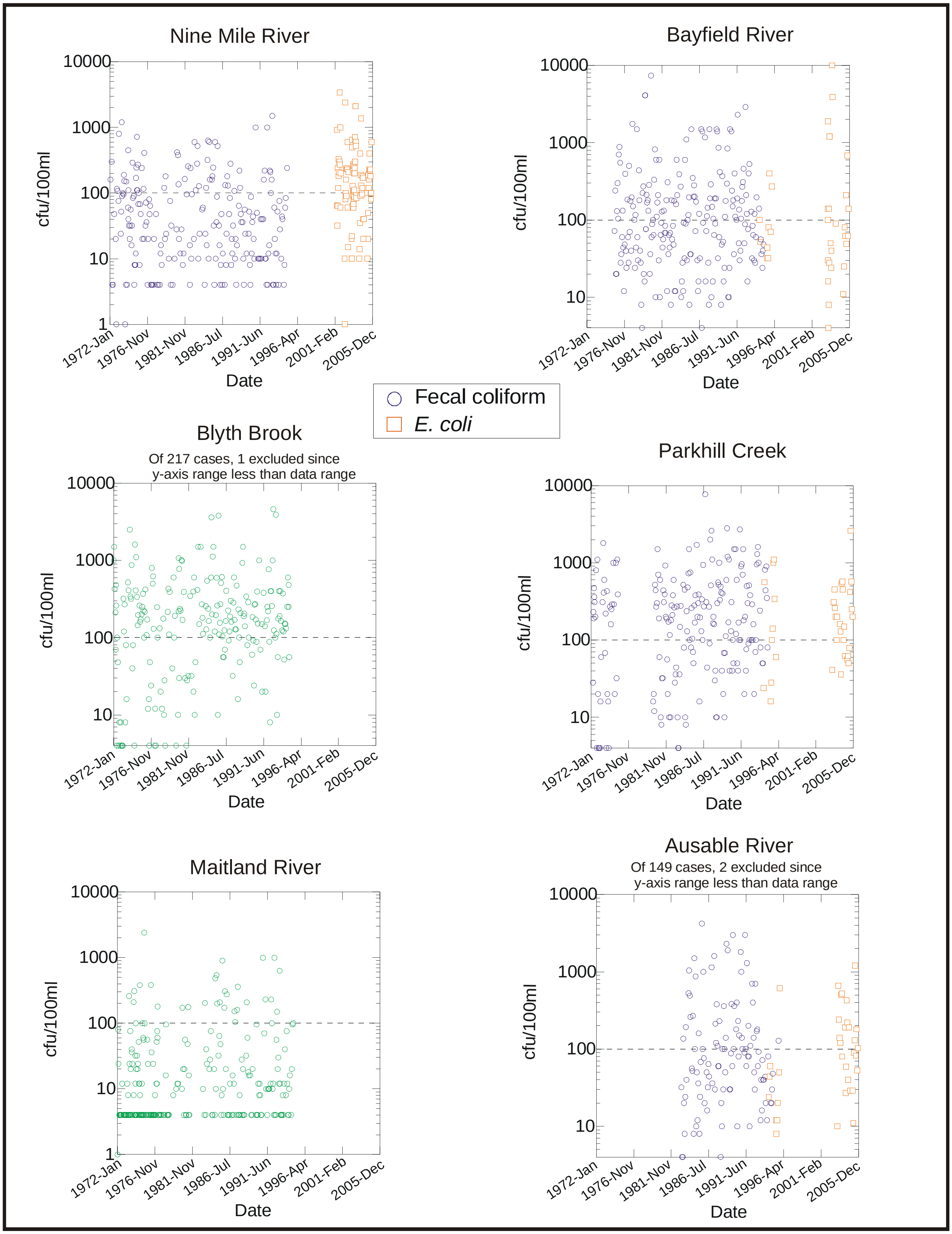


Figure 2-9: Bacteria concentrations in major watercourses in the Ausable Bayfield Maitland Valley Source Protection Region, 1972-2005
Fecal Coliform measured until 1994, *E.coli* from 1995 to present.

2.2.1.3 Spatial Trends

Spatial trends of current water quality are represented in map form and in statistical graph form. Forty-six water quality sites are compared for nitrate, total phosphorus and *E. coli* by grouping all data collected in the years 2001-2005. The details of the water quality data by site can be found in Table 2-4.

The maps have been prepared with the both the site concentration as well a delineating the contributing area to the sites based on the measured water quality data. These maps should be interpreted with caution, because for larger upstream areas there may be tributaries with different concentrations due to geology, point, and non-point source uses. This case is evident for the NMSalem site on the total phosphorus map.

Nitrate

Nitrate results are presented on WC Map 2-2, with the intervals for classifying the sites based on the summary statistics from pooling all the nitrate data. Box and whisker plots in Appendix C illustrate that for main branch watercourses, nitrate concentrations generally increase southward. The results reflect a continuum from more groundwater fed systems to more surface water systems and may also reflect changes in land management. The southern portion of the study area is characterized by:

Less forest cover
- Higher proportion of clay soils
- Increased proportion of agricultural land tile drained
- Increased drainage density
- Higher percentage of row cropping

Nitrate is identified as an issue in the area, with all branches except two having at least one site with a median concentration above the aquatic protection limit. The Nine Mile and Middle Maitland generally fall below the median. As well, the headwaters of the Middle Maitland and the lower branch of the Main Maitland median concentrations are below the aquatic protection limit.

The shoreline streams behave more uniformly since there is not the variation of natural watershed characteristics from north to south. The high concentrations of nitrate in headwater streams (portrayed in pink on WC Map 2-2) demonstrate the possible effects of higher drainage densities and the movement of nitrate. For a given volume of water, there is proportionally more land area in contact with the stream. The Blyth site clearly contrasts the differences between groundwater based streams and surface water streams. Of greatest concern is the Upper Bayfield site where the median is above the drinking water objective.

Total Phosphorus

Total phosphorus results are presented on WC Map 2-3. The maps and Appendix C plots highlight that for the 27 main branch watercourses, concentrations are generally similar and do not reflect an increase to the south as does nitrate concentration. This could be attributed to the dominant pathway of phosphorus being bound to soil particles, specifically clay particles. The sites that have median concentrations above the PWQO (Middle Maitland, Parkhill and Ausable) all have higher proportions of clay soil, and have higher percentages of row cropping, resulting in higher potential for soil erosion.

The 13 shoreline streams also behave more uniformly since the entire shoreline is of similar soil texture properties. The four watercourses that have medians above the PWQO may highlight areas with more severe erosion problems or a point source.

The higher concentrations of total phosphorus in headwater streams compared to main branch stations demonstrate the possible affects of higher drainage densities and the affects of dilution and/or in stream biological processes that cycle phosphorus.

Bacteria (E.coli)

E.coli results are presented on WC Map 2-4 for the sites. For main branch watercourses, concentrations are generally similar, with median concentrations at or slightly above the recreational PWQO. On the graphs in Appendix C, two sites stand out, the upper Middle Maitland River and Black Creek, which indicate the potential for more continual sources of *E.coli*. The similarity between the results highlights that the presence of indicator bacteria is not related to general watershed characteristics and the associated variation in water pathways.

The shoreline streams are generally similar, with median concentrations generally above the recreational PWQO. The watercourses that have higher medians and larger variance also appeared to have higher phosphorus concentrations. Headwater streams have higher concentrations, demonstrating the possible affects of higher drainage densities and the affects of dilution and/or die off of bacteria. Further examination of this relationship is necessary.

Table 2-4: Nitrate, total phosphorus and *E. coli* concentrations at current water quality monitoring sites in the Ausable Bayfield Maitland Valley Source Protection Region

Watershed / Site	Years	Nitrate as N (mg/l) n	median	25th	75th	max	Total Phosphorus (mg/l) n	median	25th	75th	max	*E.Coli* (cfu/100ml) n	median	geomean	25th	75th	max
Nine Mile River																	
Lucknow	01-05	41	1.25	1.06	1.80	6.23	41	0.021	0.018	0.03	0.088						
Port Albert	01-05	134	1.69	1.26	2.40	6.48	75	0.018	0.012	0.025	0.182	93	130	132	67.25	262.5	3400
Maitland River																	
North Maitland																	
Salem	05	14	6.13	5.76	7.97	13.90	14	0.012	0.009	0.02	0.412	13	1000	683	357.5	1900	7000
B-Line	04-05	16	2.95	1.78	4.56	8.61	16	0.013	0.011	0.019	0.033						
Little Maitland																	
Jamestown	01-05	41	4.26	2.19	6.83	9.17	41	0.024	0.02	0.035	0.1						
Middle Maitland																	
NE Listowel	04-05	29	6.16	1.80	7.99	14.00	29	0.071	0.043	0.099	0.294	27	1000	709	190	2200	10000
Trowbridge	01-05	41	2.51	0.55	6.68	10.20	42	0.06	0.035	0.084	0.206						
Wingham	04-05	17	4.67	2.46	7.16	10.70	17	0.025	0.019	0.036	0.137						
Middle Maitland Tributaries																	
Henfryn	01-05	41	6.11	1.20	9.66	14.80	41	0.044	0.027	0.076	0.184						
Beauchamp	04-05	17	4.81	3.71	7.36	9.52	17	0.031	0.021	0.073	0.17						
South Maitland																	
Summerhill	04-05	17	4.31	2.48	6.21	10.60	17	0.02	0.016	0.026	0.076						
Lower Maitland																	
Blyth East	04-05	28	3.22	2.46	3.92	7.17	28	0.037	0.028	0.05	0.343	27	280	261	102.5	890	6300
Blyth	01-05	42	3.64	2.34	4.82	10.10	42	0.032	0.023	0.043	0.081						
Zetland	01-05	41	4.31	1.83	6.26	9.74	41	0.024	0.017	0.033	0.102						
Benmiller	03-05	62	3.88	1.43	5.74	10.50	49	0.019	0.013	0.039	0.315	57	100	91	43.25	210	2400
Goderich	01-05	41	3.79	1.08	5.52	9.89	41	0.016	0.013	0.021	0.051						
Bayfield River																	
Upper Bayfield																	
Dublin	03-05	26	9.91	2.82	11.50	20.30	26	0.056	0.027	0.099	0.978	25	600	441	163	1325	4700
Silver Creek	05	8	3.71	2.80	6.38	9.15	8	0.018	0.014	0.024	0.094	8	157	111	70	255	320
Seaforth	03-05	26	7.01	1.76	9.36	17.60	26	0.026	0.017	0.04	0.144	26	385	323	150	660	2300
Lower Bayfield																	
Bannockburn	03-05	26	5.48	3.10	8.15	13.10	26	0.028	0.017	0.061	0.218	26	211	355	123	1000	50000
Steenstra	03-05	21	10.40	7.81	11.55	14.00	21	0.046	0.024	0.07	1.08	18	260	165	100	820	8200
Varna	01-05	60	6.70	3.28	9.30	14.40	60	0.03	0.016	0.053	0.611	26	71	105	28	210	10000
Parkhill Creek																	
Upstream Parkhill	03-05	26	6.07	2.60	9.50	14.30	26	0.082	0.048	0.113	0.401	26	175	171	80	410	2800
Downstream Parkhill	03-05	26	4.81	1.53	7.22	11.10	26	0.115	0.08	0.136	0.249	25	200	180	74.75	427.5	2600
Ausable River																	
Main Branch																	
Staffa	03-05	26	8.11	6.96	9.12	12.40	26	0.025	0.015	0.034	0.057	26	780	623	250	1600	7300
Exeter	01-05	41	6.73	3.43	9.00	14.30	41	0.101	0.059	0.16	1.17	25	200	120	68	290	720
Springbank	03-05	26	4.96	2.43	8.67	10.70	26	0.068	0.05	0.1	0.277	26	135	138	70	300	1600
Thedford	01-05	40	4.92	2.41	7.37	12.50	40	0.048	0.036	0.096	0.388	26	125	136	53	240	24000
Ausable Tributaries																	
Black	01-05	41	6.55	4.82	8.18	13.50	41	0.046	0.028	0.072	0.23	26	755	933	510	3800	11000
Nairn	03-05	26	4.75	3.86	7.06	11.40	26	0.019	0.011	0.029	0.088	26	185	130	51	380	1100
Decker	01-05	41	5.14	0.23	9.27	17.80	41	0.049	0.033	0.079	0.172	26	170	167	73	490	17000
Little Ausable																	
Huron Park	04-05	29	7.83	2.78	11.13	16.50	29	0.048	0.026	0.07	0.503	27	280	321	105	697.5	67000
Lucan	01-05	41	6.57	0.13	9.63	15.70	41	0.029	0.022	0.05	0.228	26	74.5	77	31	180	1700
Shoreline Watersheds (north to south)																	
Boyd	01-05	51	5.18	0.51	7.55	13.00	21	0.03	0.015	0.039	0.085	51	230	213	70	609	9500
Eighteen Mile	01-05	62	3.72	1.10	5.80	9.79	31	0.028	0.018	0.042	0.143	62	256	226	76	540	7700
Kintail	01-05	63	0.50	0.10	4.27	11.30	33	0.13	0.039	0.221	0.333	63	240	208	62.5	688	17000
Kerrys	01-05	99	3.60	1.67	6.35	13.10	55	0.027	0.018	0.061	0.36	97	280	244	86	712.5	12000
Kingsbridge	01-05	57	5.07	0.20	7.13	13.50	30	0.09	0.034	0.144	0.327	57	480	536	207.5	1550	17000
Griffins	01-05	69	1.60	0.20	6.92	19.40	39	0.106	0.038	0.163	0.501	68	569	544	210	1610	20000
Midhuron	01-05	61	2.10	0.20	6.78	13.90	33	0.067	0.032	0.168	0.721	61	240	269	88.5	835.5	5500
Boundary	01-05	77	2.81	0.54	4.42	13.50	33	0.041	0.028	0.086	0.6	77	360	314	100	857.5	11000
Bogies	01-05	63	2.87	0.34	5.83	11.00	33	0.03	0.019	0.047	0.253	63	105	146	49.25	397.5	42000
Allans	01-05	63	4.30	3.15	5.89	12.10	33	0.027	0.018	0.041	0.708	61	170	213	97.75	472.5	39000
Zurich	03-05	19	5.18	3.35	6.87	13.20	26	0.036	0.025	0.071	0.197	26	274	236	87	610	22000
Desjardine	03-05	25	4.30	0.44	7.85	14.00	25	0.034	0.018	0.044	0.145	25	110	156	45.75	570	25000
Port Franks	03-05	26	5.85	0.20	12.20	21.00	26	0.056	0.039	0.097	0.201	26	110	117	55	220	2000

Some sites have not been sampled for the entire period. Refer to the Years column.

The watersheds have been ordered from north to south, sites within each watershed ordered from upstream to downstream.

(light yellow) result exceeds the CCME Guideline of 2.93 mg/l nitrate as N, or the PWQO of 0.03 mg/l of total phosphorus or 100 cfu/100ml for *E.coli*

(orange) result exceeds the Ontario Drinking Water Standard of 10 mg/l nitrate as N

2.2.1.4 Riverine Water Quality Summary

The surface water quality in the Ausable Bayfield Maitland Valley Source Protection Region reflects traditional rural non-point source issues of nitrogen, phosphorus and bacteria. More urban contaminates such as chloride and copper are not present in concentrations above the PWQO.

Nitrogen, in the form of nitrate, is an issue throughout the area where the majority of water sampling sites outside of the Nine Mile River have at least 50 percent of the samples above the aquatic protection limit. There is a general trend for nitrogen concentrations to increase in watercourses, progressing from north to south, reflecting the shift from more groundwater fed systems to surface water systems. Headwater streams have particularly high concentrations of nitrate indicating that solutions should be aimed at the lower order stream watercourses. A focus for improvements should be applied to the Bayfield River and Parkhill Creek, and to a lesser extent the Ausable River, since the nitrate trend is still increasing. Nitrogen in the form of nitrite, while toxic, is not generally present in surface water and may indicate major degradation. High nitrite concentrations found in Black Creek, Boyle Drain and the Middle Maitland River require further investigation.

Phosphorus concentrations are not high throughout the area, with almost half of the sites having median concentrations below the PWQO. Areas requiring improvement are Parkhill Creek, Middle Maitland River, and to a lesser degree the Bayfield and Ausable Rivers. As well, four shoreline watercourses (Kintail, Kingsbridge, Griffins and at Mid Huron Beach) should also be the focus of improvements.

Bacteria concentrations (*E.coli)* are elevated throughout the area with over 85 percent of the sites having median concentrations above the recreational PWQO. Of particular concern are the upper Middle Maitland River, Black Creek, Kingsbridge and Griffins Creek. At these locations, it would seem as though there is a potential point-source of contamination. There is some indication that the smaller watercourses have higher concentrations, indicating that efforts to improve conditions could be focused at the low order stream watercourses where drainage densities are higher and flows are normally lower.

Heavy metals are elevated to concentrations of concern in some watercourses in the area, and there appears to be a relationship with WWTP discharge locations. Aluminium, cadmium and lead should be explored further for bioavailability. Decker Creek, Black Creek and the Middle Maitland around Trowbridge should be explored further with respect to sources.

2.2.2 Lake Huron

The intent of this section is to summarize trends in the concentrations of total phosphorus (TP), nitrate, chloride, and *E. coli* for two local Lake Huron water intake plants: Goderich and Port Blake (also recognized as the Grand Bend Facility or the Lake Huron Water Supply). Refer to WC Map 2-1 for intake locations.

2.2.2.1 Temporal Trends

Overall, the concentrations of total phosphorus, nitrate, chloride and *E. coli* were greater at the Goderich Water Intake Facility compared to the Port Blake Intake Facility (Table 2-5, and

Figures 2-10 through 2-13). Further, trends in the nutrients (TP and nitrate) over the past 30 years appeared to be similar at the two facilities. Exploratory analyses suggest a decrease in TP concentrations since the 1970s and potentially increasing nitrate concentrations at both locations since 1976. The following discussion focuses on the comparison of TP, nitrate, chloride, and *E. coli* concentrations at the Lake Huron water intake facilities to standards established by the Ontario Ministry of the Environment (Provincial Water Quality Objective – PWQO) and the Canadian Council of Ministers of the Environment (CCME) (Canadian Water Quality Guideline – CWQG).

Table 2-5: Summary of water quality data from the water intake plant in Goderich and Port Blake in Lake Huron (1976 to 2004). (PWQO – Provincial Water Quality Objective and CWQG – Canadian Water Quality Guideline)

Facility	Total Phosphorus (mg L^{-1}) PWQO = 0.02 mg L^{-1}	Nitrate (mg L^{-1}) DRAFT CWQG = 2.93 mg L^{-1}	Chloride (mg L^{-1}) CWQG =250 mg L^{-1}
Goderich			
n	1384	1388	1390
median	0.018	0.58	8.5
range	0.00 – 0.380	0.00 – 6.36	0.00 – 33.50
90th percentile	0.07	1.80	13.70
Port Blake			
n	1104	1105	1107
median	0.012	0.30	6.50
range	0.00 – 0.16	0.00 – 3.70	4.50 -18.50
90th percentile	0.03	0.67	7.50

Phosphorus

The median TP concentration at the Goderich Water Intake Facility (median = 0.018 mg L^{-1} over the past nearly 30 years) is similar to the Interim Provincial Water Quality Objective for TP (IPWQO = 0.02 mg L^{-1} for lakes) (Figure 2-10). The Provincial Objective was established to prevent eutrophication in lentic systems. The median TP concentration at the Port Blake Intake Facility between 1976 and 2004 was significantly lower than at Goderich (median = 0.012 mg L^{-1}; Mann-Whitney U statistic 988358.5; $p < 0.001$). However, the median concentration at the Port Blake Intake Facility is in the range of concentrations that would be considered to contribute to nearshore nutrient enrichment conditions (i.e., the 90th percentile = 0.03 mg L^{-1}).

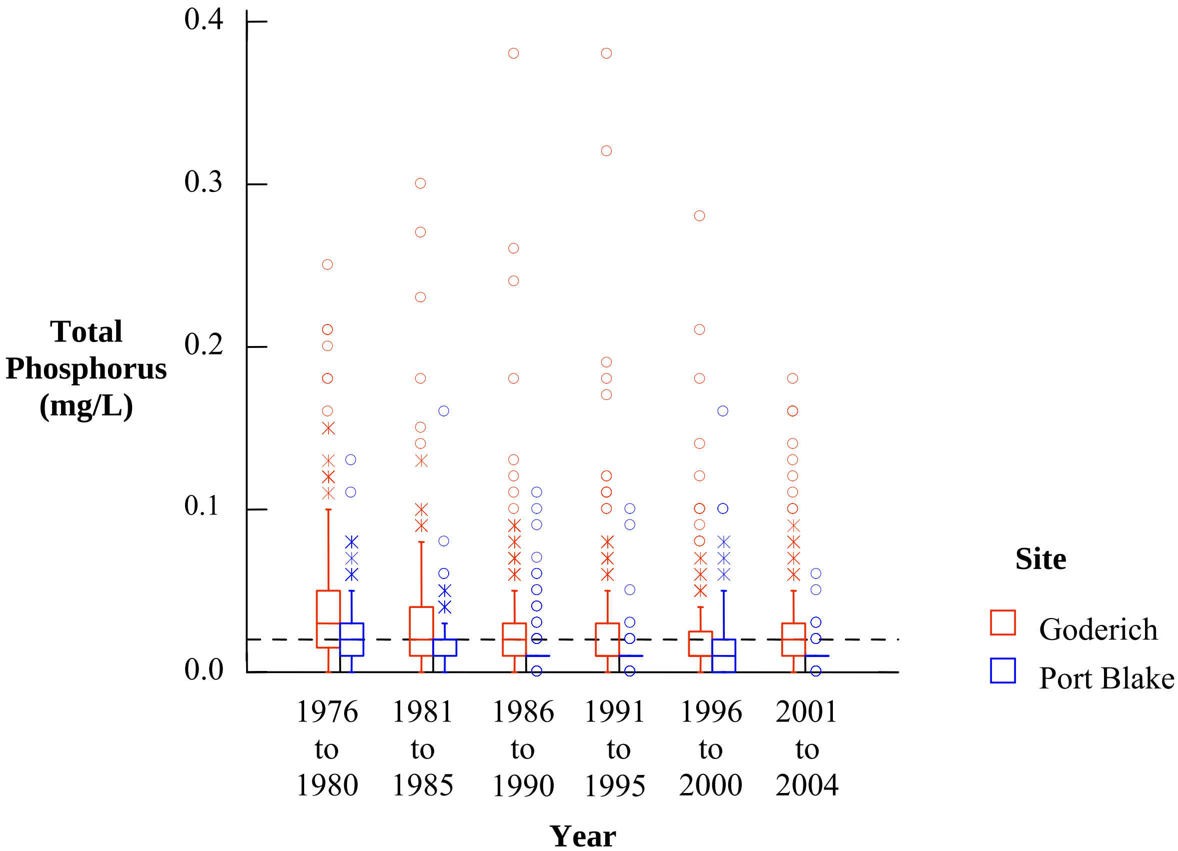


Figure 2-10: Total phosphorus concentrations (mg L^{-1}) at Goderich and Port Blake Water Intake Facilities (1976 to 2004)

The PWQO to prevent eutrophication in lakes (0.02 mg L^{-1}) is indicated with a dashed line.

Nitrate

Between 1976 and 2004, the median nitrate concentration at the Goderich Water Intake Facility was 0.58 mg L^{-1}. Concentrations of nitrate at the Goderich Facility are in the range of concentrations that would be considered to contribute to nearshore nutrient enrichment conditions (i.e., the 90^{th} percentile = 1.80 mg L^{-1}). The Canadian Council of Ministers of the Environment (2002) suggested that nitrate concentrations above 0.9 mg L^{-1} were generally associated with eutrophic conditions (algae and macrophyte blooms, shortened food chains and changes in the aquatic community). Nitrate concentrations at the Goderich station rarely exceeded a water quality objective of 2.93 mg L^{-1} (Figure 2-11 the draft Canadian Water Quality Guideline for the protection of aquatic life from direct toxic effects; CCME 2002) and never exceeded the drinking water guideline of 10 mg L^{-1} (CCME 1978). Nitrate concentrations at the Port Blake Facility (median = 0.34) were significantly lower than at the Goderich Facility (Mann-Whitney U Test Statistic 11933230; p <0.001), between 1976 and 2004.

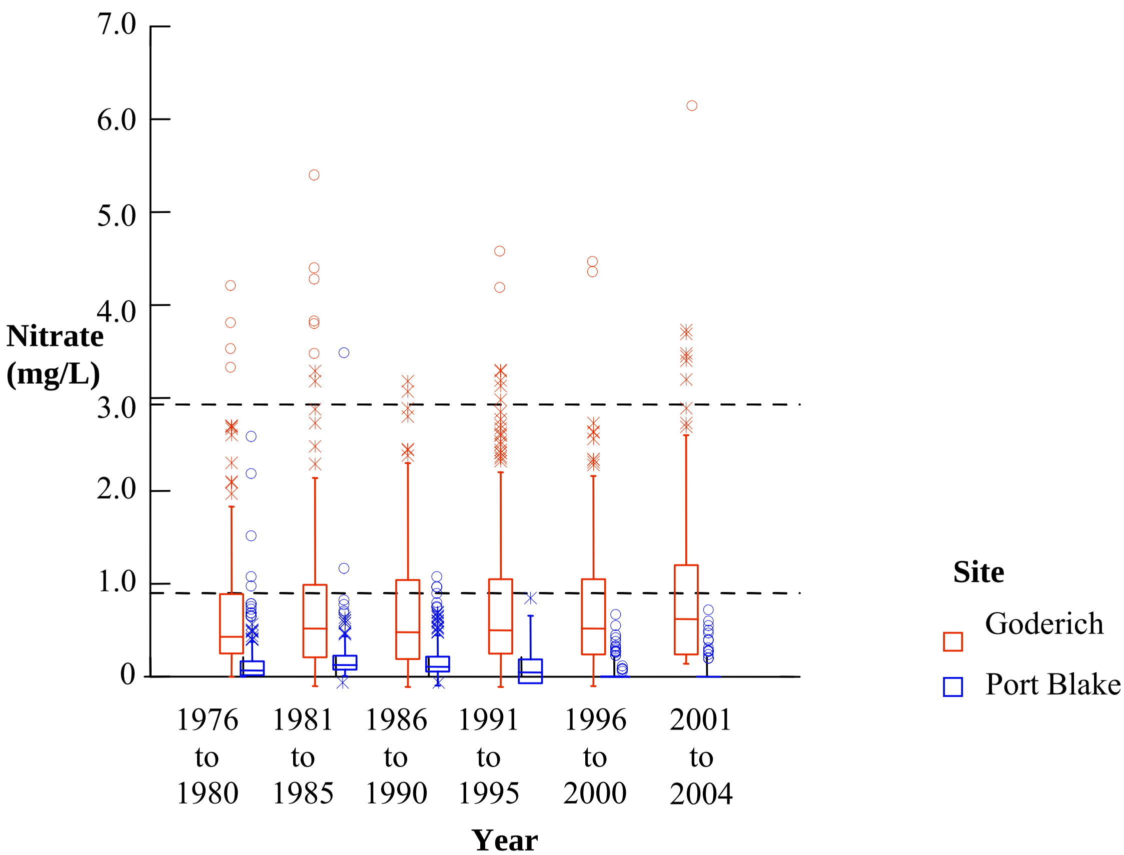


Figure 2-11: Nitrate concentrations (mg L^{-1}) at Goderich and Port Blake Water Intake Facilities (1976 to 2004)

The Canadian Council for Ministers of the Environment (CCME) standard to prevent eutrophication (0.9 mg L^{-1}) and the CCME draft guideline for the protection of aquatic life (2.93 mg L^{-1}) are indicated with dashed lines.

Chloride

The median chloride concentrations at both the Goderich and Port Blake Facilities were substantially below the Canadian guideline (Figure 2-12). Between 1976 and 2004, the median concentration at the Goderich Facility (8.5 mg L^{-1}) was higher than the median concentration at the Port Blake Facility (median = 6.5 mg L^{-1}; Mann-Whitney U Statistic 12999734.5; $p < 0.001$).

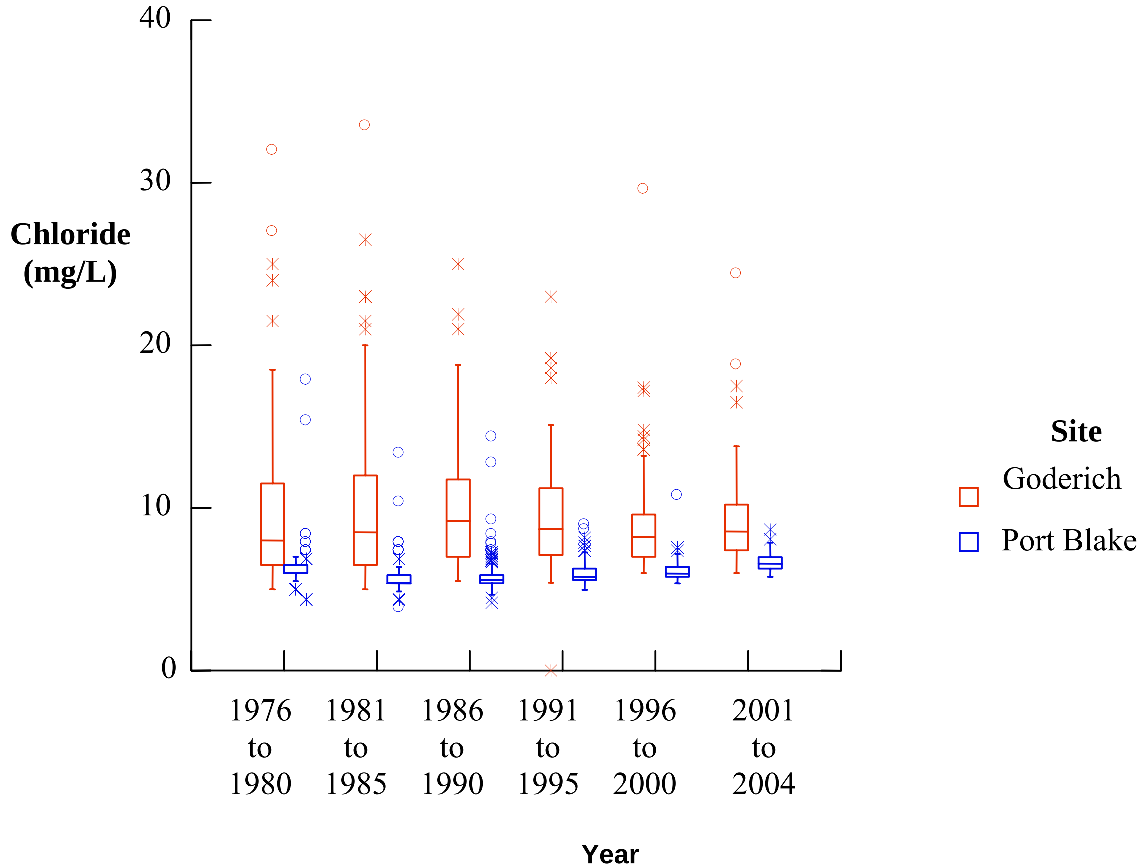


Figure 2-12: Chloride concentrations (mg L^{-1}) at Goderich and Port Blake Water Intake Facilities (1976 to 2004)

The Canadian drinking water guideline is 250 mg L^{-1} (Canadian Council for Ministers of the Environment 1999).

Bacteria

Bacterial contamination most likely poses a greater risk to water intakes in Lake Huron compared to nutrient and sediment concentrations, as discussed above. A recent report prepared by the Ministry of Environment (Howell et al. 2005) analyzed the Huron County Health Unit beach water data collected between 1993 and 2003. Over this period, the median *Escherichia coli* (*E.coli*) concentration at the beaches sampled was between 50 and 100 cfu/100 mL. The recreational water quality guideline of 100 cfu/100 mL was exceeded approximately 25 per cent of the sampling opportunity. The analysis of the Huron County Health Unit data highlighted the current understanding of bacteria in the nearshore of Lake Huron, however, it did not provide drinking water related information. The determination of *E.coli* concentrations from the raw water at the Lake Huron water intake plants is a recent undertaking and the analysis that follows is also preliminary.

Table 2-6: Summary statistics of *Escherichia coli* (*E. coli*) concentrations in raw water samples collected for the water intake plants in Goderich and Port Blake in Lake Huron (2005 to September 2006)

Facility	*n*	median	Count if >"0"	Count if = "0"	Range	90th percentile
Goderich	92	4	73 (79%)	19 (21%)	0-700	42
Port Blake	349	0	14 (4%)	335 (96%)	0-100	0

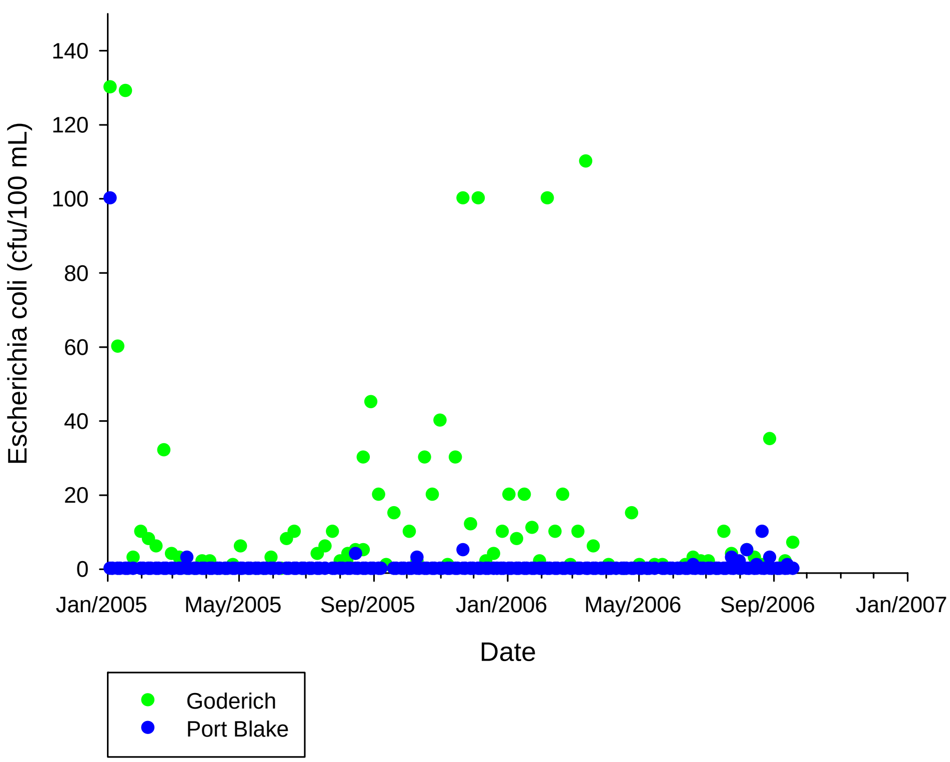


Figure 2-13*: Escherichia coli* concentrations in raw water samples collected for the Lake Huron intakes at the Goderich and Port Blake Water Treatment Facilities (2005 to 2006)
One value (y=700) missing from the Goderich Facility data (September 27, 2005)

Raw water concentrations of the fecal waste indicator organism, *E. coli*, were typically low at both water intake facilities. Concentrations of *E. coli* in the raw water samples did however, exceed the Ontario Drinking Water Standard (ODWS = 0 *E. coli* cfu/100 mL) at both locations on more than one occasion. The frequency with which the ODWS was exceeded was greater at the Goderich Facility compared to that number for the Port Blake Facility (Table 2-6 and Figure 2-13). Further, the raw water concentration of *E. coli* was greater at the Goderich Facility (median *E.coli* concentration = 4 cfu/100mL) compared to the raw water concentration of *E. coli* at the Port Blake Facility (median *E. coli* concentration = 0 cfu/100mL; Mann-Whitney U statistic 28331.5; $p < 0.001$). Although, the raw water is treated within both treatment facilities the raw water at the Goderich Facility had higher concentrations of *E.coli* more frequently than did the Port Blake Facility.

2.2.2.2 Lake Huron Intake Summary

The median concentrations of the nutrients examined in this section (TP and nitrate) at the Goderich Facility are in the range of contributing to eutrophic conditions in the nearshore of Lake Huron and were nearly twice the median concentrations at the Port Blake Facility. The median concentration of chloride and the concentration of *E. coli* are also higher at the Goderich Facility compared to the Port Blake Facility. Although both intakes are located in the nearshore environment of Lake Huron, the Goderich Facility is directly within the zone of influence of a tertiary tributary, the Maitland River. More work is needed to understand the plume, of this river and its effects on nearshore nutrient and bacteria enrichment.

2.2.3 Groundwater

This section is intended to discuss the ambient water quality of aquifers throughout the Ausable Bayfield Maitland Valley Source Protection Region. The baseline groundwater quality for these aquifers was defined in order to provide a basis for developing sound Source Protection activities. This section is preliminary in nature, and reflects the best available data at the time of writing.

It is important to note that these analyses were not tested statistically. Due to the small number of data points, these results should not be used to characterize the entire aquifer, as there can be marked differences between wells within like aquifers with respect to groundwater quality. Furthermore, the data is not of sufficient length to evaluate trends in aquifer water quality. Aquifer complexes are displayed on CWB Map 12 associated with the Conceptual Water Budget.

2.2.3.1 Overburden Aquifers

Howick

The Howick Aquifer complex is located within a large area glacial outwash and kame moraine in and around the Township of Howick. Within this area, numerous overburden wells are exploiting this shallow groundwater resource. Two wells were selected for analysis from the Howick Aquifer and are listed in Table 2-7.

Table 2-7: Representative samples for the Howick Aquifer complex

Well Name	Nitrates (mg L^{-1})	Hardness (Calculated as mg L^{-1} $CaCO_3$)	Fluoride (mg L^{-1})	Sodium (mg L^{-1})	Chloride (mg L^{-1})	Iron (mg L^{-1})	*E.coli* (cfu/100ml)
Lakelet A* n=1	0	233	0.44	3.2	1	1.78	0
Lakelet B* n=1	0.23	275	0.1	3.0	5	0.23	0

* PGMN Well – 2004 Sampling

Analysis of these results indicates that groundwater quality in the Howick Aquifer is of excellent quality, with no exceedances for any health related indicators and only two exceedances of aesthetic objectives for iron. Furthermore, the groundwater quality analyses in the Howick Aquifer indicate high quality with respect to other aquifers in the Ausable Bayfield Maitland Valley Source Protection Region, with acceptable concentrations of hardness, fluoride, chloride, and sodium, and lack of any *E.coli* results. Nitrates reported in Lakelet B may be the consequence of influence from surface water, but are at very low concentrations and are not considered a significant issue at this time.

Wyoming

The Wyoming Aquifer complex is associated with the large Wyoming moraine which runs in a north south orientation, and crosses the entire study area just east of the present day Lake Huron shoreline. Within this area, numerous overburden wells are exploiting several distinct shallow groundwater resources. Wells have been identified which can be considered representative of the Wyoming Aquifer exclusively, however, caution should be used when interpreting this data as these wells are spread widely apart and are not likely hydraulically connected. Three wells were selected for analysis from the Wyoming Aquifer and are listed in Table 2-8.

Table 2-8: Representative samples for the Wyoming aquifer complex

Well Name	Nitrates (mg L^{-1})	Hardness (Calculated as mg L^{-1} $CaCO_3$)	Fluoride (mg L^{-1})	Sodium (mg L^{-1})	Chloride (mg L^{-1})	Iron (mg L^{-1})	*E.coli* (cfu/100ml)
Kinloss* n=1	0.17	373	0.44	1.5	3	0	0
Parkhill* n=1	0	97	1.59	47.9	3	0.36	0
Rock Glen* n=1	0	422	0.63	17.8	67	0.23	0

* PGMN Well – 2004 Sampling

Analysis of these results indicates that groundwater quality in the Wyoming Aquifer is of good quality, with exceedances for the lower, health-related ODWS for sodium and for fluoride. There are also exceedances of aesthetic objectives for iron and hardness. Elevated sodium and chloride values in the Rock Glen well may be indicative of some contamination via road salt in this area. Nitrates reported in the Kinloss well may be the consequence of influence from surface water, but are at very low concentrations and are not considered a significant issue at this time.

Hensall

The Hensall Aquifer complex is an intermediate overburden aquifer located directly below and in the vicinity of the community of Hensall. Within this area, numerous overburden wells are exploiting the intermediate groundwater resource. Two wells were selected for analysis from the Hensall Aquifer but the data for these wells was not released by January 2007 for the production of this report.

The Hensall Aquifer was studied in some detail within the Groundwater Quality Assessment completed on 2001 for Huron County (Golder Associates 2001). This report identified six clusters of private domestic wells which were sampled for a comprehensive suite of indicators and one of the clusters focussed on the Hensall Aquifer.

Within this cluster (labelled M6 in the report) groundwater quality was found to be moderate. Of the 30 wells which were sampled in the cluster, 13 exceeded the ODWS for total coliform and three for *E.coli*, which may reflect the more typical and less secure practice of using bored wells for shallow aquifers rather than the quality of the aquifer itself. One sample exceeded the ODWS for nitrates, with several showing elevated concentrations in the aquifer. Iron continues to be a problem with 18 of 30 wells testing above the aesthetic drinking water objective, but all within the plausible range of naturally occurring groundwater. There were no exceedances detected for sodium. The samples were also analyzed for a more comprehensive suite, including hydrocarbons, volatile organics and pesticides, of which no significant amounts were detected.

Locating and identifying monitoring sites and historical data for the Hensall Aquifer should be a priority for future reporting and monitoring.

Holmesville

The Holmesville Aquifer complex is associated with the large glacial outwash deposit that sits between the Wyoming and Wawanosh moraines. This deposit runs the length of the Ausable Bayfield Maitland Source Protection Region in a north south orientation. Within this area, numerous overburden wells are exploiting shallow groundwater resources and springs. Wells have been identified which can be considered representative of the Holmesville Aquifer exclusively, however, caution should be used when interpreting this data as these wells are spread widely apart and may not be hydraulically connected. Four wells were selected for analysis from the Holmesville Aquifer and are listed in Table 2-9.

Table 2-9: Representative samples for the Holmesville aquifer

Well Name	Nitrates (mg L^{-1})	Hardness (Calculated as mg L^{-1} $CaCO_3$)	Fluoride (mg L^{-1})	Sodium (mg L^{-1})	Chloride (mg L^{-1})	Iron (mg L^{-1})	*E.coli* (cfu/100ml)
Hay #1* n=1	0	235	0.73	1.4	2	0.87	0
Hay #2* n=1	0	266	0.25	1.4	4	0.28	4
Hay #3* n=1	0	590	0.37	1.9	3	3.80	0
Tricks TR9* n=1	0.9	322	0	4.6	15	0	0

* PGMN Well – 2004 Sampling

Analysis of these results indicates that groundwater quality in the Holmesville Aquifer is of good quality, with exceedances of aesthetic objectives for iron and hardness. *E.coli* was also found in one of the wells in very low numbers and should be confirmed. Nitrates reported in the Tricks (TR9) well may be the consequence of influence from surface water, but are at very low concentrations and are not considered a significant issue at his time. This well also displays unusually high hardness and iron values. The hardness values are within a plausible range for naturally occurring groundwater, but are well above expected concentrations for an overburden aquifer. The unusually high iron values are likely attributed to some form of contamination, although at this time the source of that contamination cannot be determined.

North Lambton

The North Lambton Aquifer complex is a shallow overburden aquifer located in northern part of Lambton County adjacent to Lake Huron. Within this area, numerous overburden wells are exploiting the shallow groundwater resource. Three wells were selected for analysis from the North Lambton Aquifer and are listed in Table 2-10.

Table 2-10: Representative samples for the North Lambton Aquifer

Well Name	Nitrates (mg L^{-1})	Hardness (Calculated as mg L^{-1} $CaCO_3$)	Fluoride (mg L^{-1})	Sodium (mg L^{-1})	Chloride (mg L^{-1})	Iron (mg L^{-1})	*E.coli* (cfu/100ml)
Museum* n=1	0	234	0.15	3.2	10	0.84	0
PP10**	0.21	195	0.14	13.4	12	0.06	n/s
PP19**	0.14	205	0	0.8	2	0	n/s

* PGMN Well – 2004 Sampling, **ABCA North Lambton Study - 2004

Wells PP10 and PP19 were initially analyzed in 1999 and 2001 as part of Master's Thesis completed at the University of Western Ontario, and were subsequently sampled in 2001 for the Town of Bosanquet Study of Rural Water Quality in which they were sampled for microbiology and nitrates. They were again analyzed in 2004 as part of the ABCA North Lambton Aquifer characterization project for a more comprehensive suite of parameters using the PGMN protocols for sampling and analysis.

The Town of Bosanquet Study of Rural Water Quality, completed in 2001, found that 12 of 128 dug wells into the overburden aquifer had adverse bacteria results, which more likely reflects wellhead practice than actually aquifer quality. In addition, 46 of 128 wells had elevated nitrate concentrations, with 5 over the ODWS for nitrates.

Analysis of the results shown in Table 2-17 support results of the Town of Bosanquet Study that groundwater quality in the North Lambton aquifer is of moderate quality, with nitrates reported in two wells, and elevated concentrations of sodium and chloride which may indicate influence from surface water. These indicators are at low concentrations and are not considered a significant issue at this time. This well also displays unusually high hardness and iron values. The typically high iron values are likely naturally occurring.

Seaforth

The Seaforth Aquifer complex is an overburden aquifer located within the Seaforth moraine and a small glacial outwash plain located on its western flank. Within this area, numerous overburden wells are exploiting the shallow groundwater resource through dug wells. No wells could be found for analysis within the Seaforth Aquifer.

The Seaforth Aquifer was studied in some detail within the Groundwater Quality Assessment completed on 2001 for Huron County (Golder Associates 2001). This report identified six clusters of private domestic wells which were sampled for a comprehensive suite of indicators and one of the clusters focussed on the Seaforth Aquifer.

Within this cluster (labelled P1 in the report) groundwater quality was found to be poor. Of the 29 wells which were sampled in the clusters, 23 exceeded the ODWS for total coliform or *E.coli*, which may reflect the more typical and less secure practice of using bored wells for shallow aquifers rather than the quality of the aquifer itself. One sample exceeded the ODWS for nitrates, with several showing elevated concentrations in the aquifer. Iron is also a problem with 4 of 29 wells testing above the aesthetic drinking water objective, but all within the plausible range of naturally occurring groundwater. There were no exceedances detected for sodium. The samples were also analyzed for a more comprehensive suite, including hydrocarbons, volatile organics and pesticides, of which no significant concentrations were detected. Two samples had detectable amounts of hydrocarbons, eight with detectable (but very low) concentrations of trihalomethanes (THM) and three with detectable (but also very low) concentrations of perchloroethylene (PCE). Three samples also detected trace amounts of some organochlorine pesticides.

2.2.3.2 Bedrock Aquifers

Salina

The Salina formation subcrops as a narrow strip on the eastern fringe of the Ausable Bayfield Maitland Valley Source Protection Region. Three wells were selected for analysis from the Salina formation and are listed in Table 2-11.

Table 2-11: Representative samples for the Salina Aquifer

Well Name	Nitrates (mg L^{-1})	Hardness (Calculated as mg L^{-1} $CaCO_3$)	Fluoride (mg L^{-1})	Sodium (mg L^{-1})	Chloride (mg L^{-1})	Iron (mg L^{-1})	*E.coli* (cfu/100ml)
Harriston-2*	0	n/s	1.1	7.56	n/s	n/s	0
Harriston-3*	0	n/s	0.73	11.8	n/s	n/s	0
Harriston** n=1	0.54	325	0.1	3.2	4	0.67	0

* Municipal Well Data – 2004, ** PGMN Well – 2004 Sampling

Analysis of these results indicates that groundwater quality in the Salina is of good quality, with no exceedances for any health related indicators and only two exceedances of aesthetic objectives for hardness and iron. The other analyses demonstrate that the aquifer is not under the influence of surface water as indicated by the general lack or low concentrations of nitrates and the high iron and hardness values. Furthermore, the groundwater quality analyses in the Salina are of high quality with respect to other bedrock aquifers in the Ausable Bayfield Maitland Valley Source Protection Region, with acceptable concentrations of fluoride, chloride, and sodium and a lack of any *E.coli* results.

Bass Islands

The Bass Islands formation subcrops as a narrow strip on the eastern fringe of the Ausable Bayfield Maitland Valley Source Protection Region immediately west of the underlying Salina

Formation. Three wells were selected for analysis from the Bass Islands formation and are listed in Table 2-12.

Table 2-12: Representative samples for the Bass Islands aquifer

Well Name	Nitrates (mg L^{-1})	Hardness (Calculated as mg L^{-1} $CaCO_3$)	Fluoride (mg L^{-1})	Sodium (mg L^{-1})	Chloride (mg L^{-1})	Iron (mg L^{-1})	*E.coli* (cfu/100ml)
Palmerston #1*	0.3	n/s	0.27	16.9	n/s	n/s	0
Palmerston #2*	0.3	n/s	0.31	13.3	n/s	n/s	0
Palmerston #3*	0.3	n/s	0.23	8.6	n/s	n/s	0

* Municipal Well Data - 2004

Based on the available data, analysis of these results indicates that groundwater quality in the Bass Islands is of good quality with no exceedances in any indicators. The presence of low concentrations of nitrates is not considered to be a concern at present, but warrants attention for any long term sampling programs to ensure that concentrations are not increasing over time. Sodium concentrations are within the accepted naturally occurring level for bedrock aquifers in the Ausable Bayfield Maitland Valley Source Protection Region, but are approaching the lower ODWS for persons with hypertension (20 mg L^{-1}) and should be monitored carefully. The relatively low concentrations of fluoride can be considered a characteristic quality for the Bass Islands Aquifer.

Bois Blanc

The Bois Blanc formation subcrops as a narrow strip on the eastern fringe of the Ausable Bayfield Maitland Valley Source Protection Region immediately west of the underlying Bass Islands Formation. Three wells were selected for analysis from the Bois Blanc formation and are listed in Table 2-13.

Table 2-13: Representative samples for the Bois Blanc Aquifer

Well Name	Nitrates (mg L^{-1})	Hardness (Calculated as mg L^{-1} $CaCO_3$)	Fluoride (mg L^{-1})	Sodium (mg L^{-1})	Chloride (mg L^{-1})	Iron (mg L^{-1})	*E.coli* (cfu/100ml)
Gowanstown*	0	n/s	0.6	11.1	n/s	n/s	0
Gowanstown Mun. Office*	0	n/s	0.4	9.7	n/s	n/s	0
Milverton*	0	n/s	0.56	8.9	n/s	n/s	0

* Municipal Well Data - 2004

Based on the available data, analysis of these results indicates that groundwater quality in the Bois Blanc is of good quality with no exceedances in any indicators. Nitrate, fluoride and sodium concentrations are within the accepted naturally occurring level for bedrock aquifers in the Ausable Bayfield Maitland Valley Source Protection Region. The relatively low concentrations of fluoride, nitrates and sodium can be considered characteristic for the Bois Blanc Aquifer.

Lucas

The Lucas formation, of the Detroit River Group, subcrops throughout a large portion of the Ausable Bayfield Maitland Valley Source Protection Region and is the most commonly exploited aquifer in the area. The Lucas formation overlies the Bois Blanc Formation throughout and has been the subject of numerous recent investigations into karst development in the study area. Many wells which are drilled into the overlying Dundee formation extend into the Lucas Formation due to the high yields and generally high quality of the Lucas formation.

For this report, wells have been identified which can be considered representative of the Lucas exclusively, and therefore do not extend through the overlying Dundee Formation or into the underlying Bois Blanc Formation. Wells in karst areas thought to be directly connected to surface water were also excluded and will be discussed in a future section dealing with vulnerable areas. Five wells were selected for analysis from the Lucas Formation and are listed in Table 2-14.

Table 2-14: Representative samples for the Lucas Aquifer

Well Name	Nitrates (mg L^{-1})	Hardness (Calculated as mg L^{-1} $CaCO_3$)	Fluoride (mg L^{-1})	Sodium (mg L^{-1})	Chloride (mg L^{-1})	Iron (mg L^{-1})	*E.coli* (cfu/100ml)
Atwood* n=1	2.24	302	0.48	9.8	11.0	0.58	0
Amberley* n=1	0	300	2.32	13.0	5.0	0.254	n/s
Grey Twp* n=1	0.3	242	1.72	12.3	4.0	0.29	0
Pollard* n=1	0	n/s	1.58	n/s	0.4	0.671	n/s
Seaforth* n=1	0.1	403	1.47	169.0	361.0	0.1	0

* PGMN Wells – 2004 Sampling

The Lucas Formation was studied in some detail within the Groundwater Quality Assessment completed on 2001 for Huron County (Golder Associates 2001). This report identified six clusters of private domestic wells which were sampled for a comprehensive suite of indicators and three of these clusters focused on the Lucas formation.

Within these three clusters (labelled M3, M4 and M5 in the report) groundwater quality was generally found to be good. Of the 88 wells which were sampled in the three clusters, only two exceeded ODWS for nitrate and *E.coli*, none exceeded the ODWS for sodium. The samples were also analyzed for a more comprehensive suite, including hydrocarbons, volatile organics and pesticides, of which none were detected. The key groundwater quality issue identified in this report was iron, with 48 of 88 wells testing above the aesthetic drinking water objective.

Based on the data in Table 2-14, analysis of these results supports the findings of the Huron County Groundwater Quality Assessment (2001) that groundwater quality in the Lucas aquifer is of good quality with exceedances reported only in the naturally occurring indicators of hardness, fluoride and iron. Nitrates, reported in the Atwood PGMN well located in an area of thin overburden, may be indicative of influence from surface water. Sodium concentrations through the whole of the aquifer appear to be within expected ranges for natural groundwater, with the exception of the Seaforth PGMN well. This well is also elevated in chloride indicating contamination from salt as a likely source of elevated sodium concentrations, and is located in an area of historic brine well operation and may be associated with cross contamination via improperly decommissioned brine wells.

High concentrations of fluoride are a distinctive feature of groundwater from the Lucas Formation. Water quality analyses from the Lucas Formation are consistently above ODWS. In fact, the discovery of the ability of fluoride enriched water to reduce tooth decay was made in Ripley, Ontario, just north of the Ausable Bayfield Maitland Valley Source Protection Region, in wells that are exploiting the Lucas Formation for drinking water.

Another locally significant and unusual feature of groundwater quality in the Lucas formation is the presence of radiogenic isotopes. Unusually high concentrations of uranium and radium as well as dissolved radium gas have been identified in wells in the Seaforth area which exploit the Lucas Formation for drinking water. These isotopes are naturally derived and are not considered a long term health threat.

Dundee

The Dundee formation subcrops throughout the southwestern portion of the Ausable Bayfield Maitland Valley Source Protection Region and is the second most commonly exploited aquifer in the area. The Dundee formation overlies the high yielding Lucas Formation and as a consequence, many wells which are drilled into the Dundee formation extend into the Lucas Formation. The Dundee Formation, nevertheless, is a large scale aquifer of importance for the region. Four wells were selected for analysis from the Dundee formation and are listed in Table 2-15. Well, NL-2 was drilled as part of the ABCA North Lambton Aquifer characterization study and was sampled as part of that program according to the protocols established in the PGMN.

Table 2-15: Representative samples for the Dundee Aquifer

Well Name	Nitrates (mg L^{-1})	Hardness (Calculated as mg L^{-1} $CaCO_3$)	Fluoride (mg L^{-1})	Sodium (mg L^{-1})	Chloride (mg L^{-1})	Iron (mg L^{-1})	*E.coli* (cfu/100ml)
Shipka* n=1	0	77.3	1.75	76.4	4	0.1	0
Tricks* n=1	0	101	1.7	21.9	1	0.6	0
Godboldt* n=1	0	227	1.64	7.3	3	0.1	0
NL2**	0	261	1.43	291	343	0.35	0

* PGMN Wells – 2004 Sampling, **ABCA North Lambton Study - 2004

The Dundee Formation was studied in some detail within the Groundwater Quality Assessment completed on 2001 for Huron County (Golder Associates 2001). Of the six clusters, one is focused primarily on the Dundee formation. Within this cluster (labelled P2 in the report) groundwater quality was generally found to be good. Of the 30 wells which were sampled in the three clusters, only 7 exceeded ODWS for total coliform or *E.coli*, and none exceeded the ODWS for sodium or nitrates. The samples were also analyzed for a more comprehensive suite, including hydrocarbons, volatile organics and pesticides, of which none were detected. The key groundwater quality issue identified in this report was Iron, with 18 of 30 wells testing above the aesthetic drinking water objective.

Based on this data, analysis of these results supports the findings of the Huron County Groundwater Quality Assessment (2001) that groundwater quality in the Dundee formation is of good quality with the exceedances reported only in the naturally occurring indicators of hardness, fluoride and iron. High concentrations of fluoride are a distinctive feature of groundwater from the Dundee Formation. Water quality analyses from the Dundee Formation are consistently near or above the ODWS of 1.5 mg L^{-1}.

Sodium concentrations are within the accepted naturally occurring level for bedrock aquifers in the Ausable Bayfield Maitland Valley Source Protection Region, but are approaching or exceeding the lower ODWS for persons with hypertension (20 mg L^{-1}) and should be monitored carefully. Sodium concentrations within NL-2 are elevated, and coupled with the elevated concentrations of chloride in the aquifer, are indicative of some form of contamination via salt. The ABCA North Lambton Aquifer characterization study noted the possible presence of improperly decommissioned brine wells in the area which may be a source of cross contamination for the Dundee Aquifer.

Another characteristic of Dundee-derived groundwater are high concentrations of sulphates, which lead to corrosion of wells and fixtures and a distasteful odour.

Hamilton

The Hamilton formation subcrops only in a very small area on the farthest southern and western limit of the Ausable Bayfield Maitland Valley Source Protection Region overlying the Dundee Formation. Three wells were selected for analysis from the Hamilton formation and are listed in Table 2-16.

Table 2-16: Representative samples for the Hamilton Aquifer

Well Name	Nitrates (mg L^{-1})	Hardness (Calculated as mg L^{-1} $CaCO_3$)	Fluoride (mg L^{-1})	Sodium (mg L^{-1})	Chloride (mg L^{-1})	Iron (mg L^{-1})	*E.coli* (cfu/100ml)
Hamilton 1	0	481	0.37	22.1	39	6.73	0
Hamilton 2	0	222	0.5	236	273	0.17	1
Hamilton 3	0	190	2.7	216	300	0	0

All Data from ABCA North Lambton Study – 2004

The Hamilton 1, 2 and 3 wells are domestic wells that serve private residences within the community of Port Franks. These wells were initially analyzed in 2001 as part of the Town of Bosanquet Study of Rural Water Quality in which they were sampled for microbiology and nitrates and were subsequently analyzed as part of the ABCA North Lambton Aquifer characterization project for a more comprehensive suite of parameters using the PGMN protocols for sampling and analysis.

Based on the available data, analysis of these results indicates that groundwater quality in the Hamilton is highly variable and of poor quality, with at least one exceedance in all indicators, with the exception of nitrates. The highly variable concentrations of iron, sodium and chloride are indicative of some form of localized contamination. The high concentrations of fluoride in the Hamilton -3 well may be the result of analytical error or influence from the overlying Dundee formation. Fluoride and hardness concentrations are within the accepted naturally occurring level for bedrock aquifers in the Ausable Bayfield Maitland Valley Source Protection Region area. Sodium concentrations are elevated, and coupled with the elevated concentrations of chloride in the aquifer, are indicative of some form of contamination via salt. The ABCA North Lambton aquifer characterization study noted the presence of improperly decommissioned brine wells in the area which may have cross contaminated the Hamilton Aquifer. It is herein recommended that these wells be identified, located and decommissioned as soon as possible. The extremely high concentrations of iron in at least one sample, and confirmed in another sample warrant further investigation. In addition to the parameters discussed in this report, it is well known in the community by drillers and landowners that the groundwater in this aquifer is high in sulphates. The generally poor quality of water in this aquifer and the overlying North Lambton overburden aquifer (see discussion below) has led to the utilization of Lake Huron based drinking water supplies in the area.

2.2.3.3 Groundwater Quality Summary

In general the groundwater quality within the Ausable Bayfield Maitland Valley Source Protection Region is of good quality, with only minor problems identified in the production of this report. Some of the major issues identified herein include:

- Salt contamination of aquifers in areas of historic brine well operations
- Contamination of shallow overburden aquifers via surface water, in particular determining if the contamination is a reflection of overall aquifer quality, or that of wellhead practice
- Elevated concentrations of naturally occurring parameters, such as fluoride, sodium, iron, sulphate and hardness in bedrock aquifers

A summary of overall water quality for the important overburden and bedrock aquifers in the Ausable Bayfield Maitland Valley Source Protection Region is included below in tables 2-17 and 2-18, respectively.

Table 2-17: Summary of water quality for overburden aquifers in the Ausable Bayfield Maitland Valley Partnership area

Aquifer	Water Quality	Key Issues
Howick	Excellent	Iron Trace presence of nitrates
Wyoming	Good	Fluoride Iron Sodium Trace presence of nitrates
Hensall	Moderate	Bacteria Nitrates Iron
Holmesville	Good	Hardness Iron contamination Trace presence of nitrates
North Lambton	Moderate	Iron Hardness Widespread presence of nitrates Evidence of significant salt contamination
Seaforth	Poor Evidence of high susceptibility to contamination via surface water	Bacteria Hardness Iron Widespread presence of nitrates Trace presence of hydrocarbons and pesticides

Table 2-18: Summary of water quality for bedrock aquifers in the Ausable Bayfield Maitland Valley Partnership area

Aquifer	Water Quality	Key Issues
Salina	Good	Hardness Iron
Bass Islands	Good	Sodium Presence of nitrates
Bois Blanc	Excellent	None Identified
Lucas	Moderate to Good	Fluoride Iron Hardness Localized evidence of salt contamination Radionuclides
Dundee	Good	Fluoride Iron Hardness Sodium Localized evidence of salt contamination
Hamilton	Poor Highly variable	Fluoride Hardness Iron contamination Evidence of significant salt contamination

Bedrock aquifers have good water quality; however, are plagued by naturally occurring water quality problems such as fluoride, iron and sodium. Overburden aquifers tend to have excellent natural water quality; however, are more susceptible to contamination, and as a result have significant problems for highly mobile parameters such as road salt, iron and nitrates. Overburden aquifers are also more susceptible as a result of the wellhead practices that are commonly used to exploit these shallow resources. Bored and dug wells with unsealed caps are more common, and as a result can act as conduits for surface water to enter the well and lead to higher concentrations of certain parameters that do not reflect the overall quality of individual aquifers.

The results of this report should guide development of an enhanced monitoring strategy for the Ausable Bayfield Maitland Valley Source Protection Region. However, it is important to reiterate that these analyses are not statistically significant and should not be used to characterize entire aquifers, as there can be marked differences in groundwater quality between wells within an aquifer. Furthermore, as has been stated above, the data is not of sufficient length to evaluate water quality trends in these aquifers.

2.3 Microbial Source and Raw Water Characterization

A comprehensive examination of all municipal water intake quality has not been undertaken at this point in the report. There are currently two surface water intakes from Lake Huron and approximately 32 groundwater intakes: WC Map 2-5 identifies these locations.

For drinking water intakes, there are three main data sources that can be used to characterize the raw water quality and potential microbial contamination for surface water and groundwater.

These include the Drinking Water Surveillance Program (DWSP), the Drinking Water Information System and from the municipality directly or from the water system operator.

The DWSP is a voluntary program that currently monitors the raw water quality of 175 Municipal drinking water treatment plants. There are 3 treatment plants in the Ausable Bayfield Maitland Valley Source Protection Region participating in the DWSP (Exeter, Goderich, and the Lake Huron system at Port Blake).

DWIS has data from all Municipal water treatment plants which must sample raw water quality for microbial indicators under the Safe Drinking Water Act (2002). This data has not been provided to undertake a characterization.

Data has been obtained from municipalities in the Ausable Bayfield Maitland Valley Source Protection Region for water quality, but it is summary in nature and not suitable for detailed analysis.

A microbial source and raw water characterization will not be conducted at this point on the basis that DWIS data will be used in the future. The raw water quality characterization for a limited number of indicators has been prepared in the Lake Huron Intake section of this report.

A less suitable approach to characterize Municipal raw groundwater quality is through aquifer sampling for programs such as the PGMN. The major aquifers have been characterized in the groundwater section of this report, using data from municipal wells in some cases.

2.4 Discussion

Nutrient enrichment appears to be the greatest water quality impairment in the Ausable Bayfield Maitland Valley Source Protection Region. Nutrient enrichment is evident in rivers, the nearshore of Lake Huron and vulnerable overburden aquifers. This enrichment reflects the rural agricultural nature of the study areas. Indicators typical of urban water quality issues (chloride and copper) have low concentrations. Typical rural sources of nutrients include agricultural land use and urban or private waste water treatment plants. A large potential source of nutrients is from agricultural uses with some streams enriched by waste water treatment plants, especially in low flow periods.

This preliminary analysis identified two important trends. Primarily, riverine surface water concentrations for nitrate and phosphorus increase from north to south. This trend possibly reflects landscape level relationships between land use, land management, forest cover and geology. These factors require further analysis it identify the key pathway differences. Secondly, headwater streams tend to have higher concentrations of nutrients compared to main channels. Therefore, to address nutrient issues in the area, improvements may be best directed to headwater stream areas.

Results suggest that bacteria do not behave like chemical contaminants. Bacterial sampling appears to provide more site specific information. To understand the movement and sources of bacteria, more information is needed on the transport and persistence of microbial indicators.

Groundwater quality in vulnerable aquifers is being influenced by surface activities based on the concentrations of salt and nitrate. Overburden aquifer sources are most likely road salt, with some deep bedrock wells having elevated salt concentrations due to cross contamination from non-decommissioned brine wells, as seen in Goderich.

The most common groundwater quality issues in the Ausable Bayfield Maitland Valley Source Protection Region are naturally occurring elements such as iron, hardness, fluoride, and sulphate in bedrock aquifers. From a drinking water perspective, only fluoride and sulphate have health related objectives.

2.5 Implications for Source Water Protection – Municipal

Generally, drinking water source protection activities for water quality in the Ausable Bayfield Maitland Valley Source Protection Region should focus on protection of the resource, as opposed to restoration. While water is of good quality in both Lake Huron and most aquifers, rivers and streams have unacceptable concentrations of nutrients and bacteria which require restoration efforts.

Source water protection activities for water quality should also include increasing the understanding of knowledge gaps outlined in the report, and repeated in Appendix A: Data and Knowledge Gaps of Chapter 5: Summary. A further activity involves the development and operation of a monitoring system that will allow water quality conditions to be tracked to ensure concentrations are not increasing and to evaluate the effectiveness of protection efforts.

Lake Huron provides drinking water to the largest number of people of the three water systems (lake, river, or groundwater). It also provides the majority of bathing recreation in the area and is a major attraction for tourism. The quality of the drinking water at the two water intakes indicate that it is of good water quality, and if the trends outlined stay constant, it would take more then twenty years for nitrate levels to approach the aquatic protection limit. However, it is clear that these intakes, especially Goderich, are under the influence of river contamination. A better understanding of the plume dynamics and other nearshore factors are necessary to determine the magnitude of pulses of contaminants that could reach the intakes.

It is clear that nearshore water quality in the vicinity of the intakes is being enriched by river water. It is not clear how bacteria are behaving in the nearshore; bacteria are subject to a number of additional processes that nitrate and phosphorus are not. Bacteria may be deposited by itself, and may be able to lumping that would affect water at the intake. It is currently understood that bacteria are able to survive and reproduce outside of a warm blooded animal. The presence of pathogens in the area is unknown, and should be considered a data gap.

Groundwater is the next largest source of drinking water in the area. Protection of existing water quality should be the focus. Naturally occurring elements are the greatest exceedance of ODWS and a better understanding of their distribution is necessary. Further work needs to be completed to understand the extent of karst conditions in the area and the impact on water quality. Also, the impact of river contaminants to bedrock water quality in those areas that have exposed bedrock should be quantified.

Local issues have occurred including contamination of some municipal groundwater supplies with nutrients as well as salt that do need to be addressed at a local scale. The analysis of the DWIS data will assist in determining those supplies with issues and the scope of the contaminants.

Consideration needs to be given to the potential time lag for surface water pathways to groundwater, especially bedrock aquifers. The water quality conditions discussed may not represent the impacts of current practices on groundwater quality and therefore provide a false sense of security. Monitoring networks need to be developed that attempt to intercept groundwater recharge that reflects the impact of current practices on groundwater quality.

Good surface water is required for the protection of aquatic ecosystems and is important to Lake and groundwater quality protection since it is the major pathway of contaminants to Lake Huron and may be a pathway to bedrock groundwater contamination. For nutrients and bacteria, surface water in most of the area is above guidelines and restoration work is required.

A better understanding is required around sources of nitrate by examining historic changes during the large nitrate increase, as well as quantifying atmospheric deposition. The presence of pathogens in surface water is unknown, and in order to determine the impact to drinking water supplies of Lake Huron intakes, this information is required. Sources and the cycling of heavy metals need to be investigated further, but at this point they are of a greater risk to the aquatic protection then to drinking water contamination.

2.6 Water Quantity

Water quantiy is not discussed in this document; it is dicussed further in the Conceptual Water Budget and the Tier 1 Water Budget. However, WC Map 2-6 and WC Map 2-7 show the permit-to-take-water (PTTW) by point location and the water use in the region, respectively. From these water budgets, it is determined that, overall, the Ausable Bayfield Maitland Valley Source Protection Region does not have water quantity stress. There may be local issues for private well owners if the water is located in a shallow aquifer, but no issues were identified for municipal drinking water sources. The exception occurs when a large business is established in the region, like the Greenfield Ethanol facility in Hensall. The total capacity of the Hensall drinking water system is 3231 m^3/day while projected maximum demands including the facility are 3600 m^3/day increasing to 4040 m^3/day by 2027 (B.M. Ross 2006). A new water line is being built between Hensall and Exeter to extend the water from the Lake Huron Primary Water System pipeline.

2.7 Knowledge and Data Gaps

The understanding of water quality in the Ausable Bayfield Maitland Valley Source Protection Region has been supported by comprehensive monitoring networks, both long term such as the PWQMN (Provincial Water Quality Monitoring Network), and newer such as the PGMN (Provincial Groundwater Monitoring Network). However, to better understand water quality issues to support drinking water source protection planning, there are gaps in data (spatially and in some indicators) as well as knowledge (information that helps determine relationships and make decisions). The following are key items of information that would assist in developing a local source protection plan:

Data

- *E.coli* concentrations in the MVCA watershed – lack of regular sampling locations for indicator bacteria.

- Use of Enterococci and coliphage as indicators for fecal pollution; their survival is consistent with both bacterial and viral pathogens, and it has been identified that *E. coli* dies off too rapidly.
- Site-specific sampling to determine the current state of water quality at historic locations identified in the report (e.g. Palmerston)
- Waste Water Treatment Plant discharge data and dates of plant modifications (in order to relate water quality conditions with potential sources, concentrations and volumes of discharge will be collected from municipalities). Information has been collected by the municipalities but has not been summarized.
- Types and concentrations of pathogens in the area
- No groundwater quality from certain aquifers (mostly overburden and out of Huron County)
- Raw water characterization of municipal drinking water supplies (data exists)
- New water quality sampling sites on headwater streams to further understand nutrient pathways
- No data on presence of or concentrations of pesticides and pesticide breakdown products
- Identification and remediation of brine wells associated with cross contamination of groundwater aquifers.
- Seasonal trends were not considered in the analysis; do not necessarily possess water discharge data for Varna, Parkhill, etc.

Knowledge

- Determine reasons for the increase in nitrate concentration generally seen throughout the 1970s. Determine reasons for currently increasing nitrate concentrations in the Bayfield River and Parkhill Creek.
- Determine reasons for the peak in chloride concentrations in the Maitland River at Goderich and Black Creek during the mid 1980s. Investigate if brine plant operation produces correlation.
- Research the changes in agricultural practices especially related to commercial fertilizers and the replacement of mixed farming with ‘cash cropping.’
- Further analysis to relate microbial data to nutrient concentrations.
- Research the dominant pathways for nutrients should be undertaken at a sub-basin scale to determine the best method for modifying or lengthening the time of travel in that area. Determine those agricultural practices that are most effective in reducing nutrient delivery to watercourses.
- Further analysis of heavy metal data to determine bioavailability and human or aquatic concerns.
- Fate and persistence of bacteria in riverine, groundwater and large lake systems.
- Dynamics of the outlet plume of the Maitland River in Lake Huron and its relationship to the Goderich water. Potential methods include the use of conductivity to define river plume under various environmental conditions.
- Areas of karst development and the effect of this feature on groundwater quality.

In summary, the water quality data and knowledge gaps that have a higher priority include: determining the reasons behind the increase of nitrates in the 1970s; determining the reasons behind the increase in nitrates in the Bayfield River; determining the relationship between nitrate and total phosphorous with respect to forest cover, row cropping, tile drainage density, commercial fertilizer use and *E. coli* concentration, and; determining the concentrations of nutrients, *E coli* and other contaminants in headwater systems compared to main channels using a more rigorous approach.

Planned Work
In this calendar year, a number of planned undertakings will assist in the understanding of water quality in the Ausable Bayfield Maitland Valley Source Protection Region. These include:

- Raw water characterization of municipal water intakes
- Waste Water Treatment Plant discharge data and dates of plant modifications
- Statistical analysis of riverine trends and comparison of sites
- Small tributary contribution of nutrients and bacteria through a shoreline hydrology project
- Continued monitoring of groundwater and riverine water quality
- Analysis of current monitoring network and monitoring recommendations
- Studies are currently underway in Goderich and Port Blake and include coastal geomorphology and nearshore bathymetry
- Fate and persistence of bacteria in riverine, groundwater and large lake systems through the Southeast Shore Working Group.

Monitoring Recommendations
In order to develop, implement and measure progress for drinking water source protection, good water quality data is necessary. Good data depends on proper site selection, collection methods and indicator choices.

Bacterial contamination is the biggest drinking water issue as some can be the cause of waterborne illnesses. There is a need to start testing for E. coli within the Maitland Valley Region, and to measure other pathogenic indicators within the entire Source Water Protection Planning Region. Understanding loading of small gully streams in the area around Port Blake is also a high priority.

The current monitoring system for riverine, groundwater, and Lake Huron will be evaluated and recommendation will be made on sites, sampling protocol and indicators. This will be completed once the raw water characterization and Intake Protection Zones in Lake Huron are developed. At that point, all the known water quality impairments will be identified.

Initial recommendations based on riverine water quality data are more monitoring of headwater sites, especially in the Maitland watershed due to the connection to the Goderich water intake. Shallow overburden aquifer information is also limited.

2.8 References

B.M. Ross and Associates Limited. 2002. A Study of *E.coli* Loads to Lake Huron in the Goderich Area. Pamela J. Kuipers.

B.M. Ross. 2006. Municipality of Bluewater Class Environmental Assessment for Water Supply Improvements Hensall Water Works.

Dean D. and M. Foran. 1989. The Effects of Farm Liquid Waster Application on Surface Water Quality: Interim Report. Ausable Bayfield Conservation Authority.

Golder Associates Ltd. 2001. Huron County Groundwater Quality Assessment.

Health Canada. 2005. What's In your Well? – A Guide to Well Water Treatment and Maintenance. http://www.hc-sc.gc.ca/ewh-semt/water-eau/drink-potab/well_water-eau_de_puits_e.html

Howell, T., S. Abernethy, M. Charlton, A. Crowe, T. Edge, H. House, C. Lofranco, J. Milne, P. Scharfe, R. Steele, S. Sweeney, S. Watson, S. Weir, A. Weselan, and M. Veliz. 2005. Sources and mechanisms of delivery of *E. coli* (bacteria) pollution to the Lake Huron shoreline of Huron County. 270p.

Martin, H. 2005. Manure Composting as a Pathogen Reduction Strategy. Ontario Ministry of Agricultural and Rural Affairs. http://www.omafra.gov.on.ca/english/engineer/facts/05-021.htm Accessed November 2, 2006

Nicholls, K. H., G. J. Hopkins, S. J. Standke and L. Nakamoto. 2001. Trends in total phosphorus in Canadian near-shore waters of the Laurentian Great Lakes: 1976 – 1999. J. Great Lakes Res. 27: 402- 422.

Ontario Ministry of the Environment, Lake Huron Science Committee's report. 2005. Sources and Mechanisms of Delivery of *E.coli* (bacteria) Pollution to the Lake Huron Shoreline of Huron County

Vannote, R. L. and B. W. Sweeney. 1980. Geographic analysis of thermal equilibria: A conceptual model for evaluating the effect of natural and modified thermal regimes on aquatic insect communities. Am. Nat. 112: 667-695.

Appendix A: Historic PWQMN summary data and graphs for chloride, copper, nitrate, total phosphorus, residue particulate, fecal coliform and *E. coli*

All riverine water quality stations in the Ausable Bayfield Maitland Valley Source Protection Region were examined using the methodology for temporal trends outlined in the report for the six chosen indicators (chloride, copper, nitrate, total phosphorus and bacteria). After the analysis, six sites were chosen to illustrate trends in the region and are in the body of the report. As well, notable exceptions of the trends were discussed and are presented again in Appendix B.

This appendix contains the exploratory graphs and summary statistics for the other sites. The data has been grouped into five year sections.

Sites with more than four years of data are summarized in the tables. Sites with more then ten years of data, with the range of years later then the seventies, are also summarized in graph form. Sites not meeting these criteria are not reported in this appendix.

Chloride - North, Little, South and Lower Maitland River and Nine Mile River

	Major Basin	Nine Mile		North Maitland						Little Maitland			South Maitland		Lower Maitland						
	Tributary			Upper				Salem Creek	Lower						Belgrave Creek	Blyth Brook		Sharpes Creek		Main Branch	
	MOE or local ID	08007600202	08007600102	08005600802	08005600702	08005602502	08005600402	08005605002	08005603802	08005600602	08005602202	08005603502	08005601502	08005603702	08005603002	08005604402	08005600202	08005602702	08005602802	08005600302	08005600102
	Site Name	Lucknow	Port Albert	Palmer_N	Harristn	Fordwich	Wroxeter	NMSalem	B-Line	Palmer	Palme_23	Jamestown	Londesbo	Summerhill	WNC_Belg	Blyth East	Blyth	Sharpes	SharpBen	Zetland	Goderich
1964-1965	n	1	1	6	2		1			1							5			22	27
	min	14.00	12.00	16.00	10.00		13.00			25.00							11.00			9.00	16.00
	max	14.00	12.00	30.00	14.00		13.00			25.00							28.00			540.00	696.00
	median	14.00	12.00	18.50	12.00		13.00			25.00							22.00			15.00	97.00
	25th			18.00	10.00												17.75			14.00	36.50
	75th			24.00	14.00												23.50			18.00	198.25
1966-1970	n	62	64	62	100		101			100							101			99	95
	min	1.00	1.00	6.00	2.00		1.00			5.00							3.00			7.00	3.00
	max	52.00	24.00	78.00	290.00		73.00			146.00							100.00			22.00	634.00
	median	15.00	13.00	16.00	12.00		11.00			40.00							9.00			11.00	79.00
	25th	11.00	10.00	14.00	10.00		9.00			31.50							8.00			10.00	27.50
	75th	18.00	14.00	19.00	15.50		13.00			52.00							12.25			15.00	174.50
1971-1975	n	59	64	51	66		66			29	32		51				69	7	7	67	102
	min	4.00	3.00	6.00	4.00		3.00			25.00	5.00		5.00				4.00	3.00	4.50	6.00	7.00
	max	38.00	22.00	42.00	116.00		20.00			120.00	24.00		72.00				142.00	14.00	14.00	29.00	511.00
	median	18.00	13.00	18.00	16.00		13.00			55.00	12.00		13.00				10.00	4.00	6.00	15.00	50.00
	25th	14.00	10.50	17.00	13.00		11.00			47.00	9.50		10.00				8.88	3.00	5.25	12.00	21.00
	75th	24.75	16.00	21.75	20.00		15.00			70.00	14.00		16.00				13.00	4.75	6.00	19.00	130.00
1976-1980	n	55	55		58		59			48	32		58		23		61	30	45	58	50
	min	8.00	7.00		8.00		8.00			9.50	7.50		6.50		7.50		6.00	2.50	4.50	3.50	6.00
	max	39.50	20.00		70.00		215.00			140.00	19.00		23.00		17.00		23.00	6.00	12.00	130.00	275.00
	median	20.00	14.00		14.50		14.50			42.00	10.00		13.25		11.00		11.50	3.50	7.00	14.75	16.50
	25th	14.25	11.63		11.50		11.63			32.50	9.50		10.50		9.13		9.00	3.00	6.00	12.00	13.00
	75th	22.88	16.88		17.00		16.50			54.75	11.75		15.50		13.13		14.00	4.00	7.50	17.50	28.50
1981-1985	n	58	56		59		59			58			58		35		58			56	38
	min	7.50	7.00		5.00		9.00			15.00			7.00		8.00		6.00			5.70	2.70
	max	35.50	22.00		110.00		710.00			112.00			33.00		37.50		31.00			395.00	475.00
	median	21.25	15.75		14.50		14.50			45.50			14.50		12.00		13.50			16.00	90.25
	25th	16.50	12.25		12.00		12.63			33.00			12.50		10.63		12.00			14.00	43.50
	75th	24.50	17.75		18.00		16.00			64.00			17.50		13.75		16.00			18.00	135.00
1986-1990	n	56	55		55		55			54		38	56				57			53	53
	min	6.99	7.27		0.14		8.78			18.50		10.27	11.00				9.00			5.20	14.46
	max	32.90	23.50		53.00		29.40			222.00		29.37	31.80				160.00			208.00	613.00
	median	21.65	15.50		16.50		17.20			52.75		17.90	16.45				12.90			18.00	99.00
	25th	18.00	14.38		14.23		14.93			40.33		15.50	14.40				11.00			16.23	63.96
	75th	27.55	19.38		23.21		18.45			75.00		20.40	19.00				14.63			21.00	219.25
1991-1995	n	52	50		43		42			43		38	42				41			42	40
	min	7.60	6.00		10.60		10.00			16.80		9.60	7.10				6.70			9.70	15.80
	max	55.50	77.80		44.60		179.00			137.00		29.30	35.50				28.30			83.60	318.00
	median	19.70	15.35		16.10		15.60			57.10		16.10	15.45				11.60			16.80	74.10
	25th	15.60	12.70		14.75		13.80			38.45		14.40	12.90				9.70			15.00	35.30
	75th	23.95	17.50		20.40		17.10			91.33		18.90	17.00				15.10			19.70	95.20
1996-2000	n	20	21									20					20			20	19
	min	9.80	10.00									18.00					10.40			14.80	13.00
	max	37.60	24.80									36.80					33.00			36.80	95.00
	median	25.60	19.20									26.70					18.60			23.90	38.00
	25th	22.90	15.75									23.00					15.00			23.00	31.10
	75th	30.90	22.20									33.70					23.90			30.20	66.65
2001-2005	n	41	41						16			41		17		14	42			41	41
	min	11.00	11.80						14.80			17.20		11.80		3.50	11.20			16.40	15.30
	max	31.10	24.60						54.90			30.60		21.90		9.90	28.50			34.50	91.70
	median	22.20	17.60						19.80			24.40		17.10		6.20	16.20			23.00	26.50
	25th	17.78	15.68						16.95			21.10		15.30		4.90	14.00			20.28	19.05
	75th	24.80	21.03						21.55			27.25		20.48		6.60	19.40			27.48	34.00

Chloride - Middle Maitland River

	Major Basin	Middle Maitland River																
	Tributary	Above Listowel		Chapman	Below Listowel				Boyle Drain		Beachamp	Lower Middle Maitland						
	MOE or local ID	08005601402	08005604302	08005602102	08005601302	08005600902	08005601902	08005602602	08005601002	08005602002	08005604102	08005601802	08005601102	08005600502	08005601602	08005603102	08005601702	08005603902
	Site Name	Listw_NE	NE Listowel	Chapman	Listowel	Trowbridge	Grey_Elm	Ethel	Milvertn	Henfryn	Beauchamp	Grey	Brusl_12	Brus_DSc	Brussl_D	Bruss_16	Morris	Wingham
1964-1965	n					2			5					1				
	min					11.00			13.00					12.00				
	max					24.00			306.00					12.00				
	median					17.50			94.00					12.00				
	25th					11.00			57.25									
	75th					24.00			178.50									
1966-1970	n					100			67				60	100				
	min					4.00			7.00				3.00	2.00				
	max					400.00			203.00				340.00	129.00				
	median					37.50			38.00				10.00	16.00				
	25th					18.00			22.25				8.00	10.50				
	75th					97.50			79.50				12.00	26.00				
1971-1975	n	52		33	52	67	35	7	53	33		33	21	60	45		33	
	min	5.00		12.00	4.00	5.00	4.00	7.50	8.00	4.00		5.00	5.00	6.00	7.00		5.00	
	max	160.00		140.00	510.00	367.00	149.00	43.00	370.00	54.00		169.00	243.00	105.00	128.00		79.00	
	median	26.50		84.00	59.50	63.00	25.00	17.00	54.00	14.00		17.00	15.00	33.00	19.00		16.00	
	25th	16.00		45.25	27.00	29.25	20.25	16.25	34.50	11.75		12.75	7.75	23.50	14.00		12.00	
	75th	50.50		109.00	198.50	155.00	57.50	33.25	99.75	17.25		30.00	31.00	49.50	32.00		21.25	
1976-1980	n	59			59	60			12					10	45	12		
	min	9.00			3.50	5.00			31.00					17.50	8.00	12.50		
	max	95.00			105.00	200.00			300.00					63.00	47.50	36.50		
	median	20.50			24.50	36.25			110.25					40.00	17.50	19.50		
	25th	16.63			19.13	24.00			64.25					28.00	15.00	13.75		
	75th	31.38			36.88	62.75			195.00					58.00	24.50	30.25		
1981-1985	n	36			60	59			59							58		
	min	12.00			9.50	13.00			12.50							9.00		
	max	275.00			58.50	260.00			250.00							37.00		
	median	20.50			24.00	32.00			68.50							17.75		
	25th	16.00			20.75	24.13			45.00							15.00		
	75th	28.75			31.00	46.75			109.50							21.00		
1986-1990	n				54	54			56	39						56		
	min				2.53	2.85			14.50	10.00						10.10		
	max				360.00	124.00			948.00	116.00						47.00		
	median				27.31	38.75			124.00	23.80						19.12		
	25th				20.50	26.00			79.86	21.05						16.60		
	75th				34.00	77.30			187.50	37.26						25.29		
1991-1995	n			1	42	43			42	39						42		
	min			24.90	10.50	10.20			12.70	9.10						9.20		
	max			24.90	160.00	142.00			444.00	39.00						58.60		
	median			24.90	27.05	37.40			102.00	19.00						18.75		
	25th				19.70	20.48			72.90	17.20						16.40		
	75th				47.00	57.58			159.00	23.08						22.20		
1996-2000	n				19	20		21		21								
	min				31.40	25.80		17.20		16.20								
	max				172.00	173.00		122.00		166.00								
	median				68.40	88.30		44.00		27.60								
	25th				43.05	55.30		31.70		25.25								
	75th				121.60	156.50		85.85		37.90								
2001-2005	n		14		24	42		24		41	17							17
	min		14.50		31.20	17.20		21.20		13.60	11.80							16.40
	max		33.60		195.00	189.00		118.00		68.80	21.20							58.60
	median		19.90		94.30	82.10		43.00		29.60	16.20							24.20
	25th		18.20		62.10	53.60		38.10		25.45	15.00							20.70
	75th		22.40		176.00	133.00		73.55		34.65	17.38							35.93

Chloride - Bayfield River and Parkhill Creek

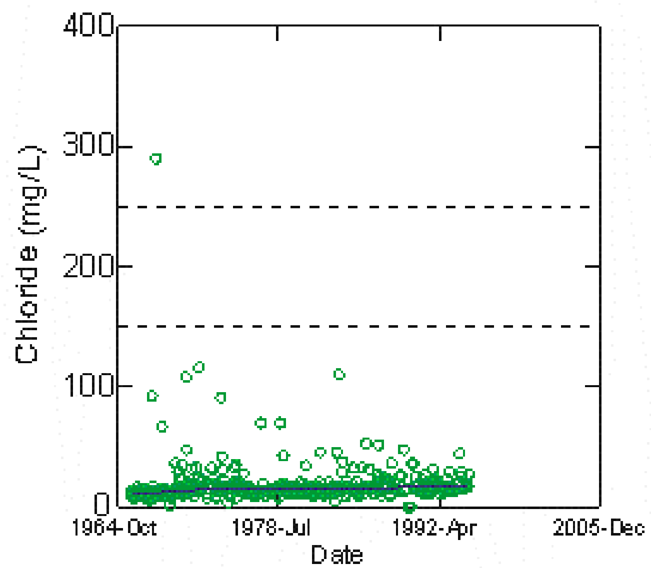
	Major Basin	Bayfield River														Parkhill Creek							
	Tributary	Bannockburn	Liffy Ditch			Silver Creek		Upper Bayfield			Steenstra	Lower Bayfield				Upper Parkhill					Tributary	Lower Parkhill	
	MOE or local ID	MBBAN1	HBLIF1	08004000402	08004000502	08004001102	08004000302	08004000202	08004000902	08004000602	HBSTEEN1	08004001002	08004000802	08004000102	08004000783	08002200302	MPMCGUF1	08002200402	08002200902	08002201202	08002201802	08002201302	08002200102
	Site Name	Bannockburn	Dublin	HBLIF2	HBLIF3	Silver	MBSILV1	Seaforth	MBHAN1	MBCLIN2	Steenstra	MBGRANT	Varna	MBBAY1	MBBAY2	HPCAM	Upstream Parkhill	MPDAM	MPHARM	Downstream Parkhill	MPTRI1	MPGBEND2	MPGBEND1
1964-1965	n			5	5		5	5						5		5		5					5
	min			10.00	11.00		21.00	13.00						11.00		53.00		12.00					6.00
	max			170.00	179.00		59.00	55.00						19.00		270.00		70.00					21.00
	median			42.00	53.00		50.00	43.00						15.00		217.00		24.00					11.00
	25th			22.00	25.25		42.00	23.50						12.50		175.25		15.00					9.00
	75th			147.50	89.75		56.75	46.75						16.00		237.00		49.00					19.50
1966-1970	n			63	65		65	65						64		73		13	56				70
	min			1.00	5.00		2.00	2.00						2.00		13.00		3.00	5.00				5.00
	max			115.00	98.00		236.00	87.00						40.00		233.00		177.00	80.00				77.00
	median			11.00	13.00		31.00	16.00						13.50		49.00		10.00	14.00				10.00
	25th			9.00	9.00		22.00	13.00						11.00		38.00		7.75	10.00				8.00
	75th			20.25	23.00		46.50	28.25						17.00		90.00		18.75	22.00				15.00
1971-1975	n			9	45		48	46	6	35			6	57	23	52			15	36		29	63
	min			6.00	7.00		17.00	9.00	22.00	12.00			13.00	7.00	9.00	12.00			8.00	6.00		8.00	5.00
	max			72.00	86.00		88.00	92.00	30.00	56.00			23.00	26.00	34.00	86.00			38.00	40.00		27.00	36.00
	median			15.00	23.00		41.00	26.50	24.50	25.00			19.00	14.00	13.00	44.50			15.00	14.00		13.00	12.00
	25th			11.75	15.75		28.00	20.00	23.00	19.25			17.00	11.00	11.00	32.50			9.50	12.00		11.00	9.00
	75th			47.00	37.00		65.50	56.00	27.00	34.75			21.00	16.00	14.75	64.00			16.75	17.50		15.25	15.00
1976-1980	n								59	59		32	62							11		60	
	min								7.00	6.50		7.00	7.00							18.50		8.50	
	max								80.00	63.50		29.00	47.00							35.00		80.00	
	median								25.00	27.50		18.50	18.00							21.50		21.00	
	25th								20.25	21.50		14.50	14.00							20.13		16.75	
	75th								36.25	34.88		21.00	22.00							27.88		25.50	
1981-1985	n					34			59	58			59							60		58	
	min					11.00			9.50	10.00			10.50							10.50		11.50	
	max					63.00			65.00	43.00			30.50							71.50		75.50	
	median					27.25			24.00	24.25			19.00							20.00		21.75	
	25th					22.00			20.63	22.00			17.13							17.25		17.50	
	75th					32.50			28.88	31.00			21.38							23.00		25.50	
1986-1990	n					56			55	56			57							58		55	
	min					10.00			12.00	12.00			11.00							11.50		8.57	
	max					67.80			98.30	112.00			58.20							46.35		43.40	
	median					29.25			27.78	31.00			25.00							22.30		22.60	
	25th					25.37			21.50	23.89			21.88							18.90		19.93	
	75th					38.85			36.48	36.05			28.86							25.10		25.75	
1991-1995	n					48			44	47			49							51		45	
	min					10.40			10.30	10.60			9.90							11.20		13.90	
	max					62.30			162.00	79.50			41.00							50.20		43.80	
	median					28.15			27.40	27.70			23.10							20.10		24.00	
	25th					23.80			21.20	21.35			19.35							17.53		20.48	
	75th					42.55			36.05	38.43			27.18							24.88		26.48	
1996-2000	n								7				7							26	7		
	min								19.40				13.20							18.70	13.60		
	max								46.40				29.80							40.90	30.60		
	median								23.00				21.40							24.15	19.40		
	25th								21.85				18.95							20.10	17.30		
	75th								38.05				25.80							28.00	25.45		
2001-2005	n							26	15				60								15		
	min							14.70	18.40				13.40								21.50		
	max							76.90	188.00				35.40								34.80		
	median							25.65	36.00				23.50								23.80		
	25th							22.30	29.50				20.55								22.45		
	75th							35.40	92.43				26.30								28.35		

Chloride - Ausable River

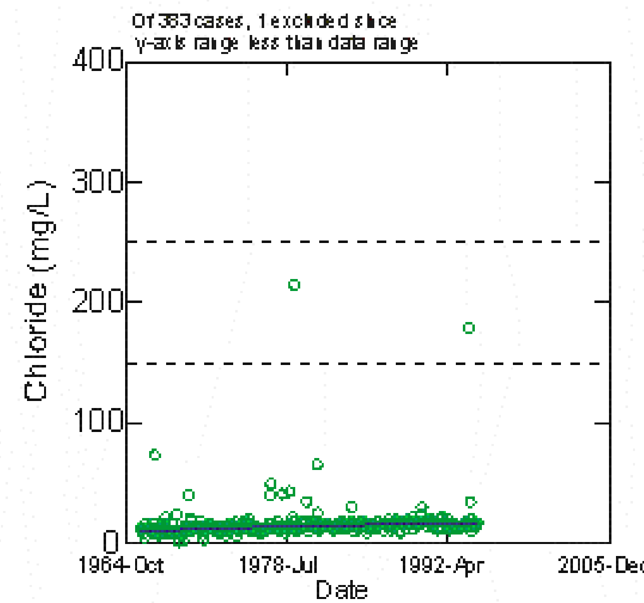
	Major Basin	Ausable															
	Tributary	Black Creek	Little Ausable River		Nairn Creek	Ausable River								Decker Creek		The Cut	
	MOE or local ID	08002200702	08002201402	08002201002	MANAIRN1	08002200802	08002201702	08002200602	08002201602	08002200502	08002201102	08002202002	08002201502	08002201902	08002200202	08002100202	08002100102
	Site Name	Black	Huron Park	Lucan	Nairn	Staffa	MAMOR2	MATHAMES	Exeter	HATRIB	MAMTCARM	Springbank	MAGLAS1	Decker	MADECK3	Thedford	MAWAL
1964-1965	n																
	min																
	max																
	median																
	25th																
	75th																
1966-1970	n	69		23		68		71		69					70		
	min	15.00		8.00		5.00		4.00		2.00					10.00		
	max	236.00		33.00		62.00		910.00		35.00					100.00		
	median	67.00		14.00		10.50		21.00		7.00					30.00		
	25th	47.25		11.00		8.50		13.25		6.00					21.00		
	75th	93.50		19.75		13.00		68.50		9.25					57.00		
1971-1975	n	58	103	57		52	21	52	6	17	42		1		58		39
	min	8.00	6.90	5.00		7.00	8.00	8.00	9.00	2.00	9.00		20.00		11.00		9.00
	max	117.00	196.00	42.00		28.00	18.00	862.00	175.00	9.00	240.00		20.00		83.00		46.00
	median	15.00	16.00	13.00		13.00	11.00	29.50	37.00	7.00	25.00		20.00		41.50		15.00
	25th	12.00	13.50	10.00		11.50	10.00	17.00	21.00	6.00	17.00				26.00		13.00
	75th	46.00	19.50	19.00		15.00	13.25	153.50	65.00	8.00	34.00				59.00		18.00
1976-1980	n	59	324	57			61		60		58				59		42
	min	7.00	5.00	6.00			0.18		6.50		7.00				17.00		9.00
	max	35.00	39.00	50.50			22.50		230.00		38.50				130.00		30.50
	median	15.50	14.00	17.00			13.00		21.50		19.00				43.50		15.50
	25th	13.00	11.00	14.75			11.50		17.00		16.00				36.13		13.50
	75th	19.75	15.75	20.13			15.50		32.00		22.50				65.00		20.00
1981-1985	n	60		57			60	1	58		59				57	36	
	min	10.50		12.00			9.00	20.50	9.50		10.00				9.50	10.00	
	max	39.50		37.50			93.00	20.50	108.00		48.50				84.50	45.00	
	median	18.25		20.00			16.00	20.50	20.75		19.50				37.00	19.25	
	25th	16.00		16.88			14.50		18.00		18.00				26.25	16.25	
	75th	21.00		23.13			17.75		27.00		22.50				50.63	22.75	
1986-1990	n	56		55			56		57		53				56	49	
	min	8.50		8.50			3.00		12.00		10.00				20.00	10.50	
	max	60.40		67.50			30.91		111.00		40.45				133.00	38.66	
	median	22.62		23.00			16.87		27.00		23.50				69.25	20.49	
	25th	18.33		20.28			14.75		20.86		19.95				54.95	19.50	
	75th	29.00		27.17			20.20		36.05		28.25				83.85	24.09	
1991-1995	n	48		47			49		44		45				49	80	
	min	11.00		13.20			9.10		10.20		9.70				43.70	13.60	
	max	66.00		50.80			24.80		148.00		61.00				618.00	64.70	
	median	20.20		22.50			16.50		22.45		20.10				93.90	21.05	
	25th	17.10		18.50			15.08		19.40		17.95				68.45	19.15	
	75th	27.05		27.70			17.93		39.10		22.18				150.25	24.15	
1996-2000	n	7		7					7					7		31	
	min	12.60		12.80					13.80					28.80		7.80	
	max	80.40		31.00					48.00					48.60		31.20	
	median	22.00		25.40					25.60					39.60		19.00	
	25th	17.95		16.95					18.80					33.20		18.05	
	75th	32.25		26.15					43.15					41.05		21.75	
2001-2005	n	41	17	41					41			26		41		40	
	min	14.60	17.60	17.00					18.80			14.10		30.20		12.40	
	max	182.00	47.80	50.40					192.00			41.20		77.80		40.30	
	median	21.30	27.00	28.40					39.30			29.20		49.80		27.00	
	25th	18.88	23.50	23.88					27.43			25.60		41.58		23.75	
	75th	27.80	30.98	33.30					53.93			31.80		57.25		29.70	

North Maitland

Harriston
08005600702

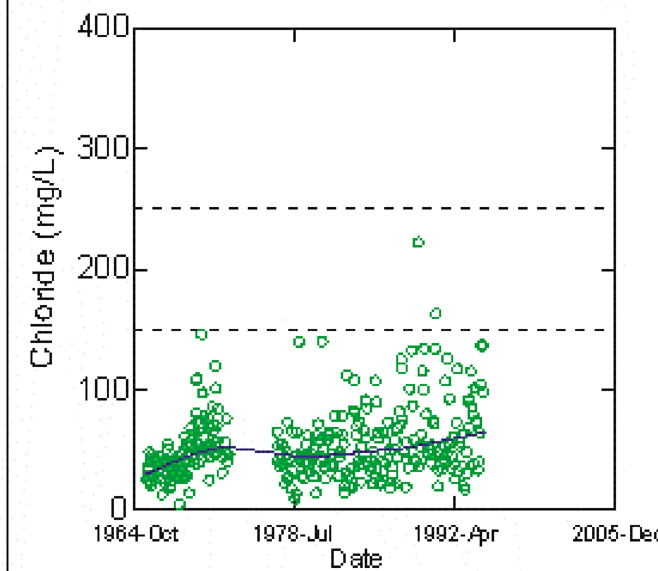


Wroxeter
08005600402

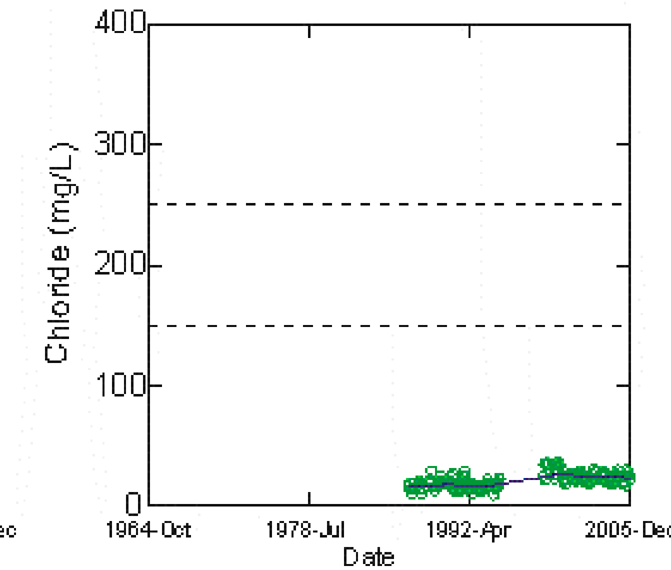


Little Maitland

Palmer
08005600602

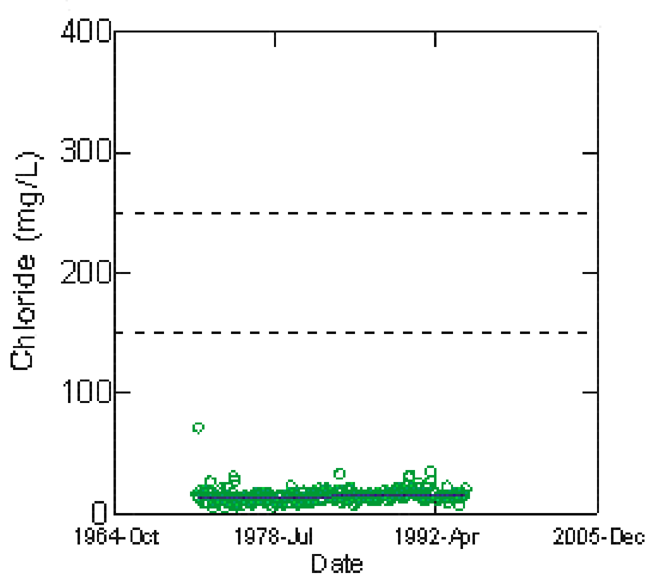


Jamestown
08005603502



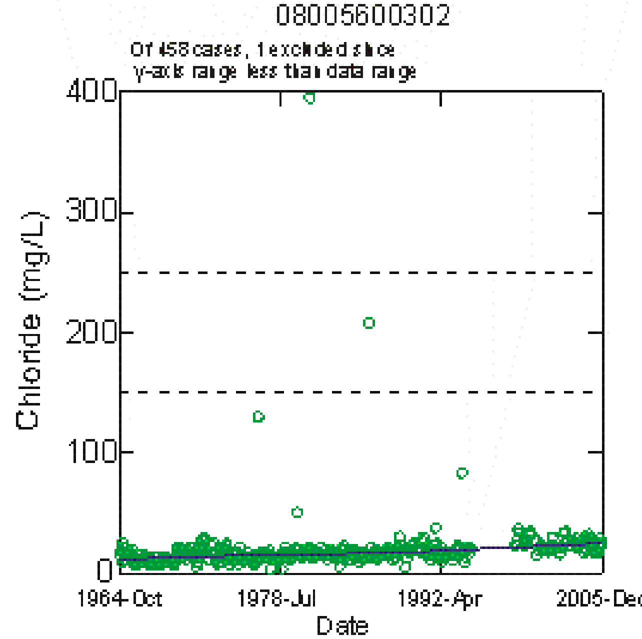
South Maitland

Londesborough
08005601502



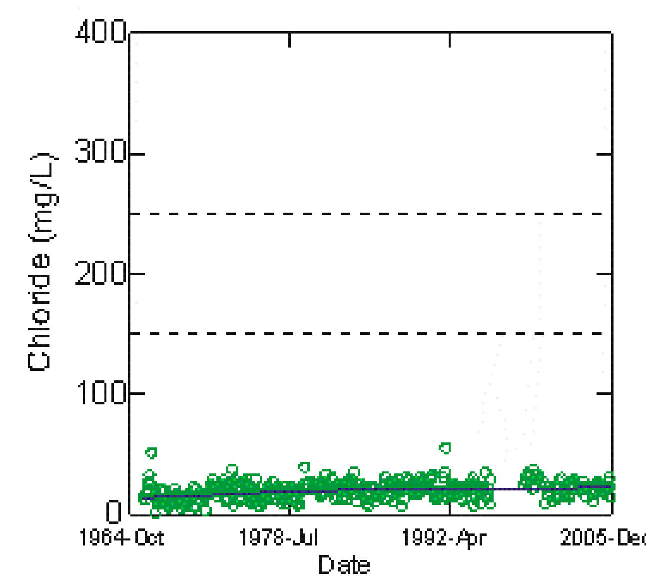
Lower Maitland

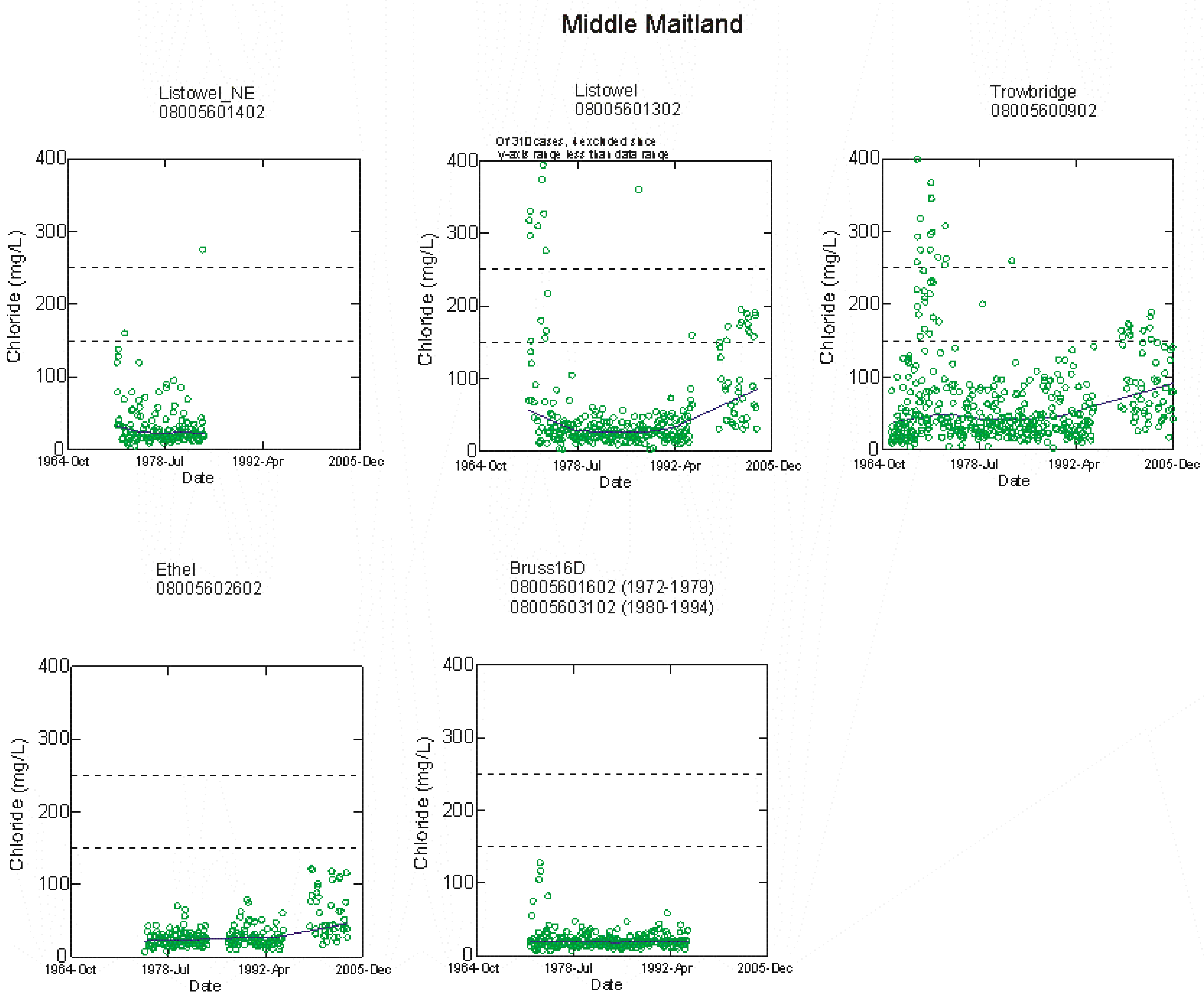
Zetland
08005600302

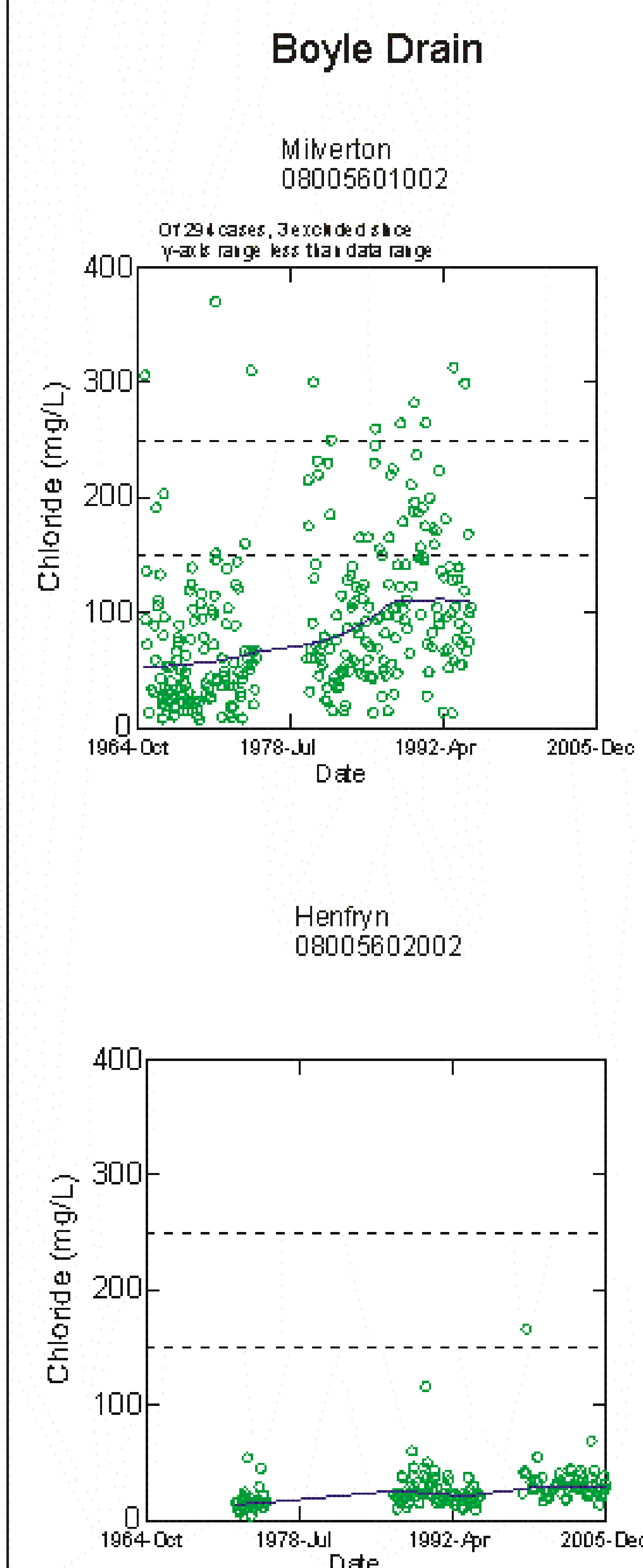


Nine Mile

Lucknow
08007600202

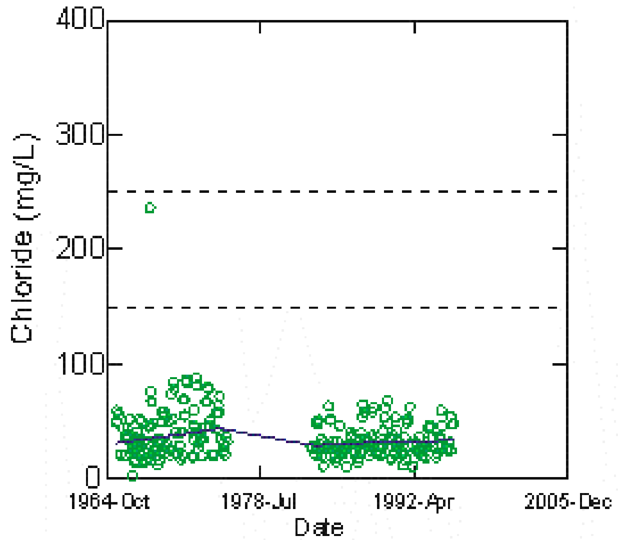



Middle Maitland
Listowel_NE
08005601402
Listowel
08005601302
Of 310 cases, 4 excluded since y-axis range less than data range
Trowbridge
08005600902
Ethel
08005602602
Bruss16D
08005601602 (1972-1979)
08005603102 (1980-1994)
Chloride (mg/L)
0
100
200
300
400
1964-Oct
1978-Jul
1992-Apr
2005-Dec
Date

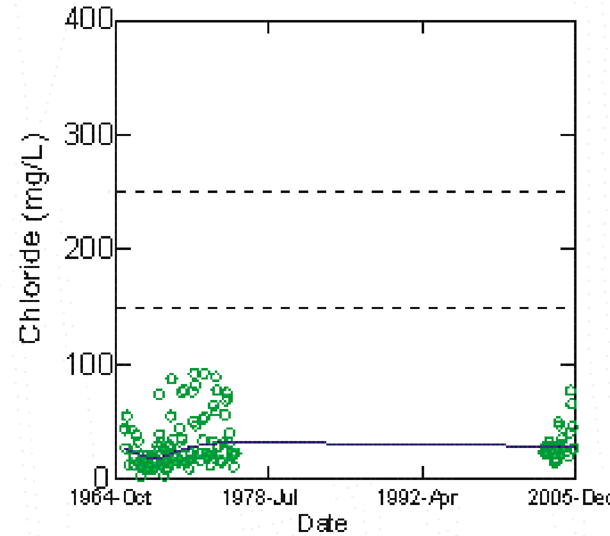

Boyle Drain
Milverton
08005601002
Of 294 cases, 3 excluded since y-axis range less than data range
Henfryn
08005602002
Chloride (mg/L)
0
100
200
300
400
1964-Oct
1978-Jul
1992-Apr
2005-Dec
Date

Bayfield River

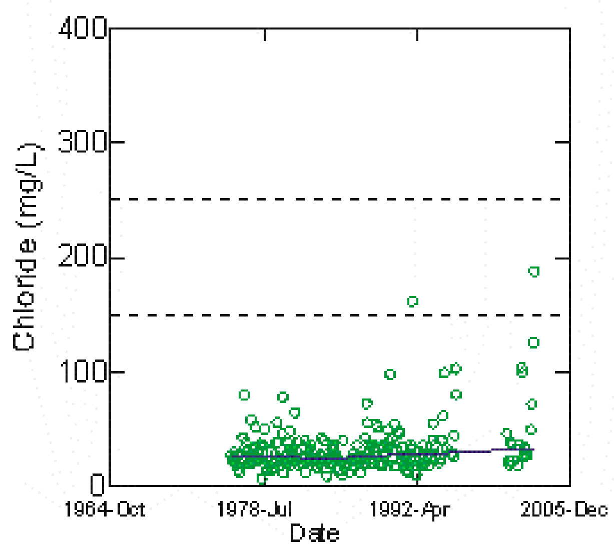
MBSILV1&2 (Silver Creek)
08004000302 (1965-1975)
08004001102 (1983-2005)



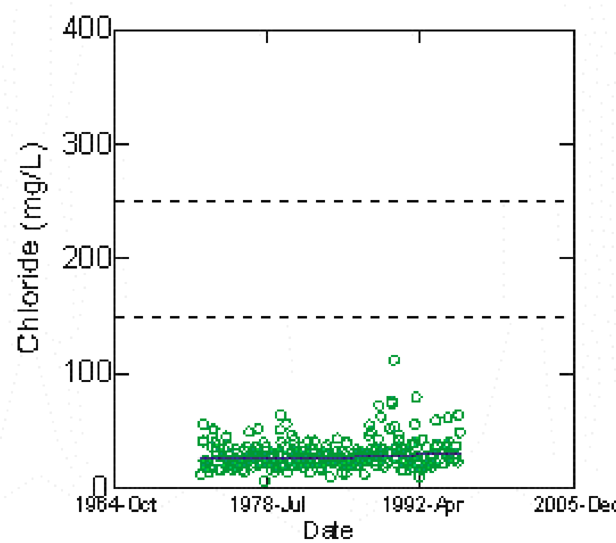
MBSEA1
08004000202



MBHAN1
08004000902

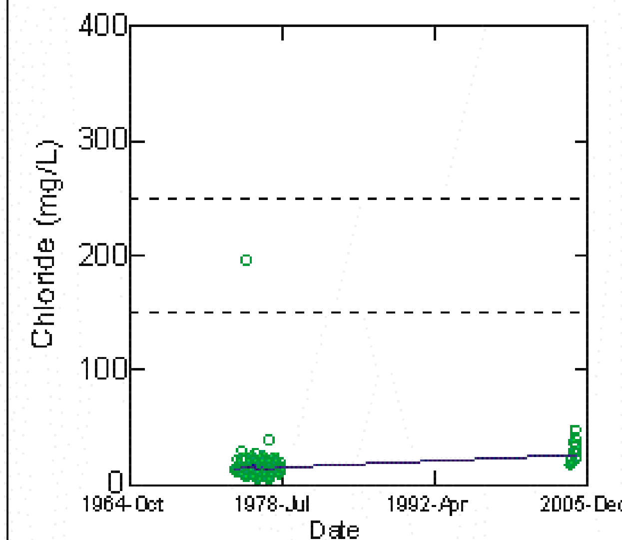


MBCLIN2
08004000602

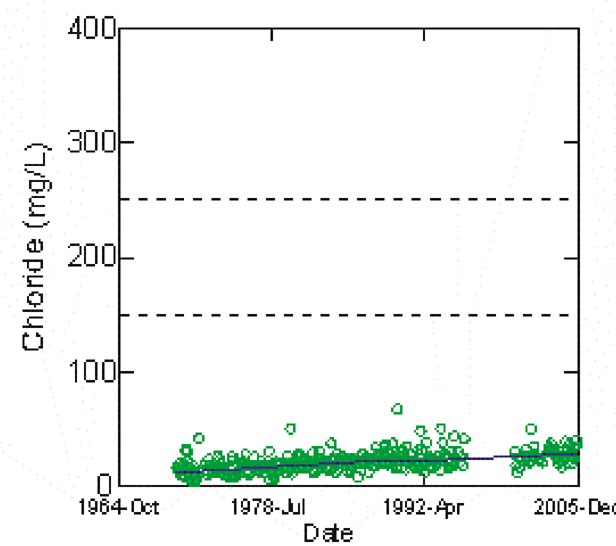


Little Ausable

ABCA14
08002201402

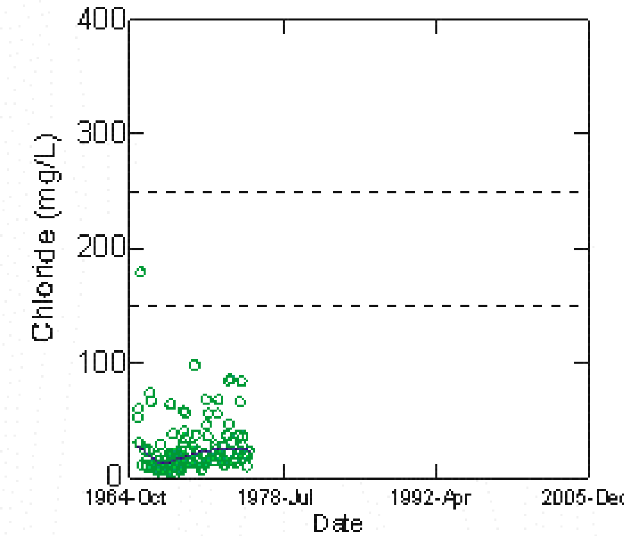


MALIT2
08002201002

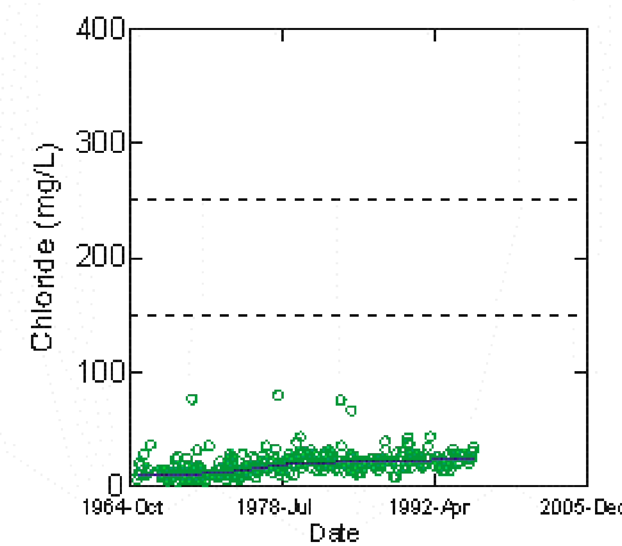


Parkhill Creek

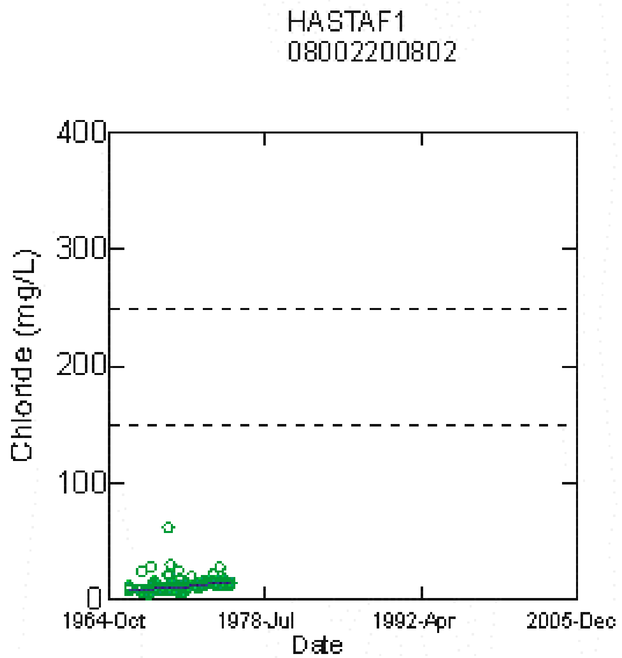
HBLIF3
08004000502

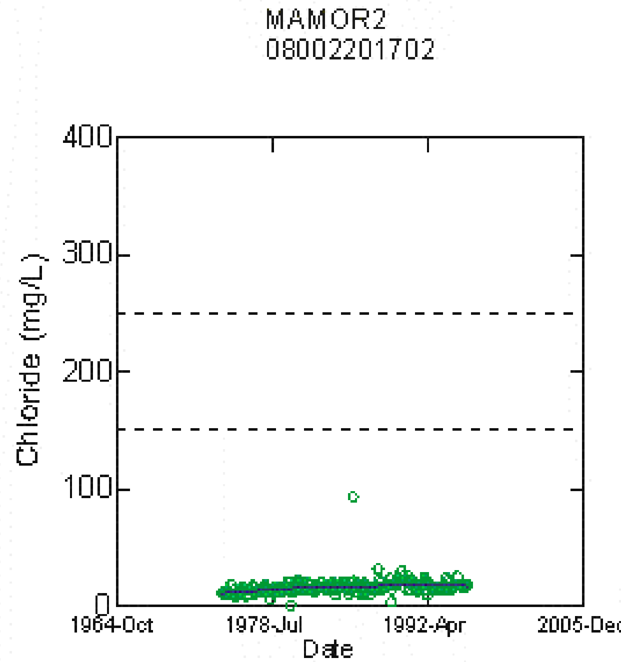


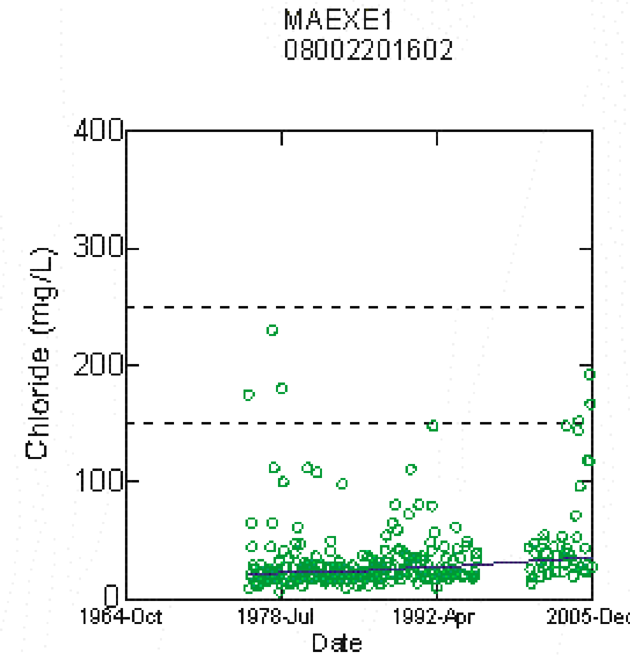
MPGBEND1&2
08002200102 (1965-1975)
08002201302 (1974-1995)

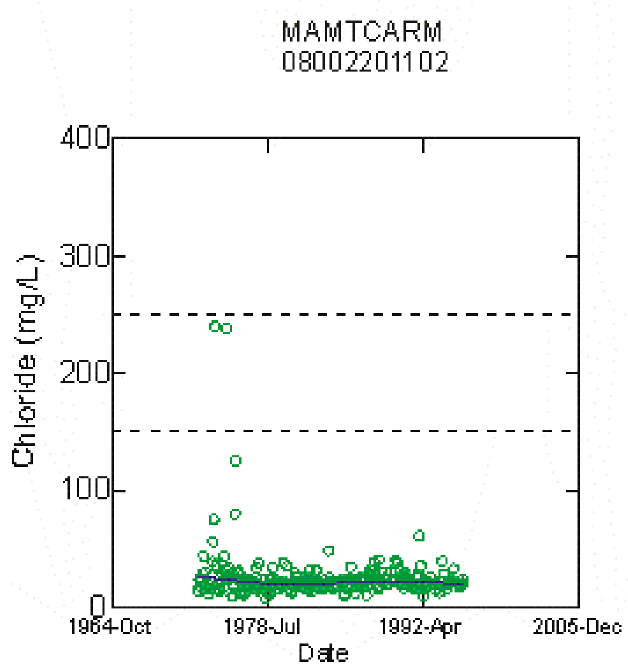


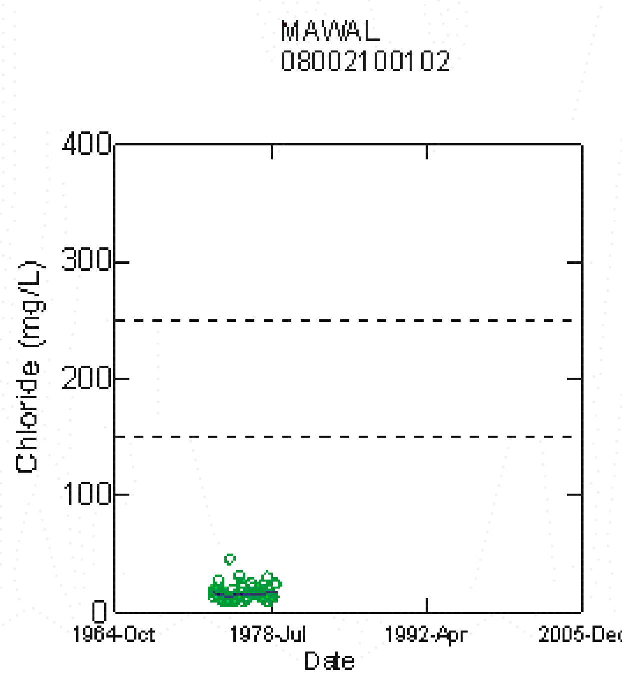
Ausable River



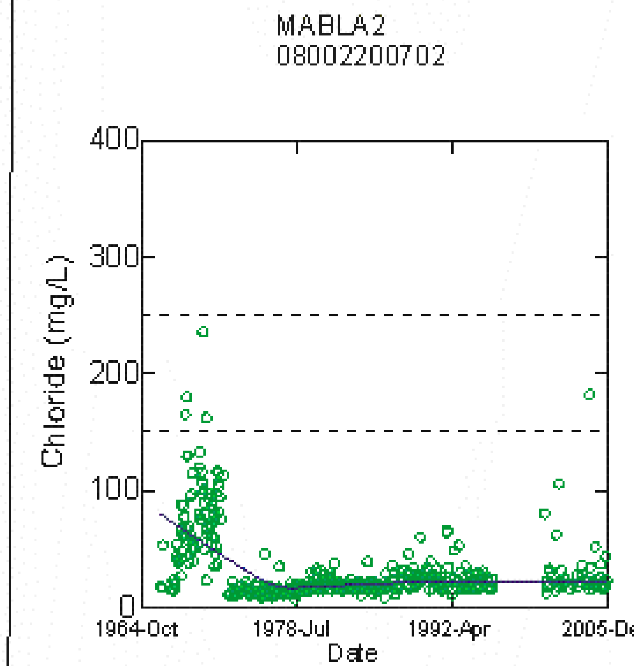




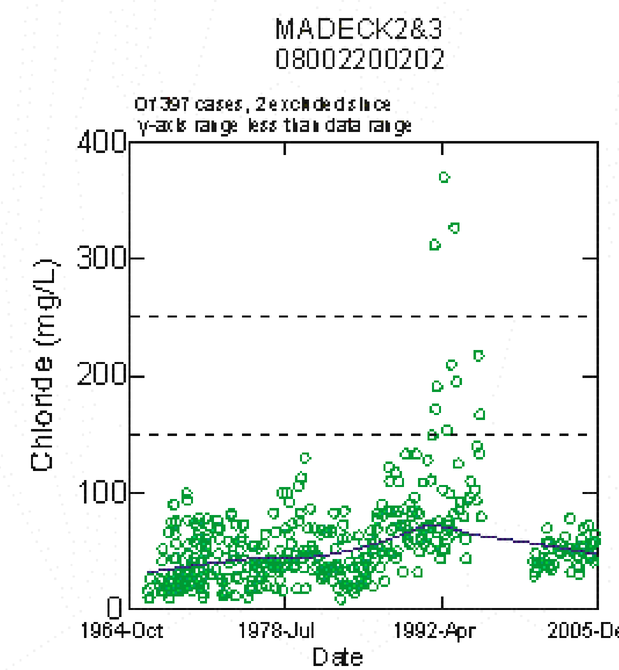




Black Creek



Decker Creek



Copper - North, Little, South and Lower Maitland River and Nine Mile River

	Major Basin	Nine Mile		North Maitland						Little Maitland			South Maitland		Lower Maitland						
	Tributary			Upper				Salem Creek	Lower						Belgrave Creek	Blyth Brook		Sharpes Creek		Main Branch	
	MOE or local ID	08007600202	08007600102	08005600802	08005600702	08005602502	08005600402	08005605002	08005603802	08005600602	08005602202	08005603502	08005601502	08005603702	08005603002	08005604402	08005600202	08005602702	08005602802	08005600302	08005600102
	Site Name	Lucknow	Port Albert	Palmer_N	Harristn	Fordwich	Wroxeter	NMSalem	B-Line	Palmer	Palme_23	Jamestown	Londesbo	Summerhill	WNC_Belg	Blyth East	Blyth	Sharpes	SharpBen	Zetland	Goderich
1964-1965	n																				
	min																				
	max																				
	median																				
	25th																				
	75th																				
1966-1970	n																				
	min																				
	max																				
	median																				
	25th																				
	75th																				
1971-1975	n		5																		4
	min		0.050																		0.030
	max		0.050																		0.050
	median		0.050																		0.050
	25th		0.050																		0.040
	75th		0.050																		0.050
1976-1980	n																				26
	min																				0.001
	max																				0.070
	median																				0.010
	25th																				0.010
	75th																				0.010
1981-1985	n		32		34					33			33							30	50
	min		0.001		0.002					0.003			0.001							0.001	0.001
	max		0.047		0.062					0.022			0.240							0.012	0.023
	median		0.007		0.004					0.006			0.007							0.003	0.006
	25th		0.005		0.003					0.004			0.003							0.002	0.004
	75th		0.010		0.010					0.010			0.010							0.009	0.009
1986-1990	n		44		48					49			49							47	49
	min		0.001		0.001					0.001			0.001							0.001	0.001
	max		0.088		0.011					0.027			0.450							0.007	0.023
	median		0.002		0.002					0.004			0.002							0.002	0.002
	25th		0.002		0.002					0.003			0.002							0.002	0.002
	75th		0.004		0.003					0.005			0.004							0.003	0.003
1991-1995	n		44		43					44			44							43	45
	min		0.001		0.001					0.001			0.001							0.001	0.001
	max		0.005		0.003					0.080			0.004							0.003	0.003
	median		0.001		0.001					0.002			0.001							0.001	0.001
	25th		0.001		0.001					0.002			0.001							0.001	0.001
	75th		0.001		0.001					0.003			0.001							0.002	0.002
1996-2000	n	21	20									19					20			19	21
	min	-0.003	-0.002									-0.002					0.000			-0.002	-0.002
	max	0.007	0.002									0.002					0.034			0.006	0.002
	median	0.001	0.001									0.001					0.001			0.001	0.001
	25th	0.000	0.000									0.000					0.001			0.000	0.000
	75th	0.001	0.001									0.001					0.001			0.001	0.001
2001-2005	n	41	41						16			41		17			42			41	41
	min	0.000	0.000						0.000			0.000		0.000			0.000			0.000	0.000
	max	0.004	0.004						0.002			0.004		0.002			0.008			0.005	0.004
	median	0.001	0.001						0.001			0.001		0.001			0.001			0.001	0.001
	25th	0.001	0.001						0.001			0.001		0.001			0.001			0.001	0.001
	75th	0.001	0.001						0.001			0.002		0.001			0.002			0.002	0.001

Copper - Middle Maitland River

	Major Basin	Middle Maitland River																
	Tributary	Above Listowel		Chapman	Below Listowel				Boyle Drain		Beachamp	Lower Middle Maitland						
	MOE or local ID	08005601402	08005604302	08005602102	08005601302	08005600902	08005601902	08005602602	08005601002	08005602002	08005604102	08005601802	08005601102	08005600502	08005601602	08005603102	08005601702	08005603902
	Site Name	Listw_NE	NE Listowel	Chapman	Listowel	Trowbridge	Grey_Elm	Ethel	Milvertn	Henfryn	Beauchamp	Grey	Brusl_12	Brus_DSc	Brussl_D	Bruss_16	Morris	Wingham
1964-1965	n																	
	min																	
	max																	
	median																	
	25th																	
	75th																	
1966-1970	n																	
	min																	
	max																	
	median																	
	25th																	
	75th																	
1971-1975	n																	
	min																	
	max																	
	median																	
	25th																	
	75th																	
1976-1980	n																	
	min																	
	max																	
	median																	
	25th																	
	75th																	
1981-1985	n					34			34					1		34		
	min					0.001			0.002					0.012		0.001		
	max					0.017			0.020					0.012		0.020		
	median					0.004			0.005					0.012		0.004		
	25th					0.003			0.003							0.003		
	75th					0.010			0.010							0.009		
1986-1990	n					49			51							49		
	min					0.001			0.001							0.001		
	max					0.016			0.014							0.027		
	median					0.003			0.004							0.003		
	25th					0.002			0.003							0.002		
	75th					0.003			0.005							0.003		
1991-1995	n					43			42							44		
	min					0.001			0.001							0.001		
	max					0.004			0.012							0.003		
	median					0.001			0.001							0.001		
	25th					0.001			0.001							0.001		
	75th					0.002			0.002							0.002		
1996-2000	n				20	19		21		21								
	min				0.000	0.000		-0.002		-0.001								
	max				0.007	0.012		0.004		0.004								
	median				0.001	0.001		0.001		0.002								
	25th				0.001	0.001		0.001		0.001								
	75th				0.002	0.002		0.002		0.002								
2001-2005	n				24	41		24		41	17							17
	min				0.001	0.001		0.001		0.001	0.000							0.001
	max				0.014	0.005		0.004		0.005	0.004							0.003
	median				0.002	0.001		0.002		0.002	0.001							0.001
	25th				0.001	0.001		0.001		0.001	0.001							0.001
	75th				0.003	0.002		0.002		0.002	0.002							0.002

Copper - Bayfield River and Parkhill Creek

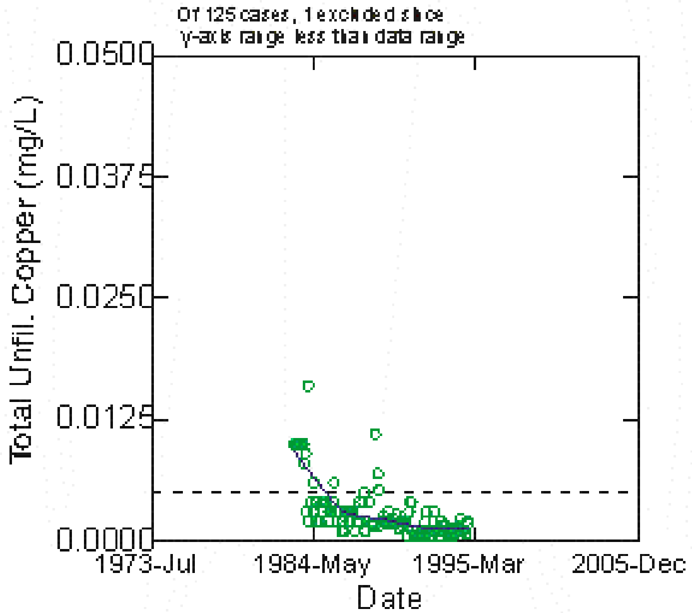
	Major Basin	Bayfield River														Parkhill Creek							
	Tributary	Bannockburn	Liffy Ditch			Silver Creek		Upper Bayfield			Steenstra	Lower Bayfield				Upper Parkhill					Tributary	Lower Parkhill	
	MOE or local ID	MBBAN1	HBLIF1	08004000402	08004000502	08004001102	08004000302	08004000202	08004000902	08004000602	HBSTEEN1	08004001002	08004000802	08004000102	08004000783	08002200302	MPMCGUF1	08002200402	08002200902	08002201202	08002201802	08002201302	08002200102
	Site Name	Bannockburn	Dublin	HBLIF2	HBLIF3	Silver	MBSILV1	Seaforth	MBHAN1	MBCLIN2	Steenstra	MBGRANT	Varna	MBBAY1	MBBAY2	HPCAM	Upstream Parkhill	MPDAM	MPHARM	Downstream Parkhill	MPTRI1	MPGBEND2	MPGBEND1
1964-1965	n																						
	min																						
	max																						
	median																						
	25th																						
	75th																						
1966-1970	n																						
	min																						
	max																						
	median																						
	25th																						
	75th																						
1971-1975	n													1	3							2	1
	min													0.030	0.050							0.050	0.050
	max													0.030	0.070							0.050	0.050
	median													0.030	0.050							0.050	0.050
	25th														0.050							0.050	
	75th														0.065							0.050	
1976-1980	n																					5	
	min																					0.010	
	max																					0.040	
	median																					0.010	
	25th																					0.010	
	75th																					0.025	
1981-1985	n								34	34			34							32		34	
	min								0.001	0.001			0.001							0.002		0.001	
	max								0.050	0.031			0.040							0.020		0.020	
	median								0.003	0.004			0.005							0.005		0.007	
	25th								0.003	0.003			0.002							0.004		0.005	
	75th								0.010	0.010			0.010							0.006		0.010	
1986-1990	n								57	56			58							59		56	
	min								0.001	0.001			0.001							0.001		0.001	
	max								0.011	0.020			0.009							0.020		0.018	
	median								0.003	0.003			0.002							0.004		0.004	
	25th								0.002	0.002			0.002							0.003		0.003	
	75th								0.004	0.004			0.003							0.005		0.006	
1991-1995	n								44	46			49							50		44	
	min								0.001	0.001			0.000							0.001		0.000	
	max								0.006	0.009			0.008							0.004		0.006	
	median								0.001	0.001			0.001							0.002		0.003	
	25th								0.001	0.001			0.001							0.002		0.003	
	75th								0.002	0.002			0.002							0.003		0.004	
1996-2000	n								7				7								7		
	min								0.001				0.000								0.003		
	max								0.003				0.007								0.004		
	median								0.002				0.002								0.003		
	25th								0.002				0.001								0.003		
	75th								0.003				0.004								0.004		
2001-2005	n							26	14				50							26	14		
	min							0.000	0.000				0.000							0.001	0.002		
	max							0.002	0.003				0.005							0.004	0.004		
	median							0.001	0.002				0.001							0.002	0.003		
	25th							0.001	0.001				0.001							0.002	0.002		
	75th							0.001	0.002				0.002							0.002	0.004		

Copper - Ausable River

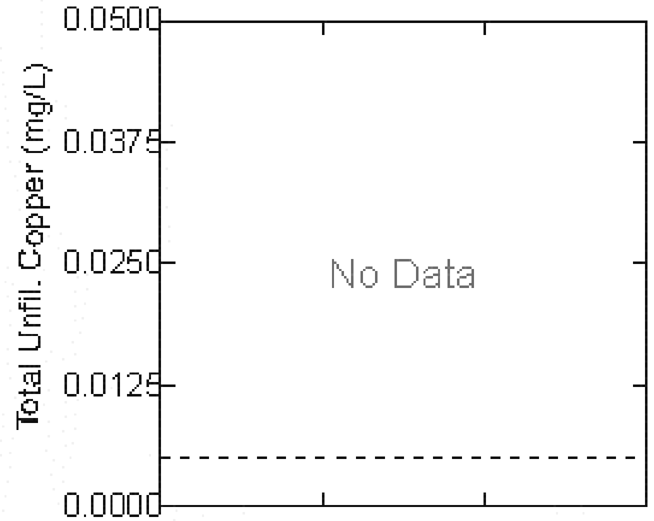
	Major Basin	Ausable															
	Tributary	Black Creek	Little Ausable River		Nairn Creek	Ausable River								Decker Creek		The Cut	
	MOE or local ID	08002200702	08002201402	08002201002	MANAIRN1	08002200802	08002201702	08002200602	08002201602	08002200502	08002201102	08002202002	08002201502	08002201902	08002200202	08002100202	08002100102
	Site Name	Black	Huron Park	Lucan	Nairn	Staffa	MAMOR2	MATHAMES	Exeter	HATRIB	MAMTCARM	Springbank	MAGLAS1	Decker	MADECK3	Thedford	MAWAL
1964-1965	n																
	min																
	max																
	median																
	25th																
	75th																
1966-1970	n																
	min																
	max																
	median																
	25th																
	75th																
1971-1975	n		102										1				4
	min		0.001										0.006				0.050
	max		0.130										0.006				0.110
	median		0.009										0.006				0.050
	25th		0.004														0.050
	75th		0.021														0.080
1976-1980	n		81														31
	min		0.001														0.001
	max		0.038														0.120
	median		0.003														0.010
	25th		0.002														0.010
	75th		0.004														0.010
1981-1985	n	36		31				1	33		34				33	295	26
	min	0.001		0.001				0.003	0.002		0.003				0.001	0.001	0.003
	max	0.021		0.034				0.003	0.029		0.030				0.020	0.120	0.074
	median	0.003		0.005				0.003	0.003		0.004				0.006	0.006	0.009
	25th	0.002		0.004					0.002		0.003				0.004	0.004	0.006
	75th	0.007		0.010					0.010		0.006				0.010	0.010	0.012
1986-1990	n	58		56					58		54				56	243	
	min	0.001		0.001					0.001		0.001				0.001	0.001	
	max	0.007		0.025					0.006		0.050				0.032	0.043	
	median	0.003		0.003					0.003		0.004				0.005	0.004	
	25th	0.002		0.002					0.002		0.003				0.003	0.003	
	75th	0.004		0.003					0.003		0.005				0.006	0.005	
1991-1995	n	48		47				1	43		43				47	235	
	min	0.000		0.000				0.001	0.001		0.001				0.001	0.001	
	max	0.005		0.005				0.001	0.003		0.004				0.014	0.010	
	median	0.001		0.001				0.001	0.001		0.002				0.002	0.002	
	25th	0.001		0.001					0.001		0.001				0.002	0.002	
	75th	0.002		0.002					0.002		0.002				0.003	0.003	
1996-2000	n	7		7					7					7		31	
	min	0.001		0.001					0.001					0.002		0.001	
	max	0.007		0.004					0.003					0.006		0.006	
	median	0.002		0.002					0.002					0.003		0.003	
	25th	0.002		0.002					0.002					0.003		0.002	
	75th	0.003		0.003					0.003					0.004		0.004	
2001-2005	n	40		40					40			26		40		39	
	min	-0.001		0.000					0.000			0.001		0.001		0.001	
	max	0.003		0.003					0.006			0.004		0.005		0.005	
	median	0.001		0.001					0.001			0.002		0.002		0.002	
	25th	0.001		0.001					0.001			0.002		0.002		0.002	
	75th	0.001		0.002					0.002			0.002		0.002		0.003	

North Maitland

Harriston
08005600702

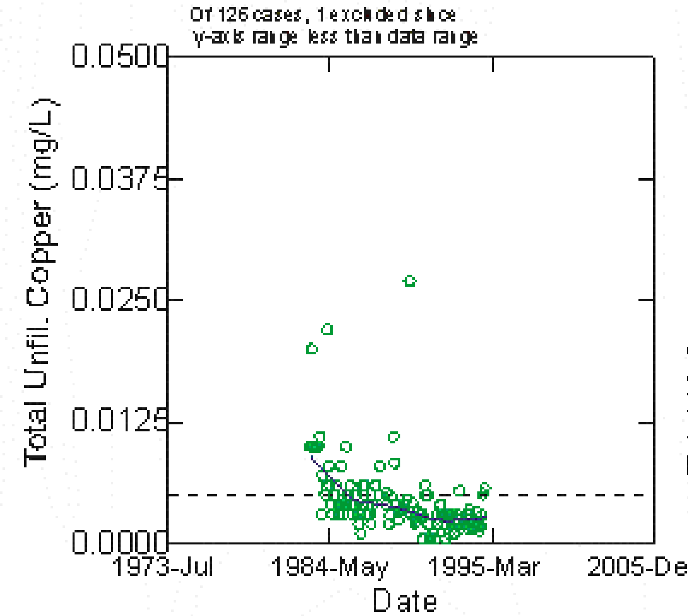


Wroxeter
08005600402

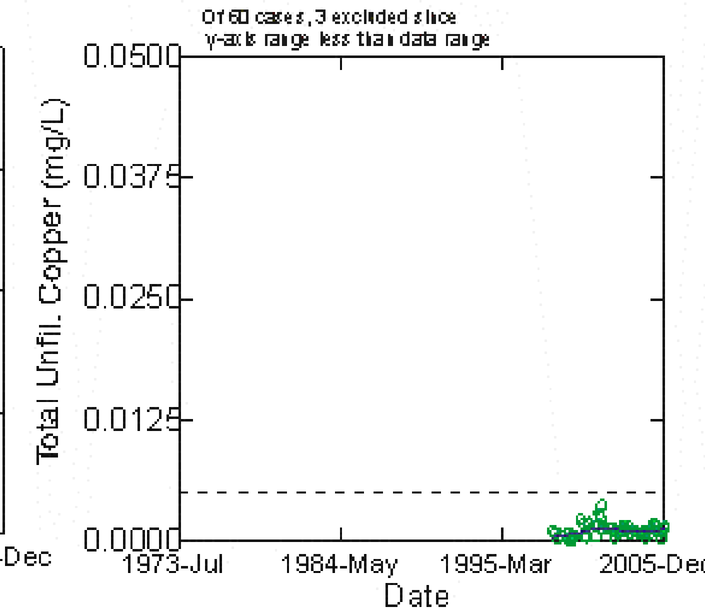


Little Maitland

Palmer
08005600602

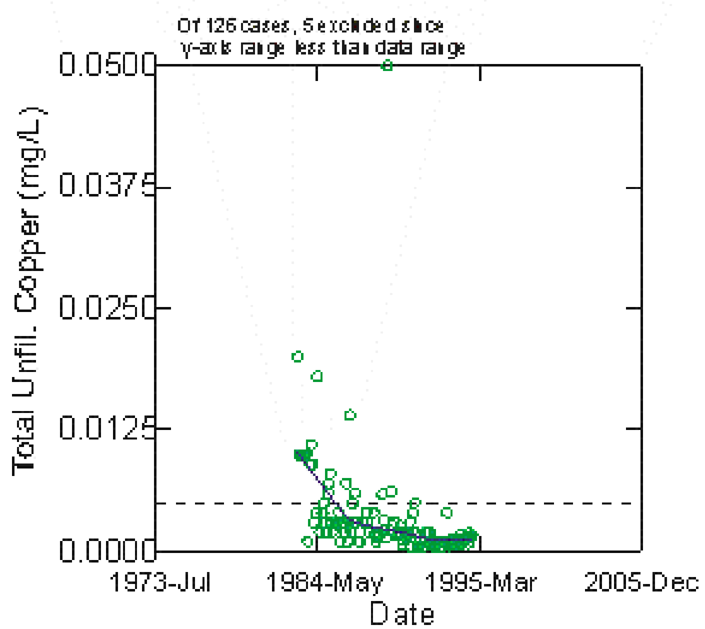


Jamestown
08005603502



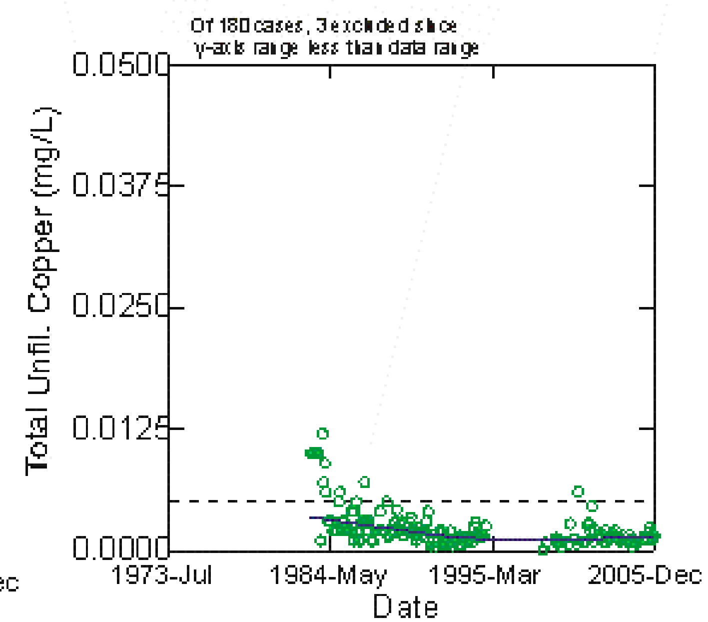
South Maitland

Londesborough
08005601502



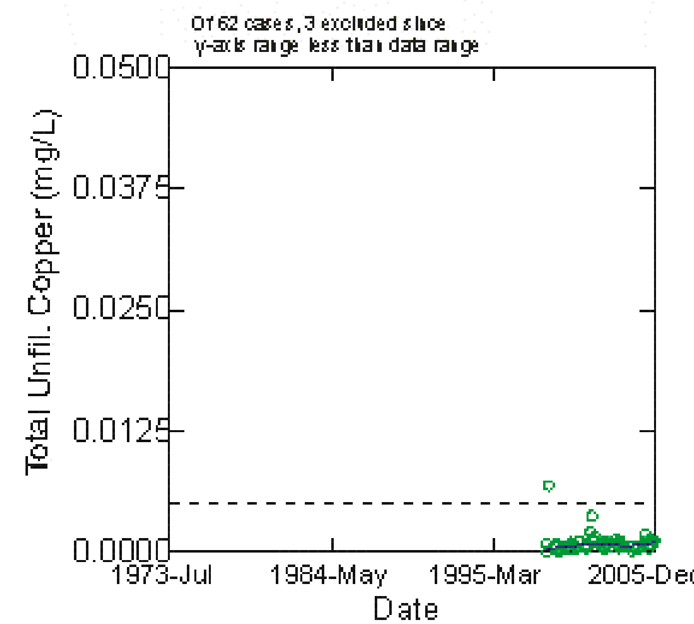
Lower Maitland

Zetland
08005600302



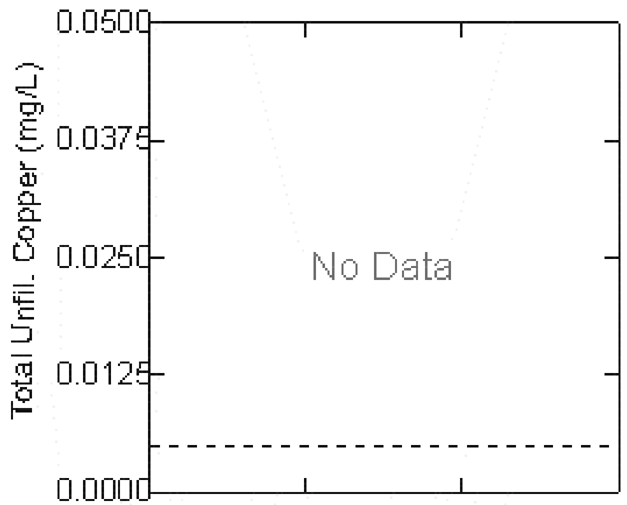
Nine Mile

Lucknow
08007600202

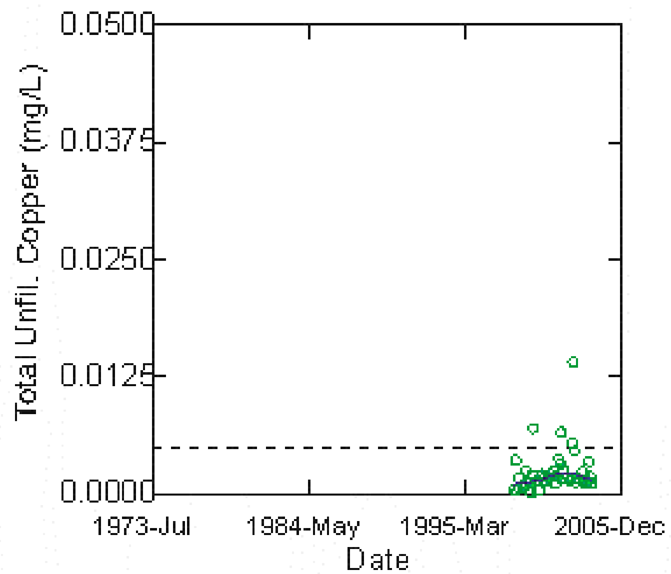


Middle Maitland

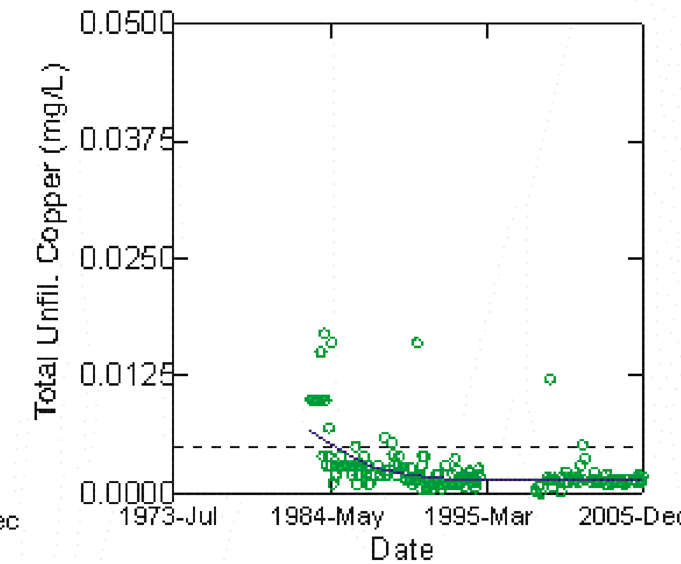
Listowel_NE
08005601402



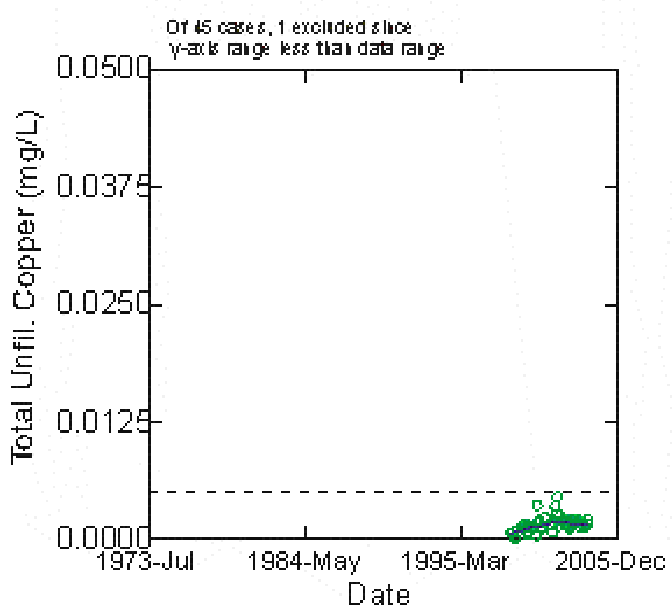
Listowel
08005601302



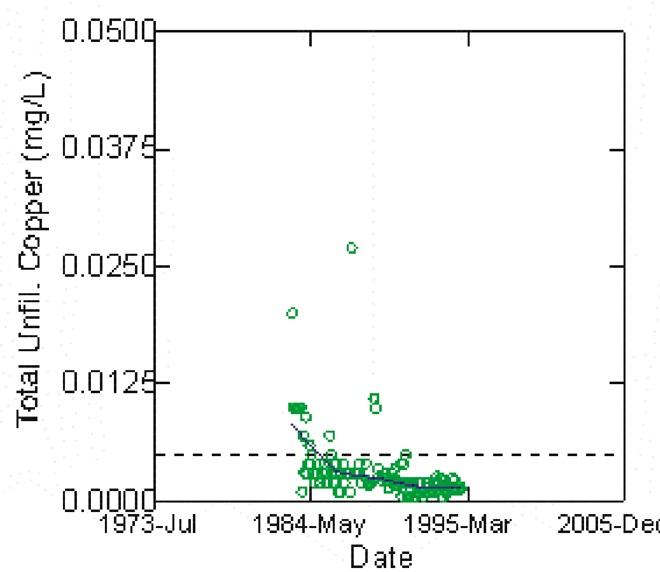
Trowbridge
08005600902



Ethel
08005602602

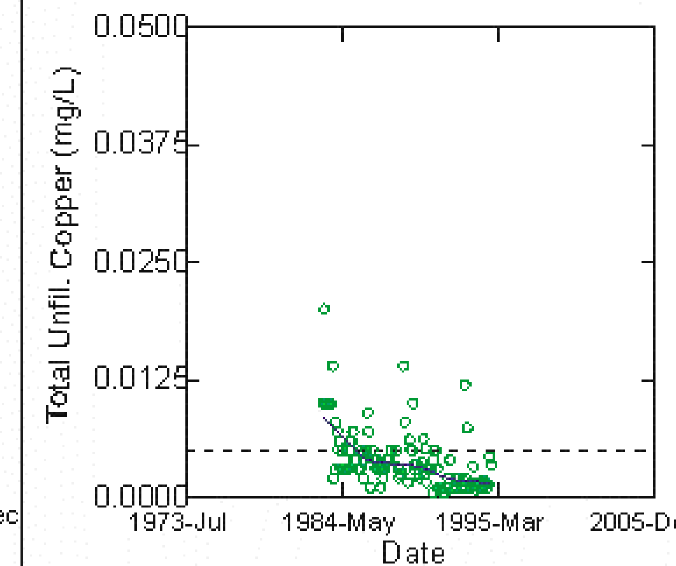


Bruss16
08005603102

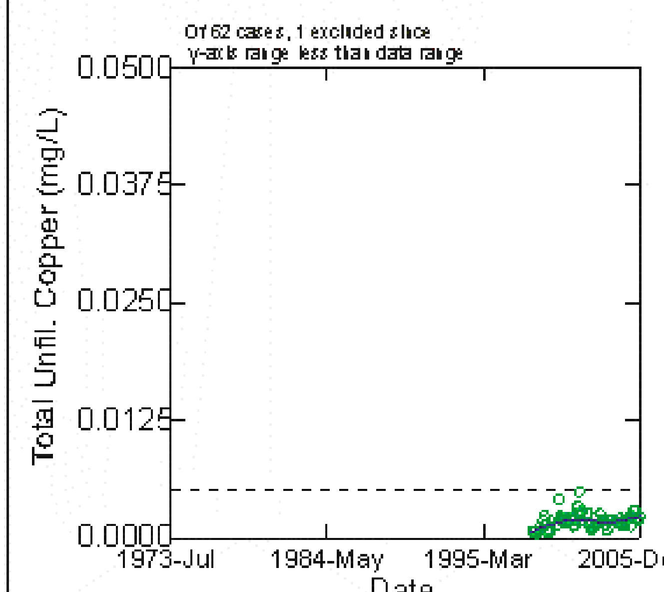


Boyle Drain

Milverton
08005601002

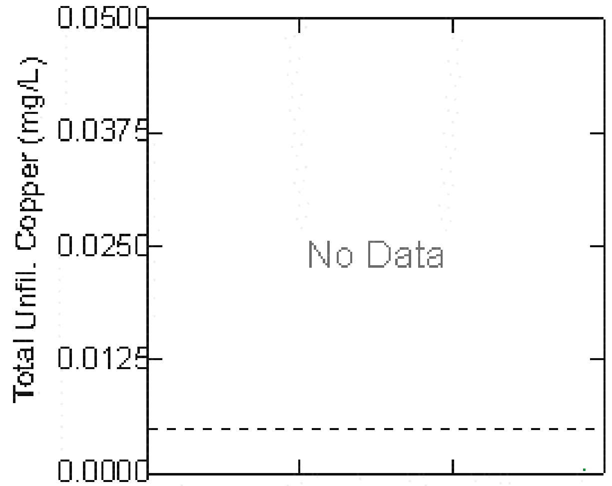


Henfryn
08005602002

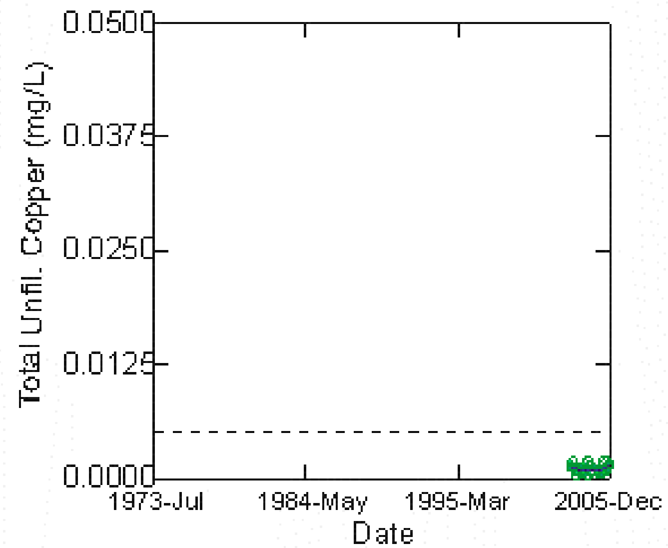


Bayfield River

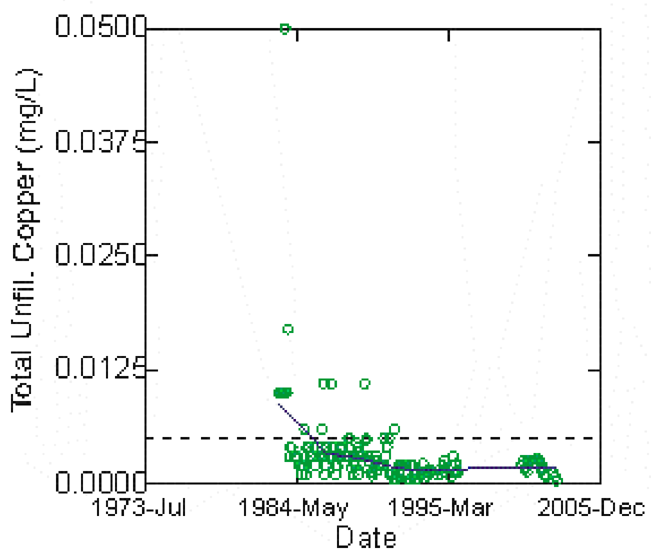
MBSILV1&2 (Silver Creek)
08004000302 (1965-1975)
08004001102 (1983-2005)



MBSEA1
08004000202



MBHAN1
08004000902



MBCLIN2
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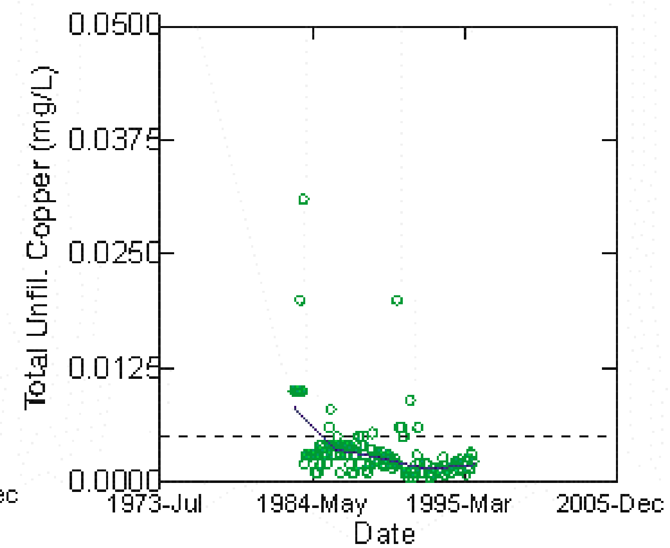
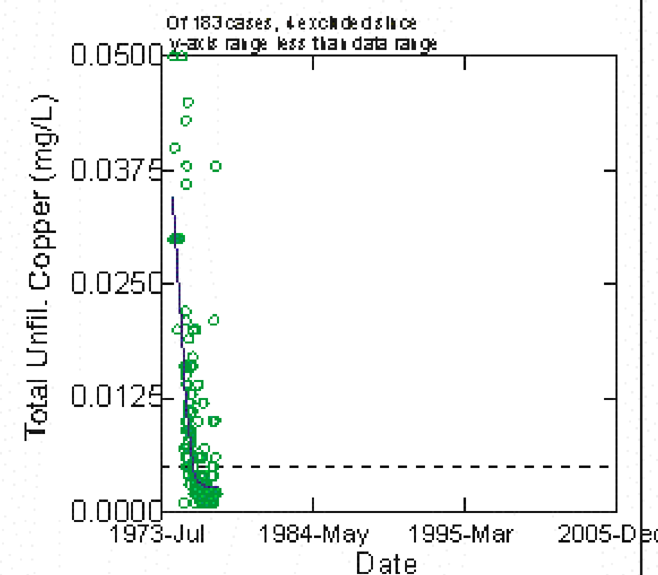
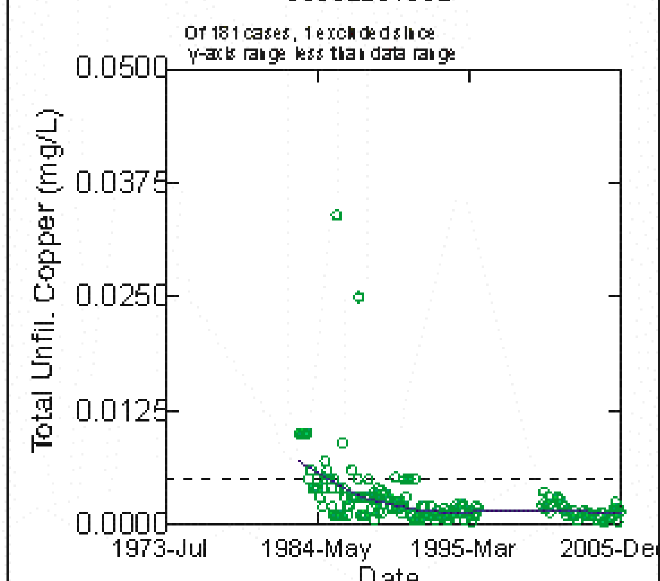


Little Ausable

ABCA14
08002201402

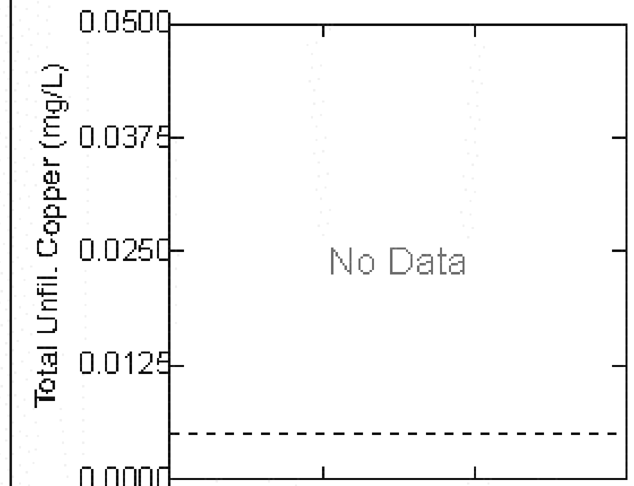


MALIT2
08002201002

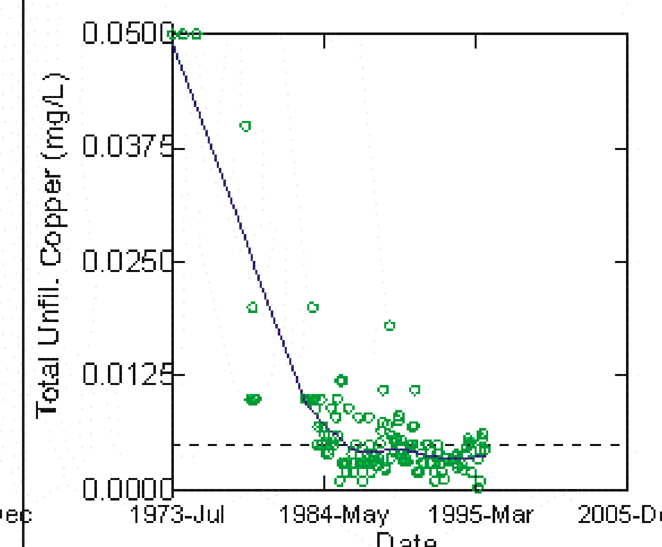


Parkhill Creek

HBLIF3
08004000502

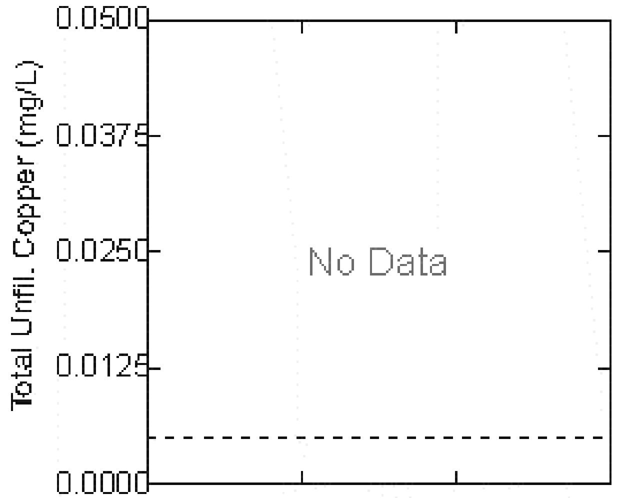


MPGBEND1&2
08002200102 (1965-1975)
08002201302 (1974-1995)

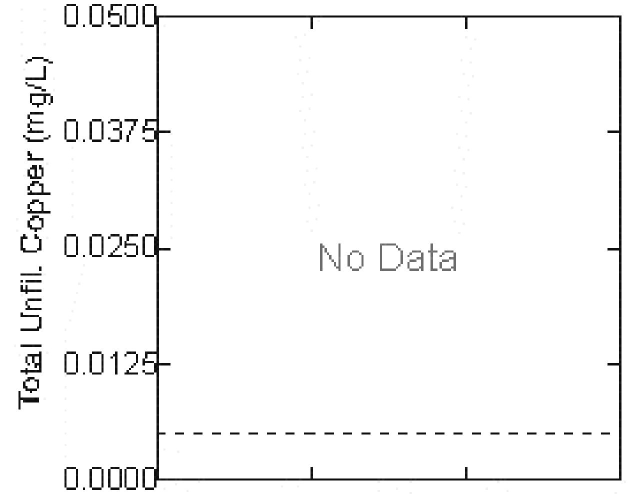


Ausable River

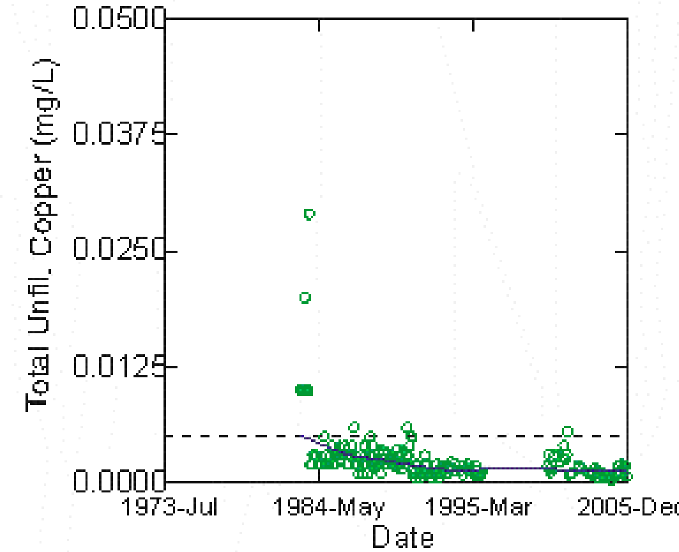
HASTAF1
08002200802



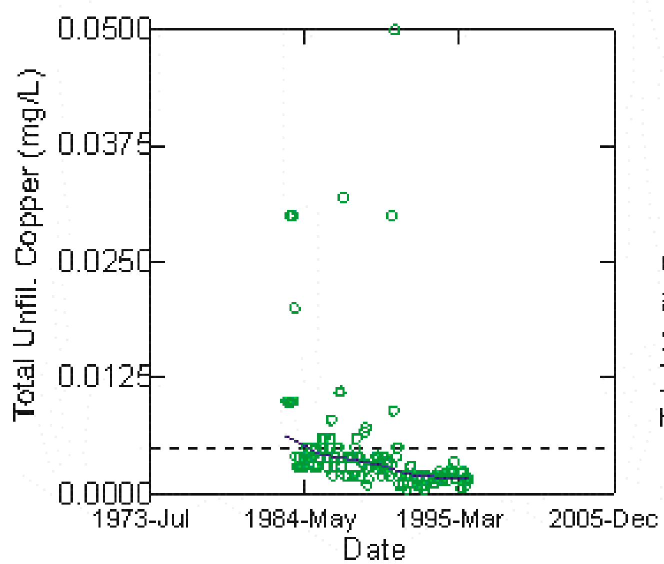
MAMOR2
08002201702



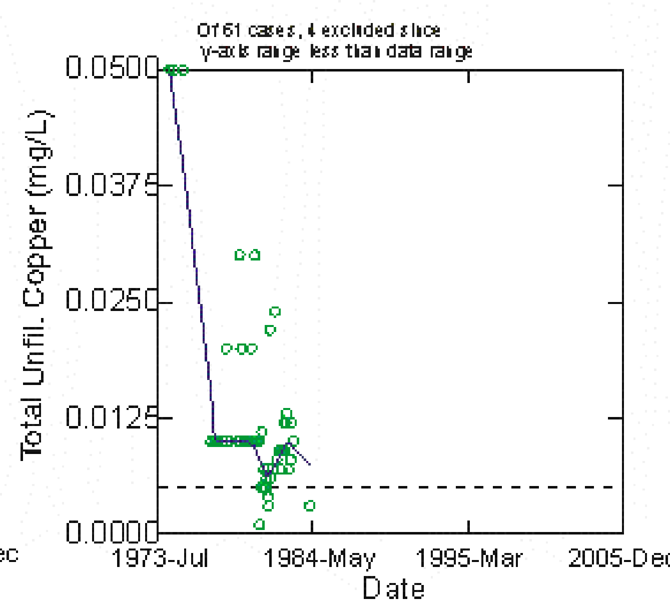
MAEXE1
08002201602



MAMTCARM
08002201102

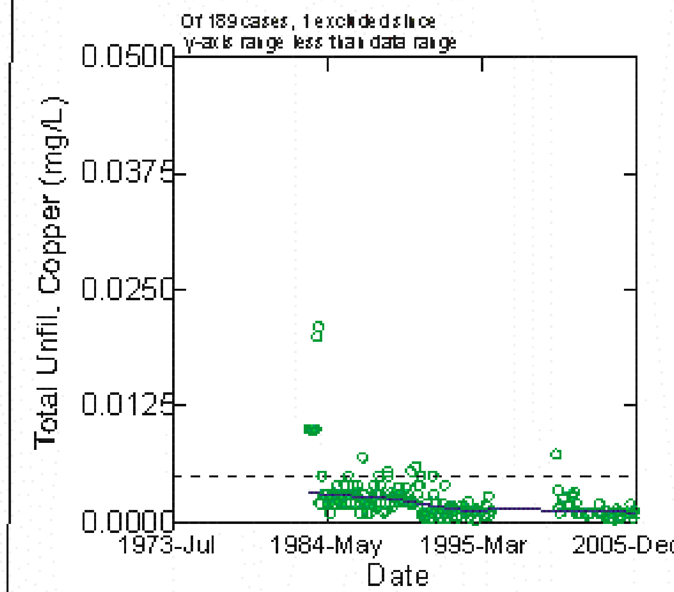


MAWAL
08002100102



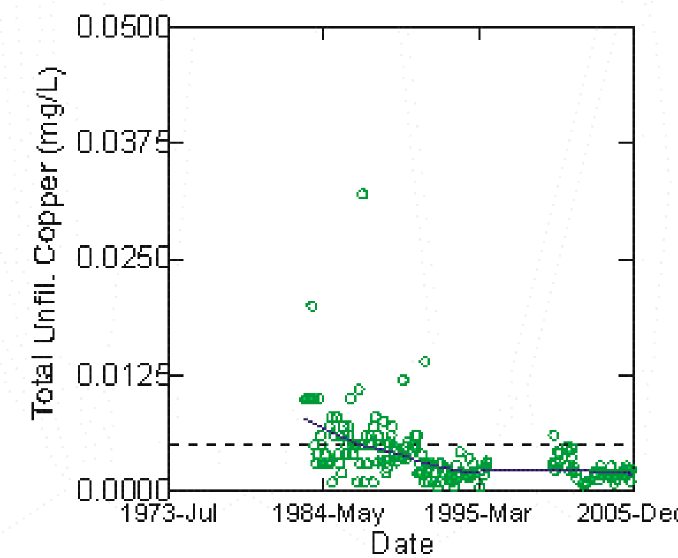
Black Creek

MABLA2
08002200702



Decker Creek

MADECK2&3
08002200202



Nitrate - North, Little, South and Lower Maitland River and Nine Mile River

	Major Basin	Nine Mile		North Maitland						Little Maitland			South Maitland		Lower Maitland						
	Tributary			Upper				Salem Creek	Lower						Belgrave Creek	Blyth Brook		Sharpes Creek		Main Branch	
	MOE or local ID	08007600202	08007600102	08005600802	08005600702	08005602502	08005600402	08005605002	08005603802	08005600602	08005602202	08005603502	08005601502	08005603702	08005603002	08005604402	08005600202	08005602702	08005602802	08005600302	08005600102
	Site Name	Lucknow	Port Albert	Palmer_N	Harristn	Fordwich	Wroxeter	NMSalem	B-Line	Palmer	Palme_23	Jamestown	Londesbo	Summerhill	WNC_Belg	Blyth East	Blyth	Sharpes	SharpBen	Zetland	Goderich
1964-1965	n	1	1	2	2		1			1							4			1	8
	min	0.80	0.50	1.00	0.90		1.10			2.20							0.15			1.00	0.15
	max	0.80	0.50	1.50	1.00		1.10			2.20							1.00			1.00	1.50
	median	0.80	0.50	1.25	0.95		1.10			2.20							0.20			1.00	0.68
	25th			1.00	0.90												0.15				0.20
	75th			1.50	1.00												0.63				0.90
1966-1970	n	61	63	59	100		102			102							100			100	96
	min	0.04	0.10	0.01	0.01		0.03			0.01							0.01			0.01	0.01
	max	4.70	2.50	2.00	2.60		2.00			3.00							4.00			2.60	3.50
	median	0.48	0.48	0.92	0.50		0.80			0.80							1.00			0.95	0.79
	25th	0.27	0.25	0.39	0.18		0.39			0.20							0.34			0.26	0.14
	75th	0.77	0.96	1.45	0.93		1.25			1.20							1.50			1.45	1.25
1971-1975	n	62	67	56	72		72			35	32		58				76	7	7	73	108
	min	0.04	0.14	0.01	0.01		0.07			0.01	0.04		0.01				0.01	0.01	1.07	0.01	0.01
	max	8.72	2.40	8.00	3.90		5.20			4.40	27.00		11.00				10.00	6.30	2.34	6.50	6.20
	median	0.44	0.56	1.05	0.72		1.27			1.00	1.50		3.41				1.55	0.47	1.78	1.34	1.05
	25th	0.33	0.33	0.30	0.14		0.55			0.21	0.18		1.58				0.38	0.11	1.38	0.21	0.20
	75th	1.10	1.28	2.00	1.50		2.00			2.35	2.75		5.80				3.25	1.09	2.24	2.33	2.50
1976-1980	n	55	55		58		59			48	32		57		23		61	30	45	58	62
	min	0.29	0.28		0.04		0.20			0.37	0.07		0.10		1.41		0.01	0.08	0.54	0.04	0.00
	max	2.70	3.24		4.93		5.75			8.40	4.06		12.10		6.49		11.10	1.97	4.30	6.03	5.93
	median	0.82	1.16		1.38		2.00			1.69	1.88		4.20		3.40		2.60	0.37	2.50	2.12	1.93
	25th	0.57	0.67		0.45		0.85			1.29	0.72		1.42		1.86		1.04	0.25	1.87	0.60	0.54
	75th	1.40	1.95		2.28		2.80			2.49	2.30		6.72		4.43		4.74	0.56	3.10	3.10	3.20
1981-1985	n	58	56		59		59			58			58		35		58			57	54
	min	0.60	0.84		0.00		0.46			0.30			0.19		1.51		0.71			0.03	0.10
	max	5.40	4.30		4.70		8.62			5.70			9.70		6.53		11.60			6.00	7.30
	median	1.53	1.99		2.59		3.15			3.12			5.53		4.14		4.70			3.50	3.52
	25th	0.96	1.47		0.70		1.64			1.50			3.90		2.42		2.62			1.67	2.03
	75th	2.19	2.82		3.28		3.88			4.30			7.20		5.04		6.30			4.81	5.37
1986-1990	n	56	54		55		54			55		38	54				57			49	52
	min	0.10	0.10		0.00		0.00			0.10		0.10	0.10				0.02			0.10	0.01
	max	2.90	4.70		5.80		13.60			13.20		8.10	15.30				10.00			7.80	7.90
	median	1.35	2.00		2.40		3.30			5.50		4.05	5.35				4.20			3.40	2.95
	25th	0.80	1.30		0.23		0.80			2.65		1.10	3.20				2.40			1.40	0.80
	75th	1.90	2.80		3.80		4.60			7.88		5.80	7.20				5.88			4.53	4.75
1991-1995	n	51	50		42		41			41		37	41				41			40	40
	min	0.02	1.00		0.10		0.70			3.40		0.20	0.50				0.20			0.20	0.30
	max	4.60	4.70		7.90		7.00			13.90		8.60	12.20				7.70			9.30	8.60
	median	1.30	1.90		3.10		3.30			6.40		3.30	5.10				3.70			3.95	3.50
	25th	0.90	1.40		1.60		2.38			5.60		2.10	3.35				2.43			2.40	1.85
	75th	1.80	2.50		3.80		4.33			7.80		4.93	6.23				4.33			4.85	4.60
1996-2000	n	21	21									20					21			20	19
	min	0.39	0.53									0.01					1.42			0.04	0.02
	max	2.89	4.68									11.20					11.60			10.50	12.90
	median	9.35	1.71									0.99					4.05			1.49	1.18
	25th	0.56	0.86									0.57					2.34			0.21	0.09
	75th	1.62	2.34									6.15					5.72			5.93	5.25
2001-2005	n	41	134					14	16			41		17		28	42			41	41
	min	0.70	0.69					5.54	1.32			0.75		1.54		0.03	1.22			0.32	0.20
	max	6.23	6.48					13.90	8.61			9.17		10.60		7.17	10.10			9.74	9.89
	median	1.25	1.69					6.13	2.95			4.26		4.31		3.22	3.64			4.31	3.79
	25th	1.06	1.26					5.76	1.78			2.19		2.48		2.46	2.34			1.83	1.08
	75th	1.80	2.40					7.97	4.56			6.83		6.21		3.92	4.82			6.26	5.52

Nitrate - Middle Maitland River

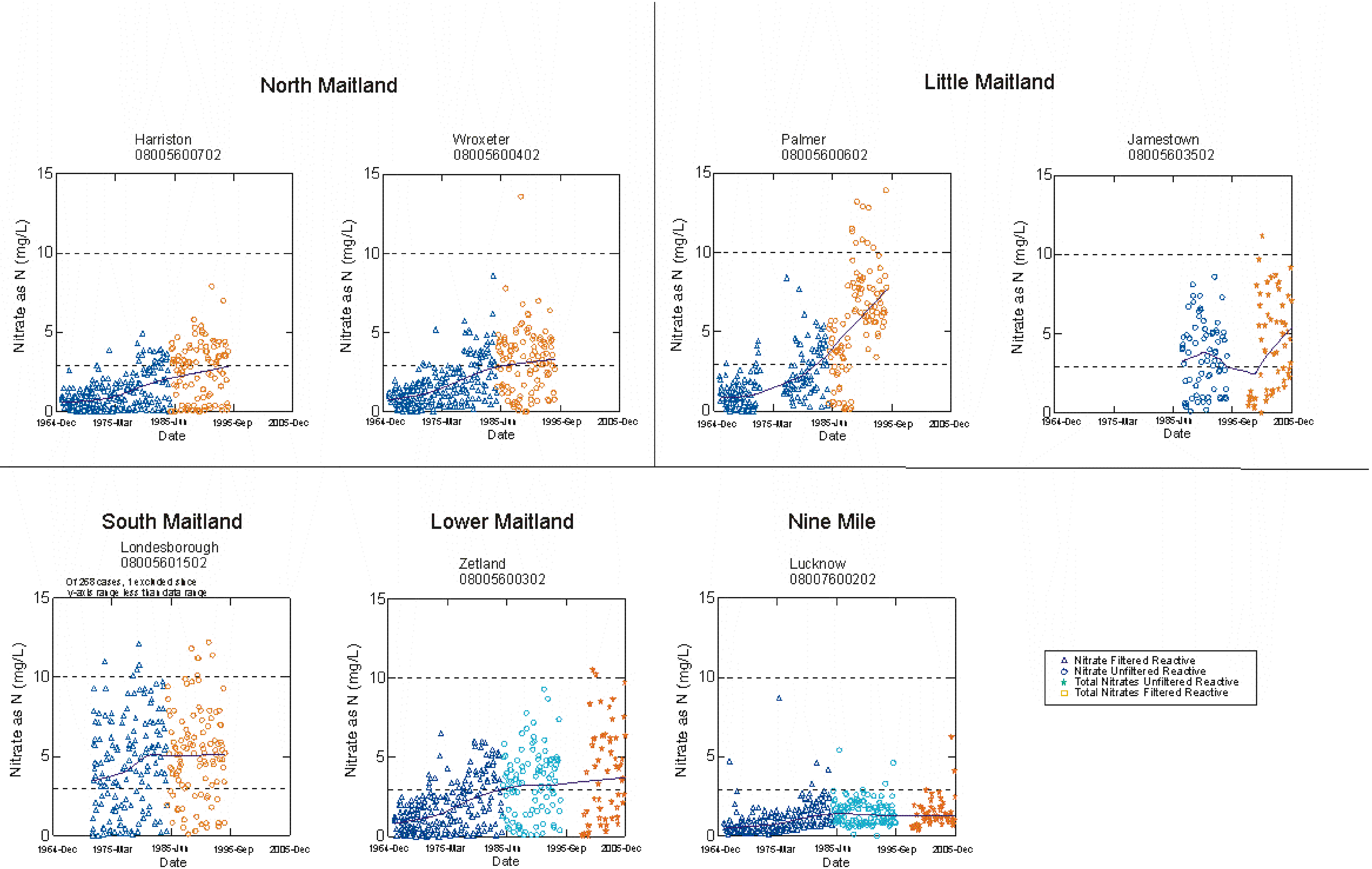
	Major Basin	Middle Maitland River																
	Tributary	Above Listowel		Chapman	Below Listowel				Boyle Drain		Beachamp	Lower Middle Maitland						
	MOE or local ID	08005601402	08005604302	08005602102	08005601302	08005600902	08005601902	08005602602	08005601002	08005602002	08005604102	08005601802	08005601102	08005600502	08005601602	08005603102	08005601702	08005603902
	Site Name	Listw_NE	NE Listowel	Chapman	Listowel	Trowbridge	Grey_Elm	Ethel	Milvertn	Henfryn	Beauchamp	Grey	Brusl_12	Brus_DSc	Brussl_D	Bruss_16	Morris	Wingham
1964-1965	n					2		1						1.25				
	min					1.10		3.00						1.25				
	max					1.25		3.00						1.25				
	median					1.18		3.00										
	25th					1.10												
	75th					1.25												
1966-1970	n					101		63					61	102				
	min					0.01		0.01					0.01	0.01				
	max					5.00		8.00					5.50	4.50				
	median					0.80		1.60					1.50	1.23				
	25th					0.39		0.56					0.11	0.20				
	75th					1.20		2.88					2.90	1.80				
1971-1975	n	58		33	58	74	35	60	33	7		33	22	60	52		33	
	min	0.01		0.06	0.01	0.01	0.01	0.01	0.01	0.01		0.01	0.01	0.01	0.01		0.03	
	max	26.00		5.90	23.00	26.00	7.00	9.70	8.60	2.05		8.90	5.40	8.40	8.20		7.60	
	median	1.15		1.40	0.78	0.99	1.20	2.75	1.30	1.19		1.70	0.53	1.75	1.94		1.80	
	25th	0.01		0.42	0.11	0.01	0.40	0.90	0.28	0.29		0.53	0.01	1.04	0.49		3.55	
	75th	3.00		1.90	2.80	2.40	3.43	5.50	3.78	1.83		3.60	4.10	3.15	4.00		3.60	
1976-1980	n	59			58	60		12		57				10	45	12		
	min	0.01			0.01	0.01		0.01		0.01				0.50	0.02	0.46		
	max	7.50			6.03	5.92		9.13		9.90				6.30	9.80	6.53		
	median	1.75			1.40	1.57		3.30		1.86				1.79	2.33	3.74		
	25th	0.22			0.36	0.05		0.30		0.39				1.32	0.19	1.39		
	75th	2.70			2.30	2.57		5.55		3.70				4.40	4.30	4.82		
1981-1985	n	36			60	59		59		35						58		
	min	0.01			0.01	0.01		0.01		0.10						0.17		
	max	7.14			6.29	6.30		12.30		9.00						8.70		
	median	3.07			2.29	2.79		4.80		4.30						4.37		
	25th	1.05			0.77	0.10		2.53		2.20						2.47		
	75th	4.45			3.80	4.08		7.54		5.95						5.60		
1986-1990	n				52	54		56	38	45						56		
	min				0.10	0.10		0.10	0.10	0.10						0.30		
	max				11.60	9.70		16.80	16.20	14.50						10.80		
	median				2.75	2.95		5.20	5.00	4.50						4.10		
	25th				0.85	0.50		2.80	0.60	1.58						3.00		
	75th				4.55	4.50		8.00	8.30	7.28						5.85		
1991-1995	n			1	41	42		42	39	39						41		
	min			3.40	0.10	0.10		0.10	0.10	0.50						0.20		
	max			3.40	10.50	9.80		13.30	12.90	11.10						12.90		
	median				3.90	3.15		4.45	4.20	4.50						4.40		
	25th				2.13	1.00		2.70	2.38	2.70						2.78		
	75th				5.08	4.40		6.30	5.83	5.75						5.35		
1996-2000	n				19	20			21	21								
	min				0.07	0.01			0.01	0.01								
	max				12.00	11.90			14.70	13.90								
	median				1.13	0.54			0.80	0.76								
	25th				0.75	0.02			0.02	0.03								
	75th				6.03	6.04			9.72	8.11								
2001-2005	n		29		24	41			41	24	17							17
	min		0.02		0.51	0.01			0.01	0.05	0.74							0.18
	max		14.00		9.81	10.20			14.80	12.10	9.52							10.70
	median		6.16		2.70	2.51			6.11	4.56	4.81							4.67
	25th		1.80		1.38	0.55			1.20	0.70	3.71							2.46
	75th		7.99		6.56	6.68			9.66	8.54	7.36							7.16

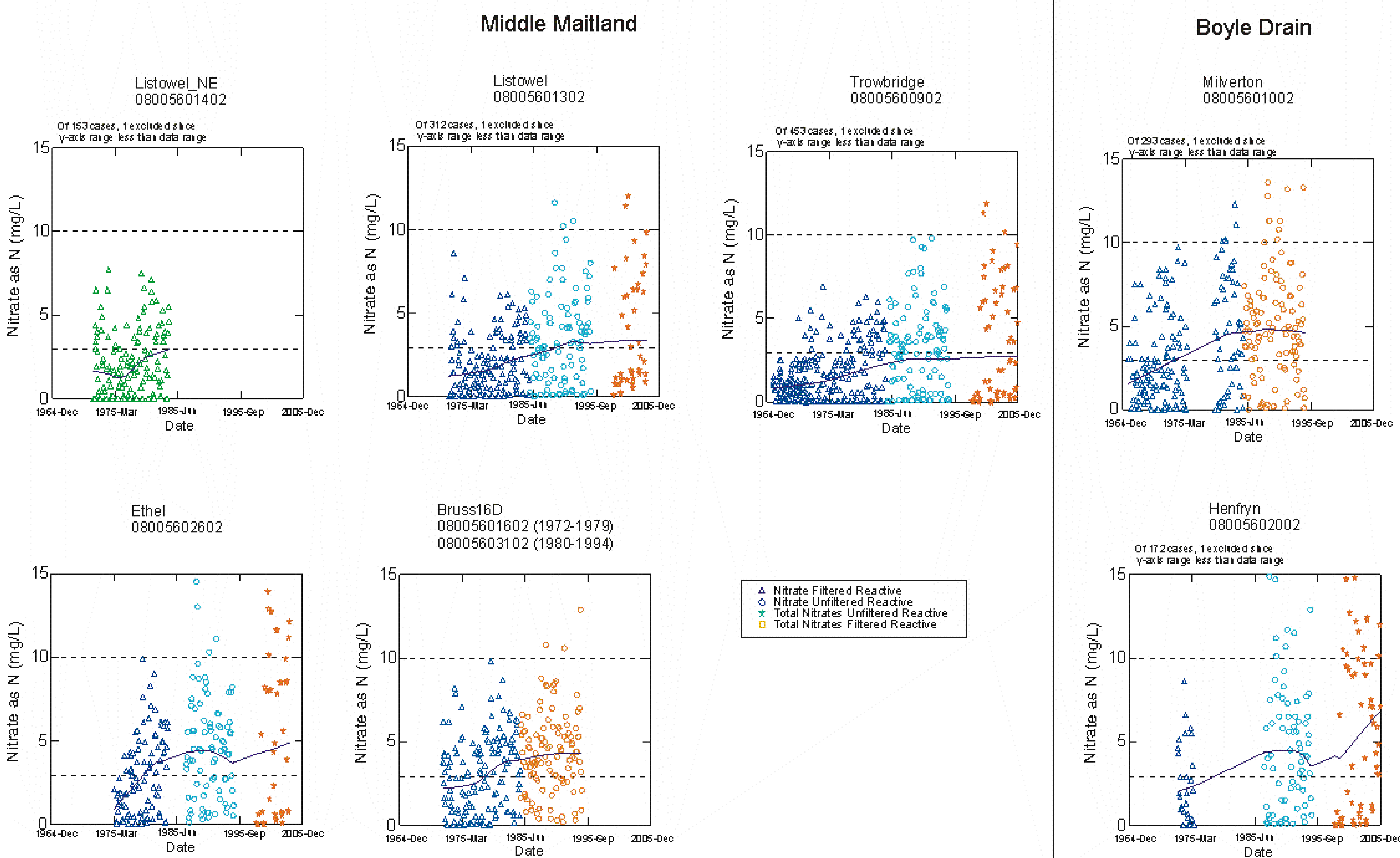
Nitrate - Bayfield River and Parkhill Creek

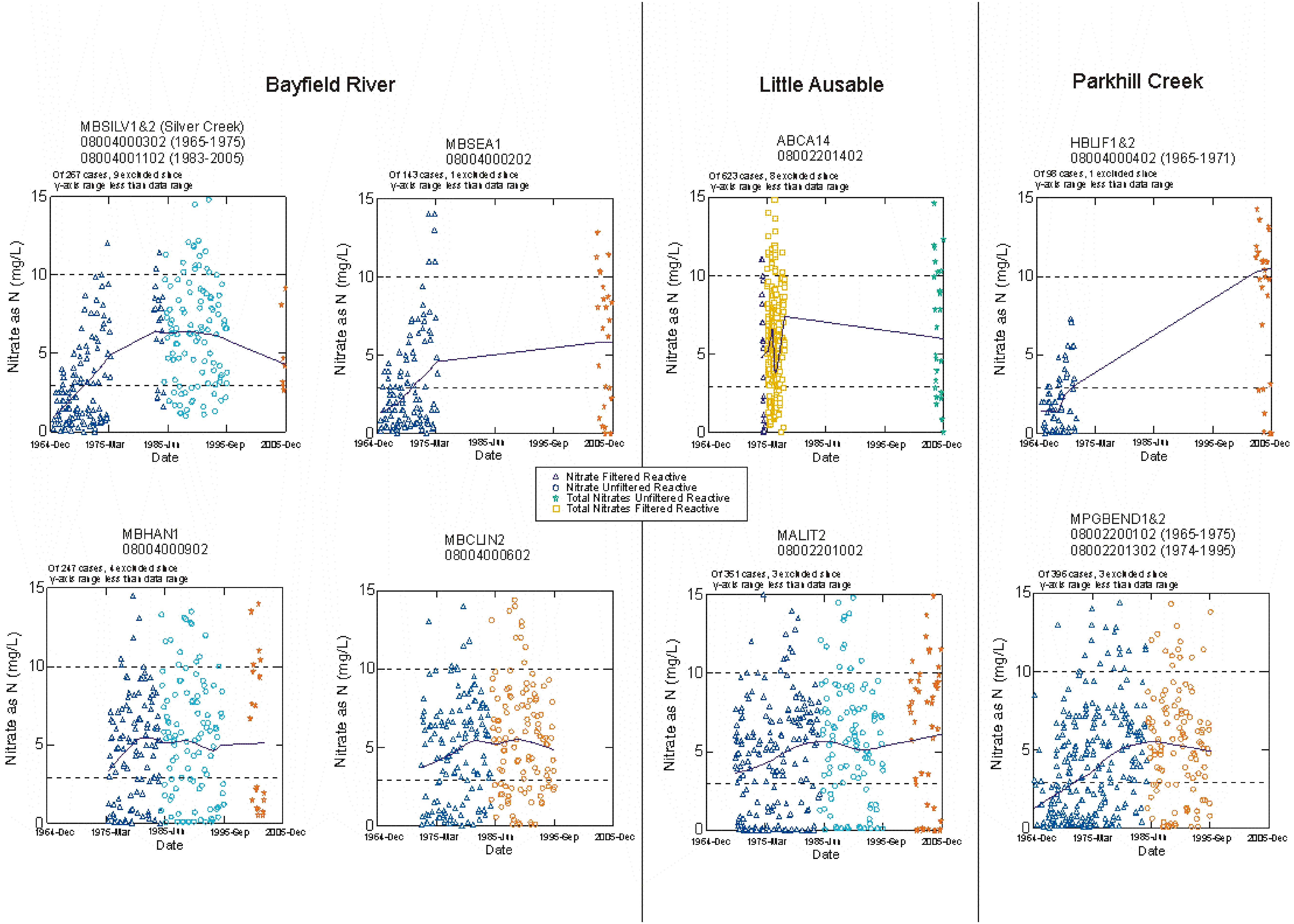
	Major Basin	Bayfield River														Parkhill Creek							
	Tributary	Bannockburn	Liffy Ditch			Silver Creek		Upper Bayfield			Steenstra	Lower Bayfield				Upper Parkhill					Tributary	Lower Parkhill	
	MOE or local ID	MBBAN1	HBLIF1	08004000402	08004000502	08004001102	08004000302	08004000202	08004000902	08004000602	HBSTEEN1	08004001002	08004000802	08004000102	08004000783	08002200302	MPMCGUF1	08002200402	08002200902	08002201202	08002201802	08002201302	08002200102
	Site Name	Bannockburn	Dublin	HBLIF2	HBLIF3	Silver	MBSILV1	Seaforth	MBHAN1	MBCLIN2	Steenstra	MBGRANT	Varna	MBBAY1	MBBAY2	HPCAM	Upstream Parkhill	MPDAM	MPHARM	Downstream Parkhill	MPTRI1	MPGBEND2	MPGBEND1
1964-1965	n			1	2		4	5						4		2		1					5
	min			2.00	0.15		0.20	0.20						1.50		2.80		4.00					0.25
	max			2.00	3.00		2.50	3.00						3.00		5.00		4.00					8.50
	median			2.00	1.58		0.65	0.40						2.50		3.90		4.00					3.10
	25th				0.15		0.35	0.28						2.00		2.80							2.16
	75th				3.00		1.65	1.41						2.75		5.00							5.88
1966-1970	n			62	64		65	63						61		75		14	55				74
	min			0.02	0.01		0.01	0.05						0.02		0.01		0.02	0.01				0.02
	max			7.30	7.60		17.00	7.20						6.90		25.00		44.00	6.30				13.00
	median			1.50	1.50		2.00	1.50						1.60		1.40		0.60	1.30				1.28
	25th			0.20	0.31		0.74	0.63						0.13		0.33		0.15	0.26				0.34
	75th			2.50	3.00		3.20	3.00						2.90		3.15		2.50	3.18				3.40
1971-1975	n			9	46		52	49	6	36			6	60	23	59			15	43		29	71
	min			0.17	0.01		0.01	0.06	0.14	0.09			0.60	0.01	0.01	0.01			0.03	0.02		0.17	0.09
	max			7.10	21.00		12.00	14.00	7.10	13.00			7.50	11.00	9.10	14.00			6.70	11.00		14.00	13.00
	median			3.20	3.20		3.55	3.00	2.12	4.30			1.63	1.65	1.50	3.10			2.20	2.80		3.35	2.40
	25th			0.80	0.74		0.95	0.86	0.46	0.82			0.70	0.13	0.38	0.39			0.52	0.52		0.46	0.30
	75th			5.53	7.20		6.75	7.23	4.30	6.50			3.70	6.10	5.30	4.88			4.20	4.58		7.08	5.20
1976-1980	n								59	59		32	62							11		60	
	min								0.03	0.01		0.77	0.24							2.76		0.14	
	max								15.10	14.00		9.80	14.40							10.00		27.00	
	median								5.20	4.75		4.05	5.05							6.80		5.20	
	25th								1.29	1.33		2.00	2.10							4.88		1.80	
	75th								7.18	6.68		6.30	6.90							8.38		7.70	
1981-1985	n					34			60	58			59							60		58	
	min					1.59			0.01	0.05			0.28							0.01		0.43	
	max					16.10			13.30	13.10			12.30							12.50		15.80	
	median					7.70			5.99	6.05			5.90							5.40		6.10	
	25th					5.77			2.85	3.26			3.32							3.95		4.00	
	75th					8.61			7.90	7.70			7.52							6.45		6.80	
1986-1990	n					56			55	56			56							58		54	
	min					1.00			0.10	0.10			0.60							0.00		0.10	
	max					24.40			16.20	14.40			13.70							16.20		15.10	
	median					6.30			5.20	5.35			5.00							5.05		5.70	
	25th					3.10			1.83	2.35			2.75							3.30		3.00	
	75th					10.50			9.10	8.60			8.15							8.20		8.50	
1991-1995	n					48			45	47			49							51		45	
	min					1.10			0.10	0.10			0.30							0.10		0.10	
	max					15.30			12.00	9.70			9.40							15.80		13.80	
	median					6.60			5.40	5.20			5.30							4.10		4.80	
	25th					3.69			1.15	2.60			3.13							1.90		2.33	
	75th					8.55			7.00	7.08			6.75							6.65		6.40	
1996-2000	n								7				7								7		
	min								1.46				2.52								1.18		
	max								18.80				14.50								20.60		
	median								9.64				7.72								8.70		
	25th								6.91				5.77								5.87		
	75th								12.65				9.63								11.31		
2001-2005	n	26	26			8		26	15		21		60				26			26	15		
	min	0.50	0.01			2.64		0.01	5.19		6.02		0.79				0.01			0.01	0.17		
	max	13.10	20.30			9.15		17.60	14.00		14.00		14.40				14.30			11.10	14.70		
	median	5.48	9.91			3.71		7.01	2.13		10.40		6.70				6.07			4.81	5.23		
	25th	3.10	2.82			2.80		1.76	0.91		7.81		3.28				2.60			1.53	0.95		
	75th	8.15	11.50			6.38		9.36	9.38		11.55		9.30				9.50			7.22	9.51		

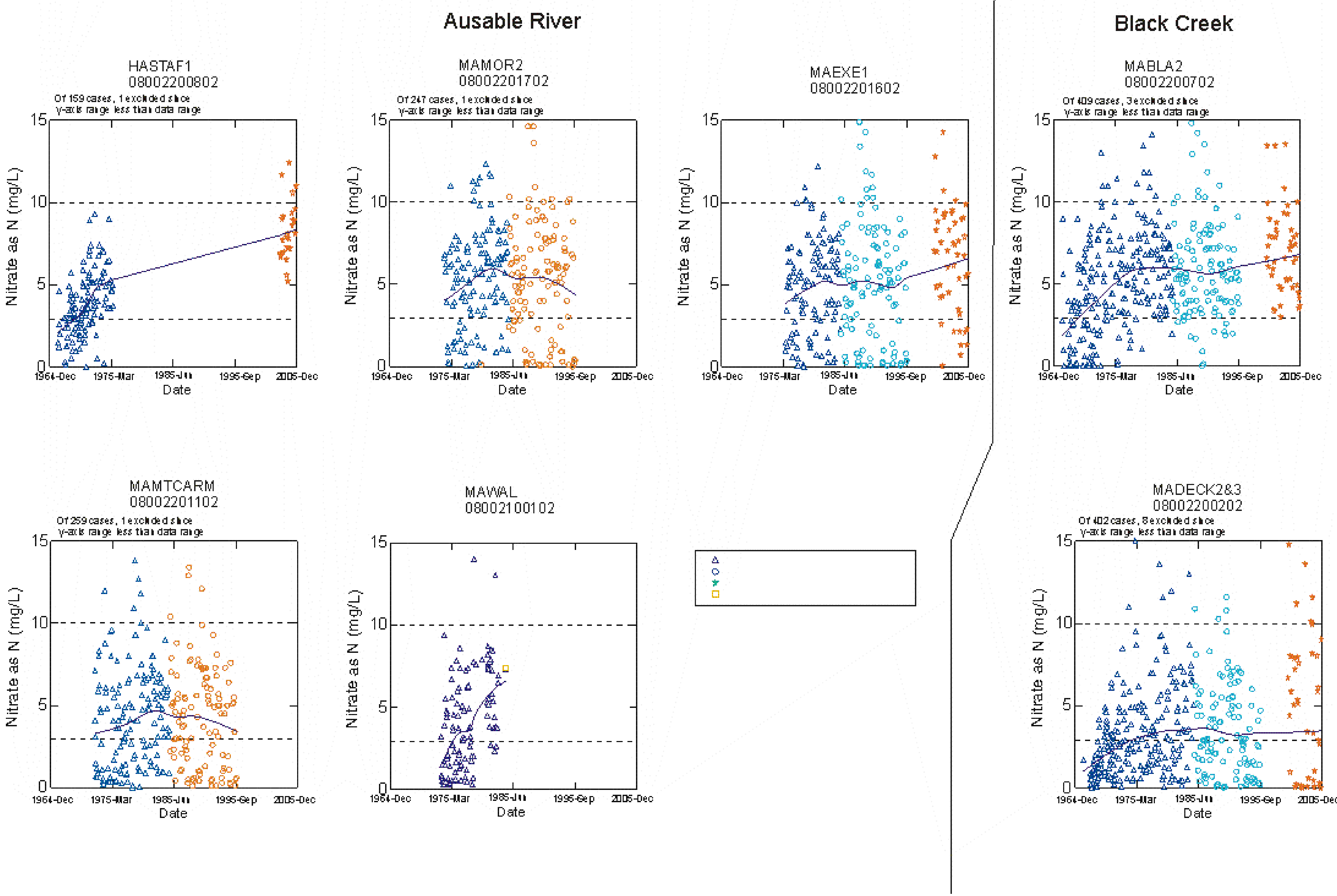
Nitrate - Ausable River

	Major Basin	Ausable															
	Tributary	Black Creek	Little Ausable River		Nairn Creek	Ausable River								Decker Creek		The Cut	
	MOE or local ID	08002200702	08002201402	08002201002	MANAIRN1	08002200802	08002201702	08002200602	08002201602	08002200502	08002201102	08002202002	08002201502	08002201902	08002200202	08002100202	08002100102
	Site Name	Black	Huron Park	Lucan	Nairn	Staffa	MAMOR2	MATHAMES	Exeter	HATRIB	MAMTCARM	Springbank	MAGLAS1	Decker	MADECK3	Thedford	MAWAL
1964-1965	n																
	min																
	max																
	median																
	25th																
	75th																
1966-1970	n	72		23		73		74		73					69		
	min	0.01		0.03		0.01		0.02		0.17					0.01		
	max	9.00		9.70		32.00		8.00		8.50					6.40		
	median	2.80		4.60		3.00		2.50		2.60					1.30		
	25th	0.33		1.41		1.90		0.92		1.58					0.75		
	75th	4.25		6.15		3.60		3.80		3.43					2.55		
1971-1975	n	66	103	64		60	22	60	6	17	44		1		66		39
	min	0.01	0.01	0.01		0.19	0.19	0.02	1.00	1.30	0.23		6.50		0.09		0.29
	max	16.00	22.00	15.00		9.30	11.00	9.90	7.20	6.00	12.00		6.50		15.00		9.40
	median	5.15	5.40	3.90		4.95	5.04	4.30	2.47	3.50	3.35		6.50		2.80		1.68
	25th	2.20	3.03	0.13		3.76	1.49	0.83	1.28	2.40	0.68				1.40		0.54
	75th	7.70	9.28	5.90		6.00	6.60	6.55	4.90	3.93	6.05				4.60		4.28
1976-1980	n	59	491	57			61		60		58				58		44
	min	1.04	0.01	0.01			0.01		0.01		0.01				0.04		0.32
	max	30.10	20.40	14.00			12.30		12.20		13.80				13.60		14.00
	median	6.00	5.30	5.30			5.22		5.00		3.85				3.08		3.21
	25th	4.11	3.40	1.63			2.62		2.07		1.43				1.50		1.82
	75th	7.80	7.10	7.65			7.13		6.69		6.40				5.30		6.10
1981-1985	n	60		57			60	1	58		59				57	453	29
	min	1.99		0.01			0.86	8.50	0.26		0.44				0.18	0.03	2.34
	max	14.10		12.10			11.70	8.50	10.20		10.40				16.00	27.80	13.00
	median	6.52		6.40			6.31	8.50	5.79		5.08				4.40	5.25	6.50
	25th	4.44		2.73			4.10		3.27		2.96				1.88	3.94	4.25
	75th	7.39		7.69			7.82		7.20		6.45				6.41	6.99	7.66
1986-1990	n	56		55			54		56		53				56	244	
	min	0.02		0.10			0.04		0.10		0.10				0.00	0.04	
	max	14.80		15.80			15.70		14.90		16.10				15.70	30.20	
	median	5.50		6.20			5.45		5.35		4.40				2.90	4.62	
	25th	3.65		3.10			3.20		2.40		1.68				1.70	3.60	
	75th	8.05		9.18			8.80		8.50		7.30				5.60	6.44	
1991-1995	n	48		47			50		45		45				48	235	
	min	1.90		0.10			0.00		0.10		0.10				0.10	0.01	
	max	11.00		10.80			10.20		9.00		9.30				7.30	22.60	
	median	5.35		4.60			5.80		4.90		4.50				2.60	4.51	
	25th	3.90		1.33			1.30		0.88		0.90				0.65	1.85	
	75th	6.40		6.80			7.00		6.30		5.43				4.86	6.06	
1996-2000	n	7		7					7					7		31	
	min	6.06		5.74					4.87					1.00		1.06	
	max	13.40		17.00					12.80					16.80		19.50	
	median	7.90		8.18					8.31					6.73		5.80	
	25th	6.77		7.60					7.02					4.76		5.00	
	75th	9.66		10.48					9.38					13.11		7.15	
2001-2005	n	41	29	41	26	26			41			26		41		40	
	min	2.98	0.01	0.01	0.01	5.18			0.06			0.33		0.01		0.36	
	max	13.50	16.50	15.70	11.40	12.40			14.30			10.70		17.80		12.50	
	median	6.55	7.83	6.57	4.75	8.11			6.73			4.96		5.14		4.92	
	25th	4.82	2.78	0.13	3.86	6.96			3.43			2.43		0.23		2.41	
	75th	8.18	11.13	9.63	7.06	9.12			9.00			8.67		9.27		7.37	


North Maitland
Harriston
08005600702
Wroxeter
08005600402
Little Maitland
Palmer
08005600602
Jamestown
08005603502
South Maitland
Londesborough
08005601502
Of 268 cases, 1 excluded since y-axis range less than data range
Lower Maitland
Zetland
08005600302
Nine Mile
Lucknow
08007600202
Nitrate as N (mg/L)
Date
1964-Dec
1975-Mar
1985-Jun
1995-Sep
2005-Dec
Nitrate Filtered Reactive
Nitrate Unfiltered Reactive
Total Nitrates Unfiltered Reactive
Total Nitrates Filtered Reactive


Middle Maitland
Boyle Drain
Listowel_NE
08005601402
Of 153 cases, 1 excluded since
y-axis range less than data range
Listowel
08005601302
Of 312 cases, 1 excluded since
y-axis range less than data range
Trowbridge
08005600902
Of 453 cases, 1 excluded since
y-axis range less than data range
Milverton
08005601002
Of 293 cases, 1 excluded since
y-axis range less than data range
Ethel
08005602602
Bruss16D
08005601602 (1972-1979)
08005603102 (1980-1994)
Henfryn
08005602002
Of 172 cases, 1 excluded since
y-axis range less than data range
Nitrate as N (mg/L)
Date
1964-Dec
1975-Mar
1985-Jun
1995-Sep
2005-Dec
Nitrate Filtered Reactive
Nitrate Unfiltered Reactive
Total Nitrates Unfiltered Reactive
Total Nitrates Filtered Reactive


Bayfield River
Little Ausable
Parkhill Creek
MBSILV1&2 (Silver Creek)
08004000302 (1965-1975)
08004001102 (1983-2005)
Of 257 cases, 9 excluded since y-axis range less than data range
MBSEA1
08004000202
Of 143 cases, 1 excluded since y-axis range less than data range
ABCA14
08002201402
Of 623 cases, 8 excluded since y-axis range less than data range
HBLIF1&2
08004000402 (1965-1971)
Of 98 cases, 1 excluded since y-axis range less than data range
MBHAN1
08004000902
Of 247 cases, 4 excluded since y-axis range less than data range
MBCLIN2
08004000602
MALIT2
08002201002
Of 351 cases, 3 excluded since y-axis range less than data range
MPGBEND1&2
08002200102 (1965-1975)
08002201302 (1974-1995)
Of 396 cases, 3 excluded since y-axis range less than data range
Nitrate as N (mg/L)
Date
1964-Dec
1975-Mar
1985-Jun
1995-Sep
2005-Dec
Nitrate Filtered Reactive
Nitrate Unfiltered Reactive
Total Nitrates Unfiltered Reactive
Total Nitrates Filtered Reactive


Ausable River
Black Creek
HASTAF1
08002200802
Of 159 cases, 1 excluded since
y-axis range less than data range
MAMOR2
08002201702
Of 247 cases, 1 excluded since
y-axis range less than data range
MAEXE1
08002201602
MABLA2
08002200702
Of 409 cases, 3 excluded since
y-axis range less than data range
MAMTCARM
08002201102
Of 259 cases, 1 excluded since
y-axis range less than data range
MAWAL
08002100102
MADECK2&3
08002200202
Of 402 cases, 8 excluded since
y-axis range less than data range
Nitrate as N (mg/L)
Date
1964-Dec
1975-Mar
1985-Jun
1995-Sep
2005-Dec
0
5
10
15

Total Phosphorus - North, Little, South and Lower Maitland River and Nine Mile River

	Major Basin	Nine Mile		North Maitland						Little Maitland			South Maitland		Lower Maitland						
	Tributary			Upper				Salem Creek	Lower						Belgrave Creek	Blyth Brook		Sharpes Creek		Main Branch	
	MOE or local ID	08007600202	08007600102	08005600802	08005600702	08005602502	08005600402	08005605002	08005603802	08005600602	08005602202	08005603502	08005601502	08005603702	08005603002	08005604402	08005600202	08005602702	08005602802	08005600302	08005600102
	Site Name	Lucknow	Port Albert	Palmer_N	Harristn	Fordwich	Wroxeter	NMSalem	B-Line	Palmer	Palme_23	Jamestown	Londesbo	Summerhill	WNC_Belg	Blyth East	Blyth	Sharpes	SharpBen	Zetland	Goderich
1964-1965	n	1	1	8	2		1			1							5			1	15
	min	0.039	0.039	212.000	0.039		0.026			0.078							0.026			0.065	0.013
	max	0.039	0.039	474.000	0.052		0.026			0.078							0.229			0.065	0.118
	median	0.039	0.039	409.000	0.045		0.026			0.078							0.052			0.065	0.052
	25th			378.000	0.039												0.041				0.026
	75th			445.000	0.052												0.102				0.064
1966-1970	n	60	61	62	100		99			99							101			100	95
	min	0.007	0.007	1.000	0.020		0.007			0.040							0.013			0.007	0.007
	max	1.830	0.190	860.000	1.300		0.373			11.275							1.200			0.575	0.220
	median	0.029	0.023	395.000	0.100		0.033			0.621							0.072			0.040	0.020
	25th	0.020	0.013	360.000	0.078		0.020			0.354							0.050			0.029	0.013
	75th	0.046	0.033	450.000	0.191		0.048			1.758							0.101			0.059	0.030
1971-1975	n	61	67	20	72		72			35	32		58				76	7	7	73	109
	min	0.014	0.006	310.000	0.029		0.006			0.100	0.016		0.007				0.014	0.008	0.004	0.016	0.008
	max	0.200	0.360	610.000	1.900		0.300			4.700	1.000		0.250				0.300	0.030	0.036	0.250	0.460
	median	0.031	0.020	430.000	0.160		0.028			1.800	0.040		0.031				0.047	0.015	0.008	0.040	0.022
	25th	0.024	0.014	390.000	0.088		0.021			0.702	0.029		0.022				0.039	0.011	0.006	0.030	0.015
	75th	0.040	0.034	460.000	0.370		0.043			2.975	0.053		0.056				0.072	0.023	0.028	0.060	0.038
1976-1980	n	55	55		57		59			48	32		58		23		61	30	44	57	65
	min	0.011	0.006		0.014		0.009			0.015	0.018		0.010		0.007		0.009	0.003	0.002	0.008	0.003
	max	0.134	0.214		1.020		2.100			2.750	2.300		0.740		0.118		0.250	0.078	0.048	1.210	0.590
	median	0.023	0.016		0.090		0.023			0.755	0.037		0.024		0.015		0.030	0.018	0.009	0.032	0.015
	25th	0.018	0.012		0.058		0.016			0.387	0.028		0.018		0.012		0.023	0.009	0.006	0.022	0.010
	75th	0.036	0.025		0.175		0.036			1.275	0.054		0.036		0.023		0.043	0.023	0.012	0.044	0.025
1981-1985	n	56	56		59		59			56			58		35		58			57	54
	min	0.010	0.006		0.024		0.008			0.089			0.010		0.007		0.016			0.012	0.006
	max	0.295	0.380		0.560		0.375			3.680			0.530		0.270		0.280			0.280	0.400
	median	0.025	0.022		0.091		0.028			0.653			0.033		0.021		0.041			0.038	0.018
	25th	0.019	0.015		0.048		0.020			0.320			0.022		0.012		0.029			0.025	0.011
	75th	0.036	0.041		0.145		0.044			1.240			0.060		0.027		0.063			0.053	0.028
1986-1990	n	56	54		54		55			54		39	56				57			53	52
	min	0.012	0.007		0.018		0.009			0.042		0.016	0.008				0.012			0.016	0.005
	max	0.148	0.240		1.950		0.255			10.800		0.204	0.300				0.173			1.130	0.195
	median	0.020	0.017		0.086		0.022			0.258		0.030	0.025				0.036			0.035	0.015
	25th	0.017	0.012		0.035		0.017			0.100		0.021	0.019				0.026			0.024	0.011
	75th	0.024	0.028		0.135		0.031			0.840		0.049	0.042				0.059			0.055	0.024
1991-1995	n	52	51		43		42			43		38	42				42			43	43
	min	0.010	0.007		0.013		0.010			0.026		0.013	0.012				0.014			0.010	0.008
	max	0.160	0.124		0.188		0.440			0.565		0.148	0.087				0.335			0.240	0.190
	median	0.020	0.015		0.040		0.021			0.070		0.025	0.023				0.032			0.028	0.020
	25th	0.016	0.014		0.023		0.018			0.049		0.019	0.018				0.025			0.023	0.014
	75th	0.025	0.021		0.056		0.031			0.109		0.032	0.035				0.047			0.043	0.030
1996-2000	n	21	21									20					21			19	19
	min	0.004	0.004									0.004					0.002			0.008	0.002
	max	0.056	0.120									0.140					0.260			0.140	0.156
	median	0.020	0.016									0.018					0.032			0.020	0.012
	25th	0.012	0.010									0.011					0.016			0.016	0.008
	75th	0.029	0.020									0.024					0.049			0.034	0.023
2001-2005	n	41	75					14	16			41		17		28	42			41	41
	min	0.012	0.002					0.003	0.006			0.009		0.007		0.011	0.009			0.002	0.005
	max	0.088	0.182					0.412	0.033			0.100		0.076		0.343	0.081			0.102	0.051
	median	0.021	0.018					0.012	0.013			0.024		0.020		0.037	0.032			0.024	0.016
	25th	0.018	0.012					0.009	0.011			0.020		0.016		0.028	0.023			0.017	0.013
	75th	0.030	0.025					0.020	0.019			0.035		0.026		0.050	0.043			0.033	0.021

Total Phosphorus - Middle Maitland River

	Major Basin	Middle Maitland River																
	Tributary	Above Listowel		Chapman	Below Listowel				Boyle Drain		Beachamp	Lower Middle Maitland						
	MOE or local ID	08005601402	08005604302	08005602102	08005601302	08005600902	08005601902	08005602602	08005601002	08005602002	08005604102	08005601802	08005601102	08005600502	08005601602	08005603102	08005601702	08005603902
	Site Name	Listw_NE	NE Listowel	Chapman	Listowel	Trowbridge	Grey_Elm	Ethel	Milvertn	Henfryn	Beauchamp	Grey	Brusl_12	Brus_DSc	Brussl_D	Bruss_16	Morris	Wingham
1964-1965	n					2			5					1				
	min					0.157			0.196					0.118				
	max					0.699			21.961					0.118				
	median					0.428			20.327					0.118				
	25th					0.157			1.079									
	75th					0.699			21.225									
1966-1970	n					100			66				59	100				
	min					0.011			0.021				0.020	0.020				
	max					3.500			180.000				9.500	1.100				
	median					0.421			0.450				0.095	0.140				
	25th					0.237			0.261				0.600	0.091				
	75th					1.030			0.780				0.237	0.229				
1971-1975	n	58		33	58	74	35	7	59	33		33	22	60	52		33	
	min	0.023		0.051	0.007	0.005	0.024	0.040	0.050	0.012		0.026	0.012	0.100	0.025		0.017	
	max	0.620		2.800	2.700	2.000	0.750	0.108	5.500	0.360		0.500	7.000	3.400	0.930		0.320	
	median	0.081		0.710	0.155	0.345	0.130	0.061	0.680	0.076		0.075	0.180	0.230	0.099		0.040	
	25th	0.038		0.148	0.100	0.200	0.072	0.052	0.260	0.043		0.040	0.100	0.150	0.070		0.028	
	75th	0.110		1.725	0.220	0.550	0.220	0.084	1.875	0.113		0.110	2.100	0.835	0.150		0.083	
1976-1980	n	59			59	60		57	12					10	45	12		
	min	0.013			0.021	0.025		0.032	0.161					0.210	0.026	0.014		
	max	0.450			1.920	1.350		0.295	2.600					3.000	0.670	0.072		
	median	0.047			0.092	0.138		0.087	0.795					0.745	0.056	0.029		
	25th	0.036			0.064	0.076		0.070	0.338					0.510	0.042	0.019		
	75th	0.082			0.141	0.203		0.136	0.325					2.400	0.800	0.050		
1981-1985	n	36			59	59		35	59							58		
	min	0.020			0.036	0.024		0.029	0.045							0.011		
	max	0.900			6.150	0.540		0.255	7.400							0.167		
	median	0.058			0.088	0.113		0.080	0.620							0.042		
	25th	0.038			0.065	0.061		0.052	0.236							0.024		
	75th	0.098			0.139	0.168		0.132	0.928							0.068		
1986-1990	n				52	54		45	56	39						55		
	min				0.028	0.026		0.036	0.003	0.018						0.010		
	max				0.370	0.710		0.400	6.700	0.570						0.270		
	median				0.083	0.097		0.076	0.478	0.060						0.039		
	25th				0.054	0.051		0.055	0.328	0.041						0.024		
	75th				0.111	0.166		0.120	1.235	0.117						0.067		
1991-1995	n			1	41	43		40	41	39						42		
	min			0.031	0.018	0.019		0.032	0.075	0.021						0.013		
	max			0.031	0.286	0.850		0.184	4.850	1.290						1.690		
	median			0.031	0.060	0.091		0.065	0.315	0.058						0.041		
	25th				0.042	0.046		0.047	0.188	0.043						0.023		
	75th				0.085	0.141		0.095	0.495	0.106						0.068		
1996-2000	n				19	20		21		21								
	min				0.038	0.022		0.016		0.012								
	max				0.284	0.210		0.520		0.152								
	median				0.132	0.051		0.060		0.054								
	25th				0.066	0.041		0.034		0.036								
	75th				0.180	0.101		0.092		0.071								
2001-2005	n		29		24	42		24		41	17							17
	min		0.011		0.028	0.015		0.019		0.015	0.011							0.008
	max		0.294		0.556	0.206		0.184		0.184	0.170							0.137
	median		0.071		0.131	0.060		0.062		0.044	0.031							0.025
	25th		0.043		0.065	0.035		0.035		0.027	0.021							0.019
	75th		0.099		0.204	0.084		0.096		0.076	0.073							0.036

Total Phosphorus - Bayfield River and Parkhill Creek

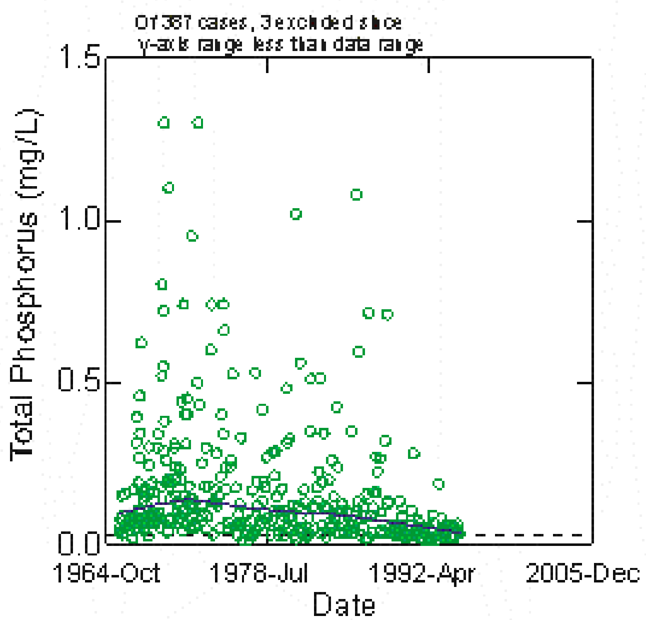
	Major Basin	Bayfield River														Parkhill Creek							
	Tributary	Bannockburn	Liffy Ditch			Silver Creek		Upper Bayfield			Steenstra	Lower Bayfield				Upper Parkhill					Tributary	Lower Parkhill	
	MOE or local ID	MBBAN1	HBLIF1	08004000402	08004000502	08004001102	08004000302	08004000202	08004000902	08004000602	HBSTEEN1	08004001002	08004000802	08004000102	08004000783	08002200302	MPMCGUF1	08002200402	08002200902	08002201202	08002201802	08002201302	08002200102
	Site Name	Bannockburn	Dublin	HBLIF2	HBLIF3	Silver	MBSILV1	Seaforth	MBHAN1	MBCLIN2	Steenstra	MBGRANT	Varna	MBBAY1	MBBAY2	HPCAM	Upstream Parkhill	MPDAM	MPHARM	Downstream Parkhill	MPTRI1	MPGBEND2	MPGBEND1
1964-1965	n			5	5		4	5						8		6		5					8
	min			0.118	0.092		0.392	0.157						0.033		0.105		0.039					0.033
	max			1.961	10.327		1.242	1.830						0.137		21.961		0.137					0.131
	median			0.471	0.294		0.771	0.438						0.049		2.092		0.065					0.075
	25th			0.167	0.170		0.477	0.255						0.039		0.261		0.049					0.055
	75th			1.324	4.592		1.111	0.948						0.088		2.941		0.093					0.098
1966-1970	n			63	63		64	64						63		76		13	56				75
	min			0.007	0.003		0.010	0.003						0.007		0.150		0.023	0.036				0.012
	max			1.600	10.980		10.000	5.200						0.130		11.797		0.810	0.392				0.627
	median			0.060	0.092		0.310	0.110						0.050		0.620		0.092	0.110				0.070
	25th			0.036	0.050		0.181	0.062						0.033		0.320		0.083	0.067				0.052
	75th			0.117	0.289		0.790	0.338						0.072		1.400		0.112	0.159				0.101
1971-1975	n			9	46		52	49	6	35			6	60	23	59			15	43		29	71
	min			0.054	0.039		0.037	0.030	0.029	0.045			0.008	0.015	0.020	0.120			0.054	0.058		0.034	0.030
	max			0.910	2.200		3.200	2.500	0.094	1.400			0.053	2.200	0.150	8.200			0.300	0.270		0.280	0.350
	median			0.100	0.185		0.255	0.220	0.054	0.140			0.025	0.056	0.041	0.440			0.110	0.130		0.110	0.072
	25th			0.077	0.088		0.130	0.097	0.041	0.087			0.012	0.034	0.029	0.242			0.094	0.087		0.071	0.056
	75th			0.450	0.720		0.495	0.377	0.065	0.210			0.036	0.090	0.054	1.675			0.128	0.168		0.155	0.100
1976-1980	n								59	59		32	62							11		60	
	min								0.020	0.028		0.015	0.008							0.066		0.033	
	max								0.650	0.770		0.180	0.520							0.250		0.385	
	median								0.080	0.108		0.049	0.046							0.141		0.093	
	25th								0.053	0.076		0.025	0.027							0.087		0.071	
	75th								0.120	0.189		0.079	0.074							0.193		58.000	
1981-1985	n					34			59	58			59							60		0.054	
	min					0.010			0.013	0.019			0.011							0.066		0.600	
	max					0.540			0.400	0.270			0.226							0.325		0.110	
	median					0.033			0.050	0.052			0.033							0.143		0.085	
	25th					0.023			0.032	0.040			0.020							0.107		0.156	
	75th					0.051			0.102	0.093			0.067							0.181		55.000	
1986-1990	n					56			54	56			57							58		0.036	
	min					0.007			0.010	0.012			0.010							0.053		1.060	
	max					0.200			0.280	0.346			3.560							0.405		0.106	
	median					0.032			0.049	0.045			0.026							0.137		0.082	
	25th					0.018			0.035	0.033			0.019							0.100		0.145	
	75th					0.055			0.100	0.071			0.055							0.164		45.000	
1991-1995	n					48			45	47			50							51		0.042	
	min					0.001			0.008	0.007			0.007							0.064		0.315	
	max					0.790			1.010	1.750			1.750							0.440		0.100	
	median					0.025			0.040	0.028			0.020							0.130		0.078	
	25th					0.017			0.026	0.020			0.015							0.103		0.126	
	75th					0.045			0.065	0.045			0.035							0.156			
1996-2000	n					8			7				7								7		
	min					0.008			0.014				0.012								0.048		
	max					0.094			0.342				0.260								0.200		
	median					0.018			0.064				0.018								0.146		
	25th					0.014			0.021				0.016								0.116		
	75th					0.024			0.083				0.117								0.193		
2001-2005	n	26	26					26	15		21		60				26			26	15		
	min	0.004	0.007					0.009	0.016		0.009		0.008				0.033			0.032	0.075		
	max	0.218	0.978					0.144	0.131		1.080		0.611				0.401			0.249	0.172		
	median	0.028	0.056					0.026	0.043		0.046		0.030				0.082			0.115	0.092		
	25th	0.017	0.027					0.017	0.036		0.024		0.016				0.048			0.080	0.078		
	75th	0.061	0.099					0.040	0.052		0.070		0.053				0.113			0.136	0.123		

Total Phosphorus - Ausable River

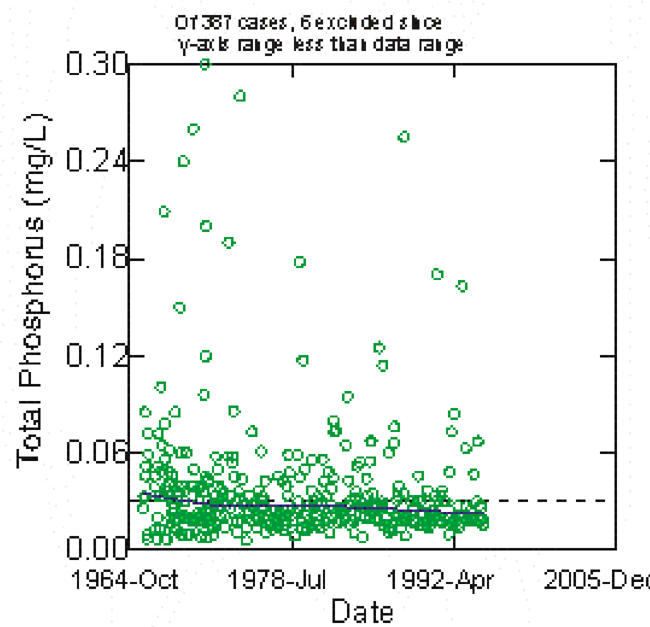
	Major Basin	Ausable															
	Tributary	Black Creek	Little Ausable River		Nairn Creek	Ausable River								Decker Creek		The Cut	
	MOE or local ID	08002200702	08002201402	08002201002	MANAIRN1	08002200802	08002201702	08002200602	08002201602	08002200502	08002201102	08002202002	08002201502	08002201902	08002200202	08002100202	08002100102
	Site Name	Black	Huron Park	Lucan	Nairn	Staffa	MAMOR2	MATHAMES	Exeter	HATRIB	MAMTCARM	Springbank	MAGLAS1	Decker	MADECK3	Thedford	MAWAL
1964-1965	n																
	min																
	max																
	median																
	25th																
	75th																
1966-1970	n	72		23		72		73		72					70		
	min	0.007		0.018		0.013		0.020		0.007					0.052		
	max	32.614		0.420		18.000		3.300		2.940					5.300		
	median	0.980		0.055		0.360		0.275		0.021					0.329		
	25th	0.490		0.041		0.118		0.091		0.013					0.170		
	75th	2.494		0.070		0.846		0.780		0.039					0.752		
1971-1975	n	66	185	64		60	22	59	6	17	44		2		66		39
	min	0.012	0.009	0.010		0.010	0.007	0.056	0.034	0.006	0.052		0.030		0.084		0.023
	max	7.600	8.083	0.310		0.500	0.140	3.400	0.700	0.130	0.440		0.045		2.800		0.590
	median	0.139	0.059	0.061		0.040	0.037	0.200	0.177	0.022	0.150		0.037		0.340		0.061
	25th	0.051	0.034	0.039		0.023	0.028	1.220	0.111	0.014	0.102		0.030		0.170		0.040
	75th	0.720	0.102	0.090		0.086	0.064	0.668	0.320	0.035	0.185		0.045		0.800		0.115
1976-1980	n	59	985	57			61	1	60		58				57		65
	min	0.015	0.000	0.020			0.010	0.048	0.013		0.023				0.030		0.024
	max	1.430	0.920	0.780			0.540	0.048	0.910		0.420				1.700		1.020
	median	0.050	0.058	0.062			0.029	0.048	0.057		0.099				0.200		0.054
	25th	0.034	0.033	0.038			0.022		0.041		0.070				0.115		0.038
	75th	0.105	0.114	0.118			0.039		0.134		0.155				0.592		0.084
1981-1985	n	60	29	57			60		58		59				57	312	28
	min	0.012	0.011	0.015			0.014		0.016		0.300				0.035	0.020	0.036
	max	0.395	0.503	1.100			0.540		1.070		0.245				0.780	2.720	0.250
	median	0.040	0.048	0.051			0.031		0.055		0.102				0.099	0.116	0.072
	25th	0.029	0.026	0.028			0.026		0.033		0.057				0.055	0.058	0.054
	75th	0.070	0.070	0.099			0.050		0.108		0.147				2.140	0.245	0.098
1986-1990	n	56		55			55		57		53				55	245	
	min	0.016		0.020			0.016		0.021		0.043				0.028	0.002	
	max	0.705		0.445			0.338		3.100		0.500				2.580	1.250	
	median	0.045		0.062			0.038		0.059		0.101				0.200	0.080	
	25th	0.030		0.040			0.026		0.041		0.063				0.106	0.056	
	75th	0.076		0.092			0.072		0.155		0.159				0.390	0.159	
1991-1995	n	48		47			50		45		45					236	
	min	0.010		0.006			0.014		0.010		0.034					0.002	
	max	0.535		0.795			0.275		0.230		0.340					2.630	
	median	0.039		0.038			0.036		0.039		0.083					0.062	
	25th	0.024		0.029			0.027		0.025		0.051					0.040	
	75th	0.080		0.054			0.055		0.070		0.111					0.096	
1996-2000	n	7		7					7					7		31	
	min	0.024		0.016					0.036					0.016		0.024	
	max	0.524		0.442					0.272					0.940		0.864	
	median	0.164		0.036					0.060					0.052		0.076	
	25th	0.062		0.026					0.046					0.032		0.046	
	75th	0.288		0.177					0.213					0.141		0.195	
2001-2005	n	41		41	26	26			41			26		41		40	
	min	0.012		0.012	0.002	0.009			0.014			0.033		0.015		0.022	
	max	0.230		0.228	0.088	0.057			1.170			0.277		0.172		0.388	
	median	0.046		0.029	0.019	0.025			0.101			0.068		0.049		0.048	
	25th	0.028		0.022	0.011	0.015			0.059			0.050		0.033		0.036	
	75th	0.072		0.050	0.029	0.034			0.160			0.100		0.079		0.096	

North Maitland

*Harriston
08005600702

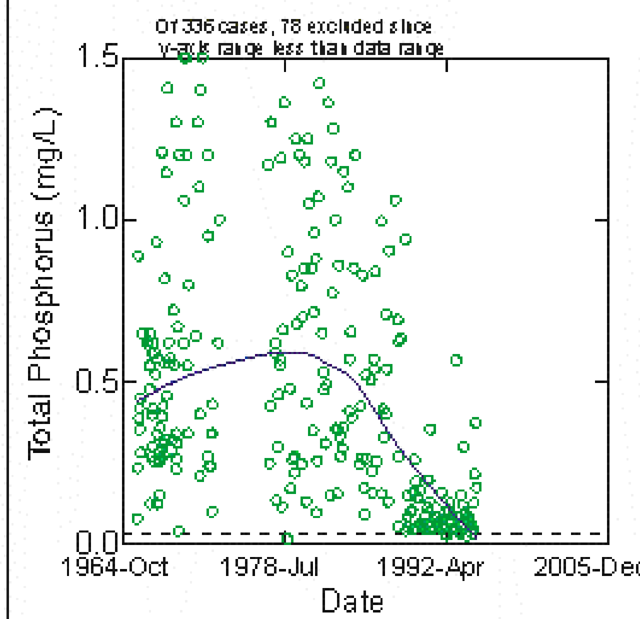


Wroxeter
08005600402

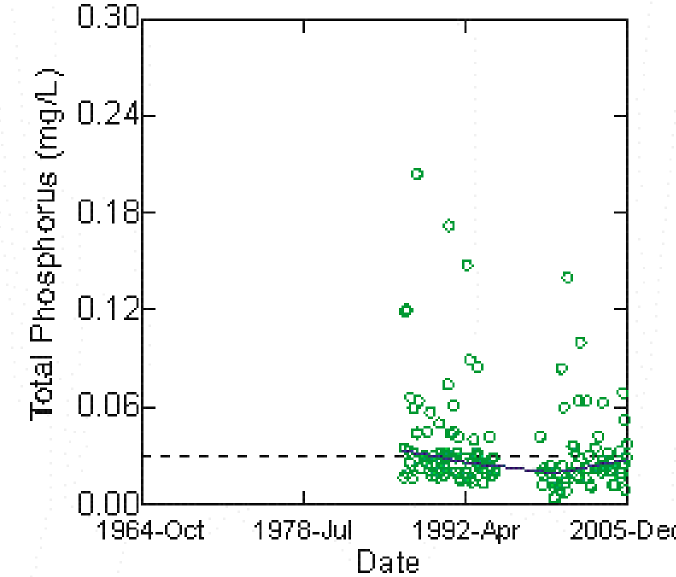


Little Maitland

*Palmer
08005600602

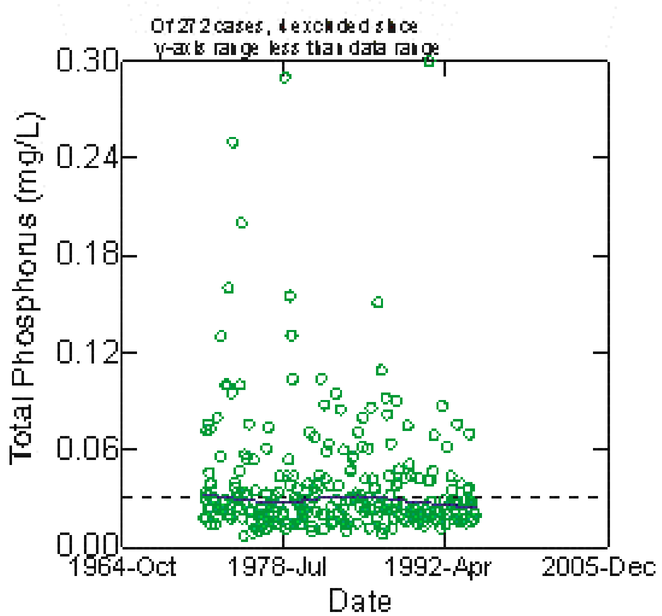


Jamestown
08005603502



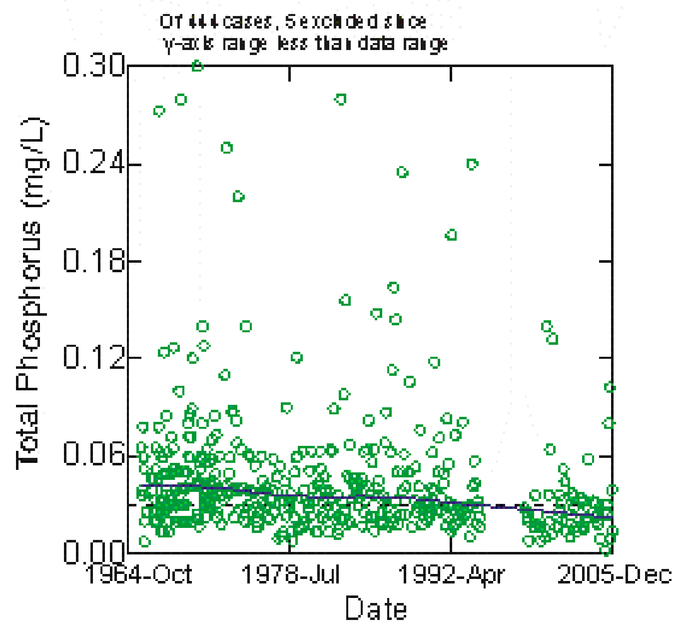
South Maitland

Londesborough
08005601502



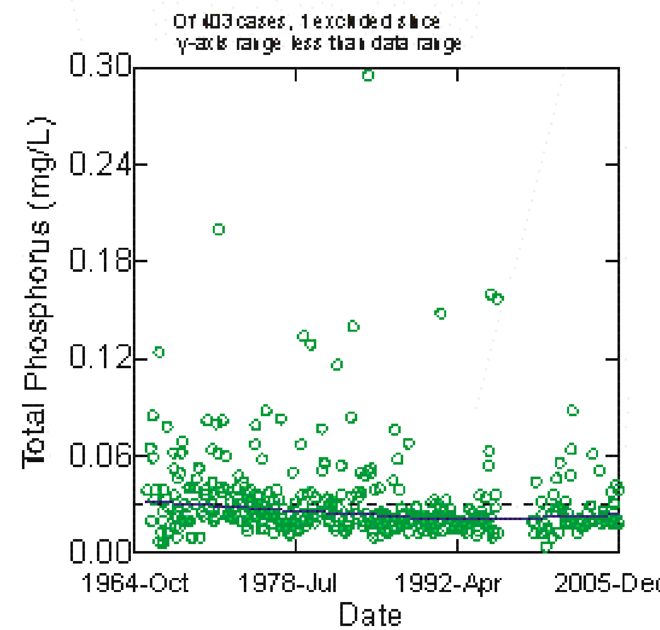
Lower Maitland

Zetland
08005600302



Nine Mile

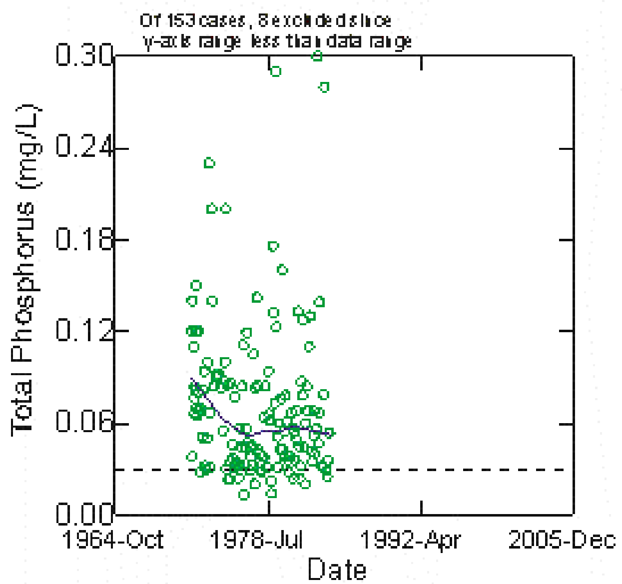
Lucknow
08007600202



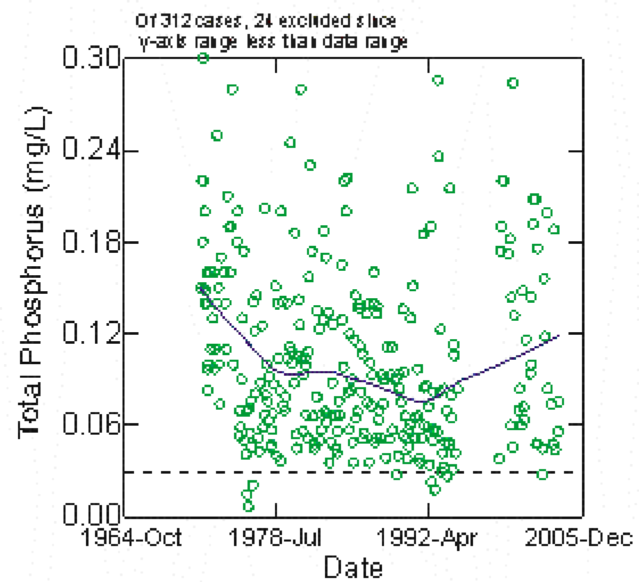
* Note: y-axis range extended to fit data

Middle Maitland

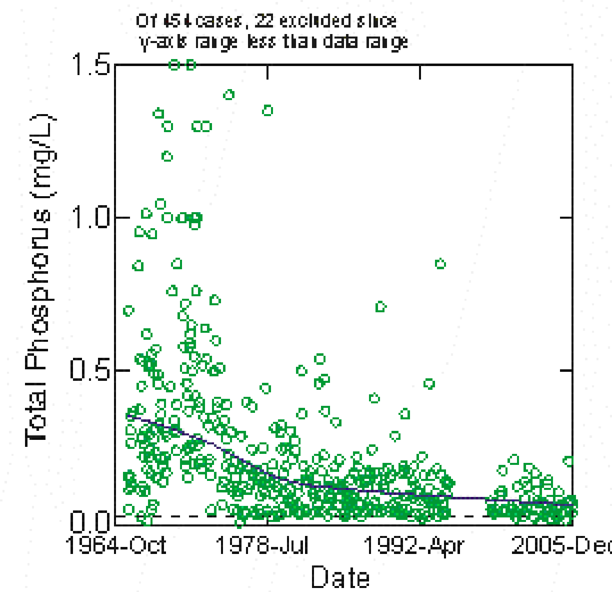
Listowel_NE
08005601402



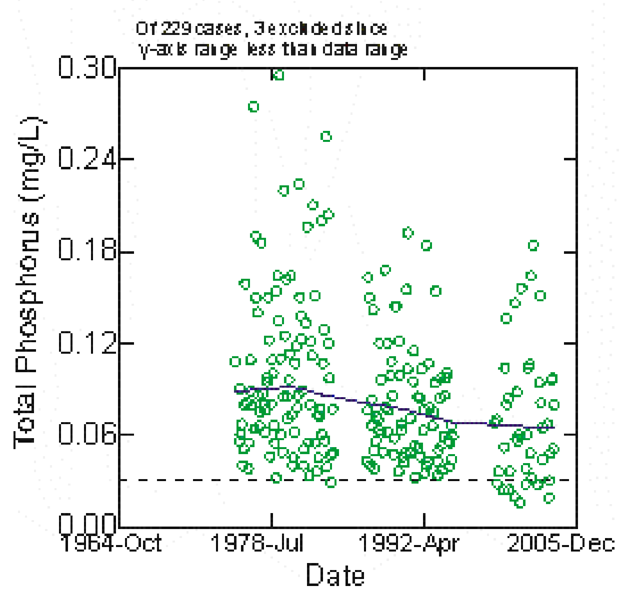
Listowel
08005601302



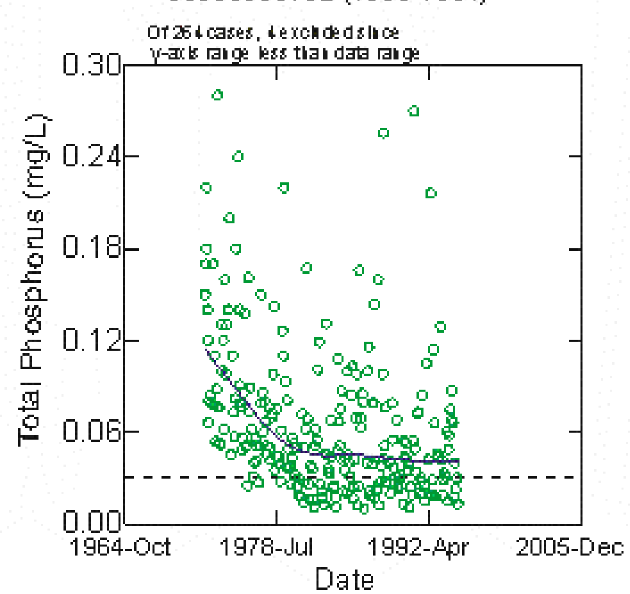
*Trowbridge
08005600902



Ethel
08005602602



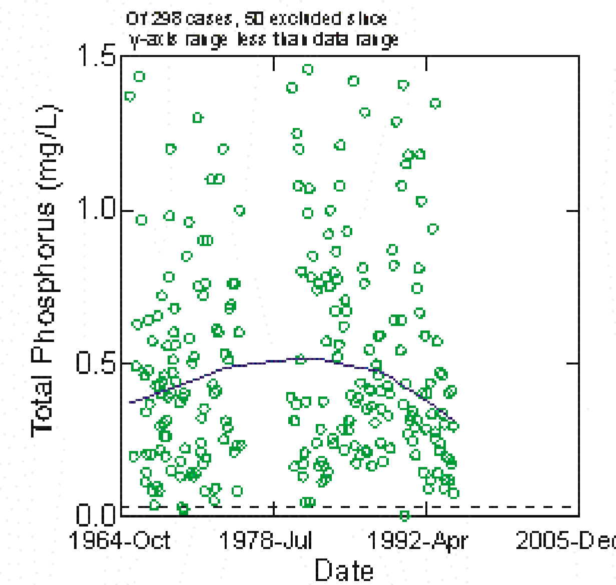
Bruss16D
08005601602 (1972-1979)
08005603102 (1980-1994)



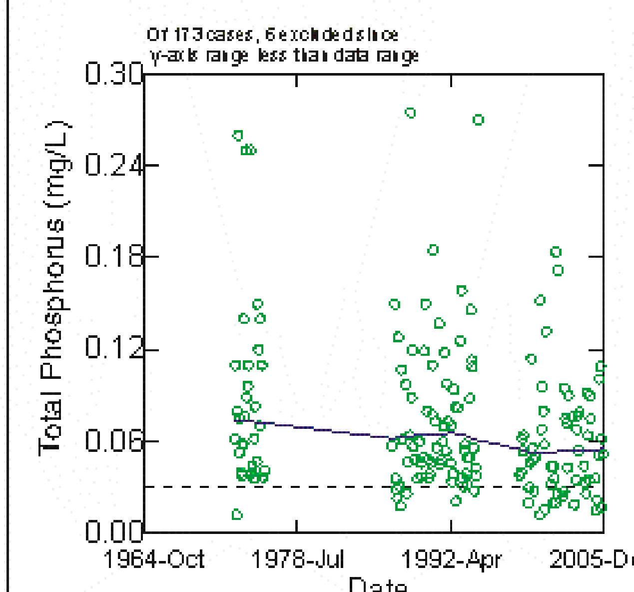
* Note: y-axis range extended to fit data

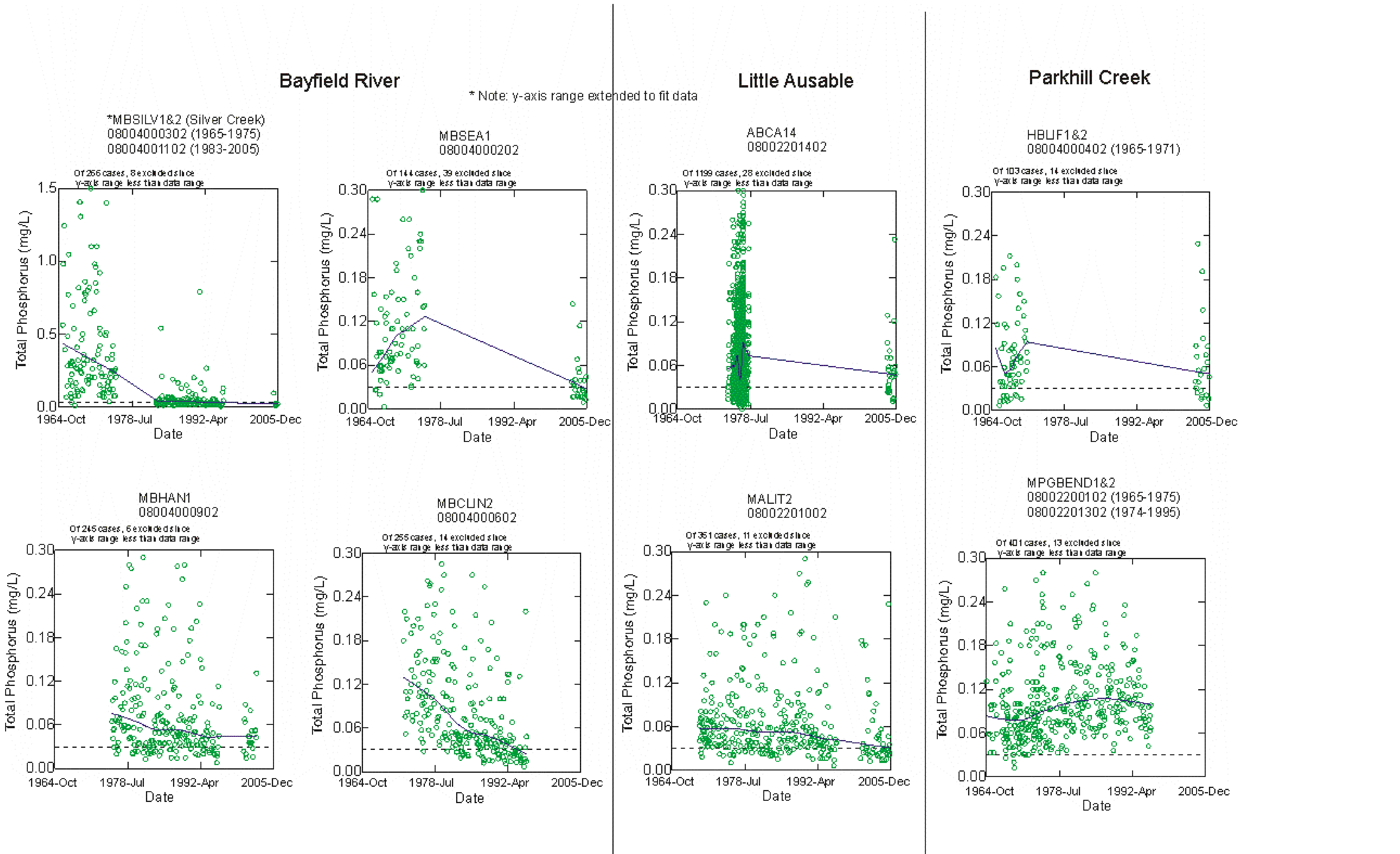
Boyle Drain

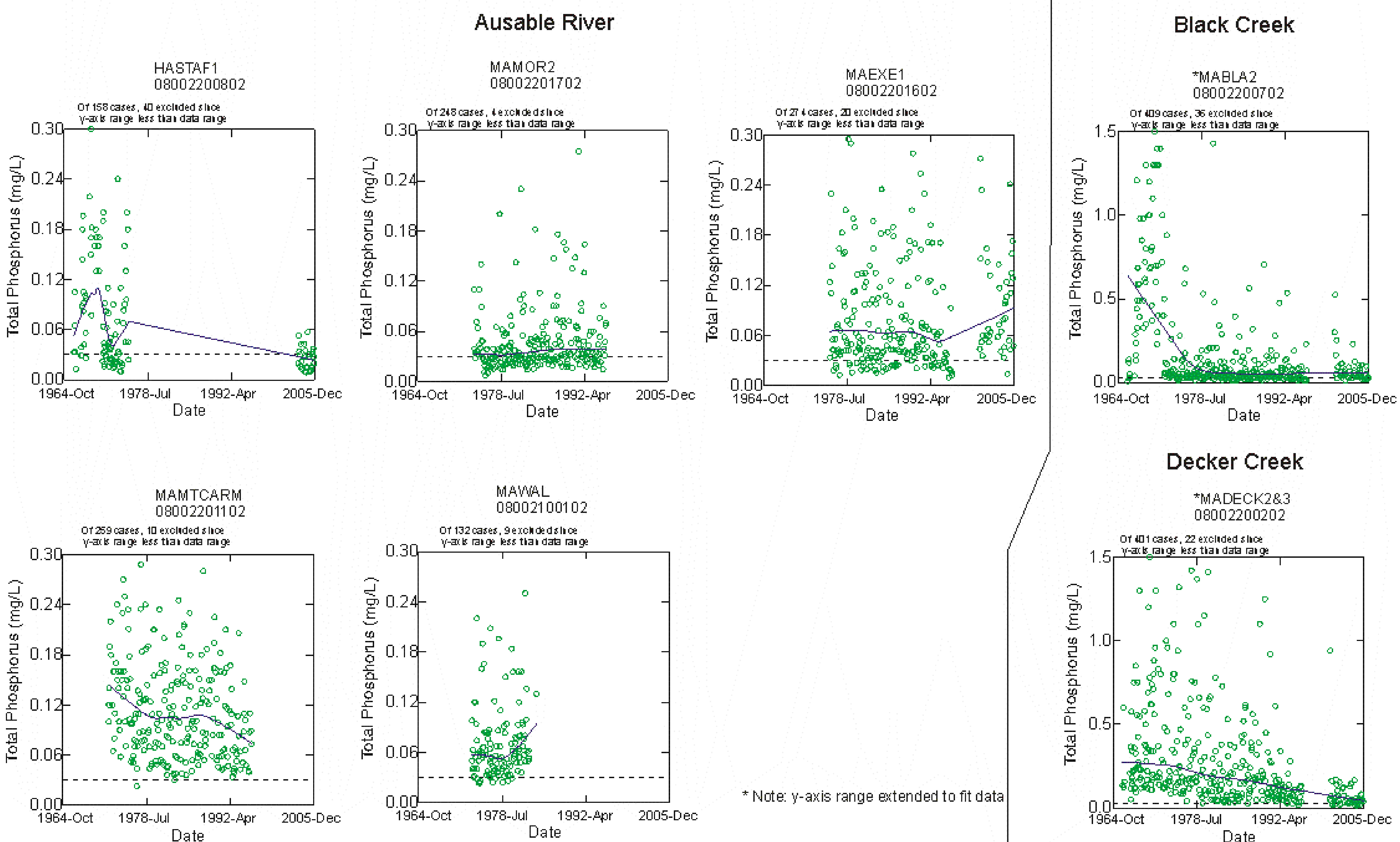
*Milverton
08005601002



Henfryn
08005602002




Bayfield River
* Note: y-axis range extended to fit data
Little Ausable
Parkhill Creek
*MBSILV1&2 (Silver Creek)
08004000302 (1965-1975)
08004001102 (1983-2005)
Of 256 cases, 8 excluded since y-axis range less than data range
MBSEA1
08004000202
Of 144 cases, 39 excluded since y-axis range less than data range
ABCA14
08002201402
Of 1199 cases, 28 excluded since y-axis range less than data range
HBLIF1&2
08004000402 (1965-1971)
Of 103 cases, 14 excluded since y-axis range less than data range
MBHAN1
08004000902
Of 245 cases, 6 excluded since y-axis range less than data range
MBCLIN2
08004000602
Of 255 cases, 14 excluded since y-axis range less than data range
MALIT2
08002201002
Of 351 cases, 11 excluded since y-axis range less than data range
MPGBEND1&2
08002200102 (1965-1975)
08002201302 (1974-1995)
Of 401 cases, 13 excluded since y-axis range less than data range
Total Phosphorus (mg/L)
Date
1964-Oct
1978-Jul
1992-Apr
2005-Dec


Ausable River
HASTAF1
08002200802
Of 158 cases, 40 excluded since y-axis range less than data range
MAMOR2
08002201702
Of 248 cases, 4 excluded since y-axis range less than data range
MAEXE1
08002201602
Of 274 cases, 20 excluded since y-axis range less than data range
MAMTCARM
08002201102
Of 259 cases, 10 excluded since y-axis range less than data range
MAWAL
08002100102
Of 132 cases, 9 excluded since y-axis range less than data range
Black Creek
*MABLA2
08002200702
Of 409 cases, 36 excluded since y-axis range less than data range
Decker Creek
*MADECK2&3
08002200202
Of 401 cases, 22 excluded since y-axis range less than data range
Total Phosphorus (mg/L)
Date
1964-Oct
1978-Jul
1992-Apr
2005-Dec
0.00
0.06
0.12
0.18
0.24
0.30
0.0
0.5
1.0
1.5
* Note: y-axis range extended to fit data

Residue Particulate - North, Little, South and Lower Maitland River and Nine Mile River

	Major Basin	Nine Mile		North Maitland						Little Maitland			South Maitland		Lower Maitland						
	Tributary			Upper				Salem Creek	Lower						Belgrave Creek	Blyth Brook		Sharpes Creek		Main Branch	
	MOE or local ID	08007600202	08007600102	08005600802	08005600702	08005602502	08005600402	08005605002	08005603802	08005600602	08005602202	08005603502	08005601502	08005603702	08005603002	08005604402	08005600202	08005602702	08005602802	08005600302	08005600102
	Site Name	Lucknow	Port Albert	Palmer_N	Harristn	Fordwich	Wroxeter	NMSalem	B-Line	Palmer	Palme_23	Jamestown	Londesbo	Summerhill	WNC_Belg	Blyth East	Blyth	Sharpes	SharpBen	Zetland	Goderich
1964-1965	n				31					29							36			28	35
	min				1.00					1.00							1.00			1.00	1.00
	max				46.00					169.00							68.00			76.00	31.00
	median				6.00					8.00							3.00			4.50	7.00
	25th				4.00					4.00							2.00			2.00	3.00
	75th				12.75					15.00							6.00			7.00	12.50
1966-1970	n	64	66		101		101			102							101			101	96
	min	1.00	1.00		1.00		1.00			3.00							1.00			1.00	1.00
	max	35.00	54.00		110.00		90.00			2000.00							170.00			63.00	70.00
	median	10.00	15.00		10.00		5.00			15.00							7.00			5.00	5.00
	25th	5.00	5.00		5.00		4.00			10.00							5.00			5.00	5.00
	75th	15.00	15.00		15.00		15.00			24.00							15.00			15.00	15.00
1971-1975	n	20	57		35		31			30			17				35	6	6	36	107
	min	5.00	0.00		5.00		5.00			5.00			5.00				5.00	1.00	3.00	5.00	0.00
	max	15.00	60.00		70.00		60.00			90.00			15.00				15.00	15.00	15.00	60.00	80.00
	median	15.00	15.00		5.00		5.00			10.00			5.00				5.00	15.00	15.00	5.00	15.00
	25th	12.50	15.00		5.00		5.00			5.00			5.00				5.00	15.00	15.00	5.00	5.00
	75th	15.00	15.00		10.00		10.00			10.00			5.00				5.00	15.00	15.00	10.00	15.00
1976-1980	n	33	34		58		36			36	9		36		23		39	29	44	58	66
	min	1.00	1.50		1.00		0.50			2.00	0.50		0.50		0.50		0.50	1.00	0.50	0.50	0.50
	max	55.00	135.00		38.00		50.00			39.00	15.00		20.00		39.00		89.00	52.00	19.00	40.00	505.00
	median	6.00	10.75		7.00		4.25			7.50	5.50		5.00		4.00		5.00	15.00	6.75	8.50	6.50
	25th	4.00	6.80		3.80		2.80			6.00	2.38		2.55		1.78		3.10	4.00	2.00	4.00	3.00
	75th	8.70	17.50		15.00		7.50			14.75	8.50		6.75		6.63		8.00	15.00	15.00	15.00	14.50
1981-1985	n	58	56		59		59			58			58		35		58			57	54
	min	0.70	1.50		0.10		0.30			0.90			0.40		0.10		0.10			1.00	0.40
	max	39.40	99.60		36.50		25.90			26.40			26.40		74.70		43.80			64.90	45.80
	median	4.40	11.75		5.50		3.90			5.00			5.05		2.90		5.10			5.30	3.80
	25th	3.10	6.40		2.55		2.18			3.10			3.10		2.00		2.80			3.10	2.30
	75th	8.10	22.20		10.33		7.08			7.40			8.70		6.35		8.90			9.33	6.00
1986-1990	n	54	54		53		54			52		38	55				57			48	53
	min	0.60	2.60		0.50		0.20			0.30		1.00	1.20				1.90			0.60	1.10
	max	43.70	156.20		48.80		75.00			36.50		41.50	66.80				45.10			57.40	79.50
	median	5.00	8.55		5.00		5.00			5.00		5.00	5.00				5.00			5.00	5.00
	25th	4.70	5.00		4.58		3.40			5.00		5.00	5.00				5.00			4.90	3.10
	75th	5.00	22.80		8.78		5.60			8.95		6.00	7.70				6.55			9.60	7.63
1991-1995	n	50	51		43		42			42		36	42				42			41	43
	min	2.00	3.10		2.90		2.40			2.60		2.30	1.50				2.30			2.10	2.30
	max	125.00	75.60		42.50		221.00			107.00		27.80	41.80				98.70			174.00	46.30
	median	5.00	8.00		5.40		5.00			5.10		5.15	5.05				5.65			6.20	6.90
	25th	5.00	5.15		5.00		5.00			5.00		5.00	5.00				5.00			5.00	4.33
	75th	8.60	13.85		8.53		7.10			10.10		8.30	8.20				9.00			10.03	11.68
1996-2000	n	21	21									20					21			20	19
	min	1.50	3.00									1.50					2.00			1.50	1.50
	max	13.50	121.00									16.00					98.50			24.50	73.00
	median	3.50	12.00									3.25					3.00			6.00	3.50
	25th	3.00	6.25									2.00					2.50			4.00	2.50
	75th	9.13	22.25									5.00					5.13			7.75	5.38
2001-2005	n	41	41					14	16			41		17		28	42			41	41
	min	2.70	2.00					0.70	1.00			0.60		1.00		2.80	0.60			1.20	1.00
	max	26.50	51.90					63.20	5.40			15.50		16.70		520.00	18.40			12.00	31.40
	median	4.80	11.80					1.50	2.35			4.00		4.50		7.35	3.40			5.00	4.00
	25th	3.98	6.15					1.10	1.60			2.50		3.18		4.75	2.50			3.08	2.65
	75th	7.43	18.63					2.00	3.25			6.23		7.10		19.60	6.00			7.55	6.10

Residue Particulate - Middle Maitland River

	Major Basin	Middle Maitland River																
	Tributary	Above Listowel		Chapman	Below Listowel				Boyle Drain		Beachamp	Lower Middle Maitland						
	MOE or local ID	08005601402	08005604302	08005602102	08005601302	08005600902	08005601902	08005602602	08005601002	08005602002	08005604102	08005601802	08005601102	08005600502	08005601602	08005603102	08005601702	08005603902
	Site Name	Listw_NE	NE Listowel	Chapman	Listowel	Trowbridge	Grey_Elm	Ethel	Milvertn	Henfryn	Beauchamp	Grey	Brusl_12	Brus_DSc	Brussl_D	Bruss_16	Morris	Wingham
1964-1965	n					25			10				9	17				
	min					3.00			3.00				2.00	1.00				
	max					77.00			98.00				29.00	18.00				
	median					13.00			22.00				5.00	4.00				
	25th					7.00			15.00				4.50	2.00				
	75th					17.50			58.00				11.75	8.25				
1966-1970	n					102			67				61	101				
	min					2.00			5.00				1.00	1.00				
	max					508.00			492.00				180.00	458.00				
	median					15.00			26.00				10.00	10.00				
	25th					10.00			15.00				5.00	5.00				
	75th					20.00			66.00				15.00	15.00				
1971-1975	n	17		31	17	33	33	6	25	31		32	22	24	24		32	
	min	5.00		5.00	5.00	5.00	4.00	4.00	5.00	3.00		8.00	5.00	5.00	5.00		4.00	
	max	10.00		80.00	40.00	130.00	80.00	15.00	240.00	55.00		180.00	140.00	30.00	50.00		50.00	
	median	5.00		15.00	5.00	10.00	15.00	15.00	10.00	15.00		15.00	12.50	5.00	15.00		15.00	
	25th	5.00		15.00	5.00	5.00	15.00	15.00	5.00	11.25		15.00	5.00	5.00	5.00		15.00	
	75th	5.00		15.00	6.25	21.25	15.00	15.00	25.00	15.00		15.00	50.00	10.00	15.00		15.00	
1976-1980	n	36			36	37		57	12						45	12		
	min	1.00			0.50	0.10		0.50	2.50						0.50	0.50		
	max	48.00			57.00	49.00		25.00	108.00						54.00	12.50		
	median	6.00			5.55	5.10		7.00	15.50						14.00	3.00		
	25th	3.75			3.50	2.58		3.38	7.10						5.75	1.75		
	75th	8.50			8.75	11.50		15.00	66.65						15.00	6.00		
1981-1985	n	36			60	59		35	59							58		
	min	0.60			0.40	0.10		0.90	0.30							0.10		
	max	110.60			87.40	26.60		94.00	341.80							50.80		
	median	4.85			4.40	3.70		5.80	12.90							3.20		
	25th	2.90			2.80	1.90		4.50	5.98							1.60		
	75th	8.25			6.55	5.70		11.23	35.83							6.30		
1986-1990	n				46	51		45	53	38						55		
	min				2.00	0.90		2.30	1.50	1.10						1.20		
	max				82.80	101.10		87.00	231.90	118.00						46.10		
	median				5.00	5.00		8.00	12.70	6.65						5.00		
	25th				4.00	4.78		5.00	6.60	5.00						5.00		
	75th				5.10	7.03		5.00	25.53	15.00						5.23		
1991-1995	n			1	41	43		5.825	43	39						42		
	min			5.00	2.70	0.90		40.00	4.70	2.90						2.00		
	max			5.00	108.00	129.00		2.20	1395.00	938.00						99.00		
	median			5.00	6.10	8.60		47.20	14.60	12.20						5.00		
	25th				5.00	5.00		7.20	7.03	7.95						5.00		
	75th				11.10	17.43		5.00	27.40	20.03						12.40		
1996-2000	n					20		14.5		21								
	min					1.00		1.00		1.50								
	max					37.50		21.00		36.00								
	median					2.50		3.00		8.00								
	25th					2.00		2.00		3.88								
	75th					3.50		9.13		13.38								
2001-2005	n		29		24	42		24		41	17							17
	min		1.10		0.80	0.00		0.80		1.80	0.70							0.90
	max		43.60		48.00	38.50		44.50		37.00	17.70							10.60
	median		4.30		3.95	4.50		3.00		6.00	3.60							2.90
	25th		2.68		2.70	2.70		1.90		3.25	2.90							1.60
	75th		9.33		5.90	7.80		4.35		8.83	7.18							5.25

Residue Particulate - Bayfield River and Parkhill Creek

	Major Basin	Bayfield River														Parkhill Creek							
	Tributary	Bannockburn	Liffy Ditch			Silver Creek		Upper Bayfield			Steenstra	Lower Bayfield				Upper Parkhill					Tributary	Lower Parkhill	
	MOE or local ID	MBBAN1	HBLIF1	08004000402	08004000502	08004001102	08004000302	08004000202	08004000902	08004000602	HBSTEEN1	08004001002	08004000802	08004000102	08004000783	08002200302	MPMCGUF1	08002200402	08002200902	08002201202	08002201802	08002201302	08002200102
	Site Name	Bannockburn	Dublin	HBLIF2	HBLIF3	Silver	MBSILV1	Seaforth	MBHAN1	MBCLIN2	Steenstra	MBGRANT	Varna	MBBAY1	MBBAY2	HPCAM	Upstream Parkhill	MPDAM	MPHARM	Downstream Parkhill	MPTRI1	MPGBEND2	MPGBEND1
1964-1965	n			5	5		6	9						7		9		9					6
	min			2.00	15.00		6.00	1.00						1.00		7.00		8.00					14.00
	max			45.00	40.00		132.00	15.00						29.00		352.00		39.00					56.00
	median			15.00	31.00		11.00	6.00						10.00		31.00		20.00					19.00
	25th			11.00	15.00		7.00	1.75						8.25		9.00		10.00					15.00
	75th			24.00	37.00		15.00	8.00						17.00		48.75		22.50					55.00
1966-1970	n			64	64		66	65						64		76		15	56				72
	min			2.00	1.00		4.00	2.00						4.00		6.00		15.00	15.00				12.00
	max			158.00	450.00		185.00	60.00						298.00		806.00		930.00	213.00				784.00
	median			13.50	13.00		15.00	12.00						15.00		15.00		51.00	26.00				30.00
	25th			5.00	5.00		12.00	5.75						9.00		15.00		32.25	15.00				15.50
	75th			17.50	17.00		23.00	15.00						18.50		26.50		78.25	54.00				54.00
1971-1975	n			8	39		45	42	6	31			6	60	23	54			15	38		29	71
	min			15.00	5.00		5.00	5.00	2.00	2.00			1.00	0.00	5.00	5.00			15.00	5.00		9.00	0.00
	max			130.00	75.00		90.00	70.00	20.00	90.00			18.00	300.00	100.00	470.00			95.00	190.00		111.00	290.00
	median			30.00	15.00		15.00	15.00	15.00	15.00			15.00	15.00	15.00	15.00			25.00	20.00		30.00	20.00
	25th			20.00	15.00		15.00	15.00	15.00	15.00			8.00	41.82	15.00	15.00			15.00	15.00		23.75	15.00
	75th			55.00	25.00		15.00	15.00	15.00	15.00			15.00	15.00	18.75	20.00			38.75	50.00		60.00	30.00
1976-1980	n								59	59		32	62	30						11		60	
	min								0.50	0.20		0.50	0.50							6.90		1.00	
	max								170.00	276.00		22.50	179.00							91.70		214.00	
	median								9.00	5.50		5.00	6.75							32.40		25.25	
	25th								4.08	2.58		2.25	3.00							10.50		14.75	
	75th								15.00	15.00		14.25	15.00							50.83		49.00	
1981-1985	n					34			59	58			59							59		58	
	min					0.10			0.10	0.10			0.50							1.00		3.90	
	max					403.30			201.00	81.70			92.90							202.40		274.20	
	median					2.95			5.80	2.85			3.40							30.00		34.90	
	25th					1.40			3.23	1.50			2.03							14.00		15.60	
	75th					5.40			11.75	5.80			7.80							62.38		56.00	
1986-1990	n					54			54	56			56							58		55	
	min					1.50			0.40	1.30			0.90							4.00		4.70	
	max					73.30			108.00	104.00			136.00							272.00		237.00	
	median					5.00			5.00	5.00			5.00							30.90		30.70	
	25th					5.00			5.00	5.00			5.00							15.70		16.98	
	75th					7.30			10.40	7.10			7.25							49.50		53.38	
1991-1995	n					47			44	45			48							51		45	
	min					2.60			2.40	2.40			1.40							5.00		8.90	
	max					328.00			461.00	923.00			844.00							110.00		178.00	
	median					5.00			6.80	5.00			5.00							38.40		35.30	
	25th					5.00			5.00	5.00			5.00							20.25		23.38	
	75th					9.95			20.15	15.35			5.00							50.10		54.85	
1996-2000	n								7				7								7		
	min								2.50				2.00								8.00		
	max								167.00				164.00								84.00		
	median								11.50				2.50								69.50		
	25th								4.00				2.00								31.75		
	75th								73.25				32.88								82.88		
2001-2005	n	18	18			8		26	15		21		60				18			26	15		
	min	1.00	1.00			0.60		1.60	1.50		1.00		1.60				1.00			10.70	14.00		
	max	153.00	150.00			15.70		39.80	13.50		883.00		319.00				98.00			71.10	56.50		
	median	5.00	5.50			3.25		4.50	4.00		8.00		5.50				21.50			32.60	30.20		
	25th	2.00	2.00			1.15		2.70	3.13		2.75		3.30				8.00			21.40	25.63		
	75th	10.00	9.00			7.65		11.60	5.85		16.00		13.65				44.00			48.80	40.93		

Indicator is Total Suspended Sediment

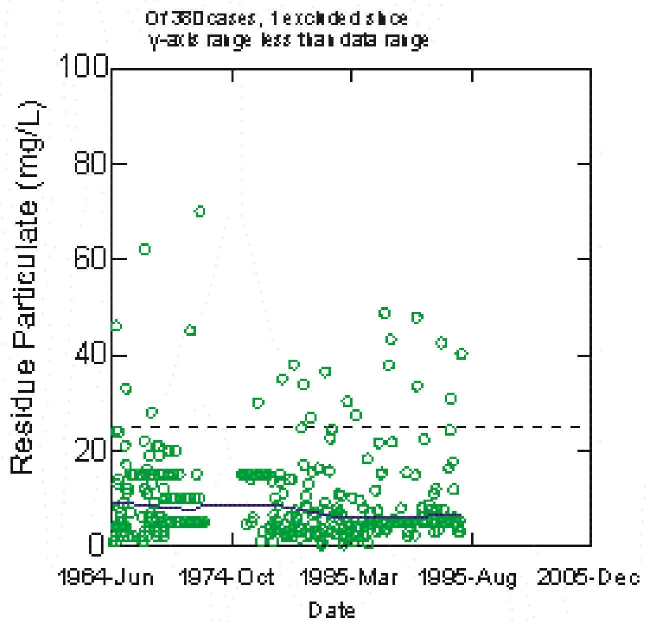
Residue Particulate - Ausable River

	Major Basin	Ausable															
	Tributary	Black Creek	Little Ausable River		Nairn Creek	Ausable River								Decker Creek		The Cut	
	MOE or local ID	08002200702	08002201402	08002201002	MANAIRN1	08002200802	08002201702	08002200602	08002201602	08002200502	08002201102	08002202002	08002201502	08002201902	08002200202	08002100202	08002100102
	Site Name	Black	Huron Park	Lucan	Nairn	Staffa	MAMOR2	MATHAMES	Exeter	HATRIB	MAMTCARM	Springbank	MAGLAS1	Decker	MADECK3	Thedford	MAWAL
1964-1965	n																
	min																
	max																
	median																
	25th																
	75th																
1966-1970	n	71		22		72		75		75					74		
	min	1.00		15.00		7.00		2.00		1.00					12.00		
	max	709.00		21.00		840.00		178.00		296.00					396.00		
	median	15.00		15.00		19.50		15.00		15.00					38.00		
	25th	15.00		15.00		15.00		15.00		15.00					20.00		
	75th	37.75		15.00		49.50		15.00		15.00					69.00		
1971-1975	n	61	88	60		55	22	55	6	16	39				61		39
	min	1.00	2.00	3.00		5.00	5.00	5.00	1.00	15.00	5.00				4.00		0.00
	max	190.00	240.00	75.00		110.00	45.00	55.00	60.00	20.00	90.00				950.00		350.00
	median	15.00	15.00	15.00		15.00	15.00	15.00	15.00	15.00	20.00				30.00		20.00
	25th	15.00	13.75	15.00		15.00	15.00	10.00	15.00	15.00	15.00				15.00		15.00
	75th	15.00	25.00	15.00		20.00	15.00	15.00	42.00	15.00	30.00				61.25		31.50
1976-1980	n	59	496	57			61		60		58				59		65
	min	0.50	0.50	0.50			0.50		0.50		0.50				0.50		0.50
	max	63.00	426.00	93.00			131.00		128.00		227.00				748.00		838.00
	median	7.00	12.75	11.00			9.00		10.25		15.00				18.00		23.00
	25th	3.25	7.00	4.00			4.63		5.00		9.00				13.75		11.38
	75th	15.00	23.00	15.00			15.00		15.00		36.00				34.50		39.25
1981-1985	n	60		56			60	1	58		59				57	314	28
	min	0.10		0.90			0.10	2.90	0.10		0.10				1.50	1.60	4.90
	max	207.80		504.60			28.90	2.90	111.50		47.70				261.40	2434.00	91.10
	median	3.55		5.45			3.45	2.90	4.20		12.60				21.50	63.26	32.45
	25th	2.05		3.00			2.05		2.90		4.58				12.68	34.04	18.10
	75th	6.70		9.70			6.00		8.90		27.08				37.33	164.20	42.10
1986-1990	n	55		55			55		56		53				56	245	
	min	0.80		1.50			0.90		1.30		2.40				5.00	2.20	
	max	180.00		93.30			74.90		81.20		180.00				217.00	1270.00	
	median	5.00		6.60			5.00		5.00		16.80				23.50	50.40	
	25th	5.00		5.00			5.00		5.00		6.78				13.95	32.23	
	75th	8.70		13.80			12.93		12.20		25.18				36.60	92.28	
1991-1995	n	47		48			50		43		45				49	222	
	min	1.80		3.20			1.70		1.70		5.00				3.90	4.80	
	max	272.00		396.00			94.20		70.00		63.80				147.00	771.00	
	median	5.00		6.55			5.00		5.00		11.10				24.60	39.15	
	25th	5.00		5.00			5.00		5.00		6.08				15.78	24.00	
	75th	15.10		21.55			10.10		8.50		28.90				44.35	66.80	
1996-2000	n	7		7					7					7		31	
	min	4.00		4.00					3.00					3.00		11.00	
	max	136.00		223.00					120.00					843.00		447.00	
	median	9.50		14.00					7.50					19.00		58.00	
	25th	5.88		6.75					5.25					13.00		26.25	
	75th	34.75		40.50					30.25					69.25		130.00	
2001-2005	n	41	29	41	18	18			41					41		40	
	min	0.70	2.70	0.50	1.00	1.00			1.20					3.10		9.90	
	max	38.30	289.00	86.30	28.00	23.00			13.30					120.00		151.00	
	median	4.10	10.80	4.70	8.50	5.50			3.60					15.00		23.70	
	25th	2.90	7.73	2.50	5.00	5.00			2.30					10.40		17.40	
	75th	7.80	19.53	7.18	16.00	8.00			6.50					26.20		44.55	

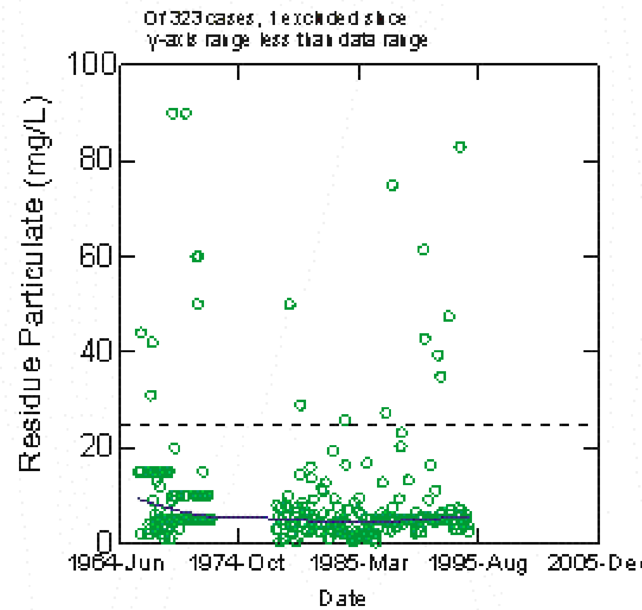
Indicator is Total Suspended Sediment

North Maitland

Harriston
08005600702

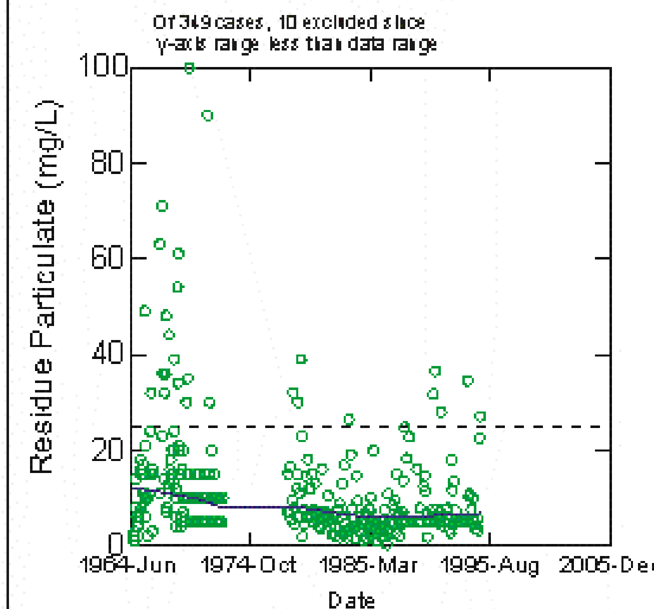


Wroxeter
08005600402

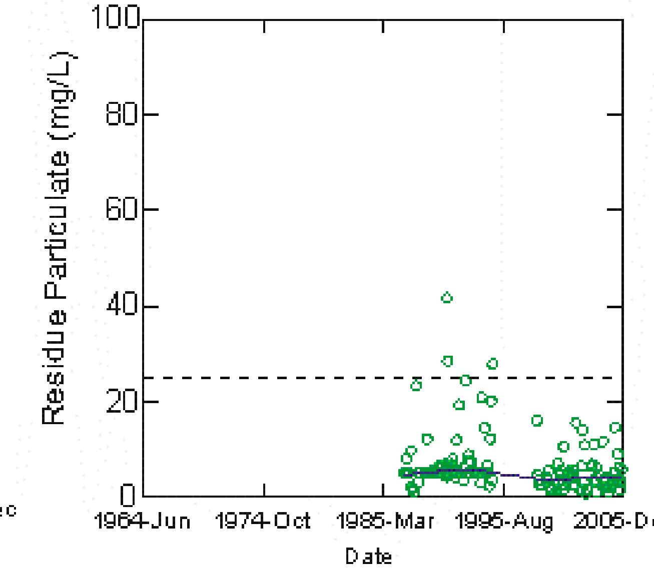


Little Maitland

Palmer
08005600602



Jamestown
08005603502



South Maitland

Londesborough
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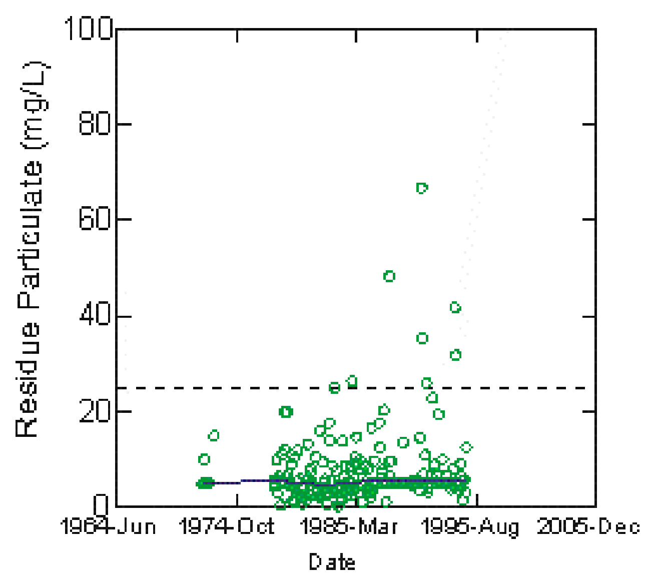
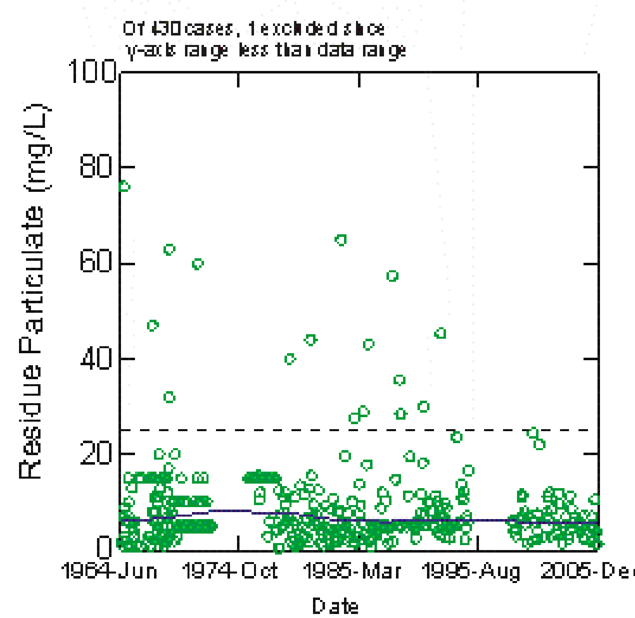


Lower Maitland

Zetland
08005600302



Nine Mile

Lucknow
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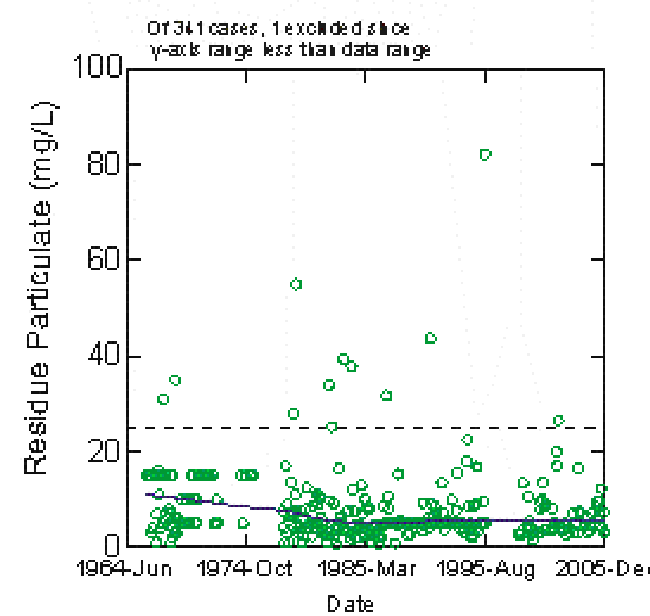
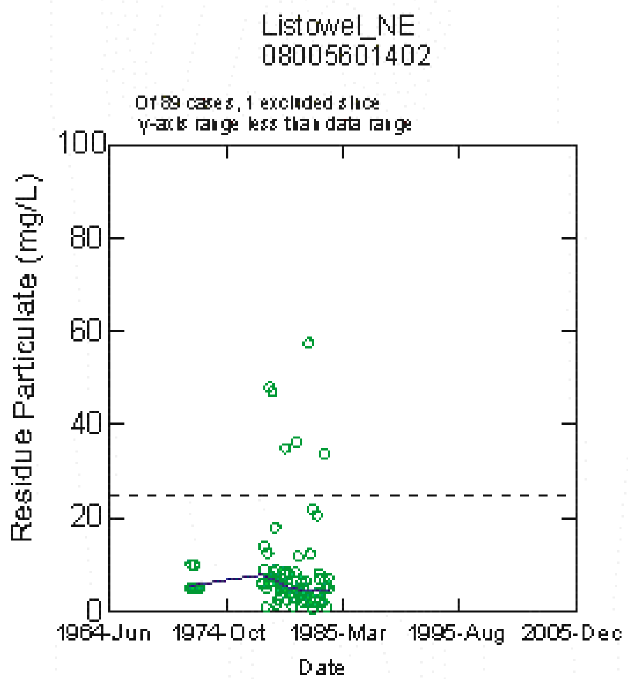
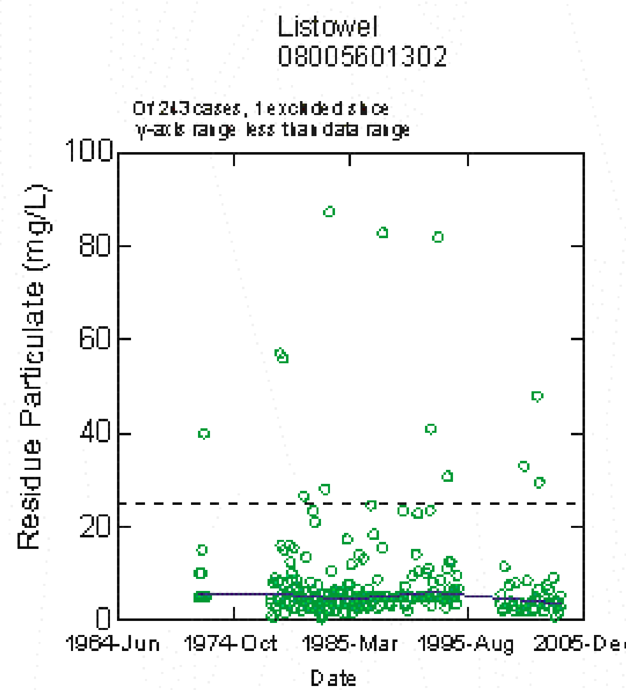
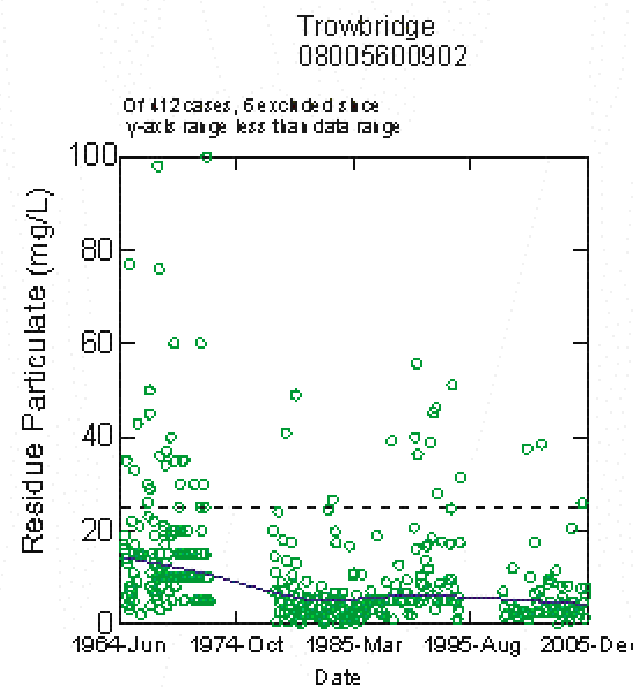
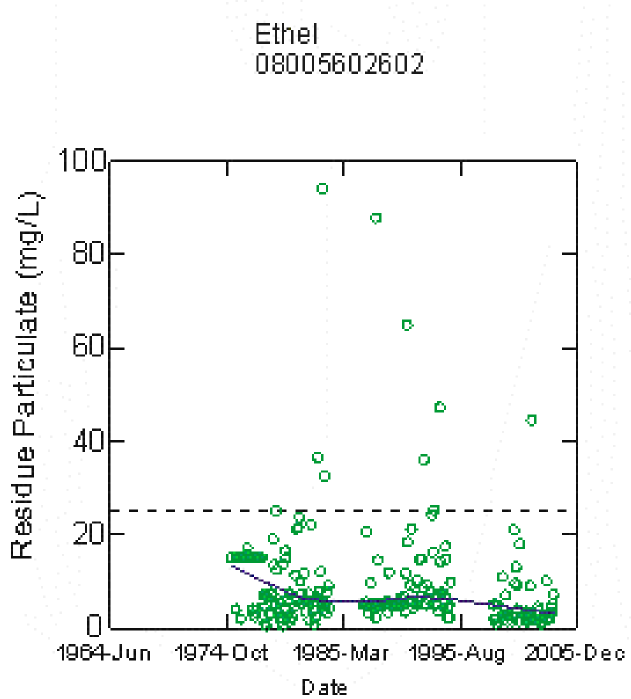


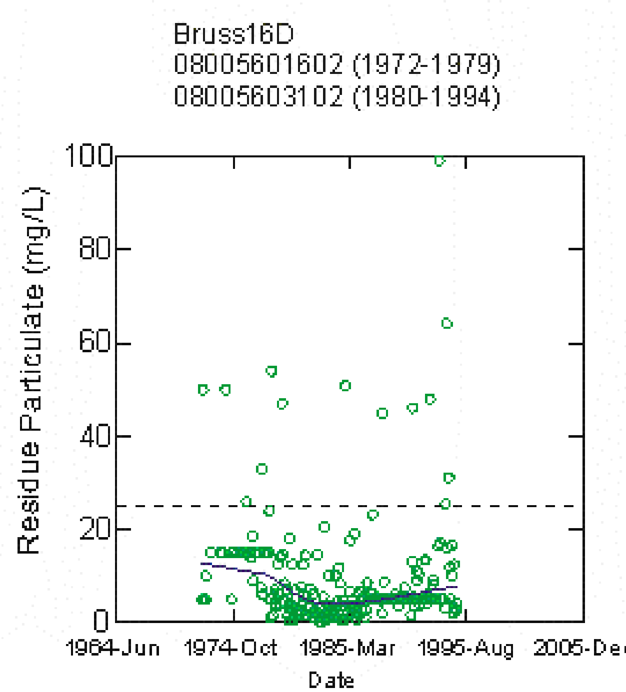
Middle Maitland



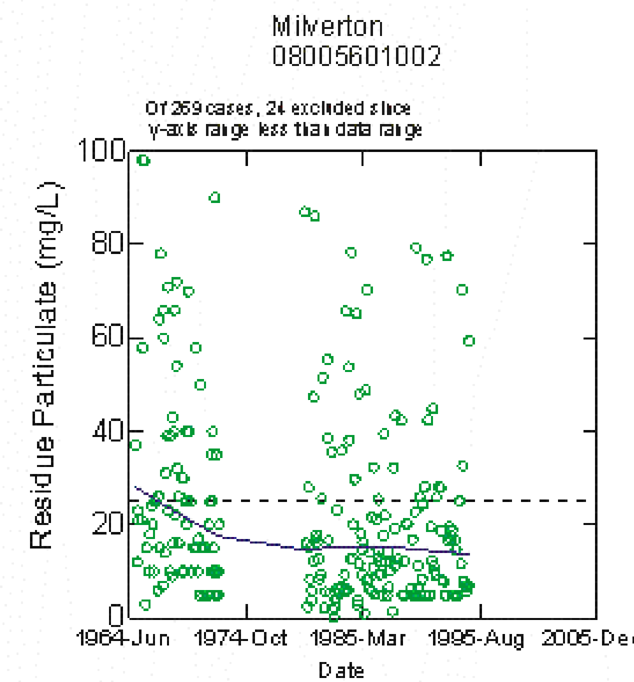


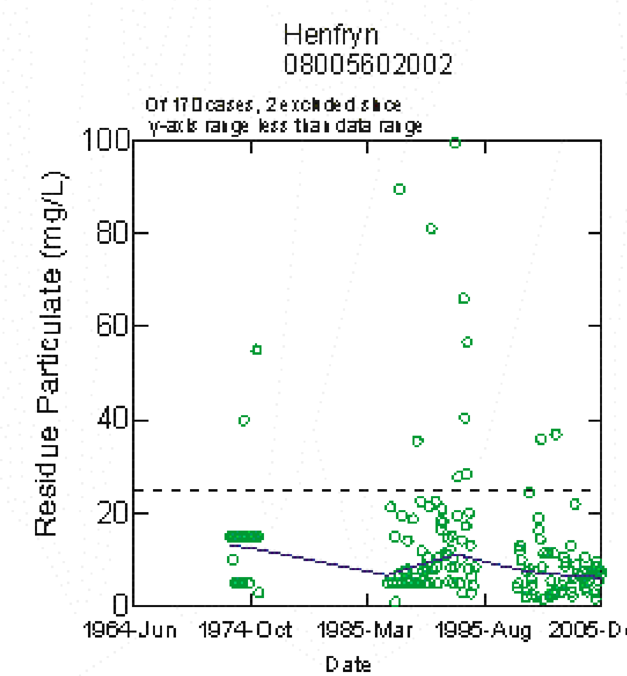


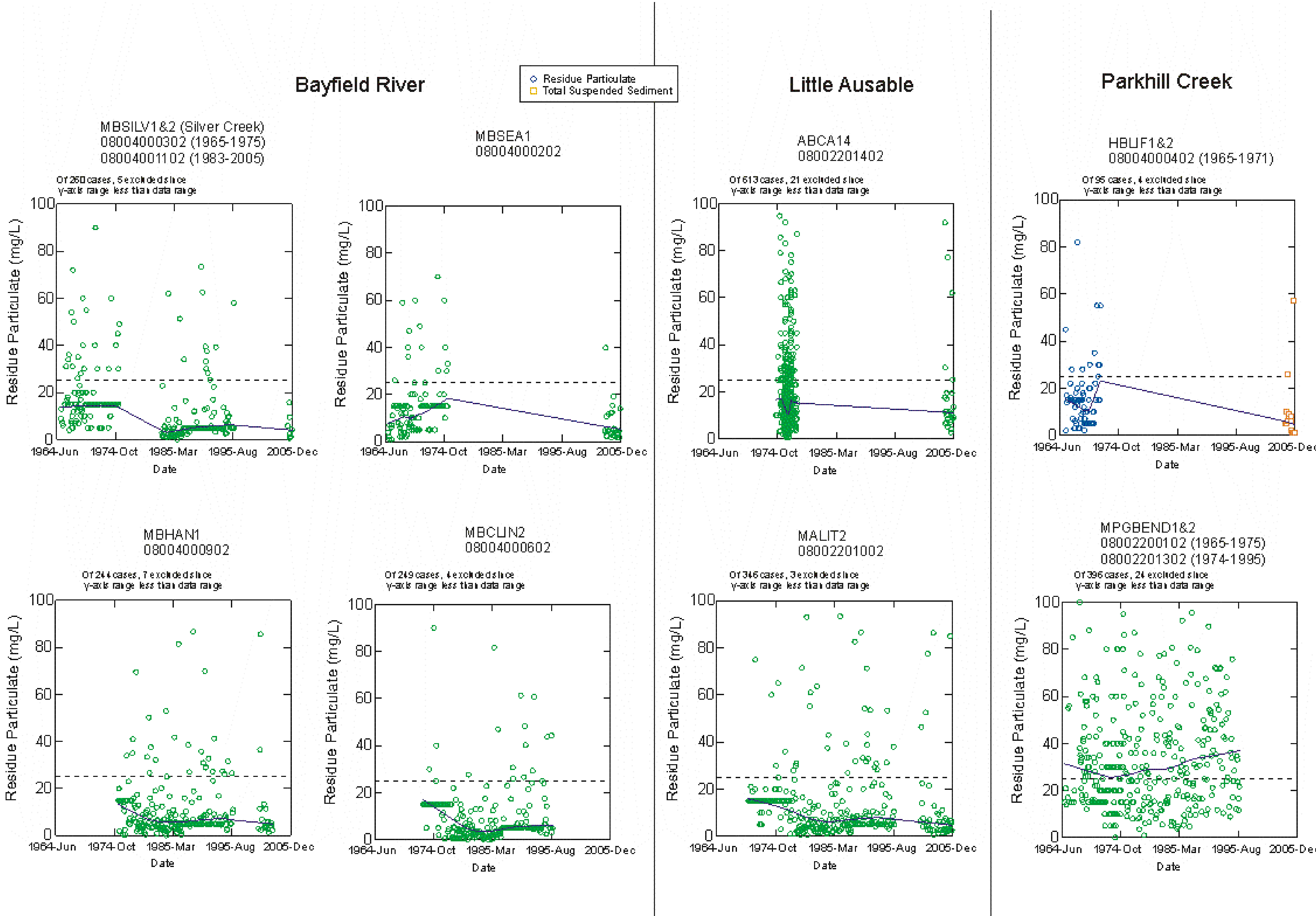




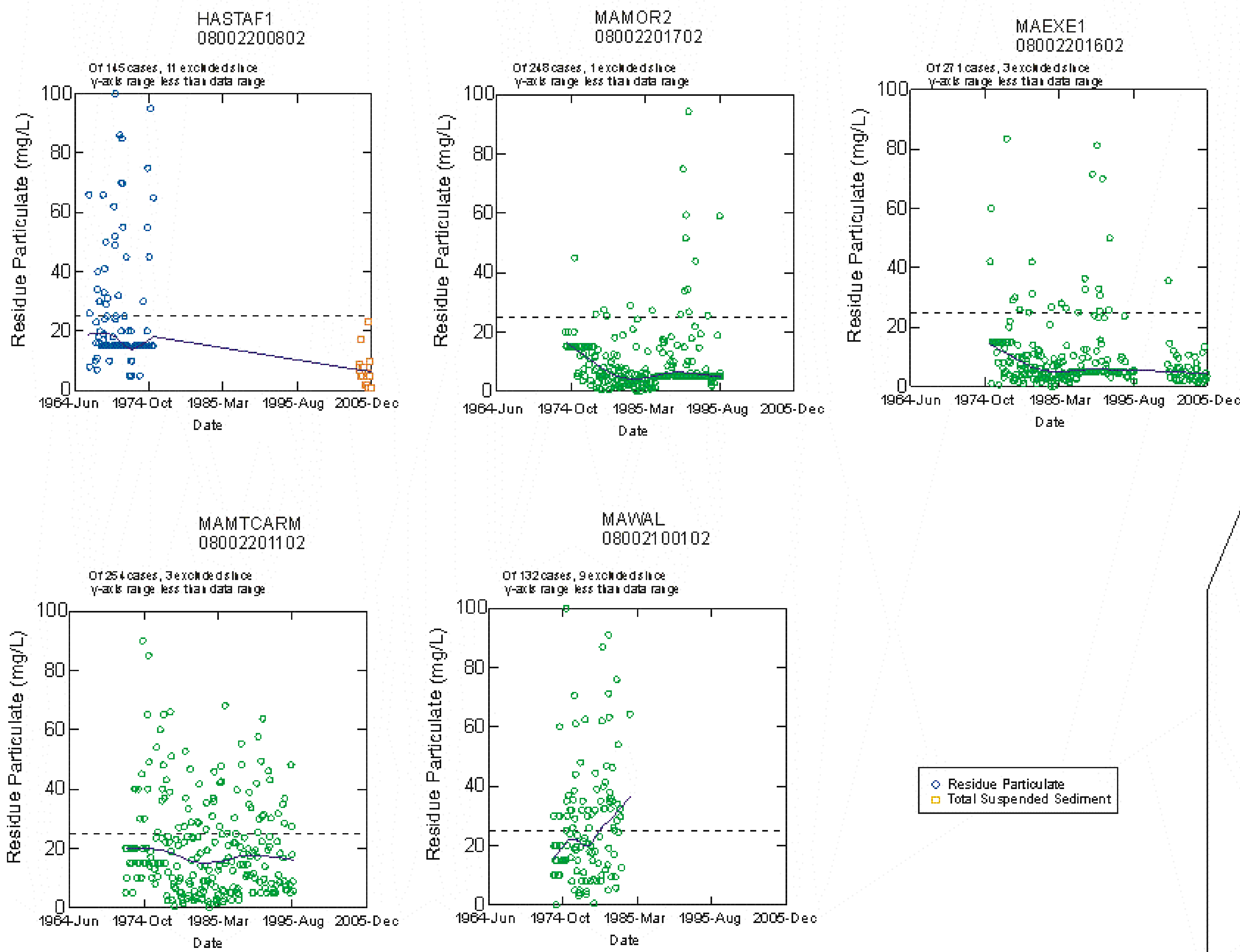
Boyle Drain



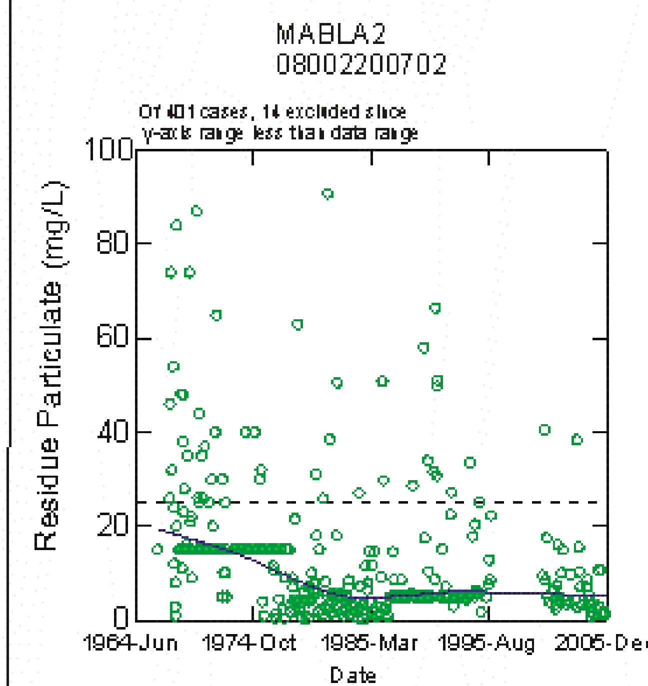



Bayfield River
Little Ausable
Parkhill Creek
Residue Particulate
Total Suspended Sediment
MBSILV1&2 (Silver Creek)
08004000302 (1965-1975)
08004001102 (1983-2005)
Of 260 cases, 5 excluded since y-axis range less than data range
MBSEA1
08004000202
ABCA14
08002201402
Of 613 cases, 21 excluded since y-axis range less than data range
HBLIF1&2
08004000402 (1965-1971)
Of 95 cases, 4 excluded since y-axis range less than data range
MBHAN1
08004000902
Of 244 cases, 7 excluded since y-axis range less than data range
MBCLIN2
08004000602
Of 249 cases, 4 excluded since y-axis range less than data range
MALIT2
08002201002
Of 346 cases, 3 excluded since y-axis range less than data range
MPGBEND1&2
08002200102 (1965-1975)
08002201302 (1974-1995)
Of 396 cases, 24 excluded since y-axis range less than data range
Residue Particulate (mg/L)
Date
1964-Jun
1974-Oct
1985-Mar
1995-Aug
2005-Dec
0
20
40
60
80
100

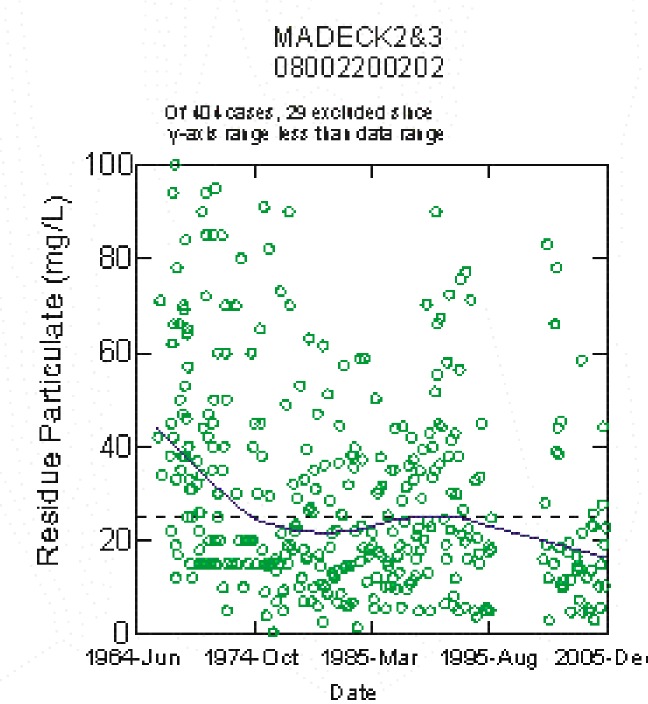
Ausable River



Black Creek



Decker Creek



Bacteria - North, Little, South and Lower Maitland River and Nine Mile River

		Major Basin	Nine Mile		North Maitland						Little Maitland			South Maitland		Lower Maitland						
		Tributary			Upper				Salem Creek	Lower						Belgrave Creek	Blyth Brook		Sharpes Creek		Main Branch	
		MOE or local ID	08007600202	08007600102	08005600802	08005600702	08005602502	08005600402	08005605002	08005603802	08005600602	08005602202	08005603502	08005601502	08005603702	08005603002	08005604402	08005600202	08005602702	08005602802	08005600302	08005600102
		Site Name	Lucknow	Port Albert	Palmer_N	Harristn	Fordwich	Wroxeter	NMSalem	B-Line	Palmer	Palme_23	Jamestown	Londesbo	Summerhill	WNC_Belg	Blyth East	Blyth	Sharpes	SharpBen	Zetland	Goderich
Fecal Coliform	1964-1965	n																				
		min																				
		max																				
		median																				
		25th																				
		75th																				
	1966-1970	n																				
		min																				
		max																				
		median																				
		25th																				
		75th																				
	1971-1975	n		52	40	45		45			14							46			45	76
		min		1	4	4		4			4							4			4	1
		max		1200	14000	70000		1110			4800							2500			1200	2400
		median		68	110	204		16			430							198			40	4
		25th		18	36	77		8			180							40			12	4
		75th		133	297	503		60			1000							370			131.5	24
	1976-1980	n		40		41		39			29							44			41	49
		min		4		4		4			190							4			4	4
		max		420		3800		430			47900							1070			920	384
		median		20		220		30			1220							131			50	4
		25th		6		48		10.5			436							18			16	4
		75th		74		540		92			2100							319			117	17
	1981-1985	n		41		41		44			42							40			41	33
		min		4		10		4			100							4			4	4
		max		630		41000		1000			69000							3800			1140	900
		median		88		600		80			2550							218			92	24
		25th		15		242.5		33			1100							105			40	4
		75th		241		1500		142			8500							527			258	173
	1986-1990	n		47		45		47			45							46			48	44
		min		4		4		4			16							16			4	4
		max		1000		2400000		1000			240000							1500			1500	1000
		median		24		430		32			710							167			68	10
		25th		10		126		16			405							92			20	4
		75th		55		710		88			4450							284			294	24
	1991-1995	n		41		40		38			40							41			40	42
		min		4		4		4			24							8			4	4
		max		1500		2300		1200			5700							8			1500	1000
		median		28		148		42			208							17200			53	12
		25th		10		66		20			108							168			20	4
		75th		78		365		124			495							109			186	56
E. coli	1996-2000	n																400				
		min																				
		max																				
		median																				
		25th																				
		75th																				
	2001-2005	n							13								27					
		min							28								12					
		max							7000								6300					
		median							1000								280					
		25th							357.5								102.5					
		75th							1900								890					

Bacteria - Middle Maitland River

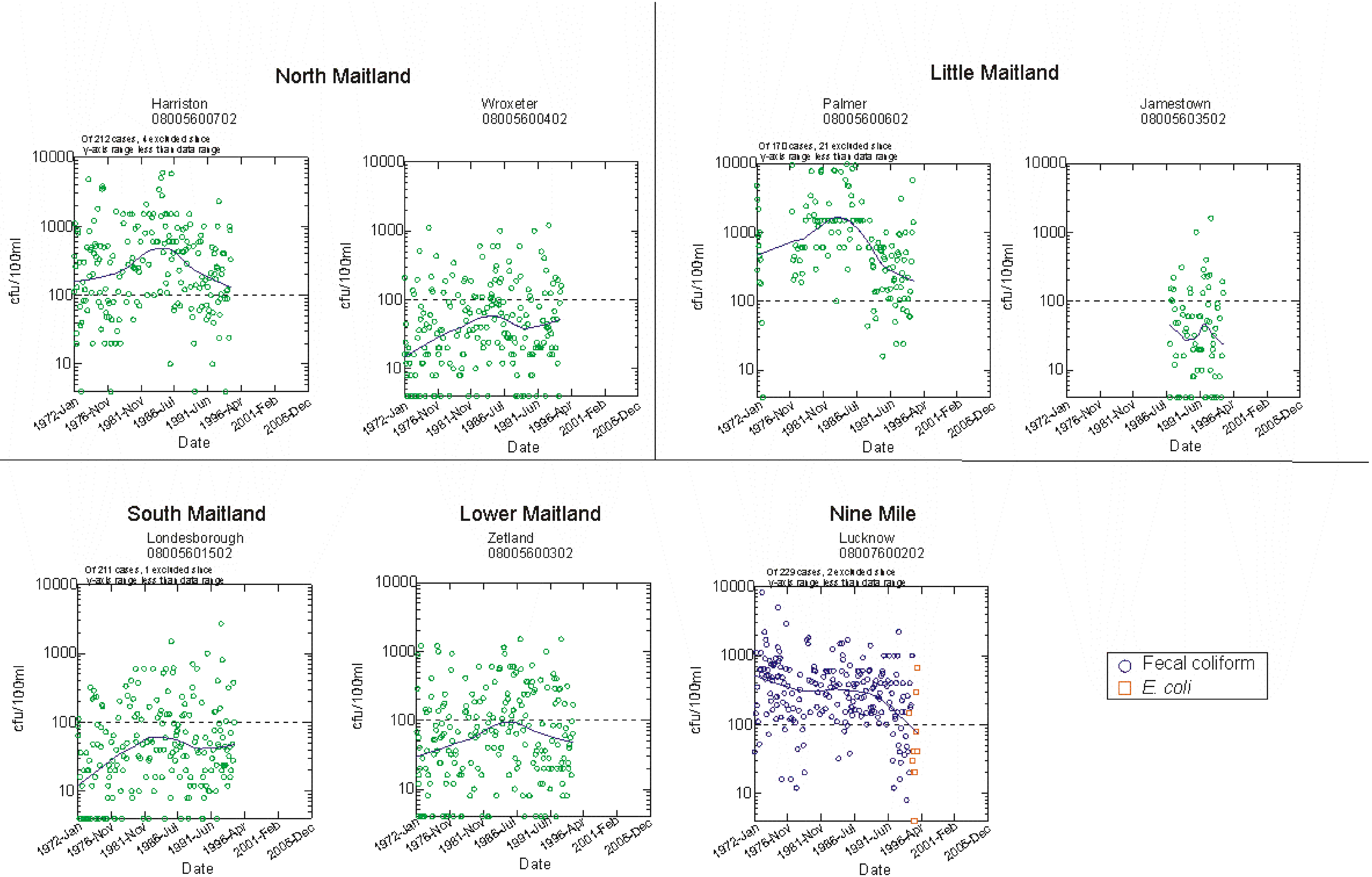
		Major Basin	Middle Maitland River																
		Tributary	Above Listowel		Chapman	Below Listowel				Boyle Drain		Beachamp	Lower Middle Maitland						
		MOE or local ID	08005601402	08005604302	08005602102	08005601302	08005600902	08005601902	08005602602	08005601002	08005602002	08005604102	08005601802	08005601102	08005600502	08005601602	08005603102	08005601702	08005603902
		Site Name	Listw_NE	NE Listowel	Chapman	Listowel	Trowbridge	Grey_Elm	Ethel	Milvertn	Henfryn	Beauchamp	Grey	Brusl_12	Brus_DSc	Brussl_D	Bruss_16	Morris	Wingham
Fecal Coliform	1964-1965	n																	
		min																	
		max																	
		median																	
		25th																	
		75th																	
	1966-1970	n																	
		min																	
		max																	
		median																	
		25th																	
		75th																	
	1971-1975	n					43			40	29				30	45			
		min					4			4	4				4	4			
		max					16700			1100000	5400				37000	26000			
		median					104			543	40				910	210			
		25th					43			64	7				320	51			
		75th					313			1800	137				5200	882.5			
	1976-1980	n					42			8					10	30	9		
		min					4			20					280	12	10		
		max					600			150000					300000	3800	260		
		median					74			1050					1500	232	60		
		25th					36			435					440	140	19		
		75th					150			17250					13400	480	149		
	1981-1985	n					43										43		
		min					8										4		
		max					1500										77000		
		median					190										70		
		25th					65										28		
		75th					440										230		
	1986-1990	n					46				31						45		
		min					4				4						4		
		max					1600				6000						1000		
		median					88				170						32		
		25th					36				38						11		
		75th					448				508						68		
	1991-1995	n					39				37						41		
		min					10				10						4		
		max					1100				4300						2200		
		median					160				160						32		
		25th					50.5				78						16		
		75th					246.5				299						111		
E. coli	1996-2000	n																	
		min																	
		max																	
		median																	
		25th																	
		75th																	
	2001-2005	n		27															
		min		20															
		max		10000															
		median		1000															
		25th		190															
		75th		2200															

Bacteria - Bayfield River and Parkhill Creek

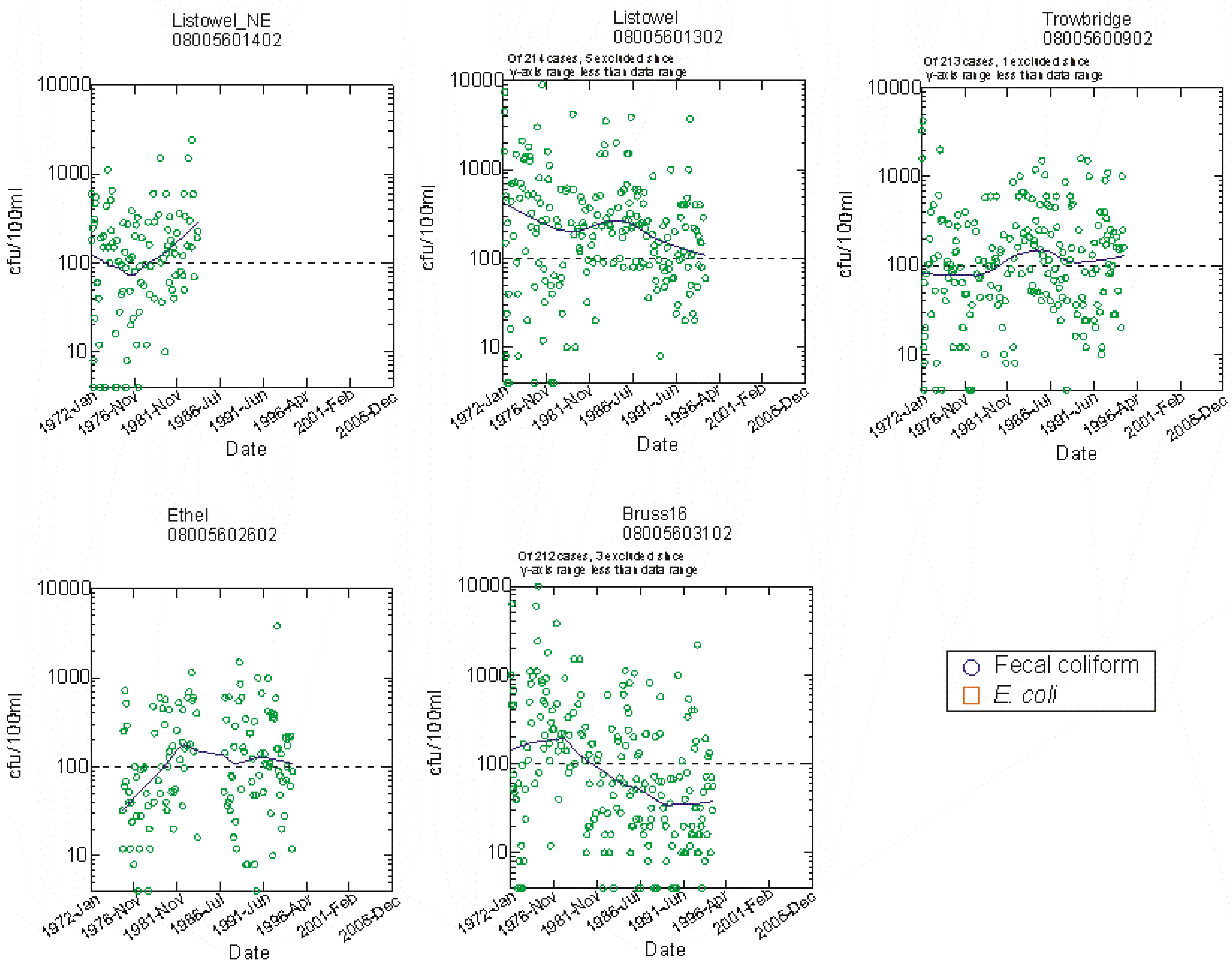
		Major Basin	Bayfield River														Parkhill Creek							
		Tributary	Bannockburn	Liffy Ditch			Silver Creek		Upper Bayfield			Steenstra	Lower Bayfield				Upper Parkhill					Tributary	Lower Parkhill	
		MOE or local ID	MBBAN1	HBLIF1	08004000402	08004000502	08004001102	08004000302	08004000202	08004000902	08004000602	HBSTEEN1	08004001002	08004000802	08004000102	08004000783	08002200302	MPMCGUF1	08002200402	08002200902	08002201202	08002201802	08002201302	08002200102
		Site Name	Bannockburn	Dublin	HBLIF2	HBLIF3	Silver	MBSILV1	Seaforth	MBHAN1	MBCLIN2	Steenstra	MBGRANT	Varna	MBBAY1	MBBAY2	HPCAM	Upstream Parkhill	MPDAM	MPHARM	Downstream Parkhill	MPTRI1	MPGBEND2	MPGBEND1
Fecal Coliform	1964-1965	n																						
		min																						
		max																						
		median																						
		25th																						
		75th																						
	1966-1970	n																						
		min																						
		max																						
		median																						
		25th																						
		75th																						
	1971-1975	n				35		40	37	6	35			6	47	20								
		min				4		4	4	12	4			20	0	4								
		max				53000		11000	7100	1300	27000			300	1360	550								
		median				910		730	400	190	240			101	90	62								
		25th				88		175	135	80	25			20	21	20								
		75th				1875		1800	1057.5	610	807.5			240	272.5	196								
	1976-1980	n								59	58		31	61									59	
		min								10	4		4	4									8	
		max								2500	3000		10600	7400									15000	
		median								270	187		150	100									168	
		25th								104	76		76	39									81	
		75th								570	480		294	275									397.5	
	1981-1985	n					30			55	54			56									55	
		min					4			10	4			8									4	
		max					1500			5300	1500			1500									3200	
		median					228			200	154			87									130	
		25th					40			71.5	56			36									72	
		75th					528			370	350			198									297.5	
	1986-1990	n					52			51	52			53									50	
		min					4			20	4			4									10	
		max					11000			8800	3700			1500									7500	
		median					225			244	301			110									140	
		25th					80			130	84			27									56	
		75th					600			597.5	725			291.5									500	
	1991-1995	n					40			36	39			39									36	
		min					12			52	10			16									30	
		max					44000			5100	7000			2900									2800	
		median					270			315	140			100									120	
		25th					100			86	82			42									75	
		75th					895			890	391			194.5									215	
E. coli	1991-1995	n					8			8	8			9									9	
		min					48			88	20			32									10	
		max					610			1000	1000			400									150	
		median					338			270	208			70									56	
		25th					160			194	70			41									27.5	
		75th					400			400	340			143									108	
	1996-2000	n																						
		min																						
		max																						
		median																						
		25th																						
		75th																						
	2001-2005	n	26	25			8		26			18		26				26						
		min	10	6			12		20			0		4				7						
		max	50000	4700			320		2300			8200		10000				2800						
		median	211	600			157		385			260		71				175						
		25th	123	163			70		150			100		28				80						
		75th	1000	1325			255		660			820		210				410						

Bacteria - Ausable River

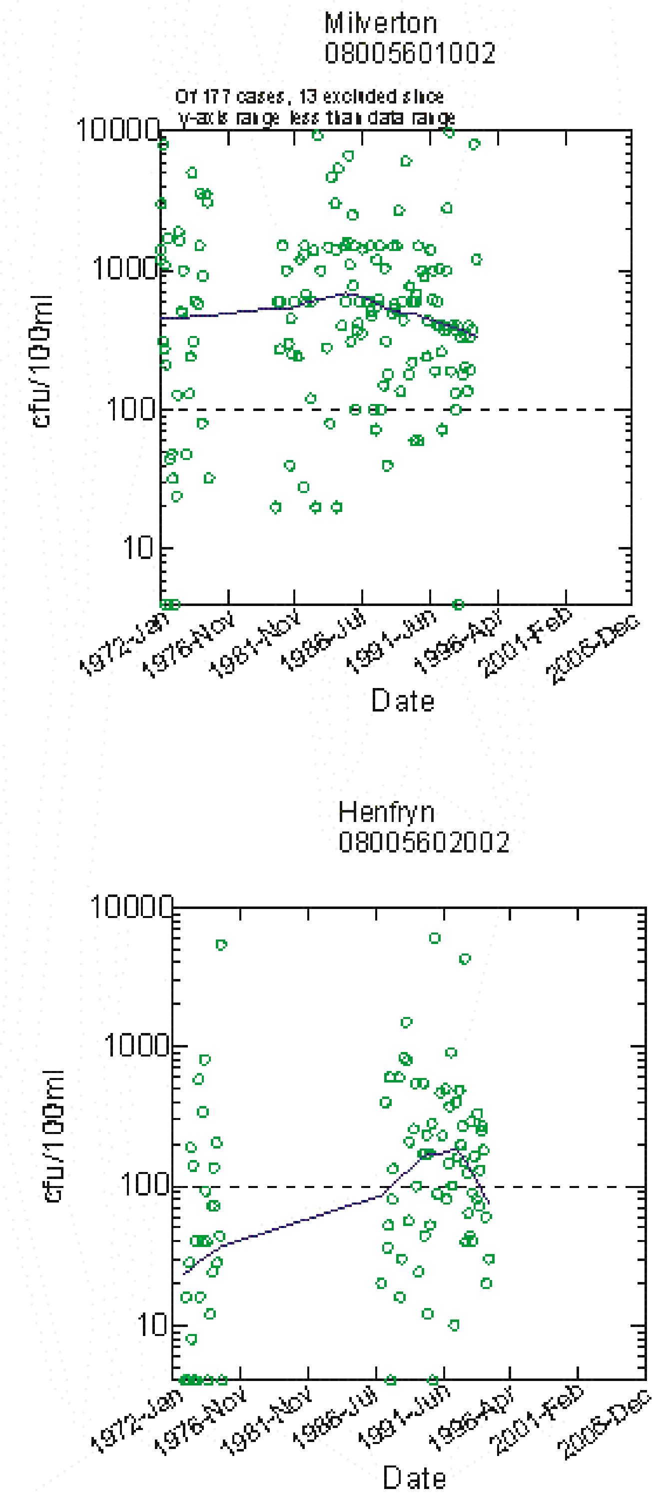
		Major Basin	Ausable															
		Tributary	Black Creek	Little Ausable River		Nairn Creek	Ausable River								Decker Creek		The Cut	
		MOE or local ID	08002200702	08002201402	08002201002	MANAIRN1	08002200802	08002201702	08002200602	08002201602	08002200502	08002201102	08002202002	08002201502	08002201902	08002200202	08002100202	08002100102
		Site Name	Black	Huron Park	Lucan	Nairn	Staffa	MAMOR2	MATHAMES	Exeter	HATRIB	MAMTCARM	Springbank	MAGLAS1	Decker	MADECK3	Thedford	MAWAL
Fecal Coliform	1964-1965	n																
		min																
		max																
		median																
		25th																
		75th																
	1966-1970	n																
		min																
		max																
		median																
		25th																
		75th																
	1971-1975	n		55				21		6								
		min		12				4		120								
		max		49000				2400		3700								
		median		540				12		440								
		25th		197.5				4		140								
		75th		1800				85		3300								
	1976-1980	n		51				60		60								
		min		1				4		4								
		max		5400				1500		11000								
		median		110				16		310								
		25th		50				4		106								
		75th		367.5				76		850								
	1981-1985	n						55		53								
		min						4		4								
		max						900		1500								
		median						16		180								
		25th						4		46								
		75th						67		382.5								
	1986-1990	n						52		53								
		min						4		4								
		max						2900		7800								
		median						20		280								
		25th						4		163								
		75th						126		670								
	1991-1995	n						41		36								
		min						4		10								
		max						1800		6700								
		median						20		270								
		25th						8		110								
		75th						62		400								
E. coli	1991-1995	n						8		8								
		min						4		4								
		max						20		1700								
		median						4		94								
		25th						4		40								
		75th						9		262								
	1996-2000	n																
		min																
		max																
		median																
		25th																
		75th																
	2001-2005	n		27		26	26			25			26		26			
		min		8		4	20			0			10		2			
		max		67000		1100	7300			720			1600		17000			
		median		280		185	780			200			135		170			
		25th		105		51	250			68			70		73			
		75th		697.5		380	1600			290			300		490			

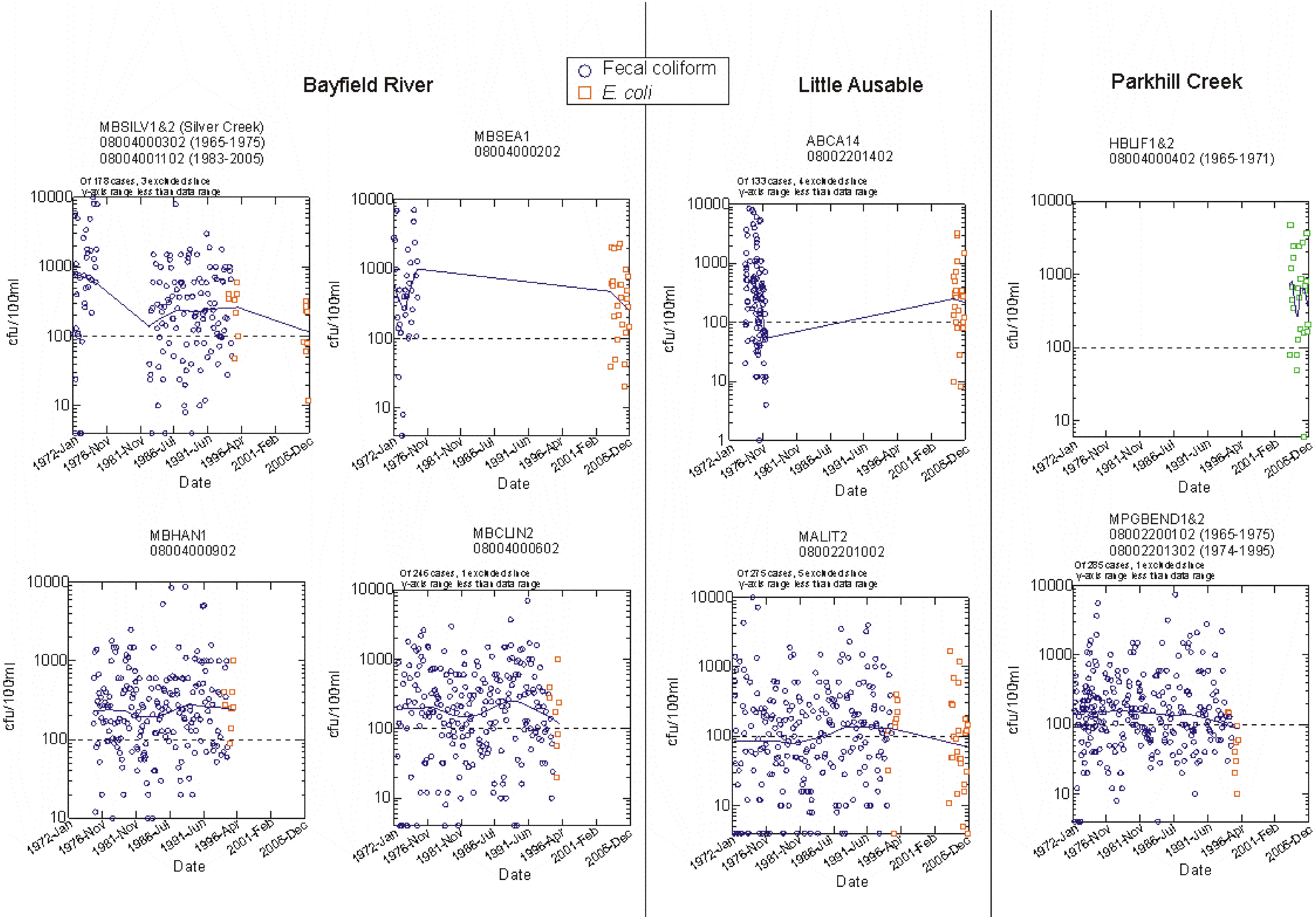

North Maitland
Harriston
08005600702
Of 212 cases, 4 excluded since
y-axis range less than data range
Wroxeter
08005600402
Little Maitland
Palmer
08005600602
Of 170 cases, 21 excluded since
y-axis range less than data range
Jamestown
08005603502
South Maitland
Londesborough
08005601502
Of 211 cases, 1 excluded since
y-axis range less than data range
Lower Maitland
Zetland
08005600302
Nine Mile
Lucknow
08007600202
Of 229 cases, 2 excluded since
y-axis range less than data range
cfu/100ml
10000
1000
100
10
1972-Jan
1976-Nov
1981-Nov
1986-Jul
1991-Jun
1996-Apr
2001-Feb
2005-Dec
Date
Fecal coliform
E. coli

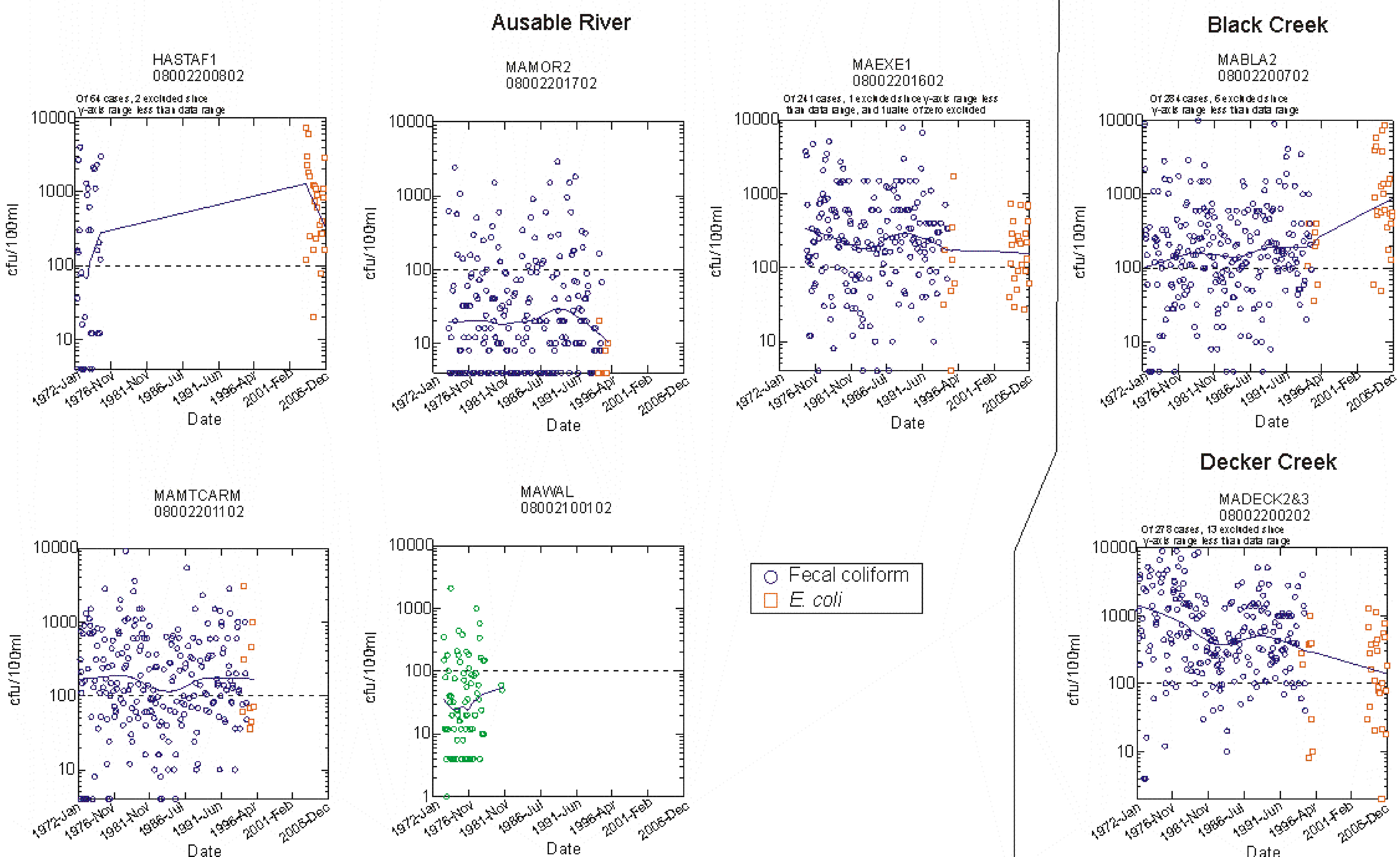
Middle Maitland



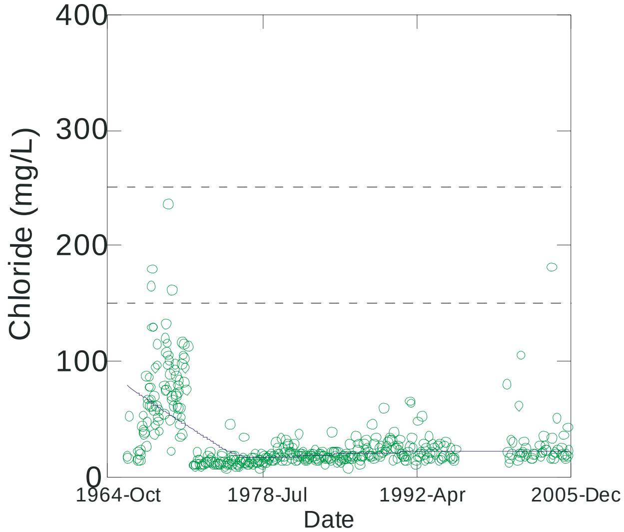
Boyle Drain



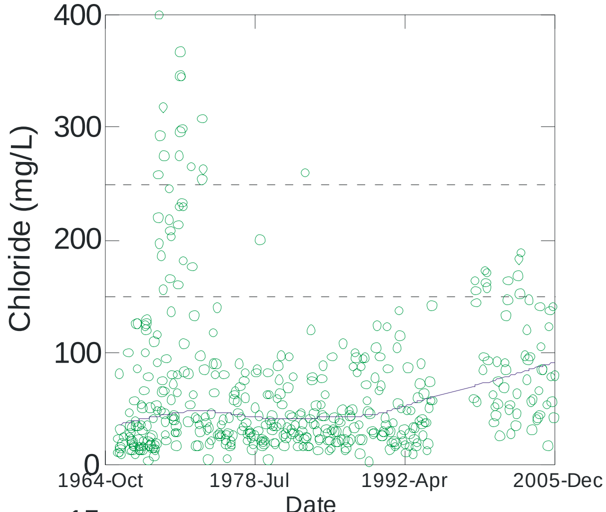

Fecal coliform
E. coli
Bayfield River
Little Ausable
Parkhill Creek
MBSILV1&2 (Silver Creek)
08004000302 (1965-1975)
08004001102 (1983-2005)
Of 178 cases, 3 excluded since y-axis range less than data range
MBSEA1
08004000202
ABCA14
08002201402
Of 133 cases, 4 excluded since y-axis range less than data range
HBLIF1&2
08004000402 (1965-1971)
MBHAN1
08004000902
MBCLIN2
08004000602
Of 246 cases, 1 excluded since y-axis range less than data range
MALIT2
08002201002
Of 275 cases, 5 excluded since y-axis range less than data range
MPGBEND1&2
08002200102 (1965-1975)
08002201302 (1974-1995)
Of 285 cases, 1 excluded since y-axis range less than data range
cfu/100ml
Date
1
10
100
1000
10000
1972-Jan
1976-Nov
1981-Nov
1986-Jul
1991-Jun
1996-Apr
2001-Feb
2005-Dec


Ausable River
HASTAF1
08002200802
Of 64 cases, 2 excluded since y-axis range less than data range
MAMOR2
08002201702
MAEXE1
08002201602
Of 241 cases, 1 excluded since y-axis range less than data range, and 1 value of zero excluded
MAMTCARM
08002201102
MAWAL
08002100102
Black Creek
MABLA2
08002200702
Of 284 cases, 6 excluded since y-axis range less than data range
Decker Creek
MADECK2&3
08002200202
Of 278 cases, 13 excluded since y-axis range less than data range
cfu/100ml
Date
Fecal coliform
E. coli

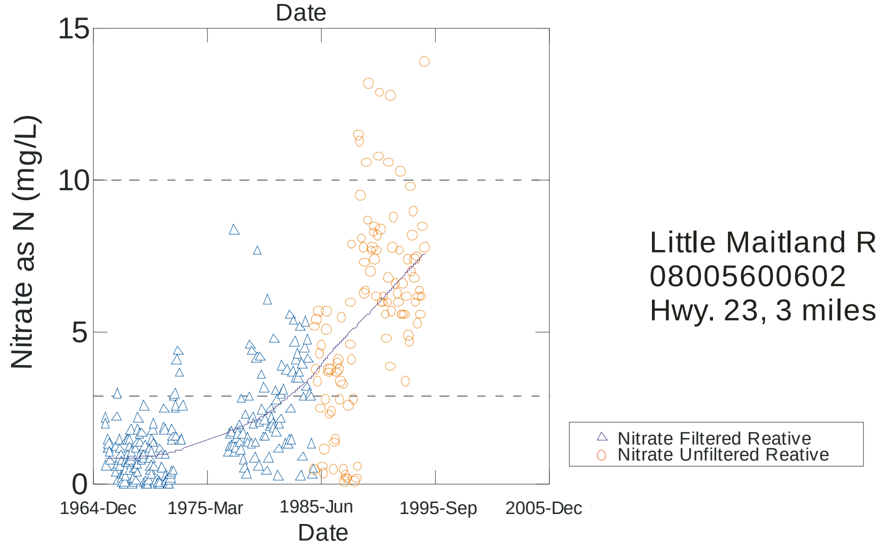
Appendix B: Selected Historic PWQNM sites with Different or Significant Trends



Black Creek
08002200702
Airport Line, West of Hensall

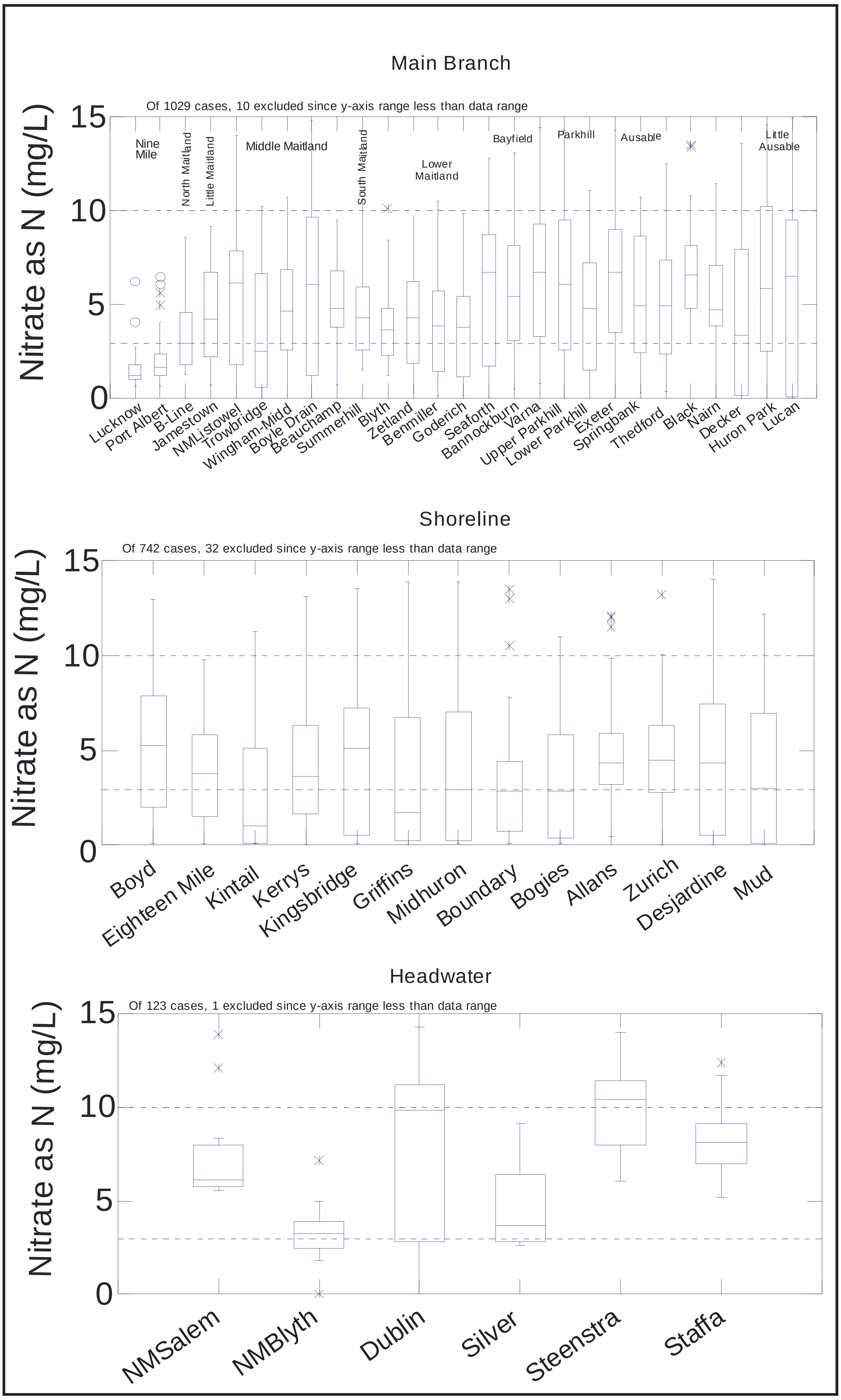


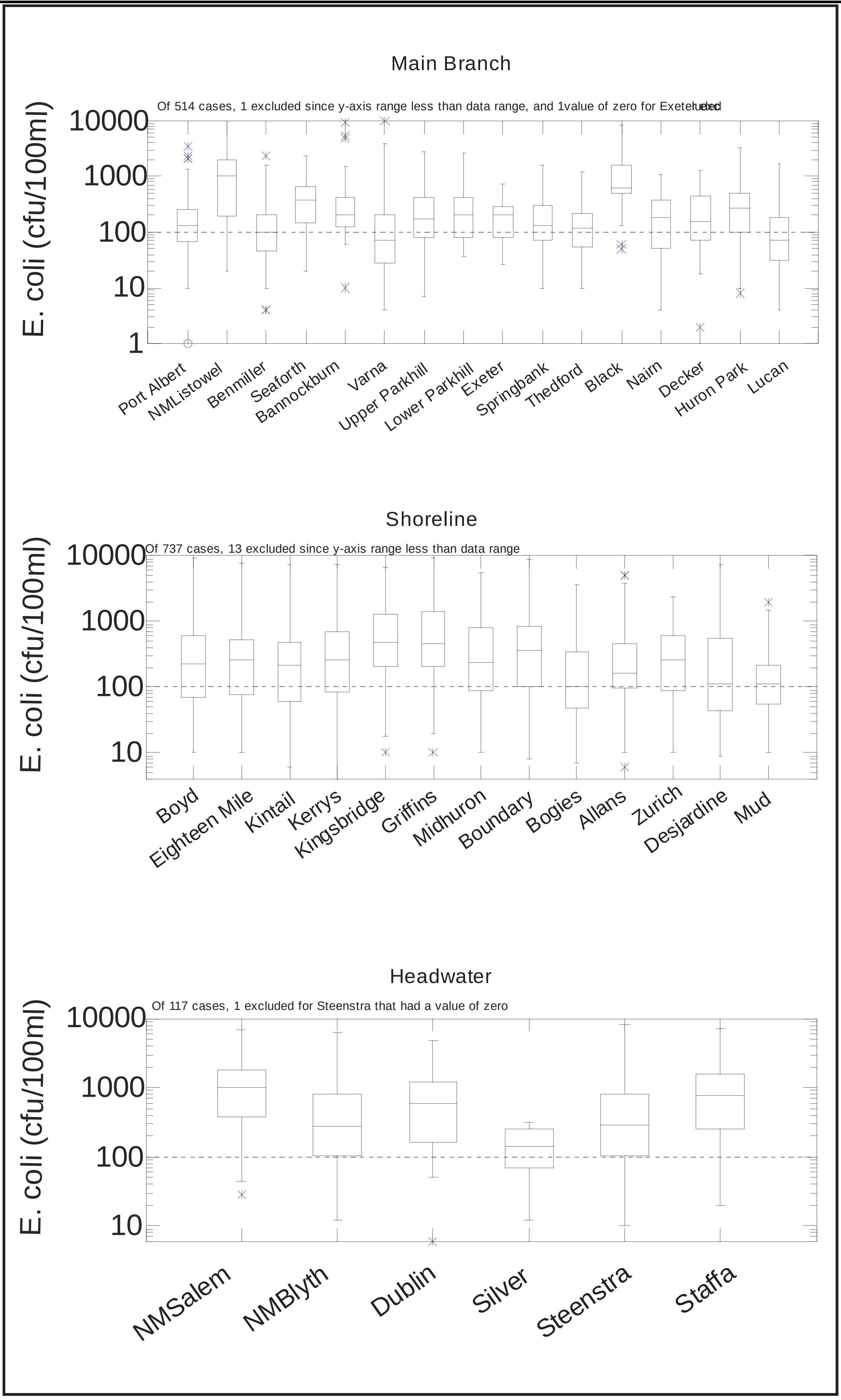
Middle Maitland River
08005600902
Trowbridge

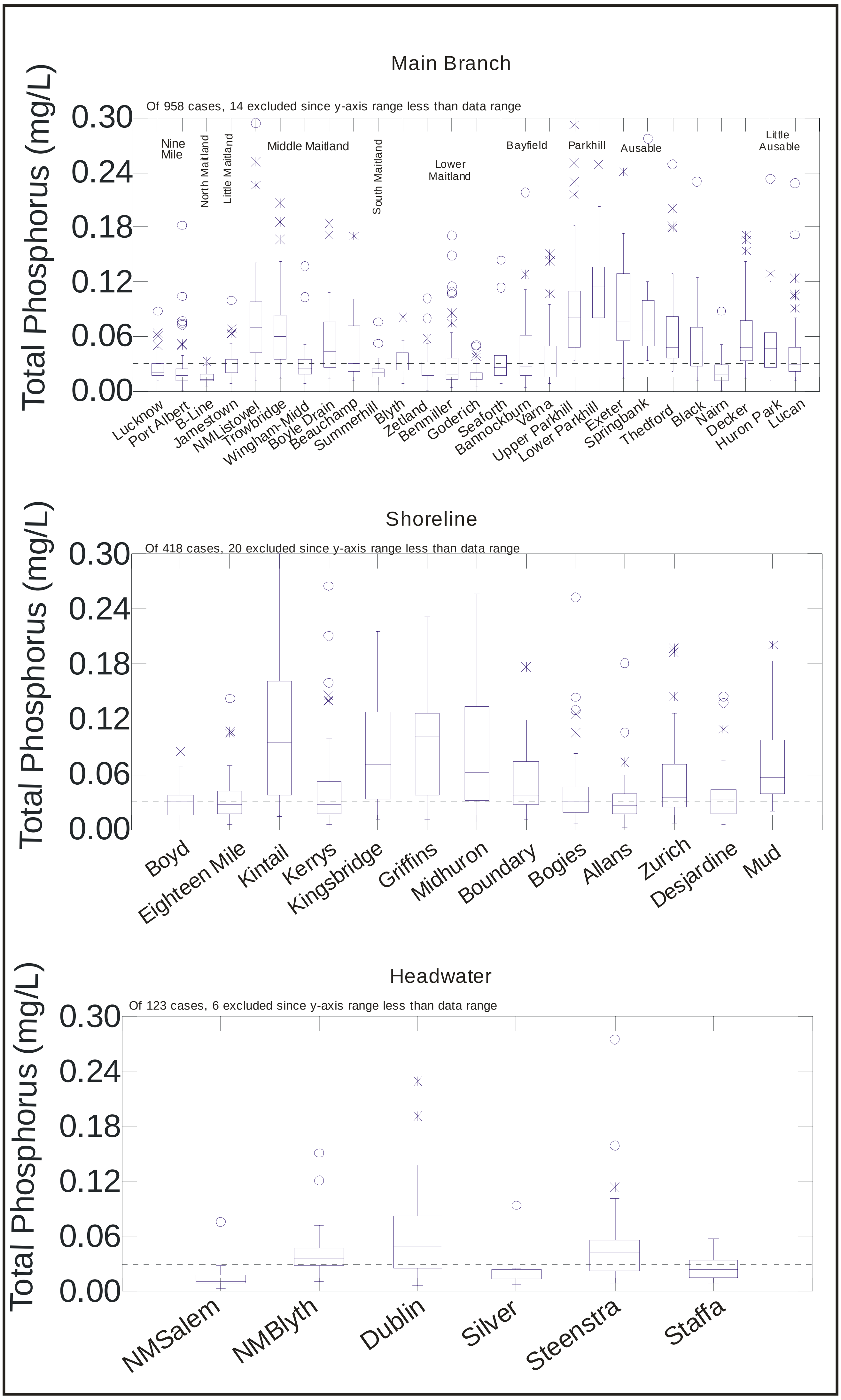


Little Maitland River
08005600602
Hwy. 23, 3 miles SW Palmerston

Appendix C: Spatial Trend Statistical Graphs (2001-2005) – nitrate, total phosphorus and *E. coli*




Main Branch
Of 514 cases, 1 excluded since y-axis range less than data range, and 1value of zero for Exeter excluded
E. coli (cfu/100ml)
10000
1000
100
10
1
Port Albert
NMListowel
Benmiller
Seaforth
Bannockburn
Varna
Upper Parkhill
Lower Parkhill
Exeter
Springbank
Thedford
Black
Nairn
Decker
Huron Park
Lucan
Shoreline
Of 737 cases, 13 excluded since y-axis range less than data range
E. coli (cfu/100ml)
10000
1000
100
10
Boyd
Eighteen Mile
Kintail
Kerrys
Kingsbridge
Griffins
Midhuron
Boundary
Bogies
Allans
Zurich
Desjardine
Mud
Headwater
Of 117 cases, 1 excluded for Steenstra that had a value of zero
E. coli (cfu/100ml)
10000
1000
100
10
NMSalem
NMBlyth
Dublin
Silver
Steenstra
Staffa


Main Branch
Of 958 cases, 14 excluded since y-axis range less than data range
Total Phosphorus (mg/L)
0.30
0.24
0.18
0.12
0.06
0.00
Nine Mile
North Maitland
Little Maitland
Middle Maitland
South Maitland
Lower Maitland
Bayfield
Parkhill
Ausable
Little Ausable
Lucknow
Port Albert
B-Line
Jamestown
NMListowel
Trowbridge
Wingham-Midd
Boyle Drain
Beauchamp
Summerhill
Blyth
Zetland
Benmiller
Goderich
Seaforth
Bannockburn
Varna
Upper Parkhill
Lower Parkhill
Exeter
Springbank
Thedford
Black
Nairn
Decker
Huron Park
Lucan
Shoreline
Of 418 cases, 20 excluded since y-axis range less than data range
Total Phosphorus (mg/L)
Boyd
Eighteen Mile
Kintail
Kerrys
Kingsbridge
Griffins
Midhuron
Boundary
Bogies
Allans
Zurich
Desjardine
Mud
Headwater
Of 123 cases, 6 excluded since y-axis range less than data range
Total Phosphorus (mg/L)
NMSalem
NMBlyth
Dublin
Silver
Steenstra
Staffa

Appendix D: Catalogue of WC Maps in the Accompanying Map Book

WC Map 2-1: Surface Water Monitoring Sites

WC Map 2-2: Nitrate Concentration: 2001-2005

WC Map 2-3: Phosphorous Concentration: 2001-2005

WC Map 2-4: E. coli Levels: 2001-2005

WC Map 2-5: Drinking Water Intakes, Large Municipal Residential

WC Map 2-6 Permits to Take Water in the ABMV Region

Chapter 3

VULNERABLE AREAS INVENTORY

Version 1.0
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Prepared by

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3 Vulnerable Areas

Recent drinking water-related public health outbreaks in North America (e.g., Walkerton, North Battleford, and Milwaukee) have prompted public agencies to advance a more comprehensive approach to safeguarding drinking water. In Ontario, this “multi-barrier” approach involves a more complete understanding of activities that occur within the drinking water intake area (source protection planning), professional training for water treatment plant managers and improved water treatment plants, water distribution systems and programs for monitoring drinking water. The first step among these approaches is to protect our surface and groundwater from contamination and overuse through source protection planning (Conservation Ontario 2005).

Understanding vulnerable areas is a critical step in the development of a source water protection plan. Vulnerable areas can be defined as those areas where the potential impacts of human activity on the land surface are more likely to cause impacts on available sources of drinking water, in terms of both water quantity and water quality.

For the purposes of developing source water protection plans for Ausable Bayfield and Maitland Valley watersheds, the first step in identifying these areas is developing an inventory of these vulnerable areas, necessarily at a regional scale. Numerous studies have been completed in recent years that developed methodologies for and identified vulnerable areas. The intention of this chapter is to summarize this readily available information.

Vulnerable areas are unique to the source of drinking water for which they were developed, such that an area may be vulnerable with respect to one source, but not be considered to be vulnerable with respect to another. In addition, the activities that may impact one source may not be considered a threat to another. As a result of this relationship, it is appropriate to discuss vulnerable areas according to the sources for which they were developed, and this chapter is structured as such. This fact is also important for consideration during the development of the Source Protection Plans, as each source will require unique strategies in order to mitigate the threats in the vulnerable areas.

3.1 Vulnerable Areas to Groundwater Resources

Groundwater is overwhelmingly the most utilized source of drinking water throughout the Ausable Bayfield Maitland Source Protection Source Protection Region (the “study area”). It is estimated that over 85% of the population of the study area rely on groundwater for their personal supplies, including both municipal and private wells (see Table 3-1). Protecting groundwater resources will be a key element of all source protection plans in the study area.

Groundwater resources in the study area have been divided into two major groupings of aquifers, namely bedrock and overburden aquifers. Bedrock aquifers are the most reliable, from both a water quality and quantity perspective, and readily available as they underlie the whole of the study area. These bedrock aquifers are considered to be relative secure aquifers, as they are protected by thick sequences of unconsolidated glacial material. Bedrock aquifers are also less susceptible to water quantity issues due to the large volume of water that flows through the system. Overburden aquifers are sporadically dispersed, as they are associated with coarse grained glacial or glaciolacustrine deposits. Overburden aquifers are highly variable in their quality and quantity, and are more susceptible to both contaminations from anthropogenic activity and drought conditions.

There are a number of different approaches that have been applied in order to identify the vulnerable areas for (both bedrock and overburden) aquifers in the study area. These are generally developed from the geology of the area, and reflect a general rule that coarser grained materials allow for faster movement (i.e. they have higher hydraulic conductivities) of water, as both groundwater flow within aquifers and infiltrating water from the ground surface to the water table. Faster travel times for infiltration and groundwater flow allow contaminants in water less opportunity for attenuation and dilution. Aquifers with higher hydraulic conductivities allow water to be discharged at higher rates, making them more susceptible to changes in recharge rates.

3.1.1 Well Head Protection Areas (WHPA)

Well Head Protection Areas (WHPA) were generated for the study area as part of the MOE Groundwater studies completed for Lambton, Huron, Bruce, Huron and Perth Counties (2003) and for Wellington County (2005). A WHPA is the two-dimensional projection onto the ground surface of the three-dimensional volume of groundwater that is pumped from a well field. WHPAs themselves are composed of a number of Well Head Capture Zones (WHCZ) that reflect the time required for water to move to the well from different areas of the aquifer. These Time-Of-Travel (TOT) WHCZ's were applied for all municipal groundwater supplies within the study area as part of the MOE Groundwater studies.

TOT capture zones that were calculated for municipal supplies that had WHPAs delineated for them are listed in Table 3-1.

Table 3-1: Wellhead Protection Areas (WHPA for SWP Area)

Municipality	Well	Population	WHPA Size	100m	50 day	2 year	5 year	10 year	25 year	SWAT
ACW	Century Heights	200	3 km^2		√	√		√	√	No
	Huron Sands (Seasonal System)	120	2.1 km^2		√	√		√	√	No
	Benmiller	75	5 km^2		√	√				No
Central Huron	Van de Wetering	45	2 km^2		√	√		√	√	No
	Dundass	20			√	√		√	√	
	S.A.M.	36	4.2 km^2		√	√		√	√	No
	McClinchey	39	3 km^2		√	√		√	√	No
	Clinton 1,2 & 3	3117	18 km^2		√	√		√	√	No
	Auburn	272	1.7 km^2		√	√		√	√	No
	Kelley	43	2.4 km^2		√	√		√	√	No
North Huron	Blyth 1 & 2	987	2.2 km^2		√	√		√	√	Yes
	Wingham Well 3 & 4	2885	5 km^2		√	√		√	√	Yes
Huron East	Brussels 1 (Turnberry St.)	1277	3.6 km^2		√	√		√	√	Yes
	Brussels 2 (Church St.)	1277	2 km^2		√	√		√	√	Yes
	Brucefield	175	2.6 km^2		√	√		√	√	No
North Perth	Listowel 1, 4, & 5	7000	2.4 km^2		√	√		√	√	No
	Listowel 6	42	0.7 km^2		√	√		√	√	No
	Atwood (Smith)		2.2 km^2		√	√		√	√	No
	Atwood (Bowman Court)	260	2.5 km^2		√	√		√	√	No
	Gowanstown	105	0.5 km^2		√	√		√	√	No
Minto	Clifford 1, 2, 3, & 4	835	2.6 km^2		100 day		√	√	√	No
	Harriston	1985	14 km^2		100 day		√	√	√	No
	Palmerston	2450	12.9 km^2		100 day		√	√	√	No
Morris Turnberry	Belgrave (Jane & McCrae)	383	4 km^2		√	√		√	√	No
Bluewater	Zurich 1 & 3	900	6.9 km^2		√	√		√	√	No
	Hensall 1, 2 & 4	1100	3.5 km^2		√	√		√	√	No
	Harbour Lights	100	4.5 km^2		√	√		√	√	No
	Carriage Lane	100	0.35 km^2		√	√		√	√	No
Warwick	Arkona				√	√		√	√	No
Huron-Kinloss	Lucknow				√	√		√	√	No
	Whitechurch				√	√		√	√	No
South Huron	Exeter					√	√	√		No

Methodology

Delineation of wellhead protection areas (WHPAs) is accomplished through the application of numerical groundwater models. The physical relationships governing the movement of groundwater can be incorporated into numerical models to simulate the existing groundwater flow system. Once calibrated, this model can be used to determine the pathways of groundwater in the aquifer and to calculate the travel time between any two points along those pathlines. TOT capture zones for pumping wells are calculated by releasing many particles originating in a circle around the well, and running the model in reverse. These capture zone results from the basis for delineating WHPAs for the municipal well.

Limitations of WHPA Modeling Results

WHPAs produced from numerical models incorporate a number of assumptions, input parameters, and boundary conditions. Each model is a representation of the understanding of the area surrounding the municipal well, and in all cases this representation has been simplified to facilitate model development. The WHPA modeling results represent a best estimate of the actual WHPAs and provide excellent guidance regarding the specific water source for each well.

As additional information becomes available the numerical models will be revised and WHPAs re-evaluated. Furthermore, water taking will be different in the future, as communities grow and additional groundwater wells are developed.

One important limitation is that the capture zones are projected to ground surface, and does not reflect the time required for water to travel from ground surface to the aquifer. This is particularly true when the wells that are being evaluated pump water from a deep aquifer that is overlain with fine-grained sediments (silts and clays).

Results

WC Map 3-1 shows, at a regional scale, the TOT capture zones that were produced as part of the MOE groundwater studies. The size and shape of WHPAs are largely a function of the amount of water being pumped, the permeability of the aquifer from which it is being pumped, and the overall regional gradient. Large WHPAs occur in areas where there are high gradients, high permeabilities and large volumes being pumped.

Of particular importance to this study are those WHPAs in which the aquifer is considered to be susceptible to impact from surface water, or the well is considered to be Groundwater Under the Direct Influence of surface waters (GUDI wells). These WHPAs reflect a high probability of impact on the aquifer via surface activities and will necessitate a different approach to mitigating potential impacts than those WHPAs that are not susceptible or GUDI.

3.1.1.1 Surface to Well Advection Time (SWAT) Well Head Protection Areas

In order to address some of the limitations of the original TOT WHPAs developed, during the MOE sponsored groundwater studies, a number of pilot projects were undertaken in the area to develop Surface to Well Advection Time (SWAT) capture zones for a select group of municipal wells. SWAT incorporates the time it takes for water to infiltrate through the unsaturated zone to the water table, as well as the TOT from that point to the actual well.

Methodology

In order to determine the travel times through the unsaturated zone an advection time calculation was done using estimated average porosities and saturation values. This advection time estimates, based on the understanding of the local geology, the time required for any given water particle to travel from the ground surface to the top of an aquifer. Once the advection time is calculated it was added to the previously defined TOT capture zones to determine the total SWAT.

Results

Municipal wells, for which WHPAs have been delineated, at the time of writing this report, are listed in Table 3-1. This table outlines the capture zones which have been defined, and the methodology used in developing the WHPA. Those wells that have a SWAT WHPA have necessarily already had a TOT WHPA calculated for them.

The use of the SWAT information allows for greater understanding of the influence of activities on the ground surface on the actual wells in these areas. Those wells with significant potential impact, based on this SWAT modeling, will likely require different planning and implementation tools in order to accomplish the goal of protecting the long term sustainability of the well.

As part of the ongoing Municipal Technical studies, SWAT WHPAs are being delineated for all large municipal wells in the study area.

3.1.2 Intrinsic Susceptibility Index and Aquifer Vulnerability Index

Intrinsic Susceptibility Index (ISI), along with the earlier Aquifer Vulnerability Index (AVI), is a calculated value that estimates the susceptibility of a groundwater resource to contamination. The susceptibility of an aquifer to contamination is a function of the susceptibility of its recharge area to the infiltration of contaminants, which can be evaluated using ISI.

ISI mapping is available for the entire study area from a number of county groundwater studies, including: Huron County (2003); Perth County (2003); Grey and Bruce Counties (2003); Lambton County (2003); Middlesex and Elgin Counties (2003); and Wellington County (2005). These studies were undertaken with funding from the Ontario Ministry of the Environment and as such were expected to utilize a standardized methodology for determining ISI. However, minor modifications to the ISI calculation were encountered, and as a result an Edge-Matching project was undertaken to rectify these issues.

Methodology

As part of the Edge-matching study, ISI Mapping was redeveloped using a common methodology. Map development begins with assigning an ISI value for each well within the Water Well Information System (WWIS) for the study area. This is accomplished by summing the product of the thickness of each unit (b) in the well log and a corresponding K-factor (see Appendix A), as represented in the equation below. The thickness (a.k.a. depth) for which ISI was calculated at each well is calculated from the ground surface to the water table for the unconfined aquifer, and from the ground surface to the top of any confined aquifer.

$$ISI = \sum i1 \ \ bi \bullet KFi$$

where:

- i = the number of geologic units recorded in the water well record (borehole)
- b = the thickness of each geologic unit recorded in the water well record.
- K_F = the Representative K-Factor as outlined in the MOE Terms of Reference:

After assigning individual wells ISI values, the mapping was developed by interpolating these values between wells. These interpolated areas were then subdivided and classified following the Technical Terms of Reference into one of 3 susceptibility groupings: low (ISI > 80), medium (30 ≤ ISI ≤ 80) and high (ISI < 30) (MOE 2001).

In areas of thin overburden it was recognized that the vulnerability to the underlying aquifers was increased due to the highly fractured nature of the bedrock. In order to accommodate these concerns, polygons representing overburden thickness of less than 6.0 meters were assigned an ISI value of 20 (high susceptibility). In some areas with documented karst development, polygons representing the identified karst areas within the study area were overlain and assigned an ISI value of 20 (high susceptibility). Where modifications to the original ISI mapping were made, the ISI map was re-interpolated to provide a final ISI map.

ISI mapping for the entire study area are shown in WC Map 3-2 accompanying this report. Areas with high susceptibility tend to be those that have very shallow overburden deposits. Areas with known sinkhole development also show high susceptibility. It is important to note that for the study area groundwater resources tend to be relatively well protected from surface activities.

Limitations of ISI mapping

It is important to understand the limitations of the produced ISI mapping when developing a Source Water Protection Plan. Although ISI mapping is a well-documented and accepted methodology in Ontario for assessing aquifer vulnerability, it does have a number of limitations, including:

1. ISI mapping is intended to be viewed and interpreted at a regional scale and is not intended to be interpreted at a property or site-specific scale
2. The primary source of data for calculating ISI is the Well Water Information System (WWIS), which is known to have several deficiencies in both the lack of records for existing wells, and more importantly, in the location of the existing records.
3. ISI does not take into account hydrogeological characteristics of aquifers which may make them more or less susceptible
4. ISI is interpolated between known data points and does not take into account geological features/boundaries that may be the cause of significant differences between the points.
5. ISI cannot account for the condition of existing wells, which may represent a more important pathway for the contamination of aquifers than infiltration of meteoric water.

These limitations in mind, ISI is still a useful tool in evaluating the overall susceptibility of a given aquifer at a regional scale. However, it is most important to note that ISI should never be substituted for comprehensive site-specific investigation, and a qualified geoscientist should determine the accuracy of the index at a property scale.

3.1.3 MOE Groundwater Susceptibility Mapping

Initial attempts at defining the hydrogeologic environments susceptible to contamination were carried out by the Ontario Ministry of Environment (MOE 1985a). Broad scale mapping was created that separated the province into distinct hydrogeologic environments. These environments were subsequently evaluated for their susceptibility to contamination, based on:

1. The permeability of the materials commonly found at the ground surface;
2. Groundwater movement in the materials;
3. The presence of major shallow aquifers; and
4. The use of groundwater in the area.

These regions were developed primarily upon the existing quaternary geologic and physiographic mapping for the province. Based on this broad scale mapping effort the study area is dominated by 'highly variable' susceptibility, with areas of high susceptibility associated with the former Lakes Nippising-Algonquin shoreline deposits, and kame deposits within the Wawanosh and Wyoming moraines. The broad region defined as the 'Huron Slope' (Chapman and Putnam 1984) was considered to be low susceptibility, primarily as a function of the fine grained sediments and soils in this area.

A further refined version of this mapping was created for a portion of the study area (MOE 1985b). This map used an identical methodology and divided the area in the vicinity of Seaforth into hydrogeologic environments. These were based primarily on the physiography of the area. As part of this mapping, areas of moraine (including kames), glacial outwash and glaciolacustrine shoreline deposits were identified as highly susceptible to contamination, as well as areas with exposed bedrock.

These mapping sets are considered a good reference point for understanding the susceptibility of groundwater resources for the area. However, these maps are focused primarily on the surficial geology of the area and do not address the vulnerability of the important bedrock aquifer system.

3.1.4 Shallow Susceptibility Index Mapping (SSI)

During the "Improvind Access to Water Resource Information in Agricultural Watersheds" phase II pilot study (also referred to as My Land, Our Water - MYLOW study) completed by the Maitland Valley and Saugeen Valley Conservation Authorities, it was recognized that ISI and MOE Susceptibility mapping were insufficient for those areas. In fact, due to local shallow groundwater conditions and a large Old Order Mennonite population serviced by shallow wells it was determined that the ISI layer underestimated the vulnerability of this region. This was primarily due to a lack of data points, attributed to underreporting of shallow bored and dug wells and the subsequent lack of inclusion in the MOE water well database (WWIS).

In order to address these concerns, and acknowledging the limited well information, another vulnerability layer was developed to give landowners an alternative to ISI. The Surficial Susceptibility Index (SSI) is a semi-quantitative method for estimating the security of potential shallow aquifer based on the permeability of the soils and the first subsoil layer (Quaternary geology) – the higher the permeability, the higher the susceptibility.

Methodology

The susceptibility of these shallow aquifers can be estimated by overlay of the permeability of the soils and the quaternary geology in a GIS environment. In order to do this, the soils layer and quaternary geology layer were overlain and simplified values given to each type of soil and geological unit. The combination of different soils and subsoil types were given values based on their estimated rate of infiltration in order to approximate the susceptibility of a given area.

Soil permeability values were derived from the hydrologic soil classification groupings, where "A" soils are the most permeable and "D" the least. Soils with more than one association were grouped according to the best fit with known data. Geological materials were similarly grouped in just two groupings, low permeability and high permeability, based on existing quaternary geological mapping and the materials associated with each type of deposit. These groupings, for both soils and quaternary geology, are highly simplified, but allow for not only a comparison of the relative susceptibility of each area, but also as a predictor for where shallow overburden aquifers may be encountered. The matrix for determining the SSI is shown below in Table 3-2.

Table 3-2: Matrix for determining Shallow Groundwater Susceptibility values based on hydrologic soil grouping and permeability of quaternary geology

	Soils		
Geology	D	B/C	A
Low permeability	1	3	5
High permeability	2	4	6

In SSI, values from 1 to 3 are considered low susceptibility, 4 and 5 considered moderately susceptible and 6 is considered highly susceptible to contamination. Refer to Appendix B for the classification of soil and geology units.

Limitations of SSI

SSI is developed primarily as a predictive tool and is based on both the soils mapping and quaternary geology mapping, as well as broad scale geological interpretation. As a result, the final product has incorporated a number of potential errors, and should be viewed as such. It is important to note that no field verification of this methodology has been undertaken.

Results

SSI is presently available for the Maitland Valley portion of the study area only. The results of the SSI for this region are weighted heavily by the quaternary geology. This is partially a product of the genetic association of soils with the underlying quaternary geology. SSI mapping is shown in WC Map 3-3. SSI does highlight areas that are not identified by existing ISI mapping and is considered a useful tool for defining where ISI needs to be refined or more investigative work completed.

3.1.5 Localized Vulnerability Issues (outside WHPAs)

3.1.5.1 Recharge/Discharge Areas

Areas where groundwater interacts with the ground surface are critical to develop our understanding of both groundwater and surface water systems. These areas are also extremely sensitive, as they allow interactions between relatively good quality, un-impacted groundwater with commonly impacted surface waters. Areas that allow this interaction are commonly separated into 'discharge areas' where groundwater is being outlet into surface water bodies, and 'recharge areas' where surface water is infiltrating into groundwater bodies.

Discharge Areas

Discharge areas are important sources of water for surface water bodies. High quality and consistent quantities of water being discharged into streams and lakes from aquifers provide essential water for the natural function of those streams and lakes. Estimating areas of discharge can be accomplished by comparing the known water table surface with the ground surface. Where that water table surface is higher than the ground surface, one could reasonably expect to find groundwater discharging onto the ground surface or into streams and lakes. Realistically, the geology and soils of the area may preclude the discharge of water due to its fine texture and resultant low permeabilities. As a result, it is often difficult to predict where discharge is occurring without considering the geology and soil structure of the ground surface in a given area.

The most reliable method for delineating discharge areas is through the aquatic ecology of the streams and rivers themselves. Streams, drains and lakes throughout the study area have had their aquatic habitat intensively studied and classified. The results have been used to categorize the watercourses (and even specific reaches of individual watercourses) into cold and warm water fisheries habitat.

In order to create a map of predicted discharge areas from overburden aquifers, the water table elevation layer was intersected with the ground surface layer in a GIS environment. If geological and soil conditions permit, discharge areas can be predicted in regions where the water table surface is above the ground surface.

WC Map 3-4 shows the distribution of these discharge areas and cold and warm water streams throughout the study area. Of interest is the association of cold water streams with coarser grained quaternary deposits, including those associated with moraines, glacial outwash and contact deposits, as well as glaciolacustrine shoreline deposits. These coldwater streams then represent discharge from overburden aquifers, rather than the deeper bedrock aquifers.

The relatively small percentage of the study area where discharge from overburden aquifers is predicted is noted. This corresponds well with known cold-water subwatersheds, and wetlands (e.g. Nine Mile River upstream of Lucknow and Hay Swamp). The southern portion of the study area has a proliferation of discharge areas, which may reflect a more refined water table elevation layer in that area, largely due to the increased number of overburden wells available to develop that information.

Recharge Areas

Recharge areas are those areas from which aquifers are being replenished by surface waters. These areas are inherently vulnerable as they allow generally poorer quality surface water access to otherwise well-protected groundwater resources. It is important to recognize that recharge is essential for maintaining water levels within a given aquifer, as it is the only input of water. Recharge is happening throughout the region, as a given portion of rainfall is infiltrated through the soil surface. Outlining a recharge area, therefore, is largely a subjective exercise aimed at identifying those areas where the recharge rates are considered to be high.

Understanding recharge in the study area is a complex exercise, as there exists numerous aquifers, all of which have their own recharge areas and discharge areas. For overburden aquifers, which are for the most part unconfined, recharge is happening *in situ*. That is, meteoric water (precipitation) is infiltrating through the soil and near-surface quaternary sediment and eventually reaching the water table, effectively recharging those aquifers. The location of these recharge areas can thus be delineated by the existing distribution of these quaternary materials (see, for example, MOE Susceptibility mapping from 1985).

The more difficult task is in defining recharge areas for confined aquifers in the study area, particularly the deep bedrock aquifer system. Bedrock aquifers are exposed only in a very small area throughout the study area, and as a result, infiltrating surface water must pass through intermediate overburden aquifers before ultimately recharging the bedrock aquifer (an exception to this is sinkholes, which are discussed below in section 3.1.5.2). Effectively, recharge to the deeper bedrock aquifer is from overlying overburden aquifers, rather than meteoric water.

With this fact in mind, an experimental procedure was developed in order to try to identify those areas, where:

1. The geology allows for high rates of groundwater flow; and
2. The hydraulic conditions exist that allow for this flow to occur.

In order to accomplish the first, the concept of geological "windows" was developed. Geological windows are areas where the grain-size of the materials is considered coarse enough to allow for rapid movement, or flow, of groundwater – sands and gravels. In order to determine where these "windows" exist, GIS data layers created as part of the MOE Groundwater studies were manipulated.

Rather than try and identify those areas with thick sequences of sand and/or gravel overlying the bedrock, a negative reasoning approach was utilized, as it is easier to identify areas with no significant silt or clay layer. The approach is listed below:

1. Ground Surface (m.a.s.l.) – Bedrock surface (m.a.s.l.) = Overburden thickness (m)
2. Overburden thickness (m) – Sand & Gravel thickness (m) = thickness of silt and clay (m)
3. Where Thickness of silt and clay < 1m = geological "windows"

This was done by subtracting the bedrock surface elevation (in metres above sea level – m.a.s.l.) from the ground surface elevation, which gives an estimate of the thickness of the overburden in any given location. From there, the thickness of sand and gravel, calculated in the MOE Groundwater studies, could be subtracted from the overburden thickness. The resultant overburden thickness should be composed of either silt or clay. For the purposes of this procedure, we considered anything less than 1m thickness of silt and clay to be insignificant (note that due to interpolation errors for all the data layers, there were some negative values which are theoretically impossible). WC Map 3-5 was created which outlines these geological "windows" in the overburden.

Having mapped where the geology is favourable for rapid groundwater movement, the second stipulation must be satisfied in order to delineate recharge areas that have hydraulic conditions that allow for recharge to occur. The first hydraulic condition is to allow for rapid infiltration of meteoric water and is generally satisfied by the geological "windows" procedure described above. Areas with no significant clay or silt layer are expected to have high infiltration rates.

The second condition that must be satisfied is that water pressure in the shallow aquifers must be greater than the bedrock aquifers – where a downward gradient exists. This pressure manifests itself in the elevation of the water table and potentiometric surfaces, respectively. The pressure was calculated by subtracting the potentiometric surface (in m.a.s.l.) from the water table surface (in m.a.s.l.). Where this value is negative (i.e. the potentiometric surface is higher than the water table) it is assumed that water is being discharged from the higher pressure bedrock aquifer into the overburden aquifer. Where this value is positive (i.e. the water table surface is higher than the potentiometric surface) it is assumed that water is being recharged into the bedrock aquifer from the overburden aquifer. This exercise was intended to delineate where water may have 'quick' access to the bedrock aquifer from the surface.

In order to define our recharge areas, the areas where recharge is expected to occur to the bedrock aquifer from the overburden aquifer were intersected with the geological windows, creating areas where recharge to the bedrock aquifers is expected. Conversely, areas where discharge is expected were intersected with the geological windows in order to determine where significant discharge from the bedrock aquifer to the overburden may be occurring. These areas are shown in WC Map 3-6. Recharge and discharge occurs throughout the entire area, but the map highlights the most important areas of interaction. The bedrock aquifer is considered very well protected where no constructed pathways are available; the Source Protection Region has very thick overburden.

It is important to address the limitations of this procedure in order to understand the reliability of the information presented. Firstly, the data sources that are being utilized to develop this information are interpolated layers from regional scale studies and may not be accurate at a smaller scale. Accordingly, this information should be viewed from a regional perspective and should never replace good quality site-specific geological interpretation. Secondly, the primary data source for these layers is the WWIS, for which locations and particularly elevations are suspect, once again highlighting the regional scale at which this information should be viewed. The third and most salient limitation is in understanding that this procedure completely ignores any horizontal flow of groundwater in the overburden aquifers. In fact, recharge through the geological windows may originate from distal areas and flow through the overburden aquifer a significant distance (and time) before recharging the bedrock aquifer. The fourth and final limitation is that this is a non-quantitative, conceptual geological method for where recharge is occurring. Three-Dimensional groundwater modeling may provide more accurate and hydrogeologically significant recharge areas.

3.1.5.2 Karst Aquifers and Sinkholes

Karst is a term originally developed to describe the typical topography that develops in areas where significant dissolution of the bedrock has occurred. It has since been applied to any dissolution feature found in bedrock, and includes caves, solution-enhanced fracturing and sinkholes. Karst features have been identified due to the carbonate composition of the Paleozoic rocks underlying the study area.

Karst features within an aquifer allow for rapid transport of water both within and between aquifers. This, by default, makes those aquifers with karst features more susceptible to contamination and less likely to have the capacity to mitigate any impact. In the study area, the most dramatic karst features are found in the form of sinkholes. Sinkholes can loosely be defined as areas where surface waters are directly accessing the bedrock aquifers and are recognized by semi-circular depressions. These depressions are commonly situated in low areas, and as such surface drainage is directed towards them. The situation has been further exacerbated by the use of sinkholes as outlets to municipal drains, which occurred post European settlement of the area.

In order to investigate the potential impacts of sinkholes on local water supplie,s the Ausable Bayfield Conservation Authority has carried out two studies. The first study focused on a well known area of sinkholes concentrated along the boundary between the Municipalities of Huron east and West Perth, near Staffa. Sinkholes were located and information was collected and stored in a common database.

The second phase of the project extended the scope of the project to include all sinkholes within the study area. Sinkholes were identified and mapped, and information stored in a common database for further analysis. In addition, two boreholes were drilled in attempt to outline the geological characteristics and environments that favour development of sinkholes.

With respect to understanding vulnerable areas associated with sinkholes, the primary concern must be with the areas of the ground surface that drain into the sinkholes. These areas contribute water to surface water bodies that are in turn drained into a sinkhole, which allows for rapid infiltration into the bedrock aquifer and circumventing the process of infiltration through overburden materials. In addition, aquifers in which sinkholes have been identified are more likely to have additional karst-like properties, such as high permeabilities and enhanced fracture flow within them.

Sinkholes identified in the database have been plotted and the areas which drain into them in WC Map 3-7. These areas will require special consideration during the development of a source protection plan.

3.1.5.3 Village Well Fields

Village well fields are areas that will require special attention in the development of a Source Protection Plan. Village well field are those areas/villages that have no municipally operated water system, and rather rely on numerous private/shared systems, owned and operated by the landowners. There exists significant debate over the number of wells/homes required to delineate a settlement as a village well field, or whether regard should be had for density of wells/homes within the settlement. It is often difficult to define the boundary of an unorganized settlement. No definitive guidance has been established for the categorization of a settlement as a village well field.

These areas are of particular concern, largely because of the concentrated population, all utilizing on-site septic disposal systems. Private well head practices also tend to be less rigorous than that of municipal systems and poorly situated, improperly constructed wells present a dense distribution of potential pathways for the contamination of the aquifer. Once contaminated, nearby wells are likely to be contaminated without significant dilution due to the high density of homes in these areas. In essence, village well fields are of concern due to the fact that there exists significant threats, multiple potential pathways and a high population of receptors (i.e.

water users) within a restricted area. These effects are further exacerbated by the fact that these areas have sporadic to non-existent treatment for potable water supplies. In effect, there are no "barriers" for drinking water protection in these areas.

No comprehensive mapping of these areas has been made available for the development of a source protection plan at this time. A list of significant communities that lack any municipal system is provided in Appendix C, and was developed by canvassing municipal and conservation authority staff. However, there also does not exist a standardized or recommended methodology for evaluating the potential vulnerability within village well fields. This should be considered a significant data gap that needs to be addressed prior to development of a source water protection plan.

3.2 Surface Water Vulnerability

Delineating areas that are susceptible from surface water bodies is a more complicated task than for groundwater. In general, the natural susceptibility of a given watercourse is defined by the soils, slope, and precipitation patterns of its drainage area. The other major factor contributing to the susceptibility of a given watercourse is the land use and land management practices within its drainage area. Although soil, slope, and precipitation data are readily available, susceptibility cannot be accurately defined without considering land use and land management. These data are often outdated and in constant flux, as land management practices vary seasonally, and between landowners.

Overall, three approaches for determining the susceptibility of a water course have been utilized, including: the use of the Universal Soil Loss Equation (USLE) and Modified USLE (MUSLE) developed for and utilized by the US Department of Agriculture (Wishmeier and Smith 1978); the time-of-travel (TOT) approach, whereby a given period of time for water running off the ground takes to join a receiving watercourse is evaluated, and; the use of standard runoff hydrograph approaches to hydrologically model the drainage area. Of these approaches, the hydrologic modeling approach is the most fruitful and accurate.

In the study area, very little data exists for surface water vulnerability, with the exception of the Run-off index created as part of the phase II pilot study completed by the Maitland Valley and Saugeen Valley Conservation Authorities, and flood plain mapping created for emergency management.

3.2.1 Surface Water Vulnerability – Runoff Index

A Runoff Index (RI) was created as part of the phase II pilot study completed by the Maitland Valley and Saugeen Valley Conservation Authorities. The goal for development of this index was to provide a guide for landowners about the risk of runoff from their property, where a higher risk for runoff has a greater potential for contaminating surface water with sediment, nutrients and/or bacteria. The chosen methodology was designed for and is more suited to an agricultural watershed.

Methodology

The RI includes a variant of the Time of Travel approach, incorporates actual runoff hydrographs in the calculation. A modified unit hydrograph approach was used to calculate the runoff proportion. The main modification is that the runoff proportion is calculated from the soil and slope characteristics for each pixel in the watershed versus an area weighted single value for an entire catchment (i.e. using a lumped approach). The major variables for the calculation were:

1) The curve number (CN) for each pixel was assigned based on the soil hydrologic group and percent slope. The initial CN value range was based on a row crop scenario. This will overestimate runoff of permanent pasture and hay and grain systems. See table Appendix D for a listing of soil types and hydrologic soil groups. In selecting the CN value, the higher end of the range was selected since the watershed condition was assumed to be saturated, or condition III. This is to simulate the times of the year when soil is more likely to be bare and wet (i.e. spring). This will again lead to an overestimate of the amount of runoff that would occur when the soil is drier.
2) Deep percolation (FC) was determined by soil type. See Appendix D for a listing of soil types and FC values.

Based on water quality information in response to rainfall, and based on rainfall patterns, an Atmospheric Environment Service (AES) 50 mm, 8 hour storm with 30% distribution was selected.

An important consideration is that the estimated runoff is conservative and is based on a worst case (i.e. highest potential runoff) scenario. For defining levels of runoff potential, the following categories are used, based on the percentage of the rainfall (50mm) that would run off from the 8 hour storm:

Low – 0- 15% of the rainfall amount ran off
Medium – more than 15% to 30% of the rainfall amount ran off
High – greater than 30% of the rainfall amount ran off

Limitations
These estimates are for each pixel in the watershed and do not take into account runoff water derived from upslope areas. Also, this methodology does not indicate areas that are contaminating surface water since no transport function is included. A steep slope may produce runoff, but if it infiltrates on more level ground before reaching a watercourse it may have no impact on water quality.

Results
WC Map 3-8 shows the RI calculated for the Maitland valley portion of the Study Area. The maps highlight areas of high slopes and/or finer grained soils, corresponding to subwatersheds considered to be dependant on precipitation for flows, versus those which are dependant on groundwater discharge. This methodology is valuable for identifying areas at a broad scale where erosion and subsequent loss of soil may be an issue from an agricultural perspective, however, it does not differentiate between areas closer or further from a given water course.

3.2.2 Modified RI

The RI developed as part of the phase II pilot study completed by the Maitland Valley and Saugeen Valley Conservation Authorities was modified for the middle Maitland watershed in order to accommodate for distance from the watercourse. This was accomplished by overlying the RI layer and a series of buffers around watercourses in a GIS environment. Table 3-3, below is the matrix used to define these areas.

Table 3-3: Matrix for identifying vulnerable areas for the modified RI

Runoff Risk Rating	100 m	250 m	500 m
Low	6	7	7
Moderate	3	4	5
High	1	2	3

By accommodating distance to watercourses, the impact of given activities in specific areas can be more easily related to water quality in the watershed. WC Map 3-9 shows the mapping developed for the middle Maitland watershed.

3.2.3 Flood Plain Mapping

In general, those areas located closest to a watercourse are thought to contribute more to the water quality of the watercourse as a whole. In particular, those areas which are periodically flooded can be considered vulnerable areas, not only for the potential damage caused by flooding, but also due to the potential water quality impacts from flood waters over the lands themselves.

Flood plain mapping has been created for most major branches of the Ausable, Bayfield and Maitland Rivers for the purpose of emergency management and the development of zoning by-laws. These maps are created from hydraulic models that simulate water levels during flood events of varying magnitude. It has not been established what magnitude flood event, typically measured as a probability of occurrence within a given time period (i.e. a 1 in 5 year flood is less magnitude than a 1 in 100 year flood), should be considered to define a vulnerable area. Nor is it well understood what impacts a discrete flooding event has on the long term water quality of a watercourse.

No comprehensive mapping exists for flood plains at this point. However, flood plains, typically the regional (1 in 350 years) or 1 in a 100 year floods, have been incorporated into zoning by-laws where they exist. As a result, very few new structures have been permitted within flood plains.

As part of source protection planning, floodplains could be considered and policies within them revisited in order to protect surface water bodies.

3.3 Surface Water Intakes in the Nearshore of the Great lakes

The Great Lakes region is home to 37 million Canadians and Americans, and more than 40 million people rely on the Great Lakes drainage basin for their drinking water. The Great Lakes are the source of drinking water for approximately 75 per cent of Ontario's population. Water from the Great Lakes also drives the region's economy. Every day, 56 billion gallons of water provide for municipal, agricultural and industrial uses. More than 250 million tons of cargo, primarily iron ore, coal and grain, are shipped on the Great Lakes annually. The shipping industry alone brings $3 billion to the region each year and provides 60,000 American and Canadian jobs. The Great Lakes region also provides for nearly 30 per cent of American and Canadian agricultural production. One-third of the land within the Great Lakes drainage area is used for agriculture, primarily for corn and soybean production and for livestock (International Joint Commission 2004). The multiple-use nature of the water in this unique ecosystem means that a more complete understanding of activities that occur within the Great Lakes drinking water intake area may be a complex undertaking.

There are three main types of drinking water intakes from the surface water of the Great Lakes. Water intakes may (1) extend into the lake (offshore), (2) be located within the nearshore lake environment, or (3) be within a connecting channel. Various considerations should be made for the water intakes at the different locations. The primary intent of this section is to review potential factors that may affect water quality for Great Lake nearshore intakes. A secondary component of the paper is to identify protection options for drinking water intakes within nearshore environments of the Great Lakes. This review is intended to provide a general overview of factors influencing nearshore water quality and potential protection options; a more comprehensive discussion of these issues can be found in the citations listed in the reference section of this report. Further, this discussion will focus on specifics of the southeast shore of Lake Huron.

3.3.1 Nearshore Water Quality

The nearshore is recognized as the interface between the land and the open lake. Edsall and Charlton (1997) defined the various components of the Great Lakes ecosystem and suggested that the nearshore waters occupy a band of varying width around the perimeter of each lake between the land and the deeper offshore waters of the lake. This band is thought to be approximately 5 to 10 km from shore (Howell 2005, pers. comm.). The band is narrowest where the slope of the lake bed is steep and continuous. More specifically, Edsall and Charlton (1997) defined the nearshore waters as the area that begins at the shoreline, or the lakeward edge of the coastal wetlands, and extend offshore to the deepest lakebed depth contour, where the thermocline typically intersects with the lake bed in late summer or early fall.

In the Great Lakes, offshore chlorophyll and total phosphorus (TP) concentrations have met or exceeded target concentrations set by international agreement. The 1972 Great Lakes Water Quality Agreement has resulted in reduced phosphorus loadings to the Lakes. For example, in Lake Erie, TP from tributaries, municipal and industrial sources and connecting channels declined from a high in 1968 of 27,944 tonnes to 12,349 tonnes in 1982 (Fraser 1987). Yet, deterioration of nearshore conditions as indicated by the resurgence of *Cladophora* in the 1990s (Hiriart-Baer 2003), and recent postings (i.e., advisories or closures) of Great Lake beaches (Howell et al. 2005) have suggested that the nearshore Great Lake environment is not comparable to the more oligotrophic offshore conditions.

In the nearshore zone of the Great Lakes, the principal sources of nutrients are multiple and complicated with respect to timing and location. Edsall and Charlton (1997) listed combined sewer overflows (CSO), sewage treatment plant effluents and tributaries draining agricultural and rural areas as primary nutrient sources. Fraser (1987) acknowledged that control measures aimed at non-point sources of phosphorus would be required to further reduce TP loadings.

The nearshore lake environment is a primary concern for the public as it is this area that the public is most likely to observe and use. Drinking water intakes from the nearshore of the Great Lakes serve 75 to 80 per cent of Ontarians. Assessment of the potential threats and risks to these drinking water sources will be included in the upcoming efforts under source water protection.

3.3.1.1 Factors affecting nearshore water intake zones

Characteristics of the nearshore zone that potentially influence intake water quality include:

- local current patterns;
    - thermal regime (thermal bars, upwelling/downwelling);

   - prevailing wind (direction and velocity);
   - long term and shorter term seasonal weather patterns (periods of precipitation, storm events);
   - local bathymetry (i.e., proximity to a shallow bay may mean that bottom sediments are re-suspended into the intake water column);
- tributary characteristics (i.e., proximity, tributary discharge, water quality of tributary, watershed activities);
- other local influences (shipping routes and activities, recreational use and shoreline modifications);
- sediment and substrate characterization in the local lakebed (benthic nepheloid layer);
- biology and
- atmospheric deposition (Ontario Ministry of the Environment 2006).

3.3.1.1.1 Water Movement

There are many processes that result in water movement in the Great Lakes. Offshore currents are influenced by the morphometry of the lake basin, the lake's stratification structure and exposure to wind (Wetzal 1983). Beeton and Saylor (1995) suggested the primary factors influencing Lake Huron water movement include hydraulic currents and currents from wind and spatial gradients in water density due mainly to temperature differences. Hydraulic discharge results from lake inflows and outflows. In Lake Huron, for example, hydraulic currents are created by inflows from the St. Mary's River from Lake Superior and the Straits of Mackinac from Lake Michigan, and the outflow from St. Clair River.

Wind-driven transport is a dominant feature of circulation in the lakes. Waves are generated by the wind blowing over the lake. Prevailing winds along the southeast shore of Lake Huron are from the west and northwest with the most severe storms from the north and northwest (Reinders and Associates 1989). The magnitude of the waves is dependent upon wind speed, the duration of the wind, and the fetch (distance over which the wind blows). Wind can also result in oscillations at the lake surface and internally deep with the basin. Strong winds may also displace more water at one end of the lake than at the other. After the cessation of the wind, the tilted water flows back and overshoots equilibrium. The resulting rocking of the entire water mass is termed seiches (Wetzal 1983). Potential for seiche conditions is inversely related to lake depth. Because of Lake Huron's great depth, storm surges are usually small in magnitude (Beeton and Saylor 1995).

Horizontal pressure differences caused by wave motions and long-lasting spatial variations in thermocline depths also cause currents. A thermocline results when stratification occurs in dimictic lakes (i.e., lakes that mix twice a year). The water column in dimictic lakes mixes completely in the spring and the fall. In the summer months, the upper, surface waters become warmer and less dense than deeper waters (water is most dense at 4 °C). Density differences in the water cause increased resistance to mixing of the waterbody and the water column becomes thermally stratified. The thermocline is that layer of water where there is maximum rate of water temperature change with depth. Accumulations of dense or light waters produce pressure gradients that result in water movement from high to low pressure.

In Lake Huron, Howell et al. (2005) summarized offshore circulation patterns of the central basin, west of the Bruce Peninsula as characterized by a cyclonic gyre. In seasons of stratification (summer and winter) currents move southward on the west coast and turn northward on the east coast.

Nearshore currents are complicated by local winds, lake bathymetry and geographic features of the shoreline (Howell et al. 2005). As waves travel from offshore to the nearshore, the wave shape changes; the height of the waves is determined by the nearshore bathymetry (i.e., the depths of water close to the shoreline) (Reinders and Associates 1989). The Lake Huron Centre for Coastal Conservation (2004) noted that studies conducted by the Ontario Ministry of the Environment in 1984 found that sediment resuspension (and associated increase in pathogen concentration) was linked to the slope geometry of the nearshore ramp. Gradual foreshore slopes at Ipperwash and Sauble Beach result in waves breaking further offshore. However, the fine sand conditions that are also related in part to the coastal features supported a higher concentration of bacteria than the coarse sand at Grand Bend or Goderich.

Table 3-4: Nearshore slope and sediment characteristics of beaches along the southeast shore of Lake Huron (taken from Lake Huron Centre for Coastal Conservation 2004)

	Ipperwash	Grand Bend	Goderich	Sauble
Slope (%)	3	30	40	3
Substrate	fine sand	coarse sand	coarse sand	fine sand

Water temperature differences can also be established between nearshore and offshore areas. Seasonal stratification in the Great Lakes is influenced by the formation of thermal bars. Warm thermal bars occur in the spring, when nearshore shallow waters warm faster and are separated from cooler offshore waters. Cold thermal bars may occur in the fall, when nearshore waters cool faster than warmer offshore waters. Water column mixing, due to wind, is more common in the fall and may result in fewer cold thermal bars at this time of year. Thermal bars along nearshore areas create a sharp density front which can reduce the mixing with offshore waters, trapping nutrients and suspended solids from the nearshore area. Meteorological conditions such as air temperature and wind mixing affect the rate at which thermal bars progress offshore to the midlake (Edsall and Charlton 1997). Thus, the timing and the duration of the thermal bars in the spring and the fall may influence nearshore water quality (Howell et al. 2005).

Movement of water and the constituents suspended in the water column ensures that water quality conditions of the nearshore are variable and may be unpredictable.

3.3.1.1.2 Tributary effects

Although there is a seemingly obvious connection between conditions in the tributaries and conditions in the nearshore, only infrequent attempts have been made to directly relate nearshore water quality to tributary water quality and discharge volume (Howell et al. 2005). For example, Edsall and Charlton (1997) suggest that the suspended material in the Great Lakes was more a function of shoreline erosion rather than tributary input. Edsall and Charlton (1997) also cited a lack of information regarding pesticide loadings and did not mention nutrient contributions from tributaries. Although not in specific reference to the Great Lakes, general sources of nutrients to water bodies include municipal and industrial wastewater discharge, agricultural fertilizer use, aquaculture operations, forestry practices and atmospheric deposition (Chambers et al. 2001). Literature that relates nearshore nutrient enriched conditions in the Great Lakes specifically to local tributaries is limited.

The following section will focus on an example in the southeast shore of Lake Huron to illustrate potential effects of a tributary on nearshore water quality conditions

3.3.1.2 Lake Huron Case Example

In 1977, the Upper Lake Reference Group, the Ontario Ministry of the Environment and Environment Canada concluded that the water quality of Lake Huron was excellent except in localized nearshore areas (*in* Jackson et al. 1985). Areas near the outlet of the Saugeen River, Maitland River and Parkhill River (mistakenly referred to as the Ausable River) showed signs of eutrophication and further investigation of these areas was conducted in 1980. In 1985, Jackson et al. (1985) concluded that nutrient entrapment from tributary and municipal (sewage treatment plant) loadings, storm-induced sediment resuspension, and increased shoreline erosion accounted for the mesotrophic conditions in the nearshore enriched zones.

A more current review of the water quality data from two water supply intakes from southeastern Lake Huron between 1976 and 2004, may in part contribute to the discussion about the potential impacts of tertiary tributaries to nearshore water quality conditions. Beginning in 1976, indicators of water quality have been collected twice a month year-round at the intake of municipal water treatment plants. Although, trends in total phosphorus (TP) concentrations for 18 municipal water treatment plants in the Great Lakes were recently evaluated (Nicholls 2001), this information has not been reported to water managers in a form that highlights the nearshore Lake Huron conditions. WC Map 3-1 depicts the two drinking water intakes in the Source Protection Region: the Lake Huron Primary Water Supply System (Port Blake) and the Goderich Water Treatment Plant.

Water quality data from the Goderich and Port Blake (north of Grand Bend) facilities were examined with an exploratory procedure, LOWESS (locally weighted regression), to detect potential time series trends (SYSTAT version 11, 2004). Difference in concentrations for two variables (TP and nitrate) between the two locations was determined with non-parametric Mann-Whitney U Tests (SYSTAT version 11, 2004).

Graphs of the water quality data appear as box and whisker plots. The box length shows the central 50 per cent of the values from the 25th percentile to the 75th percentile. The median is indicated as the central line within the box. The whiskers and asterisks denote 1.5 and 3 times, respectively, the absolute values between the 25th percentile and the 75th percentiles. The empty circles represent values that are beyond 3 times the absolute values between the 25th percentile and the 75th percentile.

Overall, the concentrations of the nutrients, TP and nitrate, were greater at the Goderich water intake facility compared to the Port Blake intake facility (Table 3-5, Figures 2 and 3). Further, trends in TP and nitrate over approximately the last 30 years appeared to be similar at the two facilities. Exploratory analyses suggest a decrease in TP concentrations since the 1970s and potentially increasing nitrate concentrations at both locations since 1976.

Table 3-5: Summary of water quality from the water intake plant in Goderich and Port Blake in Lake Huron (1976 to 2004)

Facility	Total Phosphorus (mg/L) PWQO = 0.02 mg/L	Nitrate (mg/L) CWQG = 2.93 mg/L
Goderich		
n	1384	1388
median	0.018	0.58
range	0.00 – 0.380	0.00 – 6.36
90th percentile	0.065	1.80
Port Blake		
n	1104	1105
median	0.012	0.34
range	0.00 – 0.16	0.00 – 3.70
90th percentile	0.03	0.67

(PWQO – Provincial Water Quality Objective and CWQG – Canadian Water Quality Guideline)

Phosphorus

Total phosphorus includes dissolved phosphorus and forms bound to organic and inorganic material in water. In many aquatic systems phosphorus is the nutrient limiting primary production (i.e., plant growth). When phosphorus is added the first response may be increased productivity, and although this may be an aesthetic concern, increased productivity is beneficial to aquatic life. However, beyond a certain point detrimental effects become apparent due to eutrophication from nutrient over-enrichment.

The median TP concentration at the Goderich water intake facility (median = 0.018 mg/L) over the past 28 years is similar to the Provincial Water Quality Objective for TP (PWQO = 0.02 mg/L). The provincial objective was established to prevent eutrophication in lentic systems. The median TP concentration at the Port Blake intake facility between 1976 and 2004 was significantly lower than the objective (median = 0.012 mg/L; Mann-Whitney U statistic 988358.5; $p < 0.001$). However, concentrations of TP at the Port Blake intake facility were in the range of concentrations that would be considered to contribute to nearshore nutrient enrichment conditions (i.e., the 90th percentile = 0.03 mg/L) (Figure 2).

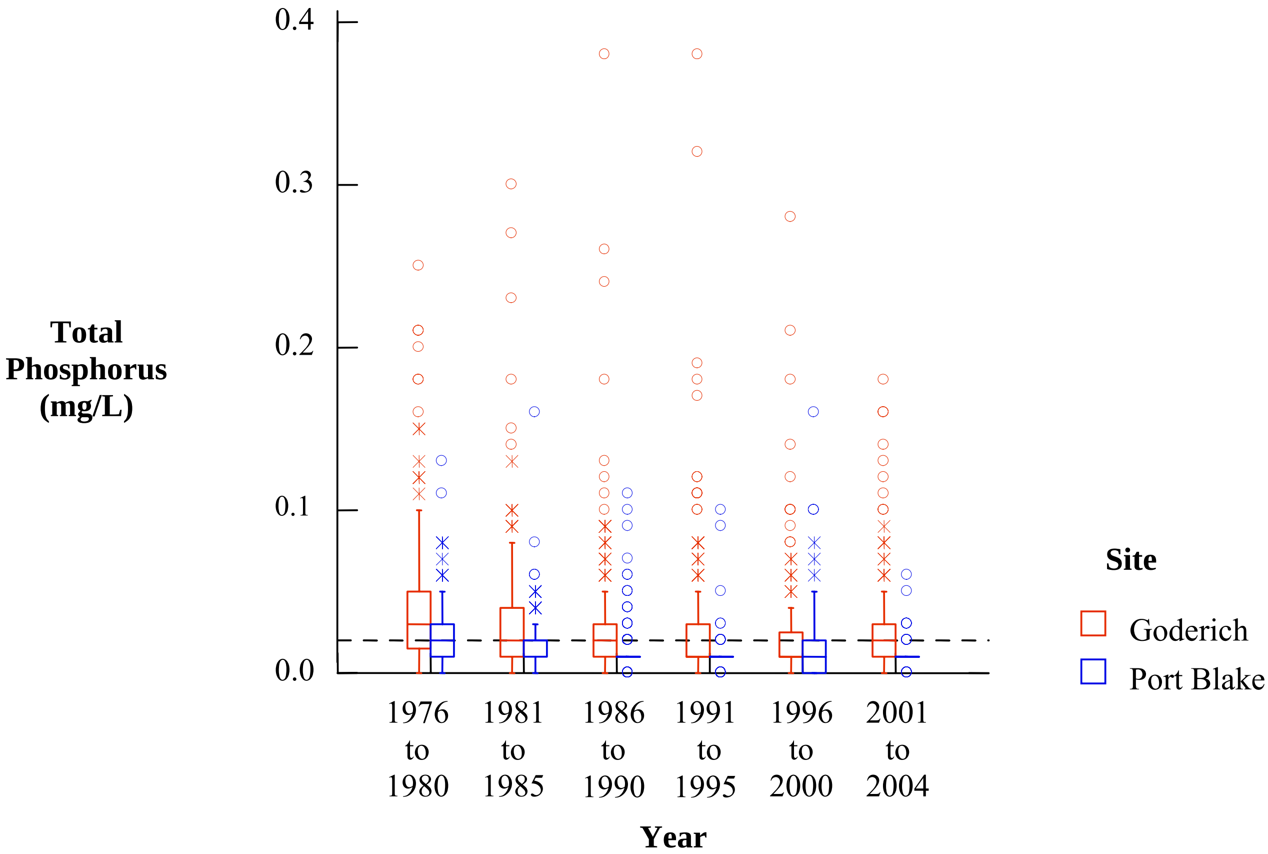

Figure 3-1:Total phosphorous concentrations (mg/L) at Goderich and Port Blake water intake facilities (1976 to 2004)
The Provincial Water Quality Objective to prevent eutrophication in lakes (0.02 mg/L) is indicated with a dashed line.

Nitrate
Nitrate is the primary source of nitrogen for aquatic plants. All forms of inorganic nitrogen (nitrite and ammonia) have the potential to undergo nitrification to nitrate. In well-oxygenated systems, increasing concentrations of inorganic nitrogen increase the risk of algae blooms and eutrophication.

The Canadian Council of the Ministers of the Environment (2002) suggested that nitrate concentrations above 0.9 mg/L were generally associated with eutrophic conditions (i.e., algae and macrophyte blooms, shortened food chains and changes in the aquatic community). Between 1976 and 2004, the median nitrate concentration at the Goderich water intake facility was 0.58 mg/L. Overall, these concentrations were in the range of concentrations that would be considered to contribute to nearshore nutrient enrichment conditions (i.e., the 90th percentile = 1.80 mg/L) (Figure 3).

Nitrate concentrations at the Goderich station rarely exceeded the water quality objective of 2.93 mg/L (the draft Canadian Water Quality Guideline for the protection of aquatic life from direct toxic effects; CCME 2002) and never exceeded the drinking water guideline of 10 mg/L (CCME 1978). Nitrate concentrations at the Port Blake facility (median = 0.34 mg/L) were significantly lower than at the Goderich facility (Mann-Whitney U Test Statistic 11933230; p <0.001), between 1976 and 2004.

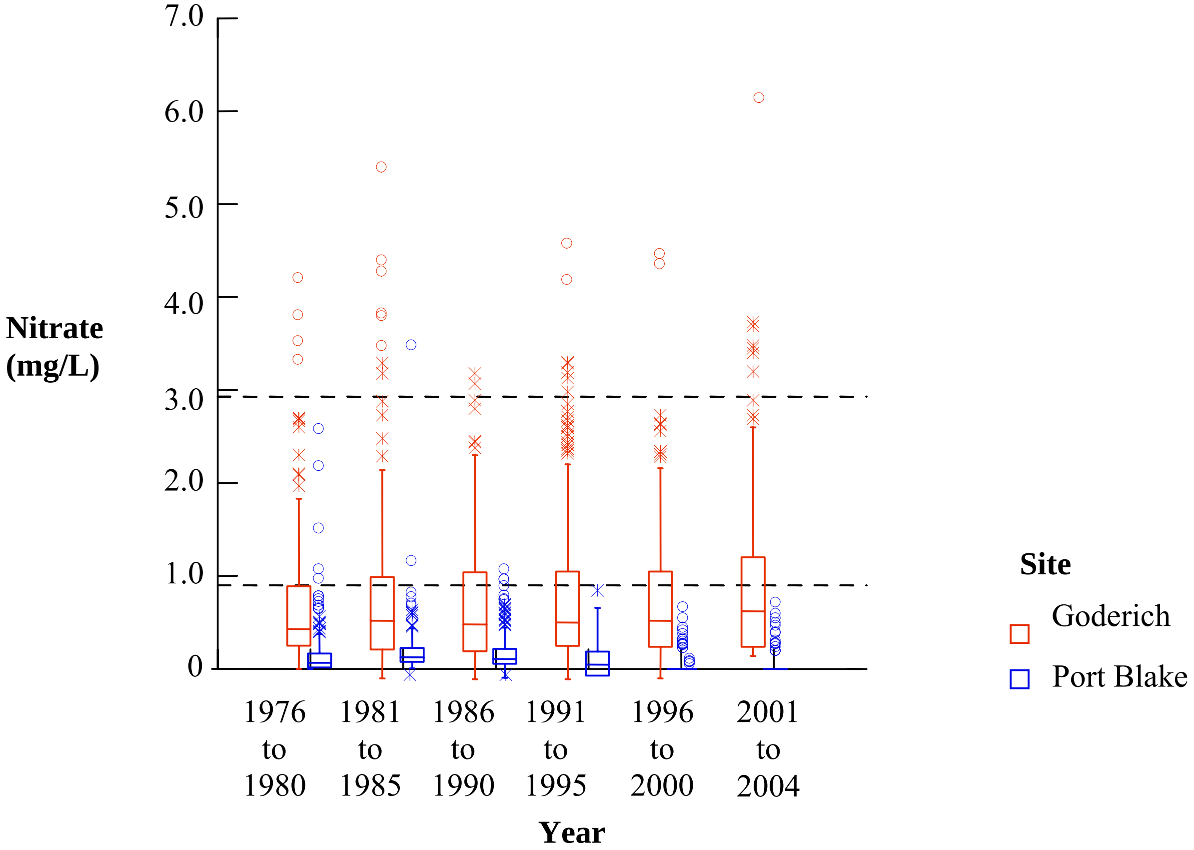

Figure 3-2: Nitrate concentrations (mg/L) at Goderich and Port Blake water intake facilities (1976 to 2004)
The Canadian Council for Ministers of the Environment (CCME) standard to prevent eutrophication (0.9 mg/L) and the CCME draft guideline for the protection of aquatic life (2.93 mg/L) are indicated with dashed lines.

Results

The concentrations of the nutrients (TP and nitrate) at the Goderich facility were in the range of contributing to eutrophic conditions in the nearshore zone of Lake Huron, and were significantly greater than the concentrations at the Port Blake facility. Although both intakes are located in the nearshore environment of Lake Huron, the Goderich facility is directly within the zone of influence of a tertiary tributary, the Maitland River. The data presented in this analysis suggests that the Maitland River is contributing to the nutrient-enriched conditions of the nearshore environment of Lake Huron.

Further, Steele et al. (2006) also indicated that there are potentially higher concentrations of nutrients in the Ausable, Bayfield and Parkhill rivers compared to the Maitland River. There are no water intake plants within the zone of influence for these rivers. Thus, there are no long-term data to illustrate the potential impacts these tributaries may have on the nearshore of Lake Huron. However, Jackson et al. (1985) indicated that lake water quality was moderately enriched at Grand Bend, near the outlet of the Parkhill Creek, the Maitland River in Goderich and the Saugeen River in Southampton. It is therefore reasonable to suggest that the tributaries of the southeast shore of Lake Huron are contributing, and have been contributing to the enriched conditions in the nearshore.

Currently there are attempts to document the volume and the quality of the discharge from selected Lake Huron tributaries (Howell et al. 2005). In Lake Huron, determining the volume of the discharge may influence the size of the mixing zone, while identifying the concentration of the pollutant will help to determine the contaminant load (Howell et al. 2005). Understanding these important factors will help to determine the potential nutrient enrichment impacts of tertiary tributaries upon the nearshore.

3.3.1.3 Other Local Influences

One consideration that may be beyond the scope of an intake zone assessment is the potential impact of a major chemical spill in the Great Lakes. In 2004, the International Joint Commission expressed concern about the increase in major spills in the connecting channel from Lake Huron to Lake Erie between 2002 and 2004. For example, in April 2002, a large oil spill (estimated at 378,500-1,000,000 litres) occurred in the Rouge River. In August 2003, a major regional power blackout led to several overflows from wastewater treatment plants and an unacceptable delay in reporting of a vinyl chloride spill in Sarnia. In February 2004, a discharge of methyl ethyl ketone and methyl isobutyl ketone was discharged into the St. Clair River. Water treatment plant operators downstream are concerned about the frequency with which they have been closing their water intakes due to these spills (International Joint Commission 2004).

Other shoreline considerations for nearshore environments described more completely by Edsall and Charleton (1997) are the potential effects of combined sewer outfalls (CSOs), wildlife and other industrial activities.

3.3.1.3.1 Sediment Characteristics

Sediment and substrate characterization in the local lakebed will also affect the variability in nearshore water quality conditions. Sediment plays a major role in the transport of P in aquatic systems (Stone and English 1993). The availability of P for lake algae depends on the species of P attached to the fine-grained material (Stone and English 1993) and the patterns of sediment transport (particularly deposition, and re-suspension rates) (Howell et al. 2005). The factors that determine deposition and re-suspension rates are also variable and dependent on particle size and density, water temperature, total suspended material (Rosa 1985) and nearshore wave energy (mediated by bathymetry and geographic features) (Howell et al. 2005).

3.3.1.3.2 Biology

Hecky et al. (2004) have suggested that conditions of nutrient enrichment in the nearshore may be exacerbated by an introduced dressenid mussels. Zebra mussels (*Dreissena polymorpha*) are an exotic and invasive mussel species that were first noticed in 1988 in Lake St. Clair. Hecky et al. (2004) summarized the current supposition that these benthic organisms are sequestering nutrients that had previously been transported offshore. An important source of nutrients to the nearshore Great Lake environment is non-point sources (Fraser 1987). Stone and English (1993) found that most of the non-point phosphorus is fine-grained particulate material. Prior to dreissenid colonization the fine-grained material was thought to have been transported offshore. The filtering and potential retention of this material by the zebra mussels is currently thought to be contributing to nutrient enriched conditions of the nearshore.

3.3.1.3.3 Atmospheric Deposition

When pollutants, both natural and anthropogenic, are released into the atmosphere, they can eventually return, or be deposited back to the land or water. This process occurs through wet deposition, dry deposition and air-water gas exchange, and can contribute significant pollution loadings to the Great Lakes. Such compounds include, but are not limited to sulphur, nitrogen and mercury compounds, other heavy metals, anthropogenic pesticides and industrial by-products (US EPA 2001). Nitrogen compounds are of concern because of the eutrophication that occurs with excessive nitrogen loading. Burning of fossil fuels and agricultural activities (i.e., fertilizer application, feedlots, waste lagoons) are the main anthropogenic sources of nitrogen, while forest fires and microbial activity contribute to the natural sources of nitrogen (US EPA 2001). Unfortunately atmospheric deposition is not a localized problem and contaminants can travel and be deposited extensive distances from their source.

The Integrated Atmospheric Deposition Network (IADN) is a joint program (US and Canada) formed to assess the impact of atmospheric deposition. Estimates on pollutant loadings to the Great Lakes are made every two years (Blumberg et al. 2000).

3.3.1.3.4 Summary of Factors Influencing Nearshore Water Quality Conditions

In a recent review of Lake Huron's nearshore water quality information, Howell et al. (2005) summarized the microbiological studies that had been conducted in 1984 and 1985 by the Ministry of the Environment (Palmateer and Huber 1984 *in* Howell et al. 2005). Bacteria concentrations tended to be higher in beach water samples on days when the lakes were considered "rough" and a number of factors were examined to determine what contributed to "rough" water conditions (Table 3 – from Howell et al. 2005). The specific scenarios that contribute to roughness and enhanced bacterial concentrations were documented to be numerous. These factors, when combined with the broad lake dynamics (as discussed above - thermal gradients, wind direction, speed and duration and tributary runoff) ensure that nearshore water quality conditions tend to be variable and difficult to predict.

Table 3-6: A summary of the factors that effect bacteria concentrations along the south-east shore of Lake Huron (taken directly from Howell et al. 2005)

Factor	Effect on Bacteria	Remarks
rainfall events	increased concentrations in some instances but not all	some locations may have too many confounding inputs to respond to rainfall alone (e.g., Goderich)
lake roughness / wave height	increased concentrations due to sediment resuspension	measurements somewhat empirical and not quantitative
hours of sunlight	decreased concentrations	ND
swimmer density	some increase concentrations	ND
number of seagulls	no correlation	ND
plumes from major rivers	increased concentrations when wind directed plume towards the beach	related to wind direction
wind direction	south-westerly winds increased concentrations	influenced lake roughness, wave height and river plume direction
storm sewers	little effect except in unique circumstances	sewage inputs discovered and remedial action taken to reduce bacterial counts
sewage treatment plant (Goderich)	difficult to assess	beaches at Goderich had potential inputs from too many sources
sewage bypass events	only one event recorded – not significant to data collected during study period	
boats and marinas	no significant contribution	
agricultural watercourses	highest Bacterial concentrations within creeks, high levels at drainage points,	some evidence that contamination at beaches coming from these drains
sediment resuspension	higher concentrations with greater turbidity	anecdotal as data isn't presented in this manner. Factors and events that cause sediment resuspension also result in increased bacterial levels.
human fecal input	localized situations (Duffus Creek and Walkers Drain)	evidence came from investigation of a variety of factors
agricultural input	localized situations and some microbial source tracking evidence and investigative observation	human fecal input not excluded Some bias due to locations chosen for source tracking studies

ND: Not discussed in detail in these reports

3.3.2 Intake Protection Zone

It is well understood that the assessment of intakes that extend into the Great Lakes presents a difficult scoping exercise. The United States Environmental Protection Agency (US EPA) has devised a protocol that would help to characterize the susceptibility of the intake area with respect to local conditions (Brogren and Sweat 2000). In 1999, a working group from the US EPA Region V (six western Great Lake states) was formed to provide guidance on assessments for drinking water from the Great Lakes. The working group consisted of representatives from the Great Lake states, water utilities with intakes on the Great Lakes, US EPA - Region V representatives and other interested parties. In 2000, the working group recommended an assessment protocol for Great Lake sources.

The preliminary assessment involves an initial survey of local water impacts:

i) review intake location studies,

ii) interview senior operators at the treatment plant to understand raw water quality fluctuations, and

iii) analyse water quality records (particularly bacteriological concentrations, alkalinity and turbidity).

The next step is to determine the Critical Assessment Zone (CAZ). Two factors are assumed to determine the sensitivity of the intake; length of the intake pipe and water depth of the intake structure. Shallower, nearshore intakes are considered more sensitive to shoreline influences than offshore, deep intakes.

If the assessment indicates that intake is not impacted by potential shoreline contaminants, the assessment should reference general Great Lakes water quality (Michigan Department of Environmental Quality 1999). This critical zone assessment, based on linear distance, has the potential to overlook the consequences of local currents moving contaminants to within the intake zone. The preliminary assessment requirements to analyse local water quality conditions should help to ensure that offshore, typically more oligotrophic conditions, are not used for analyses in inappropriate situations in the US.

In Ontario, the draft guidance for the analysis of surface water vulnerability (Ministry of the Environment 2006) suggests as a first step the need to characterize intake information such as:

- technical characteristics related to the intake (i.e, depth of crib and length of intake pipe);
- discussions with the water treatment plant operators about response times to shutting down the plant;
- review of existing engineering reports with information regarding the hydrodynamic and hydrological conditions;
- bathymetry of the lake bed near the intake;
- limnology (e.g., lake thermal structure) in the intake area;
- local and regional current/flow and drift patterns and vectors;
- prevailing wind direction and intensity;
- long term and seasonal weather patters as they influence wave generation, magnitude and direction;
- a raw water quality (i.e., bacterial concentrations, taste and odour compounds, suspended solids) profile;
- local watershed influences;
- local and regional shipping routes and patterns;
- local recreational uses;
- historical shoreline and substrate trends;
- historical land uses; and
- shoreline modifications.

The purpose of delineating zones around the Great Lakes intakes is to protect them from immediate contaminants that might enter from nearby areas or known sources. In Ontario, two zones have initially been proposed. The first zone (Intake Protection Zone 1 - IPZ-1) is a 1 km radius around the intake crib. The second zone (IPZ-2) is proposed to account for the influence of shore watercourses. This zone has been determined by 1) water plant shut down response time and 2) average maximum water velocity. The influence of variable or fluctuating currents should be considered under the IPZ-2 determination.

In both the US and Ontario initial water assessments, the survey of conditions at the intake (and within 1 km radius or the local plant response time) is critical to determining risk to these sources of drinking water. Although the zones are necessary for risk management decisions, it is important to understand that the complex and interacting factors (as discussed above - thermal gradients, wind direction, speed and duration and tributary runoff) ensure that nearshore water quality conditions tend to be variable and difficult to predict. For example, along the south east shore of Lake Huron there will be the direct contributions that the Maitland River has on the Goderich intake facility and this will be important to categorize from a risk management perspective. However, due to the complex environment of the nearshore, nutrients and contaminants from tributaries outside of the intake protection zone or the critical assessment zone may also potentially influence intakes.

3.3.2.1 Conclusions for Great Lakes Intake Protection Zones

The Great Lakes are the source of drinking water for approximately 75 per cent of Ontario's population. Many of the drinking water intakes occur in the nearshore of the Great Lakes. Nearshore water quality is considered nutrient enriched compared to offshore waters which have a more oligotrophic condition. As reviewed in the preceding discussion there are many factors that contribute to nutrient enriched conditions of the nearshore. Although there is a seemingly obvious connection between conditions in the tributaries and conditions in the nearshore, more recognition of tributaries as conduits of non-point source pollutants, particularly nitrogen and phosphorus, may be required to address nearshore water quality issues.

The source protection planning process provides water managers with a choice to continue to treat nearshore diminished water quality symptoms (beach closures, aesthetic problems with algal blooms, drinking water intakes, problems with fisheries), or begin to identify and manage the source of the contamination. When faced with a particularly damaging ecosystem impact, policy responses tend to focus on treating particular symptoms, with little emphasis on focused on preventing the integrated sources of stress that cause these symptoms. Worte (2005) outlined how the water management sector in Ontario evolved with an issue based infrastructure in response to crisis situations. In Ontario, there are seven pieces of federal legislation and 15 pieces of provincial legislation that have jurisdiction over water issues. The different legislative requirements involve many agencies with conflicting objectives and policies and the potential to duplicate efforts. This approach is regarded as costly and may not be considered effective in ensuring good water quality in the nearshore lake environment.

The Watershed Based Source Protection Implementation Committee (2004) recommended that source water protection principles, strategies, and policies should be incorporated into existing Great Lakes programs and resulting agreements so that they are protected and improved as sources of drinking water. The source protection planning process provides such an opportunity, and has the ability to identify and remediate pollution issues most directly, or most likely to impact nearshore waters. In order to do so the source protection planning process needs to embrace an ecosystem-based management approach. Ecosystem Management is an integrative, interdisciplinary, adaptive, and collaborative approach to policymaking, planning, and management. It is grounded in the best scientific information available and recognizes uncertainties and the understanding that human activity and ecosystems are inextricably linked.

The goal of ecosystem management is to sustain and/or restore ecosystem integrity and biological diversity at all spatial and temporal scales through scientific understanding and collaborative decision-making (Randolph 2003). Watershed based approaches to land use management offer the best opportunity to minimize negative impacts associated with non-point sources of nitrogen and phosphorus (Carpenter and Lathrop 1999).

Globally, one of the greatest environmental threats to human populations remains access to safe water and sanitation (World Health Organization 2006). The amount of fresh water on earth is very small in comparison to the water of the oceans. The Laurentian Great Lakes of North America - Lakes Superior, Huron, Michigan, Ontario and Erie - constitute the largest mass of fresh water on earth with a volume of liquid 24,620 km^3, or 20 % of the world's freshwater (Wetzal 1983). The immensity of this resource is matched by the paramount responsibility water managers in the Great Lakes basin have to improve nearshore conditions in these Lakes to ensure the continued access to safe and usable water.

3.4 Potential Future Sources of Drinking Water

Possible future source of drinking water is an issue that will be address in the Municipal Long Term Water Supply Strategies. Historically, there have been no issues related to water quantity as there is not much growth in the region. There may be occasions such as the development of the Greenfield Ethanol plant in Hensall where water quantity is insufficient. The abundance of groundwater and proximity to Lake Huron provide sources of drinking water for such cases. Water quality remains a greater factor in discussing future sources of drinking water.

3.5 Conclusions

Vulnerable areas have been defined using several different methodologies for both surface and groundwater resources. It is important in the development of the source protection plan for the study area to not only delineate these areas as accurately as possible, but also to understand the methodologies used to derive them. These methodologies are necessarily limited by the data available in developing them, as well as the scale at which they were developed. It is essential, therefore, to consider these limitations during development of the plan.

3.6 Data and Knowledge Gaps

Well Head Protection Areas

WHPAs are produced from models that incorporate a number of assumptions, parameters and boundary conditions. As more information becomes available, these models will be revised and WHPAs will be re-evaluated. In addition, models will only reflect current conditions, and will have to be revisited when additional development takes place and communities grow. As of the production of this document, municipal studies are still underway that delineate SWAT WHPAs for all large municipal wells in the study area. This information is currently a data gap but will be filled in the near future.

Intrinsic and Shallow Susceptibility Index Mapping

ISI mapping is intended for use at a regional scale; information for this mapping derives from the Well Water Information System (WWIS) which has a lack of information both for records of existing wells, but the location of known records. As well, it does not take into consideration the conditions of a well, which can play a role as a potential contamination pathway for an aquifer. ISI cannot be used locally and should not be substituted for a site-specific investigation performed by a professional. SSI can be a useful tool for defining where ISI needs to be refined, but SSI itself needs field verification.

Recharge/Discharge Areas

Like ISI, the procedure used to calculate recharge areas of bedrock aquifers also uses WWIS as a source for locations and elevations, and the information may be suspect. The procedure also ignores any horizontal flow of groundwater in overburden aquifers and it is a non-quantitative, conceptual geological method. Three-dimensional groundwater modelling may provide more accurate and hydrogeologically significant recharge areas.

Village field wells

Village field wells are an important category of vulnerable areas, but information on their location and records have not been released due to privacy issues. These areas are of particular concern due to the concentration of population in a village which use private on-site septic disposal systems and the fact that they create multiple pathways for potential contamination of an aquifer. Appendix D lists communities without a municipal system. At the current time, there is no way to assess the vulnerability of village field wells; this data and knowledge gap is significant and needs to be addressed before the construction of a source protection plan.

Surface Water Vulnerability-Runoff Index

Estimates of surface water runoff do not take into account runoff from upslope areas. A modified Runoff-Index has only been calculated for the Middle Maitland subwatershed, and this information would be useful to other areas of the SPR as it differentiates areas on their distance to a watercourse. Tile drainage cannot be taken into account because there is no reliable mapping available and because there is not a systematic and defensible method that currently exists.

Nearshore Water Quality

Literature relating to the effect of local tributaries on the water quality of the nearshore of the Great Lakes is limited; however the water quality data comparing Port Blake to Goderich indicates that the plume from the Maitland River affects the area around the intake at Goderich. There are currently attempts to document the effect of select tertiary tributaries of the nearshore (Howell et al. 2005) and this will help to understand the potential for nutrient enrichment of the nearshore by tributaries. The nearshore presents an environment which is difficult to predict – there are a number of factors that influence nearshore water quality including thermal gradients, wind direction, speed, duration and tributary runoff. These factors must be understood to determine how tributaries impact intake protection zones and to address water quality issues.

Table 3-7: Data Gap Reporting for the Vulnerable Areas Chapter of the Ausable Bayfield and Maitland Valley Watershed Characterization

WC Deliverable	Data Set Name	Data Gap Problem	Comment
WC WC Map 19 Vulnerable aquifers as defined in groundwater studies.		Does not exist	Need help from consultant.
WC WC Map 20 Identify potential future drinking water sources.		Does not exist	Need input from municipalities regarding MLTWSS.

3.7 References

Beeton, A.M. and J.H. Saylor. 1995. Limnology of Lake Huron - The Lake Huron Ecosystem: Ecology, Fisheries and Mangement. pp. 1-37.

Blumberg, K., Botts, L., Brown, T.H., Holsen, T.M. and A. Johnson. 2000. Atmospheric deposition of toxics to the Great Lakes: integration science and policy. The Delta Institute. 62p.

Brogren, B.B. and M.J. Sweat. (2000, September 15). Michigan Source Water Assessment Program. Presented at the Michigan Section AWWA Annual Conference.

Canadian Council of the Ministers of the Environment. 2002. Canadian Water Quality Guidelines for the Protection of Aquatic Life: Nitrate Ion. In: Canadian environmental quality guidelines, 1999, Canadian council of Ministers of the Environment, Winnipeg.

Carpenter, S.R. and R.C. Lathrop. 1999. Lake restoration: capabilities and needs. Hydrobiologia 395/396: 19-28.

Carpenter, S.R., Caraco, N.F., Correll, D.L., Howarth, R.W., Sharpley, A.N. and V.H. Smith. 1998. Non-point pollution of surface waters with phosphorus and nitrogen. Ecological Applications 8: 559-568.

Chambers, P.A., Guy, M., Roberts, E.S., Charlton, M.N., Kent, R., Gagnon, C., Gore, G. and N. Foster. 2001. Nutrients and their impact on the Canadian environment. Agriculture and Agri-Food Canada, Environment Canada, Fisheries and Oceans Canada, Health Canada and Natural Resources Canada. 241p.

Chapman, L.J. and D.F. Putman, 1984. The Physiography of Southern Ontario. Ontario Geological Survey, Special Volume 2, 270p.

Conservation Ontario. 2005. Source Water Protection Presentation. Reviewed by M. Veliz. January 26, 2006. http://conservationontario.on.ca/source_protection/files/SWP_overview_Nov05.pdf.

Edsall, T.A. and M.N. Charlton. 1997. Near-shore waters of the Great Lakes. *In* State of the Great Lakes Ecosystem Conference, 1996. US Environmental Protection Agency and Environment Canada, Windsor, Ont.

Fraser, A.S. 1987. Tributary and point source total phosphorus loading to Lake Erie. Journal of Great Lakes Research 13: 659-666.

Grey-Bruce County, 2003. Groundwater Management Study.

Hecky, R.E., Smith, R.E.H., Barton, D.R., Guildford, S.J., Taylor, W.D., Charlton, M.N. and T. Howell. 2004. The nearshore phosphorus shunt: a consequence of ecosystem engineering by dreissenids in the Laurentian Great Lakes. Canadian Journal of Fisheries and Aquatic Science 61: 1285-1293.

Hiriart-Baer, V.P. 2003. Proposal for a policy in OPA 198 to prevent additional Lake Ontario shoreline fouling by nearshore algae. 78p.

Howell, T., Abernethy, S., Charlton, M., Crowe, A., Edge, T., House, H., Lofranco, C., Milne, J., Scharfe, P., Steele, R., Sweeney, S., Watson, S., Weir, S., Weselan, A. and M. Veliz. 2005. Sources and mechanisms of delivery of *E. coli* (bacteria) pollution to the Lake Huron shoreline of Huron County. 270p.

Huron County, 2003. Huron Groundwater Management Study.

International Joint Commission. 2004. Twelfth Biennial Report on Great Lakes Water Quality. ISBN 1-894280-45-8. 73p.

Jackson, M.B., Nakamotot, L.K. and S.L. Wong. 1985. The nearshore water quality of southeastern Lake Huron 1980. Ontario Ministry of the Environment, Water Resources Branch.

Lake Huron Centre for Coastal Conservation. 2004. Nearshore water quality – a preliminary report on historical nearshore water quality information for Southeastern Lake Huron. 49p.

Lambton County, 2003. Lambton Groundwater Management Study.

Michigan Department of Environmental Quality. 2000. Assessment Protocol for Great Lakes Sources. 6p.

Middlesex County, 2003. Middlesex – Elgin Groundwater Management Study.

Ministry of the Environment, 1985a. Hydrogeologic Environments and the Susceptibility of Ground Water to Contamination. Map S100.

Ministry of the Environment, 1985b. Hydrogeologic Environments and the Susceptibility of Ground Water to Contamination: Seaforth Sheet. Map S2227.

Neary, B.P. and J.H. Leach. 1992. Mapping the potential spread of the Zebra Mussel (*Dreissena polymorpha*) in Ontario. Canadian Journal of Fisheries and Aquatic Science 49: 406-415.

Nicholls, K.H., Hopkins, G.J., Standke, S.J. and Lynda Nakamoto. 2001. Trends in total phosphorus in Canadian near-shore waters of the Laurentian Great Lakes: 1976-1999. Journal of Great Lakes Research 27: 402-422.

Ontario Ministry of the Environment. 2006. Assessment Report: Guidance Module 4, Surface Water Vulnerability Analysis. DRAFT. 31p.

Ontario Ministry of the Environment, 2001. Groundwater Studies 2001/2002. Technical Terms of Reference.

Palmateer, G. and D. Huber. 1984. Lake Huron beaches – factors affecting microbiological water quality in 1894 summary report. Southwest Region, Ontario Ministry of the Environment. 77p.

Perth County, 2003. Perth Groundwater Management Study.

Randolph, John. 2003. *Environmental and Land Use Management.* Washington, DC: Island Press.

Reinders, F.J. and Associates. 1989. Lake Huron Shore Processes Study. Report prepared for Ausable Bayfield Conservation Authority, Maitland Valley Conservation Authority, St. Clair Region Conservation Authority and Saugeen Valley Conservation Authority.

Stone, M. and M.C. English. 1993. Geochemical composition, phosphorus speciation and mass transport of fine-grained sediment in two Lake Erie tributaries. Hydrobiologia 253: 17-29.

US EPA. 2001. Frequently Asked Questions About Atmospheric Deposition - A Handbook for Watershed Managers. EPA-453/R-01-009. 97p.

Waterloo Hydrogeologic, Inc., 2004. Sinkhole Investigation for Areas Mainly within the Municipalities of Huron East and West Perth: Final Report.

Waterloo Hydrogeologic, Inc., 2005. Sinkhole Extension Study.

Waterloo Hydrogeologic, Inc., 2005. Grey and Bruce Counties Municipal Groundwater Supply Vulnerability Pilot Study: Final Report.

Waterloo Hydrogeologic, Inc., 2005. Perth County Municipal Groundwater Supply Vulnerability Pilot Study: Final Report.

Waterloo Numeric Modelling Corp., 2005. Huron County Municipal groundwater Supply Vulnerability Pilot Study: Final Report.

Watershed Based Source Protection Implementation Committee. 2004. Watershed Based Source Protection: Implementation Committee Report to the Minister of the Environment. 128p.

Wellington County, 2005. Wellington Groundwater Management Study.

Wetzel, R.G. 1983. Limnology 2nd Edition. Saunders College Publishing. 753p.

Worte, C. (2005, November16). Conservation Authority Watershed management Programs and source Water Protection. Presented at the A.D. Latornell Conservation Symposium.

Appendix A: Generic Representative Permeability (K-factor)

Geomaterial	Representative K-Factor (dimensionless)	K-Value (m/s) @75% range	Highest K-Value (m/s)
Gravel Weathered dolomite/limestone Karst Permeable basalt	1	1.00E-01 1.00E-06 1.00E-03 1.00E-03	0.1
Sand	2	1.00E-2	1.00E-2
Peat (organics) Silty sand Weathered clay (<5m below surface) Shrinking/fractured & aggregated clay Fractured igneous & metamorphic rock Weathered shale	3	1.00E-3 1.00E-4 1.00E-4** 1.00E-4** 1.00E-5 1.00E-5***	1.00E-3
Silt Loess Limestone/dolomite	4	1.00E-6 1.00E-6 1.00E-6	1.00E-6
Weathered/fractured till Diamicton (sandy, silty) Diamicton (silty, clayey) Sandstone	5	1.00E-7 1.00E-7*** 1.00E-8*** 1.00E-7	1.00E-7
Clay till Clay (unweathered marine)	8	1.00E-9*** 1.00E-10	1.00E-9
Unfractured igneous & metamorphic rock	9	1.00E-13	1.00E-13

From Schedule C of the MOE Terms of Reference, November 2001.

Appendix B: Soil and Geology Values for SSI

The classes for estimating the permeability of the Quaternary Geology Units for the Maitland Valley CA watershed are listed below. Relative classifications were developed specifically for this project and may not be suitable for use in other applications or analysis.

Permeability Rating for SSI	Standard Code Unit Name from ABCA, MVCA and UTRCA Quaternary Geology Digitizing Project
Low	Catfish Creek Till: stony, clayey silt to silty sand matrix
Low	Cultural features: fill; man-made deposits
Low	Dunkeld Till (Huron-Georgian Bay lobe): silt matrix
Low	Elma Till (Huron-Georgian Bay lobe): stony, silt to sandy silt matrix
Low	Glaciolacustrine Deep Water deposits: clay, silt, silty and very fine sand;
Low	Maryhill Till (Erie lobe): clay matrix
Low	Modern Fluvial deposits: clay, silt, sand, gravel, muck; alluvial and stream deposits, deposited on modern flood plains
Low	Mornington Till (Huron-Georgian Bay lobe): silty clay matrix
Low	Organic deposits: muck, peat, marl; bog and swamp deposits
Low	Port Stanley Till (Erie lobe): silty clay to sandy silt matrix
Low	Rannoch Till (Huron lobe): silty clay to sandy silt matrix
Low	St. Joseph Till (Huron lobe): silt to silty clay matrix
Low	Stratford Till (Huron-Georgian Bay lobe): sandy silt matrix
Low	Tavistock Till (Huron-Georgian Bay lobe): silty clay to sandy silt matrix
Low	Wartburg Till (Huron-Georgian Bay lobe): clay matrix
Low	Wildwood Silts (Huron lobe): silt; lacustrine deposits
High	Bass Island Formation: dolostone
High	Bedrock: Undifferentiated
High	Bois Blanc Formation: limestone with chert
High	Detroit River Group: limestone, dolostone
High	Dundee Formation: limestone
High	Eolian deposits: fine sand, silt; dunes and sand plains
High	Eolian deposits: fine to medium sand; dunes and sand plains
High	Fluvial deposits: gravel, sand, silt; alluvial deposits
High	Glaciofluvial Ice-contact deposits: gravel; esker, kame, end moraine, ice-marginal delta and subaqueous fan deposits
High	Glaciofluvial Ice-contact deposits: sand, silt; esker, kame, end moraine, ice-marginal delta and subaqueous fan deposits
High	Glaciofluvial Ice-contact deposits: undifferentiated sand, gravel, silt and till; esker, kame, end moraine, ice-marginal delta and subaqueous fan deposits
High	Glaciofluvial Outwash deposits: gravel, gravelly sand; proglacial river and deltaic deposits
High	Glaciofluvial Outwash deposits: sand; proglacial river and deltaic deposits
High	Glaciolacustrine Beach and Shoreline deposits: coarse sand, gravel; beach, bar, deltaic, shallow water and nearshore deposits
High	Glaciolacustrine Shallow Water deposits: fine to medium sand; deltaic and nearshore deposits
High	Hamilton Group: shale, limestone

High	Lacustrine Shoreline deposits: sand, gravel; nearshore and beach deposits
High	Older Fluvial deposits: sand, gravel; alluvial deposits
High	Salina Formation: shale, dolostone, evaporites

Primary Material attribute of the quaternary Geology mapping and the corresponding SSI rating

Permeability Rating for SSI	**Primary Material Attribute Provincial Quaternary Geology Layer from OGDE**
Low	Clay, silt
Low	Clay, silt, sand, gravel
Low	Diamicton
Low	Organic Deposits
High	Gravel
High	Paleozoic Bedrock
High	Sand
High	Sand, Gravel
High	Silt, sand
High	Silt, Sand, Gravel

Appendix C: Potential Village Well Fields

The following is a list of communities with no municipal water treatment facilities, compiled by Municipal and Conservation Authority Staff, organized by Municipality.

Municipality	Community
North Wellington	Kenilworth
Minto	Teviotdale
Howick	Fordwich Gorrie Wroxeter Lakelet
North Perth	Monkton Kurtzville Atwood* Trowbridge Newry
Huron East	Ethel Cranbrook Egmondville Walton Winthrop
Morris and Turnberry	Lowertown Wingham Bluevale
North Huron	Auburn**
Ashfield-Colborne-Wawanosh	St. Helen's Auburn** Nile Port Albert Lakeshore wells*** Fernhurst Glen/Bishop's Subdivision Kingsbridge
Central Huron	Holmesville Londesborough Lakeshore wells***
Bluewater	Varna Kippen Bayfield*
West Perth	Dublin St. Columban Staffa Cromarty
South Huron	Kirkton
Huron Kinloss	Holyrood

*Portion of the village is serviced by municipal wells,
** Shared area between ACW, North Huron and Central Huron (1 municipal well in central Huron),
***many wells spread along entire shoreline.

Appendix D: Soil Values for Runoff Index

The values for the runoff index for soil hydrologic characteristics are listed below.
Values were used for this project that may not be suitable for other applications or analysis

Basin Runoff Forecast Unit Calibration of the Saugeen and Maitland Watersheds by Jack MacPherson 1978-1982.

		County	Class	A Horizon (cm)	S %	Fc mm/hr
Berrien Sandy Loam	Bes	Bruce	B-A	22.86	31.0	7.0
		Grey				
		Wellington				
	Bes	Huron	B-A	25.40	30.9	7.4
Bookton Sandy Loam	Bos	Bruce	B-A	20.32	31.0	7.0
		Grey				
		Wellington				
	Bos	Huron	B-A	12.70	30.9	7.0
Bottom Land	BL	Bruce	B	30.48	31.3	6.1
	BL	Grey	B	30.48	31.3	6.1
	BL	Wellington	B	30.48	31.3	6.1
Brady Sandy Loam	Bsl	Bruce	B-A	33.02	31.0	7.5
	Bsl	Grey	B-A	30.48	31.0	7.0
	Bs	Wellington	B-A	20.32	31.0	7.6
	Brs	Huron	A-B	20.30	33.0	8.9
Breypen	Bp	Bruce	B-D	2.54	26.0	3.0
	Bp	Grey	B-D		26.0	3.0
		Wellington				
Bridgman Sand	Bis	Bruce	B	15.24	24.4	6.3
		Grey				
		Wellington				
Brighton Sand		Bruce				
	Brs	Grey	B	30.48	32.3	6.8
		Wellington				
Brisbane Loam	Brl	Bruce	B	25.40	30.0	5.0
	Brl	Grey	B	25.40	30.0	6.0
	Bl	Wellington	B	17.78	30.0	6.0
	Brl	Huron	B	27.90	30.0	5.8
Brookston Clay Loam	Bc	Perth	B-C	17.78	25.7	3.5
	Bc	Bruce	B-C	17.78	25.7	3.5
	Bc	Grey	B-C	17.78	25.7	3.5
	Bnc	Wellington	B-C	15.24	25.7	3.8
	Bc	Huron	B-C	20.30	25.7	3.9
Brookston Loam		Bruce				
		Grey				
	Bnl	Wellington	B	15.24	30.0	7.6
Brookston Silt Loam	Bs	Perth	B	17.78	31.3	3.8

	Bs	Bruce	B	17.78	31.3	3.8
		Grey				
	Bns	Wellington	B-C	15.24	25.7	3.8
	Bs	Huron	B	20.30	31.3	4.0
Brookston Silty Clay Loam	Bsc	Huron	C-B	20.30	23.3	3.8
Burford Loam	Bg	Perth	B	48.30	30.0	4.0
	Bg	Bruce	B	40.64	30.0	6.1
	Bg	Grey	B	25.40	30.0	5.5
	Bg	Wellington	B	30.48	30.0	5.0
	Bg	Huron	B	40.60	30.0	5.9
Chesley Clay Loam	Cc	Bruce	B-C	12.70	25.7	3.5
		Grey				
		Wellington				
Chesley Silt Loam	Cs	Bruce	B	12.70	31.3	4.5
		Grey				
		Wellington				
Chesley Silty Clay Loam	Csc	Bruce	C-B	12.70	23.3	3.5
	Csc	Grey	C-B	12.70	23.3	3.5
		Wellington				
Colwood Silt Loam		Bruce				
		Grey				
	Cos	Wellington	A-B	15.24	36.3	8.4
Donnybrook Sandy Loam	Dsl	Perth	B-A	58.40	31.0	7.0
	Dos	Bruce	B-A	43.18	31.0	7.6
	Dos	Grey	B-A	40.64	31.0	7.6
	Db	Wellington	B-A	25.40	31.0	7.0
	Dos	Huron	B-A	61.00	31.0	7.6
Dumfries Loam	Dl	Bruce	B	35.56	30.0	5.8
		Grey				
	Dl	Wellington	B	30.48	30.0	4.0
	Dl	Huron	B	27.90	30.0	6.0
Dumfries Sandy Loam	Ds	Huron	B-A	27.90	30.9	7.6
Dumfries-Hillsburgh		Bruce				
		Grey				
	Dl-Hif	Wellington	B	35.56	30.0	7.6
Eastport Gravel	Eg	Bruce	B	91.44	24.4	6.4
		Grey				
		Wellington				
Eastport Sand	Es	Bruce	B	15.24	24.4	6.3
		Grey				
		Wellington				
Elderslie Clay Loam	Ecl	Bruce	B-C	17.78	25.7	3.5
		Grey				
		Wellington				

Elderslie Silt Loam	Esl	Bruce	B	17.78	31.3	4.5
		Grey				
		Wellington				
Elderslie Silty Clay Loam	Esc	Bruce	C-B	17.78	23.3	3.5
	Esc	Grey	C-B	10.16	23.3	3.5
		Wellington				
	Psc	Huron	C-B	20.30	23.3	3.9
Farmington Loam		Bruce				
	Fl	Grey	B-A	12.70	30.9	6.1
	Fl	Wellington	B-A	12.70	30.9	6.1
Fox Sandy Loam	Fsl	Bruce	B-A	66.04	31.0	7.6
	Fsl	Grey	B-A	58.42	31.0	7.6
	Fs	Wellington	B-A	60.96	31.0	7.6
	Fs	Huron	A	56.00	32.7	8.9
Gilford Loam	Gil	Perth	B	17.80	30.0	6.1
	Gil	Bruce	B	15.24	30.0	6.1
	Gil	Grey	B	15.24	30.0	6.1
	Gil	Wellington	B	20.32	30.0	6.1
	Gil	Huron	B	17.80	30.0	6.1
Granby Sand	Gs	Bruce	B	17.78	32.3	6.9
	Gs	Grey	B	20.32	32.0	6.9
	Gs	Wellington	B-A	17.78	31.0	7.6
Granby Sandy Loam	Gsl	Bruce	B-A	17.78	31.0	7.5
		Grey				
	Grs	Wellington	B-A	17.78	31.0	7.5
	Gs	Huron	B-A	20.30	30.9	7.6
Guelph Loam	Gl	Perth	B	33.60	30.0	4.0
Guerin Loam	Gul	Huron	B	22.90	30.0	6.1
Harkaway Loam	Hal	Bruce	B	12.70	30.0	6.0
	Hal	Grey	B	10.16	30.0	6.0
Harkaway Silt Loam	Has	Bruce	B	12.70	31.3	6.1
	Has	Grey	B	10.16	31.3	6.1
		Wellington				
Harriston Loam	Hl	Bruce	B	45.72	30.0	5.8
	Hl	Grey	B	45.72	30.0	5.8
	Hl	Wellington	B	48.26	30.0	5.8
	Hl	Huron	B	48.30	30.0	5.0
Harriston Silt Loam	Hsi	Perth	B	50.80	31.3	4.0
	Hs	Bruce	B	50.80	31.3	5.8
	Hs	Grey	B	45.72	31.3	5.5
	Hs	Wellington	B	48.26	31.3	6.1
	Hs	Huron	B	48.30	31.3	5.0
Huron Clay Loam	Huc	Perth	B-C	25.40	25.7	3.5
	Huc	Bruce	B-C	27.94	25.7	3.5
		Grey				
	Huc	Wellington	B-C	43.18	25.7	3.8

	Huc	Huron	B-C	25.40	25.7	3.5
Huron Loam	Hul	Bruce	B-C	27.94	25.7	3.8
		Grey				
	Hul	Wellington	B-C	43.18	25.7	3.8
Huron Silt Loam	Hus	Perth	B	25.40	31.3	3.3
	Hus	Bruce	B	27.94	31.3	4.5
		Grey				
	Hus	Wellington	B	43.18	31.3	4.0
	Hus	Huron	B	25.40	31.3	3.5
Killean Loam	Kl	Bruce	B	30.48	30.0	6.5
		Grey				
		Wellington				
Lily Loam		Bruce				
	Lyl	Grey	B	15.24	30.0	5.8
	Lyl	Wellington	B-A	17.78	31.0	7.6
Listowel Loam	Ll	Bruce	B	30.48	30.0	5.0
	Ll	Grey	B	25.40	30.0	5.0
	Ll	Wellington	B	30.48	30.0	6.0
	Ll	Huron	B	33.00	30.0	6.0
Listowel Silt Loam	Lsi	Perth	B	35.60	31.3	4.5
	Ls	Bruce	B	30.48	31.3	4.5
	Ls	Grey	B	25.40	31.3	4.5
	Lis	Wellington	B	30.48	31.3	6.1
	Ls	Huron	B	17.80	31.3	6.1
London Loam	Li	Perth	B	22.90	30.0	4.0
Lyons Loam	Lyl	Huron	B-A	20.30	30.0	7.6
Muck	M	Bruce	D	0.00	27.0	3.5
	M	Grey	D	0.00	27.0	3.5
	M	Wellington	D	0.00	27.0	3.5
	M	Huron	D	0.00	27.0	3.5
Osprey Loam	Ol	Bruce	B	7.62	30.0	5.2
	Ol	Grey	B	5.08	30.0	5.0
		Wellington				
Parkhill Loam	Pl	Perth	B	15.24	30.0	5.8
	Pal	Bruce	B	15.24	30.0	5.8
	Pal	Grey	B	15.24	30.0	5.0
	Pal	Wellington	B	17.78	30.0	5.8
	Pal	Huron	B	17.80	30.0	5.8
Parkhill Silt Loam	Pas	Bruce	B	17.78	30.0	5.8
	Pas	Grey	B	15.24	31.3	6.0
	Pas	Wellington	B	17.78	31.3	6.0
	Pas	Huron	B	17.80	31.3	6.1
Peat	P	Bruce	D	0.00	27.0	3.8
	P	Grey	D	0.00	27.0	3.8
	P	Wellington	D	0.00	27.0	3.8
Perth Clay Loam	Pc	Perth	B-C	25.40	25.7	3.5
	Pc	Bruce	B-C	33.02	25.7	3.5

		Grey				
	Pc	Wellington	B-C	17.78	25.7	3.8
	Pc	Huron	B-C	20.30	25.7	3.8
Perth Loam		Bruce				
		Grey				
	Pl	Wellington	B-C	17.78	25.7	3.8
Perth Silt Loam	Ps	Perth	B	25.40	31.3	3.3
	Ps	Bruce	B	33.02	31.3	4.0
		Grey				
	Ps	Wellington	B	17.78	31.3	4.5
	Ps	Huron	B	20.30	31.3	3.9
Perth Silty Clay Loam	Psc	Huron	C-B	20.30	23.3	3.9
Pike Lake Loam		Bruce				
	PLl	Grey	B-A	27.94	31.0	7.5
		Wellington				
Plainfield Sand	Pls	Bruce	B-A	7.62+	31.0	7.6
		Grey				
		Wellington				
Sargent Loam	Sg	Bruce	B	7.62	30.0	5.0
	Sg	Grey	B	7.62	30.0	4.5
		Wellington				
Saugeen Clay Loam	Sc	Bruce	B-C	17.78	25.7	3.5
		Grey				
		Wellington				
Saugeen Silt Loam	Ss	Bruce	B	10.16	31.3	4.2
		Grey				
		Waterloo				
Saugeen Silty Clay Loam	Ssc	Bruce	C-B	17.78	23.3	3.5
	Ssc	Grey	C-B	15.24	23.3	3.8
		Wellington				
Sullivan Sand	Sus	Bruce	B	7.62	32.3	6.9
	Sus	Grey	B	7.62	32.3	6.9
		Wellington				
Tecumseth Sand		Bruce				
	Ts	Grey	B	20.32	32.3	6.9
		Wellington				
Teeswater Silt Loam	Tes	Bruce	B	48.26	31.3	4.2
		Grey				
	Tes	Wellington	B	60.96	31.3	4.2
	Tes	Huron	B	45.70	31.3	5.5
Toledo Clay Loam	Tc	Bruce	B-C	15.24	25.7	3.5
	Tc	Grey	B-C	15.24	25.7	3.4
	Tc	Wellington	B-C	15.24	25.7	3.5
	Tc	Huron	B-C	17.80	25.7	3.8
Toledo Silt Loam	Ts	Bruce	B	15.24	31.3	3.0
		Grey				

		Wellington				
	Ts	Huron	B	17.80	31.3	5.5
Vincent Silty Clay Loam	Vsc	Bruce	C-B	7.62	23.3	3.8
	Vsc	Grey	C-B	10.16	23.3	3.5
		Wellington				
Waterloo Sandy Loam	Wsl	Perth	B-A	40.60	31.0	7.0
	Wsl	Bruce	B-A	43.18	31.0	7.0
	Wsl	Grey	B-A	35.56	31.0	7.0
		Wellington				
Wauseon Sandy Loam	Was	Bruce	B-A	20.32	31.0	4.5
		Grey				
		Wellington				
	Was	Huron	B-A	22.90	30.9	7.2
Wiarton Loam	Wl	Bruce	B	15.24	30.0	5.8
		Grey				
		Wellington				
Wiarton Silt Loam	Ws	Bruce	B	15.24	31.3	5.9
	Ws	Grey	B	17.78	31.3	5.9
		Wellington				

Appendix E: Catalogue of WC Maps in the Accompanying Map Book

WC Map 3-1: Well Head Protection Areas and Water Systems

WC Map 3-2: Intrinsic Susceptibility Mapping

WC Map 3-3: Surficial Susceptibility Index

WC Map 3-4: Discharge from Overburden Aquifer

WC Map 3-5: Geologic Windows

WC Map 3-6: Recharge and Discharge Bedrock Aquifer

WC Map 3-7: Sinkhole and Sinkhole Drainage Area

WC Map 3-8: Runoff Index

WC Map 3-9: Modified Runoff Index

Chapter 4

EXISTING THREATS INVENTORY

Version 1.0
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4 Existing Threats Inventory

The Source Protection Plan is required to complete a thorough analysis of known past, existing, and future sources of threats in the Ausable Bayfield Maitland Valley watersheds. Identifying known and documented threats, issues, and concerns is important to provide the basis for future analysis and understanding of existing threats within the watershed regions.

The guidance module "Existing Specific Threats Inventories" section 6.0 of the Watershed Characterization produced by the Ontario Ministry of the Environment (MOE) outline the criteria involved in for this chapter. According to the guidance module, the focus of this chapter is to provide information on threats that have been identified through previous study for both ground and surface water. This chapter does not however, separate threats by ground and surface water, but by the type and character of the threats.

An overview of the results of this inventory is provided in table format which provides a complete overview of identified threats, documentation, and geographic location (if applicable). This inventory is built on the assumption that anything that has the potential of effecting water quality and quantity in any degree is considered a threat. The level of knowledge and documented proof of this threat will categorize each threat into either an issue or concern.

An **issue** is an identified and acknowledged threat to ground and surface water to some degree through previous study or historical proof. It is important to note that a threat is not necessarily an issue. A **concern** as identified within this chapter has been acknowledged as a possible threat to some degree, but has had no known or identified impact to ground and/or surface water. For example, in all groundwater studies that have been referenced, all listed potential contaminant sources to ground and surface water have been included as a concern within this chapter.

Appendix A (Categories of Threats) provides the basis of discussion for the text. The table is categorized by major themes that represent related threats. Since this chapter aims to provide a general overview of known threats to the watershed as a whole, many of the threats identified could have impacts on both ground and surface water. It is important to note that threats to water quantity will be discussed in greater detail in the water budget chapter of the watershed assessment.

Most of the documentation within this chapter is attained from regional ground water studies, related Ausable Bayfield Conservation Authority and Maitland Valley Conservation Authority studies and reports, environmental consultant studies for the region, minutes from local environmental committees, and discussions among stakeholders. The term "source protection Region" will be used in reference to the Ausable Bayfield Maitland Valley watershed region.

4.1 Categories of threats/issues/concerns

Appendix A provides a detailed listing of all known contaminant sources for the region. The table is grouped into categories of related threats. Many of the categories also interrelate with other categories listed, and these inter-relationships will be discussed within the text portion of this document. It is important to note that many of the contaminant sources outlined within Appendix A are prevalent throughout the Source Protection Region.

4.1.1 Agricultural Activities
(Refer to WC Map 4-1)

Agricultural activities dominate the Ausable-Bayfield and Maitland Valley Source Protection Region. As stated in the watershed description (Chapter 1), the Maitland watershed has the highest level of livestock manure production/ha in Canada with the Ausable Bayfield watershed having the 7th highest in Canada (Statistics Canada 2001). The impacts of livestock production within these watersheds and the subsequent effect or by-products are considered one of the central threats to water quality both in areas that impact ground and surface water as non-point source pollution.

4.1.1.1Application of Nutrients

Agricultural activities that involve application of nutrients to the land (this includes fertilizers, manure, septage) have been raised as an issue as trends have shown an increase in nitrates, biological nutrients, and phosphorous into streams. The applications of manure pose a risk for biological and nitrate contaminations in groundwater as determined by many groundwater studies within the region. The risk increases within areas that have high aquifer vulnerability (Waterloo Hydrogeological 2004).

Municipal wells which service the village of Hensall, in the municipality of Bluewater, and individual wells in the Staffa area of East Huron have elevated nitrate levels, likely related to the application of fertilizers. The ABCA sinkhole study (2004), Huron County Groundwater study (2001), and the Hensall Pilot Study on Groundwater Protection strategies (2003) have documented these issues extensively.

Manure application on tile drained land has been identified as an issue that arose out of the Dean and Foran 1989 report. At least 75% percent of the agricultural land within the Source Protection Region has been tile-drained (Dean and Foran 1989).

4.1.1.2 Liquid Manure and Septage

In areas where pump out sewage and biosolids/septage is used, there is a public concern as noted in the MVCA Water Action Team minutes, but there is no documentation to support this concern at this time. The pumping out of biosolids must be approved by the MOE. The Upper Thames River Conservation Authority underwent a project to minimize the incidence of manure spills into watercourses several years ago. According to the data surrounding this project, the major causes of manure spills (in order of prevalence) were spray irrigation of liquid manure, insufficient manure storage, equipment failure, and transportation related (UTRCA No date). High trajectory irrigation guns for land application were banned, however, under the *Nutrient Managemnent Act* in 2002. In addition, other concerns surrounding liquid manure have been addressed by best management practices. In an earlier study which looked at the effect of land application of manure on water quality, macropores were determined to be the main pathway of manure components to travel through the soil (Taylor and Foran 1993). The recommendation that tillage occurs on tile drained land prior to land application has been adopted by the agricultural community.

The transportation of liquid manure has become more prevalent for many rural regions including the ABCA/MVCA Watershed. The increase of liquid manure transportation has led to an increase in the number of spills. Spills can flow into surface water or leach into ground water sources which could contaminate drinking water supplies as well as damage aquatic habitats. Manure spills can also contaminate the soil by concentrating a large amount of nutrients making crop growth difficult (OMAFRA 2006).

With respect to pump out sewage or the spreading of liquid manure, the incidence of spills have caused concern due to a 2004 liquid manure spill in St. Joseph that affected the surrounding area including the Grand Bend shoreline (Lakeshore Advance 2004).

The Nearshore Water Quality Report (2004) studied water and beach quality data on the Lake Huron shoreline. The study reported that sewage by-passes have been a source of contamination and acute liquid manure spills and an issue for water quality and beach pollution. The study also indicates chronic levels of pollution due to faulty septic systems, livestock access to streams, and agricultural run-off (Lake Huron Centre for Coastal Conservation 2004).

As Appendix A indicates, land application of nutrients has been identified as an issue throughout the Source Protection Region. The application of fertilizers has been a central component for study within this region. The magnitude of each threat is dependant on its relation to its impact to ground and surface water supplies. All studies completed that reference agricultural activities as contaminant sources for water supplies require further analysis to obtain existing data.

4.1.1.3 Storage

Groundwater studies show that there is no evidence that manure storage within capture zones affects municipal water (Dillon Consulting 2004). There is also no evidence at this point of chemical storage on farms as being an issue. It is recognized that the Hensall water system contaminants may be related to chemical storage, but more data is required (Stauttener 2006).

4.1.2 Municipal Wastewater/landfills (incl. private)/Septic tanks

(Refer to WC Map 4-2)

4.1.2.1 Landfills

In terms of landfills, two main issues arise in the Source Protection Region; existing landfills near wetlands and municipal wells, and historical landfills located on marginal lands, former pits or quarries, or in ravines (Dillon Consulting 2004).

The Hensall landfill in the municipality of Bluewater is within the capture zone of the Hensall/Zurich municipal well (B.M. Ross 2003). Howick and Mid-Huron area have landfills near wetlands as indicated in the Huron County Groundwater study (Golder Associates 2001).

4.1.2.2 Septic Systems

Septic systems are a major source of bacterial pollution (Lake Huron Centre for Coastal Conservation 2004). Many septic systems are undersized, minimized, or aged septic systems that are not treating waste effectively and have a chronic negative impact on water quality. This is an issue documented throughout the region especially along the lakeshore of Lake Huron (WPSC minutes Apr 7, 2004). There is limited knowledge on the septic systems of this area (along the Lake Huron coastline) as well as systems adjacent to the beaches of Lake Huron and migration of bacteria (OMOE 2005). Existing records of septic systems within the region in general are incomplete (WPSC minutes June 17, 2004).

The Municipality of South Huron will be undergoing a project to connect the Villages of Crediton and Centralia to the municipal wastewater/storm sewer system (B.M. Ross 2004). Both villages are currently functioning on private septic systems for each individual residence. Many of the septic systems within this area are either failing or malfunctioning. Evidence shows sewage bubbling to the surface and flowing directly into storm drains towards the Ausable River. Many residences have attempted to alleviate the problem by hooking their drainage system to farm tile drainage in neighbouring fields or storm drains. Farm tiles drain directly into open water courses in many cases. This area is also experiencing high levels of *E. coli* in storm drains (Giberson 2006). The practice of tying in septic system to storm drains or tile drains is, however, illegal.

4.1.2.3 Municipal Wastewater/Storm Sewer

In many municipalities where municipal wastewater and storm sewers are in place, storm water bypasses and overflows by cross connections is an issue. The discharge of chlorine and ammonia from wastewater into Lake Huron is also an issue that has been discussed through various site specific studies (Luinstra 2006).

Many of the more urbanized areas of the Source Protection Region contain municipal or communal systems that collect and treat sewage and waste water. Although most of these sewage treatment systems provide secondary treatment and disinfection, the discharge from these systems can cause an increase in microbial release into the surrounding environment. In addition, sewage treatment by-passes and overflow occur during times of heavy rains and snow melt, which cause an overflow of microbial load to by-pass the treatment facility and flow into neighbouring watercourses. The Town of Goderich had been the only facility that directly discharged into Lake Huron (Howell et al. 2005), but received funding from the Canada-Ontario Municipal Rural Infrastructure Fund (COMRIF) to complete the separation of storm and sanitary sewers and to upgrade the sewage treatment plant to prevent the occasional release of partially treated sewage into the lake during high rainfall events (Ashfield Colborne Lakefront Association 2005). The Town of Goderich is anticipating to complete the project by April, 2008.

The Municipalities of Lambton Shores, Bluewater, and South Huron, are participating in the Grand Bend and Area Sanitary Sewage Servicing Master Plan to provide municipal sewage services to the area. This has been due to the fact that malfunctioning septic systems and discharges from the Grand Bend Sewage Treatment Facility have been adversely affecting groundwater and surface water in this region (Dillon Consulting 2000).

The Bluewater Shoreline Rate Payers Association hired GAP Environmental Services to conduct a study on the connections between the Zurich sewage lagoons and *E. coli* DNA found in shoreline sediment. This study investigated if there is a relationship between the lagoons and pollutants on the shoreline (WPSC minutes Dec 16, 2004). The study did find that the multiple potential sources along the St. Joseph's ravine (agricultural, residential, wildlife) likely impacts the water quality at St. Joseph's beach (GAP 2005).

Below is a table that represents municipal exceedances for sewage treatment plant operations within the Source Protection Region that was reported by the MOE for 2004.

Table 4-1: Municipal Wastewater Contaminant Sources 2004, MOE Data, for the Ausable Bayfield Maitland Valley Region

2004 Municipal Sewage Monthly Summary				
Municipality	County/Region	Type	No. of Exceedances	Facility Action
Bayfield	Bluewater	*E. coli*	1	Operational process modification
Clinton	Central Huron	Total suspended solids	2	Equipment modified, repaired, replaced, or recalibrated
Listowel	North Perth	Ammonia	2	None required
Exeter	South Huron	*E. coli*	3	Operational process modification, conducting a study
Ripley	Huron-Kinloss	Total suspended solids	1	Conducting study
Lucan	Lucan Biddulph	Phosphorous Suspended solids	5	Equipment modified, repaired, replaced, or recalibrated
Ilderton	Middlesex Centre	Ammonia Low ph effluent Phosphorous Suspended solids	4	Treatment process upgrades, additional monitoring, Equipment modified, repaired, replaced, or recalibrated

* Source: Sewage Municipal & Private: Southwestern Region, 2004

4.1.3 Wells: Municipal/Individual
(Refer to WC Map 4-3)

4.1.3.1 Individual Wells

All individual wells can be seen as a concern and many issues relating to municipal wells could also be issues within individual or communal wells. Private wells and non-decommissioned wells provide a pathway for contaminated surface water to enter deep aquifers.

There is some evidence of concern within the Huron Region and North Lambton, but due to rights of privacy, individual wells are not identified (Luinstra interview 2006). Results from the Huron County Health Unit show a decrease in water samples from individual wells that have been unsafe (refer to table 4-2). It is important to note that the data in this table is to show trends within this region. The accuracy of this data may be questioned due to the fact that individual wells may have been sampled more than once, thus skewing the results.

Table 4-2: Huron County Health Unit Private Water Samples: % and yearly comparison of total safe and unsafe water samples 2003-2006

Year	% Safe Water Samples	% Unsafe Water Samples
2003	73.4 %	19.0 %
2004	77.0 %	15.3 %
2005	73.9 %	3.5 %
2006	79.6 %	2.3 %

* Source: Huron County Health Unit Private Water Samples Reports

There are many unreported individual wells and abandoned wells. Many individual wells have not been located and many abandoned wells are not properly decommissioned. Many lakeshore areas have not identified wells on a map. The Ministry of Natural Resources in partnership with the Conservation Authorities are working on documenting the number of decommissioned wells within each region (Well Water Information System 2006).

4.1.3.2 Municipal wells

All municipal wells within the Source Protection Region show signs of fluoride: a naturally occurring substance within this area. As Appendix B indicates, the municipal wells in Belgrave in the Municipality of Morris-Turnberry, have test results of nitrate contamination. These wells are GUDI (groundwater under the Direct Influence of surface water) wells and are more susceptible to surface water influences. The Hensall wells within the municipality of Bluewater also indicate higher than average nitrate levels in three of their four wells (Luinstra spreadsheet 2006). Concerns have been raised over nitrate concentrations in the Atwood and Kinloss municipal wells reported with the Provincial Groundwater Monitoring Network (WAT minutes Apr 21, 2004).

The Hensall water supply system has been heavily documented as an issue. The Hensall wells 1, 2, and 4 have had a history of higher than average nitrate concentrations. This may be due to fertilizer application in the area, but more data is required to determine this relationship. The Provincial water standards are a maximum of 10 units of nitrate (10 mg/L), and all three wells have been higher on many testing results. The aquifer that supplies water for these wells is a fairly large and shallow aquifer which makes it more susceptible to contamination (Stauttener 2006). The Municipality is currently working on a project to run pipeline from the Lake Huron Regional Water Supply to be used for municipal water (B.M. Ross 2003).

The Huron County groundwater study explains that shallow wells indicate higher levels of *E.coli* and nitrates as indicated in the Usborne area wells. The wells in Arkona, which were identified in the Lambton County Groundwater Study as being vulnerable to contamination due to exposed bedrock areas, are now out of service as of November 2006 and are planned for decommissioning in 2007. Toxins such as herbicides and pesticides are also detected in some sampling especially at heavy rain times (WPSC minutes Apr 7, 2004).

4.1.4 Surface Water Runoff

(Refer to WC Map 4-4)

4.1.4.1 Sinkholes

A sinkhole is a surface depression caused by a collapse of soil or overlying formation above fractured or cavernous bedrock. Sinkholes can act as a pathway for contaminant sources and has been identified as an issue (Waterloo Hydrogeologic 2004).

The Sinkhole Study for West Perth and Huron East determined that many sinkholes within this region are outlets for agricultural drains that enable nitrates, pathogens, and pesticides to enter into an aquifer. Many municipal drain outlets are located within the capture zone of a sinkhole (Waterloo Hydrogeologic 2004). This study highlights sinkhole-groundwater interaction, whereby water entering sinkholes has a likely impacting private wells (WPSC minutes Apr 7, 2004). This issue has also been documented in both the Huron and Perth groundwater studies.

4.1.4.2 Effluents into the River

Soil, nutrients, and pathogens run-off into watercourses from neighbouring agricultural land that cause a source of contamination for water quality. Many regions are affected by higher than average nitrate levels which has adverse affects to water quality and ecosystem health (WAT minutes Dec 7, 2005).

4.1.4.3 Industrial Runoff

The Middle Maitland Subwatershed primarily within the area below Listowel has shown incidences of heavy metals as a source of contamination (WAT minutes Dec 7, 2005). More data is required to understand the linkages between industrial runoff and sources of contamination of both surface and groundwater quality within this region and throughout the Source Protection region.

4.1.5 Transportation

(Refer to WC Map 4-5)

4.1.5.1 Road Salt

Road salt has been identified as a potential contaminant depending on the quantity used, and can result in high sodium chloride concentrations within the areas along roadsides. The incidence of chloride contamination has been identified as an issue in certain areas, but only due to the fact that those areas have been studied (Steele et al. 2006). There may be other areas where chloride contamination is also an issue. According to Environment Canada, most claims from property owners against transport authorities are related to contamination of well water from salt released into groundwater (Dillon Consulting 2004).

4.1.5.2 Spills

Transportation spills along highway and rail lines have been raised as a concern, but more data is required to determine rating. There is no official data that documents these concerns.

4.1.6 Industrial Contamination
(Refer to WC Map 4-6)

Industrial spills within the Source Protection Region that include, but are not limited to, the Belgrave Co-op Ammonium spills and the Hensall Spill have been documented by the Spills Action Centre through the Ministry of the Environment (Luinstra Interview 2006). The information available in the MOE spills database makes it difficult to assess the degree of risk to groundwater posed by recorded spill incidences (Dillon Consulting 2004).

The groundwater studies for this Source Protection Region outline the most common potential contaminant sources as fuel storage tanks, historical use and disposal practices, and spills (Waterloo Hydrogeologic 2003). A common source of contamination is retail fuel outlets (Dillon Consulting 2004).

Aggregate extraction has been documented within all ground water studies for the region as potential contaminant sources. Those areas where aggregate extraction influences a cold water stream can cause ecological contamination by MOE standards. As sand and gravel are taken away, this increased the temperature on the stream, thus affecting the ecology of the stream and its proper functioning (Luinstra 2006).

4.1.7 Drainage
(Refer to WC Map 4-7)

4.1.8 Growth/Development
(Refer to WC Map 4-8)

Concerns over the expansion of the cottage industry and infrastructure capacity (such as septic systems) have been raised for water quality along the Lake Huron shoreline. Septic systems are one of the major issues in this region especially along the lakeshore as well as under serviced hamlets. Tourism and the cottage industry in many areas along the Lake Huron shoreline have increased over the years. More information is required of the impacts of development to water quality (Lake Huron Centre for Coastal Conservation 2004).

A study by Dr. Allan Crowe outlines that beach front properties along the Lake Huron shoreline have shown to contribute a major portion of *E. coli* contamination found in the groundwater below the beach area. Alterations to the natural sand dune environment by residential development along the shoreline have lead to increasing levels of *E. coli* contamination (Crowe 2006).

Identified growth areas within the Ausable-Bayfield Maitland Valley Source Protection Region include:

- Port Franks
- Listowel
- Bluewater (Bayfield)
- Lambton Shores (Grand Bend)
- Seaforth
- Lucan

The 'Grand Bend and Area Sanitary Sewage Services Master Plan' is currently underway to provide municipal sewage services to the area. Dillon Consulting will continue their environmental impact studies on the adverse affects of construction on ground and surface water (Lambton Shores No date). Further research is required to address the relationship of development and its impact to water quality.

4.1.9 Oil/Natural Gas

(Refer to WC Map 4-9)

Oil and natural gas wells have the potential to pose a contaminant threat since incorrectly sealed or abandoned wells can act as a direct pathway for surface contaminants to migrate into the aquifer, or via cross contamination from the oil well to the aquifer. Many concerns have been raised about issues relating to oil and natural gas, but there is no official data to support these concerns at this time (Waterloo Hydrogeologic 2003b). Elevated chloride and Sodium levels, as well as radionuclide issues in the Seaforth area, may be related to non-decommissioned brine wells in that area.

4.1.10 Wildlife

At Goderich beach, the contamination of fecal matter from geese has been identified as an issue (Goderich Environmental Committee #3, 2005). The MOE study (2005) by Howell describes fecal pollution problems at beaches along the Lake Huron shoreline. *E. coli* and fecal coliforms were proven to be the main contaminant sources that originated from faulty septic systems, agricultural activities, and sewage treatment plants. The study also discusses the incidence of gulls and geese as potential contaminant sources although more study is required (OMOE 2005). When natural dunes have been eroded, it allows beaches to stay wet, encouraging bacteria from geese droppings to spread down from the surface. Dr. Allan Crowe, of the Canadian Centre for Inland Waters, has been quoted as saying that the swash zone is high in *E.coli* concentrations along Great Lake shorelines (McGuiness 2006). A study from the University of Guelph also suggests that there is a relationship between algae and *E.coli* whereby the bacteria reproduce on the algae and are able to survive for a long time on algae mixed with sand (McGuiness 2006).

4.1.11 Air Borne Threats

Air pollution within the Great Lakes watershed takes less than a day to reach the lakes. The air quality of the Lake Huron shoreline is among the worst in Southern Ontario. Ground level ozone levels have been measured at nearly twice those of Toronto. Other chemicals that can be deposited into Lake Huron through air transport include pesticides, lead, mercury, PCB's, furan, and dioxins. More research is required as to the magnitude of these potential contaminant sources on Lake Huron (Sivers No date).

4.1.12 Cemeteries and Funeral Establishments

Cemeteries have been raised as a concern and have been noted in most groundwater studies for this region as a potential threat. There is no official evidence on the impacts of cemeteries either current or historical as a contaminant source.

The disposal of blood and human tissue has also been raised as a concern. Under regulation 347 of the *Environmental Protection Act*, any part of the human body including tissues and bodily fluids except fluids, extracted teeth, hair, nail clippings and the like that are not infectious, are considered pathological waste. Pathological waste is a form of hazardous waste and must be disposed at a hazardous waste facility.

The disposal of non-infectious blood is permitted to be discharged directly to sewers. Most hospitals do not dispose of human blood to sewers in large quantities (above 300 millilitres) (Ontario Hospital Association, 2002). In addition, the World Health Organization has stated that the concentration of blood-borne pathogens is diluted; therefore their viability is reduced by other constituents in sewage and during treatment (Ontario Hospital Association, 2002). The WHO also stated that it is unlikely that these pathogens constitute a health threat. There is minimal literature on this subject and the OHA recommended to the Ministry of the Environment to engage in further study to determine if the disposal of human blood in sanitary sewers could affect human health (Ontario Hospital Association, 2002).

4.1.13 Intakes

(Refer to WC Map 4-10)

The relationship between the effects of water treatment plants and surface water intakes into Lake Huron has been documented as an issue (Golder Associates 2001). The issue of suspended sediment, old filtration materials (back flush), and the incidence of alum, sand, and charcoal have been identified as contaminant sources around surface water intakes (Goderich Environmental Committee # 2 2002).

4.1.13.1 River Influence

The effect of tributaries, rivers, streams that collect contaminants like nitrate, pathogens, and possibly pesticides flow into Lake Huron. Areas like the Goderich intake is very close to the mouth of the Maitland River.

4.1.13.2 Marinas

Many surface water intakes along the Lake Huron shoreline are close to marinas which can cause adverse water quality conditions for water surrounding the intake. Fuel storage, high use shipping lanes, village discharge, and holding tank pumping have the potential to affect water quality (Luinstra 2006).

Dredging and maintenance dredging of the harbour can stir up contaminant sources that have settled at the bottom of the Lake. Dredging can create a plume of sediment that could impact a surface water intake that may be in close proximity (Steele 2006).

4.1.14 Water Takings/Quantity

(Refer to WC Map 4-11)

The issues and concerns on water taking will be covered in depth in the water budget chapter. Many issues relating to industry, golf courses, and camp grounds have been raised as concerns for water quality throughout the watershed (Luinstra interview 2006).

4.2 Conclusion

This chapter has outlined documented existing, historical, and future threats within the Ausable-Bayfield Maitland Valley Source Protection Region. Trends and characteristics within the region have determined three main categories from Appendix A as the most prevalent issues to water quality These categories are agricultural activities, septic systems, and municipal infrastructure.

As the Source Protection Region is primarily agricultural-based, agricultural activities that involve the application of nutrients onto land is one of the most prominent issues affecting both surface and ground water throughout the region. More information is required for agriculture non-point source pollution (refer to section 4.0.1.).

The Source Protection Region contains a large percentage of rural regions that function on individual septic systems. Poorly maintained and/or improperly functioning septic systems have been identified as a main issue that has been well documented. Evidence also indicates that septic systems and their relation to water quality requires further analysis to understand the magnitude of the issue throughout the Source Protection Region (Refer to section 4.0.2.2.).

Infrastructure capacity (this includes aging infrastructure) and growth and development pressures have been outlined as a major issue especially along the Lake Huron shoreline (Refer to section 4.0.8).

For many of the threats outlined in Appendix A, further research is required to understand the extent to which many of the threats are significant contaminant sources to water quality for the Source Protection Region. The subsequent chapters within the technical assessment, especially the water budget and threats inventory, will provide further analysis to determine the extent of existing, future, and historical threats in the Source Protection Region.

4.3 Knowledge and Data Gaps

Agricultural Activities
Septage hauler licensed sites with information on quantity per hectare would be useful information. More information is required on the rate and range of occurrences for pesticide use. Abattoirs are noted as a concern, but more data is required to determine whether they can be considered an issue.

Landfills
Landfills have been documented as a potential threat, but more analysis is required to determine whether they are a significant contaminant source to water quality. At the former Grand Bend Landfill, there are now Lambton County Ground Water Monitoring Wells in place.

Drainage
Lake Burwell and Lake Smith are water management areas. More information is required on the hydrologic impacts of wetland draining.

Marinas

The occurrence of dredging of harbours may be considered a potential threat to drinking water quality. The Goderich harbour is close to the surface water intake, and dredging the harbour may be a potential threat. There is no documentation at this time to prove this is actually a threat.

Table 4-3: Data Gap Reporting for the Existing Threats Inventory Chapter of the Ausable Bayfield Maitland Valley Watershed Characterization

WC Deliverable	Data Set Name	Data Gap Problem	Comment
		No gap problem identified	

4.4 References

Ausable Bayfield Conservation Authority and Maitland Valley Conservation Authority Staff. 2006. Meeting Minutes: Existing Threats in the ABCA/MVCA Planning Region. Ausable Bayfield and Maitland Valley Conservation Authority Partnership, Clinton, Ontario, Aug. 24, 2006.

Ashfield Colborne Lakefront Association. 2005. Minutes of the Coordinators Meeting, 2005-05-13. http://www.northwesthuron.com/org/CC-2005-05.html

Beatty, B. W. and R. Duncan. 1997. Village of Hensall Hydrogeological Study. Prepared for B.M. Ross & Associates.

B.M. Ross and Associates Ltd. 2003. Report on Pilot Study-Groundwater Protection Strategy for Hensall Municipal Well Supplies. Report for the Municipality of Bluewater, Zurich, Ontario.

B.M. Ross and Associates Ltd. 2004. Municipality of South Huron Class Environmental Assessment for Construction of Crediton/Centralia Sanitary Sewers: Screening Report. Municipality of South Huron, Exeter, Ontario.

Burnside Environmental. 2001a. Township of Minto: Groundwater Management and Protection Study. Ontario Ministry of the Environment.

Burnside Environmental. 2001b. Township of Wellington North: Groundwater Management and Protection Study. Ontario Ministry of the Environment.

Crowe, A. 2006. Healthy and Degraded Beach Ecosystems: A Link to E. coli at Beaches? Presentation at “Is the Coast Clear?” Conference, Lake Huron Centre for Coastal Conservation, Grand Bend, Ontario, July 21, 2006.

Dean D. and M. Foran. 1989. The Effects of Farm Liquid Waste Application on Surface Water Quality: Interim Report. Ausable-Bayfield Conservation Authority.

Dillon Consulting Ltd. 2000. Municipal Class Environmental Assessment (EA). Study for Municipalities of Lambton Shores, Bluewater, and South Huron.

Dillon Consulting Ltd. And Golder Associates Ltd. 2004a. Lambton County Groundwater Study. Ontario Ministry of the Environment

Dillon Consulting Ltd. And Golder Associates Ltd. 2004b. Middlesex-Elgin Groundwater Study. Ontario Ministry of the Environment
www.Thamesriver.org/Groundwater/Groundwater_study_report

Fuller, R. and M. E. Foran. 1989. Clean Up Rural Beaches (CURB) Plan for the Lake Huron Beaches in the Maitland Valley Conservation Authority Watershed. For Ontario Ministry of the Environment. Maitland Valley Conservation Authority.

GAP EnviroMicrobial Services. 2005. DNA Fingerprinting Analysis of Escherichia coli to Investigate Potential Fecal Pollution Sources Impacting St. Joseph Beachwater. http://www.bsra.ca/wq_GAP_dna.doc Accessed October 16, 2007.

Giberson, D. 2006. Interview Oct 18, 2006. Manager of Operations Water & Sewer, Municipality of South Huron, Exeter, Ontario.

Goderich Environmental Committee Minutes. 2002. Meeting #2 on July 26, 2002. Goderich, Ontario.

Goderich Environmental Committee Minutes. 2005. Meeting #3 on Feb 10, 2005. Goderich, Ontario.

Golder Associates Ltd. 2001. Groundwater Quality Assessment: Huron County Groundwater Study . County of Huron, Department of Planning and Development.

Hillman-Rapley L. 2004. Manure Spill Seeps into Golf Course. Article in the Lakeshore Advance, Sept 22, 2004. Grand Bend, Ontario.

Howell, T., S. Abernethy, M. Charlton, A. Crowe, T. Edge, H. House, C. Lofranco, J. Milne, P. Scharfe, R. Steele, S. Sweeney, S. Watson, S. Weir, A. Weselan, and M. Veliz. 2005. Sources and Mechanisms of Delivery of *E. coli* (bacteria) Pollution to the Lake Huron Shoreline of Huron County.

Huron County Health Unit. No date. Pathogens and Your Well Water: Keeping Your Well Safe to Drink. Retrieved on Oct. 2, 2006 from
http://www.huroncounty.ca/healthunit/pages/enviro/wells/wells_overview.html

Huron County Health Unit. 2003. Huron County Health Unit Private Water Samples: Yearly Report.

Huron County Health Unit. 2004. Huron County Health Unit Private Water Samples: Yearly Report.

Huron County Health Unit. 2005. Huron County Health Unit Private Water Samples: Yearly Report.

Huron County Health Unit. 2006. Huron County Health Unit Private Water Samples: Yearly Report.

Huron Water Protection Steering Committee (WPSC). 2004. Meeting Minutes April 7, 2004. Central Huron Municipal Office, Clinton, Ontario.

Huron Water Protection Steering Committee (WPSC). 2004. Meeting Minutes Dec 16, 2004. Central Huron Municipal Office, Clinton, Ontario.

Huron Water Protection Steering Committee (WPSC). 2004. Meeting Minutes June 17, 2004. OMAF Building, Clinton, Ontario.

International Water Consultants Ltd., B.M. Ross and Associates Ltd. and Waterloo Numerical Modeling Corp. 2003. County of Huron Groundwater Assessment and Municipal Wellhead Source Protection Study. Ontario Ministry of the Environment.

Lake Huron Centre for Coastal Conservation. 2004. Nearshore Water Quality – A Preliminary Report on Historical Nearshore Water Quality Information for Southeastern Lake Huron.

Lambton Shores Municipality. n.d. Grand Bend and Area Sanitary Sewage Services Master Plan: Notice of Completion. Retrieved Oct 18, 2006 from: http://www.lambtonshores.ca/

Luinstra, B. 2006. Goderich IPZ Proposal. Prepared by Luinstra Earth Sciences for the Town of Goderich.

Luinstra, B. 2006. Issues Inventory Spreadsheet. Luinstra Earth Sciences, Kincardine, Ontario.

Luinstra, B. 2006. Interview on Sept 11, 2006. Geologist for Luinstra Earth Sciences. Kincardine, Ontario.

McGuiness, E. Bird poop likely closing beaches. Hamilton Spectator. February 15, 2006, pA4.

Ontario Hospital Association. 2002. Member Response to the Waste Management Policy Branch Ministry of the Environment Respecting *Strengthening Ontario's Hazardous Waste Management Framework Regulation 347/Regulation 362* EBR Registry Number: RA01E0023

Ontario Ministry of Agriculture and Rural Affairs (OMAFRA). 2006. Info Sheet # 17: Manure Use and Management. Ministry of Agriculture, Food, and Rural Affairs. Retrieved on Dec 10, 2006 from: http://www.omafra.gov.on.ca/english/environment/efp/infosheet_17.htm

Ontario Ministry of the Environment (OMOE). 2004. Sewage: Municipal and Private for Southwestern Region. Retrieved Dec 10, 2006 from: http://www.searchontario.gov.on.ca/cgi-in/e_search_results.pl?offset=0&owner_id=ene&url=http%3A%2F%2Fwww.ene.gov.on.ca&query=STP+huron&type=all&contenttype=&language=en&spell=suggest&lemmatize=1&include_exclude1=1&search_text1=&search_where1=body&include_exclude2=1&search_text2=&search_where2=body&include_exclude3=0&search_text3=&search_where3=body&sortby=&hits=10&date=&size_scope=%3C&size=&size_metric=b&dsc=teaser

Onatio Ministry of the Environment (OMOE). 2005. Sources and Mechanisms of Delivery of E. coli (bacteria) Pollution to the Lake Huron Shoreline of Huron County . Ontario Ministry of the Environment. Report by Dr. Todd Howell.

Ontario Ministry of the Environment (OMOE). No date.. DWSP Monitoring Drinking-Water Systems Southwestern Region. Retrieved on Sept 15, 2006 from: http://www.ene.gov.on.ca/envision/water/dwsp/0002/southwestern/southwestern. Htm

Ontario Ministry of Natural Resources (OMNR). 2006. Water Resources Information Program (WRIP): Water Well Data Improvement Project based on Ministry of the Environment, Water Well Information System (WWIS), 2003.

Sivers, A. No date. Working Toward Clarity. The Lake Huron Centre for Coastal Conservation Website. Retrieved Oct 18, 2006 from: http://lakehuron.on.ca/water/working-toward-clarity.asp

Stauttener, B. 2006. Interview Oct 18, 2006. Utilities Manager, Municipality of Bluewater, Zurich, Ontario.

Steele, Rick. 2006. Personal Communication on Dec. 14, 2006. Watershed Information Coordinator. Maitland Valley Conservation Authority.

Statistics Canada. 2001. A Geographical Profile of Manure Production in Canada

Taylor, H.E. and M. E. Foran. 1993. Comparison of Solid, Liquid and Storage Runoff Manure of the Tile Drain and Groundwater Quality. Ausable Bayfield Conservation Authority.

Upper Thames River Conservation Authority. No date. Livestock Manure Pollution Prevention Project. Upper Thames

Conservation Authority. Retrieved Dec 10, 2006 from: http://thamesriver.on.ca/Landowner_Programs/P3_spray_irrigation.htm#INTRODUCTION

Water Action Team (WAT) Minutes. 2003. Maitland Watershed Partnerships: Water Action Team Meeting, Dec 3, 2003. MVCA Administration Centre, Wroxeter, Ontario.

Water Action Team (WAT) Minutes. 2004. Maitland Watershed Partnerships: Water Action Team Meeting, Apr 21, 2004. MVCA Administration Centre, Wroxeter, Ontario.

Water Action Team (WAT) Minutes. 2005. Maitland Watershed Partnerships: Water Action Team Meeting, Dec 7, 2005. MVCA Administration Centre, Wroxeter, Ontario.

Waterloo Hydrogeologic Inc. 2003a Grey and Bruce Counties Groundwater Study. Ontario Ministry of the Environment. http://www.greybrucegroundwaterstudy.on.ca/study_info.htm

Waterloo Hydrogeologic Inc. 2003b. Perth County Groundwater Study. Ontario Ministry of the Environment. http://www.perthgroundwaterstudy.on.ca/

Waterloo Hydrogeologic Inc. 2004. Sinkhole Investigation for Areas Mainly within the Municipalities of Huron East and West Perth. CD. Ausable-Bayfield Conservation Authority

Appendix A: Categories of Threats: Issue or Concern

Threat/issues/Concerns	Description	Contaminant	Threat/issue/concern	Data Gaps	Documentation	Geographic Location
4.1.1 Agricultural activities	Application of fertilizers	Nitrates, phosphorous to streams	issue	Cause of increasing trend 1970-1985, and still increasing in Ausable and Bayfield Rivers	Water quality chapter PGMN Wells, Hensall drinking water reports, Hensall Study ABCA sinkhole study, Huron County groundwater quality study (2001)	Entire region historically, still high levels, still increasing in Ausable and Bayfield Rivers Tricks Creek + Denfield Area, Hensall water supply, East Huron (Staffa Area)
	Land application of manure	Nitrates, pathogens	Issue		Spills Action Centre records WPSC minutes	Throughout area
	Manure storage within capture zones	Antibiotics/hormones/ pathogens	Concern		Groundwater studies for the region	Throughout area
	Chemical storage		Concern		Groundwater studies for the region	Throughout area
	Tile drainage (manure application on tile drainage)	pathogens	Issue		Dean/Foran for ABCA Report 1989 WPSC minutes	Throughout area
	Pump out sewage: human waste, animal waste Biosolids/septage	Pathogens, nitrogen	Concern	Not supported by scientific documentation or study.	Water action team minutes Nearshore Water Quality Report	Throughout area
	Pesticides	Endocrine disruptors, pesticides	Concern	Not supported by scientific documentation or study.	Water action team minutes	Presence in region

	Abattoirs- Disposal issues Livestock disposal		Concern, but requires more data to determine rating	Not supported by scientific documentation or study.	Water action team minutes Provincially regulated	Rendering facility in Atwood
4.1.2 Municipal wastewater/landfills (incl. private)/septics	Junk yards/ Automobile yards	Iron levels are high due to sandy soils	Issue	No official studies done	PGMN data Exeter Groundwater Study	Zurich Wellhead Zone Cudmore Well, Exeter
	Municipal land fill sites/private land fill sites (Canada Waste) and closed landfill sites within capture zones or near wetlands		Issue		Hensall study, all groundwater studies	Hensall land-fill is within the capture zone of Hensall/Zurich municipal well Hensall/Exeter, ACW, Howick and Mid-Huron have landfills near wetlands
	Waste water treatment plants Municipal sewage by-passes Ageing sewage and landfill infrastructure	Pathogens, phosphorus, nitrate, heavy metals	Issue	Actual discharge values- may be available in by-pass reports from the MOE.	All groundwater studies for the region Goderich E.C. Minutes Goderich IPZ Proposal WPSC minutes	Crediton or Centralia is trying to hook into the Exeter system Listowel for phosphorus, and all surrounding areas within the region Goderich Zurich Sewage Lagoon
	Dump sites at the back of many farm	Metals, Chemicals, Pesticides etc.	Concern	No official documentation	Concern noted from CA staff	Throughout Region
	Septic Tanks-Poor maintenance	pathogens	Issue/concern		CURB study, WPSC minutes WAT minutes	Throughout Region

4.1.3 Wells: municipal/individual	Improperly de-commissioned wells Private and abandoned wells in SWP areas Not properly maintained Abandoned farms incl. Decommissioned wells	Surface and sub-surface issue	Issue	Known history of wells that have been decommissioned	WWIS Well Update Project Phase 1 WPSC minutes	Through out the region, specifically Hamlets in North Perth Gudi wells in Exeter Usborne Area
	Municipal wells	Nitrate, phosphorous, pathogens	Issue		Hensall Study Well Issues Inventory WPSC Minutes WAT Minutes Huron Groundwater Study	Clinton Exeter: Cudmore, Springs Hensall wells Belgrave wells Atwood Kinloss
	Private Wells	Pathogens, nitrate	Concern	Amount of contamination		Hamlets on private wells and septic: Wroxeter, Gorrie, Fordwich, Atwood, Newry, Trowbridge, Cranbrook, and more
4.1.4 Surface Water Runoff	Effluents into the River	Nitrates, phosphorus	Issue		Water quality chapter WAT Minutes	Phosphorus in Parkhill Creek, Nitrate in Ausable and Bayfield, headwater streams
	Storm water management Effluent in ponds Run-off from parking lots		Issue		Water quality chapter	Throughout region

	Sink Holes Outlets for agricultural drains in some areas	Nitrates, pathogens, pesticides	Issue		Sink Hole Study and Huron and Perth Ground water studies WPSC Minutes	West Perth and Huron East
	Industrial run-off, e.g. Auto industry/car dealerships Factories-Cambell's Soup Serving Plant		Issue (Listowel)	Not well documented/ no data	WAT minutes	Listowel
4.1.5 Transportation	Road Salt Identified as a potential contaminant substance Quantity used Salt Storage	Sodium Chloride concentrations	Issue		Water quality chapter, PGMN data Lambton County Groundwater Study	Overriding issue MTO Substations, salt storage in Vanastra
	All spills along Highway & Railway lines Switching yards next to industrial sites Shipments falling off	Salt transportation	Concern More data to determine rating	No official data		Hwy8 Palmerston switch yard
	Truck transportation	Radio active material	Concern More data to determine rating	No official data	Lake Huron Centre for Coastal Conservation Website	Many rural routes towards Bruce County
4.1.6 Industrial Contamination	Soft Coal storage sites Next to water courses		More data to determine rating	Soft Coal storage sites		
	Exposure of aquifer to air pollution		Concern More data to determine rating			
	Co-ops Storage and transfer of chemicals	Pesticides, nitrate	Issue		MOE data, Spills Action Centre	Various locations

	Industrial discharge Into a watercourse	Metals, chemicals	Issue	No official data	MOE/certificates of approval	Spinrite – Listowel
	Goderich salt mine Chloride Trans-shipment Natural occurrence	Salt pollution	Issue	Require more data	Water quality Chapter WPSC Minutes Goderich IPZ Proposal	Goderich
	Storage of chemicals near recharge areas wetlands	Heavy metals	Concern	No official documentation	Concern noted by CA staff Exeter Groundwater Study	Hicks Well, Exeter
	Transformer substations	Storage of PCBs	Concern	No access to data	MOE data	Sites outlined in groundwater studies
	Aggregate Extraction Oil tanks Chemicals Heavy machinery	Nitrate levels	Issue	Require more data	All Groundwater studies for the region	
	Other Industrial sites for storage/use of chemical i.e. Dry Cleaners		Concern	More data to determine rating	No official data	
	Brownfields Not properly decommissioned		Concern	More data to determine rating	No official data	Arkona
4.1.7 Drainage	Wetland areas Municipal drainage Enclosure of headwater drains	Quantity Concern Nitrate concentrations	Concern with no official evidence	Hydrologic impacts of wetland draining	Drain reports, Hay Swamp Study although no official evidence	Hay Swamp Hullet Marsh Lake Burwell Lake Smith-bog

4.1.8 Growth/development	Cottage Industry , Lakeshore Development, Expansion Septic system capacity and reporting		Concern		Water Action Team	Lakeshore areas
	Sub-Divisions Within flood plain		Concern	No official data		Harriston
	Development Installation of urban services affecting water quality, existing development in flooplains. Aging infrastructure Impacts on recharge		Concern, implications are not understood at this time	No official data, currently under going study		Lambton Shores pipe/sewer construction
4.1.9 Oil/Natural Gas	Oil, salt, or natural gas wells Not properly decommissioned Lack of knowledge of location of oil/gas wells		Concern	No official data Large data gap	PGMN sampling	Seaforth, Pinery areas are issues
	Oil Pipeline		Concern (spills)		Water action team	South end of ABCA watershed (Inter-provincial)
	Oil Extraction/Natural Gas & storage		Concern	Map from Union gas	No official data	Lambton Shores Greenway Hwy 83 between Dashwood and Port Blake
4.1.10 Wildlife	Geese, seagulls, and deer waste along nearshore.	Beach contamination	Issue		Goderich E.C. minutes WPSC minutes	Goderich Lake Huron shoreline

					OMOE Study	
4.1.11 Air borne threats	Number of bad air days		Concern		Water Action Team	
4.1.12 Cemeteries	Cemeteries Traces of embalming fluids in a high groundwater area		Concern		All ground water studies for the region	
4.1.13 Intakes	Marinas (surface water intakes) Fuel storage Shipping Village discharge Pumping the holding tanks Anchors catching intake cages		Issue		Goderich IPZ Proposal	Port Blake Goderich
	River influence	Nitrate, pathogens, maybe pesticides	Issue	Pathogen dynamics in lake from river mouth	Water quality chapter	Goderich
	Intakes Suspended sediment Old filtration materials (back flush); alum, sand, charcoal Filtration maintenance		Issue		All Groundwater studies for the region Goderich E.C. Minutes	Goderich, Port Blake
4.1.14 Water Takings/Quantity (Part of Water Budget)	Golf courses		Issue/concern	Permits to Take Water	Covered in Water budget	Across Watershed
	Camp grounds		Concern		Covered in Water budget	Across Watershed
	Water quantity demands Wells run dry		Concern		Covered in Water budget	Across Watershed
	Climate change Water quantity		Concern	Climate predictions	Covered in Water budget	Across Watershed
	Big industry Water taking Contaminants discharge		Concern	List of potential contaminators High water users	Covered in Water budget	Across Watershed

Appendix B: Municipal Wells and Intakes Within the Ausable Bayfield Maitland Valley Planning Area

Municipality	Municipal Well	Quality Issue (Natural)	Quality Issue (Activity)
Ashfield-Colborne-Wawanash	Century Heights	Fluoride, hardness, iron	
	Maitlandview Estates (To be Decomissioned)	Fluoride, hardness, iron	
	Century Heights New Well (WHPA To be determined)	Fluoride, hardness, iron	
	Huron Sands (Seasonal System)	Fluoride, hardness, iron	
	Benmiller	GUDI well, capture zone extends to river	
	Dungannon (WHPA To be Determined)	Fluoride, hardness, iron	
Central Huron	Van de Wetering	Fluoride, hardness , iron	
	Dundass &	Fluoride, hardness , iron	
	S.A.M.	Fluoride, hardness , iron	
	McClinchey	Fluoride, hardness , iron	
	Clinton 1,2 & 3	Fluoride, hardness , iron	
	Auburn	Fluoride, hardness , iron	
	Kelley	Fluoride, hardness , iron	
North Huron	Blyth 1 & 2	Fluoride, hardness , iron	
	Belgrave (Humphrey) To be	Fluoride, hardness , iron GUDI well - any activity a problem	

	Decommissioned		
	Wingham Well 3 & 4	Fluoride, hardness , iron	
Huron East	Brussels 1 (Turnberry St.)	Fluoride, hardness , iron	
	Brussels 2 (Church St.)	Fluoride, hardness , iron	
	Brucefield	Fluoride, hardness , iron	
	Seaforth	radionuclides, fluoride	salt contamination,
North Perth	Listowel 1, 4 & 5	Fluoride, hardness , iron	
	Listowel 6	Fluoride, hardness , iron	
	Atwood (Smith)	Fluoride, hardness , iron	
	Atwood (Bowman Court)	Fluoride, hardness , iron	
	Gowanstown	Fluoride, hardness , iron	
	Atwood (WHPA to Be Determined)	Fluoride, hardness , iron, sulfate	
Minto	Clifford 1, 2, 3 & 2	Sulfate, hardness , iron	
	Harriston	Sulfate, hardness , iron	
	Palmerston	Sulfate, hardness , iron	
	Minto Pines (WHPA to be determined)		
Morris Turnberry	Belgrave (Jane)	GUDI well - Fluoride, hardness	Nitrate,
	Belgrave (McCrae)	GUDI well - Fluoride, hardness	Nitrate,
Bluewater	Zurich 1 & 3	Fluoride, sulfate, Iron	

	Hensall 1, 2 & 4		Nitrates
	Harbour Lights	Fluoride, hardness , iron	
	Carriage Lane	Fluoride, hardness , iron	
South Huron	Springs Collector		
	Hicks Well		
	Moodie Well		
	Cudmore Well		
	Moodie Well		
Goderich	Intake	Maitland connections, salt mine, highway intersecting river,	
		storm water outfall, lake sediment, wildlife	
Port Blake	Intake		

*Source: Luinstra, Brian. 2006. Issues Inventory Spreadsheet. Luinstra Earth Sciences.

Appendix B: Catalogue of WC Maps in the Accompanying Map Book

Chapter 5
SUMMARY

Version 1.0
January 2007

5 Summary

The following chapter offers a summary of the four chapters included in this document: the Watershed Description, Water Quality, Vulnerable Areas and Existing Threats Inventory. Data and knowledge gaps are identified for each chapter in Appendix A.

5.0 Watershed Description

The source water planning regions of the Ausable Bayfield and Maitland Valley share many watershed characteristics. Their jurisdictions are adjacent to one another, they both have a strong agricultural base and their major rivers systems flow to Lake Huron.

The chapter lists stakeholders and partners in the process, which have been developed over a period of time. These stakeholders include municipalities, of which there are 6 upper tier and 24 lower tier within the planning area; health units; provincial ministries; First Nations; federal departments; adjacent conservation authorities; non-governmental organizations; industry; and members of the public. These individuals and organizations will use this document as a resource in developing a source water protection plan.

The chapter describes the five watersheds through bedrock geology, quaternary geology, and hydrology which include physiography, topography, soils and surface hydrology. The whole of the area is influenced by Lake Huron with respect to climate, and experiences a long growing season due to its latitude in relation to much of the rest of Canada. The lake tends to moderate continental hot summers and cold winters in the region, although there is some variation with respect to precipitation.

Documented aquifer use is listed. Aquifers are formations that supply drinking water when tapped by a well. There are several types of aquifers such as bedrock aquifers, overburden aquifers, confined overburden aquifers and shallow unconfined aquifers. Historically, many locally significant overburden aquifers were used but have since been replaced with treated municipal servicing using Lake Huron water sources. Overburden thickness is an indicator of the aquifer's protection from possible contamination and is shown on WC Map 3-1. In the north of the planning region, there are shallower areas including sinkholes around Brussels and in the lower sections of the Maitland River. Groundwater flow maps indicate that groundwater systems originate to the east of the planning region. Other sources of groundwater recharge come from sinkholes and, in an area around Lucan, with a low bedrock water table. Groundwater and surface features are used to rate the areas for recharge and the Maitland watershed is the highest, followed by Bayfield with an intermediate recharge ability. The Nine Mile, Ausable, and the Shorelines and Gullies watersheds have a low recharge potential. Discharge is strongest in the Ausable Gorge and the lower Maitland. Because overburden discharge is more often associated with spillways and kames, overburden springs are more prevalent in the northern watersheds. Interactions between surface water and groundwater can create potential pathways for contamination. The most vulnerable areas are shallow, unconfined aquifers that tend to occur in overburden recharge areas.

Natural heritage features play an important role in trapping sediments and contamination, partially 'cleaning' surface water. Natural heritage features, which include wetlands, Areas of Natural and Scientific Interest, and woodlots, rely on clean, adequate sources of water. Historically, forests in southern Ontario were cleared for agriculture: the forest remnants tend to be on the poorer quality soils such as the local examples of the Dunes, Ausable Gorge, and Hay Swamp. Livestock grazing was cited as a major contributor to the decrease in overall forest health as it decimated the critical lower tiers of woodlots and depleted seed banks. The shift from grazing has created a noticeable difference in health of the woodlot system especially since funding has been made available to retire fragile or marginal land. Southern Ontario does have high capability soils compared to central or northern Ontario, so there is still pressure to keep land as usable farm, and the area has not seen as high gains as central or northern Ontario. Many woodlots have not yet recovered from human and livestock disturbance, and are still young and immature, lacking large old growth. Areas of the planning area range from a low of 10.3% forest cover to a high of 25.0%.

Linked to forest presence, southern Ontario used to have more cold/cooler water habitat and associated fish species. With the clearance of forests, however, there was reduced protection and shade. Many of the streams have changed to warm water and have problems with algae growth. Sedimentation because of development and bank erosion from lack of vegetation can also cause problems for sensitive fish species. Although there are 83 different species confirmed within the Ausable watershed, most sites sampled 10 species or less, which indicates poor water quality for aquatic species. In the Bayfield area, a decline of less tolerant salmonids was noted along with a deterioration of the water quality, but there has been some improvement with the remediation of Trick's Creek. The Shorelines and Gullies watershed has the most vegetated gully systems, and cold water systems support runs of migratory salmonids.

The source water planning area is on the northern fringe of the Carolinian Zone; the most biologically diverse regions of its size in Canada. Fish, mussels and aquatic reptiles that are deemed 'species at risk' are listed, and it is anticipated that more fish and mussel species will be added to the list in 2007-2008. As for invasive species, the common carp and zebra mussel are known invasives, with anecdotal evidence to suggest that the Round Goby may have made it as far upstream as Parkhill Dam. Narrow tolerances make aquatic macroinvertebrates a valuable indicator of water quality. In the Ausable, Bayfield and Shoreline and Gullies watershed, fairly pollution-intolerant species were found.

The relative remoteness of the area and the rich soils discouraged human settlement, but encouraged agriculture and the planning region has the highest rates of livestock and manure concentrations. Even today, there is no city within the planning region although there is sizeable cottage development along the lakeshore; the largest urban centre is Goderich with a population of 7,500. Only with the creation of good roads and highways has tourism to the lake boomed along with industries like manufacturing. Within the source water planning region Huron County has the greatest area, and smaller sections are located in the counties of Lambton, Perth, Bruce, Middlesex and Wellington. Population projections are listed for all of the six counties within the source water protection planning boundaries; estimated populations are taken from County official plans and from the Ministry of Finance for estimates on 5, 10 and 25 year population sizes.

Agricultural employment has declined and employment in the commercial and industrial sectors has increased. Tourism has also seen a sharp increase and may see more growth due to the rising cost of gasoline and the area's close proximity to several major cities. Recreation is highly dependent on good water quality for beach use.

The area is notable for agriculture and the watersheds range from 65-97% prime land (see Table 1-7). The Bayfield and Shore Streams and Gullies watersheds have a large proportion of cultivated land: 84% and 82 % respectively. The Maitland watershed has the highest livestock manure production per hectare in Canada and is also ranked high in manure components of nitrogen and phosphorous compared to other areas (Statistics Canada 2001). Huron County has shown a decline in the number of cattle housed, but an increase in poultry and swine (Bonte-Gelok and Joy 1999). In the long term, changes in farming practices has seen mixed farms give way to 'cash cropping' and intensification of production (ABCA 1979; MVCA 1989). Other land uses include aggregate extraction, landfills, oil and gas, wastewater treatment and conservation lands.

Drinking water sources within the area are predominantly from groundwater. In towns, sources tend to be municipal wells whereas in rural areas the source tends to be individual or communal wells: most are bedrock wells. A shift from individual wells to municipal wells is an emerging trend. The southern half of the planning region tends to be sourced from the Lake Huron intake at Port Blake. Most of Lambton County and North Middlesex are supported by the pipeline, so much that well drilling has almost ceased in the area. The City of London, which is outside the Ausable Bayfield Maitland Valley watershed, also receives its water from the intake at Port Blake. In Huron County, 24% of the population is dependent on surface water included the Town of Goderich, parts of the Village of Bayfield and sections of South Huron and Bluewater. In the Huron County Groundwater Study, livestock is listed as the biggest user of water for drinking, washing and cooling and also for cleaning of equipment. Domestic use and aggregate washing are also sizable users of groundwater. In Perth County, the Campbell Soup/Horizon Poultry in Listowel uses five times Perth's portion of domestic use. Groundwater for Huron County is expected to serve both the present and well into the future, and estimates that withdrawals are 17% of aquifer recharge. In the Wellington-Minto report, and estimated 1% of infiltrated groundwater is used.

Current long-term monitoring programs include the provincial water quality network, which is done monthly, the provincial groundwater monitoring network, and stream flows. Past monitoring efforts have included shorter-term programs such as the Clean Up Rural Beaches (CURB) program. Stream water quality is worse during rainfall events, but monitoring often missed the sharp peak in concentrations. Benthic monitoring began in the Ausable Bayfield in 2000 to help identify recent water quality; the Maitland Valley Conservation Authority has a benthic program as well. Contaminants in the area tend to be the agriculturally associated ones of phosphorous, nitrates, sediment and bacteria. Heavy metals and other pollutants from industry do not appear to be a problem.

5.1 Water Quality

Rather than providing a detailed analysis of all water quality parameters, the aim of this chapter was to give a broad environmental scan of water quality conditions at select sampling sites. The major water systems surface water (rivers and streams and Lake Huron) and groundwater. Water quality issues in rural areas tend to arise from non-point source pollution and are a function of the pathway of water through the hydrological system. The longer the pathway of water, the more chance it has that contaminants can become bound, filtered, diluted, and chemically or biologically stabilized.

Six indicators were chosen to be examined in the chapter: chloride, copper, nitrate, phosphorous, total suspended sediment, and *Escherichia coli* (*E. coli*).

Chloride is not typically found in groundwater or surface water and can be an indication of contamination especially by road salt, but is also derived from sewage effluent, septage, animal waste and potash. Another potential pathway for chloride is through improperly decommissioned brine wells.

Copper is a persistent element that can indicate heavy metal contamination from human activities. The largest potential source of copper is from human effluent.

Nitrate is the most common form of nitrogen in aerobic conditions and potential sources are from lawn fertilizer, manure, septic systems, sewage treatment effluent and atmospheric deposition. The inert mineral nitrate is highly soluble and persistent in anaerobic conditions. For this study, the presence of nitrate in an aquifer represents a connection with surface water, although the degree of connection is not proportional to the concentration of nitrates.

Phosphorous is associated with higher rainfall and runoff. Through a process called adsorption, it is generally found in areas where there is higher clay content. Phosphorous can be an indicator of agricultural and lawn fertilizer, manure, septic systems, sewage treatment effluent and milkhouse washwater. Phosphorous is not persistent in infiltrating water, therefore, it is not an important indicator for groundwater.

Suspended sediment is an indicator of soil erosion, and higher concentrations are associated with silt or clay soil. Concentrations of carbon, nitrogen and phosphorous on the surface of suspended sediment tend to be 10-100 greater than in the water column.

E. coli, a member in the group of fecal coliform, inhabits intestines of warm-blooded animals and indicates a potential for harmful bacteria and human pathogen. *E. coli* is found in almost all surface waters, but does not persist in the anaerobic conditions of groundwater. *E. coli* in a well could indicate an interaction with surface water and is likely a reflection on the construction and quality of a well.

Other indicators are also useful to determine water quality, particularly in groundwater. Hardness is a naturally occurring characteristic of groundwater: if an aquifer is not hard, it could indicate an interaction with surface water. Iron occurs both naturally and as contamination and can be an aesthetic issue as it leaves an oxidized residue on household fixtures and piping. Sodium occurs both naturally and as a result of contamination. Like chloride, it can indicate contamination from road salt and improperly decommissioned brine wells. Fluoride is naturally occurring in the source protection planning area and at low concentrations can be considered a health benefit.

There are two intakes in the Ausable Bayfield Maitland Valley Planning Region. Both intakes are from Lake Huron; one is located Port Blake (north of Grand Bend) and a second is located at Goderich. Although there are no riverine sources of drinking water, river water influence both the lake intakes and potentially groundwater. For instance, the mouth of the Maitland River is located in close proximity to the intake at Goderich, and the plume from the river can affect the quality of the nearshore. As well, during the dry months of the year the Bayfield River does not run in certain sections but will emerge further downstream, thus indicating an interaction with groundwater. For the analysis of surface water data, the information came from the Provincial Water Quality Monitoring Network (PWQMN), the Ashfield-Colborne Lakeshore Association (ACLA) and ABCA enhance water quality stream network.

Temporal changes were determined for the six water quality indicators mentioned and attributed to a five year block starting with 1961-1965 and ending with 2001-2005. For the purpose of reporting on temporal trends, six PWQMN sites were selected: Blyth Brook , Ausable River, Bayfield River, Maitland River, Nine Mile River and Parkhill Creek.

At many stations, chloride has had a slight increase in concentration of the years, but none of sites have had any concentrations above the Provincial Water Quality Objectives (PWQO) of 250 mg L^{-1} in the last five years. The Maitland River at Goderich has had the highest concentrations which peaked in 1989 and have since declined. The results reflect a rural-watershed and the limited use of road salt. Chloride concentrations are below the levels of concern and continued monitoring would ensure that chloride does not become a drinking water issue.

Copper concentrations have stayed constant or slightly declined and no sites currently have copper concentrations over the PWQO of 5mg L^{-1}. Concentrations of copper are not of concern at this point, and continued monitoring will ensure that it does not become a drinking water issue.

The analysis for determining nitrate concentrations has changed over the years. However, a visual scan of the data does not indicate that the methodological change influenced the trends. Nitrate concentrations have increased over the record, and the concentrations are above the aquatic protection limit of 2.93 mg L^{-1} for more than 50% of the time at five out of the six sites. The increasing trend peaked in the Maitland River around 1985, and has remained steady or even declined. The trend has continued in the Bayfield River, Parkhill Creek and the Ausable River. Because all sites show the same trend, it indicated that there was a widespread adoption of land management practices that increased the amount of nitrate in the watercourses. The greatest increase in nitrate concentration occurred between 1970 and 1985, which, based on anecdotal evidence, could be related to the increased use of commercial fertilizers and the replacement of mixed farming with ‘cash cropping’. Further examination of this supposition is required.

Total phosphorous concentrations are at or slightly above the PWQO of 0.03 mg L^{-1} for five of the six sites, but there have been some significant improvements along the Middle Maitland River which have been attributed to improvements in effluent quality at the Listowel Wastewater Treatment Plant.

Suspended sediment has declined or remained constant in four out of six sites with trend lines below the aquatic protection limit of 25 mg L^{-1}. Samples from Parkhill Creek have been higher than the limit in more than 50% of the samples, but have declined since 1985. The trend line for total phosphorous at Parkhill is similar to the trend line for suspended sediment, thus indicating that they have the same mechanisms of transport. The declines in sediment loads could be attributed to various agricultural and soil erosion initiatives that have been initiated since the 1980s.

Bacteria (fecal coliform and *E. coli*) showed no trends in 4 of the 6 sites. Nine Miles had an increasing trend in bacteria concentrations, although this could be due to the increase in samples taken after 2001 for the ACLA program.

For spatial trends, only three indicators were evaluated (nitrate, total phosphorous and *E. coli*) over 46 sites. For a more comprehensive comparison between sites, the sites were divided into three groupings of main branch, shoreline and headwater streams. This was due in part to the impact that stream order may have on water quality (Vannote et al. 1981). Specific sites were not compared, but this grouping was useful for discussion, and a statistical comparison will be done in the future.

WC Maps 2-2, 2-3 and 2-4 show both the site concentration as well as the area contributing to the sites, but for larger upstream areas there may be different concentrations due to geology, point and non-point source uses. Nitrate concentrations (WC Map 2-2) generally increased from north to south. The southern portion of the region is thought to be characterized by less forest cover, higher proportion of clay soils, increased proportion of tile drainage, increased drainage density and higher percentage of row cropping. Further examination is required to determine if there is a relation in nitrate concentration and physiography. Of greatest concern is the Upper Bayfield site where is the median is above the drinking water objective.

For total phosphorous (WC Map 2-3), there is not a north-south trend like nitrate, but higher concentrations of phosphorous may be related to the higher content of clay in local soils (Middle Maitland, Parkhill and Ausable). The dominant pathway for phosphorous is to be bound to soil particles: especially clay particles.

E.coli (WC Map 2-4) does not appear to be associated with general watershed characteristics. In the main branches of watercourses and along shoreline streams, concentrations are very similar and the median concentrations are above the recreational Provincial Water Quality Objective (PWQO) of 100 *E. coli* colony forming units/100 mL; 85% of the sites are above this PWQO. For the upper Middle Maitland and Black Creek, they have high concentrations of *E. coli*, indicating a continual point source. Watercourses with a higher median and larger variance for *E. coli* concentrations also appeared to have higher phosphorous concentrations. Further examination of this relationship is necessary.

The trends of total phosphorous, nitrate and chloride for the intakes on Lake Huron at Port Blake and Goderich were also examined. Overall, the concentrations of these indicators were higher at the Goderich Water Intake Facility compared to the Port Blake Water Facility. Trends in total phosphorous and nitrate over the past 30 years were similar at both facilities. There has been a decrease in total phosphorous since the 1970s and an increase in nitrate concentrations since 1976. The median for total phosphorous concentration was slightly below the PWQO of 0.02 mg/L for lakes. The median for total phosphorous was less at the Port Blake facility (0.012 mg/L), but within range of concentrations expected to contribute to the enrichment of the nearshore environment. Nitrate concentrations at the Goderich facility rarely exceeded the draft Canadian Water Quality Guideline (CWQG) of 2.93 mg/L for the protection of aquatic life and never exceeded the drinking water guideline of 10 mg/L. Nitrate concentrations at the Port Blake facility were significantly lower than at Goderich. Chloride concentrations were well below the CWQG of 250 mg/L at Goderich (8.5 mg/L) and Port Blake (6.5 mg/L). The Goderich facility, located in the plume of the Maitland River, had consistently higher medians for all three indicators compared to the Port Blake facility. More work must be done to understand the plume and its affect on the nearshore environment, particularly on the Goderich Water Intake Plant.

Groundwater plays an important role in the source protection planning region and serves 75-80% of the population in the area. Unfortunately, less information is available on groundwater and only for the period after 2001. Data has come from the Provincial Groundwater Monitoring Network, county and municipal monitoring. Given the extended residence times in aquifers (25-500 years), the information can only characterize the current conditions of aquifers rather than provide any meaningful trends. Statistical analysis was not completed due to the short record of data collection. As well, most sampling to date has focused on the end water quality provided from a well and does not discern between natural conditions and the infrastructure used to deliver the water, which may have an influence.

Overall, the groundwater quality within the Ausable Bayfield Maitland Valley watershed is of good quality. Overburden aquifers tend to have excellent natural water quality, but are more susceptible to contamination due to their shallow nature. Except for the Seaforth aquifer, overburden aquifers within the area range from moderate to excellent water quality. The Seaforth aquifer suffers from poor water quality and is exploited through numerous dug wells. In one cluster of domestic wells within the aquifer, 79% exceeded the ODWS for total coliform or *E. coli*. Some samples also had detectable amounts of hydrocarbons, and low amounts of trihalomethanes, perchloroenthylene, and organochlorine pesticides. Bedrock aquifers also have good quality water and are less susceptible to contamination, but can have naturally high levels of fluoride, sodium and iron.

Except for of the Hamilton aquifer located in Port Franks, bedrock aquifers within the region range from moderate to excellent water quality. The Hamilton aquifer has at least one exceedance in every indicator except for nitrates, and the highly variable concentrations of iron, sodium and chloride may indicate some form of localized contamination. High sodium concentrations coupled with chloride indicate that salt is a form of contamination. The ABCA North Lambton characterization study noted that there were improperly decommissioned brine wells in the area, and the high concentrations of iron warrant further investigation. As well, it is understood by local drillers and landowners that the water is high in sulphates. The generally poor water quality of this and the North Lambton overburden aquifer has led to the utilization of Lake Huron as a drinking water source.

Nutrient enrichment, evident in rivers, streams, vulnerable overburden aquifers and the Lake Huron nearshore, appear to be the greatest impairment to water quality and reflects the rural agricultural nature of the watershed. Headwater streams tend to have higher concentrations of nutrients compared to main channels, and restoration efforts should be focused in these areas. While surface drinking water intakes at the lake typically have good water quality, it is evident that the plume from tributaries affects this resource, and a better understanding of the nearshore environment and plume dynamics will help to determine the pulse of contaminants that could reach intakes. The analysis of Drinking Water Information System (DWIS) data will aid in determining the scope of contaminants.

5.2 Vulnerable Areas

Considering the scope required to create a source protection plan for the Ausable Bayfield Maitland Valley, it was necessary to develop a vulnerable areas inventory at the regional level.

Well Head Protection Areas (WHPA) were delineated through the OMOE groundwater studies for each county; the size and shape of the WHPA are predominantly a function of the amount of water being pumped, the permeability of the aquifer, and the overall regional gradient (WC Map 3-1). Wells with significant potential impact, based on SWAT modelling, will likely require different planning and implementation tools in order to protect the long term sustainability of the well.

ISI mapping was used to estimate the susceptibility of groundwater resources to contamination (WC Map 3-2). Areas with shallow overburden deposits show high susceptibility, like the areas around the Old Ausable Channel, Nairn, Bayfield, and various locations in the Maitland Valley watershed. Overall, the study area is relatively well protected from surface activities.

As for vulnerability issues outside of WHPAs, there is an association noted between coldwater streams with coarser grained quaternary deposits, thus representing discharge from overburden aquifers rather than the deeper bedrock aquifers (WC Map 3-4). The southern portion of the study area has a number of discharge areas which may reflect a more refined water table elevation layer in that area.

Recharge areas for overburden aquifers can be easily defined by delineating areas with quaternary materials while bedrock aquifers receive recharge water through the overlying overburden aquifers. Recharge areas for bedrock aquifers were determined by intersecting the areas where recharge is expected to occur from the overburden aquifer to the bedrock aquifer with areas where there were ‘geologic windows’: where the overburden thickness of silt or clay was less than 1 metre (WC Map 3-6).

In order to understand sinkholes, the Ausable Bayfield has carried out two studies in two areas: one considered the effect of sinkholes on groundwater resources on the well known sinkhole cluster in West Perth near Staffa, while the other extended the scope to include all other sinkholes within the source water planning area (WC Map 3-7). Primary concern is for the ground areas that contribute to surface water bodies and are, in turn, drained into a sinkhole which allows for rapid infiltration and circumvention of infiltration through overburden materials. Sinkhole areas in this region will require special consideration when developing a source protection plan.

Surface water vulnerability was analyzed using a run-off index created as part of the phase II project and flood plain mapping created for emergency management. Categories of low, medium and high runoff were used and are plotted on WC Map 3-8. Because most areas had a medium or high potential runoff (the Shorelines and Gullies Watershed had a predominantly high runoff rating) it highlights areas of high slopes and/or finer soils. A modified runoff was used for the Middle Maitland to accommodate for the distance from watercourse and can be used to relate given activities in specific areas to water quality (WC Map 3-9). Floodplain areas have been incorporated into zoning by-laws where they exist, but as a part of source water planning, their policies could be revisited.

In the Lake Huron case study, the concentrations of total phosphorous and nitrate were greater at the Goderich intake facility compared to the Port Blake intake facility. Both facilities had a median that was below the Provincial Water Quality Objective for phosphorous (PWQO = 0.02 mg/L), with Port Blake significantly lower than the provincial objective, but both results were within a range to consider to contribute to nearshore nutrient enrichment conditions. Both facilities were also well below the Canadian Water Quality Guideline for nitrate (CWQG = 2.93 mg/L) and never exceeded the drinking water guideline (10mg/L). Goderich was significantly higher than Port Blake in nitrate concentration, and within range for contributing to eutrophic conditions in the nearshore of Lake Huron. This may be due to the Goderich intake being located under the influence of the Maitland River. Water quality monitoring data has indicated that the Ausable, Bayfield and Parkhill Rivers have even higher concentrations of nutrients than the Maitland, and although they are not near a drinking water intake, they are likely to contribute to nutrient enrichment of the nearshore.

Vulnerable areas have been defined using several different methodologies for both surface and groundwater resources. It is important in the development of the source protection plan for the study area to not only delineate these areas as accurately as possible, but also to understand the methodologies used to derive them. These methodologies are necessarily limited by the data available in developing them, as well as the scale at which they were developed. It is essential, therefore, to consider these limitations during development of the plan.

5.3 Threats: Issues or Concerns

'Specific Threats' are defined as any contaminant (chemical or pathogen) either currently or potentially having the ability to negatively affect a drinking water source. Threats exist in areas where water quality is known to be contaminated and possible sources for contaminants have been identified. In the Ausable Bayfield Maitland Valley Planning Region, an assumption is made that any anything that affects either water quality or quantity is considered a threat. Any identified threat is then quantified into either an issue or a concern.

Issues are defined through semi-quantitative risk assessment and from existing information on watershed characteristics, local knowledge, and drinking water supply problems. Sources of information for issues are reports, research and monitoring results. They are identified when concentrations of contaminants have exceeded or are approaching water quality guidelines. Concerns are different from issues in that they are not supported by scientific information. Concerns are often raised as public discussions and complaints and documented in meeting minutes, newspaper articles, or correspondence.

The chapter aims to provide a general view of known threats to the watershed as a whole. Many of the threats categories inter-relate and can affect both groundwater and surface water. Livestock production and its subsequent effect and by-products are known to be considered a central threat to water quality in the area and can affect both groundwater and surface water. The application of nutrients such as fertilizers, manure and septage is considered an issue as trends have shown increases in concentrations of nitrates, biological nutrients and phosphorous in streams and the risk increases as the vulnerability of the aquifer increases. Pump out sewage and biosolids/septage has also raised some concerns, but there is no documentation to support this concern at this time. The increase in transportation of liquid manure has led to an increase in liquid manure spills as well as the other causes such as spray irrigation of liquid manure, insufficient manure storage and equipment failure. However, groundwater studies have shown that there is no evidence that manure storage within capture zones affect municipal water.

Landfills have been identified as potential threats, and there are landfills, such as the Hensall landfill, that are located within the municipal wellhead capture zone. More analysis is needed to determine whether landfills constitute a threat. At the former Grand Bend Landfill, there are now Lambton County Ground Monitoring Wells in place. These will hopefully aid in determining the potential for groundwater contamination.

Septic systems are a major source of bacterial pollution, and many systems are malfunctioning, undersized, or aged, and are not property treating waste. The issue has been documented especially along the shore of Lake Huron, and the Ausable river area is experiencing high levels of *E. coli* in storm drains when residents attempt to alleviate the problem by hooking their system to farm tile drains.

Chlorine and ammonia discharge into Lake Huron from wastewater has been discussed in a variety of specific studies (Luinstra 2006). In the more urbanized areas with sewage treatment plants, despite receiving primary and secondary disinfection, discharge from these facilities can cause an increase in the microbial release into the surrounding environment. The Municipalities of Lambton Shores, Bluewater, and South Huron are participating in the 'Grand Bend and Area Sanitary Sewage Master Plan' to provide municipal service to the area in hopes of remedying the effects of malfunctioning septic systems and discharges from the Grand Bend sewage treatment facility. The Town of Goderich was the only facility that directly discharged into Lake Huron (Howell et al. 2005). In 2005, the town applied for COMRIF (Canada-Ontario Municipal Rural Infrastructure Fund) funds and received 1.5 million dollars to complete the separation of storm and sanitary sewers and to upgrade the sewage treatment plant to stop the occasional release of partially treated sewage into Lake Huron during periods of heavy rainfall (ACLA 2005). The Town has until 2009 to complete the project.

All municipal wells in the area have fluoride, which is a naturally occurring element in the area. Some wells have been identified with nitrate issues: wells in Belgrave have test results of nitrate concentration; Hensall wells have higher than average nitrate levels in 3 of the 4 wells; and wells in Atwood and Kinloss have nitrate issues identified through the PGMN. The Provincial standards set a drinking water standard of 10 mg per litre.

Other threats considered are effluents in the river from agricultural and industrial runoff. Agricultural runoff can create higher than average nitrate levels and industrial runoff can cause incidences of heavy metals. Industrial spills are documented by the MOE and a common source of contamination is retail fuel outlets through fuel storage tanks, historical use, and disposal practices.

Transportation creates two identified threats: road salt and spills. Road salt has been documented as an issue only in certain areas and is related to claims made by property owners against transport authorities related to the contamination of a well from salt release into groundwater.

Individual wells, along with sinkholes and oil and natural gas wells, can act as preferential pathways for sources of contamination by connecting surface water with groundwater. Especially of concern are the wells (including oil and natural gas) that have not been property decommissioned. No official data indicates that there are issues that relate to specifically oil and gas contamination of water.

Fecal matter from geese has been identified as an issue for the shoreline of Lake Huron, although more study is required. Cemeteries are a concern with no documented evidence.

The influence of tributaries on Lake Huron is noted in the 'Water Quality' chapter of this document. At Goderich, the water intake is located in close proximity to the mouth of the Maitland River. Rivers tend to act as a pipeline that collects contaminants from runoff and other sources before discharging into a larger body of water. Dredging of a harbour, like the Goderich harbour, can create a plume of sediment that may impact the nearby water intake. Marinas along the shore can also affect water quality. Fuel storage, high-use shipping lanes and holding tank pumping can have the potential to affect water quality.

For many threats described, there is further research needed to determine the extent to which they are a contaminant source for water quality. Subsequent modules, in particular the Threats Inventory and the Water Budget, will provide more analysis to determine the historical, existing, and future threats to drinking water in the source protection planning region.