# THE THAMES RIVER WATERSHED

# SYNTHESIS REPORT

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# TABLE OF CONTENTS

**LIST OF FIGURES & TABLES**

# INTRODUCTION

## Background

The majority of the Thames River watershed is located within the Carolinian Life Zone, which is recognized as one of the most biologically diverse regions in Canada. The Thames River watershed is linked to the Great Lakes, via Lake St. Clair. The upper Thames still flows through ancient glacial spillways, while the lower portion of the river emerged after thousands of years as a glacial lake (Thames River Background Study Research Team (TRBSRT) 1998).

The Thames watershed has been a significant human cultural heritage site for the past 11,000 years. Aboriginal people used the Thames River (known as Askunessippi or “Antler River”) for shelter, fishing, hunting and transportation. They were also the first to apply cultivation in the area (between 500 and 1650 AD), a transition that allowed for more permanent settlement and supported larger numbers of people. Four First Nations groups have settled permanently along the Thames River: 1) Delaware Nation, 2) Munsee-Delaware Nation, 3) Oneida Nation of the Thames, and 4) Chippewas of the Thames (TRBSRT 1998).

European settlement of the Thames River watershed began in the late 1700s. Many of the first settlers were United Empire Loyalists, who moved north after the War of American Independence. The river continued to serve as an important transportation route, and most of the early settlements were located on the river’s banks and shores (TRBSRT 1998). Today the watershed basin is home to almost half a million inhabitants, representing many different nationalities.

The Thames River originates northeast of London and flows 273 km through the agricultural heartland of southwestern Ontario to Lake St. Clair, which drains into Lake Erie (Figure 1). The river drains 5,285 square kilometres of land, which makes it the second largest watershed in southwestern Ontario (TRBSRT 1998). The river consists of three distinct branches in its upper portion: 1) the North Thames begins north of Mitchell and flows through St. Marys; 2) the Middle Thames begins southwest of Tavistock and flows through Thamesford where it joins the South Thames; and 3) the South Thames starts west of Tavistock and passes through Woodstock. The North and South branches meet in London at the historic Fork of the Thames. From there, the Thames flows into its lower portion or main channel in a southwesterly direction through Chatham and into Lake St. Clair (TRBSRT 1998).

There are a number of features of the Thames River that create an array of habitat opportunities for aquatic species. The post-glacial landscape, the dynamic physical features, fluctuating water levels, pools and riffles, high nutrient levels, the presence of both coldwater and warmwater streams, and the Carolinian influence all contribute to its biological diversity (TRBSRT 1998). The watershed's complex system contains one of the most diverse communities of freshwater fishes and mussels in Canada. The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) has designated 25 aquatic or semi-aquatic species (7 mussels, 6 reptiles, 12 fishes) found in the Thames River watershed as Extirpated, Endangered, Threatened or Special Concern (Table 1).

There are, however, concerns about the ability of the Thames River to sustain its diverse aquatic population. The upper Thames River is situated in a highly developed urban and rural sector of southern Ontario, and faces problems from land uses supporting a large human population. The watershed land base is also intensively used for both livestock and crop agriculture. The water quality of the Thames and its tributaries has been affected in the past century as a result of all of these human activities. Preservation efforts are imperative to protect this biologically significant watershed habitat and in turn, the species that live there.

## Objectives

The primary objective of this report is to synthesize all pertinent information affecting species at risk in the Thames River watershed. The goal in synthesizing this information is to identify key patterns and trends in limiting factors, habitat quality, and distributions of aquatic species at risk in the watershed. In doing so, conservation priorities can be assigned to habitat types, threats and subwatershed areas. This synthesis report will be the framework for developing a recovery strategy for the Thames River aquatic ecosystem.

## Approach

The primary documents used in this report are: The Upper Thames River Watershed Report Cards (U.S. EPA *et al*. 2001), The Thames River Watershed Background Study for Nomination under the Canadian Heritage River System (TRBSRT 1998), and Aquatic Species at Risk in the Thames River Watershed, Ontario (Cudmore *et al.* 2004). The above documents are recent, thorough and relevant to species at risk in the Thames River watershed. Other data used in this report came from the Provincial Water Quality Monitoring Network (PWQMN), the Upper Thames River Conservation Authority (UTRCA) and the Lower Thames Valley Conservation Authority.

For the purposes of watershed management, the watershed was divided into 47 subwatersheds and 14 subwatershed groups (Figure 2). The subwatersheds are either major tributaries or sections of the main branches of the Thames River. Watershed boundaries within the report were created by the UTRCA, agreed upon by the Recovery Team and used in this report, as well as in the Recovery

Strategy. They were manually defined on 1:50,000 National Topographic Series maps (1994, 95) and table digitized to create a digital copy of the data. The boundaries are general in nature because of the dates and scale of the maps they were generated from, and may not necessarily reflect the subwatershed boundaries used for other purposes by the conservation authorities. To date, more research has taken place in the upper Thames than in the lower Thames. At the time of writing recent data for the lower Thames did not exist in sufficient quantity to produce detailed watershed assessments.

To accomplish the primary objective, this document integrates:

- Geology and fluvial geomorphology
- Landcover, including riparian zones and land use breakdown
- Drainage factors including tile drainage, dams, channelization and flooding
- Water quality
- Factors influencing the distributions of aquatic species at risk
- Species at risk distribution trends, primary threats and important habitat areas

## UNDERLYING GEOLOGY

### Physiography

The valley of the Thames River, like most valleys in southern Ontario, can be classified as fluvial, which is slightly entrenched in a gentle landscape of glacial till, clay and sand plains (Figure 3) (TRBSRT 1998). It flows through materials deposited by the meltwater of a glacier, rather than the river's own alluvial deposits. Above the Forks of the Thames in London, the Thames River spillway is about 1-1.3 kilometres wide and up to 33 metres deep. The upper Thames River is confined by its valley; there are steep valley slopes or bluffs on at least one side, often in the direction of the associated moraine, and gentler terracing on the other bank. Below the Forks to the Chatham-Kent county line, the valley is about the same width but its depth is generally less than 23 metres. In contrast, the river is generally not confined by its valley below the old lake plain downstream of Chatham, where it is so shallowly entrenched that dykes have been constructed to control flooding of the adjacent lands. The level of the river at the mouth is higher than the surrounding land (TRBSRT 1998).

Much of the soil in the Thames River basin is well-suited to agriculture. Luvisolic soils predominate in the mid- to upper Thames watershed. Luvisolic soils are well to imperfectly drained soils that have developed under deciduous or mixed forest cover in moderate to cool climates, where the parent materials are generally neutral to alkaline (limestone). In contrast, gleysolic soils predominate in the lower Thames in the Chatham to Lake St. Clair area. Gleysolic soils, which are poorly drained and are saturated through part or most of the year, make up a large part of Essex and Kent Counties (TRBSRT 1998).

### Soil Erosion and Delivery

A shift in the types of crops grown in southwestern Ontario, and a corresponding increase in drainage works in the 1960s, led to a subsequent increase in soil erosion. Erosion rates for southern Ontario are among the highest in Canada (Coote *et al*. 1981). Most soil is lost through water erosion, with much of the sediment entering streams and lakes. Sedimentation rates are the highest during spring runoff, in the months of February, March and April (Coote *et al*. 1981). Soil erosion and delivery were classified into four categories for The Upper Thames River Watershed Report Cards (UTRCA 2001). Soil loss categories included: low (0.1-2.24 tonnes/ha of soil delivered to a watercourse per year), average (2.25-6.7 tonnes/ha of soil delivered to a watercourse per year), high (greater than 6.7 tonnes of soil delivered to a watercourse per year), and Unclassified (forested or urban lands). Of the 28 subwatersheds within the upper Thames River, the average percentage of watershed area in the high soil loss category was 9% (ranging from 0.0-26.4 tonnes/hectare/year) (Figure 4). The average percentage of watershed area in the average soil loss category was

9.2% (ranging from 0.0-36.4 tonnes/hectare/year). The majority of the upper Thames watershed falls into the low soil loss category, where an average of 67.8% of the watershed area falls into this group (ranging from 3.8-93.8 tonnes/hectare/year). For the upper Thames watershed, an average of 14% is unclassified (ranging from 0.6-95.2 tonnes/hectare/year). Soil loss in the lower Thames watershed is mainly moderate (Figure 5).

### Velocity/Gradient

As the water travels downstream from the headwaters near Tavistock, it generally picks up speed and volume. During low flow conditions, the Thames reaches its maximum velocity of 0.75 m/sec near Byron just below the Forks. However, by the time it reaches Thamesville, it has slowed down considerably to 0.30 m/sec. This change is largely due to the drop in gradient. The elevation of the river falls at a moderate rate from the headwaters near Tavistock to Delaware (1.9 m/km), begins to flatten out between Delaware and Kent Bridge, then flattens out considerably between Kent Bridge and the mouth (<0.2 m/km). In general, it takes 7-10 days for water to travel from Tavistock to Lake St. Clair (273 km) during the summer, and only 3-4 days during the spring freshet in March and April.

## LANDCOVER

### Riparian Forest Cover

The riparian zone includes the islands, banks and floodplain regions of the river (TRBSRT 1998). The trees, shrubs and herbaceous plants that grow in the riparian zone include species that can tolerate flooding and scouring from ice and moving water, as well as other disturbances. A healthy riparian zone supports a diversity of aquatic habitats, shades the river, is highly productive, provides habitat and cover, and adds agricultural value to lands (Primary Industries, Water and Environment 2003). Riparian zones are also vital for stabilizing the bank (reducing erosion), and intercepting nutrients and suspended solids in the form of overland runoff. The loss of riparian vegetation (principally through agriculture or urbanization) reduces shading, which increases the incident light and causes variation in water temperature, resulting in an increase in aquatic vegetation growth (Bailey and Yates 2003).

Riparian forest cover was calculated for The Upper Thames River Watershed Report Cards (UTRCA 2001) (Figure 6). Forest cover information was taken from 1994 National Topographic Series (NTS) maps on a scale of 1:50,000. Types of forest cover in this calculation included deciduous and coniferous woods, treed swamps, plantations and mature shrub thickets. Other natural non-woody habitats, such as meadows, old fields, cattail marshes, and tallgrass prairies, also act as riparian cover in the watershed, but were not included in the forest cover calculations.

The buffer zone for the Thames was defined as the area of land that lies within 20 metres on both sides of every watercourse in the watershed (UTRCA 2001). The riparian forest cover is the percent of the buffer zone that is forested. For all 28 subwatersheds in the upper Thames River, the average riparian forest cover was 24.4% and ranged from 6.6-43.2%. The riparian forest cover has not yet been calculated for the lower Thames River, though only 4.6% of the total watershed remains in forested cover (mainly small woodlots).

According to the Framework for Guiding Habitat Rehabilitation (Environment Canada *et al*. 1998), a recommendation of 75% of stream length should be native vegetation. Additionally, a 30 metre wide buffer of native vegetation adjacent to streams is recommended. The primary function of buffers is to protect and enhance aquatic habitat by maintaining water temperatures and adding essential nutrients, removing sediment and excess nutrients, and facilitating wildlife movement along the watercourse (Environment Canada *et al*. 1998). Larger buffers are required when the buffer is in poor condition, where soils are less permeable or highly erodable, where slopes are steep, or where the adjacent land use is intensive (Environment Canada *et al*. 1998).

## Land Use

Agriculture is the dominant land use in the Thames River watershed (Figure 7). An average of 77.8% of land in the upper Thames River (UTRCA 2001), and 88.1% of the lower Thames is agricultural land. An average of only 12.3% of the land in the upper watershed and 4.6% of the lower watershed is forested land, mostly in the form of small woodlots.

Some of the impacts from urban land use are related to the amount of impervious surfaces within the watershed, as they have a direct effect on stream hydrology and water quality, and a strong effect on stream habitat and biota (Bailey and Yates 2003). An impervious surface is any surface that is covered by an impenetrable material, such as asphalt, concrete, brick or stone. Highly compacted soils can also act as impervious surfaces. Impervious land cover is defined as the sum of roads, parking lots, sidewalks, rooftops, and other impermeable surfaces of the urban landscape (Schueler and Holland 2000). These surfaces decrease infiltration rates and increase surface runoff. The guideline for the percentage of imperviousness in an urbanizing watershed is 15% to maintain stream water quality and quantity and leave biodiversity relatively unimpaired (Environment Canada *et al*. 1998). In contrast, the commonly accepted standard for assessing low-density residential areas is 25% imperviousness, while high density residential and/or industrial areas are ranked at 50% imperviousness (Paragon 1994). Only 7.95% of the Thames River watershed landscape is classified as urban; however, the amount of impervious cover is unknown. The City of London has 289 km$^2$ of urbanized area.

## DRAINAGE

The land base of the Thames River is primarily rural, except for the larger urban centres of Stratford, Woodstock, London and Chatham. The primary land uses include industry and agriculture. There are three branches of the upper Thames (North, Middle and South Branch) and 46 subwatersheds and numerous micro-watersheds in the entire watershed. The land base is interspersed with numerous drains, creeks, streams and rivers (de Laronde 2001).

The settlement and development of the watershed have brought many changes to the Thames with efforts to manage the river for a variety of purposes. These changes include the construction of dams and barriers, municipal drains, tile drains and channelization.

### Dams and Barriers

Dams and other structures such as road and train crossings, culverts and weirs create barriers or impoundments on watercourses. A dam is built directly on the watercourse with the key objective of water storage or retention, diversion or flood control. Water is held back, forming a lake or pond, technically known as an impoundment. Barriers to aquatic wildlife can be composed of anything from woody debris, concrete steps, steep slopes or gradients, excessively high velocity flow, or may even be chemical or thermal in nature. Barriers do not store significant amounts of water (i.e. negligible impoundment) (de Laronde 2001). Dams, culverts, weirs, check dams and other engineered structures can all act as barriers that change the sediment transport capacity, temperature, flow regime, and alter the aquatic habitat and community composition (Bailey and Yates 2003).

Prior to 1980, there were a number of floods along the Thames that prompted the provincial government to support and endorse the construction of private dams to prevent flooding and to augment river flow. Since that time, dams and barriers have been constructed primarily for agricultural and industrial purposes (Figure 8).

There are now approximately 173 dams/barriers in the upper Thames watershed alone (de Laronde 2001). Due to the difficulty of identifying dam and barrier locations, it is highly likely that the total number of barriers in the upper watershed may be double the 173 identified in the 2001 inventory. These structures range from low-head/low flow barriers to large concrete or earthen dams (de Laronde 2001). Three large dams and reservoirs (Fanshawe, Pittock, Wildwood) have been built in the upper Thames for flood control. A 1991 dam inventory conducted in the lower Thames valley found 65 dams. Almost all of these were small, privately-owned structures, classed as recreational. In addition to these smaller structures there are three large structures within the lower Thames, one on Sharon Creek and two on McGregor Creek.

## Municipal Drains

The Upper Thames River and Lower Thames Valley Conservation Authorities (UTRCA and LTVCA, respectively) have been involved with the Municipal Drain Classification Project since 1998 in partnership with Fisheries and Oceans Canada and other Conservation Authorities. Aquatic biologists assessed the sensitivity of fish habitat in municipal drains based on stream flows (permanent or intermittent), water temperature, habitat and indicator fish species (i.e. baitfish, trout, pike, bass). The drains were then categorized to enable class authorization of maintenance activities in open surface drains that have resilient (or little) fish habitat, while protecting drains that support significant (or sensitive) fish habitat.

The Municipal Drain Classification Project categorized 4924 km of watercourses in the upper Thames watershed (J. Schwindt, Upper Thames River Conservation Authority, pers. comm.).

## Tile Drainage

A tile drain is defined as a drainage system constructed of tile, pipe or tubing of any material (e.g. clay, cement, plastic) installed beneath the surface of agricultural land for the purpose of improving the land’s productivity (Revised Statutes of Ontario 1990). Excess soil water can enter the tile and be removed from the field, thus preventing flooding and water retention in agricultural lands. One purpose of tile drains is to lower the water table, thereby improving the quality of the growing medium for agricultural plants. Tile drains are installed along a slope and the excess soil liquid drains in the direction of the slope and eventually emerges in a watercourse. In addition to draining water, tile drains facilitate the drainage of soil nutrients such as nitrogen and phosphorus, as well as liquid manure.

Disadvantages of tile drains include reduced recharge of aquifers and increased transfer of contaminants which are not filtered through buffers (nitrogen from row cropped lands, fine grained sediment particles from irrigated lands). Advantages include reduction of soil erosion and better timing of cultivation (essential for reduced herbicide inputs such as in organic crop production) (OMAF 2004).

The extent of tile drainage within the Thames River watershed is not accurately known. Southwestern Ontario had the highest rate of drainage works activity in the province during the 1960s and early 1970s for both open and tile drains (Select Committee on Land Drainage 1974).

### Channelization

Channelization is any river or stream channel engineering works undertaken for the purpose of flood control, navigation, drainage improvement or reduction of channel migration potential. These modifications can include such activities as straightening, widening, deepening or relocating existing stream channels, which result in more uniform channel cross-sections, steeper stream gradients and reduced average pool depths (Brooks 2003).

Channelization has the potential to change the natural stream pattern, dimension and profile and increase the rate of sedimentation via accelerated erosion and subsequent deposition. Channelization can have profound effects on riparian vegetation communities. It can affect a system's ability to absorb hydraulic energy and filter nutrients, cause interruptions to different life stages of aquatic organisms, alter instream temperatures and sediment characteristics, and change the rate of erosion and sediment transport/deposition (Brooks 2003).

No channelization works, as defined under the Drainage Act, have been carried out on the Thames River (S. Vander Veen, Ontario Ministry of Agriculture and Food, pers. comm.). However, if the broadest definition of channelization is applied, there have been numerous channelization projects conducted in this area, including a 3.3 km diversion channel between Thames River and McGregor Creek, and over 42 km of dykes to protect low-lying lands in the lower portion of the watershed.

## WATER QUALITY

Surface water quality refers to the physical, chemical and biological characteristics of a particular water system (Chambers *et al*. 2003). The water quality of the Thames River varies with the seasons, vegetation cover, substrate, and the different types of land uses through which it flows.

Water quality of the Thames River has been monitored since the 1960s. The UTRCA and LTVCA collect samples as partners in the Ministry of the Environment's Provincial Water Quality Monitoring Network (PWQMN). As of 2003, 23 sites were being monitored in the upper Thames and nine in the lower Thames.

The water quality data collected in the Thames since the 1960s provides information on long-term trends in river water quality. This data has shown some areas of improvement in the upper Thames and other areas that are still in need of work. Phosphorus levels at most sites and metal concentrations indicate a gradual downward trend while nitrate and chloride levels exhibit an increasing trend. Likewise, benthic monitoring has shown areas within the watershed of both improvement and decline.

In 2001, parameters of water quality were combined to assign “grades” to the upper Thames River subwatersheds (UTRCA 2001). Grades ranged from B to D-. Gregory Creek, Plover Mills and Komoka Creek received the highest water quality grade for the upper watershed, while Dingman Creek received the lowest.

The parameters described below have been measured in the Thames River over a period of ten years (1990–2000). The provincial and Canadian Water Quality Guidelines (CWQG) given for most of these parameters (except for nitrate and chloride) are defined based on acceptable levels for humans. In addition, the Canadian Council of Ministers of the Environment (CCME) has developed guidelines for safe levels of a variety of parameters for freshwater and marine organisms. These guidelines are based on available toxicity data for the most sensitive species of plants and animals found in Canadian waters (CCME 2002), and are included where possible.

The following indicator parameters are monitored as they are of use in assessing watershed health:
1) Nutrients – phosphorus, nitrogen (nitrates)
2) Bacteria – total coliform, *Escherichia coli*
3) Toxic Compounds – chlorides, metals (copper, lead, zinc) and other compounds
4) Turbidity/dissolved solids/suspended solids/conductivity
5) Benthic invertebrates
6) Additional parameters – pH, alkalinity, water temperatures, dissolved oxygen and biochemical oxygen demand

## 1) Nutrients

Nutrients are common elements in watercourses that receive runoff from agricultural practices, wastewater treatment plants, faulty septic systems and industrial wastes. Manure, fertilizers and sewage contain high levels of nitrogen, phosphorus and bacteria. The Thames River is nutrient-rich in comparison to other rivers across Canada (TRBSRT 1998).

### *1a) Phosphorus*

Phosphorus is an essential nutrient for plant and animal life and is part of the cycle of decomposition and photosynthesis. It can be present in dissolved or particulate forms. Total phosphorus is a measurement of all the forms of phosphorus that can exist in water: 1) particulate inorganic phosphorus – bound to sediment particles; 2) soluble inorganic phosphorus – decomposing manure, plant residues, fertilizer, sewage, industrial wastewater; 3) organic phosphorus – soil, plant residues, manure, sewage; and, 4) phosphates – the most biologically accessible form (Maaskant *et al.* 2003). As phosphorus is an essential nutrient for plant and animal life and binds to soil particles, the amount of phosphorus is a good indicator of watershed runoff from agricultural lands (UTRCA 2001). Phosphorus is not usually found in high concentrations in surface water because it is actively taken up by plants (CCME 1999).

High levels of phosphorus from domestic and industrial effluents (including enhanced cleaning products), and urban and agricultural outputs, including chemical fertilizers, livestock wastes or manure spills, can enter the Thames River via runoff or tile drains (UTRCA 1998). Other inputs include atmospheric deposition and soil erosion (CCME 1999).

Although levels of phosphorus achieved via anthropogenic activities may not necessarily reach toxic levels for humans, excess phosphorus may accumulate in the water over time and lead to eutrophication. Nutrient loading produces increased growth of algae (algal bloom), cyanobacteria, water hyacinths and duckweed, which eventually die, fall to the bottom of the river and are decomposed by aerobic bacteria. This decomposition depletes much needed dissolved oxygen, which is essential to most aquatic organisms (U.S. EPA 2003a). As oxygen is used up, anaerobic bacteria predominate and the river bottom becomes devoid of aquatic animals, accompanied by the foul smelling anaerobic metabolic by-products such as hydrogen sulphide and methane. Also, an algal bloom can block much needed sunlight from entering the water, causing underwater plants (such as grasses) to die. Many of these plants serve as food and/or habitat for other aquatic inhabitants (U.S. EPA 2003a).

According to the Provincial Water Quality Objective (PWQO), the provincial guideline for phosphorus is 30 μg/L (UTRCA 2001). Concentrations of phosphorus that exceed this level tend be found in areas with higher livestock production, cropping systems and clay soils.

Total phosphorus values in the upper Thames River ranged between 13-1550 μg/L (1991-1995) and 6-4220 μg/L (1996-2000). The mean phosphorus value for the 15 monitoring sites was over the recommended guideline in both sample periods. The Dorchester subwatershed had the lowest phosphorus values between the years of 1991-95, but recorded the highest values the following sampling period. The River Bend subwatershed had the highest levels in 1991-95, and the second-highest from 1996-2000. Since the 1970s, phosphorus levels at most sites in the watershed have shown a gradual downward trend but remain above the provincial guidelines for the protection of aquatic life. Some sites show increasing levels of phosphorus including the Thames River at Mitchell, Reynolds Creek and Trout Creek (UTRCA 2004).

### *1b) Nitrogen*

Nitrogen exists in four forms including: un-ionized ammonia ($NH_3$), ammonium ion ($NH_4^+$), nitrate ion ($NO_3^-$) and nitrite ion ($NO_2^-$). The vast majority of available nitrogen in surface waters is in the most stable form of nitrogen (the nitrate ion). Kjeldhal nitrogen is a measure of the total nitrogenous matter excluding nitrate and nitrite. The total Kjeldahl nitrogen concentration, less the ammonia nitrogen concentration, gives a measure of the organic nitrogen present (Maaskant *et al.* 2003). Anthropogenic sources of nitrate include chemical fertilizers, municipal and industrial wastewater, decomposition of sewage wastes, feedlot discharges and leachate from waste disposal dumps and sanitary landfills (CCME 1999).

Nitrate can be toxic to aquatic organisms, resulting in acute toxic affects at high concentrations and chronic effects at lower concentrations. (Maaskant *et al.* 2003). As a result of the sensitivity that many aquatic species show to nitrate toxicity (especially amphibians), a new CWQG guideline of 3 mg/L nitrate-N was set. Recorded values of nitrate+nitrite in the upper Thames River range between 0.1–23.0 mg/L (1991-1995) and 0.0–22.0 mg/L (1996-2000). The CCME guideline for freshwater life has been set at 0.06 mg/L for nitrite. All subwatersheds that recorded mean nitrate+nitrite values were over the recommended limits for the ten year sampling period.

Concentrations of nitrogen found in ammonium in water also pose a concern for fish that are highly sensitive to free soluble $NH_3$. Ammonium concentrations of up to 5 mg/L may be associated with manure spills. In comparison, toxic to chronic toxicity levels for some fishes (e.g. rainbow trout (*Onchorhynchus mykiss*)), have been reported at 0.02 and 0.16 mg/L, respectively (King *et al.* 1994). The CCME guideline for freshwater life (un-ionized ammonia) has been set at 0.019 mg/L.

Un-ionized ammonia levels in the upper Thames River have been recorded as between 0.0–0.122 mg/L (1991-1995) and 0-0.097 mg/L (1996-2000). Only one subwatershed (Avon) was over the CCME guideline during 1991-1995 (mean values), and no subwatersheds had mean values over the guidelines during the 1996-2000 period. Nitrate levels at all monitoring sites in the upper Thames River watershed have shown an increasing trend over the past 30 years. This trend is seen in many parts of the province (UTRCA 2004).

## 2) Bacteria

The two indicator organisms used to assess the level of bacterial contamination of water are fecal coliform and *Escherichia coli*. Fecal coliform bacteria are the group of bacteria found in the feces of humans and other animals. *E. coli* is one type of fecal coliform. *E. coli* typically makes up 90% of the fecal coliform feces and high levels are indicative of fecal contamination and the possible presence of intestinal, disease-causing organisms. Neither fecal coliform nor *E. coli* testing differentiates between human or animal waste.

Many sources contribute to microbiological contamination including combined sanitary sewer overflows, unsewered residential and commercial areas, and failing private, household and commercial septic systems. Other sources include agricultural runoff (manure), fecal coliforms from animal/pet fecal waste washed into storm sewers by heavy rains, wildlife waste (e.g. from large populations of gulls or geese), and illegal dumping of recreational vehicle holding tanks. Other factors affecting contamination levels are shallow water levels and higher air temperatures (Lake Erie LaMP 2004).

Water guidelines for bacteria in Ontario are based on human uses. The drinking waters standard is 0 counts/100 mL while the recreational use guideline is 100 counts per 100 mL.

Levels of bacteria in the upper Thames River range between 58–762 counts/100 mL and can be attributed to both urban and agricultural inputs - sewage spills, farm and industrial runoff and faulty septic systems. Fecal bacteria levels in the upper Thames River watershed have shown different trends for different locations. Significant increasing trends are seen at Thames River sites below Mitchell, Thamesford, Ingersoll and Tavistock, and in Trout Creek below Wildwood Reservoir. Significant decreasing trends are seen in the Thames at Komoka and in the Avon River. The Thames upstream and downstream of Fanshawe Reservoir consistently shows lower levels of bacteria that are closer to the provincial objective for recreational use (i.e. 100 *E. coli*/100 mL sample) (UTRCA 2004).

## 3) Toxic Compounds

While there are some natural sources of toxic substances, these typically occur over large areas at low concentrations, and are not included in the following discussion. Instead, the discussion focuses on anthropogenic sources of toxic substances: the many compounds contained in sewage, wastes and industrial runoff that are hazardous to stream health. In addition, seemingly benign compounds, once discharged into the environment, may combine with other pollutants to form toxic compounds and threaten both human and animal life. The direct and synergistic effects of these hazardous compounds on aquatic populations should be considered.

### *3a) Chlorides*

High concentration of chloride ions ($Cl^-$) can be toxic to aquatic organisms, while lower levels can show chronic effects on growth and reproduction. Aquatic species can be adversely affected by prolonged exposures to chloride concentrations greater than 220 mg/L (RiverSides Stewardship Alliance 2001). Chloride ions are very stable and highly mobile, which means that nearly all chloride applied as road salt will eventually migrate to surface water or groundwater (Maaskant *et al.* 2003). Anthropogenic sources of chloride include: calcium chloride used in wastewater treatment, water softeners, industrial processes, potassium chloride (potash) used as fertilizer, industrial effluent, sewage and irrigation drainage, and sodium chloride as road salt. It is estimated that 25–50% of applied road salt can enter groundwater (CCME 1999). Areas of the watershed that are near urban centres tend to have higher levels of chloride contamination due to salting of roads and highways from sodium chloride. Road salts have been defined as "toxic" by the *Canadian Environmental Protection Act 1999* (Maaskant *et al.* 2003). Chronic chloride toxicity can occur at concentrations of > 200 mg/L of chlorides in water.

Chloride levels in the upper Thames River range between 0-654 mg/L (1991-1995) and 15-1300 mg/L (1996-2000). The Dingman subwatershed recorded the highest chloride levels (mean values) for both sampling periods. Over the past 30 years, chloride levels have shown a continual increase at sites across the watershed, but in most cases remain below the Environment Canada level of toxicity for sensitive aquatic species. The Avon River and Dorchester Swamp Creek have shown significant increases. Watercourses in urban areas tend to have the highest chloride contamination.

### *3b) Metals*

Metal contamination usually occurs through one of three pathways: aqueous phase, ingestion of prey and sedimentary phase. Benthic organisms, often filter-feeders or deposit-feeders, usually become exposed to metals through all three pathways (Vernet 1992). Many factors affect metal toxicity including availability, species' sensitivity, exposure (dose and duration), presence of other metals or compounds, dissolved oxygen and pH (Nriagu 1978).

In addition to copper, lead and zinc, as discussed in this section, other metals present in the aquatic environment (such as silver, mercury and cadmium) can have deleterious impacts on aquatic organisms.

#### Copper

Copper is an essential element but can be toxic to aquatic organisms at elevated levels. It is strongly adsorbed to particulate matter (including iron, manganese oxides and organic matter), and is relatively immobile, causing accumulation in riverbeds. Photosynthesis and algae growth are inhibited at copper concentrations of 1-6 μg/L. Copper levels of 50 μg/L are fatal to most phytoplankton (Eisler 1997), while levels as low as 0.04-3.2 μg/L can cause a 50% reduction in phytoplankton growth rates (Langston and Bebianno 1998). Benthic organisms can be exposed to particulate and dissolved copper, as well as sediment-bound copper, through surface contact and sediment ingestion

(CCME 1999). Effects on benthic invertebrates include a decrease in survival, growth, respiration and reproduction, as well as tissue damage and altered behaviour (Nriagu 1978). High copper levels affect fish spawning, growth and survival, lower resistance to disease, alter behaviour, change respiration and osmoregulation, inhibit enzymes, and cause damage to kidneys, liver and gills (Nriagu 1978). Adverse effects on fish behaviour, growth, migration and metabolism can be seen at levels of 4-10 μg/L (Eisler 1997). Levels of 5-25 μg/L can be lethal to some fish species after just four days (Nriagu 1978). Amphibians are also susceptible to copper toxicity, but individual species can vary greatly in their tolerance. Northern leopard frogs (*Rana pipiens*) are extremely sensitive to copper, while Fowler's toads (*Bufo fowleri*) are quite tolerant (Nriagu 1978).

Mussels are particularly sensitive to high copper concentrations (Metcalfe-Smith et al. 2000). When exposed to copper, most molluscs respond by closing their valves, reducing their filtration rates and inhibiting cardiac functions. These responses act as defense mechanisms to limit the animal's exposure to the toxin, but are only effective for short-term exposures (Eisler 1997). Acute toxicity can occur at levels of 39-930 μg/L (dependent on species and other environmental factors); while chronic effects such as decreased growth and survival can be observed at levels of 15 μg/L (Nriagu 1978).

Anthropogenic sources of copper contamination include paints, electrical conductors, plumbing fixtures & pipes, pesticides, fungicides, wood preservatives and sewage treatment effluent (CCME 1999).

The CCME guideline for unfiltered total copper is 2-4 μg/L for freshwater aquatic life. Copper levels in the upper Thames River watershed range between Not Detected–11 μg/L (1991-1995) and 0.5–11 μg/L (1996-2000). Mean copper levels for all monitored subwatersheds were under the CCME guidelines in 1991-95, except for the Avon which exceeded these levels during 1996-2000.

### Lead

Lead is a nonessential trace element that is toxic to aquatic organisms at elevated levels. Toxic effects of lead include increased mortality, decreased benthic invertebrate abundance and diversity and abnormal development. Lead can accumulate in the tissues of organisms over time, affecting the central nervous system of animals. Benthic organisms are exposed to particulate and dissolved lead in surface waters as well as to sediment-bound lead through surface contact and ingestion of sediments (CCME 1999).

Lead enters aquatic systems through runoff and is deposited in bed sediments with particulate matter (iron, manganese oxides) or can be precipitated out of solution with carbonate or sulphide. Anthropogenic sources of lead include: batteries, lead smelting, burning of fossil fuels, municipal waste incineration and wastewater, sewage sludge, phosphate fertilizers and certain pesticides (CCME 1999).

CCME guidelines for lead concentrations and freshwater aquatic life are 1-7 μg/L. Lead levels in the upper Thames River range between Not Detected–8 μg/L. Mean lead values for all sites were under the CCME guidelines.

Zinc

Zinc is an essential trace element required for functioning in both animals and plants. However, it is toxic to aquatic organisms at elevated levels. Toxic effects of zinc include decreased benthic invertebrate diversity and abundance, increased mortality, and behavioral changes. Benthic organisms can be exposed to both particulate and dissolved forms of zinc in surface waters or through sediment contact and ingestion (CCME 1999).

Zinc accumulates in bed sediments due to its affinity for aquatic particles (iron, manganese and organic matter). Anthropogenic sources of zinc include: electroplaters, smelting and ore processors, mine drainage, domestic and industrial sewage, combustion of solid wastes and fossil fuels, road surface runoff, and corrosion of zinc alloy (CCME 1999).

The CCME guideline for zinc is 30 μg/L for freshwater aquatic life. Zinc levels in the upper Thames range from Not Detected–57 μg/L (1991-1995) and 0.5–331 μg/L (1996-2000). All upper Thames monitoring sites are at levels below this guideline.

Metal concentrations (copper, lead, zinc) in river water throughout the upper Thames River watershed show encouraging results with a significant decline over the past three decades.

### *3c) Other Compounds*

Persistent Bioaccumulative Toxic Chemicals: Mercury and Polychlorinated Biphenyls (PCBs)

Research over the past 25 years has shown that a variety of persistent, bioaccumulative contaminants in the Great Lakes food chain are toxic to wildlife. Contaminants usually persist in surface waters at very low concentrations and then tend to bioaccumulate in aquatic organisms and become concentrated at levels that are much higher than in the water column (Lake Erie LaMP 2004). Effects on the endocrine system and tumor formations have been detected in fish populations and effects on the immune system have also been documented (Lake Erie LaMP 2004). Mercury and PCBs are the more commonly researched of these contaminants, though they are not tested for in routine water sampling programs in rivers such as the Thames.

Substances such as mercury and PCBs do not readily break down in the environment; they enter the aquatic environment and build up through the food chain. As these contaminants bioaccumulate in aquatic organisms, the concentration of contaminants in the tissues of top predators, such as trouts and salmons, can be millions of times higher than the concentration in the water (Lake Erie LaMP 2004).

Mercury interferes with the normal functions of biological membranes (i.e. cells, gills), denatures nucleic acids and inhibits enzymes. Inorganic mercury and mercury in aqueous solution are very toxic to a wide range of organisms including bacteria, freshwater algae and fishes. Factors such as chloride ions, sulphides and pH can affect mercury toxicity (Langston and Bebianno 1998).

Animals exposed orally to PCBs developed effects on the hepatic, immunological, neurological, developmental and reproductive systems. Effects have also been reported in the gastrointestinal and hematological systems (ATSDR 1998). Toxicological wildlife survey data was used through the Great Lakes to confirm presence of deformities or other reproductive problems in sentinel wildlife species. The spiny softshell turtle (*Apalone spinifera*) was observed to have had exposure above effect levels likely caused by PCBs and other organochlorines causing reproductive impairment (Lake Erie LaMP 2004).

### Pharmaceuticals, Hormones and other Organic Wastewater Contaminants

Over the past few decades, an increasing concern has developed about the potential and inadvertent contamination of water resources from the production, use and disposal of the numerous chemicals used to improve industrial, agricultural and medical processes (Lake Erie LaMP 2004). Even some commonly used household chemicals have raised concern. These types of contaminants are not part of routine water sample testing on the Thames River.

Analgesics, anti-inflammatory drugs, birth control chemicals, anti-depressants and cholesterol-lowering drugs have all been found in the effluent from water treatment plants discharging into the Detroit River, although at low concentrations (Lake Erie Millennium Network 2003). The U.S. Geological Survey conducted the first nationwide reconnaissance of the occurrence of pharmaceuticals, hormones and other organic wastewater contaminants (OWCs). The compounds detected represent a wide range of residential, industrial and agricultural origins and uses, with 82 of the 95 OWCs being found during this study. Measured concentrations for this study were generally low and rarely exceeded drinking water guidelines, drinking water health advisories or aquatic life criteria. However, many compounds do not have such guidelines established (Lake Erie LaMP 2004).

Wastewater from a number of different industries (e.g. dry-cleaners, textile and clothing industries, fabricated metals and chemical products) often contains potentially toxic chemicals (Lee *et al*. 2002). Effluent from sewage treatment plants has been shown to reduce the growth rate of fathead minnows (*Pimephales promelas*) (Wren *et al.* 2000), cause heavy metal accumulation in the soft tissues of freshwater mussels (Paine and Larose 2000), and interfere with the sexual development of many frog species (Mackenzie *et al*. 2000).

Terrestrial species can also be negatively impacted, as they are exposed to toxic chemicals from consuming aquatic species.

Pesticides

The term "pesticide" is a collective term that includes all chemicals used to kill or control pests. This includes herbicides (weeds), insecticides (insects), fungicides (fungi), nematocides (nematodes) and rodenticides (vertebrates) (Ongley 1996).

Agricultural use of pesticides is a subset of the larger spectrum of industrial chemicals used in modern society. The American Chemical Society database indicates that there were some 13 million chemicals identified in 1993 with some 500,000 new compounds being added annually. In the Great Lakes, for example, the International Joint Commission has estimated that there are more than 200 chemicals of concern in the water and sediments of the Great Lakes ecosystem. Because the environmental burden of toxic chemicals includes both agriculture and non-agricultural compounds, it is difficult to separate the ecological and human health effects of pesticides from those of industrial compounds that are intentionally or accidentally released into the environment. However, there is evidence that agricultural use of pesticides has an impact on water quality and leads to environmental consequences (Ongley 1996). Yang *et al.* (2001) discovered that chemical compounds can persist in the tissue of freshwater mussels for up to a year after initial exposure.

Pesticide monitoring on the upper Thames River began in 2004, with 12 monitoring sites (out of the 28 upper Thames subwatersheds). Samples are being monitored for in-use pesticides including Phenoxy Acid, herbicides (e.g. 2,4-D, MCPA), triazine herbicides (atrazine), and organophosphorus insecticides (chlorpyrifos, diazon) (K Maaskant, Upper Thames River Conservation Authority, pers. comm.).

### 4) Turbidity / Dissolved Solids / Suspended Solids / Conductivity

Turbidity is a measure of the cloudiness of water resulting from suspended particles such as clay, silt, organic matter and microorganisms. Turbidity is measured by quantifying the degree to which light traveling through a water column is scattered by the suspended particles. High turbidity may reduce light transmission and therefore reduce photosynthesis of aquatic plants. High turbidity may also interfere with biological processes (e.g. filter feeding, respiration) (Maaskant *et al.* 2003).

The Thames River has been divided into three categories based on Jackson Turbidity Units: High - > 20, Medium 5.1–20.0 and Low 0–5.0. The upper branches of the Thames are moderately turbid (9.4–13.2) while the lower Thames is highly turbid (69.5) (TRBSRT 1998).

Total dissolved solids (TDS) refer to minerals, salts, metals, cations or anions dissolved in water. TDS is defined either by total filterable residue in mg/L or by conductivity in microSiemens/cm (see conductivity below) (CCME 1999). There is a direct linear relationship between the concentration of dissolved solids and conductivity (Maaskant *et al.* 2003). The Canadian maximum acceptable concentration guideline of 500 mg/L is based primarily on aesthetic considerations of palatability (CCME 1999).

Suspended solids consist of silt, clay, fine particles of organic and inorganic material, plankton and other microscopic organisms. Fine particles are also significant carriers of phosphorus, metals and other hazardous contaminants.

Elevated levels of suspended solids have a number of detrimental effects on aquatic organisms including impaired fish growth and health (clogging/damaging gills, blanketing spawning areas), disruption of benthic invertebrates and periphyton community health, and impairment of filter feeding in mussels. Soil erosion is the most common source of suspended solids to a watercourse. Anthropogenic factors contributing to increased suspended solids include runoff from agricultural lands, construction sites, industrial wastewater and mining activities (Maaskant *et al.* 2003). Natural levels of suspended sediments in streams vary widely depending on sediment type, stream flow and stream morphology.

Levels of suspended solids are naturally high in those areas of the Thames River that are characterized by erodable substrates and high stream flow (Maaskant *et al.* 2003). Recorded values of suspended solids in the upper Thames River watershed range between 0-486 mg/L (1991-1995) and 1-656 mg/L (1996-2000). The subwatersheds of Dingman (1991-95) and North Woodstock (1996-2000) recorded the highest levels of suspended solids.

Conductivity, or specific conductance, is a measure of water's ability to conduct an electrical current and is an indicator of the level of suspended solids and pollutants in water (Lind 1979). Electrical conductivity measures an estimate of the total dissolved salts or the total dissolved ions in water and is expressed in µs/cm. The more ions present in the water, the higher the amount of electrical current that is measured. Conductivity is influenced by temperature and, in unpolluted waters, typically increases 2-3% for every degree Celsius (Lind 1979).

Conductivity is influenced by geology, the size of the watershed, atmospheric inputs, evaporation rates, bacterial metabolism and pollutants (which increase the amount of salts and ions present). Sources of pollutants can include: 1) wastewater from sewage treatment plants and septic systems; 2) urban runoff (especially salt from de-icing roads); and, 3) agricultural runoff (ammonium, phosphorus, nitrate-nitrogen from fertilizers, pesticides, herbicides) (Lind 1979). Overall conductivity in the upper Thames is high at 299-2210 µs/cm (1991-1995) and 387-4230 µs/cm (1996-2000), likely caused by a high amount of suspended solids and/or accumulated dissolved ions. The subwatersheds of Avon and Dingman had the highest conductivity readings of all upper Thames monitoring sites over the ten year period (1991-2000).

### 5) Benthic Invertebrates

Data collected on the benthic invertebrate community of a river is useful for providing an indication of stream health. Benthic invertebrates live in the water for the entire aquatic stage of their life cycle and many are not able to leave the substrate. These characteristics make benthic invertebrates very sensitive to any physical or chemical changes in their habitat (Gibbs 1998). They also differ in the amount and types of pollution that they tolerate which means that overall water quality affects which types of organisms will survive (U.S. EPA 2003b). These factors make benthic organisms good indicators of water quality.

Benthic water quality monitoring has been undertaken throughout the upper Thames watershed as a joint project of UTRCA and the University of Western Ontario since 1994. Inhabitants of the stream substrate are collected at sampling sites selected to represent the 28 upper Thames subwatersheds. Benthic sampling has been conducted throughout the upper Thames at over 250 sites in the past ten years. Sampling is conducted in the early summer and again in the fall with approximately 1000 samples being collected and analyzed annually.

A system called the Family Biotic Index (FBI) is used to assess water quality. Each species of benthic invertebrate is given a score that relates to pollution tolerance. A larger FBI number indicates organisms with a greater pollution tolerance and, thus, poorer water quality in the system (UTRCA 2001).

The UTRCA's benthic monitoring program ties into a province-wide effort called the Ontario Benthos Biomonitoring Network (OBBN). This program provides consistent monitoring protocols to assess aquatic ecosystems. The OBBN was developed by Environment Canada and the Ontario Ministry of the Environment.

The results of benthic sampling have been incorporated in the UTRCA Watershed Report Cards (UTRCA 2001). Since that time, 2003 benthic results show the following upper Thames subwatersheds to be declining in benthic health: River Bend, The Forks, Dorchester, Medway Creek, Pottersburg Creek, South Thames and Otter Creek. With the exception of Otter Creek, the other six subwatersheds listed have a strong urban influence with the percentage of urban land use in the subwatershed higher than the upper Thames watershed average. Dingman Creek, although still considered degraded, is showing trends of improvement, along with Stoney Creek and Gregory Creek.

## 6) Additional Parameters

Alkalinity, pH, temperature and biochemical oxygen demand are point-in-time measurements that are useful in interpreting other water quality parameters as well as evaluating overall stream health. However, these inorganic parameters do reflect anthropogenic processes and are used with other parameters to assess water quality trends.

### *6a) pH*

The relative acidity or alkalinity of surface waters is measured by pH. The Canadian Heritage Rivers System categorizes pH as high alkaline ($>$ 7.3), neutral (6.6–7.3) and low-acidic ($<$ 6.3). Alterations of pH can occur naturally as a result of the rocks and soils of the basin. Anthropogenic processes such as nutrient cycling and the discharge of industrial and sewage treatment processes to aquatic systems can also result in changes in pH. The Thames River is classified as high alkaline (8.0 – 8.5), which reflects the alkalinity of the limestone soil (TRBSRT 1998). The CCME recommended guidelines for freshwater aquatic life in the range of 6.5-9.0.

### *6b) Alkalinity*

Alkalinity is a measure of the water's ability to neutralize acid and is usually expressed in terms of equivalence to calcium carbonate ($CaCO_3$). Alkalinity buffers aquatic ecosystems from changes in pH (Maaskant *et al.* 2003). Water quality parameters can influence pH and include nutrients (phosphate, carbonate, ammonia, silicate and sulphide species), metals (iron, manganese and magnesium), organic acids (amino, humic and fulvic acids), gases (carbon dioxide and hydrogen sulphide) and particulates (aluminum, iron and manganese oxides and hydroxides, clay minerals, organic detritus and plankton). Alkalinity does not usually exceed 500 mg/L of $CaCO_3$ (CCME 1999). Alkalinity levels in the upper Thames River watershed have been reported as Not Detected–1767 mg/L $CaCO_3$ (1991-1995) and 18–319 mg/L $CaCO_3$ (1996-2000).

### *6c) Water Temperatures*

Temperature affects the molecular, cellular and tissue functions of an organism and can alter the community structure of an ecosystem. Water temperatures fluctuate throughout the year according to the ambient air temperature. The Thames River is fed primarily by warmwater streams and warm runoff from land, but there are also several coldwater streams sustained by groundwater discharges. The lower Thames is approximately two degrees warmer than the upper Thames due to the air temperature differences between the two reaches (TRBSRT 1998).

### *6d) Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD)*

The amount of dissolved oxygen (DO) varies daily and seasonally and also with temperature and photosynthetic reactions (Maaskant *et al.* 2003). Approximately 35% of the dissolved oxygen is derived from the atmosphere while the remaining

65% comes from photosynthetic processes of aquatic plants. The decomposition of organic matter by aerobic organisms and oxidation of inorganic wastes may reduce dissolved oxygen and lead to anaerobic conditions (CCME 1999). This may result in concentrations of dissolved oxygen that are below the requirements for the maintenance of aquatic life of both coldwater and warmwater organisms. The PWQO guideline for DO is >5–8 mg/L for warmwater biota and > 4–7 mg/L for coldwater biota (Maaskant *et al.* 2003).

Biochemical Oxygen Demand (BOD) is the amount of oxygen that is consumed by bacteria and other microorganisms while they decompose organic matter under aerobic conditions at a specified temperature. Five-day BOD ($BOD_5$) is the amount of oxygen consumed in 5 days at 20°C. There are no specific guidelines for BOD, but levels must be low enough to sustain adequate dissolved oxygen concentrations for the survival of aquatic organisms.

## SPECIES AT RISK

All species considered for the Thames River Recovery Strategy are semi- or fully aquatic, have historical records from the Thames River and are designated by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2004) as Extirpated, Endangered, Threatened or Special Concern. A total of 25 aquatic species at risk (7 mussels, 6 reptiles and 12 fishes) fit the above criteria and will be the main focus of the forthcoming recovery strategy (Table 1). In addition to these 25 aquatic species at risk, numerous other aquatic and terrestrial species are expected to benefit from improvements to the aquatic and riparian ecosystem.

A discussion of the factors influencing aquatic species at risk distribution and abundance in the Thames River watershed is presented below. Then, a summary of each group of aquatic species at risk (mussels, reptiles and fishes) in the watershed, their primary threats and their important habitat areas follows. This summary was derived from a more detailed report by Cudmore *et al.* (2004). Information summarizing the biological, physical and chemical data from this synthesis report will then be used to assign conservation priorities to habitat types, the main threats facing species at risk, and subwatershed groups.

### Factors Influencing Aquatic Species at Risk Distribution and Abundance in the Thames River Watershed

The following section discusses the main natural and anthropogenic factors that influence aquatic species at risk distribution and abundance within the Thames River watershed. The anthropogenic stresses are presented in order of decreasing importance based on the known or assumed limiting factors of the species at risk in the Thames River watershed (as outlined in Cudmore *et al*.

2004). The following discussions are by no means exhaustive, but rather focus on the assumed current primary cause and effect relationships.

### *Habitat Availability and Biotic Factors*

The quality and availability of appropriate habitat is an important factor influencing all aquatic species at risk. Of all aquatic species at risk, the freshwater mussels, as a group, are likely the most restricted by their habitat requirements. Due to the sessile life strategy of freshwater mussels, they are unable to move to more appropriate habitat should this feature become degraded or lost. Mussel distributions are influenced by the availability of preferred substrate type.

Snakes and turtles utilize several different substrate features, both in the river and within the riparian zone, for various activities (e.g. basking, hibernating, nesting, foraging). It has been shown that turtles require specific habitat features for various types of life activities, but just as important are the natural corridors between these habitat features. It is unknown, but assumed, that these natural corridors between habitat features, either for different life stages or seasonal or daily requirements are necessary for all aquatic species at risk.

Several fish species at risk are limited in their distribution and abundance by their narrow habitat requirements. For example, information to date indicates that eastern sand darters seem to be strongly associated with only fine sand-dominated substrates.

Biotic features also limit the distribution and abundance of aquatic species at risk. For mussel species, their specific larval host(s) must be present in the area at the time of glochidial release. Therefore factors affecting the distribution and abundance of host species have an indirect effect on mussel distributions. Table 2 presents a summary of freshwater mussel host species and their status in the Thames River watershed. Many reptile and fish species at risk are extreme specialists in their diets. For example, queen snakes consume mainly freshly-molted crayfishes, and it may be that only one species of crayfish is consumed. The distribution and abundance of some reptile and fish species at risk, therefore, is highly dependant on the distribution and abundance of their prey items.

### *Siltation and Turbidity*

An increase in suspended sediments leads to an increase in turbidity, limiting light penetration and net primary production of algae and plants. Suspended sediments also may directly damage macrophytes by scouring leaves and stems and smothering periphyton and macrophytes (Bailey and Yates 2003). Sediment deposition can accumulate in pools, thus reducing wintering habitat and can alter the substrate composition, ultimately burying important gravel and cobble habitats needed for spawning success of fishes (Bailey and Yates 2003). Suspended sediments can impair respiration, reduce feeding efficiency for filter feeders, smother or bury mussels, and interfere with visual cues in locating food, mates or larval hosts. If high concentrations of suspended sediments occur over even a short period of time, it can have extreme effects on aquatic biota (Environment Canada *et al.* 1998).

There are numerous factors within the Thames River watershed that contribute to elevated siltation and turbidity levels. Agriculture, which covers 77.8% of the upper Thames landscape and 88.1% of the lower Thames landscape, is likely one of the principal sources of sedimentation. Urban areas also contribute to this sedimentation through the hardening of surfaces, sewer installations, storm water outlets and roads construction.

Overland runoff deposits soils directly into drains and rivers, resulting in increased suspended solids in the river system. The negative environmental effects associated with drainage works has long been known, and the cumulative effect of extensive drainage works has often been overlooked (Select Committee on Land Drainage, 1974). Livestock access to the water destabilizes the banks causing erosion, which also contributes to the suspended sediments.

As indicated above, the subwatersheds in the upper Thames watershed having a considerable portion of land within the “high” or “average” soil loss category are likely key contributors to the high siltation and turbidity levels. Efforts to reduce sedimentation in the Thames River watershed may have a greater impact if they were concentrated in these subwatersheds (e.g. Middle Thames 21.2%, Mud 19.9%, and Reynolds 26.4%). Soil loss and delivery in the lower Thames watershed also indicate that some areas have high soil loss.

Riparian zones are important in stabilizing streambanks, reducing erosion and intercepting overland runoff. Livestock grazing causes banks to be trampled and destroys riparian vegetation, thereby increasing both erosion rates and the quantity of sediments (Bailey and Yates 2003). The loss of riparian zones through ploughing to the edge of the riverbank also likely contributes significantly to sediment loadings. When comparing the buffer zones of the subwatersheds, it becomes apparent that several subwatersheds are in dire need of buffer zone improvement. In particular, the Whirl and North Mitchell subwatersheds have the least amount of forested buffer (6.6% and 6.7% respectively), and also have the highest percentage of watershed area in agricultural use (92% and 93% respectively).

Dams cause upstream sedimentation, which fills the interstitial spaces between rocks and cobbles, essentially burying fish and benthic invertebrate habitat (Bednarek 2001). The lack of suspended sediment in the discharged water downstream of dams can increase erosion in the river channel, resulting in the loss of pool-riffle sequences, bank collapse and loss of riparian areas (Poff *et al*. 1997; Bednarek 2001).

Channelization contributes to erosion due to a stream's natural inclination to recover its original channel shape following alteration. As a result of straightening, bank steepness increases, the underlying alluvium is exposed and water velocity increases (Bailey and Yates 2003).

### *Nutrient Loadings*

Nutrients such as phosphorus and nitrogen compounds are loaded into the Thames River system through a variety of sources, including: manure and fertilizer applications to farmland, manure spills, sewage treatment plants and faulty domestic septic systems. In the upper Thames watershed alone there are 19 sewage treatment plants of varying degrees of treatment, that discharge wastewater into the Thames (UTRCA 2001). Faulty septic systems can be a major contributor of nutrients and bacteris to the Thames (Hayman 1989). Bacteria levels in the Thames are often well above provincial recreational use standards (100/100 mL), an indicator of manure and human waste in the water.

Since agriculture is by far the dominant land use in the watershed, several key factors relating to aquatic species at risk threats resulting from agricultural practices need to be addressed. Not only the aforementioned increase in siltation, but high nutrient loadings in the river can often be attributed to livestock manure spreading practices. High levels of nitrogen and phosphorus in the water can result in algal blooms. Oxygen is removed from the water by the bacteria that decompose dead algae. In some instances, dissolved oxygen concentrations can fall to near zero, which results in fish kills. Manure spills have been the leading cause of fish kills in Ontario since 1988 (UTRCA 1998).

Tile drainage increases the speed at which nutrients are delivered into the watercourse**.** Rainfall, cropping system and rate of fertilizer application has the greatest impact, while placement method and tillage have a lesser impact on the rate of nitrogen loss via tile drains (Zucker and Brown 1998). Soil mineralization, time of application, presence of nitrification inhibitors and tile spacing and depth can also affect the rate nitrates travel through subsurface drainage (Follett and Hatfield 2001).

The settling of nutrients and sediments in reservoirs behind dams and other large barriers can lead to reduced nutrient loads downstream and loss of habitat structure. These two factors could combine to cause a general decline in productivity below a dam (Poff *et al*. 1997). Human activities such as agriculture and organic waste disposal around impoundment areas make the water reservoirs susceptible to cultural eutrophication, which is evident through algal blooms and an increase in macrophyte growth. An increase in primary production increases the biochemical oxygen demand, which decreases the dissolved oxygen concentrations resulting in hypoxia or even anoxia (Bailey and Yates 2003). Fanshawe Lake has experienced extensive algal blooms and elevated levels of coliforms nearly every summer since the early 1980s. Fish kills and loss of benthic invertebrate diversity are a result of low dissolved oxygen concentrations (Bailey and Yates 2003).

### *Toxic Compounds*

Toxic chemicals find their way into the watercourse through a variety of anthropogenic pathways. Pesticides (insecticides and herbicides) used in agriculture, golf courses and urban areas enter into the watercourse through runoff. Herbicides may contribute to a reduction of plant growth, while insecticides could alter the aquatic insect community in the river. Both of these results likely have an indirect effect on habitat and food availability for mussels, reptiles and fish species at risk. The chemicals also pose direct health risks to the organisms themselves.

Roadways contribute to the introduction of salts, heavy metals, oils and grease into the watershed. Industry, agriculture, and municipal spills also contribute significantly to the toxic compounds found in the water. The Upper Thames River Watershed Report Cards (UTRCA 2001) identified the reported spills per subwatershed from 1988-2000, and the results indicate that certain subwatersheds may contribute significantly to toxicity levels. Three notable subwatersheds are Avon, Pottersburg and The Forks, where reported spills occurring between 1988 and 2000 were numbered at 45, 55, and 113, respectively (UTRCA 2001). Oils and fuels accounted for the majority of the spills. Episodic fish kills are often reported as a result of a chemical spill in the water. Effects of spills on mussel and reptile populations are more difficult to observe, although it is assumed they have a significant negative impact.

Impervious surfaces collect and accumulate urban pollutants that are quickly washed off and delivered directly to aquatic systems (Schueler and Holland 2000). Streams with surrounding landcover of 11-15% imperviousness experienced a decline in aquatic diversity, as compared to streams with less than 10% impervious land cover (Schueler and Holland 2000).

### *Altered Water Flow*

A lack of overbank flows from flood control dams limits the lateral exchange of nutrients, sediment and organisms between riparian and aquatic habitat, thus causing a shift in species compositions as generalists out-compete more specialized species (Poff *et al*. 1997). Lack of overbank flow has also been found to have a substantial effect on turtle nesting success. When flooding is prevented, so is the natural scouring action of sandy banks. These banks become vegetated in the absence of scouring and become unsuitable nesting habitat for turtles.

Flash floods that may occur in the summer are controlled by releasing moderate amounts of water from the dams for a longer period of time. Turtle nests are able to withstand flash flooding; however, eggs do not survive if the nests are inundated with water for a longer period of time (ca. 48hrs). In 2002, field researchers observed 41 spiny softshell nests become flooded for an extended period of time as a direct result of controlled water release from the Fanshawe Dam. Hatching success for these nests would have been zero in the absence of human intervention. It is suspected that flood management practices have been contributing significantly to the extremely low recruitment in spiny softshells (S. Gillingwater, Upper Thames River Conservation Authority, pers. comm.). Altered flow patterns from more water (e.g. well water, pipeline water from Lake Huron), caused by increasing populations, leads to altered baseflows (e.g. 60-70% of the flow leaving the upper Thames River basin during the summer) (UTRCA 2004).

The level of impact on streams from urban land use is related to the amount of impervious surfaces within the watershed, as they have a direct effect on stream hydrology and water quality, and a strong effect on stream habitat and biota (Bailey and Yates 2003). Impervious surfaces decrease water infiltration rates and increase surface runoff. This increase in surface runoff leads to higher peak discharges, decreased flood peak width and shortened lag times between rain events and associated flood peaks (Paul and Meyer 2001). An increase in surface runoff contributes to channel incision (steepening of banks), increased undercutting and bank collapse and wider and deeper channels (Poff *et al.* 1997). Streambank erosion results in, along with habitat degradation, the loss of pool and riffle sequences and overhead cover and an increase in suspended sediment loadings (Schueler and Holland 2000). In urban areas, bank stabilization techniques such as concrete or rip rap structures are employed to minimize property damage; however, this leads to even further incision (Poff *et al.* 1997). Higher water flows also lead to a less stabilized bed and a change in bed composition leading to a decrease in species diversity. Additionally, the more water leaves the watershed as runoff, the less there is to recharge groundwater reserves, which could decrease baseflow discharge (Bailey and Yates 2003).

### *Barriers to Movement*

Dams act as physical barriers that fragment and isolate populations of aquatic species at risk (Bailey and Yates 2003). Dams also indirectly affect the distribution of mussel species by limiting the movement of their fish host species. To a more limited extent, dams and barriers also affect the distribution of reptile species. Though reptiles may be able to cross over small water barriers on land, the larger dams in the Thames represent a significant obstacle, especially Fanshawe Dam. Spiny softshells are present on either side, but are unlikely to cross over the dam (S. Gillingwater, pers. comm.). Dams and barriers also prevent species from following their natural migration routes.

### *Exotic Species*

Exotic species are affecting the distribution and abundance of native aquatic species throughout southern Ontario. Common carp (*Cyprinus carpio*) are widespread in the Thames (J. Schwindt, pers. comm.) and may be having an impact on the watershed. The feeding behaviour of this species disturbs the substrate, causing the area to become highly turbid. The resulting turbidity directly impacts the sensitive mussel and fish species. Water impoundments have more generalist and non-native species of fish than natural lakes (Bailey and Yates 2003). Not surprisingly, the most dominant fish species in Fanshawe Reservoir is the common carp (Bailey and Yates 2003).

Zebra mussels (*Dreissena polymorpha*) have invaded the Great Lakes waters, decimating native mussel populations. Zebra mussels attach to the shells of native mussels in great numbers, resulting in the blockage of feeding and respiratory siphons, thereby killing them. Several species of Unionidae in the Lake St. Clair/Detroit River system have been extirpated as a direct result of zebra mussel invasion (Mackie 1991, Gillis and Mackie 1994). Until recently, zebra mussels had not been present in the Thames River watershed, except for at the mouth. In the fall of 2002, the presence of zebra mussels was confirmed by the Ontario Federation of Anglers and Hunters (OFAH) in Fanshawe Reservoir. Since that time mussel surveys in the Thames River have revealed that zebra mussels have moved as far downstream as Thamesville (T. Morris, Fisheries and Oceans Canada, unpub. data). The establishment of this aggressive exotic species may have a devastating impact on the native mussels in the Thames.

Another exotic species that has the potential to impact the native aquatic species is the round goby (*Neogobius melanostomus*) should this species invade the watershed. This pollution-tolerant species impacts native fish species by displacing them from optimal habitat, and eating the eggs and young of the native species.

Other exotic species such as the rainbow trout (*Oncorhynchus mykiss)*, brown trout (*Salmo trutta*), phragmites (*Phragmites spp.)* and purple loosestrife (*Lythrum salicaria*) may also potentially have an impact on the aquatic species at risk in the Thames River; although the nature of the impacts are unknown.

*Disturbance*

Any disturbance of the habitat in and around the river may also contribute to restricting species presence in the area. Human recreational activities are common throughout the watershed and may contribute to habitat disturbance. Canoeing is a popular and relatively low-impact activity; however in areas where mussel species at risk occur, the impact of substrate disturbance may be considerable (Metcalfe-Smith and McGoldrick 2003). Though necessary, extensive research and survey efforts can create disturbance to animals and their environment. Any activities occurring in the riparian zone may directly disturb any reptiles that use the area. Sensitive turtle nesting sites have been observed to be trampled by foot and bicycle paths, and littered with broken glass and other debris (S. Gillingwater, pers. comm.). The presence of a high number of people may also dissuade wary reptiles from basking or nesting, thus rendering the area inadequate for use.

Any development in the riparian zone likely alters important habitat. Shoreline stabilization structures are likely a key contributor to habitat alteration. When bank stabilization structures are constructed, the resulting higher flows cause the bed to become destabilized, in addition to directly altering the bank habitat (Bailey and Yates 2003). Habitat alteration may be significant in some recreation or urban areas where grass is mowed to the edge of the watercourse.

Recreation activities can lead to a decrease in habitat quality (through pollution and turbidity), bank stability and riparian vegetation cover. Disturbance (physical, noise) can affect local wildlife, causing physiological reactions, interruptions of normal activities, displacement or nest abandonment, lowering of fitness and survival and increases in mortality (Waller *et al*. 1999).

### *Thermal Pollution*

An unnatural increase in water temperature would be expected to negatively affect the physiology and behaviour of aquatic species (especially coldwater species). It leads to a decrease in the amount of dissolved oxygen present, as well as increasing the likelihood of algae blooms. A lack of riparian vegetation reduces shade to the water surface, allowing solar radiation to warm the water surface. Artificial reservoirs increase water temperature as a result of holding water and increasing the water surface area. The large reservoirs such as Fanshawe, Wildwood, and Pittock would be expected to contribute to temperature increase. Additionally, the temperature of discharge water from treatment facilities (and other industries) is often significantly warmer than that of the river and, therefore, would be expected to contribute to thermal pollution. Surface runoff (from roads, cultivated fields, urban centres) may also contribute to an increase in water temperatures, as heat is absorbed by, and reflected off of, impervious surfaces (Schueler and Holland 2000).

## Overview of the Species at Risk in the Thames River Watershed

A separate report has been compiled with each species at risk's distinguishing characteristics and general biology, distribution, official global, national (US and Canadian), and subnational (Ontario) ranks, as well as its current status within the Thames River (Cudmore *et al.* 2004). The habitat used by the species, along with information on reproduction, diet and the threats and limiting factors within the Thames River watershed were also presented in that report. The information provided was used to assigned conservation priorities for each of the species at risk in the Thames River watershed (Table 1) (see Cudmore *et al.* 2004 for how the priority rankings were assigned and Appendix A for definitions). The key trends, threats and important habitat types are summarized below for each group of species at risk (mussels, reptiles and fishes).

## Mussels

Following the criteria outlined in Cudmore *et al.* (2004), three mussel species are Possibly Extirpated (snuffbox, round hickorynut and kidneyshell) and four species were ranked as High priority (wavy-rayed lampmussel, round pigtoe, mudpuppy mussel and rayed bean).

Historical and current distribution in the Thames River was compiled by combining the 47 subwatersheds into 14 subwatershed groups (Table 3). This information was acquired through historical data and a 1997-1998 survey on the Thames, Middle Thames and North Thames Rivers (Metcalfe-Smith *et al.*. 1998). An intensive sampling effort (4.5 person-hours per site) was combined with a timed-searched method in this survey, which is one of the most effective methods for detecting rare species (Strayer *et al*. 1997). Sites that were known to support rare mussel species and/or diverse mussel communities in the past were targeted. The results of this study found only fresh or weathered valves (no live specimens) for five of the seven mussel species (round hickorynut, rayed bean, kidneyshell, mudpuppy mussel, snuffbox). Only the wavy-rayed lampmussel and the round pigtoe were found alive in the 1997-1998 study. The results must be interpreted with caution considering the obvious limitations of sampling a small number (16) of sites, all located in the upper Thames watershed. The lower Thames is deeper and thus more difficult to survey. Additional freshwater mussel sampling was conducted during the summers of 2003 and 2004. Field data will be compiled from these two field seasons and will be used to update the freshwater mussel distribution and abundance information in the forthcoming Thames River Recovery Strategy.

### Primary Threats

All adult freshwater mussels are sedentary filter feeders. This combination of life history characteristics makes mussels particularly vulnerable to changes in their environment, as they are directly vulnerable to poor water quality and are not able to relocate should their habitat become unsuitable. Sedimentation and siltation are primary threats for all freshwater mussels, as sediments could bury mussels, foul suitable riffle/run habitats, interfere with filter feeding and/or lessen the success of luring host species as a result of reduced visibility. Pollutants such as high concentrations of ammonia and copper have been noted as a significant threat to freshwater mussels (Jacobson *et al*. 1993, Jacobson *et al*. 1997, Metcalfe-Smith *et al.* 2000, Mummert *et al*. 2003). Mussels are more sensitive to toxins than most other aquatic animals, and are particularly sensitive to heavy metals (Havlik and Marking 1987, as cited in U.S. Fish and Wildlife Service 1994). High levels of phosphorus, nitrogen and chlorides would also have a negative impact on mussels. Many of the pollutants in the Thames River can be attributed to intensive agriculture, municipal and industrial discharge and road salt (see Water Quality section this report).

The larval stage of freshwater mussels are obligate parasites on host-specific fish, or amphibians in the case of the mudpuppy mussel. Without the appropriate host species, glochidia cannot complete their life cycle, and recruitment is unsuccessful. Any factors negatively affecting glochicial host species also have an indirect impact on mussels. Water barriers fragment host populations, therefore effectively fragmenting and genetically isolating mussel populations. The only means for mussels to relocate and expand their range is while attached as larvae to their hosts. If the host is isolated between water barriers, mussels are unable to expand their range.

### Important Mussel Areas

The seven freshwater mussel species at risk were mapped according to their priority ranking in order to decipher any trends in important mussel areas within the Thames River watershed (Figure 10). Comparing information from Table 3 and Figure 10, it can be seen that the Middle Thames subwatershed group (consisting of the Middle Thames and Mud Creek subwatersheds) is an important live mussel area. The absence of mussel observations in the lower Thames between Chatham and Lake St. Clair is most likely attributed to the lack of sampling effort in that region. Mussel surveys have not been conducted in the branches of Whirl Creek, Black Creek, Avon River, Flat Creek, Fish Creek, Trout Creek, Cedar Creek, Medway Creek, Oxbow Creek and Dingman Creek; therefore, the importance of these areas with respect to mussel species at risk cannot be evaluated until surveys have been conducted in these areas. The Chatham-mouth subwatershed group (Chatham downstream to the mouth) historically has had many mussel species, but none have been found recently due to lack of surveys.

## Reptiles

Of the six reptile species at risk in the Thames River watershed, only the stinkpot is considered Possibly Extirpated; three were considered to be of High priority (spotted turtle, spiny softshell and queen snake); one Medium priority (eastern ribbonsnake); and one Low priority (northern map turtle) using the ranking criteria outlined in Cudmore *et al.* (2004) (Table 1).

The wary and elusive nature of snakes and turtles has made accurate population estimates and trends difficult to obtain. Historical and current distribution by subwatershed group (Table 3) were estimated from historic records and ongoing field monitoring efforts of the Upper Thames River Conservation Authority (S. Gillingwater, unpub. data).

### Primary Threats

Because reptiles (especially turtles) are generally long-lived, late-maturing and produce relatively few offspring, they are particularly vulnerable to decline. Any increase in adult mortality could have a severe impact on the population. The primary limiting factors for adult reptiles in the Thames River watershed include habitat destruction or alteration, human interference and road mortality (Cudmore *et al.* 2004). Alteration of sensitive nesting habitat, combined with a high level of nest predation, results in extremely low nesting success for the spiny softshell. The queen snake is extremely specialized in its diet, primarily consuming freshly-molted crayfishes. As a result, the health of the local crayfish population is a considerable limiting factor for the queen snake. Crayfishes are currently not specifically sampled for in any of the existing monitoring programs being conducted in the watershed.

### Important Reptile Areas

The aquatic or semi-aquatic reptile species at risk were mapped according to their priority ranking and location occurrences in the watershed since 1990 (Figure 11). It is difficult to interpret trends from this data for several reasons. First, the stinkpot has not been recorded in the watershed since the early 1980s, and the spotted turtle is (and most likely always has been) rare in the watershed, likely due to the rarity of preferred wetland habitat. Additionally, unlike repeatable sampling techniques for mussels and fishes, surveying for snakes and turtles is often restricted to opportunistic sightings. Turtles and snakes will often flee at the slightest disturbance, thus accurate identification and individual counts are difficult. Despite the difficulties in surveying, several areas in the watershed stand out as important reptile areas (Table 3 and Figure 11). Most were in the middle section of the watershed, in the subwatershed groups of Medway, Dingman and Dorchester, which are in the most urbanized area in the watershed. The absence from Chatham to Lake St. Clair does not necessarily mean species absence, because recent sampling effort has been concentrated in the Upper Thames.

## Fishes

The 12 fish species at risk in the Thames River watershed were prioritized according to the guidelines in Cudmore *et al.* (2004). Two species are Possibly Extirpated (gravel chub, lake chubsucker); three species were considered to be of High priority (eastern sand darter, northern madtom and black redhorse); six were ranked as Medium priority (northern brook lamprey, bigmouth buffalo, silver shiner, pugnose minnow, river redhorse and spotted sucker); and one species (greenside darter) was ranked as Low priority.

A wide variety of methodology was utilized in collecting fish data on the Thames, including backpack electrofishing, seine netting, gill netting, trawling and minnow trapping (Holm and Boehm 1998, J. Schwindt, pers. comm.). Much of the Thames has been surveyed for fish species (Cudmore *et al.* 2004). Data has been collected from the Upper Thames River Conservation Authority, Lower Thames Valley Conservation Authority, the Ontario Ministry of Natural Resources, the Royal Ontario Museum, and Fisheries and Oceans Canada and the historical and current distributions were compiled by subwatershed group (Table 3).

Species at risk surveys were conducted throughout the Thames River watershed during the summers of 2003-2004. Field data will be compiled from these two field seasons and used to update the fish species at risk distribution and abundance information in the forthcoming Thames River Recovery Strategy.

### Primary Threats

Turbidity and siltation are noted as primary threats for the majority of the fish species at risk in the Thames River watershed (Cudmore *et al.* 2004). Poor water quality (see Water Quality section in this report) is also primary threat for many fish species through habitat loss or degradation. Water barriers also pose a significant threat by fragmenting or restricting movement of fish populations.

### Important Fish Areas

Mapping the fish species at risk by their conservation priorities and occurrences (Figure 12) reveals the absence of species observations from the area east of the Wildwood Reservoir at St. Marys. This absence cannot be attributed to lack of survey locations, as this area has been surveyed extensively (Figure 13). Wabuno and Dingman Creeks have a notable lack of fish species at risk observations. There is also an absence of fish observations from the lower Thames despite considerable sampling effort. On the other hand, there is an apparent clustering of fish observation data just downstream of the large dams (Fanshawe, Wildwood, Pittock) and from the Medway Creek subwatershed group (Table 3).

## Conservation Priorities

### Habitat

The aquatic species at risk were grouped into four broad habitat preferences in order to identify similarities and patterns in habitat use (adapted from Dextrase *et al*. 2001) (Figure 14). These groupings do not necessarily represent specific microhabitat or seasonal requirements, nor do they imply obligatory habitat use. Many of the species demonstrate significant overlap in habitat preferences. However, some of the species were found in only one habitat group: eastern ribbonsnake, pugnose minnow, round hickorynut, eastern sand darter, lake chubsucker, snuffbox, wavy-rayed lampmussel, kidneyshell and greenside darter. Of these two species (eastern sand darter and wavy-rayed lampmussel) are High priority species occupying the sandy riffles and pools and the gravel riffles and flats groups, respectively. Therefore, it can be assumed that because of the High priority status of these species and their habitat specialist nature, that these two habitat groups are important High priority areas.

All mussel species at risk can be broadly classified as requiring sandy riffles and pools and/or gravel riffles and flats as the general substrate preferences. Reptiles were generally found toward the other end of the habitat spectrum from mussels; preferring river/wetland edges and/or soft vegetated substrates. Two species (spiny softshell and northern map turtle) also use sandy riffles and pools. Of the 11 fish species at risk, none were found to use the river/wetland edge habitat of the Thames River. Most fish species were found in the sandy riffles and pools or the gravel riffles and flats.

Of the 10 High priority species at risk, most (8) used the sandy riffles and pools or gravel riffles and flats has habitat areas during their life cycle, further providing evidence that these habitat areas should be considered High priority.

### Threats

Summarizing the threats facing the 25 aquatic species at risk in the Thames River watershed indicates that siltation, water quality and habitat loss are the main factors affecting these species (Table 4). Looking at the diagrams adapted from Jacques Whitford Environment Ltd. (2001), we see the potential effects from the main sources (agriculture, urbanization, dams and reservoirs) of siltation, water quality and habitat loss (Figures 15-17). Therefore, these threats and their sources should be considered High priority in development remediation or recovery efforts.

### Subwatershed Group

Two types of priorities can be ranked for the subwatershed groups: conservation and rehabilitation.

### Conservation

Combing the maps of the current distributions and priorities of all 25 aquatic species at risk in the Thames River watershed (Figures 10-12), the patterns and trends in distribution are unclear. Unlike the Sydenham River, where most species at risk occurrences were concentrated in one main branch of the river (Dextrase *et al*. 2001), many of the Thames River species at risk are spread out throughout much of the watershed. The area from Chatham to Lake St. Clair has few species observations, which may be indicative of relatively reduced sampling effort and the challenges of sampling for species at risk in non-wadeable portions of rivers and streams.

Table 3 shows that only a few subwatershed groups contain a high diversity of species at risk (five or more): Medway, Dorchester, Middle Thames and Komoka-Chatham. Therefore, these four subwatershed groups could be considered High priority areas.

### Rehabilitation

Combining information on physical and chemical information (threats) with historical occurrence of species at risk indicates that some watershed groups are more degraded than others and/or are declining in the diversity of the number of species at risk they contain. With respect to degraded conditions using information previously reported for the geology, land cover, drainage and water quality conditions of the Thames River, the subwatershed areas of Dingman

Creek, Avon, Dorchester, River Bend, Trout Creek and North Mitchell may be the most degraded subwatershed and, therefore, should be considered High priority areas with respect to a need for rehabilitation. Further research is required to support this and to determine the extent of degradation in the lower Thames.

The most notable decline in the number of species at risk occurred in the Chatham-mouth subwatershed group (Table 3). Historically, ten species at risk were present in this area prior to 1990; however, currently only two species have been found to exist here. Further research is required to determine the causes for such a decline or to determine if this is a factor of under-sampling.

## SUMMARY

To aid in prioritizing recovery actions and to direct limited resources, conservation priorities were assigned to all species at risk, habitat types, threats and subwatershed groups. Low priority species appear to be stable in the Thames River watershed and elsewhere; therefore, where funding is limited, conservation efforts should be focused on the Medium and High priority species. Conservation efforts for those species that are Possibly Extirpated will likely focus on further surveys to dispute or confirm the status and/or investigations into possibly repatriating the species to the Thames. The High and Medium priority species are: wavy-rayed lampmussel, round pigtoe, mudpuppy mussel, rayed bean, spotted turtle, spiny softshell, queen snake, northern madtom, black redhorse and eastern sand darter (High); and eastern ribbonsnake, northern brook lamprey, bigmouth buffalo, silver shiner, pugnose minnow, river redhorse and spotted sucker (Medium).

The habitat types used by High priority habitat specialists and by most aquatic species at risk in the Thames River watershed were sandy riffles and pools and gravel riffles and flats. Therefore these two habitat types were given a High priority for conservation.

Of the numerous threats, most acting in combination, faced in the Thames River watershed by aquatic species at risk, siltation, water quality and habitat loss were factors facing the majority of these species. Therefore, recovery efforts for the aquatic species at risk should focus on these factors.

Subwatershed groups were prioritized for conservation efforts (those containing a higher diversity of species at risk) and these High priority subwatershed groups were found to be: Medway, Dorchester, Middle Thames and Komoka-Chatham. Using information on geology, forest cover, drainage and water quality, six subwatershed groups were found to be the most degraded: Dingman Creek, Avon, Dorchester, River Bend, Trout Creek and North Mitchell. Therefore, rehabilitation efforts should be focused on these areas. The Chatham-mouth subwatershed group was noted has having the greatest loss of the number of species at risk from historical records, and therefore research in this area is required to confirm the loss, or to determine the cause(s) for the decline.

## CONCLUSIONS

There are valid concerns about the ability of the Thames River to maintain and sustain its diverse aquatic population. The Thames River is situated in a highly developed urban and rural sector of southern Ontario and faces problems from land uses supporting a large human population. The water quality of the Thames and its tributaries has been drastically affected in the past century as a result of this human activity.

Information from this synthesis report, Aquatic Species at Risk in the Thames River Watershed (Cudmore et al. 2004), the Background Study for Nomination under the Canadian Heritage Rivers System (UTRCA 1998) and Upper Thames River Watershed Report Cards (UTRCA 2001) will be used to prepare an ecosystem recovery strategy for the 25 aquatic species at risk in the Thames River watershed. This ecosystem recovery strategy will outline recovery goals, objectives, strategies and actions for addressing the issues and threats facing the Thames River watershed and its aquatic species at risk. As information continues to be gathered from ongoing work, any updated information will be presented in the recovery strategy.

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## GLOSSARY OF TERMS

Alluvium – recent deposits by modern rivers and streams, highly variable in texture.

Benthic Invertebrates - organisms such as insects and worms that lack backbones and live all or part of their life cycle in the sediments or bed of a watercourse or water body.

Conductivity – a measure of the ability of a substance (e.g. water sample) to conduct an electrical current. The greater the concentration of dissolved solids, the higher the conductivity, and the higher the indication of pollution.

Drain – either open ditches or closed systems such as pipes or tiles buried in the ground, that serve to remove excess water from the land.

FTU (Formazin Turbidity Units) – standard unit of turbidity measurement, where the intensity of scattered light of a sample of water is compared against a standard sample of formazin (hydrazine sulfate and hexamethylenetetramine) dissolved in distilled water. The FTU is gradually being replaced by the NTU (Nephelometric Turbidimeter Unit).

Morraine – a knobby ridge of either boulder clay built by a thrust of a glacier or gravel and sand deposited at the edge of a glacier by escaping meltwater.

Riparian Zone – an area of 20 metres on either side of the watercourse.

Spill – the release into the natural environment of a pollutant that originates from a structure, vehicle, or other container, and that is abnormal in light of all circumstances (Ministry of the Environment). The study (The Upper Thames River Watershed Report Cards 2001) included municipal, industrial and agricultural spills.

Spillway – channel created by flowing glacial meltwater.

Till – a mixture of clay, sand, pebbles, and boulders deposited by a glacier, often occurring in layers that reflect the history of the glacier.

Turbidity – A measure of the degree to which light is scattered by suspended particulate material and soluble coloured compounds in the water. It provides an estimate of the muddiness or cloudiness of the water due to clay, silt, finely divided organic and inorganic matter, soluble coloured organic compounds, plankton, and microscopic organisms.

Watershed – an area of land drained by a river and its tributaries and including each river's headwaters and deltas (where the river enters a lake); line of separation between waters flowing to different rivers, basis or seas.