Research Site

The 10.5 km^2 TLW is located approximately 60 kilometers (km) north of Sault Ste. Marie, Ontario and at the northern margin of the Great Lakes - St. Lawrence forest region. The relatively undisturbed, uneven-aged tolerant hardwood forest is dominated by mature to over-mature sugar maple that is over 150 years old. Minor components include yellow birch, red maple, ironwood, white spruce and white pine. On upland sites, ninety percent of the basal area is sugar maple, 9% are other hardwoods, and 1% is conifer. On lowland sites, the conifer proportion is greater. There has been no disturbance since a mid-1950s harvest of veneer/sawlog quality yellow birch and white pine. Stands regenerate through gap dynamics and are in equilibrium as far as above-ground net phytomass accumulation. Gross growth is significant but mortality offsets growth gains.

The drainage system consists of many first-order streams that drain through four lakes, supporting lake and brook trout communities. The four lakes, Batchawana, Wishart, Little Turkey and Turkey Lakes, are connected by Norberg Creek, which drains into Lake Superior via the Batchawana River. The lakes range from 5.8 hectares (ha) (Batchawana South) to 52 ha (Turkey) in area, and from 4.5 meters (m) (Wishart) to 37 m (Turkey) in depth. The relatively high amount of precipitation received at the TLW causes the lakes to flush fairly rapidly. Water renewal times vary from 0.2 years at Wishart to 1.2 years at Batchawana North.

The terrain is rugged with total relief of 300 m from Batchawana Mountain (626 m) to the watershed outlet. The site is underlain by metamorphic silicate bedrock, with minor occurrences of granitic materials and is overlain with glacial tills of variable depth. Soils have developed in a stony, silty-loam ablation till that overlies bedrock or sandy, compacted basal till. TLW soils are predominately podzolic with well-developed organic horizons (LFH layers) and accumulation of organic matter (10%), iron and aluminum in the B horizon. The pH of the mineral soil is 4.0 at the surface, increasing to 5.5 at depth.

The watershed's high relief and leeward position relative to Lake Superior influences the quantity of precipitation at the site. Annual total precipitation has ranged from 893 millimeters (mm) in 1997 to 1542 mm in 1988 with a mean of 1198 mm. The TLW is showing evidence of climate change. The annual mean daily air temperature, 4.5 °C, has been increasing since 1980 at a statistically significant rate of 0.118°C per year and the amount of annual precipitation is decreasing, although not at a statistically significant rate.

The site is reserved for research use by the OMNR and remains exempt from commercial forestry and mineral exploration. A base camp is located near the watershed; electricity for laboratories, office space and living quarters is provided by diesel generators. Analyses of water, soil and vegetations samples are performed by dedicated scientists and technical staff in the Water Chemistry Laboratory and Forest Soils Laboratory at the Great Lakes Forestry Centre (GLFC) in Sault Ste. Marie.

For More Information

For more information about the Turkey Lakes Watershed Study, data and publications, contact:

Natural Resources Canada (NRCan)
Communications Branch, Ontario Region
(705) 541-5596

Visit: www.tlws.ca

Turkey Lakes Watershed

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History

Established in 1979, the Turkey Lakes Watershed Study (TLWS) is one of the longest running ecosystem studies in Canada. Researchers from Natural Resources Canada, Environment Canada and Fisheries and Oceans Canada established the research watershed to evaluate the impacts of acid rain on terrestrial and aquatic ecosystems. Since its inception, the study has taken a multi-disciplinary approach to investigating the processes that govern ecosystem responses to natural and anthropogenic perturbations.

Partnerships and collaboration are part of the founding principles behind the TLWS. Researchers from the Ontario Ministry of Natural Resources (OMNR) and various universities have made significant contributions to the study. Its goal has been to improve our ability to measure, model and predict effects of human activity on ecosystem function. Over time, research and monitoring have expanded to explore the effects of forest harvesting, climate change, aquatic habitat manipulations and toxic contaminants.

A Steering Committee meets annually, deliberating on cost-shared agreements associated with common field and laboratory infrastructure, field operations and safety, research proposals; promoting joint publications and maintaining an overall publication list; and organizing occasional workshops. The Committee is comprised of senior scientists from each agency and serves as a point of contact among researchers. Ongoing support from the Government of Canada has allowed research across a range of disciplines, in turn attracting funding opportunities from outside sources. The longevity of the TLW partnership and collaboration provides a unique look at how various environmental stressors have affected an entire forest ecosystem.

Major Objectives

The goal of the TLWS is to obtain a whole-ecosystem analysis of the biogeochemical processes operating at the site. This permits system models to be developed and validated. The holistic approach that has been adopted from the outset allows research to evolve and expand from its original acidification focus to include evaluations of other environmental issues.

Advancement of our scientific knowledge of forest ecosystems and a baseline of long-term environmental data enables study results to inform Canadian governments on environmental policy and forest management legislation.

Achievements

More than 24 scientists work with over 25 years of data from the TLW. Ongoing research and monitoring by researchers from across the country has led to a number of achievements:

» The results from the TLWS contributed to the development of the Canada-U.S. Air Quality Agreement in 1991, which continues to document the recovery from acid rain and influence development of new policy;

» Ongoing contributions to Canadian Acid Rain Assessments, reports initiated by the Canadian Council of Ministers of Environment and Energy to develop a national strategy for acid rain;

» TLWS results are also extensively used in other international fora, e.g. the United Nations Economic Commission for Europe International Cooperative Programs on Acidification and Integrated Monitoring;

» The research and monitoring associated with TLW Harvesting Impacts Project has influenced the development o f revised Forest Management Guidelines in Ontario;

» The production of more than 300 scientific publications;

» Host to a significant number of MSc and PhD theses;

» The collection of scientific partners with common goals and objectives.

Partnership

TLWS is a multi-disciplinary study with cooperative relationships among government, industry, and academia. Each organization has assisted in maintaining the field and laboratory infrastructure needed to develop the consistent, long-term research datasets that are its hallmark. Environment Canada, NRCan, and Fisheries and Oceans Canada are three federal departments with central funding responsibility, while the OMNR bears administrative responsibility for the Crown Land reserve of TLW.

» Water Science and Technology, National Water Research Institute (NWRI), Environment Canada

» Great Lakes Forestry Centre (GLFC), Natural Resources Canada (NRCan)

» Great Lakes Laboratory for Fisheries and Aquatic Science (GLLFAS), Fisheries and Oceans Canada

» Canadian Wildlife Service (CWS), Environment Canada

» Atmospheric Science and Technology, Environment Canada

» Ontario Ministry of Natural Resources (OMNR)

» Laurentian University

» McGill University

» McMaster University

» Ontario Forest Research Institute (OFRI)

» Queen's University

» Trent University

» University of Guelph

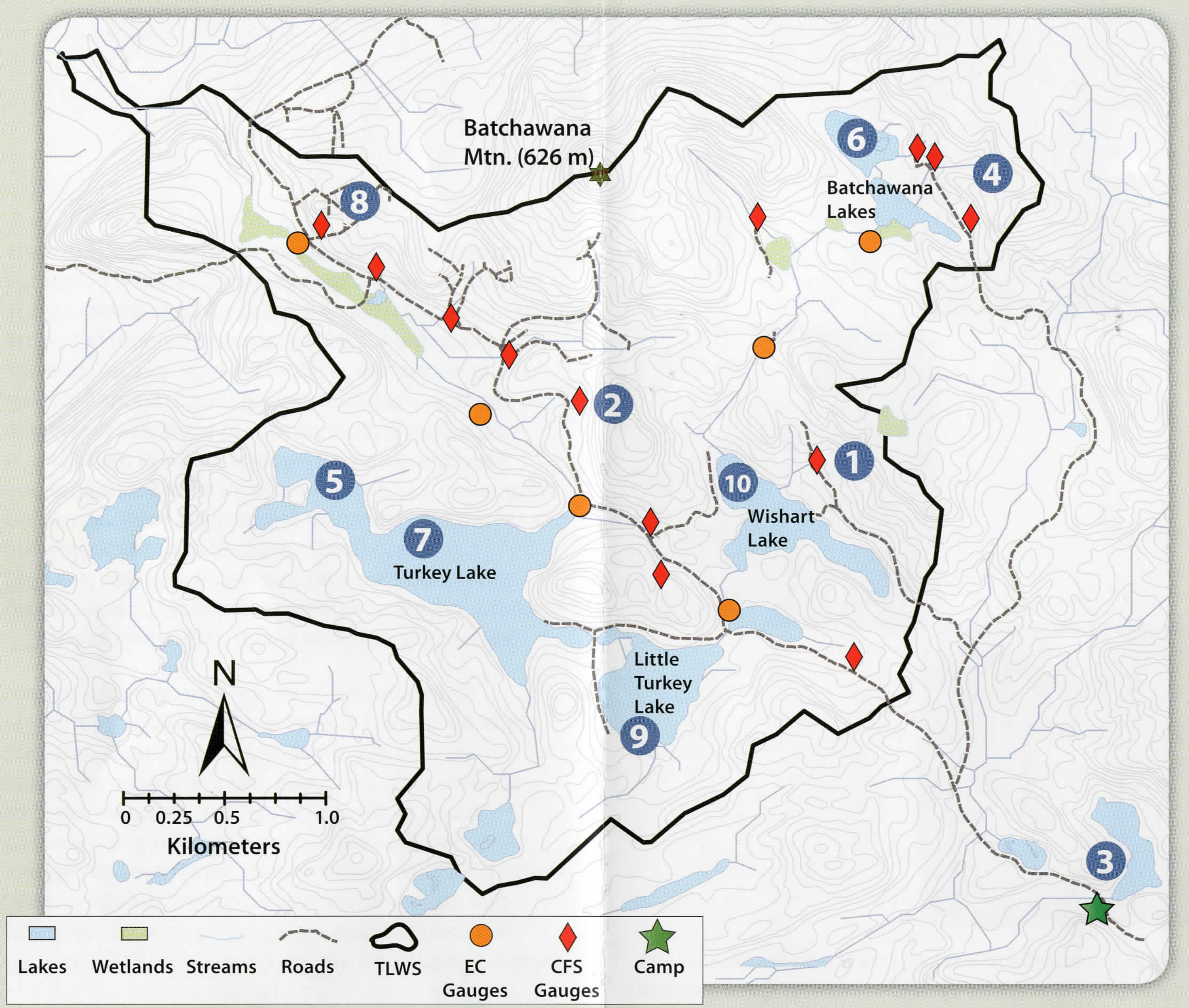
» University of New Brunswick

» University of Toronto

» University of Waterloo

» University of Western Ontario

» Wilfrid Laurier University



❼ Acid Rain Biomonitoring Program

The Canadian Wildlife Service (CWS) has studied the effects of acid rain on waterbirds and their habitats since 1980. Chemistry, food chains (fish, invertebrates) and waterbirds are monitored in 600 lakes, some in the TLW. Lakes tend to be small (< 20 ha, often headwaters), range in acidity (pH), and often lack fish. In the TLW and surrounding Algoma region, small lakes and wetlands are poorly buffered against acidifying pollutants. Common waterbirds include fish-eating species (Common Loon, Common Merganser), dabbling ducks (Mallard, Black Duck) and diving ducks (Hooded Merganser, Ring-necked Duck, Common Goldeneye). Effects of acid rain on waterbirds vary with their foraging habits and lake acidity. Adverse effects arise from shifts in habitat quality or diet, notably for fish-eating species. Some improvements in Algoma breeding habitats are predicted under existing Canadian and U.S. pollution control targets for 2010 but further emissions reductions are needed to protect and enhance the recovery of acid-sensitive lakes across the region.

❶ Soil and Ground Water

Acid deposition and forest harvesting can contribute to forest decline through the leaching of nutrients from the soil. Surface water chemistry can also be affected. Water moving through the soil is sampled using a network of lysimeters and wells. Leaching of base cations from the soil, particularly calcium and magnesium, is related to atmospheric deposition of sulphate and nitrate from reduced vegetation nitrogen uptake after forest harvesting. Organic acids derived from decomposition of plant materials and nitrate from natural processes within the soil also contribute significantly to cation leaching. Ground water chemistry is dominated by weathering of carbonate minerals in the basal till. Adsorption or desorption processes in the mineral soil, buffer soil water sulphate concentrations against annual changes in precipitation sulphate concentrations. The imposition of emission controls has reduced sulphate concentrations in precipitation and has therefore resulted in lower nutrient losses in forest soils. Changes are also regulated by natural soil processes. The chemistry of soil material and the pathway of water through the profile determine the impact of ground water on surface water chemistry.

❷ Stream Monitoring

Since 1980, thirteen headwater streams and Norberg Creek have been monitored for discharge and chemistry. Discharge is continuously measured at weirs or other flow control structures on each stream. Water samples are collected on a weekly to biweekly basis, with more frequent sampling occurring during high flow periods, e.g. spring snowmelt. There is considerable variation in the chemical composition of the streams. At higher elevations, the streams exhibit substantially less acid neutralizing capacity than those at lower elevations. Decreases in sulphate deposition have been mirrored in stream water chemistry, but full recovery from acid rain is not yet complete. The long-term trend in stream discharge (or runoff) reflects the warming at TLW since 1980. Due to increases in evapotranspiration, water yield from the headwater basins is declining at a rate of 3% per decade.

❸ Meteorology and Atmospheric Deposition

Meteorological variables (precipitation quantity, snowpack water equivalent, air temperature, relative humidity, wind speed and direction, barometric pressure, and solar radiation) and the chemistry of atmospheric deposition are measured at the Canadian Air and Precipitation Monitoring Network site (CAPMoN) outside of the basin boundary. Oxides of sulphur and nitrogen are the atmospheric pollutants that form the predominant acids in "acid rain". Three types of deposition are measured at the TLW. "Bulk" deposition is that which accumulates in a continuously open collector. "Wet-only" deposition is measured using the CAPMoN collector, which opens only when it is raining or snowing. "Dry" deposition, which occurs when it is not raining or snowing, is estimated using air concentrations of acidifying gases and particles that are measured by drawing air through a filter located 10 m above the ground surface. Sulphate concentrations in bulk deposition have declined at a statistically significant rate of 0.08 mg/L/yr throughout the period of study at the TLW, reflecting reduced sulphur dioxide emissions from upwind sources. In contrast, nitrate concentrations in bulk deposition have changed very little over the same time period.

❽ Forest Harvesting Impacts Study

In 1997, a forest harvesting study was initiated in the lower part of TLW to examine the impacts of partial harvesting systems on biogeochemical processes and forest succession and productivity. Three harvesting systems were tested: a shelterwood cut, removing ~42% of basal area; a selection cut, removing ~29% of basal area; and a diameter limit cut, removing ~89% of basal area. The diameter limit cut was intended as a high impact experimental treatment; this silvicultural system is not used in this forest type. More nutrients were left on site in the form of harvesting residues (e.g. slash) than was removed in logs. Increases in nutrient leaching, primarily nitrate, calcium and potassium, were observed in both soil and stream water following harvest in proportion to the harvest intensity. Short-term (3-5 years) increases in streamflow were observed in all treatments, with the response being proportional to harvest intensity. Partial harvesting at up to 42% basal area removal in riparian (streamside) and upland forests did not adversely affect over-stream canopy cover and shade levels, leaf litter (food resource) inputs, fine sediment deposition rates, or aquatic invertebrate communities. Intensive harvesting at about 90% basal area removal did affect all of those in-stream conditions, and ongoing studies are tracking the recovery of aquatic invertebrate communities to that level of disturbance.

❾ Habitat Manipulation Experiment

The goal of the habitat manipulation experiment, initiated in 1998, was to determine the effects of large-scale aquatic habitat losses on the biota in the TLW. The experiment first focused on the effects that the removal of structurally complex woody habitat from the littoral area of the lakes would have on the fish and benthic invertebrate communities. This work is ongoing, and preliminary results indicate that there are limited impacts on the biotic communities. The second part of the experiment focuses on the amount and distribution of coarse wood in the littoral area of these lakes, along with the rate of input from riparian areas.

❿ Long-term Monitoring of Aquatic Biota

Fisheries and Oceans Canada began conducting research on the effects of acid rain on aquatic biota in 1979. The long-term monitoring of the fish communities in the watershed continues to this day. Research focused on the long-term effects of pH changes on the biotic community, particularly focusing on impacts to the fish communities. Many studies, such as determining the body burden of contaminants in fish and *in situ* bioassays of salmonid risk to pH fluctuations, were conducted as part of the broad research program.

❹ Snowpack Chemistry

The snowpack that accumulates in the TLW is usually much greater than 1 m deep due to lake effect snowfall. Hence, stream flow generated during spring snowmelt in March and April is almost always the largest hydrological event each year. Snowmelt commonly results in short-term changes in the chemistry of the streams and near-surface waters of the lakes. The release of sulphate and other chemicals that are stored in the snowpack along with simple dilution, contribute to episodic acidification during spring runoff. Snowpack and precipitation monitoring occasionally documents inputs to the TLW that originated from extremely distant sources. For example, dust from the southwest USA and/or Mexico has been identified twice in the snowpack, and radionuclides produced by the Chernobyl reactor explosion in 1986 were detected at the TLW.

❺ Lake Ice Phenology

The duration of permanent lake ice cover has been declining by somewhat less than one day per year. Most of the decline is due to ever-later dates of ice formation in the early winter. Trends in the duration of lake ice have been used as an indicator of climate change.

❻ Lake Chemistry, Trends and Budgets

The input and output of water and chemicals, known as lake mass budgets, have been monitored throughout the study. Due to the geology and geomorphology of the TLW, the headwater lake (Batchawana) has calcium and alkalinity concentrations that are approximately half those observed in lowest elevation lake (Turkey). In contrast, sulphate, which enters the lakes from atmospheric deposition, shows little variation between lakes. The reduced sulphate concentrations in precipitation have caused a general downward trend in the concentration of sulphate and calcium in the lakes. The lakes are therefore recovering from the effects of acid rain, but it will take many years, likely decades, before they re-stabilize. At that time, their calcium concentrations may be lower than historical levels.