Bat Hibernacula in the Karst Landscape of Central Manitoba:

Protecting Critical Wildlife Habitat while Managing for Resource Development

By

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ABSTRACT

The Grand Rapids uplands in central Manitoba is a karst area of intense resource development. Current activities include timber extraction, mineral exploration, a hydro-electric generating station, established and potential hydro-electric transmission lines. Significant features of this karst landscape include 60 known caves, 11 of which provide critical over-wintering habitat for two species of bats, *Myotis lucifugus* and *Myotis septentrionalis* and possibly *Eptesicus fuscus*. The issue that I addressed was how to protect critical wildlife habitat while managing for profitable resource management.

Little information existed prior to this study about the bat hibernacula in central Manitoba. Therefore, baseline temperature and relative humidity data were collected every six hours from October 16, 1999 to May 28, 2000 from four bat hibernacula: Firecamp, Iguana Crypt, Microwave and Cutters Cave. Bat activity was also monitored in each cave over the same time period. Cave temperatures were not constant throughout the winter, and were found to be lower than the anticipated mean temperature of 4-5 °C. The overall mean temperature of Cutters Cave was 1.1 °C, Firecamp was 1.7 °C, Microwave was 2.1 °C and Iguana Crypt was the warmest at 4.8 °C. These overall mean temperatures were found to be significantly different using Duncan's Multiple Range Test. The relative humidity sensors may have become saturated, recording questionable readings of relative humidity above 100%. However, the accuracy of the logger was only 4%. The overall mean relative humidities were calculated to be 96% in Firecamp, 100% in Microwave, 103% in both Iguana Crypt and Cutters Cave.

The Wildlife Branch of Manitoba Conservation issued Bat Hibernacula Management Guidelines in 1996. These guidelines were reviewed during this study and compared with guidelines for karst, caves or bat hibernacula from British Columbia, Alberta, Ontario, Quebec, New Brunswick, Missouri and Alaska. Once a review of these guidelines was completed, best management practices were determined and recommendations made to government, industry and other stakeholders.

Best practices include undertaking a karst management plan for the Grand Rapids area, including a cave inventory and classification system where bat hibernacula would be classified as sensitive habitat. Appropriate management guidelines should be prescribed by an interdisciplinary management committee, which may include prohibiting resource development above or near bat hibernacula (i.e. removed from the commercial land base) as recommended by the BC Ministry of Forests and Alaska Forest Service. The current operating practices of Tolko Industries Ltd., Manitoba Hydro and Falconbridge Ltd. were also reviewed. Currently, only Tolko Industries Ltd. has specific guidelines for working near bat hibernacula, but these are not consistent with guidelines recommended by Manitoba Conservation.

Resource developers should endeavor to implement all provincial guidelines. However, in order to ensure protection of karst features such as caves (especially bat hibernacula) Manitoba Conservation should ensure these guidelines are implemented by including them in work permits under *The Crown Lands Act* and/or drafting them as regulations under the appropriate statute.

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INTRODUCTION

1.0 BACKGROUND

The province of Manitoba is entirely underlain by Precambrian Shield but over top of the Shield lies younger, sedimentary rock that was formed during the Phanerozoic Eon. This younger rock layer is made up mainly of carbonate rock, namely dolomite and limestone. Today, expanses of this carbonate rock layer are exposed in Manitoba's Interlake region and, to a lesser degree, in the Hudson Bay Lowlands (McRitchie and Monson, 2000).

All lands that are underlain by carbonate rocks are considered to be karst lands (USDA, 1997). Karst is a type of topography that develops as a result of the dissolution of soluble rocks, such as limestone and dolomite. It produces a variety of features, including sinkholes and caves. In general, caves can provide habitat for many species of wildlife, including otters, deer, bear, wolves and bats. The use of caves by animals can range from providing deer with a cool place to rest in the summer to providing critical hibernating habitat for bats.

Caves have been found in three main areas of Manitoba – the southern Interlake, Lake St. Martin and Grand Rapids Uplands (Fig. 2). As of 1999, the Speleological Society of Manitoba has located sixty (60) caves in the Grand Rapids uplands. Only eleven (11) of these caves are known to be suitable for use as over-wintering habitat for bats (Asmundson and Larche, 1996). In fact, Twente (1960) examined 500 caves and mines in Utah, and concluded that almost all of them did not have a suitable structure to provide the temperature range needed for bat hibernation.

1.1 Importance of Cave Temperature and Relative Humidity to Bats

"Bats seem to select hibernation sites on the basis of temperature and humidity, but the precise means by which they do this remain unknown and each species has its own optimal conditions" (Brigham, 1993). Therefore, temperature and relative humidity are two important characteristics of bat hibernacula. Bats do not have an extra cache of food stored during the winter, they rely solely on their body fat to survive during the hibernation period. It is therefore critical that they locate hibernation sites (caves) with temperatures between 1°C and 5°C that will allow them to ensure their fat reserves last over this length of time. The sites must be cool enough to keep their metabolism rates low but not so cold as to risk freezing or trigger frequent arousals that could potentially deplete fuel resources (Fenton, 1983).

"Moisture, in the form of humidity, may be even more critical than ambient temperature to hibernating bats. Natural arousals, which probably account for 80-90% of the total drain on fat reserves through the winter, are mediated by water loss." (Brigham, 1993). Bats do not drink during the hibernation period, so a high relative humidity (greater than 90%) is important to prevent bats from dehydrating during hibernation (Fenton, 1983). Bats that hibernate in more humid sites should be able to remain torpid longer than bats in dry sites (Brigham, 1993).

Caves that are selected by bats, therefore, must meet specific requirements in terms of temperature and relative humidity, as well as structure, air circulation and location relative to feeding areas (Hill and Smith, 1992). Caves must be deep enough and have a specific internal microclimate (i.e. relative humidity, temperature, and airflow) in order to provide the conditions necessary to allow for bat hibernation from September through April (Dubois, 1998). These caves provide essential over-wintering habitat for bats as they protect bats from predation, freezing and desiccation. (Asmundson and Larche, 1996).

The three species of bat that hibernate in Manitoba depend on caves for their survival: the little brown bat (*Myotis lucifugus*) (Fig. 1), the northern long-eared bat (*Myotis septentrionalis)* and the big brown bat (*Eptesicus fuscus*). *M. lucifugus* is the species most commonly found hibernating in caves.

Fig.1: The little brown bat (*Myotis lucifugus*) (Tuttle, 1988).

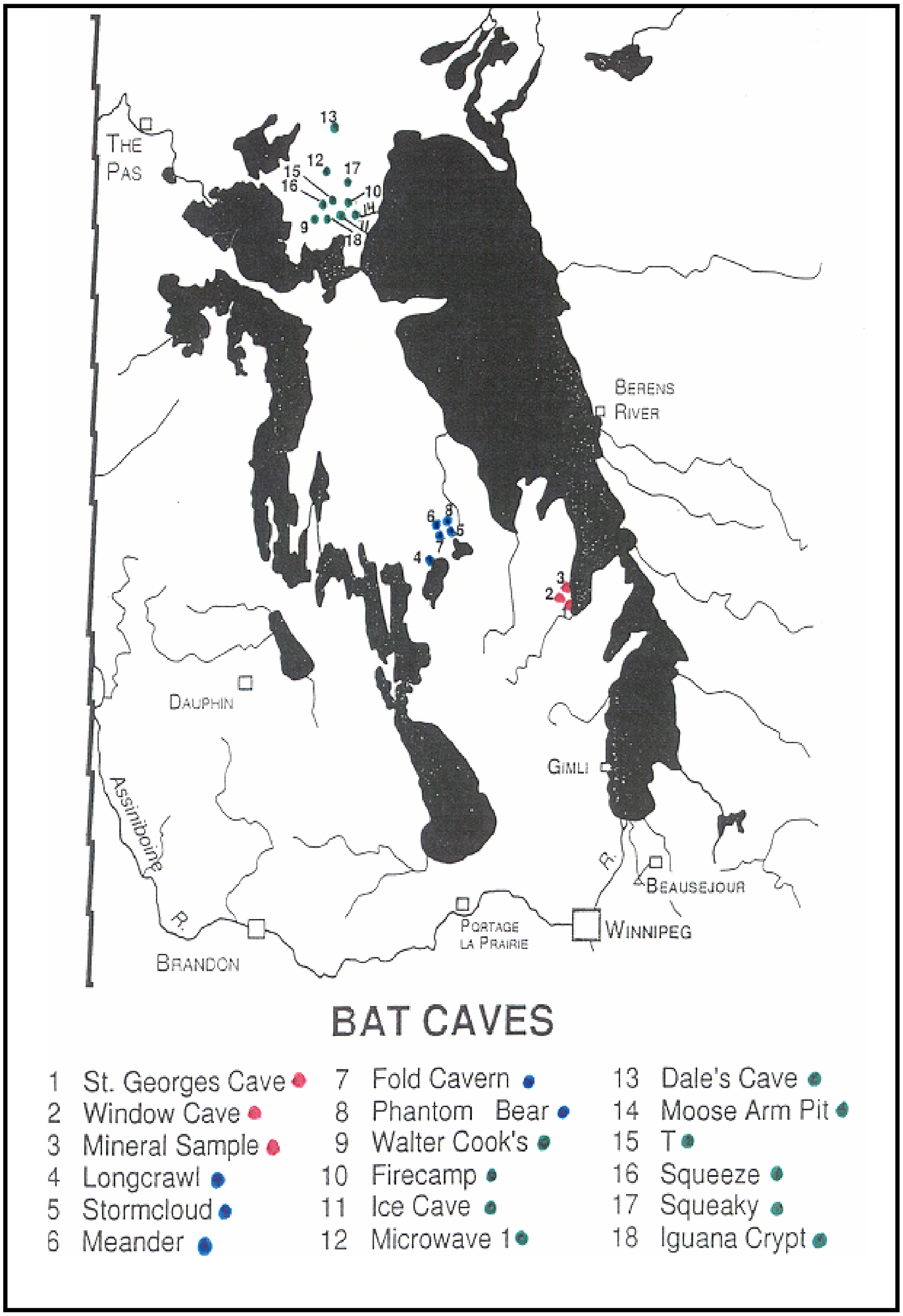

Fig.2: Location of bat hibernacula in Manitoba, including three of the four study caves (Cutters Cave is not shown)(after Asmundson and Larche, 1996).

1.2 THE ISSUE

Very little is known about the ecology of bats in the boreal forest (Repap Manitoba Inc., 1996a). As outlined in Tolko Industries Ltd. Environmental Impact Statement (1996b), the hibernation requirements of bats are site-specific and if these sites (i.e. hibernacula) are adversely impacted, bat population numbers could also be affected.

Whether the removal of trees growing above caves affects the microclimate of the cave (such as temperature and relative humidity) is not clear. However, cave entrances are “sensitive and critical to the cave ecosystem” (USDA, 1997) and if they become blocked or if artificial entrances (i.e. holes) are created, airflow may be compromised which may alter the relative humidity and temperature regime of the cave. Such was the case with the endangered Indiana bat. It is believed that 50% of the population decline was a result of habitat alteration, such that cave entrance alterations resulted in increased temperatures in the cave making them unsuitable for bat survival (Humphrey, 1978 *in* Asmundson and Larche, 1996).

Several caves known to exist in the karst lands of central Manitoba, north of Grand Rapids, provide critical over-wintering habitat for two species of bats. Current resource development in the Grand Rapids uplands is mainly timber harvesting, but there is also some mineral exploration, and the potential for expansion of the current hydro-electric transmission line system. These resource development operations may have an impact upon caves, and especially bat hibernacula, in karst areas. If forest harvesting or mineral exploration takes place on or near a hibernaculum, it may be deserted or destroyed (Asmundson and Larche, 1996). The issue is how to protect critical wildlife habitat while managing for profitable resource development in this fragile karst area.

1.3 RESEARCH OBJECTIVES

This study reviewed and assessed provincial and state management guidelines for the conservation of caves and bat hibernacula in karst areas. Secondly, this study examined the over-wintering habitat requirements of the little brown bat in the Grand Rapids Uplands of Manitoba. The specific objectives of this study were:

1. To describe the known, general effects of resource development on bat hibernacula located in karst areas in other jurisdictions
2. To review the current provincial/state guidelines regarding the management of bat hibernacula in karst areas
3. To determine the operating procedures of resource developers (Tolko Manitoba, Manitoba Hydro and others) working near bat hibernacula in karst areas of central Manitoba
4. To define the characteristics of caves used in central Manitoba as over-wintering habitat for the little brown bat, in terms of temperature and relative humidity
5. To determine the approximate length of the hibernation period of the little brown bat in central Manitoba
6. To incorporate Traditional Ecological Knowledge, regarding bats and bat hibernacula, of Aboriginal and local people residing in and around Grand Rapids
7. To compare the current operating procedures of resource developers in karst areas of central Manitoba with "best practice" operating procedures in karst areas elsewhere (as determined from the guideline review); and
8. To make recommendations to Manitoba Conservation, Tolko Industries Ltd., and Manitoba Hydro for the mitigation of potential resource development impacts on bat hibernacula.

1.4 NEXT STEPS

To address the issue and undertake the objectives identified in this chapter, relevant literature was reviewed and is presented in the next chapter. Research methods are described in Chapter 3, results are presented in Chapter 4 and discussed in Chapter 5, conclusions and recommendations are outlined in Chapter 6.

2.0 KARST TOPOGRAPHY

Karst topography represents approximately 20% of the earth's land surface and can be found in two main types of carbonate rock – limestone and dolomite (White *et al*., 1995). Karst topography is found throughout the Interlake region of Manitoba (Fig. 3), and represents a unique landscape of Canada, and possibly the world. The karst topographic features found here, while not uncommon features in themselves, are rare to the semi-arid continental climate and flat terrain characteristic of the Interlake (Sweet *et al*., 1988).

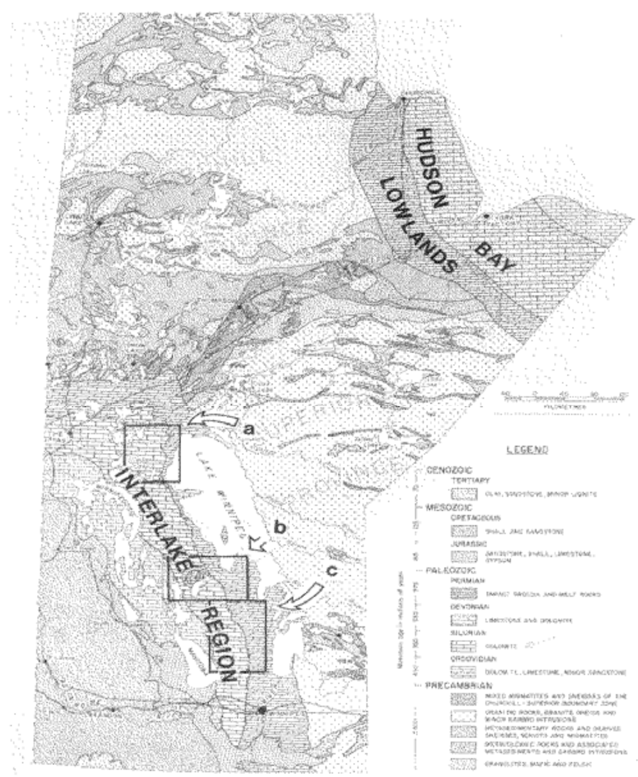

Figure 3: Map showing the limestone/dolomite areas of Manitoba, and three locations in the Interlake Region where caves are known to exist (McRitchie and Monson, 2000).

"Karst landscapes are complex three-dimensional integrated natural systems comprised of rock, water, soil, vegetation, and atmosphere elements (Fig. 4). Nearly all of the karst solution process is moderated by factors operating on the surface of the karst and in the upper skin of the rock" (Gillieson, 1996). Surface vegetation regulates the flow of water into the karst system: leaf litter intercepts the water, and roots affect soil infiltration. The metabolic uptake of water by plants, especially trees, may regulate the quantity of water available to feed cave formations. Surface actions become subsurface environmental impacts primarily through the transfer of water in the karst system.

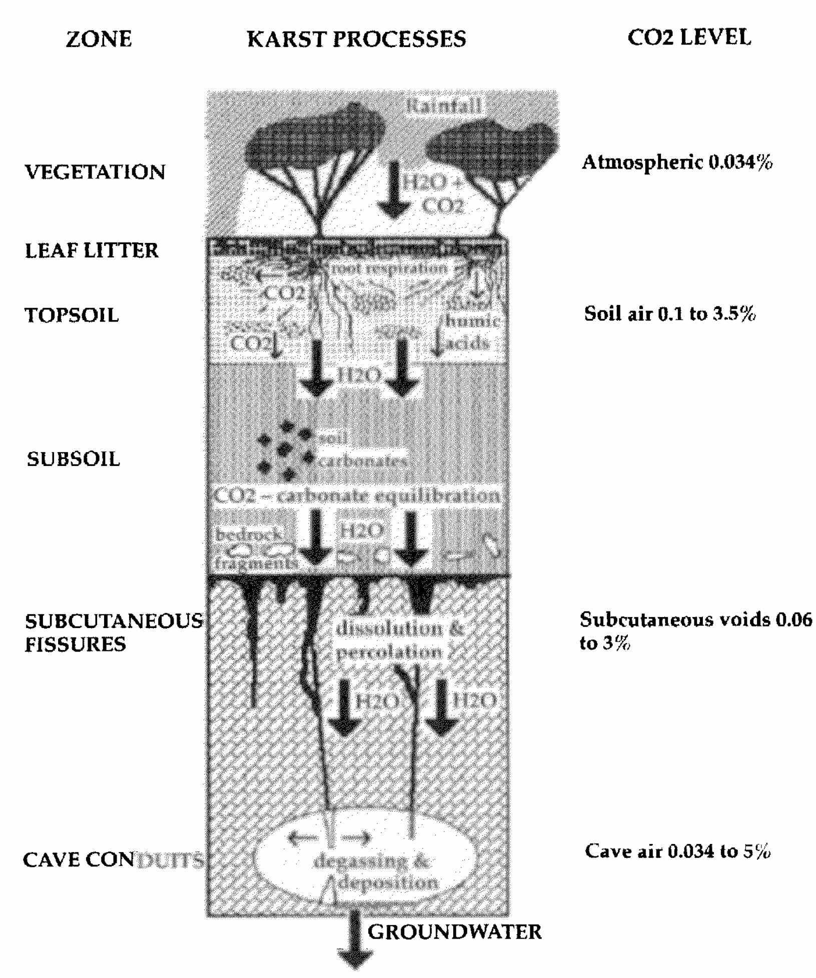

Figure 4: Formation of karst landscapes (Gillieson, 1996).

It is important to note that a key characteristic of a karst area is that the surface and subsurface are interconnected (Aley, 1990 *in* Gill, 1991), and therefore, environmental problems, such as the contamination of groundwater, are heightened in karst lands. Pollutants are quickly conveyed, with little to no filtration, from areas of recharge (sinkholes) to areas of discharge (springs or wells) (Kastning, 1995a).

Karst lands, therefore, add another dimension to land-use planning - a vertical, underground dimension. The surface of karst lands is pockmarked by fissures that become points of entry into the subsurface below. Water and sediment are rapidly transferred to the underground system which may then emerge at distant springs, across surface watersheds (USDA, 1997). Many springs and streams are discharged from the base of a 100-km long escarpment in the Grand Rapids uplands area to flow east into Lake Winnipeg (McRitchie and Monson, 2000).

Karst is produced by the action of water on limestone and dolomite, resulting in dissolution that allows the development of internal drainage, the production of sinking streams and closed depressions. Below the surface, these drainage paths become enlarged and can result in systems of conduits, some of which form caves (White *et al*., 1995).

There have been 60 caves located and explored in the Grand Rapids uplands (McRitchie and Monson, 2000), with many more likely to be discovered. Caves provide a stable environment over extended periods of time and, therefore, can provide habitat for complex and interacting populations of organisms (White *et al*., 1995).

2.1 Bat Hibernacula

The karst lands north of Grand Rapids provide essential over-wintering habitat to *Myotis lucifugus* and *Myotis septentrionalis* and possibly *Eptesicus fuscus* in the form of underground caves. While there are close to 60 surveyed caves in the Grand Rapids uplands only 11 are known to be used as hibernacula (McRitchie and Monson, 2000).

There are a variety of possible criteria involved in hibernacula selection by bats. The cave must be deep enough and have a suitable structure that provides for the necessary microclimatic conditions (temperature, relative humidity, and air flow). Raesly and Gates (1987) found that *Myotis lucifugus* chose hibernacula (caves and mines) located in Maryland, Pennsylvania and West Virginia that were large in passage length and height and had regions of low ambient temperature (minimum ambient temperature was found to be –0.7 °C and maximum ambient temperature was 11.6 °C). Hibernacula should have a high relative humidity and a cool ambient temperature to keep the bat's metabolism low, but warm enough to prevent the bat from freezing (Fenton and Barclay, 1980). High humidity is an important factor because of the potential for water loss through respiration or evaporative water loss from the body surface resulting in dehydration (Fenton, 1970).

Davis *et al.* (2000) found that hibernacula located on northern Vancouver Island are characterized by winter microclimatic temperatures of 3-4°C and relative humidity close to 100%. Fenton (1970) suggests that the optimal humidity for hibernating *Myotis lucifugus* is above 85%. However, Raesly and Gates (1987) have also suggested that in addition to microclimate and physical structure, the external habitat such as the location of foraging areas, may play an important role in hibernacula selection. They conclude, "roost selection is not a simple process involving only a few microclimatic variables".

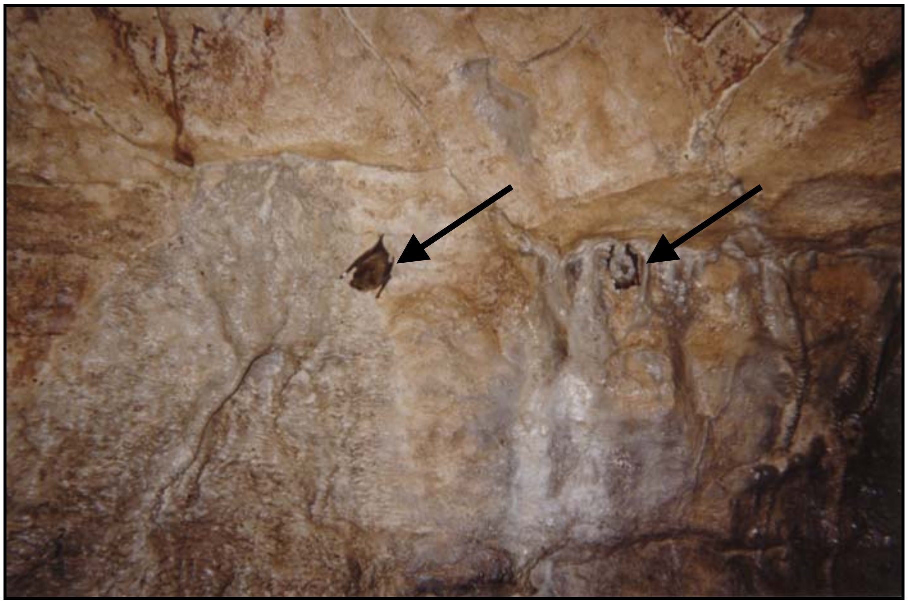

Plate 1: A dormant (right) and active bat (left) in Iguana Crypt.

In addition, the cave must provide a degree of safety from predators, especially red squirrels *(Tamiasciurus hudsonicus*), as torpid bats are defenseless. In fact, torpid bats appear to be dead. Their breathing is imperceptible and their heart rate is very slow (25 bpm versus 400 bpm when active). Their bodies are cold to the touch and often covered in condensation (Yalden and Morris, 1975) (Plate 1).

Several characteristics of the little brown bat and the northern long-eared bat (e.g. long-lived, nocturnal habits, low reproductive rates and non-cyclical populations) allow these bats to maintain stable population levels within stable habitats. However, these same traits may cause their populations to be vulnerable when their habitat is altered (Findley, 1993; Parker *et al*., 1995).

2.2 THE ECOLOGICAL SIGNIFICANCE OF BATS

All six bat species in Manitoba are obligate insectivores and may be important components of the temperate forest ecosystem as regulators of insect populations (Thomas et al., 1999). They are beneficial to humans by feeding on nocturnal insects such as mosquitoes and agricultural pest species, consuming greater than 50% of their body weight in insects each night (Brigham, 1993).

In autumn (usually the middle of August) the phenomenon of the mating swarm begins (Fenton, 1970). Bats return to hibernation sites to mate, hence the caves of the Grand Rapids uplands are important for two aspects of the bats' life cycle - reproduction and hibernation. "The conservation of bats is only possible if the critical habitats and resources they depend on are protected" (Brigham, 1993).

The hibernation period comes to an end around April or May. The males disperse throughout the province but the pregnant females roost together in maternity colonies. These can be hollow trees but are often house attics. These summer roosts have warm ambient temperatures to promote rapid growth of the newborn bats (Brigham, 1993). All bats have a very low reproductive rates with most species, including the little brown bat, producing only one young per year (Barclay, 1993).

2.3 STATUS OF BATS IN MANITOBA

There are six species of bats indigenous to Manitoba, and as of 1995 they have all been listed as protected species under Schedule A, Division 6 of *The Wildlife Act*. This designation makes it illegal to capture or kill bats or destroy their habitat. However, bats can be killed or captured to protect personal property or under special permit

(Asmundson and Larche, 1996). Currently none of the bats indigenous to Manitoba are listed as an endangered species under Manitoba's *Endangered Species Act*. According to the Bat Hibernacula Management Guidelines issued by Manitoba Conservation in 1996, little brown bat (*Myotis lucifugus*), silver-haired bat (*Lasionycteris noctivagans*) and hoary bat (*Lasiurus cinereus*) populations are abundant in the province. The population status of the northern long-eared (*Myotis septentrionalis*), the big brown (*Eptesicus fuscus*) and the red bat (*Lasiurus borealis*) were not known as of 1996 (Asmundson and Larche, 1996).

The Manitoba Conservation Data Centre assigns the little brown bat a global rank of G5 (globally abundant and secure) and a provincial rank of S2N,S5B (non-breeding occurrences for the species in the province are rare; breeding occurrences are abundant and secure). The northern long-eared bat has a global rank of G4 (globally abundant and apparently secure, but of long-term concern) and a provincial rank of S3S4N (non-breeding occurrences range between uncommon to widespread and apparently secure, but of long-term concern), S4B (breeding occurrences are widespread and apparently secure, but of long-term concern). Neither are listed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) or under Manitoba's *Endangered Species Act.*

2.4 Hibernation

Winter presents a metabolic challenge to Manitoba's insectivorous bats, as it does to all warm-blooded animals, with low temperatures increasing thermoregulatory costs and energy requirements at a time when food supplies have diminished to little or none (Thomas, 1995). Bats have become adapted for winter survival by either undergoing migration or hibernation. Three of Manitoba's bat species migrate prior to the onset of winter and are only residents from early May until late September: the silver-haired bat, the red bat, and the hoary bat. The other three species remain in Manitoba year-round: the little brown bat, the northern long-eared bat and the big brown bat (Dubois, 1998). These species undergo hibernation throughout the winter months, lowering their body temperatures close to ambient temperature, thereby lowering thermoregulatory costs and reducing their metabolic rates by as much as 99% (Thomas *et al*., 1990; Wang and Hudson, 1971 in Thomas, 1995). Both migration and hibernation are survival techniques critical to the life history of bats (Davis *et al*., 1996).

Bats are one of many groups of mammals that have the ability to undergo controlled hypothermia, a physiological adaptation that allows them to reduce body temperatures close to ambient temperature. As a comparison, black bears (*Ursus americanus*) allow their body temperatures to fall only a few degrees below normal body temperature (31 - 33 °C), whereas some bats can reduce their body temperatures down to 5 °C. When this occurs for several days or longer during winter, it is referred to as *hibernation*. When it occurs for only part of a day (and for the remainder of the day the animal maintains a high body temperature) during any season, it is referred to as *daily torpor*. Hibernation occurs in some bat species, while daily torpor occurs in many bat species. Bats that undergo daily torpor exercise controlled hypothermia (lowered body temperatures) during the day, and have higher body temperatures at night, when their energy demands are greatest (Hill and Wyse, 1989).

Bats are unique mammals because they have the capability of true flight. Flight benefits the bat by allowing it to travel at a much faster rate and at a lower energy cost than it could be achieved travelling an equal distance on the ground. However, their flight adaptations do not lend themselves to building nests or tunneling, so they must rely on natural sites such as caves or trees for roosting and hibernation (Altringham, 1996). In fact, bats are the "only group of vertebrates that are well represented in caves" (Dwyer, 1971).

Of the three bat species that over-winter in Manitoba, only one, *Eptesicus fuscus*, has not yet been found to use caves as hibernacula (Asmundson and Larche, 1996). The other two species, *M. lucifugus* and *M. septentrionalis,* do rely on caves and Dubois (1998) reported that less than 1% of the bats banded in one hibernaculum have ever been found in another.

2.5 Resource Development in the Grand Rapids Uplands

2.5.1 Timber Harvesting

The Grand Rapids uplands region is located on both productive and non-productive forested lands; the area is dominated by jack pine (*Pinus banksiana*), black spruce (*Picea mariana*), and trembling aspen (*Populus tremuloides*) (Gill, 1991). All of the bat hibernacula in this study are located within Forest Management Licence Area No. 2 held by Tolko Industries Ltd. (formerly, Repap Manitoba Inc.). Specifically, they are found within Unit 51 and Unit 53 of the Saskatchewan River Forest Section. The clear-cut method of harvesting is employed on the landscape (Plate 2 & 3).

Since this study was initiated, Iguana Crypt has been protected from all resource development, including forestry operations. Iguana Crypt, along with five other caves (including another bat hibernaculum), lie within a 3200-hectare area that was declared the Walter Cook Upland Caves Park Reserve in December, 2001.

Plate 2: Forestry operations near Grand Rapids.

Plate 3: A clear-cut logging area on the karst landscape.

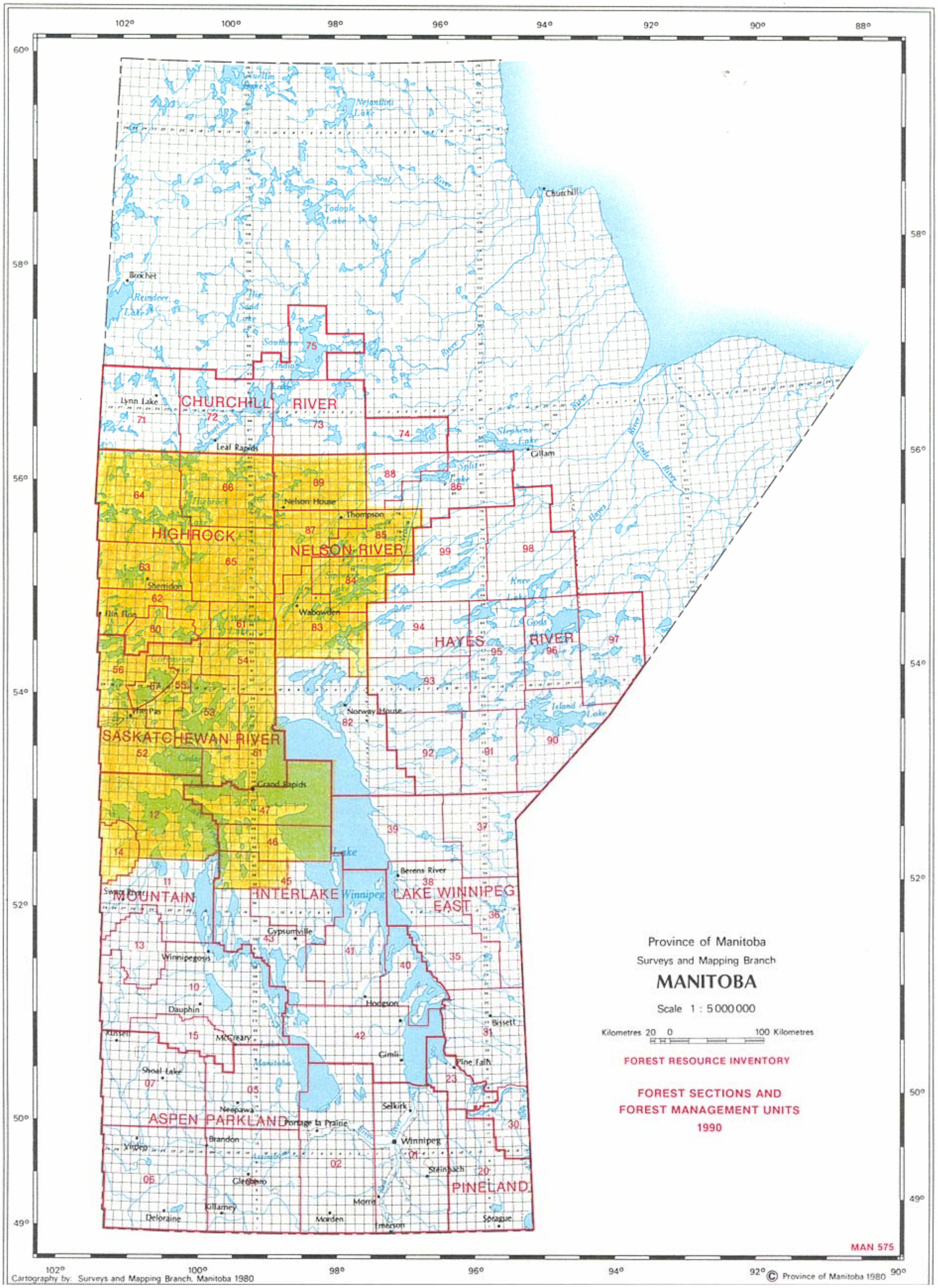

Figure 5. Tolko Industries Ltd. Forest Management Licence Area No. 2. (Manitoba DNR, 1990)

2.5.2 Hydro-Electric Transmission Line Expansion

The Grand Rapids uplands is located within a major conduit of hydro-electric power extending between northern and southern Manitoba. Grand Rapids itself has a hydro generating station that is located on the Saskatchewan River and has a capacity of more than 472 Megawatts. It also acts as the controlling station for Manitoba Hydro's entire power system. Initially, two transmission lines were constructed to transmit electricity from the Grand Rapids generating station to the Dorsey Converter Station at Rosser, Manitoba. There were additional transmission lines added later, including a line north to Ponton, Manitoba that connects to the northern generating stations on the Nelson River (Manitoba Hydro, 1997) (Fig. 6).

A transmission line is located within a right-of-way (ROW), or a cleared area of land between 40 and 80 meters in width (Plates 4 & 5). Where multiple transmission line facilities are necessary, the ROW is wider. The removal of trees and shrubs changes the vegetation cover for the entire width of the ROW. Subsequent vegetation growth is controlled either mechanically or through the use of selective herbicides (Berger, 1995).

"If new [hydro-electric] generation is developed in the north there will be a need for new transmission lines to the south" (Mason, 2003). If Manitoba Hydro were to expand its current network of transmission lines through the Grand Rapids uplands region, there could be a potential impact on the underlying caves. The construction of transmission lines involves the clearing of trees, digging of borrow pits and the use of heavy machinery (Berger, 1995). Subsequent impacts would be similar to those caused by timber harvesting and mineral extraction operations. While the Bat Hibernacula Management Guidelines (1996) are not specific to hydro-electric transmission line construction, Manitoba Hydro does have a series of environmental protection measures that are employed during transmission line projects.

Plate 4: Example of a right-of-way for hydro-electric transmission line, showing access road.

Plate 5: Hydro-electric transmission lines along Highway #6 north of Grand Rapids.

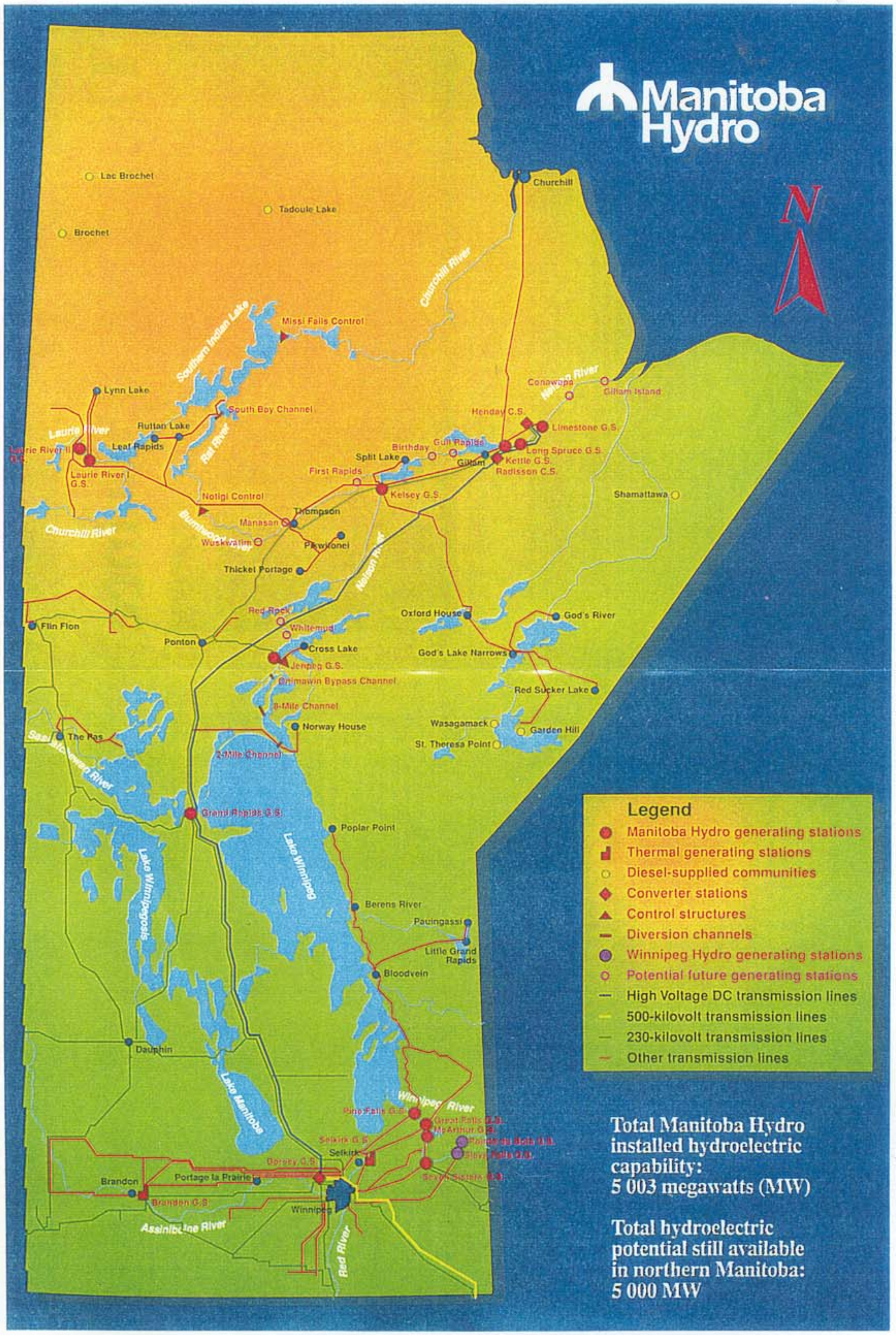

Figure 6: Distribution of Manitoba Hydro transmission lines in the study area (Manitoba Hydro, 1998).

2.5.3 Mineral Exploration

The Grand Rapids uplands area may overlie nickel-copper deposits and possibly lead-zinc deposits (Gill, 1991). Falconbridge Ltd. currently has seven mineral claims within the study area and there are four mineral exploration licence areas north of the study area (Fig. 7). During this study, Falconbridge Ltd. was undertaking exploratory drilling operations at William Lake, 80 kilometers north of Grand Rapids (Plates 6&7). Drilling is the final phase of mineral exploration. If the first few holes indicate there is a mineral deposit, a series of holes are then drilled to quantify the deposit (determination of length, depth, thickness and grade) (Fogwill and Bamburak, 1986).

Mining operations may have a variety of effects on karst features, especially caves. They may affect the local hydrological regime and/or water quality. Road construction may break down or modify cave entrances. Debris may be dumped directly into sinkholes, or enter a karst system indirectly through the water system. Caves may be directly impacted through excavation. Mining infrastructure such as roads may increase human access to the caves (B.C. Ministry of Lands, Parks and Housing, 1980 in Gill, 1991). Human visitation can result in the disturbance or persecution of cave fauna and vandalism of the cave environment.

Plate 6: Drill site of Falconbridge Inc. located near William Lake.

Plate 7: Other heavy equipment involved in mineral exploration – water en route to drill site.

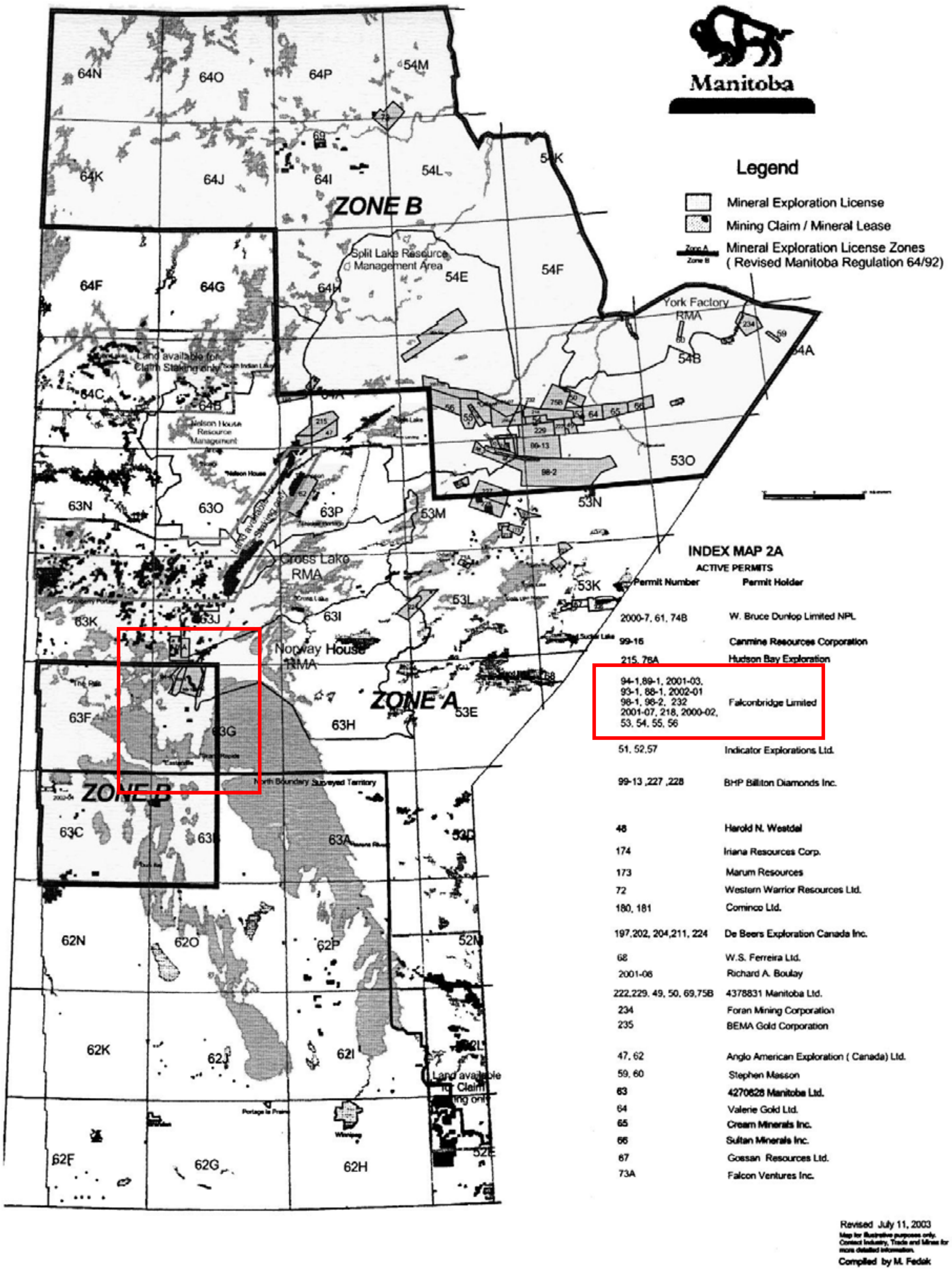

Figure 7: Location of mineral exploration licence areas & mining claims (Industry, Trade and Mine, 2003).

2.5.4 Other Disturbances

It is now known that both tactile and non-tactile disturbance of bats during their hibernation period induces stress and an accelerated energy loss (Thomas, 1995). It has been estimated that one arousal from hibernation uses 108 mg of fat, which is roughly equivalent to the same amount of energy required for 67 days of hibernation (Thomas *et al.*, 1990). Bats naturally awaken periodically throughout their hibernation period, but if these arousals become more frequent due to other disturbances (i.e. presence of predators or humans in the hibernaculum), then their energy reserves may be depleted prematurely and their overwintering survival becomes tenuous.

Vibrations from vehicular traffic may also be implicated in causing unnecessary arousals during the hibernation period. Microwave Cave, in particular, lies in close proximity to an access road. Falconbridge Ltd. carries out the majority of its exploration drilling during the winter months (Robertson, pers. comm.), which corresponds to part of the hibernation period of *M. lucifugus*. While the Forest Management Guidelines for Wildlife in Manitoba (1989) do not make specific reference to bats, they do suggest that all-weather access roads and all long-term seasonal roads avoid identified unique and sensitive wildlife habitat.

2.6 Apparatus for Monitoring Temperature and Relative Humidity in Caves

Elliot and Clawson (1999) used the Hobo H8 Pro Series® data logger to record temperatures and relative humidities of Missouri bat caves used by *Myotis sodalis* and *Myotis grisescens.* The Hobo H8 Pro Series data logger sold by Onset Computer Corporation was used. One logger has two channels for recording both temperature and relative humidity.

The rationale they provided for using this equipment in their study was that these loggers are weatherproof, have an advertised accuracy of $\pm$ 0.2°C and $\pm$ 3% RH and have a memory capacity of 64K. However, they encountered problems with a build-up of resistance in some of the 3.6-volt lithium batteries that caused some of the loggers to not work properly. Onset now uses a different brand of batteries in their loggers to avoid these problems. As well, they found that the loggers recorded relative humidity levels up to 105%, which is not feasible.

Elliot and Clawson (1999) mounted the loggers on the ceiling using screw anchors, drills and hand tools. A thin disc of clay was placed between the logger and the rock to keep the logger in close contact with the cave wall. This was done so the logger would equilibrate more with the rock temperature rather than the air temperature as it is hypothesized that *Myotis sodalis* and *Myotis grisescens* choose the location of their roost based on rock temperature, not air temperature. They also recorded ambient air temperature outside of the cave entrances

Martin Davis (2000) did a similar study on Vancouver Island. He did not specify which brand of data loggers he used, only that he placed pairs of temperature and relative humidity loggers in caves and on surface sites at sea level, mid-elevations and high elevations. They were placed at 10 meters and 100 meters, respectively, within the caves. He did not indicate how they were fastened to the rock, if at all.

2.7 Summary

This literature review indicates that the Grand Rapids uplands is an area of intense resource development (Fig. 8). It is also a fragile karst landscape that provides critical cave habitat for some species of bats. It identifies threats to this habitat and other studies that have been undertaken (including a review of equipment used) to better understand why only certain caves are chosen as hibernacula.

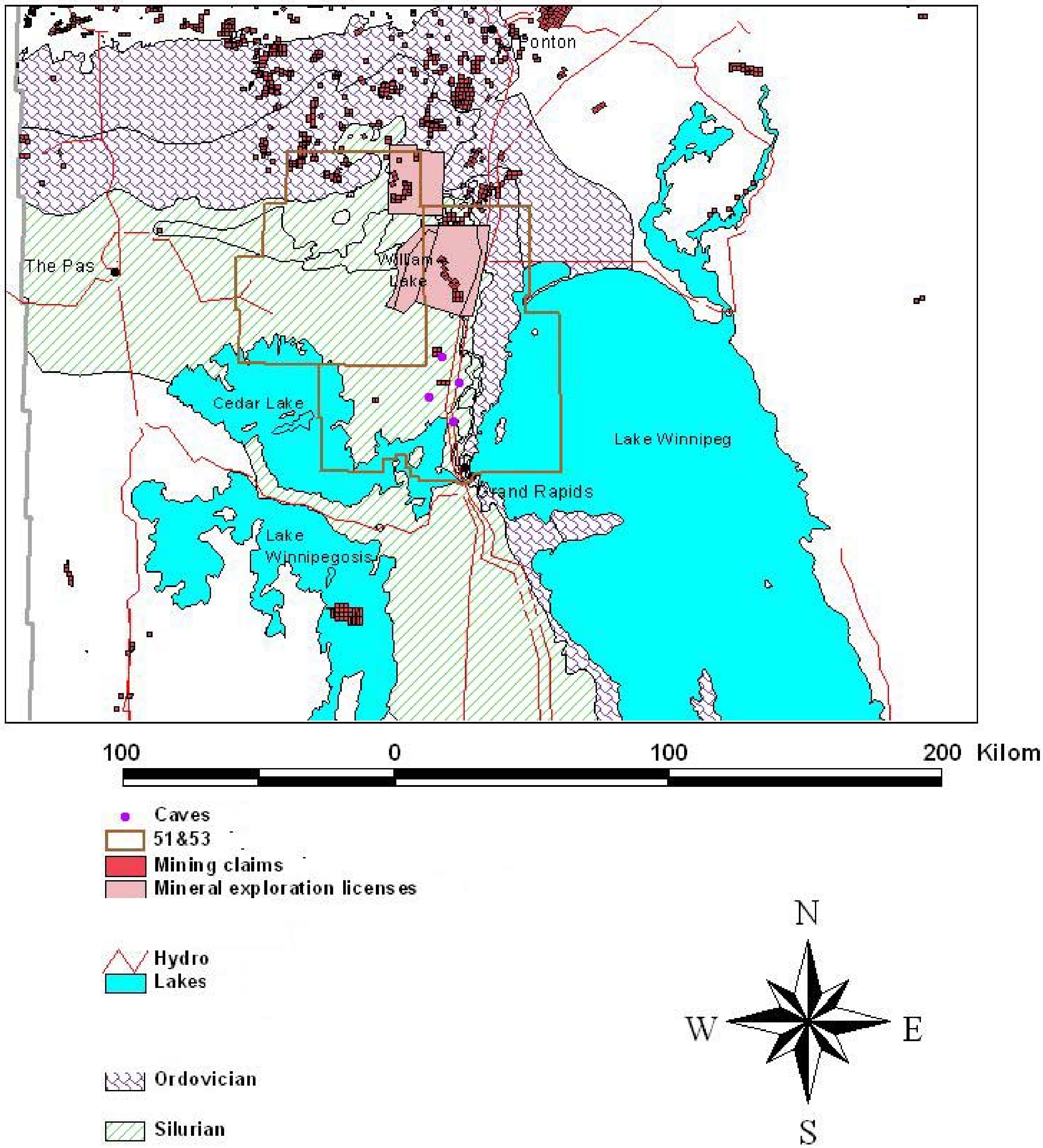

Figure 8: Map of the Grand Rapids uplands showing the various types of resource development in the area: Forest Management Units 51 and 53, mining claims, mineral exploration license areas, hydro-electric transmission line corridors as well as the location of the four study caves.

3.0 OVERVIEW OF RESEARCH METHODS

This study combined a literature review with fieldwork. Prior to this study, little information existed specific to the bat hibernacula in the Grand Rapids uplands. Of the sixty (60) caves that had been surveyed in the Grand Rapids uplands when this study was started, eleven (11) are known to be bat hibernacula. Of these eleven hibernacula, four (4) were chosen for this study: Iguana Crypt, Microwave, Firecamp and Cutters Cave.

Field research was carried out to determine the temperature and relative humidity regimes of the four caves and to determine when the bats were using the caves for over-wintering habitat. This information may provide a more accurate indication of the critical hibernation period during which time bats should not be disturbed. These data were used in conjunction with information from the literature to provide a more complete understanding of the over-wintering habitat requirements of bats in Manitoba.

Karst topography occurs worldwide, therefore the issues associated with management of this landscape are also global. A literature review was conducted to determine the possible effects of resource development on the over-wintering habitat of bats. A review of current guidelines associated with the management of bat hibernacula in karst areas was incorporated into this study. As well, a review of the operating procedures undertaken by resource development companies working near bat hibernacula in the Grand Rapids Uplands was also undertaken.

Informal personal interviews were conducted with Aboriginal people and local residents of Grand Rapids. Aboriginal people have a special knowledge and understanding of wildlife that should be reflected in management programs (Wildlife

Ministers' Council of Canada, 1990). Local people whose families have lived in the area for generations may also provide information about changes on the landscape and subsequent changes in wildlife populations over time.

3.0.1 Temperature and Relative Humidity monitoring

In each of the four study caves, one HOBO H8 Pro Series data logger**,** to measure and record temperature and relative humidity, was deployed on October 16, 1999 and removed May 28, 2000 (Plates 8, 9, 11, 13). Refer to Figures 9, 10, 11, and 12 for the location of data loggers within each cave. The relative humidity sensor has an accuracy of +/- 4% in intermittent condensing environments and the temperature sensor has an accuracy of +/- 0.4 ° C.

To protect the data loggers from water droplets, a housing unit was constructed from empty plastic (margarine) containers with rectangular openings cut just beneath the rim to allow for airflow. The back of the logger was secured to the bottom of the container by glue and Velcro. The containers were placed upside down on rock ledges in the caves, such that the data logger was suspended above the ledge. This protective housing is similar to the "rain shields" marketed by the manufacturer.

3.0.2 Bat Activity

In each of the four caves, one Trailmaster 550 Passive Infrared Game Monitor®, to record bat flight movements, was deployed on October 16, 1999 and removed on May 28, 2000 (Plates 8, 9, 12). Refer to figures 9, 10, 11 and 12 for the location of game monitors in each cave. Electronic monitoring is discreet and a less disruptive method than cave inspection for studying bat movements (Davis *et al,* 2000).

Plate 8: Researcher placing instruments in Iguana Crypt.

Plate 9: Data logger and game monitor in Cutters Cave.

Plate 10: Game monitor in Firecamp Cave.

Plate 11: Data logger in Firecamp Cave.

Plate 12: Game monitor in Microwave Cave.

Plate 13: Data logger in Microwave Cave.

3.0.3 Local Knowledge of Bats and Caves

Two sampling methods were undertaken to acquire local knowledge about caves, bats and bat hibernacula from members of the Grand Rapids First Nation and residents of the town of Grand Rapids in February 2001. The first method employed was the "snowball" sampling method in which an initial participant lead the researcher to other participants who then lead the researcher to additional participants.

The second method used was the "convenience" sampling method, also known as the "haphazard" or "accidental" sampling method. This method finds participants who are most conveniently available at the time. This method was used during a Manitoba Conservation Parks and Natural Areas open house that the researcher was asked to assist with. The open house provided information to local residents about unique karst features, including caves, and biological resources, including bats, that exist near Grand Rapids. The objective of this open house was to elicit support for the protection of some of these resources through the establishment of a provincial Ecological Reserve.

3.1 THE STUDY AREA

The study area is located north of Grand Rapids in the Interlake region of Manitoba. It lies within the Mid-Boreal Lowlands Ecoregion of the Boreal Plains Ecozone and is located within Units 51 and 53 of the Saskatchewan River Forest Section of Forest Management Licence Area No. 2 (Repap Manitoba Inc., 1996a).

3.2 THE STUDY CAVES

A sample of 4 bat hibernacula ("study caves") was chosen from a population of 11 known bat hibernacula in the Grand Rapids uplands. These easily accessible hibernacula were chosen in consultation with Mr. Jack Dubois and they represent the variety of situations present in the karst area. Iguana Crypt is surrounded by forest cover, Cutters Cave is surrounded by a clear-cut area, Firecamp lies in a forested area adjacent to an open area that burned in a forest fire, and Microwave lies in a forested area but in close proximity to an access road. The four caves are described in detail below.

3.2.1 Microwave Cave

Microwave Cave was first surveyed in 1988, but discovered a few years earlier. The cave entrance lies next to a logging road, but is otherwise buffered by trees (Plate 14). It is 24.6 meters in length and 9.8 meters deep (Sweet *et al*., 1988), with a small entrance in flat-lying dolomite pavement that opens into an 8-meter deep shaft (Plate 15). The walls of this cave are highly fractured. The sloping floor at the bottom of this cave leads to a smaller second shaft that slopes upward towards the road, but does not quite reach the (Fig. 9).

Water is often associated with this cave, and standing water levels may fluctuate from 0 to 3 meters (Sweet *et al*., 1988). During summer storms, this cave acts as a sump for the low-lying areas around it. The surface run-off has been so great that at times the entrance shaft has been described as a "cascading waterfall". Bats have often been found in this cave (McRitchie and 2000). The population of bats occupying this cave was estimated from 5 counts done between May 1989 and May 1998. The estimated average number of individuals was 116 (range = 30-174; Dubois, pers. comm).

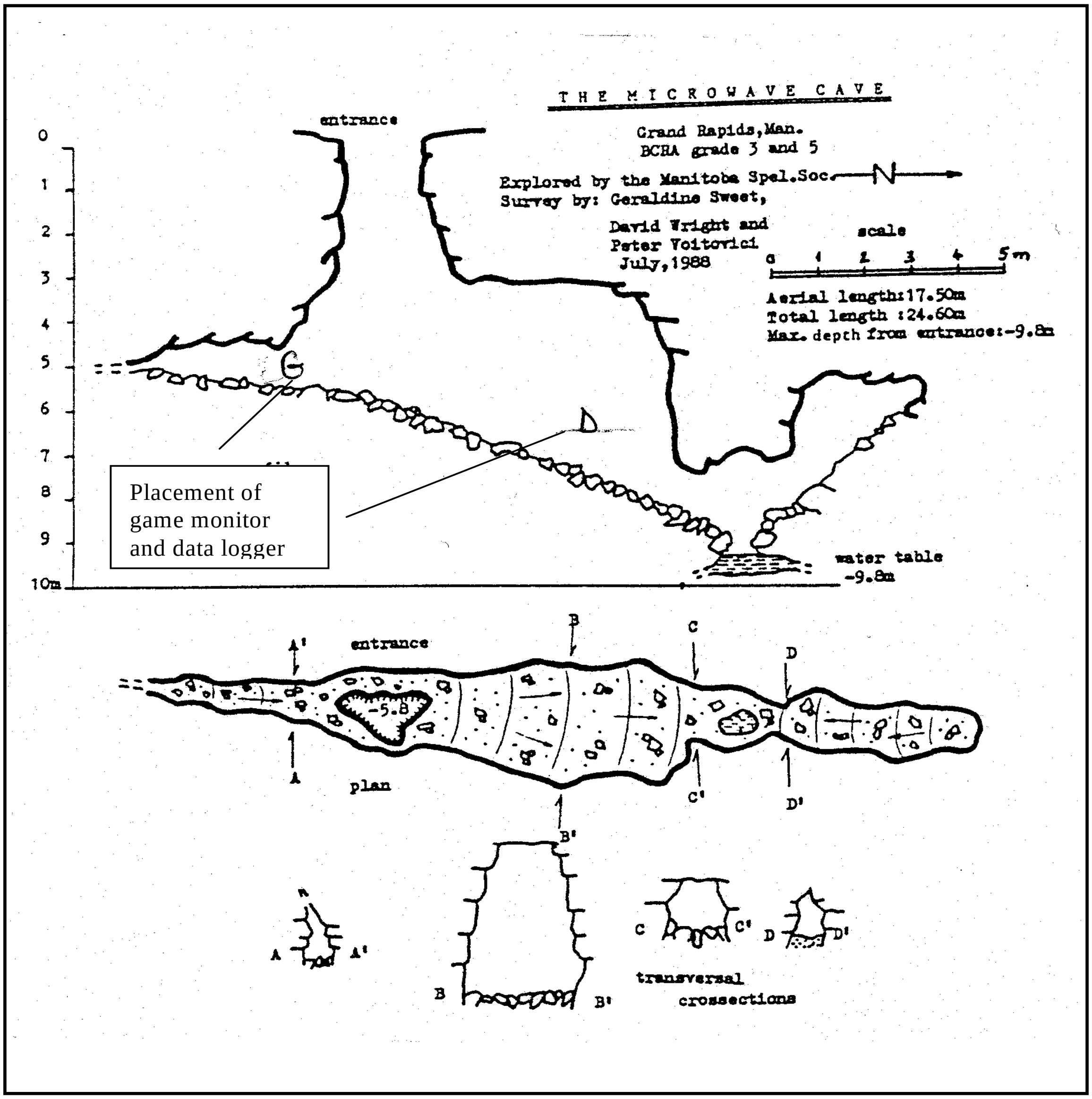

Figure 9: Diagram of Microwave Cave showing location of game monitor (G) and data logger (D) (after McRitchie and Monson, 2000).

Plate 14: Entrance to Microwave Cave

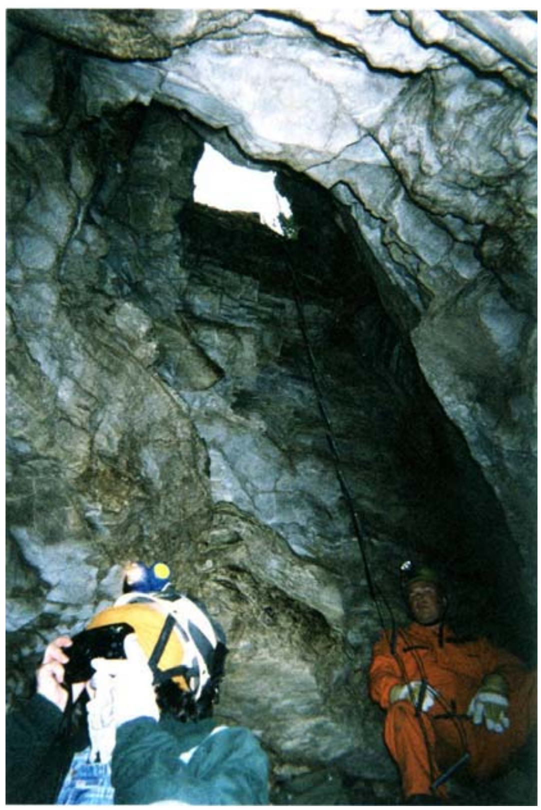

Plate 15: Inside Microwave Cave, note entrance at top of plate.

3.2.2 Firecamp Cave

Firecamp Cave has a narrow entrance, in part due to two boulders lodged in the opening, which then enlarges into a 7-meter deep shaft (Plate 16 & 17). This shaft leads to a breakdown-strewn floor that extends for another 3 meters (McRitchie and Monson, 2000). There is a recess, one meter in diameter, on the northwest wall of the shaft, located 2 meters above the floor (Fig. 10).

Water is not usually found in Firecamp, but this cave does provide some drainage for melt-water during spring and after summer storms. Bats have been commonly found in the crannies and recesses of the north wall, particularly where the main chamber narrows to the east (McRitchie and Monson, 2000). The population of bats occupying this cave was estimated from 5 counts done between May 1989 and October 1992. The estimated average number of individuals was 37, (range = 10-75; Dubois, pers. comm).

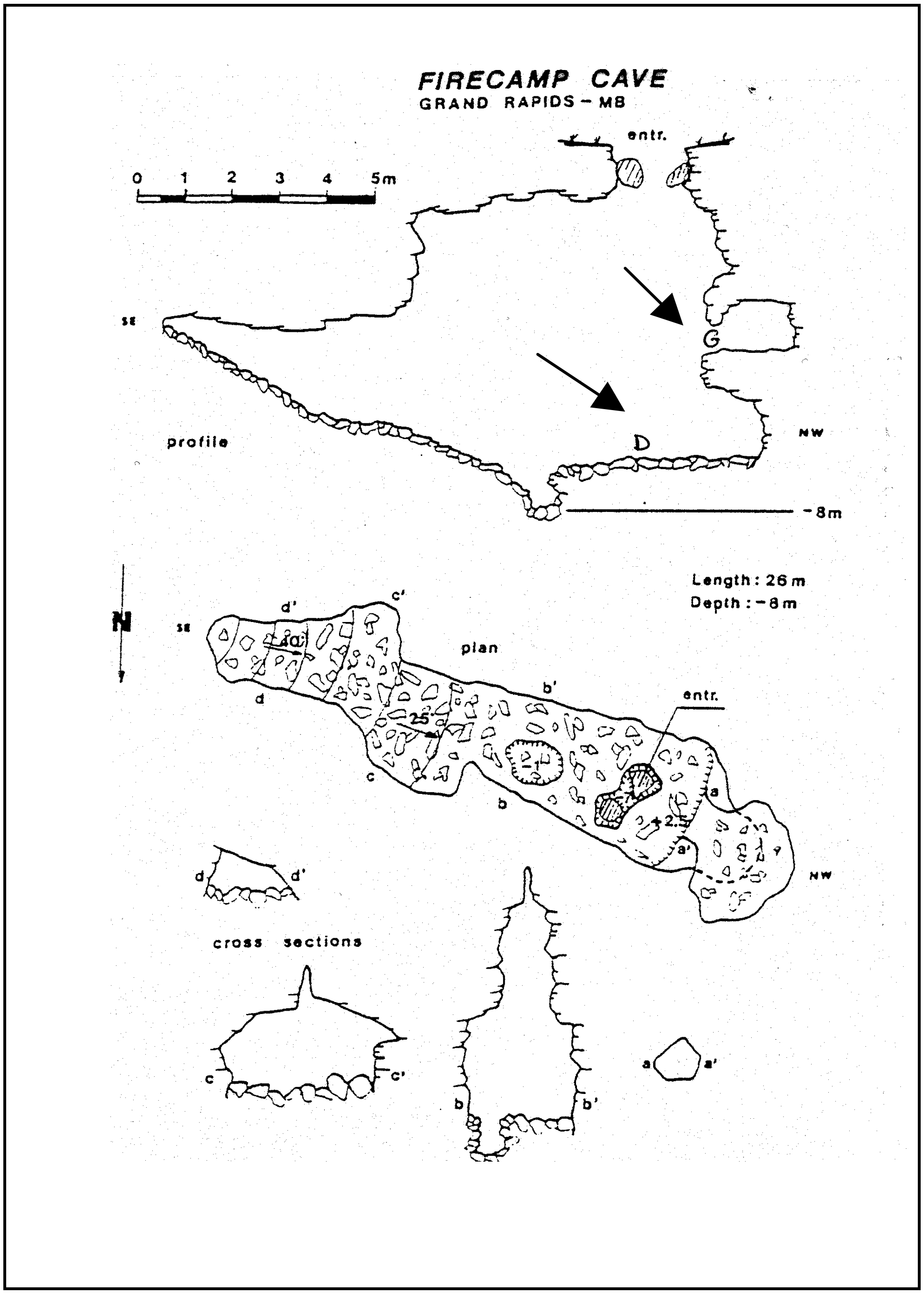

Figure 10: Diagram of Firecamp Cave showing location of game monitor (G) and data logger (D) (after McRitchie and Monson, 2000).

Plate 16: Looking west off Highway #6 towards Firecamp Cave, which lies just within the tree line.

Plate 17: Entrance into Firecamp Cave, note opening at top of plate.

3.2.3 Iguana Crypt

Iguana Crypt was first located in 1991. Most of the surrounding area was burned in the fire of 1987, but the cave itself lies in relatively undisturbed forest (Plate 18). Unlike the previously described caves, this cave has a small entrance and a long shaft that runs nearly parallel to the surface. For the first 20 meters, the shaft angles down from the surface by only 30 degrees, becoming nearly horizontal at the main chamber (Fig. 11). This cave has some excellent speleothems, including stalactites. In October 1991 more than 100 bats were recorded within this cave (McRitchie and Monson, 2000) (Plate 19), and signs of its use as a bear den were noted in 1999. The population of bats occupying this cave was estimated from 4 counts done between September 1991 and May 1998. The estimated average number of individuals was 131 (range = 65-223; Dubois, pers. comm).

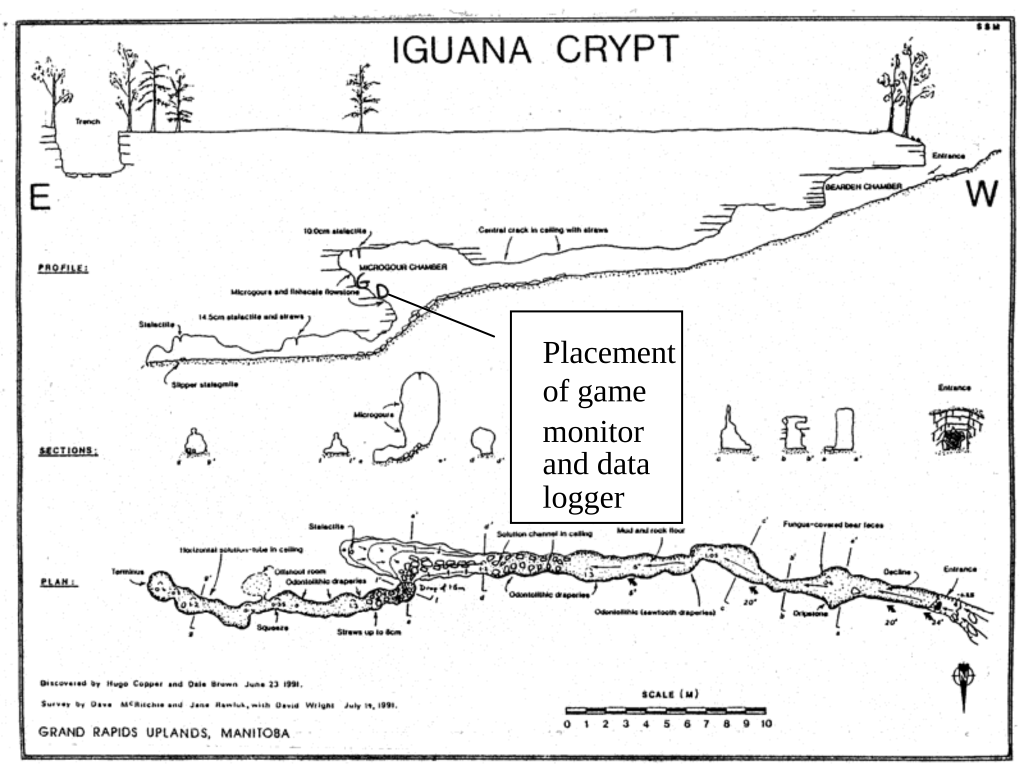

Figure 11: Diagram of Iguana Crypt showing location of game monitor (G) and data logger (D) (after McRitchie and Monson, 2000).

Plate 18: Descending into Iguana Crypt

Plate 19: Bats roosting on ceiling of Iguana Crypt as researcher enters cave.

3.2.4 Cutters Cave

This is the most recently discovered of all the study caves, being located in 1997 by Tolko Industries Ltd. during harvesting operations. Cutters Cave is, therefore, situated in a clear-cut logged area (Plate 20), about 20 meters from standing timber. The surface opening is long and narrow, appearing as a fissure in the (Fig. 12). Entry requires a vertical descent. The cave is shallower than the other study caves, with a total depth of 6.7 meters (Plate 21).

Only a few bats have been observed in this cave since its discovery in 1997 (8 individuals in May 1998). Bat guano has also been noted in the past, which indicates previous use of this cave by bats. However, no bats were observed in October 1999 or May 2000, during this study. It is possible that this cave may have acted as a hibernaculum for many more bats prior to being logged.

The effects of logging on cave microclimate are not well documented in the literature. However, it is possible that this surface disturbance may have negatively impacted the cave's microclimate temperature or relative humidity, creating an environment that is no longer suitable to bat hibernation. For example, without the shelter of the coniferous trees (see Plate 21) it is possible that surface winds are carried into the cave by their own force. "Surface wind is one of four main causes of air circulation affecting cave temperature. Surface winds carried into or through caves by their own force may be of some importance in certain instances, but most examples are limited to a cave with a short simple tunnel between its two or more entrances, *or to a relatively shallow cave with a large entrance*" (Tuttle and Stevenson, 1977). Cutters is a shallow cave with a relatively large entrance. Cold surface winds blowing across the prairie-like landscape of this clear-cut may cause a significant decrease in cave temperature over the winter months.

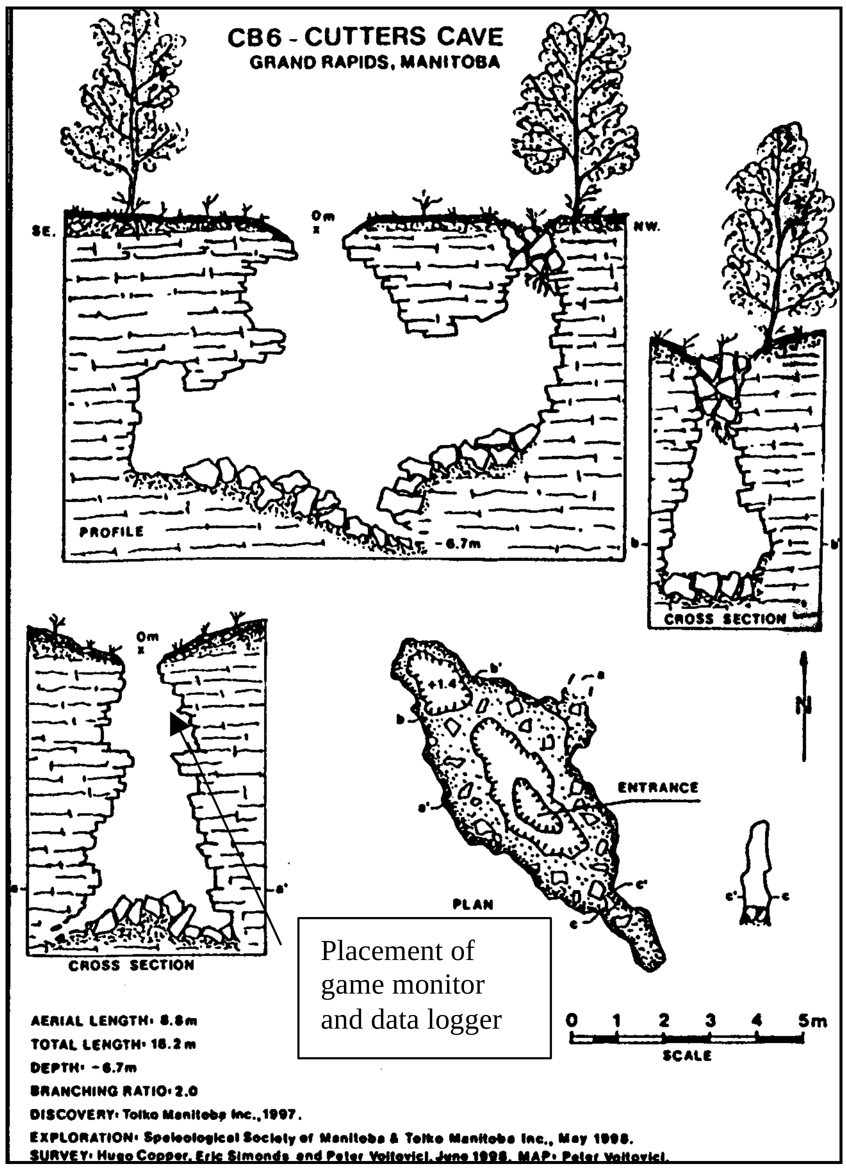

Figure 12: Map of Cutters Cave (Voitovici, 1998).

Plate 20: Entrance to Cutters Cave as indicated by the yellow arrow.

Plate 21: Ms. Kim Monson, member of the SSM, inside Cutters Cave.

3.3 PERMIT ACQUISITION

A permit to enter the four study caves and carry out scientific research (Wildlife Scientific Permit No. WSP 99013) was obtained through Manitoba Natural Resources, Wildlife Branch by Mr. Jack Dubois, Associate Curator of Mammalogy, Manitoba Museum of Man and Nature. Time spent within the caves was kept to a minimum and bats were not handled at any time. Data loggers and game monitors were placed in the caves on October 14 and 15, 1999, and left unattended until May 26-28, 2000, the approximate period of hibernation for *M. lucifugus*.

3.4 SAFETY PRECAUTIONS

Safety equipment consisted of caving helmets with battery-operated lights, a secondary light source (flashlight), climbing gear (harness and ropes), and a cable ladder. Members of the Speleological Society of Manitoba volunteered their time and effort in ensuring safe caving practices were carried out at all times.

3.5 LIMITATIONS

For this study in the Grand Rapids uplands, only one Hobo Pro Series data logger (recording both temperature and relative humidity) was placed in each cave, with the assumption that this would represent the mean temperature within the area of the cave where most bats were hibernating.

However, a similar field study to this one was carried out by Davis *et al.* (1996) on the northern part of Vancouver Island, British Columbia. Davis *et al*. placed On-Set temperature and relative humidity data loggers within caves, and on the surface, at three different elevations. The loggers in that study were placed 10 meters within the cave entrance, deep within the cave (>100 meters from the entrance), and outside the entrance.

A major limitation of this study was that temperature and relative humidity could only be recorded at one site within each cave rather than at various locations to provide a better profile of the temperature and relative humidity in each cave.

3.6 Statistical Analysis

The General Linear Model (GLM) procedure (Statistical Analysis System – SAS) was used to test for statistical differences in mean temperature and also in relative humidity between the four caves. Duncan's Multiple Range Test was used as a *post hoc* test to determine if the respective means were significantly different. The Pearson Correlation Coefficient was calculated to determine the degree of correspondence between cave temperature and bat activity.

3.7 Summary

Results of this study are outlined in the next chapter. A completed Master's thesis will be offered to Manitoba Department of Conservation, Tolko Industries Ltd., Manitoba Hydro, and Falconbridge Ltd. to be used as a reference in the management of resource development operations near bat hibernacula located in karst areas.

4.0 EFFECTS OF RESOURCE DEVELOPMENT ON KARST, CAVES AND BAT HIBERNACULA

Over the last century, land management practices have been carried out with little, if any, consideration given to their potential effects on bats and bat habitat. Today, in environmental and resource management, it is becoming more widely accepted that every species has a right to survival (Hamilton-Smith, 2001) and the actions of many resource developers are beginning to reflect this. For example, the majority of guidelines for bats, caves and karst that were reviewed in this study were written between 1994 and 2001, with only two of the reviewed documents being written in the 1980s. In 1987, The U.S. Forest Service in Alaska began to map and identify caves and karst in relation to proposed timber harvesting. In 1995, the Province of British Columbia initiated research on the management of cave and karst resources in forest environments.

However, current forestry operations, mineral exploration, and hydro-electric transmission line construction are all land management practices occurring in the Grand Rapids uplands that may impact karst, caves and ultimately bats. Conserving the ecological integrity of this karst area depends upon preserving the dynamic interaction between the karst landforms and the water, gases, soils, bedrock and biotic components of this system. An “abnormal perturbation in any one of [these] will have implications for all the others” (Hamilton-Smith, 2001). This section will identify potential impacts that may result from resource development activities as reported in the literature.

Most impacts that were reviewed were in relation to forestry operations, but it should be noted that these impacts could just as easily be the result of other resource development activities. Any development that alters the surface landscape could cause similar impacts to caves and cave fauna, including ROW and transmission line construction, mineral exploration, highway construction, quarrying, etc.

4.0.1 Potential Effects of Forestry Operations

The International Union for Conservation of Nature and Natural Resources (IUCN) struck a World Commission on Protected Areas (WCPA) Working Group on Cave and Karst Protection. This Working Group published Guidelines for Cave and Karst Protection in 1997. This document indicates that forestry operations may have an adverse effect on caves.

The dissolution of limestone is moderated mainly by what is happening on the surface and immediately below the surface of a karst area. Clearcutting of forests in a karst area may “radically” change the local hydrology and affect water quality as surface vegetation regulates the flow of water through a karst system. Leaf litter and root systems minimize the amount of water that can infiltrate the soil. Trees can be major regulators of water quantity through their ability to absorb water from the soil and transport it via the xylem. Thus, trees regulate the amount of water available to supply speleothems. Trees are also the major contributors to CO_2 levels in the soil as they achieve 20-25% of their atmospheric gas exchange through root respiration.

The removal of surface vegetation can also impact soil quality and the biological dynamics of the soil (Hamilton-Smith, 2001). This could subsequently alter the water regime within the cave below which, in turn, could impact the microflora resulting in alterations to the entire food chain of cave fauna.

The British Columbia Ministry of Forests (Vancouver Region) undertook research relating to the management of cave and karst resources in forest environments. The report that was issued indicates that impacts to caves and karst from forestry operations depend on the sensitivity of the karst area, the harvesting methods employed, the quantity and quality of forestry roads being built and the associated ecological attributes of the karst area (Blackwell, 1995).

The report indicates that clearcutting, while one the most efficient and cost-effective methods of harvesting, has been associated with the degradation of caves and karst areas in B.C. and around the world. It indicates that the removal of trees is associated with increased surface runoff, sedimentation and woody debris, which can move through the karst system and impact the hydrogeologic, biological and recreational characteristics of the karst area. It reports that clearcutting can alter the aesthetic appeal of a cave site, introduce fuels and pollutants, clear critical habitat at cave entrances, and alter cave temperature, humidity and air flow. However, the report does not cite any literature in which studies were conducted to prove that the microclimate of caves was altered by surface tree removal.

According to this report, other forestry operations that may have potential negative impacts on caves include road development and bulldozing. Road development may fill in cave entrances, causing caves with weak ceilings to collapse, or destroy caves by blasting. The construction and maintenance of logging roads increases public accessibility to the caves, resulting in further adverse impacts on caves and cave fauna.

Bulldozing and clearcutting may have an impact on groundwater and/or surface streams and clearcutting may result in the destruction of habitat that is also used by cave-dwelling animals (for e.g., bat species that roost in both trees and caves). It may disturb soils, water quality and cause scouring or the siltation of cave passages. This may result in the death of cave-dwelling animals and/or the discoloration of speleothems. Timber cutting, yarding of logs across or dumping of slash in cave openings can plug cave passages. This has the potential to increase the carbon dioxide levels within the caves, which has adverse impacts upon cave-dwelling animals and may slow the growth of cave formations.

Repap Manitoba Inc's Environmental Impact Statement indicates that access development (road construction and maintenance of primary all-weather roads) and harvesting activities (logging) have "significant/mitigable" impact on bats.

The 1997 Land and Resource Management Plan for the Tongass National Forest (located on the Prince of Wales Island in Alaska) also indicates that forestry operations may have impacts on karst and caves. "On karst landscapes worldwide, timber harvest has led to serious, often long-term declines in soil depth and fertility, in some cases culminating in permanent deforestation". In karst lands, and as was evident during fieldwork in the Grand Rapids uplands, tree roots extend into cracks of the limestone bedrock. As the roots pump water and nutrients back into the tree canopy, productivity of the site is tied up in this nutrient cycle and in the forest canopy. Once trees are harvested this nutrient cycle is interrupted for a long period of time.

The Tongass National Forest plan also indicates that there is strong evidence that after timber harvesting takes place, there is a large increase in surface runoff. Soils tend to be thin and residual in karst areas, and can become extremely dry once the forest canopy is removed. If harvesting occurs on steep slopes, without proper log suspension, much of the soil is removed and the slopes may remain as bare rock. If harvesting occurs on flat terrain, as is the case in the Grand Rapids uplands, soil loss can still occur as soils and nutrients move vertically down into the karst system, beyond the rooting depth of vegetation. This is especially true in areas of heavy rainfall and well-developed sub-surface drainage. While the Grand Rapids uplands may not be considered an area of heavy rainfall, it does have a well-developed sub-surface drainage pattern exemplified by the many lakes that drain internally into the "underlying cavernous carbonate formations" rather than through a surface drainage pattern. Cavities in the limestone bedrock that have been found as deep as 80-100 m (McRitchie and Monson, 2000) are also a testament to its well-developed sub-surface drainage. To mitigate these effects, the plan indicates that leaving slash (splinters, chips, uprooted stumps, etc) in the harvested area would help protect the shallow and fragile soils from erosion and drying.

4.0.2 Potential Effects of Mineral Exploration and Extraction Operations

The Province of British Columbia issued a discussion paper on cave resources in British Columbia in 1980. This paper indicates that mining and mineral exploration can have a variety of negative impacts on caves mainly caused by blasting and road development.

Blasting or in-filling to create roads that are located near caves may collapse or alter cave entrances. The entrance of a cave is a sensitive area that is critical to the cave ecosystem (Tongass, 1997). Road development can increase the accessibility to caves. Flushing of streams and dumping of debris into caves can occur resulting in cave features becoming scoured or passages being clogged by sediment-laden streams. This may not be as much of an issue for Manitoba's caves which do not have active river systems in them.

Total or partial collapse or excavation of a cave system can also occur (Province of British Columbia, 1994). Gypsum and limestone mining can directly impact caves by quarrying away caves (McAlpine, 1983).

4.0.3 Potential Effects of Hydro-electric Transmission Line Construction

Rights-of-way affect the landscape differently than other types of construction activities. They are elongated, narrow corridors that transect the landscape across many kilometers, whereas buildings, mineral exploration sites or individual cut blocks affect a specific site. Often, maintenance access roads parallel the transmission lines.

Many hydro-electric transmission line rights-of-way were established years ago when little was known about karst and its fragility. However, today many rights-of-way projects will map areas of carbonate rock and sometimes undertake an inventory of the karst features, especially caves. Unfortunately, mapping and inventories may not be conducted carefully which can lead to important karst features being missed and potentially destroyed (Kastning, 1995b).

There are five karst environmental issues that need to be considered when planning for rights-of-way corridors in karst areas: land instability and collapse, flooding and siltation, groundwater contamination, destruction of caves or their contents, and the alteration of hydrologic pathways. Some parts of the karst landscape may be very unstable and prone to collapse. For example, the ceiling of a cave may collapse due to the construction of a tower over top of its thin ceiling. The removal of vegetation along rights-of-way may lead to flooding and siltation in sinkholes. As both transmission line rights-of-way and access roads require the removal of vegetation, they can increase erosion resulting in sediment being washed into sinkholes or caves. If it is washed into sinkholes, the sediment may plug the natural drainage system of the sinkhole and cause flooding, especially under severe weather conditions.

Herbicides are often used to control vegetation along rights-of-way or on access roads. Surface run-off can transport herbicides from the surface into groundwater supplies where they may be discharged through wells or springs. "Contamination is the prevailing environmental problem in karst terrain" (Kastning, 1995b).

Caves may be destroyed or new entrances created during construction of rights-of-way, highways or railways. "There may be subtle, yet significant, damage to delicate cave ecosystems. In some cases the effects are catastrophic." (Kastning, 1995b). New entrances to caves could cause changes in airflow, temperature or relative humidity, which may render the cave unsuitable as a hibernacula.

"Wildlife and their distinctive habitats may be impacted in several ways by transmission line facilities" (Berger, 1995). These impacts can be subdivided into three categories: construction impacts (including access, right-of-way (ROW) clearing or tower construction); line maintenance inspection or repairs and impacts related to the presence and operation of the transmission line (Berger, 1995).

With regard to bat hibernacula, ROW construction work would likely have the greatest impact to bat habitat in the Grand Rapids uplands. Transmission line construction activities are usually undertaken during the winter, which is the time when bats are hibernating. Construction activities include the clearing of forested areas, the creation of foundations for towers which may involve blasting or excavation, and the digging of burrow pits for back fill material for roads (Berger, 1995). These activities require the use of heavy machinery. Access trails may also be developed, especially in northern Manitoba. As well, accidental impacts may occur that could also affect karst areas, these include the spillage of oils, chemicals, fuels, and lubricants along the right of way (Berger, 1995).

4.0.4 Potential Impacts of Human Visitation (Spelunkers and Researchers)

It is estimated that Cavern Lake Cave, one of the largest granite caves in Ontario, was used as a hibernaculum by 5,000 bats in the 1940s. Fewer than 200 bats were using this cave by the early 1970s. This decline was directly related to high human use and abuse of the cave, which was easily accessible by a passable roadway and two trails. The Cavern Lake Provincial Nature Reserve was established in 1975. The cave is home to at least four species of bat: the little brown bat, the big brown bat, the rarer Keen's long-eared bat, and the red bat. In the summer the cave is a roosting site and in winter a hibernation site (Ontario Parks Website, 2003).

In a proposed management plan for Cadomin Cave in Whitehorse Wildland Park in Alberta, impacts caused by people are referred to as “internal impacts” as opposed to the “external impacts” caused by surface industrial activities.

The Cadomin Cave proposed plan suggests that caves do not have a carrying capacity as one person passing through a cave impacts the cave and may irrevocably alter it. Visitor impacts to caves include soil compaction from foot traffic, crushing and trampling of vegetation outside cave entrances, inappropriate fecal waste and urine disposal, harassment or disturbance of cave fauna, cave vandalism, and changes to the cave microclimate such as a rise in CO_2 or drop in relative humidity which can lead to speleothems drying out.

4.1 Review of Bat Hibernacula Management Guidelines

It was the original intention of this study to review management guidelines specific to bat hibernacula. However, once a review of the literature was undertaken, it became clear that guidelines for karst and caves were more prevalent than for bat hibernacula. However, in almost all documents examined, bat hibernacula were dealt with in the various applicable sections of the documents. Therefore, what was reviewed were either karst management plans, conservation plans for caves, forest land management plans, or habitat management guidelines for bats from various provinces and states. This review was undertaken in order to provide resource developers working the Grand Rapids uplands with best management practices and to make recommendations to Manitoba Conservation for revisions to their current guidelines. Guidelines were reviewed from the following provinces and states: British Columbia, Manitoba, Ontario, Quebec and New Brunswick, Missouri and Alaska as well as global guidelines for karst and caves issued by the International Union for Conservation of Nature and Natural Resources. The guidelines are detailed below and then summarized in Table 1.

4.1.1 Guidelines in Manitoba

The Wildlife Branch of Manitoba Conservation issued Bat Hibernacula Management Guidelines in December 1996. Guidelines are provided for five types of potential impacts: forestry operations, mineral exploration/extraction, spelunking, research and dissemination of hibernacula locations.

Currently, there are two main guidelines governing forestry operations and mineral extraction operations in Manitoba. First, it is recommended that consultation between Manitoba Conservation and the forestry and mining companies occurs prior to harvesting and road development or mineral exploration, blasting, and mining development. The second recommendation is that the use of heavy machinery (skidders, trucks, cats for forest operations and heavy equipment used in mineral exploration, extraction or equipment transport) should not occur within 200 meters of a "hibernaculum" (under the forestry guideline) or "cave" (under the mining guideline). There is no reason provided for the broader restriction on mining, compared to forestry, operations (i.e. there are more caves than there are bat hibernacula).

There is a third guideline specific to forestry operations, namely that bats and bat habitat should be included in the Wildlife Guidelines for Forest Harvesting. The Forestry Branch of Manitoba Conservation has issued Forest Management Guidelines for Wildlife in Manitoba but as of December 1989 these do not include guidelines specific to bats. Wildlife included are moose, woodland caribou, elk, white-tailed deer, furbearers, raptors, passerines, colonial nesting birds, waterfowl and upland game birds. General guidelines for forest management activities only make reference to sensitive wildlife habitats (i.e. "all weather access roads will avoid identified unique and sensitive wildlife habitats"). These guidelines are currently being revised, and will include management guidelines for bats (Crichton, pers. comm.).

The Bat Hibernacula Management Guidelines also include guidelines for spelunking that include prohibiting access to hibernacula between September 15th and May 1st. It also recommends that rock and debris on the ceiling, sides, floor and openings of the cave not be disturbed. Similar guidelines exist for researchers – that activities should not occur between September 15th and May 1st, unless "they contribute significantly to scientific knowledge."

The last set of bat hibernacula guidelines recommends that the Wildlife Branch keep cave locations confidential. Exact cave locations are only to be provided upon approval of the Wildlife Director and this information should be prohibited from "sharing, publishing or for guiding other individuals to the caves."

The Forestry Branch of Manitoba Conservation also provides some guidelines for resource development being undertaken in karst areas. These guidelines are within new Forest Practices Guidebooks currently being produced as part of their Forest Practice Initiative which is intended to "advance 'best' practices through guidelines and standards for sustainable forest management activities in Manitoba" (Delaney 2003). The first guidebook entitled "Pre-Harvest Surveys" recommends that a component of the pre-harvest survey should be the recording and mapping of sinkholes and other significant features. It also indicates that "specific guidelines are enforceable when identified on Work Permits". The Forest Practice Initiative will not only involve the publication of guidebooks but may include presentations, field discussions, or training courses.

4.1.2 Guidelines in BC

In British Columbia, the Ministry of Forests is responsible for karst and cave management. This Ministry has developed and maintains a cave/karst management operational handbook and a general inventory system for karst and caves on Crown land on behalf of all provincial agencies. The Ministry also acts as a communication link between forest companies and cavers.

In the Cave/Karst Management Handbook for the Vancouver Forest Region (1994), the Ministry identifies caves as “unique non-renewable resources”. The management of caves involves both surface and subsurface resources and cave management is considered as an essential component of integrated resource management. This handbook provides forest staff with guidance on the potential impacts of forestry operations. It details the components of a karst/cave inventory classification and records system:

1) A cave inventory and classification card with cave name, location, descriptive information, and classification and management type.
2) A reference number for each cave to be kept on file and to be placed at the entrance of the cave. Each file for an inventoried cave would have inventory and classification records; history of the cave, directions for reaching the cave entrance; photographs; records of entry; records of present or previous stewardship activity.
3) A master cave location map showing the exact locations of inventoried caves and another general map showing only cave areas. The report indicates that field inventories and classification should be undertaken by qualified staff in the Forest Service or forest companies or by contractors or volunteers acting under formal agreements with the Forest Service and /or licensees. Licensees should identify all proposed development within known karst areas (accomplished by consulting geological bedrock maps that show known areas of limestone). If a proposed development lies within a karst area, a systematic surface inventory should be initiated to locate cave entrances within the area. If forest company personnel (cruisers, consultants, engineers, etc) or spelunkers discover cave entrances, the locations should be plotted on topographic maps for submission to the Ministry of

Forests. The Ministry of Forests is responsible for compiling, maintaining and safeguarding relevant information and for ensuring that appropriate forestry company personnel are aware of the cave and karst values in proposed development areas. The Ministry, in consultation with cave experts, is also responsible for the appropriate classification and management of specific caves.

The manual includes cave management considerations for both surface and subsurface impacts in the evaluation and approval of timber harvesting cut blocks and road location plans. Specific clauses are to be included in five-year development plans and cutting permits. Companies are required to ensure and provide proof that their operational staff and contractors have followed all cave and karst management guidelines in all karst areas. Companies are encouraged to educate operational staff and contractors. After completion of timber harvesting, the BC Forest Service may restrict road access to protect caves that require moderate to intensive management activities from public access. Specific guidelines are provided for both the surface and subsurface environment.

General guidelines include identifying all cave entrances in the field using bright yellow flagging tape with “caution” labels (in large letters) around the entire entrance. Field personnel are to be thoroughly briefed on the special protection measures required for significant caves (those caves requiring moderately and most-intensive management). Harvesting activities should be closely monitored to ensure guidelines are adhered to. A follow-up meeting between the BC Forest Service and the licensee is recommended to determine the effectiveness of the recommendations and guidelines and to determine whether further requirements are needed.

Surface and subsurface considerations involve the assignment of a "management type" to each cave. There are three management types:

***Least Intensive* –** no special prescriptions required to protect caves of this type (caves that contain few or no items of scientific value and are open to all recreational/educational uses) from the effect of timber harvesting and/or other surface activities.

***Moderately Intensive* –** caves are open to all recreational/educational use. Management will be in the form of outreach and education regarding cave conservation, safety, known cave hazards or precautions or equipment requirements. These caves may contain formations that are of unusual quality or are very delicate. Surface management guidelines will be implemented and will not allow surface activity to interrupt cave water flow, cause collapse or blockage of entrances, or result in the destruction of cave formations or secondary deposits**.**

***Most Intensive* –** caves will only be open to extremely limited recreational/educational use or non-consumptive scientific study and permission is needed to access the caves. These caves contain unusual and or fragile formations or items of scientific value, which could and/or would be seriously disturbed or destroyed by visitation (archaeological, biological, or paleontological in nature or very rare cave formations). This also includes a biological species, which has a delicate habitat, or is in danger of extinction in the area or within the particular caves. No surface activity of any sort will be permitted above caves in this category.

While Manitoba's Grand Rapids caves fit into the "most intensive" category which indicates that no surface activity is permitted, the guidelines for moderately intensive management are most applicable and are summarized below:

- **Planning and construction for roads and landings:** roads are to be located at a reasonable distance from known cave entrances and not over caves with thin ceilings. It is also recommended that, where appropriate, roads are closed after completion of timber harvesting.

- **Right-of-way felling, clearing and subgrade construction:** right-of-way trees are to be felled away from cave entrances; drilling or blasting must be avoided over or near known cave entrances; blasted rock should be prevented from landing in or blocking cave entrances; construction debris or sidecast material must not be introduced in the cave entrance or into water bodies flowing in the cave; operations should cease if a slide occurs which enters or could enter a cave.

- **Pits and quarries (for developing road surface materials):** Ballast quarrying near known cave entrances and passageways should be avoided; drainage of water or other harmful products from pits and quarries should be prevented from entering caves.

- **Fuel storage**: Spilling of fuel should be avoided during fuel storage and fueling operations on karst landscapes and especially near known caves**.**

- **Planning and operations for felling and yarding:** The obstruction of cave entrances should be minimized. Felling and yarding should not occur across known cave entrances to avoid debris accumulations and should be done away from entrance streams. Non-merchantable and residual trees should be maintained around cave entrances. Buffer zones ("leave strips or reserve areas") should be left in relation to wind firm boundaries. During yarding operations, logs should be suspended over caves identified as having thin ceilings.
- **Ground skidding:** Ground disturbances should be minimized and emphasis should be placed on maintaining residual trees around cave entrances. The use of heavy equipment (wheeled or tracked) should be prohibited over caves with thin ceilings and exposure of mineral soil should be avoided.
- **Silviculture planning, scarification and burning:** Silviculture requirements (regarding reforestation, juvenile spacing, weeding, etc) should be identified during preharvest surveys for areas surrounding known significant caves. Where there are shallow soils and caves present, slash burning on limestone bedrock should be avoided. Herbicide use should be highly restricted. These activities should not be undertaken in protected areas, leave strips, reserve areas or near significant cave entrances.

4.1.3 Guidelines in Alberta

A Karst Management Proposal was submitted to Alberta Environment for Whitehorse Wildland Park in 2001. Even though an inventory of the Canadian Rockies has identified 172 caves, the Whitehorse Wildland Park is the first provincial park in Alberta to contain a significant cave - Cadomin Cave. It is one of the caves that is a popular tourist attraction and it is also a bat hibernaculum.

The proposed management plan acknowledges that caves and karst are special places. It identifies threats to karst and caves and categorizes these threats as external and internal. External threats are those caused by industrial activity occurring on the surface or within the hydrological boundaries of the karst area (it specifically identifies forestry operations, limestone extraction and tourism as industries that have impacted the cave). Internal threats are those caused by people entering the cave (human visitation).

To assess the impacts to a cave, the plan proposes that it must first be inventoried and the resources categorized in order to effectively assess threats. In this plan, the resources are grouped as fauna, climate, speleogens and speleothems. For the purposes of this review, only impacts to cave fauna and climate were reviewed.

One of the key indicators of the "fauna" resource are bats and the areas of concern are harassment and disturbance to individuals or roosting sites and alterations to the cave climate and degradation of water quality for the aquatic invertebrate fauna. In terms of the "climate" resource (microclimate), key indicators are temperature, CO_2 levels, relative humidity, radon, airflow and rate, the water chemistry, water turbidity and pathogens. Areas of concern include: interruption/sedimentation of subsurface drainage channels, pollution from fuel spills and residues from forestry activities, alterations to the relative humidity, temperature, $CO_{2,}$ and particulate matter resulting from large numbers of people entering in the cave.

Other impacts resulting from resource development activities occurring near caves include an effect on groundwater percolation, sedimentation from soil erosion, and deterioration of water quality caused by runoff from nearby industrial sites. To avoid these deleterious effects, resource development and industrial activities should be avoided within the hydrological catchment area of the cave.

Cadomin Cave is closed to public access from September 1 to April 30. “It is against the law to disturb hibernating bats and if [someone] accesses Cadomin Cave during the restricted time period [they] may be charged since the area is monitored” (Travel Alberta, 2003).

4.1.4 Guidelines in Ontario

The Habitat Management Guidelines for Bats of Ontario (Gerson, 1994) emphasize the protection of bat habitat in mines. Guidelines for hibernacula protection are limited, and recommendations include having Ontario Ministry of Natural Resources (OMNR) district offices prepare a list of the locations of known caves and mines that are used as hibernacula. It suggests that land acquisition, signs and/or fences can protect hibernacula. It also suggests that marginal hibernacula be protected, but does not provide for a definition of marginal hibernacula. The guidelines suggest caves may be threatened by land development, but the example given is of a cave on private land that is threatened by vandals and increased visitation. Other recommendations include the use of signs, gates and fences. The majority of this report concentrates on mitigating threats caused by human visitation and does not provide guidelines that can be used by industry, except for one. It recommends that trails and roads be blocked or allowed to deteriorate in order to reduce the accessibility to hibernacula.

4.1.5 Guidelines in Quebec

The Protection Program for Bat Hibernacula in Quebec was issued by the Wildlife and Habitats Department in November 1996. This document describes the "problem situation" in Quebec in terms of bats and bat habitat and it also describes a potential hibernacula protection program (goal, objectives and implementation plan). This is a reactive report, not a set of proactive guidelines as was issued by Manitoba Conservation. It acknowledges the vulnerability of hibernating bats and suggests that a major mortality factor of bats is disturbances to hibernacula. It suggests that a common species like the little brown bat could become threatened if their hibernacula are not properly protected as bats from several thousand square kilometers converge on specific sites annually, making residential populations vulnerable.

The document also suggests that the greatest risk to the bats is during the winter when caves are visited regularly by spelunkers who attempt to enlarge cave entrances. As well, it concludes that the sealing of mine shafts has impacted bat populations in Quebec, "it is clear that the continue application of the mine safety program in its current form may threaten certain bat populations and result in a reduction in biodiversity at the provincial and local levels". The bat protection program objectives include developing 15 hibernacula by 2001 and the preparation of development guidelines for every mine that is to be closed and has the potential to house bats.

4.1.6 Guidelines in New Brunswick

The Status and Conservation of Solution Caves in New Brunswick (1983) examines threats to caves and their contents and provides suggestions for the protection of caves and recommendations for their conservation. Threats to caves identified in this document include mining and mineral exploration, forestry operations, permanent closure of entrances, visitors to the caves and groundwater contamination.

The first method suggested to protect caves is the education of cave visitors. Education includes posting educational or interpretive signs at cave entrances, which the guidelines suggest could “prove valuable in protecting New Brunswick caves and cave bats”. Another form of protection is to limit the amount of information that is released (restricting access to cave maps with exact cave locations and limiting the dissemination of newly discovered caves).

The second method suggests that research be conducted as the development of conservation policies and plans requires information about the resource. Useful information includes data on invertebrate and vertebrate fauna utilizing caves, microclimatic conditions, cave mapping and identification of caves used as bat hibernacula.

On private lands where landowners want to fill in or block caves, a negotiation agreement could be used to protect the cave. This would also involve erecting fences or gates to protect livestock. Gating of caves on public land is also recommended as a way to protect bat hibernacula.

The final method of protection that is suggested is through legislation. Legislation could be used to provide full protection of a cave or restrict access to the cave. Examples of New Brunswick legislation that were cited include *The Endangered Species Act*, *The Ecological Reserves Act*, *The Historic Sites Protection Act*, *The Clean Environment Act*, and, under federal legislation, *The National Parks Act*.

4.1.7 Guidelines in Missouri

“Best Management Practices for the Indiana Bat” was published by the Missouri Department of Conservation in June 2000. It states that the reason for the decline in Indiana bat populations since the 1950s include human disturbance during hibernation, vandalism, alterations to the caves (building of solid gates) and natural hazards such as river flooding and temperatures below 0°C. “The protection of caves and karst is essential to provide for bat winter roosting sites”. Specific guidelines are given for forestry operations, and include retaining specific tree species that are used by Indiana Bats, allowing timber cutting only between October 1 and March 31 to reduce disturbing maternity roosts, and minimizing access to areas with known roost sites to prevent bats from abandoning these roosts. For hibernacula management, it is recommended to avoid access to hibernacula from September 1 to April 30. It also recommends that road and trail construction, logging and urban development be minimized “near hibernacula in the 100 foot (30.48 meter) buffer zone to avoid water runoff, siltation and adversely changing the climate of the cave”. A disclaimer is provided that indicates compliance with these best management practices is not mandatory under Missouri law or by any regulation under the Missouri Conservation Commission.

4.1.8 Guidelines in Alaska

The Tongass National Forest, Land and Resource Management Plan (1997) provides forest-wide standards and guidelines for both karst and cave resources. Caves that are identified as bat hibernacula are considered to be significant caves. The essence of the strategy is to "maintain, to the extent feasible, the natural karst processes and the productivity of the karst landscape while providing for other land uses where appropriate." This includes maintaining the capability of the karst landscape to regenerate a forest once it has been harvested; to maintain the quality of water coming from the karst hydrologic systems, and to protect the values of significant cave systems.

Recommendations include maintaining a karst resource management program that identifies, evaluates and provides for karst resources. It emphasizes partnerships between caving groups, scientists and resource developers as well as universities and other research entities. It notes that the importance of the entire karst system should be considered in karst management, not just karst features. It recommends education and interpretive programs to promote an understanding of karst landscapes. It provides details for undertaking a karst landscape assessment. This assessment involves the following steps:

1) Identify potential karst lands (i.e. those lands underlain by carbonate rock).
2) Undertake an inventory of those karst lands and cave resources prior to resource development. In this inventory, the degree of epikarst development is identified (that is, the surface of the karst - a veneer of fissures and cavities that collect and transport source water and nutrients below to the underlying karst conduits).
3) Delineate the karst hydrologic system and catchment area.

4) Assess the vulnerability of the karst area to management activities. There are three categories of vulnerability: low, moderate and high. If an area is found to have low vulnerability, no special conditions are required to protect the area; if it has moderate vulnerability, forest management activities can still be carried out under more restrictive guidelines than for those activities undertaken on non-karst lands. If the area is considered highly vulnerable, they should be managed for karst values only and not for commercial forestry operations. Details on how to assess vulnerability are provided in the Appendix of this land management plan.

   One criteria for determining vulnerability is the presence or absence of caves. Those with no caves are considered to be low or moderately vulnerable karst lands, depending on other criteria. Those considered to be highly vulnerable are those lands where caves are present (along with other criteria). Lands under this classification should be excluded from quarrying, timber management and related activities. Recreational activities should be limited. If forest management activities occur on low to moderately vulnerable lands that are contiguous with these ones, roads may be allowed if no other options are available.

Specific management guidelines are provided for cave resources as well. These guidelines are outlined below:

1) Karst lands should be managed to protect and maintain significant caves and cave resources (i.e. any biological, cultural, mineralogical, paleontological, geological, hydrological, and recreational resources occurring in caves).

Guidelines are included for determining cave significance in the land management plan and are discussed in this review later.

2) Caves should be located, mapped, described, evaluated and resource values documented.
3) A cave resource management strategy should be developed. Strategies are provided, along with standards and guidelines.
4) Public education to promote an awareness and appreciation of caves and their importance and to educate cavers about cave safety and responsible use of caves.
5) Caves should be classified based on management objectives as either sensitive, directed access or undeveloped.
6) Details about cave locations should not be made public nor made available under Freedom of Information Act. A cave coordinator should be employed to maintain information about the caves and to provide information on a "need-to-know" basis.

If the karst area is defined as being moderately vulnerable (it should be noted that this means no caves are present), then the guidelines indicate that timber harvesting, road development, quarry development are not to be undertaken within 100 feet or 30.48 meters (at a minimum) from the edge of a sinkhole.

If the karst area is identified as being highly vulnerable (i.e. caves may be present) then timber management and related activities, and quarry development will not be allowed in these areas. Recreational development would be limited and road development across this area is deemed "inappropriate". "Karst lands found to be of unquestionably high vulnerability shall be identified and removed from the commercial forest lands suitable land base".

4.1.9 Global

The "Guidelines for Cave and Karst Protection" were issued by the World Commission on Protected Areas for the Working Group on Cave and Karst Protection and the World Conservation Union in 1997. The document provides thirty-one (31) guidelines. It also proves a framework for a management plan at the site level. This framework should describe the karst area and provide a "detailed delineation". It should review the key resources of the area and identify threats and issues. It should clarify the desired goals in protecting the area (of concern); it should identify principles and strategies in the management of the area and provide methods to be adopted in monitoring the effectiveness of the plan.

Table 1: A summary of the Karst, Cave and Bat Hibernacula Management Guidelines that were Reviewed in this Study.

	BRITISH COLUMBIA	ALBERTA	MANITOBA	ONTARIO	QUEBEC	NEW BRUNSWICK	MISSOURI	ALASKA
Agency, and Date	Developed by the Ministry of Forests 1994	A Karst Management Proposal developed for Alberta Environment 2001	Developed by the Wildlife Branch 1996	Habitat Management Guidelines for Bats developed by the Ontario Ministry of Natural Resources 1994	A protection program for bat hibernacula developed by the Wildlife and Habitats Department 1996	Independent paper regarding the status and conservation of caves 1983	Best Management Practices issued by Missouri Department of Conservation 2000	Tongass National Forest Land and Resource Management Plan 1997
Threats Identified	Forestry activities	Forestry operations, limestone extraction, tourism, and human visitation	Forestry, mineral exploration, spelunkers, researchers	Human visitation to caves	Describes the current "problem situation" in Quebec and potential protection program, mainly as a result of the sealing of mine shafts	Mining operations and mineral exploration, forestry operations, cave closures, visitors and groundwater contamination	Main threats identified as human disturbance during hibernation, vandalism, alternations to the caves, natural hazards (below freezing temperatures, flooding)	Forest-wide standards and guidelines for both karst and caves. Karst lands should be managed to protect and maintain significant caves and cave resources
Conservation, management or mitigation tools recommended or used	Provides management categories for the surface and a cave classification system	Cave inventory and cave categorization	Provides specific guidelines for forestry and mineral exploration operations	Focuses on minimizing human visitation to cave sites	Creation of 15 hibernacula by 2001	Restrict access to cave locations	Specific guidelines provided for forestry operations	Maintain a karst management program
	Companies are required to provide proof that operational staff/contractors have followed all cave and karst management guidelines	Closing access to Cadomin Cave from September to May	Emphasizes need for inventory and categorization of caves	Locations of caves and mines used as hibernacula should be mapped	Preparation of development guidelines for every mine closure	Emphasizes outreach and education for cave visitors including interpretive signs at cave entrances	Guidelines are not mandatory	Restrict access to cave locations
	Cave and karst inventory system			Protect hibernacula through land acquisition, signs or fences		Cave inventories		Education and Interpretive Programs

4.2 Current Operating Practices of Resource Developers

4.2.1 Operating Practices of Tolko Industries Ltd.

Tolko Industries Ltd’s (formerly Repap Manitoba) Environmental Impact Statement for 1997-2009 indicates that the company has been made aware of the significance of bat hibernacula and has acquired data about their “general location” from Manitoba Conservation’s Wildlife Branch. It indicates that the company has “been made aware of the location of 10 active bat hibernacula in the Grand Rapids area and will provide adequate buffers around them”.

In the Forest Management Planning and Operating Practices (FMPOP) document located in the Appendices of the 1997-2009 Forest Management Plan, it indicates that when operations are planned near known sites, Tolko will provide information and maps to Manitoba Conservation’s Wildlife Branch for review. If operations are close to “known bat caves”, Tolko will be informed (by Manitoba Conservation) and modifications to planning operations will be made. The modifications that are to be applied “when operations are planned in close proximity to cave sites” are as follows:

- “Roads and landings will be located 100 meters from the cave entrance or known sensitive cave feature (e.g. sinkhole).
- A 100-meter treed buffer will be maintained around the cave entrance site.”

It should be noted that these guidelines found in the FMPOPs in the Appendices section of the Forest Management Agreement (dated October 1996) do not occur in the FMPOPs Operators Guide dated March 1999.

Tolko Industries Ltd. has Forest Management Planning and Operating Practices (FMPOPs) which are detailed in an Operators Guide. The manual outlines the practices that are to be followed in the company's Forest Management Licence (FML) area. The objective of these practices is to "ensure responsible forest management and environmental protection when forestry activities, including logging, are carried out".

This current manual was last updated in March, 1999 and does not provide any objectives or operating guidelines specific to working in areas of karst, caves or bat hibernacula. One section entitled "Specific Operating Conditions" has the objective of ensuring "prescribed operating conditions for each harvest area provide adequate environmental protection of soils, water, fish and wildlife resources". It states the need for this objective is that each harvest area has local conditions that require specific operating procedures. This is to be done with the Area Supervisor prior to operations commencing at a "block entry meeting".

Mr. Doug Hunt, Tolko's current Forestry Superintendent, indicates the company has "recently employed an environmental management system and the protection of sinkholes is noted in tailgate meetings with contractors before they enter a block to start harvesting" (Doug Hunt, pers. comm.). In the "Project Tailgate Checklist" one planning activity that is to be reviewed is "known sensitive areas (e.g. raptor nests, salt licks, sinkholes)" and a second is the review of key buffer locations.

Tolko Industries Ltd. has produced a very detailed (581 pages) Forest Management Plan. It provides detailed information about the biophysical environment for Tolko's FML area (FML No. 2), including information on geology, topography, soils, climate, vegetation, hydrology, wildlife, other resource uses, and much more. However, it should be noted that it only refers to the underlying limestone and sedimentary rock in the Boreal Lowlands and does not refer to the karst landscape or to the sensitivity of this landscape which lies within Tolko's FML area.

The Environmental Impact Statement (EIS) reads: "Section 3.2.1 of the FMP provides a detailed description of the primary geological features of FML Area No.2. The description includes an overview of the various formations, ages and composition of the major rock types together with a generalized map of the bedrock geology. The description represents a complete summary of the available information relevant and pertinent to FML Area No. 2. Activities related to access development, harvesting, forest renewal and forest protection as described in the FMP are not expected to have significant impact on the geological resources of FML Area No. 2." For example, "harvesting activities are not expected to impact the bedrock geology of FML Area No.2."

Regarding surface water, the EIS indicates that "removal of the overstorey from a site results in several potential effects on surface waters. Fewer active root systems result in less water uptake and a lower saturation point for the ground. Moreover, a lack of canopy cover allows more precipitation to reach the ground, which also results in greater accumulations of water on the surface. Disturbance and/or removal of understorey components in a cut block also decreases the water retention capability of an area which increases amounts of surface water. This may result in increased runoff and stream flow."

In terms of groundwater, the EIS indicates that "most activities outlined in the FMP will have none to insignificant impacts on groundwater resources within the FML Area". Harvesting activities "that significantly alter infiltration rates (either increased through greater degrees of puddling and percolation or decreased through surface runoff diverting water from settling and infiltrating the soil profile) may have a potential impact on local aquifers and related contribution to base flow in watercourses.” It goes on to say that “by minimizing the disturbance to residual groundcover and forest litter layer, changes to infiltration rates will be minimized and impacts will be insignificant”.

4.2.2 Operating Practices of Manitoba Hydro

Manitoba Hydro does not have any guidelines that are specific to working near bat hibernacula, caves or karst (Mason, pers. comm.). However, they do have general environmental protection measures that are discussed in “Fur, Feathers and Transmission Lines” (Berger, 1995), a document produced by Manitoba Hydro that explains “how rights-of-way affect wildlife”.

It states that the best way to avoid negatively impacting wildlife habitat is to “avoid sensitive sites”. Manitoba Hydro undertakes a habitat inventory and analysis prior to construction of transmission lines to identify “unique or unusual” habitats. A *Site Selection and Environmental Assessment* study considers all potential impacts on wildlife habitat. Local people are also engaged to determine where “special management practices” may be needed. Various methods might be employed in mitigating impacts to wildlife habitat, any mitigation measures that will be used are incorporated into a detailed *Environmental Protection Plan*.

4.2.3 Operating Practices of Falconbridge Ltd.

Falconbridge Ltd. does not have any specific policy for working in karst areas, near caves or bat hibernacula. Mr. Denis Kemp, Director of Environmental Performance, indicated that “ as far as exploration goes we do not have a specific policy on such habitat [bat hibernacula in karst areas]," (pers. comm, 2003). He did indicate that "such an item would be raised as an issue in our initial environmental survey of a site" as per Falconbridge's sustainable development policy and other written practices.

Mr. Jamie Robertson, Director Exploration for North America, indicates that while Falconbridge Ltd. does not have guidelines specific to caves and karst topography, there are guidelines to ensure environmental protection during all aspects of exploration work. Geologists are expected to research any environmental or cultural sensitivities in each area and address those sensitivities in work plans. "For example, in the William Lake areas, our geologists followed the Manitoba Parks Branch proposed guidelines regarding the bat caves to ensure that our drills and vehicles avoid those areas. They mark those sites on our maps and ensure that our contractors also avoid any sensitive areas. On all projects, we routinely inspect all drill sites to ensure that they have been properly cleaned up, photographed, documented and approved".

Falconbridge Ltd. is involved with a new initiative of the Prospectors and Developers Association of Canada called E3 – Environmental Excellence in Exploration. This initiative will be a source of best management practices for mineral exploration companies.

Falconbridge Ltd. commits to sustainable development and publishes an annual sustainable development report. The policy requires the company to "design, construct, operate, decommission and re-assess operations while promoting continual improvement in order to meet or surpass applicable environmental…. regulations, laws and company standards". The policy also indicates that the company will conduct regular environmental audits and ensure that its activities are conducted "in a responsible and ethical manner, which will help maintain the long-term sustainability and aesthetic quality of its surrounding”. However, the policy and report focus on mining and processing rather than exploration. Mr. Jamie Robertson acknowledges this but indicates that “it does show our strong commitment to the environment” (Robertson, pers. comm.).

4.3 MICROCLIMATE CHARACTERISTICS OF THE FOUR STUDY CAVES

4.3.1 Temperature

The climate of a cave is referred to as the cave's microclimate. It is a key component of cave ecosystems and can also indicate the condition of a cave. "Microclimate is important to karst processes such as speleothem deposition, the aesthetics of a cave and the well-being of cave fauna and human visitors" (Rollins and Yonge, 2001). Temperature is one aspect of cave microclimate that was monitored in this study. In each study cave, temperatures were recorded from October 16, 1999 to May 25, 2000, the approximate hibernation period of the little brown bat.

Daily temperatures were recorded at 0:600, 12:00, 18:00 and 24:00 hours, respectively. These four temperatures were then averaged to provide a daily mean temperature. The daily mean temperatures were averaged over the entire month to provide a monthly mean temperature. The seasonal temperature profile of each cave is shown in Figures 13-16. Table 2 summarizes the monthly mean temperatures for each cave, including sample size (number of days temperature was recorded in each month from October 1999 to May 2000) and standard deviations.

The General Linear Model procedure was used to first determine if overall mean cave temperature varied with sampling site. While controlling for months, this analysis yielded an F-value of 597 (df=3), indicating a significant ($P<.0001$) main effect of cave site on microclimate temperature. Duncan's Multiple Range Test was employed for posthoc comparisons of individual means. It demonstrated that the overall mean temperature of each cave was significantly different from each of the other caves sampled (Iguana Crypt: 4.8°C; Microwave: 2.1°C; Firecamp: 1.7°C and Cutters Cave: 1.1°C).

The General Linear Model procedure was then used to see if there was a significant cave-month interaction for temperature. Since a “straight” line for temperatures over a period of eight months should not be expected, a quadratic curve was fitted to the graphed data. The question of interaction becomes “do the caves follow the same curvatures even if they have different overall levels”? This analysis yielded an F-value of 75 (df=3) indicating a significant ($P<.0001$) cave-month interaction; the temperatures follow different curves. The temperatures were significantly different between caves over time.

Table 2: Mean monthly temperature (in °C) recorded from October 16, 1999 to May 25, 2000 in the study caves.

Month and Sample Size	Mean Temperature with Standard Deviation for each Cave							
	Microwave		Iguana Crypt		Cutters		Firecamp	
	Mean Temp	**SD**	**Mean Temp**	**SD**	**Mean Temp**	**SD**	**Mean Temp**	**SD**
October 99 (n=16)	5.5	.18	6.6	.03	5.4	.28	5.8	.08
November 99 (n=30)	4.4	.66	6.5	.20	3.7	.91	5.0	.41
December 99 (n=31)	1.7	1.35	5.7	.30	-0.8	2.04	2.9	.95
January 00 (n=31)	1.5	.43	4.9	.21	-0.2	.07	-0.2	.74
February 00 (n=29)	1.7	.36	4.4	.21	0.1	.50	-0.2	.48
March 00 (n=31)	0.9	.98	3.9	.21	1.4	.49	0.4	.30
April 00 (n=30)	1.1	.52	3.5	.21	-0.2	.81	0.8	.19
May 00 (n=25)	1.8	.21	3.3	.25	1.5	.38	1.3	.17
Overall Mean Temperature*	2.1	1.58	4.8	1.18	1.1	2.03	1.7	2.09

*Calculated from raw data (i.e. data that includes four readings for each day – none of this data has been averaged).

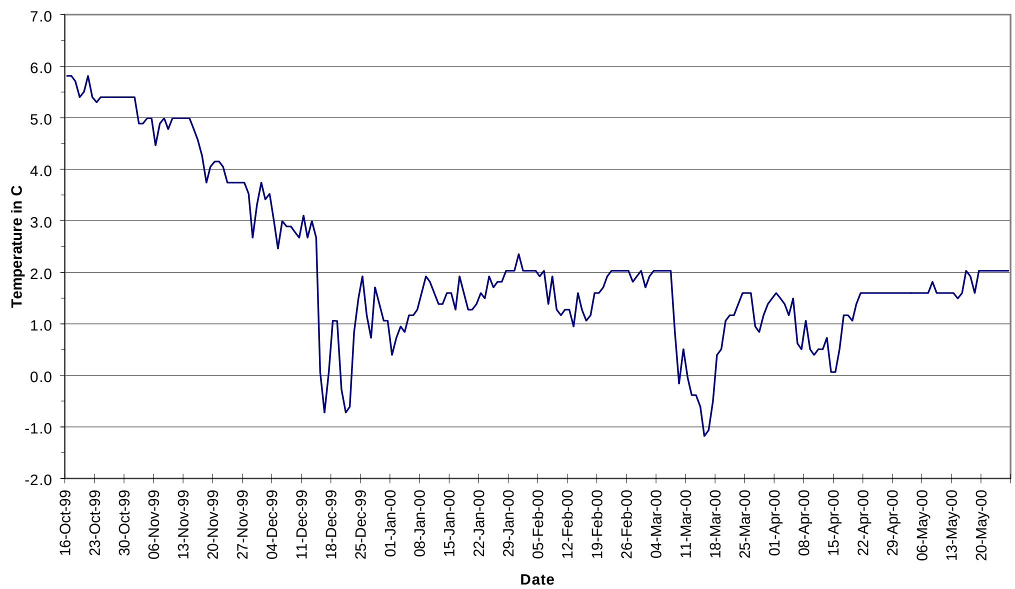

Figure 13. Mean Daily Temperature in Microwave Cave during the 99-00 Hibernation Period

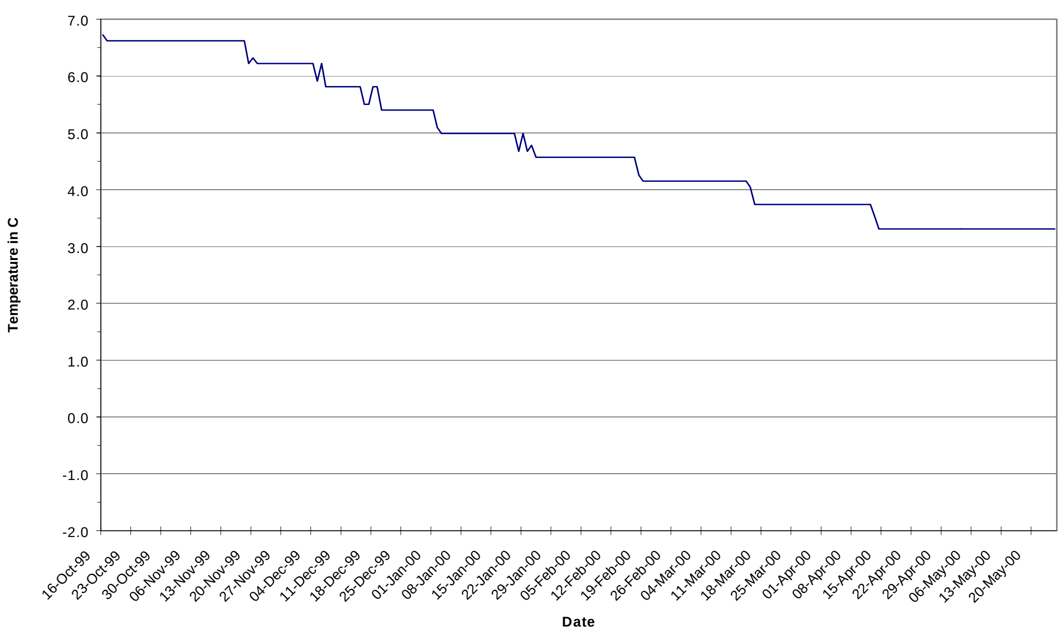

Figure 14. Mean Daily Temperature in Iguana Crypt during the 99-00 Hibernation Period

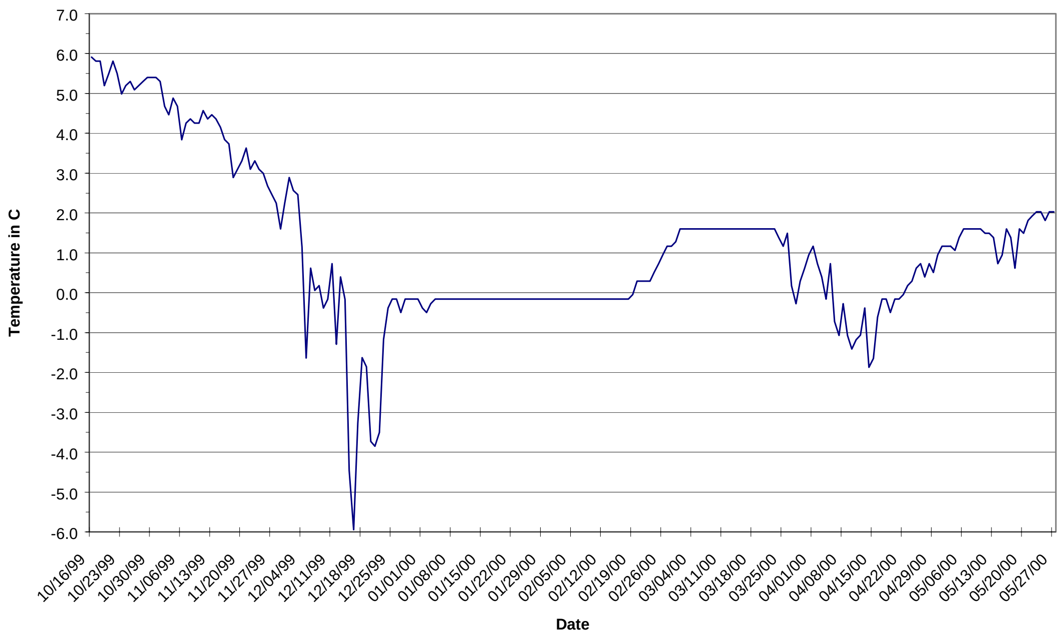

Figure 15. Mean Daily Temperature in Cutters Cave during the 99/00 Hibernation Period

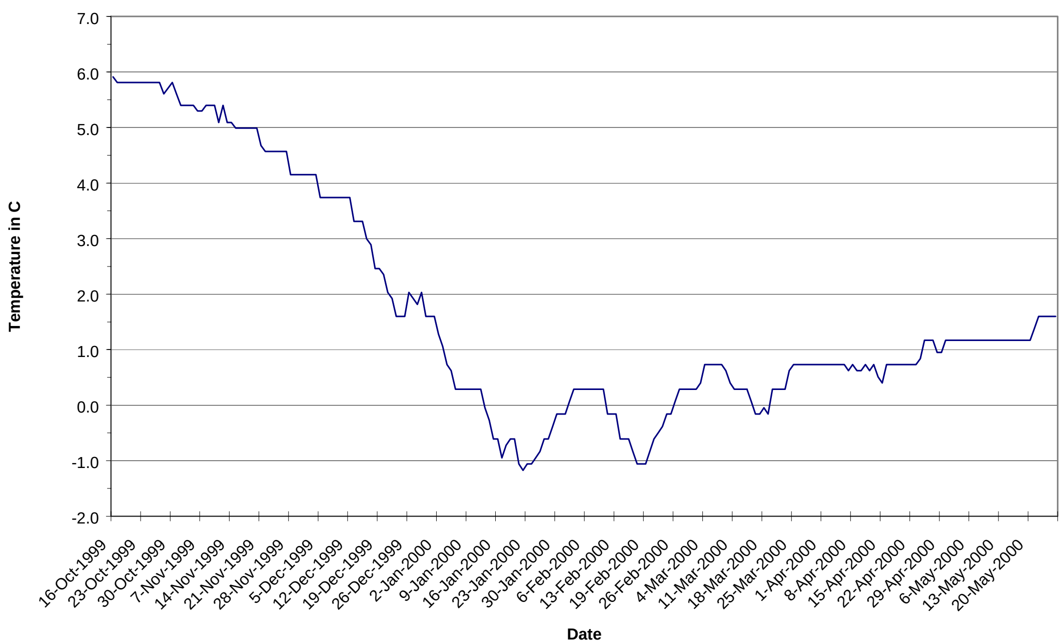

Figure 16. Average Daily Temperature in Firecamp Cave during 99-00 Hibernation Period

4.3.2. Relative Humidity

Relative humidity was recorded daily at 0:600, 12:00, 18:00 and 24:00 hours, respectively. These four recordings were then averaged to provide a daily mean relative humidity for each cave (Figures 17 – 20). The daily mean relative humidity was averaged over the entire month to provide a monthly mean relative humidity. Table 3 summarizes the monthly mean relative humidity of each cave, indicating standard deviations and sample size (number of days in each month that relative humidity was recorded from October 1999 to May 2000).

Relative humidity levels were recorded above 98% in all caves except for Firecamp. At this site, relative humidity started out with a relative humidity in excess of 100% in October and declined to 86% in January. After January, the relative humidity continued to increase to 102%, indicating that the sensor may have become saturated. The relative humidity in Microwave fluctuated between 98% and 99% from October to March. The relative humidity then increased in April and May to greater than 100%. The loggers in Cutters Cave and Iguana Crypt may have become saturated within the first two months, recording relative humidity up to 104%.

All four data loggers produced some data that indicated a relative humidity above 100%. Given that the accuracy of the data loggers is +/- 4%, it is possible that these readings could be as low as 96% or as high as 104%. Therefore, this data was statistically analyzed using the General Linear Model (GLM) procedure. However, it is also possible that the relative humidity sensors became saturated and produced erroneous readings in excess of 100%.

An analysis of the daily mean relative humidity data indicates all caves except Iguana Crypt have a significant curvature. The curvature coefficient for Iguana Crypt is not significant; it has a T-test value of –1.7 (df=1) and P=.09. The curvature coefficients for the other three caves are significant at P=.001 The curvature coefficient for Firecamp (T-test value of 27.7, df=1) and Microwave (T-test value of 4.6, df =1) is significant and positive whereas the curvature coefficient for Cutters Cave (T-test value of –3.3, df=1) is significant and negative. Therefore, since the shapes of the curves are very different for the four caves, there is a cave-month interaction for relative humidity. Relative humidity was significantly different between caves over time.

Table 3. Mean monthly relative humidity (in %) recorded from October 16, 1999 to May 25, 2000.

MONTH AND SAMPLE SIZE	MEAN RELATIVE HUMIDITY WITH STANDARD DEVIATION FOR EACH CAVE							
	MICROWAVE		IGUANA CRYPT		CUTTERS		FIRECAMP	
	Mean RH	**SD**	**Mean RH**	**SD**	**Mean RH**	**SD**	**Mean RH**	**SD**
October 99 (n=16)	98	.82	100	.33	100	.43	100	.38
November 99 (n=30)	99	.85	100	.28	101	.25	100	.77
December 99 (n=31)	98	.92	102	.15	101	1.08	96	2.77
January 00 (n=31)	99	.46	102	.36	103	.61	86	3.75
February 00 (n=29)	99	.49	103	.46	104	.00	88	6.63
March 00 (n=31)	99	2.25	104	.04	104	.00	96	4.52
April 00 (n=30)	102	1.05	104	.00	104	.26	101	.39
May 00 (n=25)	104	.35	104	.00	103	.94	102	.25
Overall Mean RH*	100	2.07	103	1.39	103	1.48	96	6.81

*Calculated from raw data (i.e. data that includes four readings for each day – none of this data has been averaged).

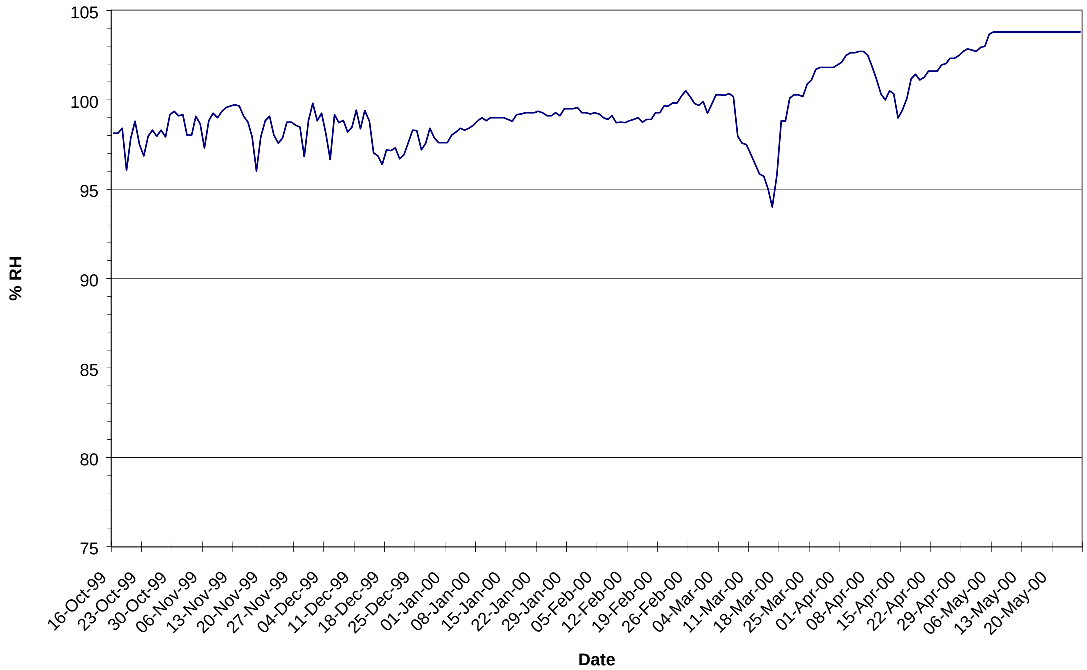

Figure 17: Mean daily relative humidity in Microwave Cave from Oct 16, 1999 to May 28, 2000.

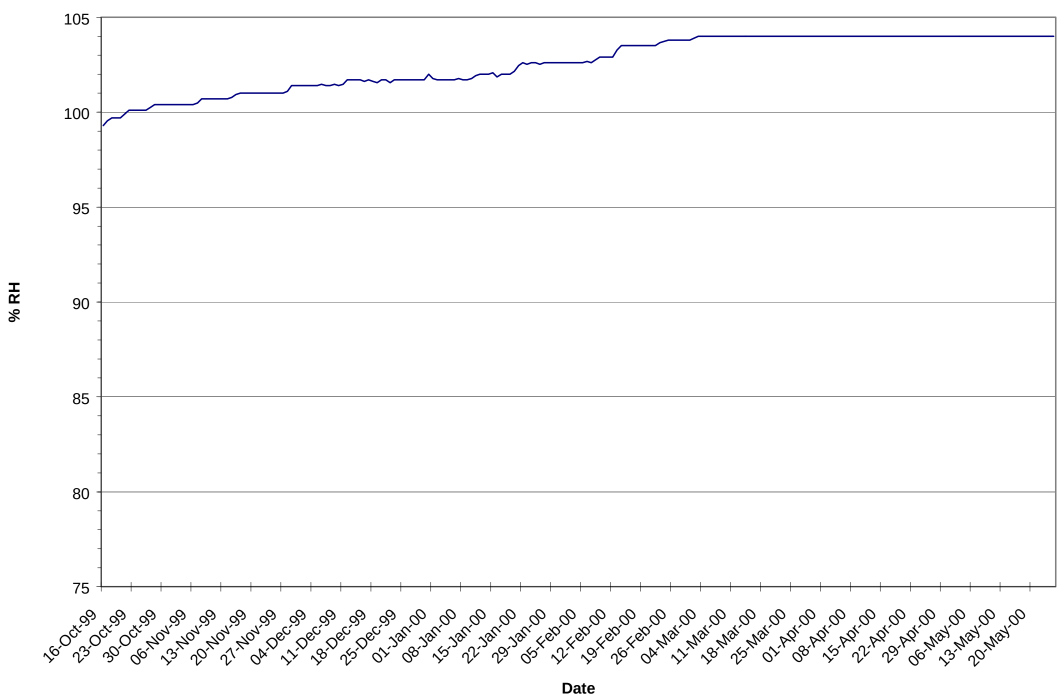

Figure 18: Mean daily relative humidity in Iguana Crypt from Oct 16, 1999 to May 28, 2000.

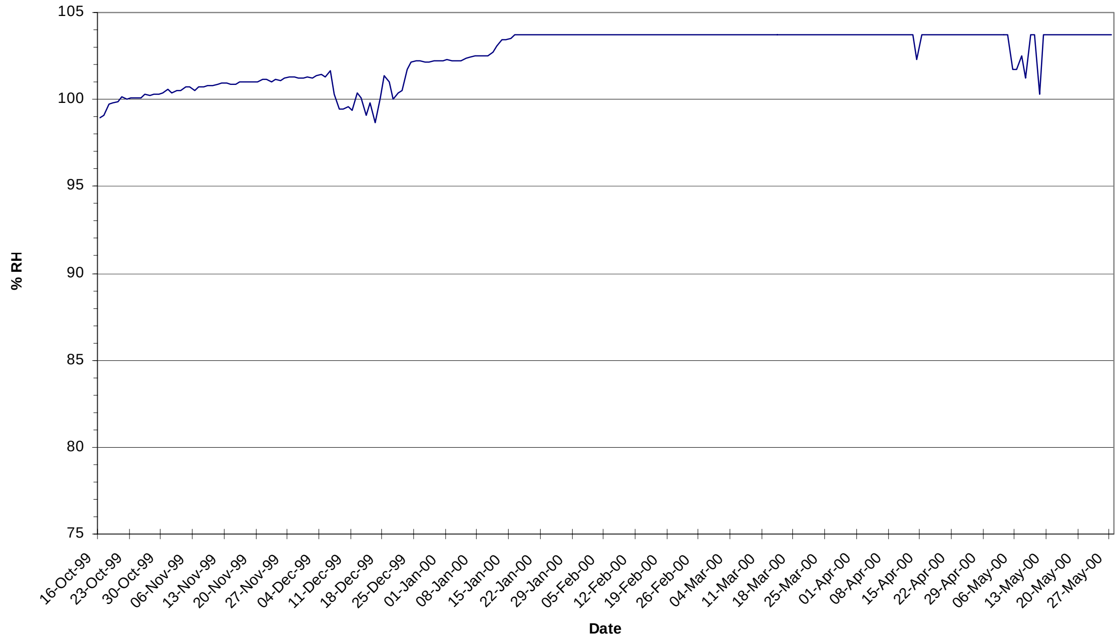

Figure 19: Mean daily relative humidity in Cutters Cave from Oct 16, 1999 to May 28, 2000.

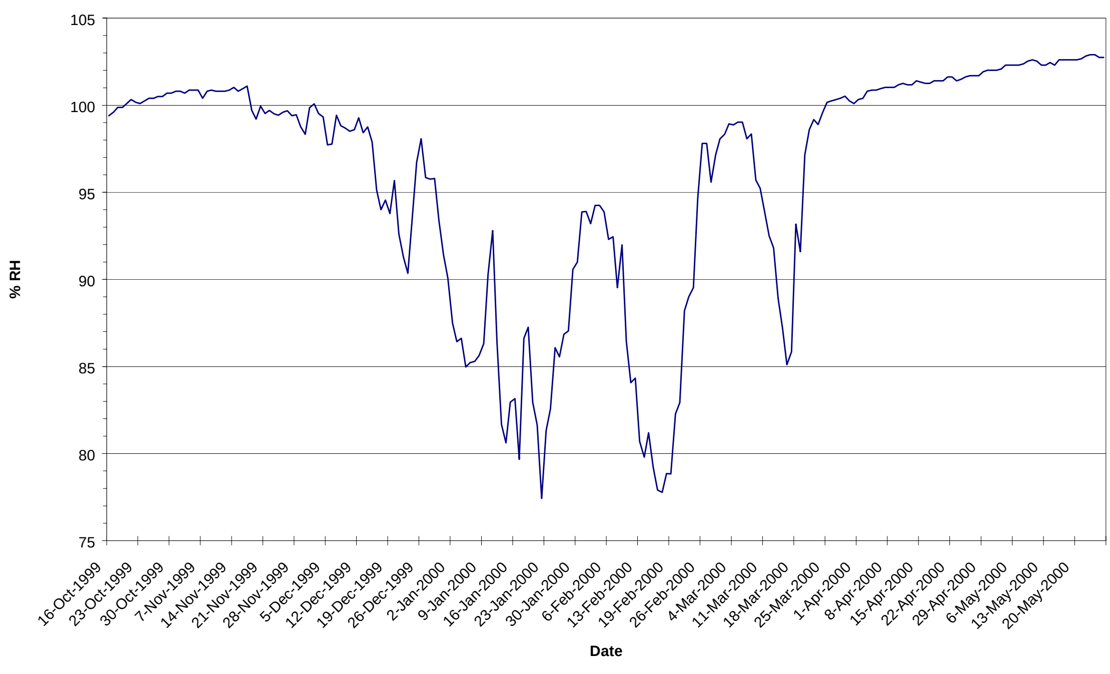

Figure 20: Mean daily relative humidity in Firecamp from Oct 16, 1999 to May 28, 2000.

4.4 BAT ACTIVITY FROM OCTOBER 1999 TO MAY 2000

Trailmaster Game Monitors were used to determine bat activity from October 16, 1999 to May 28, 2000. These monitors use passive, infrared technology and are heat and motion sensors. The monitors receive heat and motion information in pulses. They record the presence of animals in an area of study by recording times that the monitor detects warm-bodied animal movement within its area of sensitivity. The monitors cannot differentiate between mammal species, for example, bats and squirrels, but they can be set to detect small mammals rather than large mammals, and vice versa.

The monitors had to be set to detect small mammals. Determining a P value and a Pt value does this (Table 4). The P value is the number of infrared pulses required to be considered an event. The Pt value is the time allowed to get the required number of pulses. The P1 setting is very sensitive (good for small animals) and the P5 setting is least sensitive (best for large animals). Trailmaster indicates that P1 is too sensitive for normal applications.

Table 4: P and Pt settings used in each of the study caves.

Cave	P Setting	Pt Setting
Cutter's Cave	2 infrared pulses	2.5 seconds (more sensitive)
Firecamp	2 infrared pulses	3.0 seconds (most sensitive)
Iguana	2 infrared pulses	1.0 seconds (least sensitive)
Microwave	2 infrared pulses	2.5 seconds (more sensitive)

As the time allowed to get the required pulses decreases (Pt goes down), the sensitivity to small mammals decreases. For example, at P2 and Pt2.5 an animal must "interrupt" 2 pulse windows within a 2.5-second time period to be recorded as an event.

Thomas (1995) used passive infrared game monitors to quantify flight movements of bats, but did not indicate the settings (P and Pt values) that he used. A Pt setting of 2.5

was originally planned for use in my study. However, the Pt settings for Firecamp and Iguana Cave were erroneously set at settings different from Cutters and Microwave. This error, though, provided an opportunity to observe the results of the various settings.

From the following graphs (Figures 20-23), one can see that the Pt setting for Iguana Cave was set too low at 1.0 second and therefore not sensitive enough to record all bat activity (some activity is expected throughout the hibernation period due to natural arousals). This may account for no activity throughout much of the winter in Iguana Crypt. The Pt setting was set too high for Firecamp Cave (3.0 seconds) and therefore was set too sensitive and recorded much more activity (i.e. it may have recorded the movements of one individual many times). The best Pt to use appears to be a Pt of 2.5 as was done in Microwave and Cutters Cave. However, to determine the most accurate setting, the game detector should have been calibrated with an independent measure of bat activity such as visual observations or a video recording. The total number of events per cave each month was calculated and the results are presented in Table 5.

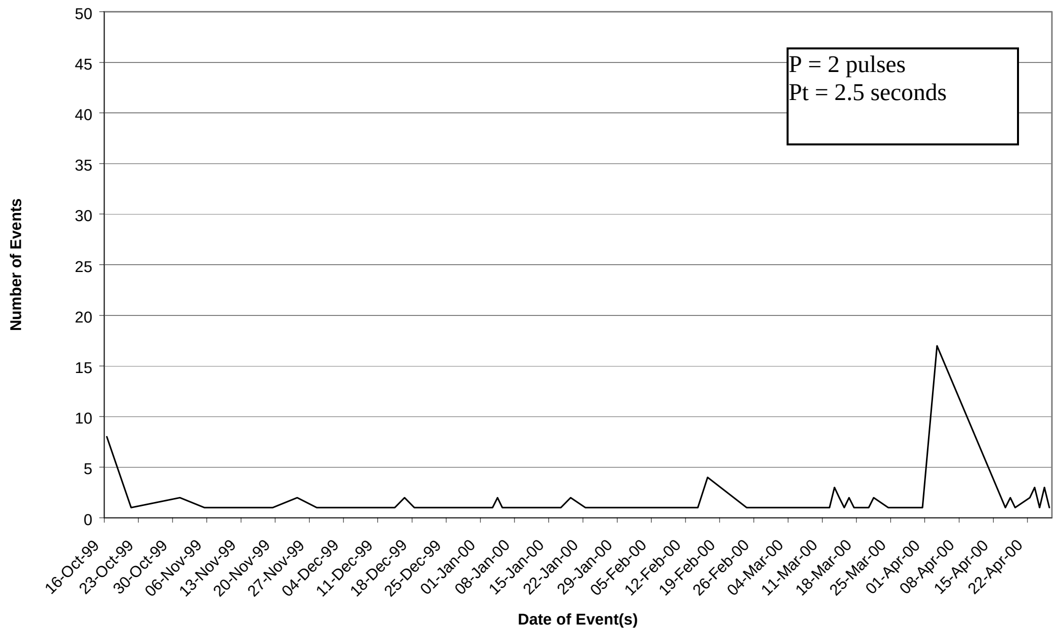

Figure 21: Activity from October 16, 1999 to April 26, 2000 in Microwave Cave.

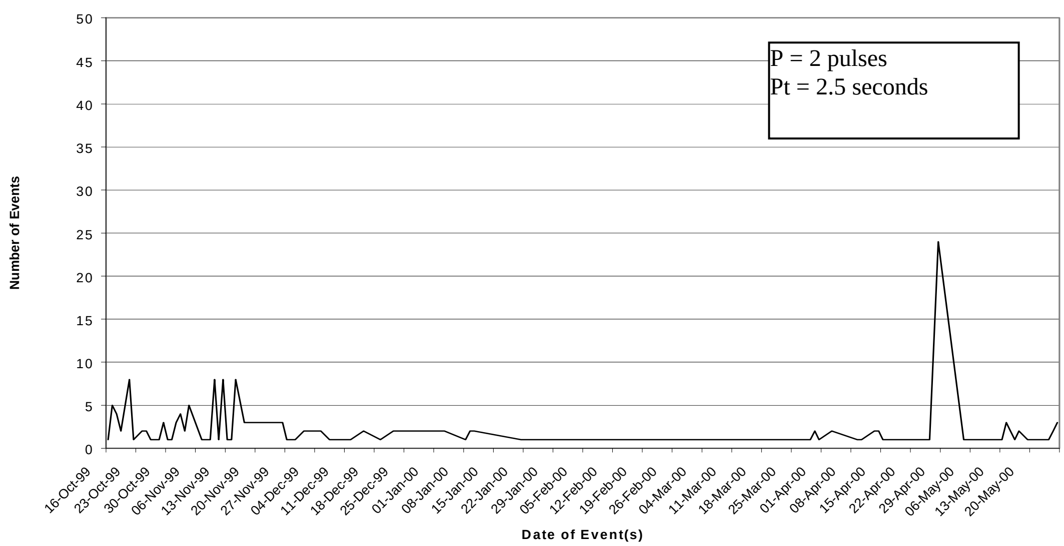

Figure 22: Activity from October 16, 1999 to May 28, 2000 in Cutters Cave

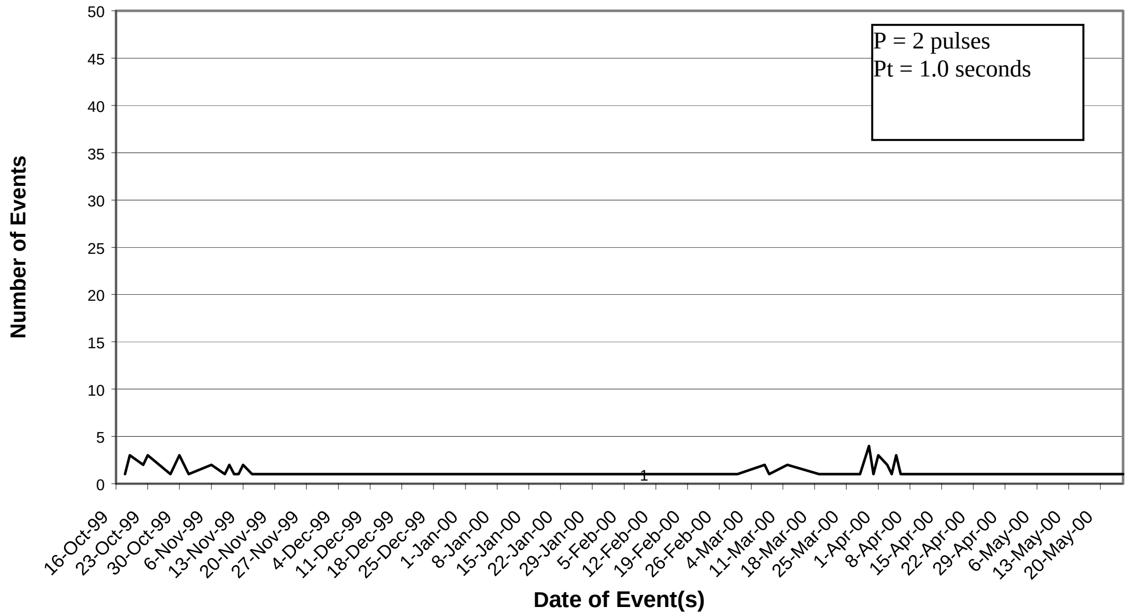

Figure 23: Activity from October 16, 1999 to May 28, 2000 in Iguana Crypt.

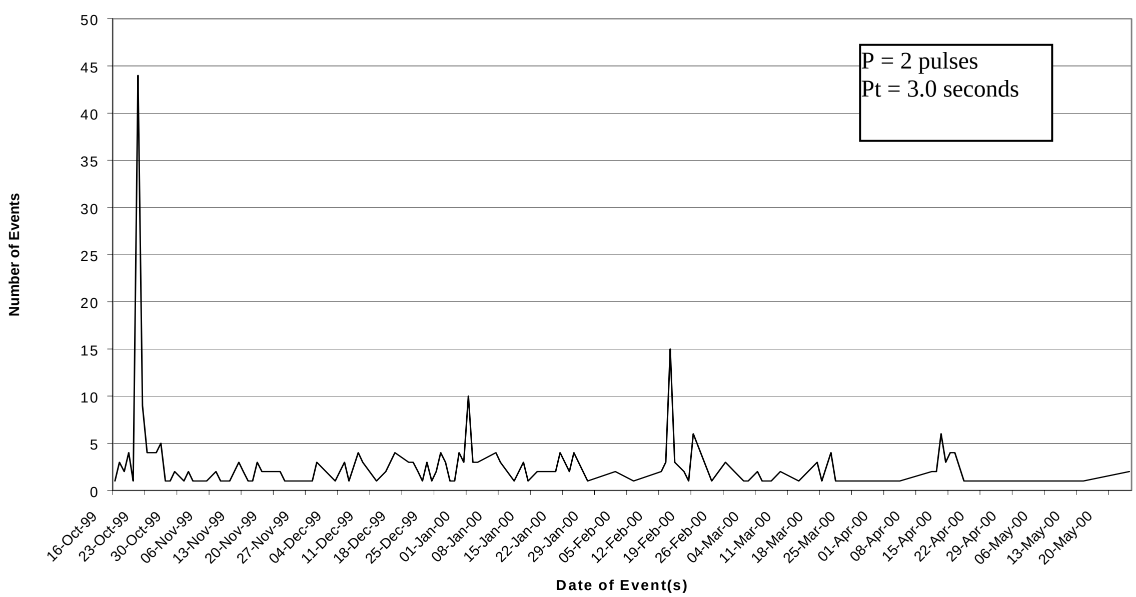

Figure 24: Activity from October 16, 1999 to May 28, 2000 in Firecamp Cave.

Table 5: The total number of events each month that were recorded in each study cave from October 1999 to May 2000.

Month	Cutters		Firecamp		Iguana		Microwave	
	n	**# of events**	**n**	**# of events**	**n**	**# of events**	**n**	**# of events**
Oct	14	32	16	87	6	13	3	11
Nov	18	57	24	36	9	12	6	7
Dec	13	20	22	52	1	1	12	13
Jan	5	8	16	45	4	4	12	14
Feb	1	1	13	43	4	4	8	11
Mar	5	6	14	21	10	15	14	19
Apr	9	35	11	26	11	16	8	30
May	15	22	4	5	4	4	no data	no data

4.5 Statistical Analysis of the Activity Data

The Pearson Correlation Coefficient was calculated to determine the degree of linear relationship between overall mean cave temperature and bat activity. Due to the questionable relative humidity data, only the temperature data was analyzed with the bat activity data.

In Microwave, there was an inverse relationship between temperature and bat activity, such that as temperature increased activity decreased, but this trend was not significant (r=-.0.07, df=194, P=.36). In Cutters Cave, there was a significant (P<.0001) positive relationship between temperature and activity such that as temperature increased, activity increased (r= .27, df=225). In Firecamp, there was also a positive (P=.006) and significant relationship between temperature and activity such that as temperature increased, activity increased (r=0.18, df=225). In Iguana Crypt, there was a positive, albeit non-significant (P=.44) relationship between temperature and activity, such that as temperature increased, activity increased (r=0.05, df=225).

4.6 Local Knowledge of Bats and Caves

Manitoba Hydro provided an initial contact from Grand Rapids First Nation to initiate the snowball sampling method, but unfortunately several attempts to contact this individual were unsuccessful. Professor Thomas Henley of the Natural Resources Institute provided a second contact. This second individual suggested the researcher contact the mayor of Grand Rapids, Mr. Robert Buck, to begin the interview process (Plate 22). Mayor Buck was most helpful in locating additional interviewees (Plate 23). As a result of this method, seven individuals were interviewed. However, only two individuals were interviewed using all 20 pre-determined questions (see Appendix A for the list of questions). The other five interviews were conversations that incorporated as many of the questions as time and conservation would allow. These were held with local residents who were Tolko contractors that were working on the landscape at the time of the interview (Mr. Art Samatte, Mr. Shane Samatte, Mr. Joe Guibocg, Mr. Lloyd Foeir, Mr. Carl Ferland).

During Manitoba Conservation's Parks and Natural Areas open house, the researcher was able to talk with approximately 15 local residents about their knowledge of bats and caves. The structured interview questions were not used but rather an open-ended conversation interview structure was employed, incorporating as many of the questions as possible.

Both interview methods did not result in structured answers to questions. The conversations could only provide a general sense of what the local people knew about bats and caves. As well, it was not clear from any of the participants if they were members of the Grand Rapids First Nation or residents of the town of Grand Rapids. Two individuals did live in town (i.e. not on the reserve) but all others that participated were not asked to indicate their Aboriginal treaty status. Therefore, while these interviews were originally meant to capture “traditional ecological knowledge” they only succeeded in capturing local knowledge from a small sample size.

At the open house, most people that were “interviewed” were aware that there were caves and bats in the area. Only one woman, who considered herself to be a long-time resident, did not know about the existence of any caves in the area. Some people were aware that bats used the caves, but not everyone, including some of the local timber contractors.

Some of the Tolko contractors relayed stories about how they had gotten their forestry equipment, such as delimbers and skidders, stuck in “holes” meaning the caves. Some individuals who knew the locations of various caves, described one as L-shaped and forty feet deep. Another individual indicated there were caves north of Little Limestone Lake. They indicated that some caves were also known to be large snake hibernacula or used by bears as hibernacula.

One individual that Mayor Buck introduced the researcher to, Ms. Stella Cook, was very familiar with the caves and bats. Her father, the late Mr. Walter Cook, was a well-respected member of the community who lived in Grand Rapids his entire life. Ms. Cook indicated that it was her father that advised the provincial government that the bats over-wintered in caves around Grand Rapids, and indicated that he saw “hundreds” of bats in some caves. The proposed Ecological Reserve was named after Mr. Cook, and was declared the Walter Cook Upland Caves Park Reserve in December 2001.

Plate 22: Mr. Robert Buck, Mayor of Grand Rapids, the researcher's initial contact, briefing another local resident on the research project and determining interest in participation in an interview.

Plate 23: Researcher talking with Mayor Buck and three other local Tolko contractors at a logging site off Ochre Lake Road in Feb 2001. Pictured from left to right: Mr. Robert Buck; Mr. Carl Ferland; Mr. Joe Guibocg; Mr. Lloyd Foeir.

5.0 MANAGEMENT GUIDELINES

From a review of the potential impacts of resource development on karst and bat hibernacula it is clear there are gaps between how the land can be affected by resource development, the provincial guidelines in place in Manitoba to mitigate these impacts, and the current operating practices of resource developers.

Manitoba Conservation's Bat Hibernacula Management Guidelines encompass all the potential threats (types of resource development that may have impacts) identified by the various guidelines from other jurisdictions except for hydro-electric transmission line and ROW construction. However, the guidelines are not as detailed, nor as restrictive, as those provided by British Columbia or Alaska. For example in the Tongass National Forest plan, highly vulnerable karst areas (i.e. those areas where caves are present) should be managed to conserve the karst values and "timber management and related activities should be excluded from these lands".

The Manitoba guidelines only provide recommendations for 200-meter buffer zones around caves and bat hibernacula. Guidelines from other jurisdictions have stricter guidelines. They recommend that in moderately vulnerable lands (i.e. lands where the karst is moderately developed and solutional karst features, **excluding caves**, are present) timber harvesting, road construction, and quarry development should not occur within a minimum of 100 feet (30.48 meters) from the edge of any sinkhole. If a cave is present, then these activities should not occur over the known "significant" cave. As well, these activities should not occur on lands "that are close enough to the entrance of a significant cave to be capable of altering the microclimate of the cave's entrance and/or cave features within”. The guidelines also indicate that when buffers are maintained they must be windfirm. “There is no credible standard buffer distance that will provide the assurance required to protect the systems from blowdown of the forest within a given buffer”. The buffers must be carefully designed and take into consideration wind direction patterns, blowdown history, previous adjacent harvest, topography, and stand windfirmness.

Manitoba’s guidelines do not promote any public education (interpretive programs) or outreach programs for industry about bats and caves. The need for public education programs about bats and caves was mentioned in many of the guidelines. Target audiences should include industry, researchers, and spelunkers. Local people and school children would also benefit from public education programs about bats and caves.

Some guidelines suggest interpretive programs or signage at caves. “Sign posting can educate visitors, condition their behavior and reduce ignorant damage” (Kiernan, 1989). This signage would only be beneficial for caves that are not bat hibernacula and are located in public parks, such as the Karst Springs self-guiding interpretive trail in Grass River Provincial Park. However, Cadomin Cave in Alberta is both a well known cave for hiking and a bat hibernaculum that is signed indicating no visitation during the hibernation period. The area is monitored such that these guidelines regarding visitation are enforced.

The cave locations in Grand Rapids are kept relatively secret and would not benefit from public signage. However, human visitation to the Grand Rapids caves is an issue. During my study, individuals did find and enter Microwave cave in May 2000 prior to the end of this study, when bats were still hibernating. Therefore, bats in the Grand

Rapids area are at risk of disturbance by human visitation to hibernacula during the hibernation period.

Every two years there is a Karst Summit in Grand Rapids where members of the Speleological Society of Manitoba (SSM), researchers and some Manitoba Hydro and Tolko Industries Ltd. employees attend. This provides information about the cave and bat resources in the area. This is one example of an outreach program, however greater attendance from industry, especially on-the-ground operators, would benefit from this program. “General public education programs can instill a deep seated understanding and sensitivity and enhance responsibility…” (Kiernan, 1989).

The importance of education and outreach programs cannot be over-stated. It is the local people that are contracted by Tolko to carry out logging operations. If cave locations are missed during the pre-harvest surveys they may be located during logging operations, but unless the contractor realizes the importance and fragility of the caves, he may log over it or fill it with debris. If an area resident is made aware of the importance of these “holes in the ground” as critical habitat, he may feel a sense of ownership for these non-renewable resources and be more inclined to work cautiously around them. The local contractors need to be made aware why they are asked to leave buffers around certain sites. Participation in programs like the Karst Summit meetings is essential for ensuring that best management practices are carried out “on the ground”.

The Manitoba guidelines do not suggest that a karst management strategy be established or that a cave inventory of the area be undertaken. As with any resource, caves and karst cannot be properly managed without knowing more about the resource in question. A karst/cave inventory system is in place in the Tongass National Forest in Alaska and for lands in BC under the direction of the Ministry of Forests.

A formal cave inventory system is currently not in place in Manitoba. However, the Speleological Society of Manitoba has undertaken “close collaboration and exchanges of information with Tolko Industries Ltd. (previously Repap) officials and field personnel, whose on-site references have provided the club with numerous new [cave] locations to check” (McRitchie and Monson, 2000). Manitoba Conservation’s Conservation Database Centre has locations of some of the bat hibernacula but they have not yet been incorporated into their GIS database (Greenall, pers. comm). The SSM also houses locations of caves as does Tolko Industries Ltd. There is a need for a centralized cave location database where all this information can be brought together and made available only to those who need it. Caves could then be evaluated and classified as outlined in the Cave Resources Management section of the Karst and Cave Resources Forest-wide Standards and Guidelines of the Tongass National Forest Land and Resource Management Plan.

In this plan, caves classified as sensitive caves would be identified as those “unsuitable for exploration by the general public either because of their pristine condition, unique resources, or extreme safety hazards and would be closed with “entry allowed by permit only”. Caves that act as bat hibernacula are considered to be habitat that is critical to bat survival. These caves are, therefore, given the highest value under the category of “biological resources” which rates caves on a scale of 0 (no biological components) to 5 (biological components are very numerous and highly sensitive to disturbance).

5.1 Current Operating Procedures of Resource Developers

5.1.1 Tolko Industries Ltd.

While only Tolko Industries Ltd. has specific operational procedures for working near bat hibernacula (as outlined in the appendices of their FMP but not their Operator's Guide), Manitoba Hydro and Falconbridge Ltd. have other environmental practices in place that could be expanded to help mitigate some impacts to bat hibernacula. However, none of the resource companies have any operational procedures for working in sensitive karst areas.

Tolko Industries Ltd has limited operational practices specific to working near bat hibernacula. However, their practices do not adhere to Manitoba Conservation's guidelines. Within their forestry operations, they will locate roads and landing only 100 meters from a cave entrance or sensitive cave feature and will only maintain a 100-meter buffer around cave entrance sites. This indicates the need for guidelines that can be enforced such as those being incorporated into the new Forest Practices Guidebooks being drafted by Manitoba Conservation.

5.1.2 Manitoba Hydro

While Manitoba Hydro does not have operational procedures specific to transmission line development in karst areas or near bat hibernacula, they do have other wildlife mitigation methods as outlined in their publication "Fur, Feathers and Transmission Lines" (Berger, 1995). The following are some examples of mitigation methods that Manitoba Hydro already employs, and which may mitigate impacts to bat hibernacula:

- “Leaving natural vegetation buffers between the line and sensitive wildlife habitat.” Similar to leaving buffer zones around caves and bat hibernacula.

- “Employing construction methods and timing appropriate to the local site (e.g., suspend operations during a sensitive time period such as nest initiation, egg-laying, calving)”. This would mean suspending operations during the hibernation period (September to May) which may not be feasible.

- “Retaining dens and roost trees”. This would mean ensuring caves used by bats are not damaged or made unsuitable, which includes maintaining a vegetative buffer around the caves.

- “Closing access roads when it is necessary to protect a wildlife species during all or part of a year, and when construction is completed.” Especially important once construction is completed to limit public access to bat hibernacula. Again, may not be feasible to close the access road from September to May during construction operations.

- “All fuels, oils and lubricants are stored in dedicated areas at work camps and marshaling yards at a safe distance from sensitive features. All waste oils and lubricants are stored in appropriate containers and removed from the project areas as required under applicable Manitoba environmental legislation.” This is very important in karst areas as pollutants are so easily transferred through the limestone and into the cave environment and groundwater.

5.1.3 Falconbridge Ltd.

Falconbridge Ltd. has a sustainable development policy in which the company indicates that it will undertake baseline studies and impact assessments prior to initiating any mining project. As well, Falconbridge acknowledges that traditional knowledge can provide valuable information (such as information about migration periods) and guidance to the company. For example, at Falconbridge Ltd. operations in northern Quebec, the company learned that some sea mammals could be affected by shipping traffic between March and June. Falconbridge, therefore, does not ship during these months.

5.2 MICROCLIMATE CHARACTERISTICS OF GRAND RAPIDS HIBERNACULA

5.2.1 Temperature Data

While statistical analysis of the temperature data indicated that mean overall temperatures differed significantly for each of the four caves, the values ranged over only a few degrees, from a minimum of 1.1 °C to a maximum of 4.8 °C (Table 6). The temperature range commonly reported for hibernacula of *M. lucifugus* in Ontario is between 1°C and 5°C but they can tolerate temperatures as low as -4°C (Fenton, 1983).

Table 6. Overall mean temperatures with standard deviations (SD) for each of the study caves from Oct 16, 1999 to May 25, 1999

Microwave		**Iguana Crypt**		**Cutters Cave**		**Firecamp**	
Temp	**SD**	**Temp**	**SD**	**Temp**	**SD**	**Temp**	**SD**
2.1 °C	1.57	4.8 °C	1.18	1.1 °C	2.03	1.7 °C	2.09

Caves are known to have stable temperatures that usually approximate the annual mean surface air temperature of the region (Fenton, 1983). For the Grand Rapids area, the Environment Canada Weather Office reports that the mean annual air temperature is 0.8 °C (SD=1.2°C) based on climate data from 1971-2000 at the Grand Rapids Hydro Weather Station (53° 9’ N; 99° 16’ W). The average temperature of the four caves was calculated to be 2.4 °C, or 1.6 °C higher than the mean annual air temperature of the Grand Rapids area.

It is the circulation of either air or water that provides the link between the internal cave environment and the external environment. It is through either of these two media that cave temperatures vary above or below the mean annual surface temperature and it is usually the impact of air flow that has the greater effect as most caves have some air circulation, but not all caves have water flow (Tuttle and Stevenson, 1977). Such is the case with the four study caves.

Both Microwave and Firecamp Caves have similar structures, one entrance with a vertical shaft that opens into a larger chamber. Microwave is 9.8 meters deep and Firecamp is 8.0 meters deep. The mean temperature from mid-October to the end of May was 2.1 °C in Microwave and 1.7 °C in Firecamp, so that Firecamp was only 0.4 °C cooler than Microwave.

Iguana Crypt has a different structure than both Microwave and Firecamp. While it too has only one entrance, it has a horizontal shaft (passage) that opens to a larger cavity. The total depth of the cave is 11.5 meters, but the floor of the roosting cavity is only 8.5 meters deep and much further away from the entrance (approximately 30 meters) than Microwave and Firecamp.

Just past the cave's entrance is a vertical undulation that acts as a dam, effectively inhibiting air flow (Fig. 11). The narrow passage "also dampens temperature fluctuations through its increased cave wall surface to volume ratio, the tendency of the walls to return air to mean annual surface temperature will have maximum effect" (Tuttle and Stevenson, 1977). These characteristics in combination with the cave's single, small entrance can reduce air flow dramatically. The result will be a cave or section of cave with relatively constant temperature (Tuttle and Stevenson, 1977). Iguana Crypt had the smallest amount of deviation of the four cave's mean monthly temperatures. The mean temperature of Iguana Crypt from mid-October to the end of May was 4.8 °C. This was 2.6 °C warmer than Microwave, 3.0 °C warmer than Firecamp and 4.0 °C warmer than the mean annual surface temperature. As well, Iguana Crypt is known to be an active bear den, with the bear hibernating in the first chamber, effectively blocking the rest of the cave from the entrance and external temperatures. Fresh bear scat was observed around this cave in May 2000 when the equipment was retrieved from the cave.

Cutters Cave has a structure that is different from the three previous caves. It is more of a split in the ground or crevice-like cave with a large, long entrance (almost the length of the cave). It is the shallowest of all four caves, with a maximum depth of 6.7 meters and does not open to a larger cavity. This cave's mean temperature was 1.1 ° C, the lowest of all the study caves and it had a mean temperature closest to the mean annual surface temperature (0.8 °C; SD= 1.2 °C) suggesting that this cave was most influenced by outside temperature, which corresponds to its structure (large opening, shallow). Based on Tuttle and Stevenson (1977) caves that vary above or below the mean annual surface temperature are more likely to have greater air flow. This cave should have greater air flow compared to Iguana Crypt and yet Iguana had the greatest deviation above mean annual surface temperature and Cutters had the least. Bats were not observed in this cave in October, 1999 or May, 2000.

Cutters Cave also had the lowest minimum temperature of all the caves (approximately –6.0 °C versus –1.0 °C). During a May 1998 census of bats, it had the lowest bat population of the study caves: 8 individuals in Cutters, 223 individuals in Iguana Crypt and 174 individuals in Microwave (Firecamp was not censused). In both October 1999 and May 2000 of my study, bats were observed in Firecamp, Microwave and Iguana but not in Cutters Cave. These data and observations suggest that Cutters Cave has become sub-optimal over-wintering habitat for bats as a result of the resource development disturbance it has incurred.

5.2.2 Relative Humidity Data

Fenton (1970) found *M. lucifugus* hibernating in areas where the humidity ranged from 70% to 95% as measured by a hair hygrometer. However, when additional humidity readings were obtained using an electrolytic AMLAB porto-hygrometer, Ontario mines had humidities consistently higher than 90%. Fenton (1983) indicates that relative humidity is usually over 90% in bat hibernacula to prevent dehydration. He also suggests that the clustering behavior of hibernating bats may help to reduce water loss. Davis *et al* (1996) found that the relative humidity in caves on Vancouver Island was 100%. They were monitored using On-set temperature and relative humidity data loggers.

However, other researchers have found that water condensation around the surface of these loggers (including the HOBO H8 Pro Series RH/Temperature loggers used in this study) will provide inaccurate readings of relative humidity (greater than 100%). This is a result of the humidity sensor becoming saturated and ultimately being destroyed by continuous condensation (Messina, pers. comm).

It is possible that all four sensors became saturated in the caves during this study. This may have occurred as early as October in Cutters Cave and Iguana Crypt. It may have occurred in October and November in Firecamp but then the data indicates lower relative humidities from December until March, after which they rise over 100% again. Microwave is the only cave in which the relative humidity sensors did not record relative humidity in excess of 100% right away and resulted in some useful data. The average reading for Microwave from October 1999 until the end of March 2000 was 99%.

The data was statistically analyzed using the General Linear Model and this analysis indicated that there was a cave-month interaction, indicating that the relative humidity was significantly different between caves over time. Although statistically different, the range of relative humidity was as expected (monthly means ranged from 86% to 100%).

There was also a cave-month interaction for temperature, indicating that the temperature was significantly different between caves over time. As mentioned above, cave temperatures do approximate the mean annual surface air temperature, and so one would expect some fluctuation in cave microclimate temperatures over eight months. This fluctuation in temperature would result in fluctuations in relative humidity as well, which is most noticeable in Microwave (refer to Fig. 16 and Fig. 20).

There are pros and cons to using the Onset Hobo temperature/relative humidity data loggers in caves. The temperature sensor seemed to work fine, but the relative humidity sensor was not suitable for the cave environment. As well, rain shields should have been purchased and adhered to the cave walls. This would have been beneficial over using the margarine container but unfortunately is more damaging to the cave wall.

All four data loggers released from the margarine containers. Two remained beneath the container on the rock ledge where they were initially set up (in Iguana Crypt and Firecamp). The other two fell off the ledge and down into the rock rubble on the floor of the cave (Microwave and Cutters Cave).

As well, the game monitors should also have been secured to the cave wall, as one of the four was removed from the cave by an individual after it had apparently fallen off the ledge where it had been placed by the researcher.

5.2.3 Bat Activity Data

A review of the Trailmaster Game Monitor results indicates that there is activity throughout the hibernation period. This data complements information in the literature regarding bat movement during hibernation. Fenton (1983) relates that little brown bats arouse periodically during hibernation. He does not indicate the minimum amount of time that a bat spends in dormancy before an arousal occurs, but does note that a period of dormancy will not usually extend beyond 90 days (Fenton, 1983). Indiana bats arouse every 8 to 10 days and have been known to move within a cave during the hibernation period to locate different roosting sites with more preferable temperatures (Menzel et al., 2001). Once a bat awakens, it may engage in urinating, grooming and flight before settling back into hibernation (Fenton, 1983).

In Ontario, *Myotis lucifugus* hibernates in those parts of caves or mines where the temperature does not fall below 0°C. Clusters of bats were observed in peripheral areas of hibernacula in the fall and late spring. They moved into the deeper recesses when the temperatures at the peripheral sites fell below freezing (Fenton, 1970).

After the field season ended, further research indicated that the Hobo Onset data loggers that were used to measure temperature and relative humidity may have also disturbed the bats. The loggers produce a constant ultrasound at 32kHz. Apparently not all loggers will disturb bats, but those that do are very disruptive. As well, “mild sound and light stimuli” has been found to initiate arousal in Indiana bats as has a reduction in relative humidity below 85% (Menzel et al., 2001).

Fenton (1992) also indicates that banding of bats during the hibernation period may cause them to be disturbed. “Banded little brown bats have moved more than 120 kilometres between caves in midwinter, perhaps because of the agitation caused by banding them”. Water loss may be a key factor in triggering arousals (Speakman and Racey, 1989; Thomas and Cloutier, 1992 *in* Ministere de l’Environnement et de la Faune, 1996). When relative humidity levels are low, bats will lose body moisture more quickly and will have to wake-up in order to drink (Fenton, 1970).

The differences in Pt values meant that an analysis across the four caves regarding activity levels could not be accomplished. Only Cutters and Microwave had the same Pt level, but the activity in Cutters Cave was more likely from squirrel activity than bat activity. No bats were observed in this cave in October 1999 or in May 2000, but two squirrel middens were observed in the cave.

While a statistical analysis could not be undertaken, a review of the data does reveal some interesting facts. From the literature, it is well known that bats begin to swarm around cave entrances in August and begin to hibernate between September and October. They emerge from hibernation between April and May. Therefore, by looking at which day had the maximum number of events in a specific month (October) one can see which days had the highest activity levels. One can also look at the days with maximum activity in April and May, and perhaps March as well to see when activity peaks were occurring.

A review of the maximum number of events in October in Cutters Cave indicates a maximum of 8 events on October 21; in Firecamp, a maximum of 44 events also occurred on October 21. In Iguana Crypt, a maximum of 3 events occurred on October 19, 23, and 30. In Microwave Cave, a maximum of 8 events occurred on October 16. Therefore, the highest levels of bat activity in October occurred on October 16, 19, 21, 23 and 30.

In April, a maximum of 24 events occurred on April 28 in Cutters Cave; a maximum of 6 events occurred on April 13 in Firecamp; a maximum of 3 events occurred on April 3 and April 5 in Iguana Crypt and a maximum of 17 events occurred on April 3 in Microwave. Therefore, the highest levels of bat activity occurred on April 3, April 5, April 13 and April 28. These also represent the maximum number of events between March 1 and May 28, except for Iguana Crypt which had a maximum of 4 events on March 30. Therefore, it appears that the hibernation period of bats hibernating in these caves is variable but continues until the end of April and possibly into May as some activity continued to be recorded throughout May.

This data suggests that Manitoba Conservation's guidelines for bat hibernacula are accurate in terms of when human visitation should be prohibited (from September 15 to May 1st). This guideline could be expanded to mid-May as some activity was detected in Firecamp and Cutters Cave in May. The game monitor was not set sensitive enough and so did not record any activity in May and no data was available after April 26 for Microwave.

The last day that bat activity data is available for Microwave cave is April 26, 2000. The detector only recorded one event on this day. The monitor was retrieved by an individual in late May from within the cave. This person indicated that he and some friends were exploring the cave when they found the monitor on the cave floor. He retrieved the monitor and submitted it to the Manitoba Conservation district office in Grand Rapids. The Regional Wildlife Manager subsequently returned it to the researcher on May 28th, explaining it had just been turned into his office a couple of days earlier. As the monitor was not in working order, it was sent back to Trailmaster and the data it recorded could only be salvaged from October 16, 1999 to April 26, 2000.

While the Trailmaster Game Monitors allowed for remote observation of the cave environment during the critical hibernation period, it did have its drawbacks. From the data collected, one could not tell whether it is one bat that was being recorded or several different bats. It could not differentiate between bats and other small mammals such as red squirrels, which can access some caves. From the data, it was also not possible to determine whether it was males, females, or a combination of both sexes that were active, and, therefore, whether there was any difference in the length of the hibernation period between the sexes.

5.3 Relationship of Bat Activity to Temperature

No conclusions can be drawn from the statistical analysis of the temperature and activity data. Only two results were statistically significant – the positive relationship between activity and temperature in Cutters Cave and in Firecamp. However, the majority of activity in Cutters Cave is probably squirrel activity and not bat activity.

5.4 Local Knowledge of Bats and Caves

Most of the people interviewed were aware that there are caves near Grand Rapids. This is probably because many of them earn part of their living from the land by trapping, hunting as well as timber harvesting for Tolko Industries Inc. They do see many bats in the area, especially in autumn, but most of the participants that were interviewed did not realize that the caves provided critical overwintering habitat for those bats.

Mayor Buck was aware that the Speleological Society of Manitoba and the Manitoba Museum make several trips to the Grand Rapids area, but indicated that neither organization informs the town council or the First Nation band as to what they are doing. Local people should be engaged by those agencies such as the Wildlife Branch, the Manitoba Museum, the Speleological Society of Manitoba, and individual researchers who spend time in the Grand Rapids caves.

It was also evident that better communication is needed between Tolko Industries Inc. and individuals contracted to cut timber in the Grand Rapids area. The fragility of the karst landscape, the sensitivity of the caves, the reasons behind certain operating practices (such as why certain trees are flagged to indicate they should not be cut) needs to be communicated to the operators.

6.0 SUMMARY

The Grand Rapids uplands is an area of intense resource development, primarily timber extraction, hydro-electricity generation with the potential for increased transmission line rights-of-way and also mineral exploration. This area also contains the most northerly known bat hibernacula in Canada, providing essential over-wintering habitat for little brown bat, northern long-eared bat and possibly big brown bat populations. This research project was undertaken to assess current management guidelines for bat hibernacula and current operations of resource developers working in the Grand Rapids uplands and to provide recommendations for best management practices in this karst area.

Specific objectives were to describe the effects of resource development operations on bat hibernacula; to determine the current guidelines pertaining to the management of bat hibernacula; to determine and assess the operating procedures of resource developers working near bat hibernacula; to determine the temperature and relative humidity of caves used as hibernacula; to determine the length of the hibernation period and to incorporate local knowledge to supplement this research. Recommendations as a result of this project will be made to Manitoba Conservation, Tolko Industries Ltd., and Manitoba Hydro.

In pursuit of these objectives, four bat hibernacula were monitored for temperature and relative humidity from October 16, 1999 to May 28, 2000. Bat activity levels were monitored within each of these four hibernacula. An extensive literature review was undertaken to describe the effects of resource development operations on bat hibernacula, and review current management guidelines as a means of determining the best operating procedures for resource development in karst areas. Local knowledge was gathered to supplement this information. Tables 7 and 8 were constructed to provide a framework for drafting the following conclusions and recommendations. The framework takes into consideration all stakeholders on the landscape in terms of ecological, environmental and social factors.

6.1 CONCLUSIONS

6.1.1 General Conclusions

The Grand Rapids upland area is a fragile karst landscape that is susceptible to irreversible damage. Once a cave has been destroyed it is lost forever, therefore, caves are non-renewable resources existing in a landscape of little to no resilience.

As a working landscape, the primary resource developer on the landscape is Tolko Industries Ltd. through its timber extraction operations. Other resource developers include Falconbridge Ltd. undertaking mineral exploration operations and Manitoba Hydro's planned new generating stations which may potentially expand the north-south transmission lines on the west side of Lake Winnipeg. These activities can all negatively impact the karst landscape and its features, including those caves used by bats for critical over-wintering habitat.

Minimal management activities that take into account the karst landscape and its features have been undertaken on behalf of industry working in the area. If this continues, impacts to bat hibernacula will result in a decrease of essential over-wintering habitat for hibernating bat species that may have implications for the survival of these populations in Manitoba.

While not all the impacts are known (for example, if the removal of surface vegetation alters the microclimate of a cave) it is essential that resource developers act cautiously on the karst landscape. “Many of the changes occurring in ecosystems are only partly reversible or even completely irreversible. Once we clear a forested area to make way for subdivisions, or…industrial development, the qualities of that natural system are lost forever. A precautionary approach should be strived at, in which we would err on the side of safety in the presence of great uncertainty” (Zandbergen and Petersen, 1995).

To ensure that a precautionary approach is undertaken on karst lands, it is incumbent upon Manitoba Conservation to enforce best management practices either through regulation or guidelines that can be enforced such as those listed on work permits under *The Crown Lands Act.* It is also incumbent upon resource developers working in the fragile karst landscape to abide by all guidelines and regulations issued by Manitoba Conservation and to strive at being exemplary stewards of the unique resources found in the Grand Rapids uplands.

6.1.2 Specific Conclusions

A review of the literature has shown that resource development such as forestry operations, mineral exploration, mining activities, hydro-electric transmission line construction, as well as quarrying, highway construction and tourism can negatively impact karst areas and thus caves and bat hibernacula.

Guidelines exist for karst, caves and bat hibernacula in many jurisdictions across Canada and the United States. Manitoba and Ontario are two provinces that have management guidelines specific to bat hibernacula. Other provinces and states have forest land management plans, conservation plans for caves, or best management practices for specific bat species. These provide management guidelines for karst lands, as well as for caves and bat hibernacula.

Neither Falconbridge Ltd. nor Manitoba Hydro have written operating procedures for development occurring specifically in karst areas near bat hibernacula. However, Manitoba Hydro has indicated a willingness to incorporate such procedures into future guidelines. Tolko Industries Ltd. does have minimal guidelines in place for working near bat hibernacula but they are less restrictive than the provincial bat hibernacula management guidelines. As these provincial guidelines are not enforced, it is left to the goodwill of the resource developers to abide by them and act as stewards of the fragile karst landscape.

By undertaking a review of current karst and cave guidelines, best practices for resource developers were identified. Best practices incorporate an overall karst management strategy that includes an inventory of all caves in the karst area followed by a categorization/classification of the cave resource for management purposes. The best practice is to prohibit any resource development near and above caves that provide critical habitat for wildlife such as bats (i.e. removal from commercial land base).

In Gill's thesis entitled "Manitoba Karst: A Strategy for Action" (1991), Gill concludes "land [in the Grand Rapids area] should be set aside to protect the most significant karst sites. The optimal designation is a National Park. The second best alternative is a Provincial Wilderness Park". He recommended that the Parks Branch of (then) Manitoba Natural Resources "conduct a joint feasibility study with the Canadian Parks Service, for the purpose of establishing a park in the Grand Rapids Uplands".

Today, a federal park ("The Lowlands National Park") has been proposed for part of the Grand Rapids uplands. Manitoba Conservation and the Parks Canada Agency can protect portions of the karst landscape and particular features such as caves, especially those known to be bat hibernacula, from resource development by ensuring the boundaries of the park encompass these features. This would effectively remove caves and bat hibernacula from the commercial land base.

Bats in the Grand Rapids uplands were found to use caves from mid-October through April, and possibly into May, with mean temperatures ranging from a low of 1.1 °C to a high of 4.8 °C. However, bats begin using the caves as early as August during mating swarms (for reproduction) and begin hibernating as early as September.

The mean relative humidity of the four caves may not have been recorded accurately by the Hobo data loggers due to the highly condensing environment of the caves. However, the data do indicate that bats are using caves with very high relative humidities (>96%).

Most of the residents that the researcher spoke with were aware of bats and caves in the area, but they did not realize the sensitivity or importance of the caves to the bats. However, they do have a willingness and interest in learning about the importance of the caves, especially some of the forestry contractors who work on the karst landscape. Research and spelunking groups working in the Grand Rapids area should engage local people in their activities.

Recommendations can be made for better management of the karst and cave resources, and especially bat hibernacula, in the Grand Rapids uplands. Specific recommendations are listed below.

6.2 RECOMMENDATIONS

"While governments have an important role to play in making land-use decisions and setting the rules for appropriate management, others – industry, Aboriginal peoples, local communities and NGOs – are equally important stewards of Canada's lands and waters. However, these players have not always been systematically or effectively engaged in conservation planning over the last 10 years" (NRTEE, 2003).

- Manitoba Conservation should, therefore, establish an interdisciplinary karst management committee to draft a karst management plan for the Grand Rapids area, including a cave inventory and classification system where bat hibernacula would be classified as sensitive habitat and prescribed appropriate management guidelines. Guidelines may include the prohibition of resource development above or around caves as recommended by the BC Ministry of Forests and Alaska Forest Service. This could be accomplished by including karst features such as caves and bat hibernacula within the boundaries of the proposed Lowlands National Park.

- The interdisciplinary karst management committee should include representatives from Manitoba Conservation (the Wildlife and Ecosystem Protection Branch, Forestry Branch, Industry, Trade and Mines Branch and the Water Resources

Branch), Grand Rapids First Nation, the town of Grand Rapids, Tolko Industries Ltd, Manitoba Hydro, Falconbridge Ltd. and any other industry proposing development in the Grand Rapids uplands, the Manitoba Museum, the Speleological Society of Manitoba, the University of Winnipeg and/or Manitoba. Representation should reflect the characteristics of the entire karst system and therefore include expertise in biology, geology, hydrogeology, and culture (Blackwell, 1995). Involving stakeholders in the guideline drafting process should ensure these guidelines are implemented in the field. However, it is incumbent upon Manitoba Conservation to ensure resource developers implement these guidelines. Therefore, they must either include the guidelines in Work Permits under *The Crown Lands Act* and/or draft regulations under the appropriate statutes (*The Wildlife Act; The Forest Act*) to protect fragile karst features including caves and those used as bat hibernacula.

- The Wildlife and Ecosystem Protection Branch of Manitoba Conservation should revise the current Bat Hibernacula Management Guidelines to incorporate guidelines for hydro-line transmission tower and right-of- way construction operations.

- Tolko Industries Ltd., Manitoba Hydro, and Falconbridge Ltd. should be required to develop operational procedures for working in karst landscapes, especially where caves are present, prior to commencing any resource development. A careful inventory of the area should be undertaken and cave locations should be recorded and reported to the Wildlife Director at the Wildlife and Ecosystem Protection Branch.

- Tolko Industries Ltd.'s "Forest Management Planning and Operating Practices – Operators Guide" should be updated to include operating procedures in karst areas, especially where caves and bat hibernacula are known to exist. As is stated in the current guide, "operators play a critical role in implementing harvesting plans. The success in implementing FMPOPs cannot happen without the cooperation and understanding of people operating equipment in the field". Tolko should ensure that Area Supervisors and local operators are aware of cave locations and encourage them to report the location of any and all caves to Tolko (and ultimately to the Wildlife and Ecosystem Protection Branch) before proceeding to cut.

- The Forestry Branch of Manitoba Conservation should include specific guidelines, drafted in consultation with the Wildlife Branch, for bats and bat habitat in the next revision of the Forestry Guidelines for Wildlife. These guidelines should be incorporated into resource developers' work permits to ensure they are implemented. The Forestry Branch should also incorporate sensitive sites such as bat hibernacula into the Provincial Forest Inventory database.

- The Forestry Branch of Manitoba Conservation should ensure that the Bat Hibernacula Management Guidelines be explicitly listed within Tolko's FML Agreement under Section 15 D regarding forest management, which currently reads as "follow and implement forest management strategies to meet all the requirements of fisheries, wildlife, timber harvesting, forest renewal and any other relevant current or new guidelines for forest operations including but not limited to the following published provincial guidelines [a list of guidelines follows that does not include bat hibernacula management guidelines]."

- The Speleological Society of Manitoba should ensure that outreach and education about the karst landscape, caves, bats and bat hibernacula continues through Karst Summit meetings or other venues held in Grand Rapids and should expand into the local school system. Tolko Industries Ltd., Manitoba Hydro and Falconbridge Ltd. should ensure that they have representatives, including decision-makers and on-the-ground contractors and employees, attending and participating in these meetings.

- The Grand Rapids school board should encourage school programs that educate students about the geological and biological resources in their community. Manitoba Conservation, Manitoba Hydro, Falconbridge Ltd., and Tolko Industries Ltd. should continue to fund cave and bat research projects and should also provide support for outreach and education programs in Grand Rapids, such as the Karst Summit meetings.

- Future research should involve an analysis of microclimatic conditions between caves that have been impacted and those that have not. This may be accomplished by monitoring a cave (not used as a hibernaculum) prior to harvesting activity and then after harvesting activity has occurred above the cave. Likewise, if Firecamp, Microwave, or Iguana Crypt are impacted by resource development, the temperature and relative humidity data collected in this study could be used as baseline data to compare with data collected after the impact has occurred.

- Future research could also explore the relationship between hibernating bat populations and cave structure and microclimate. For example, it could address the question of why Iguana Crypt has higher hibernating populations of bats compared to Cutters Cave.

- More research is also needed regarding the ecology of all bats in Manitoba: data on population sizes, roosting preferences, and seasonal distributions.

Table 7: A framework for creating conclusions

THE FACTORS	CONCLUSIONS (What the Stakeholders need to do to ensure bat habitat is conserved)						
	THE STAKEHOLDERS						
	TOLKO	**MB HYDRO**	**FALCON**	**MB CON**	**SSM***	**RESEARCHERS**	**GR FN/TOWN****
Ecological	Undertake sustainable forestry practices in a way that minimizes disturbance to bats and hibernacula	Undertake hydro-line development in a way that minimizes disturbance to bats and hibernacula	Undertake mineral exploration in a way that minimizes disturbance to bats and hibernacula	Under The Wildlife Act, responsible for ensuring the protection of bats and bat habitat	Should ensure their members carry out caving in a way that minimizes impacts on caves and bats	Should ensure they carry out research in a way that minimizes impacts to bats and caves	Assist with provincial and federal efforts to establish protected areas
Social	Ensure they follow the guidelines of their Forest Management Plan			Has an obligation to the public to conserve bats and caves as these are public resources	SSM should engage local townspeople in spelunking activities (outreach)	Engage locals in research activities or inform Mayor and Chief of actions	Town and Reserve should involve selves in research and SSM activities
					Provide Outreach and Education services regarding caves	Provide Outreach and Education services regarding bats	
	Employ local people who may be familiar with the caves	Employ local people who may be familiar with the caves				Provide copies of research results (thesis) to interested parties	
Economic	Ensure they make a profit	Ensure they make a profit	Ensure they make a profit	Has an obligation to provide Crown land for resource development			Have a need and right to employment opportunities that exist with the resource developers
	Support research into the caves and bats	Support research into the caves and bats	Support research into the caves and bats	Support research into the caves and bats	Support research into the caves and bats		Support research into the caves and bats

* Speleological Society of Manitoba; ** Grand Rapids First Nation / the town of Grand Rapids

Table 8: A framework for creating recommendations

THE FACTORS	RECOMMENDATIONS (how they can do it)						
	THE STAKEHOLDERS						
	TOLKO	**MB HYDRO**	**FALCON**	**MB CON**	**SSM***	**RESEARCHERS**	**GR FN/TOWN****
Ecological	Update their FMPOPs to include special practices for working in karst areas	Include special practices for working in karst areas in their environmental protection measures	Include special practices for working in karst areas	Ensure the Bat Hibernacula and Forestry guidelines are updated and adhered to			
	Ensure thorough pre-harvest surveys are conducted;						
Social	Join and participate in the management committee	Join and participate in the management committee	Join and participate in the management committee	Establish and participate in a management committee to draft a karst management plan	Join and participate in the management committee	Join and participate in the management committee	Join and participate in the management committee
	Participate in the Karst Summit	Participate in the Karst Summit	Participate in the Karst Summit	Participate in the Karst Summit	Participate in the Karst Summit	Participate in the Karst Summit	Participate in the Karst Summit
	Ensure good communications with local contractors (on the ground personnel) to ensure good practices are carried out			Provide school and public programs	Provide school and public programs	Provide school and public programs	Encourage researchers, SSM, MC to provide education programs to schools and public
Economic	Continue to fund projects that research caves and bats	Continue to fund projects that research caves and bats	Continue to fund projects that research caves and bats	Continue to fund projects that research caves and bats			

***The Speleological Society of Manitoba; ** The Grand Rapids First Nation/the town of Grand Rapids

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GLOSSARY

Sinkhole: Surface depression formed by solution of limestone or from collapse over a underground cavity such as a cave.

Speleogens: Bedrock formations in caves.

Speleothems: Mineral cave formations usually composed of calcium carbonate such as stalagmites and stalactites.

APPENDIX A: INTERVIEW QUESTIONS

1. How long have you (or your family) lived in the Grand Rapids area?

2. Are you aware of any caves in the Grand Rapids area?

3. To the best of your knowledge, how many caves are in the Grand Rapids area?

4. Are the caves of any significance to you? If so, what is their significance?

5. Have you ever visited any caves in the Grand Rapids area? In which seasons?

6. Did you remain at the entrance of the cave or enter/descend into the cave?

7. Can you describe the physical condition of the cave(s) you were in?

8. In your opinion, what would happen to the conditions inside the caves if the trees and surrounding vegetation were removed?

9. To your knowledge, are any of the caves used by wildlife?
   If so, what types and approximately how many?

10. Are you aware that several species of bats are found in the area?

11. If you have seen bats, where, when and how often have you seen them?

12. Are bats of any significance to you? If so, what is their significance?

13. Do you feel that the bat populations have increased, decreased or remained the same over the last 50 years?

14. Are you aware of any natural changes in bat populations? If so, over what approximate time scale?

15. To your knowledge, what use do the bats make of the caves?

16. Why do bats only use some of the caves to hibernate in?

17. To the best of your knowledge, what is the most northerly cave used by bats?

18. When (in the fall) do the bats return to the caves to hibernate?

19. When (in the spring) do they leave the caves?

20. Where do the bats go once they leave the caves in the spring?

21. Do bats return to the same cave every year, or use different caves?