NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

Phase 1 Geoscientific Desktop Preliminary Assessment, Terrain and Remote Sensing Study

TOWNSHIP OF WHITE RIVER, ONTARIO

APM-REP-06144-0084

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Phase 1 Geoscientific Desktop Preliminary Assessment Terrain and Remote Sensing Study
Township of White River, Ontario

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Executive Summary

On January 28, 2013, the Township of White River expressed interest in continuing to learn more about the Nuclear Waste Management Organization nine-step site selection process, and requested that a preliminary assessment be conducted to assess the potential suitability of the White River area for safely hosting a deep geological repository (Step 3). This request followed the successful completion of an initial screening conducted during Step 2 of the site selection process.

The preliminary assessment is a multidisciplinary study integrating both technical and community well-being studies, including geoscientific suitability, engineering, transportation, environment and safety, as well as social, economic and cultural considerations. The findings of the overall preliminary assessment are reported in an integrated report (NWMO, 2014). The objective of the desktop geoscientific preliminary assessment is to determine whether the Township of White River and its periphery, referred to as the "White River area" contains general areas that have the potential to meet NWMO's geoscientific site evaluation factors.

This report presents the findings of a terrain and remote sensing study completed as part of the desktop geoscientific preliminary assessment of the White River area (AECOM, 2014). The main information sources used include the Provincial and Canadian Digital Elevation Data (CDED) elevation models, remotely sensed imagery, and maps, reports and databases available from the federal and provincial governments. The study addresses the following seven objectives:

- Evaluate the nature, areal extent and depth of overburden materials;
- Delineate the areas of exposed bedrock or relatively thin overburden cover;
- Identify features that may preserve evidence of neotectonics;
- Establish the main site accessibility constraints;
- Determine and/or confirm watershed and sub-catchment boundaries;
- Infer groundwater recharge and discharge zones and divides; and
- Infer regional and local groundwater and surface flow directions.

The White River area is dominated by land where bedrock is at or near surface. Over the majority of the area, the Precambrian bedrock is thinly covered by a discontinuous veneer of glacial sediments, dominantly ground moraine (till). Deposits of thicker drift, primarily consisting of glaciofluvial and glaciolacustrine sediments, are present in bedrock valleys and areas of lower elevation. The area is generally well-drained by a network of lakes and rivers that are present in four tertiary watersheds, two of which have flow directed southward to Lake Superior and two directed northward to James/Hudson Bay.

Groundwater flow within drift deposits and in shallow bedrock aquifers in the White River area is expected to mimic the pattern of surface flow, with groundwater divides coinciding with drainage divides and discharge occurring into creeks, rivers, lakes and wetlands.

Conclusive identification of features indicative of paleo-seismic events and reactivation of ancient bedrock structures associated with cycles of glacial loading and unloading cannot be identified using currently available sources of information. Field investigations would be required to identify any such features.

Main roads provide access to the central and southwestern portions of the White River area. Augmenting access throughout the rest of the area is an extensive network of secondary roads and trails, mainly developed to support forestry activities. The construction of new access routes, or other types of infrastructure, could be developed to any part of the White River area using construction techniques commonly employed in the Canadian Shield.

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1. Introduction

On January 28, 2013, the Township of White River expressed interest in continuing to learn more about the Nuclear Waste Management Organization nine-step site selection process (NWMO, 2010), and requested that a preliminary assessment be conducted to assess potential suitability of the White River area for safely hosting a deep geological repository (Step 3). The preliminary assessment is a multidisciplinary study integrating both technical and community well-being studies, including geoscientific suitability; engineering; transportation; environment and safety; as well as social, economic and cultural considerations (NWMO, 2014).

This report presents the findings of a terrain and remote sensing study completed as part of the desktop geoscientific preliminary assessment of the White River area. The objective of the desktop geoscientific preliminary assessment is to determine whether the Township of White River and its periphery, referred to as the “White River area”, contains general areas that have the potential to meet NWMO’s geoscientific site evaluation factors (NWMO, 2010).

1.1 Objectives

A review and interpretation of remotely sensed data was conducted as part of the Phase 1 Desktop Geoscientific Preliminary Assessment for the Township of White River (AECOM, 2014) to provide information on surficial materials and terrain conditions present in the White River area. The work completed as part of this study adds to and expands upon the knowledge of surficial conditions provided in the Initial Screening report of the area (Golder, 2012).

This study makes use of remote sensing and geoscientific information sources to address the following seven objectives:

- Evaluate the nature, areal extent and depth of overburden materials;
- Delineate the areas of exposed bedrock or relatively thin overburden cover;
- Identify features that may preserve evidence of neotectonics;
- Establish the main site accessibility constraints;
- Determine and/or confirm watershed and sub-catchment boundaries;
- Infer groundwater recharge and discharge zones and divides; and
- Infer regional and local groundwater and surface flow directions.

1.2 White River Area

The White River area covered by this report is located northeast of Lake Superior approximately 295 km east of Thunder Bay, and 240 km north-north west of Sault Ste. Marie (all straight-line distances). This L-shaped area, shown in Figure 1, is approximately 4,991 square kilometres (km^2) in size with an east-west length of 93.8 km, and with the eastern and western sides having lengths of 47.6 and 60.4 km, respectively.

The Township of White River occupies 102.2 km^2 in the southwest corner of the area and contains the settlement area of White River. The only other population centre in the area is the small settlement of Amyot, located along the rail line southeast of the township at the eastern end of Negwazu Lake. Other nearby towns are: Wawa, 75 km to the southeast; Marathon, 85 km to the west; and Hornepayne, 80 km to the northeast.

1.3 Data and Methods

1.3.1 Source Data

Data for the White River terrain and remote sensing study was collected from a variety of sources, including government organizations, such as the Ontario Geological Survey (OGS) and Natural Resources Canada (NRCan). Existing surficial and bedrock geology mapping, topographic mapping, and literature were reviewed as part of the terrain mapping process in order to gain familiarity with the area, its Quaternary history, and the surficial materials present.

1.3.1.1 Topographic Mapping

Topographic mapping of the area, with a contour interval of 20 m, was obtained from the Ontario Ministry of Natural Resources (MNR, 2013) and digital topographic data in raster format were obtained from Geobase (NRCan, 2009). The digital topographic data set had a grid resolution of between 8 and 23 m.

1.3.1.2 Canadian Digital Elevation Data (CDED)

The CDED topography data for the White River area, including a buffer zone extending in all directions outside the area, is available in 32 DEM format individual tiles, each tile covering approximately 1,200 km^2. The tile identifiers are listed in Table 1.

Table 1. Summary of CDED tiles

042c05_0100_deme	042c13_0100_deme
042c05_0100_demw	042c13_0100_demw
042c06_0100_deme	042c14_0100_deme
042c06_0100_demw	042c14_0100_demw
042c07_0100_deme	042c15_0100_deme
042c07_0100_demw	042c15_0100_demw
042c08_0100_deme	042c16_0100_deme
042c08_0100_demw	042c16_0100_demw
042c09_0100_deme	042f01_0100_deme
042c09_0100_demw	042f01_0100_demw
042c10_0100_deme	042f02_0100_deme
042c10_0100_demw	042f02_0100_demw
042c11_0100_deme	042f03_0100_deme
042c11_0100_demw	042f03_0100_demw
042c12_0100_deme	042f04_0100_deme
042c12_0100_demw	042f04_0100_demw

These files have an accuracy of <5 m and a resolution of 0.75 arc seconds, which is equivalent to approximately 16 to 23 m in the White River area. The 32 individual tiles were merged, levelled, and a colour mosaic, shaded digital elevation model was created in ErMapper (SRK, 2013).

The digital elevation model (DEM) used for this study was constructed by the Ontario Ministry of Natural Resources' Water Resources Information Program (WRIP). The best available DEM in the White River area of northern Ontario is generated from 1:20,000 source data acquired through the Ontario Base Mapping (OBM) program. Several OBM data sets were used in the DEM creation including, contours, spot heights, lake elevations derived from spot heights, water features and the WRIP stream network.

Surface analyses were performed on the digital elevation model in order to characterize slope and relief. Slope was calculated using the standard grid-based method employed in ArcGIS, which involves fitting a plane to the elevation values of a three by three neighbourhood centred on the processing cell. Slope is defined as the maximum slope of that plane, which can also be thought of as the dip of the plane, and aspect is equivalent to the dip direction. Relief was calculated in two ways. The first was by subtracting the average elevation within a radius from the elevation value in the processing cell; this was completed for two radii. The second was defined as the range in elevation within a circular window. The second relief calculation represents a high pass filter. The density of steep slopes was calculated as the number of points with a slope of at least 6° within a 2 km radius. The threshold of 6° was established as it serves to distinguish rugged bedrock-controlled areas and those with gentler slopes. Less overburden cover is expected in the former areas and greater amounts in the latter. Areas with a higher density of steeper slopes also present greater challenges to construction.

1.3.1.3 Satellite Imagery

Systeme Pour l'Observation de la Terre (SPOT) and Landsat Imagery

The SPOT 4/5 Geobase OrthoImages for the White River area, and surrounding buffer zone, are available as seven individual tiles. Each tile contains five Geotiff images representing spectral bands B1, B2, B3, MIR, and a panchromatic band, and covers approximately 8,400 km^2. Multispectral bands have a resolution of 20 m, and the panchromatic band has a resolution of 10 m. The tiles that cover the area are listed in Table 2.

Table 2. Summary of SPOT imagery scenes

s5_08355_4828_20070805_m20_utm16
s5_08426_4857_20070503_m20_utm16
s5_08438_4828_20070503_m20_utm16
s5_08509_4857_20060911_m20_utm16
s5_08522_4828_20060609_m20_utm16
s5_08551_4857_20060901_m20_utm16
s5_08602_4828_20060901_m20_utm16

For quality control, Natural Resources Canada (NRCan) provides images that have a maximum of 5% snow and ice cover, 5% cloud cover and a maximum viewing angle of 15°. NRCan orthorectified the SPOT images using three data sources: 1:50,000 scale Canadian Digital Elevation Data (CDED), National Road Network (NRN), and Landsat 7 orthoimagery. The orthoimages are provided in GeoTIFF format, projected using Universal Transverse Mercator (UTM) projection referenced to the North American Datum 1983 (NAD83).

The Landsat 7 Orthorectified imagery for the White River area is available as two tiles (023026 and 022026), each approximately 75,000 km^2 in area. Each tile contains 10 Geotiff images representing spectral bands 1 through 8 (two versions of band 6) and a multispectral image with bands 7, 4 and 3 combined. Multispectral bands have a resolution of 30 m.

1.3.1.4 Geological Mapping

Surficial geology mapping from the OGS was acquired at a scale of 1:1,000,000 (Barnett *et al.*, 1991; OGS, 1997). Larger scale 1:100,000 mapping from the Northern Ontario Engineering Geology Terrain Study (NOEGTS) series covers the entire area and provides greater detail on the distribution of surficial materials in addition to information on landforms, relief and drainage. Each NOEGTS map is accompanied by a report describing the landscape and surficial materials in the area, as well as a description of how the terrain may influence engineering decisions.

NOEGTS coverage of the White River area consists of: Study 61 - White River (Gartner and McQuay, 1980a); Study 62 - Kabinakagami Lake (Gartner and McQuay, 1980b); Study 72 - Pukaskwa River (Gartner and McQuay, 1979a); and Study 73 - Goudreau (Gartner and McQuay, 1979b). Studies 61 and 62 provide coverage for the vast majority of the area, with other reports covering only a small portion along the southern boundary. A digital compilation of the NOEGTS map data is also available (OGS and MNR, 2005).

The Quaternary geology for that portion of the White River area surrounding the settlement of White River and along the western edge of the area has been mapped at a scale of 1:50,000 by Geddes and Bajc (1985a, 1985b, 2009a, 2009b) and Geddes and Kristjansson (1986, 2009). There are two principle differences between the 1:50,000 scale and the NOEGTS mapping. The former delineates areas of bedrock outcrop, as opposed to including these in broader areas of thin drift and bedrock terrain, and illustrates a more widespread distribution of till. The differences are due largely to the fact that the NOEGTS mapping was approached from a terrain analysis perceptive where the morphology of the surface was a factor influencing classification, whereas the surficial mapping portrays the material type that occurs on the ground surface without consideration of other factors. When it is considered that the till is generally a veneer of modest thickness (1 to 3 m), and that bedrock is commonly at a relatively shallow depth (Geddes and Kristjansson, 1986), there is good agreement between the map products. Additional detail can, however, be represented on the 1:50,000 maps due to the smaller scale.

In addition to the above mapping products, literature describing surficial materials and the regional Quaternary history where also reviewed (e.g., Boissonneau, 1966; Prest, 1970; Zoltai, 1967; Geddes, 1986; Sado and Carswell, 1987; Barnett, 1992). A prime objective of the review was to confirm areas of thicker overburden cover that may obscure the surface expression of lineaments in the White River area, and to assess the degree to which variation in drift thickness occurs over relatively short distances. Attention was also paid to areas of glaciofluvial and glaciolacustrine deposits, and poorly drained wetland areas as these offer insights into drainage conditions within the area.

1.3.1.5 Aerial Photography

Aerial photographic coverage of the area, at a scale of approximately 1:54,000, was acquired from the archives of the Ontario Geological Survey. These photos were used for the terrain interpretation and mapping completed as part of the NOEGTS program (Gartner and McQuay, 1979a; 1979b; 1980a, 1980b). The review of these photographs provided an improved understanding of how the surficial materials, landforms and topography were classified during the NOEGTS mapping.

1.3.1.6 Drill Holes and Water Wells

There is limited information on groundwater resources in the White River area with the Ontario Ministry of Environment Water Well Information System Database (2013) containing records of 33 wells. The vast majority of the water wells are located within the community of White River, in close proximity to Highways 17 or 631. Of the five water wells located outside of the Township of White River, four are located west of the settlement area, along Highway 17; the records for two of these wells contain no information beyond geographic coordinates. A single well is positioned in Gourlay Township, approximately 45 km northeast of White River. Fifteen of the 16 water wells known to terminate in bedrock contain data on the thickness of overburden. In these wells the bedrock surface was encountered at depths ranging from 1.5 to 27.1 m.

The drill hole database maintained by the Ministry of Northern Development and Mines (MNDM, 2013a) contains records of 299 drill holes in the White River area. One hundred and seventy-nine records are diamond drill holes and 120 are of percussion or reverse circulation drill holes completed to bedrock. The holes were completed as part of mineral exploration programs, most commonly for precious and base metals. For this reason, the majority of the drill holes are located within rock units associated with the Dayohessarah and Kabinakagami greenstone belts or immediately adjacent to their boundaries.
Concentrations of drill holes are located around the western and northeastern sides of Dayohessarah Lake and the southwestern and northeastern sides of Kabinakagami Lake. Other smaller groupings of drill holes occur over fragments of metavolcanic and metasedimentary rock across the White River area.

Positional information for the majority of the drill holes in the database is generally good; however, the listed location for a small percentage of the older drill holes must be considered as approximate due to a lack of detail in the reporting to MNDM. Caution must be exercised when viewing the overburden thickness as reported in the database; this is because the majority of the diamond drill holes were advanced at an angle to vertical, thus artificially increasing the overburden thickness. When the angle is reported, a simple projection to vertical is required.

2. Summary of Geology

2.1 Bedrock Geology

The White River area is within the Wawa Subprovince, which is a volcano-sedimentary-plutonic terrane bounded to the east by the Kapuskasing structural zone and to the north by the metasedimentary-dominated Quetico Subprovince. The Wawa Subprovince is composed of well-defined greenstone belts of metamorphosed volcanic rocks and associated metasedimentary rocks, separated by granitoid rock units. The granitoids that separate the greenstone belts comprise 20 to 30 percent of the landmass of the Wawa Subprovince, and consist of massive, foliated and gneissic tonalite-granodiorite, which is cut by massive to foliated granodiorite and granite. The majority of the granitoids were emplaced during or after the deposition of the greenstone belts with which they are associated (Williams *et al.,* 1991).

Within the Wawa Subprovince there are two semi-linear zones of greenstone belts, the northern of which includes the Shebandowan, Schreiber-Hemlo, Manitouwadge-Hornepayne, Dayohessarah and Kabinakagami greenstone belts. The southern zone comprises the Michipicoten, Mishibishu and Gamitagama greenstone belts which are located west of the Kapuskasing structural zone, well southeast of the White River area. The Dayohessarah greenstone belt and the western portion of the Kabinakagami belt are within the White River area (Figure 2); a small portion of the Schreiber-Hemlo belt is located along the western boundary of the White River area, while the Michipicoten greenstone belt is situated approximately 25 km to the southeast. The Dayohessarah and Kabinakagami greenstone belts have been interpreted by Williams *et al.* (1991) and Stott (1999) as being part of a once continuous supracrustal belt now represented by the Manitouwadge-Hornepayne and the Black River assemblage of the Schreiber-Hemlo belts.

Several generations of Paleo- and Meso-proterozoic diabase dyke swarms, ranging in age from 2.473 to 1.14 Ga, cut all bedrock units in the White River area. The most prominent of these dyke swarms include the northwest-trending Matachewan Swarm, ca. 2.473 Ga (Buchan and Ernst, 2004); the northeast-trending Biscotasing dyke swarm, ca. 2.167 Ga (Hamilton *et al*., 2002); and the north-trending Marathon dyke swarm ca. 2.121 Ga (Buchan *et al*., 1996; Hamilton *et al*., 2002). Less numerous dykes belonging to the west-northwest-trending Sudbury (ca. 1.238 Ga; Krogh *et al*., 1987) and northeast-trending Abitibi (ca. 1.14 Ga; Ernst and Buchan, 1993) dyke swarms also crosscut the area.

The main geological units occurring in the White River area are further described below.

2.1.1 Granitoid Intrusive Rocks

2.1.1.1 Black-Pic Batholith

The Black-Pic batholith is a large, regionally-extensive intrusion that encompasses a roughly 3,000 km^2 area within the Wawa Subprovince and underlies the northwest portion of the White River area (Figure 2). It is bounded to the south by the Pukaskwa batholith and the Danny Lake stock, and to the east by the Dayohessarah greenstone belt.

The Black-Pic batholith comprises a multi-phase suite that includes hornblende-biotite, monzodiorite, foliated tonalite and pegmatitic granite with subordinate foliated diorite, granodiorite, granites and cross-cutting aplitic to pegmatitic dykes (Williams and Breaks, 1989; Zaleski and Peterson, 1993). In the White River area the batholith is described as a gneissic tonalite in a compilation map of Santaguida (2001); however, Fenwick (1967), similarly to Milne (1968), mapped the batholith as uniform, biotite granitic gneiss and biotite granite which becomes gneissic near the boundary with the Dayohessarah greenstone belt (noting that terminology used was before Streckeisen's (1976) standard classification). Fenwick (1967) also noted the occurrence of migmatites (noting that terminology used was prior to either Mehnert's (1968) or Sawyer's (2008) classifications) composed of highly altered remnants of pre-existing volcanic and sedimentary rocks mixed with variable amounts of granitic material. The migmatites occur either as a breccia type, in which fragments of the older rocks are cemented by dykes; or veins of granitic rock or a banded type, in which layers of the older material alternate with layers of granitic material.

Several generations of intrusions are present within the batholith, yielding geochronological ages ranging from ca. 2.720 Ga (Jackson *et al.,* 1998) for the earliest recognized phase to ca. 2.689 Ga for a late-stage recognized monzodioritic phase located in the Manitouwadge area, about 70 km northwest of the White River area (Zaleski *et al*., 1999). In addition, there are also younger granitic phases within the Black-Pic batholith in the Manitouwadge area which, despite a lack of geochronological information, are thought to be part of the regional suite of ca. 2.660 Ga, post-tectonic “Algoman granites” (Zaleski *et al*., 1999). Within the batholith, intrusive relationships are typically destroyed, and only metamorphic textures and associated mineral assemblages are preserved. Inclusions of relatively melanocratic members of the suite occur as foliated inclusions within later, leucocratic members (Williams and Breaks, 1989; 1996).

The Black-Pic batholith is interpreted as containing regional scale domal structures with slightly dipping foliations radiating outward from its centre (Williams and Breaks, 1989; Lin and Beakhouse, 2013). At least one such smaller-scale structure potentially exists in the White River area immediately north of the Danny Lake stock where semi-circular faults outline the position of a possible dome several kilometres in width (Figure 2). The origin and geologic description of these semi-circular features is largely unknown.

Structurally deeper levels of the tonalite suite in the Black-Pic batholith are strongly foliated with a sub-horizontal planar fabric that exhibits a poorly developed, north-trending rodding and mineral-elongation lineation (Williams and Breaks, 1989). Upper structural levels of the tonalite suite are cut by abundant granitic sheets of pegmatite and aplite, and are more massive (Williams and Breaks, 1989; Zaleski and Peterson, 1993). Just to the north of the White River area are zones of migmatized volcanic rocks, and zones of massive granodiorite to granite embodied in the Black-Pic batholith. The contact between these rocks and the tonalitic rocks of the Black-Pic batholith is relatively gradational with extensive sheeting of the tonalitic unit (Williams and Breaks, 1989; Williams *et al*., 1991).

No readily available information regarding the thickness of the batholith is available; however, its size and the geological history of the region suggest it may extend to a significant depth.

2.1.1.2 Pukaskwa Batholith

The Pukaskwa batholith (also referred to as the Pukaskwa gneissic complex) is a large, regionally-extensive intrusion covering an area of at least 5,000 km^2 in the Wawa subprovince (Figure 2). Mapping of the intrusion in the White River area was completed at a reconnaissance scale resulting in crudely defined boundaries of the batholith (Milne *et al.,* 1972; Santaguida, 2001). As mapped by Santaguida (2001), the batholith is bounded to the north by the Strickland pluton, the Danny Lake stock and the Black-Pic batholith. The contact with the Black-Pic batholith is located along a line extending from the west end of the Danny Lake stock running northwest to White Lake. The Pukaskwa batholith surrounds the western extent of the Anahareo Lake pluton and west-trending septa of the Dayohessarah greenstone belt.

The Pukaskwa batholith extends over a large portion of the south-central portion of the White River area (Figure 2) and is described in the compilation map as comprising foliated tonalite and gneissic tonalite suites (Santaguida, 2001). Regionally, the Pukaskwa batholith is a multi-phased intrusion emplaced over an extended period of time (Stott, 1999; Beakhouse and Lin, 2006; Beakhouse *et al.,* 2011).

Knowledge of the Pukaskwa batholith is primarily obtained from regional studies conducted to the west, in the vicinity of the Hemlo greenstone belt. An investigation of the batholith by Beakhouse *et al.* (2011) identified a number of lithologic associations (rock groupings) based on petrological and geochemical characteristics, three of which were volumetrically significant.

The oldest association and most abundant of the three are a group of gneissic, well-foliated tonalite to granodioritic rocks. The gneissic nature of these rocks is a composite fabric formed by: flattening or transposition of heterogeneities; metamorphic segregation or partial melting; and emplacement of sheet-like intrusive phases controlled by pre-existing anisotropy (Beakhouse *et al.*, 2011). This lithologic association is interpreted to represent rocks derived from melting of a mafic crust and emplaced during the period ca. 2.720 to 2.703 Ga (Corfu and Muir, 1989; Jackson *et al.,* 1998; Stott, 1999; Beakhouse *et al.*, 2011; Lin and Beakhouse, 2013). It is likely that the foliated tonalite and gneissic tonalite suites as described by Santiaguida (2001) in the White River area are part of this rock group.

The Pukaskwa batholith's second lithologic association, emplaced in the period between ca. 2.703 and 2.686 Ga, consists of foliated granodiorite to quartz-monzodiorite that is widespread but volumetrically limited (Beakhouse *et al.*, 2011). Corfu and Muir (1989) reported a weakly foliated granodiorite from the Pukaskwa batholith having an inferred magmatic crystallization age of ca. 2.688 Ga. Geochemical analysis indicates that the rocks of the lithological association were derived from, or due to some sort of interaction with, an ultramafic source. These rocks cut the older lithologic association described above and have a weakly to moderate foliation which is generally sub-parallel to parallel to pre-existing rock units. The geometrical, age and field relationships are interpreted as indicative of a syn-tectonic emplacement of the second lithologic association of the Pukaskwa batholith (Beakhouse *et al.*, 2011). Following the emplacement of the syn-tectonic phases, the Pukaskwa batholith was uplifted at approximately 2.680 Ga as a structural regional dome relative to flanking greenstone belts synchronously with ongoing regional sinistral transpressive deformation (Beakhouse *et al.*, 2011; Lin and Beakhouse, 2013).

The youngest lithologic association comprises a group of granodioritic to granitic units that form large, homogeneous plutons and small dikes; the geochemical signature of the rocks suggests that they are derived from melting of older intermediate to felsic crust (Beakhouse *et al.*, 2011). The rocks are dated at ca. 2.667 Ga and, therefore, are interpreted as late to post-tectonic intrusions (Davis and Lin, 2003; Beakhouse *et al.*, 2011).

As a result of mapping in the Hemlo area to the west, Jackson *et al.* (1998) and Muir (2000) have identified an intrusion termed the Bremner pluton and indicated that it may extend into the White River area south of where Highway 17 crosses the western boundary of the area. Muir's mapping (Muir, 2000) does not delineate an eastern boundary of the pluton and although Jackson *et al.* (1998) do outline the pluton, they note that the geometry of the intrusion should be regarded as preliminary. As the boundary of the pluton is uncertain and it is likely to extend only a limited distance into the White River area, it is not depicted on Figure 2 (i.e., the area is shown as being within the Pukaskwa batholith). Muir (2000) described the pluton near the boundary of the White River area as consisting of biotite-hornblende tonalite and biotite-hornblende granodiorite. Jackson *et al.* (1998) dated the Bremner pluton at ca. 2.677 Ga.

No readily available information regarding the thickness of the Pukaskwa batholith was found; however, its size and the geological history of the region suggest it may extend to a significant depth.

2.1.1.3 Strickland Pluton

The Strickland pluton occurs in the northeast portion of the White River area bordering the Dayohessarah and Kabinakagami greenstone belts. The pluton occupies an area of approximately 600 km^2 and has maximum dimensions in the area of 34 km north-south and 55 km east-west (Figure 2). Stott (1999) described the Strickland pluton as a relatively homogeneous, quartz porphyritic granodiorite; although, near the outer margin of the pluton, adjacent to the greenstone belt, granodiorite to tonalite and diorite are present. In the area west of the Kabinakagami greenstone belt, Siragusa (1977) noted that massive quartz monzonite (i.e., monzogranite in modern terminology) intrudes the granodioritic and trondhjemitic rocks in the form of medium-grained to pegmatitic dykes and small sills and irregular bodies.

Some degree of post-emplacement deformation and metamorphism of the Strickland pluton is indicated by the observed presence of fine- to medium-grained titanite and the widespread presence of hematite-filled fractures and weak alteration of silicate minerals (Stott, 1999). Stott (1999) noted that the pluton is petrographically similar to the ca. 2.697 Ga Dotted Lake batholith located in the northwestern corner of the White River area and suggested that these plutons are members of an intrusive suite commonly found along the margins of greenstone belts in this part of the Wawa Subprovince.

No readily available information regarding the thickness of the Strickland pluton was found, although it may extend to a significant depth.

2.1.1.4 Anahareo Lake Pluton

The Anahareo Lake pluton (informal name adopted in this report) is a large felsic intrusion of which approximately 690 km^2 is located within the southern and southeastern parts of the White River area (Figure 2). The pluton extends over 51 km north-south and 71 km east-west. The intrusion was mapped by Siragusa (1977, 1978) as being dominantly granodiorite and quartz monzonite (i.e., monzogranite in modern terminology). Distal from the contact with the Kabinakagami greenstone belt, these rock types are relatively uniform and appear to represent multi-phase intrusions. Migmatites of trondhjemitic composition, the least dominant granitic rock within the intrusion, are present along the pluton's boundaries and as syntectonic intrusive sheets that locally exhibit a variably developed cataclastic fabric (Siragusa, 1978).

Quartz monzonite is the youngest recognized phase of the Anahareo Lake pluton and commonly intrudes the granodioritic and trondhjemitic rocks in the form of large, coarse-grained pegmatitic dykes, sills and discordant bodies of variable size (Siragusa, 1977, 1978). This phase of the pluton is described as massive, which prompted Siragusa (1978) to suggest that these young intrusive phases post-date the major period of tectonism in the White

River area. However, no geochronological information is currently available to test this interpretation and the age of the pluton is unknown.

No detailed information is available regarding the thickness of the Anahareo Lake pluton, although it is possible the intrusion may extend to a significant depth.

2.1.1.5 Danny Lake Stock

The Danny Lake stock is an east-west-elongated intrusion (5 km wide by 22 km long) located approximately 4 km north of the Township of White River (Figure 2). The Danny Lake stock consists of hornblende porphyritic quartz monzonite to quartz monzodiorite, and is classified by Stott (1999) as a probable sanukitoid suite. Cross-cutting relationships suggest that this intrusion is the youngest intrusion in the White River area, although no absolute age is available. The Danny Lake stock locally crosscuts tonalite gneiss and envelopes amphibolite slivers that outline a tonalite gneiss dome west of Dayohessarah greenstone belt.

Considering its limited size, the intrusion may only extend to a modest depth.

2.1.1.6 Foliated Tonalite Suite Southeast Of Kabinakagami Lake

On the southeast side of Kabinakagami Lake, Santaguida (2001) outlined two packages of rock, bisected by greenstone, described as a foliated tonalite suite that occur between the Kabinakagami greenstone belt and the Anahareo Lake pluton (Figure 2). The tonalite packages extends over a distance of 29 km north-south and 25 km east-west. This suite of rocks is similar to the Anahareo Lake pluton mapped by Siragusa (1977, 1978). Siragusa (1977) described outcrops of the foliated tonalite suite within the White River area as consisting of biotite trondhjemite, trondhjemite, granodiorite and biotite granodiorite. Biotite trondhjemite is the dominant granitic rock in contact zones between the granitic and supracrustal rocks of the Kabinakagami greenstone belt and also occurs as syntectonic intrusive sheets concordant to the foliations observed in the metavolcanic rocks. The biotite trondhjemite appears as strongly gneissic, grey to brownish grey, medium-grained rock and is locally porphyritic owing to the presence of eye-shaped quartz and feldspar porphyroblasts (Siragusa, 1977).

No absolute age is available for this foliated tonalite suite, although it may be of the same age as other lithologically similar intrusions in the region. No information is available regarding the thickness of the suite.

2.1.1.7 Dotted Lake Batholith

The Dotted Lake batholith (referred to in some literature as a pluton) is located north of White Lake and straddles the western boundary of the White River area; only a small portion of the batholith is within the White River area (Figure 2). The Dotted Lake batholith is of irregular shape, approximately 20 km long and 10 km wide; no information exists on the depth to which the pluton extends. The batholith is primarily a coarse-grained, homogeneous, biotite leucotonalite to leucogranodiorite that is massive to weakly foliated to lineated away from its margin (Milne, 1968; Beakhouse, 2001). The margin of the batholith is highly strained with a well-developed penetrative fabric. Localized narrow zones of high strain also occur in the interior of the batholith associated with narrow, brittle-ductile shear zones. The Dotted Lake batholith has been dated at ca. 2.697 Ga (Beakhouse, 2001), and is interpreted to pre-date the imposition of the regional deformational fabric (Jackson *et al.*, 1998).

2.1.1.8 Tedder Granite Pegmatite

Immediately south of the Dayohessarah greenstone belt, in the area surrounding Round Lake, Stott (1999) identified an intrusive body he termed the Tedder granite pegmatite. This late stage intrusive body is a massive pegmatite containing local amphibolite and clastic metasedimentary inclusions, and very local tonalite gneiss inclusions. The tonalite gneiss inclusions are similar to the gneiss present to the west and southwest of the greenstone belt suggesting a wider distribution of this unit prior to the emplacement of the pegmatite (Stott, 1999).

The amphibolite inclusions appear to be structurally non-rotated relative to the orientation of the schistosity in the greenstone belt. Based on regional deformation patterns in the surrounding tonalite gneiss and the Dayohessarah greenstone belt, Stott (Written comm., 2014) interpreted the pegmatite to post-date at least the main phase of regional deformation and noted that there exists no evidence of subsequent regionally related penetrative deformation within the pegmatite. Consequently, it appears that the pegmatite is a late phase that intruded after the granodiorite plutons were emplaced into the regional tonalite gneisses and adjacent to the greenstone belt.

The extent of Tedder granite pegmatite is likely minor and only the northern boundary, adjacent to the greenstone belt, has been defined. Mapping by Stott (1999) has shown that the intrusion has dimensions of greater than 8 km east-west and 3 km north-south. Due to the small size and undefined shape, the outline of the pegmatite is not shown on Figure 2.

2.1.2 Greenstone Belts

2.1.2.1 Dayohessarah Greenstone Belt

The Dayohessarah greenstone belt is centred on Dayohessarah Lake in the north-central part of the White River area, and forms a narrow, north-trending arcuate belt, approximately 36 km in length and from 1.5 to 5 km in width (Figure 2).

The Archean-aged greenstone belt has been mapped by Fenwick (1967), Stott *et al.* (1995a, b, c) and Stott (1999). The following description of the greenstone belt is taken from Stott (1999). The greenstone belt is a south-plunging syncline composed of a basal sequence of massive to pillowed basalt overlain in succession by:

- A local unit of komatiitic flows, typified by spinifex-texture, and accompanying gabbro to peridotite bodies;
- Dacite to rhyolite flows and pyroclastic units; and
- A metasedimentary sequence centered on Dayohessarah Lake.

The metasedimentary assemblage of the Dayohessarah greenstone belt is the youngest supracrustal sequence in the greenstone belt and unconformably overlies the ultramafic flow sequence. This metasedimentary package is composed of basal metaconglomerate, containing metavolcanic and metasedimentary clasts, overlain by metamorphosed wacke-siltstone beds. The metasedimentary rocks appear to be derived from volcanic, sedimentary and felsic plutonic sources.

The structure of the belt appears to be dominated by the strain regime related to the emplacement of the syn-tectonic Strickland Pluton to the east (Stott, 1999). The southern end of the belt transitions into amphibolite inclusions within granite pegmatite and granodiorite intrusions, one of which trends westward toward the settlement area of White River.

No published information on the thickness of the Dayohessarah greenstone belt is available; however, exploration drilling has shown it extends to a depth of greater than 400 m. It is likely that the belt may extend to a depth of 2 to 3 km (G. Stott, Pers. Comm, 2013).

2.1.2.2 Kabinakagami Greenstone Belt

The Kabinakagami greenstone belt occurs in the northeastern part of the White River area as a northeast-trending irregularly shaped body between the Anahareo Lake and Strickland plutons (Figure 2). Within the White River area the belt has a length of approximately 40 km and varies in width from 4 to 23 km. General lithological descriptions of the Kabinakagami greenstone belt can be found in Siragusa (1977, 1978) and Wilson (1993). No internal subdivision of the belt has been completed (Williams *et al.*, 1991).

The belt is a metavolcanic-metasedimentary belt dominated by mafic metavolcanic rocks locally interbedded with mafic pyroclastic rocks and minor thin, felsic metavolcanic units, and subordinate clastic metasedimentary rocks. Locally, massive metagabbro, metapyroxenite, and minor peridotite, are in contact with the mafic metavolcanic rocks. These rocks were intruded, and locally assimilated, by trondhjemitic intrusions (Siragusa, 1977, 1978).

The metasedimentary rocks include metaconglomerate, metasandstone and paragneiss. The principal sources of clasts within the metasedimentary rocks are local metavolcanic rocks, suggesting that metasedimentary rocks were derived from a source proximal to where they were deposited (Siragusa, 1977). Metasandstones and associated paragneiss flank the east side of the metavolcanic rocks. Minor occurrences of pyrite-bearing biotite-rich paragneiss and hornblende-biotite paragneiss are found at several localities along the eastern shore of Kabinakagami Lake near the boundary of the greenstone belt and are interpreted as sulphide facies iron formation bands. At the southern end of Kabinakagami Lake, the fine- and medium-grained metasedimentary rocks grade along strike into metaconglomerate (Siragusa, 1977).

The supracrustal rocks in the Kabinakagami greenstone belt were metamorphosed to middle-greenschist to upper amphibolite facies conditions. The rocks were uplifted, deformed, and partially assimilated by the emplacement of granodioritic plutons at their margins. Subsequently, both the supracrustal and the granitic rocks were intruded by numerous diabase dykes (Siragusa, 1977, 1978). The main mapped structural feature of the belt is a northeast-trending syncline, immediately west of Kabiskagami Lake (Siragusa, 1978; Santaguida, 2001). Siragusa (1977) also noted, but did not delineate, the axis of another northeast-trending syncline between Nameigos Lake and the northeastern corner of the White River area.

2.1.3 Other Units

Numerous small lenses of mafic metavolcanic rock occur in the area to the west of the Dayohessarah greenstone belt from the northern boundary of the White River area southward to the Ruthie Lake area (Fenwick, 1967; Santaguida, 2001; Figure 2). These supracrustal rocks are surrounded by the Black-Pic batholith or the Danny Lake stock and likely represent remnant fragments of what was once a far more extensive greenstone terrain.

A gabbroic body, the mapped boundaries of which are geophysically defined, is interpreted as being located in the Bulldozer Lake area in the northwestern corner of the White River area (Santaguida, 2001). Mineral exploration mapping and drilling suggest that additional, smaller gabbroic intrusions are present to the south of this unit. Approximately 5 km southeast of the intrusion, eight boreholes encountered units described variously as mafic to ultramafic dykes and hornblende-quartz biotite gabbro which occurred as thin dykes to intrusions >60 m thick (MNDM, 2013a; AFRI files 42C14NW0003 and 42C14NW0007). The dykes were observed as being hosted by granite-tonalitic gneiss.

2.1.4 Mafic Dykes

Several generations of Paleoproterozoic and Mesoproterozoic diabase dyke swarms crosscut the White River area (Figure 2), including:

- Northwest-trending Matachewan Suite dykes (ca. 2.473 Ga; Buchan and Ernst, 2004). This dyke swarm is one of the largest in the Canadian Shield and most predominant of all dyke swarms recognized in the White River area. Individual dykes are generally up to 10 m wide, and have vertical to subvertical dips. The Matachewan dykes comprise mainly quartz diabase dominated by plagioclase, augite and quartz (Osmani, 1991);

- North-trending Marathon Suite dykes (ca. 2.121 Ga; Buchan *et al*., 1996; Hamilton *et al*., 2002). These form a fan-shaped distribution pattern around the northern, eastern, and western flanks of Lake Superior, and are fairly minor in the White River area. The dykes vary in orientation from northwest to northeast, and occur as steep to subvertical sheets, typically a few metres to tens of metres thick, but occasionally up to 75 m thick (Hamilton *et al*., 2002). The Marathon dykes comprise quartz diabase (Osmani, 1991) dominated by equigranular to subophitic clinopyroxene and plagioclase;
- Northeast-trending Biscotasing Suite dykes (ca. 2.167 Ga; Hamilton *et al*., 2002). These dykes are not numerous in the White River area;
- West-northwest-trending Sudbury Suite dykes (ca. 1.238 Ga; Krogh *et al*., 1987). These dykes are not numerous in the White River area; and
- Northeast-trending Abitibi Suite dykes (ca. 1.14 Ga; Ernst and Buchan, 1993). These dykes are not numerous in the White River area.

The five dyke swarms in the White River area are generally distinguishable by their unique strike directions, cross-cutting relationships and, to a lesser extent, by magnetic amplitude.

2.1.5 Faults

In the White River area a limited number of unnamed faults are indicated on public domain geological maps (Fenwick, 1966; Siragusa, 1977, 1978; Stott, 1995a, 1995b, 1995c; OGS, 2011); the largest of these parallels the axis of Esnagi Lake in the east-central part of the area (Siragusa, 1978; Figure 2). Mapped faults generally have either a northwest or northeast-trending orientation, although a grouping of semi-circular faults is present west of Dayohessarah Lake (OGS, 2011).

2.2 Quaternary Geology

The White River area is within the Abitibi upland physiographic region of Thurston (1991b) who subdivided the extensive James Region physiographic region of Bostock (1970). The region is characterized by abundant bedrock outcrop with shallow drift cover and a rolling to moderately rugged surface, scattered with lakes.

The Quaternary sediments, commonly referred to as drift, soil or overburden, are glacial and post-glacial materials which overlie the bedrock in the White River area. The distribution, thickness and physical characteristics of these deposits have an important influence on several aspects of the current investigation. Areas of thicker drift can hinder the interpretation of lineaments by masking their surface expression or muting the response obtained from geophysical surveys. Coarser grained surficial sediments typically have a moderate to high transmissivity and can serve as local aquifers as well as being a potential source of mineral aggregates for use in building and road construction.

The most recent major geological event in the geologic history of northern Ontario was an extended period of glacial activity that shaped the landscape and resulted in the deposition of the majority of the surficial materials that overlie the bedrock of the area (Barnett, 1992). Large ice sheets are believed to have repeatedly advanced and retreated across this part of Ontario during the Quaternary Period, which is defined as occurring between 1.8 million years and 10,000 years ago.

The last glacial stage affecting the White River area, termed the Wisconsinan, is deemed to have begun approximately 115,000 years ago and resulted in extensive and prolonged ice cover. The Wisconsinan Stage is commonly divided into three phases: Early – 115,000 to 60,000 years ago; Middle – 60,000 to 30,000 year ago; and Late – 30,000 to 10,000 years ago (Barnett, 1992).

The Early Wisconsinan corresponds to global cooling and the growth of the Laurentide Ice Sheet, the Middle Wisconsinan was a slightly warmer period, during which southern Ontario and perhaps parts of northern Ontario were ice-free, while the Late Wisconsinan saw the return of ice cover. The Late Wisconsinan glacial ice cover peaked at approximately 20,000 years ago with the glacial ice mass extending across all of Ontario and into the northern United States.

All glacial landforms and related materials within the White River area are associated with the Late Wisconsinan. Quaternary deposits and landforms in the area are thought to have formed during the latter stages of ice cover. The Quaternary (i.e., surficial) geology of the area has been mapped at different scales as discussed in section 1.3.1.4 and as shown in Figures 3 and 4.

Geddes *et al.* (1985) and Geddes and Kristjansson (1986) report that glacial striae in the White River area reveal an early north to south ice movement that was followed by a strong, regional flow of approximately 220°. Bedrock erosional features indicate that ice flow, likely in the waning stage of glacial cover, was influenced by local topographic conditions as demonstrated by striae measurements ranging from 180° to 245°. Numerous glaciofluvial esker systems, with orientations that roughly parallel the regional ice flow direction, are present across the White River area (Figure 3). Esker lengths range from 2 to >15 km.

Following retreat of the ice that deposited ground moraine (till) and glaciofluvial deposits, the lowland portions in the northern half of the White River area were inundated by the water of Glacial Lake Barlow-Ojibway (Prest, 1970; Gartner and McQuay, 1980a, 1980b). Deposition of sediments directly related to glacial activity is thought to have ended approximately 9,000 years ago.

For large parts of the White River area drift thickness over bedrock is limited and the ground surface reflects the bedrock topography. Over the majority of the area bedrock outcrops are common and the terrain is classified, for surficial purposes, as a bedrock-drift complex; i.e., thin drift cover that only locally achieves thicknesses that mask or subdue the bedrock topography (Figure 3). Valleys and lowland areas typically have extensive and thicker surficial deposits that frequently have a linear outline.

3. Topography

3.1 Elevation

The elevation difference within the White River area is moderate with a maximum range of approximately 311 masl (Figure 5). The highest point of land within the area, 622 masl, occurs approximately 13 km northeast of the settlement area of White River, and the lowest point (311 masl) is the level of Kabinakagami Lake in the northeast portion of the area.

The White River area can be viewed as consisting of a broad, dissected plateau which has higher elevations in the western and southern regions and a lower ground surface along its northern boundary. Significant variations in elevation resulting from the bedrock knob and ridge topography are prevalent in most parts of the area.

Across expanses in the southern and north-central parts of area, the elevation of knobs and intervening valleys is commonly above 400 m (Figure 5). Localized areas with elevations over 500 m are present in the area surrounding the Township of White River as well as in several of the townships along the southern White River area boundary, east of Highway 631.

Elevations of 320 to 400 m occur as a band of varying width across the northern and eastern boundaries of the area as well as a large portion of the northeast quadrant (Figure 5). All significant glaciolacustrine and organic deposits occur within this range of elevation.

3.2 Relief

Relief maps of the White River area are useful in outlining zones of thin drift located in bedrock controlled upland areas. Within the White River area, the upland regions consisting of knobby bedrock hills are typically characterized by moderate relief of approximately 60 to 80 m over distances of hundreds of metres to a few kilometres (Figure 5). The uplands are scattered throughout the area and form the dominant terrain type.

The glacial and post-glacial deposits in the northern third of the area display relief in the range of 20 to 40 m over the majority of their surface area. Limited relief is present within organic deposits, except where their surface is disrupted by hummocks of bedrock.

Relief was calculated using different approaches to highlight different aspects of the topography. These different representations of relief are presented in Figures 6 to 8. Figures 6 and 7 display relief calculated through subtracting the average elevation within a pre-defined radius (20 km and 2 km, respectively) from the elevation value in the processing cell, resulting in a value depicting the departure of a given point from the average surrounding elevation.

The use of a 20 km averaging radius (Figure 6) highlights the presence of broadly higher and lower ground within the White River area. In Figure 6, areas of greatest positive departure from the average elevation appear as a series of northeast trending bands, the most prominent of which is adjacent to the Township of White River. Several large areas of positive relief are found throughout the White River area as illustrated in the inset map of Figure 6, which highlights areas with elevation departures of 9 m or more than the surrounding average.

Several of the larger river valleys and lowland areas surrounding larger lakes appear as areas of negative deviation on Figure 6. River valleys that are clearly depicted in this manner are occupied by the Bremner and White rivers in the southwest corner, and the Kabinakagami River in the east-central part of the area. Less well defined by the use of a 20 km averaging radius, is the Shabotik River in the northwest quadrant.

The use of a 2 km averaging radius for depicting the departure of a given point from the average surrounding elevation highlights locally prominent positive or negative landforms in the White River area (Figure 7). This calculation of relief again illustrates the upland areas, but enables the recognition of linear features (valleys) separating bedrock knobs. The upland areas located north of the Township of White River and throughout the southern half of the area are again evident, as are small areas of somewhat higher relief that are scattered over the remainder of the area.

The strong positive features shown on Figure 7 are bedrock knobs that are frequently circular to rectangular in shape and are of 1 to 3 km in length with widths usually in the 1 to 2.5 km range. Relief in excess of 60 m to over 100 m above the surrounding ground regularly occurs over distances of 100 to 500 m. Bedrock and river valleys appear as negatives on Figure 7, with these being more pronounced in the bedrock dominate terrain in the southern portion of the White River area.

The inset map on Figure 7 displays areas that are at least 9 m higher than the surrounding average elevation, and emphasizes the dominance of knob and ridge terrain over the majority of the area. On the inset map, knobs (high ground) are displayed in red. Of note is the general decrease in knobby terrain in the northeast portion of the White River area (Figure 7, inset map). There does not, however, appear to be any obvious correlation between topographic relief and the bedrock geology based on mapping available for the area.

The areas of positive relief shown in Figure 6 and Figure 7 are largely indicative of zones of thinner overburden within which the bedrock may be more easily characterized by surface mapping. Conversely, areas of strong negative relief are more likely to have a thicker overburden cover making observation of the bedrock surface difficult. The trend of the areas negative relief may reflect the orientation and/or presence of underlying bedrock structures.

Figure 8 displays the range in elevations within a 250 m radius of a given point in the area. Using this approach, the maximum amount of relief calculated over this short distance is approximately 162 m. This highest relief value is coloured blue on Figure 8 and tends to occur throughout the south central portion of the area associated with the shorelines of small water bodies. Figure 8 once again illustrates the knobby surface of the White River area and highlights the greater relief in the southern portion and, to a lesser degree, the northwest quadrant. Larger, but patchy, areas of lower relief are located in the vicinity of, from east to west, Kabinakagami, Gourlay and White lakes. The inset map on Figure 8 differentiates between areas of high local relief (>31 m).

3.3 Slope

Approximately 17.4 percent (867 km^2) of the White River area is represented by slopes greater than 6 degrees (Figure 9). These steep slopes are generally associated with topography in areas of bedrock terrain and there is a correlation with areas of higher relief (Figure 5). A concentration of steep slopes occurs in a southeast trending belt that arcs north of the Township of White River from Highway 17 in the west to the mid-point of the southern area boundary. A high number of steep slopes are also present either side of Esnagi Lake in the southeast corner of the White River area.

The ruggedness of the area immediately north of the Township of White River is illustrated by the fact that the steep slopes make-up the majority of the land surface (Figure 9). Elsewhere the terrain has a more distinctively knobby nature; here the tops of the knobs, and occasional ridges, frequently have lower slopes than the surrounding terrain creating a circular or semi-circular pattern evident on Figure 9. Often, the steep slopes form northeastern facing cuestas. The north-central and northeastern portions of the White River area exhibit a paucity of steep slopes, as does the area east of White Lake in the northwest corner.

Assuming that areas with steep slopes are indicative of areas with no or limited overburden, and areas displaying gentler slopes may be indicative of somewhat thicker overburden, a map showing the density of slopes greater that 6 degrees was generated (Figure 10). Areas of low slope density on this figure highlight potential areas of thicker overburden that may obscure the surface expression of lineaments, or introduce uncertainty to the mapping and geologic interpretation of the area.

Figure 10 illustrates the ruggedness of the land immediately north and east of the Township of White River where large areas have a relatively higher density of slopes >6°. In general, the southern portion of the area has higher steep slope densities than the land to the north, except in the zone bounded by Kwinkwaga Lake, Dayohessarah Lake and the northern edge of the area.

In the White River area the use of slope density mapping (Figure 10) as an indicator of potential thick drift is best done by interpreting the data in conjunction with the surficial geology (Figures 3 and 4). The general good correlation between areas of low density of steep slopes and areas with overburden gives confidence in the quality of the surficial geology mapping.

4. Drainage

The distribution of surface water and surface water drainage in the White River area are important factors to consider in the preliminary assessment. Larger lakes can completely or partially conceal the surface expression of geological structures thus adding uncertainty to the results of a lineament interpretation comparing surficial and geophysical data sets (SRK, 2013).

The White River area straddles the Atlantic and Arctic watersheds. The former covers the majority of western portion of the area with drainage towards Lake Superior via a number of rivers, while the latter drains a greater percentage of the eastern and northern parts of the area with flow directed towards James Bay. Surface water flow patterns are also a useful surrogate for shallow groundwater flow.

4.1 Waterbodies and Wetlands

The numerous lakes within the White River area occupy approximately 10 percent (514 km^2) of the land surface. While the lakes are widespread, lake density is greatest in areas of high elevation and relief (Figure 11) and, as such, more lakes occur in bedrock dominated terrain in the southern and west-central portions of the area. Lower lake density is present in a large area to the north of an arcing line that runs from Matthews Lake, on the northern boundary, to north of Oba Lake in the east. This area corresponds with the most extensive deposits of glaciolacustrine, glaciofluvial and organic sediments. Local concentrations of small lakes, however, are present in this area within some large glaciofluvial deposits. Notable examples occur in Bayfield Township immediately west of highway 631, in an esker-outwash complex, and in Derry and Ermine townships east of Kabinakagami Lake, where the lakes are associated with a southward trending esker system (Figure 11).

Lakes in the White River area range in size, although the majority have a surface area of less than 2.0 km^2. The larger water bodies (>2.5 km^2) in the White River area are listed in Table 3.

A lake sediment sampling survey conducted by the GSC recorded lake depths at approximately 355 locations in the White River area (Friske *et al.*, 1991). While it was the intent of this survey to sample the deepest part of the lakes, this cannot be confirmed. Nevertheless, the lake sediment survey data do provide a general picture of minimum lake depths (Figure 11). Bathometric surveys have been conducted by the MNR for 59 lakes in the White River area; however, the accuracy of these surveys is questionable (C. Bolton, written comm., 2013). Lake depth data in the areas of the Dayohessarah and Kabinakagami greenstone belts are also available as a result of lake and water sampling conducted by Jackson (2002a, 2002b, 2003a, 2003b).

Table 3. Size of lakes larger than 2.5 km^2 in the White River area.

Lake	Area (km^2)	Perimeter (km)
Kabinakagami*	123.2	374.4
White*	60.9	182.8
Esnagi*	46.0	254.6
Oba*	25.5	110.0
Negwazu	14.3	43.0
Nameigos	13.5	47.8
Dayohessarah	11.2	44.9
Gourlay	9.9	31.1

Table 3. Size of lakes larger than 2.5 km^2 in the White River area.

Mosambik	9.8	19.5
Pokei	8.7	22.4
Kwinkwaga	8.6	53.5
Anahareo	8.5	19.2
Matthews	6.1	16.3
Duffy	4.9	20.3
Hambleton	3.5	19.0
Caribou	3.4	28.5
Tukanee	3.2	13.1
Upper Duffy	2.7	18.3
Round	2.6	7.4
Pike	2.6	16.2

* Lake extends beyond boundary of the White River area

Table 4 indicates that approximately 60 percent of the sample sites measured by Friske *et al.* (1991) have a water depth of less than 5 m and nearly 86 percent are less than 10 m deep. Lakes deeper than 20 m account for only 3.7 percent of the sites sampled.

Table 4. White River area lake depth data (from Friske *et al*., 1991).

Lake Depth (m)	Number of Lake Sites	Percentage
<5.0	210	59.1
5.1 – 10.0	95	26.8
10.1 – 15.0	19	5.3
15.1 – 20.0	18	5.1
>20.1	13	3.7

No correlation between lake size and depth can be determined based on the available data. Deeper lakes are concentrated in the western and southeastern parts of the area were bedrock terrain is prevalent. This area is largely underlain by the Black-Pic batholith, the Denny Lake stock, an unnamed foliated tonalite body and the informal named Anahareo Lake pluton.

Generally shallower lake depths in the northeastern corner of the area likely reflect infilling of bedrock basins by glaciolacustrine sediments. Significant bedrock units in this area are the Strickland pluton, the Dayohessarah greenstone belt, and an area of foliated tonalite and a relative limited portion of the Anahareo Lake pluton.

Wetlands are developed at scattered locations along water courses in the area and in rock floored basins (Figure 3). Organic deposits associated with the wetlands are expected to have a limited thickness based on mapping conducted in the southwest portion of the White River area (Geddes and Bajc, 2009a; Geddes and Kristjansson, 2009), the Hemlo area to the east (Geddes *et al.*, 1985) and other areas of the Canadian Shield.

4.2 Watersheds

A watershed, also known as a catchment, includes all of the land that is drained by a watercourse and its tributaries. Watershed boundaries are defined by heights of land. Boundaries are set where a height of land causes water to flow away from topographic highs (MNR, 2013). The delineation of drainage divides are therefore useful for determining surface flow directions and also contribute to an initial understanding of the shallow groundwater flow system.

The White River area straddles the Atlantic and Arctic watersheds, which drain via the Lake Superior/Great Lakes/St. Lawrence River and James/Hudson Bay water systems, respectively. The Arctic watershed is represented in the area by two tertiary level watersheds, the Nagagami and the Upper Kabinakagami, which drain the majority of the land in the eastern half of the area (Figure 12, inset map). Drainage towards Lake Superior is through the Michipicoten-Magpie and White tertiary watersheds; the overall flow direction in the former is southward, while the general drainage direction of the latter is westward toward White Lake. Tertiary watersheds, as defined by MNR, are generally the equivalent of the sub-sub-division of drainage areas as defined by the Water Survey of Canada.

The boundaries of the quaternary watersheds for the White River area were created using the Spatial Analyst Extension of ESRI's ArcGIS to compute the flow direction from a DEM and then employing the watershed function to determine contributing area. This analysis produced watershed boundaries that are generally consistent with the quaternary watershed boundaries developed by the MNR (MNR, 2013). The analysis conducted as part of this study delineated drainage divides at a finer level than completed by MNR (Figure 12). Further subdivision of the watersheds is possible as each of the many lakes in the area represents a distinct catchment area. Given the scale of the area and the scope of the current study, such a detailed delineation was not undertaken.

The horizontal positional accuracy of the watershed boundaries is variable depending on the nature and spatial distribution of the raw DEM information, and thus cannot be quantified without onsite investigation and verification. In general, positional accuracy in northern Ontario is within 400 m, but there is no statistical level of confidence available.

4.3 Surface Flow

The orientation of the drainage network within the White River area is largely controlled by bedrock structural features (faults and lineaments) and the irregular topography of the terrain. Due to this control, the majority of waterways, including lakes, have, in order of dominance, a northeast, north or northwest orientation. While the overall drainage in the Atlantic and Arctic watersheds are southwest and northeast, respectively, the catchment areas of individual lakes within the watersheds have stream segments with multiple flow directions (Figure 12).

The larger rivers draining the area's watersheds are fed by numerous smaller creeks and streams that effectively drain all parts of the White River area. While there is generally a high density of streams and rivers in the area, it is somewhat lower in the region surrounding Kabinakagami Lake where glaciolacustrine, glaciofluvial and organic deposits occupying a significant percentage of the landscape.

Typically, segments of the waterways in the White River area are on the order of 2 to 10 km, as they flow into and out of lakes occurring along the drainage paths. A relationship exists between the length of stream segments and relief: shorter segments are present in highland regions, and longer segments in lower relief regions associated with glaciolacustrine deposits. Gradients of the watercourses vary; those of smaller streams are generally moderate, while longer rivers, such as the Kabinakagami, Shabotik and White, have lower gradients. Rapids and small waterfalls are common in the area.

Periods of higher stream flow are related to the spring melt (March - May) and, to a lesser degree, increased autumn precipitation (October – November). While flows decrease in the summer months, regional data (no gauging stations exist in the area) from Environment Canada (2013) indicate that significant precipitation events during this part of the year can significantly increase flow for a short period of time. This is a reflection of rapid runoff from the bedrock terrain the area.

5. Terrain Characteristics

An understanding of the distribution and thickness of overburden within the White River area is essential for interpreting the distribution of lineaments mapped from satellite imagery and topographic surface data (SRK Consulting , 2013), particularly with respect to lineament length and density. Thick drift deposits are able to mask the surface expression of lineaments. In areas of discontinuous drift deposits, the drift can conceal minor lineaments, producing low apparent lineament density and can censor the lengths of major structures. In areas of thick and extensive overburden, major structures can remain undetected using only satellite imagery and/or aerial photographs, particularly if these areas also contain large lakes.

Areas of exposed bedrock or thin drift are more readily amenable to characterization. Thin drift terrain allows easier investigation of bedrock units through outcrop mapping, the identification of bedrock structures and preliminary rock mass characterization.

The purpose of this section is to provide information to help enhance the understanding of overburden deposits in the White River area. Sections 5.1 and 5.2 present reviews of the water well and drill hole data, respectively, on overburden thickness in the White River area. Details on the expected composition, distribution and thickness of surficial deposits within the terrain units are presented in Section 5.3.

5.1 Water Well Data

Data on overburden thickness from water well records held by the Ontario Ministry of the Environment (MOE) were reviewed to supplement the information on overburden deposits outlined by the terrain mapping component of this study. There is limited information on the depth of overburden for the White River area in the Ontario Ministry of Environment Water Well Database (2013) as only 33 wells are in the database (Table 5). Two wells reportedly in the area were deemed to have incorrect geographic co-ordinates and were excluded from consideration.

The vast majority of the water wells are located within the settlement area of White River, in close proximity to Highways 17 or 631. Of the five water wells located outside of the Township of White River, four are west of the settlement area, along Highway 17 and the other is in Gourlay Township, approximately 45 km northeast of White River (Figure 3).

Fifteen water well records contain data on the depth to bedrock. In these wells the bedrock surface was encountered at depths ranging from 1.5 to 27.1 m. The 15 wells confirmed to end in overburden had depths ranging from 4.6 to 38.7 m indicating that bedrock would be found at a greater depth. The water wells terminating in overburden are generally located in glaciofluvial deposits in the vicinity of the settlement area of White River.

Table 5. Ministry of Environment water well data for the White River area.

MOE Well ID	Depth of Well (mbgs)	Depth to Bedrock (mbgs)	Static Water Level (mbgs)	Water Well Type (aquifer)
1102615	91.4	13.7	8.5	Bedrock
1102616	99.1	13.4	8.5	Bedrock
1102820*	49.4	14.3	5.2	Bedrock
1103474	31.1	27.1	3	Bedrock
1103475	30.8	26.8		Bedrock
1103476	18.3	15.8	2.4	Bedrock
1103477	17.7	15.8		Bedrock
1103489	15.8	14.9		Bedrock
1103490	17.7	15.8		Bedrock
1103492	30.8	26.8		Bedrock
1103493	31.1	27.1	3	Bedrock
1104022	82.6	1.5	4.9	Bedrock
1106570	16.5	16.2	1.5	Bedrock
1106572	23.8	23.8	2.1	Bedrock
1106577	18	18	1.2	Bedrock
7039453*	15			Bedrock
1103488	14.9	NR		Overburden
1104023	21.9	NR	1.8	Overburden
1104027	9.1	NR	2.1	Overburden
1104165	19.5	NR	3	Overburden
1106559	17.7	NR	1.5	Overburden
1106569	14.9	NR	1.8	Overburden
1106571	22.3	NR	1.8	Overburden
1106573	19.2	NR	0.9	Overburden
1106574	18	NR	1.5	Overburden
1106575	17.7	NR	1.2	Overburden
1106576	17.7	NR	1.5	Overburden
1107233	6	NR		Overburden
7049968	4.6	NR		Overburden
7120857*	38.7	NR		Overburden
7142005	4.6	NR	3	Overburden
7197863*				Unknown
7197864*				Unknown

NR – Bedrock not reached; Blank Fields – data not reported * - located outside of the Township of White River

5.2 Ontario Drill Hole Database

The drill hole database maintained by the Ministry of Northern Development and Mines (2013) contains records of 299 drill holes in the White River area. The majority of the drill holes are located over mafic metavolcanic rocks that form part of either the Dayohessarah or Kabinakagami greenstone belts (Figure 3). The most notable concentrations of drill holes are located around the western and northeastern sides of Dayohessarah Lake and the southwestern and northeastern sides of Kabinakagami Lake. Other smaller groupings of drill holes occur over fragments of metavolcanic and metasedimentary rock across the White River area.

The average depth of overburden recorded in the drill logs is 8.1 m, with just over a third of the holes having <3.0 m of drift cover. In viewing the overburden thickness data contained in this database it must be noted that a large number of the drill holes were advanced at an angle. For those drill holes with a recorded depth of <5 m of overburden, the drill angle does not add appreciably to the indicated thickness of the surficial sediments. However, a large majority of the drill holes reporting greater than 5.0 m of drift were oriented at an angle to vertical, thus artificially increasing the overburden thickness more significantly. When the depth is corrected for drill angle the average overburden thickness decreases to 6.9 m and approximately 41 percent of the holes have <3 m of overburden (Table 7). The thickest sequence of overburden recorded from an angled drill hole was 51.8 m; when corrected to horizontal the depth was reduced to 44.9 m.

A factor influencing the average depth of overburden calculated from drill holes is that 120 of these are holes that were drilled specifically for overburden sampling in areas of deeper drift. The bulk of the overburden holes were drilled in glaciofluvial deposits in the northeast corners of Abraham and Knowles townships. The average depth of drift encountered in these holes was 12.0 m. When these overburden holes are excluded, the average overburden thickness for the remainder of the drill holes in White River area is approximately 4.5 m, with 54 percent of the holes encountering bedrock within <3 m.

Table 6. Overburden depth in exploration drill holes in the White River area (MNDM, 2013a). Depth is corrected for drill angle.

Depth of Overburden (m)	Number of Drill Holes	Percentage
<1.1	23	7.7
1.1 – 3.0	101	33.8
3.1 – 5.0	39	13.0
5.1 – 10.0	64	21.4
>10.1	72	24.1

5.3 Terrain Units

5.3.1 Morainal

The most common glacial deposit in the White River area is stony, sandy till (ground moraine) which forms a veneer in rocky upland areas (Figure 4). The till composition is variable and two types are regionally recognizable (Geddes *et al.*, 1985; Geddes and Bajc, 1985a; Geddes and Kristjansson, 1986). A moderately loose, very stony variety with a sandy texture that is of local derivation dominates in areas of thin till cover in the western part of the area. A calcareous, silty till, rich in "exotic" carbonate lithologies derived from the James Bay Lowland, is common in the northern part of the White River area (Geddes and Kristjansson, 1986). This latter till occurs in two facies, one of which is stone poor, massive, silty and quite dense. The other more dominant facies is less compact and slightly sandier, and has a variable stone content. In some areas, the calcareous till is capped by coarser, locally derived till or till-like material. Geddes and Kristjansson (1986) note that in areas where there is little relief on the land surface, the calcareous till in usually prominent, especially in areas on the leeside of significant topographic features. It is typical of the stony till to have a more hummocky, or moranic surface expression.

Till thickness is variable and while depths of several metres are present locally, thicknesses are typically less than 3 m (A. Bajc, pers comm., 2013). Gartner and McQuay (1980a, 1980b) report that the till is seldom more than 1 m thick on the crests of the hills, but can thicken to 5 m or more on the flanks and in the valleys between the bedrock hills.

Areas of ground moraine shown on Figure 3 are zones of lesser relief indicating the till thickness may be sufficient to subdue the bedrock topography. In the area south and west of Dayohessarah Lake, the till forms a patchy blanket over highland areas (OGS, 1997) and is, in places, gently fluted (Geddes and Kristjansson, 1986). Although the ruggedness of the surface in this area suggests that the till thickness is generally of limited depth, it may locally mask the relief of the underlying bedrock surface.

In areas where the ground moraine forms only a veneer over the bedrock, construction will often involve blasting, rock excavation and grading. In areas of thicker till, the clast-rich nature of the material requires equipment capable of moving and/or breaking-up boulders. While till is not suitable for use as aggregate due to its fines (i.e. silt and clay) content, it can be used as fill.

5.3.2 Glaciofluvial

Two types of glaciofluvial deposits are present in the White River area, ice-contact stratified drift deposits (ICSD) and outwash deposits. The ICSD deposits are associated with a number of esker-kame complexes that trend in a south-southwest direction across the area (Figure 3). All the complexes have a well-developed, if discontinuous, central esker ridge(s) which is frequently flanked by kettled kame terraces and occasionally by outwash (Geddes and Bajc, 1985a, 1985b, 2009a, 2009b; Geddes and Kristjansson, 1986. 2009). The ICSDs consist primarily of stratified, well to poorly sorted sand and gravel that locally can achieve thicknesses of several tens of metres, as evidenced by the logs of the exploration overburden drill holes. For example, approximately 8 km east of the Township, where a south trending glaciofluvial complex crosses Highway 631, a series of exploration drill holes extend across a narrow bedrock valley. Here over a lateral distance of approximately 165 m, the depth to bedrock varies from 1.4 to 13.9 m; two drill holes 25 m apart have overburden depths of 2.4 and 12.3 m (MNDM 2013a, assessment file 42C11SE0010).

Glaciofluvial outwash deposits occur as areas of limited relief along the esker-kame complexes and within the larger modern drainage systems, such as the Gum, Kwinkwaga, Shabotik and White rivers (Figure 3). Smaller deposits, occupying topographic lows and bedrock valleys, are scattered across the area. The thickness of the outwash deposits are likely to be variable, but may be substantial where they are proximal to ICSD features. Deposits are generally well-sorted and consist predominantly of stratified sand, with a low clast content; however, locally they are coarser grained and gravel-rich (Geddes and Kristjansson, 1986).

In terms of engineering geology considerations, glaciofluvial deposits are suitable for most types of construction and/or development. Excavations should not encounter serious problems and material can generally be reused as fill and compacted with normal equipment; occasionally boulder-rich material may require screening or additional handling. Difficulties may arise in areas where bedrock is close to the surface and blasting may be required for excavations or in low lying areas where a shallow groundwater table may necessitate dewatering (Gartner and McQuay, 1980a, 1980b). In the White River region, most glaciofluvial deposits are of low to moderate relief and are well-drained Areas mapped as glaciofluvial deposits also frequently contain subordinate amounts of ground moraine, rock knobs and organic terrain; these areas may present additional engineering challenges.

5.3.3 Glaciolacustrine

Glaciolacustrine sediments in the area consist of fine sand, silt and minor clay deposited in shallow lakes within bedrock controlled basins (Figure 3). The largest of these deposits are located: south and east of White Lake; northeast of Dayohessarah Lake; and in the northeast corner of the area surrounding Kabinakagami Lake (Gartner and McQuay, 1980a, 1980b). Other small deposits, such as those around Picnic Lake, occur throughout the area (Geddes and Kristjansson, 2009).

Based on the logs of water wells and surficial mapping in surrounding areas, the glaciolacustrine deposits can achieve a thickness of over 20 m. The larger glaciolacustrine deposits are likely to be of variable thickness, as is indicted by the occurrence of outcrops and rock knobs (Gartner and McQuay, 1980a, 1980b).

The engineering properties of glaciolacustrine materials, notably those with high percentages of silt and clay, may cause difficulties for construction. Potential problems include: low bearing strength for footings and foundations; slope instability and susceptibility to erosion and gullying; frost susceptible soils; and difficulties with compaction of relocated material (Gartner and McQuay, 1980a, 1980b). In addition, where the glaciolacustrine deposits are thin over rock, blasting may be required for deeper excavations.

5.3.4 Organic and Alluvial

Bogs and organic-rich alluvial deposits, consisting of sand, silt and organic debris, are present along several on the water courses in the area (Figure 3). These deposits tend to be relatively narrow (<200 m), although their width can increase notably where they surround lakes.

Larger expanses of organic terrain, some of several square kilometres in size, are present in the north-central and northeastern parts of the White River area. These deposits may be developed on finer grained glaciolacustrine deposits and/or outwash which occupy lowland areas. Smaller occurrences of organic terrain exist in bedrock controlled basins throughout the White River area.

The organic deposits in the area are characterized by poor drainage and high water tables, in addition to having poor engineering characteristics due to the fact they consist of compressible materials (Gartner and McQuay, 1980a, 1980b).

5.3.5 Eolian

Eolian deposits, consisting of fine to medium sand, are present as parabolic dunes developed on some outwash plains (Gartner and McQuay, 1980a; Geddes and Kristjansson, 1986) (Figure 3). Dunes, formed in post-glacial time, have heights of only a few metres in the White River area.

5.3.6 Bedrock

The majority of the White River area consists of extensive tracts where bedrock is at or near surface (Figure 3). It is common in these areas of bedrock terrain for the rock to be overlain by a veneer, or in some instances a blanket, of overburden, most frequently ground moraine (till). The overburden is often in the range of 1 to 3 m in thickness; however, on the sides of some of the bedrock hills, and in the low areas between hills, the overburden can thicken to as much as 5 m. Areas mapped as bedrock by Gartner and McQuay (1980a, 1980b, 1980c) contain 15 to 45 percent outcrop and frequently occur within what Geddes and Bajc (2009a, 2009b) and Geddes and Kristjansson (2009) termed bedrock-drift complex.

Mapping by Gartner and McQuay (1979a, 1979b, 1980a, 1980b) indicates that bedrock knobs are the dominant landform in bedrock terrain and although drainage is usually good, organic deposits are commonly found in low, poorly drained areas between bedrock hills. Relief in bedrock terrain varies across the White River area; it is lowest in the northeast corner, where it is commonly in the 40 to 60 m range, and greatest in the southwest quadrant where surface elevation differences of 80 to >100 m occur. Areas of notable relief due to bedrock topography are present immediately north and east of the Township of White River, and in the extreme southwest corner of the area.

Engineering design and construction in areas of bedrock terrain is constrained by the irregular bedrock surface and, in instances, by high, steep bedrock slopes. Below-ground excavations will routinely require blasting and the placement of rock fill as part of site grading; however, footing conditions for supporting foundations are likely to be excellent. Route alignments for various types of infrastructure (e.g., roads, railways, pipelines) are likely to require cut-and-fill sections through bedrock (Gartner and McQuay, 1980a, 1980b).

6. Groundwater

6.1 Groundwater Flow, Recharge and Discharge

Water wells confirmed to be developed in overburden are largely within glaciolacustrine deposits occupying the central portion of the Township of White River. Wells terminating in sand and gravel have reported tested pumping rates of 4.5 to 909 L/min; however, yields are likely not reflective of aquifer capacity, as the wells primarily supply residences with limited demand. Overburden wells have completion depths ranged from 4.6 to 38.7 mbgs with static water levels of 0.9 to 3.0 mbgs (MOE, 2013).

Within the White River area 16 water wells are recorded as being developed in bedrock. These wells reach a maximum depth below ground surface of between 15.0 and 99.1 m. Reported tested pumping rates range from 4.5 to 1,250 L/min with static water levels ranging from 1.2 to 8.5 mbgs (MOE, 2013).

The White River area is characterized by significant areas where bedrock is at or near the surface. Groundwater recharge in these areas is through an interconnected fracture network present in the bedrock. Recharge via the fracture network can be rapid but is largely restricted to a near surface zone. Gartner and McQuay (1980a) note that groundwater resources within bedrock are limited to fractures, faults and fissures making the occurrence of bedrock aquifers unpredictable.

Groundwater flow off the uplands is to flanking valleys and depressions where the bulk of the groundwater discharges either directly to waterways or into surficial deposits occupying the lower ground. Surficial deposits on the highland bedrock areas, most commonly till, are usually thin (<3 m) and relatively coarse-grained allowing downward infiltration to the bedrock surface.

The sand-rich outwash plains found along bedrock valleys in the White River area are recharged by ground and surface flow from the bedrock highlands and direct precipitation (rain and snow). Groundwater discharge from these deposits is as baseflow to streams and rivers which transect them. The presence of a shallow water table in many of the valley outwash deposits is suggested by the fact that the elevation of the dissecting waterway is often within a few metres of the surrounding ground surface.

The large glaciofluvial (esker) deposits that trend south and southwest across the area are also zones of significant groundwater recharge. Creeks and streams are generally lacking over these glaciofluvial systems; however, the water levels in kettle lakes that frequently flank the esker crests indicate a generally shallow water table. The influence of regional bedrock structures, such as the mapped faults in the area, on the rate and volume of groundwater flow is not known at present.

No information on groundwater flow at typical repository depths (approximately 500 m) was found during this study.

7. Neotectonic Features

The geology of the White River area is typical of many areas of the Canadian Shield, which has been subjected to numerous glacial cycles during the last million years, resulting in post-glacial isostatic rebound in the northern portion of the North America plate. During the maximum extent of the Wisconsinan glaciation, approximately 21,000 years ago (Barnett, 1992), the Earth's crust was depressed by more than 340 m in the Minnesota/North Dakota area (Brevic and Reid, 1999), due to the weight of glacial ice. The amount of crustal depression in the White River area would be of a somewhat greater magnitude, due to its closer proximity to the main centre of glaciation located over Hudson's Bay.

Post-glacial isostatic rebound began with the waning of the continental ice sheets and is still occurring across most of Ontario. Vertical velocities show present-day uplift of about 10 mm/a near Hudson Bay, the site of thickest ice at the last glacial maximum (Sella *et al*., 2007). The uplift rates generally decrease with distance from Hudson Bay and change to subsidence (1-2 mm/a) south of the Great Lakes. The ''hinge line'' separating uplift from subsidence is consistent with data from water level gauges along the Great Lakes, showing uplift along the northern shores and subsidence along the southern ones (Mainville and Craymer, 2005). The current rate of isostatic uplift in the White River area is not precisely known, although Lee and Southam (1994) estimate that the land is rising at a rate of 2.9 mm/a at Michipicoten, Ontario, some 75 km to the south-southeast.

The movement and interaction of tectonic plates also creates horizontal stresses that result in the compression of crustal rocks. The mean of the current major horizontal principal stress orientation in central North America, based on the World Stress Map (Zoback, 1992) is NE (63° ±28°). This orientation coincides roughly with both the absolute and relative plate motions of North America (Zoback, 1992; Baird and McKinnon, 2007), and is controlled by the present tectonic configuration of the North Atlantic spreading ridge (Sbar and Sykes, 1973) which has likely persisted since the most recent Paleocene-Eocene plate reorganization (Rona and Richardson, 1978; Gordon and Jurdy, 1986).

The stresses associated with cycles of ice loading and unloading, acting along with tectonic stresses, may result in seismic events related to displacements along ancient discontinuities in the bedrock. The study of neotectonic features in the White River area may reveal the timing and magnitude of past seismic activity and deformations. Conclusive evidence of features indicative of reactivation of ancient bedrock structures could not be made using the information available in the current study. Field investigations would be required to identify such features since, under appropriate conditions, it may be possible to identify neotectonic features in bedrock and overburden, as discussed below.

7.1 Types of Bedrock Neotectonic Features

Existence of bedrock, neotectonic features can be used to extend the seismic record for a region well into the past. In the White River area, should any pop-up features be present, they may be recognized by their narrow, linear shape which could extend for hundreds of metres (White *et al.,* 1973). Such features would likely only be found in areas of bedrock outcrop or thin overburden cover (<1 to 2 m). It is possible that tree cover, typical of that found in the boreal forest, would assist in making their identification difficult when interpreting air photo or other remotely sensed imagery. Faults resulting from neotectonic activity may be equally challenging to discern from ancient features. Recent faults (i.e., post-glacial faults) may show evidence of displacement, fresh brecciation or an unhealed character suggestive of recent formation.

7.2 Types of Overburden Neotectonic Features

The most common neotectonic feature in glaciated terrain is faulting caused by movement of the bedrock which is reflected in the overlaying surficial sediments. Displaced (faulted) post-glacial beach ridges in the lower Great Lakes have provided evidence of movement and allowed a determination as to the post-glacial timing of the feature's formation (McFall and Allam, 1990). Under the appropriate conditions, soft sediment deformation preserved in glacial sediments can also be an indication of post-depositional movement associated with paleo-seismic events. Doughty *et al.* (2013) suggest that deformation of glaciolacustrine and overlying post-glacial sediments in Lake Timiskaming, ~445 km to the east of White River, are a reflection of neotectonic faulting associated with the Timiskaming graben.

In the White River area neotectonic activity would best be recognized in stratified material such as fine-grained glaciolacustrine and glaciofluvial deposits. Disrupted or faulted bedding is more easily discerned in such materials as opposed to unsorted or coarse-grained deposits such as till and gravel. In the area, deposits most favourable for the preservation of neotectonic features are located in the glaciolacustrine sediments found in the northern third of the area (Figure 3). The sand-rich segments of the glaciofluvial outwash deposits found in bedrock controlled valleys across the White River area could also possibly display such features.

The examination of natural and man-made exposures, such as those found in stream/river sections and excavations would provide the best opportunity to locate any evidence of recent movement. Sedimentological studies of the material would be required to separate recent soft-sediment deformation from that caused by processes active at the time of deposition, such as dewatering, faulting resulting from the melting of buried ice blocks or glaciotectonic movement (Slattery, 2011).

8. Accessibility Constraints

Access to the White River area is via Ontario King's Highway 17 (the Trans Canada Highway) which enters the area along its southern boundary and trends northwest, exiting at the mid-point of the western side (Figure 1). Provincial Highway 631 runs east from White River before turning northward to Hornepayne. Good access to the interior of the area is provided by a network of secondary roads and trails connecting to the two provincial highways. A rail line operated by Canadian Pacific Railways closely follows the route of Highway 17 west of White River, before trending eastward along the southern boundary of the area. A rail line operated by the Algoma Central Railway, that trends northeast from Dubreuilville to Hearst, crosses the extreme southeast corner of the White River area.

The road access shown on Figure 13 is based on the Ministry of Natural Resources (MNR) road segment file obtained from Land Information Ontario. The MNR road segment file contains resource access roads constructed for and used by conventional (i.e., street legal) vehicles. Additional, but not all, forest access roads identified on satellite images of the White River area have been added to the Figure 13.

Secondary roads, primarily developed during forestry operations, may or may not be maintained following the completion of logging in an area. In some cases, culverts or river crossings have been removed or deteriorated thus restricting access. Locally, trails of narrow width and short length have been developed; however, the condition and usability of these trails is highly variable.

All major geological bodies present in the White River area are accessible by means of the existing road network. Roads are developed across large extents of the Black-Pic batholith, the Strickland pluton, the Anahareo pluton, the Danny Lake stock and the foliated tonalite suite of rocks present in the southwest corner of the White River area.

The principal constraint to developing access to most parts of the White River area is the modest to occasionally severe relief which, in places, is represented by steep slopes of varying heights. Significant slopes are most frequently located in areas of bedrock dominated terrain; particularly the area in and surrounding the Township of White River.

Throughout the area few natural constraints to development exist, other than topography and the position of lakes and, in a limited number of instances, large wetlands. As is the case for many of the existing roads in the White River area, new roads can follow bedrock valleys as a means of reducing construction difficulties. The larger valleys are frequently floored by glaciofluvial or, less often, by sand-rich glaciolacustrine deposits that have a relatively level surface and can locally serve as a ready source of construction material.

Road and infrastructure development (e.g., power lines) can be achieved using standard construction techniques commonly used in the Canadian Shield.

The development of access corridors will need to deal with several issues and obstacles, the most notable of which are:

- Rugged, bedrock surfaces in highland areas;
- Numerous river and stream crossings; and
- The need to circumnavigate lakes
- Large wetland areas.

9. Summary

The terrain and remote sensing study conducted as part of the Phase 1 Desktop Geoscientific Preliminary Assessment for the Township of White River and surrounding area demonstrated that the region is dominated by land where bedrock is at or near surface. Over the majority of the area, the Precambrian bedrock is thinly covered by a discontinuous veneer of glacial sediments, the most common of which is ground moraine (till); however, in the southwestern portion of the area the till forms a patchy, thin blanket over highland areas. Till thickness is commonly between 1 and 3 m; however, depths of >5 m are not uncommon.

Coarse-grained glaciofluvial deposits, occurring as large esker-outwash complexes, are present in some of the larger south and southwest trending valleys across the White River area. Extensive glaciolacustrine deposits occur in the northwest and northeast corners of area with smaller deposits, present throughout the remainder of the area. The depth of material present in areas mapped as glaciofluvial and glaciolacustrine deposits are commonly sufficient to mask the bedrock topography.

Elevation differences in areas mapped as bedrock terrain are typically on the order of 40 to 80 m; however, in the area immediately north and east of the Township of White River relief of 80 to 100 m is common. In areas of either glaciofluvial or glaciolacustrine deposits relief is usually on the order of 20 to 40 m.

Relief maps derived from the DEM of the White River area are useful for interpreting the distribution of overburden thickness by dividing the area into zones of negative or positive relief. The zones of strong positive relief are more likely to have thinner overburden that allows the bedrock to be characterized more easily. Conversely, zones of strong negative relief, notably those with a linear trend, can be indicative of bedrock structures and often contain thicker accumulations of glacial deposits.

The White River area straddles the Atlantic-Arctic watershed boundary, with approximately equal amounts of land on either side of the divide. The area's drainage network is contained within four, tertiary level watersheds, two with flow directed southward to Lake Superior with the others having flow directed northward to James/Hudson Bay. Drainage of the area is generally good with a high density of lakes and waterways, although large deposits of organic terrain (wetlands) occur in the north-central part of the area. The majority of recharge to the waterways is through direct runoff or a shallow, fracture-controlled, groundwater system in bedrock.

Shallow groundwater flow systems exist across the area, with discharge to creeks, rivers, lakes and wetlands or surficial deposits occupying lowlands and valleys. Groundwater flow within drift deposits and in shallow bedrock aquifers in the White River area is expected to mimic the pattern of surface flow, with groundwater divides coinciding with drainage divides. Information on shallow aquifers in the region is cursory and completely lacking for deep bedrock flow systems.

The area is tectonically stable with no known neotectonic activity, although isostatic recovery associated with the last glaciation continues in the region, albeit at a very low rate. Conclusive identification of features indicative of paleo-seismic events and reactivation of ancient bedrock structures due to cycles of glacial loading and unloading overprinted onto the tectonic stress field cannot be identified using currently available sources of information. Field investigations would be required to identify any such features

The main road network in the White River area provides relatively good access to the central and southwestern parts of the area. Augmenting this network throughout the remainder of the area is a well-developed, interconnected series of roads and trails constructed during timber harvesting.
The construction of new access routes, or other infrastructure, could be developed to any part of the White River area using construction techniques commonly employed in the Canadian Shield. Given the knobby terrain in the bedrock dominated portions of the area, construction may involve considerable blasting and movement of rock.

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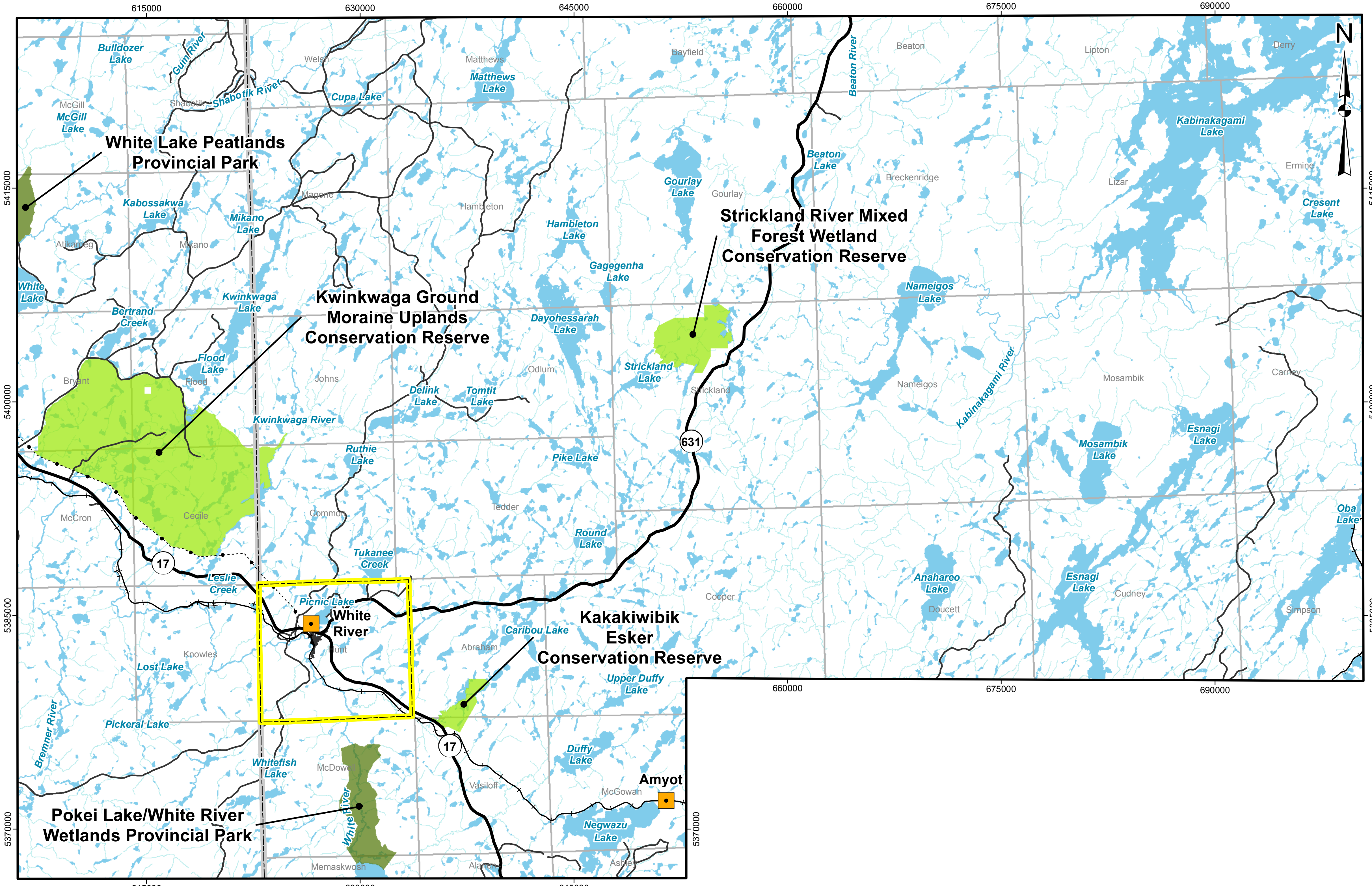
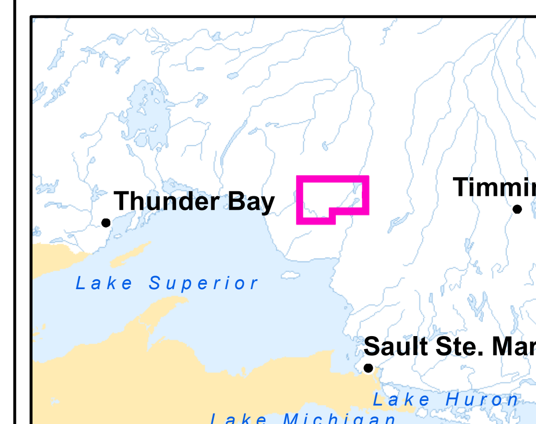




Legend

- Settlement
- White River Municipal Boundary
- Township Boundary
- District Boundary
- Main Road
- Local Road
- Railway
- Abandoned Railway Right-of-way
- Hydro Line
- Waterbody
- Watercourse

Protected Areas

- Provincial Park
- Conservation Reserve

Data Sources:
Base Data: MNR LIO, obtained 2009-2013
- Settlement: LIO Cities and Towns
- Road: LIO Road Segment
- Provincial Parks: LIO Provincial Parks
- Conservation Reserves: LIO Conservation Reserves
- Waterbody: LIO Waterbody
- Watercourse: LIO Watercourse
- Utility Lines: LIO Utlity Line
- Municipalities: LIO Upper, Single and Lower Tier

10 km

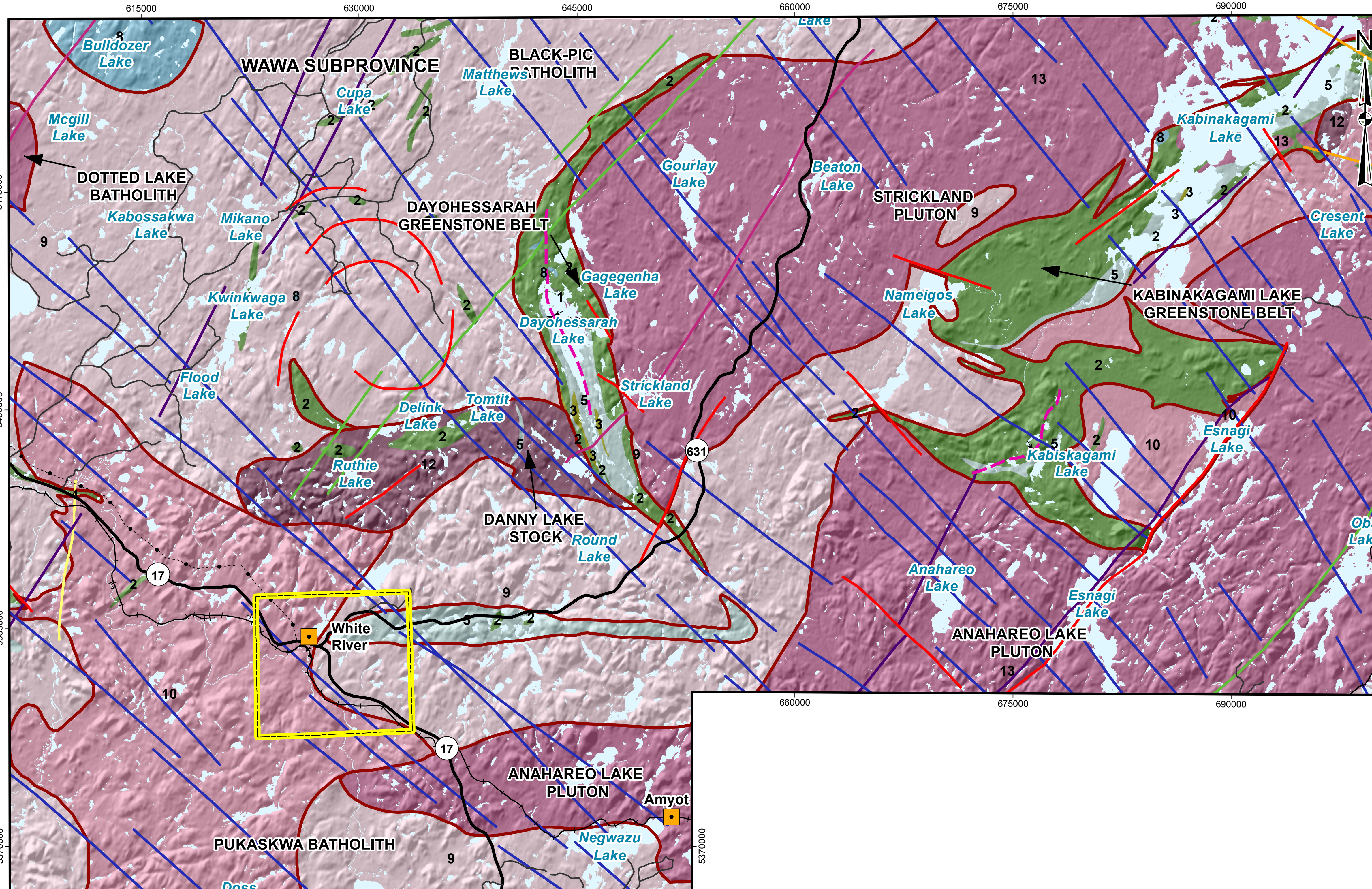
AECOM

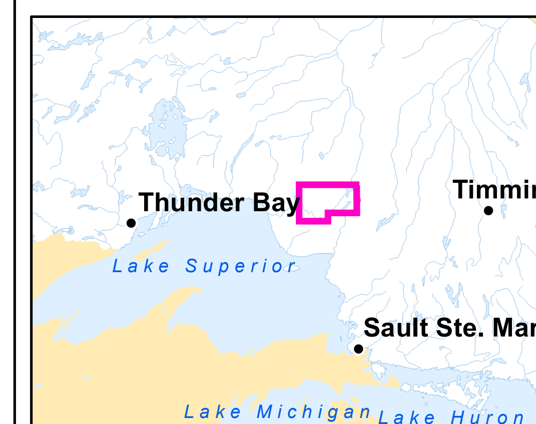
PROJECT
Phase 1 Geoscientific Desktop Premliminary Assessment
Terrain and Remote Sensing Study, White River

TITLE
Township of White River and Surrounding Area

DESIGN	KR	23 AUG 2013	Figure 1	REVISION 1
GIS	GF	29 AUG 2013		UTM ZONE 16
CHECK	xx			NAD 1983
REVIEW	xx			1:300,000

Path: P:\60297733\900-CAD-GIS\920 GIS-Graphics\Remote Sensing Report\ReportMXDs\Revision 2 - White River\Jan 16 2013\60297733_Fig 1 Township of White River and Surrounding Area.mxd





Legend

- Settlement
- White River Municipal Boundary
- Main Road
- Local Road
- Railway
- Abandoned Railway Right-of-way
- Hydro Line
- Waterbody
- Faults
- Major Fold (Syncline Approximate)
- Bedrock Geology Contact

Mapped Dykes

- Abitibi mafic dyke
- Biscotasing mafic dyke
- Marathon, Kapuskasing or Biscotasing mafic dyke
- Matachewan mafic dyke
- Sudbury mafic dyke
- unknown

Bedrock Geology

- 13: Granite-granodiorite
- 12: Diorite-monzonite- granodiorite
- 10: Foliated tonalite suite
- 9: Gneissic tonalite suite
- 8: Gabbro
- 5: Metasedimentary rocks
- 4: Felsic volcanic rocks
- 3: Felsic and intermediate metavolcanic rocks
- 2: Mafic metavolcanic Rocks

Data Sources:
Base Data: MNR LIO, obtained 2009-2013
Bedrock Geology: OGS M2666, 2001 (1:250,000)
Faults: OGS MRD 126-REV1, 2011 (1:250,000)
Dykes: OGS MRD 126-REV1, 2011 (1:250,000)
Intrusions: Generalized from OGS M2666, 2001 (1:250,000)
Underlay: Hillshade DEM, MNR Elevation and Slope

10 km

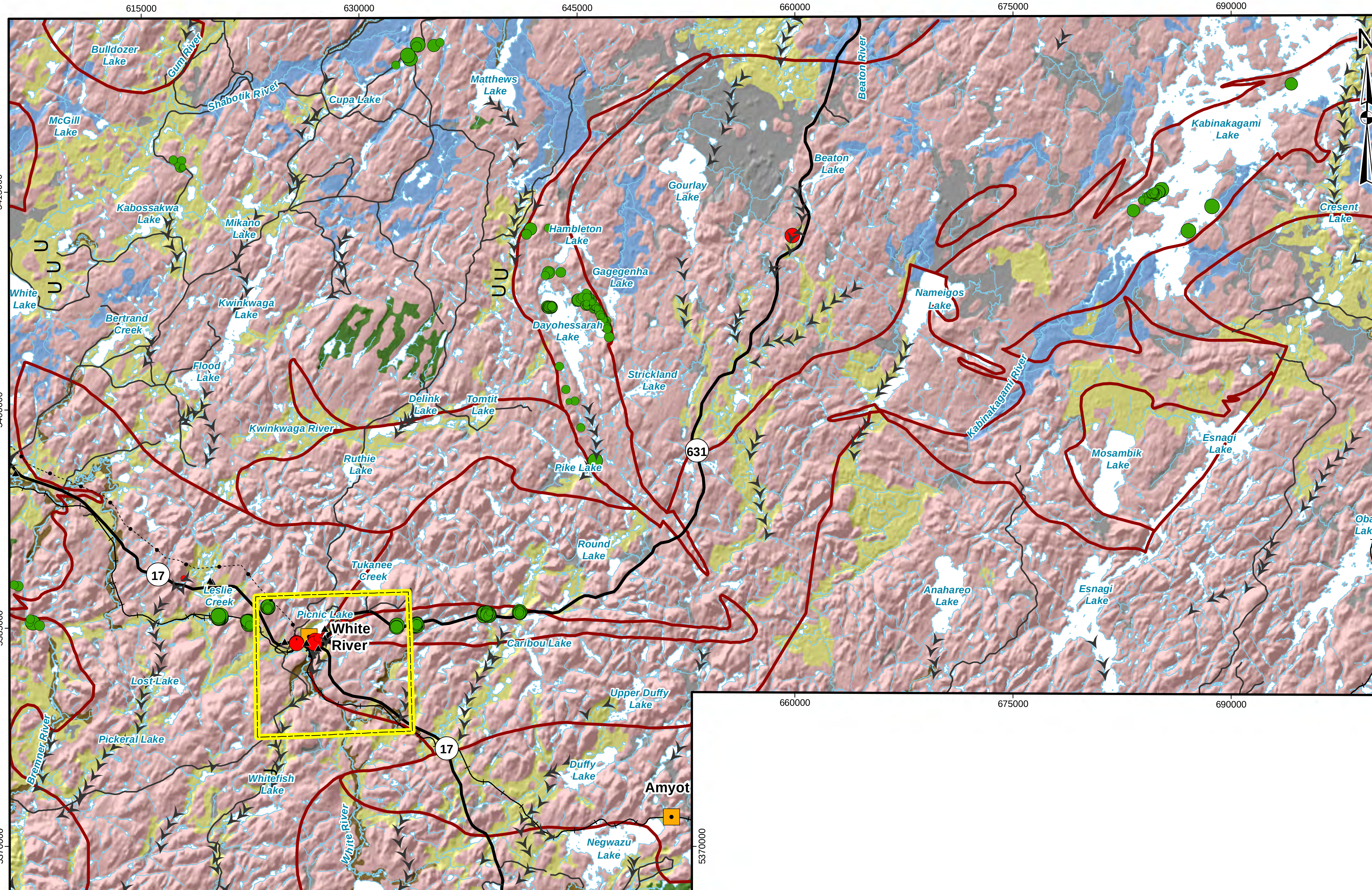
AECOM

PROJECT
Phase 1 Geoscientific Desktop Premliminary Assessment
Terrain and Remote Sensing Study, White River

TITLE
Bedrock Geology of the White River Area

DESIGN	KR	23 APR 2013	**Figure 2**	REVISION 1
GIS	GF	17 OCT 2013		UTM ZONE 16
CHECK	xx			NAD 1983
REVIEW	xx			1:300,000

Path: P:\60297733\900-CAD-GIS\920 GIS-Graphics\Remote Sensing Report\ReportMXDs\Revision 2 - White River\Jan 16 2013\60297733_Fig 2 Bedrock Geology of the White River Area.mxd



Legend

- Settlement
- White River Municipal Boundary
- Main Road
- Local Road
- Railway
- Abandoned Railway Right-of-way
- Hydro Line
- Waterbody
- Watercourse
- Bedrock Geology Contact
- Sand Dunes
- Eskers

Water Well (MOE)

Depth to Bedrock (m)

- Depth Unknown
- <1
- 1.1 - 3.0
- 3.1 - 5.0
- 5.1 - 10.0
- >10.1

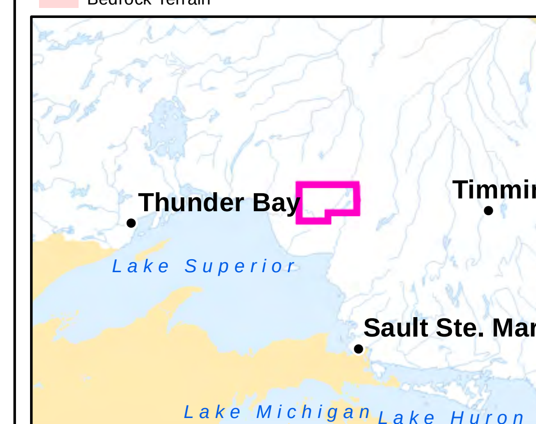
Drill Hole (MNDM)

Depth to Bedrock (m)

- <1
- 1.1 - 3.0
- 3.1 - 5.0
- 5.1 - 10.0
- >10.1

Surficial Geology

- Morainal Terrain
- Glaciofluvial Terrain
- Glaciolacustrine Terrain
- Alluvial Terrain
- Organic Terrain
- Bedrock Terrain



Data Sources:
Base data: MNR LIO, obtained 2009-2013
Overburden: OGS MRD-160 NOEGTS 2006
Water Well: MOE Water Well Information System
Drill Hole: MNDM Drill Hole Database
Intrusions: Generalized from OGS M2666, 2001 (1:250,000)
Underlay: Hillshade DEM, MNR Elevation and Slope

10 km

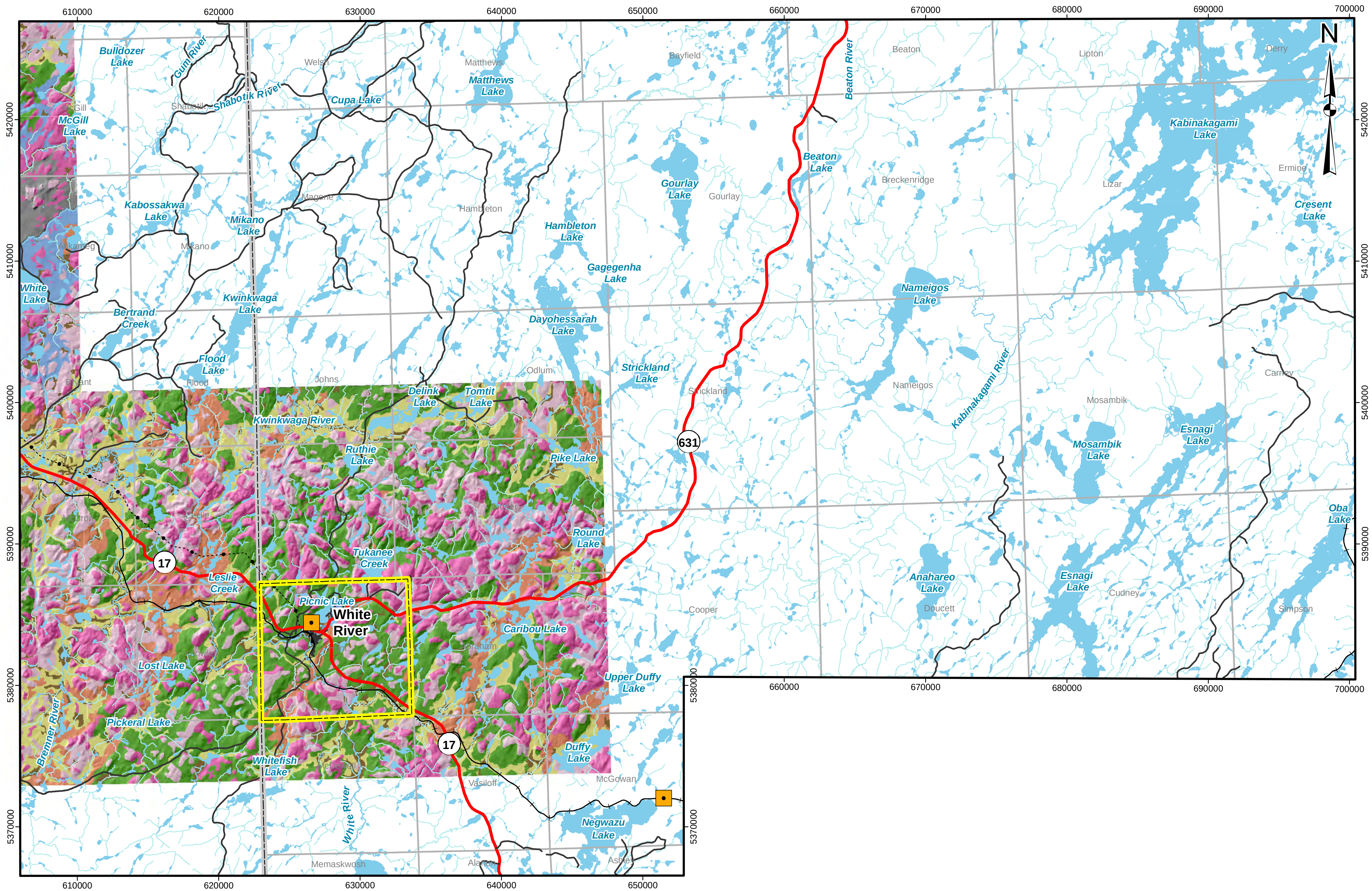
AECOM

PROJECT
Phase 1 Geoscientific Desktop Premliminary Assessment
Terrain and Remote Sensing Study, White River

TITLE
Surficial Geology of the White River Area

DESIGN	KR	23 APR 2013	**Figure 3**	REVISION 1
GIS	GF	29 AUG 2013		UTM ZONE 16
CHECK	xx			NAD 1983
REVIEW	xx			1:300,000

Path: P:\60297733\900-CAD-GIS\920 GIS-Graphics\Remote Sensing Report\MXDs\Revision 2 - White River\Jan 16 2013\60297733_Fig3_SurficialGeology_WhiteRiver.mxd

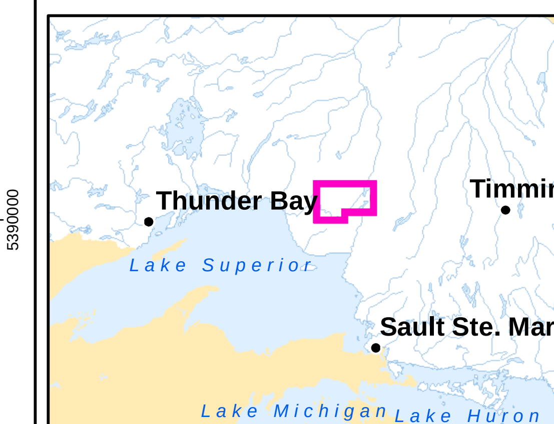


Legend

- Township Boundary
- District Boundary
- White River Municipal Boundary
- Settlement
- Main Road
- Local Road
- Railway
- Hydro Line
- Waterbody
- Watercourse

Surficial Geology

- Swamp and Alluvium Deposits
- Glaciolacustrine Deposits
- Glaciofluvial Outwash Deposits
- Glaciofluvial Ice-Contact Deposits
- Till
- Bedrock Drift Complex
- Precambrian Bedrock



Data Sources:
Base Data: MNR LIO, obtained 2009-2013
Geology: OGS M2681; M2682; M2683

10 km

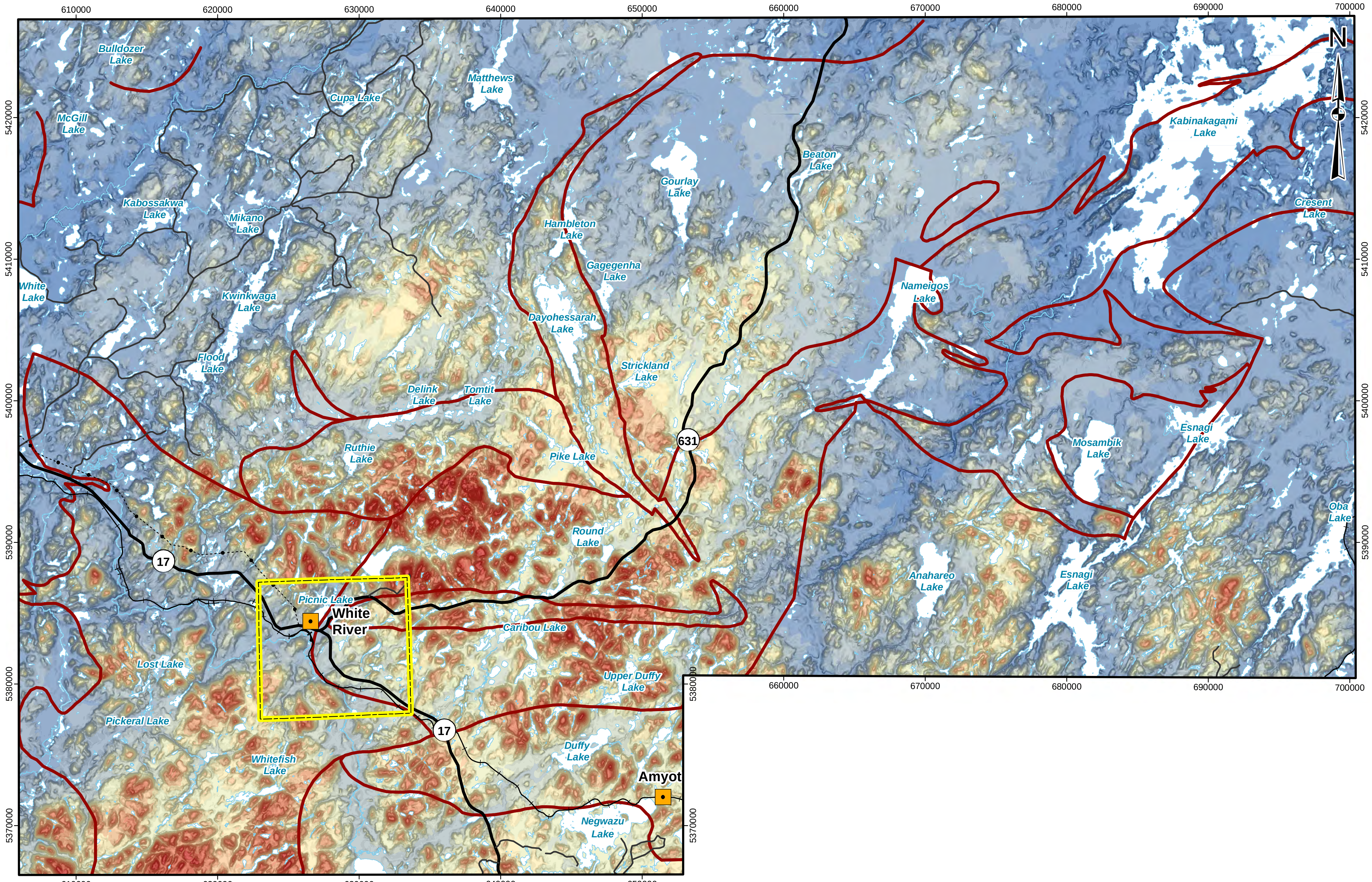
AECOM

PROJECT
Phase 1 Geoscientific Desktop Premliminary Assessment
Terrain and Remote Sensing Study, White River

TITLE
Area of 1:50,000 Scale Surficial Mapping

DESIGN	GF	21 AUG 2013	Figure 4	REVISION 1
GIS	GF	21 AUG 2013		UTM ZONE 16
CHECK	xx			NAD 1983
REVIEW	xx			1:300,000

Path: P:\60297733\900-CAD-GIS\920 GIS-Graphics\Remote Sensing Report\ReportMXDs\Revision 2 - White River\Jan 16 2013\60297733_Fig4_Area of 1-50000 Scale Surficial Mapping.mxd

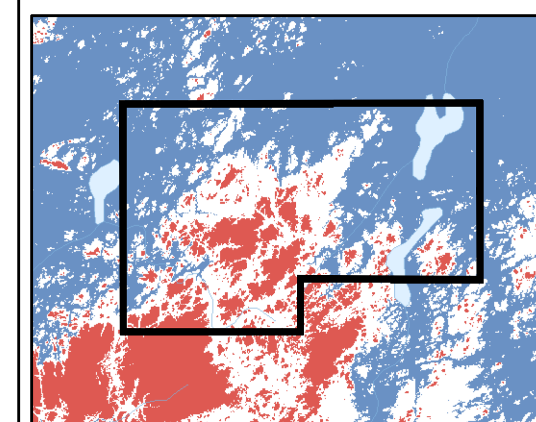


Legend

Settlement
White River Municipal Boundary
Main Road
Local Road
Railway
Abandoned Railway Right-of-way
Hydro Line
Waterbody
Bedrock Geology Contact

Elevation (m)
311 - 340
341 - 361
362 - 381
382 - 401
402 - 418
419 - 434
435 - 451
452 - 471
472 - 490
491 - 511
512 - 536
537 - 622

Slope (°)
0 - 1
1.1 - 2
2.1 - 3
3.1 - 4
4.1 - 5
5.1 - 6
6.1 - 83.1



Elevation (m)
311 - 381 | 382 - 438 | 439 - 622

Data Sources:
Base data: MNR LIO, obtained 2009-2013
Elevation and Slope: Ontario Ministry of Natural Resources
Intrusions: Generalized from OGS M2666, 2001 (1:250,000)

10 km

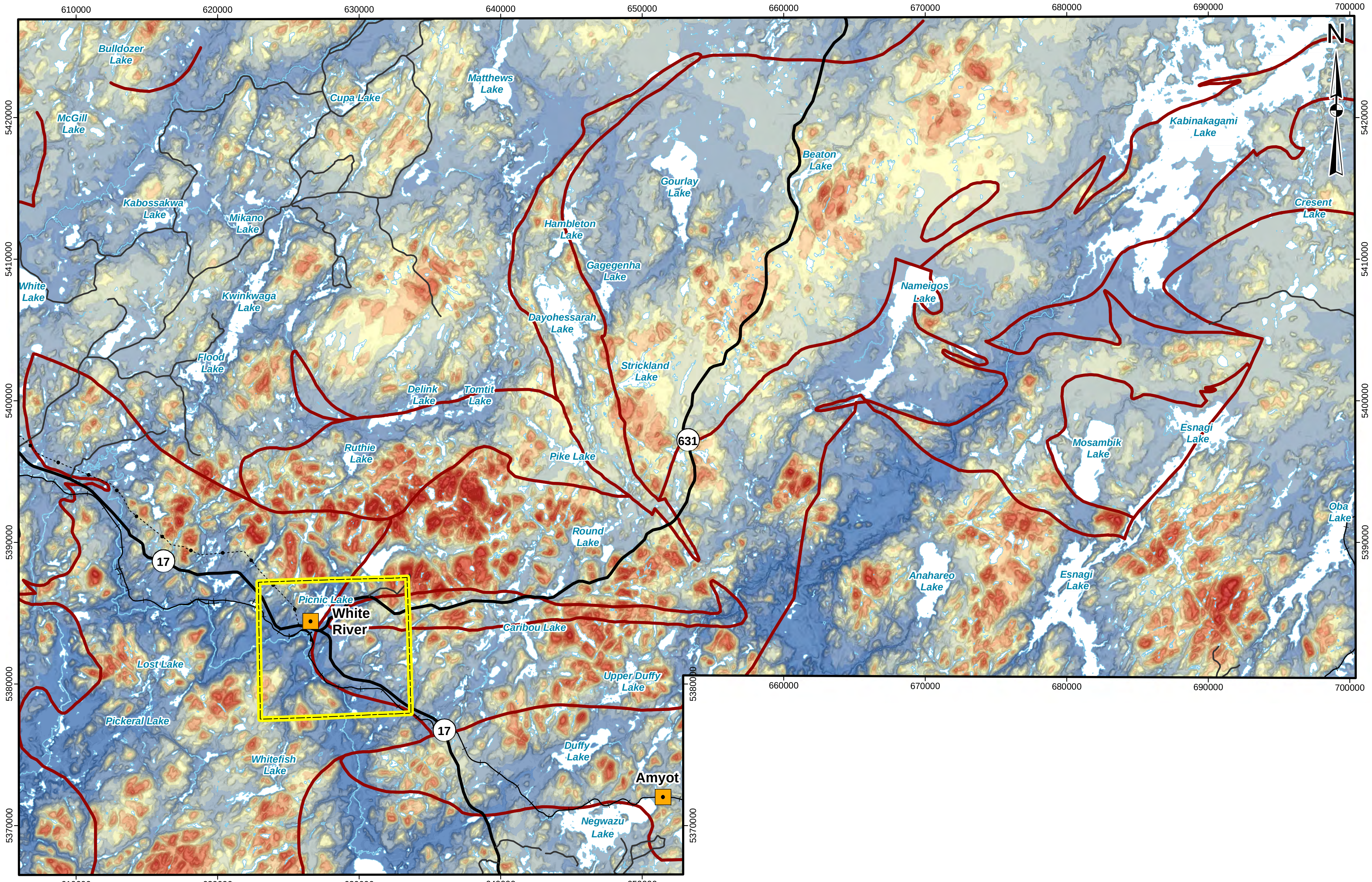
AECOM

PROJECT
Phase 1 Geoscientific Desktop Premliminary Assessment
Terrain and Remote Sensing Study, White River

TITLE
Elevation and Major Topographic Features

DESIGN	KR	23 APR 2013	Figure 5	REVISION 1
GIS	GF	29 AUG 2013		UTM ZONE 16
CHECK	xx			NAD 1983
REVIEW	xx			1:300,000

Path: P:\60297733\900-CAD-GIS\920 GIS-Graphics\Remote Sensing Report\ReportMXDs\Revision 2 - White River\Jan 16 2013\60297733_Fig5_Elevation_WhiteRiver.mxd



Legend

- Settlement
- White River Municipal Boundary
- Main Road
- Local Road
- Railway
- Abandoned Railway Right-of-way
- Hydro Line
- Waterbody
- Bedrock Geology Contact

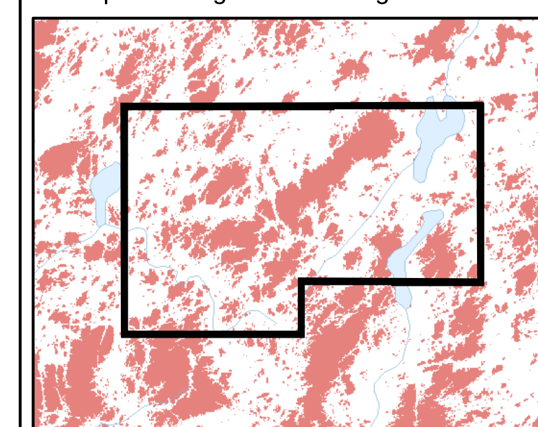
Slope (°)

- 0 - 1
- 1.1 - 2
- 2.1 - 3
- 3.1 - 4
- 4.1 - 5
- 5.1 - 6
- 6.1 - 83.1

Relief (m)

- -72 - -40
- -39 - -22
- -21 - -9
- -8 - 5
- 6 - 18
- 19 - 31
- 32 - 46
- 47 - 61
- 62 - 80
- 81 - 106
- 107 - 191

Map Showing Blocks of High Ground



Relief (m)

-72 - 8 9 - 191

Data Sources:
Base data: MNR LIO, obtained 2009-2013
Elevation and Slope: Ontario Ministry of Natural Resources
Intrusions: Generalized from OGS M2666, 2001 (1:250,000)

10 km

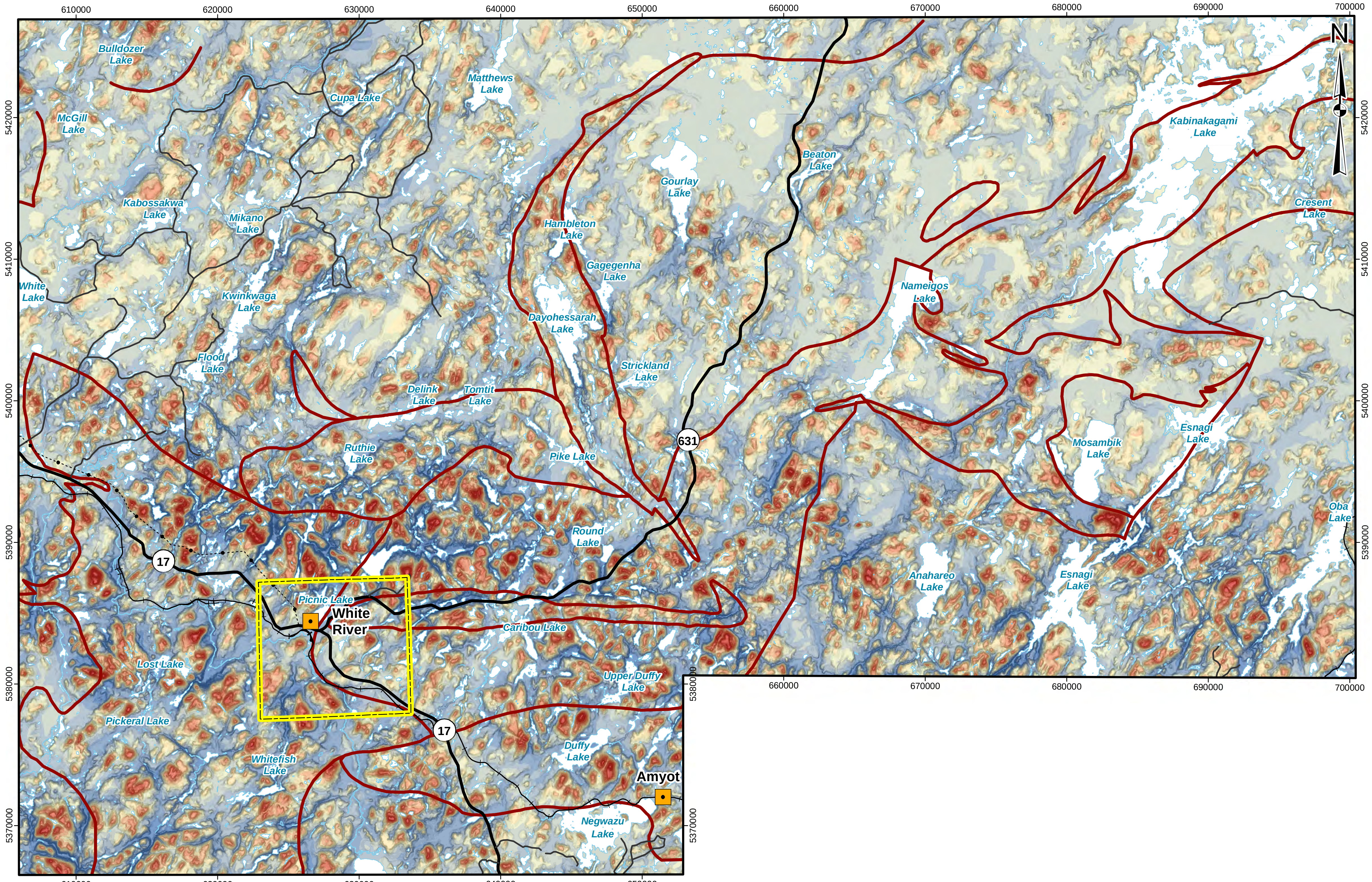
AECOM

PROJECT
Phase 1 Geoscientific Desktop Premliminary Assessment
Terrain and Remote Sensing Study, White River

TITLE
Departure from Average Elevation within a 20 km Radius

DESIGN	KR	23 APR 2013	**Figure 6**	REVISION 1
GIS	KR	29 AUG 2013		UTM ZONE 16
CHECK	xx			NAD 1983
REVIEW	xx			1:300,000

Path: P:\60297733\900-CAD-GIS\920 GIS-Graphics\Remote Sensing Report\ReportMXDs\Revision 2 - White River\Jan 16 2013\60297733_Fig6_20kmRelief_WhiteRiver.mxd



Legend

- Settlement
- White River Municipal Boundary
- Main Road
- Local Road
- Railway
- Abandoned Railway Right-of-way
- Hydro Line
- Waterbody
- Bedrock Geology Contact

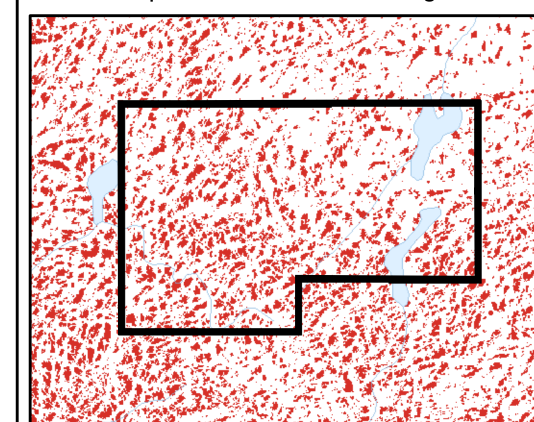
Slope (°)

- 0 - 1
- 1.1 - 2
- 2.1 - 3
- 3.1 - 4
- 4.1 - 5
- 5.1 - 6
- 6.1 - 83.1

Relief (m)

- -71 - -28
- -27 - -15
- -14 - -6
- -5 - 2
- 3 - 10
- 11 - 20
- 21 - 33
- 34 - 47
- 48 - 68
- 69 - 127

Map of local knobs and ridges



Relief (m)

- -71 - 8
- 9 - 127

Data Sources:
Base data: MNR LIO, obtained 2009-2013
Elevation and Slope: Ontario Ministry of Natural Resources
Intrusions: Generalized from OGS M2666, 2001 (1:250,000)

10 km

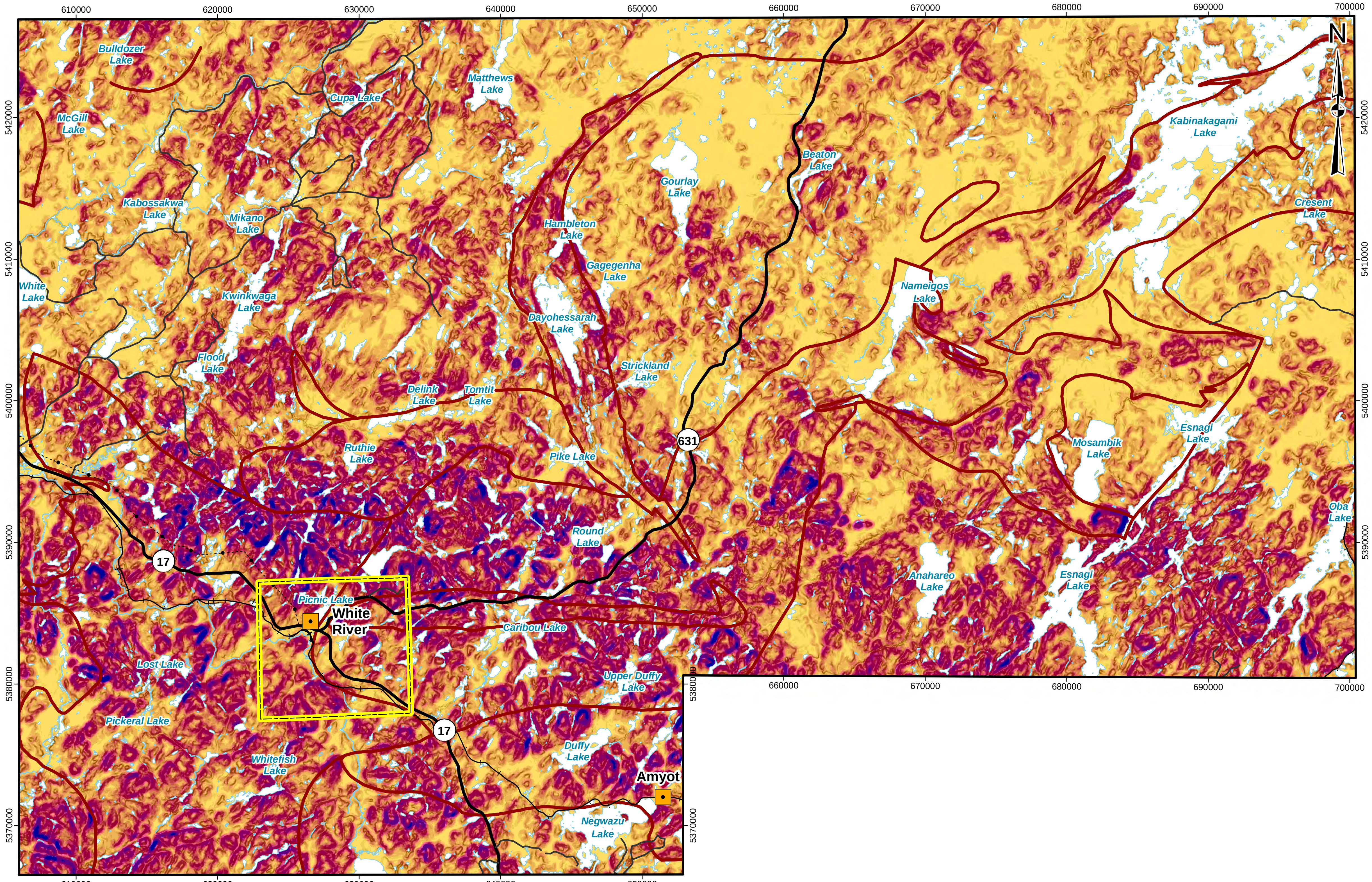
AECOM

PROJECT
Phase 1 Geoscientific Desktop Premliminary Assessment
Terrain and Remote Sensing Study, White River

TITLE
Departure from Average Elevation within a 2 km Radius

DESIGN	KR	23 APR 2013	Figure 7	REVISION 1
GIS	GF	29 AUG 2013		UTM ZONE 16
CHECK	xx			NAD 1983
REVIEW	xx			1:300,000

Path: P:\60297733\900-CAD-GIS\920 GIS-Graphics\Remote Sensing Report\ReportMXDs\Revision 2 - White River\Jan 16 2013\60297733_Fig7_2kmRelief_WhiteRiver.mxd



Legend

- Settlement
- White River Municipal Boundary
- Main Road
- Local Road
- Railway
- Abandoned Railway Right-of-way
- Hydro Line
- Waterbody
- Bedrock Geology Contact

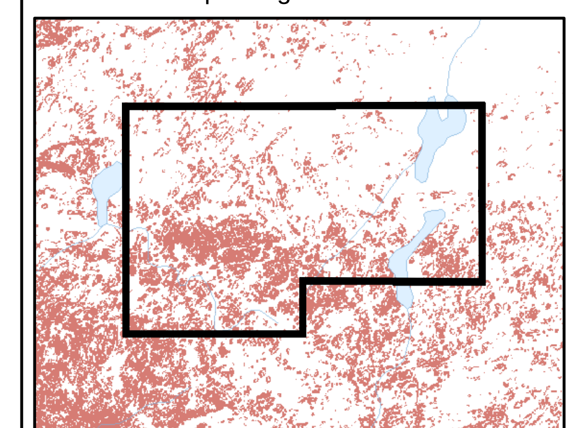
Relief (m)

- 0 - 9
- 10 - 18
- 19 - 27
- 28 - 37
- 38 - 48
- 49 - 61
- 62 - 76
- 77 - 97
- 98 - 162

Slope (°)

- 0 - 1
- 1.1 - 2
- 2.1 - 3
- 3.1 - 4
- 4.1 - 5
- 5.1 - 6
- 6.1 - 83.1

Map of high relief area



Relief (m)

0 - 31 32 - 162

Data Sources:
Base data: MNR LIO, obtained 2009-2013
Elevation and Slope: Ontario Ministry of Natural Resources
Intrusions: Generalized from OGS M2666, 2001 (1:250,000)

10 km

AECOM

PROJECT

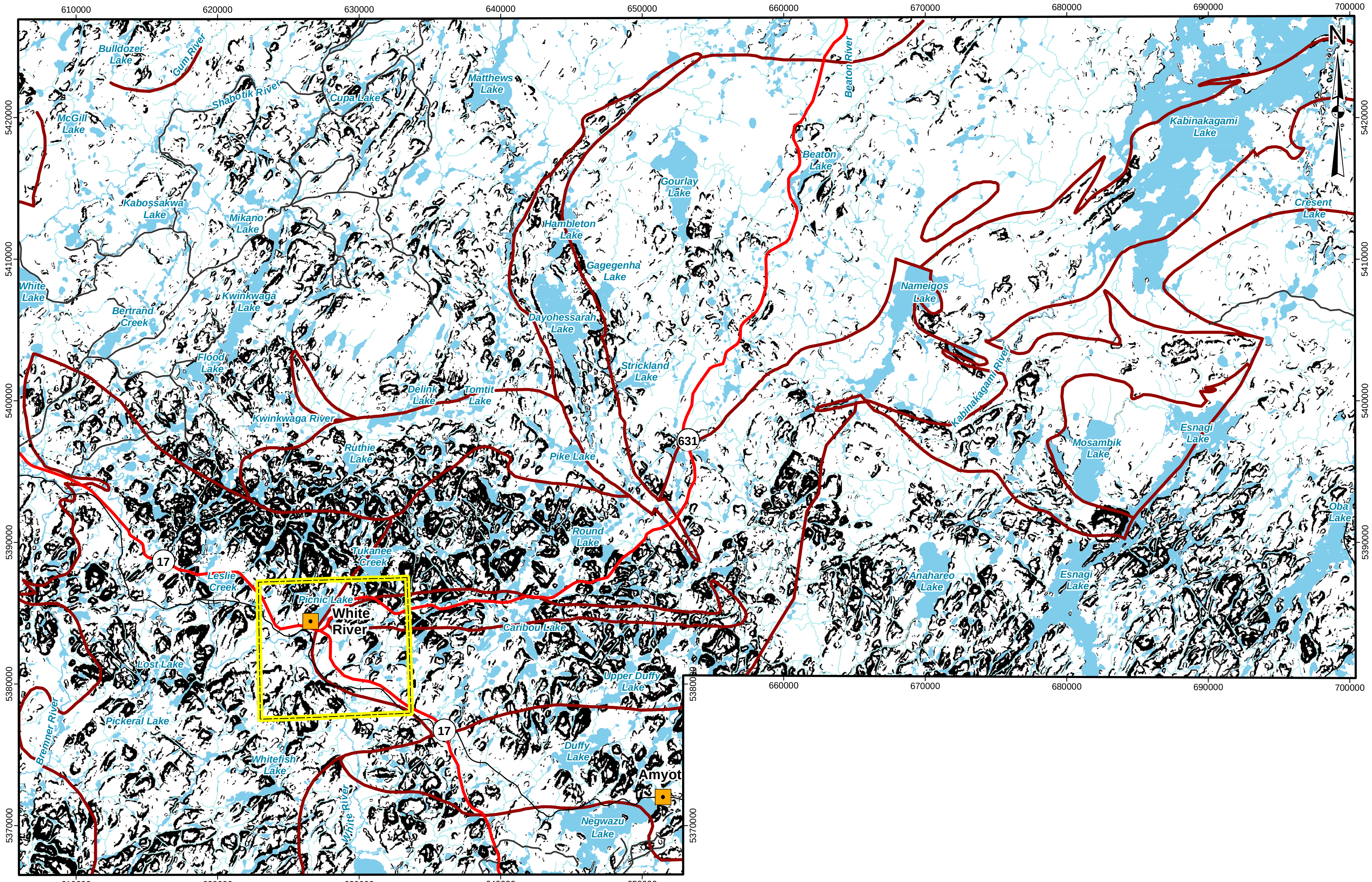
Phase 1 Geoscientific Desktop Premliminary Assessment
Terrain and Remote Sensing Study, White River

TITLE

Departure from Average Elevation within a 250 m Radius

DESIGN	KR	23 APR 2013	Figure 8	REVISION 1
GIS	GF	29 AUG 2013		UTM ZONE 16
CHECK	xx			NAD 1983
REVIEW	xx			1:300,000

Path: P:\60297733\900-CAD-GIS\920 GIS-Graphics\Remote Sensing Report\ReportMXDs\Revision 2 - White River\Jan 16 2013\60297733_Fig8_250kmRelief_WhiteRiver.mxd



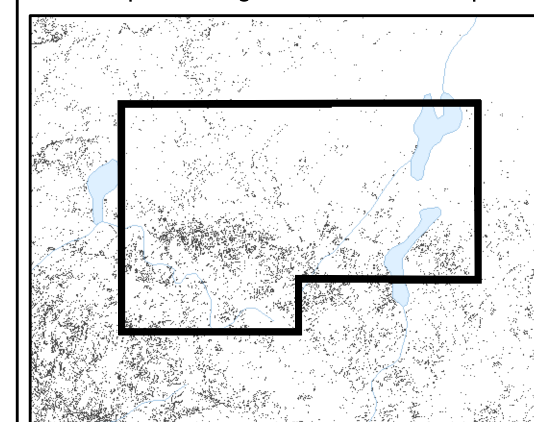
Legend

- Settlement
- White River Municipal Boundary
- Main Road
- Local Road
- Railway
- Abandoned Railway Right-of-way
- Hydro Line
- Waterbody
- Watercourse
- Bedrock Geology Contact

Slope (°)

- 0 - 6
- 6.01 - 83.1

Map Showing Areas 10° or steeper



Slope (°)

0 - 10 10.01 - 83.1

Data Sources:
Base data: MNR LIO, obtained 2009-2013
Elevation and Slope: Ontario Ministry of Natural Resources
Intrusions: Generalized from OGS M2666, 2001 (1:250,000)

10 km

AECOM

PROJECT

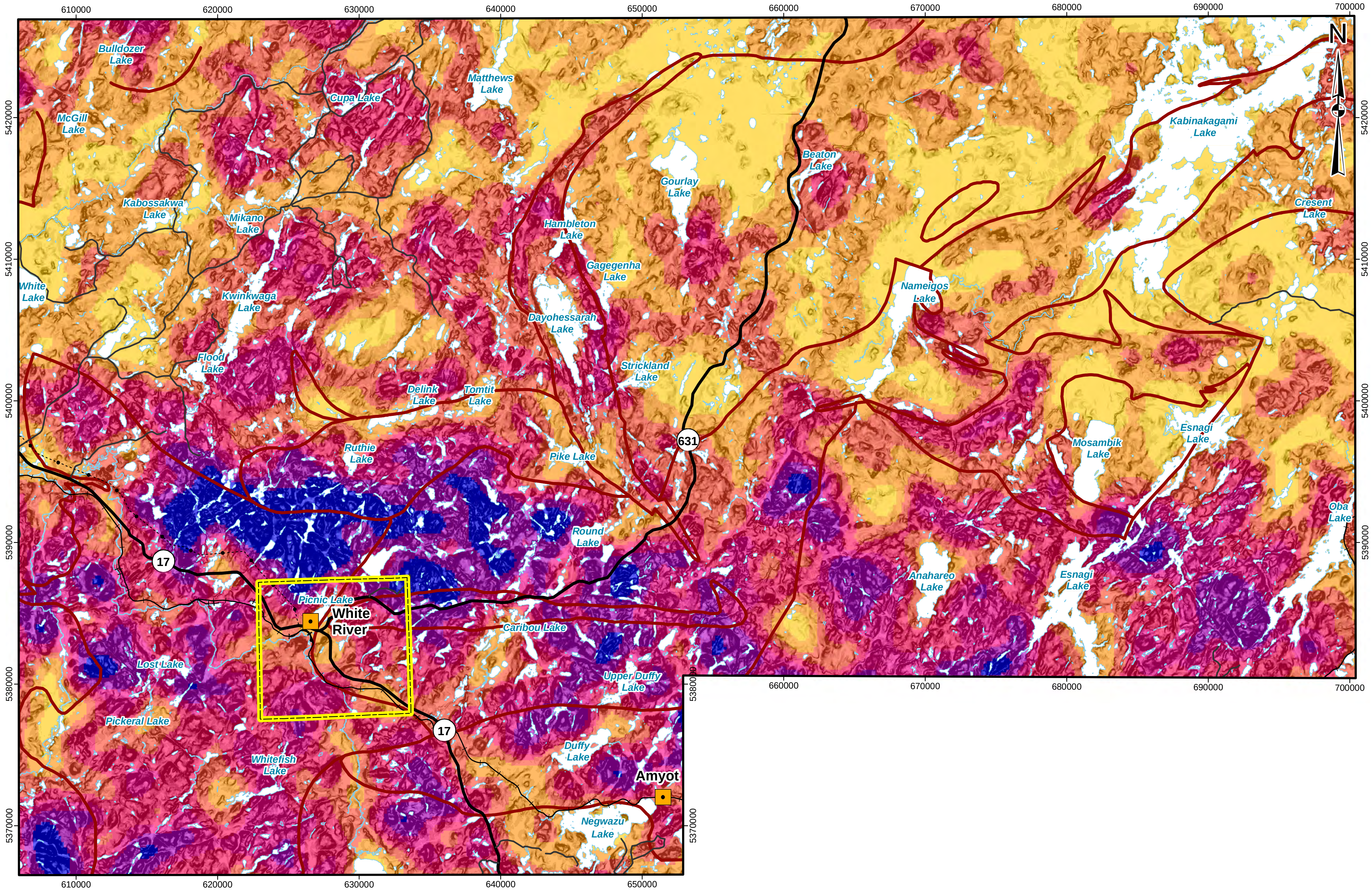
Phase 1 Geoscientific Desktop Premliminary Assessment
Terrain and Remote Sensing Study, White River

TITLE

Areas of 6° or Steeper
Slope in the White River Area

DESIGN	KR	23 Apr 2013	Figure 9	REVISION 1
GIS	KR	14 Jun 2013		UTM ZONE 16
CHECK	xx			NAD 1983
REVIEW	xx			1:300,000

Path: P:\60297733\900-CAD-GIS\920 GIS-Graphics\Remote Sensing Report\ReportMXDs\Revision 2 - White River\Jan 16 2013\60297733_Fig9_SlopeGrtr6_WhiteRiver.mxd



Legend

- Settlement
- White River Municipal Boundary
- Main Road
- Local Road
- Railway
- Abandoned Railway Right-of-way
- Hydro Line
- Waterbody
- Bedrock Geology Contact

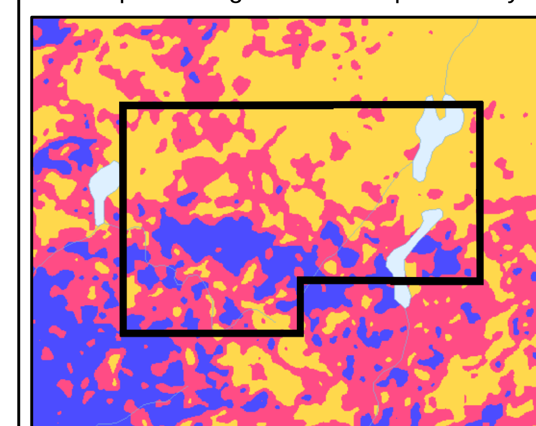
Slope Density
points/km

- 15 - 153
- 154 - 257
- 258 - 361
- 362 - 473
- 474 - 594
- 595 - 749
- 750 - 1,116

Slope (°)

- 0 - 1
- 1.1 - 2
- 2.1 - 3
- 3.1 - 4
- 4.1 - 5
- 5.1 - 6
- 6.1 - 83.1

Map Showing Areas of Slope Density



Slope Density (points/km)

15 - 274 | 275 - 512 | 513 - 1,116

Data Sources:
Base data: MNR LIO, obtained 2009-2013
Elevation and Slope: Ontario Ministry of Natural Resources
Intrusions: Generalized from OGS M2666, 2001 (1:250,000)

10 km

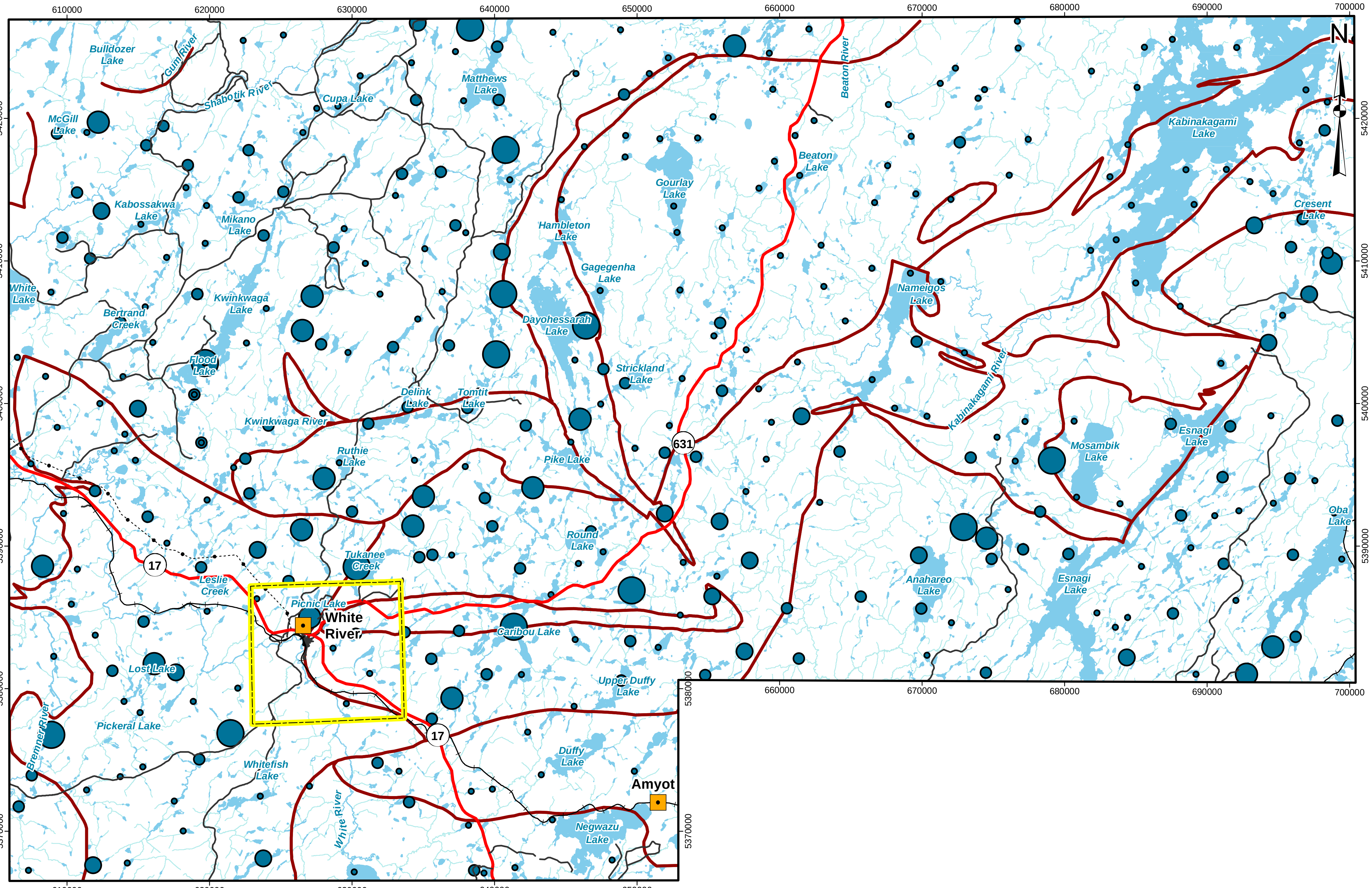
AECOM

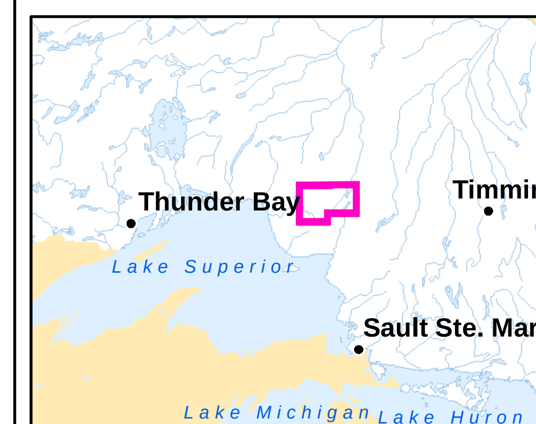
PROJECT
Phase 1 Geoscientific Desktop Premliminary Assessment
Terrain and Remote Sensing Study, White River

TITLE
Density of steep (>6°) slopes within a 2 km radius

DESIGN	KR	23 Apr 2013	Figure 10	REVISION 1
GIS	KR	14 Jun 2013		UTM ZONE 16
CHECK	xx			NAD 1983
REVIEW	xx			1:300,000

Path: P:\60297733\900-CAD-GIS\920 GIS-Graphics\Remote Sensing Report\ReportMXDs\Revision 2 - White River\Jan 16 2013\60297733_Fig10_SlopeDensity_WhiteRiver.mxd





Legend

- Settlement
- White River Municipal Boundary
- Main Road
- Local Road
- Railway
- Hydro Line
- Waterbody
- Watercourse
- Bedrock Geology Contact

Lake Depth (m)

- <5.0
- 5.1 - 10.0
- 10.1 - 15.0
- 15.1 - 20.0
- >20.1

Data Sources:
Base Data: MNR LIO, obtained 2009-2013
Lake Depth: GSC, Open File 2362
Intrusions: Generalized from OGS M2666, 2001 (1:250,000)

10 km

AECOM

PROJECT

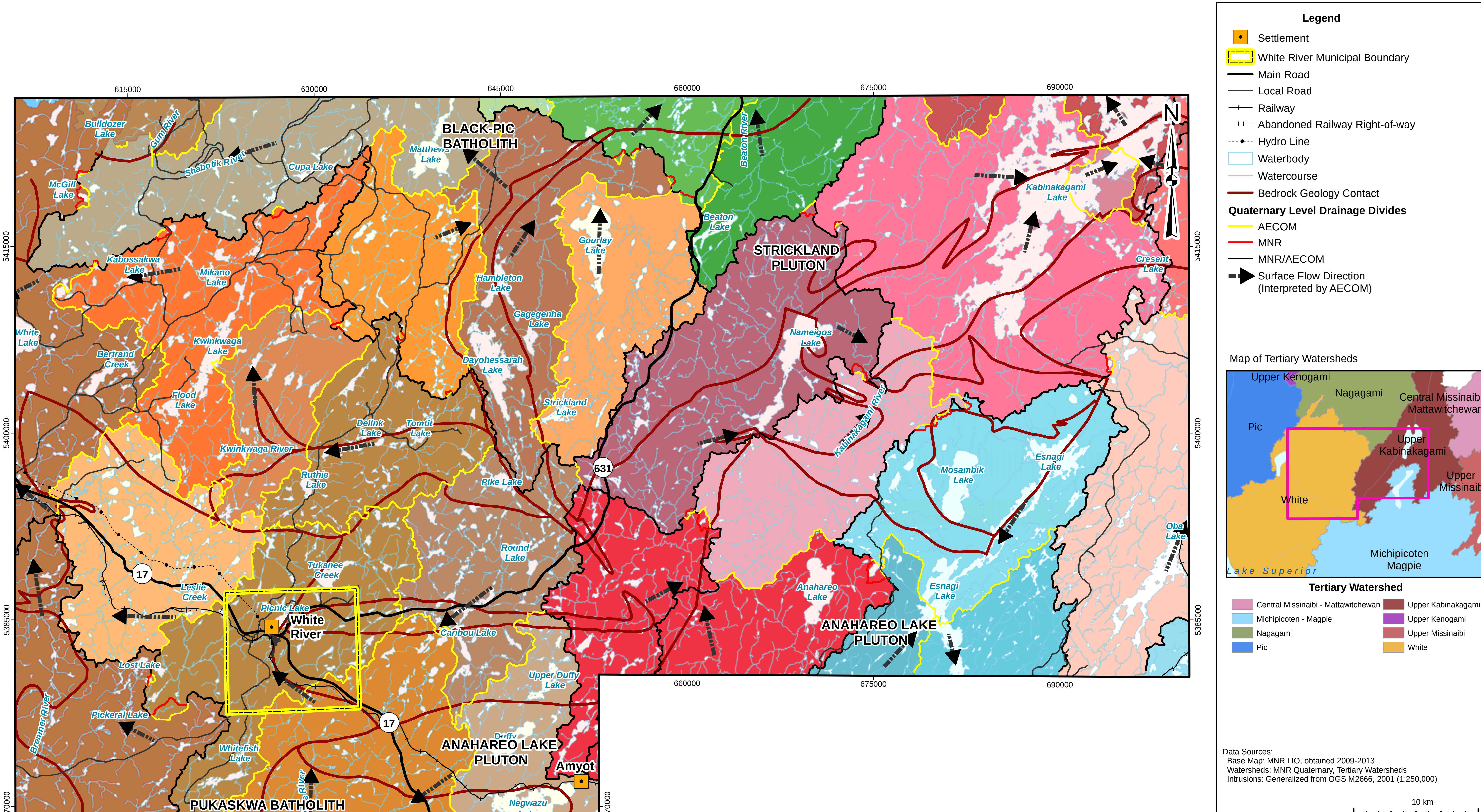
Phase 1 Geoscientific Desktop Premliminary Assessment
Terrain and Remote Sensing Study, White River

TITLE

Surface Drainage Features in the White River Area

DESIGN	KR	23 Apr 2013	Figure 11	REVISION 1
GIS	KR	14 Jun 2013		UTM ZONE 16
CHECK	xx			NAD 1983
REVIEW	xx			1:300,000

Path: P:\60297733\900-CAD-GIS\920 GIS-Graphics\Remote Sensing Report\ReportMXDs\Revision 2 - White River\Jan 16 2013\60297733_Fig11_Surface Drainage Features in the_WhiteRiver.mxd



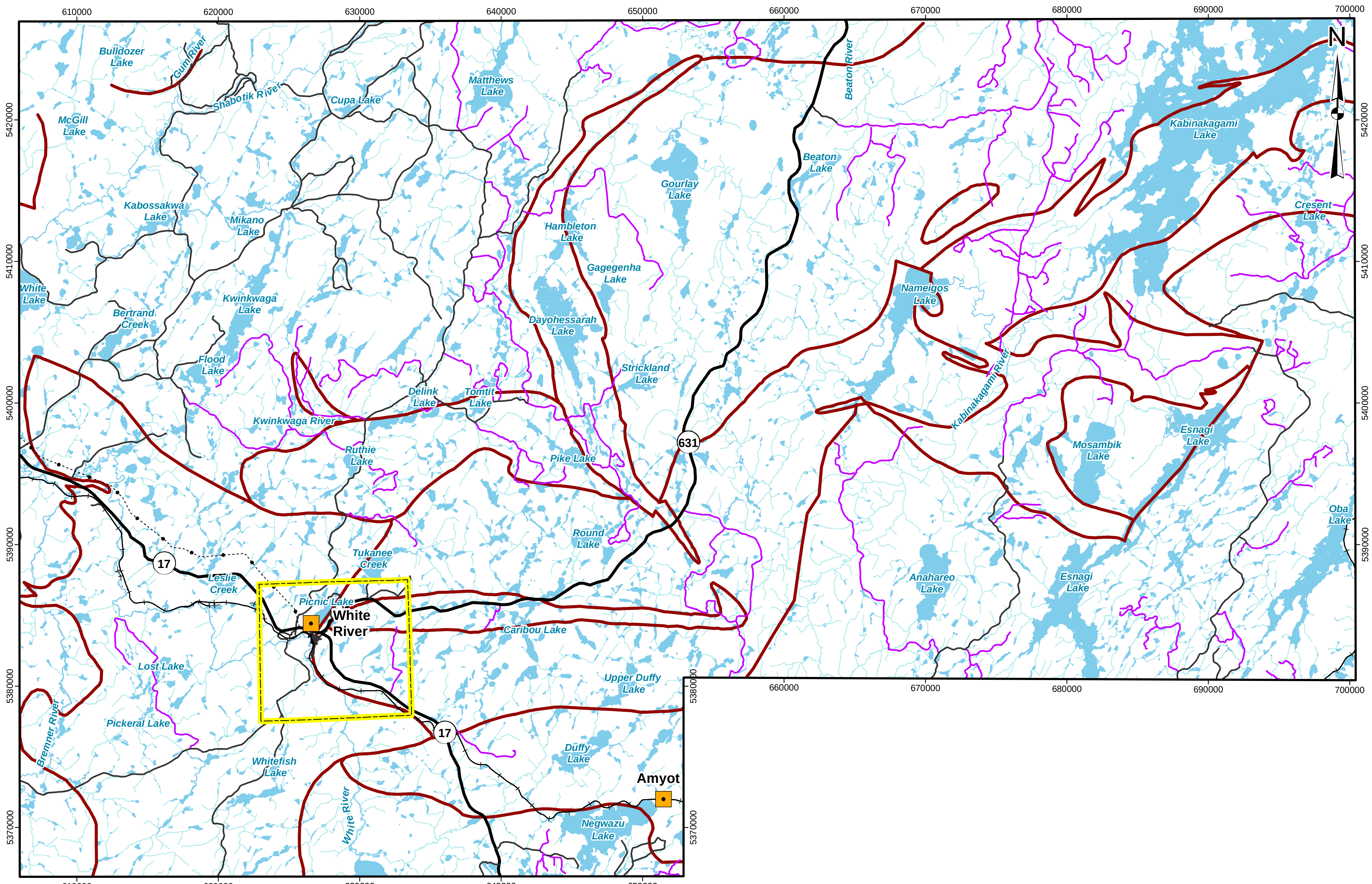
AECOM

PROJECT
Phase 1 Geoscientific Desktop Premliminary Assessment
Terrain and Remote Sensing Study, White River

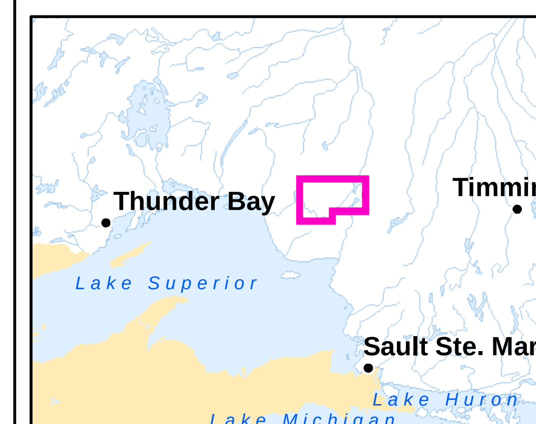
TITLE
Drainage Features within the White River Area

DESIGN	KR	23 Apr 2013	**Figure 12**	REVISION 1
GIS	KR	14 Jun 2013		UTM ZONE 16
CHECK	xx			NAD 1983
REVIEW	xx			1:300,000

Path: P:\60297733\900-CAD-GIS\920 GIS-Graphics\Remote Sensing Report\ReportMXDs\Revision 2 - White River\Jan 16 2013\60297733_Fig12_Watersheds within the WhiteRiver.mxd



Legend
- Settlement
- White River Municipal Boundary
- Main Road
- Local Road
- AECOM added roads (approximated)
- Railway
- Abandoned Railway Right-of-way
- Hydro Line
- Waterbody
- Watercourse
- Bedrock Geology Contact



Data Sources:
Base Data: MNR LIO, obtained 2009-2013
Intrusions: Generalized from OGS M2666, 2001 (1:250,000)

10 km

AECOM

PROJECT
Phase 1 Geoscientific Desktop Premliminary Assessment
Terrain and Remote Sensing Study, White River

TITLE
Road Network of the White River Area

DESIGN	KR	23 AUG 2013	Figure 13	REVISION 1
GIS	GF	29 AUG 2013		UTM ZONE 16
CHECK	xx			NAD 1983
REVIEW	xx			1:300,000

Path: P:\60297733\900-CAD-GIS\920 GIS-Graphics\Remote Sensing Report\ReportMXDs\Revision 2 - White River\Jan 16 2013\60297733_Fig13_Road Network of the White River Area.mxd