NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

Phase 1 Geoscientific Desktop Preliminary Assessment, Processing and Interpretation of Geophysical Data

TOWNSHIP OF WHITE RIVER, ONTARIO

APM-REP-06144-0085

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PHASE 1 GEOSCIENTIFIC DESKTOP PRELIMINARY ASSESSMENT

PROCESSING AND INTERPRETATION OF GEOPHYSICAL DATA

Township of White River, Ontario

Prepared for

AECOM Canada Ltd.
and
Nuclear Waste Management Organization (NWMO)

by

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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 (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). 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", contain general areas that have the potential to meet NWMO's geoscientific site evaluation factors.

This report presents the findings of a geophysical data interpretation assessment completed as part of the desktop geoscientific preliminary assessment of the White River area (AECOM, 2014a). The purpose of this assessment was to perform a detailed interpretation of all available geophysical data (e.g., magnetic, electromagnetic, gravity and radiometric) for the White River area, Ontario. The aim is to identify additional information that can be extracted from the data, in particular that relating to the coincidence of geophysical features with mapped lithology and structural features in the White River area.

The geophysical data covering the White River area show variability in resolution. Low-resolution geophysical data, particularly the magnetic, gravity and radiometric data obtained from the Geological Survey of Canada (GSC), cover the entire White River area. Three higher resolution magnetic/electromagnetic surveys were obtained from the Ontario Geological Survey (OGS) covering approximately 10% on the margins of the White River area. Magnetic and electromagnetic images obtained from an assessment file provided higher resolution coverage over approximately 5% in the middle of the area.

The coincidence between the geophysical data and the mapped lithology (this report) and structural features (SRK, 2014) was interpreted using all available geophysical data sets (e.g., magnetic, electromagnetic, gravity and radiometric). In general the coincidence between the geophysical interpretations and the published geological maps is locally in good agreement, but in some locations the geophysical data provided new interpretations.

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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 geophysical data interpretation assessment completed by Paterson, Grant & Watson Limited (PGW) as part of the desktop geoscientific preliminary assessment of the White River area (AECOM, 2014a). The objective of the desktop geoscientific preliminary assessment is to determine whether the White River area contains general areas that have the potential to meet NWMO's geoscientific site evaluation factors. The assessment focused on the Township of White River and its periphery, referred to as the "the White River area".

1.1 Objective of the Assessment

Geophysical data forms an important component of assessing a region for its potential suitability to host a deep geological repository, and to assist in the identification of general potentially suitable areas.

The purpose of this assessment was to perform a review of available geophysical data for the White River area, followed by a detailed interpretation of all available geophysical data (e.g., magnetic, electromagnetic, gravity and radiometric) to identify additional information that could be extracted from the data, in particular regarding the coincidence of geophysical features with mapped lithology and structural features in the White River area.

The role of the geophysical interpretation is to extrapolate our current understanding of the mapped lithology and extent of overburden cover to assess how the distributions of rock units may change at depth. Drillholes, wells and other underground information may be available at individual points to supplement geological data acquired on surface. However, where these individual data points are limited (or non-existent), such as for much of the White River area, the critical advantage of airborne geophysical data is that it provides a basis for interpreting the subsurface physical properties across the area. This is particularly important in areas where bedrock exposure is limited by surface water bodies and/or overburden cover (i.e., glacial sediments) such as in parts of the White River area. A secondary role of geophysics is that it often elucidates certain characteristics of geological formations and structures that may not be easily discerned from surface mapping and analysis. Thirdly, it highlights tectonic and regional-scale features that may not be easily extracted from studies of a particular area on a more detailed scale.

1.2 Township of White River and Surrounding Area

The White River area (4,991 km^2) incorporates the Township of White River (102.2 km^2) and surrounding areas as shown on Figure 1. It is situated in Northern Ontario, about 295 km east of Thunder Bay and 85 km east of Marathon, near the northeastern end of Lake Superior (all distances are straight line).

1.3 Qualifications of the Geophysical Interpretation Team

The team responsible for the geophysical review, processing and interpretation investigation component of the Phase 1 geoscientific desktop preliminary assessment of potential suitability for the White River area consisted of qualified experts from Paterson, Grant & Watson Limited (PGW). The personnel assigned to this assessment were as follows:

Stephen Reford, B.A.Sc., P.Eng. – project management, geophysical interpretation, report preparation

Mr. Reford is a senior consulting geophysicist and Vice-President of PGW. Mr. Reford has 32 years of experience in project management, acquisition and interpretation of airborne magnetic, electromagnetic, radiometric, gravity and digital terrain data for clients throughout Canada and around the world. Projects include management of the geophysical component of Operation Treasure Hunt for the Ontario Ministry of Northern Development and Mines as well as a similar role for the Far North Geoscience Mapping Initiative (2006-2009). Mr. Reford has served as a consultant to the International Atomic Energy Agency (IAEA) in gamma-ray spectrometry and is co-author of two books on radioelement mapping.

Winnie Pun, M.Sc. – data processing and map preparation

Ms. Pun will soon complete her second year as a consulting geophysicist for PGW after completing her M.Sc. in geophysics at the University of Toronto. She has prepared hundreds of geophysical maps for publication by government agencies in Nigeria and Botswana, and most recently has carried out several 2D/3D magnetic and gravity modelling studies on several iron ore projects.

Edna Mueller-Markham, M.Sc. – data processing and map preparation

Ms. Mueller-Markham is a senior consulting geophysicist for PGW. She has 19 years of experience in project management, acquisition, processing and modelling of airborne magnetic, electromagnetic, radiometric, gravity and digital terrain data throughout and gamma-ray spectrometer surveys for clients throughout Canada and around the world. In recent years, she has provided management and quality control for a number of OGS magnetic, gravity and electromagnetic surveys, and has reprocessed numerous industry surveys published by OGS.

Nikolay Paskalev, M.Sc. – GIS preparation

Mr. Paskalev has been the Manager, Geomatics and Cartography for Watts, Griffis and McOuat Limited (geological consultants) since 2006 and has been with the company since 2001. His work there has included a nationwide GIS of geology, ores and industrial minerals for Egypt, a GIS compilation of geological maps for a large part of Saudi Arabia and a Radarsat and DEM study for gold exploration in Sumatra. He has also worked part-time for PGW for the last 12 years, and most recently prepared a nationwide GIS for the geophysical interpretation of Nigeria. In 2011, he incorporated World GeoMaps Inc. for consulting in geomatics, cartography and GIS.

Dr. D. James Misener, Ph.D., P.Eng. – geophysical reviewer

Dr. Misener is President of PGW and a senior geophysicist with 38 years of experience in all aspects of geophysics and geophysics software applications. Dr. Misener founded Geosoft Inc. and led its development of world-leading geosciences software applications until he succeeded Dr. Paterson as President of PGW. He has directed implementation of geophysical data processing systems; initiated and managed major continental scale compilations of aeromagnetic/marine magnetic data in North America and worldwide including interpretation of aeromagnetic, radiometric, gravity and electromagnetic surveys in; Algeria, Brazil, Cameroon, Niger, Ivory Coast, Zimbabwe, Malawi, Kenya, China, Suriname, and Ireland.

2 SUMMARY OF PHYSICAL GEOGRAPHY AND GEOLOGY

The following sections on Physical Geography, Bedrock Geology, Structural History, Quaternary Geology and Land Use present summaries of the information presented in AECOM (2014a), SRK (2014) and AECOM (2014b) where applicable, in order to provide the necessary context for discussion of the results of this geophysical assessment (Section 5.0).

2.1 Physical Geography

Physical geography in the White River area is described in detail in AECOM (2014b). A summary of the main features is provided here for reference.

The White River area is located within the Abitibi Upland physiographic region (Thurston, 1991), a subdivision of the extensive James physiographic region (Bostock, 1970). The region is generally characterized by abundant bedrock outcrop with shallow drift cover and a rugged topography.

Bedrock-controlled terrain dominates the majority of the area and results in significant differences in elevation over short distances; the maximum relief within the White River area is approximately 311 m. 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 corner of the White River area. Notable variations in elevation caused by the relief of the bedrock surface are prevalent throughout the majority of the White River 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.

Within the White River area the upland regions, consisting of bedrock hills and ridges, are typically characterized by moderate relief of (approximately 60 to 80 m) over distances of hundreds of metres to a few kilometres. The uplands are scattered throughout the area and form the dominant terrain type. Glaciolacustrine, organic, and to a lesser degree, glaciofluvial deposits and areas of ground moraine, represent areas of limited relief, although many of these deposits are characterized by protrusions of bedrock. The glaciolacustrine 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.

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 of which flow southward into Lake Superior, and two which drain northward to James/Hudson Bay.

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 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 direction 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 1).

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 stream 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 rivers, have lower gradients. Rapids and small waterfalls are common in the White River area.

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 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 zone to the north of an arching line that runs from Matthews Lake, on the northern boundary, to north of Oba Lake in the east. This zone corresponds with the most extensive deposits of glaciolacustrine, glaciofluvial and organic sediments. Local concentrations of small lakes' however, are present in this zone within some large glaciofluvial deposits.

2.2 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.

2.2.1 Granitoid Intrusive Rocks

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.

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 Santaguida (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.

<u>Strickland Pluton</u>

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.

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.

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.

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.

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).

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 (pers. 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.

2.2.2 Greenstone Belts

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).

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.

2.2.3 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.

2.2.4 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.

2.2.5 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).

2.2.6 Metamorphism

Studies on metamorphism in Precambrian rocks across the Canadian Shield have been summarized in a few publications since the 1970s (e.g., Fraser and Heywood,1978; Kraus and Menard, 1997; Menard and Gordon, 1997; Berman et al., 2000; Easton, 2000a; 2000b; and

Berman et al., 2005) and the thermochronological record for large parts of the Canadian Shield is documented in a number of studies (Berman et al., 2005; Bleeker and Hall, 2007; Corrigan et al., 2007; and Pease et al., 2008).

The Superior Province of the Canadian Shield largely preserves low pressure – high temperature Neoarchean (ca. 2.710-2.640 Ga) metamorphic rocks. The relative timing and grade of regional metamorphism in the Superior Province corresponds to the lithological composition of the subprovinces (Easton, 2000a; Percival et al., 2006). Subprovinces comprising volcano-sedimentary assemblages and synvolcanic to syntectonic plutons (i.e., granite-greenstone terranes) are affected by relatively early lower greenschist to amphibolite facies metamorphism. Subprovinces comprising both metasedimentary- and migmatite-dominated lithologies, such as the English River and Quetico, and dominantly plutonic and orthogneissic domains, such as the Winnipeg River, are affected by relatively late middle amphibolite to granulite facies metamorphism (Breaks and Bond, 1993; Corfu et al., 1995). Subgreenschist facies metamorphism in the Superior Province is restricted to limited areas, notably within the central Abitibi greenstone belt (e.g., Jolly, 1978; Powell et al., 1993). Most late orogenic shear zones in the Superior Province and Trans-Hudson Orogen experienced lower to middle greenschist retrograde metamorphism. Post-metamorphic events along faults in the Abitibi greenstone belt show a drawn-out record through Ar/Ar dating to ca. 2.500 Ga the value of which remains unclear (Powell et al., 1995).

A widespread Paleoproterozoic tectonothermal event, the Trans-Hudson Orogeny, involved volcanism, sedimentation, plutonism and deformation that affected the Churchill Province through northernmost Ontario, western Manitoba, northern Saskatchewan and Nunavut (e.g., Skulski et al., 2002; Berman et al., 2005). This event was associated with ca. 1.84 to 1.8 Ga collisional convergence of the Archean Hearne domain and Superior Province (Kraus and Menard, 1997; Menard and Gordon, 1997; Corrigan et al., 2007). Associated metamorphism at moderate to high temperatures and low to moderate pressures resulted in amphibolite facies metamorphism that overprinted Archean metamorphic signatures in Archean rocks of the Churchill Province, and a complex brittle overprint in Archean rocks of the Superior Province (e.g., Kamineni et al., 1990)

Along the eastern flank of the Canadian Shield, the Grenville Province records a complex history of episodic deformation and subgreenschist to amphibolite and granulite facies metamorphism, from ca. 1.300 Ga to 950 Ma (Easton, 2000b; Tollo et al., 2004 and references therein). Lower greenschist metamorphism was documented along faults in the vicinity of Lake Nipigon and Lake Superior and is inferred to be the result of ca. 1 Ga far-field reactivation during the Grenville Orogeny (Manson and Halls, 1994).

In northwestern Ontario, the concurrent post-Archean effects, including the Trans-Hudson Orogen, are limited to poorly documented reactivation along faulted Archean terrane boundaries (e.g., Kamineni et al., 1990 and references therein). Most late orogenic shear zones in the Superior Province and Trans-Hudson Orogen experienced lower to middle greenschist retrograde metamorphism (e.g., Kamineni et al., 1990 and references therein).

Overall, most of the Canadian Shield preserves a complex episodic history of Neoarchean metamorphism overprinted by Paleoproterozoic tectonothermal events culminating at the end of the Grenville orogeny ca. 950 Ma. The distribution of contrasting metamorphic domains in the Canadian Shield is a consequence of relative uplift, block rotation and erosion resulting from Neoarchean orogenesis, subsequent local Proterozoic orogenic events and broader epeirogeny during later Proterozoic and Phanerozoic eons.

All Precambrian rocks of the White River area display some degree of metamorphism. The Dayohessarah greenstone belt is typically characterized by amphibolite facies metamorphism (Stott, 1999). This amphibolite facies metamorphic grade may be a manifestation of an amphibolite grade contact metamorphic aureole bordering the Strickland pluton (Stott, 1999). Little information regarding the metamorphic grade of the exposed rocks of the Kabinakagami greenstone belt is available in the reviewed literature. Based on ages obtained from metamorphic monazites, Zaleski et al. (1995; 1999) suggested that near-peak metamorphism of the Manitouwadge-Hornepayne greenstone belt occurred between 2.675 and 2.669 Ga. It can be inferred that the Dayohessarah and Kabinakagami belts may have been subjected to metamorphism during this period, as the age constraints given by Zaleski (1995; 1999) correspond well with the 2.675 ±1 and 2.661 ±1 Ga periods of regional metamorphism recognized by Schandl et al. (1991) and Davis et al. (1994).

Typical metamorphic grades in plutonic rocks within the White River area are variable from non-metamorphosed to amphibolite grade in metamorphic contact aureoles. No records exist that suggest that rocks in the White River area may have been affected by thermotectonic overprints related to post-Archean events.

2.3 Structural History

Information on the structural history of the White River area is based predominantly on insights derived from structural investigations of the Manitouwadge and Dayohessarah greenstone belts (Polat, 1998; Zaleski et al., 1994; Peterson and Zaleski, 1999) and the Hemlo gold deposit and surrounding region (Muir, 2003). Additional studies by Lin (2001), Percival et al. (2006), Williams and Breaks (1996) and Lin and Beakhouse (2013) have also contributed to the structural understanding of the area. These studies were performed at various scales and from various perspectives. Consequently, the following summary of the structural history of the White River area should be considered as a “best-fit” model that incorporates relevant findings from all studies.

Few detailed investigations of the structural history of the White River area have been completed; however, the structural history of the Manitouwadge and nearby Schreiber-Hemlo greenstone belts are generally well characterized and suggests up to of six phases of deformation (Polat, 1998; Peterson and Zaleski, 1999; Lin, 2001; Muir, 2003). Polat et al. (1998) interpreted that the Schreiber-Hemlo and surrounding greenstone belts represent collages of oceanic plateaus, oceanic arcs and subduction-accretion complexes amalgamated through subsequent episodes of compressional and transpressional collision. On the basis of overprinting relationships between different structures Polat et al. (1998) suggested that the Schreiber-Hemlo greenstone belt underwent at least two main episodes of deformation. This can be correlated with observations from Peterson and Zaleski (1999) and Muir (2003), who reported at least five and six generations of structural elements, respectively. Two of these generations of structures account for most of the ductile strain, and although others can be distinguished on the basis of crosscutting relationships, they are likely the products of progressive strain events. Integration of the structural histories detailed in Williams and Breaks (1996), Polat (1998), Peterson and Zaleski (1999), Lin (2001), and Muir (2003) suggests that six deformation events occurred within the White River area. The first four deformation events (D_1-D_4) were associated with brittle-ductile deformation and were typically associated with deformation of the greenstone belts. D_5 and D_6 were associated with a combination of brittle deformation, and fault propagation through all rock units in the White River area. The main characteristics of each deformation event are summarized below.

The earliest recognizable deformation phase (D_1) is associated with rarely preserved small-scale isoclinal folds, ductile faults that truncate stratigraphy and a general lack of penetrative foliation development. Peterson and Zaleski (1999) reported that planar D_1 fabrics are only preserved locally in outcrop and in thin section. Locally in the White River region D_1 deformation may have produced a strain aureole within the margins of the Pukaskwa batholith and surrounding country rocks which formed a local S_1 fabric. D_1 deformation is poorly constrained to between ca. 2.719 and ca. 2.691 Ga (Muir, 2003).

D_2 structural elements include prevalent open to isoclinal F_2 folds, an axial planar S_2 foliation and mineral elongation L_2 lineations (Peterson and Zaleski, 1999). Muir (2003) interpreted D_2 to have resulted from progressive north-northeast- to northeast-directed compression that was coincident with the intrusion of various plutons, including phases of the Pukaskwa batholith. The S_2 foliation is the dominant meso- to macro-scale regional fabric evident across the study area. Ductile flow of volcano-sedimentary rocks between more competent batholiths (e.g., Pukaskwa) may also have occurred during this deformation phase (e.g., Lin and Beakhouse, 2013). D_2 deformation is constrained to between ca. 2.691 and ca. 2.683 Ga (Muir, 2003).

D_3 deformation comprised northwest-southeast shortening as a result of on-going regional-scale dextral transpression and produced macroscale F_3 folds, and local shear fabrics that exhibit a dextral shear sense and overprint of D_2 structures (Peterson and Zaleski, 1999; Muir, 2003). D_3 deformation did not develop an extensive penetrative axial planar and (or) crenulation cleavage. D_3 deformation is constrained to between ca. 2.682 and ca. 2.679 Ga (Muir, 2003).

D_4 structural elements include isolated northeast-plunging F_4 kink folds with a Z-asymmetry and a moderate, northeast plunge, and associated small-scale fractures and faults overprinting D_3 structures. D_3-D_4 interference relationships are best developed north of the White River area in the Manitouwadge greenstone belt and in rocks of the Quetico Subprovince. D_4 deformation is roughly constrained to between ca. 2.679 and ca. 2.673 Ga (Muir, 2003).

Details of structural features associated with the D_5 and D_6 deformation events are limited in the literature; however, where described, they manifest as brittle and brittle-ductile faults of various scales and orientations (Lin, 2001; Muir, 2003). Within the Hemlo greenstone belt, Muir (2003) suggested that local D_5 and D_6 faults offset the Marathon, and Biscotasing dyke swarms (all ca. 2.2 Ga), and as such, suggested that in the Hemlo region, D_5 and D_6 faults propagated after ca.

2.2 Ga. However, since there are no absolute age constraints on specific events, the entire D_5-D_6 interval of brittle deformation can only be constrained to a post-2.673 Ga timeframe that may include many periods of re-activation attributable to any of several post-Archean tectonic events, as described above.

The geological and structural history of the White River area is summarized in Table 1.

Table 1: Summary of the Geological and Structural History of the White River Area (adapted from AECOM, 2014a)

Approximate Time period (years before present)	Geological Event
2.89 to 2.77Ga	Progressive growth and early evolution of the Wawa-Abitibi terrane by collision, and ultimately accretion, of distinct geologic terranes.
2.770 – 2.673 Ga	- ca. 2.720 Ga: Onset of volcanism and subordinate sedimentation associated with the formation of the Dayohessarah and Kabinakagami greenstone belts. - ca. 2.720 Ga: Emplacement of oldest recognized phase of Black-Pic batholith. - ca. 2720-2.703 Ga: Emplacement of oldest lithologic association of Pukaskwa batholith. - ca. 2703-2.686 Ga: Emplacement of second lithologic association of Pukaskwa batholith. - ca. 2.697 Ga: Intrusion Dotted Lake pluton, and possibly of Strickland pluton. - ca. 2.689 Ga: Emplacement of younger recognized phase of Black-Pic batholith. - ca. 2.677 Ga: emplacement of Bremner pluton. - ca. 2.719 to 2.677 Ga: Four periods of ductile-brittle deformation (D_1-D_4). - D_1: ca. 2.719 – 2.691 Ga - D_2: ca. 2.691 – 2.683 Ga → Main phase of coalescence of the Wawa and Quetico subprovinces (Corfu and Stott, 1996) - D_3: ca. 2.682 – 2.679 Ga → sinistral transpressive deformation, structural domal uplift of Pukaskwa Batholith - D_4: ca. 2.679 – 2.673 Ga - ca.2.688 to 2.675: Regional metamorphism (Muir, 2003)
2.675 and 2.669 Ga	Peak metamorphism of regional greenstone belts.
2.667 Ga	Youngest lithologic association of Pukaskwa Batholith.
2.5 to 2.1 Ga	- ca. 2.5 Ga: Supercontinent fragmentation and rifting in Lake Superior area. Development of Southern Province - ca. 2.473 Ga: Emplacement of the Matachewan dyke swarm. - ca. 2.167 Ga: Emplacement of Biscotasing dyke swarm. - ca. 2.121 Ga: Emplacement of the Marathon dyke swarm.
1.9 to 1.7 Ga	Penokean Orogeny in Lake Superior and Lake Huron areas; possible deposition and subsequent erosion in the Manitouwadge area.
1.238 Ga	- ca. 1.238 Ga emplacement of the Sudbury dyke swarm

1.150 to 1.090 Ga	Rifting and formation of the Midcontinent Rift. - ca. 1.14 Ga: Emplacement of the Abitibi dyke swarm.
540 to 355 Ma	Possible coverage of the area by marine seas and deposition of carbonate and clastic rocks subsequently removed by erosion.
145 to 66 Ma	Possible deposition of marine and terrestrial sediments of Cretaceous age, subsequently removed by erosion.
2.6 to 0.01 Ma	Periods of glaciation and deposition of glacial sediments.

2.4 Quaternary Geology

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. Their distribution, thickness and physical characteristics have an important influence on several aspects of the current assessment. Areas of thicker drift can hinder the interpretation of lineaments by masking their presence in satellite imagery 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.

All glacial landforms and related materials within the White River area are associated with the Late Wisconsinan. The Quaternary (i.e., surficial) geology of the area has been mapped at different scales as discussed in AECOM, 2014b.

Geddes et al. (1985) and Geddes and Kristjansson (1986) reported 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°. For the large parts of the White River area drift thickness over bedrock is limited and the ground surface reflects the bedrock topography (Geddes and Kristjansson, 1985). Over the majority of the area bedrock outcrops are common and the terrain is classified, for surficial mapping 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.

The remote sensing and terrain evaluation completed as part of the Phase 1 preliminary assessment (AECOM, 2014b) provides a detailed assessment of the type, distribution and thickness of surficial deposits in the White River area (Figure 3).

The most common glacial deposit in the White River area is stony, sandy till (ground moraine) which forms a veneer in rocky upland areas. In the White River area the till composition is variable and two types are regionally recognizable (Geddes et al., 1985; 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) noted 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 morainic surface expression.

Till thickness is variable; while depths of several metres are present locally; thicknesses are typically is less than 3 m (A. Bajc, pers. comm., 2013). Gartner and McQuay (1980a, 1980b) reported 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.

The impact that the variable distribution of Quaternary sediments has on the results of the geophysical interpretation will be discussed in Section 5.

2.5 Land Use

The vast majority of the White River area is undeveloped Crown Land with privately held residential and business properties located almost exclusively within the settlement area of White River. Private land, held as mineral patents, also occurs in Lizar Township, west of Kabinakagami Lake and in and Derry Township in the northeast corner of the White River area. Several small parcels of land designated as Crown Reserves are scattered across the area.

Mineral exploration is active in the area and numerous active mining claims, and a small number of patents, are held by prospectors and mining companies (MNDM, 2013b). The majority of the mining claims occur in three areas: a large rectangular shaped block centred on Dayohessarah Lake (primarily over the Dayohessarah greenstone belt); a northeast trending group between Nameigos Lake and Kabinakagami Lake (over the central part of the Kabinakagami greenstone belt); and west of White River, south of Highway 17. A range of exploration work is conducted on the claims to assess the mineral potential including geologic mapping, drilling, and geochemical and geophysical surveys. A number of aggregate operations are extracting sand and gravel in the area (MNR, 2013a). The majority of the pits are located adjacent to the routes of Highways 17 and 631. Natural resources are discussed further in Section 5.

Forestry is a long-standing use of the land and has been an economic mainstay of the White River area. The area falls within MNR’s Magpie, Nagagami and White River forestry management units (MNR, 2013b). Timber harvesting has occurred over large expanses of the White River area.

Forestry sector activities result in the development of an extended road and/or trail network, although some of this access is of a temporary (e.g., open only while logging is on-going) or seasonal nature (e.g., winter roads). Access to the many lakes and remote areas within the White River area allows use of the land for hunting and fishing by the local population and visitors to the region.

3 GEOPHYSICAL DATA SOURCES AND QUALITY

For the White River area, geophysical data were obtained from available public-domain sources, particularly the Ontario Geological Survey (OGS) and the Geological Survey of Canada (GSC). To supplement these data, geophysical surveys performed in the White River area by the mining industry were reviewed, as available from assessment files.

The quality of the available data was assessed to determine which data sets are suitable for inclusion in this assessment. The geophysical surveys covering the White River area show variability in data set resolution, which is a function of the flight line spacing, the sensor height and equipment sensitivity. In particular, where more than one data set overlaps, the available data were assembled using the highest quality coverage. Various geophysical data processing techniques were applied to enhance components of the data most applicable to the current assessment. The integrity of the higher quality data was maintained throughout.

3.1 Data Sources

The geophysical data covering the White River area show variability in dataset resolution. Low-resolution geophysical data, particularly the magnetic, gravity and radiometric data obtained from the Geological Survey of Canada (GSC), cover the entire White River area. The higher resolution geophysical coverage consists of three magnetic and frequency-domain electromagnetic (FDEM) surveys from OGS. They cover a small portion of the White River area in the northeast, northwest and southwest (Figure 4).

Due to the lack of high-resolution data over most of the White River area, the OGS Assessment File Research Imaging Database (AFRI) was reviewed. Several assessment files comprising airborne geophysical surveys that focused on the greenstone belts in the White River area were identified and reviewed. Only one assessment file (20004804; Fugro, 2008), which provided colour images from a high-resolution magnetic and FDEM survey, was useful for the geophysical interpretation. The geophysical data sets are summarized in Table 2 and the characteristics of each of the data sources are discussed in detail below.

Table 2. Summary of the characteristics for the geophysical data sources in the Township of White River and surrounding area

Product	Source	Type	Line Spacing/ Sensor Height	Line Direction	Location	Date	Additional Comments
Ontario #8	GSC, 2013	Fixed wing magnetic	805 m/305 m	0°	Western half of White River area	1959	Locally superseded by higher resolution coverage.
Ontario #17	GSC, 2013	Fixed wing magnetic	805 m/305 m	0°	Eastern half of White River area	1963	Little overlap with high-resolution coverage.
North Shore Lake Superior, section 1 (East)	GSC, 2013	Fixed wing magnetic, radiometric	5000 m/123 m	0°	Entire White River area	1982	Only radiometric survey available.
GDS1024 Oba-Kapuskasing	OGS, 2003	Helicopter magnetic, FDEM, VLF-EM	200 m/ MAG 45 m FDEM 30 m VLF-EM 45 m	176°	Northeast White River area	1986	3-frequency Aerodat system.
GDS1205 Manitouwadge (block H)	OGS. 2002a	Helicopter magnetic, FDEM	200 m/ MAG 45 m FDEM 30 m	170°	Northwest White River area	1989	4-frequency Dighem IV system, flown for Noranda Exploration Company, Ltd.
GDS1207 Hemlo	OGS, 2002b	Helicopter magnetic, FDEM, VLF-EM	100 m/ MAG 55 m FDEM 40 m VLF-EM 55 m	0°	Southwest White River area	1983	3-frequency Aerodat system.
AFRI No. 20004804 (Fugro, 2008)	OGS, 2013	Helicopter magnetic, FDEM	100 m/ MAG 30 m FDEM 30 m	123° (north)/ 69° (south)	Central White River area	2008	5-frequency Dighem system, flown for Corona Gold Corp. over the Dayohessarah greenstone belt
GSC Gravity Coverage	GSC, 2013	Ground gravity measurements	5-15 km		Entire White River area	1946-2001	Irregular distribution of 32 station measurements

GSC – Geological Survey of Canada
OGS – Ontario Geological Survey

3.1.1 Magnetic Data

Magnetic data over the White River area were collected by various surveys using different survey parameters outlined in Table 2. Magnetic surveys help in the understanding of geological and structural variations caused by different rock types associated with their content of magnetic minerals, such as magnetite and pyrrhotite. Magnetic maps show the distribution of magnetic and non-magnetic geologic bodies within the subsurface, and are particularly useful for delineating spatial geometry of bodies of rock, and the presence of faults and folds.

The resolution of the retrieved magnetic datasets varies within the White River area. Surveys were flown over a period of 31 years, over which time the quality and precision of the equipment as well as the quality of the processing has improved. Variability in the quality of the survey coverage also influenced the ability of the magnetic data to identify geological structures of interest relevant to this assessment.

Low-resolution magnetic data from the GSC (Ontario #8 and #17) provides complete coverage of the entire White River area (GSC, 2013). Magnetic data from these surveys form part of the GSC Regional Magnetic Compilation data and were flown at a terrain clearance of 305 m and flight line spacing of 805 m, providing them with a relatively low spatial resolution. Additional, high resolution surveys from the OGS (Oba-Kapuskasing Survey, Manitouwadge Survey and Hemlo Survey) were flown at a lower terrain clearance (45 and 55 m) compared to the GSC surveys, and with flight line spacing of 200 m and 100 m (OGS, 2002a; 2002b; 2003). These surveys focused on areas with mineral exploration potential, covering the greenstone belts and also the adjacent intrusive and metasedimentary rocks. The OGS Manitouwadge Survey was part of several FDEM survey blocks originally flown for Noranda Exploration Company, Ltd. The high-resolution coverage amounts to approximately 10 percent on the margins of the White River area.

Assessment files archived at the OGS were reviewed for the White River area, and consist of six airborne geophysical surveys, that focused on relatively small areas within and near the greenstone belts. One assessment file of particular interest (AFRI number 20004804; Fugro, 2008) provides high-resolution coverage over most of the Dayohessarah greenstone belt. It consists of a helicopter-borne magnetic and FDEM survey flown in 2008 for Corona Gold Corp. over an arcuate block measuring roughly 30 km by several km of varying width (Figure 4). The magnetic survey was flown with 100 m line spacing at 30 m terrain clearance. The assessment report included the survey report provided by the airborne survey contractor, with several geophysical maps. Although the digital geophysical data were not available for the survey, the magnetic data were incorporated into this assessment in the form of raster maps of the total magnetic field and its first vertical derivative, which were extracted from the report and georeferenced (Figure 17). The results are incorporated in the interpretation section of this report.

3.1.2 Gravity Data

Gravity data provides complete coverage of the White River (GSC, 2013), consisting of an irregular distribution of 32 station measurements within the White River area, comprising roughly a station every 5 to 15 km.

The gravity measurements were retrieved as Bouguer corrected data. The Bouguer correction is applied to compensate for the gravity effect of the material between the measurement station and the datum elevation. However, the contribution to the measurement of the gravity effects of the surrounding topographic features (i.e., terrain correction) was not applied by the GSC.

Despite the fact that data are of good quality, the sparseness of the measurement locations in the White River area can only be used to provide information about large scale geologic features. The resolution of the acquired gridded data is 2 km by 2 km.

3.1.3 Radiometric Data

The GSC radiometric datasets provide complete coverage of the White River area (GSC, 2013). The acquired data show the distribution of natural radioactive elements at surface: uranium (eU), thorium (eTh) and potassium (K), which can be interpreted to reflect the distribution of mineralogical and geochemical information in the area. The GSC radiometric data were flown at 5,000 m line spacing at a terrain clearance of 123 m above the surface over the White River area (Table 2).

Retrieved radiometric data consisted of measurements of four variables:
- Potassium, K (%);
- Equivalent uranium, eU (ppm);
- Equivalent thorium, eTh (ppm); and
- Total Air Absorbed Dose Rate (nGy/h).

3.1.4 Electromagnetic Data

One frequency-domain electromagnetic (FDEM) survey available from the OGS was retrieved from the Manitouwadge survey (OGS, 2002a) (Figure 4). This survey acquired FDEM data using a Dighem IV system to measure the inphase and quadrature components of four different frequencies (one coaxial and three coplanar coil pairs), towed below a helicopter with the sensor at a nominal terrain clearance of 30 m. The survey was flown at 200 m flight line spacing, providing relatively high spatial resolution.

A second frequency-domain electromagnetic (FDEM) survey available from the OGS was retrieved from the Hemlo survey (OGS, 2002b) (Figure 4). This survey acquired FDEM data using an Aerodat III system to measure the inphase and quadrature components of three different frequencies (two coaxial and one coplanar coil pairs), towed below a helicopter with the sensor at a nominal terrain clearance of 40 m. The survey was flown at 100 m flight line spacing, providing relatively high spatial resolution. The survey also acquired total field and quadrature VLF-EM data using the Cutler, Maine transmitter, with the sensor at a nominal terrain clearance of 55 m. The FDEM data were used in preference to the VLF-EM data in the interpretation due to their superior response to bedrock sources and less sensitivity to strike direction of the conductors.

A third frequency-domain electromagnetic (FDEM) survey available from the OGS was retrieved from the Oba-Kapuskasing survey (OGS, 2003) (Figure 4). This survey acquired FDEM data using an Aerodat system to measure the inphase and quadrature components of three different frequencies (two coaxial and one coplanar coil pairs), towed below a helicopter with the sensor at a nominal terrain clearance of 30 m. The survey was flown at 200 m flight line spacing, providing relatively high spatial resolution. The survey also acquired total field and quadrature VLF-EM data using the Cutler, Maine and Annapolis, Maryland transmitters, with the sensor at a nominal terrain clearance of 45 m. The FDEM data were used in preference to the VLF-EM data in the interpretation due to their superior response to bedrock sources and less sensitivity to strike direction of the conductors.

In addition, each FDEM survey included an EM anomaly database with the sources classified as bedrock, surficial or cultural.

One assessment file (AFRI number 20004804; Fugro, 2008) provides high resolution coverage over most of the Dayohessarah greenstone belt. It consists of a helicopter-borne magnetic and FDEM survey flown in 2008 for Corona Gold Corp. over an arcuate block measuring roughly 30 km by several km of varying width (Figure 4). This survey acquired FDEM data using an Dighem system to measure the inphase and quadrature components of five different frequencies (two coaxial and three coplanar coil pairs), towed below a helicopter with the sensor at a nominal terrain clearance of 30 m. The survey was flown at 100 m flight line spacing, providing relatively high spatial resolution. The assessment report included the survey report provided by the airborne survey contractor, with several geophysical maps. Although the digital geophysical data were not available for the survey, the electromagnetic data were incorporated into this assessment in the form of raster maps of the apparent resistivity for each of the three coplanar coil pairs (900 Hz, 7,200 Hz, 56,000 Hz), which were extracted from the report and georeferenced (Figure 17). The results are incorporated in the interpretation section of this report.

3.2 Data Limitations

There is a fairly stark contrast between the high resolution of the magnetic surveys that cover roughly 15% of the White River area and the older regional low resolution coverage over the remainder. Nevertheless, the magnetic data reflect quite coherent responses that elucidate the mapped geology, particularly in areas of limited bedrock exposure. The smaller intrusions, dyke swarms and main structural regimes are clearly delineated by the magnetic data, regardless of resolution, but at different levels of detail.

All four data types considered (magnetic, gravity, radiometric and electromagnetic) contribute to the interpretation. The limitation in applying these data types to the White River area is governed mainly by the following factors:

- Coverage and quality of data – types available, density of the coverage, vintage and specifications of the instrumentation;
- Overburden – areal extent, thickness and physical properties; and
- Bedrock lithologies – physical properties and homogeneity (e.g., batholith contacts can be easily mapped but batholiths themselves are sometimes quite homogeneous, making geophysical characterization of internal structure difficult).

The user of the geophysical information must bear in mind that each method relies on characterizing a certain physical property of the rocks. The degree to which these properties can be used to translate the geophysical responses to geological information depends mainly on the amount of contrast and variability in that property within a geological unit and between adjacent geological units. The usability of each data set also depends on its quality, especially resolution.

The images from the Corona Gold magnetic and electromagnetic survey (Fugro, 2008) over the Dayohessarah greenstone belt were incorporated in the geophysical interpretation to provide improved delineation of the igneous rocks in that area.

4 GEOPHYSICAL DATA PROCESSING

All data were processed and imaged using the Oasis montaj software package (Geosoft, 2013). Three additional magnetic grids were prepared using the Encom PA software package (Pitney Bowes, 2013). The grids that resulted from the various processing steps were also loaded in ArcMAP 10 (ESRI, 2013) using a Geosoft plug-in.

4.1 Magnetic

All surveys in the White River area where projected to the UTM16N/NAD83 coordinate system. Magnetic data from the surveys were gridded at a cell size of ¼ the line spacing. The resultant grids were examined for level noise along the survey lines and as a result, microlevelling was applied to the GSC surveys Ontario #8 and #17. The resultant grids were regridded to a common grid cell size of 40 m.

The surveys were knitted together using Oasis montaj (Geosoft, 2013), where the suture path between the grids was along the edge of the grid with the original higher resolution grid cell size so that the most detailed data was retained in the final product. The resultant grid was the residual magnetic intensity grid (i.e., total magnetic field after IGRF correction) and the basis for preparing the enhanced magnetic grids.

Reduction to the Pole (RTP)

The direction (inclination and declination) of the geomagnetic field varies over the Earth and influences the shape of the magnetic responses over geological sources. At the North Magnetic Pole the inducing magnetic field is vertical (i.e., inclination of 90° and declination of 0°), which results in the magnetic response being a symmetric positive magnetic peak over a source, in the absence of dip and magnetic remanence. Transforming the measured magnetic field to a pole reduced magnetic field simplifies the interpretation, particularly to determine the location and geometry of the sources (Baranov, 1957). For the White River area, the residual magnetic intensity grid was reduced to the pole using a magnetic inclination of 77.8° N and magnetic declination of 4.7° W (Figure 5).

The RTP filter, computed from the residual magnetic field after it is transformed to the Fourier domain, is defined as follows:

$$L(\theta) = \frac{[\sin(I) - \ i \cdot \cos(I) \cdot \cos(D - \theta)]^2}{[sin^2(I_a) + cos^2(I_a) \cdot cos^2(D - \theta)] \cdot [sin^2(I) + cos^2(I) \cdot cos^2(D - \theta)]}$$

$$if \ (|I_a| < |I|), I_a = I \qquad \text{(eq. 4.1)}$$

Where:
L(θ) = pole-reduced magnetic field for wavenumber θ
I = geomagnetic inclination
I_a = inclination for amplitude correction (never less than I).
D = geomagnetic declination
i = imaginary number in the Fourier domain.

First Vertical Derivative of the Pole Reduced Field (1VD)

The vertical derivative is commonly applied to the RTP magnetic field data in the Fourier domain to enhance shallower geologic sources in the data (Figure 7). This is particularly useful for locating contacts (e.g., the anomaly texture is revealed) and mapping structure (Telford et al., 1990). It is expressed as:

$$1VD = {}^{dRTP}/_{dZ} \qquad \text{(eq. 4.2)}$$

where Z is the vertical offset.

One limitation of this filter is that the higher order derivatives tend to also enhance the high frequency noise in the data set. To reduce noise that resulted from aliasing during the minimum curvature gridding process, an 8th-order 100 m low-pass Butterworth filter was also applied.

Removal of Dyke Signatures

The magnetic responses in the White River area are significantly influenced by the Matachewan, Biscotasing and Marathon dyke swarms due to their widespread prevalence across the area and the amplitude of their magnetic anomalies compared to the relatively subdued responses over most of the bedrock. As a result, directional filters were applied along the approximate strike direction of each swarm to better image the bedrock responses. Grids of the pole-reduced magnetic field, its first vertical derivative and tilt angle were prepared by removing the signal for a median strike direction of 142° (Matachewan swarm), 32° (Biscotasing swarm) and 11° (Marathon swarms) and with all three removed. The result with all swarms removed is presented for the pole-reduced magnetic field (Figure 6) and its first vertical derivative (Figure 8).

The directional filter, applied in the Fourier domain, is defined as follows:

$$L(\theta) = |\cos\left(\alpha - \theta + \frac{\pi}{2}\right)| \qquad \text{(eq. 4.3)}$$

Where:
L(θ) = magnetic field for wavenumber θ
α = direction to be rejected

Upward continued grids of the pole-reduced magnetic field to levels 500 m, 1,000 m and 2,000 m above the observation surface were also prepared, as an alternate form of suppressing the dyke responses and viewing the bedrock geology responses on a regional scale.

Second Vertical Derivative of the Pole Reduced Field (2VD)

The second vertical derivative is commonly applied to the RTP magnetic field data in the Fourier domain to further enhance shallower geologic sources in the data (Figure 9). This is particularly useful for locating contacts (e.g., the anomaly texture is revealed) and mapping structure close to surface (Telford et al., 1990). It is expressed as:

$$2VD = {d^2RTP}/{dZ^2} \qquad \text{(eq. 4.4)}$$

where Z is the vertical offset.

To reduce noise that resulted from aliasing during the minimum curvature gridding process, an 8th-order 300 m low pass Butterworth filter was also applied.

Tilt Angle of the Pole Reduced Field

The tilt angle (Miller and Singh, 1994) has been applied to the RTP magnetic field data to preferentially enhance the weaker magnetic signals (Figure 10). This is particularly useful for mapping texture, structure, and edge contacts of weakly magnetic sources. It is expressed as:

$$TILT = \tan^{-1}\left\{\frac{\frac{dRTP}{dZ}}{\sqrt{\left([\frac{dRTP}{dX}]^2+[\frac{dRTP}{dY}]^2\right)}}\right\} \qquad \text{(eq. 4.5)}$$

where *X* and *Y* are the horizontal offsets in the east and north directions.

The first vertical derivative is computed in the Fourier domain whereas the horizontal derivatives in X and Y are computed in the space domain. To reduce noise that resulted from aliasing during the minimum curvature gridding process, an 8th-order 200 m low pass Butterworth filter was also applied.

Analytic Signal Amplitude

The amplitude of the analytic signal (AS) (Figure 11) is the square root of the sum of the squares of the derivatives in the horizontal (X and Y) and vertical (Z) directions (i.e., the Fourier domain first vertical derivative and the space domain horizontal derivatives in X and Y), computed from the total magnetic field (Nabighian, 1972):

$$AS = \sqrt{\left([\frac{dT}{dX}]^2 + [\frac{dT}{dY}]^2 + [\frac{dT}{dZ}]^2\right)} \qquad \text{(eq. 4.6)}$$

To reduce noise that resulted from aliasing during the minimum curvature gridding process, an 8th-order 150 m low pass Butterworth filter was also applied.

The analytic signal is useful in locating the edges of magnetic source bodies, particularly where remanence complicates interpretation. It is particularly useful to interpret the contacts of intrusions.

Depth to Magnetic Sources Using Source Parameter Imaging (SPI™)

The SPI method locates the depths of edges in the gridded magnetic data (Thurston and Smith, 1997). It assumes a 2D sloping contact or 2D dipping thin sheet model. The SPI solutions extracted from the pole reduced magnetic field grid are stored in a database. The SPI values calculated are depths between the magnetic source and the instrument height. If the survey was flown at a constant terrain clearance, then the drape height could be subtracted from the SPI value to result in a depth below surface. For the GSC surveys, only the average flying height was known. For the remaining surveys (Manitouwadge, Oba-Kapuskasing and Hemlo), the radar altimeter data were included in the survey database and were consequently used to more accurately determine the distance between the magnetic sensor and the computed depth to the magnetic source. The radar altimeter channel was gridded at the original grid cell size and sampled back to the SPI database. If the value of the depth to source is <0, i.e., above ground, it is set to a value of zero. Thus, the SPI depth with respect to the ground surface is calculated as:

- SPI_depth = SPI_value – average flying height, if no radar data is available; or
- SPI_depth = SPI_value – radar value, if available.

The SPI depths were calculated for each individual data set in the White River area, taking into account that the elevation of the magnetic sensor (Figure 12). Low resolution grids are biased with deeper basement depths due to the lack of high-frequency content. Thus, where a high resolution survey overlaps with a low resolution regional survey, the SPI depths from the low resolution grid were excluded. The final SPI depth grid was calculated with a grid cell size of 200 m.

Encom Magnetic Grids

A series of grids were created to highlight the edges of both shallow and deep sources and to categorize anomalous zones into different areas (Shi and Butt, 2004). These grids are:

- rtpzsedge – gradient filters applied to the pole reduced magnetic field to emphasize edges;
- rtpzsedgezone – gradient filters and amplitude equalization filters applied to the pole reduced magnetic field to emphasize edges;
- rtpzsplateau – gradient filters and amplitude equalization filters applied to the pole reduced magnetic field to emphasize homogeneous blocks bounded by edges.

Magnetic Peaks, Troughs and Edges

The semi-automated extraction of magnetic anomaly peaks, troughs and edges is useful for delineating structure, foliation, texture and contacts. Anomaly peaks typically trace the center of a source or the more magnetic horizons within a larger source. Anomaly troughs often complement the peaks, indicating a less magnetic horizon. They also may map a remanent (i.e., reversely) magnetized source, or magnetite depletions (e.g., along a fault) which are a less magnetic source in a more magnetic host rock. Anomaly edges mark geological contacts or the boundaries of horizons within a geological unit. Offsets and orientation changes in the peaks, troughs and edges are useful for mapping faults and shears. Detection for peaks, troughs and edges was performed based on the CET (Centre for Exploration Targeting) Grid Analysis package in Oasis montaj (Geosoft, 2013).

The phase symmetry method, a frequency-domain approach based on axes of symmetry, is used to identify arbitrarily oriented line features. The 2D image is analyzed with 1D profiles in multiple orientations and varying scales. A line feature exhibits strong symmetry responses from profiles in all orientations not parallel to the line itself. Symmetry is closely related to periodicity: the symmetry point in the spatial domain corresponds to either a minimum or maximum of its local Fourier components. Thus the detection is carried out by frequency analysis.

The frequency analysis is performed by wavelet transform, which estimates local frequency using complex valued log-Gabor filters. The filters are comprised of an even symmetric (cosine) wavelet and an odd symmetric (sine) wavelet, each modulated by a Gaussian. These filters at different scales respond to particular bands of frequencies. The local frequency information is obtained from the convolution of the wavelet filters with the 2D data. An array of filter response vectors are generated for each point in the signal for each scale. Localized frequency representation is produced from these vectors. The frequency component is represented as a complex number; its real and imaginary parts are the outputs from the even and odd symmetry filter responses, respectively. At the point of symmetry, frequency components are at their amplitude extrema. This corresponds to where the absolute values of the outputs are high from even symmetry filter and low from odd symmetry filter, for all frequencies. This 1D analysis is performed in multiple orientations to extend to 2D analysis (Holden et al., 2008).

An amplitude threshold is then applied to the output symmetry grid, to distinguish cells that contain signal of interest from the background. A lower threshold value leads to the detection of more features, but may also introduce noise in the data. The resulting grid is binary: 1 for regions of interest and dummies for background. The grid is then skeletonized to trendlines. This process also sets the minimum valid line length.

The smallest filter wavelength used in this analysis for the White River area was four cells (equivalent to 160 m), over three scales. The filter sizes were therefore 160 m, 320 m and 640 m. All orientations were considered in the search for symmetry. A threshold value of 0.1 was applied, and a minimum line length of 3 cells (120 m) was set.

Edges were enhanced by computing the balanced horizontal gradient magnitude (TDX) (Cooper and Cowan, 2006) from the RTP grid, as modified by Fairhead and Williams (2006):

$$TDX = \tan^{-1}\left\{\frac{\sqrt{\left([\frac{dRTP}{dX}]^2+[\frac{dRTP}{dY}]^2\right)}}{\frac{dRTP}{dZ}}\right\} \qquad \text{(eq. 4.7)}$$

The first vertical derivative is computed in the Fourier domain whereas the horizontal derivatives in X and Y are computed in the space domain.

The TDX of the pole-reduced magnetic field is a more accurate locator of source edges and less susceptible to noise in the data than other forms of edge detectors. Pilkington and Keating (2009) confirmed that TDX and its analog, “theta mapping”, produce identical results and are the most robust of the edge detection techniques applicable to potential field data.

The positive peak values are extracted by applying an amplitude threshold to the TDX grid to identify cells of interest. The resulting grid is binary and is skeletonized to locate the source edges. In this project, a threshold value of 0.9 was used.

The peaks, troughs and edges generated using the CET methods were not submitted directly for further lineament analysis. The ENCOM grids and TDX images are not presented in this report. However, all of these maps and images were used as guides during the manual interpretation process. The accuracy and reliability of these products were greatly influenced by the resolution of the original magnetic data.

4.2 Gravity

The following four gravity grids and their gravity station locations (32 gravity measurements) were downloaded for the White River area, extracted from the GSC gravity compilation (GSC, 2013) at 2000 m grid cell size:

- Bouguer gravity field (Figure 13);
- First vertical derivative of the Bouguer gravity field (Figure 14);
- Total horizontal gradient of the Bouguer gravity field; and
- Isostatic residual gravity field.

All grids were reprojected to the White River area's coordinate system, UTM16N/NAD83. The first vertical derivative was computed by the GSC using the same methodology applied to the pole reduced magnetic field, as described in Section 4.1. The total horizontal gradient of the Bouguer gravity provided similar results as the first vertical derivative, and therefore was not presented in this report. The isostatic residual compensates for mass deficiencies at depth predicted from topography, preserving the shorter wavelength components of the field due to nearer surface sources. In the White River area, the isostatic residual field closely resembles the Bouguer gravity field due to the relatively gentle topography, and therefore was not presented in this report. The GSC applied standard gravity reduction methods to compute the free air and Bouguer gravity fields. A Bouguer correction density of 2.67 g/cm^3 was applied, the typical value for the Canadian Shield. As the regional data for the White River area were collected in 1965 and earlier, station elevations were likely determined using barometric altimeters (much less accurate than GPS) and terrain corrections were not applied.

4.3 Radiometric

The following seven radiometric grids (radioelement concentrations and ratios) were downloaded for the White River area, extracted from the GSC radiometric compilation (GSC, 2013) at 250 m grid cell size:

- Potassium (K %);
- Thorium (eTh ppm);
- Uranium (eU ppm);
- Total air absorbed dose rate (nGy/h);
- Thorium over potassium ratio (eTh/K);
- Uranium over potassium ratio (eU/K);
- Uranium over thorium ratio (eU/eTh).

The determination of the radioelement concentrations, dose rate and ratios followed the methods and standards published by the International Atomic Energy Agency (IAEA, 2003), many of which were developed at the GSC. All grids were reprojected to the White River area's coordinate system, UTM16N/NAD83. The dose rate is a calibrated version of the measured "total count", and reflects the total radioactivity from natural and man-made sources. The radiometric data are presented in Figure 15 as a ternary RGB image of the three radioelements, with the intensity of potassium (%) displayed in red, equivalent thorium (ppm) in green and equivalent uranium (ppm) in blue. Areas of highest intensity in all three radioelements show light colours and trend towards white. Areas of lowest intensity of all three radioelements are dark colours and trend towards black.

4.4 Electromagnetic

The electromagnetic (EM) surveys typically focus on the greenstone belts, extending into the edges of neighbouring granites and sometimes encompassing smaller plutons (Figure 4). Certain intrusions that have known mineral potential have also been flown (e.g., in the Abitibi Subprovince). Helicopter surveys generally have better signal/noise than fixed wing surveys due to closer proximity of the EM transmitter, EM receiver and magnetometer to the ground.

FDEM surveys typically include a grid of apparent resistivity (conductivity is simply the inverse). Newer surveys have an apparent resistivity for three frequencies reflecting shallower (highest frequency) to deeper (lowest frequency) responses – this helps in discriminating between overburden and bedrock responses. Coplanar coils are more responsive to mapping subhorizontal horizons, whereas coaxial coils are better suited to map subvertical conductors.

All surveys are delivered with an EM anomaly database, where individual anomalies have been picked along flightlines and then classified as bedrock source, surficial source (e.g., overburden) or cultural (e.g., hydro line). Bedrock anomalies usually incorporate a vertical plate or similar model to provide an estimate of depth-to-top and conductivity. The depth values give an indication of overburden thickness, assuming the conductor subcrops.

The analysis of the EM data herein consisted mainly of plotting the EM anomalies over the gridded images provided by OGS and joining bedrock anomalies into quasi-linear conductors, where the character of the EM response remained consistent along strike. Typically, these conductors follow the ductile horizons that are evident in the mapped geology and magnetic data.

For the electromagnetic surveys in the White River area, the following data products were available:

- Oba-Kapuskasing (OGS, 2003) - apparent resistivity grid from the 4,186 Hz coplanar coil pair
- Manitouwadge (OGS, 2002a) - apparent resistivity grids from the 900 Hz, 7,200 Hz and 56,000 Hz coplanar coil pairs;
- Hemlo (OGS, 2002b) - apparent resistivity grid from the 4,500 Hz coaxial coil pair and VLF total field grid;
- Corona Gold magnetic and electromagnetic survey (Fugro, 2008) - apparent resistivity images from the 900 Hz, 7,200 Hz and 56,000 Hz coplanar coil pairs.

All of the data grids were examined. The apparent resistivity grids were converted to apparent conductivity grids by taking the inverse. In the case of Manitouwadge (OGS, 2002a), the mid-frequency grid (7,200 Hz) is displayed in Figure 16. Although it is less reflective of bedrock sources than the low-frequency grid (900 Hz), it is less noisy for this survey and is more directly comparable to the mid-frequency grids available for the other two surveys (OGS, 2002b; 2003).

The images of the apparent resistivity over the Dayohessarah greenstone belt (Fugro, 2008; Figure 17) show the progression from shallow (surficial) at the highest frequency to deeper (bedrock) sources at the lowest frequency.

5 GEOPHYSICAL INTERPRETATION

5.1 Methodology

The coincidence of geophysical units with mapped lithology and structural features were identified and interpreted for the White River area using all available geophysical data sets. In particular, the pole reduced magnetic field and its first vertical derivative were the most reliable for mapping variations in geological contacts, identifying heterogeneity, and delineation and classification of structural lineaments (faults, dykes). The results from the structural lineament interpretations are presented in the lineament report for the White River area (SRK, 2014). The first and second vertical derivatives were used to trace quasilinear magnetic anomaly peaks to emphasize the ductile features. These ductile features are interpreted as being associated with the internal fabric to the rock units and may include in places sedimentary or volcanic layering, tectonic foliation or gneissosity, and magmatic foliation (shown on Figure 9). Enhanced grids of the magnetic field data were used to assist in the interpretation:

- Pole-reduced magnetic field – magnetic units (Figures 5 and 6);
- Pole-reduced first and second vertical derivatives – boundaries, texture, foliation (Figures 7, 8 and 9);
- Tilt angle – subtle magnetic responses (Figure 10); and
- Analytic signal – anomaly character, texture, boundaries (Figure 11).

Gravity data were of insufficient resolution to be used for interpretation of geological units and boundaries. However, some general characterizations of the regional scale units were possible (Figures 13 and 14). Similar comments apply to the radiometric data (Figure 15). The electromagnetic data (Figure 16) were not used for tracing geological contacts as the magnetic data proved greatly superior from a mapping perspective in the White River area. However, certain geological features were evident in the electromagnetic data and are discussed below in the results.

The coincidence of the lithological units with the geophysical data was mainly recognized in the magnetic images from their anomaly amplitude, texture, width, and orientation characteristics. The automated peaks, troughs and edges generated from the magnetic data assisted in more accurate location of contacts. The magnetic anomaly characteristics and geophysical contacts were compared to the current bedrock geologic map in order to identify similarities and/or changes in the lithological contact locations. In some cases, difference in the boundaries determined from the magnetic data and the mapped boundaries may reflect a subsurface response which may not match the mapped surface contacts (e.g., dipping unit) and/or a contact extended through locations with limited outcrop exposure (e.g., under overburden and drainage cover). Results of the coincidence between the geophysical interpretation and the bedrock geologic map are presented in Figure 18. The geophysical data were evaluated against the following published geological maps:

- Ontario Geological Survey, 2011, 1:250,000 scale bedrock geology of Ontario, Miscellaneous Release Data 126-Revision 1 (OGS, 2011) (Figure 2); and

- Ontario Geological Survey, 2001. Precambrian geology compilation series – White River sheet; Map 2666, scale 1:250,000 (Santaguida, 2001).

5.2 Results

The following section presents a regional-scale description and interpretation of each geophysical data set in the White River area, followed by detailed interpretations of geophysical responses of the intrusive rocks (Figure 18). Using the published regional bedrock geology maps as a starting point, the geophysical results discuss the relationship between the interpreted geophysical units and the mapped bedrock lithology for the White River area. Outlines of geophysical units are presented in Figure 18. The geophysical units referred to in this section generally match those of the published regional bedrock geology (OGS, 2011).

5.2.1 Magnetic

The magnetic data over the White River area exhibits variable magnetic responses associated with a number of geological features, including the greenstone belts and discrete intrusions in the Wawa Subprovince. The low-resolution magnetic data coverage in the White River area makes distinction between the different mapped bedrock units difficult. This may result from a lack of magnetic susceptibility contrast between adjacent rock units, or may be due to low-resolution data coverage over the majority of the White River area.

In general, the magnetic data across the Wawa Subprovince show variability associated with the bedrock units that have been mapped in the White River area consisting of granite-granodiorite, foliated tonalite suite and gneissic tonalite suite. In some locations the variability in magnitude and character of the magnetic responses depicts subtle changes that may be associated with contacts between the intrusive bedrock units and changes in internal bedrock lithologies. These changes in magnetic response are best expressed on the maps of the reduced to pole magnetic field (Figure 5), and its first and second vertical derivative grids (Figures 7 and 9). In particular, the magnetic data provides evidence of linear magnetic anomalies with high magnitudes attributed to the presence of dykes, where in many cases these anomalies obscure the response from the intrusive plutons and batholiths in the area. Figure 6 and 8 demonstrate the usefulness of the cosine filter in removing the dyke response based on their characteristic strike direction and emphasizing the magnetic responses associated with the remaining regional-scale bedrock features.

Across the White River area the magnetic responses vary from high intensity in the Strickland pluton in the northeast part of the White River area trending westward through the Black Pic batholith, and a weak response in the Anahareo Lake pluton in the southeast of the White River area (Figure 5). The magnetic responses within these mapped bedrock unit tend to show internal variability in the magnetic intensity, which may indicate a high degree of inhomogeneity. This inhomogeneity may be attributed to variability in the amount of magnetic minerals present. Within the smaller areas with higher resolution coverage, the character of the magnetic data more clearly reflects the anomalies that may reflect discrete geological contacts and curvilinear ductile patterns.

In the White River area the Dayohessarah greenstone belt has been flown with high-resolution magnetic data, where as no known high resolution survey covers the Kabinakagami Lake greenstone belt. These greenstone belts generally show moderate to high curvilinear magnetic anomalies at their core, reflecting intermediate to mafic metavolcanic horizons, with variable strike direction as indicated by the geological mapping. The extent of the interpreted mafic metavolcanics is less than indicated by the published maps, but incorporating the adjacent magnetic lows, which likely reflect intermediate to felsic metavolcanics and/or metasediments, the contacts between the greenstone belts and adjacent rocks correlate well. Magnetic highs outlined in the northwest part of the White River area often overlap or are located adjacent to slivers of mafic metavolcanic rocks, and are attributed to that rock type.

Much of the observed magnetic response in the White River area is associated with the presence of northwest-trending and north to northeast-trending linear high anomalies. These linear anomalies are predominantly mapped as diabase dykes of the Matachewan, Biscotasing and Marathon swarms. The northwest-striking Matachewan dyke swarm is most prominent and shows clear linear magnetic highs across much of the eastern half of the area, and separated into clusters in the western half. The northeast-striking Biscotasing dyke swarm also shows clear linear magnetic highs across much of the White River area. However, these dykes tend to be less prevalent and variable in their spacing compared to the Matachewan dyke swarm, and are slightly more magnetic overall. The Marathon dykes strike north-northeast and are mainly located sporadically throughout the White River area, show a generally lower magnetic amplitude than the other two swarms. These dykes tend to be more poorly sampled due to their trend being near parallel to the dominant flight line directions, and they generally have lower magnetic amplitude compared to the other two swarms. A more comprehensive interpretation of both dyke and fault lineaments in the White River area is include in SRK (2014). In many cases, Matachewan dykes are interpreted to occupy faults and are observed to cross cut the subprovince boundary zone, some of which show offsets along strike.

Despite the widespread dyke activity, few foliation and ductile lineaments are also apparent in areas of higher resolution data and to some extent in the low-resolution data (SRK, 2014). Foliation is restricted to a few intrusions, whereas the curvilinear ductile fabric is apparent in the greenstone belts.

5.2.2 Gravity

The Bouguer gravity data and gravity station locations across the White River area are presented in Figure 13, and its first vertical derivative in Figure 14. Although the gravity data were of insufficient resolution to be used for interpretation of geological units and boundaries, some general characterizations of the regional-scale units were possible.

A regional gravity low is distributed throughout the south-central White River area and correlates well with the granite-granodiorite bedrock of the Anahareo Lake pluton, and to some extent the gneissic tonalite suite of the southern part of the Black Pic batholith. The lowest gravity response is centred 25 km east of White River, suggesting that the Anahareo Lake pluton may thicken in that area. In addition, the gravity data show two prominent regional-scale anomalies with high gravity response associated with the larger greenstone belts in the White

River area, most prominently the Kabinakagami greenstone belt and a smaller amplitude anomaly near the Dayohessarah belt. The anomaly over the Kabinakagami greenstone belt is defined by three gravity stations overlying the mapped greenstone belt, and two gravity stations located a few kilometers outside of the mapped boundary, which may be influenced by greenstone units distributed in the subsurface. The high magnitude point anomaly near the Dayohessarah belt is only limited to a single gravity station measurement which is located a few kilometers outside the mapped boundary, within the Black Pic batholith.

5.2.3 Radiometric

Radiometric data in the White River area were of insufficient resolution to be used for interpretation of geological units and boundaries (Figure 15), although some regional-scale descriptions were possible. In the case where the overburden material is locally derived from the underlying bedrock, it may serve as a proxy when interpreting the radiometric data.

The radiometric data covering the southern part of the White River area shows a high response comprising all three radioelements that extends across several mapped rock types. To some extent, this may reflect higher terrain elevations in this region and less interference from overburden and water cover. This anomalous response increases southwest of the White River area over a large contiguous block of gneissic tonalite that extends to the shore of Lake Superior. In the north, the radiometric responses are generally lower in radioelements which may reflect a higher amount of overburden material in the area as well as the presence of larger water bodies and greenstone belt units. Locally, a few concentrated eU and eTh anomalies are observed, although these anomalies have not been attributed to any known geological feature based on mapping. Most of the geophysical units in this area cannot be differentiated by their radiometric responses.

For the GSC radiometric compilation within the White River area, the radioelement responses are summarized in Table 3.

Table 3. **Radioelement response statistics**

Radioelement	Minimum*	Maximum	Mean
Potassium (%)	0.03	2.38	0.92
Equivalent uranium (ppm)	-0.22	3.85	0.76
Equivalent thorium (ppm)	0.18	20.93	2.95
Natural air absorbed dose rate (nGy/h)	0.76	102.28	23.69

*Negative values are not unusual due to the statistical nature of gamma-ray spectrometer data and grid interpolation effects.

These levels are typical of those found in granite-greenstone terrain (IAEA, 2003).

The generally low uranium levels suggest low radon risk. However, radon risk is also quite dependent on soil permeability and should be verified by soil gas measurements (IAEA, 2003). The highest uranium response in the area is located in the northeast corner of the Pukaskwa batholith a few km north of White River.

5.2.4 Electromagnetic

The electromagnetic (FDEM) data shown in Figures 16 and 17 presents the distribution of apparent conductivity within the survey areas, which covers roughly 15% of the White River area.

The apparent conductivity data from survey GDS1024 (OGS, 2003) shows high magnitude responses that tend to be mainly coincident with the location of small lakes and larger water bodies, as well as with locations of mapped overburden deposits. These highly conductive anomalies are most likely associated with conductive sediments in the lake bottoms and within the overburden units. Smaller high magnitude anomalies in this survey area may also be coincident with the location of mapped mafic metavolcanic horizons within the Kabinakagami greenstone belt; however the coincidence does not appear to be strong. In locations where bedrock is exposed, the apparent conductivity tends to be uniformly low suggesting that the bedrock in the survey area is electrically resistive.

Survey GDS1205 (OGS, 2002a) similarly shows bedrock units as having a uniformly low apparent conductivity, with localized high magnitude anomalies associated with either conductive overburden or lake sediments. Locally, a few linear conductivity anomalies have been observed, particularly in the eastern side of the survey. These anomalies tend to be coincident with the location of north-northeast trending linear magnetic features corresponding to dykes, as well as the presence of minor north-northeast trending drainage features. In this case, the apparent conductivity response may result from electrically conductive minerals either with the drainage related sediments, or from the bedrock itself.

Similar to the other surveys, apparent conductivity data from survey GDS1207 (OGS, 2002b) shows small high magnitude responses that tend to be mainly coincident with the location of small lakes and larger water bodies, as well as with locations of mapped overburden deposits. In addition, some of the stronger conductivity values are mainly coincident with cultural features along the northern part of the survey area, such as the railway, the main road, and the hydro-line. The coverage of GDS1207 is focused on the Bremner pluton, which is electrically resistive. A ring of conductive responses towards the margin partially correlates with wetlands and creeks, mixed in with the above-mentioned cultural sources. The magnetic, EM and topographic data indicate an oval-shaped intrusion at the southeast limit of the larger “spoon-shaped” Bremner pluton. The responses can be generalized as electrically resistive bedrock and fairly extensive conductive cover (overburden and drainage-related sediments).

Most of the conductivity apparent in the Corona Gold survey (Fugro, 2008), particularly at the higher frequencies, are highly correlated with drainage (Figure 17). Some discrete bedrock conductors are also apparent, particularly at 900 Hz, as north-northwest to north-striking anomalies that are coincident with or subparallel to ductile, mafic magnetic stratigraphy in the Dayohessarah greenstone belt.

5.3 Geophysical Interpretation of the Prospective Geology in the White River Area

The following section provides more detailed interpretations with a focus on the prospective bedrock geology in the White River area. These interpretations include a description of the geophysical characteristics of each bedrock unit, as well as a refinement of their geologic contacts, where possible, and the identification of internal heterogeneities within the structures where present. These interpreted features are presented alongside the current bedrock geology mapping on Figure 18, noting that the interpretations are preliminary and require future geologic validation.

5.3.1 Black-Pic Batholith

The Black-Pic batholith is mapped by the OGS as regionally-extensive intrusion within the Wawa Subprovince, and underlies the northwest portion of the White River area (Figure 18). The bedrock geology is predominantly mapped as gneissic tonalite suite, with lesser amounts of mafic volcanics resulting in a number of different magnetic responses. Magnetic units A (north half) and B to E tend to correlate with the gneissic tonalite suite of the Black-Pic batholith (Figure 18). However, coincidence between the outlines of these magnetic responses and the bedrock geology tends to be hindered by both the presence of low resolution data, and the abundance of dykes cutting through the Black-Pic batholith.

Within the northwestern portion of the White River area, geophysical units A, D and E tend to show fairly uniform and weaker background magnetic responses associated with the Black-Pic batholith. These responses tend to be predominant throughout most of the Black-Pic batholith in the White River area and may be attributed to a lack of dyke response present in these areas, as well as a decrease in magnetic minerals of the bedrock lithology. Unit B shows an elevated magnetic response, matching a similar magnetic response to that over the Strickland Lake pluton (unit L) to the east on the opposite side of the Dayohessarah greenstone belt. The higher magnetic responses associated with these geophysical units may reflect an abundance of magnetic minerals of the bedrock lithology, as well as an increased presence of diabase dykes. In general, much of the variability in magnetic responses shown within the Black-Pic batholith presumably corresponds to numerous generations of intrusions as well as younger granitic rock phases identified within the batholith (Jackson et al., 1998; Zaleski et al., 1999).

The eastern boundary of the Black-Pic batholith (units A, B and E) tends to be clearly bounded by the Dayohessarah greenstone belt, in which the edge of the greenstone belt units correspond to a weak response in the reduced to pole magnetic data (Figure 5) as well as low variability in the vertical derivatives. Locally, highly altered remnants of greenstone belt units are variability mixed within the Black-Pic batholith (Fenwick, 1967), which tend to show elongated higher magnitude responses (e.g. two zones within central part of unit A near the southern margin of the batholith). These responses in the magnetic data are broadly coincident with thin greenstone units shown on the bedrock geology map (Figure 18).

The gravity response over the Black-Pic batholith is relatively flat with moderate amplitude, in contrast to the high associated with the Dayohessarah greenstone belts and the lows over the Strickland pluton, Anahareo Lake pluton and parts of the Pukaskwa batholith. This suggests that the Black-Pic batholith may be composed of denser rock or may reflect a thinner intrusive unit compared to others in the White River area. Additionally, the Black-Pic batholith generally shows low radioelement responses, at least partly due to lower elevation, resulting in more wetlands and drainage. The minimal FDEM coverage over the batholith shows it to be of uniformly low conductivity, with local higher conductivities associated with water bodies, drainage features and overburden units.

5.3.2 Pukaskwa Batholith

The Pukaskwa batholith is a regionally extensive intrusion in the Wawa subprovince bounded to the north by the Strickland pluton, the Danny Lake stock and the Black-Pic batholith (Santaguida, 2001). Bedrock units, as shown on the bedrock geology map, consist of gneissic tonalite suite and foliated tonalite suite (Figures 2 and 18). These units tend to show a distribution of predominantly weak to moderate magnetic response across the southern part of the White River area, in particular compared to the Black-Pic batholith and the Strickland pluton (Figure 5).

Within the southern portion of the White River area, the southern part of unit A within the Pukaskwa batholith shows a fairly uniform and weak background magnetic response that is indistinguishable from the northern part of this unit interpreted over the Black-Pic batholith. Within the Pukaskwa batholith, unit A correlates fairly well with the mapped foliated tonalite suite. Unit A encompasses most of the Danny Lake stock and the nearby Tedder granite pegmatite intrusion located northeast of White River (Stott, 1999), neither of which shows a distinct magnetic response. Due to the small size and undefined shape of the Tedder intrusion, the outline of the Tedder granite pegmatite intrusion is not shown on Figures 2 or 18.

To the east, the western part of unit F encompasses an area of fairly uniform and low background magnetic response which is associated with the gneissic tonalite suite that extends east and northeast of White River within the Pukaskwa batholith. This geophysical unit shows a generally flat response and low amplitude and incorporates most of a band of east-west striking metasediments (unit G). These metasediments are reflected by a slightly lower magnetic response with a strike that cuts the northwest-oriented magnetic responses associated with the dykes. The contacts between unit F and adjacent magnetic units do not correspond particularly well with the boundaries of the mapped geological units (Figure 18). This discrepancy may partially result from the crudely defined boundaries of the batholith that have been mapped at a reconnaissance scale (Milne et al., 1972; Santaguida, 2001). The slightly higher magnetic responses associated with geophysical unit H may reflect a subtle increase in background magnetic response reflecting the increased presence of magnetic minerals of the bedrock lithology, as well as locally an increased response from the diabase dykes present. The distribution of the geophysical units throughout the Pukaskwa batholith may broadly reflect the distribution of multi-phased intrusions that comprise the entire batholith body (Stott, 1999; Beakhouse and Lin, 2006; Beakhouse et al., 2011).

Along the northern part of the Pukaskwa batholith, Unit O represents a relatively strong magnetic response, which extends over the mapped boundary into the Black-Pic batholith (Figure 18). This unit is much more magnetic than the remainder of either the Pukaskwa or

Black-Pic batholith. This may reflect variations in the degree of metamorphism preserved in the bedrock, or changes in lithology. The boundary between high and low resolution data made identifying the geophysical unit boundary difficult. Despite this, the similarity of magnitude between units O and N suggests that the two units may be related. Although unit N extends east over the mapped Pukaskwa batholith, it has a distinct high magnetic response with concentric foliation that is interpreted to reflect the Bremner pluton (Thompson, 2006). This discrepancy may suggest the Bremner pluton extends to depth, or the reconnaissance level bedrock geology mapping may be updated. Jackson et al. (1998) and Muir (2000) have identified the Bremner pluton to extend into the White River area, although the eastern boundary of the pluton is poorly constrained.

A discrete gravity low occurs over a significant portion of the Pukaskwa batholith, particularly corresponding to magnetic unit F interpreted from the magnetic data, and extending westwards over units A and H. This gravity response may reflect a thicker portion of the batholith. In places due to the limited distribution of gravity stations, this gravity low also extends well into the Anahareo Lake pluton. The radiometric responses are relatively high in all three radioelements over the Pukaskwa batholith, which tends to partially correspond to higher elevation resulting in more exposed bedrock. Although the data is of low resolution, the radiometric responses are broadly coincident with the mapped portion of the Pukaskwa batholith. The FDEM coverage in the Pukaskwa batholith is extremely limited and indicates a fairly uniform low conductivity response, whereas the local high conductivity responses are generally associated with overburden deposits and drainage features.

5.3.3 Anahareo Lake Pluton

The Anahareo Lake pluton is a large felsic intrusion located within the southern and southeastern parts of the White River area (Figure 2). The bedrock geology consists solely of granite to granodiorite based on the bedrock geology map, which shows a fairly uniform distribution of weak magnetic response (Figure 5), where the interpreted magnetic units (eastern part of unit F and Units I to K) are subdivided based on variations in magnetic response, mainly intensity (Figure 18). Foliation is evident at a few locations but is generally lacking due to the low-resolution data and ubiquity of dyke responses. Unit I, located along the easternmost portion of the Anahareo Lake pluton in the White River area, shows increased variability in the northwest trending dyke responses. Additionally, this response contrasts sharply with the adjacent geophysical units F and K, which show pronounced magnetic lows with weaker dyke responses present. Although the dyke responses shown in unit I are elevated in magnitude, the background magnetic responses of the pluton tend to be weak, similar to the remaining geophysical unit responses. The magnetic responses of unit F reflect the lowest magnitudes within the Anahareo Lake pluton, which is bounded on its northern side by slightly weaker responses of the metavolcanic and metasedimentary units of the Kabinakagami Lake greenstone belt. Unit J reflects an area of higher background magnetic response relative to the surrounding unit F, a contrast that is better defined immediately south of the White River area. The magnetic amplitude of unit J increases gradually towards the southeast, reflecting a greater number of dykes present. Siragusa (1977, 1978) suggest that the Anahareo Lake pluton bedrock is relatively uniform and appears to represent multi-phase intrusions. The lower responses associated with units F and K, as compared to units I and J, could reflect different phases of the pluton in addition to the variability introduced by the northwest trending dykes.

A regional gravity low correlates well with the granite-granodiorite of the Anahareo Lake pluton, particularly with interpreted magnetic units F and J. The strongest low is centred 25 km east of White River, suggesting that the Anahareo Lake pluton thickens in that area. The exposed southern part of the Anahareo Lake pluton, other than over the lakes, shows relatively high radioelement responses, whereas the subdued responses further north occur in areas of overburden cover. There is no FDEM coverage over this pluton.

5.3.4 Strickland Pluton

The Strickland pluton occurs in the northeast portion of the White River area bordering the Dayohessarah greenstone belt to the west and Kabinakagami greenstone belt to the southeast. The greenstone units tend to show a well defined magnetic response that allows these geological contacts as well as adjacent Strickland pluton contacts to be interpreted without great difficulty.

The granite-granodiorite of the Strickland pluton is subdivided into magnetic units F (northern part), L and M in the northeast part of the White River area (Figure 18). The pluton is dominated by a moderate to strong magnetic response, where individual units are predominantly characterized by variations in magnetic intensity, as well as variations in limited foliation and dyke intensity. Although broad geophysical units are identified, the geological contacts are generally inconsistent with the geophysical units due to the low-resolution data and ubiquity of dyke responses. Unit L shows a higher background magnetic intensity comprising the majority portion of the mapped Strickland pluton (Figure 18). The magnetic field decreases gradationally to the southwest which reflects, at least partially, a reduced number of northwest-striking dykes. The northern part of unit F shows the lowest magnetic intensity which tends to represent a gradational change from unit L of the Strickland pluton into the gneissic tonalite of the Pukaskwa batholith to the south. Units B and C show more moderate responses. All three geophysical units bound the Kabinakagami greenstone belt to the southeast, as well as units F and L bound the Dayohessarah greenstone belt to the west. The higher magnetic response associated with unit M may indicate that it incorporates slivers of metavolcanic rocks associated with the Kabinakagami greenstone belt. Most if this unit lies over Kabinakagami Lake. Although these greenstone belts tend to show fairly distinct magnetic low responses along their boundaries, their responses do not precisely coincide with the mapped geological contacts on the bedrock geology maps (Figure 18). The distributions of the geophysical units throughout the Strickland pluton are assumed to reflect changes of lithology and associated mineralogy.

Gravity data over the Strickland pluton does not show a correspondence to the geometry shown on the bedrock geology map. A regional gravity low over the Anahareo Lake pluton extends northwards through the centre of the Strickland pluton, possibly reflecting a thickening of the latter at that location. The radioelement concentrations are generally low other than towards the southwest, perhaps reflecting inhomogeneities within the pluton. There is no FDEM coverage over this pluton.

5.3.5 Danny Lake Stock

The Danny Lake stock, composed of diorite-monzonite-granodiorite, cannot be distinguished by its magnetic response from the neighbouring batholiths and plutons, although there is a contrast with the lower response of the Dayohessarah greenstone belt along its eastern contact, as well as locally, high magnetic responses from greenstone slivers within the northern portion of the Danny Lake stock. The central part of magnetic unit A covers the stock (Figure 18).

Gravity data over the Danny Lake stock are extremely sparse, with only a single station measurement located along the northern contact. The gravity response tends to be relatively flat and represents regional changes between a gravity high associated with the Dayohessarah greenstone belt to the northeast and a gravity low in the northern part of the Pukaskwa batholith to the southwest. The stock is located where the radioelement responses transition from higher concentrations in the southern part of the White River area to lower concentrations in the north. The FDEM images (Figure 17) that cover the western margin of the stock indicate that it is resistive.

5.3.6 Other Plutons

Unit N abuts the western boundary of the White River area (Figure 18). It delineates the eastern part of the Bremner pluton which extends several kilometres to the northwest. It shows curvilinear foliation of various orientations with some concentric patterns. It is located on the eastern margin of the Hemlo greenstone belt, described by Thompson (2006) as one of three late synorogenic intrusions, with metamorphism to upper greenschist at some locations. As discussed in section 5.3.2, the higher magnetic response of unit O to the north may be associated with the Bremner pluton rather than the gneissic and foliated tonalites of the Black-Pic batholith mapped in that area.

Unit P covers the southeast part of the Bulldozer Lake gabbro intrusion (informal name) in the northwest corner of the White River area, most of which is located northwest of the boundary. The intrusion shows some concentric foliation along its margins and variable internal fabric. Its strong magnetic response and fabric clearly contrasts with the weaker and fairly uniform response of the surrounding Black-pic batholith. The intrusion’s contact interpreted from the magnetic data agrees quite well with the mapped contact.

6 SUMMARY OF RESULTS

The purpose of this assessment was to identify and obtain the available geophysical data for the Township of White River and surrounding area, followed by a detailed interpretation of all available geophysical data (e.g., magnetic, electromagnetic, gravity and radiometric) to identify additional information that could be extracted from the data, in particular regarding the coincidence of geophysical features with mapped lithology and structural features in the White River area.

The geophysical data covering the White River area show variability in data set resolution. Low-resolution geophysical data, particularly the magnetic, gravity and radiometric data obtained from the Geological Survey of Canada (GSC), cover the entire White River area. Three additional magnetic/electromagnetic surveys obtained from the Ontario Geological Survey (OGS) provided higher resolution coverage over approximately 10% on the margins of the White River area. Images from a high-resolution magnetic/electromagnetic survey assessment file (Fugro, 2008) provide coverage of the Dayohessarah greenstone belt.

The coincidence between the geophysical data and the mapped lithology were interpreted using all available geophysical data sets (e.g., magnetic, electromagnetic, gravity and radiometric). The interpretation honoured the dykes, faults and other structure prepared by SRK (2014). In particular, the pole reduced magnetic field (RTP) and its first vertical derivative (1VD) were the most reliable for mapping variations in geological contacts and identifying heterogeneity. At a regional scale, the coincidence between the interpretation of geophysical units and the published geological maps is locally in good agreement.

Across the White River area, magnetic responses vary from high intensity in the Strickland pluton in the northeast part of the White River area trending westward through the Black Pic batholith, and a weak intensity in the Anahareo Lake pluton in the southeast of the White River area. Within the northwestern portion of the White River area, geophysical units A, D and E tend to show fairly uniform and weaker background magnetic responses associated with the Black-Pic batholith. These responses tend to be predominant throughout most of the Black-Pic batholith in the White River area and may be attributed to a lack of dyke response present in these areas, as well as a decrease in magnetic minerals of the bedrock lithology. Unit B shows an elevated magnetic response, matching a similar magnetic response to that over the Strickland Lake pluton (unit L) to the east on the opposite side of the Dayohessarah greenstone belt. The higher magnetic responses associated with these geophysical units may reflect an abundance of magnetic minerals of the bedrock lithology, as well as an increased presence of diabase dykes. In general, much of the variability in magnetic responses shown within the Black-Pic batholith presumably corresponds to numerous generations of intrusions as well as younger granitic rock phases identified within the batholith (Jackson et al., 1998; Zaleski et al., 1999).

The southern part of unit A within the Pukaskwa batholith shows a fairly uniform and weak background magnetic response that is indistinguishable from the northern part of this unit interpreted over the Black-Pic batholith. Within the Pukaskwa batholith, unit A correlates fairly well with the mapped foliated tonalite suite. To the east, the western part of unit F encompasses an area of fairly uniform and low background magnetic response which is associated with the gneissic tonalite suite that extends east and northeast of White River within the Pukaskwa batholith. The distribution of the geophysical units throughout the Pukaskwa batholith may broadly reflect the distribution of multi-phased intrusions that comprise the entire batholith body (Stott, 1999; Beakhouse and Lin, 2006; Beakhouse et al., 2011). These magnetic units do not correspond particularly well with the boundaries of the mapped geological units (Figure 18).

The bedrock geology of the Anahareo Lake pluton consists solely of granite to granodiorite based on the bedrock geology map, which shows a fairly uniform distribution of weak magnetic response (Figure 5). Siragusa (1977, 1978) suggest that the Anahareo Lake pluton bedrock is relatively uniform and appears to represent multi-phase intrusions. The lower magnetic responses and weaker dyke responses associated with units F and K, as compared to units I and J (Figure 18), could reflect different phases of the pluton in addition to the variability introduced by the northwest trending dykes.

The granite-granodiorite of the Strickland pluton is subdivided into magnetic units F (northern part), L and M in the northeast part of the White River area (Figure 18). The pluton is dominated by a moderate to strong magnetic response, where individual units are predominantly characterized by variations in magnetic intensity, as well as variations in limited foliation and dyke intensity. Unit L shows a higher background magnetic intensity comprising the majority portion of the mapped Strickland pluton (Figure 18). The northern part of unit F shows the lowest magnetic intensity which tends to represent a gradational change from unit L of the Strickland pluton into the gneissic tonalite of the Pukaskwa batholith to the south. Units B and C show more moderate responses.

Much of the observed magnetic response in the White River area is associated with the presence of northwest-trending and north to northeast-trending diabase dykes responses attributed to the Matachewan, Biscotasing and Marathon swarms. The northwest-striking Matachewan dyke swarm is most prominent and shows clear linear magnetic highs across much of the eastern half of the area, and separated into clusters in the western half. The northeast-striking Biscotasing dyke swarm also shows clear linear magnetic highs across much of the White River area. However, these dykes tend to be less prevalent and variable in their spacing compared to the Matachewan dyke swarm, and are slightly more magnetic overall. The Marathon dykes strike north-northeast and are mainly located sporadically throughout the White River area, show a generally lower magnetic amplitude than the other two swarms.

The greenstone belts in the White River area generally show moderate to high curvilinear magnetic anomalies at their core, reflecting intermediate to mafic metavolcanic horizons, with variable strike direction as indicated by the geological mapping. The extent of the interpreted mafic metavolcanics is less than indicated by the published maps, but incorporating the adjacent magnetic lows, which likely reflect intermediate to felsic metavolcanics and/or metasediments, the contacts between the greenstone belts and adjacent rocks correlate well. Magnetic highs outlined in the northwest part of the White River area often overlap or are located adjacent to slivers of mafic metavolcanic rocks, and are attributed to that rock type.

Resolution of the gravity data were insufficient to be used for interpretation of geological units and boundaries. However, some general characterizations of the regional scale geological units were possible. The gravity data show higher responses associated with the larger greenstone belts, most prominently with the Kabinakagami greenstone belt and smaller amplitude anomalies over the Dayohessarah belt and the east end of the Hemlo belt. Regional gravity lows correlate well with the granite-granodiorite of the Strickland pluton and Anahareo Lake pluton. A discrete gravity low is centred on the northern half of the Pukaskwa batholith.

Radiometric responses due to the presence of potassium, uranium and thorium related minerals are typically elevated in granitic rocks compared to volcanic rocks, and this relationship is seen in the White River area. The radiometric data show a swath of well-defined high response in all three radioelements that traverses the entire White River area, covering the southern 40%, across several mapped rock types and geophysical units. To some extent, this reflects the higher elevations in this region, leading to fresher bedrock exposure and less interference from overburden and water cover. This anomalous response increases southwest of the White River area over a large contiguous block of gneissic tonalite that extends to the shore of Lake Superior, and encompasses gneissic tonalite southeast of the area as well. Within the White River area, this area of high response extends across most of the Pukaskwa batholith and Strickland pluton, suggesting that the gneissic tonalite is more widespread than heretofore mapped. In the north, the radiometric responses are generally low, reflecting to some extent more overburden, water cover and the greenstone belts. Most of the geophysical units in this area cannot be differentiated by their radiometric responses.

The electromagnetic (FDEM) data and images cover roughly 15% of the White River area. The responses can be generalized as electrically resistive bedrock and fairly extensive conductive cover (overburden and drainage-related sediments). Survey GDS1024 shows conductive responses in bedrock associated with magnetic mafic metavolcanic horizons in the Kabinakagami greenstone belt as well as conductive overburden responses under the lakes. The coverage of GDS1207 is focused on the Bremner pluton, which is electrically resistive. The magnetic, and EM data indicate an oval-shaped intrusion at the southeast limit of the Bremner pluton. Survey GDS1207 similarly shows resistive bedrock where exposed and conductive overburden in low-lying areas. The Bulldozer Lake gabbro intrusion shows concentric patterns in the EM data. FDEM images from an assessment file over the over the Dayohessarah greenstone belt show discrete bedrock conductors associated with mafic volcanic horizons.

Respectfully Submitted,

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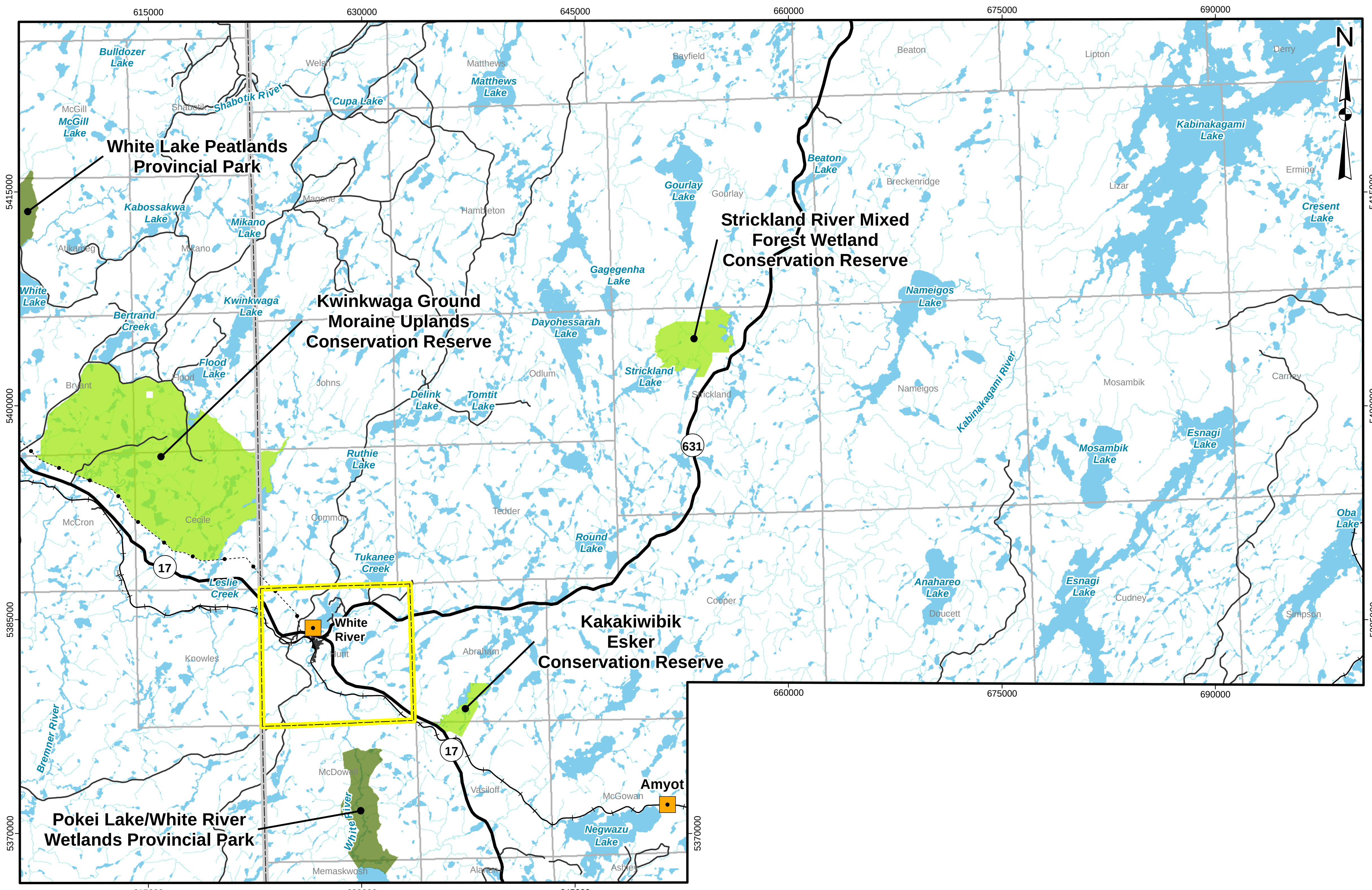
FIGURES



Legend

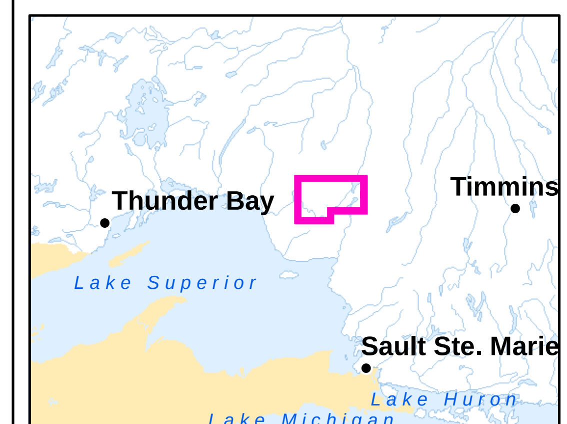
- Settlement
- White River Municipal Boundary
- Township Boundary
- District Boundary
- Main Road
- Local Road
- Railway
- Abandoned Railway Right-of-way
- Hydro Line

Water Features

- 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

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AECOM

PROJECT

Phase 1 Geoscientific Desktop Preliminary Assessment
Geophysical Study, White River

TITLE

Township of White River and Surrounding Area

DESIGN	KR	23 AUG 2013	Figure 1	REVISION 1.1
GIS	GF	29 AUG 2013		UTM ZONE 16
CHECK	SR	25 FEB 2014		NAD 1983
REVIEW	MA	26 FEB 2014		1:300,000

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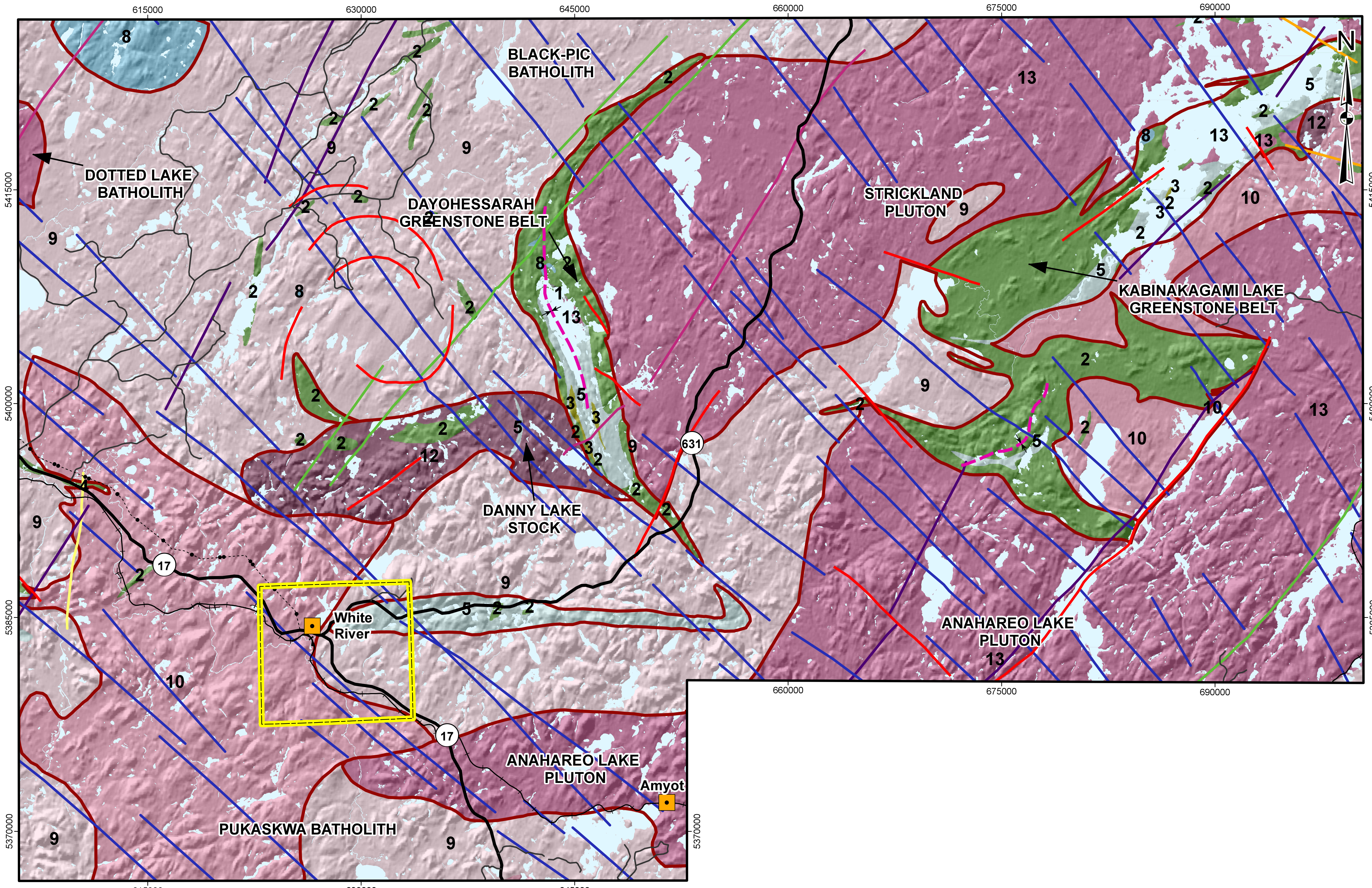


Legend

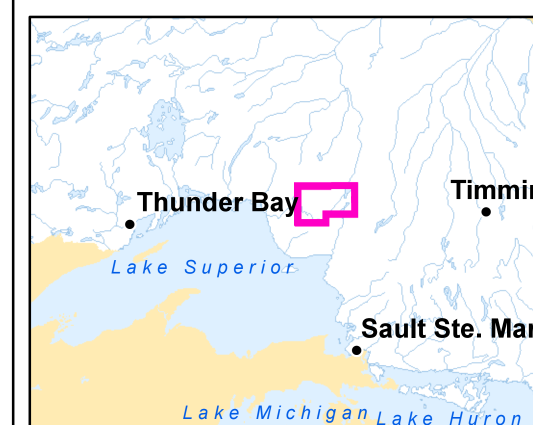
- Settlement
- White River Municipal Boundary
- Main Road
- Local Road
- Railway
- Abandoned Railway Right-of-way
- Hydro Line
- Waterbody
- Faults
- Major Fold (Syncline Approximate)
- Bedrock Geology Contact

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

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AECOM

PROJECT
Phase 1 Geoscientific Desktop Preliminary Assessment
Geophysical Study, White River

TITLE
Bedrock Geology of the Township of White River and Surrounding Area

DESIGN	KR	23 APR 2013	**Figure 2**	REVISION 1.2
GIS	GF	17 OCT 2013		UTM ZONE 16
CHECK	SR	3 SEPT 2014		NAD 1983
REVIEW	MA	3 SEPT 2014		1:300,000

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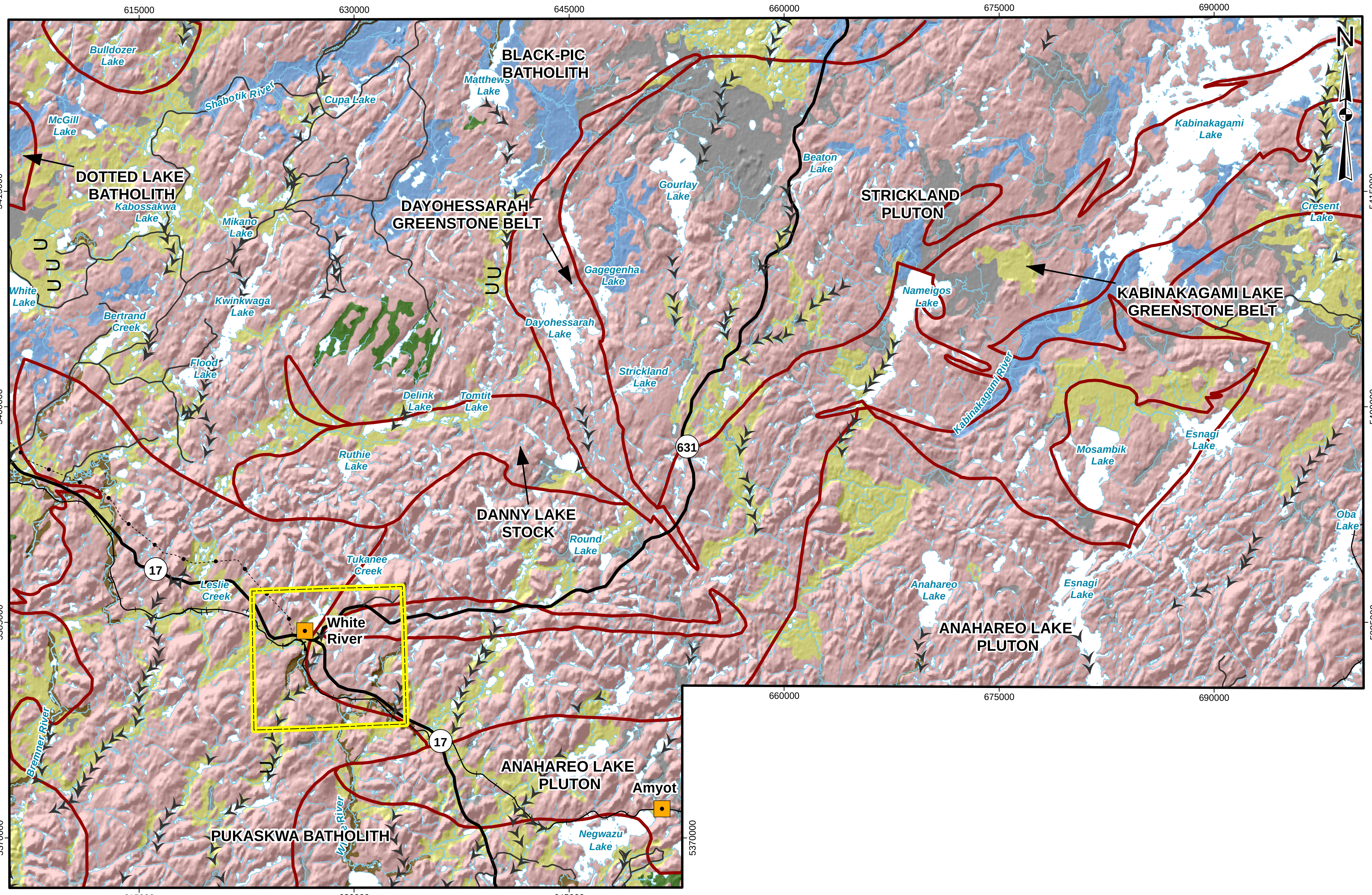


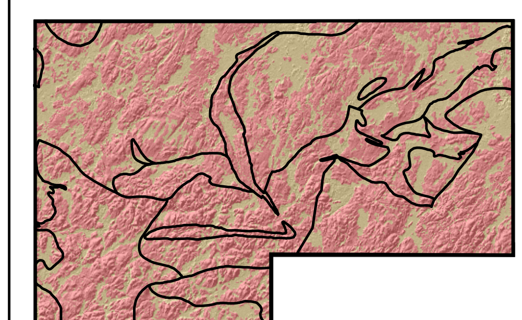
Legend

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

Surficial Geology

- Morainal Terrain
- Glaciofluvial Terrain
- Glaciolacustrine Terrain
- Alluvial Terrain
- Organic Terrain
- Bedrock Terrain
- Sand Dunes
- Eskers

MAP OF SURFICIAL LANDFORMS AND WATERBODIES



Bedrock Geology Contact   Surficial/Water (35%)   Bedrock Terrain (65%)

Data Sources:
Base Data: MNR LIO, obtained 2009-2013
Overburden: OGS MRD-160, NOEGTS 2006
Intrusions: Generalized from OGS M2666, 2001 (1:250,000)
Underlay: Hillshade DEM, MNR Elevation and Slope

10 km

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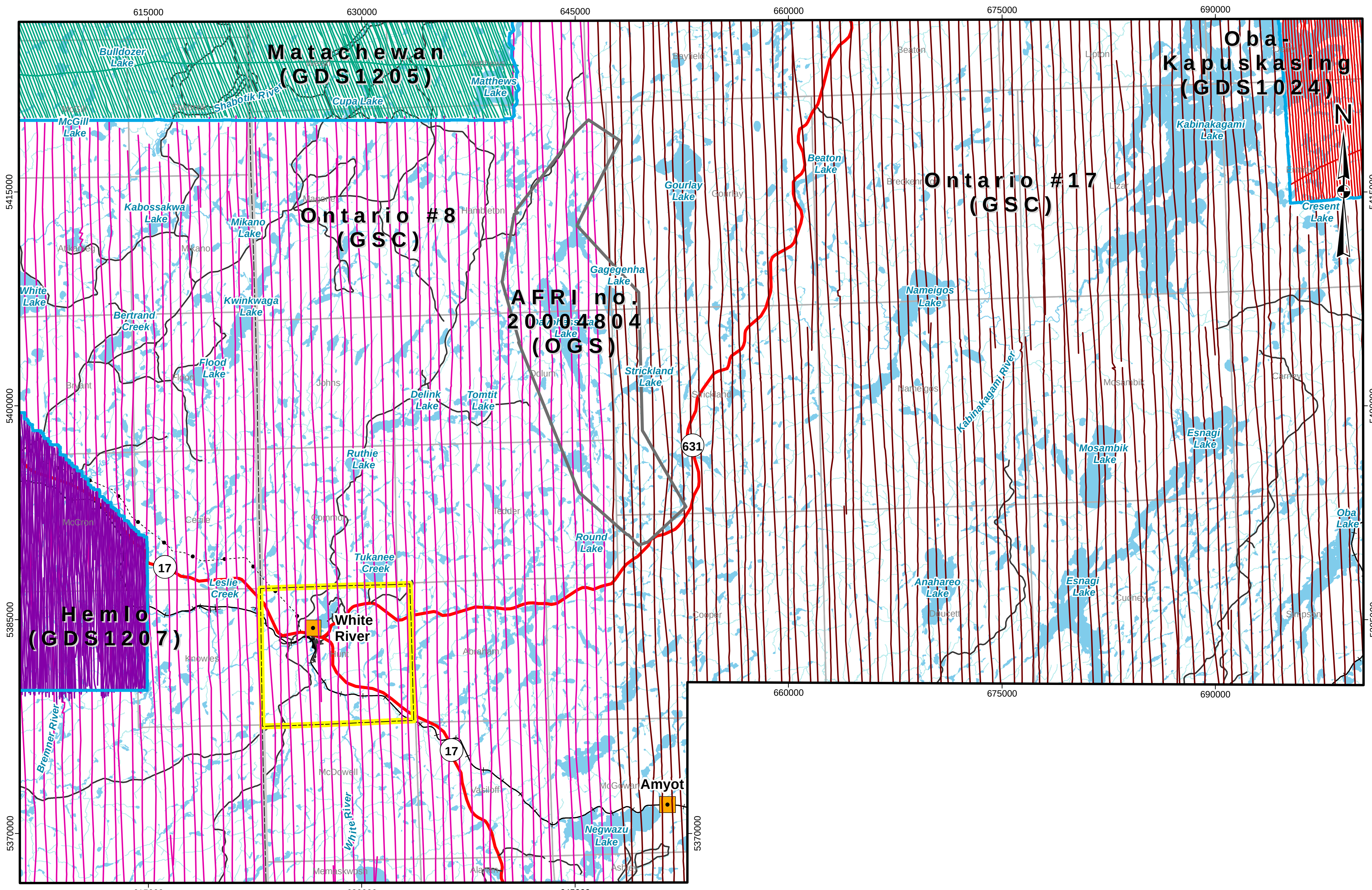
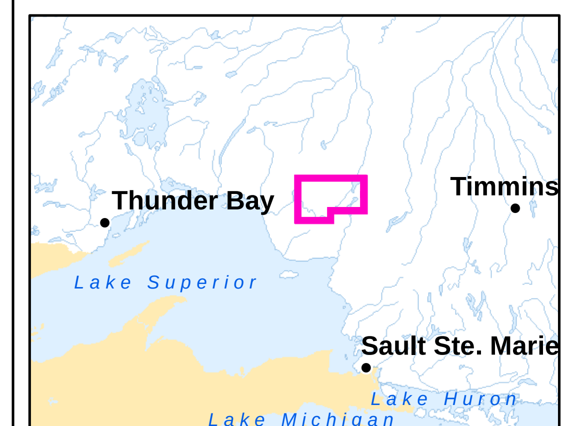
PROJECT
Phase 1 Geoscientific Desktop Preliminary Assessment
Geophysical Study, White River

TITLE
Surficial Geology of the Township of White River and Surrounding Area

DESIGN	KR	23 Apr 2013	Figure 3	REVISION 1.1
GIS	KR	16 OCT 2013		UTM ZONE 16
CHECK	SR	25 FEB 2014		NAD 1983
REVIEW	MA	26 FEB 2014		1:300,000

Path: C:\Users\Stephen\PGW\2013-18\Proc\maps\ArcGIS\Feb 2014\White River\Fig3_PGW_White_River_Surficial_Geology_Draft.mxd





Legend

- Settlement
- White River Municipal Boundary
- Township Boundary
- District Boundary
- Main Road
- Local Road
- Railway
- Abandoned Railway Right-of-way
- Hydro Line
- Waterbody
- Watercourse
- High resolution geophysical survey outlines
- Industry geophysical survey outlines
- Flightpath OGS GDS1024 Oba-Kapuskasing
- Flightpath OGS GDS1205 Manitouwadge
- Flightpath OGS GDS1207 Hemlo
- Flightpath GSC Ontario #8
- Flightpath GSC Ontario #17

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

Geophysics: Geological Survey of Canada - Aeromagnetic Surveys - Ontario #8, Ontario #17
Ontario Geological Survey - Geophysical Surveys - GDS1024, GDS1205, GDS1207
- Geology Ontario - AFRI no. 20004804

10 km

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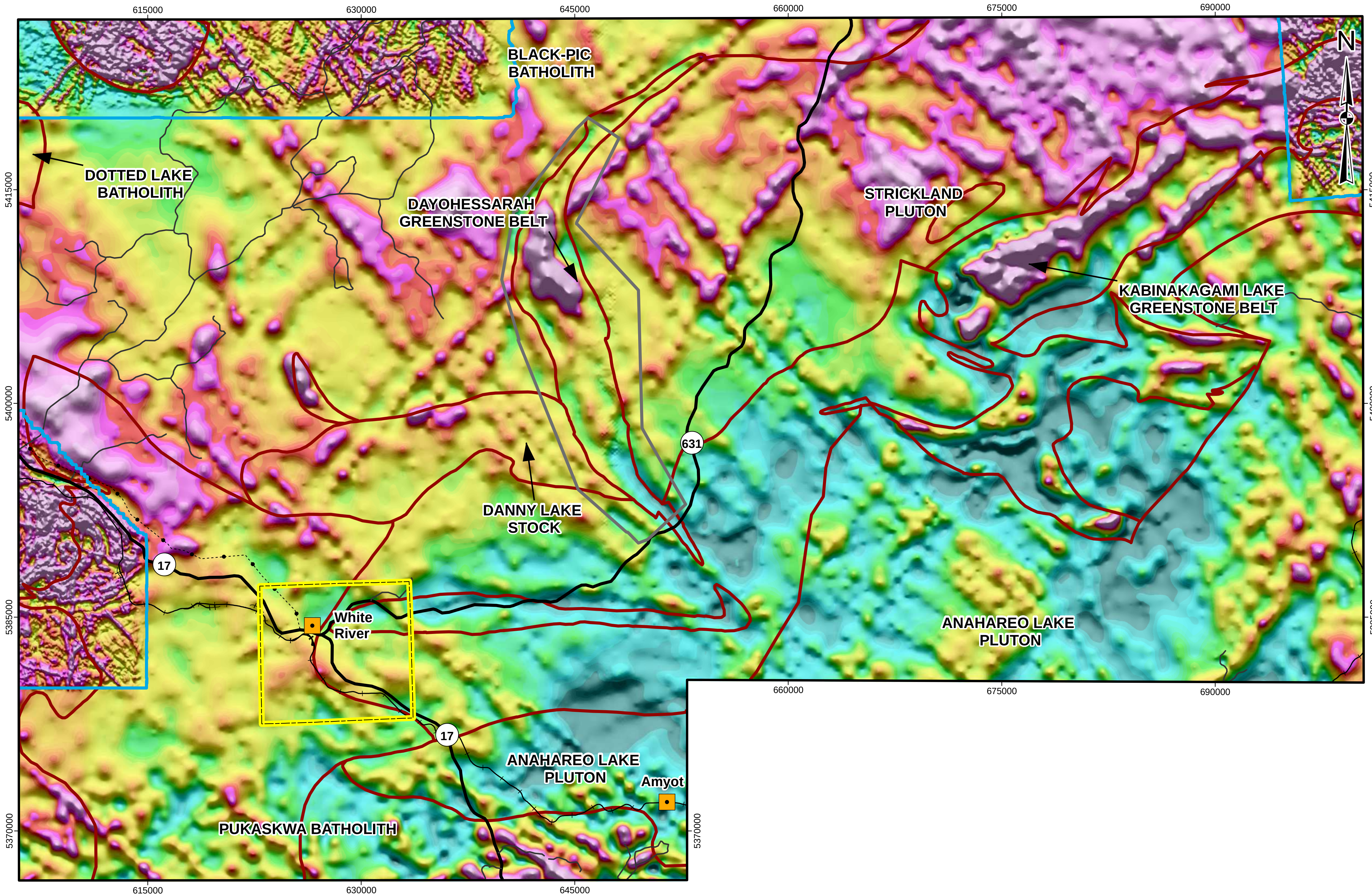
PROJECT
Phase 1 Geoscientific Desktop Preliminary Assessment
Geophysical Study, White River

TITLE
Airborne Geophysical Coverage of the Township of White River and Surrounding Area

DESIGN	KR	23 AUG 2013	Figure 4	REVISION 1.1
GIS	GF	29 AUG 2013		UTM ZONE 16
CHECK	SR	25 FEB 2014		NAD 1983
REVIEW	MA	26 FEB 2014		1:300,000

Path: C:\Users\Stephen\PGW\2013-18\Proc\maps\ArcGIS\Feb 2014\White River\Fig4_PGW_White_River_Flightpath_Draft.mxd

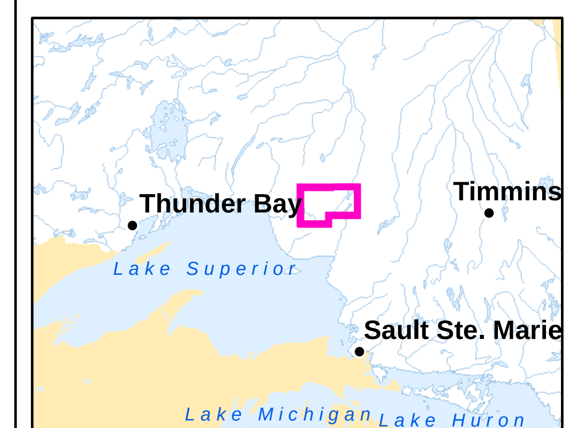


Legend

- Settlement
- White River Municipal Boundary
- Main Road
- Local Road
- Railway
- Abandoned Railway Right-of-way
- Hydro Line
- Bedrock Geology Contact
- High resolution geophysical survey outlines
- Industry geophysical survey outlines

Pole-reduced Magnetic Field (nT)

2374, 148, 100, 72, 52, 38, 26, 14, 4, -4, -12, -20, -28, -36, -44, -50, -58, -68, -76, -84, -92, -102, -112, -122, -132, -146, -160, -176, -200, -370



Data Sources:
Base Data: MNR LIO, obtained 2009-2013
Geophysics: Geological Survey of Canada - Aeromagnetic Surveys - Ontario #8, Ontario #17
Ontario Geological Survey - Geophysical Surveys - GDS1024, GDS1205, GDS1207
- Geology Ontario - AFRI no. 20004804
Intrusions: Generalized from OGS M2666, 2001 (1:250,000)

10 km

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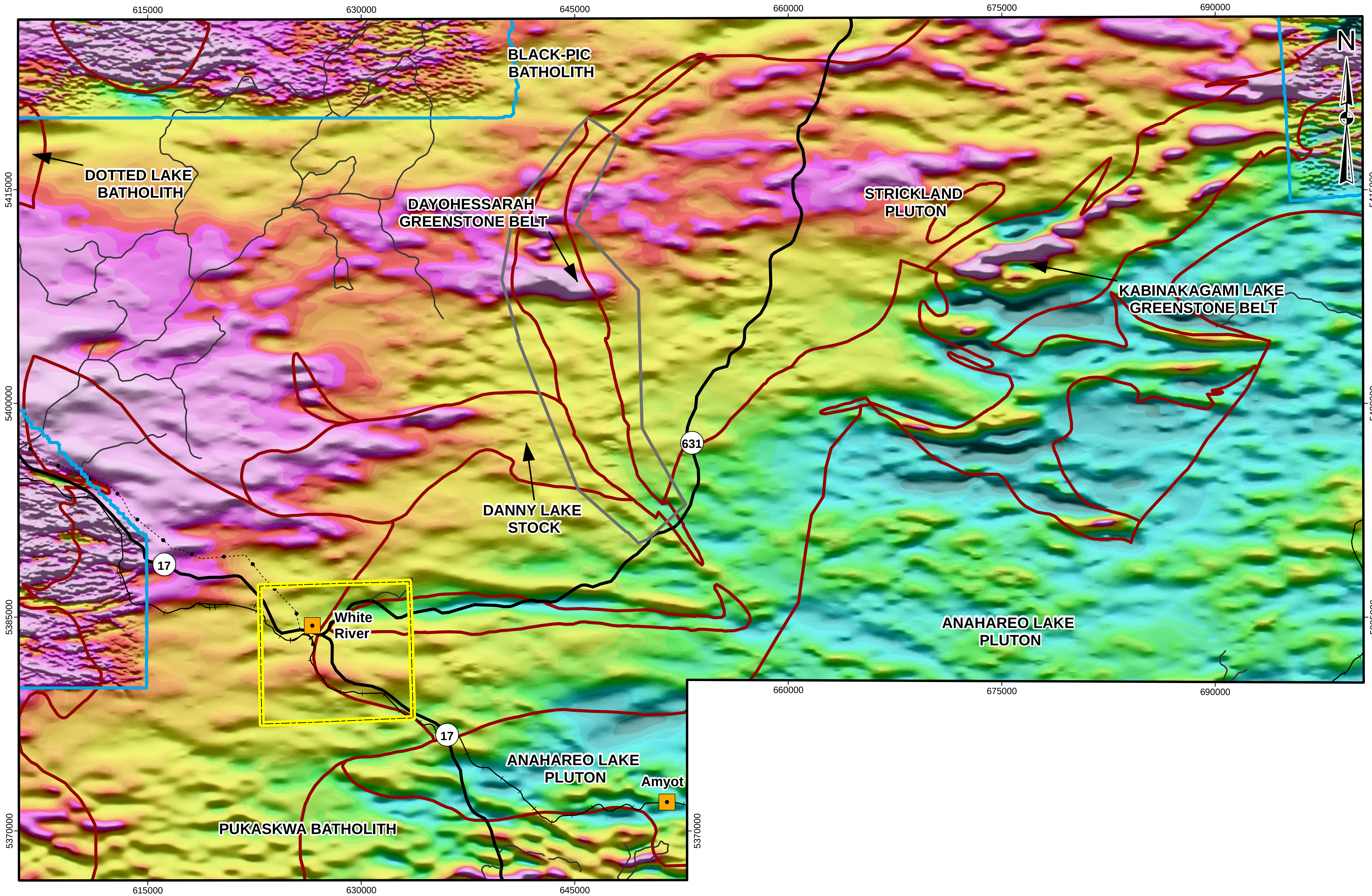
PROJECT
Phase 1 Geoscientific Desktop Preliminary Assessment
Geophysical Study, White River

TITLE
Residual Magnetic Field Reduced to Pole

DESIGN	KR	23 APR 2013	**Figure 5**	REVISION 1.1
GIS	WP	12 SEP 2013		UTM ZONE 16
CHECK	SR	25 FEB 2014		NAD 1983
REVIEW	MA	26 FEB 2014		1:300,000

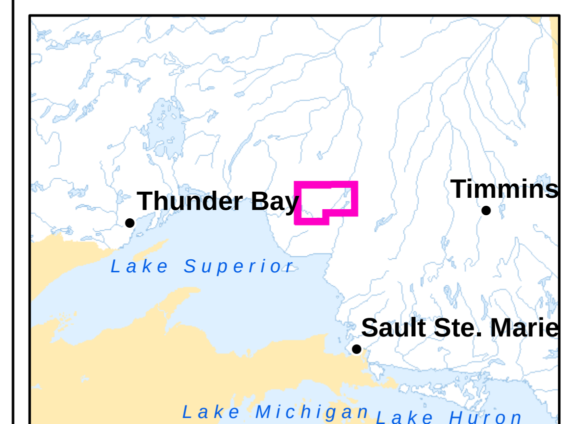


Legend

- Settlement
- White River Municipal Boundary
- Main Road
- Local Road
- Railway
- Abandoned Railway Right-of-way
- Hydro Line
- Bedrock Geology Contact
- High resolution geophysical survey outlines
- Industry geophysical survey outlines

Pole-reduced Magnetic Field (nT)

936, 84, 66, 56, 48, 44, 38, 34, 30, 26, 22, 18, 14, 10, 4, 0, -6, -14, -20, -26, -32, -36, -40, -46, -50, -56, -60, -68, -80, -221



Data Sources:
Base Data: MNR LIO, obtained 2009-2013
Geophysics: Geological Survey of Canada - Aeromagnetic Surveys - Ontario #8, Ontario #17
Ontario Geological Survey - Geophysical Surveys - GDS1024, GDS1205, GDS1207
- Geology Ontario - AFRI no. 20004804
Intrusions: Generalized from OGS M2666, 2001 (1:250,000)

10 km

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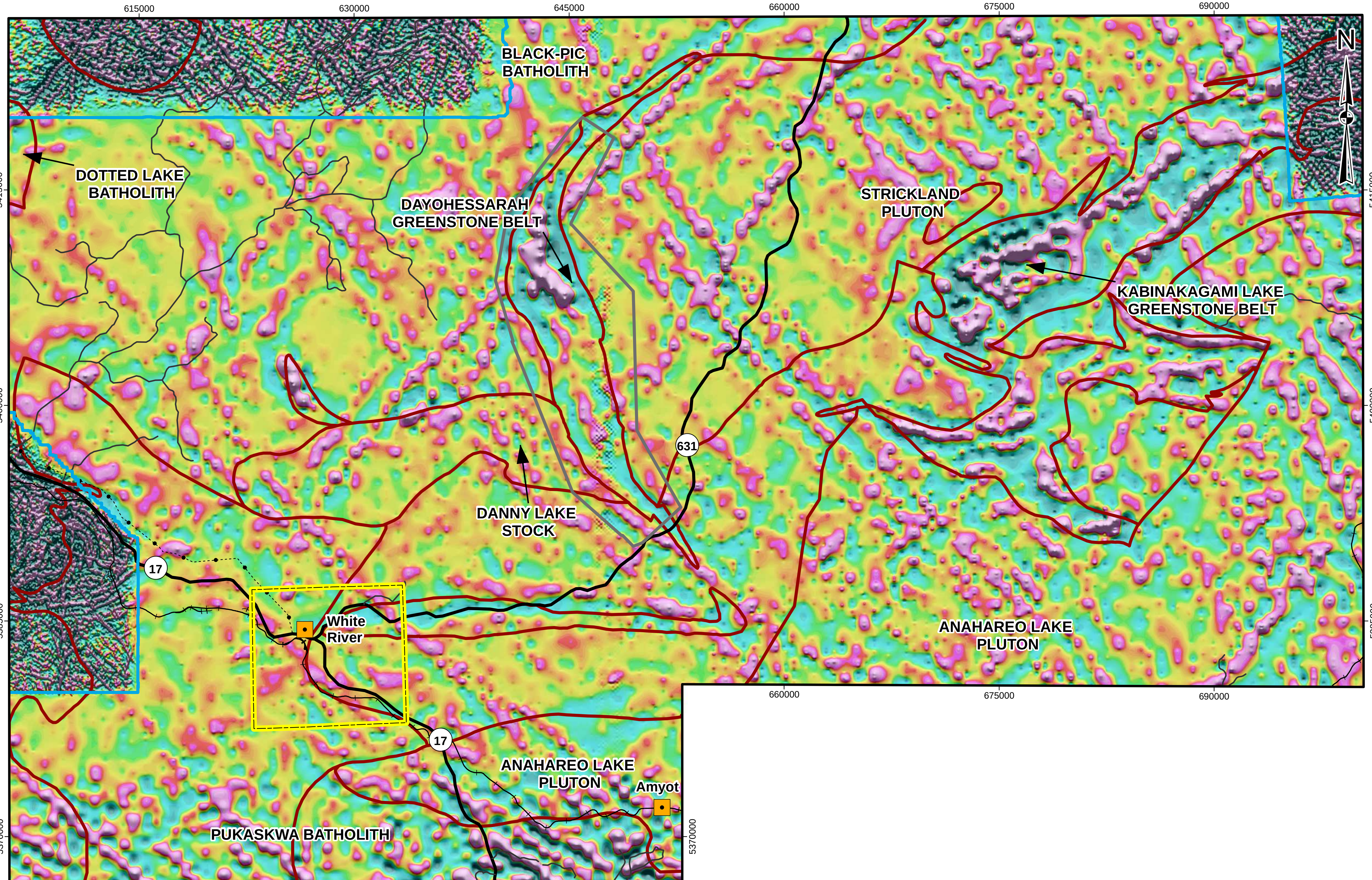
PROJECT
Phase 1 Geoscientific Desktop Preliminary Assessment
Geophysical Study, White River

TITLE
Residual Magnetic Field Reduced to Pole with Dyke Responses Removed

DESIGN	KR	23 APR 2013	Figure 6	REVISION 1.1
GIS	WP	12 SEP 2013		UTM ZONE 16
CHECK	SR	25 FEB 2014		NAD 1983
REVIEW	MA	26 FEB 2014		1:300,000

Path: C:\Users\Stephen\PGW\2013-18\Proc\maps\ArcGIS\Feb 2014\White River\Fig6_PGW_White_River_Mag_RTPNodykes_Draft.mxd

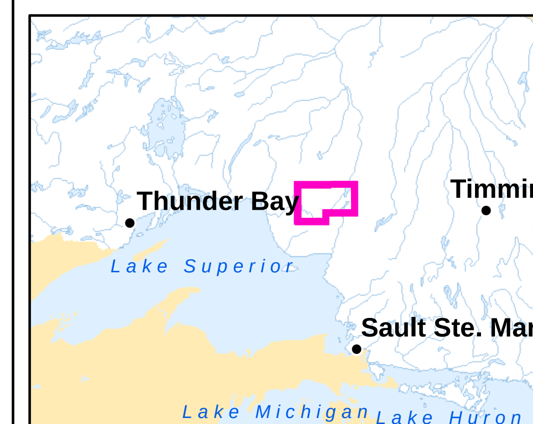


Legend

- Settlement
- White River Municipal Boundary
- Main Road
- Local Road
- Railway
- Abandoned Railway Right-of-way
- Hydro Line
- Bedrock Geology Contact
- High Resolution Geophysical Survey Outlines
- Industry Geophysical Survey Outlines

First Vertical Derivative of the Pole-reduced Magnetic Field (nT/m)

31.416, 0.290, 0.170, 0.115, 0.090, 0.070, 0.050, 0.040, 0.030, 0.020, 0.010, 0.005, 0.000, -0.005, -0.010, -0.015, -0.020, -0.030, -0.035, -0.040, -0.050, -0.055, -0.065, -0.075, -0.090, -0.105, -0.130, -0.170, -0.275, -11.349



Data Sources:
Base Data: MNR LIO, obtained 2009-2013
Geophysics: Geological Survey of Canada - Aeromagnetic Surveys - Ontario #8, Ontario #17
Ontario Geological Survey - Geophysical Surveys - GDS1024, GDS1205, GDS1207
- Geology Ontario - AFRI no. 20004804
Intrusions: Generalized from OGS M2666, 2001 (1:250,000)

10 km

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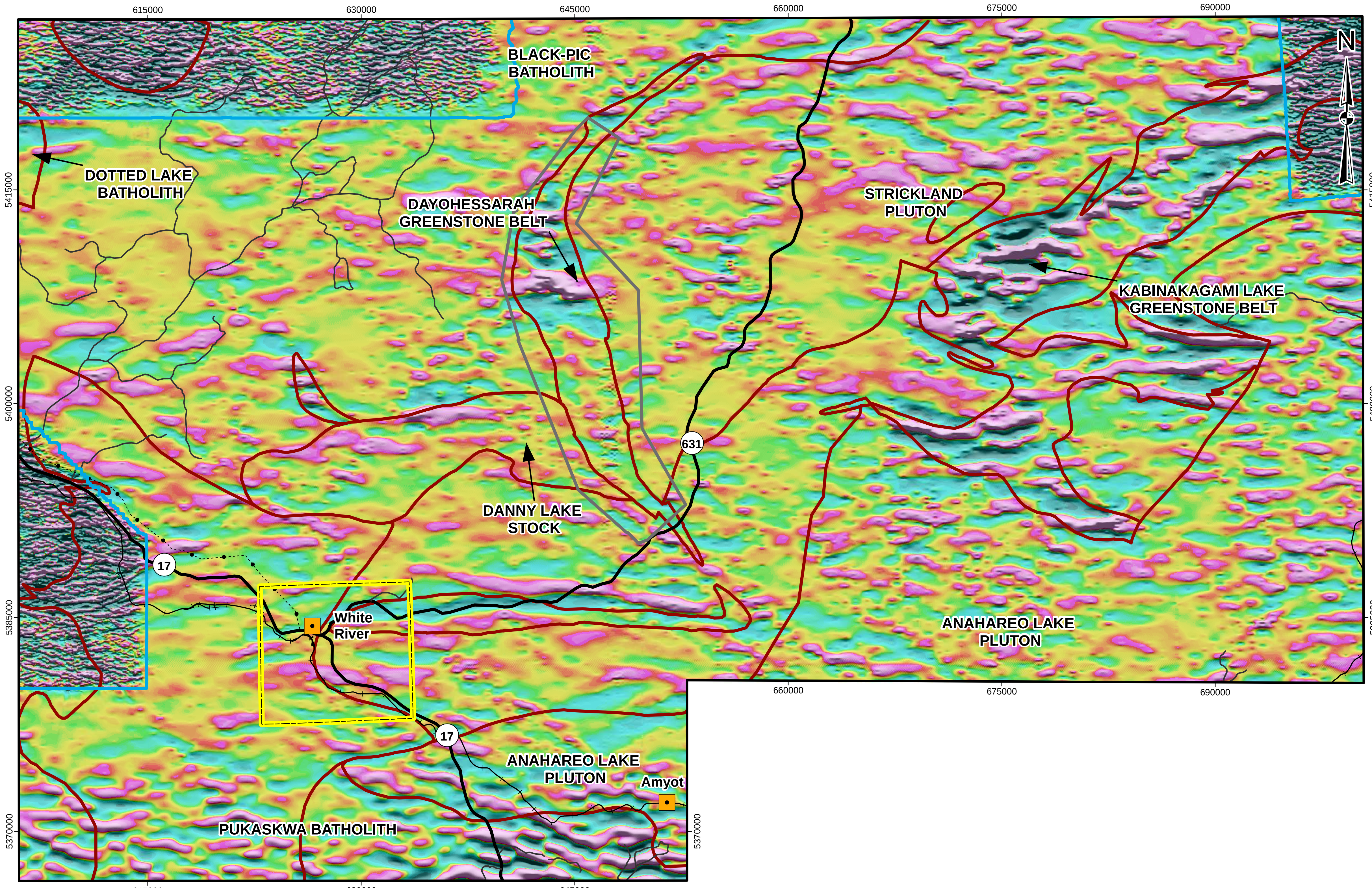
PROJECT
Phase 1 Geoscientific Desktop Preliminary Assessment
Geophysical Study, White River

TITLE
First Vertical Derivative of the Pole-reduced Magnetic Field

DESIGN	KR	23 APR 2013	Figure 7	REVISION 1.1
GIS	WP	12 SEP 2013		UTM ZONE 16
CHECK	SR	25 FEB 2014		NAD 1983
REVIEW	MA	26 FEB 2014		1:300,000

Path: C:\Users\Stephen\PGW\2013-18\Proc\maps\ArcGIS\Feb 2014\White River\Fig7_PGW_White_River_Mag_RTP1VD_Draft.mxd

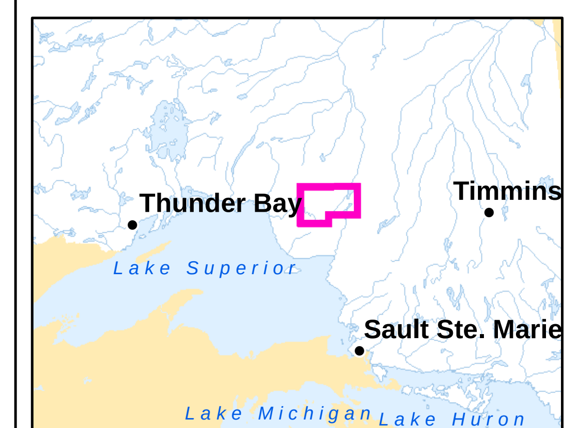


Legend

- Settlement
- White River Municipal Boundary
- Main Road
- Local Road
- Railway
- Abandoned Railway Right-of-way
- Hydro Line
- Bedrock Geology Contact
- High Resolution Geophysical Survey Outlines
- Industry Geophysical Survey Outlines

First Vertical Derivative of the Pole-reduced Magnetic Field (nT/m)

10.681
0.090
0.050
0.035
0.026
0.020
0.016
0.012
0.009
0.007
0.005
0.003
0.001
0.000
-0.002
-0.004
-0.006
-0.007
-0.009
-0.011
-0.014
-0.017
-0.020
-0.023
-0.028
-0.034
-0.042
-0.056
-0.090
-5.023



Data Sources:
Base Data: MNR LIO, obtained 2009-2013
Geophysics: Geological Survey of Canada - Aeromagnetic Surveys - Ontario #8, Ontario #17
Ontario Geological Survey - Geophysical Surveys - GDS1024, GDS1205, GDS1207
- Geology Ontario - AFRI no. 20004804
Intrusions: Generalized from OGS M2666, 2001 (1:250,000)

10 km

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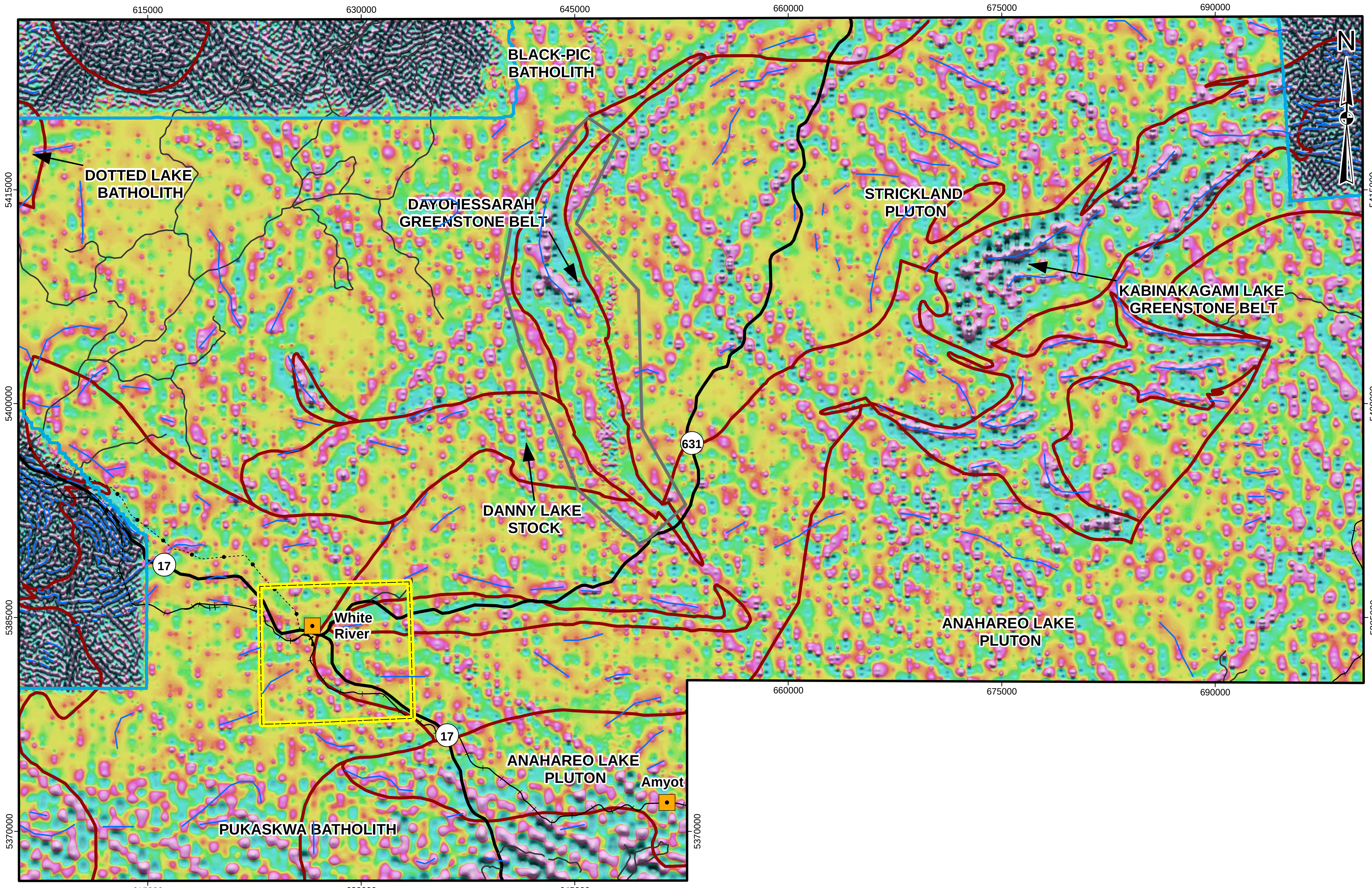
PROJECT
Phase 1 Geoscientific Desktop Preliminary Assessment
Geophysical Study, White River

TITLE
First Vertical Derivative of the Pole-reduced Magnetic Field with Dyke Responses Removed

DESIGN	KR	23 APR 2013	Figure 8	REVISION 1.1
GIS	WP	12 SEP 2013		UTM ZONE 16
CHECK	SR	25 FEB 2014		NAD 1983
REVIEW	MA	26 FEB 2014		1:300,000

Path: C:\Users\Stephen\PGW\2013-18\Proc\maps\ArcGIS\Feb 2014\White River\Fig8_PGW_White_River_Mag_RTP1VDNodykes_Draft.mxd

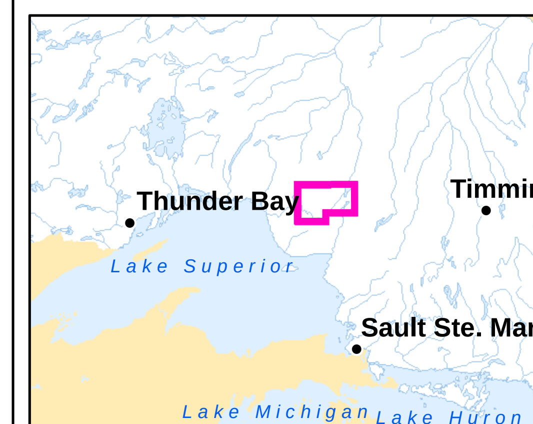


Legend

- Settlement
- White River Municipal Boundary
- Main Road
- Local Road
- Railway
- Abandoned Railway Right-of-way
- Hydro Line
- Bedrock Geology Contact
- High Resolution Geophysical Survey Outlines
- Industry Geophysical Survey Outlines
- Magnetic foliation and ductile lineaments

Second Vertical Derivative of the Pole-reduced Magnetic Field (nT/m2)

0.22096
0.00174
0.00075
0.00046
0.00032
0.00023
0.00017
0.00013
0.00010
0.00007
0.00005
0.00003
0.00001
0.00000
-0.00001
-0.00002
-0.00004
-0.00005
-0.00007
-0.00009
-0.00011
-0.00014
-0.00017
-0.00021
-0.00027
-0.00035
-0.00048
-0.00078
-0.00197
-0.09689



Data Sources:
Base Data: MNR LIO, obtained 2009-2013
Geophysics: Geological Survey of Canada - Aeromagnetic Surveys - Ontario #8, Ontario #17
Ontario Geological Survey - Geophysical Surveys - GDS1024, GDS1205, GDS1207
- Geology Ontario - AFRI no. 20004804
Ductile lineaments and foliation - SRK Consulting (Canada) Inc. (2014)
Intrusions: Generalized from OGS M2666, 2001 (1:250,000)

10 km

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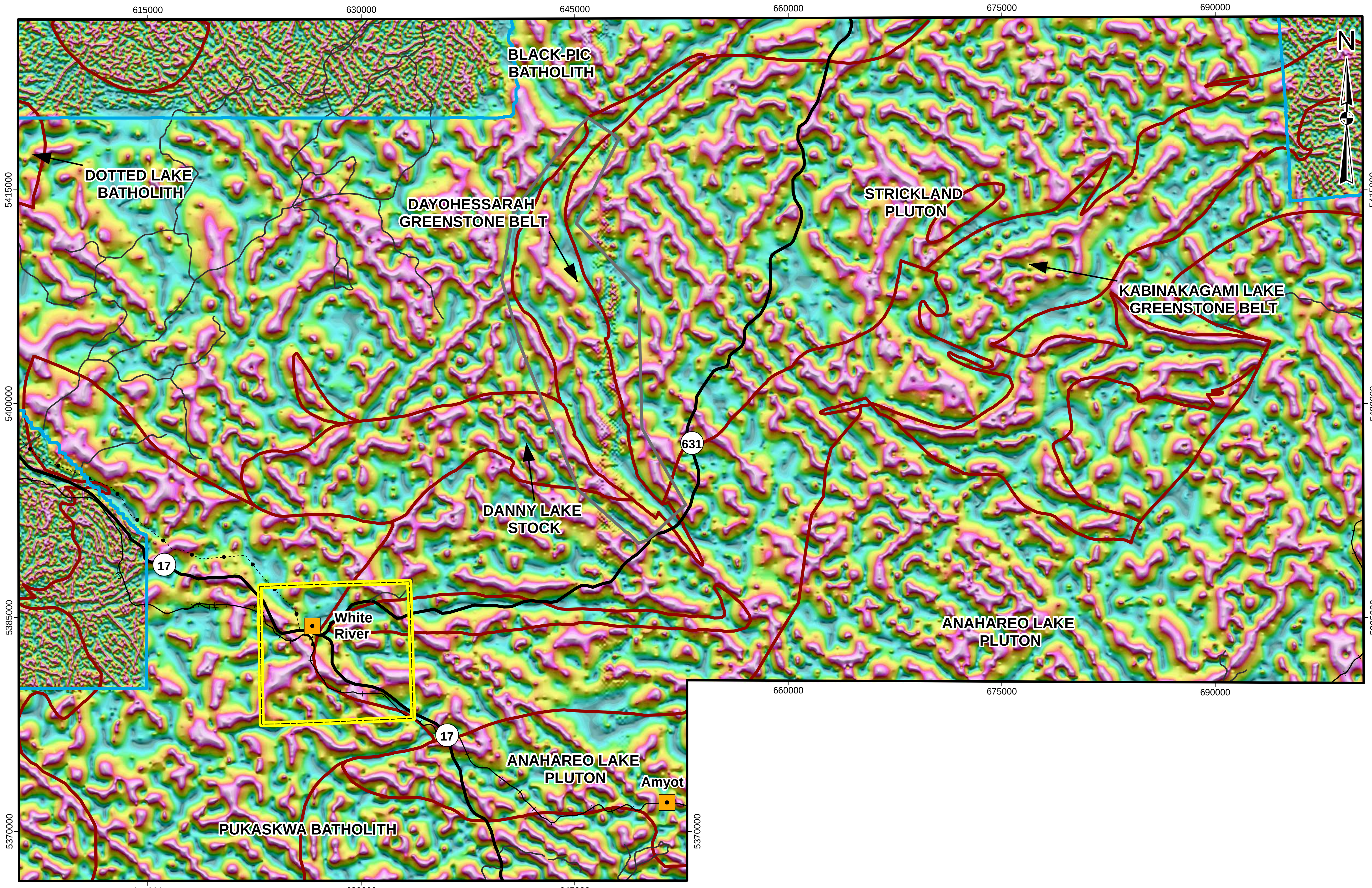
PROJECT
Phase 1 Geoscientific Desktop Preliminary Assessment
Geophysical Study, White River

TITLE
Second Vertical Derivative of the Pole-reduced Magnetic Field

DESIGN	KR	23 APR 2013	**Figure 9**	REVISION 1.2
GIS	WP	12 SEP 2013		UTM ZONE 16
CHECK	SR	11 JUL 2014		NAD 1983
REVIEW	MA	11 JUL 2014		1:300,000

Path: C:\Users\Stephen\PGW\2013-18\Proc\maps\ArcGIS\July 2014\White River\Fig9_PGW_White_River_Mag_RTP2VD.mxd

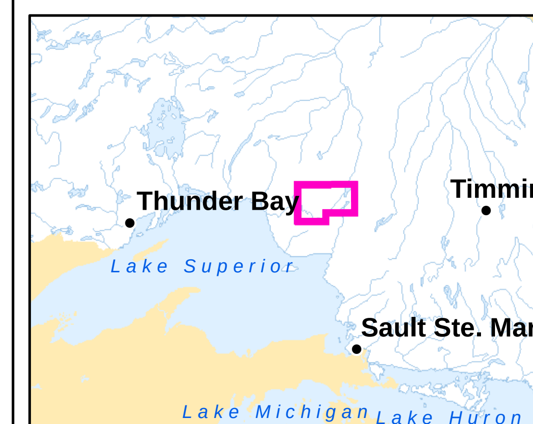


Legend

- Settlement
- White River Municipal Boundary
- Main Road
- Local Road
- Railway
- Abandoned Railway Right-of-way
- Hydro Line
- Bedrock Geology Contact
- High Resolution Geophysical Survey Outlines
- Industry Geophysical Survey Outlines

Tilt Angle of the Pole-reduced Magnetic Field (radians)

1.53, 1.20, 1.10, 0.95, 0.85, 0.73, 0.60, 0.50, 0.40, 0.30, 0.20, 0.10, 0.00, -0.05, -0.15, -0.25, -0.35, -0.45, -0.55, -0.60, -0.70, -0.80, -0.85, -0.95, -1.00, -1.10, -1.15, -1.25, -1.35, -1.65



Data Sources:
Base Data: MNR LIO, obtained 2009-2013
Geophysics: Geological Survey of Canada - Aeromagnetic Surveys - Ontario #8, Ontario #17
Ontario Geological Survey - Geophysical Surveys - GDS1024, GDS1205, GDS1207
- Geology Ontario - AFRI no. 20004804
Intrusions: Generalized from OGS M2666, 2001 (1:250,000)

10 km

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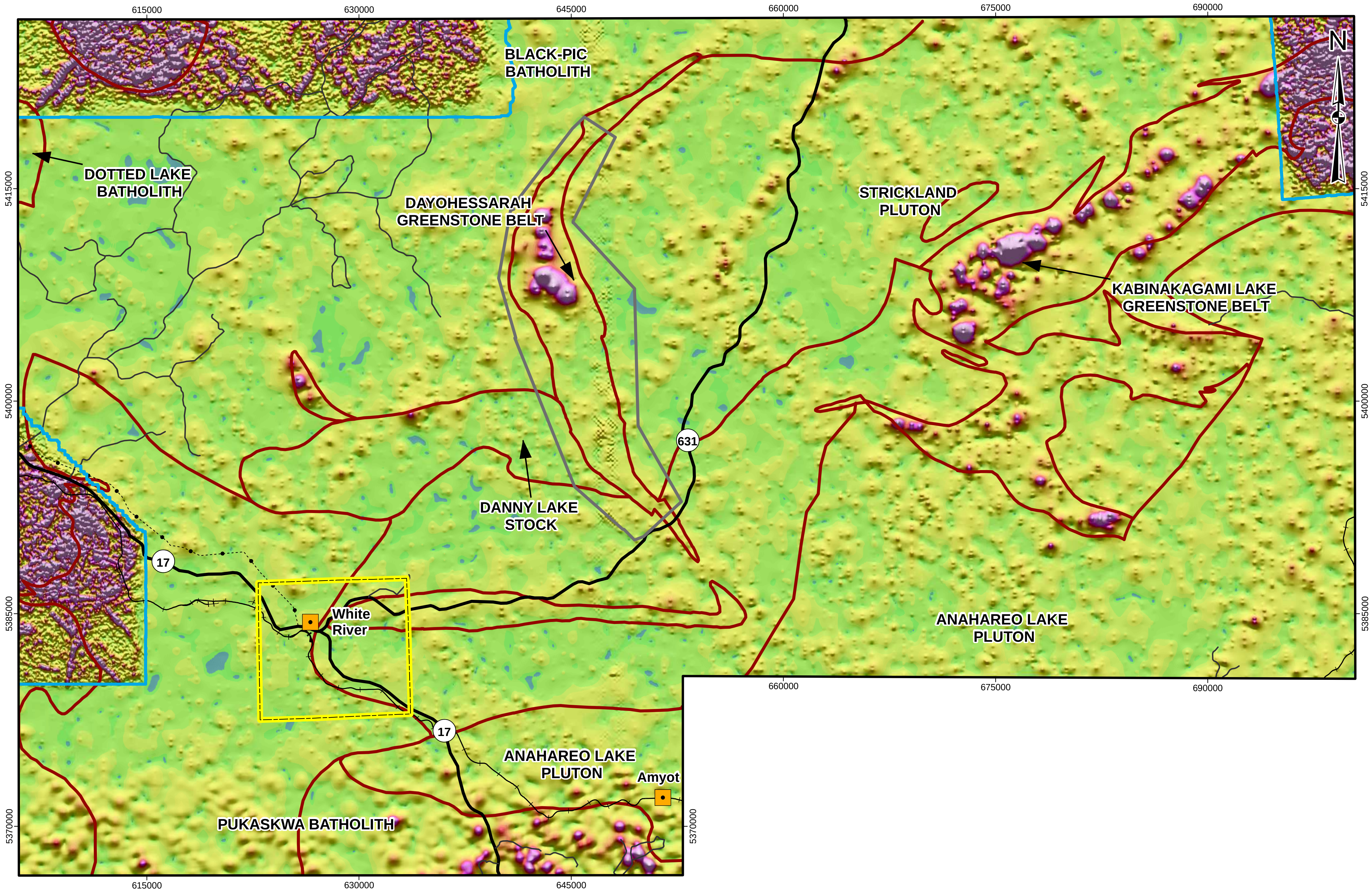
PROJECT
Phase 1 Geoscientific Desktop Preliminary Assessment
Geophysical Study, White River

TITLE
Tilt Angle of the Pole-reduced Magnetic Field

DESIGN	KR	23 APR 2013	**Figure 10**	REVISION 1.1
GIS	WP	12 SEP 2013		UTM ZONE 16
CHECK	SR	25 FEB 2014		NAD 1983
REVIEW	MA	26 FEB 2014		1:300,000

Path: C:\Users\Stephen\PGW\2013-18\Proc\maps\ArcGIS\Feb 2014\White River\Fig10_PGW_White_River_Mag_RTPTilt_Draft.mxd

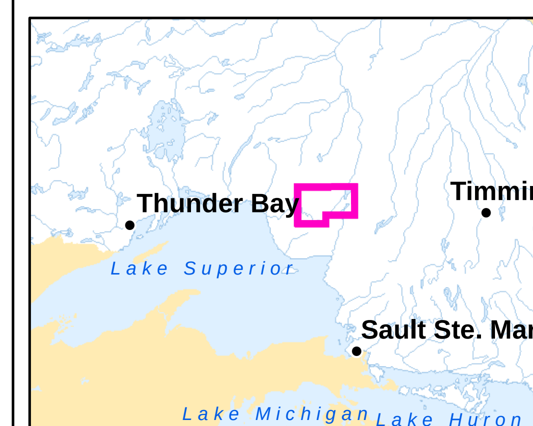


Legend

- Settlement
- White River Municipal Boundary
- Main Road
- Local Road
- Railway
- Abandoned Railway Right-of-way
- Hydro Line
- Bedrock Geology Contact
- High Resolution Geophysical Survey Outlines
- Industry Geophysical Survey Outlines

Analytic Signal Amplitude of the Residual Magnetic Field nT/m)

28.17
0.85
0.73
0.64
0.58
0.53
0.48
0.44
0.40
0.36
0.32
0.29
0.25
0.22
0.19
0.16
0.12
0.09
0.06
0.02
0.01
0.00



Data Sources:
Base Data: MNR LIO, obtained 2009-2013
Geophysics: Geological Survey of Canada - Aeromagnetic Surveys - Ontario #8, Ontario #17
Ontario Geological Survey - Geophysical Surveys - GDS1024, GDS1205, GDS1207
- Geology Ontario - AFRI no. 20004804
Intrusions: Generalized from OGS M2666, 2001 (1:250,000)

10 km

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PROJECT
Phase 1 Geoscientific Desktop Preliminary Assessment
Geophysical Study, White River

TITLE
Analytic Signal Amplitude of the Residual Magnetic Field

DESIGN	KR	23 APR 2013	**Figure 11**	REVISION 1.1
GIS	WP	12 SEP 2013		UTM ZONE 16
CHECK	SR	25 FEB 2014		NAD 1983
REVIEW	MA	26 FEB 2014		1:300,000

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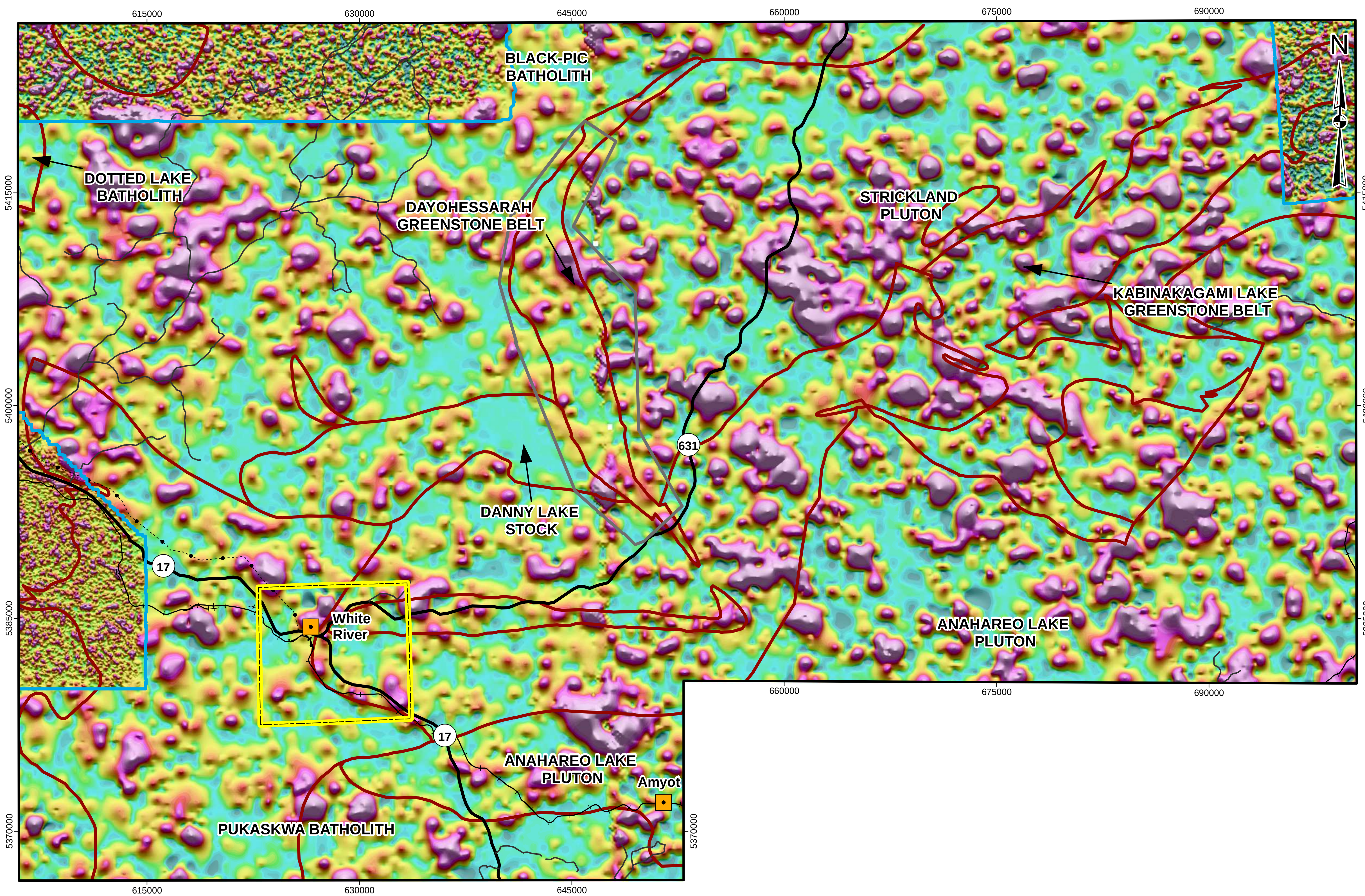
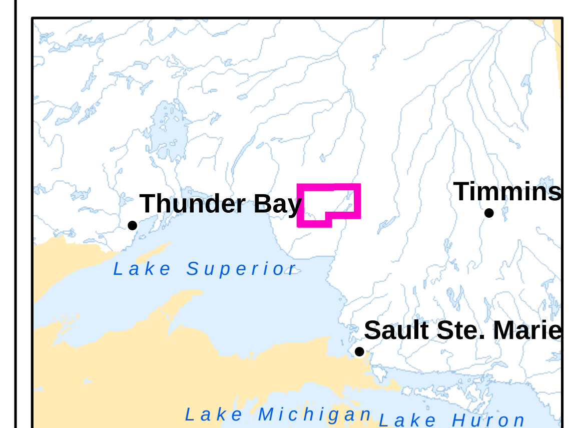


Legend

- Settlement
- White River Municipal Boundary
- Main Road
- Local Road
- Railway
- Abandoned Railway Right-of-way
- Hydro Line
- Bedrock Geology Contact
- High Resolution Geophysical Survey Outlines
- Industry Geophysical Survey Outlines

Depth to Magnetic Sources (m below surface)

30645
675
460
358
294
245
207
177
152
131
113
98
83
71
59
49
40
31
24
17
12
7
3
1
0
-1
-3
-7
-16
-823



Data Sources:
Base Data: MNR LIO, obtained 2009-2013
Geophysics: Geological Survey of Canada - Aeromagnetic Surveys - Ontario #8, Ontario #17
Ontario Geological Survey - Geophysical Surveys - GDS1024, GDS1205, GDS1207
- Geology Ontario - AFRI no. 20004804
Intrusions: Generalized from OGS M2666, 2001 (1:250,000)

10 km

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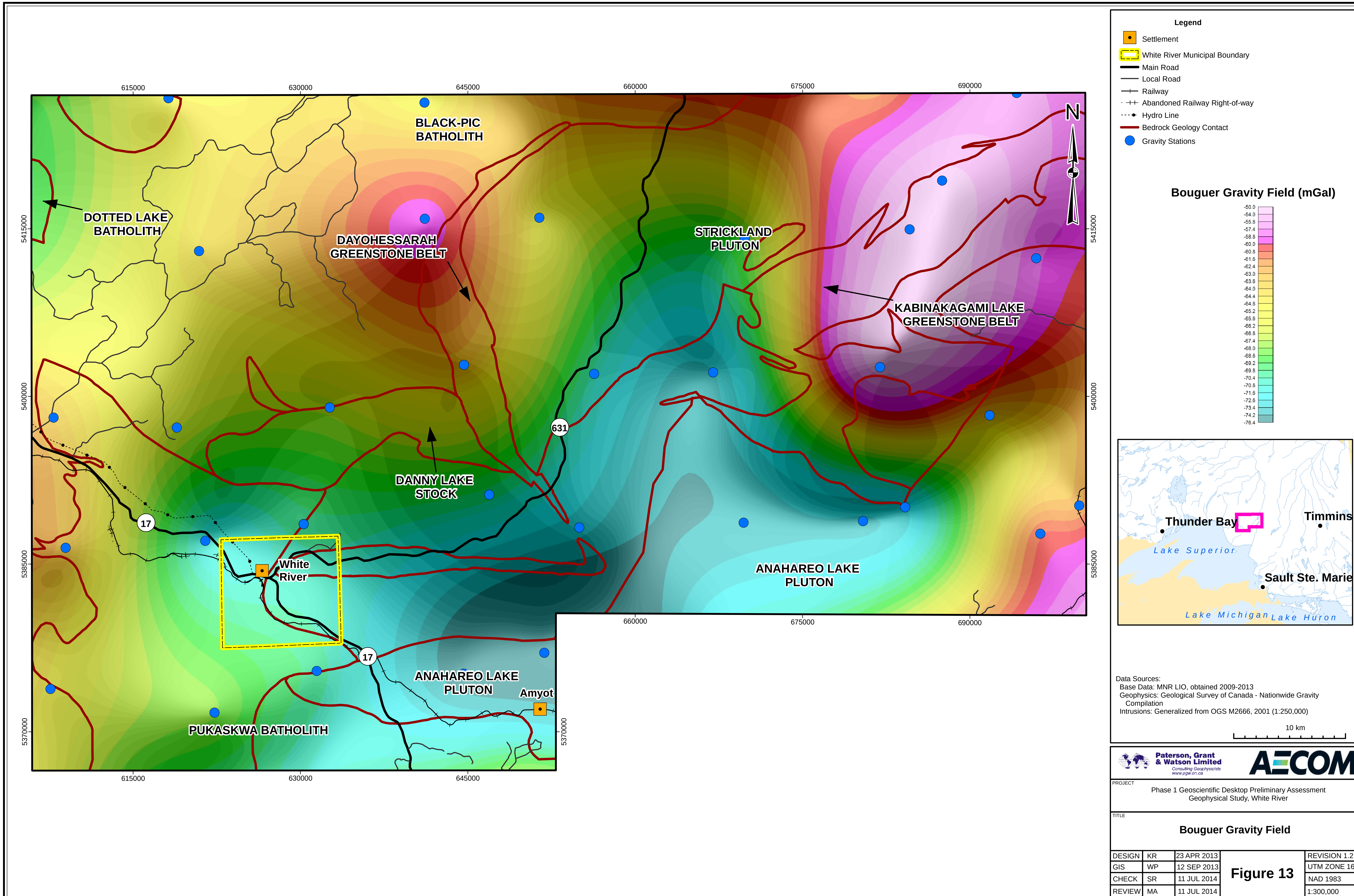
Phase 1 Geoscientific Desktop Preliminary Assessment
Geophysical Study, White River

TITLE
Depth to Magnetic Sources from Source Parameter Imaging

DESIGN	KR	23 APR 2013	**Figure 12**	REVISION 1.1
GIS	WP	12 SEP 2013		UTM ZONE 16
CHECK	SR	25 FEB 2014		NAD 1983
REVIEW	MA	26 FEB 2014		1:300,000

Path: C:\Users\Stephen\PGW\2013-18\Proc\maps\ArcGIS\Feb 2014\White River\Fig12_PGW_White_River_Mag_SPIDepth_Draft.mxd


BLACK-PIC
BATHOLITH
DOTTED LAKE
BATHOLITH
DAYOHESSARAH
GREENSTONE BELT
STRICKLAND
PLUTON
KABINAKAGAMI LAKE
GREENSTONE BELT
DANNY LAKE
STOCK
ANAHAREO LAKE
PLUTON
White
River
ANAHAREO LAKE
PLUTON
Amyot
PUKASKWA BATHOLITH
17
17
631
N
615000
630000
645000
660000
675000
690000
5415000
5400000
5385000
5370000
Legend
Settlement
White River Municipal Boundary
Main Road
Local Road
Railway
Abandoned Railway Right-of-way
Hydro Line
Bedrock Geology Contact
Gravity Stations
Bouguer Gravity Field (mGal)
-50.0
-54.0
-55.8
-57.4
-58.8
-60.0
-60.8
-61.6
-62.4
-63.0
-63.6
-64.0
-64.4
-64.8
-65.2
-65.6
-66.2
-66.8
-67.4
-68.0
-68.6
-69.2
-69.8
-70.4
-70.8
-71.6
-72.6
-73.4
-74.2
-76.4
Thunder Bay
Timmins
Lake Superior
Sault Ste. Marie
Lake Michigan
Lake Huron
Data Sources:
Base Data: MNR LIO, obtained 2009-2013
Geophysics: Geological Survey of Canada - Nationwide Gravity Compilation
Intrusions: Generalized from OGS M2666, 2001 (1:250,000)
10 km
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PROJECT
Phase 1 Geoscientific Desktop Preliminary Assessment
Geophysical Study, White River
TITLE
Bouguer Gravity Field
DESIGN KR 23 APR 2013
GIS WP 12 SEP 2013
CHECK SR 11 JUL 2014
REVIEW MA 11 JUL 2014
Figure 13
REVISION 1.2
UTM ZONE 16
NAD 1983
1:300,000
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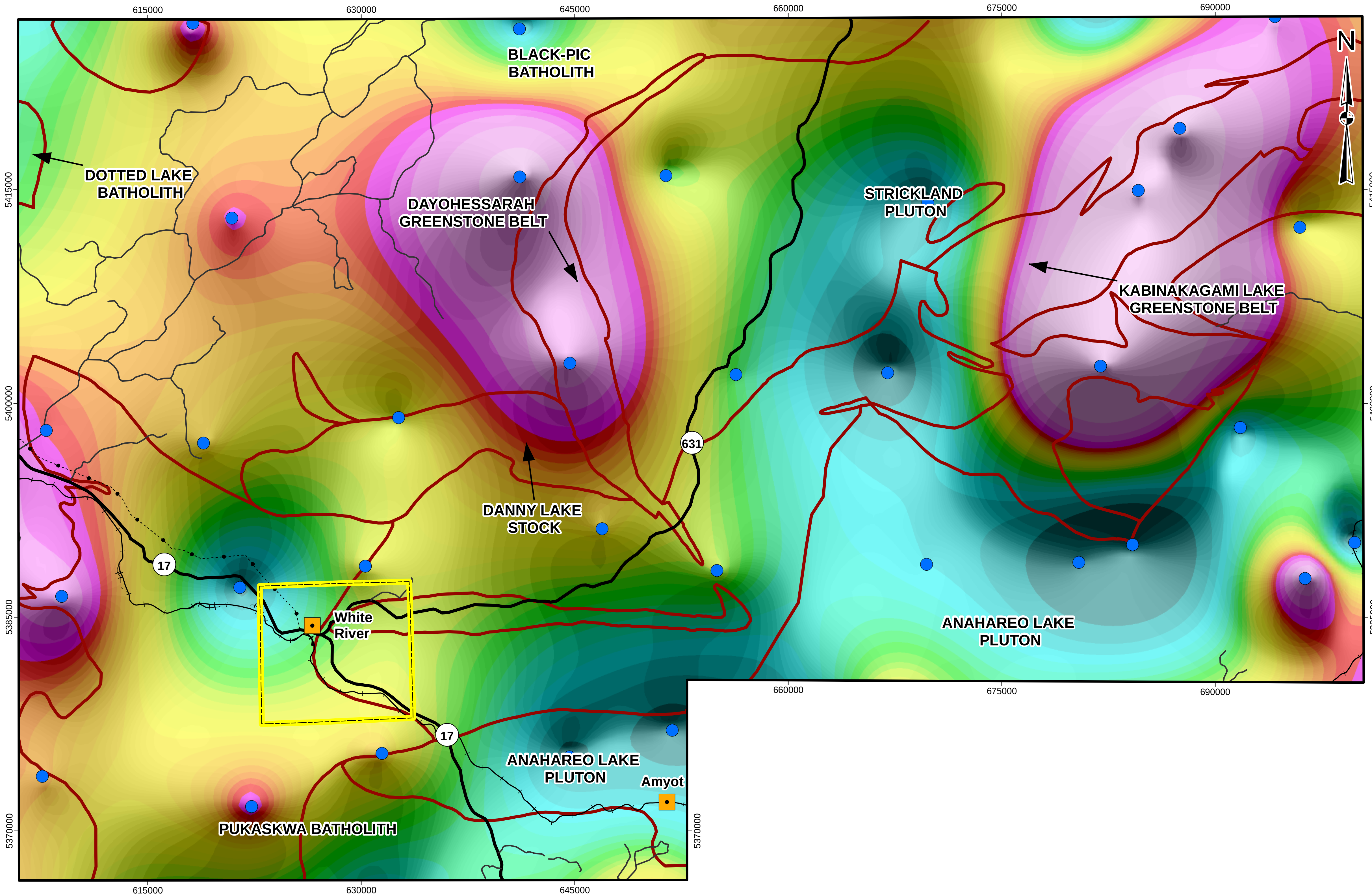
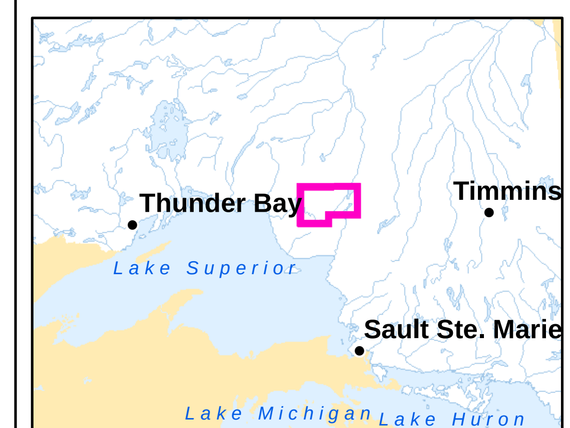


Legend

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

First Vertical Derivative of the Bouguer Gravity Field (mGal/m)

0.00338
0.00070
0.00030
0.00012
0.00002
-0.00006
-0.00012
-0.00016
-0.00020
-0.00024
-0.00028
-0.00032
-0.00036
-0.00040
-0.00042
-0.00048
-0.00052
-0.00056
-0.00062
-0.00066
-0.00072
-0.00078
-0.00084
-0.00090
-0.00098
-0.00106
-0.00116
-0.00128
-0.00148
-0.00362



Data Sources:
Base Data: MNR LIO, obtained 2009-2013
Geophysics: Geological Survey of Canada - Nationwide Gravity Compilation
Intrusions: Generalized from OGS M2666, 2001 (1:250,000)

10 km

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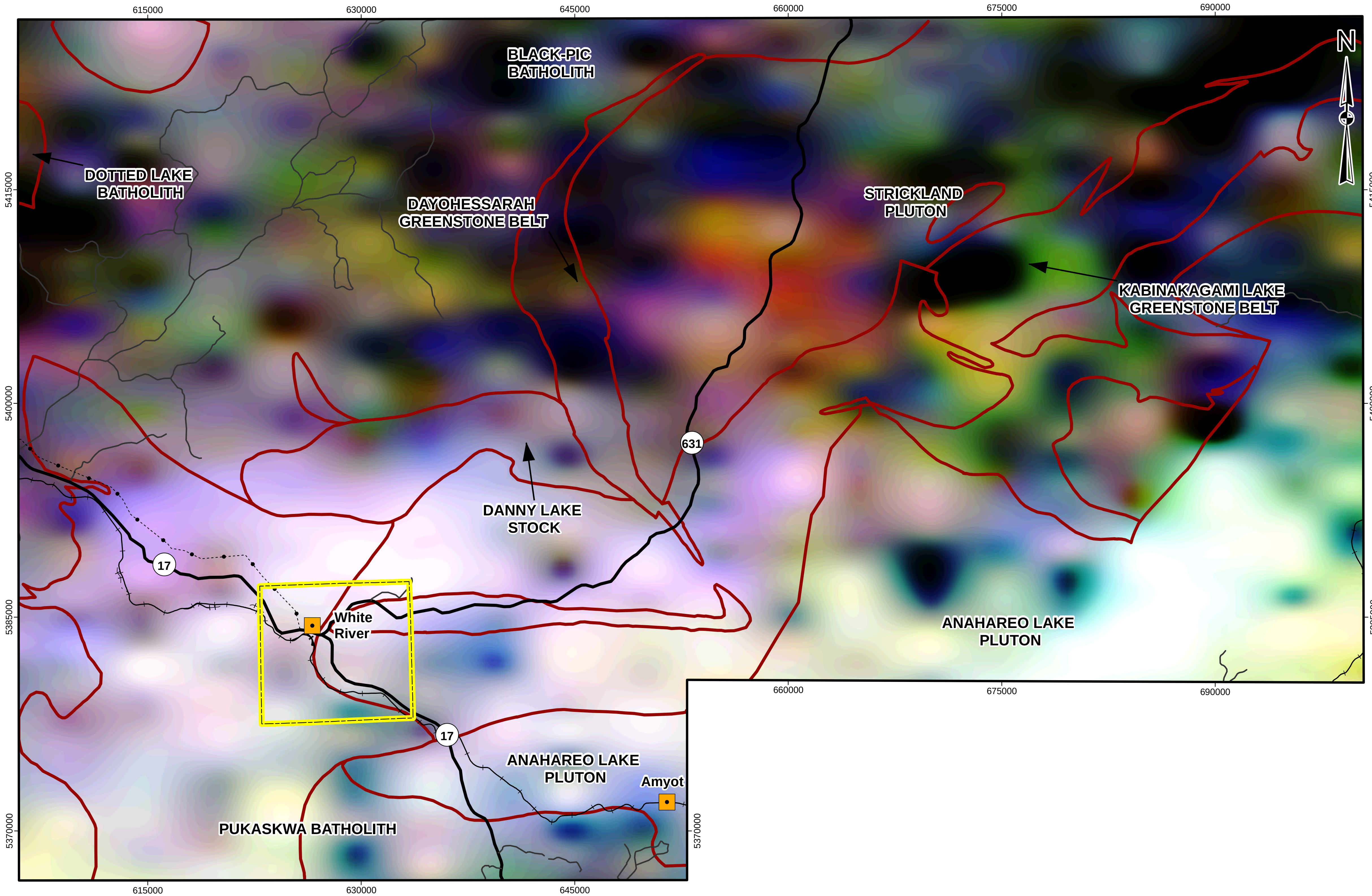
PROJECT
Phase 1 Geoscientific Desktop Preliminary Assessment
Geophysical Study, White River

TITLE
First Vertical Derivative of the Bouguer Gravity Field

DESIGN	KR	23 APR 2013	**Figure 14**	REVISION 1.2
GIS	WP	12 SEP 2013		UTM ZONE 16
CHECK	SR	11 JUL 2014		NAD 1983
REVIEW	MA	11 JUL 2014		1:300,000

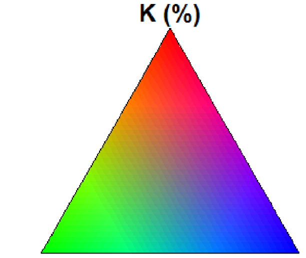
Path: C:\Users\Stephen\PGW\2013-18\Proc\maps\ArcGIS\July 2014\White River\Fig14_PGW_White_River_Grav_Bouguer1VD.mxd

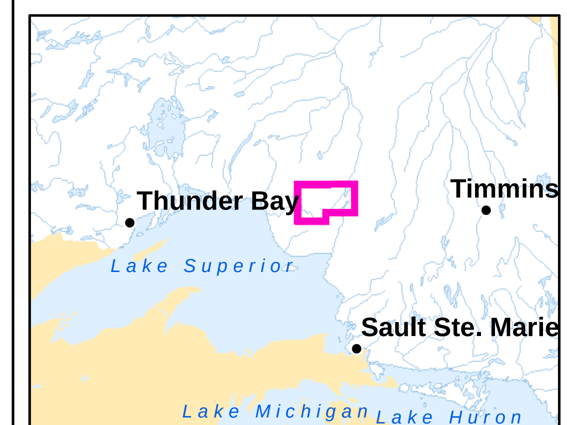


Legend

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

Radiometric Ternary Image
RGB = K-eTh-eU





Data Sources:
Base Data: MNR LIO, obtained 2009-2013
Geophysics: Geological Survey of Canada - Nationwide Radiometric Compilation
Intrusions: Generalized from OGS M2666, 2001 (1:250,000)

10 km

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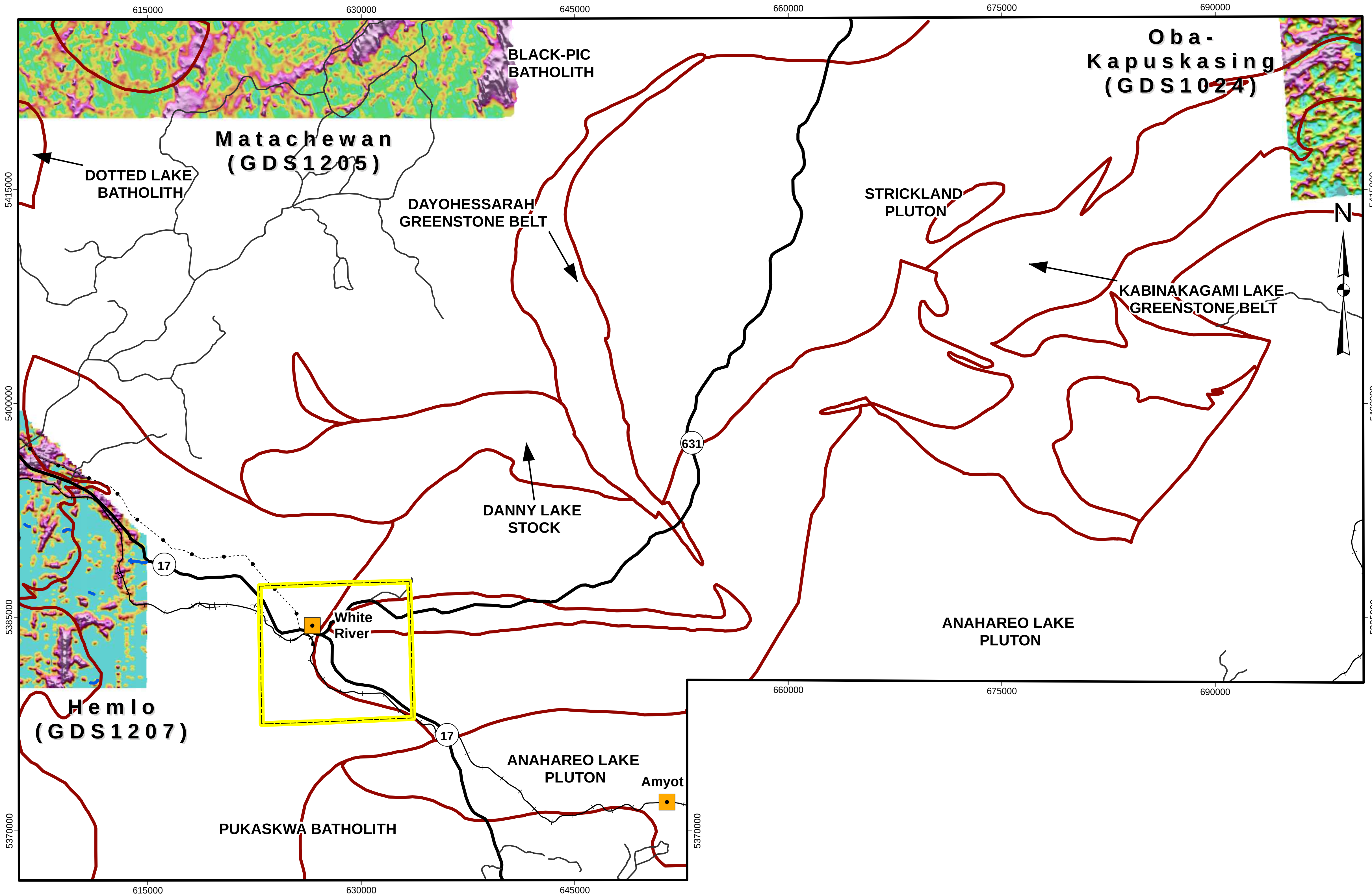
Phase 1 Geoscientific Desktop Preliminary Assessment
Geophysical Study, White River

TITLE
Radiometric Ternary Image (RGB = K-eTh-eU)

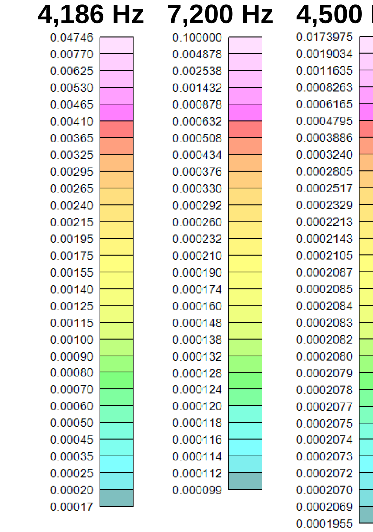
DESIGN	KR	23 APR 2013	Figure 15	REVISION 1.1
GIS	WP	12 SEP 2013		UTM ZONE 16
CHECK	SR	25 FEB 2014		NAD 1983
REVIEW	MA	26 FEB 2014		1:300,000

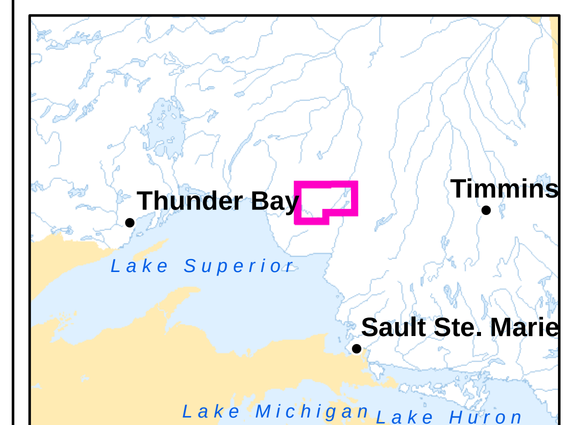
Path: C:\Users\Stephen\PGW\2013-18\Proc\maps\ArcGIS\Feb 2014\White River\Fig15_PGW_White_River_Rad_Ternary_Draft.mxd



Legend

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





Data Sources:
Base Data: MNR LIO, obtained 2009-2013
Geophysics: Ontario Geological Survey - Geophysical Surveys - GDS1024, GDS1205, GDS1207
Intrusions: Generalized from OGS M2666, 2001 (1:250,000)

10 km

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PROJECT
Phase 1 Geoscientific Desktop Preliminary Assessment
Geophysical Study, White River

TITLE
EM Conductors over Apparent Conductivity

DESIGN	KR	23 APR 2013	Figure 16	REVISION 1.1
GIS	WP	12 SEP 2013		UTM ZONE 16
CHECK	SR	25 FEB 2014		NAD 1983
REVIEW	MA	25 FEB 2014		1:300,000

Path: C:\Users\Stephen\PGW\2013-18\Proc\maps\ArcGIS\Feb 2014\White River\Fig16_PGW_White_River_EM_Conductivity_Draft.mxd

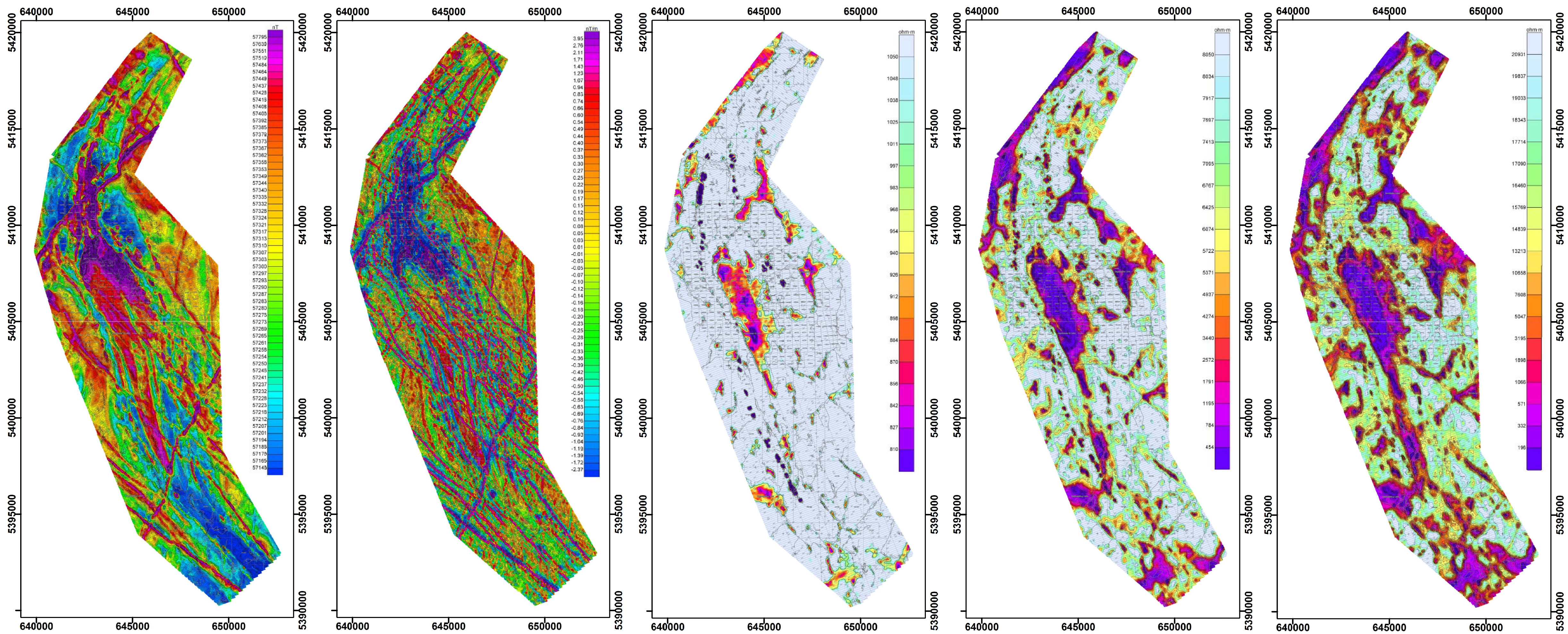
Total Magnetic Field (nT)

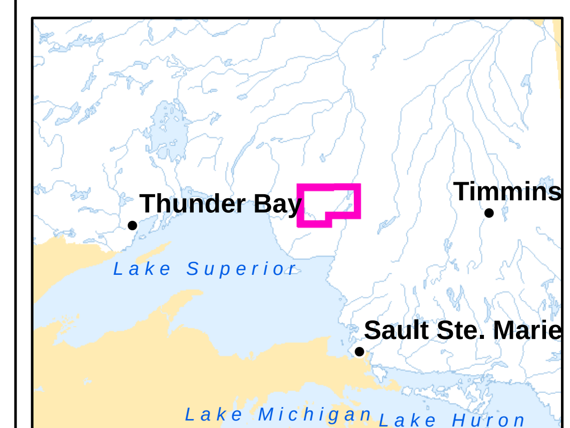
First Vertical Derivative of the Total Magnetic Field (nT/m)

Apparent Resistivity - 900 Hz (ohm-m)

Apparent Resistivity - 7,200 Hz (ohm-m)

Apparent Resistivity - 56,000 Hz (ohm-m)





Data Sources:
Base Data: MNR LIO, obtained 2009-2013
Geophysics: Ontario Geological Survey - Geology Ontario
- AFRI no. 20004804

70 km

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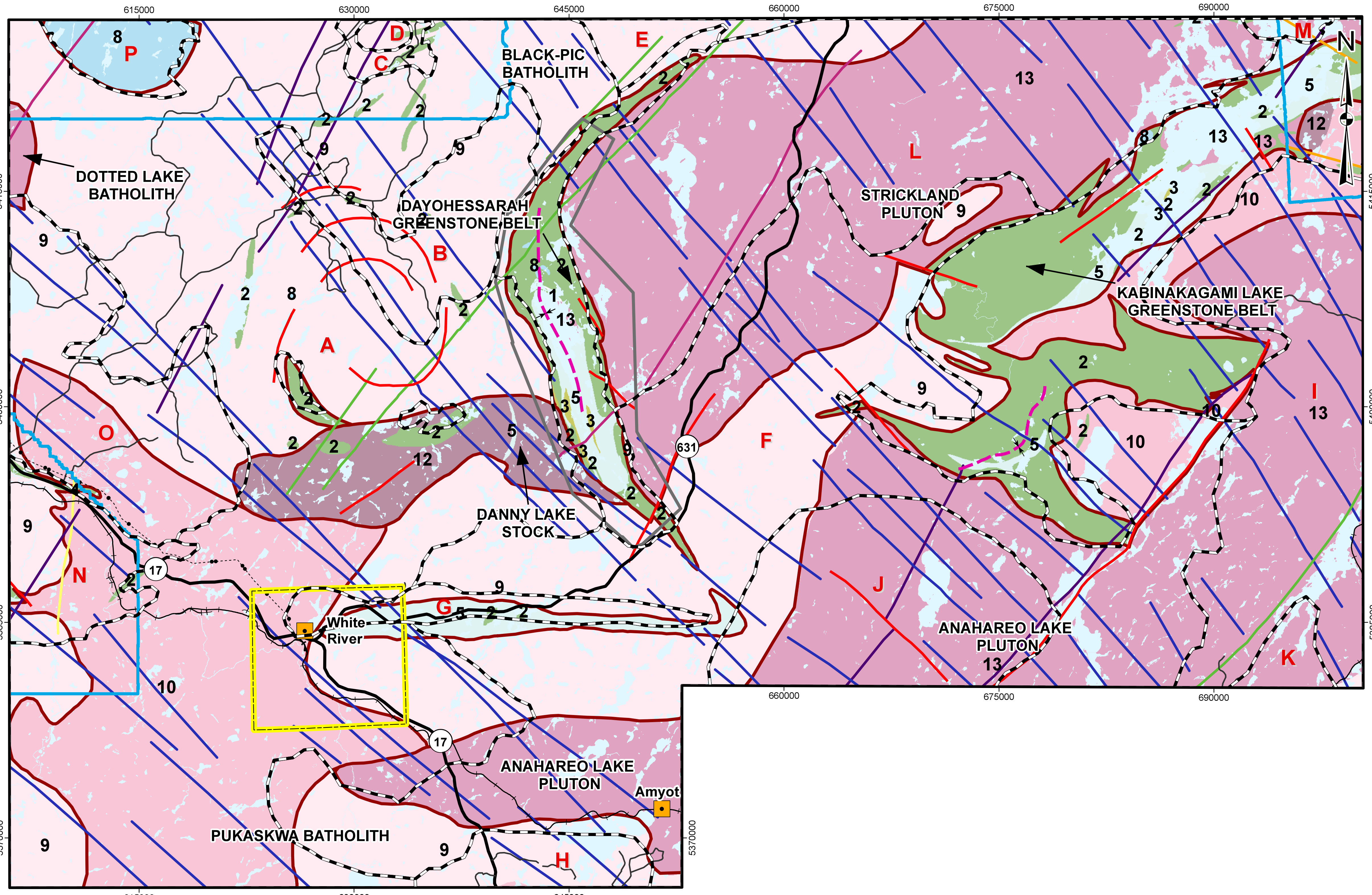
Geophysical Study, White River

TITLE
Magnetic and Electromagnetic Images from AFRI File No. 20004804

DESIGN	KR	23 APR 2013	**Figure 17**	REVISION 1.1
GIS	WP	12 SEP 2013		UTM ZONE 16
CHECK	SR	25 FEB 2014		NAD 1983
REVIEW	MA	26 FEB 2014		

Path: C:\Users\Stephen\PGW\2013-18\Proc\maps\ArcGIS\Feb 2014\White River\Fig17_PGW_White_River_AFRI_20004804_Draft.mxd



Legend

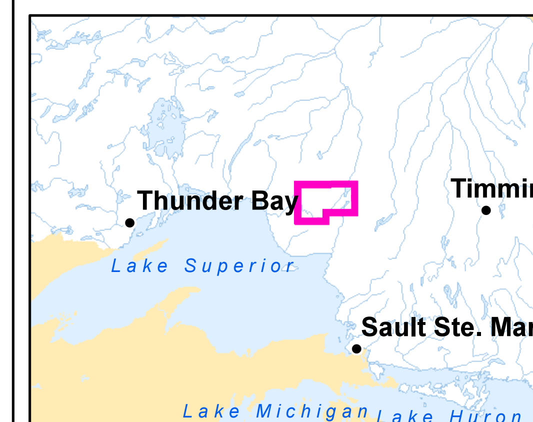
- Settlement
- White River Municipal Boundary
- Main Road
- Local Road
- Railway
- Abandoned Railway Right-of-way
- Hydro Line
- Waterbody
- Faults
- Major Fold (Syncline Approximate)
- Bedrock Geology Contact

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
- High Resolution Geophysical Survey Outlines
- Industry Geophysical Survey Outlines
- A Geologic units interpreted from geophysics



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)

10 km

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PROJECT
Phase 1 Geoscientific Desktop Preliminary Assessment
Geophysical Study, White River

TITLE
Geophysical Interpretation Showing Distribution of Bedrock Units for the Township of White River and Surrounding Area

DESIGN	KR	23 APR 2013	Figure 18	REVISION 1.3
GIS	GF	17 OCT 2013		UTM ZONE 16
CHECK	SR	3 SEPT 2014		NAD 1983
REVIEW	MA	3 SEPT 2014		1:300,000

Path: D:\2013-18\Proc\maps\ArcGIS\July 2014\Fig18_PGW_White_River_Bedrock_Geology_Interpretation.mxd