NUCLEAR WASTE MANAGEMENT ORGANIZATION
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Phase 2 Geoscientific Preliminary Assessment

Geological Mapping

TOWNSHIP OF WHITE RIVER AND AREA, ONTARIO

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Phase 2 Geoscientific Preliminary Assessment

Geological Mapping
Township of White River and Area, Ontario

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PHASE 2 GEOSCIENTIFIC PRELIMINARY ASSESSMENT

GEOLOGICAL MAPPING,

TOWNSHIP OF WHITE RIVER AND AREA, ONTARIO

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V2.0	03-10-2017	Revisions from Geoscientific Review Group review

EXECUTIVE SUMMARY

This technical report documents the results of the Phase 2 Geological Mapping activity completed in 2016 as part of the Phase 2 Geoscientific Preliminary Assessment, to further assess the suitability of the White River area to safely host a deep geological repository. This study followed the successful completion of the Phase 1 Geoscientific Desktop Preliminary Assessment (AECOM, 2014), which identified withdrawal areas for further field studies. Geological mapping was completed within and around two of these withdrawal areas.

The purpose of the Phase 2 Geological Mapping is to advance understanding of the bedrock geology of the withdrawal areas, with an emphasis on observation and analysis of bedrock structure and lithology. Information collected during Phase 2 Geological Mapping also helps to identify areas of exposed bedrock, assess overburden thickness, and identify surface constraints within and around the withdrawal areas, which might affect suitability.

Observations were conducted at select locations that were accessed using existing secondary roads, trail networks and waterbodies, as well as some off-trail hiking. The two areas were mapped over a total period of 55 days by one mapping team using a consistent workflow and standardized digital data collection system. Observations were made at a total of 373 locations in and around the two withdrawal areas, including 169 locations in the Strickland pluton area and 204 locations in the Anahareo Lake pluton area.

A digital data collection protocol was applied and observations were compiled into a GIS-compatible database. This includes information on bedrock character (lithology, magnetic susceptibility, gamma ray spectrometry, structure, rock strength), fracture character, bedrock exposure and surface constraints. This report details the field observation for the withdrawal areas.

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1.0 INTRODUCTION

This technical report presents the results of Observing General Geological Features (OGGF) and Detailed Geological Mapping conducted in 2016 as part of the Phase 2 Geoscientific Preliminary Assessment, to further assess the suitability of the White River area (Figure 1.1) in northern Ontario, to safely host a deep geological repository. Phase 2 OGGF and Detailed Geological Mapping build on the results of the Initial Screening (Golder, 2012) and Phase 1 Geoscientific Desktop Preliminary Assessment (AECOM, 2014a). For the purpose of this report, OGGF and Detailed Geological Mapping will be collectively referred to as “Geological Mapping”.

The Phase 1 Geoscientific Desktop Preliminary Assessment identified four general potentially suitable areas warranting further studies such as high-resolution geophysical surveys and geological mapping; one potentially suitable area is located in the Strickland pluton, two in the Anahareo Lake pluton and one in the Pukaskwa batholith. Subsequent Phase 2 high-resolution geophysical surveys and interpretation (SGL, 2017), lineament interpretation (SRK, 2017) and geological mapping were conducted in two of the four potentially suitable areas identified in Phase 1 (Golder, 2012). The geological mapping data presented in this report therefore only focuses on two of the potentially suitable areas identified in the Phase 1 Geoscientific Desktop Preliminary Assessment (AECOM, 2014A), including the Strickland pluton area and the Anahareo Lake pluton area (Figures 1.1 and 1.2).

The objective of Phase 2 Geological Mapping is to advance understanding of the bedrock geology of the two potentially suitable areas assessed, with an emphasis on observation and analysis of bedrock structure and lithology, in the context of the results from the Phase 2 Airborne Geophysical assessment (SGL, 2017) and the Phase 2 Lineament Assessment (SRK, 2017). Information collected during Phase 2 Geological Mapping also helped identify areas of exposed bedrock, assess overburden thickness, and identify surface constraints affecting accessibility within the areas.

The Phase 2 Geological Mapping activity was completed by Amec Foster Wheeler Environment and Infrastructure (Amec Foster Wheeler) and Dr Michael Cooley, an independent structural geologist subcontracted to Amec Foster Wheeler. The observations were conducted at select locations that were accessed using existing secondary roads, trail networks and waterbodies, as well as some off-trail hiking and access by float plane and helicopter (Figure 1.2).

1.1 Scope of Work and Work Program

The Phase 2 Geological Mapping activity was carried out in two phases, including an initial Observing General Geological Features (OGGF) followed by Detailed Geological Mapping. The same data was collected during both phases of mapping, with the main difference being the accessibility of the outcrops visited during the two phases. During OGGF observations were made primarily along existing roads and trails, occasionally involving walking short distances off these trails. The findings from the OGGF results were preliminary assessed in conjunction with data collected from other field studies such as airborne geophysical surveys (SGL, 2017) and lineament interpretations (SRK, 2017) to help determine the focus of the Detail Geological Mapping phase, which involved investigating as many locations of exposed bedrock as possible within and around the potentially suitable areas.

The Phase 2 Geological Mapping work, including OGGF and Detailed Geological Mapping, was carried out in three stages as follows:

Stage 1: Pre-mapping planning stage;
Stage 2: Mapping stage; and
Stage 3: Synthesis and reporting stage.

During the pre-mapping planning stage, a plan for the OGGF and Detailed Geological Mapping was developed for one area in the Strickland pluton and one in the Anahareo Lake pluton, both to the east of the White River community (Figure 1.2). During geological mapping (Stage 2), geological information was collected in accordance with the work plan defined during Stage 1 (See Section 4 Methodology) and during Stage 3 the information collected was analysed, compiled and is documented in this report.

Geological mapping in the White River area was conducted in the summer of 2016 over a total period of approximately 55 mapping days, including three separate mapping periods. During each mapping period one mapping team, consisting of two geologists, undertook the work. Several GIS datasets were used as base maps for planning and undertaking the Phase 2 Geological Mapping, including predictive outcrop mapping generated by NWMO using remote sensing data (Section 4.0), high-resolution satellite imagery, recently-acquired high-resolution geophysical data (SGL, 2017) and interpreted lineaments (SRK, 2017).

1.2 Qualifications of the Team

The core team of Amec Foster Wheeler that undertook the mapping and subsequent collation and reporting of data comprised:

- Dr Martin Shepley PGeo — Project Manager
- Ivan Severinsky PGeo — QA/QC lead
- Dr Michael Cooley PGeo — Lead Structural Geologist
- Martin Little PGeo — Assistant Geologist
- John Balinski PGeo — Assistant Geologist

A summary of the qualifications of the core team is provided below.

Dr Martin Shepley has a DPhil in structural geology from the University of Oxford, UK and is registered as Professional Geoscientist in the Provinces of Ontario and Newfoundland and Labrador and Chartered Geologist with the Geological Society of London. He has over twenty years of experience in managing and executing projects in the fields of hydrogeology and structural geology in the UK, Europe, Canada, Mexico and South America for mining, water resources and radioactive waste disposal.

Ivan Severinsky has a BSc in geology from the University of Western Ontario and is registered as Professional Geoscientist in the Provinces of Ontario and Saskatchewan. He has over thirty years of experience in conducting and managing geotechnical and aggregate resource projects in Ontario, Manitoba and Saskatchewan.

Dr Michael Cooley has an MSc and a PhD in structural geology from Queen's University and is registered as a Professional Geoscientist in Ontario and in Alberta. He has over five years of academic field experience using GIS data collection methods for mapping geological structures and has worked the past eleven years as a structural geology consultant for the mineral exploration industry.

John Balinski has a BSc in geology from Brock University and is registered as a Professional Geoscientist in the Province of Ontario. He has thirty years of experience in conducting petrographic examinations and bedrock investigations for industrial mineral resources across the whole of North America.

Martin Little has an MSc in Earth Sciences from Brock University and is registered as Professional Geoscientist in the Province of Ontario. He has over 10 years of experience in performing, training, and supervising geologic/geotechnical core logging and orientated geotechnical core logging required for aggregate resource assessment and mining drill programs. In addition, he has supervised field work for aggregate resource assessments while supervising the Amec Foster Wheeler petrographic laboratory.

1.3 Report Organization

The report is subdivided into five main sections:

- Section 2.0 provides a description of the White River area with respect to its location on the Canadian Shield and its physiography.
- Section 3.0 reviews the geology of the White River area, which includes the understanding prior to this study of the geological units, their distribution and their tectonic history.
- Section 4.0 provides an outline of the methodology of the three stages of the present mapping project and an overview of the methods used to collect the geological data.

- Section 5.0 is the bulk of this report. It provides a comprehensive description of all the data collected in the mapping areas of the Strickland pluton (Section 5.1) and Anahareo Lake pluton (Section 5.2) with greater detail provided on the dyke swarms (Section 5.3).
- Section 6.0 synthesizes the data collected and the conclusions drawn from this study.

Appendix A provides supporting tables for the methodology described in Section 4.0 and Appendix B provides information on remote predictive bedrock analysis used for the pre-mapping planning stage described in Section 1.04.1.1.

2.0 DESCRIPTION OF THE WHITE RIVER AREA

2.1 Location

The Township of White River is located in Northern Ontario near the northeastern end of Lake Superior (index map of Figure 1.1). The two largest conurbations closest to White River are Thunder Bay and Sault Ste. Marie, which are approximately 300 km to the west and 250 km to the south respectively. The Township has an areal extent of approximately 110 km^2 (Figure 1.1). The two areas examined (Strickland pluton and Anahareo Lake pluton) both lie eastwards of the Township. The Strickland pluton is located approximately 40 km to the northeast of the Township and is directly accessible from Highway 631. The Anahareo Lake pluton is located approximately 30 km to the east of the Township, but cannot be accessed directly from any main roads.

2.2 Physiography

The Township of White River and surrounding lands is an area of relatively low relief and mostly gentle topography lying within the Abitibi Upland subdivision of the Canadian Shield physiographic region (Thurston, 1991). This physiographic subdivision is characterized by undulating topography where bedrock is at outcrop or covered by a thin layer of Quaternary glacial deposits or post-glacial soils (Thurston, 1991). Bedrock outcrops tend to occur in the elevated areas (bedrock knolls), whereas the superficial deposits tend to be more prevalent in the valleys.

The topography for the Township of White River is relatively flat in comparison to the two withdrawal areas. The Strickland pluton area has topography in the range of approximately 330 to 430 metres above sea level, but the bedrock knolls are nevertheless still mostly quite rounded. The drainage pattern of the water bodies within the Strickland pluton area show some indication of prevalent orientations towards the northeast and northwest at the map scale shown on Figure 1.1. The alignment of drainage channels with linear topographic trends is more evident at the scale of the outcrop and is discussed further in Section 5.1.2. Overall, the Strickland pluton area straddles a major drainage divide with the western margin lying within the Atlantic Watershed (via Lake Superior and the St. Lawrence River) and the larger eastern part lying within the Arctic Watershed (via Hudson Bay).

The Anahareo Lake pluton area has more rugged topography than the Strickland pluton area with topography in the range of 340 to 520 metres above sea level. This is particularly evident in the northern part of the Anahareo Lake pluton area where notable cliff faces occur of the order of tens of metres high. Similar to the Strickland pluton area the drainage appears to be preferentially aligned to the northeast and northwest, which becomes more evident at the outcrop scale, as discussed further in Section 5.2.2. The Anahareo Lake pluton area lies immediately to the east of the major drainage divide, occurring entirely within the Arctic Watershed.

3.0 SUMMARY OF GEOLOGY

Details of the geology of the White River area were described in the Phase 1 Geoscientific Desktop Preliminary Assessment (AECOM, 2014a). The following sections provide brief descriptions of the geologic setting, bedrock geology, structural history and mapped structures, metamorphism and Quaternary geology of the White River area. The focus of the following sections are the bedrock units identified during Phase 1 as being potentially suitable to host a deep geological repository and the important structural features in the area.

3.1 Geological Setting

The White River area is located within the Archean Superior Province of northern Ontario. The Superior Province is a stable craton created from a collage of ancient plates and accreted juvenile arc terranes that were progressively amalgamated over a period of more than 2 Ga (e.g., Percival et al., 2006). The Superior Province covers an area of approximately 1,500,000 km^2 and is divided into subprovinces, including the Wawa Subprovince within which the White River area is located.

The Wawa Subprovince comprises multiple units of volcanic and associated metasedimentary rocks (greenstone belts) separated by extensive granitoid plutons and batholiths. These greenstone belts typically occur in elongate, narrow, geometries and represent volumetrically a relatively minor percentage of the rocks. The surrounding granitoid bodies are composed primarily of tonalite to granodiorite, and represent the vast majority of the rocks present throughout the White River area.

Four generations of Paleoproterozoic diabase dyke swarms, ranging in age from ca. 2.473 to 1.238 Ga, intrude all bedrock units in the White River area (Krogh et al., 1987; Hamilton et al., 2002; Buchan and Ernst, 2004; Halls et al., 2006).

3.2 Bedrock Geology

The White River area is situated 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.

There are two semi-linear to arcuate zones of greenstone belts within the Wawa Subprovince, the northern of which includes the Shebandowan, Schreiber-Hemlo, White River-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 1.2). 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 kilometres 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 White River-Hornepayne and the Black River assemblage of the Schreiber-Hemlo belts.

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). The granitoids in the White River Phase 2 assessment area include the Strickland and Anahareo Lake plutons, the Pukaskwa batholith and to a lesser extent the Black-Pic batholith.

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 of interest occurring in the White River area are further described below.

3.2.1 Strickland Pluton

The Strickland pluton occurs in the northern portion of the White River area bordering the Dayohessarah and Kabinakagami greenstone belts. The pluton extends to the northeast of the study area, occupies an area of approximately 600 km^2 and has maximum dimensions (including areas beyond the study area) of 34 kilometres north-south and 55 kilometres east-west (Figure 1.2). 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.

The Strickland pluton has recently been modelled, using gravity and aeromagnetic data, with a roughly constant thickness slightly over 2 km with internal density variations or alternatively with a constant density and variable thickness with a maximum around 4 km in the central part of the pluton (SGL, 2017).

3.2.2 Pukaskwa Batholith

The Pukaskwa batholith (also referred to as the Pukaskwa gneissic complex) is a large, regionally-extensive intrusion covering an area of at least 5,000 km^2 in the Wawa Subprovince (Figure 1.2). 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 Pukaskwa batholith surrounds the western extent of the Anahareo Lake pluton.

The Pukaskwa batholith extends over the central portion of the White River area (Figure 1.2) and is described as comprising foliated tonalite and gneissic tonalite suites (Santaguida, 2001). Regionally, the Pukaskwa batholith is a multi-phased intrusion emplaced over an extended time period (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 subparallel 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 as a regional dome structure relative to flanking greenstone belts at approximately 2.680 Ga and synchronous 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 dykes. 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 (Davis and Lin, 2003; Beakhouse et al., 2011).

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.

3.2.3 Anahareo Lake Pluton

The Anahareo Lake pluton (informal name adopted in AECOM, 2014a) 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 1.2). The pluton extends west of the study area and has maximum dimensions (including areas beyond the study area) of over 51 kilometres north-south and 71 kilometres 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.

The Anahareo Lake pluton has recently been modelled using gravity and aeromagnetic data (SGL, 2017). With a constant density model the pluton has a maximum depth of 3.6 km, while a varying density model yields a maximum depth to base of approximately 2.3 km.

3.2.4 Black-Pic Batholith

The Black-Pic batholith is a regionally-extensive intrusion that encompasses roughly 3,000 km^2 within the Wawa Subprovince and underlies only a very small portion along the northern and western boundaries of the White River area. It is bounded to the south by the Strickland pluton, the Pukaskwa batholith, and the Danny Lake stock, and to the east by the Dayohessarah greenstone belt (Figure 1.2).

The Black-Pic batholith comprises a multi-phase suite that includes hornblende-biotitemonzodiorite, 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 that becomes gneissic near the boundary with the Dayohessarah greenstone belt (noting that the 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 as either a breccia type, in which fragments of the older rocks are cemented by dykes; and 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 Black-Pic batholith, yielding geochronological ages ranging from ca. 2.720 Ga (Jackson et al. 1998) for the earliest recognized rock unit to ca. 2.689 Ga for a late-stage monzodioritic unit (Zaleski et al., 1999). In addition, there are also younger granitic phases within the Black-Pic batholith 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 foliation pattern recognized within the Black-Pic batholith was interpreted to define regional scale domal structures characterized by broad antiforms and tight synforms (Williams and Breaks, 1989; Lin and Beakhouse, 2013). At least one such smaller-scale structure potentially exists to the west of White River Phase 2 assessment area, immediately north of the Danny Lake stock where semi-circular faults outline the position of a possible dome several kilometres in width.

Structurally deeper levels of the tonalite suite in the Black-Pic batholith are strongly foliated with a subhorizontal 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 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.

3.2.5 Foliated Tonalite Suite

On the southeast side of Kabinakagami Lake, Santaguida (2001) outlined two packages of foliated tonalite suite rock, bisected by greenstone, that occur between the Kabinakagami greenstone belt and the Anahareo Lake pluton (Unit 10 on Figure 1.2). The tonalite packages extends over a distance of 29 kilometres north-south and 25 kilometres east-west, but only a small amount occurs within the White River area. 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 granitoid rock in contact zones between the granitoid 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.

3.2.6 Mafic Dykes

Four generations of Paleoproterozoic and Mesoproterozoic diabase dyke swarms cross-cut the White River area (Figure 1.2), 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).
- Northeast-trending Biscotasing Suite dykes (ca. 2.167 Ga; Hamilton et al., 2002). These dykes are not considered to be numerous in the White River area.
- 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.
- West-northwest–trending Sudbury Suite dykes (ca. 1.238 Ga; Krogh et al., 1987). These dykes are not considered to be numerous in the White River area.

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

3.3 Structural History

Information on the structural history of the White River area is based predominantly on insights derived from structural investigations of the White River 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), and Williams and Breaks (1996) have also contributed to the structural understanding of the area. The aforementioned 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. The structural history of the White River area is described below and summarized in Table 3.3.1.

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. These deformation events 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 cross-cutting relationships, they are likely the products of progressive deformation events.

Table 3.3.1 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 2.673 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
2.675 and 2.669 Ga	Peak metamorphism of regional greenstone belts
< 2.673 Ga	Two phases of brittle deformation (D_5-D_6)
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 White River 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

Approximate Time Period (years before present)	Geological Event
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

Integration of the structural histories detailed in Williams and Breaks (1996), Polat et al. (1998), Peterson and Zaleski (1999), Lin (2001), and Muir (2003) suggest that six deformation events occurred within the White River area. The first four deformation events (D_1-D_4) are associated with ductile and brittle-ductile deformation. 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 (F_1) folds, ductile shear zones that truncate stratigraphy, and a general lack of penetrative foliation development. Peterson and Zaleski (1999) reported that an S_1 foliation is only preserved locally in outcrop and in thin section. 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 L_2 mineral elongation 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. The S_2 foliation is the dominant meso- to macro-scale fabric evident regionally. Ductile flow of volcano-sedimentary rocks between more competent batholiths may also have occurred during D_2 deformation. This generation of deformation is constrained to between ca. 2.691 and ca. 2.683 Ga (Muir, 2003).

D_3 deformation was the result of northwest-southeast shortening during regional dextral transpression. D_3 structural elements include macroscale F_3 folds, including the regional scale isoclinal fold developed within the Manitouwadge greenstone belt, and local shear fabrics that exhibit a dextral sense of motion and overprint 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 associated small-scale fractures and faults overprinting D_3 structures. D_3-D_4 interference relationships are best developed 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 to brittle faults and brittle-ductile shear zones 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 post-Archean tectonic re-activation.

3.3.1 Mapped Structures

In the White River area, five unnamed faults are indicated on public domain geological maps that are considered to be associated with D_5-D_6 brittle deformation (Fenwick, 1966; Siragusa, 1977, 1978; Stott, 1995a, b, c; Santaguida, 2001; OGS, 2011; Figure 1.2). The longest unnamed fault parallels the axis of Esnagi Lake in the southeast corner of the area (Siragusa, 1978). A northeast-trending mapped fault is located crossing the western margin of the White River area and is mapped as juxtaposing the Pukaskwa batholith against the Strickland pluton. A northwest-trending mapped fault is located at the southern extent of Nameigos Lake that is shown offsetting the Kabinakagami Lake greenstone belt with a dextral strike-separation. A northwest-trending mapped fault is located within the Anahareo Lake pluton, southwest of Anahareo Lake. Finally, a mapped west-northwest-trending fault is located at the northern extent of Nameigos Lake that is shown as truncating the Pukaskwa batholith against the Strickland pluton and the Kabinakagami Lake greenstone belt.

In the Kabinakagami Lake greenstone belt, Siragusa (1977) reported that it is likely that a northeast-trending strike-slip fault with horizontal displacement of 240 m is present in a narrow valley, to the north of the inlet of the Kabinakagami River.

Fenwick (1967) and Siragusa (1977) noted that lineaments parallel the trend of two sets of diabase dykes, which strike either northeast or northwest, and assumed that the lineaments formed from the weathering of diabase dykes or from vertical joints.

3.4 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 lithologically variable 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 English River and Quetico, and dominantly plutonic and orthogneissic domains, such as 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).

In general, most of the Canadian Shield preserves a complex episodic history of Neoarchean metamorphism overprinted by Paleoproterozoic tectonothermal events culminating at ca. 950 Ma, at the end of the Grenville orogeny. 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 metamorphism may be a manifestation of a medium (or high) grade contact 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 White River-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 et al. (1994; 1999) correspond well with the 2.675 ±1 and 2.661 ±1 Ga periods of regional metamorphism recognized by Schandl et al. (1991).

Typical metamorphic conditions in plutonic rocks within the White River area are variable from non-metamorphosed to amphibolite facies in metamorphic contact aureoles. No evidence to date suggest that rocks in the White River area were affected by thermal overprints related to post-Archean events.

3.5 Quaternary Geology

Quaternary geology of the White River area is described in detail in the remote sensing and terrain evaluation completed as part of the Phase 1 Desktop Preliminary Assessment (AECOM, 2014b). An overview of the relevant Quaternary features is summarized below.

The Quaternary sediments, commonly referred to as drift, soil, or overburden, in the White River area comprise glacial and post-glacial materials that overlie the bedrock. All glacial landforms and related materials are associated with the Wisconsinan glaciation, which began approximately 115,000 years ago (Barnett, 1992). 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 oriented approximately 220 degrees (°). 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°.

Till thickness is variable. While depths of several metres are present locally, thicknesses are typically less than 3 m (A. Bajc, pers. comm., 2013). Gartner and McQuay (1980a, 1980b) 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. For large parts of the White River area, drift thickness over bedrock is limited and the ground surface reflects the bedrock topography (Geddes and Kristjansson, 1986). Over the majority of the area, bedrock outcrops are common and the terrain is classified, for surficial purposes, as a bedrock-drift complex, i.e., thin drift cover that, only locally, achieves thicknesses that mask or subdue the bedrock topography. Valleys and lowland areas typically have extensive and thicker surficial deposits that frequently have a linear outline.

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

Glaciolacustrine sediments in the area consist of fine sand, silt, and minor clay deposited in shallow lakes within bedrock controlled basins. The largest of these deposits is located proximal to Nameigos Lake (Gartner and McQuay, 1980a, 1980b). Other small deposits typically occur towards the northeast of the area (Geddes and Kristjansson, 2009).

Bogs and organic-rich alluvial deposits, consisting of sand, silt and organic debris, are present along several of the water courses in the White River area. These deposits tend to be relatively narrow (<200 m), although their width can increase notably proximal to lakes. Larger expanses of organic terrain, some of several square kilometres in size, are present in the northeastern and northwestern parts of the White River area near Nameigos and Gourlay lakes, respectively. These deposits may be developed on finer-grained glaciolacustrine deposits and/or outwash that occupy lowland areas. Smaller occurrences of organic terrain exist in bedrock-controlled basins throughout the White River area.

4.0 METHODOLOGY

The following sections provide an overview of the methods implemented in order to fulfill the requirements of the technical scope of work for the Phase 2 Geological Mapping completed by Amec Foster Wheeler and Dr. Michael Cooley for the White River area in Ontario. Phase 2 Geological Mapping in the White River area focused within and around the two withdrawal areas for mapping that were identified in the Phase 1 Geoscientific Desktop Preliminary Assessment (AECOM, 2014a), including the Strickland pluton area and the Anahareo Lake pluton area.

The OGGF component of the Phase 2 Geological Mapping was intended to acquire a reasonably-sized initial data set at easily accessible outcrops in order to define priority areas on which to concentrate during the subsequent Detailed Outcrop Mapping component. The data collected at each outcrop for both of these components was the same. The methods described below include tasks associated with planning, implementation, and reporting of the Phase 2 Geological Mapping.

4.1 Pre-mapping Planning Stage

In order to optimize the time and resources available, a pre-mapping planning stage of the Phase 2 Geological Mapping activity was completed prior to mobilizing to the White River area. This stage included the development of a list of available source data (Appendix A, Table A.1) and equipment requirements (Appendix A, Table A.2), for planning and implementing the two components of the Phase 2 Geological Mapping. This stage also included the development of a summary list of daily field tasks allocated to each mapping team member (Appendix A, Table A.3).

The key geological attributes to be investigated, along with the methods identified to observe and capture the relevant information at each bedrock outcrop location (Appendix A, Table A.4), were also outlined in the pre-mapping planning stage. This included the use of a digital data capturing method, which for this activity included an ArcGIS compatible data-logging instrument. The instrument consisted of a Trimble (T41 or equivalent) handheld computer that included a customized version of ArcPad data collection software (SRK, 2016) with a database specifically set-up to capture the attributes listed in Table A.4. The database is consistent with a modified version of the GanFeld database used in previous OGGF mapping projects. The GanFeld system is an Ontario Geological Survey (OGS) standard system for data collection which was originally provided in an open file format by the Geological Survey of Canada (Shimamura et al., 2008). Entry of geological information into the data collector followed a simple data collection protocol (SRK, 2016) which directed the observer to the appropriate digital form within the database system to capture the appropriate geological information for each geological characteristic being investigated. Additional guidance relevant to the documentation of the geological characteristics is provided in Table A.4 (Appendix A) and, specifically for geomechanical characterization, in Table A.5 (Appendix A).

4.1.1 Predicted Outcrop Filtering and Defining Daily Traverses

The results from a remote predictive bedrock mapping exercise, provided by the NWMO, show the distribution of predicted bedrock outcrop locations within and around the withdrawal areas (Figure 1.2). The process that was used to undertake the remote predictive bedrock mapping exercise is included in Appendix B below. These predicted outcrops serve as input for the task of defining traverses for the Phase 2 Geological Mapping, as they represent potential targets for direct investigation of exposed bedrock. The spatial distribution of predicted outcrop locations in relation to their distance to the existing road and trail network, and to the key geological features to be investigated during the Phase 2 Geological Mapping, was assessed.

The subset of easily accessible outcrops identified to be visited during the initial OGGF component of mapping included predicted outcrops located within 100 metres of existing roads and trails (and where applicable, electrical power and rail corridors) in and around the withdrawal areas. The subset of outcrops identified to be visited during the Detailed Outcrop Mapping stage included outcrops located more than 100 metres from existing roads and trails, and focused within the withdrawal areas. These two subsets of the predicted outcrops were individually assessed for proximity to the key geological features, including interpreted lineaments, interpreted geophysical anomalies and mapped geological bedrock units and their contacts. Outcrops that were coincident with, or near to, key geological features, and in close enough proximity that they could reasonably be examined during one day of mapping, were grouped together to form daily traverses.

This assessment defined the daily traverses for the OGGF stage of the Phase 2 Geological Mapping. A simplified outline for the Detailed Outcrop Mapping component was also initially developed, and practical knowledge of any accessibility constraints for each area was incorporated from the OGGF mapping to refine the traverse plan for the Detailed Outcrop Mapping component, prior to returning to the field for the second and third site visits. During the course of both the OGGF and the Detailed Outcrop Mapping stages, the daily traverses were adjusted to accommodate several considerations, including method(s) of access, weather and overall progress of the mapping.

4.2 Mapping Stage

The information included above provided the planning approach to be taken to meet the objectives of the geological mapping activity, including both the OGGF and Detailed Outcrop Mapping phases. At each identified outcrop traverse location, the geological attributes identified in Table A.4 (Appendix A) were investigated.

Prior to starting mapping, a reconnaissance fly-over was done to assess the results from the remote predicted outcrop activity and to get an overall understanding of the lay of the land. Further ground-truthing of the predicted outcrops was also completed by helicopter during the mapping, which in some cases led to modification of traverses identified during the pre-mapping stage.

An important additional aspect of the Phase 2 Detailed Geological Mapping was the non-technical workflow that was followed on a daily basis to allow the technical work to be done to meet the required objectives. This included morning safety briefings, equipment calibration checks, data quality assurance checks, and planning for the next mapping day (Appendix A, Table A.3). A telephone conference was held with NWMO every evening during the course of the mapping campaign in order to discuss all aspects of the on-going work.

This workflow provided the mechanism for communicating progress with the NWMO during mapping and for prioritizing traverses or making changes to planned traverses. The daily log documented the completion of the safety debriefing, calibration check and data back-up.

4.2.1 Proterozoic Mafic Dyke Scanline Fracture Mapping Exercise

Along with compiling observations on Proterozoic mafic dykes that were encountered on daily OGGF and Detailed Outcrop Mapping traverses, well-exposed examples of mafic dykes were identified as candidates for a scanline fracture mapping exercise, after the completion of the Detailed Outcrop Mapping. The emplacement of these Proterozoic mafic dykes, as outlined in Section 3, is understood to post-date the penetrative regional ductile deformation that is characteristic of the Superior Province. However, the relationship between dyke emplacement and the brittle deformation history of the Superior Province is less well constrained. The purpose of the scanline fracture mapping exercise is to assess both the nature and extent (if any) of the damage to the bedrock caused by dyke emplacement and the nature and extent of brittle deformation overprinting the dykes themselves. A summary of the method employed to complete each scanline fracture mapping exercise is described below.

Where a suitable target dyke is located, a scanline is laid out perpendicular to the strike of the dyke contact. One metre intervals were marked for reference along the strike direction, shifting the line to a parallel location where necessary (e.g. overburden cover). Observations of the type and distribution (spacing) of brittle deformation features (veins, faults, joints) were collected systematically within a 1 to 2 m wide swath parallel to the scanline line perpendicular to strike of dyke contact and extending as far as possible into the adjacent bedrock beyond the dyke contacts. Additional characteristics such as fracture infill, cross-cutting relationships and offsets were noted, if present. A sketch of the scanline was drawn, and photographs taken, to highlight key features (dyke contacts, prominent fractures, shifts in the scanline, overburden cover, etc.). Magnetic susceptibility readings were made at each 1 m interval, with five readings used to obtain an average for each measurement location. Host rock foliation on both sides of the dyke was also recorded, if present. The results from the scanline fracture mapping exercise of one Matachewan mafic dyke is included in Section 5.3.1.3 of this report. All exposures encountered of mafic dykes from the other Proterozoic swarms were relatively small and not suitable for undertaking a detailed scanline fracture mapping exercise.

Note also that due to the magnetic properties of the dykes, compass readings were significantly affected when placed close to the ground surface. In order to achieve the most accurate measurements for joints within the dyke, measurements were made approximately 1.5 m above the ground, and measuring the dip with the clinometer.

4.3 Synthesis and Reporting Stage

Following the completion of the Detailed Outcrop Mapping stage, this report was prepared describing the results from the OGGF and Detailed Outcrop Mapping components of the Phase 2 Geological Mapping. The report is focussed on the objective of increasing the overall understanding of the key geological attributes for the withdrawal areas and the identified withdrawal areas. This report includes the methodologies applied and an interpretation and analysis of the field observations in terms of an update on the new state of knowledge that the observations provide, specific to the withdrawal areas.

Shapefiles of the compiled mapping observations were delivered to NWMO and are in accordance with the types of information entered into the observation database. The list of shapefiles delivered includes:

- Station.shp
- Lithology.shp
- Structure.shp
- Linework.shp
- Samples.shp
- Magnetic Susceptibility.shp
- Gamma Ray Spectrometry.shp
- Photographs.shp

All digital photographs were delivered in a zipped folder. Field notebooks were provided by means of a zipped folder of scanned pages. The data delivery also included a summary calibration report that includes copies of all calibration reports provided by third-party equipment providers and summary of results from all calibration activities undertaken during the mapping activities.

Metadata accompanying each shapefile and zipped folder, along with the calibration report, was prepared according to metadata guidelines provided by the NWMO. A summary overview of the mapping observations is presented in Section 5.0 of this report.

5.0 GEOLOGICAL FINDINGS

This section summarizes the field observations from the geological mapping activities undertaken in the White River area (Figure 1.1) within and around two of the potentially suitable areas identified during Phase 1 Preliminary Assessment (AECOM, 2014a) on the Strickland and Anahareo Lake plutons (Figure 1.2). The two mapped areas are further referred to as the Strickland pluton area and the Anahareo Lake pluton area.

The Amec Foster Wheeler mapping team for both map areas comprised:

- Dr Michael Cooley (P.Geo) Lead Structural Geologist
- Martin Little (P.Geo) Assistant Geologist
- John Balinski (P.Geo) Assistant Geologist (alternate)

A total of 55 mapping days were completed over three periods:

- July 1,2016 – July 21, 2016
- August 3, 2016 – August 22, 2016
- September 9, 2016 – September 22, 2016

Of the 55 mapping days, 23 were spent mapping within the Strickland pluton area and 30 days within the Anahareo Lake pluton area. Geological observations were recorded at a total of 169 mapping stations in the Strickland pluton area and 204 in the Anahareo Lake pluton area (Figure 1.2). In addition to these mapping stations, a detailed scanline mapping exercise was undertaken at one well-exposed Matachewan dyke on Highway 631 within the Strickland pluton area (Section 5.3.1.3). Access to much of the Anahareo Lake pluton area is along the logging road that runs north-south through the area. Consequently, a wider and more evenly spread distribution of mapping stations has been achieved for this area in comparison to the Strickland pluton area (Figure 1.2).

Observations from the Strickland pluton and Anahareo Lake pluton areas are described in Sections 5.1 and 5.2, respectively. Observations relating to Proterozoic mafic dykes and Archean felsic dykes are included in Section 5.3. A summary of the key findings is presented in Section 6.0. The complete dataset of geological mapping observations is provided as a separate data delivery.

5.1 Strickland Pluton Area

The Strickland pluton area is located to the northeast of the community of White River, along Highway 631 (Figures 1.2 and 5.1.1). The Strickland pluton area is underlain primarily by the Strickland pluton, previously mapped as a large igneous body of granite-granodiorite composition. The southeastern part of the area falls along the boundary between the Strickland pluton and adjacent gneissic tonalite and greenstone belt units. A total of 169 mapping stations were visited in the Strickland pluton area (Figure 5.1.1). The following sections provide information regarding accessibility and surface constraints, bedrock exposure and overburden thickness, lithology, and structure, of the Strickland pluton area.

5.1.1 Accessibility and Surface Constraints

A summary of observations on accessibility and surface constraints (e.g., obstructions) for the Strickland pluton area (Figure 1.2; Figure 5.1.1) is provided below.

The Strickland pluton area was mapped between July and mid-September 2016. Weather conditions were generally hot with little rainfall. Consequently, many small tributaries and low lying areas were dry, facilitating access during the period when mapping was undertaken. Larger tributaries, ponds and lakes had low water levels which allowed safe passage across natural features such as fallen vegetation or beaver dams and provided large flat areas for the safe landing of helicopters.

Access to the northeastern part of the Strickland pluton area is good via Highway 631 and connecting logging roads and trails. Road cuts along Highway 631 allowed for excellent access to well exposed outcrop (Figure 5.1.2a). Narrow shoulders, steep drainage ditches and engineered granular fill along the highway resulted in limited areas to disembark from vehicle. The existing local logging road network in the north portion of the mapping area east of Highway 631 was well constructed, with maintained bridges and culverts, and passable by 4×4 vehicle along the major artery trending west-east. Deterioration and overgrowth (tall grasses, brush and alder trees) of many north-south-trending roadways in the northeast portion of the map area required the use of ATV and subsequent traverse by foot to access outcrop.

An existing logging road in the northwest portion of the Strickland pluton area west of Highway 631 was passable by 4×4 vehicle. Small, locally constructed bridges over washouts restricted further access to ATVs (Figure 5.1.2b). These roads deteriorated with overgrowth and large diameter alder trees where further traverse by foot was required to reach outcrop. A network of new logging roads, not shown on Figure 1.2 and Figure 5.1.1, provided additional access to the west portion of the map area, southwest of Highway 631. The main arteries of these recently used logging roads in the southwest portion of the mapping area were generally passable by 4×4 vehicle. However, road drainage in low lying areas was poor. This area was characterized by the presence of small ponds, swamp, and bog which restricted the traverses to foot. Contact with local logging companies revealed they were not active in the area at the time of mapping.

Outcrops are sparse in the southeastern part of the Strickland pluton area and access by road is largely not possible (Figure 5.1.1). A helicopter was required to access these hard to reach locations. Meandering river channels, bog and dense vegetation around waterways reduced possible landing sites and restricted accessibility to much of this area. These conditions are reflected in the location and overall lower number of mapping stations visited. Nameigos Lake, located in the southeastern part of the Strickland pluton area, was accessed by float plane and a boat was used to access outcrop along the lake shore.

5.1.2 Bedrock Exposure and Overburden Thickness

Out of a total of 169 mapping stations visited in the Strickland pluton area, 164 (97%) were locations of bedrock outcrop and 5 (3%) were locations where overburden was encountered. Overall, the occurrence of bedrock outcrops was found to be consistent with the predicted bedrock outcrops shown on Figure 5.1.1. Within the Strickland pluton area overburden thickness was commonly less than one metre as encountered at mapping stations along Highway 631 and existing logging roads. Similar overburden thicknesses were encountered in the more remote areas accessed by helicopter and float plane. Variations related to bedrock exposure and overburden thickness in different portions of the Strickland pluton area are described below.

Few bedrock outcrops were encountered along recent logging roads traversing the highest elevations of the north portion of the mapping area, east of Highway 631. Here overburden was sandy till and assessed to be greater than 3 m thick (mapping stations 16MC0305 to 16MC0309; Figure 5.1.2c). In the north central portion of the Strickland pluton area, overburden was deposited as rolling hillocks and generally composed of sandy till, with thickness ranging between one metre and three metres.

The northwest portion of the Strickland pluton area, west of Highway 631, generally had overburden thicknesses of 1 m or less. Sandy deposits greater than three metres thick nevertheless were encountered locally within the area. The central-western portion of the map area, also west of Highway 631, was generally low-lying swamp. Low water levels between the months of July to mid-September 2016 exposed outcrop targets within this area (Figure 5.1.2d). Overburden thickness was typically less than 1 m and characterized by rich organic material.

The low-lying central, south, and southeastern portions of the Strickland pluton area, characterized by meandering river channels, small ponds and bogs, typically had overburden thicknesses less than 1 m at the mapping stations visited. However, with the exception of the Nameigos Lake shore, there are few bedrock outcrops in the south and southeast, as indicated by the predicted bedrock outcrop (Figure 5.1.1).

5.1.3 Lithology and Physical Character

The descriptions below provide an overview of the main and minor bedrock lithological units observed in the Strickland pluton area, as well as their main physical characteristics. Lithological units described below as main units tend to occur as the predominant rock type covering at least 60% of the exposed bedrock, by area, at any individual bedrock outcrop station, and are observed at a high frequency of bedrock outcrop stations overall. Minor lithological types described below may occasionally occur as the main rock type at individual bedrock outcrop stations, but in general they occur infrequently, and represent only a small portion overall of the bedrock in the Strickland pluton area.

Two main Archean-aged lithological units are identified in the Strickland pluton area, including tonalite and granodiorite (Figure 5.1.3). Field appearance and some properties of these units are shown in Figures 5.1.4 and 5.1.5. The transition between these units is sometimes gradational at the outcrop scale; however, their occurrence and character are described separately below because there is a clear pattern of predominantly tonalite in the northern half of the Strickland pluton area and predominantly granodiorite in the southern half. Additional minor Archean-aged lithological units observed included a heterogeneous, but small volume, mixture of gneissic tonalite and mafic schist (Figure 5.1.6). A summary of the bedrock characteristics of these units is provided in Table 5.1.1. In addition to these units, Proterozoic mafic dykes, and minor felsic to intermediate dykes (likely of Archean age), were identified throughout the Strickland pluton area. These mafic and felsic dyke occurrences are discussed separately in Section 5.3.

Table 5.1.1 Summary of Bedrock Characteristics by Lithology Type for the Strickland Pluton

Lithological Unit	Area where Identified	Weathered and (Fresh Colour)	Crystal Form	Fabric	Grain Size	Average Magnetic Susceptibility ($\times10^{-3}$ SI)	Gamma Spectrometry	Strength
Tonalite	North	Off white to light grey (Light grey to grey)	Equigranular	Mostly foliated	Mostly coarse-grained (5-10 mm)	4.77	539-1135	R4 to R5
Granodiorite	North (subsidiary)	Off white to light grey, some red (Light grey)	Equigranular	Foliated	Mostly coarse-grained (5-10 mm)	3.72	848-1272	R4 to R5
Granodiorite	South	White to light grey to pink (Light grey, dark grey to pink)	Equigranular	Massive to foliated	Coarse-grained (5-10 mm)	3.18	868-1574	R3 to R5
Tonalite	South (subsidiary)	Off white to light grey (Light grey to grey)	Equigranular	Mostly foliated	Mostly coarse-grained (5-10 mm)	3.83	762-987	R3 to R5
Felsic / aplite dykes	North and south	White to light grey to pink (Light grey, dark grey to pink)	Equigranular	Massive to foliated	Very fine-grained (0.1-0.5 mm) to fine-grained (0.5-1 mm)	2.85	695-1868	R3 to R6
Intermediate dykes	South (rare)	Light grey to black	Equigranular	Massive to foliated	Fine-grained (0.5-1 mm) to	1.51	674-1950	R3 to R5

Lithological Unit	Area where Identified	Weathered and (Fresh Colour)	Crystal Form	Fabric	Grain Size	Average Magnetic Susceptibility (×10^{-3} SI)	Gamma Spectrometry	Strength
		(Light grey to black)			medium-grained (1-5 mm)			
Schist	Localized (rare)	Light green to brown (Dark green to brown)	Equigranular	Foliated	Fine-grained (0.5-1 mm)	Not measured	Not measured	R2 to R3
Gneiss	Localized, Nameigos Lake in South	Light grey (Light grey)	Inequigranular	Foliated	Medium-grained (1-5 mm)	5.32	760-1138	R4

5.1.3.1 Main Lithology 1 = Tonalite

The most common rock type in the Strickland pluton area is a coarse-grained biotite tonalite. It was encountered at 107 out of 164 (65%) bedrock outcrop stations. In 86 of these occurrences, it constituted at least 90% of the outcrop by area, with the remainder being 30 to 60% of the outcrop by area. The distribution of the tonalite occurrences indicates that it underlies the majority of the northern and western portions of the Strickland pluton area (Figure 5.1.3). Additional tonalite occurrences were observed in the southern half of the Strickland pluton area as a unit texturally similar to, and gradational into, the granodiorite. A total of 76 representative rock samples of tonalite main lithology were collected from the Strickland pluton area. Three additional isolated sub-metre scale tonalite dykes, accounting for less than 10% of the outcrop by area, were also observed in the southern half of the Strickland pluton area. These small dykes are considered further in Section 5.3.4 with the felsic dykes.

A lithological boundary for the main body of tonalite, separating it from predominantly granodiorite to the south, is interpreted to trend roughly east-northeast through the middle of the Strickland pluton area, as shown in Figure 5.1.3. This interpreted contact is generally parallel to observed igneous flow foliations on both sides of the contact and is constrained by outcrop control through the middle of the Strickland pluton area. The continuation of the contact along the northwestern boundary of the mapping area is less well constrained. At the outcrop scale transitions between tonalite and granodiorite are gradational with no evidence of localization of ductile or brittle deformation features along contacts. Some field examples of tonalite are shown in Figures 5.1.4a and 5.1.4b.

The tonalite has a conspicuous salt and pepper, white and black, speckled texture (Figure 5.1.4b). It is generally light grey to grey when fresh and off white to light grey or pink when weathered. It consists of approximately 50% plagioclase, 30% quartz, 5% potassium feldspar and 3% biotite. The alignment of quartz and biotite define a weak to moderately well-developed igneous flow foliation. The tonalite also locally contains traces of euhedral to subhedral brown-red titanite, and traces of finely disseminated magnetite. Average crystal sizes in the tonalite are 5 – 10 mm (coarse-grained) with anhedral interlocking textures; however, approximately 5% of the quartz commonly displays slightly more coarse grain sizes and can appear round or augen-like.

A total of 143 rock hardness measurements were made on the tonalite in the Strickland pluton area. It exhibited a very strong (R5) character in 124 instances (87%), a strong (R4) character in 17 additional instances (12%) and a medium strong (R3) in two additional instances (1%).

A total of 88 magnetic susceptibility measurements were made on the tonalite in the Strickland pluton area (Figure 5.1.4c), including 77 occurrences in the northern portion of the area and an additional eleven in the southern portion of the area. In the northern occurrences, the tonalite yielded a moderately high average magnetic susceptibility of 4.77×10^{-3} S.I., with a range of

10.66 × 10^{-3} S.I. across the average, and a standard deviation of 2.23 × 10^{-3} S.I. In the southern occurrences, the tonalite yielded a slightly lower average magnetic susceptibility of 3.83 × 10^{-3} S.I., with a range of 10.13 × 10^{-3} S.I. across the average, and a standard deviation of 2.57 × 10^{-3} S.I.

A total of 83 gamma ray spectrometry measurements were made on tonalite in the Strickland pluton area (Figure 5.1.4d), including 72 occurrences in the northern portion of the area and an additional 11 occurrences in the southern portion of the area. The measurements yielded the following results for the northern occurrences:

- Total count (range 596, average 696, Std. Dev. 115)
- %K (range 1.3, average 1.2, Std. Dev. 0.2)
- U ppm (range 3.0, average 0.3, Std. Dev. 0.5)
- Th ppm (range 4.3, average 2.2, Std. Dev.0.9)

The measurements yielded the following results for the southern occurrences:

- Total count (range 225, average 842, Std. Dev. 70)
- %K (range 0.6, average 1.5, Std. Dev. 0.2)
- U ppm (range 1.3, average 0.3, Std. Dev. 0.4)
- Th ppm (range 2.7, average 2.1, Std. Dev. 0.8)

The tonalite had %K below 1.7, which would be expected for this lithology.

5.1.3.2 Main Lithology 2 = Granodiorite

The second most common rock type in the Strickland pluton area is a coarse-grained biotite granodiorite. It was observed at 43 out of 164 (26%) bedrock observation stations. In 35 of these occurrences, it constituted at least 90% of the outcrop by area, with the remainder being 30 to 60% of the outcrop by area. The distribution of these occurrences indicates that granodiorite primarily underlies the southern half of the Strickland pluton area (Figure 5.1.3). Locally, throughout the southern half of the Strickland pluton area, the granodiorite grades into less common, but texturally similar tonalite. Additional isolated granodiorite occurrences were also observed in the northern half of the Strickland pluton area, where they account for between 30 and 90% of any outcrop by area. A total of 39 representative rock samples of granodiorite were collected from the Strickland pluton area. One additional isolated granodiorite sill was also observed in the northern half of the Strickland pluton area. This sill is considered further in Section 5.3.4 with the felsic dykes.

As described in Section 5.1.3.1 the gradational contact of the granodiorite with the tonalite to the north is generally parallel to observed igneous flow foliations on both sides of the contact and is constrained by outcrop control across the middle of the Strickland pluton area (Figure 5.1.3). Field examples of granodiorite are shown in Figures 5.1.5a and 5.1.5b).

The granodiorite is usually light grey or pink when fresh and off white to light grey or pink when weathered. It consists of anhedral coarse interlocking feldspar crystals of plagioclase (40%) and potassium feldspar (30%) and up to 15% round quartz eyes <10mm, and 2% biotite (Figure 5.1.5b). The alignment of quartz and biotite define a weak to moderately well-developed igneous flow foliation. The granodiorite also locally contains traces of euhedral to subhedral brown-red titanite and magnetite.

A total of 53 rock hardness measurements were made on the granodiorite in the Strickland pluton area. It exhibited a very strong character in 35 instances (66%), a strong (R4) character in 12 instances (23%) and a medium strong (R3) character in six instances (11%).

A total of 41 magnetic susceptibility measurements were collected on granodiorite in the Strickland pluton area (Figure 5.1.5c), including 37 occurrences in the southern portion of the area and an additional four in the northern portion of the area. In the southern occurrences, the granodiorite yielded a moderately high average magnetic susceptibility of 3.18×10^{-3} S.I. with a range of 5.55×10^{-3} S.I. across the average, and a standard deviation of 1.25×10^{-3} S.I. In the northern occurrences, the granodiorite yielded a slightly higher average magnetic susceptibility of 3.72×10^{-3} S.I. with a range of 2.61×10^{-3} S.I. across the average, and a standard deviation of 0.98×10^{-3} S.I.

A total of 40 gamma ray spectrometry measurements were collected on the main granodiorite intrusive phases in the Strickland pluton area (Figure 5.1.5d), including 35 occurrences in the southern portion of the area and an additional five occurrences in the northern portion of the area. The measurements yielded the following results for the southern occurrences:

- Total count (range 706, average 1079, Std. Dev. 200)
- %K (range 1.1, average 2.1, Std. Dev. 0.3)
- U ppm (range 4.2, average 0.5, Std. Dev. 0.9)
- Th ppm (range 2.9, average 2.3, Std. Dev. 0.6)

The measurements yielded the following results for the northern occurrences:

- Total count (range 424, average 1043, Std. Dev. 151)
- %K (range 1.0, average 2.0, Std. Dev. 0.4)
- U ppm (range 0.6, average 0.2, Std. Dev. 0.2)
- Th ppm (range 4.8, average 3.2, Std. Dev.2.0)

The granodiorite had %K within 1.7 and 3.0, which would be expected for this lithology.

5.1.3.3 Minor Lithological Units

Minor lithological units identified in the Strickland pluton area, primarily outside the withdrawal area, include gneissic tonalite and mafic schist. They are described together as a single heterogeneous 'gneiss and schist' assemblage because of the limited number of occurrences of each in the area and their generally overlapping distributions. These occurrences are primarily in the southeastern portion of the Strickland pluton area (Figure 5.1.6).

Gneiss and Schist
Gneiss and schist were observed at a total of seven out of 164 (5%) bedrock outcrop stations in the Strickland pluton area, including five occurrences of gneissic tonalite, one occurrence of gneissic tonalite with mafic schist and one occurrence of mafic schist. All of these occurrences are along the western shoreline of Nameigos Lake in the southeastern corner of the Strickland pluton area, except for one occurrence of mafic schist in the centre of the area, within the main body of tonalite (Figure 5.1.6). The gneissic tonalite occupies a narrow zone at the contact between greenstone belt rocks to the east and the Strickland pluton to the west. In this area, the gneissic tonalite is the dominant bedrock unit accounting for more than 90% of any outcrop, by area. Mafic schist accounts for less than 10% of any outcrop, by area. Two schist samples and five gneiss samples were collected from the Strickland pluton area.

The gneissic tonalite is light grey when fresh and weathered (Figure 5.1.7a). It has an inequigranular texture with grains ranging from 1 – 5 mm in size (medium-grained). The gneissic tonalite is strongly foliated and the foliation orientation parallels the mapped contacts of this unit as shown on existing geologic maps (Figure 5.1.6). No contacts with the adjacent greenstone belt to the east, or with the Strickland pluton to the west, were observed.

The mafic schist is dark green to brown when fresh and light green to brown when weathered (Figure 5.1.7b). It is equigranular with a grainsize of 0.5 – 1 mm (fine-grained). It exhibits a well-developed foliation.

A total of six rock hardness measurements were made on the gneissic tonalite and it exhibited a strong (R4) character in all cases. Two rock hardness measurements were taken on the schist, including one which yielded a medium strong (R3) character and another which yielded a weak (R2) character.

A total of six magnetic susceptibility measurements were collected on gneissic tonalite sub-unit in the Strickland pluton area, averaging 5.32×10^{-3} S.I. with a range of 5.73×10^{-3} S.I. across the average, and a standard deviation of 1.86×10^{-3} S.I.

A total of six gamma ray spectrometry measurements were collected on the gneissic tonalite sub-unit bedrock intrusive phases in the Strickland pluton area:

- Total count (range 378, average 946, Std. Dev. 120)

- %K (range 0.5, average 1.5, Std. Dev. 0.2)
- U ppm (range 1.1, average 0.6, Std. Dev. 0.3)
- Th ppm (range 2.8, average 4.2, Std. Dev. 0.9)

No magnetic susceptibility or gamma ray spectrometer measurements were taken for the mafic schist sub-unit.

5.1.4 Structure

Structures observed in the Strickland pluton area include features associated with both ductile and brittle deformation processes. Features described as ductile structures are described in Section 5.1.4.1. In terms of their frequency and occurrence, ductile structures are far less common than brittle structures, which are described in Section 5.2.4.2. The ductile and brittle structures are summarized in Tables 5.1.4.1 and 5.1.4.2 respectively. A description of secondary minerals and alteration follows in Section 5.1.4.3.

Table 5.1.4.1 Summary of Ductile Structures for the Strickland Pluton

Structure Type	Orientation	Peak (°)	Peak Frequency (%)	*Range (°)	Confidence
Igneous Flow Foliation	NNE	21	8		Medium-Low
	NE	40	9		Medium-Low
	ENE	56	6		Low
	ENE-E	78 90	17 11	070 - 100	High
	ESE	109 120	11 12	100 - 130	Medium
Tectonic Foliation	SE	128	16	122 - 133	Medium
	SSE	160	25	151 - 172	High
Shear Zones	NNE	018	22	009 - 024	High
	SE	135	14	118 - 160	Medium
Ductile Shear Zones	NNE	018	41	009 - 024	High
Brittle-Ductile Shear Zones	SE	148	19	140 - 155	High

* Range only reported for peaks broader than ~ 10°

Table 5.1.4.2 Summary of Brittle Structures for the Strickland Pluton

Structure Type	Orientation	Peak (°)	Peak Frequency (%)	*Range (°)	Confidence
Joints - All	NE	020 045	8 10	005 - 077	High
	SE	126	7	106 - 146	Medium
Joints - **Subhorizontal	NNE	012	10		Medium
	NE	032	8		Medium-Low
	ESE	095	10	071 - 102	Medium
	SE	123	12		Medium
	SE	139	8		Medium-Low
	SSE	162	12	150 - 170	Medium
Joints - **Intermediate	NNE	017	11		Medium-high
	NE	050	11		Medium-high
	ENE	072	13	064 - 080	High
	ESE	112	8		Medium-low
	SE	142	7		Medium-low
Joints - **Subvertical	NE	020 044	8 11	009 - 075	High
	SE	126	7	106 - 145	Medium-high
Faults - All	NNE	015	8		Medium-Low
	NE	040	15	032 - 051	High
	SE	130 140 152	15 10 11	123 - 158	High
	S	172	12		Medium-High
Veins - All	N	000	12	350 - 006	High

	NNE	024	6		Low
	NE	057	9		Medium
	ESE	110	7		Low
	SE	127 140 155	8 9 9	120 - 162	Medium
Secondary Mineral Infill - All	NNE-NE	020 047	10 11	007 - 063	High
	SE	128	7		Medium
	SE	141	6		Low
	S	176	7		Low

* Range only reported for peaks broader than ~ 10°

** Subhorizontal = 0°-30°; intermediate = 31°-60°; subvertical = 61°-90°

5.1.4.1 Ductile Structure

Foliation

There are two main types of foliation recognized in the Strickland pluton area; igneous flow foliation and tectonic foliation (Figure 5.1.8). Overall, there are 46 igneous flow foliation and ten tectonic foliation measurements from the bedrock outcrop stations in the Strickland pluton area. These two foliation types are mostly distributed in different lithological units, with the igneous flow foliation confined to the area underlain by tonalite or granodiorite, and the tectonic foliation primarily confined to the area underlain by the gneiss and schist occurrences.

Igneous Flow Foliation

Igneous flow foliation was identified in 46 instances, primarily in the granodiorite and tonalite bedrock mapped throughout the majority of the Strickland pluton area (Figures 5.1.8, 5.1.9a and 5.1.9b). Only one example of igneous flow foliation was mapped in the gneissic tonalite in the southeast part of the mapping area. This foliation type is defined primarily by aligned biotite and subtle elongated or planar quartz blebs/ribbons, and it is weakly to moderately developed where observed.

The strike orientation varies from mainly northeast to east-northeast in the southern part of the Strickland pluton area, changing to north-northeast striking in the central part of the tonalite mapped area, to generally east-west-striking along the northern part of the mapped area (Figure 5.1.8). The igneous flow foliation dip is variable, ranging from steeply northward or southward dipping, to moderately west or east dipping, to subhorizontal (Figure 5.1.9a).

The igneous flow foliation population is dominated by two broad orientation peaks (Figure 5.1.9b). One at 078° ranging between 070° and 100°, and including a secondary peak within this range at 090°. The other peak, at 120°, ranges between 100° and 130°, and includes a secondary peak within this range at 109°. Three additional subordinate peaks are evident at 021°, 040° and 056°.

In five cases a weak to moderate lineation occurs associated with the igneous flow foliation. These lineations are formed by quartz, plagioclase, K feldspar, biotite and occasionally hornblende, and plunge generally shallowly to the northeast or west to southwest (Figure 5.1.9a).

Tectonic Foliation

Tectonic foliation was measured in ten instances, primarily within the north-northeast-trending belt of gneissic tonalite in the eastern part of the Strickland pluton area along the western shore of Nameigos Lake. One instance was also observed within a xenolith of schist encountered within the central part of the Strickland pluton area (Figure 5.1.8).

Tectonic foliation is most commonly defined by aligned biotite, muscovite and hornblende, as well as feldspar (Figure 5.1.7b). In two cases a strong stretching lineation has been observed and in both instances the lineation plunges moderately to the east, consistent with the overall predominant dip direction and magnitude of the foliation itself (Figure 5.1.9c).

Tectonic foliation orientation rotates from west-northwest-striking south of Nameigos Lake through north-striking along the western shoreline of the lake to east-striking in the outlier of gneissic tonalite along the eastern boundary of the Strickland pluton area (Figure 5.1.8, Figures 5.1.9c and 5.1.9d). The dip of the tectonic foliation is predominantly easterly and remains at a relatively consistent magnitude of between 20° and 45° (Figure 5.1.9c). The one tectonic foliation surface measured within a xenolith in the centre of the Strickland pluton area dips 20° to the northeast (Figure 5.1.8).

The tectonic foliation population is dominated by two narrow orientation peaks at 128° (ranging between 122° and 133°) and 160° (ranging between 151° and 172°). The four additional peaks shown on Figure 5.1.9d represent one measurement each and are not significant for this data set totalling ten measurements.

Shear Zones

A total of 17 shear zones were measured in the Strickland pluton area (Figures 5.1.10, 5.1.11a and 5.1.11b). The total shear zone population is dominated by two orientation peaks at 018° (ranging between 009° and 024°) and 135° (ranging between 118° and 160°). The two additional peaks shown on Figure 5.1.11b represent one or two measurements each and are not significant for this data set totalling 17 measurements. While the majority of shear zones are steeply dipping, few examples range down to dips below 30°. The structures in the total shear zone population are further sub-divided into ductile and brittle-ductile shear zones, based on their outcrop character.

Ductile Shear Zones

Nine ductile shear zones, including the examples shown in Figures 5.1.12a and 5.1.12b, were measured in the Strickland pluton area ranging in width from under 1 cm to several centimetres. They are characterized by a strong to intense, asymmetric planar flattening fabric within narrow zones outside of which there generally is no fabric development and no brittle deformation. Eight were measured in the southern area underlain predominantly by granodiorite and one was measured within the tonalite body in the northern part of the mapping area.

The ductile shear zone population is dominated by one main orientation peak at 018° ranging between 009° and 024° (Figure 5.1.11c). The three additional peaks shown on Figure 5.1.11c represent one or two measurements each and are not significant for this data set totalling nine measurements. Six of the ductile shear zones were interpreted to be sinistral, including four examples that strike north-northeast (018° peak), one that strikes north-northwest and one that strikes northwest. One northwest-striking and one east-northeast-striking ductile shear zone exhibited unknown shear sense (Figure 5.1.11e). All ductile shear zones dip at greater than 70° except for one dip-slip ductile shear zone that dips 24° to the east.

Brittle-Ductile Shear Zones
Eight brittle-ductile shear zones, including the examples shown in Figures 5.1.12c and 5.1.12d, were measured in the Strickland pluton area, mostly in the south portion of the mapping area (Figure 5.1.10). Brittle-ductile shear zones are characterized by damage zones that range from thin, single slip surfaces to up several metres wide zones parallel to the brittle-ductile shear zone plane. Brittle-ductile shear zones are associated with quartz veins and hematite staining suggesting that fluid activity is associated with the development of the shear zone. Shear banding is not commonly observed but is present in one sheared mafic dyke caught up in the shear zone.

The most prominent peak of the brittle-ductile shear zone is at 148°; however, this only represents two measurements. The other peaks represent single measurements and are not significant for this data set totalling eight measurements. Three northwest-striking brittle-ductile shear zones are dextral and dip between 62° and 84°. Two brittle-ductile shear zone are interpreted as sinistral, including one striking southwest and dipping 70° and one striking west-northwest and dipping 60°. Two normal-sense brittle-ductile shear zones strike west and east and dip 20° north and 26° south, respectively and one with unknown shear sense strikes northwest (Figure 5.1.11f).

5.1.4.2 Brittle Structures

Fractures, including joints, faults and veins represent the brittle structures observed throughout the Strickland pluton area. A total of 806 fracture measurements were made in the Strickland pluton area, comprising 705 joints, 33 faults and 68 veins. The characteristics of each of these fracture types are described below.

Joints
A total of 705 joint measurements were recorded in the Strickland pluton area (Figures 5.1.13 and 5.1.14). At least one joint set was measured at all but eight bedrock outcrop stations, and most stations exhibited two or more individual joint sets. The total joint population is dominated by one broad orientation peak at 045° that ranges between 005° and 077° and also includes a secondary peak at 020°. The total joint population also exhibits an orientation peak at 126° that ranges between 106° and 146° (Figure 5.1.14b).

Of the 705 joint measurements recorded in the Strickland pluton area, 25 (4%) dip at 30° or shallower and are classified as subhorizontal. Subhorizontal joints exhibit orientation peaks at 123° and 162°, with subordinate peaks at 012°, 032°, 095° and 139° (Figure 5.1.14c). Intermediate dipping joints (31° to 60° dip magnitude) represent 53 out of 705 joint measurements (8%). Intermediate dipping joints exhibit orientation peaks at 017°, 050° and 072°, with subordinate peaks at 112° and 142° (Figure 5.1.14d). Joints are predominantly subvertically dipping overall with 627 (89%) dipping 61° to 90°. Subvertical joints exhibit orientation peaks at 044° and 126°, with a subordinate peak at 020° (Figure 5.1.14e). Overall, the subvertically dipping joints define three main joint orientation families within the Strickland pluton area, including northeast-, north-northeast- and northwest-trending families. The fourth family is subhorizontal in orientation (e.g., Figure 5.1.15a).

Few observed joints throughout the Strickland pluton area, by their geometrical arrangement, appear to represent en-echelon fractures indicative of incipient faulting. An apparent sinistral sense-of-shear was inferred for 21 joints with left-stepping overlaps measured. An apparent dextral sense-of-shear was inferred for 16 joints that showed right-stepping overlaps. Most dextral sense joints have a northeast strike, whereas sinistral sense joints have a more variable orientation. Examples of joints with sinistral and dextral sense-of-shear are shown on Figures 5.1.15b and 5.1.15d respectively.

Joint spacing is variable throughout the Strickland pluton area. A histogram showing the frequency of occurrence of joint spacing in several spacing bins is shown in Figure 5.1.14f. Out of the 705 joints measured the dominant joint spacing is 100-500 cm with a total of 287 occurrences (41%). Not surprisingly, joints with 100-500 cm joint spacing had similar orientations as the overall joint data set. Tight joint spacing, as seen on outcrop at which the minimum joint spacing is 10 cm or less, was relatively uncommon with a total of 27 measurements. These occurrences were evenly distributed across the entire Strickland pluton area and were not confined to any specific sub-area therein. Similarly, wide joint spacing of 500 cm or greater were distributed across the entire Strickland pluton area, including 164 occurrences (23%) (Figure 5.1.14f).

Faults

A total of 33 fault measurements were recorded in the Strickland pluton area (Figures 5.1.16, 5.1.17a and 5.1.17b). They are distributed relatively evenly across the area with the exception that no faults were identified in the southeastern corner underlain by the gneissic tonalite. The total fault population exhibits several main orientation peaks, including sharp peaks at 040° and 172°, and a broad peak that ranges between 123° and 158° with internal peaks at 130°, 140° and 152°. A less prominent peak at 015° is also evident. 29 of the measured faults (88%) dip in the range 61° to 90°. The shallowest dip recorded for any fault was 34°.

Fault damage zones range from mm- to cm-scale single slip surfaces to up to several metres wide zones of tightly spaced fractures parallel to the fault plane. Faults are associated with quartz veins and hematite staining. Fault zones are also locally associated with a well-defined fracture cleavage and series of parallel slickenside surfaces (Figures 5.1.18a and 5.1.18b). The slickensides are commonly well developed and coated with secondary minerals, especially quartz and chlorite. Offset of markers, such as aplite dykes or quartz veins, provide an indication for the direction of apparent displacement on many faults (Figure 5.1.18c). Where observed, displacement of markers ranges from several centimetres to decimetres.

Of the 33 fault measurements, seven are dextral faults (Figure 5.1.17c) and eight are sinistral faults (Figure 5.1.17d). In addition, 18 faults display unknown slip sense. The dextral fault population has one main orientation peak at 043° (Figure 5.1.17c). The two additional peaks shown on Figure 5.1.17c represent one measurement each and are not significant for this data set totalling seven measurements. The sinistral fault population has two orientation peaks at 130° and 172° (Figure 5.1.17d); the three additional peaks shown on Figure 5.1.17d only represent single measurements. Lineations have been measured on five faults (Figure 5.1.17e); two of these faults had sinistral displacement and one had dextral displacement.

Veins
A total of 68 veins were measured throughout the Strickland pluton area (Figures 5.1.19 and 5.1.20). They are distributed relatively evenly across the area, including in the southeastern corner underlain by the gneissic tonalite. The veins were interpreted to have been formed in extension or in association with shearing.

The total vein population exhibits one main, sharp, orientation peak at 000° and another at 057°. Another broad orientation peak ranges between 120° and 162°, within internal peaks at 127°, 140° and 155°. Two additional less prominent peaks occur at 024° and 110° (Figure 5.1.20b). 52 of the measured veins (76%) dip at 69° or greater. The shallowest dip recorded for any vein was 15° (Figure 5.1.20a).

Vein widths vary across the Strickland pluton area. 33 vein occurrences (49%) are observed to be less than 1 cm in width, 19 (28%) are between 1 – 3 cm, 9 (13%) are between 3 – 10 cm, 5 (7%) are between 10 – 30 cm and the remaining two (3%) are between 30 – 100 cm, with the maximum vein width recorded as 50 cm.

Figure 5.1.20 includes rose diagrams depicting the orientations of the most common vein infill types, including quartz, epidote, K-feldspar and chlorite. Veins are also locally described as joints with pegmatite or aplitic fill, these specific veins are described separately below in Section 5.3.4. The most common infill in veins is quartz, observed in 36 occurrences (62%). Quartz veins exhibit a similar variability in strike directions as the full vein set, with distinct orientation peaks at 058°, 125°, 142°, 157° and 180° (Figure 5.1.20c). Quartz veins are evenly distributed across the Strickland pluton area (Figure 5.1.21).

Epidote was the second most common vein fill and was noted in nineteen veins (28%). Epidote veins exhibit two main orientation peaks at 025° and 178°, with five other measurements distributed between west-southwest and northwest. Epidote was notably very common in the southeast part of the Strickland pluton area, underlain by the gneissic tonalite and absent from the west-central part of the area, underlain primarily by granodiorite (Figure 5.1.21).

An unknown pale-green siliceous material, possibly pseudotachylite, occurred in seven veins (10%), also in association with epidote. Siliceous material / pseudotachylite veins exhibits one orientation peak at 085° with four other measurements distributed between northwest and northeast.

In terms of relative timing relationships, quartz veins were observed, in some instances, to be offset by brittle faults, indicating that quartz veins formed prior to brittle faulting. Quartz veins were also identified to pre-date the pink potassic alteration.

5.1.4.3 Secondary Minerals/Alteration

Information on secondary minerals and alteration associated with fractures in the Strickland pluton area are described below and summarized in Tables 5.1.4.3 to 5.1.4.6 below, for all fractures (N = 806), including the 705 joints, 33 faults and 68 veins. The distributions of the secondary mineral and alteration types are shown on Figure 5.1.21.

Overall, 486 out of 806 total fractures (60%) observed exhibited no secondary mineral infill or alteration (Table 5.1.4.3). The most common secondary mineral and alteration types in the Strickland pluton are: a pink (potassic) alteration identified at 17% of fractures, hematite staining at 16%, quartz in 10%, epidote in 8% and K feldspar in 2%. Mineral occurrences identified as 'other' in Figure 5.1.21 include occurrences that each represent less than 2% of all secondary mineral and alteration occurrences, including pale-green siliceous material (possibly pseudotachylite), chlorite, plagioclase, biotite, muscovite, magnetite, carbonate and pyroxene. Secondary minerals with 'unknown' mineralogy were identified in 8% of all fractures. The overwhelming majority of secondary mineral infillings and alteration were observed on subvertical structures, dipping greater than 61°.

The total population of fractures with secondary mineral infilling and alteration is dominated by two adjacent orientation peaks at 020° and 047° that range between 007° and 063° (Figures 5.1.23a and 5.1.23b). This fracture population also exhibits orientation peaks at 128°, 141° and 176° (Figure 5.1.23b). Fractures with three of the four most common secondary mineral infilling and alteration show a similar pattern. Fractures with pink alteration have two main orientation peaks at 020° and 048° with lesser peaks at 073° and 175° (Figure 5.1.23c). Fractures with hematite alteration have two main orientation peaks at 020° and 045° with lesser peaks at 073° and 175° (Figure 5.1.23d). Fractures with chlorite infill have two main orientation peaks at 020° and 040° with lesser peaks at 125°, 140°, 157° and 175° (Figure 5.1.23f). Fractures with quartz infill are the exception showing a broad range of peaks between 120° and 161° with internal peaks at 127°, 141° and 153°; further peaks occur at 016°, 025°, 057°, and 178° (Figure 5.1.23e).

The pink alteration occurs in conspicuous pink to orange halos around many veins, joints and faults. These halos range from very faint pink to dark orange and are less than one centimetre to up to 15 centimetres thick. In two locations the alteration was analyzed by gamma ray scintillometer and gave higher %K values (Figure 5.1.22c) than adjacent unaltered host rocks suggesting the pink halos are the result of potassic alteration from hydrothermal fluids. The halos are resistive to weathering and erosion and commonly stand out in relief on smooth glaciated surfaces (Figure 5.1.22d). The halos primarily occur in the northern part of the Strickland pluton area underlain primarily by tonalite and are in most cases associated with the occurrence of hematite staining. In some cases, the haloes are also associated with structures that contain pale green siliceous material (possibly pseudotachylite) or epidote suggesting a possible link between the siliceous material / pseudotachylite, epidote, hematite and potassic alteration and hydrothermal fluid activity. The halos are commonly cut by younger joints and faults.

Secondary mineral infilling or alteration was identified on 233 out of 705 (33%) total documented joints, leaving the remaining 472 occurrences (67%) unfilled (Table 5.1.4.4). Filled joints include occurrences of hematite (17%), pink (potassic) alteration (17%), epidote (5%) and quartz (3%). All other secondary mineral types listed in Table 5.1.4.4 each occurred in less than 2% of all joints. In 9% of occurrences an unknown secondary mineral was observed to infill joints. The majority of secondary minerals and alteration were identified on subvertical joints.

Secondary mineral infilling or alteration was identified on 19 out of 33 (58%) total documented faults, leaving the remaining fourteen occurrences (42%) unfilled (Table 5.1.4.5). Filled faults include occurrences of quartz (36%), epidote (36%), hematite alteration (21%), pink (potassic) alteration (12%), chlorite (6%), pale green siliceous material (possibly pseudotachylite) (6%), and an unknown mineral (3%). The majority of secondary minerals and alteration were identified on subvertical faults.

Information on secondary mineral infilling and alteration relating to veins was introduced above and also summarized again in Table 5.1.4.6 below. As discussed above, the same mineral phases identified in association with faults and joints are also common to veins, including, quartz, epidote, pink (potassic) alteration, epidote and chlorite, along with very common occurrences of hematite staining.

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Table 5.1.4.3 All Fractures: Secondary Mineral Fills and Alteration for the Strickland Pluton

Mineral Phase / Alteration	All	%of Total	Subvertical Dip*	Intermediate Dip*	Subhorizontal Dip*
Potassic (Pink)	136	16.9	129	7	0
Hematite	131	16.3	127	3	1
Quartz	77	9.6	69	8	0
Unknown	67	8.3	59	8	0
Epidote	65	8.1	55	9	1
K-feldspar	19	2.4	18	1	0
Siliceous Material / Pseudotachylite (?)	14	1.7	10	4	0
Chlorite	12	1.5	10	2	0
Plagioclase	10	1.2	10	0	0
Biotite	5	0.6	5	0	0
Other	5	0.6	5	0	0
Muscovite	4	0.5	4	0	0
Magnetite	2	0.2	2	0	0
Carbonate	2	0.2	2	0	0
Pyroxene	1	0.1	1	0	0
None	486	60.3	420	42	24
Total # of Fractures	806				

* Subhorizontal = 0º-30º, intermediate = 31º-60º, subvertical = 61º-90º

Table 5.1.4.4 Joints: Secondary Mineral Fills and Alteration for the Strickland Pluton

Mineral Phase / Alteration	All	% of Total	Subvertical Dip*	Intermediate Dip*	Subhorizontal Dip*
Hematite	119	16.9	117	1	1
Potassic (Pink)	116	16.5	115	1	0
Unknown	66	9.4	58	8	0
Epidote	34	4.8	31	3	0
Quartz	23	3.3	22	1	0
K-feldspar	10	1.4	10	0	0
Plagioclase	8	1.1	8	0	0
Chlorite	6	0.9	6	0	0

Mineral Phase / Alteration	All	% of Total	Subvertical Dip*	Intermediate Dip*	Subhorizontal Dip*
Siliceous Material / Pseudotachylite (?)	5	0.7	4	1	0
Biotite	4	0.6	4	0	0
Muscovite	4	0.6	4	0	0
Magnetite	2	0.3	2	0	0
Pyroxene	1	0.1	1	0	0
Carbonate	1	0.1	1	0	0
Other	1	0.1	1	0	0
None	472	67.0	407	41	24
Total # of Joints	705				

* Subhorizontal = 0º-30º, intermediate = 31º-60º, subvertical = 61º-90º

Table 5.1.4.5 Faults: Secondary Mineral Fills and Alteration for the Strickland Pluton

Mineral Phase / Alteration	All	% of Total	Subvertical Dip*	Intermediate Dip*	Subhorizontal Dip*
Quartz	12	36.4	11	1	0
Epidote	12	36.4	10	2	0
Hematite	7	21.2	6	1	0
Potassic (Pink)	4	12.1	3	1	0
Chlorite	2	6.1	1	1	0
Siliceous Material / Pseudotachylite (?)	2	6.1	1	1	0
K-feldspar	1	3.0	1	0	0
Unknown	1	3.0	1	0	0
None	14	42.4	13	1	0
Total # of Faults	33				

* Subhorizontal = 0º-30º, intermediate = 31º-60º, subvertical = 61º-90º

Table 5.1.4.6 Veins: Secondary Mineral Fills and Alteration for the Strickland Pluton

Mineral Phase / Alteration	All	% of Total	Subvertical Dip*	Intermediate Dip*	Subhorizontal Dip*
Quartz	42	61.8	36	6	0
Epidote	19	27.9	14	4	1
Potassic (Pink)	16	23.5	11	5	0
K-feldspar	8	11.8	7	1	0
Siliceous Material / Pseudotachylite (?)	7	10.3	5	2	0
Hematite	5	7.4	4	1	0
Chlorite	4	5.9	3	1	0
Other	4	5.9	4	0	0
Plagioclase	2	2.9	2	0	0
Biotite	1	1.5	1	0	0
Carbonate	1	1.5	1	0	0
Total # of Veins	68				

* Subhorizontal = 0º-30º, intermediate = 31º-60º, subvertical = 61º-90º

5.2 Anahareo Lake Pluton Area

The Anahareo Lake pluton area is located to the east of the community of White River and south of the Strickland pluton area. The Anahareo Lake pluton area is underlain primarily by the Anahareo Lake pluton, previously mapped as a large igneous body of granite-granodiorite composition. The northwestern part of the area falls along the boundary between the Anahareo Lake pluton and adjacent gneissic tonalite. A total of 204 mapping stations were visited in the Anahareo Lake pluton area (Figure 5.2.1). The following sections provide information regarding accessibility and surface constraints, bedrock exposure and overburden thickness, lithology, and structure, of the Anahareo Lake pluton area.

5.2.1 Accessibility and Surface Constraints

A summary of observations on accessibility and surface constraints (e.g., obstructions) for the Anahareo Lake pluton area (Figure 1.2 and Figure 5.2.1) is provided below.

The Anahareo Lake pluton area was mapped between July and mid-September 2016. Weather conditions were generally hot with little rainfall. Consequently, many small tributaries and low-lying areas were dry or became dry (Figure 5.2.2a) facilitating access during the period when mapping was undertaken. Larger tributaries ponds and lakes had low water levels (Figure 5.2.2b) which allowed safe passage across natural features such as fallen vegetation or beaver dams and in some cases provided large flat areas for the safe landing of helicopters.

The entire Anahareo Lake pluton area is located southeast of Highway 631 (Figure 1.2). The western portion of the mapping area was accessed by a network of logging roads intersecting Highway 631 (Figure 1.2). The central portion of the map area was accessed by a well-maintained roadway from the town of Dubreuilville which is located south of the area shown in Figures 1.1 and 1.2.

Existing logging roads and a snowmobile/ATV trail network in the south-central, central and north-central portions of the Anahareo Lake pluton area were generally well constructed and well maintained. Several locations had experienced outwash and road deterioration in low lying areas along the main secondary road trending north-south through the area. These locations were passable by 4×4 vehicle following minor repairs. Deterioration and overgrowth (tall grasses, brush and alder trees) of many west-east-trending roadways intersecting the main north-south-trending logging road artery required the use of ATV and subsequent traverse by foot to access outcrop. Steep cliff faces and fault controlled drainage were prevalent throughout much of the area and traverses had to be altered to allow for these features.

Existing logging roads in the northwest portion of the Anahareo Lake pluton area, east of Highway 631, were generally passable by 4×4 vehicle. Deterioration and overgrowth (tall grasses, brush and alder trees) of the logging roads required traverse by foot to access outcrop. A network of overgrown logging roads south of the map area was generally only accessible by ATV. Deterioration and overgrowth (dense, large diameter alder trees) required traverse by foot to outcrop locations. The northeast portion of the map area did not have logging roads or trail networks. Instead a helicopter was used to access designated outcrops in this part of the Anahareo Lake pluton area. Meandering river channels, bog and dense vegetation around waterways reduced possible landing sites and restricted accessibility to much of the eastern half of the area.

Overgrown logging roads in the southeast portion of the mapping area were passable by 4×4 vehicle. Deterioration and overgrowth (tall grasses, brush and alder trees) of the logging roads required traverse by foot to access outcrop.

5.2.2 Bedrock Exposure and Overburden Thickness

Out of a total of 204 mapping stations visited while mapping in the Anahareo Lake pluton area, 190 (93%) were locations of bedrock outcrop and fourteen (7%) were locations where overburden was encountered (Figure 5.2.1). Within the Anahareo Lake pluton area overburden thickness was commonly less than one metre as encountered at mapping stations along existing logging roads accessed by the well-maintained roadway from Dubreuilville (Figure 1.2). Overall there was more bedrock outcrop in the Anahareo Lake pluton area in comparison to the Strickland area, as indicated by the extent and individual size of predicted outcrops (Figure 5.2.1). Variations related to bedrock exposure and overburden thickness across the Strickland pluton area are described below

The area northwest of the withdrawal area boundary was characterized by overburden of sandy till one to three metres thick with sporadic outcrop consistent with the predicted outcrop shown on Figure 5.2.1. The northern part of the withdrawal area was characterized by high relief with cliff faces of the order of tens of metres high (Figure 5.2.2c), although the tops of these hills had overburden of the order of one metre thick. The central corridor along the main logging access (Figure 5.2.1) and east portions of the withdrawal area was characterized by bedrock knolls with good exposure (Figure 5.2.2d) and had overburden one metre to three metres thick. Deposits of sand and gravel greater than three metres thick were occasionally observed near existing logging roads were material had previously been excavated.

The northwest portion of the Anahareo Lake pluton area east of Highway 631 (Figure 1.2; Figure 5.2.1) had overburden thicknesses greater than three metres thick away from the logging roads. Consistent with the low number of predicted outcrops for this area, little exposed bedrock was found. The low lying northeast portion of the Anahareo Lake pluton area was characterized by meandering river channels, small ponds and bogs and typically had overburden thicknesses less than one metre thick. Sandy gravel till greater than three metres thick with large cobbles, boulders and glacial erratics with dimensions up to five metres wide occurred through the southeast portion of the Anahareo Lake pluton area. Few bedrock outcrops were located in this area, consistent with the prediction. Of the few outcrop locations predicted, the majority turned out to be large boulders and glacial erratics.

5.2.3 Lithology and Physical Character

The descriptions below provide an overview of the main and minor bedrock lithological units observed in the Anahareo Lake pluton area, as well as their main physical characteristics. Lithological units described below as main units tend to occur as the predominant rock type covering at least 60% of the exposed bedrock, by area, at any individual bedrock outcrop station, and are observed at a high frequency of bedrock outcrop stations overall. Minor lithological types described below may occasionally occur as the main rock type at individual bedrock outcrop stations, but in general they occur infrequently, and represent only a small portion overall of the bedrock in the Anahareo Lake pluton area.

Three main Archean-aged lithology types were identified in the Anahareo Lake pluton area, including granite, tonalite and granodiorite. As described below, the granite occurs both as a continuous igneous body, primarily in the central part of the area, and as distinct pegmatitic sills intruding a heterogeneous metamorphic basement, primarily in the northern part of the area. These two forms of granite are described separately below, and their distributions are also shown individually on Figure 5.2.3. The tonalite and granodiorite exhibit only subtle mineralogical differences in the field and are described as a single gradational unit below.

Two minor lithological units, comprising a heterogeneous assemblage of gneissic and schistose metamorphic rocks and more weakly foliated granodiorites and tonalities all interlayered mainly with the pegmatite granite sills, is also described below. Their distribution is shown on Figure 5.2.7. A summary of the bedrock characteristics of these units is provided in Table 5.2.1. In addition to these units, Proterozoic mafic dykes, and minor felsic to intermediate dykes (likely of Archean age), were identified throughout the Anahareo Lake pluton area. These dyke occurrences are discussed separately in Section 5.3.

Table 5.2.1 Summary of Bedrock Characteristics by Lithology Type for the Anahareo Lake Pluton

Lithological Unit	Area where Identified	Weathered and (Fresh Colour)	Crystal Form	Fabric	Grain Size	Average Magnetic Susceptibility ($\times 10^{-3}$ SI)	Gamma Spectrometry (total count)	Strength
Granite	Central	Off white, light grey to pink (Off white, light grey to pink)	Mostly equigranular	Massive	Mostly coarse-grained (5-10 mm)	3.48	68-29700	R3 to R5
Granite Pegmatite	North	Off white, pink to orange (Pink)	Inequigranular or vari-texture	Massive	Very coarse (10 – 50 mm) to extremely coarse-grained (> 50 mm)	1.69	636-16300	R3 to R6
Granodiorite	South and central (rare)	Off white, light grey to pink (Off white, light grey to pink)	Equigranular	Mostly massive	Medium-grained (1-5 mm) to coarse-grained (1-5 mm)	4.73	1317-4036	R4 to R5
Tonalite	South and north (rare)	Off white, light grey to pink (Off white, light grey to pink)	Inequigranular to equigranular	Mostly massive	Medium-grained (1-5 mm) to coarse-grained (1-5 mm)	8.1	944-5338	R3-R5

Lithological Unit	Area where Identified	Weathered and (Fresh Colour)	Crystal Form	Fabric	Grain Size	Average Magnetic Susceptibility ($\times 10^{-3}$ SI)	Gamma Spectrometry (total count)	Strength
Gneiss (mainly tonalitic)	North, central (xenoliths)	Light grey to dark grey (Light grey, dark grey to dark green)	Vari-texture to equigranular	Foliated to gneissose	Fine-grained (0.5-1 mm) to coarse-grained (5-10 mm)	3.66	629-2403	R3 to R4
Schist (metavolcanic)	North, central (rare, xenoliths)	Brown to black (Light grey to dark green)	Equigranular	Foliated	Fine-grained (0.5-1 mm)	1.12	1242	R2 to R5
Foliated granodiorite	North (xenoliths)	Light grey (Light grey to dark grey)	Equigranular	Weakly foliated	Fine-grained (0.5-1 mm) to coarse-grained (5-10 mm)	2.33	1100-5615	R4 to R5
Foliated tonalite	North (rare, xenoliths?)	Off white to light grey (Light grey to pink)	Equigranular	Weakly foliated	Coarse-grained (5-10 mm)	1.72	1133-1155	R4 to R5
Felsic dyke and sills	Localised	Dark grey to pink (Off white to dark grey to pink)	Equigranular	Mostly massive	Very fine-grained (0.1-0.5 mm) to coarse-grained (5-10 mm)	2.37	1520-3528	R3 to R5

5.2.3.1 Main Lithology 1 = Granite

The predominant rock type in the Anahareo Lake pluton area is a coarse-grained granite. Granite was observed at 85 out of 190 (45%) bedrock outcrop stations predominantly throughout the central portion of the Anahareo Lake pluton area (Figure 5.2.3), on typically lichen covered outcrops (Figure 5.2.4a). In these occurrences, the granite usually covered more than 90% of the outcrop, by area. A region has been defined by the main cluster of occurrences that captures the area primarily underlain by the granite (yellow dashed parallel lines in Figure 5.2.3). 64 representative rock samples of granite were collected from the Anahareo Lake pluton area.

The contact between granite and granite pegmatite, described separately below, is consistently sharp and exhibits no evidence of localized brittle deformation. No contacts between granite and other lithological units described in the Anahareo Lake pluton area were observed.

The granite is off white to pink both when fresh and when weathered. The granite is predominantly equigranular (Figure 5.2.4b), with a predominant grain size of 5-10 mm (coarse-grained). The granite varies between massive and very weakly foliated, with foliation weakly defined by subtle elongate quartz blebs at only two locations.

A total of 88 rock hardness measurements were made on the granite in the Anahareo Lake pluton area. It exhibited an extremely strong (R6) in one instance (1%), very strong (R5) character in 38 instances (43%), a strong (R4) character in 40 instances (45%) and a medium strong (R3) character in nine instances (13%).

Seventy-four (74) magnetic susceptibility measurements were made on the granite in the Anahareo Lake pluton area (Figure 5.2.4c), averaging 3.48×10^{-3} S.I. with a range of 9.49×10^{-3} S.I. across the average, and a standard deviation of 2.21×10^{-3} S.I.

Sixty-eight (68) gamma ray spectrometry measurements were made on granite in the Anahareo Lake pluton area (Figure 5.2.4d).

- Total count (range 27442 average 3861 Std. Dev. 3699)
- %K (range 2.9 average 3.7 Std. Dev. 0.5)
- U ppm (range 7.2 average 2.4 Std. Dev. 1.5)
- Th ppm (range 29.1 average 25.7 Std. Dev. 7.1)

The granite had %K above 3.0, which would be expected for this lithology.

5.2.3.2 Main Lithology 2 = Granite Pegmatite

The second most common rock type in the Anahareo Lake pluton area is a granite pegmatite that primarily occurs as sills. Granite pegmatite was encountered at 62 out of 190 (33%) bedrock outcrop stations and generally covers between 30 and 90% of any observed outcrop, by area. These occurrences are mostly clustered in the northern portion of the Anahareo Lake pluton area (Figure 5.2.3). 42 representative rock samples of granite pegmatite were collected from the Anahareo Lake pluton area.

Outcrops of granite pegmatite are typically characterized by large, typically smooth and featureless 'whalebacks' (Figure 5.2.5a). Most granite pegmatite occurs as shallowly- north to northeast-dipping sill-like bodies that range from metres to tens of metres thick. The granite pegmatite intrudes, and is interlayered with: a mostly weakly-foliated granodiorite and tonalite unit or a heterogeneous assemblage of metamorphosed gneisses and schists. Both of the latter two other bedrock units are described separately below.

The contact between granite pegmatite and other lithological units is commonly sharp; however, locally within the granite pegmatite there are zones or patches of medium-grained granite which are in gradational contact. There is no evidence of brittle deformation localized along any of the contacts.

The granite pegmatite is pink when fresh and off white to pink when weathered. One of the most defining characteristics of this unit, separating it from the granite bedrock unit described below, is its inequigranular texture with 10 – 50 mm (very coarse) to >50 mm (extremely coarse) grain size (Figure 5.2.5b). No foliation or flow fabric was evident within the granite pegmatite.

A total of 67 rock hardness measurements were made on the granite pegmatite in the Anahareo Lake pluton area. The most common hardness recorded for the pegmatite is Very Strong (R5) with 41 occurrences (61%). In addition, 14 measurements (21%) yielded Extremely Strong (R6) character, ten measurements (15%) yielded Strong (R4) character and two occurrences (3%) yielded Medium Strong (R3) character.

Forty-five (45) magnetic susceptibility measurements were made on the granite pegmatite in the Anahareo Lake pluton area (Figure 5.2.5c), averaging 1.69 × 10^{-3} S.I. with a range of 10.04 × 10^{-3} S.I. across the average, and a standard deviation of 1.84 x 10^{-3} S.I.

Fifty-seven (57) gamma ray spectrometry measurements were made on the granite pegmatite in the Anahareo Lake pluton area (Figure 5.2.5d), with the following results.

- Total count (range 15666 average 3707 Std. Dev. 2179)
- %K (range 5.5 average 3.7, Std. Dev. 1.2)
- U ppm (range 47.1 average 6.4, Std. Dev. 7.5)
- Th ppm (range 137.6 average 22.1, Std. Dev. 21.0)

The granite pegmatite had %K above 3.0, which would be expected for this lithology.

5.2.3.3 Main Lithology 3 = Tonalite – Granodiorite

The next most common lithology encountered in the Anahareo Lake pluton area is a tonalite-granodiorite unit. Tonalite-granodiorite was observed at 36 out of 190 (19%) bedrock outcrop stations, primarily in the southernmost parts of the Anahareo Lake pluton area, with some exposures within the granite and the northernmost part of the Anahareo Lake pluton area (Figure 5.2.3). Tonalite and granodiorite are considered as a single bedrock unit in the Anahareo Lake pluton area because they exhibit similar textures and similar radiogenic compositions, based on the gamma ray spectrometer readings, that hover around the tonalite / granodiorite transition percent potassium of 1.7% K (as described below). There is also no simple division between areas dominated by one or the other unit, as was possible for the Strickland pluton area above. Fifteen representative rock samples of tonalite and fourteen of granodiorite were collected from the Anahareo Lake pluton area.

No contacts between tonalite-granodiorite and the main body of granite in the centre of the Anahareo Lake pluton area were directly observed and so the interpreted geological boundaries shown on Figure 5.2.3, extending in an east-west direction across the area, are constrained only by widely spaced outcrops. Acknowledging this, the boundaries highlight that the tonalite-granodiorite unit is concentrated in the southern part of the Anahareo Lake pluton area.

The tonalite-granodiorite is off white to light grey or rarely pink when fresh and off white to pink when weathered. The tonalite-granodiorite is predominantly equigranular and medium-grained (1-5 mm) (Figure 5.2.6a), although ten occurrences were identified as coarse-grained (5–10 mm). The tonalite-granodiorite is generally massive but locally exhibits a weak foliation, defined primarily by aligned biotite. Overall, the tonalite-granodiorite bedrock unit is texturally similar to that of the granodiorite encountered in the southern part of the Strickland pluton area.

A total of 41 rock hardness measurements were made on the tonalite-granodiorite. It exhibited a very strong (R5) character in 33 instances (80%), a strong (4) character in six instances (15%) and a medium strong (R3) character in two instances (5%).

Twenty magnetic susceptibility measurements were made on the tonalitic component (Figure 5.2.6c) and sixteen on the granodioritic component (Figure 5.2.6e), mostly in the southern part of the Anahareo Lake pluton area. The magnetic susceptibility results for each are as follows:

- Tonalite (range 13.3 average 8.1 Std. Dev. 3.46 × 10^{-3} S.I.)
- Granodiorite (range 9.94 average 4.73 Std. Dev. 3.18 × 10^{-3} S.I.)

Sixteen gamma ray spectrometry measurements were made on the granodiorite, mostly in the southern part of the Anahareo Lake pluton area (Figure 5.2.6d).

- Total count (range 2719 average 2223 Std. Dev. 803)
- %K (range 1.1 average 2.4 Std. Dev. 0.4)
- U ppm (range 6.3 average 2.1 Std. Dev. 1.7)
- Th ppm (range 29.5 average 15.0 Std. Dev. 8.3)

Twenty gamma ray spectrometry measurements were made on the tonalite, mostly in the southern part of the Anahareo Lake pluton area (Figure 5.2.6f).

- Total count (range 4395 average 1665 Std. Dev. 1063)
- %K (range 0.6 average 1.5 Std. Dev. 0.2)
- U ppm (range 4.8 average 1.4 Std. Dev. 1.0)
- Th ppm (range 72.7 average 13.5 Std. Dev. 16.9)

Overall the tonalite-granodiorite had %K below 3.0, which would be expected for this range of lithology.

5.2.3.4 Minor Lithological Units

Gneiss and Schist

Xenoliths or sheets of gneiss and schist were observed at nineteen out of 190 (10%) bedrock outcrop stations in the Anahareo Lake pluton area (Figure 5.2.7). This heterogeneous assemblage of metamorphic rocks includes the following sub-units: fifteen occurrences of gneiss comprising mainly gneissic tonalite, but including one gneiss occurrence each of intermediate and more mafic composition; four occurrences of schist of both felsic and mafic compositions. While the gneissic tonalite occurrences tended to cover up to 90% of any outcrop, by area, the other sub-units account for less than 60% of the outcrop in any occurrence. Three schist samples and seven gneiss samples were collected from the Anahareo Lake pluton area.

The heterogeneous gneisses and schists are mostly spatially associated with the granite pegmatite and granite occurrences in the northern and central part of the Anahareo Lake pluton area and were usually found in lower (topographically) parts of outcrops and cliff faces. The gneisses and schists primarily occur as xenoliths and screens ranging in thickness between a few tens of centimetres and several metres (Figure 5.2.8a). Together, these occurrences likely represent an older pre-existing basement of metamorphosed intrusive and extrusive rocks that were subsequently intruded and inflated by the shallowly north to northeast-dipping granite pegmatite sills.

An increase in the abundance and size of the heterogeneous gneiss and schist occurrences (Figures 5.2.8b and 5.2.8c) was noted near the central part of the Anahareo Lake pluton area (Figure 5.2.3), near the interpreted contact between granite pegmatite to the north and the coarse-grained granite to the south.

A total of nineteen rock hardness measurements were made on the various gneiss and schist sub-units. Thirteen measurements yielded a strong (R4) character, all of gneissic tonalite. Two measurements on gneissic tonalite yielded a medium strong (R3) character. Three measurements on the schist yielded a very strong (R5) character and one measurement of schist yielded a weak (R2) character.

A total of eleven magnetic susceptibility measurements were collected on the gneiss sub-unit in the Anahareo Lake pluton area, averaging 3.66×10^{-3} S.I. with a range of 17.0×10^{-3} S.I. across the average, and a standard deviation of 5.96×10^{-3} S.I. A single measurement was made on schist with a value of 1.12×10^{-3} S.I.

A total of eleven gamma ray spectrometry measurements were collected on the gneissic tonalite sub-unit bedrock in the Anahareo Lake pluton area:

- Total count (range 1775, average 1394, Std. Dev. 461)
- %K (range 1.9, average 1.6, Std. Dev. 0.5)
- U ppm (range 2.9, average 1.4, Std. Dev. 0.9)
- Th ppm (range 13.9, average 8.3, Std. Dev. 4.5)

A single gamma ray spectrometry measurement was made on schist with a total count of 1242, %K of 1.3, U ppm of 2.8, and Th ppm of 2.9.

Foliated Granodiorite and Tonalite

Xenoliths or sheets of foliated granodiorite to tonalite were observed at 21 out of 190 (11%) bedrock outcrop stations in the Anahareo Lake pluton area (Figure 5.2.7). These rocks are distinguished from the gneiss and schist described above by their weaker foliation. The foliated granodiorite is more common than the foliated tonalite occurring at nineteen of the bedrock outcrop stations; the foliated tonalite occurs at two stations. The foliated granodiorite to tonalite tend to cover less than 60% of the outcrop by area; at twelve bedrock outcrop stations (52%) they cover less than 30% of the outcrop by area. Thirteen foliated granodiorite samples and one foliated tonalite sample were collected from the Anahareo Lake pluton area.

The foliated granodiorites and tonalites are spatially associated with the granite pegmatite in the northern part of the Anahareo Lake pluton area. Similar to the gneiss and schist they primarily occur as xenoliths and screens, but possibly representing other pre-existing basement of more weakly metamorphosed intrusive rocks that was also intruded by the granite pegmatite sills.

A total of 23 rock hardness measurements were made on the foliated granodiorite to tonalite. Sixteen measurements yielded a very strong (R5) character and seven measurements yielded a strong (R4) character.

A total of twelve magnetic susceptibility measurements were collected on the foliated granodiorite sub-unit in the Anahareo Lake pluton area, averaging 2.33 × 10^{-3} S.I. with a range of 6.13 × 10^{-3} S.I. across the average, and a standard deviation of 1.75 × 10^{-3} S.I. Two measurements were made on the foliated tonalite with values of 1.32 and 2.12 × 10^{-3} S.I.

A total of fourteen gamma ray spectrometry measurements were collected on the foliated granodiorite sub-unit bedrock in the Anahareo Lake pluton area:

- Total count (range 4515, average 2063, Std. Dev. 1120)
- %K (range 1.9, average 2.3, Std. Dev. 0.6)
- U ppm (range 14.5, average 3.8, Std. Dev. 3.8)
- Th ppm (range 29.4, average 9.2, Std. Dev. 7.1)

Two gamma ray spectrometry measurements were made on the foliated tonalite with total counts of 1133 and 1155, %K of 1.6 and 1.6, U ppm of 0.0 and 0.2, and Th ppm of 7.4 and 5.0.

5.2.4 Structure

Structures observed in the Anahareo Lake pluton area include features associated with both ductile and brittle deformation processes. Features described as ductile structures are described in Section 5.2.4.1. In terms of their frequency and occurrence, ductile structures are far less common than brittle structures, which are described in Section 5.2.4.2. The ductile and brittle structures are summarized in Tables 5.2.4.1 and 5.2.4.2 respectively. A description of secondary minerals and alteration follows in Section 5.2.4.3.

Table 5.2.4.1 Summary of Ductile Structures for the Anahareo Lake Pluton

Structure Type	Orientation	Peak (°)	Peak Frequency (%)	Range (°)	Confidence
Igneous Flow Foliation	ENE	073	28	059 - 079	Medium-High
Tectonic Foliation	N	005	7		Medium-Low
	NE-ENE	043 052 071	12 13 13	030 - 079	High
	ESE	102	12	082 - 109	High

* Range only reported for peaks broader than ~ 10°

Table 5.2.4.2 Summary of Brittle Structures for the Anahareo Lake Pluton

Structure Type	Orientation	Peak (°)	Peak Frequency (%)	Range (°)	Confidence
Joints - All	NE	012 028 042	7 10 9	003 - 076	High
	SE	126	7	111 - 147	Medium-High
Joints - **Subhorizontal	NNE	017	12	358 - 026	High
	NE	038	6		Low
	NE	055	12		High
	ENE	080	7		Medium-low
	ESE	100	7	096 - 113	Low
	SE	120	7		Low
	SSE	147	7		Low
Joints - **Intermediate	NNE	029 051	13 9	021 - 060	High
	ESE	105	9		Medium
	SE	130	10		Medium-high
	SSE	147	11		High
	S	170	6		Low
Joints - **Subvertical	NE	012 027 041	6 11 9	004 - 063	High
	SE	126	7	112 - 142	Medium
Faults - All	NNE-ENE	010 025 043 057	20 13 9 10	358 - 062	High

Veins - All	NNE	012 029	10 11	003 - 037	Medium-High
	SE-SSE	131 147 165	10 8 13	121 - 173	Medium-High
Secondary Mineral Infill - All	ENE-NE	010 030 044	9 11 9	003 - 050	High
	SE	119 130	6 9	117 - 137	Medium-high
	SSE	164	6		Low

* Range only reported for peaks broader than ~ 10°

** Subhorizontal = 0°-30°; intermediate = 31°-60°; subvertical = 61°-90°

5.2.4.1 Ductile Structure

Ductile structural features observed in the Anahareo Lake pluton area comprise a tectonic foliation and an igneous flow foliation. Three localized brittle-ductile shear zones were also identified in the Anahareo Lake pluton area. These ductile structural features are described in detail below. Associated linear structures are uncommon.

Foliation

Two main types of foliation are recognized in the Anahareo Lake pluton area, including igneous flow foliation and tectonic foliation (Figures 5.2.9 and 5.2.10). Overall, six igneous flow foliations and 38 tectonic foliation measurements were recorded for the 190 bedrock outcrop stations in the Anahareo Lake pluton area. No foliation of any type was observed throughout the central and eastern parts of the map area underlain by coarse-grained granite (Figure 5.2.9).

<u>Igneous Flow Foliation</u>

Igneous flow foliation was identified primarily in the tonalite-granodiorite bedrock unit present in the northern and southern parts of the Anahareo Lake pluton area (Figure 5.2.9). Igneous flow fabric is at some outcrops very weakly to moderately developed and is defined primarily by aligned biotite and subtle elongate or planar quartz blebs/ribbons.

The igneous flow foliation mostly dips moderately towards the southeast (Figure 5.2.10a). Its total population exhibits a broad orientation peak at 073° that ranges between 059° and 079° (Figure 5.2.10b). The three additional peaks shown on Figure 5.2.10b represent one measurement each and are not significant for this data set totalling six measurements. Overall, there is a general trend of igneous flow foliation dipping outward away from the centre of the Anahareo Lake pluton area (Figure 5.2.9).

<u>Tectonic Foliation</u>

Tectonic foliation was identified within xenoliths and sheets of older metamorphosed igneous and metasedimentary rocks in the areas mapped as being underlain by granite pegmatite (Figure 5.2.9). The tectonic foliation dataset includes two instances of gneissic layering, observed in the sheets and xenoliths (e.g., Figures 5.2.8b and 5.2.13a). Tectonic foliation is most commonly defined by aligned biotite, muscovite and hornblende, as well as feldspar. In two instances this foliation includes a mineral lineation defined by aligned hornblende.

The tectonic foliation is quite variable in orientation across the Anahareo Lake pluton area (Figures 5.2.10c and 5.2.10d). The tectonic foliation population exhibits a sharp orientation peak at 005°, a cluster of peaks at 043°, 052° and 071° defining a broad northeasterly orientation, and another orientation peak at 102°. The tectonic foliation primarily dips between 31° and 60° degrees to the north or northwest, but also dips moderately to subvertically towards the south-southeast. There is also a general trend of tectonic foliation dipping outward away from the centre of the Anahareo Lake pluton area (Figure 5.2.9).

Shear Zones

A total of three shear zones were observed in the Anahareo Lake pluton area, including one shear zone to the north of the withdrawal area and one to the south of it (Figures 5.2.11 and 5.2.12). They were all identified as brittle-ductile shear zones and associated with quartz and epidote veins, and hematite staining. Locally an unknown pale-green infilling mineral was identified, which may have been pseudotachylyte or siliceous in nature. In the few observations made, damage zones of brittle-ductile shear zones vary from thin, single slip surfaces to up zones several metres wide and parallel to the shear zone plane. In one instance, an epidote-filled fracture formed in association with the shear zone. Figure 5.2.13 shows two examples of shear zones observed in the Anahareo Lake pluton area.

5.2.4.2 Brittle Structures

Fractures, including joints, faults and veins comprise the brittle deformation structures observed throughout the Anahareo Lake pluton area. A total of 754 fracture measurements were made in the Anahareo Lake pluton area, comprising 655 joints, 38 faults and 61 veins. The characteristics of each of these brittle structure types is described below.

Joints

A total of 655 joint measurements were recorded in the Anahareo Lake area (Figures 5.2.14 and 5.2.15). At least one joint set was measured at all but twenty bedrock outcrop stations, and most stations exhibited two or more individual joint sets. Only a small cluster of shallowly dipping joints is evident in the total joint dataset (Figure 5.2.15a). In addition, the joint population exhibits two main broad, steeply dipping orientations, one ranging between 003° and 076° with distinct orientation peaks at 012°, 028° and 042° and the other ranging between 111° and 147° with a broad orientation peak around 126° (Figure 5.2.15b). Figure 5.2.16 shows field examples of joints observed in the Anahareo Lake pluton area.

Out of the total joint population, 44 joints (7%) dip at 30° or shallower and are classified as subhorizontal. 580 joints (89%) dip at 61° or steeper and are classified subvertical and the remaining 40 joints (6%) dip between 31° and 60° degrees and are classified as intermediate. Subhorizontal joints (Figure 5.16c) exhibit orientation peaks at 017°, 038°, 055°, 080°, 100°, 120° and 147° (Figure 5.2.15c). Intermediate joints exhibit orientation peaks at 029°, 051°, 105°, 130°, 147° and 170° (Figure 5.2.15d). Subvertical joints exhibit orientation peaks at 012°, 027°, 041° and 126° (Figure 5.2.15e).

The geometrical arrangement of some joints provided an indication of incipient movement. An apparent dextral sense-of-shear was inferred for eight joints that showed dextral right-stepping overlaps measured throughout the Anahareo Lake pluton area. An apparent sinistral sense-of-shear (Figure 5.2.16b) was inferred for two joints with left-stepping overlaps. These joints have a northeastern strike. Most (five out of eight) dextral sense joints have a northeast-southwest strike.

A summary of joint spacing information is shown in Figure 5.2.15f. The results suggest that joint spacing is variable throughout the Anahareo Lake pluton area, but the dominant joint spacing is 100-500 cm with a total of 264 occurrences (40%). Not surprisingly, joints with 100-500 cm joint spacing had similar orientations as the overall joint data set. Very wide joint spacing, as seen on outcrops at which the minimum joint spacing is greater than 1000 cm, was observed in 66 instances (10%) across the Anahareo Lake pluton area. Tight joint spacing (Figure 5.2.16a), as seen on outcrops at which the minimum joint spacing is less than 10 cm (Figure 5.2.15f), was observed in 36 instances (5%) across the area.

Faults

A total of 38 fault measurements were recorded in the Anahareo Lake pluton area (Figures 5.2.17 and 5.2.18). Faults are observed across much of the area. The faults are uniformly steeply-dipping with 69° being the shallowest dip magnitude of any fault recorded in the Anahareo Lake pluton area (Figure 5.2.18a). The fault population exhibits one main broad orientation, ranging between 358° and 062° within which distinct orientation peaks at 010°, 025°, 043° and 057° are evident (Figure 5.2.18b).

Of the 38 fault measurements (Figure 5.2.18a), five are dextral faults, two are sinistral faults, two are reverse, and 28 faults display unknown slip sense, of which two were identified as dip slip. The dextral faults range in orientation from 325° to 055°, but there are no distinct peaks (Figure 5.2.18c). The two sinistral faults strike northerly to north-easterly and the reverse faults strike northwest and north-northeast. Lineations where measured on four of the faults (Figure 5.2.18d) of which three had unknown sense of shear and one was a northwest-striking dextral fault.

Damage zones of faults range from thin, single slip surfaces to several metres wide, tightly spaced joints parallel to the fault plane (Figures 5.2.19a and 5.2.19b). The majority of observed faults are in the former category, being less than 30 cm wide. Fault zones are locally associated with tightly spaced fractures and multiple parallel slickenside surfaces (Figure 5.2.19a). Offset of markers, such as aplite dykes or quartz veins, provide an indication for the direction of apparent displacement on many faults. Where observed, displacement of markers ranges from several centimeters to decimeters.

Veins

A total of 61 veins were measured throughout the Anahareo Lake pluton area (Figures 5.2.20 and 5.2.21). They are distributed in clusters across the entire area with vein-free domains located in the northwestern, northern and central-southwest parts of the area. The total vein population exhibits two main, broad orientations (Figures 5.2.21a and 5.2.21b), including one that ranges from 003° to 037° and within which peaks at 012° and 029° are evident, and anther that ranges from 121° to 173° and within which peaks at 131°, 147° and 165° are evident.

Vein widths vary from less than 1 cm to 50 cm across the Anahareo Lake pluton area. Out of 61 total vein occurrences, 28 (46%) were less than one cm in width, 26 (43%) were between one and three cm, four (7%) were between three and 10 cm and three (5%) were between 10 and 30 cm. Ten of the veins in the Anahareo Lake pluton area are identified as extension veins and the remainder were classed as shear veins. Two of the latter occurrences are interpreted to be associated with incipient dextral shear.

The most common infill in veins was a pale green siliceous material potentially identified as pseudotachylite with 31 occurrences (51%). Epidote was the second most common vein fill with 21 occurrences (34%). Quartz occurred in fourteen veins (23%). Many veins also exhibit pink stained halos 5 – 15 cm in width interpreted as hematite alteration, locally associated with potassic alteration.

Figures 5.2.21c, 5.2.21d and 5.2.21e show a stereonet classed according to the dominant infill for each vein. Veins of the same major infill tend to show a preferred strike with subordinate conjugate strike directions: quartz dominated veins (Figure 5.2.21c) exhibit two main orientation peaks at 135° and 013°. The four additional peaks shown on Figure 5.2.21c represent one measurement each and are not significant for this data set totalling eleven measurements. Epidote dominated veins (Figure 5.2.21c) exhibit several main orientation peaks including at 119°, 127° and 163°, as well as two lesser peaks at 007° and 027° (Figure 5.2.21d). Pale green siliceous material (possibly pseudotachylite) dominated veins exhibit one broad orientation ranging between 004° and 048° within which a major peak is evident at 030° and a minor one a 046°. Additional sharp peaks are noted at 060°, 083°, 097°, 147° and 165° (Figure 5.2.21e).

5.2.4.3 Secondary Minerals/Alteration

Information on secondary minerals and alteration associated with fractures in the Anahareo Lake pluton area are described below and summarized in Tables 5.2.4.3 to 5.2.4.6 below, for all fractures (N = 754), including the 655 joints, 38 faults and 61 veins. The distributions of the secondary mineral and alteration types are shown on Figure 5.2.22 and examples are shown on Figure 5.2.23.

Overall, 493 out of 754 total fractures (65%) observed exhibited no secondary mineral infill or alteration (Table 5.2.4.3). The most common secondary mineral and alteration types in the Strickland pluton are: a pale green siliceous material (possibly pseudotachylite) identified in 7% of fractures (Figure 5.2.23a and 5.2.23d), epidote in 7% of fractures, quartz in 7%, chlorite in 5% (Figure 5.2.23b) and pink (potassic) alteration at 3% (Figure 5.2.23c). Mineral occurrences identified as ‘other’ in Figure 5.2.22 include occurrences that each represent less than 2% of all secondary mineral and alteration occurrences, including K-feldspar, plagioclase, hematite, biotite, amphibole, pyroxene and magnetite. Secondary minerals with ‘unknown’ mineralogy were identified in 17% of all fractures. The overwhelming majority of secondary mineral infillings and alteration were observed on subvertical structures, dipping greater than 61°.

The total population of fractures with secondary mineral infilling and alteration is dominated by three adjacent orientation peaks at 010°, 030° and 044° that range between 003° and 050° (Figures 5.2.24a and 5.2.24b). This fracture population also exhibits a large orientation peak at 130°. Additional peaks at 130°, with a subordinate peak at 119°, and 164° are also evident (Figure 5.2.24b). Fractures with the four most common secondary mineral infilling and alteration show a reasonably similar pattern. Fractures with pale-green siliceous material (possibly pseudotachylite) have two main orientation peaks at 017° and 033° with lesser peaks at 059°, 147° and 163° (Figure 5.2.24c). Fractures with epidote infill have three main orientation peaks at 005°, 030° and 133° with lesser peaks at 070°, 149° and 165° (Figure 5.2.24d). Fractures with quartz infill have three main orientation peaks at 011°, 033° and 134° with a lesser peak at 162° (Figure 5.2.24e). Fractures with chlorite infill have two main orientation peaks at 012° and 035°, and with lesser peaks at 058°, 070° and 162° (Figure 5.2.24f).

The pink alteration is interpreted as a potassic alteration, similar, but less common than that observed in the Strickland pluton (Section 5.1.4.3), also occurring in conspicuous pink to orange halos around many veins, joints and faults. These halos commonly occur next to structures that contain pale green siliceous material (possibly pseudotachylite) or epidote veins suggesting a possible link between pseudotachylite, epidote and potassic alteration and hydrothermal fluid activity. The halos are commonly cut by younger joints and faults.

Secondary mineral infilling or alteration was identified on 188 out of 655 (29%) total documented joints, leaving the remaining 467 occurrences (71%) unfilled (Table 5.2.4.4). Filled joints include occurrences of chlorite (5%), quartz (4%), epidote (4%), pale green siliceous material (possibly pseudotachylite; 3%) and pink (potassic) alteration (3%). All other secondary mineral types listed in Table 5.2.4.4 each occurred in less than 2% of all joints. In 19% of occurrences an unknown secondary mineral was observed to infill joints. The majority of secondary minerals and alteration were identified on subvertical joints.

Secondary mineral infilling or alteration was identified on twelve out of 38 (32%) total documented faults, leaving the remaining 26 occurrences (68%) unfilled (Table 5.2.4.5). Filled faults include occurrences of quartz (24%), chlorite (21%), epidote (13%), pale green siliceous material (possibly pseudotachylite) (11%), K-feldspar (3%), hematite (3%) and an unknown mineral (3%). The majority of secondary minerals and alteration were identified on subvertical faults.

Information on secondary mineral infilling and alteration relating to veins was introduced above and also summarized again in Table 5.2.4.6 below. As discussed above, the same mineral phases identified in association with faults and joints are also common to veins, including, pale green siliceous material (possibly pseudotachylite), epidote, quartz, pink (potassic) alteration and K-feldspar.

Table 5.2.4.3 All Fractures: Secondary Mineral Fills and Alteration for the Anahareo Lake Pluton

Mineral Phase / Alteration	All	%of Total	Subvertical Dip*	Intermediate Dip*	Subhorizontal Dip*
Unknown	128	17.0	114	10	4
Siliceous Material / Pseudotachylite (?)	54	7.2	40	6	8
Epidote	53	7.0	50	1	2
Quartz	50	6.6	47	1	2
Chlorite	40	5.3	39	0	1
Potassic (Pink)	20	2.7	18	1	1
K-feldspar	5	0.7	3	1	1
Plagioclase	4	0.5	2	1	1
Hematite	4	0.5	4	0	0
Biotite	3	0.4	1	1	1
Amphibole	1	0.1	0	0	1
Pyroxene	1	0.1	1	0	0
Magnetite	1	0.1	1	0	0
Other	1	0.1	0	1	0
None	493	65.4	429	25	39
Total # of Fractures	754				

* Subhorizontal = 0º-30º, intermediate = 31º-60º, subvertical = 61º-90º

Table 5.2.4.4 Joints: Secondary Mineral Fills and Alteration for the Anahareo Lake Pluton

Mineral Phase / Alteration	All	%of Total	Subvertical Dip*	Intermediate Dip*	Subhorizontal Dip*
Unknown	125	19.1	113	10	2
Chlorite	30	4.6	29	0	1
Quartz	27	4.1	26	0	1
Epidote	27	4.1	26	0	1
Siliceous Material / Pseudotachylite (?)	19	2.9	18	0	1
Potassic (Pink)	15	2.3	14	0	1
Hematite	3	0.5	3	0	0
Plagioclase	1	0.2	1	0	0
Amphibole	1	0.2	0	0	1

Mineral Phase / Alteration	All	%of Total	Subvertical Dip*	Intermediate Dip*	Subhorizontal Dip*
Pyroxene	1	0.2	1	0	0
Magnetite	1	0.2	1	0	0
None	467	71.3	403	25	39
Total # of Joints	655				

* Subhorizontal = 0º-30º, intermediate = 31º-60º, subvertical = 61º-90º

Table 5.2.4.5 Faults: Secondary Mineral Fills and Alteration for the Anahareo Lake Pluton

Mineral Phase / Alteration	All	%of Total	Subvertical Dip*	Intermediate Dip*	Subhorizontal Dip*
Quartz	9	9	23.7	9	0
Chlorite	8	8	21.1	8	0
Epidote	5	5	13.2	5	0
Siliceous Material / Pseudotachylite (?)	4	4	10.5	4	0
K-feldspar	1	2.6	1	0	0
Hematite	1	2.6	1	0	0
Unknown	1	2.6	1	0	0
None	26	68.4	26	0	0
Total # of Faults	38				

* Subhorizontal = 0º-30º, intermediate = 31º-60º, subvertical = 61º-90º

Table 5.2.4.6 Veins: Secondary Mineral Fills and Alteration for the Anahareo Lake Pluton

Mineral Phase / Alteration	All	%of Total	Subvertical Dip*	Intermediate Dip*	Subhorizontal Dip*
Siliceous Material / Pseudotachylite (?)	31	50.8	18	6	7
Epidote	21	34.4	19	1	1
Quartz	14	23.0	12	1	1
Potassic (Pink)	5	8.2	4	1	0
K-feldspar	4	6.6	2	1	1
Plagioclase	3	4.9	1	1	1
Biotite	3	4.9	1	1	1
Chlorite	2	3.3	2	0	0
Unknown	2	3.3	0	0	2
Other	1	1.6	0	1	0
Total # of Veins	61				

* Subhorizontal = 0º-30º, intermediate = 31º-60º, subvertical = 61º-90º

5.3 Dykes in the White River Area

Prior to geological field mapping in the White River area, lineaments identified as Proterozoic-aged mafic dykes were interpreted by SRK (2017) based on geophysical data collected by SGL (2017). These interpreted lineaments are shown on Figure 5.3.1 for the Strickland pluton and Anahareo Lake pluton areas, respectively. The following dyke swarms were interpreted by SRK (2017) in order of prominence:

- Matachewan (northwest-trending)
- Biscotasing (northeast-trending)
- Marathon (north to north-northeast-trending)
- Sudbury (west-northwest-trending)

Individual dykes from all of these dyke swarms were identified in the White River area from field mapping, with the exception of the Sudbury dyke swarm. A summary of the mafic dykes observed during geological mapping is provided in Table 5.3.1. Mafic dykes were observed at 107 bedrock outcrop stations in the White River area, including instances where observations were made at multiple locations along the same dyke, and one bedrock outcrop station (16MC0325) where a Biscotasing dyke was observed intersecting a Matachewan dyke. 81 bedrock outcrop stations were on Matachewan mafic dykes, which were observed to be generally northwest striking and ranging in thickness from centimetres to at least 33 metres thick. Nineteen bedrock outcrop stations were on Biscotasing mafic dykes, which were generally observed to be northeast striking. Seven bedrock outcrop stations were on Marathon mafic dykes, which generally trended north to north-northeast. However, in a few locations the Marathon mafic dykes were difficult to distinguish from Biscotasing as these both locally have irregular contacts and their orientation directions overlap.

In total 32 of the SRK (2017) interpreted dyke lineaments were verified. Of these lineaments 25 were Matachewan, three were Biscotasing and three were Marathon.

One outcrop (Station 16MC0278), although with similar physical characteristics to the other mafic dykes (magnetic susceptibility = 18.8 $x10^{-3}$ S.I.; gamma ray spectrometry, total count = 918, %K = 0.9, U ppm = 0.9, Th ppm = 5.8) was believed to be an Abitibi dyke. This dyke occurred within and parallel to a prominent northeast-trending, linear, narrow and extremely low aeromagnetic anomaly interpreted to be a reversely magnetized dyke. Reversely magnetized dykes are well documented in the Abitibi dyke swarm (Ernst and Buchan, 1993).

Overall, most Proterozoic mafic dykes observed had competent contacts with little reactivation. Joints were the dominant internal structure observed within the dykes. Internal joints are predominantly subvertical and strike approximately perpendicular or parallel to the main dyke swarm trends. This is particularly evident in the numerous Matachewan mafic dykes (i.e.

statistically the greatest data set) where the dominant joint set strikes northeast (i.e. perpendicular) with a subordinate joint set striking northwest (i.e. parallel) to the dyke swarm. In most cases little deformation was observed in the host rock adjacent to the dyke.

The following three sections discuss the character of the three main Proterozoic dyke swarms in order of their frequency of occurrence in the White River area. Section 5.3.4 briefly discusses the character of the felsic and intermediate dykes and sills that occur within the White River area (Figure 5.3.4). The felsic and intermediate dykes and sills all predate the Proterozoic mafic dykes and all exhibit welded contacts.

Table 5.3.1 Proterozoic Dykes Summary Table

Dyke Swarm	Number of Bedrock Outcrop Station Occurrences	Lithology	Width (m)	Orientation	Contact Character	Gamma (Total Count)	Average Magnetic Susceptibility ($\times 10^{-3}$ SI)	Strength
Matachewan	81	Predominantly fine-grained considered to comprise hornblende, feldspar and magnetite	0.1 - 33	NW-SE	24 sharp 27 chilled 1 gradational 1 welded 28 not observed	385 to 1367	28.8	R3 to R5
Biscotasing	19	Predominantly fine-grained considered to comprise hornblende, feldspar and magnetite with large feldspar phenocrysts sometimes encountered	0.02 - 33	NE-SW	5 sharp 10 chilled 4 not observed	555 to 1143	22.5	R3 to R5
Marathon	7	Predominantly fine-grained considered to	0.3 - >10m	NNE-SSW	1 sharp 4 chilled	475-886	20.7	R3 to R5

Dyke Swarm	Number of Bedrock Outcrop Station Occurrences	Lithology	Width (m)	Orientation	Contact Character	Gamma (Total Count)	Average Magnetic Susceptibility ($\times 10^{-3}$ SI)	Strength
		comprise hornblende, feldspar and magnetite			2 not observed			

5.3.1 Matachewan Mafic Dykes

Mafic dykes of the Matachewan dyke swarm are the most populous of the three main Proterozoic dyke swarms encountered in the White River area. These dykes are generally easily distinguished as a distinct dyke swarm by their consistent northwest strike. A summary is given below of the lithological and physical character, and the main structural features of the Matachewan mafic dykes encountered in the White River area. This is followed by a presentation of a scanline fracture mapping exercise undertaken across one well-exposed Matachewan mafic dyke.

5.3.1.1 Lithology and Physical Character

Matachewan mafic dykes were encountered at 81 bedrock outcrop stations across the White River area, which represent 23% of all 354 bedrock outcrop stations in the White River area (Figure 5.3.1). The Matachewan mafic dykes were commonly quite wide and were well-exposed along their length at road cuts, but otherwise were not well exposed. 63 representative rock samples of Matachewan mafic dykes were collected throughout the White River area.

Matachewan mafic dykes exhibit variable shades of black, grey or green when fresh and black, dark to light grey, dark to light green or rarely brown when weathered (Figures 5.3.1.1a, 5.3.1.1b and 5.3.1.1c). Most Matachewan mafic dykes were fine-grained to very fine-grained, with some coarser-grained outcrops exhibiting a gabbroic texture. The usually fine-grained size made it difficult to determine the mineral assemblages in hand sample or in outcrop. Most were thought to consist primarily of hornblende and plagioclase, with accessory magnetite. Acicular matrix plagioclase was noted locally (Station 16MC0011), and plagioclase phenocrysts were observed along the southwest margin of one 18 metre wide Matachewan dyke (Station 16MC0285).

A total of 120 rock hardness measurements were made on the Matachewan mafic dykes in the White River area. Their most common hardness is Strong (R4) recorded in 61 instances (51%). 47 instances (39%) recorded a Very Strong (R5) character. twelve instances (10%) recorded a Medium Strong (R3) character.

A summary of Matachewan mafic dyke width measurements is presented in Figure 5.3.1.1f. In many locations it was not possible to determine the exact width of Matachewan mafic dykes encountered in the field due to insufficient exposure of both side of the contact, in which case only a minimum width could be determined. In 23 out of 56 bedrock outcrop stations sufficient exposure was available to make an exact width measurement, the rest of the measurements are minimum widths. Measured Matachewan mafic dyke widths ranged between 0.1 and 33 metres, with a mean of 12.1 m and a standard deviation of 11.5 metres. Just over 50% of the measured widths exceeded ten metres. The measured widths have some bias towards thinner dykes (e.g., Figure 5.3.1.1b) as the probability of encountering both dyke contacts at an outcrop is lower as dykes get wider. Overall it would appear that most Matachewan mafic dykes are greater than ten metres wide.

A total of 68 magnetic susceptibility measurements were made on the Matachewan mafic dykes yielding an average susceptibility of 28.8 × 10^{-3} S.I. (range = 46.3 × 10^{-3} S.I.; Std. Dev. = 10.7 × 10^{-3} S.I.). In ten locations where alteration was observed in mafic dyke outcrops, magnetic susceptibility values below approximately 10 × 10^{-3} S.I. were recorded for Matachewan dykes (Figure 5.3.1.1d). These instances are interpreted to be a result of destruction of magnetite from the original dyke composition, likely in association with post-dyke emplacement faulting. Excluding those values affected by magnetite destruction the average magnetic susceptibility of the Matachewan mafic dykes is 31.0 × 10^{-3} S.I., which is more than three times greater, on average, than the main Archean aged bedrock units identified in the White River area.

A total of 64 gamma ray spectrometry measurements were collected on the Matachewan mafic dykes. The results include:

- Total count (range 982, average 767, Std. Dev. 183)
- %K (range 1.4, average 0.9, Std. Dev. 0.3)
- U ppm (range 1.6, average 0.6, Std. Dev. 0.5)
- Th ppm (range 6.4, average 4.0, Std. Dev. 1.3)

The gamma ray spectrometry overall shows very limited spread in values (Figure 5.3.1.1e).

5.3.1.2 Structure

The orientation of the contact between Matachewan mafic dykes and the surrounding bedrock host was measured in 71 instances. In all instances the contact was steeply-dipping, with the majority of measured dips ranging between 75° and 90°, and northwest-southeast striking (Figures 5.3.1.2a and 5.3.1.2b). One main peak Matachewan dyke orientation trends 140°, with a secondary peak at 121°. A total range in orientations for Matachewan dyke contacts extends between 116° and 155°. No shallowly-dipping, sill-like, contacts were observed.

The character of the Matachewan dyke-host contact could be investigated closely at 53 bedrock outcrop stations. Of these, 27 dyke contacts were described as chilled and welded and exhibited mm- to cm-scale aphanitic dyke margins. 24 contacts were described as sharp, with no associated chill margin developed, but with a knife-edge transition from dyke to host. In one instance the contact was observed to be gradational where a less sharp transition was identified and in one instance it was observed to be welded.

In 44 of the 53 bedrock outcrop stations (83%) the contact zone exhibited no evidence of post-dyke emplacement brittle re-activation and is intact (Figures 5.3.1.3a and 5.3.1.3b). Nine of the 53 observed dyke-host contacts exhibited evidence of weak reactivation along the contact in the form of one or more joints developed parallel to and along the contact (Figures 5.3.1.3c, 5.3.1.3d and 5.3.1.3e). Two contacts were described as moderately reactivated, with several joints and/or open fractures occurring at the dyke contact. Only one mapping station (Station 16MC0285) was observed where the Matachewan mafic dyke contact was strongly reactivated. In this example, a metre-thick zone of epidote vein breccia and stockwork quartz veins occurs along the northeastern contact of the Matachewan mafic dyke (Figure 5.3.1.3f), interpreted to represent a fault. Magnetite destruction was evidenced by anomalously low magnetic susceptibility readings in the mafic dyke along this fault. The fault was traceable for more than 30 metres along the northeast contact of the dyke. The southwest contact of the dyke at the same bedrock outcrop station exhibited no evidence of brittle re-activation.

There was no apparent damage zone near dyke margins within the host rocks observed in the field that could be attributed to damage caused by dyke intrusion. Host rocks appeared to be no more or less fractured at or near to the contacts with Matachewan mafic dykes than in areas away from mafic dykes.

Fractures (joints and faults) recorded within Matachewan mafic dykes are presented in Figure 5.3.1.2. Only two faults were measured within Matachewan mafic dykes, along with 208 joints (Figure 5.3.1.2c). The two faults strike north-northeast and northwest, respectively. The majority of joints strike either northwest or northeast, which is either parallel or perpendicular to Matachewan mafic dykes themselves (Figures 5.3.1.2b and 5.3.1.2d). The total population of fractures within Matachewan mafic dykes includes a northwest-striking fracture set that ranges between 119° and 151° with internal peaks at 132° and 138° and a northeast-striking fracture set that ranges between 018° and 062° with internal peaks at 038° and 055°.

The spacing of joints recorded within Matachewan dykes is predominantly within the 100-500 cm range as shown on Figure 5.3.1.2e. Most closely spaced joints (< 30 cm) tend to strike northwest, parallel to the dyke-host contacts as shown on Figure 5.3.1.2f. Dyke-perpendicular joints are commonly more closely spaced adjacent to the dyke margins relative to the dyke centres; overall there are commonly more joints (i.e. tighter joint spacing) within the dykes near their margins than in the centres of the dykes. This relationship was apparent in joint spacing measurements collected across a few favourably exposed dykes (e.g. Stations 16MC0103, 16MC0260) and was also evident in the scanline exercise (Section 5.3.1.3).

Few veins were observed within the Matachewan mafic dykes; a total of eight were observed with quartz and / or epidote fill. One vein was observed with hornblende fill. Similar vein fill material also occurred along a few regular or parallel joint sets.

5.3.1.3 Dyke Scanline Exercise

A scanline fracture mapping exercise was undertaken on a well exposed Matachewan mafic dyke hosted by granodiorite on the western side of the Strickland pluton area. This dyke outcrop is located on Highway 613 at Station 16MC0021 where one of the dyke contacts is recorded (Figure 5.1.1).

The scanline was undertaken from southwest to northeast over a distance 60 metres, with all fractures being recorded within 1 metre either side of a tape measure running from the starting point (Easting 657343, Northing 5405764; UTM NAD83 Zone 16N) to the end point (Easting 657390, Northing 5405804; UTM NAD83 Zone 16N) of the scanline. In addition, five readings of magnetic susceptibility were obtained for each metre interval of the scanline. A composite summary of the scanline results is shown on Figure 5.3.1.4 with photographs of the outcrop shown on Figure 5.3.1.5. Continuity of exposure of the Matachewan mafic dyke was extremely good (Figure 5.3.1.5a) with only one gap in exposure at approximately x = 8 metres (from southwest side of section) where overburden covered a break in the outcrop along an interpreted fault. A summary of the observations is provided below.

- The Matachewan mafic dyke had a measured width along the scanline of 22.7 metres.
- 264 structural measurements were made across the scanline comprising:
    - 231 joints, including 97 measured within the Matachewan dyke; 89 measured within the granodiorite to the southwest of the dyke and 45 more to the northeast of the dyke;
    - Fourteen veins were observed in the granodiorite, but none in the Matachewan mafic dyke; vein infilling material included epidote, chlorite, quartz and pegmatite;
    - Three small mafic dykes located in the granodiorite on the southwest side of the Matachewan mafic dyke are potentially apophyses of the large dyke;
    - Three faults were identified in the granodiorite on the southwest side of the Matachewan mafic dyke;
    - Nine small felsic dykes and two igneous flow foliations were identified within the granodiorite; and
    - Both contacts of the Matachewan mafic dyke were measured; southwest contact at 135°/86° and northeast contact at 135°/87° (strike/dip).

Overall jointing is approximately perpendicular (northeast striking) or parallel (northwest striking) to the Matachewan mafic dyke contacts, but with some systematic variations across the scanline (Figure 5.3.1.4b). Key observations include:

- Most joints dip steeply with an average dip of 65º;
- Joints in the granodiorite tend to be subparallel (10º anticlockwise) or subperpendicular (10º clockwise) to the strike of the dyke;
- There are notably more joints in the granodiorite on the southwestern side of the dyke contact in comparison to the northeastern side (Figure 5.3.1.5b), particularly those striking northeast-southwest;
- The majority of joints within the Matachewan mafic dyke are perpendicular to the dyke contact;

- Both contacts of the Matachewan mafic dyke exhibited chilled margins (e.g. Figure 5.3.1.5c);
- There is a notable increase in joint frequency (i.e. tighter spacing) at both Matachewan mafic dyke contacts, mostly within the mafic dyke (Figure 5.3.1.4c), but also within the granodiorite on the northeastern side where five joints occur within 10 cm of the dyke contact;
- Other structures, such as veins, tend to have similar northwest-striking orientations as the dyke contacts (Figure 5.3.1.4b); and
- The main infill of veins and joints (if fill was present) are quartz (eleven) and epidote (ten); the majority of fractures (> 80%) with these two mineral infills have pink alteration halos (Figure 5.3.1.4d).

Eighteen magnetic susceptibility measurements were made on the host rock granodiorite on the southwestern side and seventeen on the northeastern side of the Matachewan mafic dyke (Figure 5.3.1.4e). On the southwest side they yielded an average susceptibility of 3.62×10^{-3} S.I. (range = 3.47×10^{-3} S.I.; Std. Dev. = 0.99×10^{-3} S.I.) and on the northeast side an average susceptibility of 3.92×10^{-3} S.I. (range = 2.64×10^{-3} S.I.; Std. Dev. = 0.68×10^{-3} S.I.). Overall, there are no major changes in the magnetic susceptibility of the granodiorite, which is similar to the average of 4.77×10^{-3} S.I. measured across southern half of the Strickland pluton area (Section 5.1.3.2).

A total of 23 magnetic susceptibility measurements were made on the Matachewan mafic dyke (Figure 5.4.1.4e) yielding an average susceptibility of 31.6×10^{-3} S.I. (range = 12.2×10^{-3} S.I.; Std. Dev. = 3.22×10^{-3} S.I.). There is a reduction of magnetic susceptibility of approximately 6 $\times 10^{-3}$ S.I. at both margins, tentatively correlating with the chilled dyke margin. The average magnetic susceptibility is very similar to other Matachewan mafic dykes measured across the White River area (31.0×10^{-3} S.I.), excluding those values affected by magnetite destruction (as discussed in Section 5.3.1.1 above).

5.3.2 Biscotasing Mafic Dykes

Mafic dykes of the Biscotasing dyke swarm are the second most populous of the three main Proterozoic dyke swarms encountered in the White River area. These dykes are usually easily recognized, based on orientation and character in the field, as being part of the Biscotasing dyke swarm. However, in a few locations they were difficult to distinguish from Marathon mafic dykes as both locally have irregular contacts and their orientations overlap. A summary is given below of the lithological and physical character, and the main structural features, of the Biscotasing mafic dykes encountered in the White River area.

5.3.2.1 Lithology and Physical Character

Biscotasing mafic dykes were encountered at nineteen out of 354 (5%) bedrock outcrop stations across the White River area (Figure 5.3.1). Unlike the Matachewan mafic dykes, no large exposures were encountered of wide Biscotasing mafic dykes. All exposures were relatively small (Figure 5.3.2.1a) and not suitable for detailed scanline fracture mapping. Fourteen representative rock samples of Biscotasing mafic dykes were collected throughout the White River area.

Biscotasing dykes exhibit variable shades of grey or dark green when fresh and variable shades of grey, green or brown when weathered (Figure 5.3.2.1b). Most Biscotasing mafic dykes were fine-grained (Figure 5.3.2.1b), which made it difficult to identify their constituent minerals. Most were thought to consist primarily of hornblende and plagioclase, with accessory magnetite. One 33 metre thick, very coarse-grained Biscotasing mafic dyke located in the Strickland pluton area consisted of very coarse-grained plagioclase phenocrysts within a medium- to coarse-grained matrix of plagioclase and hornblende (Stations 16MC0098, 16MC0232 (Figure 5.3.2.1a), 16MC0233, 16MC0248 and 16MC0249).

A total of twenty rock hardness measurements were made on the Biscotasing mafic dykes in the White River area. The most common hardness recorded for Biscotasing mafic dykes is Very Strong (R5) which occurred in ten instances (50%). Nine instances (45%) yielded a Strong (R4) character. One instance (5%) was described as Medium Strong (R3).

A summary of seventeen Biscotasing dyke width measurements is presented in Figure 5.3.2.1e. In three instances it was not possible to determine the exact width of Biscotasing mafic dykes, in which case a minimum dyke width was measured. Measured Biscotasing mafic dyke widths ranged from 0.02 to 33 metres (Figure 5.3.2.1.e) with a mean width 3.6 metres and a standard deviation of 8.3 metres. These width estimates are expected to have a bias towards thinner dykes (Figure 5.4.2.3b), as the probability of encountering both dyke contacts at an outcrop is lower for wider dykes.

Thirteen magnetic susceptibility measurements were made on the Biscotasing mafic dykes, yielding an average susceptibility of 22.5 × 10^{-3} S.I. (range = 42.9 × 10^{-3} S.I.; Std. Dev. = 14.4 × 10^{-3} S.I.). In three locations magnetic susceptibility values below approximately 10 × 10^{-3} S.I. are recorded for Biscotasing dykes (Figure 5.3.2.1c) and are interpreted to be due to magnetite destruction from fault-related alteration. The average magnetic susceptibility of the Biscotasing mafic dykes is 34.2 × 10^{-3} S.I. (excluding those values affected by magnetite destruction), which is more than three times greater than the main Archean aged bedrock units in the White River area.

A total of thirteen gamma ray spectrometry measurements were made on the Biscotasing mafic dykes. The results include:

- Total count (range 587, average 814, Std. Dev. 172)
- %K (range 0.8, average 0.8, Std. Dev. 0.2)
- U ppm (range 1.4, average 0.6, Std. Dev. 0.4)

- Th ppm (range 5.8, average 4.6, Std. Dev. 1.8)

The gamma ray spectrometry overall shows very limited spread in values (Figure 5.3.2.1d).

5.3.2.2 Structure

The orientation of the contact between Biscotasing mafic dykes and the surrounding bedrock host was measured in 22 instances. In all instances the contact was steeply-dipping and northeast striking (Figures 5.3.2.2a and 5.3.2.2b). The majority of measured contacts dip between 75° and 90° towards the southeast. One main, broad, Biscotasing mafic dyke orientation ranges between 028° and 070°, within which peaks at 033°, 045°, 052° and 065° are evident. Two measurements of dyke contacts lie outside the main orientation range, indicative of the slightly variable contact orientation characteristic of the Biscotasing mafic dyke swarm. No shallowly dipping sill-like contacts were observed.

The Biscotasing dyke-host contact could be investigated closely in 15 bedrock outcrop stations. Of the fifteen exposed contacts, ten were described as chilled and exhibited mm- to cm-scale aphanitic dyke margins and five were described as sharp, without evidence of chill-related grain-size reduction at the contact but with a very clear transition across it.

In 12 of the 15 bedrock outcrop stations (80%) where the contact was observed, there was no evidence of post-dyke emplacement brittle re-activation and the contact was intact (Figures 5.3.2.3a, 5.3.2.3b, 5.3.2.3c and 5.3.2.3d). At two bedrock outcrop stations, the Biscotasing-host contacts were described as weakly reactivated with one or more joints developed parallel to and along the contact (Figure 5.3.2.3e). One contact on a 50 cm wide Biscotasing mafic dyke had a moderately reactivated contact zone characterized by several closely-spaced joints and/or open fractures occurring along the contact and within the dyke itself (Station 16MC0139, Figure 5.3.2.3f).

There was no apparent damage zone observed in the field near Biscotasing mafic dyke margins within the surrounding bedrock that could be attributed to damage caused by the intrusion of the dyke itself. Host rocks appeared to be no more or less fractured at their contacts with mafic dykes than in areas away from mafic dykes. In one instance, a Biscotasing mafic dyke appears to intrude along a pre-existing fracture zone, interpreted as a dextral strike-slip fault (Figure 5.3.2.3b).

The orientation information for all joints (N = 35) recorded within Biscotasing mafic dykes is presented in Figures 5.3.2.2c and 5.3.2.2d; no faults were recorded in the Biscotasing mafic dykes. The majority of joints strike either northeast or northwest, which is either parallel or perpendicular, respectively, to the northeast-striking Biscotasing mafic dykes themselves. The majority of joints dip steeply. The total fracture population within Biscotasing mafic dykes exhibits a sharp orientation peak at 036°. Two southeast-striking peaks are also evident including one at 130° and one at 157° (Figure 5.3.2.2d).

Information on the spacing of joints within Biscotasing mafic dykes is shown on Figure 5.3.2.2e. Joint spacing is predominantly within the 30-100 cm range, however, this is from measurements made mainly on thinner dykes. There is no apparent correlation between joint spacing and orientation on Figure 5.3.2.2f.

Three veins, in total, were observed within the Biscotasing mafic dykes and all were observed to be filled with epidote. Epidote was also identified as a coating along two sets of joint surfaces formed within Biscotasing mafic dykes.

5.3.3 Marathon Mafic Dykes

Mafic dykes of the Marathon dyke swarm are the least populous of the three mafic dyke swarms in the White River area. In some cases, Marathon mafic dykes were difficult to distinguish from Biscotasing mafic dykes as both locally have irregular contacts and their orientations overlap, as described below. A summary is given below of the lithological and physical character, and the main structural features, of the Marathon mafic dykes encountered in the White River area.

5.3.3.1 Lithology and Physical Character

Marathon mafic dykes were encountered at seven out of 354 (2%) bedrock outcrop stations across the White River area. In some of these instances several parallel Marathon mafic dykes were observed within the bedrock host. Similar to the Biscotasing mafic dyke occurrences, no large exposures of Marathon mafic dykes were encountered. All exposures were relatively small (Figure 5.3.3.1a) and not suitable for detailed scanline mapping. Five representative rock samples of Marathon mafic dykes were collected throughout the White River study area.

Marathon dykes vary between black, dark grey and dark green when fresh and light to dark grey or brown when weathered. Most Marathon mafic dykes are fine-grained, making it difficult to determine their constituent minerals. Most were thought to consist of hornblende and plagioclase, with accessory magnetite.

A total of eight rock hardness measurements were made on the Marathon mafic dykes in the White River area. The most common hardness recorded for Marathon mafic dykes, in four instances (50%), is Strong (R4). In addition, three instances (37%) yielded a Very Strong (R5) character and one (13%) yielded a Medium Strong (R3) character.

A summary of ten Marathon mafic dyke width measurements is presented in Figure 5.3.3.1d. In some instances it was not possible to determine the exact width of Marathon mafic dykes, in which case a minimum dyke width was measured. Overall, half of the measured dykes were less than five metres wide, and the four were greater than ten metres wide. The width of most Marathon mafic dykes was not precisely determined due to insufficient exposure of both contacts. Suitable exposures of relatively thin Marathon dykes (<1 metre thick) were observed at two bedrock outcrop stations (three separate small dykes were measured at Station 16MC208) allowing for the thicknesses of these dykes to be measured (Fig 5.3.3.1d). Approximate estimates of dyke thicknesses were made at discontinuous outcrop exposures and the majority (four) of these were estimated as greater than ten metres thick.

Seven magnetic susceptibility measurements were made on the Marathon mafic dykes, yielding an average susceptibility of 20.7 × 10^{-3} S.I. (range = 30.8 × 10^{-3} S.I.; Std. Dev. = 9.2 × 10^{-3} S.I.). In one location the measured magnetic susceptibility value was below approximately 10 × 10^{-3} S.I. (Figure 5.4.3.1b) and this is interpreted to be due to magnetite destruction from post-emplacement alteration.

A total of six gamma ray spectrometry measurements were made on the Marathon mafic dykes (Figure 5.4.3.1c). One of these measurements (one of the two measurements at Station 16MC0209) is not included in the results as it had a total count of 3140 and was considered contaminated by the adjacent granite host rock. The results for the five reliable gamma ray spectrometry measurements include:

- Total count (range 411, average 625, Std. Dev. 138)
- %K (range 0.5, average 0.6, Std. Dev. 0.2)
- U ppm (range 1.5, average 0.6, Std. Dev. 0.5)
- Th ppm (range 3.6, average 3.2, Std. Dev. 1.2)

The gamma ray spectrometry overall shows a limited spread in values (Figure 5.3.3.1d).

5.3.3.2 Structure

The orientation of the contact between Marathon mafic dykes and the surrounding bedrock host was measured in 11 instances. In all instances the contact was identified to be steeply-dipping, with the majority of measured dips ranging between 75° and 90°, and north to north-northeast-striking (Figures 5.3.3.2a and 5.4.3.2b). One main Marathon mafic dyke orientation ranges between 340° and 012°, within which peaks at 352° and 005° are evident. Five measurements of dyke contacts lie outside the main orientation range, indicative of the local variability in contact orientations characteristic of the Marathon mafic dyke swarm. Field observations suggest that the observed variation in contact orientation for the Marathon mafic dykes is because their emplacement locally followed irregular pre-existing fractures (Figure 5.3.3.3c). No shallowly dipping sill-like contacts were observed.

The Marathon dyke-host contact was exposed and able to be investigated closely in five occurrences. Of these, four dyke contacts were described as chilled and exhibited mm- to cm-scale aphanitic dyke margins and one contact was described as sharp, without evidence of a chill-related grain-size reduction at the contact but with a very clear transition across it. None of the investigated Marathon dyke-host contacts exhibited evidence of post-emplacement brittle re-activation and all contacts are intact (Figure 5.3.3.3).

There was no apparent damage zone observed in the field near Marathon mafic dyke margins within the surrounding bedrock that could be attributed to damage caused by the intrusion of the dyke itself. Host rocks appeared to be no more or less fractured at their contacts with mafic dykes than in areas away from mafic dykes. In one instance, a Marathon mafic dyke appears to intrude along a pre-existing joint in the granite bedrock (Figure 5.3.3.3c).

The orientation information for all joints (N = 24) recorded within Marathon mafic dykes is presented in Figure 5.3.3.2. Two main joint orientations are evident, including one sharp peak at 025° and another broader peak centered at 108° and ranging between 091° and 121°. The dataset includes one additional minor fracture orientation at 138°. The majority of joints strike either north-northeast or east-southeast (Figures 5.4.3.2c and 5.4.3.2d), which is either sub-parallel or sub-perpendicular to, the north to north-northeast-striking Marathon mafic dykes themselves.

The joint spacing is predominantly within the 10-30 cm to 30-100 cm range as shown on Figure 5.4.3.2e, which is relatively low. There is no apparent correlation between joint spacing and orientation as shown on Figure 5.4.3.2f.

5.3.4 Felsic and Intermediate Dykes and Sills

Observations are summarized below relating to the character and structure of mainly felsic dykes and sills and some intermediate dykes observed in the White River area. Overall, 32 felsic dykes, three felsic sills and four intermediate dykes were observed at a total of 38 of 354 (11%) bedrock outcrop stations (Figure 5.3.4.1). The intermediate dykes were observed in the Strickland pluton area only.

The felsic and intermediate dykes and sills are in addition to the pegmatite granite observed mainly as sills and mapped in the Anahareo Lake pluton area as a main lithology at a total of 62 out of 354 (18%) bedrock outcrop stations (Figures 5.2.3 and 5.3.4.1). The lithology and physical character of the pegmatite granite of the Anahareo Lake pluton is discussed in more detail in Section 5.2.3.2.

5.3.4.1 Lithology and Physical Character

Within the White River area felsic and intermediate dykes and some sills of aplite, tonalite, granodiorite, granite and diorite / intermediate composition were identified. The felsic and intermediate dykes generally range in width from centimetre-scale to up to two metres thick. In this respect they are distinct from the Anahareo Lake pegmatite sills, which can be tens of metres thick as observed in large exposures in cliff faces.

The felsic and intermediate dykes (Figures 5.3.4.3a and 5.3.4.3b) and sills vary between light grey, dark grey, pink and beige when fresh and off white, light grey, dark grey, pink and brown when weathered. One diorite dyke appeared black either when fresh or weathered. All the felsic and intermediate dykes and sills are very fine-grained to fine-grained, making it difficult to determine their constituent minerals. In contrast, the Anahareo Lake granite pegmatite sills are all very coarse- to extremely coarse-grained.

A total of 39 rock hardness measurements were made on the felsic and intermediate dykes and sills in the White River area. The most common hardness recorded for the felsic an intermediate dykes and sills, in nineteen instances (49%), is Very Strong (R5). In addition, eleven instances (28%) yielded a Strong (R5) character, five (13%) yielded a Medium Strong (R3) character and four (10%) yielded an Extremely Strong (R6).

Sixteen magnetic susceptibility measurements were made on the felsic and intermediate dykes and sills, yielding an average susceptibility of 2.5×10^{-3} S.I. (range = 6.5×10^{-3} S.I.; Std. Dev. = 2.0×10^{-3} S.I.).

A total of thirteen gamma ray spectrometry measurements were made on the felsic and intermediate dykes and sills. The results for the thirteen gamma ray spectrometry measurements include:

- Total count (range 2854, average 1773, Std. Dev. 848)
- %K (range 3.7, average 2.3, Std. Dev. 1.0)
- U ppm (range 3.4, average 1.5, Std. Dev. 1.0)
- Th ppm (range 27.4, average 10.0, Std. Dev. 8.9)

5.3.4.2 Structure

The orientation of the contact between the felsic and intermediate dykes and sills and the surrounding bedrock host was measured in 61 instances in the Strickland pluton area. In most instances the contact was identified to be steeply-dipping, with the majority of measured dips ranging between 75° and 90°, and north to north-northeast-striking (Figures 5.3.4.2a and 5.3.4.2b). One main felsic dyke and sill orientation ranges between 091° and 163°, within which two major peaks are evident at 133° and 148° and two minor ones at 095° and 110° evident. There is one minor peak outside the main orientation range at 040°. The felsic dykes in the Strickland pluton area rarely exhibited flow foliations, and where visible they were subparallel to the felsic dyke contacts.

The orientation of the contact between the felsic dykes and sills and the surrounding bedrock host was measured in nineteen instances in the Anahareo Lake pluton area, with most measured on the granite pegmatite sills. Some of the granite pegmatite sills are shallowly north-northeast to northeast dipping (Figures 5.3.4.2c and 5.3.4.2d), which is subparallel to the interpreted dip of main granite pegmatite sill bodies within the area mapped as granite pegmatite in the northern part of the Anahareo Lake pluton area (Figure 5.2.3). Overall trends of the felsic dykes and sills are quite variable in the Anahareo Lake pluton area, but the majority strike northeast (Figure 5.3.4.2d) with two major peaks at 060° and 157°, and minor peaks at 040°, 072° 114°, 125° and 145°. However, the majority of granite pegmatite sills tend to strike northwest.

The felsic and intermediate dyke and sill contacts in both the Strickland and Anahareo Lake pluton areas were always welded when observed, and never exhibited reactivation.

6.0 SUMMARY OF FINDINGS

This report presents the results of the Phase 2 Geological Mapping conducted in the White River area in 2016. Observations were made at outcrops within and around the Strickland pluton area and the Anahareo Lake pluton area. The geological mapping was conducted using a consistent approach, presented in Section 4.0, to confirm and field verify the presence and nature of key geological features within these two areas, including, bedrock lithology and structural character, fracture character and spacing, and bedrock exposure and surface constraints.

The following sections summarize the key findings of the results presented in Section 5.0, and discusses how the newly collected geological information builds upon our historical understanding of the area (Section 3.0).

6.1 Strickland Pluton Area

6.1.1 Lithology

Three lithological units were identified in the Strickland pluton area including tonalite and granodiorite as main lithologies, and schist and gneiss as one minor lithology (Table 5.1.1 in Section 5.1), in addition to mafic dykes and felsic and intermediate dykes and sills. The Strickland pluton has been mapped as a tonalite-dominated area in the north grading into a granodiorite dominated area to the south (Section 5.1.3). This is a new geological observation as the pluton has been mapped previously as predominantly granodiorite (Section 3.2.1).

6.1.2 Structure

Section 5.1.4.1 describes the characteristics of the ductile structures observed in the Strickland pluton area, comprising igneous flow foliations, tectonic foliations and ductile and brittle-ductile shear zones. Ductile structures are relatively uncommon; the most common ductile structure is an igneous flow foliation that occurs in both the tonalite and granodiorite throughout the Strickland pluton area and trends predominantly east-west. Some tectonic foliations have been measured in the gneissic tonalite in the Lake Nameigos area, southeast of the withdrawal area and few ductile and brittle-ductile shear zones have been measured scattered across the Strickland pluton area. A summary of the statistics of the ductile structures is provided in Table 5.1.4.1.

Section 5.1.4.2 describes the characteristics of the brittle structures comprising joints, faults and veins. The secondary mineral infilling and alteration that accompanies some joints and faults and all veins is described in Section 5.1.4.3. Joints are the predominant fracture type and also the most common structure observed at the outcrop scale throughout the Strickland pluton area.

The two main joint orientation families are northeast-southwest (47%) and northwest-southeast (28%), which are both approximately parallel and / or perpendicular to the two main Proterozoic dyke swarms (Biscotasing and Matachewan, respectively). Another joint orientation family can be identified trending north-northwest to south-southeast (9%) and a small number (4%) are identified as subhorizontal with the remainder unclassified (13%). Overall, joints are predominantly subvertical (61º -90º) with joint spacing mostly within the 100-500 cm range. Northeast-southwest and northwest-southeast orientation families are also identified for the faults and veins with similar subvertical dips. The most common secondary mineral or alteration, occurring mainly along subvertical northeast-striking fractures, is a pink (potassic) alteration commonly associated with hematite staining that is common in the northern part of the Strickland pluton where tonalite is dominant. A summary of the statistics of the brittle structures is provided in Table 5.1.4.2.

6.2 Anahareo Lake Pluton Area

6.2.1 Lithology

Five lithological units were identified in the Anahareo Lake pluton area including granite, pegmatitic granite and tonalite-granodiorite as main lithologies, schist and gneiss as one minor lithology and weakly foliated granodiorite to tonalite as another minor lithology (Table 5.2.1 in Section 5.2) in addition to mafic dykes and felsic dykes. The Anahareo Lake pluton has been mapped as granitic pegmatite in the north, with granite in the centre and tonalite to granodiorite in the south (Section 5.2.3). The identification of the north being dominated by granite pegmatite sills, and mapping granite in the centre and tonalite to granodiorite in the south represents a new geological observation as the Anahareo Lake pluton had been mapped previously as granite and granodiorite (Section 3.2.3). The Anahareo Lake pluton is also characterised in some cases by the occurrence of very large xenoliths of metamorphic basement rocks within the pluton, which appears to be associated with a northeast-trending aeromagnetic low.

6.2.2 Structure

Overall the structural character of the Anahareo Lake pluton is quite similar to the Strickland pluton to the north as summarized above, particularly with respect to the brittle structures. The characteristics of the ductile structures comprising mainly tectonic foliations and few igneous flow foliations and brittle-ductile shear zones are described in Section 5.2.4.1. The tectonic foliation occurs within xenoliths of schist and gneiss, and more the weakly foliated granodiorite to tonalite that are located within the granite and particularly the pegmatitic granite. No ductile shear zones were identified in the Anahareo Lake pluton. A summary of the statistics of the ductile structures is provided in Table 5.2.4.1.

Section 5.2.4.2 describes the characteristics of the brittle structures comprising joints, faults and veins. The secondary mineral infilling and alteration that accompanies some joints and faults and all veins is described in Section 5.2.4.3. The two main joint orientation families are northeast-southwest (40%) and northwest-southeast (30%), which are both approximately parallel and / or perpendicular to the two main Proterozoic dyke swarms (Biscotasing and Matachewan, respectively). Another joint orientation family can be identified trending north-northwest to south-southeast (7%) and a small number (7%) are identified as subhorizontal with the remainder unclassified (16%). Overall joints are predominantly subvertical (61º -90º) with joint spacing mostly within the 100-500 cm range. The fault and vein orientation families are similar in that they also have subvertical dips. However, the faults tend to strike northeast-southwest or north-northeast to south-southwest and the veins tend to strike north-northwest to south-southeast or north-northeast to south-southwest. The most notable secondary minerals or alteration, occurring mainly along subvertical northeast-striking fractures, are a pale green siliceous material (possibly pseudotachylite) and epidote veins occur commonly together and sometimes associated with pink (potassic) alteration (less common than the Strickland pluton). A summary of the statistics of the brittle structures is provided in Table 5.2.4.2.

6.3 Proterozoic Mafic Dykes

The predominant large-scale structural feature within both the Strickland pluton area and Anahareo Lake pluton area are the Proterozoic mafic dykes. The northwest-southeast-trending Matachewan dyke swarm are the most numerous; in total, 25 of the SRK (2017) interpreted dyke lineaments were verified (Section 5.3). Three each of the less numerous Biscotasing and Marathon dyke swarms were also field verified. No dykes of the Sudbury dyke swarm were identified. However, one reversely magnetised, northeast-southwest-trending interpreted lineament may be part of the Abitibi dyke swarm.

6.4 Structural History of the White River Area

A brief synthesis of lithological and structural observations from the geological mapping activity is provided below as a general summary of the geological history of the White River area. The relative timing of formation of the described structures and secondary minerals are summarized, drawing on specific field observations to justify the interpretation.

Based on the data collected during mapping, the sequence of deformation for the Strickland pluton area is as follows.

- The greenstone belts and their associated sedimentary and intrusive rocks were deformed and metamorphosed.
- The Strickland pluton developed, consisting of episodic intrusion of mainly tonalitic composition, but with local pulses of granodioritic magma in the southern part of the pluton. This was closely followed by subsequent felsic dykes and aplite dykes and veins which have welded non-reactivated contacts.

- A widespread but minor period of quartz veining occurred which closely post-dated felsic dyke emplacement but pre-dated subsequent ductile shear deformation. These older quartz veins generally have welded contacts and are rarely reactivated.
- North-northeast-striking ductile sinistral faults deformed the plutons, offset felsic dykes and aplite vein markers as well as older quartz veins. Northwest-striking dextral brittle-ductile shear zones may also be associated with this episode of deformation.
- Pale-green siliceous material (possibly pseudotachylite) and epidote commonly occurs within pink stained alteration halos, suggesting these vein types occur prior to the hydrothermal event that formed the halos. Pseudotachylite is brittle ductile whereas the epidote may be synchronous with slightly shallower, cooler, and more brittle deformation. Pseudotachylite veins strike predominantly northeast and commonly have sinistral shear sense.
- Intrusion of the Matachewan mafic dykes which strike northwest.
- Formation of many of the main joint sets and epidote veins and hydrothermal alteration forming widespread occurrence of pink (potassic) alteration halos, which occurred mainly along northeast-striking brittle structures.
- Intrusion of the Biscotasing mafic dykes followed by intrusion of Marathon mafic dykes. Marathon mafic dykes seem to follow pre-existing faults and joints implying they intruded after significant brittle deformation had affected the rocks.
- Later reactivation occurs of all pre-existing brittle features by younger brittle faulting.

Overall the structural character of the Anahareo Lake pluton is quite similar to the Strickland pluton to the north. Based on the data collected during mapping the sequence of deformation for the Anahareo Lake pluton area is as follows:

- The greenstone belts and their associated sedimentary and intrusive rocks were deformed and metamorphosed.
- The Anahareo Lake pluton developed, consisting of a central portion of coarse-grained locally potassium-feldspar-porphyritic granite grading northward into shallowly north- to northeast-dipping pegmatite sills. Across an apparently sharp boundary to the south is a body of tonalite – granodiorite. However, uncertain age relations exist between the granitic phases to the north. This was closely followed by subsequent felsic dykes and aplite dykes and veins which have welded non-reactivated contacts.
- A widespread but minor period of quartz veining occurred which closely post-dated felsic dyke emplacement but pre-dated subsequent ductile shear deformation. These older quartz veins generally have welded contacts and are rarely reactivated.
- North-northeast-striking ductile sinistral faults deformed the plutons, offset felsic dykes and aplite vein markers as well as older quartz veins. Northwest-striking dextral brittle-ductile faults may also be associated with this episode of deformation.

- Pale-green siliceous material (possibly pseudotachylite) and epidote commonly is overprinted by pink-stained alteration halos, suggesting these vein types formed prior to the hydrothermal event that formed the halos. Pseudotachylite is brittle-ductile whereas the epidote may be synchronous with slightly shallower, cooler, and more brittle deformation. Pseudotachylite veins strike predominantly northeast and commonly have sinistral shear sense.
- Intrusion of the Matachewan mafic dykes which strike northwest.
- Emplacement of epidote veins and hydrothermal alteration, which occurred mainly along northeast-striking brittle structures.
- Intrusion of Biscotasing mafic dykes followed by intrusion of the Marathon mafic dykes. Marathon mafic dykes seem to follow pre-existing faults and joints implying they intruded after significant brittle deformation had affected the rocks.
- Later reactivation of all pre-existing brittle features by younger faulting.

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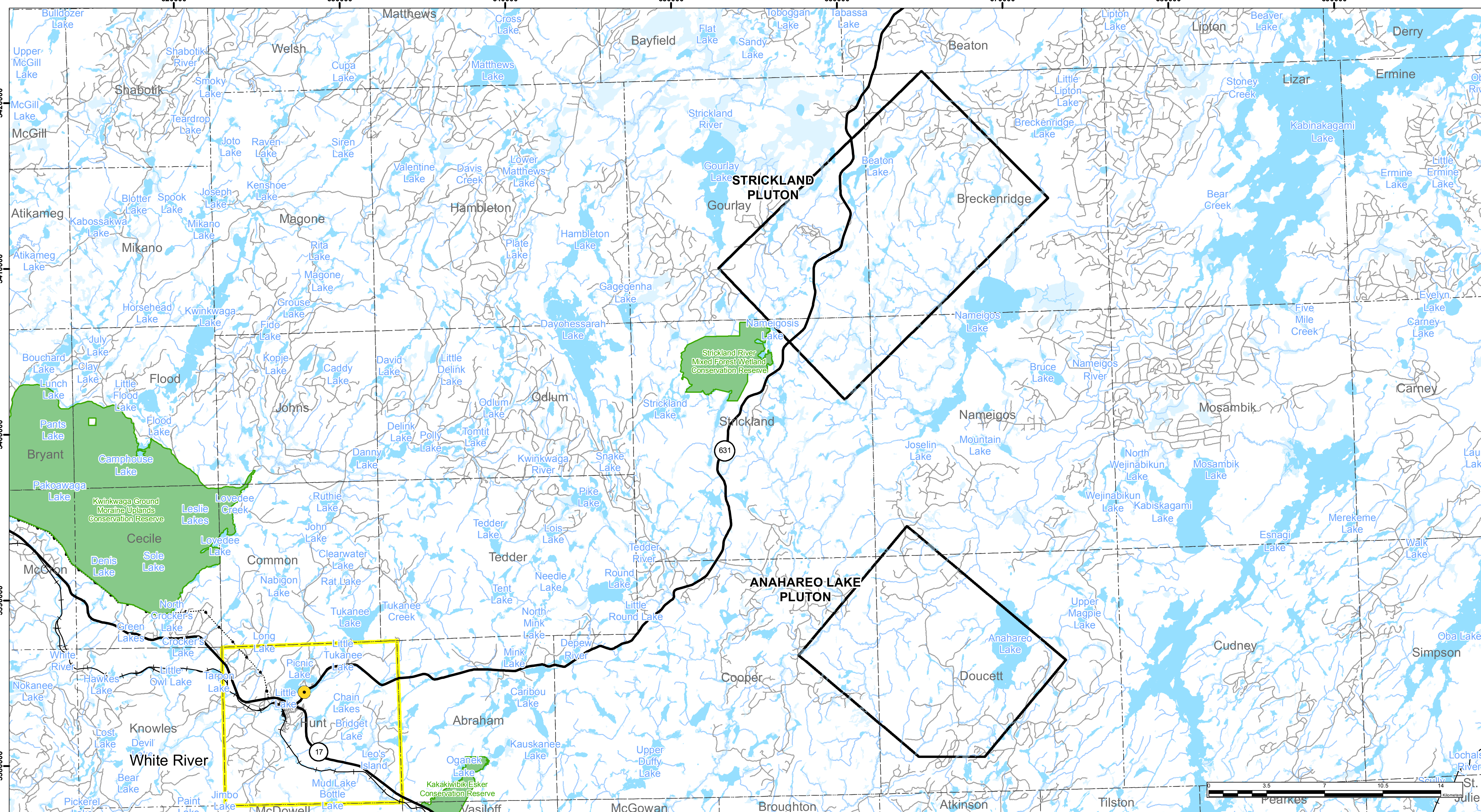
FIGURES



LEGEND

- Community
- White River Municipal Boundary
- Geographic Township
- Main Road
- Local Road
- Waterbody
- Watercourse
- Railway
- Power Transmission Line
- Wetland
- Conservation Reserve
- Withdrawal Areas

This drawing should be read in conjunction with the Amec Foster Wheeler Environment & Infrastructure Report No. TB154003.

SOURCE:
Base Data- MNR LIO obtained 2009-2015, CANMAP v2006.4

CLIENT:
nwmo
NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

Revision: v2.0

NAD 1983 Zone 16N

Drawn By: LJM 15/06/2017

Checked By: MS 15/06/2017

SCALE: 1:217,162

DETAILED MAPPING
White River Community

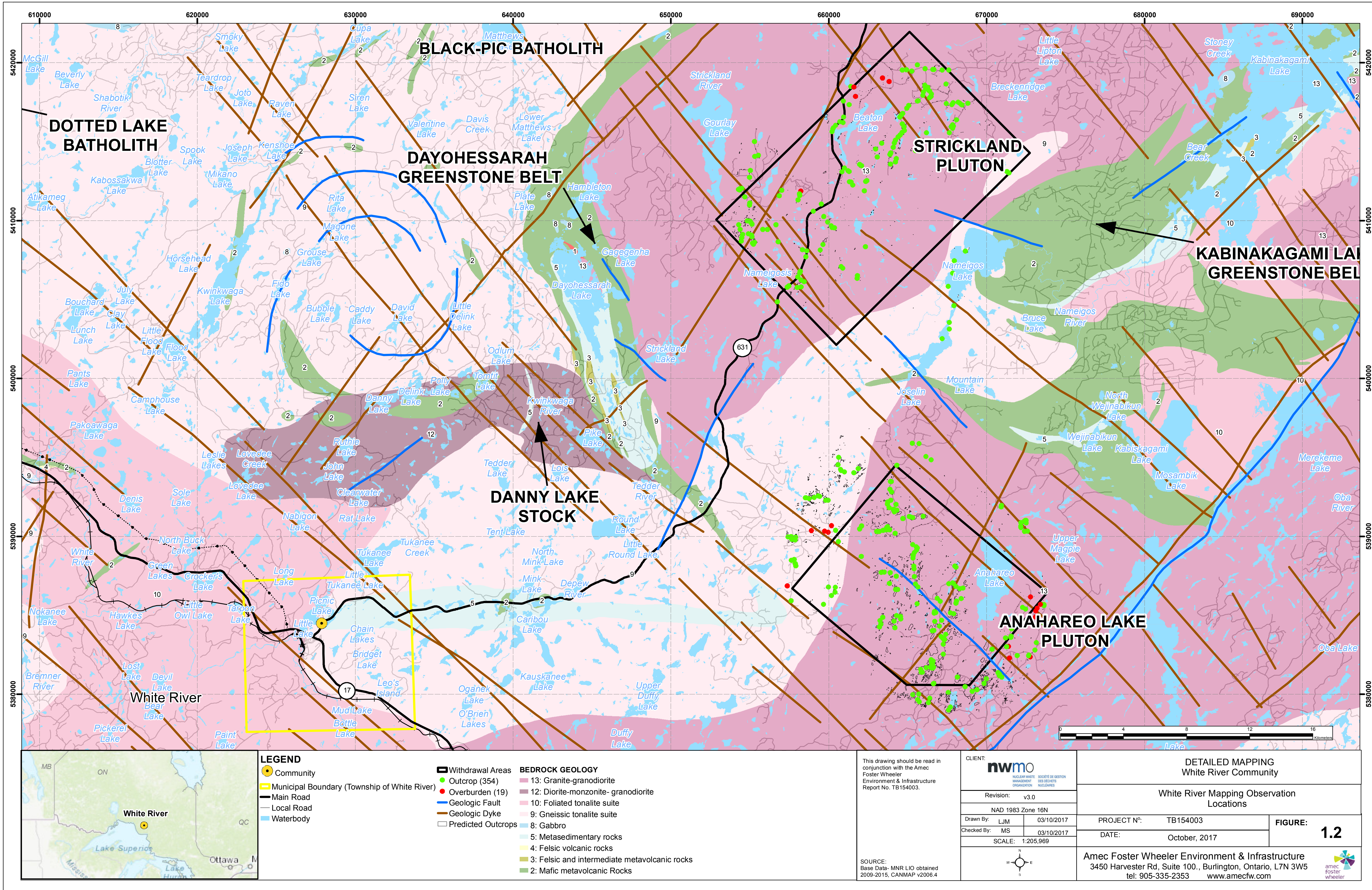
White River Study Area

PROJECT Nº: TB154003

DATE: June, 2017

FIGURE: 1.1

Amec Foster Wheeler Environment & Infrastructure
3450 Harvester Rd, Suite 100., Burlington, Ontario, L7N 3W5
tel: 905-335-2353 www.amecfw.com


BLACK-PIC BATHOLITH
DOTTED LAKE BATHOLITH
DAYOHESSARAH GREENSTONE BELT
STRICKLAND PLUTON
KABINAKAGAMI LAKE GREENSTONE BELT
DANNY LAKE STOCK
ANAHAREO LAKE PLUTON
White River
LEGEND
Community
Municipal Boundary (Township of White River)
Main Road
Local Road
Waterbody
Withdrawal Areas
Outcrop (354)
Overburden (19)
Geologic Fault
Geologic Dyke
Predicted Outcrops
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
This drawing should be read in conjunction with the Amec Foster Wheeler Environment & Infrastructure Report No. TB154003.
SOURCE: Base Data- MNR LIO obtained 2009-2015, CANMAP v2006.4
CLIENT: nwmo
Revision: v3.0
NAD 1983 Zone 16N
Drawn By: LJM 03/10/2017
Checked By: MS 03/10/2017
SCALE: 1:205,969
DETAILED MAPPING
White River Community
White River Mapping Observation Locations
PROJECT No: TB154003
DATE: October, 2017
FIGURE: 1.2
Amec Foster Wheeler Environment & Infrastructure
3450 Harvester Rd, Suite 100., Burlington, Ontario, L7N 3W5
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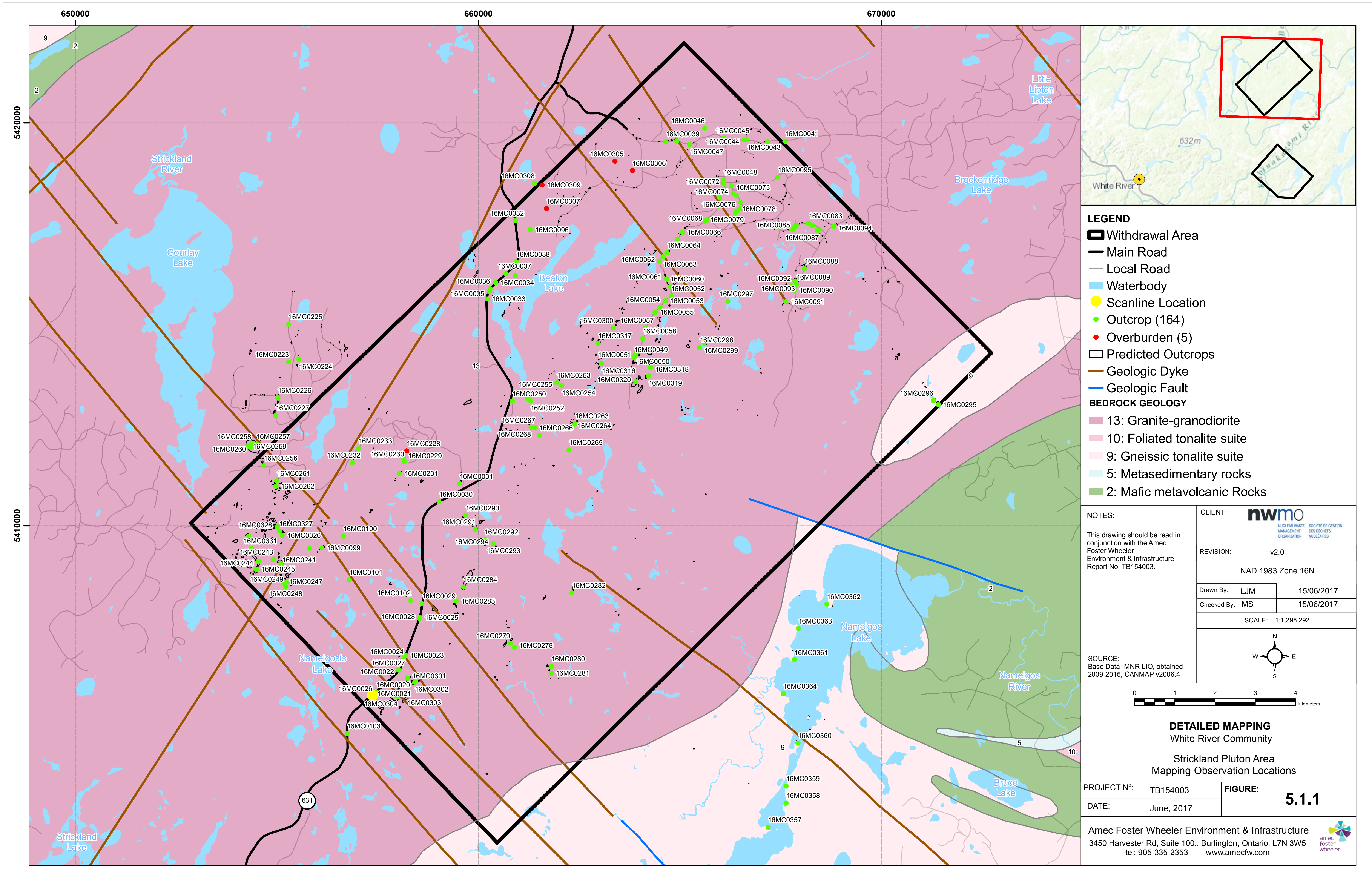
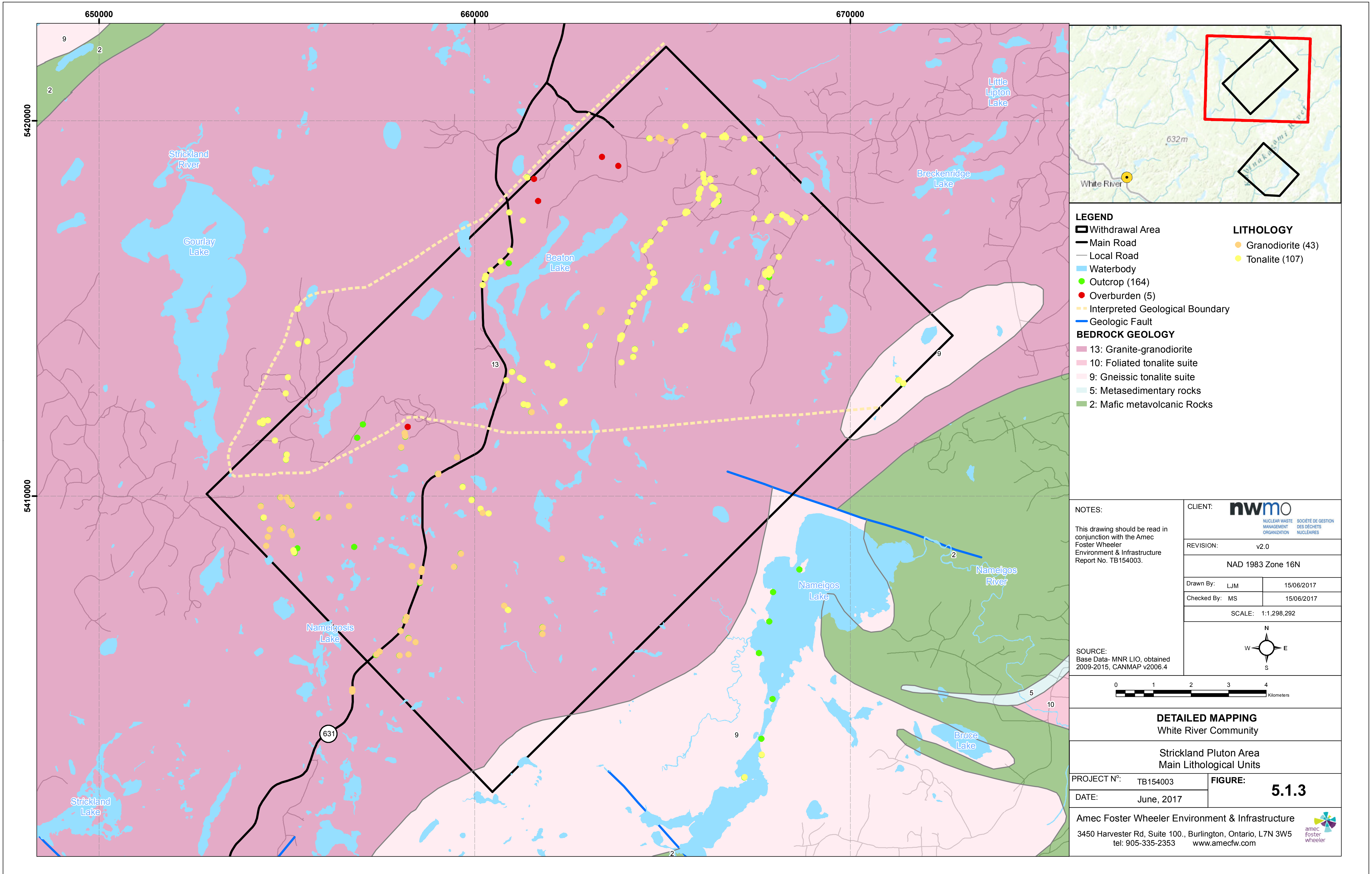


650000
660000
670000
5420000
5410000
Strickland River
Gourlay Lake
Beaton Lake
Little Lipton Lake
Breckenridge Lake
Nameigosis Lake
Nameigos Lake
Nameigos River
Bruce Lake
Strickland Lake
631
White River
632m
LEGEND
Withdrawal Area
Main Road
Local Road
Waterbody
Scanline Location
Outcrop (164)
Overburden (5)
Predicted Outcrops
Geologic Dyke
Geologic Fault
BEDROCK GEOLOGY
13: Granite-granodiorite
10: Foliated tonalite suite
9: Gneissic tonalite suite
5: Metasedimentary rocks
2: Mafic metavolcanic Rocks
NOTES:
This drawing should be read in conjunction with the Amec Foster Wheeler Environment & Infrastructure Report No. TB154003.
SOURCE:
Base Data- MNR LIO, obtained 2009-2015, CANMAP v2006.4
CLIENT:
nwmo
NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES
REVISION: v2.0
NAD 1983 Zone 16N
Drawn By: LJM 15/06/2017
Checked By: MS 15/06/2017
SCALE: 1:1,298,292
0 1 2 3 4 Kilometers
DETAILED MAPPING
White River Community
Strickland Pluton Area
Mapping Observation Locations
PROJECT N°: TB154003
DATE: June, 2017
FIGURE: 5.1.1
Amec Foster Wheeler Environment & Infrastructure
3450 Harvester Rd, Suite 100., Burlington, Ontario, L7N 3W5
tel: 905-335-2353 www.amecfw.com

Figure 5.1.2 Strickland Pluton Area – Field Examples of Accessibility and Bedrock Exposure

a) Bedrock exposures along Highway 631; view to the west of tonalite (Station 16MC0032)
b) View to the east at washed out section of old logging road only passable by ATV (Coordinates 657617E, 5412522N)
c) View to the east at steep foresets in sand, likely glacio-fluvial (Station 16MC0305, hammer for scale approximately 80 cm long)
d) View to the south-southwest along a conspicuous north-northeast-trending topographic lineament with parallel coinciding aeromagnetic low lineament interpreted to be a fault zone with alteration that caused magnetite destruction. Note quartz veining visible in lower right foreground parallel to the suspected brittle structure that likely underlies the lineament (Station 15MC0303; compass for scale, 22 cm long, points north)


650000
660000
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5410000
Strickland River
Gourlay Lake
Beaton Lake
Little Lipton Lake
Breckenridge Lake
Nameigos Lake
Nameigos River
Nameigosis Lake
Strickland Lake
Bruce Lake
631
White River
632m
LEGEND
Withdrawal Area
Main Road
Local Road
Waterbody
Outcrop (164)
Overburden (5)
Interpreted Geological Boundary
Geologic Fault
BEDROCK GEOLOGY
13: Granite-granodiorite
10: Foliated tonalite suite
9: Gneissic tonalite suite
5: Metasedimentary rocks
2: Mafic metavolcanic Rocks
LITHOLOGY
Granodiorite (43)
Tonalite (107)
NOTES:
This drawing should be read in conjunction with the Amec Foster Wheeler Environment & Infrastructure Report No. TB154003.
SOURCE:
Base Data- MNR LIO, obtained 2009-2015, CANMAP v2006.4
CLIENT:
nwmo
NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES
REVISION: v2.0
NAD 1983 Zone 16N
Drawn By: LJM 15/06/2017
Checked By: MS 15/06/2017
SCALE: 1:1,298,292
0 1 2 3 4 Kilometers
DETAILED MAPPING
White River Community
Strickland Pluton Area
Main Lithological Units
PROJECT N°: TB154003
DATE: June, 2017
FIGURE: 5.1.3
Amec Foster Wheeler Environment & Infrastructure
3450 Harvester Rd, Suite 100., Burlington, Ontario, L7N 3W5
tel: 905-335-2353 www.amecfw.com

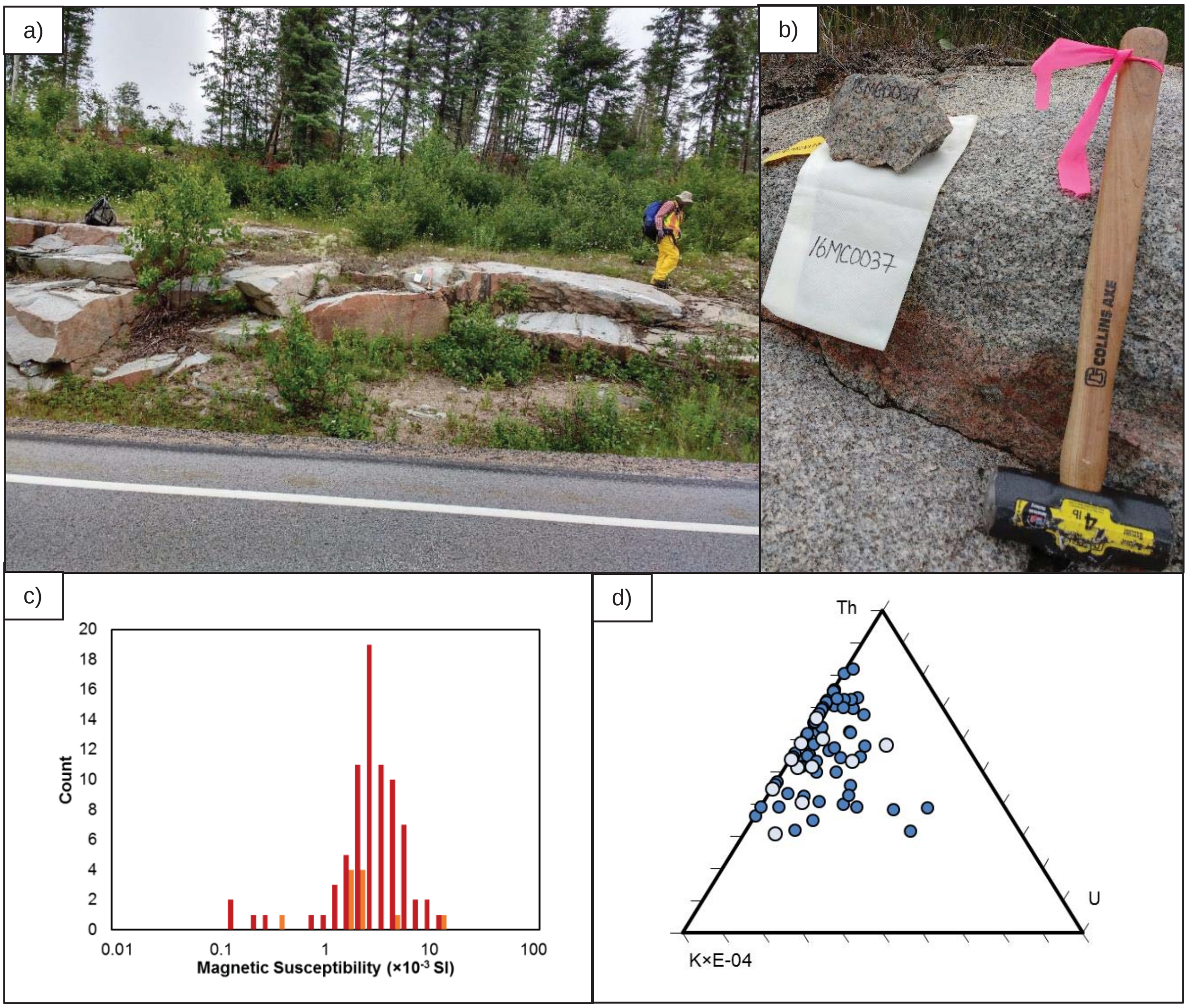


Figure 5.1.4 Strickland Pluton Area – Field Examples of Main Lithology – Tonalite

a) View to the east of coarse-grained tonalite exposed in a road cut along Highway 613 (Station 16MC0037)
b) Coarse-grained tonalite outcrop (Station 16MC0037, hammer for scale, 37 cm long)
c) Logarithmic plot of magnetic susceptibility (Northern Strickland pluton tonalite, N=77 (red); Southern Strickland pluton tonalite, N=11 (orange))
d) Ternary plot of gamma ray spectrometer data (Northern Strickland pluton tonalite, N=72 (blue); Southern Strickland pluton tonalite, N=11 (light blue))

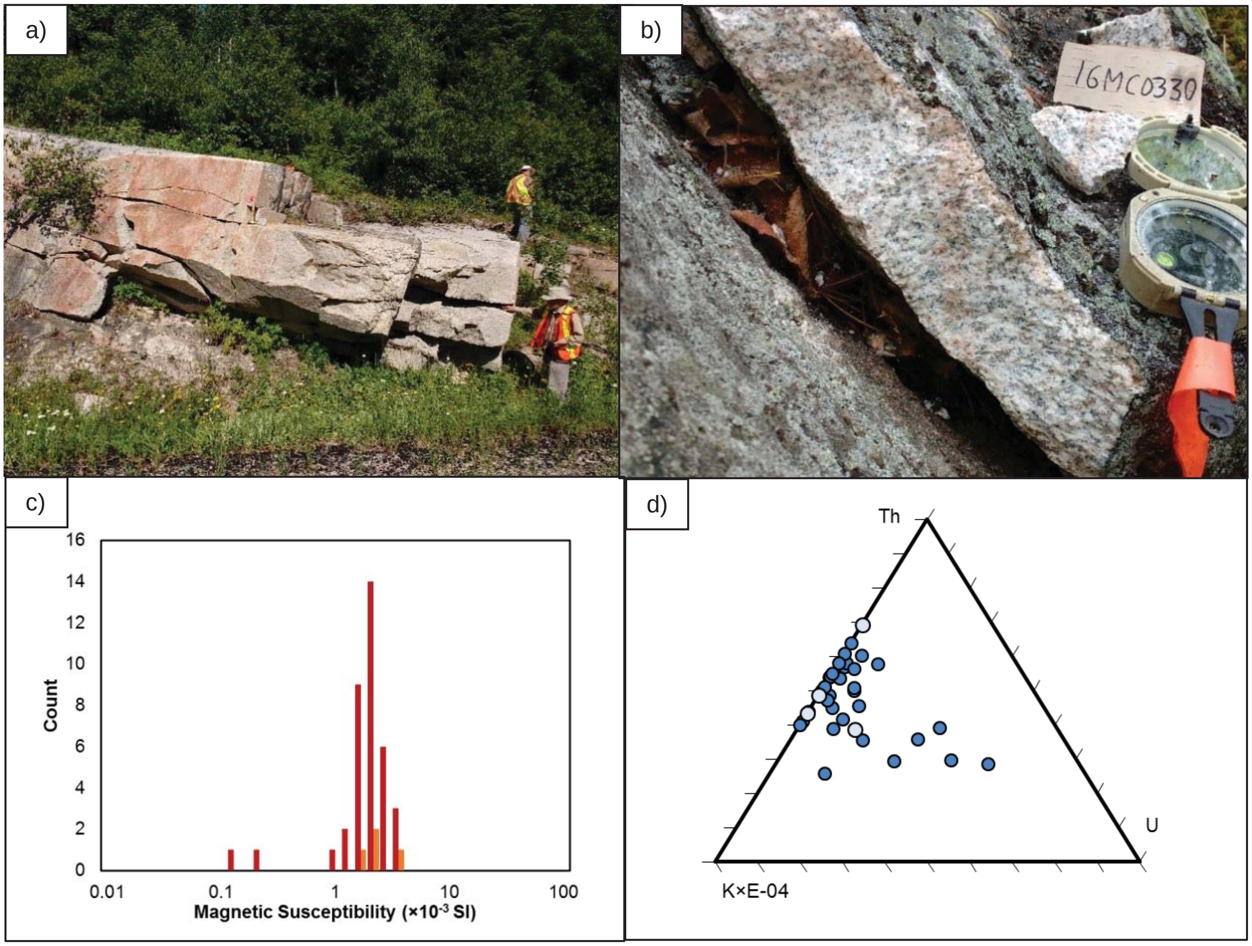
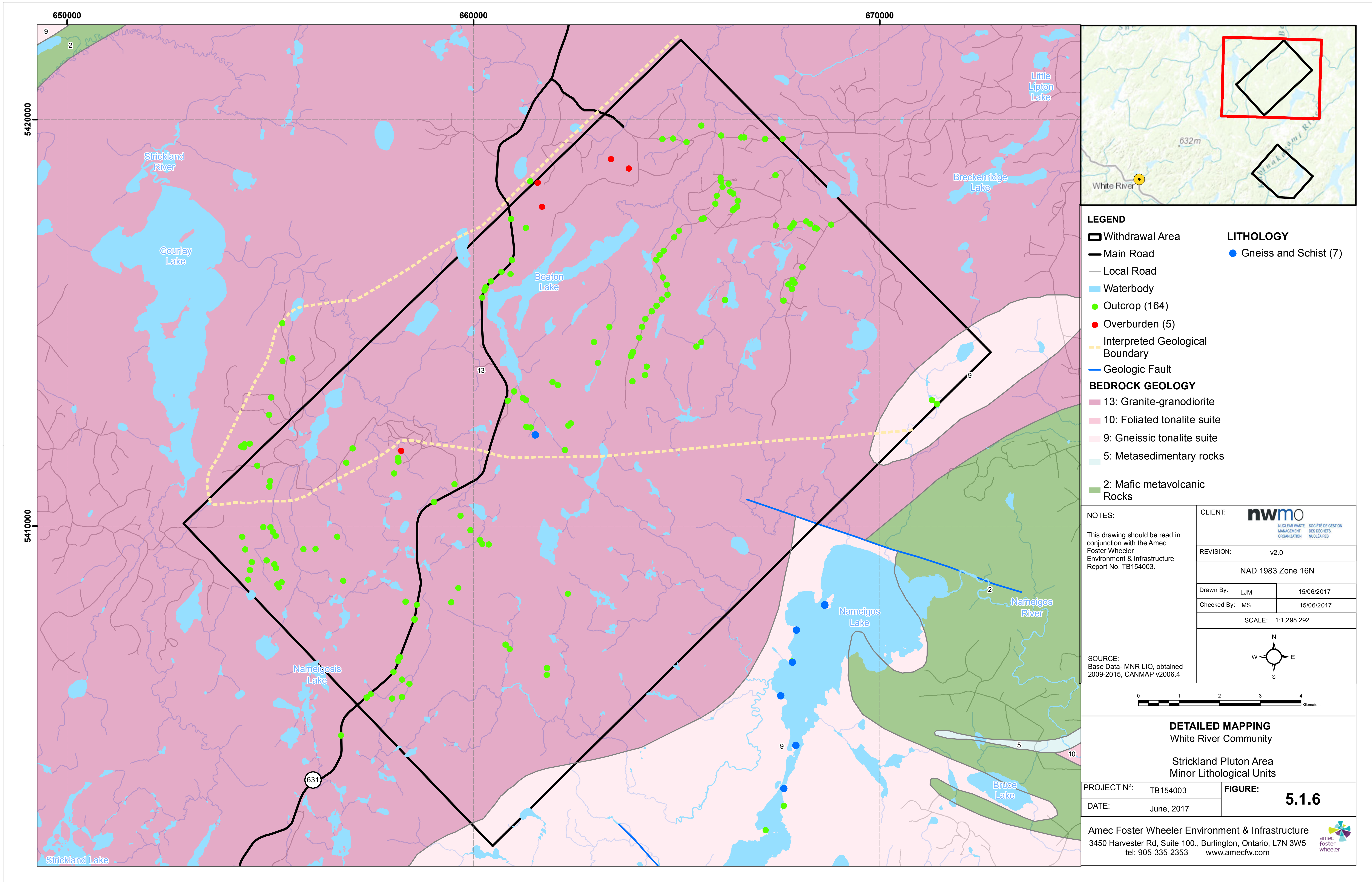


Figure 5.1.5 Strickland Pluton Area – Field Examples of Main Lithology – Granodiorite

a) View to the east of granodiorite exposed in a road cut along Highway 613 (Station 16MC0029)
b) Coarse-grained granodiorite (Station 16MC330, compass for scale 22 cm long)
c) Logarithmic plot of magnetic susceptibility (Southern Strickland pluton granodiorite, N=37 (red); Northern Strickland pluton, N = 4 (orange))
d) Ternary plot of gamma ray spectrometer data (Southern Strickland pluton granodiorite, N=35 (blue); Northern Strickland pluton granodiorite, N=4 (light blue))



650000
660000
670000
5420000
5410000
Strickland River
Gourlay Lake
Beaton Lake
Little Lipton Lake
Breckenridge Lake
Nameigos Lake
Nameigos River
Nameigosis Lake
Bruce Lake
Strickland Lake
631
13
9
2
5
10
White River
632m
LEGEND
Withdrawal Area
Main Road
Local Road
Waterbody
Outcrop (164)
Overburden (5)
Interpreted Geological Boundary
Geologic Fault
BEDROCK GEOLOGY
13: Granite-granodiorite
10: Foliated tonalite suite
9: Gneissic tonalite suite
5: Metasedimentary rocks
2: Mafic metavolcanic Rocks
LITHOLOGY
Gneiss and Schist (7)
NOTES:
This drawing should be read in conjunction with the Amec Foster Wheeler Environment & Infrastructure Report No. TB154003.
SOURCE:
Base Data- MNR LIO, obtained 2009-2015, CANMAP v2006.4
CLIENT:
nwmo
NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES
REVISION: v2.0
NAD 1983 Zone 16N
Drawn By: LJM 15/06/2017
Checked By: MS 15/06/2017
SCALE: 1:1,298,292
N
E
S
W
0 1 2 3 4
Kilometers
DETAILED MAPPING
White River Community
Strickland Pluton Area
Minor Lithological Units
PROJECT Nº: TB154003
DATE: June, 2017
FIGURE: 5.1.6
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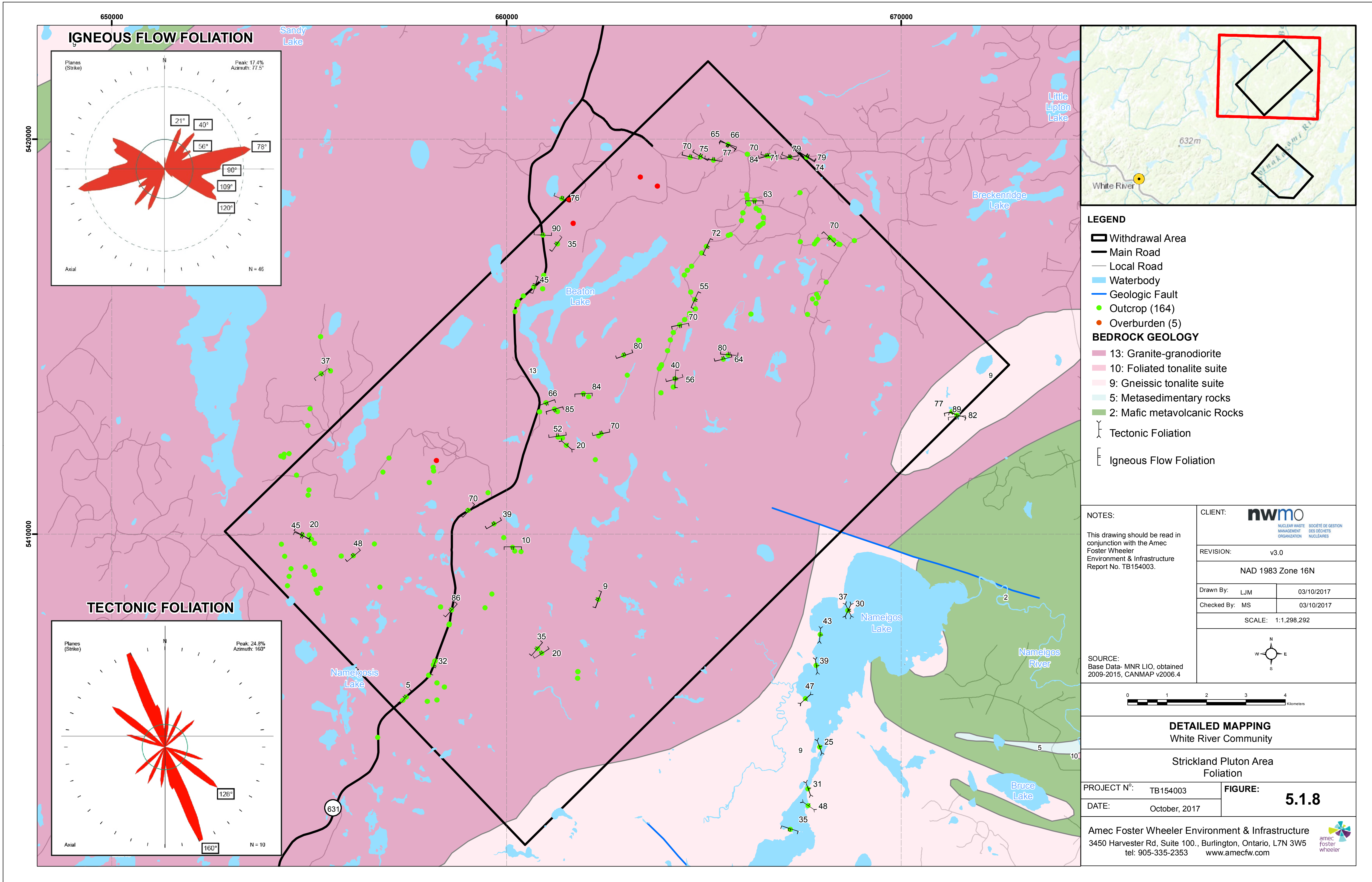
tel: 905-335-2353 www.amecfw.com
amec foster wheeler

Figure 5.1.7 Strickland Pluton Area – Field Examples of Minor Lithological Units

a) View to the northeast at gently east-dipping schistose unit, possibly a metasedimentary xenolith sheet, within gneissic tonalite along Nameigos Lake (Station 16MC0362; compass for scale, 22 cm long, points north)
b) View to the north at strongly foliated mafic schist within gneissic tonalite along Lake Nameigos (Station MC0358; compass for scale, 22 cm long, points north)



IGNEOUS FLOW FOLIATION
Planes (Strike)
Peak: 17.4%
Azimuth: 77.5°
N = 46
Axial
TECTONIC FOLIATION
Planes (Strike)
Peak: 24.8%
Azimuth: 160°
N = 10
650000
660000
670000
5420000
5410000
Sandy Lake
Little Lipton Lake
Breckenridge Lake
Beaton Lake
Nameigosis Lake
Nameigos Lake
Nameigos River
Bruce Lake
White River
632m
Winakaami R.
631
LEGEND
Withdrawal Area
Main Road
Local Road
Waterbody
Geologic Fault
Outcrop (164)
Overburden (5)
BEDROCK GEOLOGY
13: Granite-granodiorite
10: Foliated tonalite suite
9: Gneissic tonalite suite
5: Metasedimentary rocks
2: Mafic metavolcanic Rocks
Tectonic Foliation
Igneous Flow Foliation
NOTES:
This drawing should be read in conjunction with the Amec Foster Wheeler Environment & Infrastructure Report No. TB154003.
SOURCE:
Base Data- MNR LIO, obtained 2009-2015, CANMAP v2006.4
CLIENT:
nwmo
NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES
REVISION: v3.0
NAD 1983 Zone 16N
Drawn By: LJM 03/10/2017
Checked By: MS 03/10/2017
SCALE: 1:1,298,292
Kilometers
DETAILED MAPPING
White River Community
Strickland Pluton Area
Foliation
PROJECT N°: TB154003
DATE: October, 2017
FIGURE: 5.1.8
Amec Foster Wheeler Environment & Infrastructure
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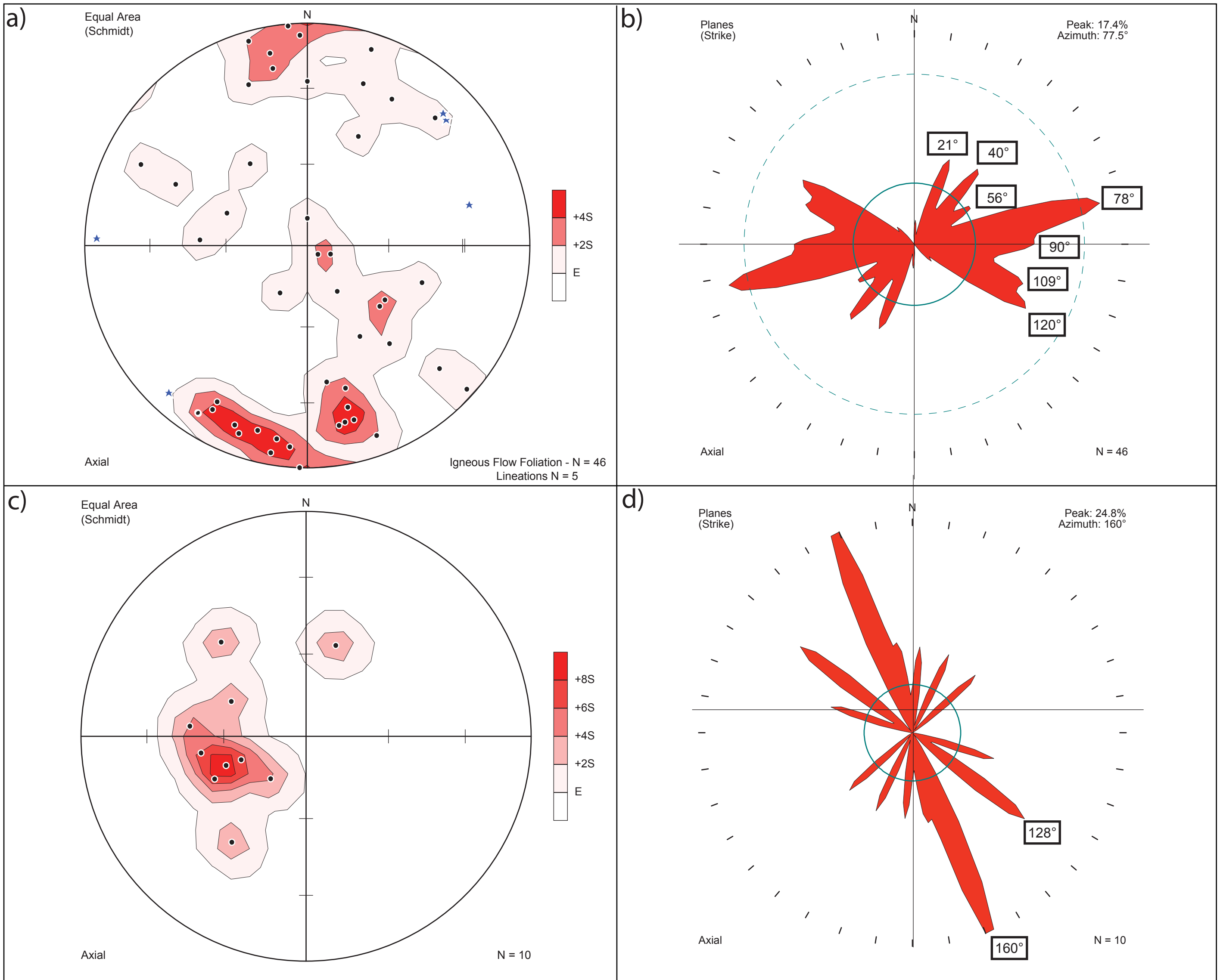

a) All igneous flow foliation data (N = 46) displayed as equal area lower hemisphere stereonet of poles to foliation plane with contours (Gaussian, K = 100) and all lineations (N = 5) on igneous flow foliation (star)
b) All igneous flow foliation data (N = 46) displayed as rose diagram of trends of foliation plane
c) All tectonic foliation data (N = 10) displayed as equal area lower hemisphere stereonet of poles to foliation plane with contours (Gaussian, K = 100)
d) All tectonic foliation data (N = 10) displayed as rose diagram of trends of foliation plane

CLIENT:

Drawn By: JS | Checked By: MS

Revision: V2.0

DETAILED MAPPING

WHITE RIVER COMMUNITY

Strickland Pluton Area - Foliation Orientation Data

PROJECT Nº: TB154003

DATE: October, 2017

FIGURE: 5.1.9

Amec Foster Wheeler Environment & Infrastructure
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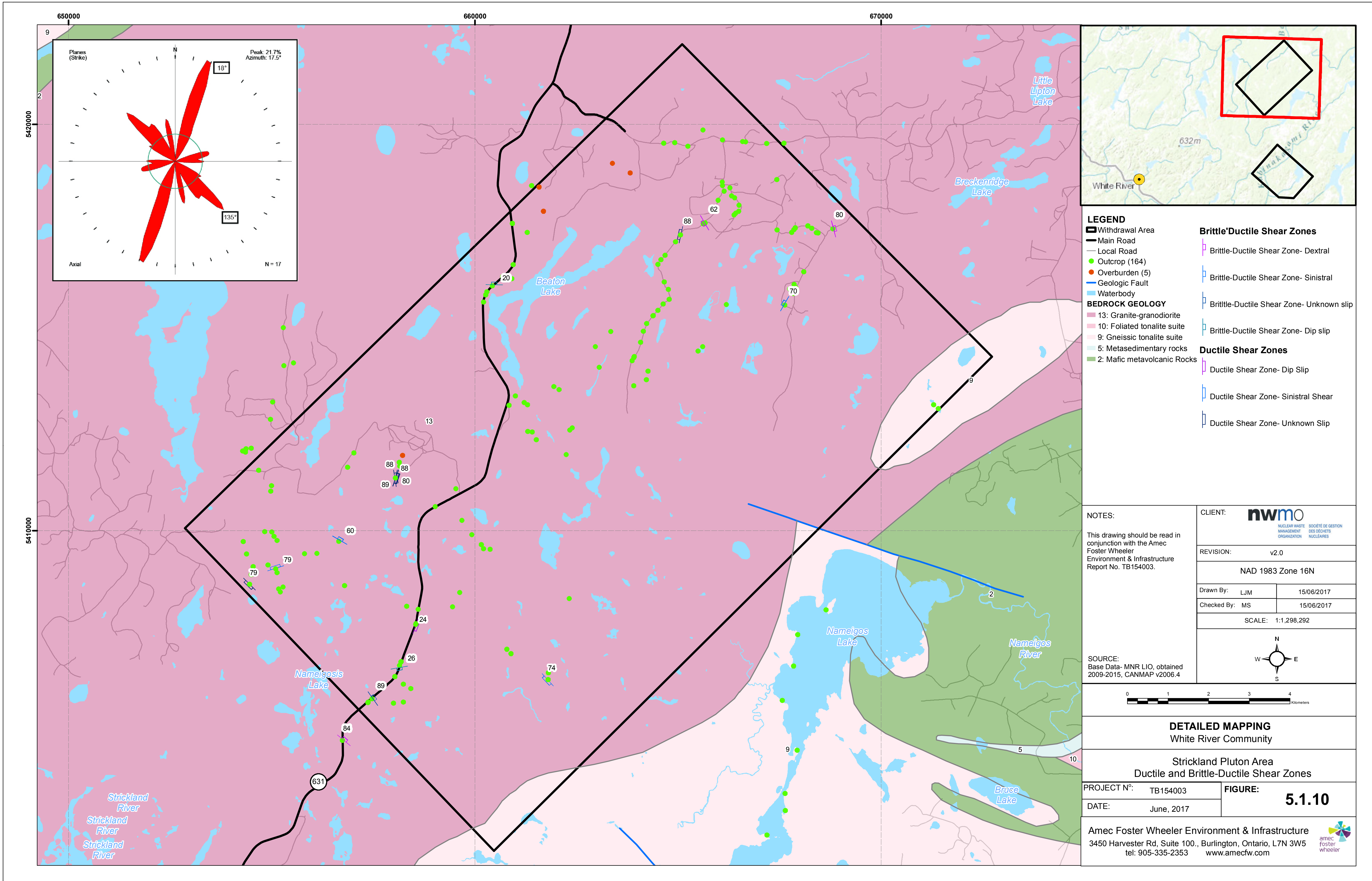

650000
660000
670000
5420000
5410000
Planes (Strike)
Peak: 21.7%
Azimuth: 17.5°
N
18°
135°
Axial
N = 17
Little Lipton Lake
Breckenridge Lake
Beaton Lake
Nameigosis Lake
Nameigos Lake
Nameigos River
Bruce Lake
Strickland River
631
632m
White River
LEGEND
Withdrawal Area
Main Road
Local Road
Outcrop (164)
Overburden (5)
Geologic Fault
Waterbody
BEDROCK GEOLOGY
13: Granite-granodiorite
10: Foliated tonalite suite
9: Gneissic tonalite suite
5: Metasedimentary rocks
2: Mafic metavolcanic Rocks
Brittle'Ductile Shear Zones
Brittle-Ductile Shear Zone- Dextral
Brittle-Ductile Shear Zone- Sinistral
Britlle-Ductile Shear Zone- Unknown slip
Brittle-Ductile Shear Zone- Dip slip
Ductile Shear Zones
Ductile Shear Zone- Dip Slip
Ductile Shear Zone- Sinistral Shear
Ductile Shear Zone- Unknown Slip
NOTES:
This drawing should be read in conjunction with the Amec Foster Wheeler Environment & Infrastructure Report No. TB154003.
SOURCE:
Base Data- MNR LIO, obtained 2009-2015, CANMAP v2006.4
CLIENT:
nwmo
NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES
REVISION: v2.0
NAD 1983 Zone 16N
Drawn By: LJM 15/06/2017
Checked By: MS 15/06/2017
SCALE: 1:1,298,292
N
W
E
S
0 1 2 3 4 Kilometers
DETAILED MAPPING
White River Community
Strickland Pluton Area
Ductile and Brittle-Ductile Shear Zones
PROJECT N°: TB154003
DATE: June, 2017
FIGURE: 5.1.10
Amec Foster Wheeler Environment & Infrastructure
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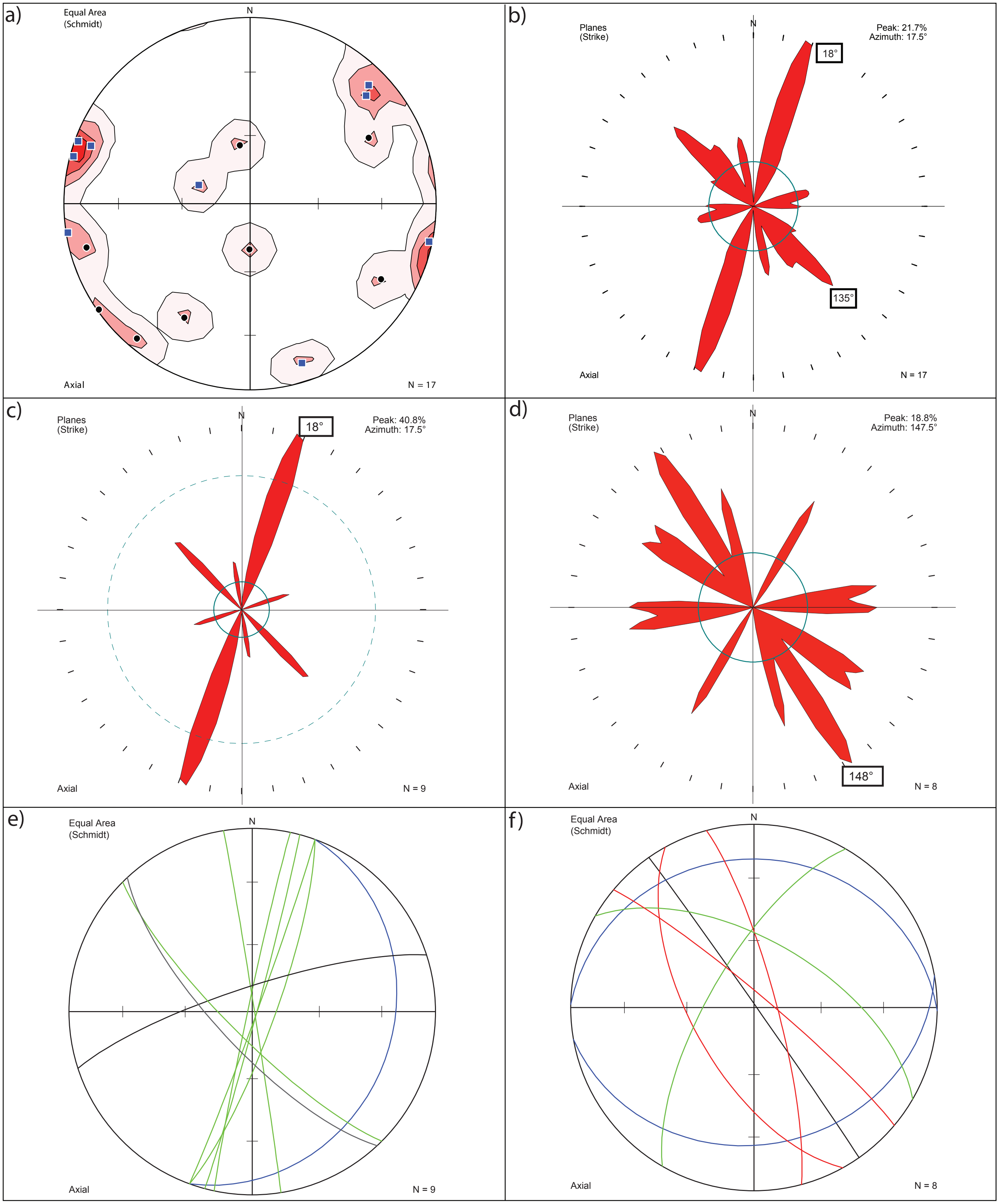
tel: 905-335-2353 www.amecfw.com



a) All ductile and brittle-ductile shear zone data (N = 17) displayed as equal area lower hemisphere stereonet of poles to shear zone plane with contours (Gaussian, K = 100) – classification: ductile (blue, square), brittle-ductile (black, circle)
b) All ductile and brittle-ductile shear zone data (N = 17) displayed as rose diagram of trends of shear zone plane
c) All ductile shear zone data (N = 9) displayed as rose diagram of trends of shear zone plane
d) All brittle-ductile shear zone data (N = 8) displayed as rose diagram of trends of shear zone plane
e) All ductile shear zone data (N = 9) displayed as equal area lower hemisphere stereonet of great circles – classification: sinistral (green; small circle), dip slip (blue), unknown (black)
f) All brittle-ductile shear zone data (N = 8) displayed as equal area lower hemisphere stereonet of great circles – classification: dextral (red), sinistral (green), dip slip (blue), unknown (black)

CLIENT: nwmo NUCLEAR WASTE MANAGEMENT ORGANIZATION SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

Drawn By: JS | Checked By: MS
Revision: V1.0

DETAILED MAPPING
WHITE RIVER COMMUNITY

Strickland Pluton Area -
Ductile and Brittle Ductile Shear Zone Orientation Data

PROJECT N°: TB154003
DATE: June, 2017
FIGURE: 5.1.11

Amec Foster Wheeler Environment & Infrastructure
3450 Harvester Rd, Suite 100., Burlington, Ontario, L7N 3W5
tel: 905-335-2353 www.amecfw.com

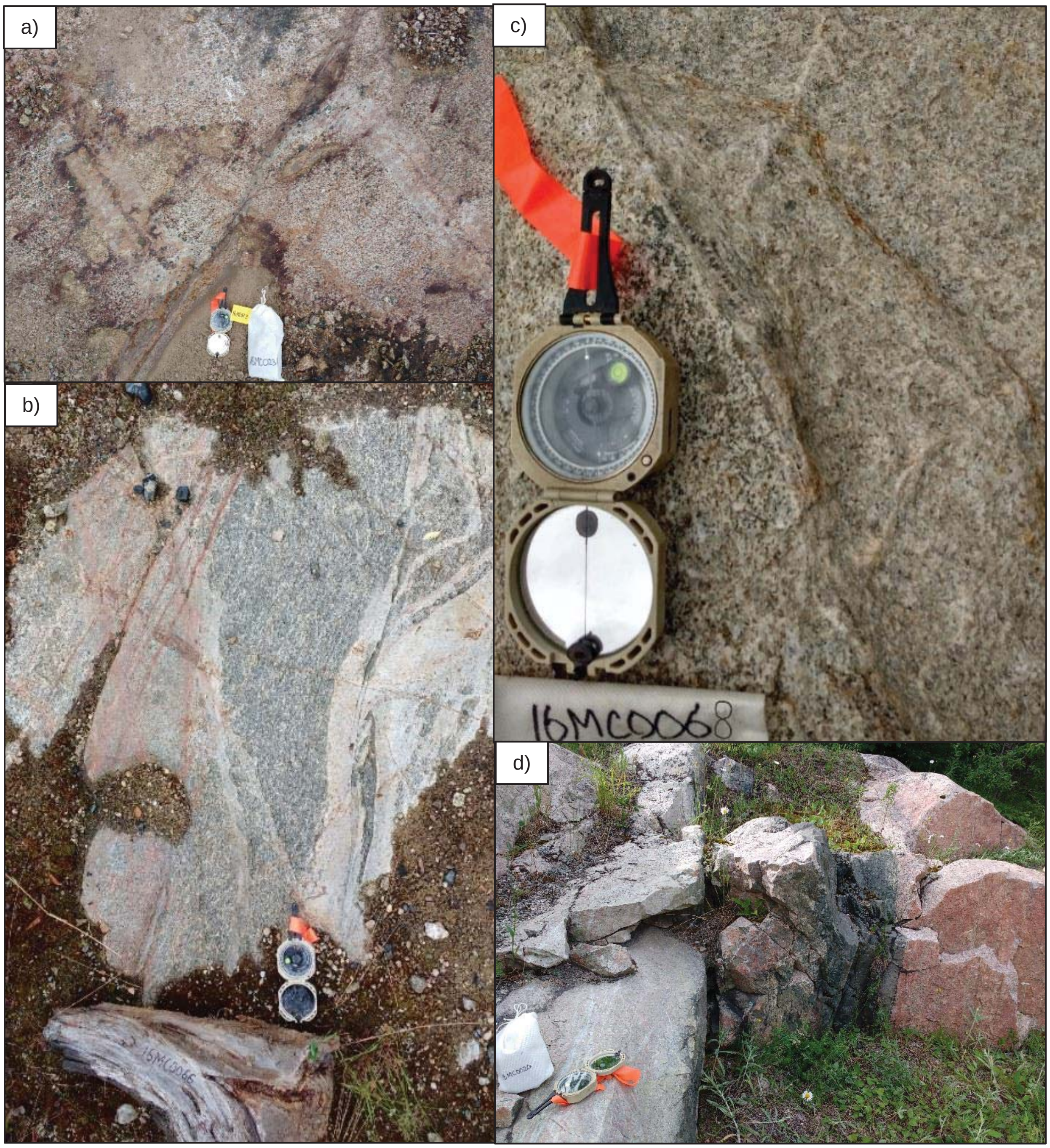
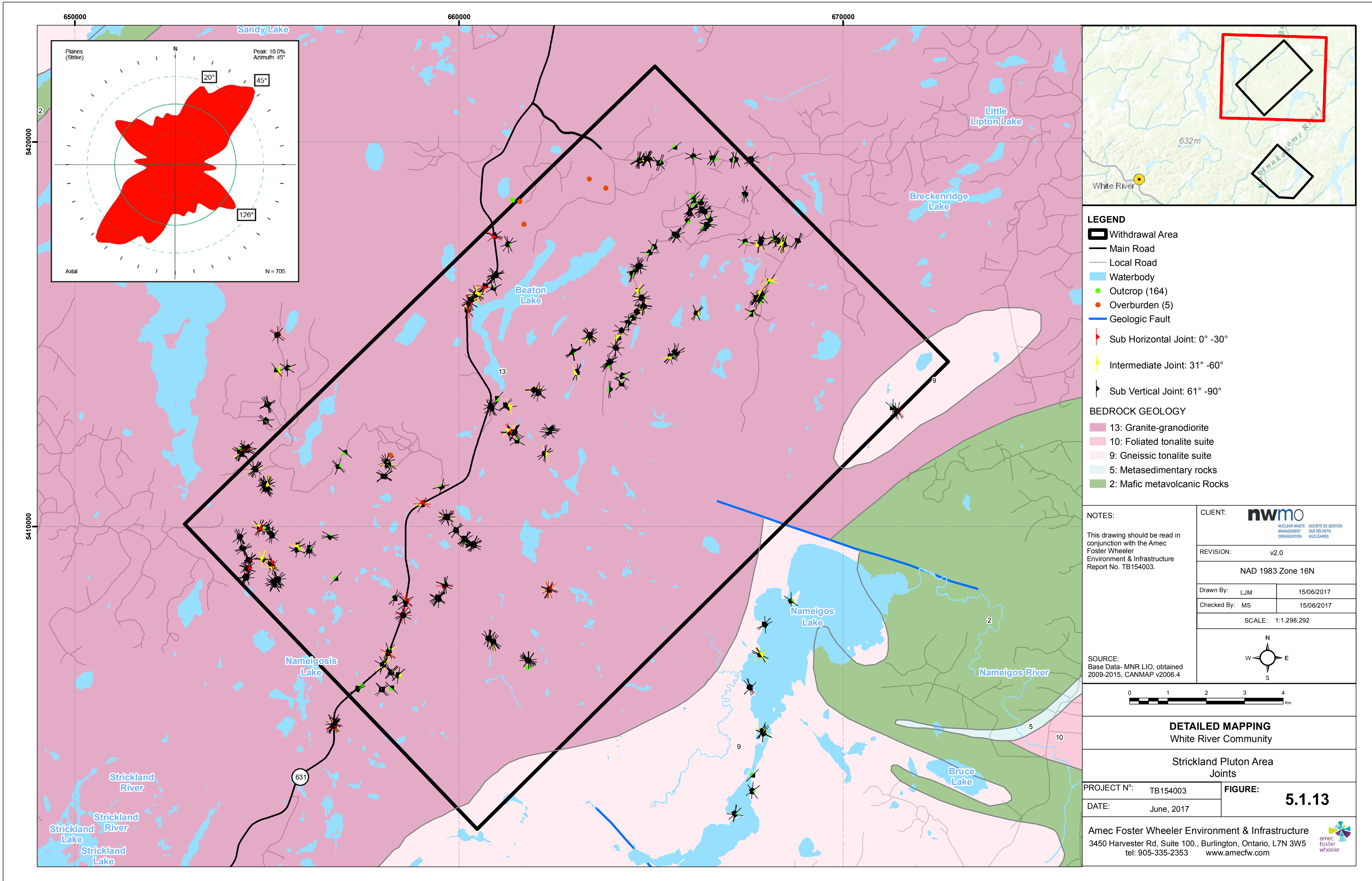
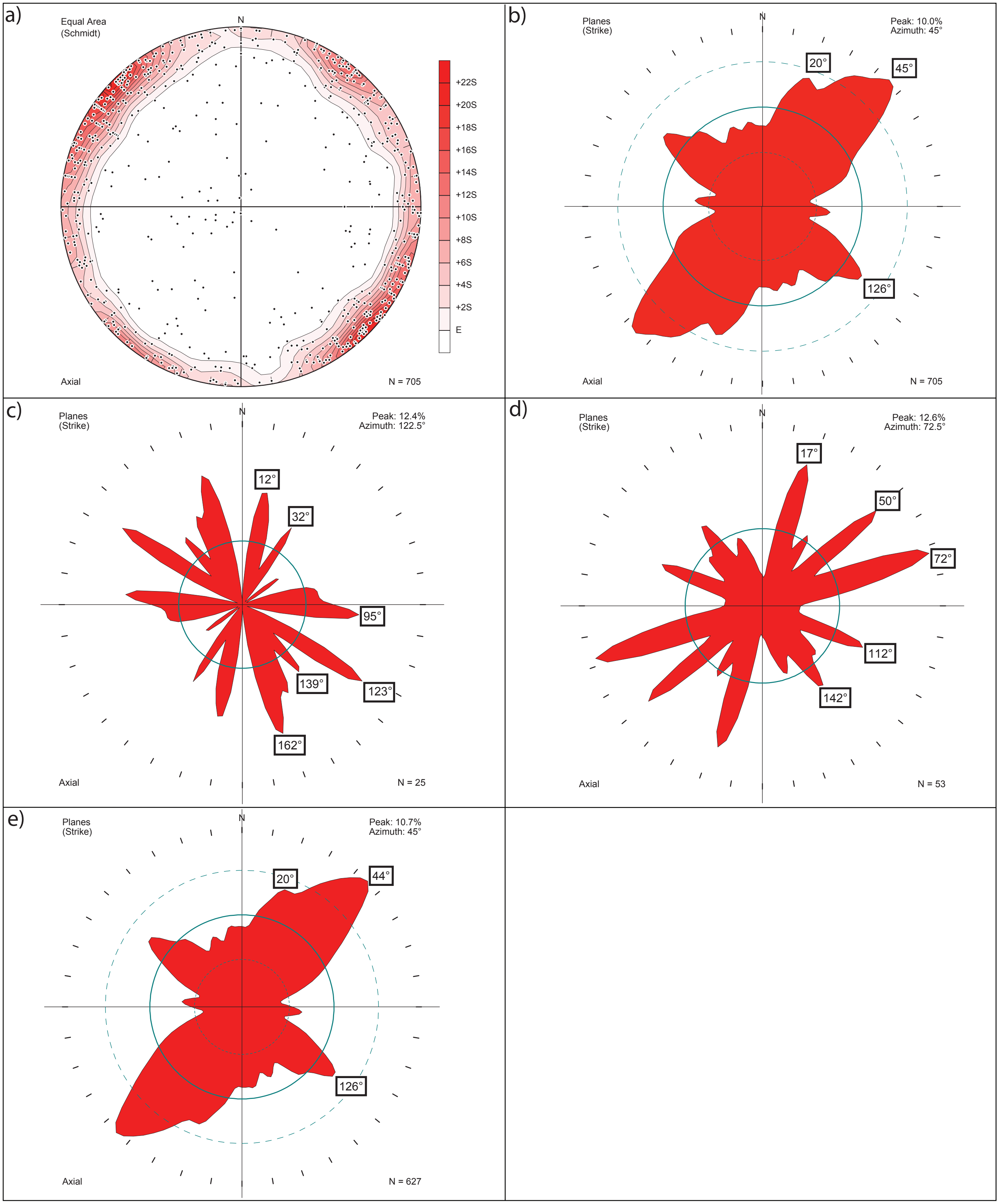


Figure 5.1.12 Strickland Pluton Area – Field Examples of Ductile Structure

a) Drag folded aplite vein showing approximately 70 cm of sinistral offset along a northeast-striking steeply dipping 2 cm thick strongly foliated ductile shear zone (Station 16MC0231; compass for scale, 22 cm long, points north)

b) Small ductile sinistral drag fold on east side of narrow ductile shear plane trending north-northeast (Station 16MC0066; compass for scale, 22 cm long, points north)
c) Shear banding developed in deformed mafic dyke (Station 16MC0020; compass for scale, 22 cm long, points north)
d) Minor north-northwest-striking dextral sense shear plane with 1-2 cm thick zone of foliation sygmoids, and possibly younger en-echelon grey quartz vein slivers look like younger sinistral reactivation (Station 16MC0068; compass for scale, 22 cm long, points north)


650000
660000
670000
5420000
5410000
Sandy Lake
Little Lipton Lake
Breckenridge Lake
Beaton Lake
Nameigosis Lake
Nameigos Lake
Nameigos River
Bruce Lake
Strickland River
Strickland Lake
Strickland Lake
631
13
9
2
5
10
Planes (Strike)
Peak: 10.0%
Azimuth: 45°
N
20°
45°
126°
Axial
N = 705
632m
White River
LEGEND
Withdrawal Area
Main Road
Local Road
Waterbody
Outcrop (164)
Overburden (5)
Geologic Fault
Sub Horizontal Joint: 0° -30°
Intermediate Joint: 31° -60°
Sub Vertical Joint: 61° -90°
BEDROCK GEOLOGY
13: Granite-granodiorite
10: Foliated tonalite suite
9: Gneissic tonalite suite
5: Metasedimentary rocks
2: Mafic metavolcanic Rocks
NOTES:
This drawing should be read in conjunction with the Amec Foster Wheeler Environment & Infrastructure Report No. TB154003.
SOURCE:
Base Data- MNR LIO, obtained 2009-2015, CANMAP v2006.4
CLIENT:
nwmo
NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES
REVISION: v2.0
NAD 1983 Zone 16N
Drawn By: LJM 15/06/2017
Checked By: MS 15/06/2017
SCALE: 1:1,298,292
N
W
E
S
0 1 2 3 4
Km
DETAILED MAPPING
White River Community
Strickland Pluton Area
Joints
PROJECT N°: TB154003
DATE: June, 2017
FIGURE: 5.1.13
Amec Foster Wheeler Environment & Infrastructure
3450 Harvester Rd, Suite 100., Burlington, Ontario, L7N 3W5
tel: 905-335-2353 www.amecfw.com
amec foster wheeler



a) All joint data (N = 705) displayed as equal area lower hemisphere stereonet of poles to joint plane with contours (Gaussian, K = 100)
b) All joint data (N = 705) displayed as rose diagram of trends of joint plane
c) Joint data dipping 0º-30º (N = 25) displayed as rose diagram of trends of joint plane
d) Joint data dipping 31º-60º (N = 53) displayed as rose diagram of trends of joint plane
e) Joint data dipping 61º-90º (N = 627) displayed as rose diagram of trends of joint plane

CLIENT: nwmo NUCLEAR WASTE MANAGEMENT ORGANIZATION / SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

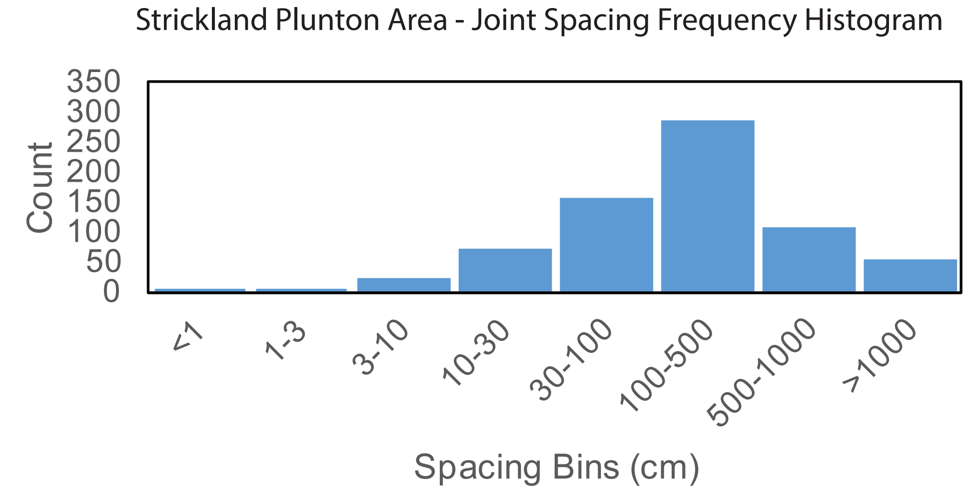
Drawn By: JS
Checked By: MS
Revision: V1.0

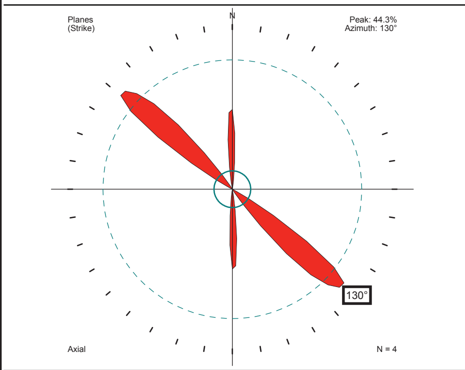
DETAILED MAPPING
WHITE RIVER COMMUNITY

Strickland Pluton Area - Joint Orientation Data

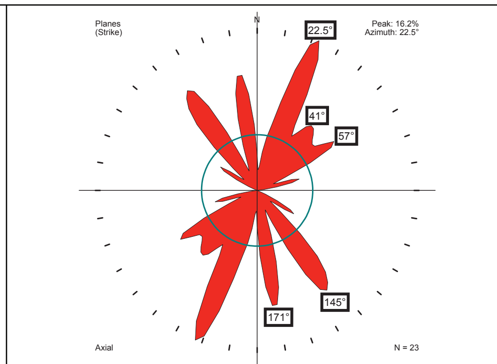
PROJECT Nº: TB154003
DATE: June, 2017
FIGURE: 5.1.14

Amec Foster Wheeler Environment & Infrastructure
3450 Harvester Rd, Suite 100., Burlington, Ontario, L7N 3W5
tel: 905-335-2353 www.amecfw.com

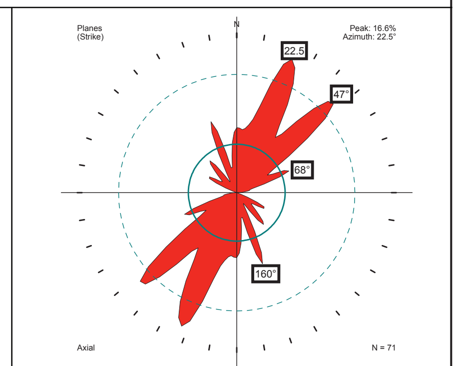




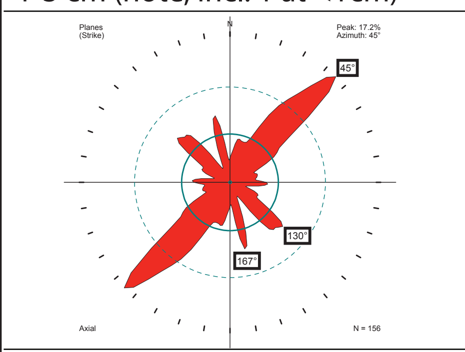
1-3 cm (note, incl. 1 at <1cm)



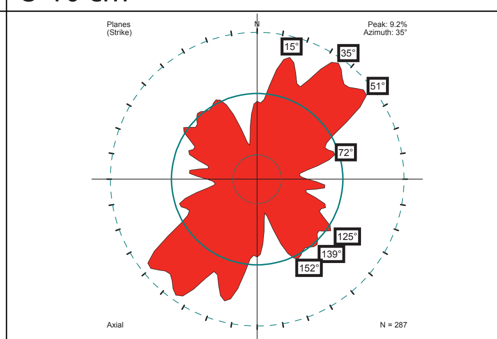
3-10 cm



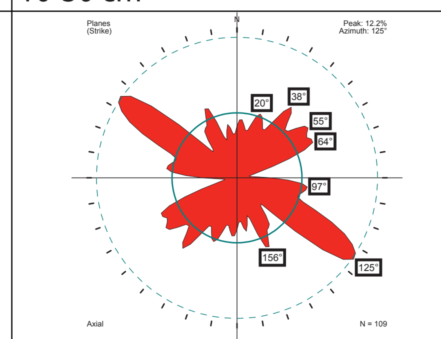
10-30 cm



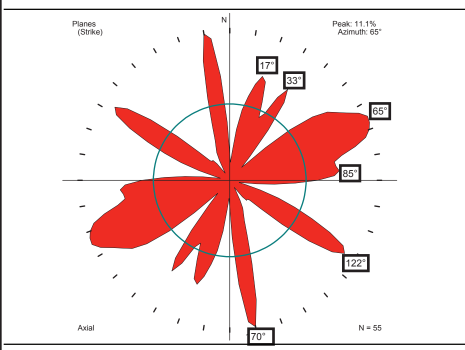
30-100 cm



100-500 cm



500-1000 cm



>1000 cm

Joint Spacing Summary

CLIENT: nwmo	**DETAILED MAPPING** WHITE RIVER COMMUNITY
Drawn By: JS / Checked By: MS / Revision: V1.0	Strickland Pluton Area - Joint Orientation Data
	PROJECT N°: TB154003 / **FIGURE:** 5.1.14f
	DATE: June, 2017
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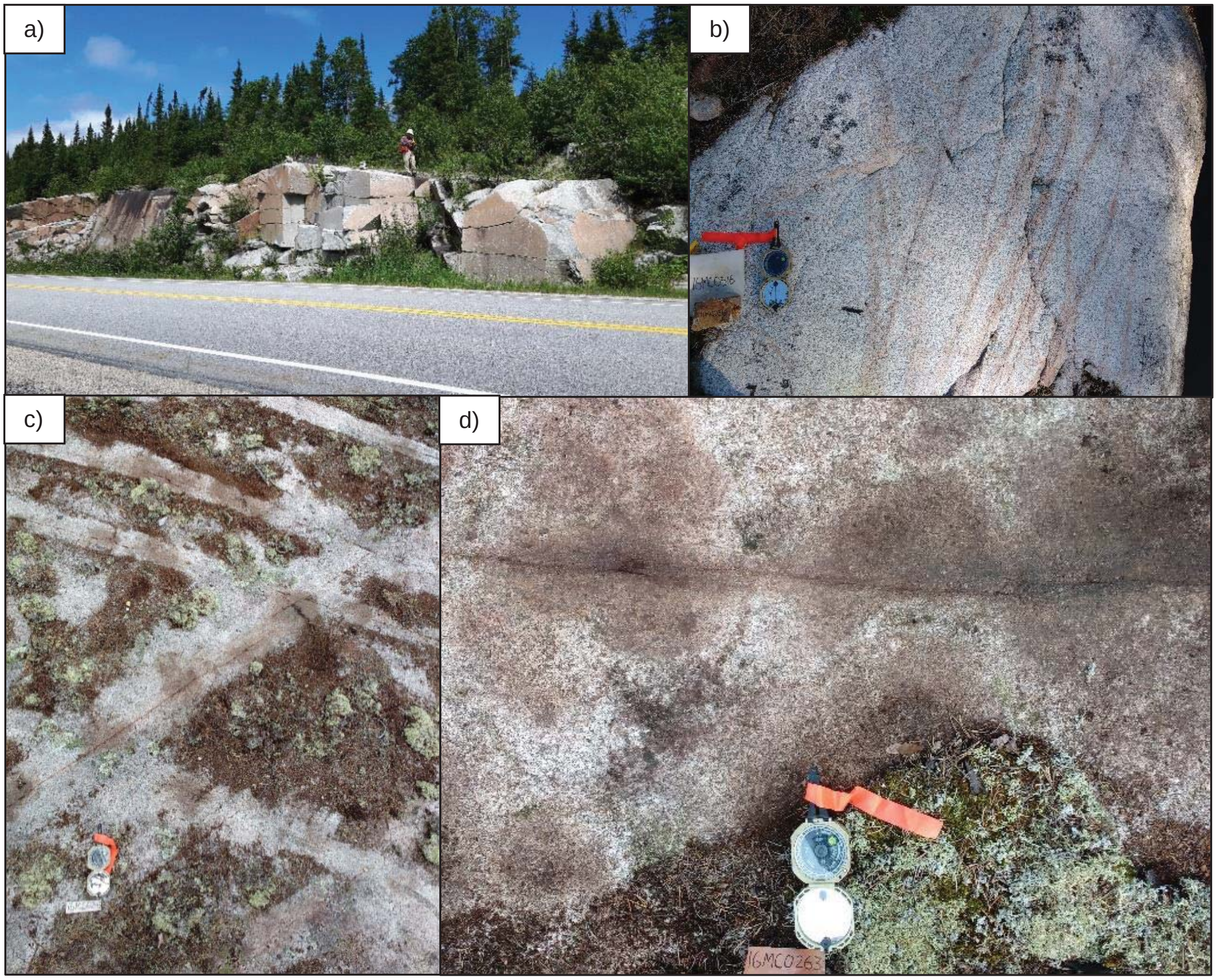
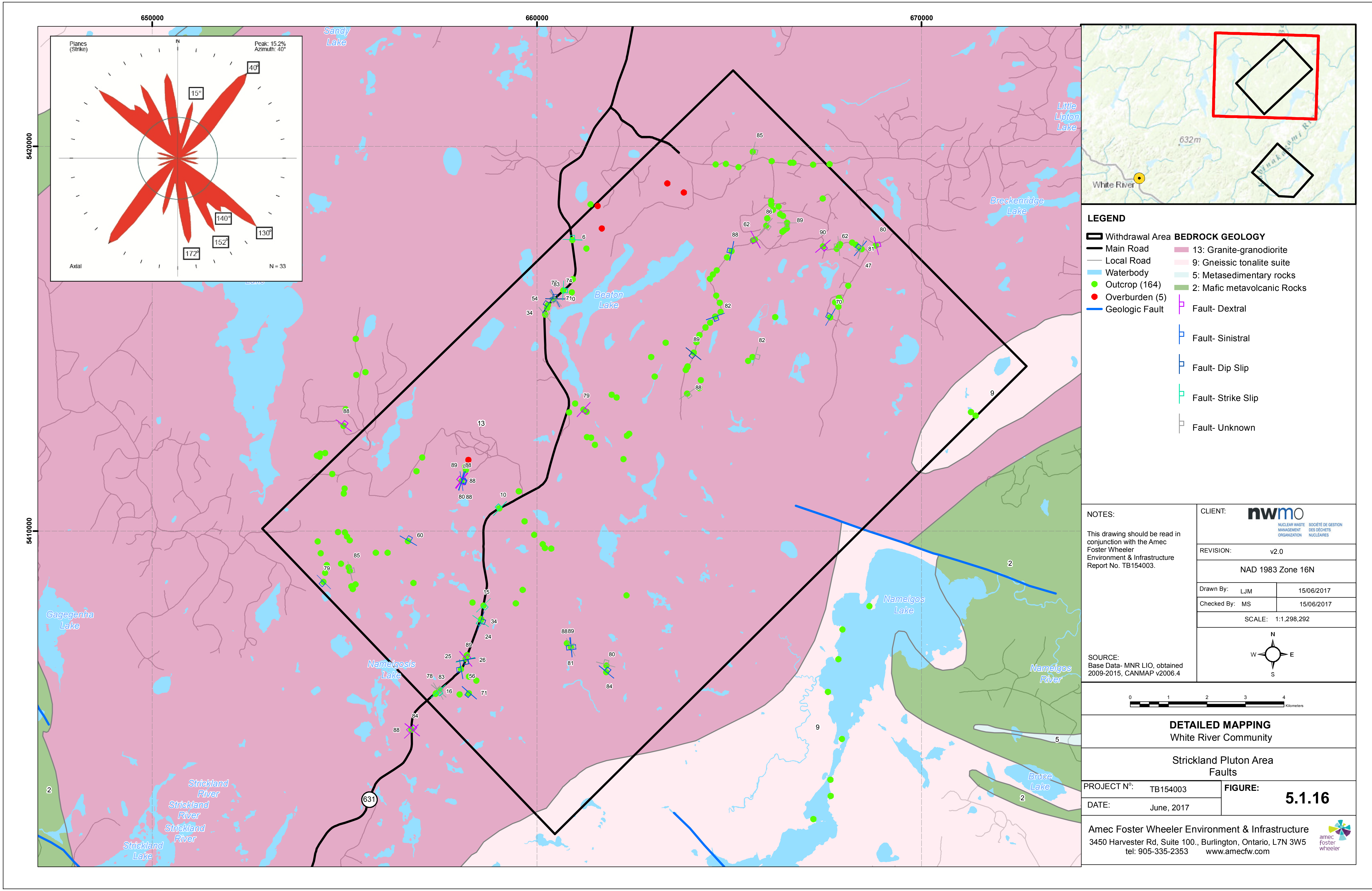


Figure 5.1.15 Strickland Pluton Area – Field Examples of Joints

a) View to the northeast on Highway 631 showing metre-space subhorizontal joints and 2 to 3 metre-spaced subvertical joints (Station 16MC0033)
b) Top to the north view (field-verified Lineament #3) showing hematite alteration along en-echelon shear joints that show an interpreted sinistral sense-of-shear (Station 16MC0316; compass for scale, 22 cm long, points north)
c) Series of conjugate joints exposed under a thin lichen cover (Station 16MC0245; compass for scale, 22 cm long, points north)
d) East-west striking steeply dipping single joint with right-stepping jogs showing an apparent dextral sense of displacement (Station 16MC0263; compass for scale, 22 cm long, points north)



650000
660000
670000
5420000
5410000
Planes (Strike)
Peak: 15.2%
Azimuth: 40°
N
40°
15°
140°
130°
152°
172°
Axial
N = 33
Sandy Lake
Little Lipton Lake
Breckenridge Lake
Beaton Lake
Nameigos Lake
Nameigosis Lake
Gagegenha Lake
Nameigos River
Bruce Lake
Strickland River
Strickland Lake
631
White River
632m
LEGEND
Withdrawal Area
Main Road
Local Road
Waterbody
Outcrop (164)
Overburden (5)
Geologic Fault
BEDROCK GEOLOGY
13: Granite-granodiorite
9: Gneissic tonalite suite
5: Metasedimentary rocks
2: Mafic metavolcanic Rocks
Fault- Dextral
Fault- Sinistral
Fault- Dip Slip
Fault- Strike Slip
Fault- Unknown
NOTES:
This drawing should be read in conjunction with the Amec Foster Wheeler Environment & Infrastructure Report No. TB154003.
SOURCE:
Base Data- MNR LIO, obtained 2009-2015, CANMAP v2006.4
CLIENT:
nwmo
NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES
REVISION: v2.0
NAD 1983 Zone 16N
Drawn By: LJM 15/06/2017
Checked By: MS 15/06/2017
SCALE: 1:1,298,292
N W E S
0 1 2 3 4 Kilometers
DETAILED MAPPING
White River Community
Strickland Pluton Area
Faults
PROJECT N°: TB154003
DATE: June, 2017
FIGURE: 5.1.16
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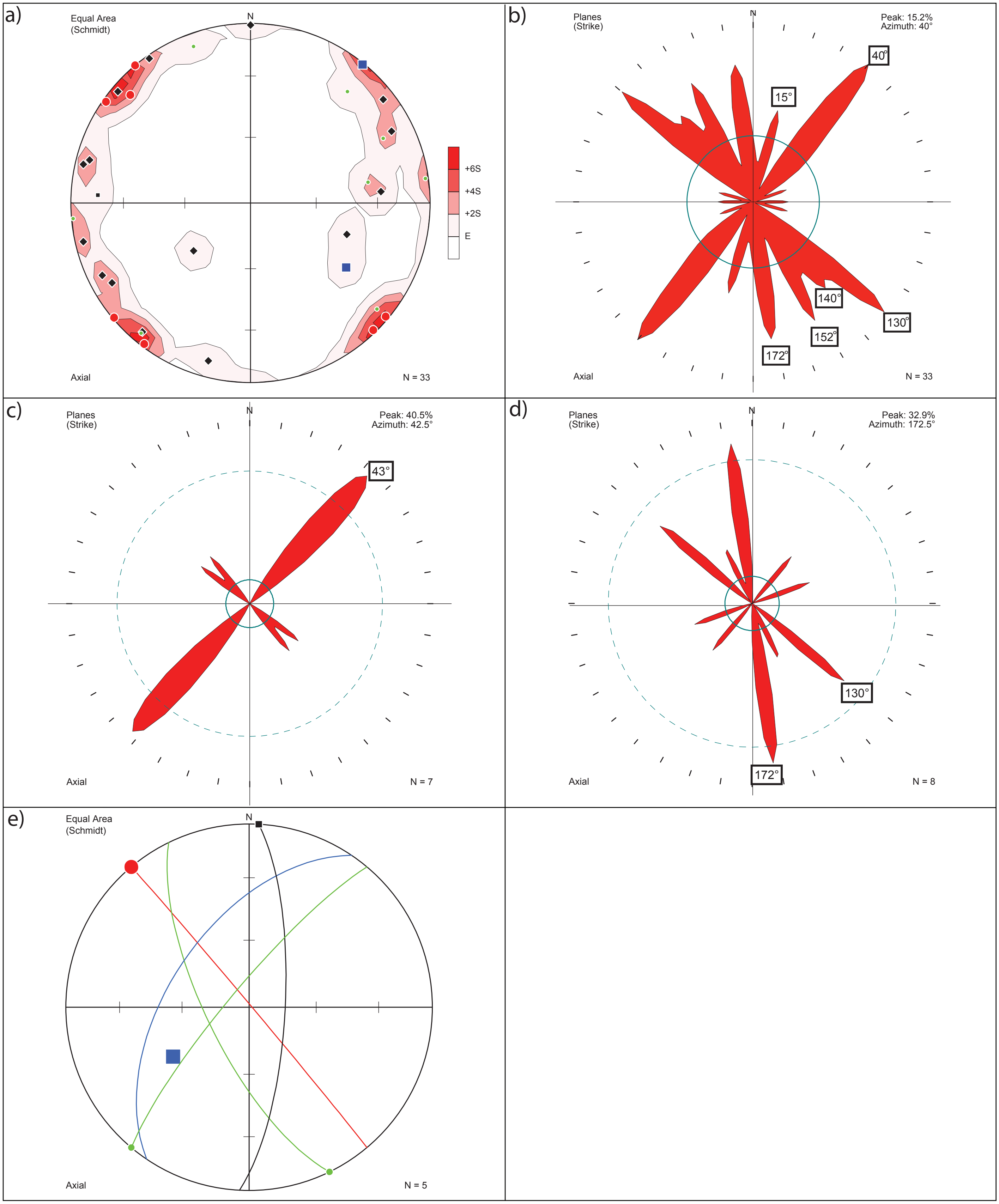
amec foster wheeler



a) All fault data (N = 33) displayed as equal area lower hemisphere stereonet of poles to fault plane with contours (Gaussian, K = 100) – classification: dextral (red; big circle), sinistral (green; small circle), strike slip (black; small square), dip slip (blue; large square), unknown (black; diamond)
b) All fault data (N = 33) displayed as rose diagram of trends of fault plane
c) All dextral faults (N = 7) displayed as rose diagram of trends of fault plane
d) All sinistral faults (N = 8) displayed as rose diagram of trends of fault plane
e) All faults with lineations (N = 5) displayed as equal area lower hemisphere stereonet of great circles – classification: dextral (red, large circle), sinistral (green, small cirlce), dip slip (blue, large square), unknown (black, square)

CLIENT: nwmo NUCLEAR WASTE MANAGEMENT ORGANIZATION / SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

Drawn By: JS | Checked By: MS
Revision: V1.0

DETAILED MAPPING
WHITE RIVER COMMUNITY

Strickland Pluton Area - Fault Orientation Data

PROJECT N°: TB154003
DATE: June, 2017
FIGURE: 5.1.17

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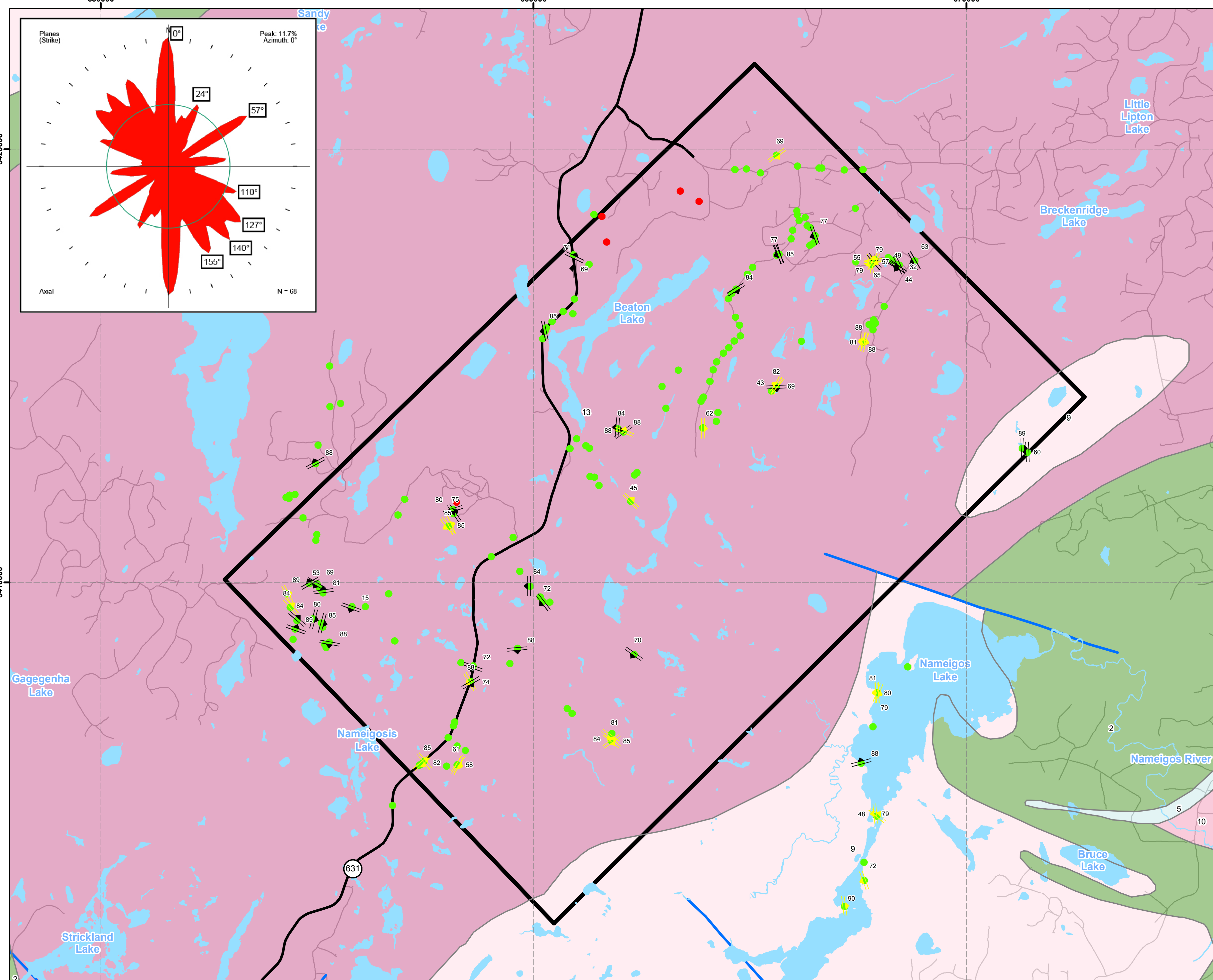
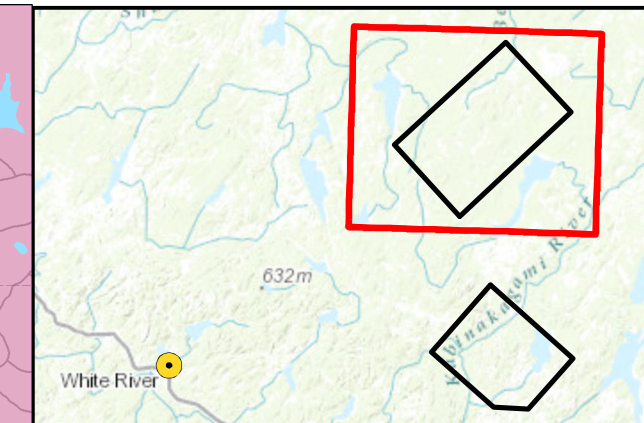
Figure 5.1.18 Strickland Pluton Area – Field Examples of Faults

a) View south at a steeply dipping fault zone showing several subparallel slip surfaces with subhorizontal slickenlines and shear steps showing apparent sinistral displacement (Station 16MC0034; compass for scale, 22 cm long, points north)
b) View to the southwest along a steep fault surface with sinistral strike slip shear steps and slickenlines. This outcrop occurs along the west side of a long narrow topographic low lineament with a subtle coinciding aeromagnetic low anomaly (Station 16MC0086; compass for scale, 22 cm long, points north)
c) View to the north at northeast-striking fault with apparent 30 cm sinistral displacement (Station 16MC0094; compass for scale, 22 cm long, points north)
d) View to the north-northeast along a conspicuous linear creek valley inferred to be part of a fault zone with parallel hematite alteration halos along sinistral shear en-echelon joints, (Station 16MC0316; compass for scale, 22 cm long, points north)





LEGEND

- Withdrawal Area
- Main Road
- Local Road
- Waterbody
- Outcrop (164)
- Overburden (5)
- Geologic Fault
- Extension
- Shear

BEDROCK GEOLOGY

- 13: Granite-granodiorite
- 10: Foliated tonalite suite
- 9: Gneissic tonalite suite
- 5: Metasedimentary rocks
- 2: Mafic metavolcanic Rocks

NOTES:

This drawing should be read in conjunction with the Amec Foster Wheeler Environment & Infrastructure Report No. TB154003.

SOURCE:
Base Data- MNR LIO, obtained 2009-2015, CANMAP v2006.4

CLIENT: nwmo NUCLEAR WASTE MANAGEMENT ORGANIZATION SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

REVISION:	v2.0		
NAD 1983 Zone 16N			
Drawn By:	LJM	15/06/2017	
Checked By:	MS	15/06/2017	
SCALE:	1:1,298,292		

N / W / E / S

0 1 2 3 4 Km

DETAILED MAPPING
White River Community

Strickland Pluton Area
Veins

PROJECT N°:	TB154003	FIGURE:	5.1.19
DATE:	June, 2017		

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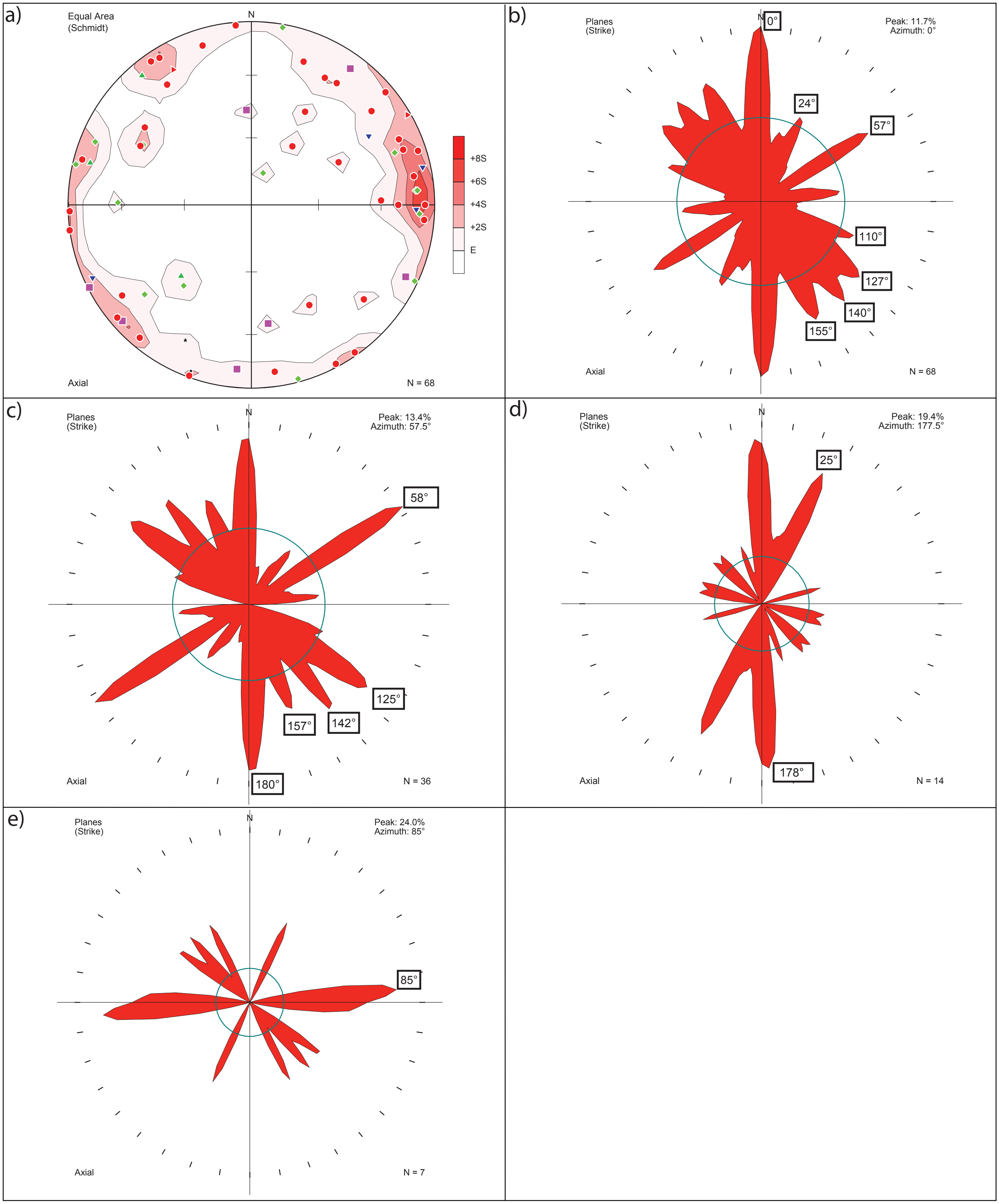
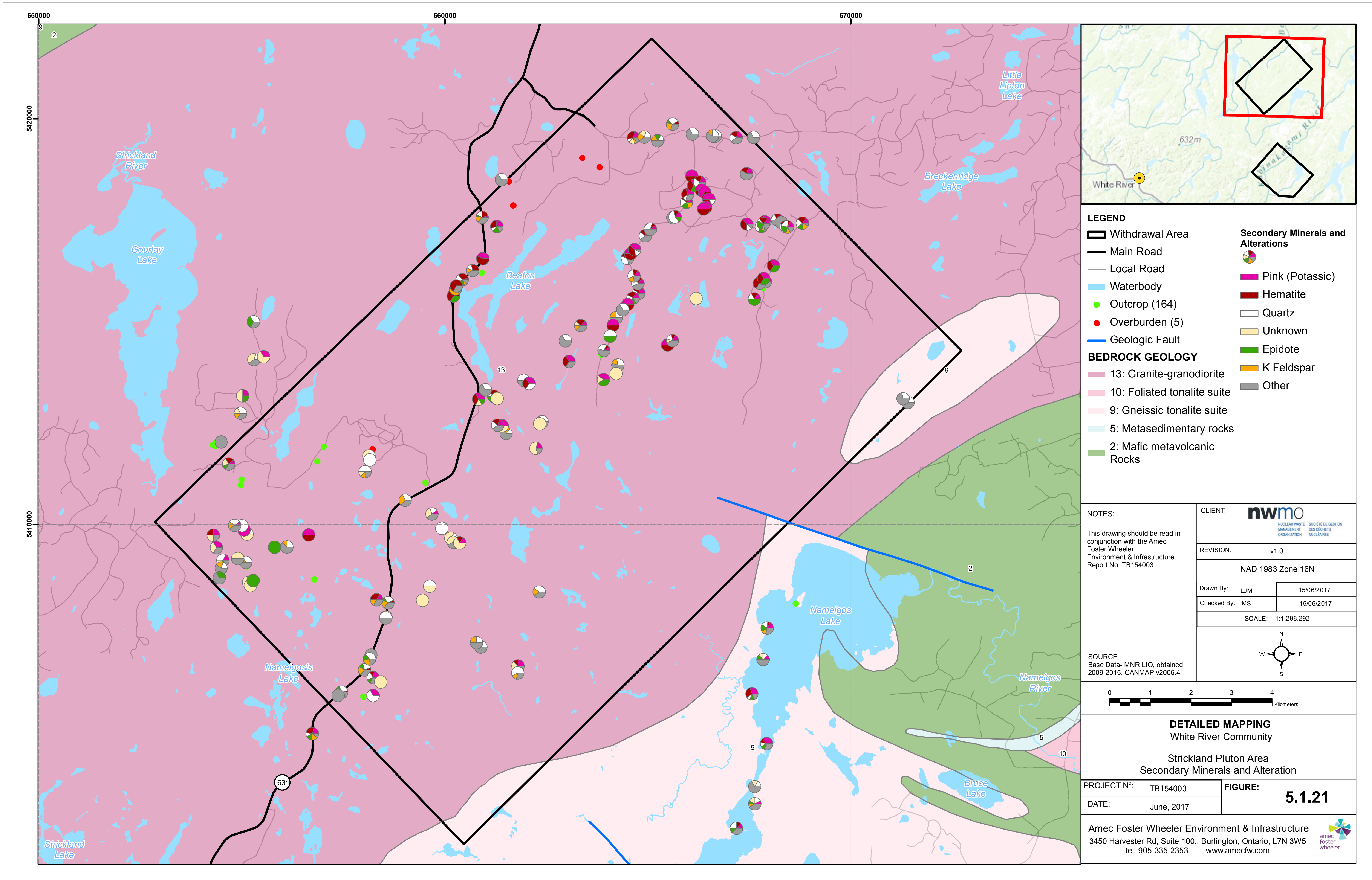


a) All vein data (N = 68) displayed as equal area lower hemisphere stereonet of poles to vein plane with contours (Gaussian, K = 100) – classification: quartz (red; big circle), epidote (green; diamond), pseudo-tachylite / silica (?) (magenta; big square), chlorite (dark green; triangle pointing up), pegmatite (blue; triangle pointing down), epithermal quartz (red; triangle pointing right)
b) All vein data (N = 68) displayed as rose diagram of trends of vein plane
c) All quartz veins (N = 36) displayed as rose diagram of trends of vein plane
d) All epidote veins (N = 14) displayed as rose diagram of trends of vein plane
e) All pseudotachylite / siliceous material (?) veins (N = 7) displayed as rose diagram of trends of vein plane

CLIENT: nwmo NUCLEAR WASTE MANAGEMENT ORGANIZATION / SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES	**DETAILED MAPPING** WHITE RIVER COMMUNITY
Drawn By: JS · Checked By: MS	Strickland Pluton Area - Vein Orientation Data
Revision: V1.0	PROJECT N°: TB154003 · FIGURE: 5.1.20
	DATE: June, 2017
	Amec Foster Wheeler Environment & Infrastructure 3450 Harvester Rd, Suite 100., Burlington, Ontario, L7N 3W5 tel: 905-335-2353 www.amecfw.com


650000
660000
670000
5420000
5410000
Strickland River
Gourlay Lake
Beaton Lake
Little Lipton Lake
Breckenridge Lake
Nameigos Lake
Nameigos River
Nameigosis Lake
Bruce Lake
Strickland Lake
631
13
9
2
5
10
632m
White River
LEGEND
Withdrawal Area
Main Road
Local Road
Waterbody
Outcrop (164)
Overburden (5)
Geologic Fault
BEDROCK GEOLOGY
13: Granite-granodiorite
10: Foliated tonalite suite
9: Gneissic tonalite suite
5: Metasedimentary rocks
2: Mafic metavolcanic Rocks
Secondary Minerals and Alterations
Pink (Potassic)
Hematite
Quartz
Unknown
Epidote
K Feldspar
Other
NOTES:
This drawing should be read in conjunction with the Amec Foster Wheeler Environment & Infrastructure Report No. TB154003.
SOURCE:
Base Data- MNR LIO, obtained 2009-2015, CANMAP v2006.4
CLIENT:
nwmo
NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES
REVISION: v1.0
NAD 1983 Zone 16N
Drawn By: LJM 15/06/2017
Checked By: MS 15/06/2017
SCALE: 1:1,298,292
N
W
E
S
0 1 2 3 4
Kilometers
DETAILED MAPPING
White River Community
Strickland Pluton Area
Secondary Minerals and Alteration
PROJECT N°: TB154003
DATE: June, 2017
FIGURE: 5.1.21
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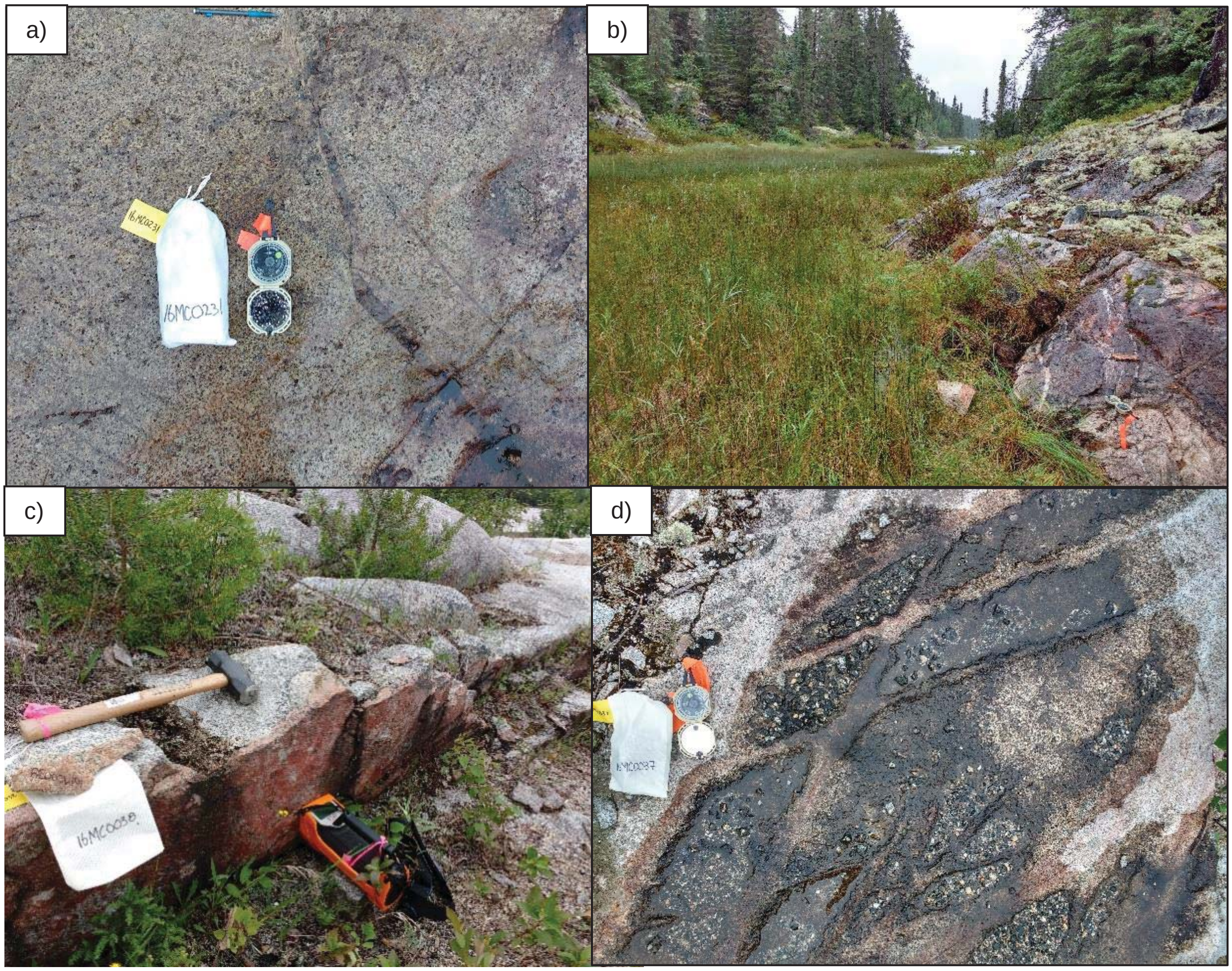
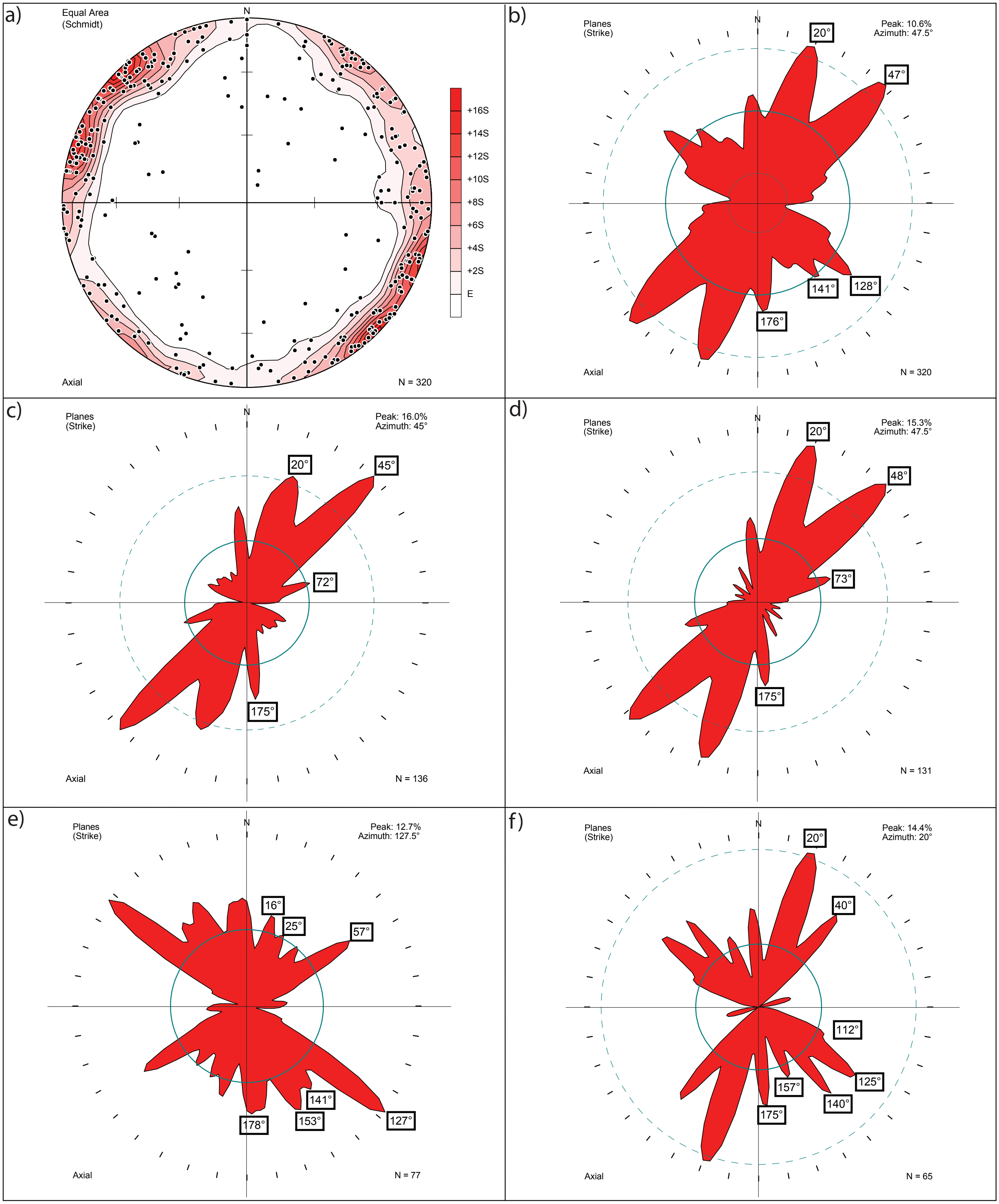


Figure 5.1.22 Strickland Pluton Area – Field Examples of Secondary Minerals and Alteration

a) Grey quartz vein with sharp contacts showing an apparent sinistral sense of dilation (Station 16MC231; compass for scale, 22 cm long, points north)
b) View to the south-southwest along a conspicuous linear creek valley, which is also likely a fault zone with parallel quartz veins in foreground at right (Station 16MC0303; compass for scale, 22 cm long, points north)
c) A five to ten centimetre thick pink alteration halo shows 2.1 percent potassium, whereas adjacent unaltered tonalite has 0.9 percent potassium (Station 16MC0038; hammer for scale, 37 cm long).
d) Pink stained conjugate joints showing evidence of alteration that has locally strengthened the rocks, making them stand out in relief on glaciated surfaces (Station 16MC0037; compass for scale, 22 cm long, points north)



a) All fracture data with secondary mineral infilling and alteration (N = 320) displayed as equal area lower hemisphere stereonet of poles to fracture plane with contours (Gaussian, K = 100)
b) All fracture data with secondary mineral infilling and alteration (N = 320) displayed as rose diagram of trends of fracture plane
c) All fracture data with pink (potassic) alteration (N = 136) displayed as rose diagram of trends of fracture plane
d) All fracture data with hematite alteration (N = 131) displayed as rose diagram of trends of fracture plane
e) All fracture data with quartz infill (N = 77) displayed as rose diagram of trends of fracture plane
f) All fracture data with chlorite infill (N = 65) displayed as rose diagram of trends of fracture plane

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Drawn By: JS | Checked By: MS
Revision: V1.0

DETAILED MAPPING
WHITE RIVER COMMUNITY

Strickland Pluton Area - Secondary Mineral Infilling and Alteration Orientation Data

PROJECT N°: TB154003
DATE: June, 2017
FIGURE: 5.1.23

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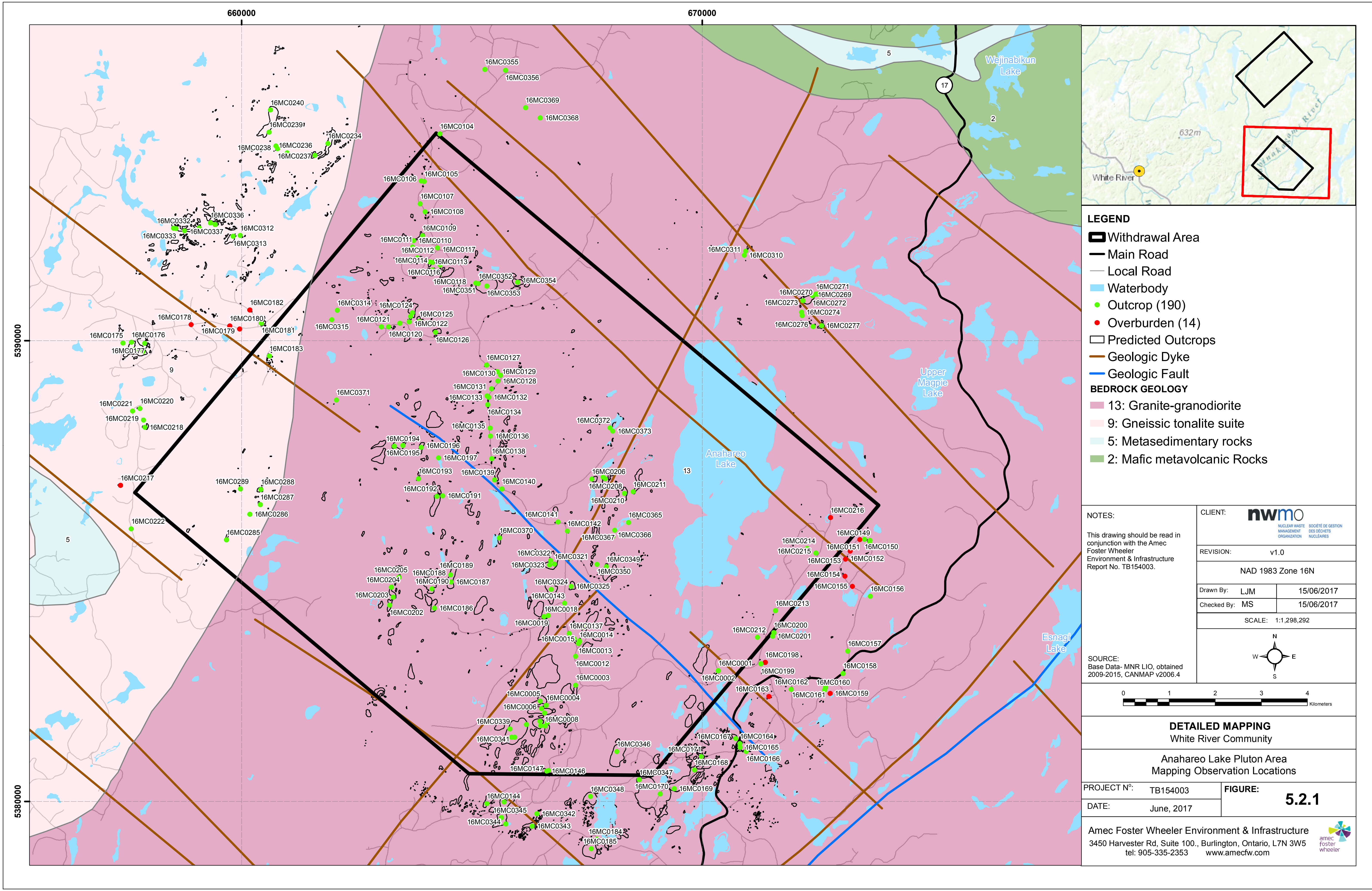

660000
670000
5390000
5380000
Wejinabikun Lake
Anahareo Lake
Upper Magpie Lake
Esnagi Lake
17
13
9
5
2
White River
632m
LEGEND
Withdrawal Area
Main Road
Local Road
Waterbody
Outcrop (190)
Overburden (14)
Predicted Outcrops
Geologic Dyke
Geologic Fault
BEDROCK GEOLOGY
13: Granite-granodiorite
9: Gneissic tonalite suite
5: Metasedimentary rocks
2: Mafic metavolcanic Rocks
NOTES:
This drawing should be read in conjunction with the Amec Foster Wheeler Environment & Infrastructure Report No. TB154003.
SOURCE:
Base Data- MNR LIO, obtained 2009-2015, CANMAP v2006.4
CLIENT:
nwmo
NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES
REVISION: v1.0
NAD 1983 Zone 16N
Drawn By: LJM 15/06/2017
Checked By: MS 15/06/2017
SCALE: 1:1,298,292
N
E
S
W
0 1 2 3 4 Kilometers
DETAILED MAPPING
White River Community
Anahareo Lake Pluton Area
Mapping Observation Locations
PROJECT N°: TB154003
DATE: June, 2017
FIGURE: 5.2.1
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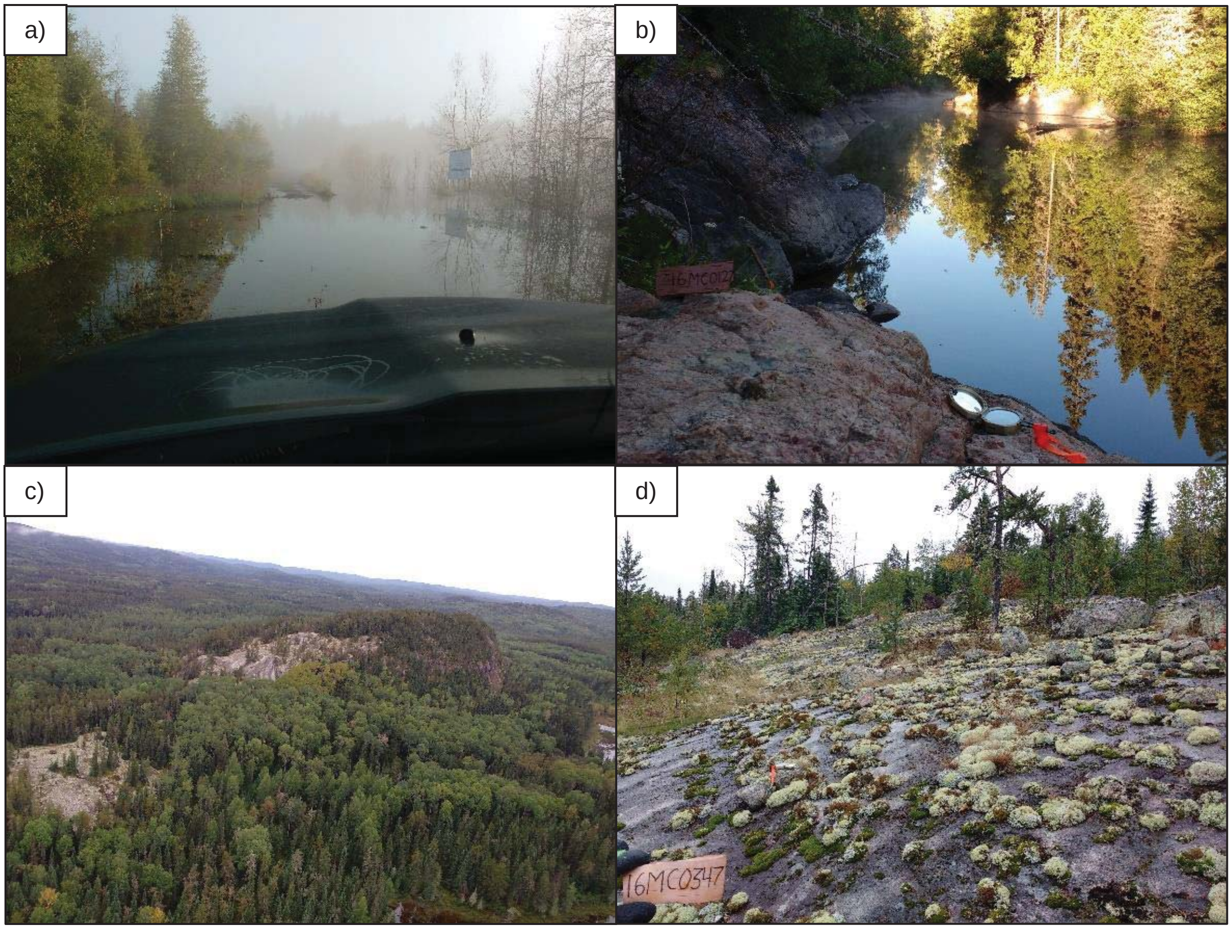
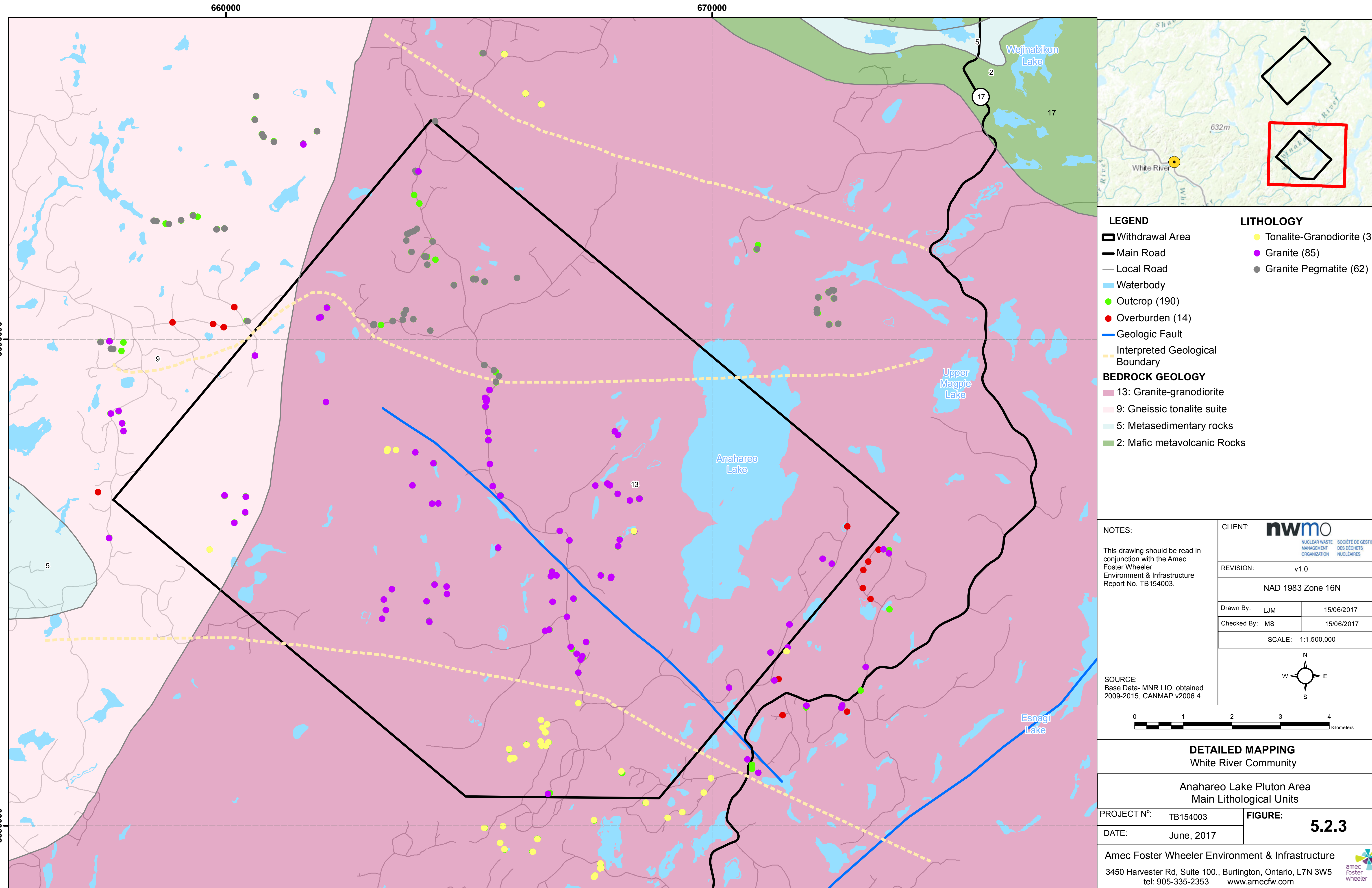


Figure 5.2.2 Anahareo Lake Pluton Area – Field Examples of Accessibility and Bedrock Exposure

a) View to the northwest at a part of the main access road to the Anahareo Lake pluton area that has been partially flooded by a beaver pond; by end of the summer the road was dry (Coordinates 670764E, 5382700N)
b) View to the southwest along a small creek valley that likely parallels a fault structure (Station 16MC0127; compass for scale, 22 cm long, points north)
c) Aerial view to the west-southwest at a prominent hill underlain by pegmatite in the northern part of the Anahareo Lake pluton area (Stations 16MC0351, 16MC0352 and 16MC0353)
d) View to the east at a smooth tonalite outcrop with few joints (Station 16MC0347; compass for scale, 22 cm long, points north on boulder at left foreground of photo)



LEGEND

- Withdrawal Area
- Main Road
- Local Road
- Waterbody
- Outcrop (190)
- Overburden (14)
- Geologic Fault
- Interpreted Geological Boundary

BEDROCK GEOLOGY

- 13: Granite-granodiorite
- 9: Gneissic tonalite suite
- 5: Metasedimentary rocks
- 2: Mafic metavolcanic Rocks

LITHOLOGY

- Tonalite-Granodiorite (36)
- Granite (85)
- Granite Pegmatite (62)

NOTES:

This drawing should be read in conjunction with the Amec Foster Wheeler Environment & Infrastructure Report No. TB154003.

SOURCE:
Base Data- MNR LIO, obtained 2009-2015, CANMAP v2006.4

CLIENT: nwmo NUCLEAR WASTE MANAGEMENT ORGANIZATION SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

REVISION: v1.0

NAD 1983 Zone 16N

Drawn By:	LJM	15/06/2017
Checked By:	MS	15/06/2017

SCALE: 1:1,500,000

N W E S

0 1 2 3 4 Kilometers

DETAILED MAPPING
White River Community

Anahareo Lake Pluton Area
Main Lithological Units

PROJECT N°: TB154003

DATE: June, 2017

FIGURE: **5.2.3**

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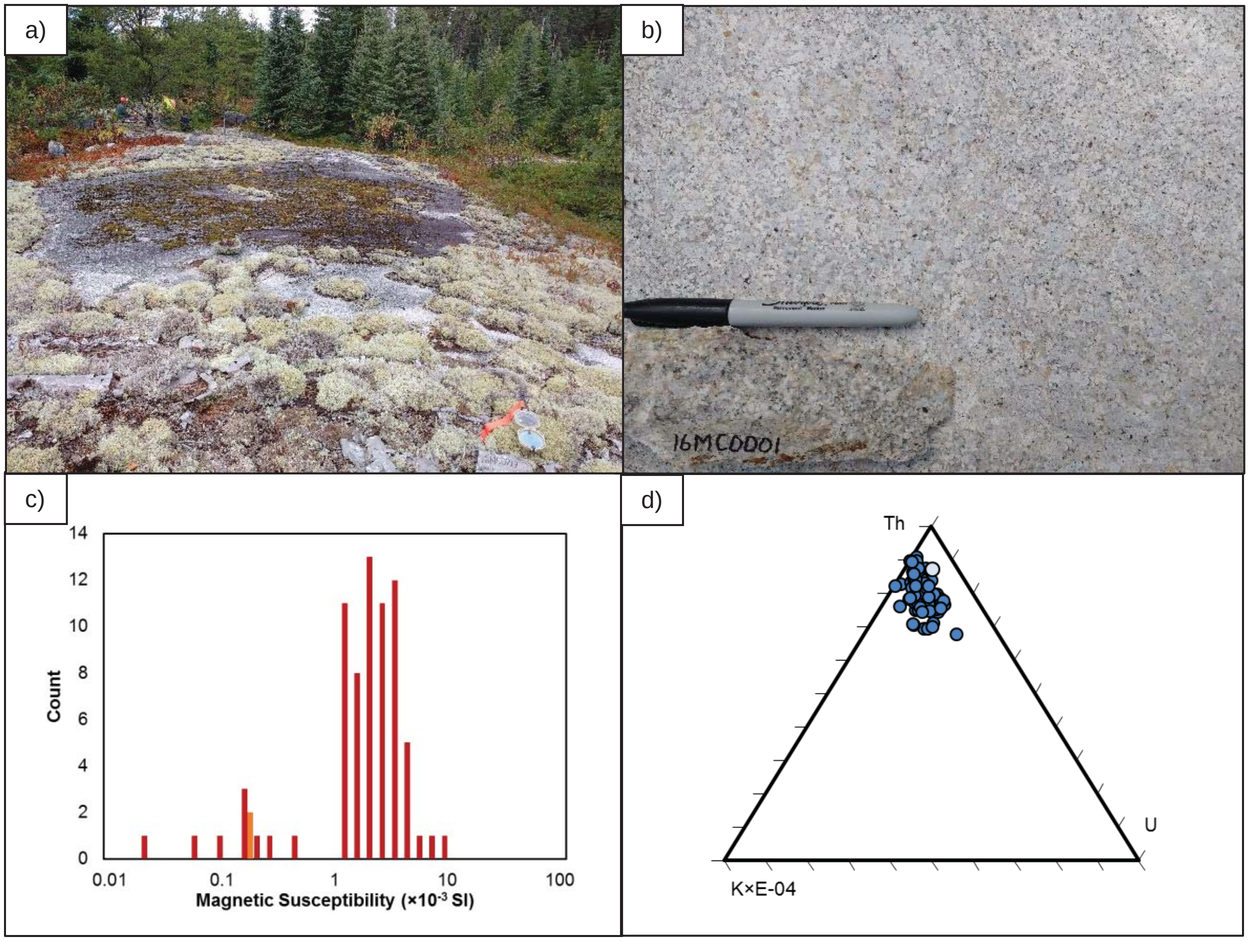


Figure 5.2.4 Anahareo Lake Pluton Area – Field Examples of Main Lithology – Granite

a) View to the north at typical lichen covered outcrop of coarse-grained granite (Station 16MC0219; compass for scale, 22 cm long, points north)
b) Close up view of coarse-grained granite (Station 16MC0001; pen for scale 14 cm)
c) Logarithmic plot of magnetic susceptibility for granite (central area, N=72 (red); outside central area, N=2 (orange))
d) Ternary plot of gamma ray spectrometer data for granite (central area, N=67 (blue); outside central area, N = 1 (light blue))

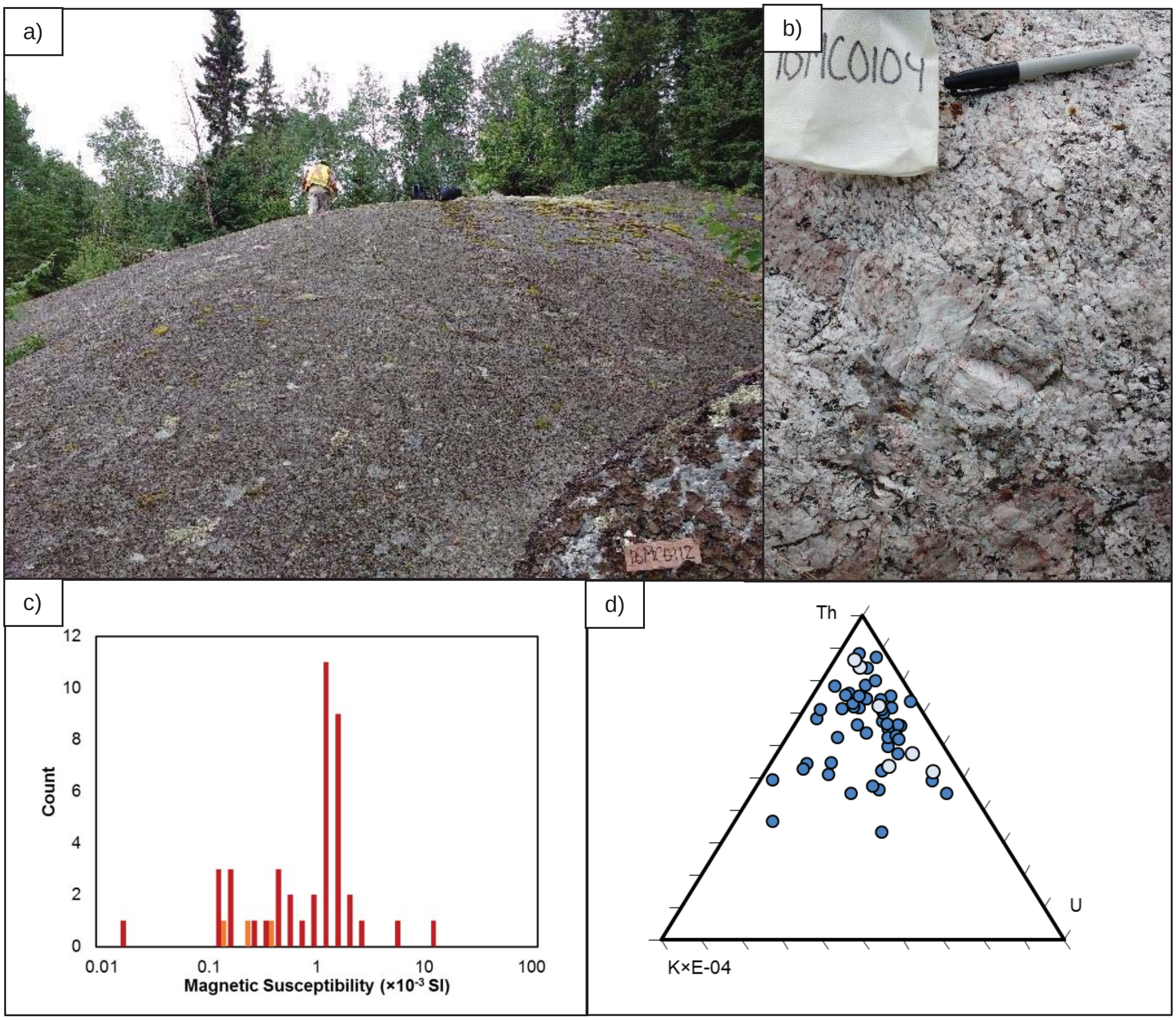


Figure 5.2.5 Anahareo Lake Pluton Area – Field Examples of Main Lithology – Granite Pegmatite

a) View to the northeast at typically smooth, featureless outcrop of granite pegmatite (Station 16MC0112; person for scale at top of outcrop)
b) Close-up view of granite pegmatite textures (Station 16MC0104; pen for scale, 14 cm long)
c) Logarithmic plot of magnetic susceptibility for granite pegmatite (northern area, N=42 (red); outside northern area, N=3 (orange))
d) Ternary plot of gamma ray spectrometer data for granite pegmatite (northern area, N=51 (blue); outside northern area, N=6 (light blue))

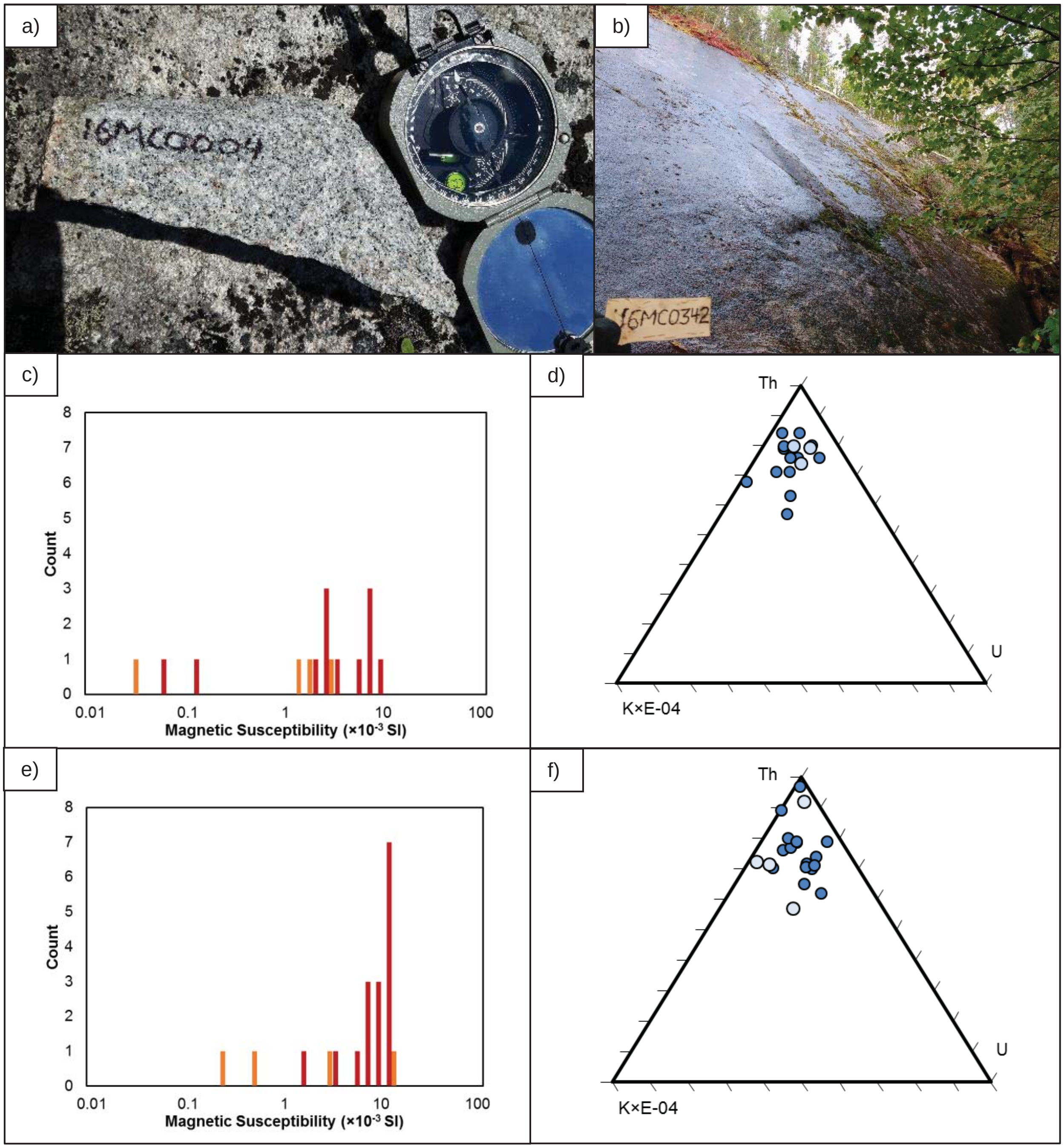
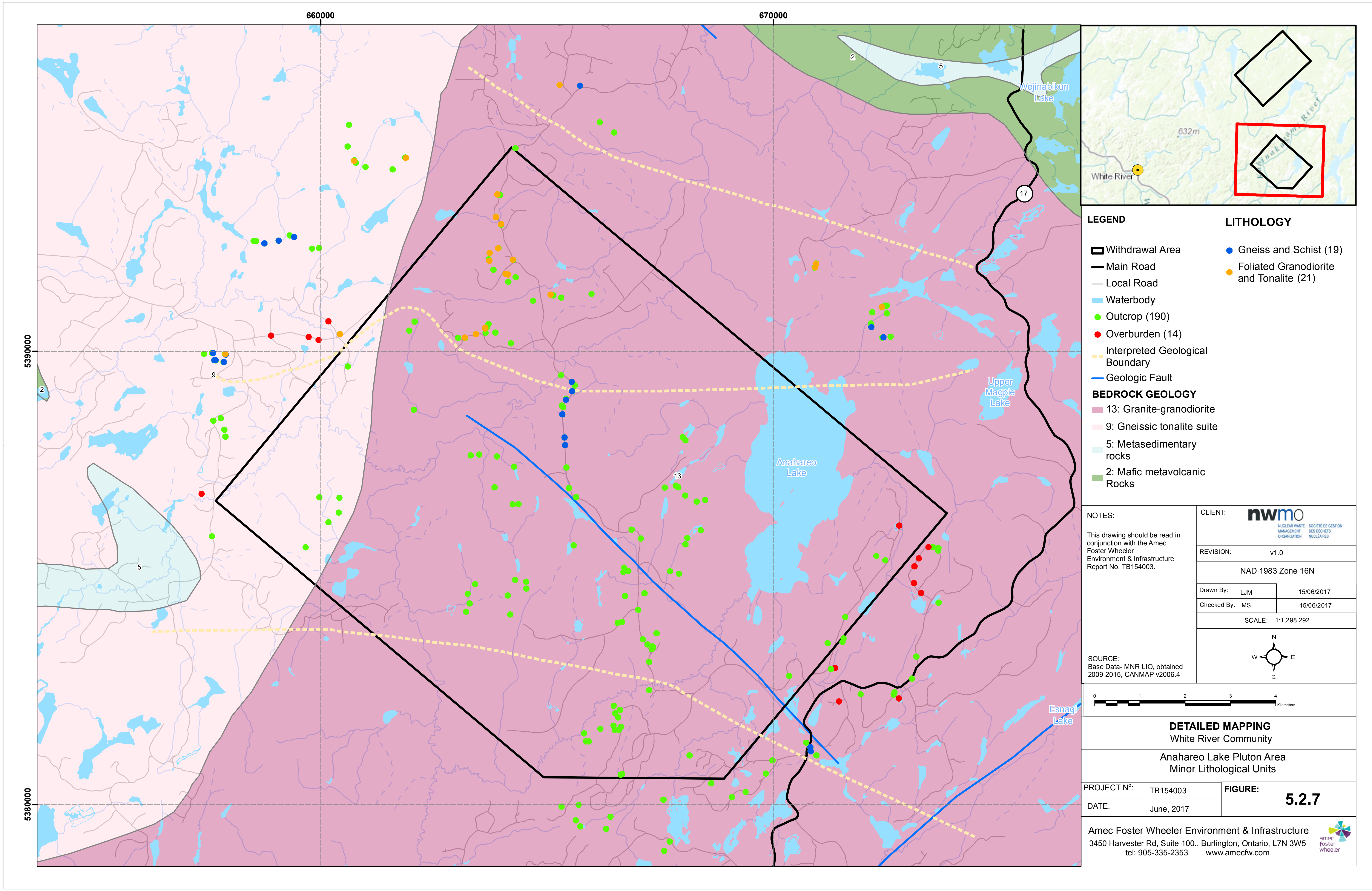


Figure 5.2.6 Anahareo Lake Pluton Area – Field Examples of Main Lithology – Granodiorite-Tonalite

a) Close-up view of tonalite textures (Station 16MC0004; compass for scale, 22 cm long, points north)

b) View to the southwest at smooth outcrop cliff of granodiorite-tonalite (Station 16MC0342; outcrop is approximately 10 metres high)
c) Logarithmic plot of magnetic susceptibility for granodiorite (southern area, N=12 (red); outside southern area, N=4 (orange))
d) Ternary plot of gamma ray spectrometer data for granodiorite (southern area, N=13 (blue); outside southern area, N=3 (light blue))
e) Logarithmic plot of magnetic susceptibility for tonalite (southern area, N=16 (red); outside southern area, N=4 (orange))
f) Ternary plot of gamma ray spectrometer data for tonalite (southern area, N=16 (blue); outside southern area, N=4 (light blue))



660000
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Wejinabikun Lake
Upper Magpie Lake
Anahareo Lake
Esnagi Lake
White River
632m
17
LEGEND
Withdrawal Area
Main Road
Local Road
Waterbody
Outcrop (190)
Overburden (14)
Interpreted Geological Boundary
Geologic Fault
BEDROCK GEOLOGY
13: Granite-granodiorite
9: Gneissic tonalite suite
5: Metasedimentary rocks
2: Mafic metavolcanic Rocks
LITHOLOGY
Gneiss and Schist (19)
Foliated Granodiorite and Tonalite (21)
NOTES:
This drawing should be read in conjunction with the Amec Foster Wheeler Environment & Infrastructure Report No. TB154003.
SOURCE:
Base Data- MNR LIO, obtained 2009-2015, CANMAP v2006.4
CLIENT:
nwmo
NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES
REVISION: v1.0
NAD 1983 Zone 16N
Drawn By: LJM 15/06/2017
Checked By: MS 15/06/2017
SCALE: 1:1,298,292
N
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S
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0 1 2 3 4 Kilometers
DETAILED MAPPING
White River Community
Anahareo Lake Pluton Area
Minor Lithological Units
PROJECT N°: TB154003
DATE: June, 2017
FIGURE: 5.2.7
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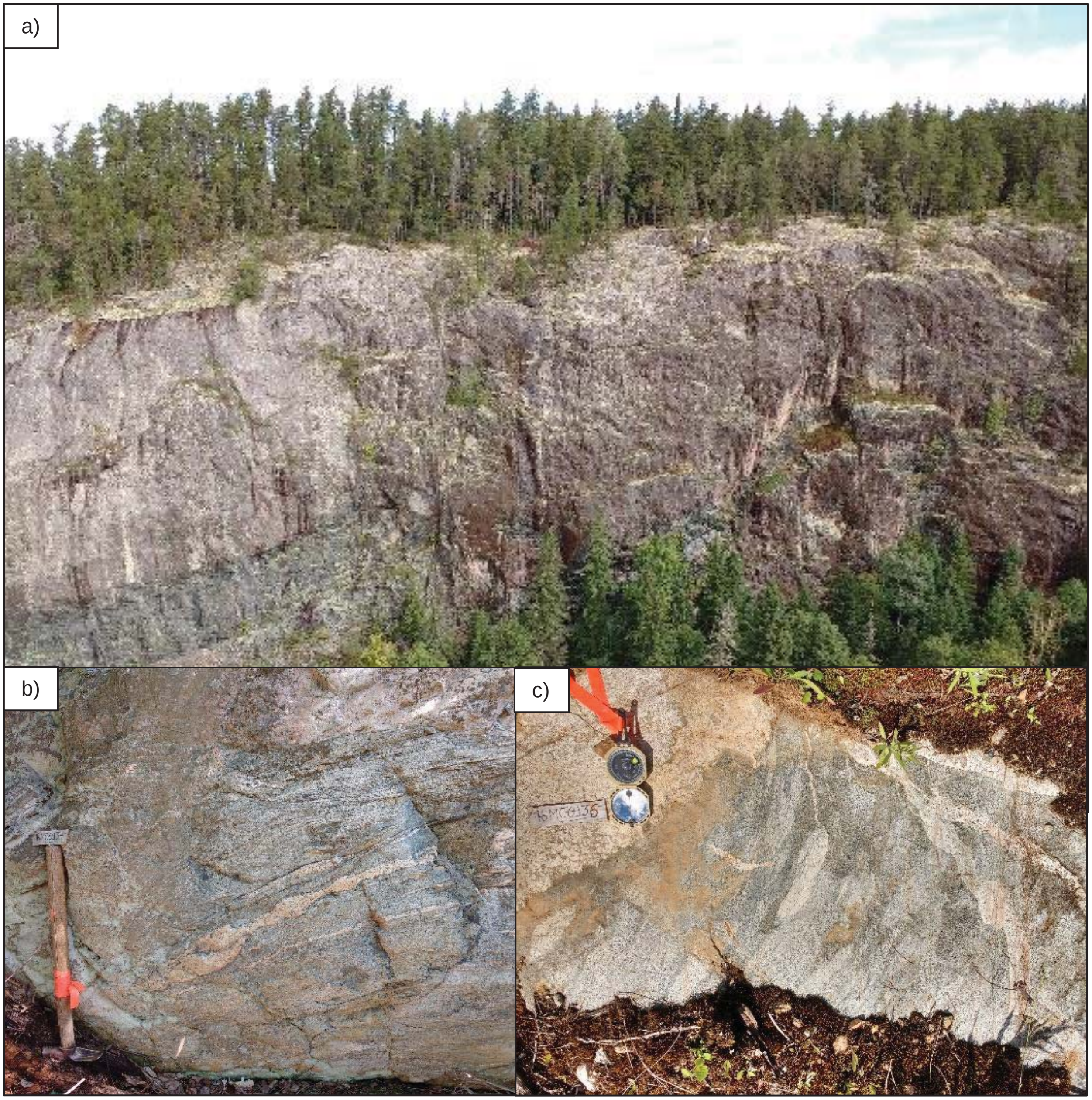
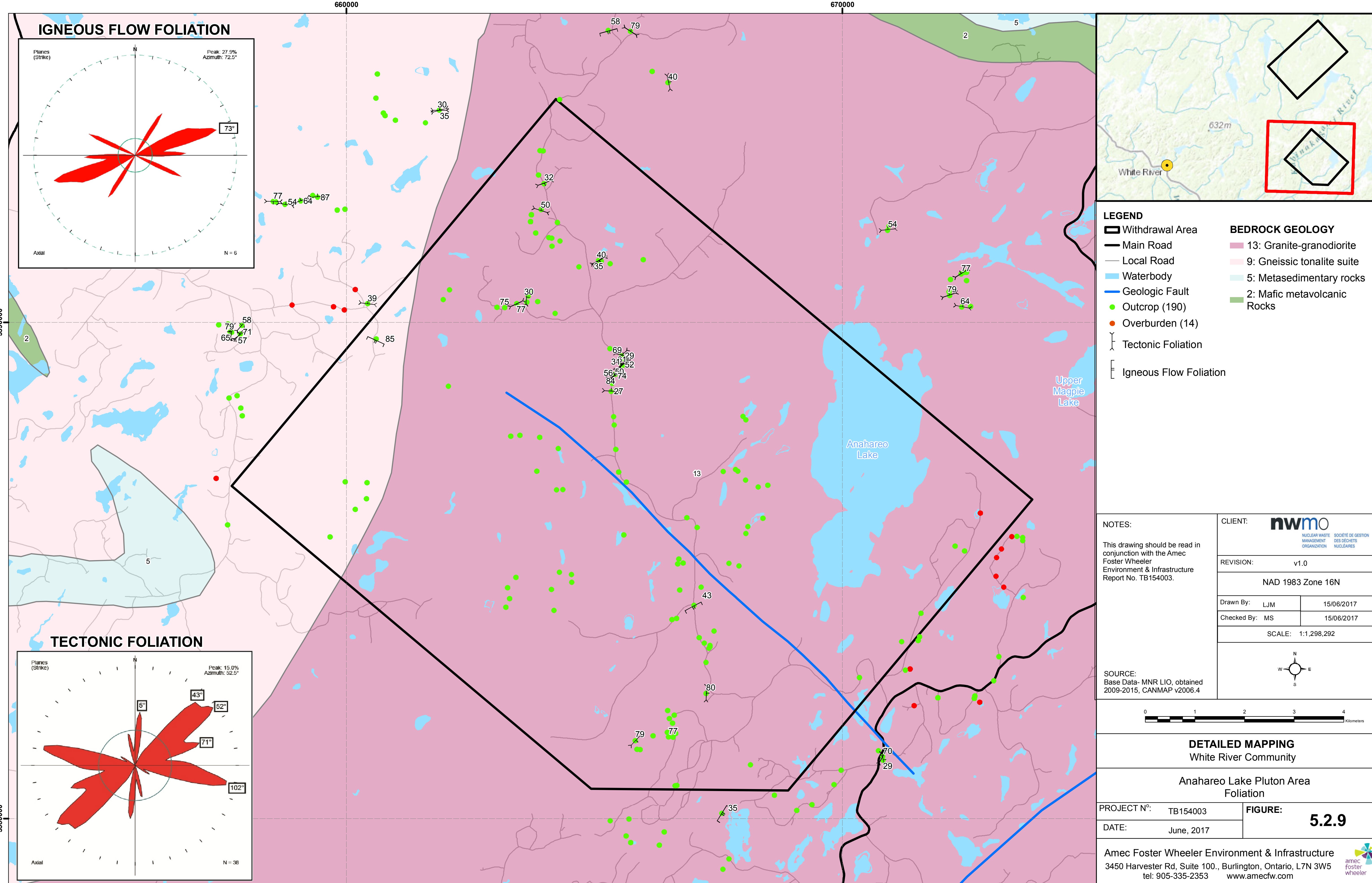


Figure 5.2.8 Anahareo Lake Pluton Area – Field Examples of Minor Lithological Units

a) View to the north at cliff face exposure of mainly granite pegmatite sill with a dark grey subhorizontal sheet of mafic schist evident in the lower left corner of the photo (Station 16MC0334; cliff face approximately 20 metres high)
b) View to the east at gneissic xenolith, part of the older metamorphic basement rocks into which the Anahareo Lake pluton intruded (Station 16MC0134; hammer for scale, 68 cm long)

c) Plan view of outcrop exposure of foliated volcanoclastic with tonalitic radiometric composition, part of the older metamorphic basement rocks into which the Anahareo Lake pluton intruded (Station 16MC0136; compass for scale, 22 cm long, points north)



NOTES:

This drawing should be read in conjunction with the Amec Foster Wheeler Environment & Infrastructure Report No. TB154003.

SOURCE:
Base Data- MNR LIO, obtained 2009-2015, CANMAP v2006.4

CLIENT: nwmo NUCLEAR WASTE MANAGEMENT ORGANIZATION / SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

REVISION: v1.0

NAD 1983 Zone 16N

Drawn By:	LJM	15/06/2017
Checked By:	MS	15/06/2017

SCALE: 1:1,298,292

0 1 2 3 4 Kilometers

DETAILED MAPPING
White River Community

Anahareo Lake Pluton Area
Foliation

PROJECT N°: TB154003
DATE: June, 2017
FIGURE: **5.2.9**

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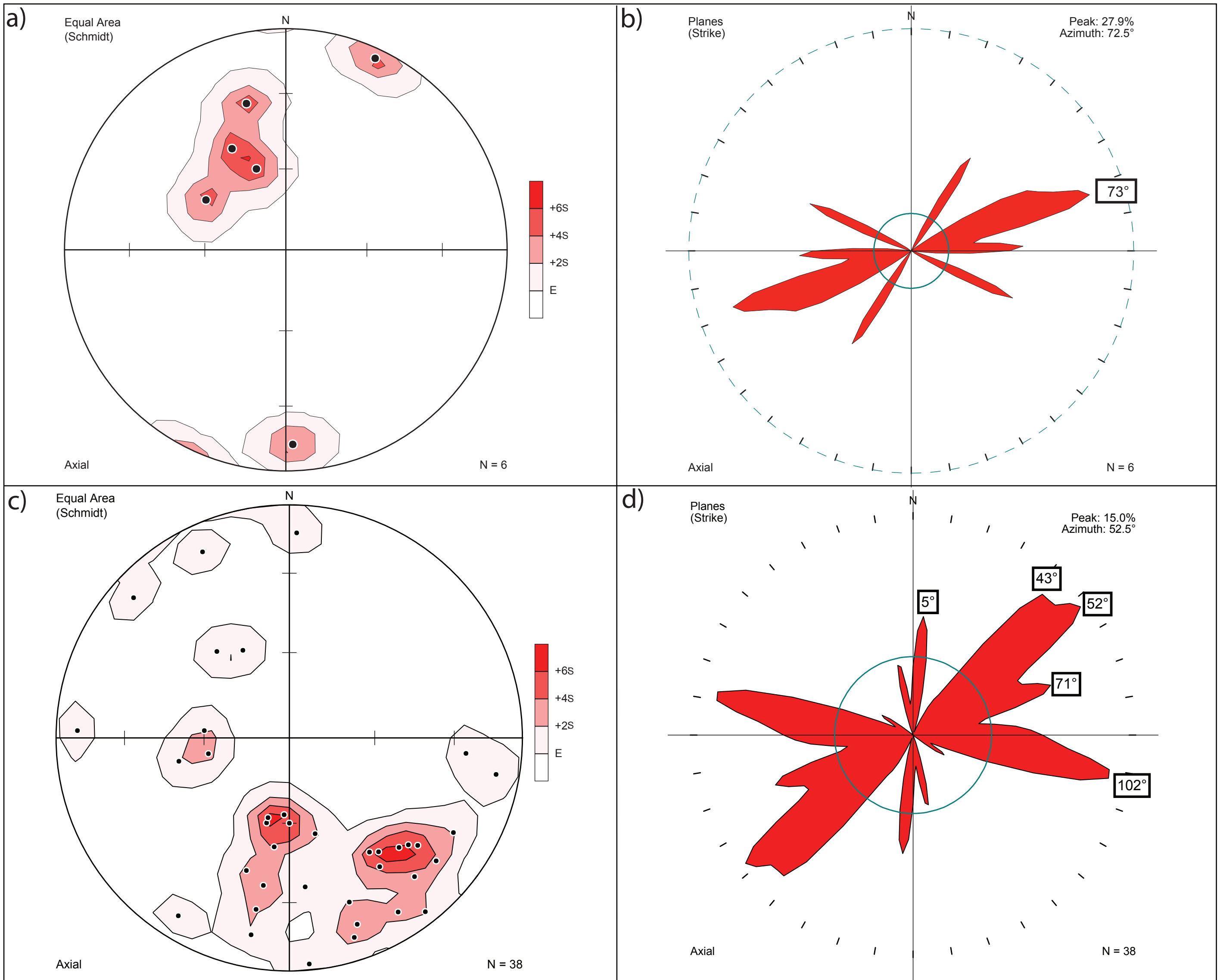
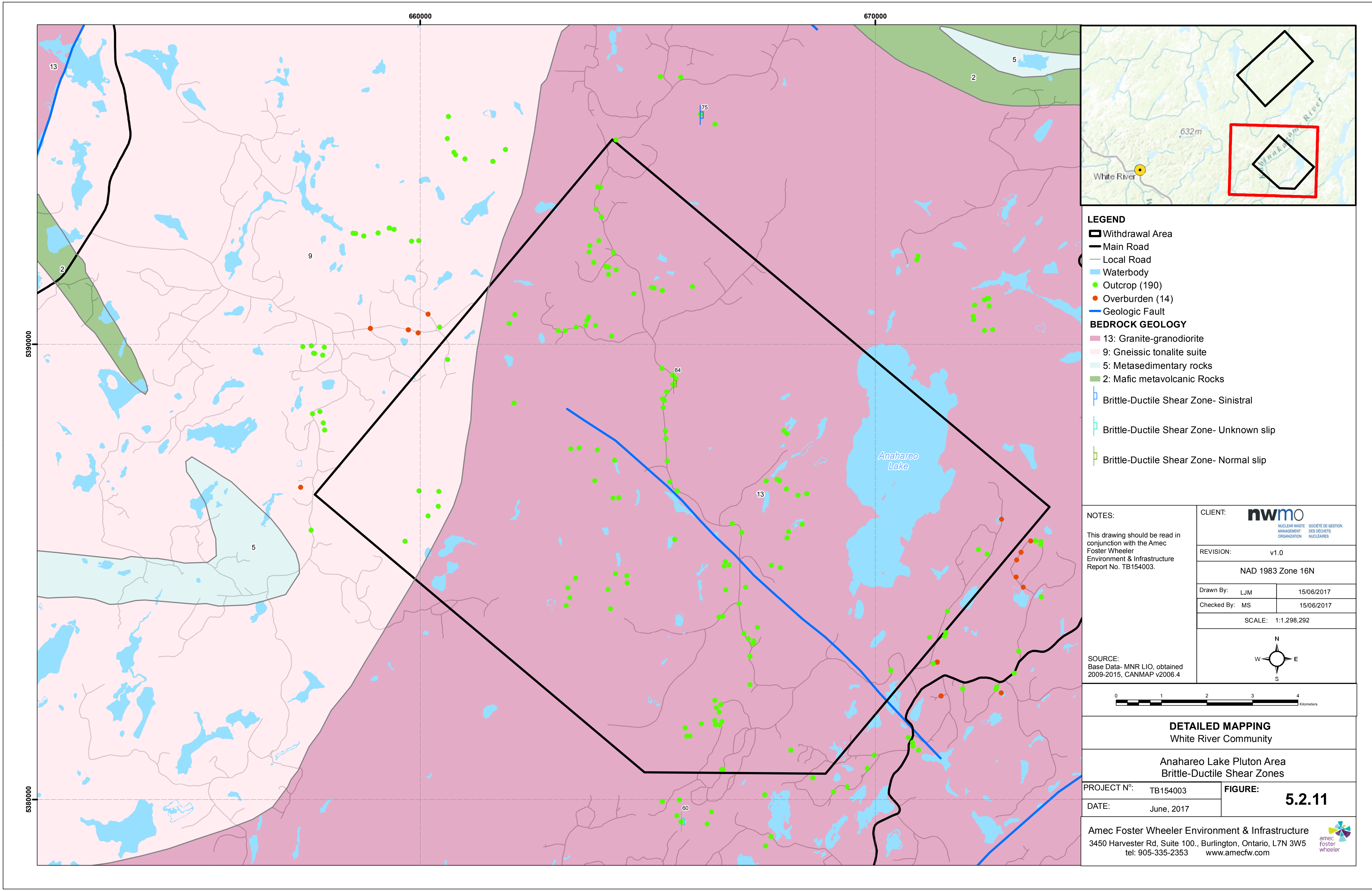


a) All igneous flow foliation data (N = 6) displayed as equal area lower hemisphere stereonet of poles to foliation plane with contours (Gaussian, K = 100)
b) All igneous flow foliation data (N = 6) displayed as rose diagram of trends of foliation plane
c) All tectonic foliation data (N = 38) displayed as equal area lower hemisphere stereonet of poles to foliation plane with contours (Gaussian, K = 100)
d) All tectonic foliation data (N = 38) displayed as rose diagram of trends of foliation plane

CLIENT: nwmo NUCLEAR WASTE MANAGEMENT ORGANIZATION / SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES	**DETAILED MAPPING** WHITE RIVER COMMUNITY
Drawn By: JS / Checked By: MS	Anahareo Lake Pluton Area - Foliation Orientation Data
Revision: V1.0	PROJECT N°: TB154003 / FIGURE: 5.2.10
	DATE: June, 2017
	Amec Foster Wheeler Environment & Infrastructure 3450 Harvester Rd, Suite 100., Burlington, Ontario, L7N 3W5 tel: 905-335-2353 www.amecfw.com


660000
670000
5390000
5380000
13
9
2
5
75
84
13
60
Anahareo Lake
632m
White River
LEGEND
Withdrawal Area
Main Road
Local Road
Waterbody
Outcrop (190)
Overburden (14)
Geologic Fault
BEDROCK GEOLOGY
13: Granite-granodiorite
9: Gneissic tonalite suite
5: Metasedimentary rocks
2: Mafic metavolcanic Rocks
Brittle-Ductile Shear Zone- Sinistral
Brittle-Ductile Shear Zone- Unknown slip
Brittle-Ductile Shear Zone- Normal slip
NOTES:
This drawing should be read in conjunction with the Amec Foster Wheeler Environment & Infrastructure Report No. TB154003.
SOURCE:
Base Data- MNR LIO, obtained 2009-2015, CANMAP v2006.4
CLIENT:
nwmo
NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES
REVISION: v1.0
NAD 1983 Zone 16N
Drawn By: LJM 15/06/2017
Checked By: MS 15/06/2017
SCALE: 1:1,298,292
N
W
E
S
0 1 2 3 4
Kilometers
DETAILED MAPPING
White River Community
Anahareo Lake Pluton Area
Brittle-Ductile Shear Zones
PROJECT Nº: TB154003
DATE: June, 2017
FIGURE:
5.2.11
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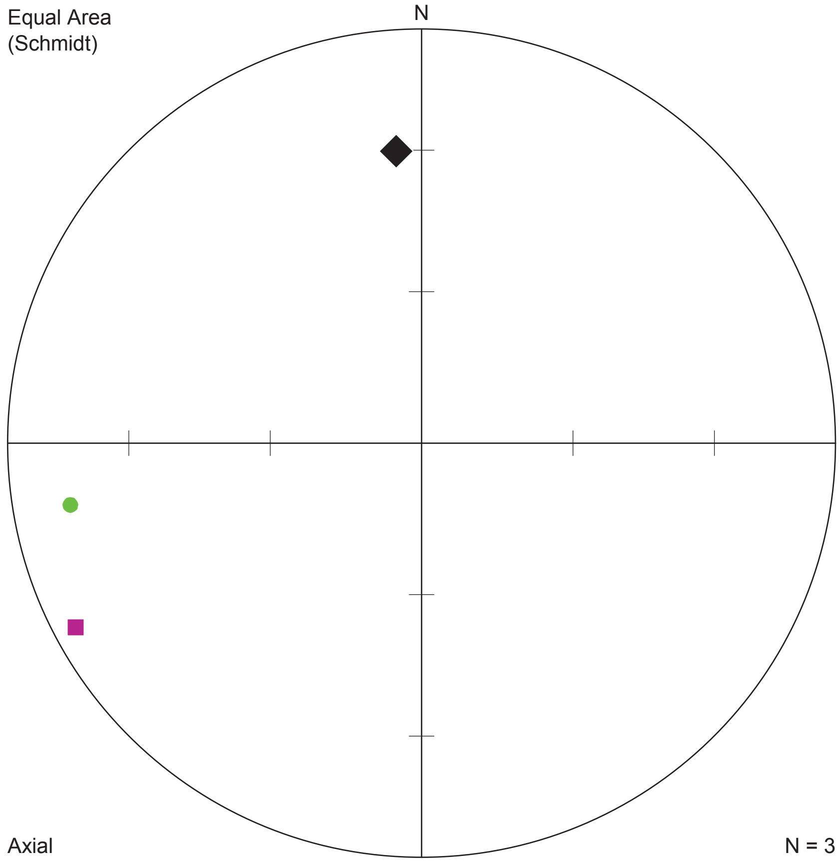
tel: 905-335-2353 www.amecfw.com
amec foster wheeler

a)



a) All brittle-ductile shear zone data (N = 3) displayed as equal area lower hemisphere stereonet of poles to shear zone plane – classification: sinistral (green; small circle), normal (magenta; small square), unknown (black; diamond)

CLIENT: NWMO

Drawn By: JS	Checked By: MS
Revision: V1.0	

DETAILED MAPPING
WHITE RIVER COMMUNITY

Anahareo Lake Pluton Area -
Brittle-Ductile Shear Zone Orientation Data

PROJECT N°: TB154003

DATE: June, 2017

FIGURE: 5.2.12

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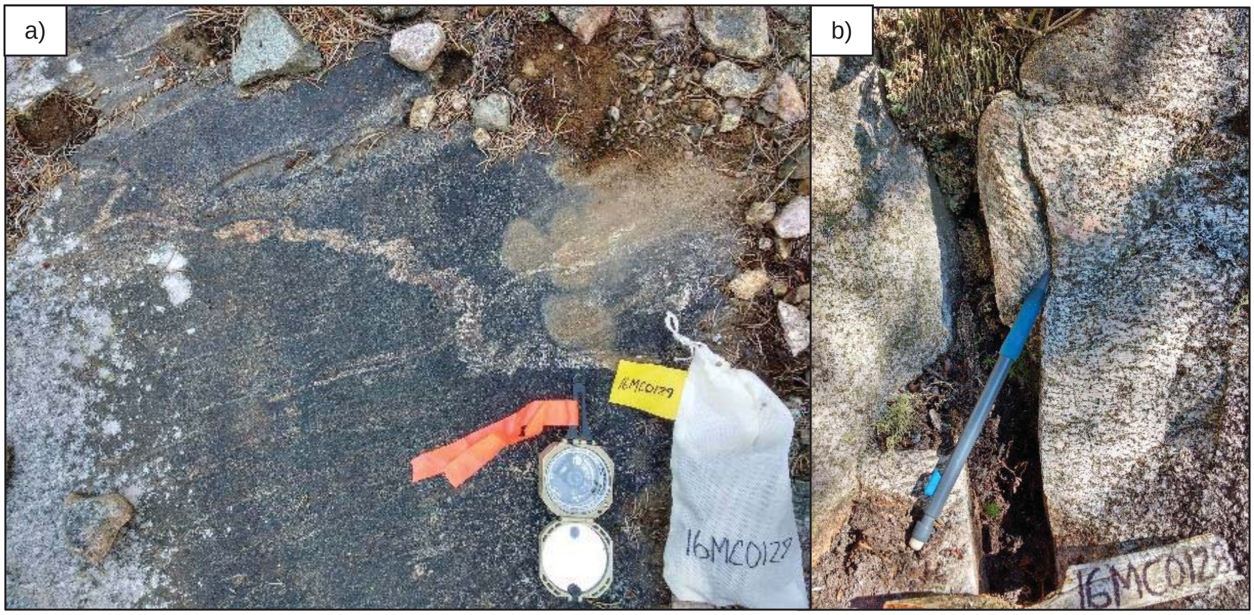
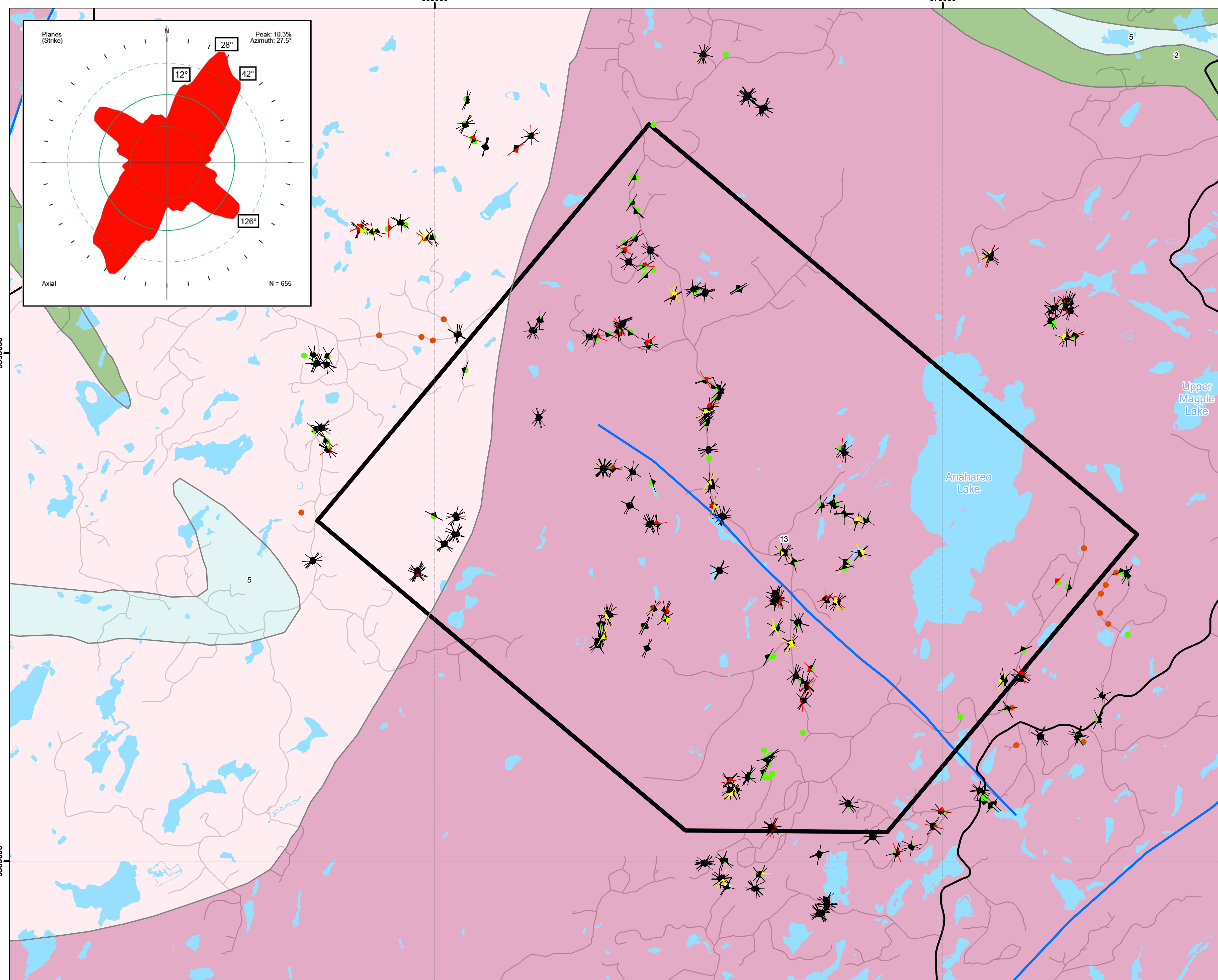
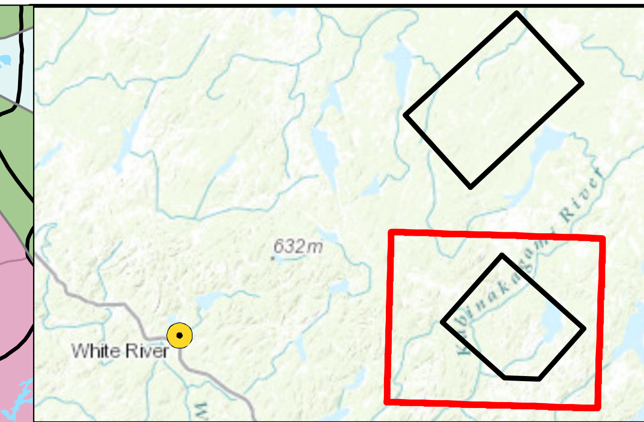


Figure 5.2.13 Anahareo Lake Pluton Area – Field Examples of Ductile Structure

a) View to the north at ptygmatically folded pegmatite vein within strongly foliated metamorphic rocks (Station 16MC0129; compass for scale, 22 cm long, points north)
b) View to the northwest of brittle-ductile shear zone with down to the northeast normal sense drag folds (Station 16MC0128; pencil for scale, 15 cm long, points north)





LEGEND

- Withdrawal Area
- Outcrop (190)
- Overburden (14)
- Main Road
- Local Road
- Waterbody
- Geologic Fault
- Sub Horizontal Joint: 0° -30°
- Intermediate Joint: 31° -60°
- Sub Vertical Joint: 61° -90°

BEDROCK GEOLOGY

- 13: Granite-granodiorite
- 9: Gneissic tonalite suite
- 5: Metasedimentary rocks
- 2: Mafic metavolcanic Rocks

NOTES:

This drawing should be read in conjunction with the Amec Foster Wheeler Environment & Infrastructure Report No. TB154003.

SOURCE:
Base Data- MNR LIO, obtained 2009-2015, CANMAP v2006.4

CLIENT: nwmo NUCLEAR WASTE MANAGEMENT ORGANIZATION SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

REVISION: v1.0

NAD 1983 Zone 16N

Drawn By: LJM 15/06/2017

Checked By: MS 15/06/2017

SCALE: 1:1,298,292

N W E S

0 1 2 3 4 Km

DETAILED MAPPING
White River Community

Anahareo Lake Pluton Area
Joints

PROJECT N°: TB154003

DATE: June, 2017

FIGURE: **5.2.14**

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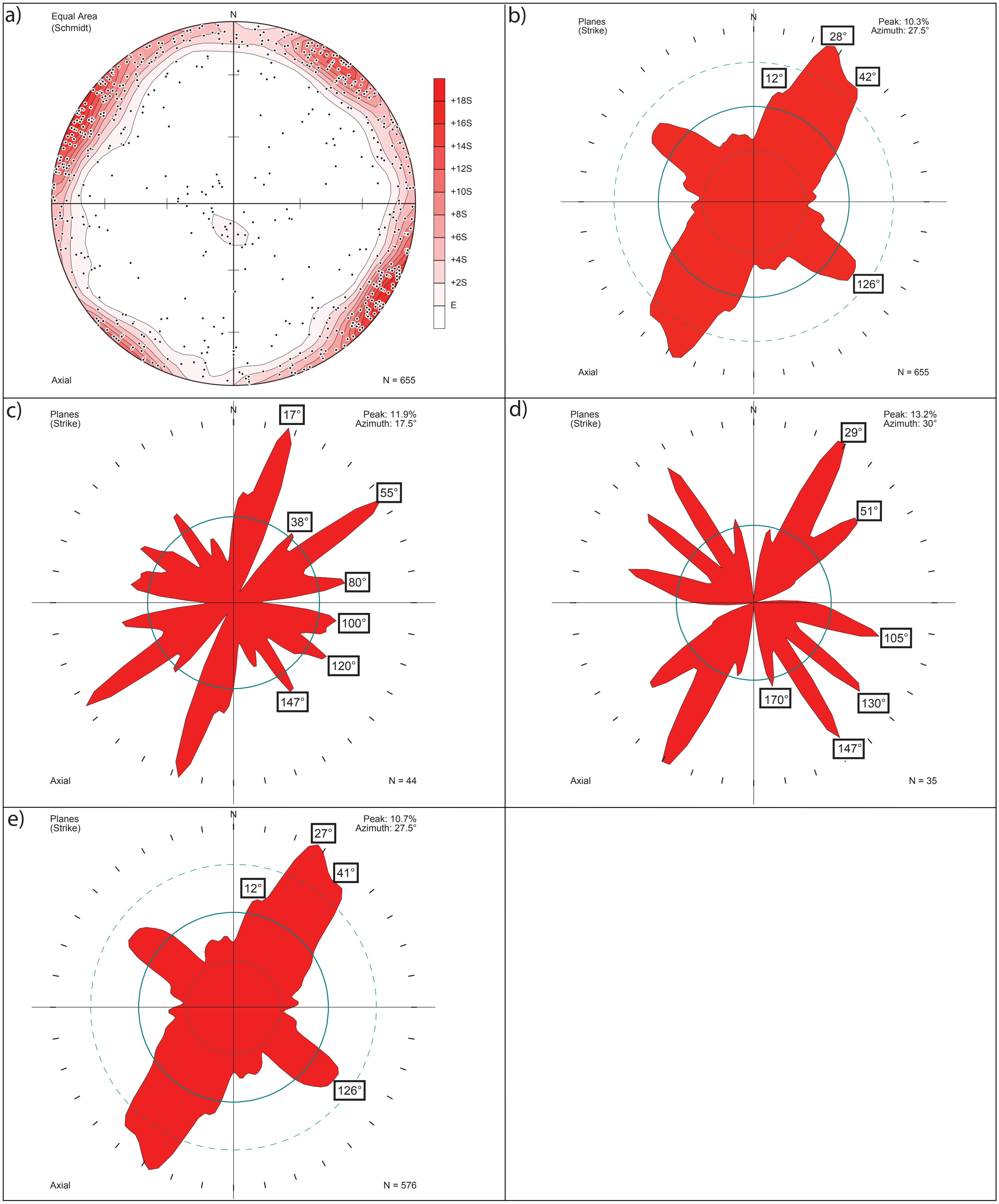

a) All joint data (N = 655) displayed as equal area lower hemisphere stereonet of poles to joint plane with contours (Gaussian, K = 100)
b) All joint data (N = 655) displayed as rose diagram of trends of joint plane
c) Joint data dipping 0º-30º (N = 44) displayed as rose diagram of trends of joint plane
d) Joint data dipping 31º-60º (N = 35) displayed as rose diagram of trends of joint plane
e) Joint data dipping 61º-90º (N = 576) displayed as rose diagram of trends of joint plane

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DETAILED MAPPING
WHITE RIVER COMMUNITY

Anahareo Lake Pluton Area - Joint Orientation Data

Drawn By: JS	Checked By: MS
Revision: V1.0	

PROJECT Nº: TB154003
DATE: June, 2017
FIGURE: 5.2.15

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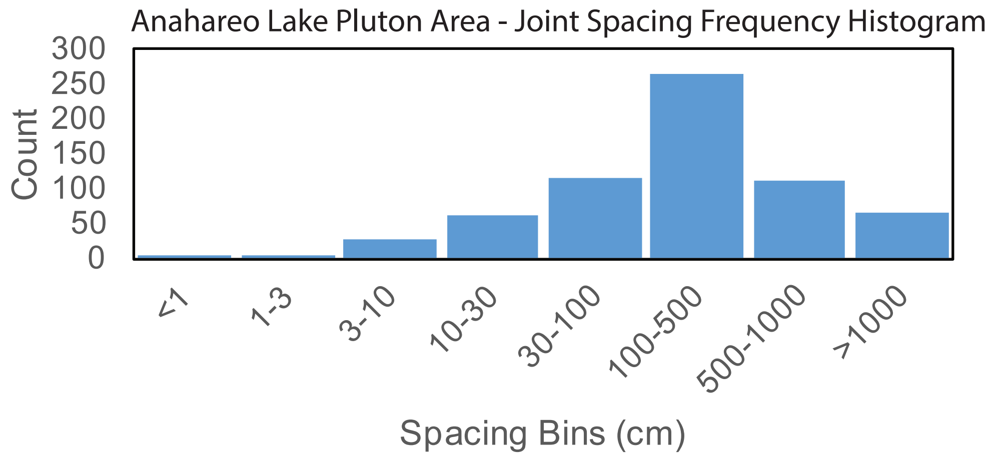
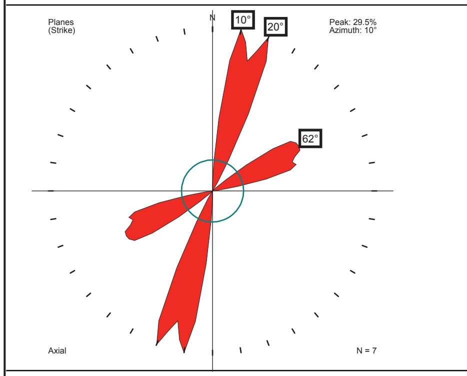
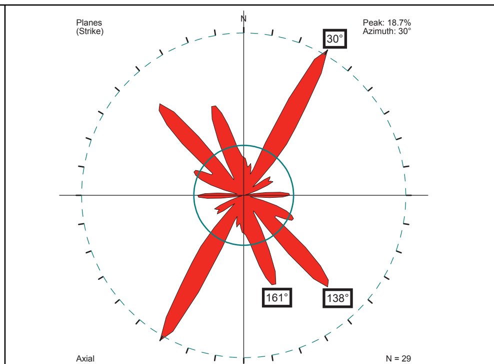
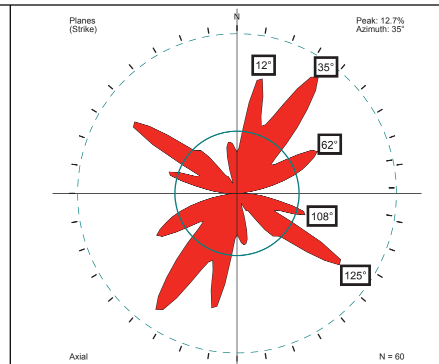




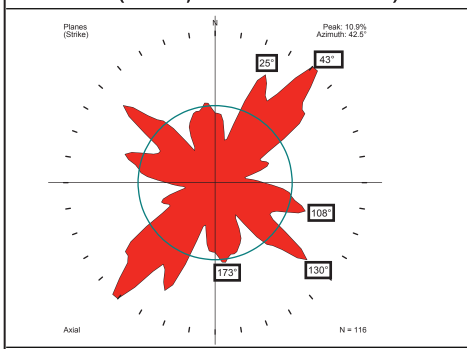
1-3 cm (note, incl. 1 at <1cm)



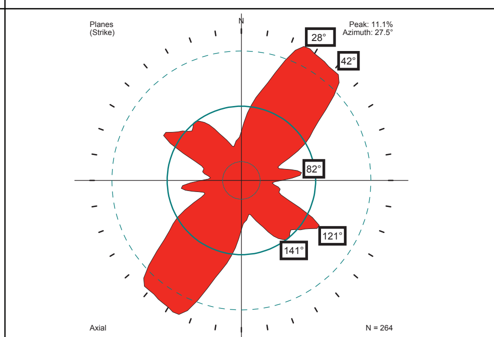
3-10 cm



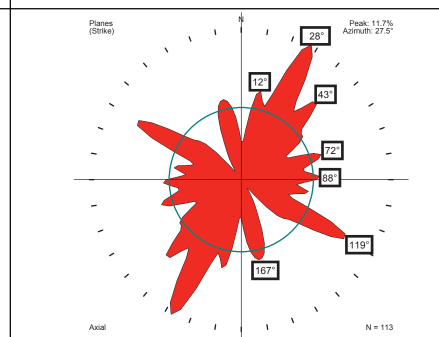
10-30 cm



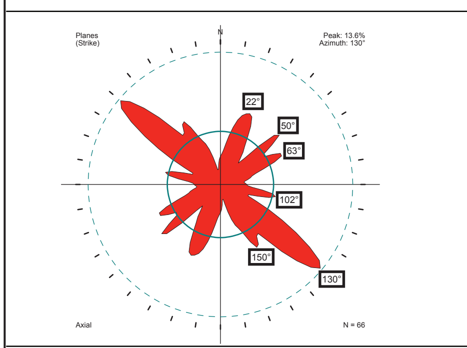
30-100 cm



100-500 cm



500-1000 cm



>1000 cm

Joint Spacing Summary

CLIENT: nwmo NUCLEAR WASTE MANAGEMENT ORGANIZATION / SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

Drawn By: JS | Checked By: MS

Revision: V1.0

DETAILED MAPPING
WHITE RIVER COMMUNITY

Anahareo Lake Pluton Area - Joint Orientation Data

PROJECT Nº: TB154003

DATE: June, 2017

FIGURE: 5.2.15f

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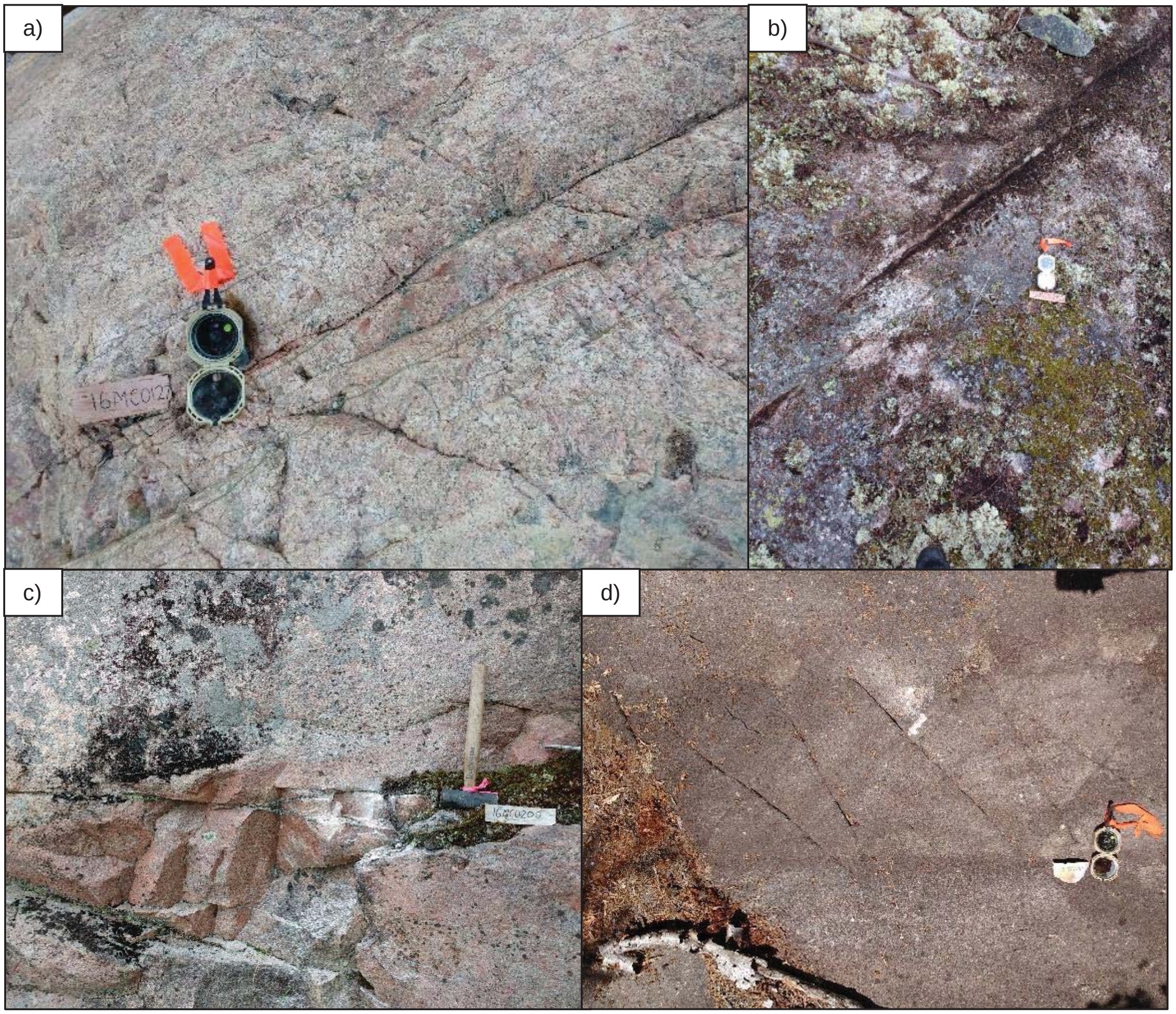
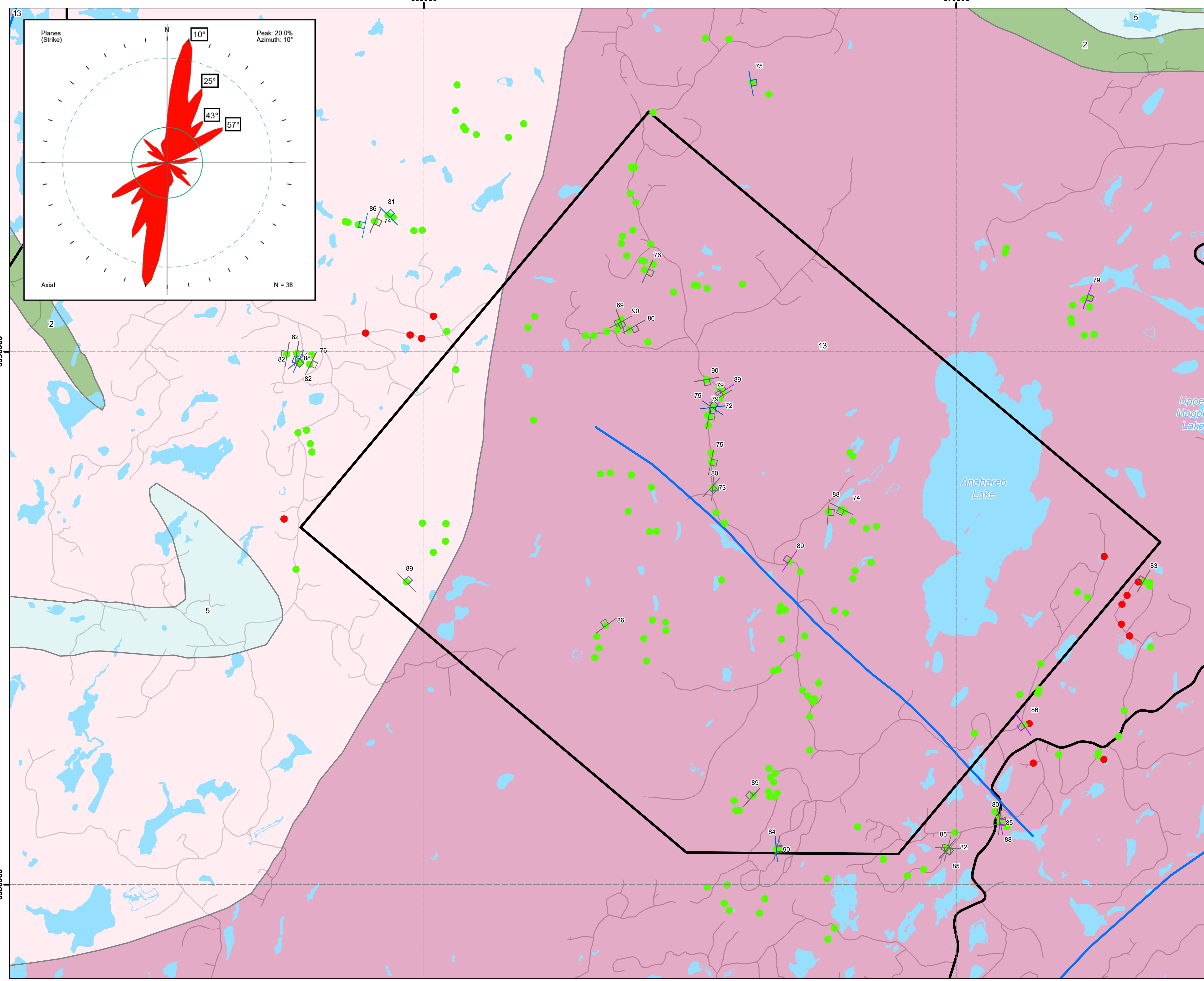
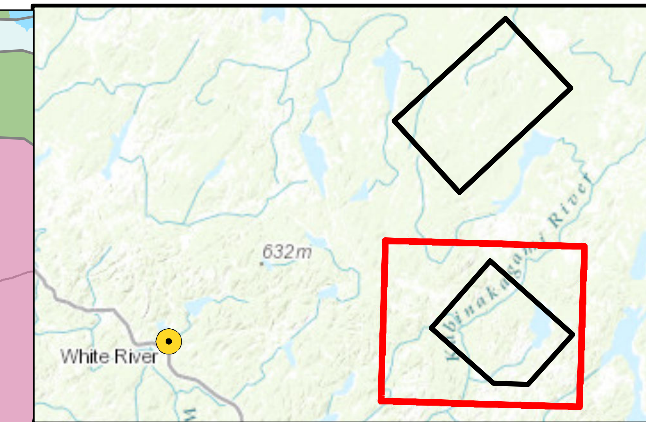


Figure 5.2.16 Anahareo Lake Pluton Area – Field Examples of Joints

a) Closely spaced, northeast-striking joints in pegmatite (Station 16MC0127; compass for scale, 22 cm long, points north)
b) Northeast-striking joint with left-stepping overlaps suggesting sinistral sense-of-shear (Station16MC0290; Compass for scale 22 cm long, points north)
c) Subhorizontal joint dipping sub-parallel to a granodiorite sill cutting granite (Station 16MC0200; view to the north, hammer for scale, 37 cm long)
d) Conjugate set of joints in a fine-grained granite dyke cutting coarse-grained tonalite-granodiorite. Note the joints terminate at the dyke margin (Station 16MC0010; compass for scale, 22 cm long, points north)





LEGEND

- Withdrawal Area
- Main Road
- Local Road
- Waterbody
- Outcrop (190)
- Overburden (14)
- Geologic Fault
- Fault- Dextral
- Fault- Sinistral
- Fault- Dip Slip
- Fault- Reverse Slip
- Fault- Unknown

BEDROCK GEOLOGY

- 13: Granite-granodiorite
- 9: Gneissic tonalite suite
- 5: Metasedimentary rocks
- 2: Mafic metavolcanic Rocks

NOTES:

This drawing should be read in conjunction with the Amec Foster Wheeler Environment & Infrastructure Report No. TB154003.

SOURCE:
Base Data- MNR LIO, obtained 2009-2015, CANMAP v2006.4

CLIENT: nwmo NUCLEAR WASTE MANAGEMENT ORGANIZATION / SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

REVISION: v1.0

NAD 1983 Zone 16N

Drawn By:	LJM	15/06/2017
Checked By:	MS	15/06/2017

SCALE: 1:1,298,292

N W E S

0 1 2 3 4 Kilometers

DETAILED MAPPING
White River Community

Anahareo Lake Pluton Area
Faults

PROJECT N°: TB154003

DATE: June, 2017

FIGURE: **5.2.17**

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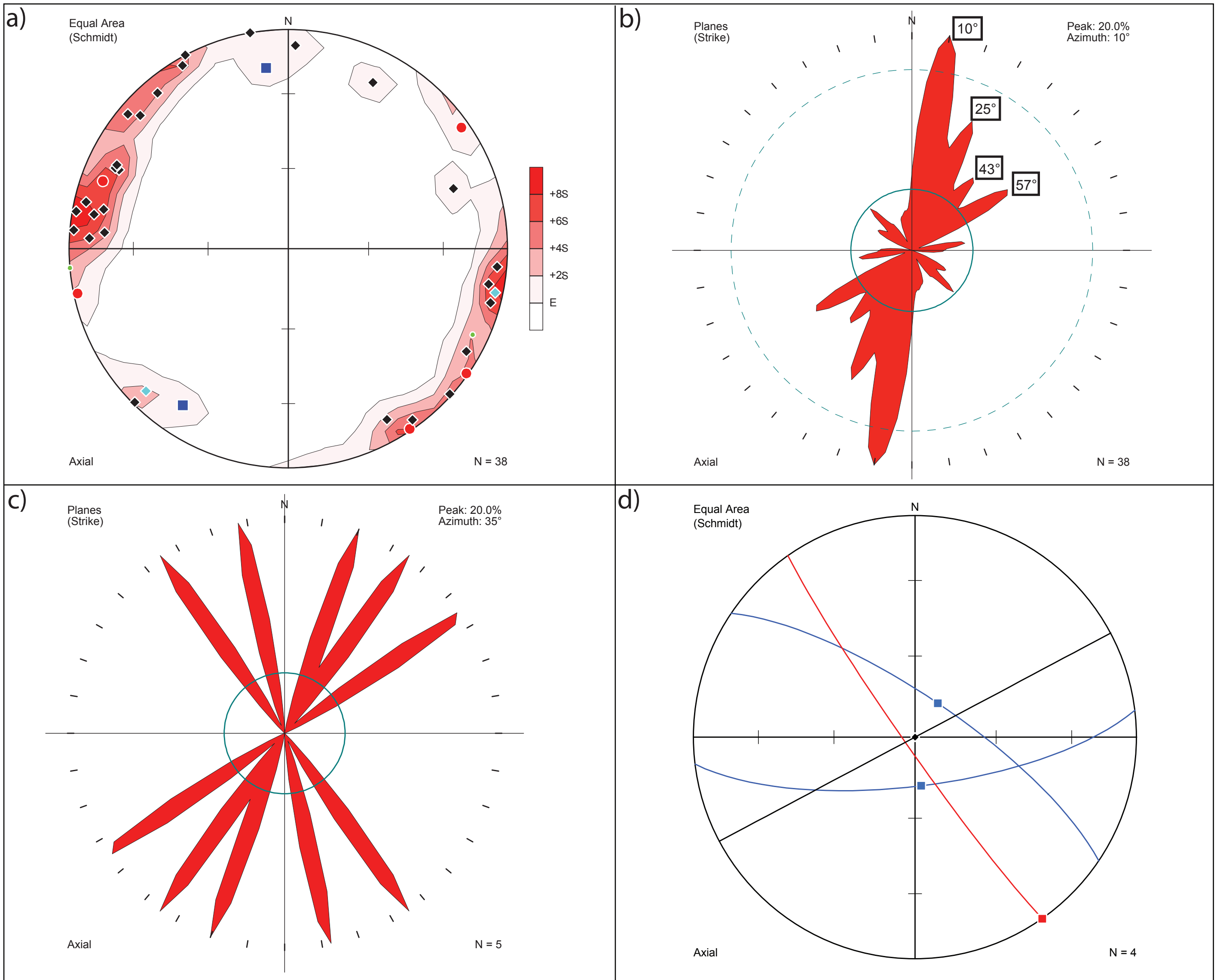


a) All fault data (N = 38) displayed as equal area lower hemisphere stereonet of poles to fault plane with contours (Gaussian, K = 100) – classification: dextral (red; big circle), sinistral (green; small circle), reverse slip (light blue; diamond), dip slip (blue; large square), unknown (black; diamond)
b) All fault data (N = 38) displayed as rose diagram of trends of fault plane
c) All dextral fault data (N = 5) displayed as rose diagram of trends of fault plane
d) All faults with lineations (N = 4) displayed as equal area lower hemisphere stereonet of great circles – classification: dextral (red; large square), dip slip (blue; large square), unknown (black; diamond)

CLIENT: nwmo NUCLEAR WASTE MANAGEMENT ORGANIZATION / SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES	**DETAILED MAPPING** WHITE RIVER COMMUNITY
Drawn By: JS / Checked By: MS	Anahareo Lake Pluton Area - Fault Orientation Data
Revision: V1.0	PROJECT N°: TB154003 / FIGURE: 5.2.18
	DATE: June, 2017
	Amec Foster Wheeler Environment & Infrastructure 3450 Harvester Rd, Suite 100., Burlington, Ontario, L7N 3W5 tel: 905-335-2353 www.amecfw.com

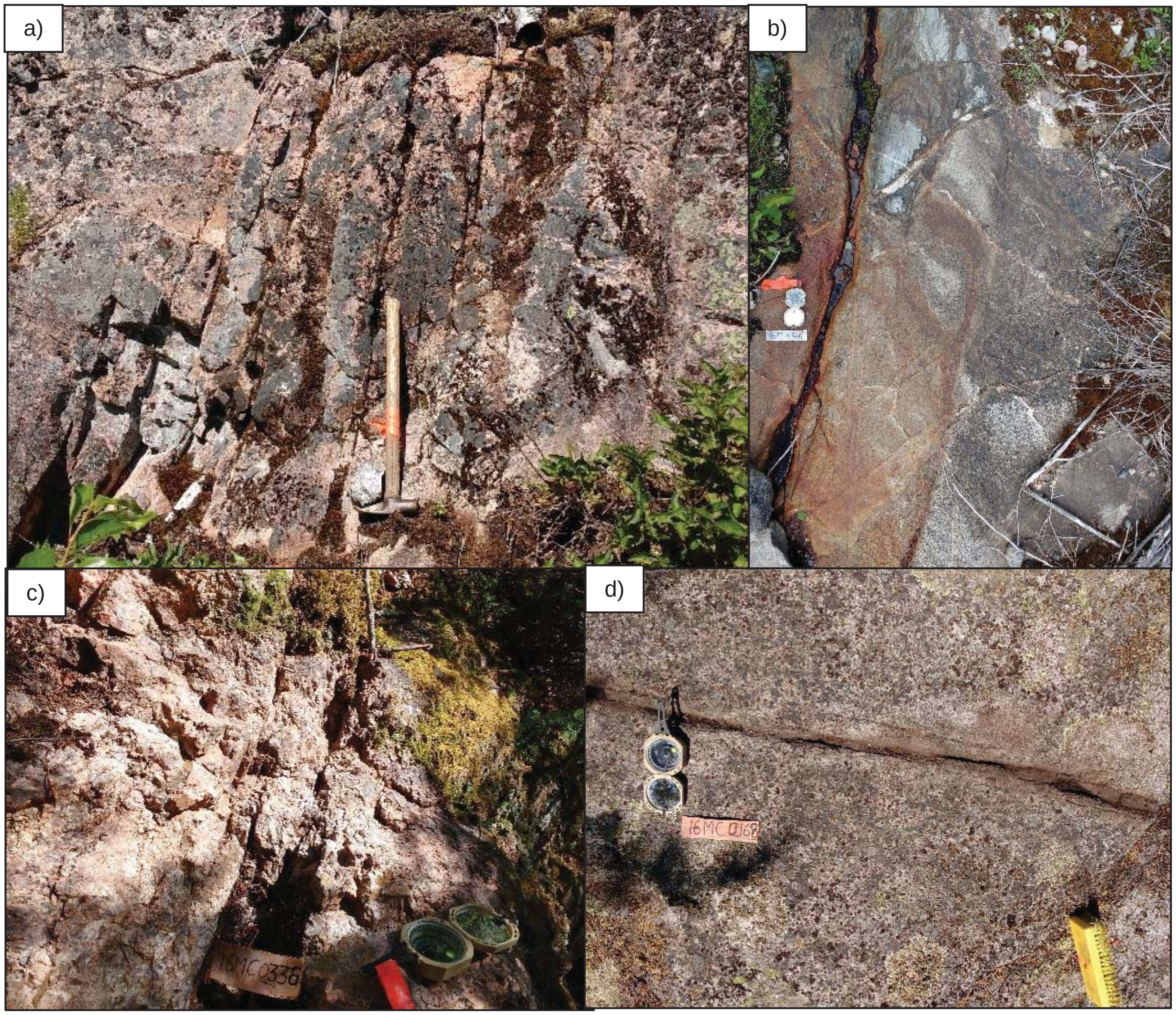
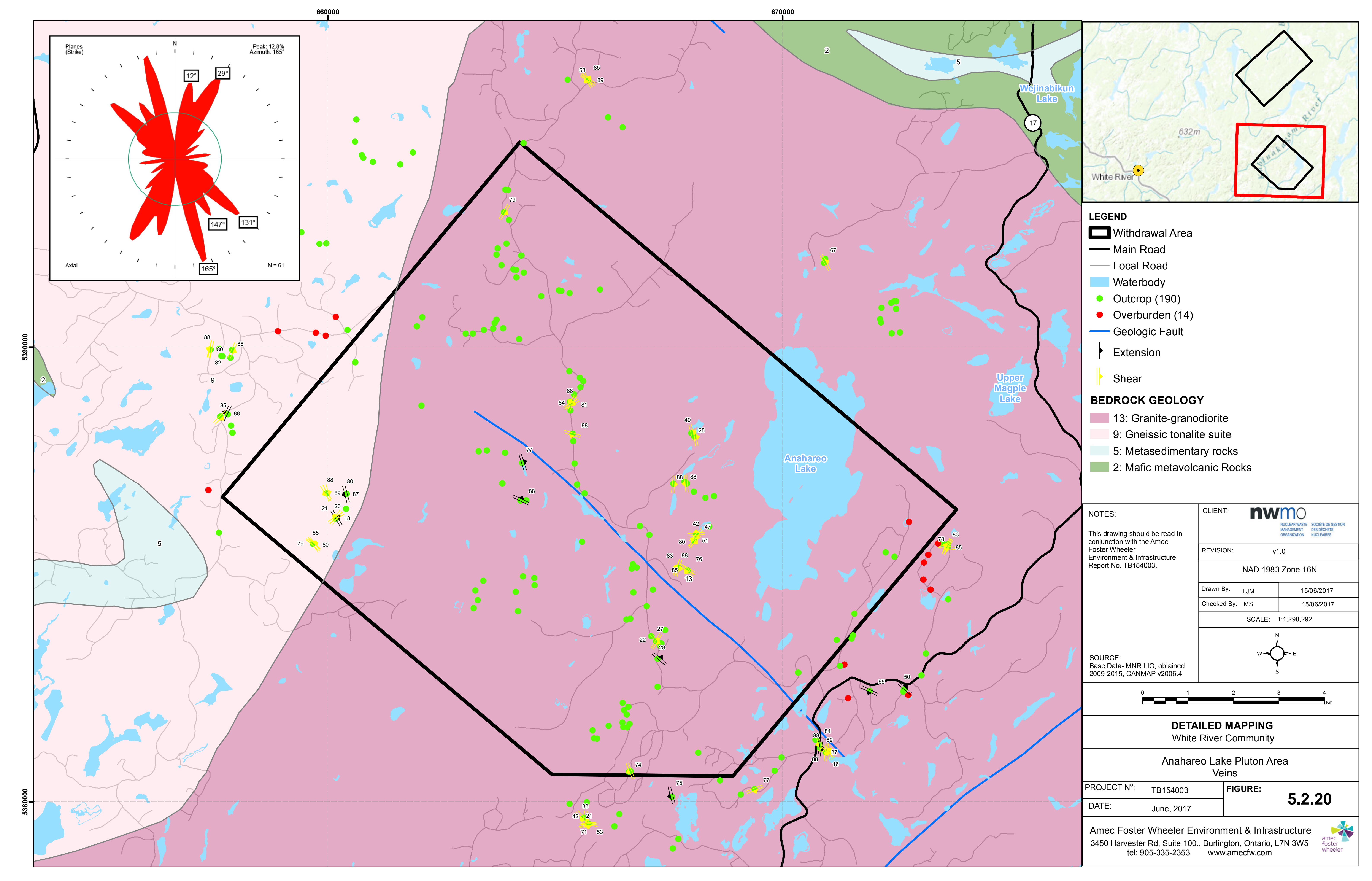


Figure 5.2.19 Anahareo Lake Pluton Area – Field Examples of Faults

a) View to the west at 1 metre wide brittle fault zone of closely spaced joints. Subvertical slickenlines indicate an episode of dip-slip displacement (Station 16MC0131; hammer for scale 68 cm long)
b) Plan view with top to the north of a single brittle fault surface (Station 16MC0136; compass for scale, 22 cm long, points north)
c) View to the southeast of a 15 cm wide brittle fault zone. Steps and slickenlines on fault planes indicate reverse-sense of slip (Station 16MC0336, compass for scale, 22 cm long, points north)
d) Plan view with top to the north of a single brittle west-northwest-striking fault with uncertain slip sense (Station 16MC0168; compass for scale, 22 cm long, points north)


660000
670000
5390000
5380000
Planes (Strike)
Peak: 12.8%
Azimuth: 165°
N
12°
29°
147°
131°
165°
Axial
N = 61
Wejinabikun Lake
17
Anahareo Lake
Upper Magpie Lake
White River
632m
LEGEND
Withdrawal Area
Main Road
Local Road
Waterbody
Outcrop (190)
Overburden (14)
Geologic Fault
Extension
Shear
BEDROCK GEOLOGY
13: Granite-granodiorite
9: Gneissic tonalite suite
5: Metasedimentary rocks
2: Mafic metavolcanic Rocks
NOTES:
This drawing should be read in conjunction with the Amec Foster Wheeler Environment & Infrastructure Report No. TB154003.
SOURCE:
Base Data- MNR LIO, obtained 2009-2015, CANMAP v2006.4
CLIENT:
NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES
REVISION: v1.0
NAD 1983 Zone 16N
Drawn By: LJM 15/06/2017
Checked By: MS 15/06/2017
SCALE: 1:1,298,292
N
W
E
S
0 1 2 3 4 Km
DETAILED MAPPING
White River Community
Anahareo Lake Pluton Area
Veins
PROJECT N°: TB154003
DATE: June, 2017
FIGURE: 5.2.20
Amec Foster Wheeler Environment & Infrastructure
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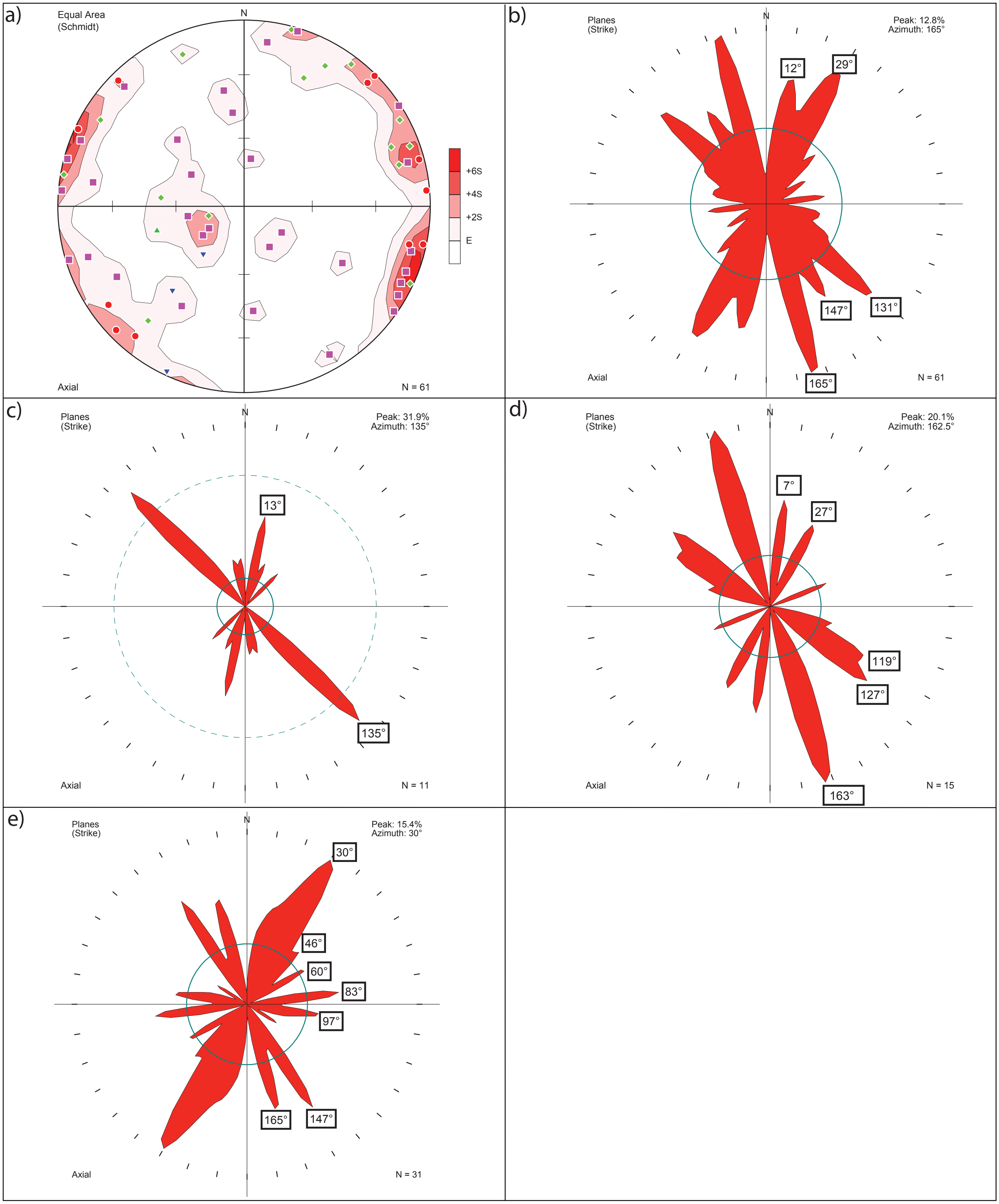
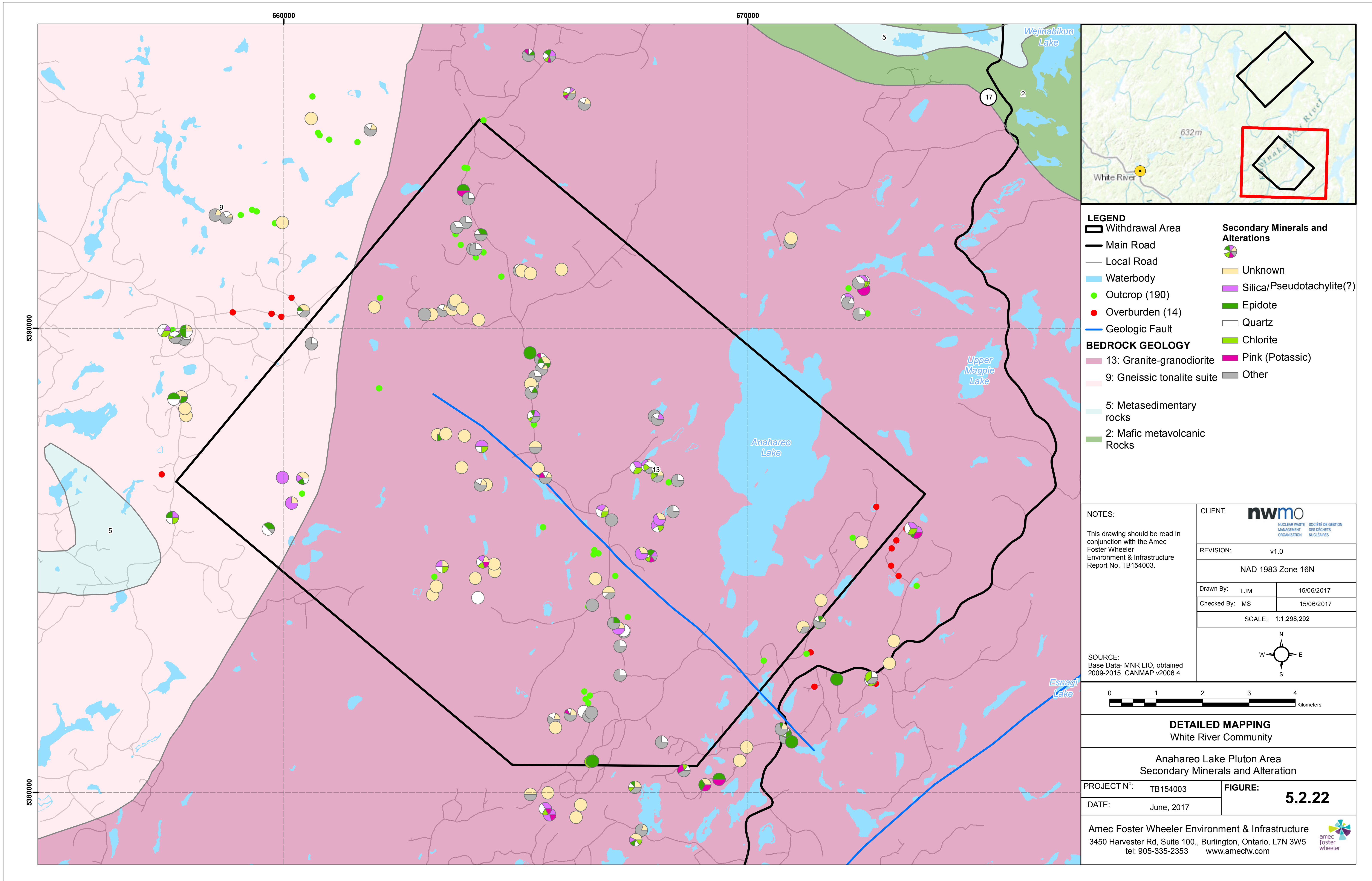
tel: 905-335-2353 www.amecfw.com



a) All vein data (N = 61) displayed as equal area lower hemisphere stereonet of poles to vein plane with contours (Gaussian, K = 100) – classification: quartz (red; big circle), epidote (green; diamond), pseudotachylite (magenta; big square), sericite (dark green; triangle pointing up), pegmatite (blue; triangle pointing down)
b) All vein data (N = 61) displayed as rose diagram of trends of vein plane
c) All quartz dominated veins (N = 11) displayed as rose diagram of trends of vein plane
d) All epidote dominated veins (N = 15) displayed as rose diagram of trends of vein plane
e) All pseudotachylite / siliceous material (?) dominated veins (N = 31) displayed as rose diagram of trends of vein plane

CLIENT: nwmo NUCLEAR WASTE MANAGEMENT ORGANIZATION / SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES	**DETAILED MAPPING** WHITE RIVER COMMUNITY
Drawn By: JS / Checked By: MS	Anahareo Lake Pluton Area - Vein Orientation Data
Revision: V1.0	PROJECT N°: TB154003 / **FIGURE:** 5.2.21
	DATE: June, 2017
	Amec Foster Wheeler Environment & Infrastructure 3450 Harvester Rd, Suite 100., Burlington, Ontario, L7N 3W5 tel: 905-335-2353 www.amecfw.com



660000
670000
5390000
5380000
Wejinabikun Lake
Upper Magpie Lake
Anahareo Lake
Esnagi Lake
17
632m
White River
LEGEND
Withdrawal Area
Main Road
Local Road
Waterbody
Outcrop (190)
Overburden (14)
Geologic Fault
BEDROCK GEOLOGY
13: Granite-granodiorite
9: Gneissic tonalite suite
5: Metasedimentary rocks
2: Mafic metavolcanic Rocks
Secondary Minerals and Alterations
Unknown
Silica/Pseudotachylite(?)
Epidote
Quartz
Chlorite
Pink (Potassic)
Other
NOTES:
This drawing should be read in conjunction with the Amec Foster Wheeler Environment & Infrastructure Report No. TB154003.
SOURCE:
Base Data- MNR LIO, obtained 2009-2015, CANMAP v2006.4
CLIENT:
nwmo
NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES
REVISION: v1.0
NAD 1983 Zone 16N
Drawn By: LJM 15/06/2017
Checked By: MS 15/06/2017
SCALE: 1:1,298,292
N
W E
S
0 1 2 3 4
Kilometers
DETAILED MAPPING
White River Community
Anahareo Lake Pluton Area
Secondary Minerals and Alteration
PROJECT N°: TB154003
DATE: June, 2017
FIGURE: 5.2.22
Amec Foster Wheeler Environment & Infrastructure
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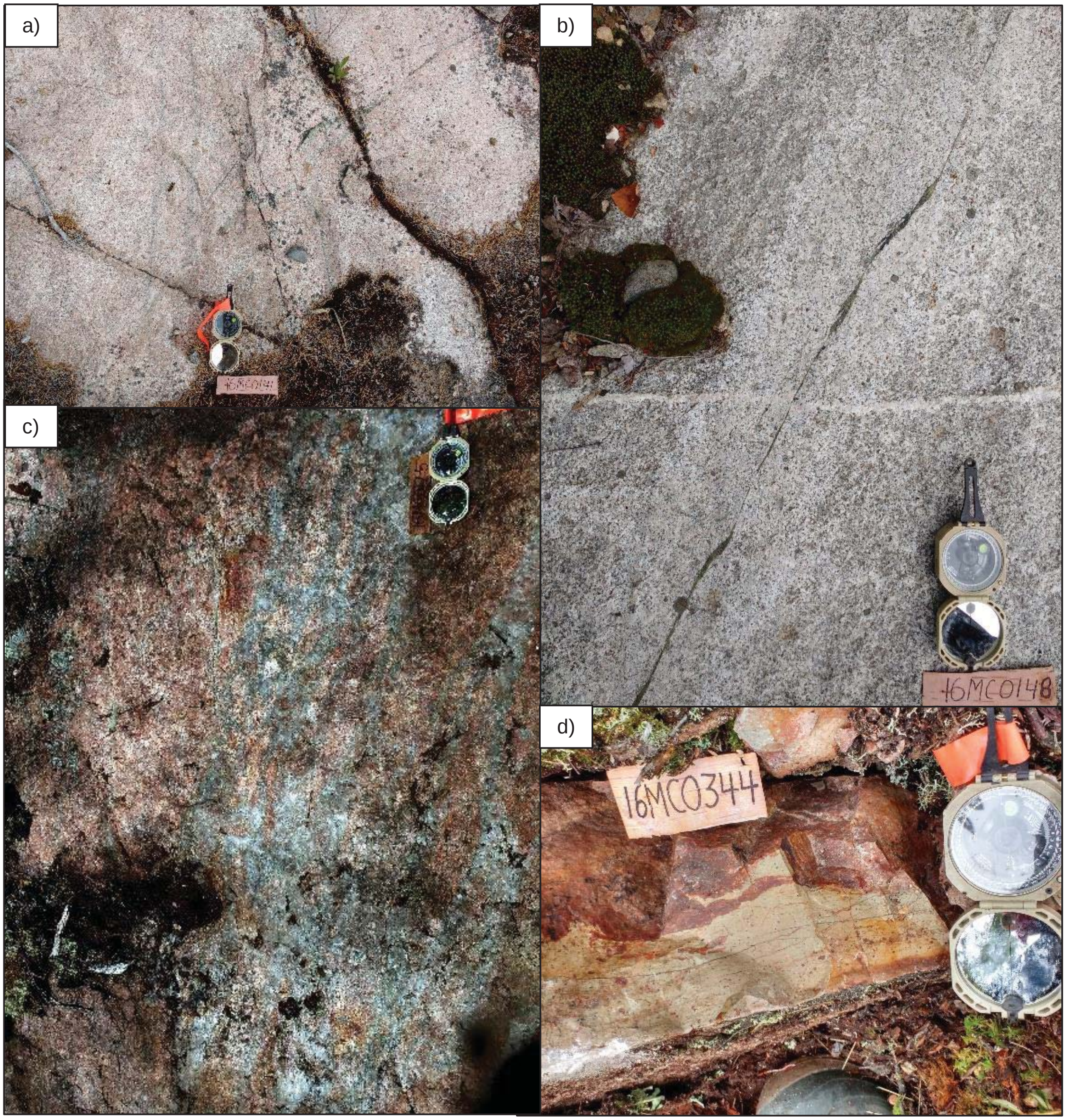
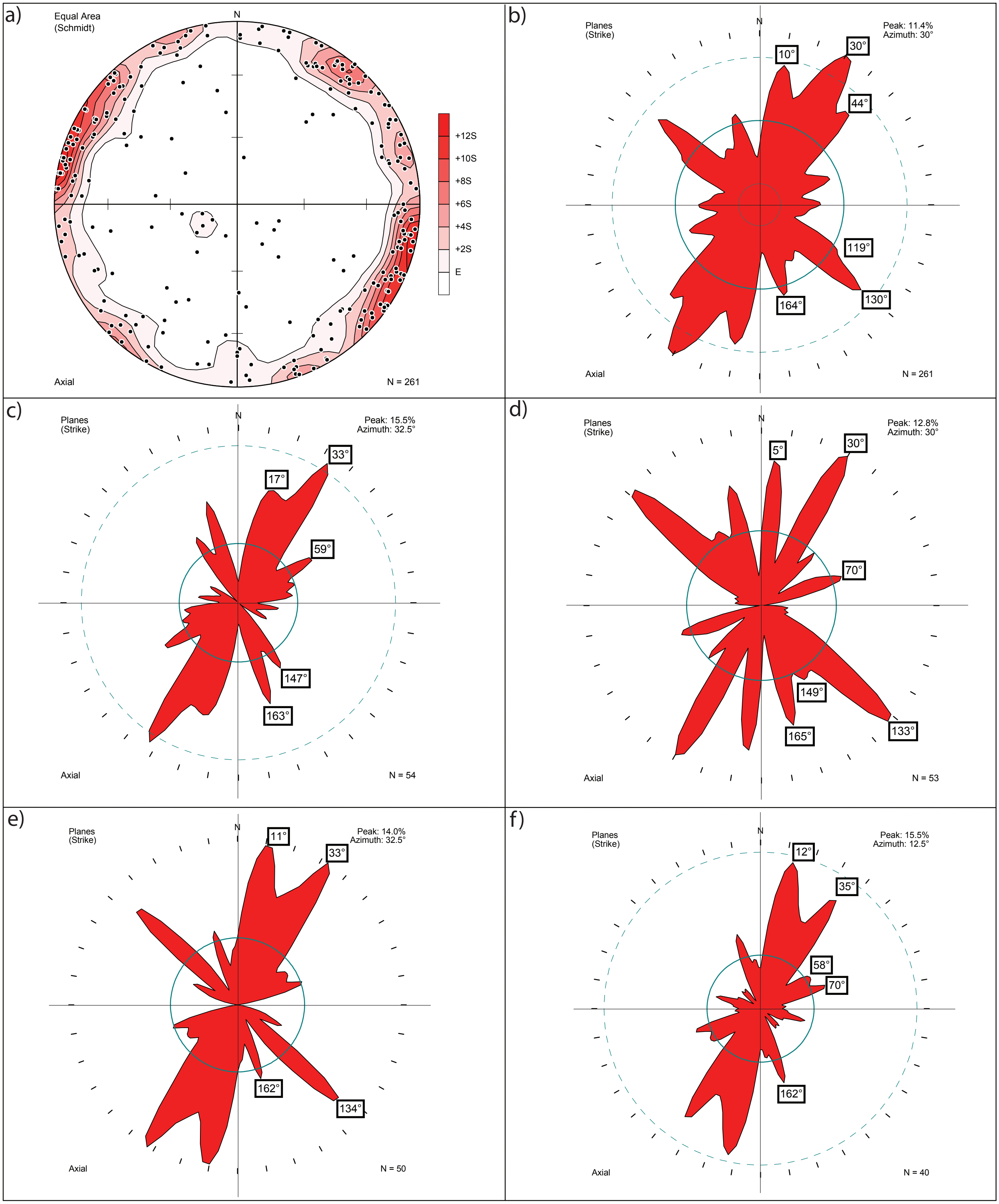


Figure 5.2.23 Anahareo Lake Pluton Area – Field Examples of Secondary Minerals and Alteration

a) Dextral horsetails and dilations in northeast-striking, pale green siliceous pseudotachylite veins (Station 16MC0141; compass for scale, 22 cm long, points north)

b) North-northeast-striking chlorite vein showing dextral sense dilations (Station 16MC0148; compass for scale, 22 cm long, points north)
c) Plan view with top to the north of a > metre wide zone of quartz vein stockwork with breccia clasts of pink, possibly potassic altered pegmatite (Station 16MC0175; compass for scale, 22 cm long, points north)
d) Subcrop boulder with a >10 cm thick band of pale green to tan coloured pseudotachylite cutting pink stained possibly potassic altered granodiorite (field-verified Lineament #10); abundant pseudotachylite veinlets and thicker (<10 cm) veins occur at this location (Station 16MC0344; compass for scale, 22 cm long, points north)



a) All fracture data with secondary mineral infilling and alteration (N = 261) displayed as equal area lower hemisphere stereonet of poles to fracture plane with contours (Gaussian, K = 100)
b) All fracture data with secondary mineral infilling and alteration (N = 261) displayed as rose diagram of trends of fracture plane
c) All fracture data with pseudotachylite / siliceous material (?) infill (N = 54) displayed as rose diagram of trends of fracture plane
d) All fracture data with epidote infill (N = 53) displayed as rose diagram of trends of fracture plane
e) All fracture data with quartz infill (N = 50) displayed as rose diagram of trends of fracture plane
f) All fracture data with chlorite infill (N = 40) displayed as rose diagram of trends of fracture plane

CLIENT: nwmo

DETAILED MAPPING
WHITE RIVER COMMUNITY

Drawn By: JS | Checked By: MS
Revision: V1.0

Anahareo Lake Pluton Area - Secondary Mineral Infilling and Alteration Orientation Data

PROJECT N°: TB154003
DATE: June, 2017
FIGURE: 5.2.24

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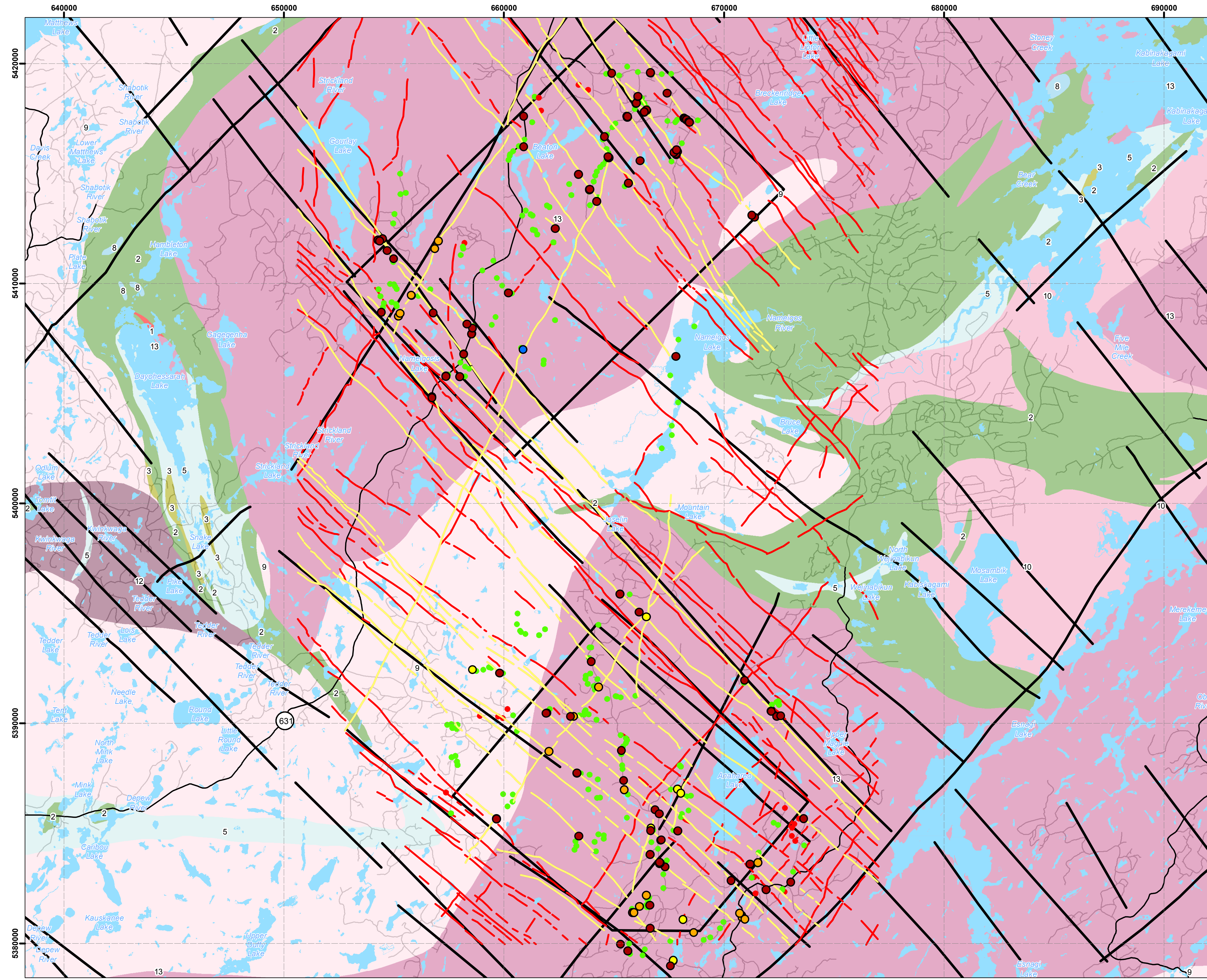

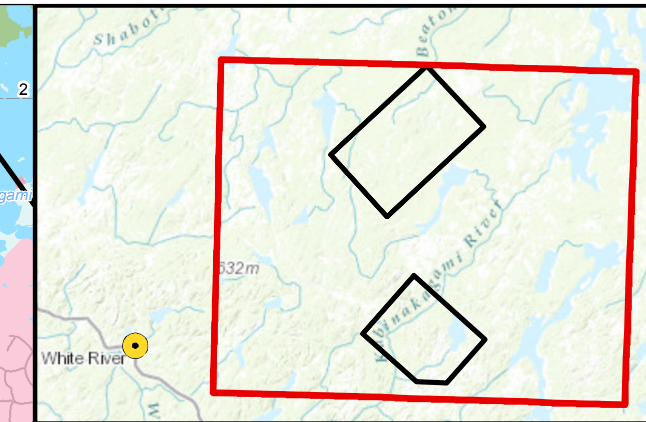

LEGEND

- Main Road
- Local Road
- Waterbody
- Withdrawal Areas
- Outcrop (354)
- Overburden (19)
- Mafic Dyke Lineaments
- Field Verified Mafic Dykes
- Geological Dyke
- Abitibi (1)
- Biscotasing (19)
- Marathon (7)
- Matachewan (81)

BEDROCK GEOLOGY

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

NOTES:

This drawing should be read in conjunction with the Amec Foster Wheeler Environment & Infrastructure Report No. TB154003.

SOURCE:
Base Data- MNR LIO, obtained 2009-2015, CANMAP v2006.4

CLIENT: nwmo NUCLEAR WASTE MANAGEMENT ORGANIZATION / SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

REVISION: v1.0

NAD 1983 Zone 16N

Drawn By:	LJM	15/06/2017
Checked By:	MS	15/06/2017

SCALE: 1:1,500,000

0 2 4 6 8 Kilometers

DETAILED MAPPING
White River Community

Distribution of Proterozoic Mafic Dykes

PROJECT N°: TB154003

DATE: June, 2017

FIGURE: **5.3.1**

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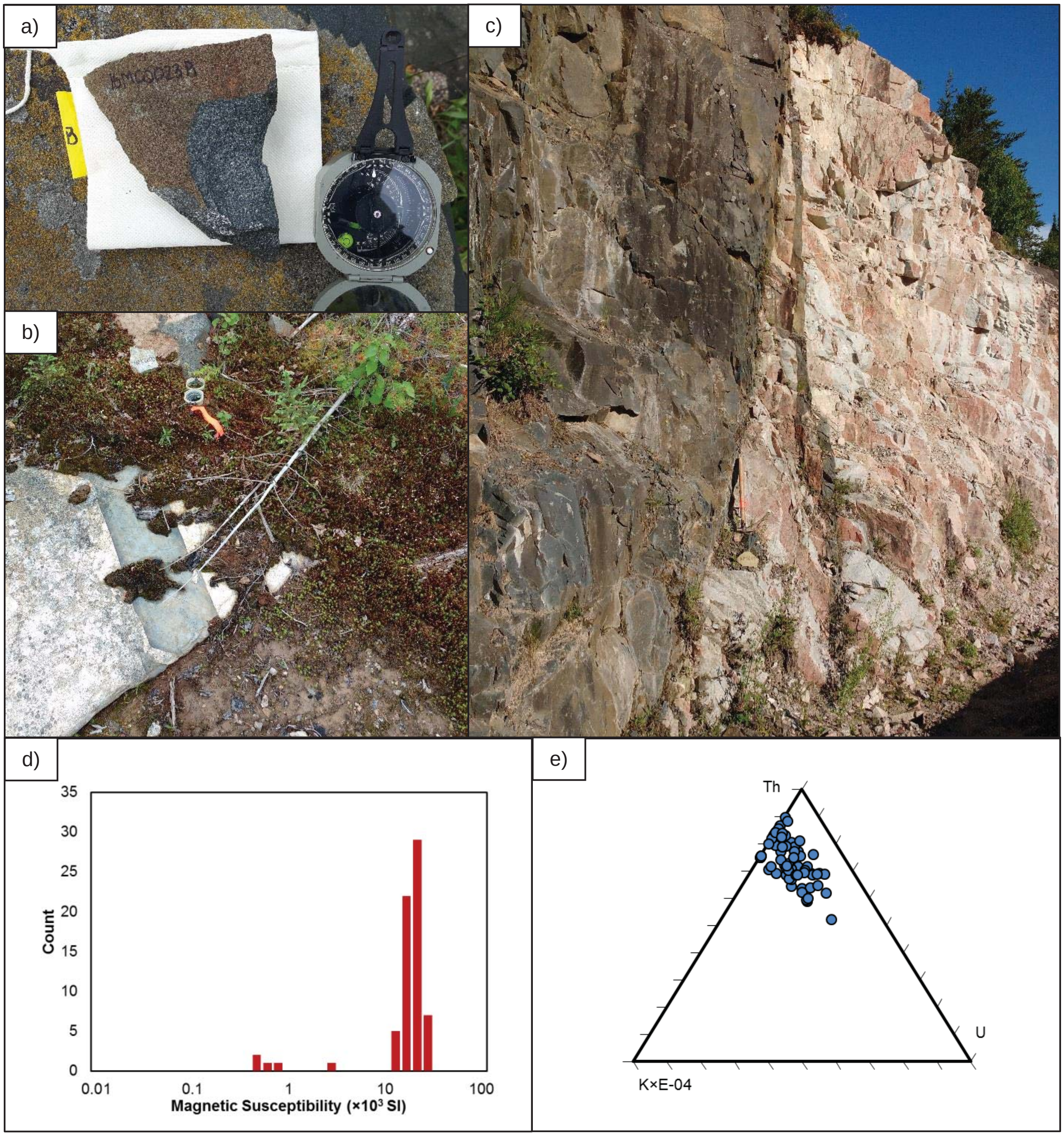

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f)

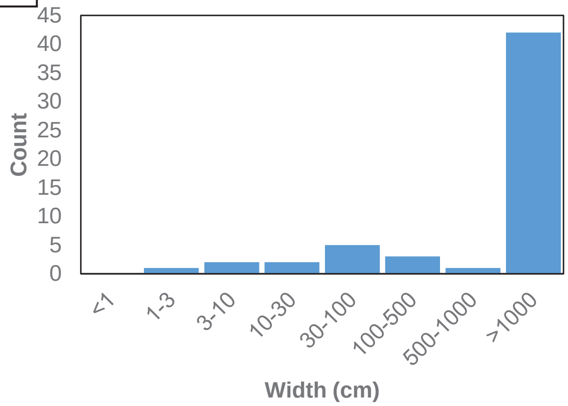
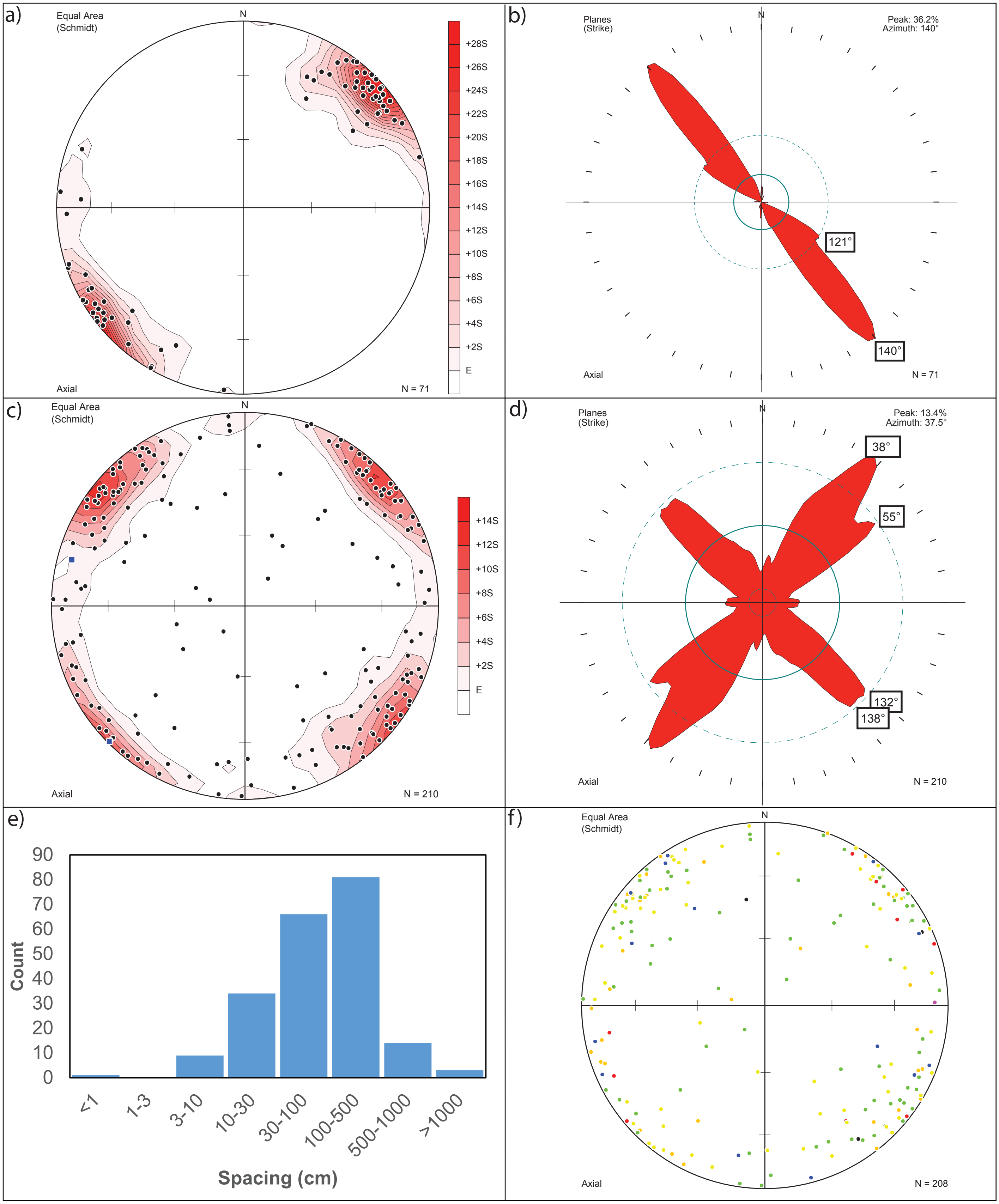


Figure 5.3.1.1 Matachewan Mafic Dykes in the White River Area

a) Sample of medium-grained Matachewan mafic dyke (Station 16MC0023; compass for scale, 22 cm long, points north)
b) Outcrop of 30 cm thick Matachewan mafic dyke cutting parallel to main dyke contact in tonalite (Station 16MC0023; compass for scale, 22 cm long, points north)
c) Large outcrop of Matachewan mafic dyke outcrop on Highway 613, northeast contact (Station 16MC0103; hammer for scale, 68 cm long, view to northwest)
d) Logarithmic plot of magnetic susceptibility (Matachewan mafic dykes, N=68)
e) Ternary plot of gamma ray spectrometer data (Matachewan mafic dykes, N=64)
f) Dyke minimum width (Matachewan mafic dykes, N=56)



a) All dyke contact data (N = 71) displayed as equal area lower hemisphere stereonet of poles to dyke contacts, with contours (Gaussian, K = 100)
b) All dyke contact data (N = 71) displayed as rose diagram of trends of contact planes
c) All within dyke fractures (N = 210; joints N = 208; faults N = 2) displayed as equal area lower hemisphere stereonet of poles to joint or fault plane with contours (Gaussian, K = 100) — classification: joint (black; dot), fault (blue; square)
d) All within dyke fractures (N = 210; joints, N = 208; faults, N = 2) displayed as rose diagram of trends of fracture planes
e) Joint spacing summary (N = 208)
f) All within dyke joints (N = 208) displayed as equal area lower hemisphere stereonet of poles to joint classified by joint spacing, in centimetres — classification: <1 (magenta), 3-10 (red), 10-30 (orange), 30-100 (yellow), 100-500 (green), 500-1000 (blue), >1000 (black)

CLIENT: nwmo	**DETAILED MAPPING** WHITE RIVER COMMUNITY
Drawn By: JS / Checked By: MS	Matachewan Mafic Dykes - Structure
Revision: V1.0	PROJECT N°: TB154003 / **FIGURE:** 5.3.1.2
	DATE: June, 2017
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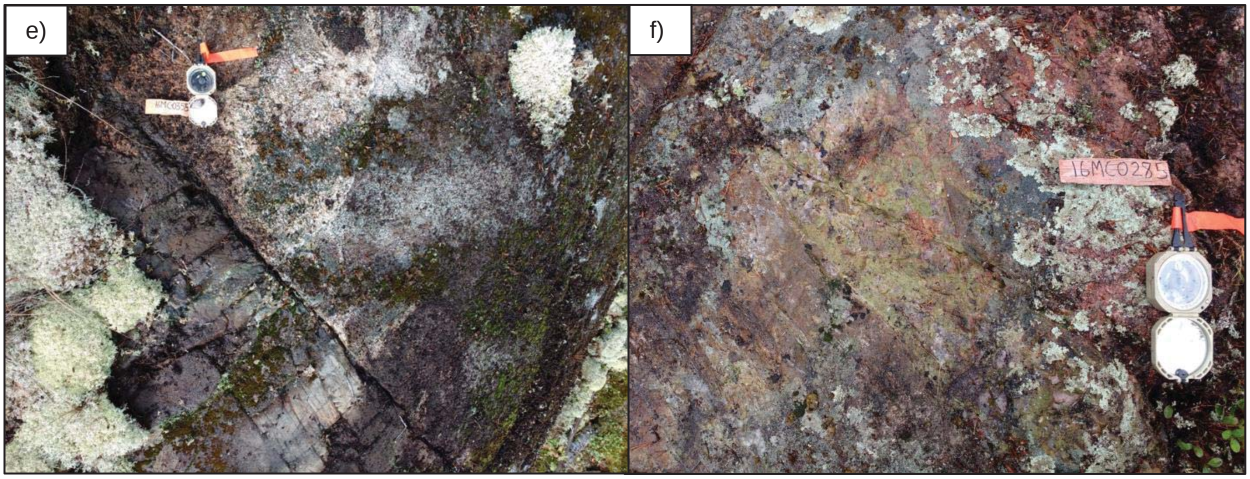


Figure 5.3.1.3 Matachewan Mafic Dykes – Field Examples of Structural Character

a) View to the east at the northeast contact of a 20 metre thick Matachewan mafic dyke exposed along Highway 613 in the Strickland pluton area. This contact shows only very minor evidence of reactivation in the form of increased joint density. Note near the top of the photo pieces of mafic dyke still attached to granodiorite (Station 16MC0021; hammer for scale 68 centimetres)

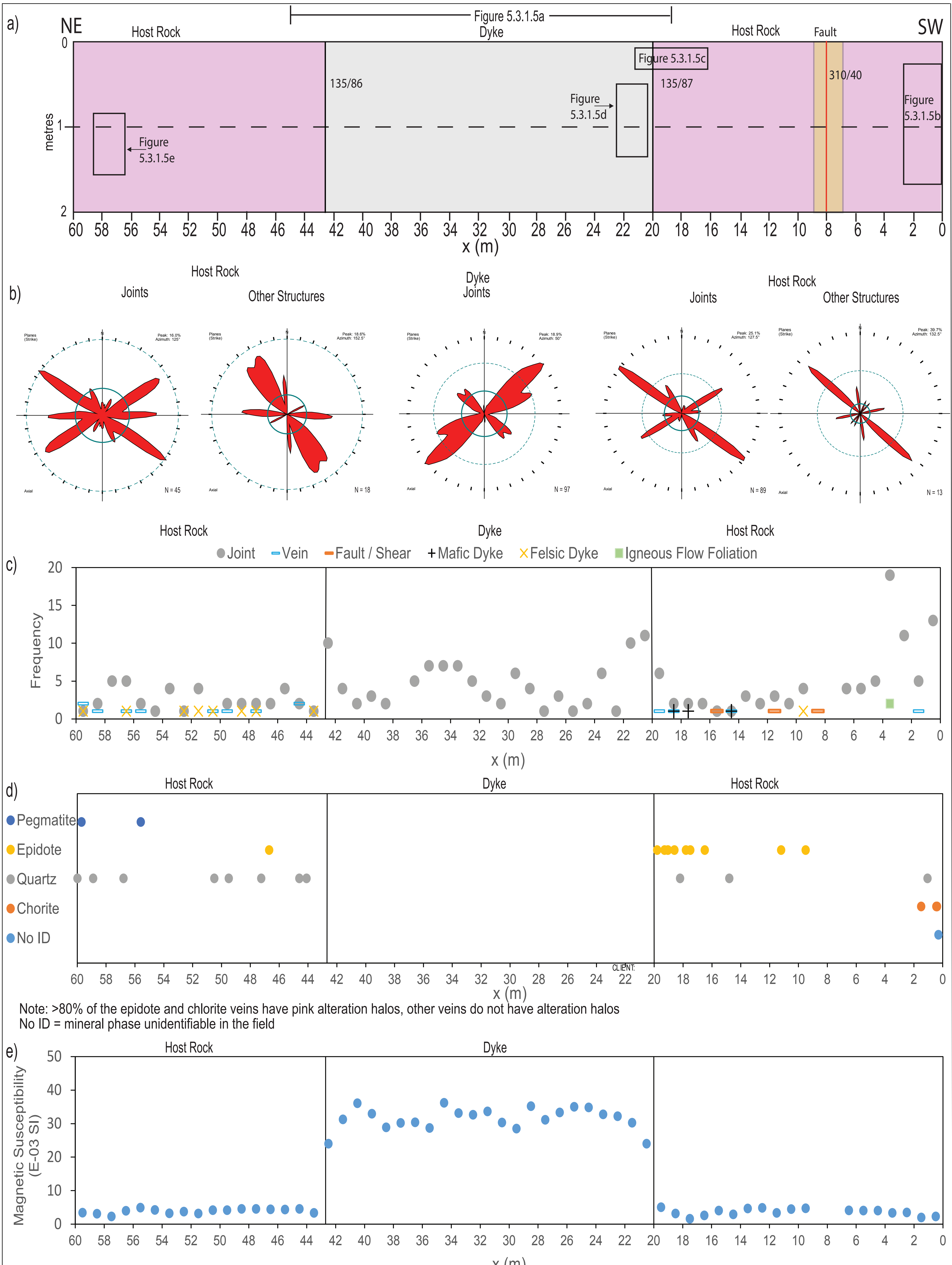
b) Example of an intact mafic dyke contact. Note a few joints cut perpendicular through the contact through both lithologies and post-date dyke emplacement (Station 16MC0089; compass for scale, 22 cm points long, points north)

c) Matachewan mafic dyke showing brittle reactivation of the dyke margin with presence of epithermal quartz veining along the contact (Station 16MC0025; compass for scale, 22 cm long, points north)

d) Example of a weakly reactivated Matachewan mafic dyke contact with several joints parallel to the dyke contact within the mafic dyke and the host rock. Dyke is to the southwest (lower left half) of the photo, foliated granite is the host rock to the upper right half of the photo (Station 16MC0019; compass for scale, 22 cm long, points north)

e) Example of a weakly reactivated Matachewan mafic dyke contact with open joint fracture along the contact showing separation of the contact, as well as several parallel joints within the adjacent mafic dyke rock only. Dyke is to the southwest (lower left half) of the photo, foliated granodiorite is the host rock to the upper right of the photo (Station 16MC0355; compass for scale, 22 cm long, points north)

f) Example of a strongly reactivated Matachewan mafic dyke contact with a 50 centimetre thick zone of hydrothermal alteration, epidote and quartz vein stockwork veining along the contact. The pink/orange rock to the upper right of the photo is hematite stained potassic altered granodiorite. Altered mafic dyke to the lower left has anomalously low magnetic susceptibility likely due to magnetite destruction (Station 16MC0285; compass for scale, 22 cm long, points north)



LEGEND

- Matachewan Mafic Dyke
- Granodiorite
- Overburden

a) Scanline Schematic
b) Rose Diagrams
c) Frequency of Structures
d) Fracture Infilling and Alteration
e) Magnetic Susceptibility

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DETAILED MAPPING
WHITE RIVER COMMUNITY

Composite Summary of Matachewan Mafic Dyke Scanline Results

Drawn By: JS	Checked By: MS
Revision: V1.0	

PROJECT Nº: TB154003
DATE: June, 2017
FIGURE: 5.3.1.4

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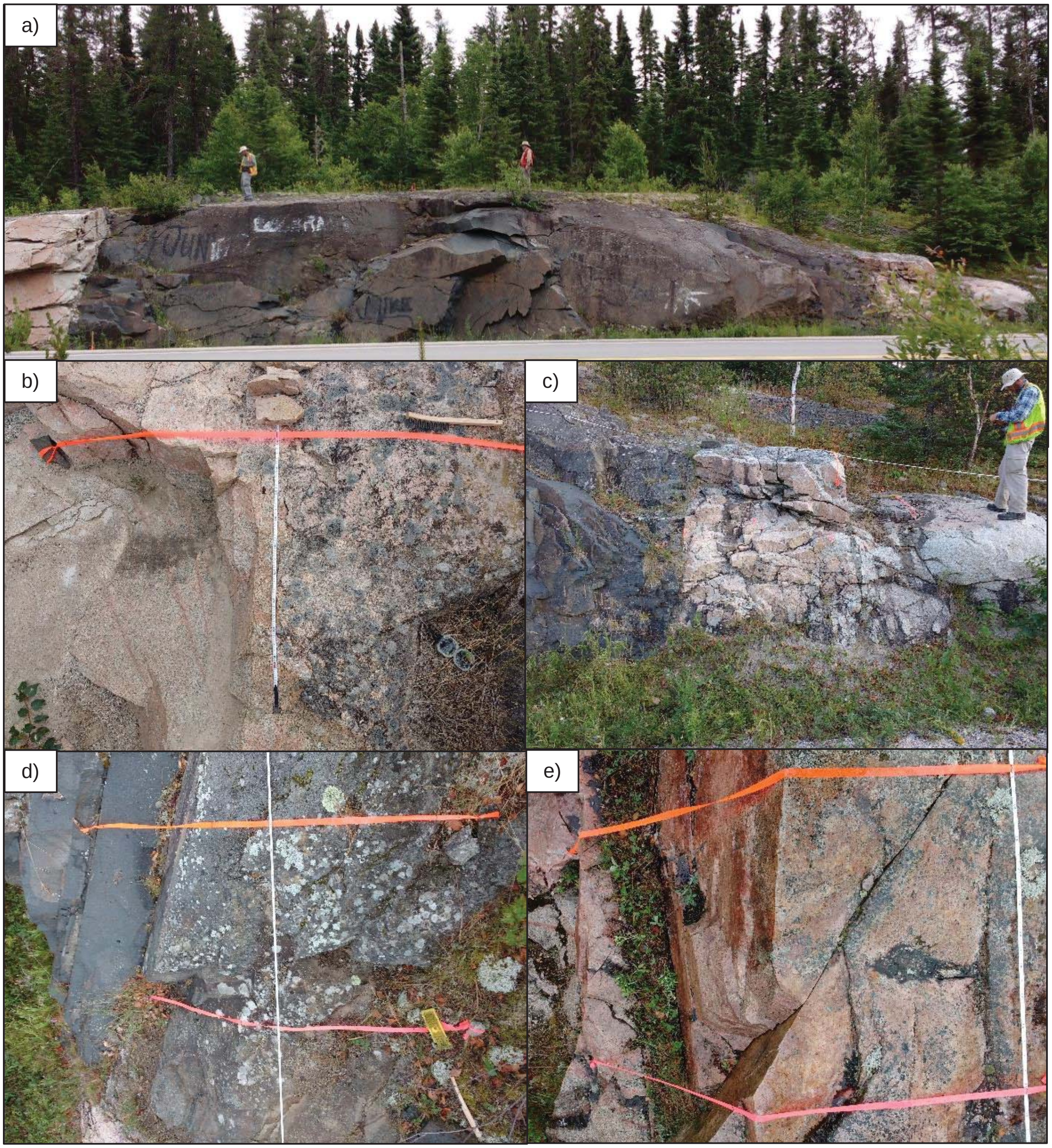


Figure 5.3.1.5 Matachewan Mafic Dyke Scanline Field Photographs

a) View to the southeast at the 22.7 metre wide Matachewan mafic dyke over which the scanline exercise was conducted. Measurements were made from right to left (southwest to northeast) and the entire section also includes 20 m of granodiorite on the right side and 17.3 m of the left side, totalling 60 m of measurement.

b) Scanline exercise first metre of measured area in granodiorite (Compass for scale, 22 cm long, points north)
c) View to the northeast at interval 16 metres to 21 metres from right to left across the southwest mafic dyke contact.
d) Scanline exercise mafic dyke interval 21 to 22 m lies between the two lines of flagging tape (top of photo is to the northeast)
e) Scanline exercise granodiorite interval 58 to 59 m lies between the two lines of flagging tape (top of photo is to the northeast)

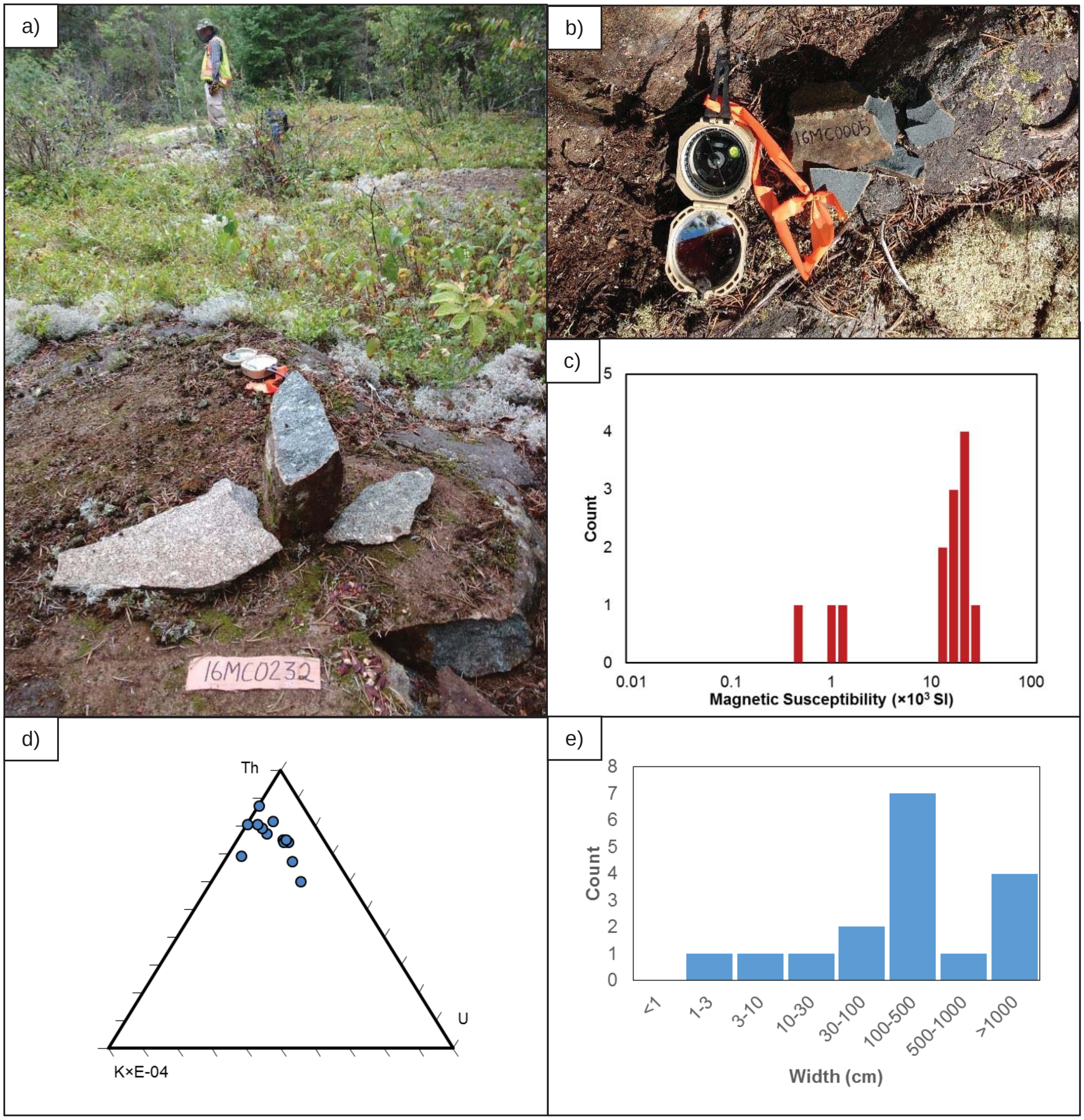
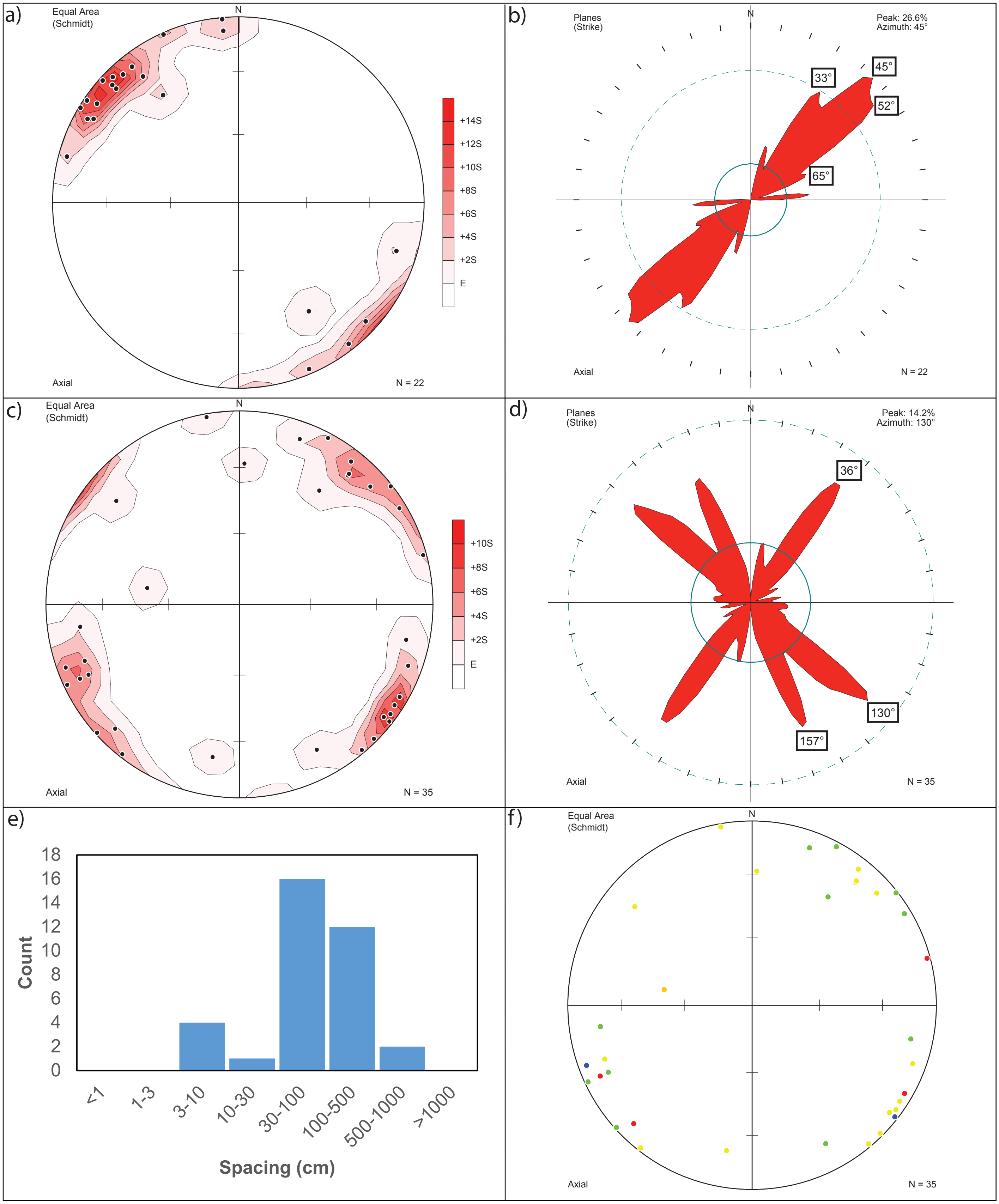


Figure 5.3.2.1 Biscotasing Mafic Dykes in the White River Area

a) Sample from margin of small (1 – 5 m wide) Biscotasing mafic dyke with no phenocrysts (Station 16MC0005; compass for scale, 22 cm long, points north)
b) Sample with very coarse-grained plagioclase phenocrysts in medium dark green matrix of small (1 – 5 m wide) Biscotasing mafic dyke (Station 16MC0232; compass for scale, 22 cm long, points north)

c) Logarithmic plot of magnetic susceptibility (Biscotasing mafic dykes, N=13)
d) Ternary plot of gamma ray spectrometer data (Biscotasing mafic dykes, N=13)
e) Dyke minimum width (Biscotasing mafic dykes, N=17)



a) All dyke contact data (N = 22) displayed as equal area lower hemisphere stereonet of poles to dyke contact with contours (Gaussian, K = 100)
b) All dyke contact data (N = 22) displayed as rose diagram of trends of contact planes
c) All within dyke joint data (N = 35) displayed as equal area lower hemisphere stereonet of poles to joint plane with contours (Gaussian, K = 100)
d) All within dyke joint data (N = 35) displayed as rose diagram of trends of joint planes
e) Joint spacing summary (N = 35)
f) All within dyke joints (N = 35) displayed as equal area lower hemisphere stereonet of poles to joint classified by joint spacing in centimetres –- classification: <1 (magenta), 3-10 (red), 10-30 (orange), 30-100 (yellow), 100-500 (green), 500-1000 (blue), >1000 (black)

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Drawn By: JS / Checked By: MS	Bicotasing Mafic Dykes - Structure
Revision: V1.0	PROJECT N°: TB154003 / FIGURE: 5.3.2.2
	DATE: June, 2017
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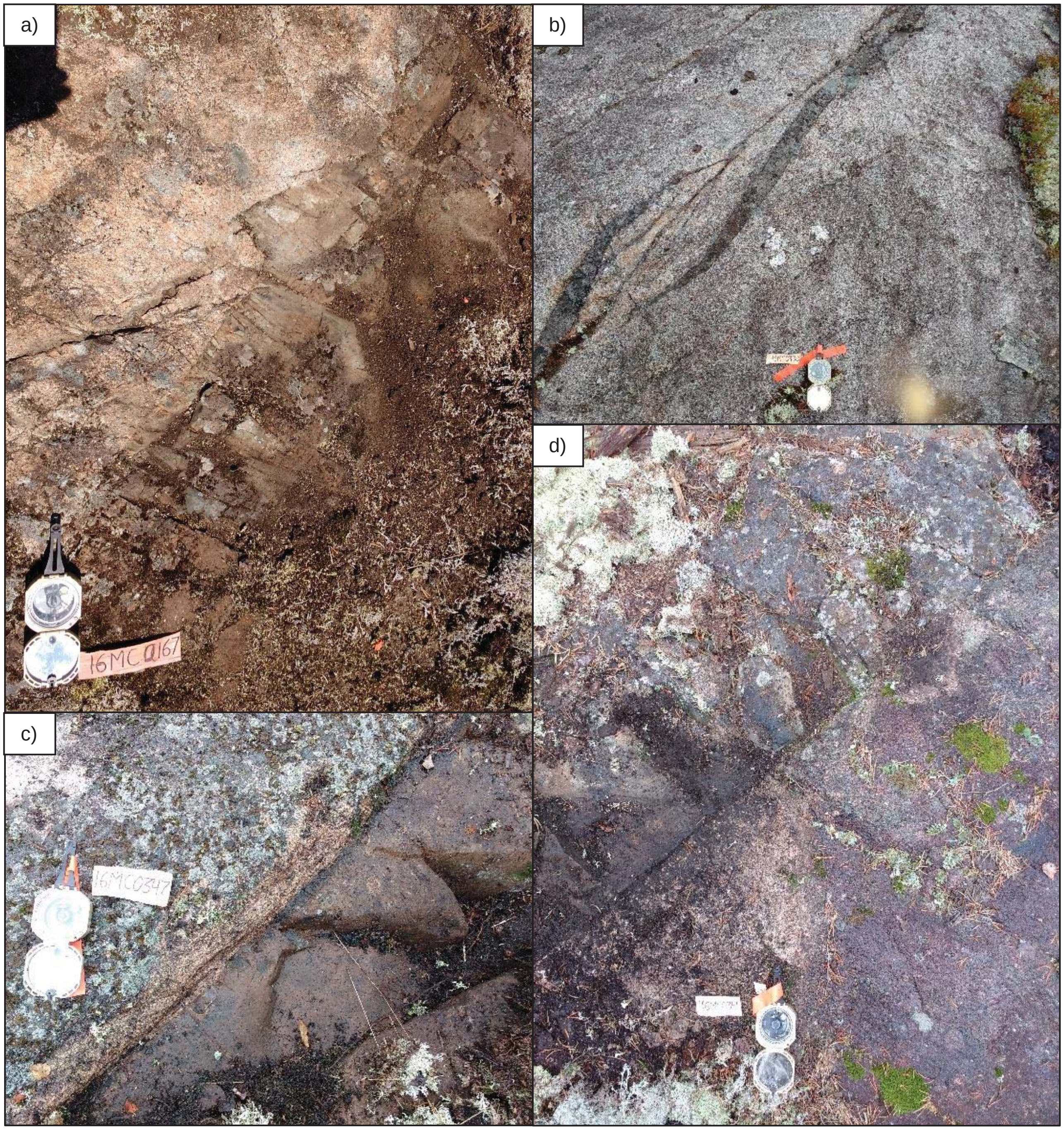

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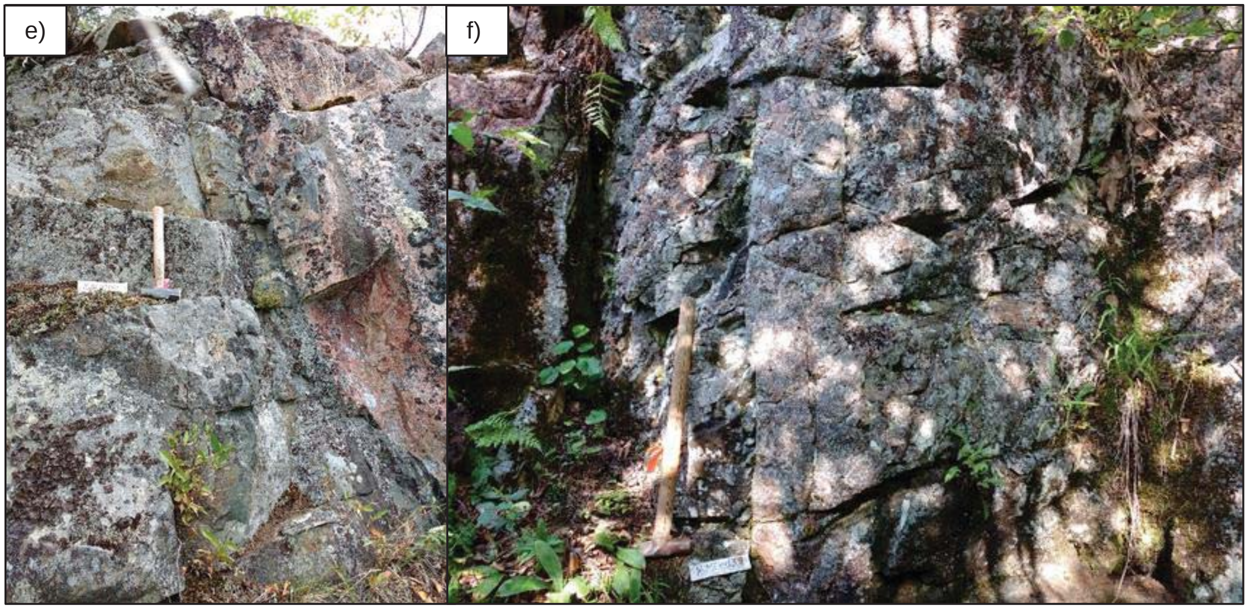


Figure 5.3.2.3 Biscotasing Dykes – Field Examples of Structural Character

a) Left-stepping jog in Biscotasing mafic dyke contact and closely spaced joints in dyke perpendicular to dyke margin (Station 16MC0167; compass for scale, 22 cm long, points north)
b) Thin northeast-striking mafic dyke veinlets of Biscotasing mafic dyke appear to be inflating a pre-existing dextral strike slip fault zone (Station 16MC0338; compass for scale, 22 cm long, points north)
c) Intact northwest contact of a Biscotasing mafic dyke with chilled margin and no evidence of brittle re-activation (Station 16MC0347; compass for scale, 22 cm long, points north)
d) Intact southeast contact of a Biscotasing mafic dyke with no evidence of brittle re-activation (Station 16MC0341; compass for scale, 22 cm long, points north)
e) Example of a weakly reactivated Biscotasing mafic dyke with several parallel joints occur along the margin of the mafic dyke and minimal jointing within the dyke (Station 16MC0200; hammer for, scale 37 cm long, view to the northeast)
f) Example of a moderately reactivated Biscotasing mafic dyke contact with several open fractures, and joints parallel to the vertically-oriented dyke contact (Station 16MC0139; hammer for scale, 68 cm long, view to the northeast)

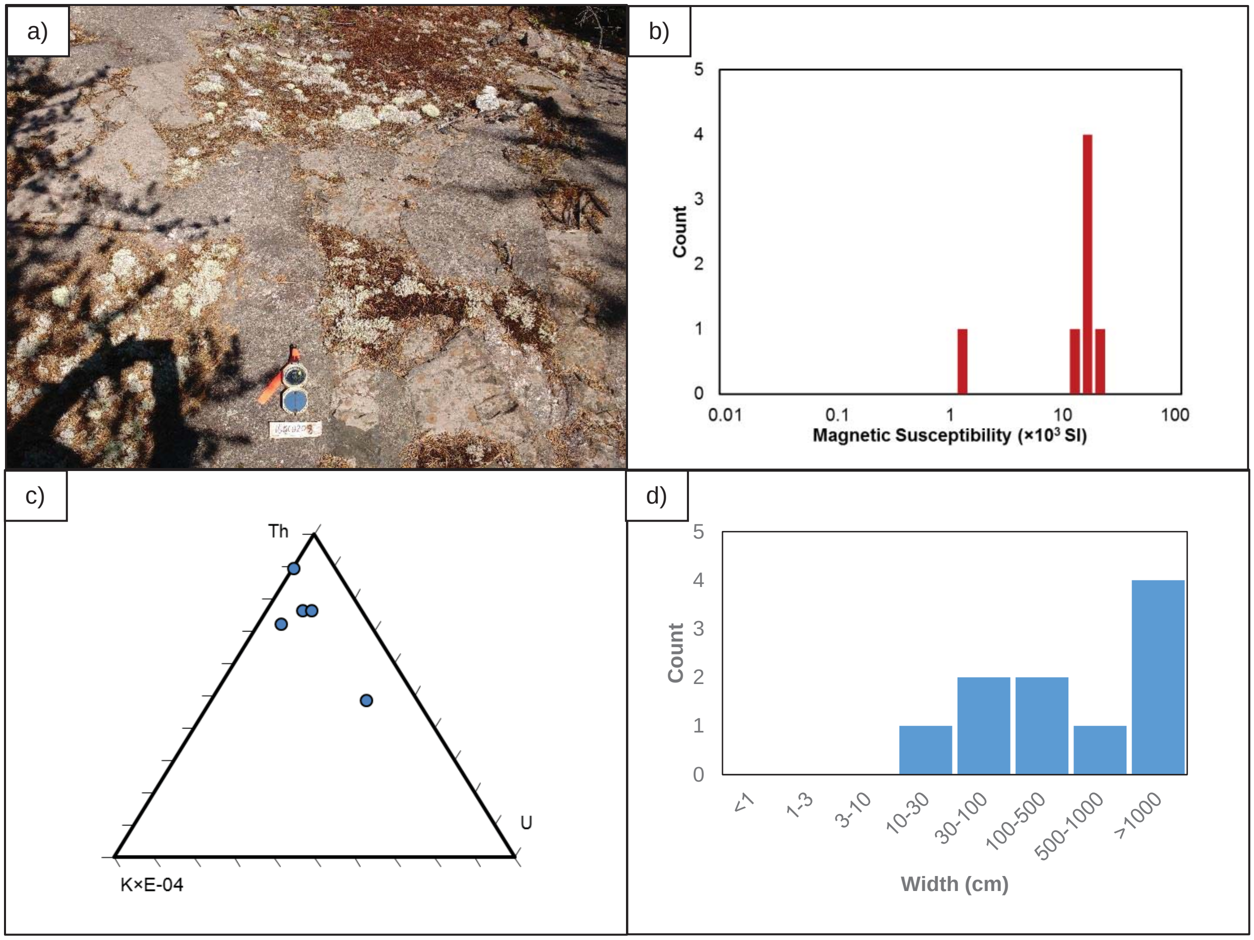
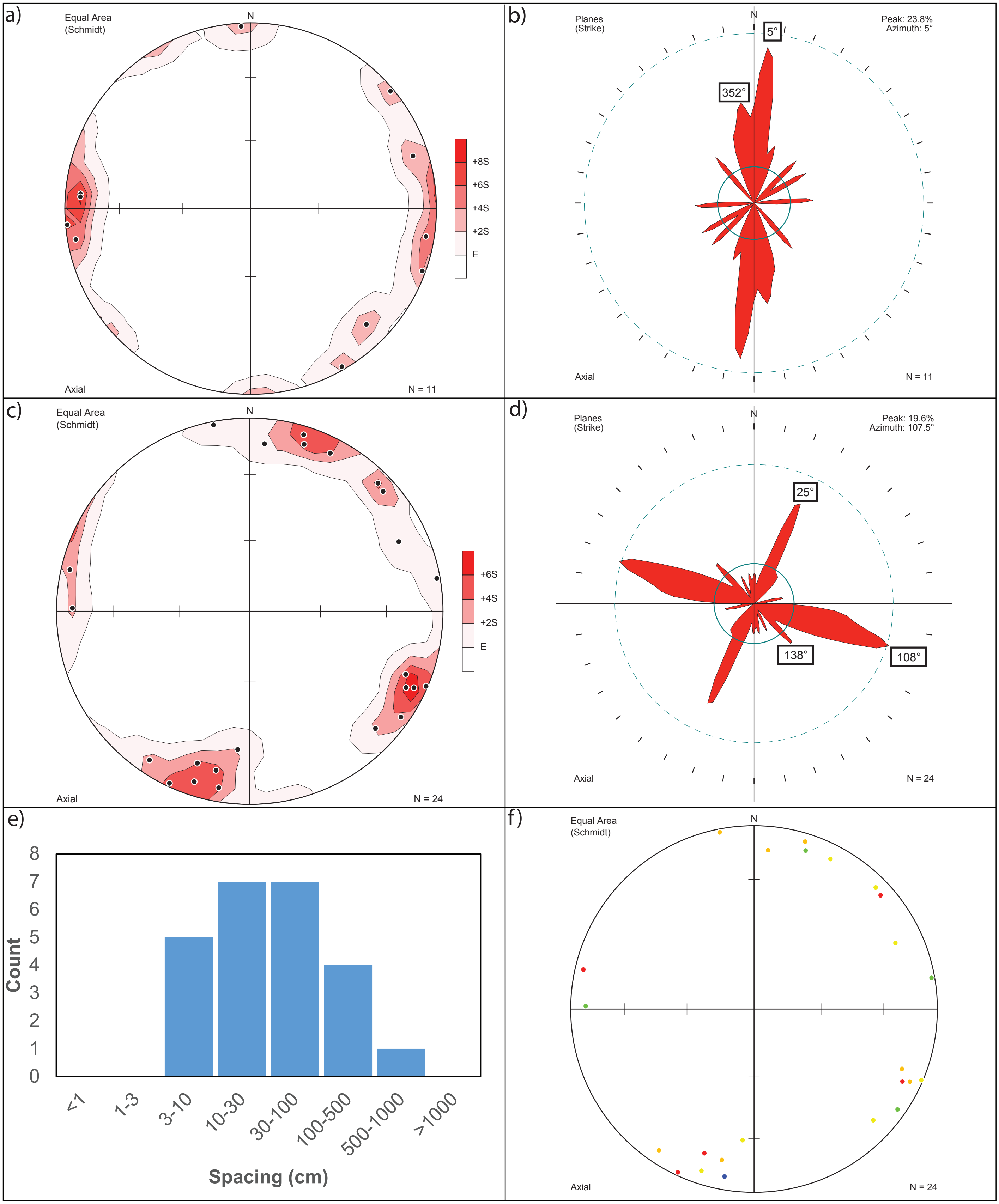


Figure 5.3.3.1 Marathon Mafic Dykes in the White River Area

a) Outcrop of two parallel, thin, north-trending Marathon mafic dykes (Station 16MC0208; compass for scale, 22 cm long, points north)
b) Logarithmic plot of magnetic susceptibility (Marathon mafic dykes, N=7)
c) Ternary plot of gamma ray spectrometer data (Marathon mafic dykes, N=5)
d) Dyke minimum width (N=10)



a) All dyke contact data (N = 11) displayed as equal area lower hemisphere stereonet of poles to dyke contact with contours (Gaussian, K = 100)
b) All dyke contact data (N = 11) displayed as rose diagram of trends of contact planes
c) All within dyke joint data (N = 24) displayed as equal area lower hemisphere stereonet of poles to joint plane with contours (Gaussian, K = 100)
d) All within dyke joint data (N = 24) displayed as rose diagram of trends of joint planes
e) Joint spacing summary (N = 24)
f) All within dyke joints (N = 24) displayed as equal area lower hemisphere stereonet of poles to joint classified by joint spacing in centimetres –- classification: <1 (magenta), 3-10 (red), 10-30 (orange), 30-100 (yellow), 100-500 (green), 500-1000 (blue), >1000 (black)

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DETAILED MAPPING
WHITE RIVER COMMUNITY

Marathon Mafic Dykes - Structure

Drawn By: JS	Checked By: MS
Revision: V1.0	

PROJECT N°: TB154003
DATE: June, 2017

FIGURE: 5.3.3.2

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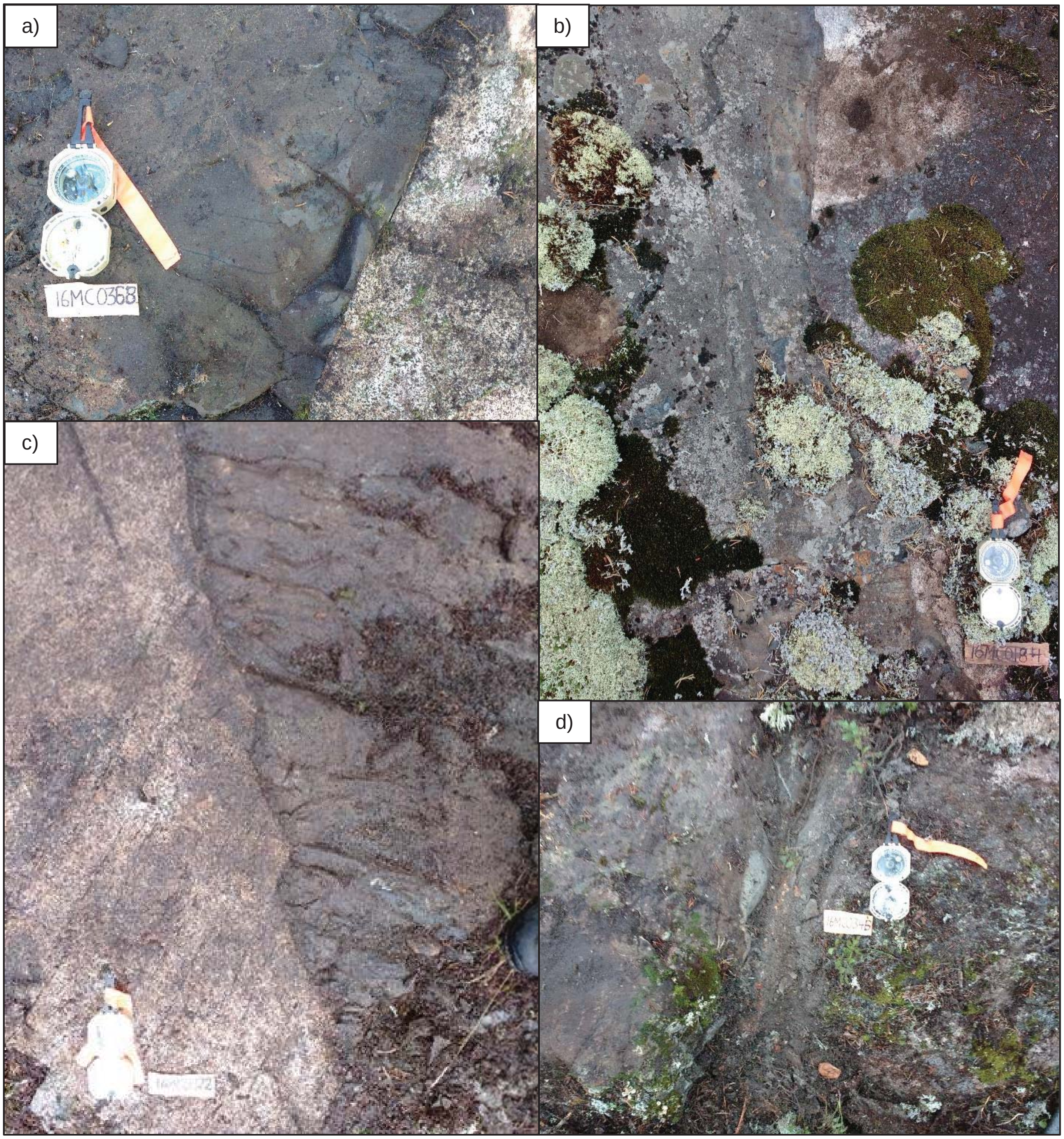
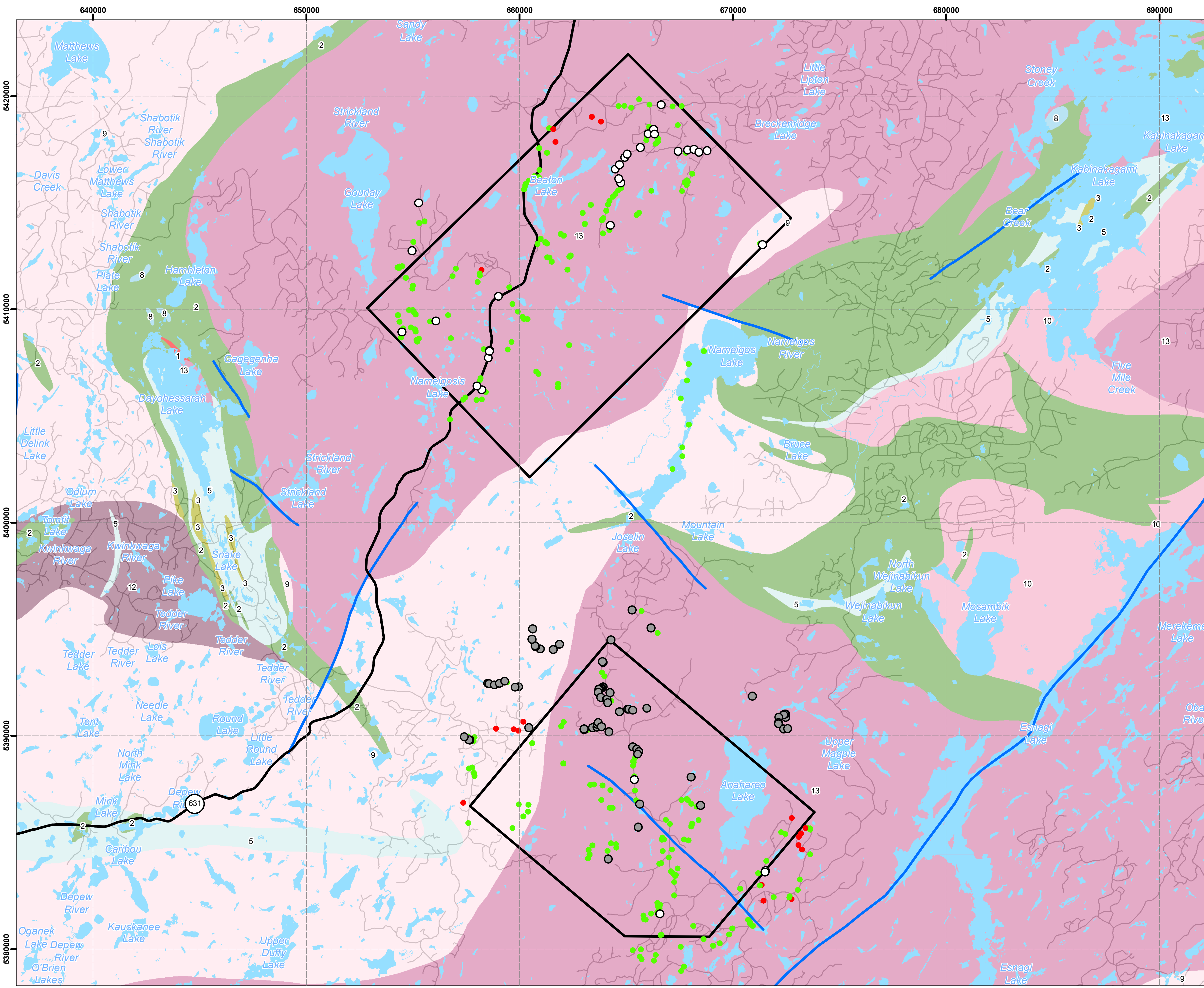
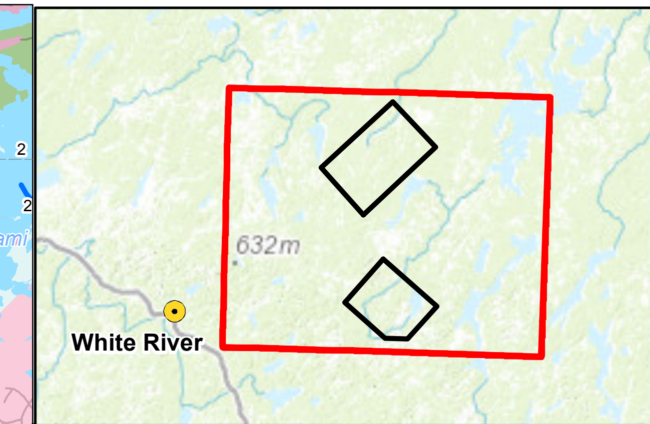


Figure 5.3.3.3 Marathon Dykes – Field Examples of Structural Character

a) North-northeast-trending segment of a Marathon mafic dyke with no evidence of a chill margin and few contact-parallel joints (Station 16MC0368; compass for scale, 22 cm long, points north)
b) Intact north-trending segment of a Marathon mafic dyke with no evidence of brittle re-activation along contact (Station 16MC0184; compass for scale, 22 cm long, points north)

c) North-northwest-trending segment of a Marathon mafic dyke showing irregular dyke contacts or jogs occurring where the dyke intersected pre-existing joints within the adjacent granite (Station 16MC0322; compass for scale, 22 cm long, points north)
d) North-trending segment of a Marathon mafic dyke with contact obscured, but with closely spaced joints at dyke contact (Station 16MC0346; compass for scale, 22 cm long, points north)





LEGEND

- Withdrawal Areas
- Main Road
- Local Road
- Waterbody
- Outcrop (354)
- Overburden (19)
- Geologic Fault
- Felsic and Intermediate Dykes and Sills (38)
- Granite Pegamatite (62)

BEDROCK GEOLOGY

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

NOTES:

This drawing should be read in conjunction with the Amec Foster Wheeler Environment & Infrastructure Report No. TB154003.

SOURCE:
Base Data- MNR LIO, obtained 2009-2015, CANMAP v2006.4

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REVISION:	v1.0	
NAD 1983 Zone 16N		
Drawn By:	LJM	15/06/2017
Checked By:	MS	15/06/2017
SCALE: 1:2,000,000		

N S W E

0 30 60 90 120 Kilometers

DETAILED MAPPING
White River Community

Distribution of Felsic and Intermediate Dykes and Sills

PROJECT N°:	TB154003	FIGURE:	5.3.4.1
DATE:	June, 2017		

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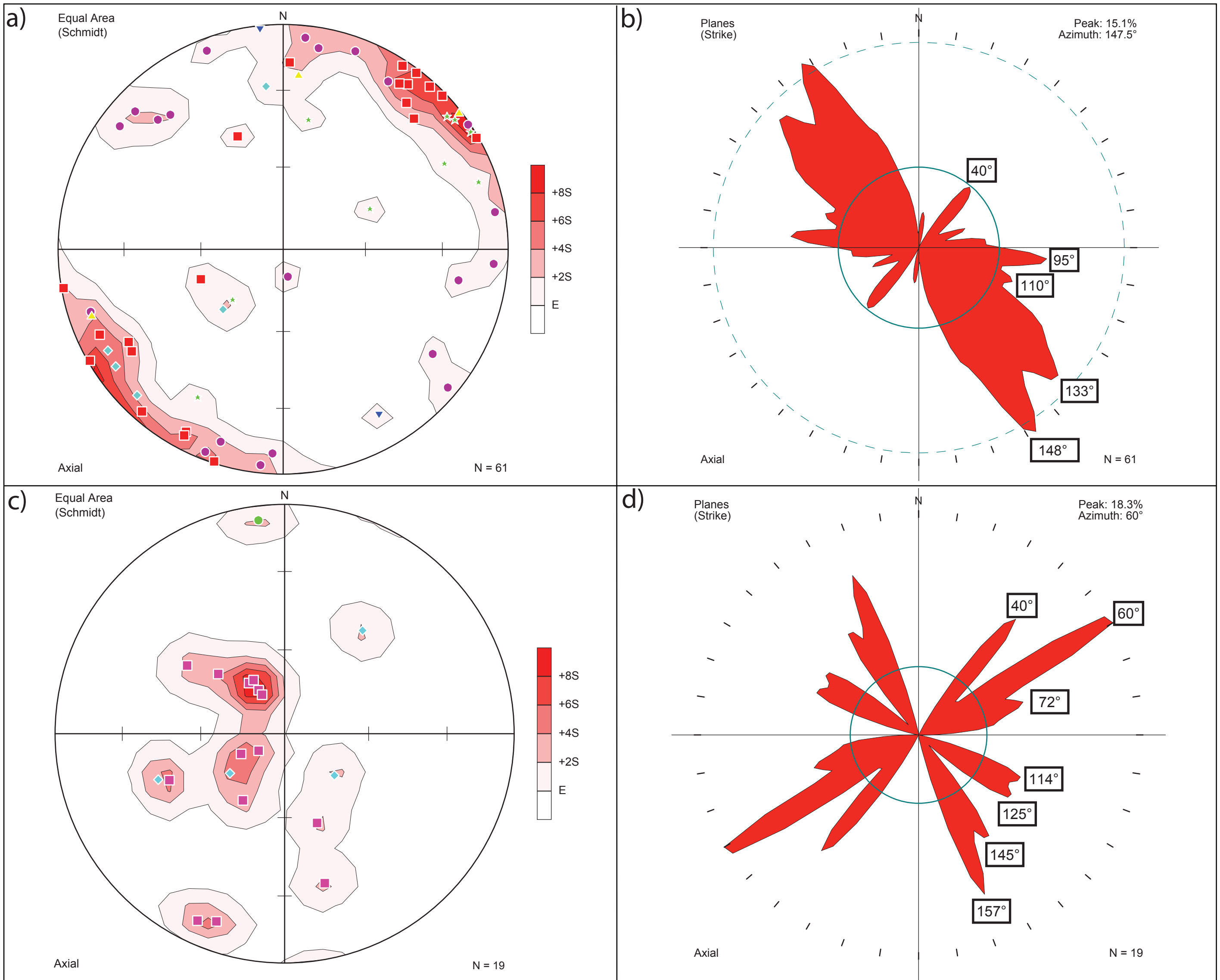

a) All felsic and intermediate dyke and sill data from the Strickland pluton area (N = 61) displayed as poles to dyke / sill contact plane with contours (Gaussian, K = 100) – classification: aplite (magenta; big circle), diorite (blue; triangle pointing down), unspecified felsic (light blue; diamond), granodiorite (green; star), unspecified intermediate (yellow; triangle pointing up); tonalite (red; big square)
b) All felsic and intermediate dyke and sill data from the Strickland pluton area (N = 61) displayed as rose diagram of trends of dyke / sill contact plane
c) All felsic dyke and sill data from the Anahareo Lake pluton area (N = 19) displayed as poles to dyke / sill contact plane with contours (Gaussian, K = 100) – classification: pegmatite (magenta; big square), unspecified felsic (light blue; diamond), granodiorite (green; star), granite (green; big circle)
d) All felsic dyke and sill data from the Anahareo Lake pluton area (N = 19) displayed as rose diagram of trends of dyke / sill contact plane

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Drawn By: JS / Checked By: MS	Felsic and Intermediate Dykes and Sills - Structure
Revision: V1.0	PROJECT N°: TB154003 / **FIGURE:** 5.3.4.2
	DATE: June, 2017
	Amec Foster Wheeler Environment & Infrastructure, 3450 Harvester Rd, Suite 100., Burlington, Ontario, L7N 3W5, tel: 905-335-2353 www.amecfw.com

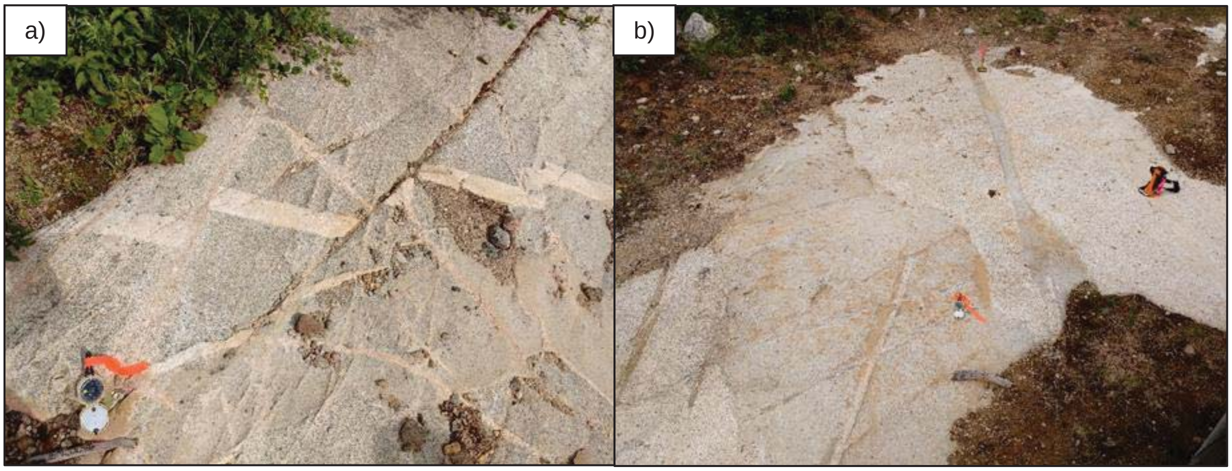

Figure 5.3.4.3 Felsic Dykes – Field Examples of Structural Character

a) Felsic aplite veins and dykes cut by brittle sinistral northeast-striking faults, view looking north (Station 16MC0094; compass for scale, 22 cm long, points north)
b) North-northwest-trending felsic dyke approximately 1 metre thick cut by north-northeast-trending aplite vein, view looking north (Station 16MC0051; compass for scale, 22 cm long, points north)

APPENDIX A

METHODOLOGY SECTION: SUPPORTING TABLES

Table A.1 Source Data Descriptions

Source Data	File Name	Format
Withdrawal areas	White_River_WithdrawalAreas_r1.shp	ESRI Shapefile
Candidate areas	White_River_ CandidateAreas_r2.shp	ESRI Shapefile
Water bodies	White_River_Water.gdb	ESRI Geodatabase
Roads network	Hornepayne_FMURoadsNagagami_r0.shp White_River_FMURoadsMagpieandWhiteRiver_r0.shp	ESRI Shapefile
Other base map data	White_River_Base_Map.gdb White_River_Earthquakes.gdb White_River_Natural_Resources_Potential.gdb White_River_Project_data.gdb White_River_Topography.gdb White_River_Wells.gdb	ESRI Geodatabase
Overburden	White_River_Quaternary_Geology.gdb	ESRI Geodatabase
Forest Resources Inventory (FRI) Imagery	WhiteRiver_RGB_8bit.tif	Tif
Geophysics - raw	WR_1VDRTP.grd WR_2VDRTP.grd WR_DEM.grd WR_MAG_RTP.grd WR_TILT.grd	Geosoft Grid
Geophysics - interpreted	White_River_Gravity_Anomalies.shp White_River_Gravity_Polylines.shp White_River_Magnetic_Anomalies.shp White_River_Magnetic_Polylines.shp	ESRI Shapefile
Bedrock Geology	White_River_Bedrock_Geology_v2.gdb	ESRI Geodatabase
Predicted outcrop locations	White_River_Outcrops_Filtered_v3.shp	ESRI Shapefile
Protected Areas	White_River_Protected_Areas.gdb	ESRI Geodatabase
Lineaments	White_River_Phs2Ext_MAG_Lins_Final_20160602_r1.shp White_River_Phs2Ext_SURFICIAL_Lins_Final_20160602_r1.shp	ESRI Shapefile

Note all geospatial files are projected to NAD-83 UTM Zone 16N

Table A.2 Equipment Requirements

Equipment	Calibration Required
Compass (Brunton Pocket Transit or similar)	Y – Check magnetic declination setting daily see Table 4 below)
Digital Camera	N
Trimble*	Y – monitor GPS position error (PDOP) throughout day, check against known map features, check with backup GPS
ArcPad software*	Y – daily check of newly uploaded data against master file database.
Magnetic Susceptibility Meter (KT-10 or KT-20)	Y – Calibrated by supplier before rental and upon return from rental period / daily check of reading at a reference rock outcrop. Certificate of Calibration to be provided by supplier and provided to NWMO.
Gamma Ray Spectrometer (RS-125 or equivalent)	Y – Calibrated by supplier before rental and upon return from rental period. Certificate of Calibration to be provided by supplier and provided to NWMO.
Weather proof notebook and Pen	N
Handheld GPS	N
Geological Hammer and rock chisel	N
Rock sample Bags	N
Personal Protective Equipment (see Amec Foster Wheeler, 2016b)	N

* Calibration requirements as work instruction TB154003 WI-1 of Amec Foster Wheeler (2016a)

** Daily check / confirmation of correct magnetic declination. Adjust compasses to within ½ degree of true declination. Declination in the White River area changes approximately ½ degree over 45 kilometres.

Table A.3 Task Allocation

Task	Responsibility
Daily safety briefing	Field Geologist
Daily equipment calibration	Field Geologist
Host rock lithology characterization	Lead Field Geologist
Host rock structural characterization	Lead Field Geologist
Digital photographs	Lead Field Geologist
Fracture characterization	Lead Field Geologist
Lineament observation/assessment	Lead Field Geologist
Digital data input	Lead Field Geologist
Manual (pencil and paper) note transcription	Lead / Field Geologist
Magnetic susceptibility measurements	Assistant Field Geologist
Rock strength assessment - Hammer test	Assistant Field Geologist
Bedrock overburden assessment	Assistant Field Geologist
Sample collection (if necessary)	Assistant Field Geologist
Surface constraint assessment	Lead / Assistant Field Geologist
Identification of potential detailed mapping areas	Lead Geologist
Daily QC verification of notebook with digital entry for two locations for each team	Lead/ Assistant Field Geologist
Daily log write-up and transmittal	Assistant Field Geologist
Daily data back-up (and back-up for the back-up)	Lead Geologist
Daily data transmittal for office QA/QC	Assistant Field Geologist
Office QA/QC	Geoscientist (Quality Management Lead)
Planning the next day traverse	Lead Geologist

Table A.4 Key General and Geological Attributes Characterized During Observing General Geological Features and Detailed Geological Mapping

		Characterization Method(s)
General Attributes	**Outcrop Location**	• Geo-locate exposed bedrock observation locations using GPS • Take representative digital photograph of outcrop area
	Bedrock exposure and overburden thickness	• Visually inspect the distribution and thickness of overburden vs. exposed bedrock during the daily traverse (in comparison to existing understanding)
	Surface Constraints	• Visually identify and geo-locate any surface constraints that would create challenges for further geological characterization activities (e.g., bridge wash-outs, poorly or unmaintained logging roads, beaver dams, steep and deep (impassable) valleys, etc.) • Visually identify access issues in areas without mapped roads or navigable waterways
Geological Attributes: Bedrock Characteristics	**Lithology**	• Visually inspect weathered and fresh rock surfaces for identification of major and minor lithological units and their constituent colour, primary minerals (e.g., granitic rocks have varying proportions of quartz, K-feldspar and plagioclase plus other minerals including micas, hornblende, etc.), grain size, texture, etc. • Name the lithological unit(s) in terms of relative abundance at the outcrop scale • Collect a representative sample(s) of the dominant lithological unit(s) at each outcrop (will require use of hammer and chisel only; fist-sized piece with both weathered and fresh surface) • Take digital photographs of representative lithological unit(s) across the area of interest [documentation will include (at a minimum), file name, scale, GPS coordinates, direction of view and description of the photo.]
	Primary and Ductile Structure	• Observe and document the bedrock structural features (e.g., bedding, foliations, lineations, folds and shear zones) • Take digital photographs/make field sketches of representative key structural features • Measure and document (by hand with compass-clinometer and subsequent digital and manual entry) • Strike and dip of planar structures

		Characterization Method(s)
		• Trend and plunge of linear structures • Orientations of fold hingelines and axial surfaces
	Geophysical and Geomechanical Character	• Record 5 magnetic susceptibility measurements for each identified lithological unit (KT10 magnetic susceptibility meter used) • Undertake gamma ray readings for each identified lithological unit using a gamma ray spectrometer (RS-125 used) • Undertake field rock strength test on representative lithologies at each station and in spatial relation to identified structural features (i.e. lineaments, fracture zones, dykes)

Geological Attributes: Fracture Characteristics		• Visually inspect the rock surface for identification of systematic fracture sets
		• Characterize fracture sets by type (joints, faults, veins, altered wallrock around fractures)
		• Measure and document (by hand with compass-clinometer and subsequent digital and manual entry)
		  ◦ Strike and dip of planar structures
		  ◦ Trend and plunge of linear structures on fracture planes
		• Document
		  ◦ Fracture mineral filling
		  ◦ Abutting, cross-cutting and intersection (relative age) relationships between fracture sets
		  ◦ Displacement (strike separations and dip separations if visible)
		  ◦ Fracture surface ornamentation
		  ◦ Fracture set spacing
		• Undertake block size analysis based on outcrop fracture geometry and spacing
		• Take representative digital photograph(s) as needed to show key fracture characteristics, for example cross-cutting relationships, damage zone width, alteration, mineral infill

Geological Attributes: Dyke Characteristics		• Visually inspect dyke for characteristic features (e.g., mineralogy, colour) • Collect a representative sample of each dyke type • Take representative digital photograph of dyke, including contact relationship with bedrock, if exposed • Document

		Characterization Method(s)
		• Internal structure (fractures) • Width • Orientation (strike and dip along bedrock contact) • Nature of bedrock contact (e.g., welded, fractured, sheared, altered, extent of damage, etc.)
	Geophysical and Geomechanical Character	• Record 5 magnetic susceptibility measurements for each identified dyke • Undertake gamma ray readings for each identified dyke • Undertake field rock strength test on each dyke

Notes:

- All observations recorded in digital format with manual (pen and paper) backup for most pertinent field observations only, unless required due to digital device failure.
- Samples stored in bags numbered in accordance with the sample number generated in the database.
- Strike and dip measurements follow Canadian right-hand-rule notation.
- Effort was made to characterize fractures of all dip magnitudes (including horizontal to shallow dipping features)

Table A.5 Field Estimates of Intact Rock Strength

Grade	Description	Field identification
R6	Extremely strong	Specimen can only be chipped with a geological hammer
R5	Very strong	Specimen requires many blows of a geological hammer to fracture it
R4	Strong	Specimen requires more than one blow of a geological hammer to fracture it
R3	Medium strong	Cannot be scraped or peeled with a pocket knife, specimen can be fractured with a single blow from a geological hammer
R2	Weak	Can be peeled with a pocket knife with difficulty, shallow indentation made by firm blow with point of a geological hammer
R1	Very weak	Crumbles under firm blows with a geological hammer, can be peeled by a pocket knife
R0	Extremely weak	Indented by thumbnail
Note: From Barton (1978)		

APPENDIX B

Remote Predictive Bedrock Analysis

Potential outcrop locations were identified through an automated object based image analysis (OBIA), filtered, and prioritized for use in planning and implementing the Phase 2 Geological Mapping in the White River area of Ontario. This work involved 2 main tasks: 1) automated OBIA and 2) manual filtering of OBIA results to produce an output of potential outcrop locations.

Object Based Image Analysis using eCognition

Automated OBIA was conducted using Trimble's eCognition 9.1 software for the two withdrawal areas identified for detailed mapping in the White River area. Forest Resource Inventory (FRI) orthoimagery of the White River area, from 2009, was the primary dataset used in the analysis. FRI imagery is 4-band (red, green, blue, near infra-red) multi-resolution, 40 cm airborne imagery collected and used for forest resource purposes by the Ministry of Natural Resources.

A ruleset was developed in eCognition which initially employed multi-resolution segmentation to develop small image objects of almost pixel size. Through a series of iterative steps, the ruleset was refined and the small image objects were merged into larger more identifiable objects of distinct classes. Areas of water were classified first, followed by those areas that are spatially and spectrally similar to exposed bedrock, such as unpaved road surfaces, sand covered areas and brightly reflecting bogs. The remaining image objects were considered to most likely represent exposed outcrop and output as a distinct data set. This raw eCognition output provided a framework for remotely interpreting the location of probable bedrock outcrops in the four potentially suitable areas.

Filtering of OBIA results

It is understood that similarities in spectral response of areas of ground cover versus areas of exposed bedrock in the White River area results in instances of false positive exposed bedrock classification when classifying by means of OBIA. In order to use the remotely predicted outcrop data set in a meaningful way for detailed outcrop mapping an additional step of manually comparing the raw output, against the FRI imagery, was required.

The process to undertake this filtering was straightforward and involved examining the FRI imagery in areas where the eCognition output showed clusters of pixels locating possible exposed bedrock. The cluster area was visually evaluated in the FRI imagery and a determination by consensus of two or more individual interpreters was made as to whether the location in question did or did not likely represent actual exposed bedrock. If it was determined likely, then the location was outlined and defined as a unique polygon. This analysis produced a set of shapefiles of polygons representing interpreted priority outcrop locations, for both withdrawal areas in the White River area (see Figure 1.2 from main report). The planning for the Phase 2 Geological Mapping activity in White River is based upon these interpreted priority outcrop locations.