2010 Report on the Central Antigonish County Land-use Planning and Climate Change Adaptation Project

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Introduction

This project was initiated by the Geological Services Division in 2007. There are two objectives for the project: (1) to develop geological products that can be used by land-use planners to make community planning decisions and (2), to provide the coastal scientific data required by the central Antigonish County community and its planners to develop climate change adaption plans. A more detailed discussion on the objectives and methodology for this project is provided by DeMont (2009). Preliminary results of the field studies are described in DeMont et al. (2010). The 2010 work program included limited field work, data interpretation and consultations with the Central Antigonish County Land-use Advisory Committee and Project Partners. The following is a summary of activities and results for calendar year 2010.

Geohazards

A review of DNR geological databases was completed in 2009-2010 to identify geohazards found in central Antigonish County. The geohazard of greatest concern is karst topography in Windsor Group gypsum and limestone.

Most of the central Antigonish County study area is underlain by the Antigonish Basin, a northeasterly elongated Carboniferous structural basin containing up to 6000 m of continental and marine sedimentary rocks. The earliest sedimentary succession in the basin is dominated by coarse-grained alluvial, fluvial and lacustrine strata of the Horton Group. The Windsor Group, which overlies this continental succession, is composed of mixed marine carbonate, evaporite and continental redbeds. Eight formations have been mapped in the Windsor Group. The Bridegville Formation, which is the lowermost unit of the Windsor Group, contains thick evaporates that are subject to deep karsting in near-surface or surface exposures. The Bridgeville Formation is overlain by the Hartshorn Formation, a succession of salt, potash and interbedded anhydrite and gypsum. Due to the soluble nature of the salt, this unit is only found in the subsurface. Strata above the Hartshorn Formation are offset by the Antigonish Thrust Fault.

The other seven Windsor Group formations contain thinner evaporite and carbonate beds deposited during periods of alternating regression and transgression of marine waters into the basin. Karst topography also develops in these beds, but it tends to be shallow and of limited areal extent.

DeMont et al. (2010) describe three styles of karst in the study area. These include (1) sinkholes developed in thick beds of relatively flat-lying Bridegville Formation gypsum, (2) structurally controlled sinkholes found along fault or fold structures and (3) sinkholes formed in steeply dipping beds of limestone and gypsum in the Addington and Hood Island formations. The 2010 field studies focused on types 1 and 2.

A LiDAR survey was flown as part of the Central Antigonish Project. LiDAR uses laser pulses fired from an aircraft sensor to accurately measure distances between the aircraft, bare ground and vegetation surfaces. The data provide enough information to develop a bare-earth digital elevation model. In essence, the vegetation is digitally stripped off the surface, giving an earth surface view which can not be obtained by aerial photographs. This bare-earth view provides an abundance of geo-referenced geological data.

DeMont, G.J. and Utting, D.J., 2011: *in* Mineral Resources Branch, Report of Activities 2010; Nova Scotia Department of Natural Resources, Report ME 2011-1, p. 5-13.

Type 2 karst is visible on the LiDAR image (Figs. 1 and 2) as a series of sinkholes developed along the mapped location of the NE-SW Monks Head Fault (Boehner and Giles, 1982). Sinkholes paralleling the Monks Head Fault are restricted to a narrow linear band approximately 180 m wide by 2.5 km long (Figs. 1 and 3). The northeast end of the band is covered by drumlins, which do not exhibit evidence of karst. The till underlying the drumlins could be clay rich, thus preventing sinkhole development, but an alternative possibility is that carbonate and evaporite units prone to development of karst topography are terminated by faults or folds.

In 2010, a traverse made across the linear (Monks Head Fault) sinkhole line north of the curvilinear sinkholes described below. The ground traverse confirmed the presence of the sinkholes, but no outcrop was found. During the site visit it was noted that there are two parallel sets of sinkholes separated by low relief ridges, suggesting the presence of two parallel beds of carbonate or evaporite. Due to a lack of outcrop, the relationship between the Monks Head Fault and the karsted sedimentary beds could not be determined. Surface irregularities in the drumlins indicate that they are collapsing into the sinkholes.

At the southwest end of this linear band the sinkholes form three distinct curvilinear lines (Fig. 2). They appear to indicate the presence of a fold

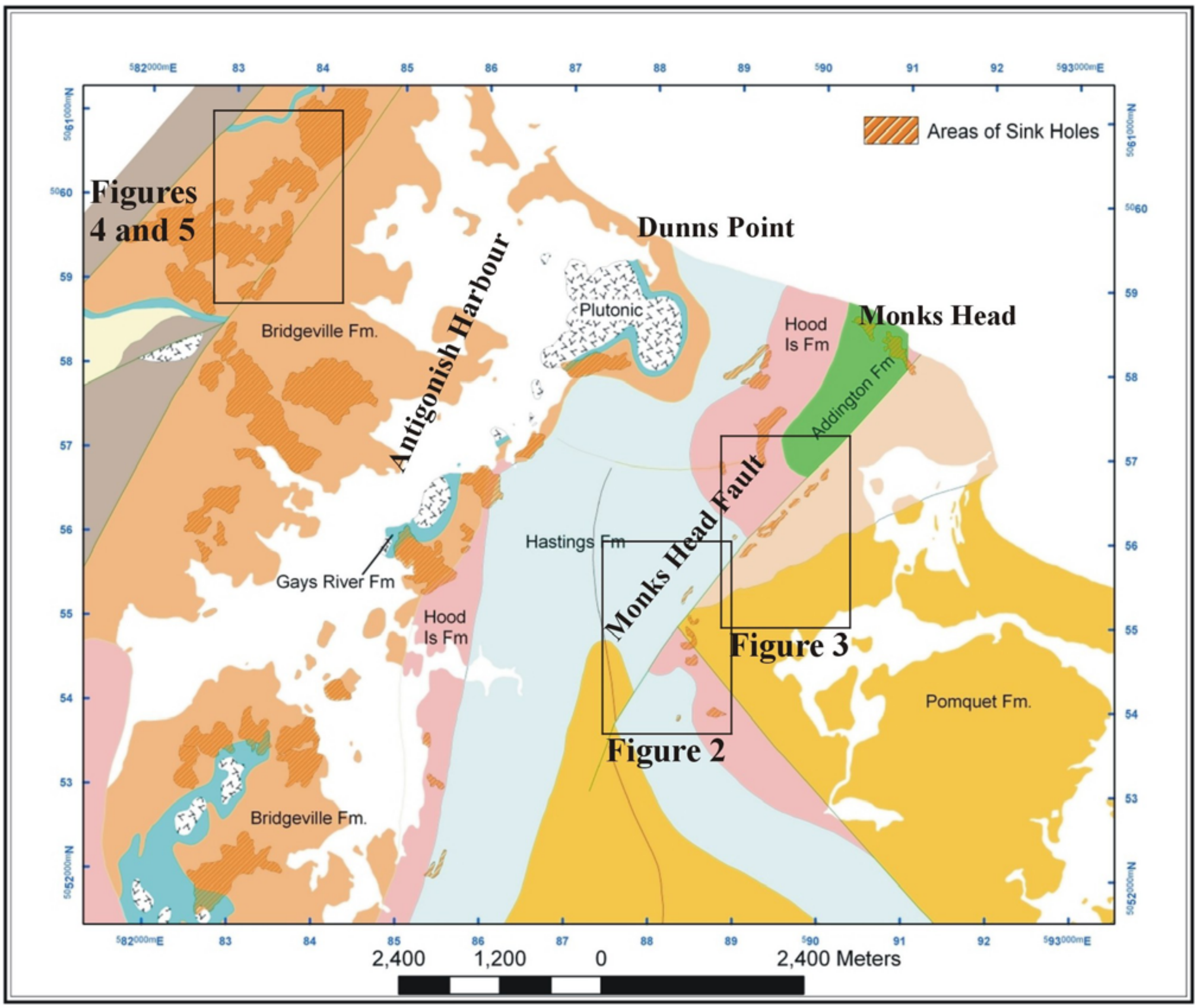

Figure 1. This map illustrates bedrock geology, the location of sinkholes and the approximate boundary of the LiDAR images shown in Figures 2-5.

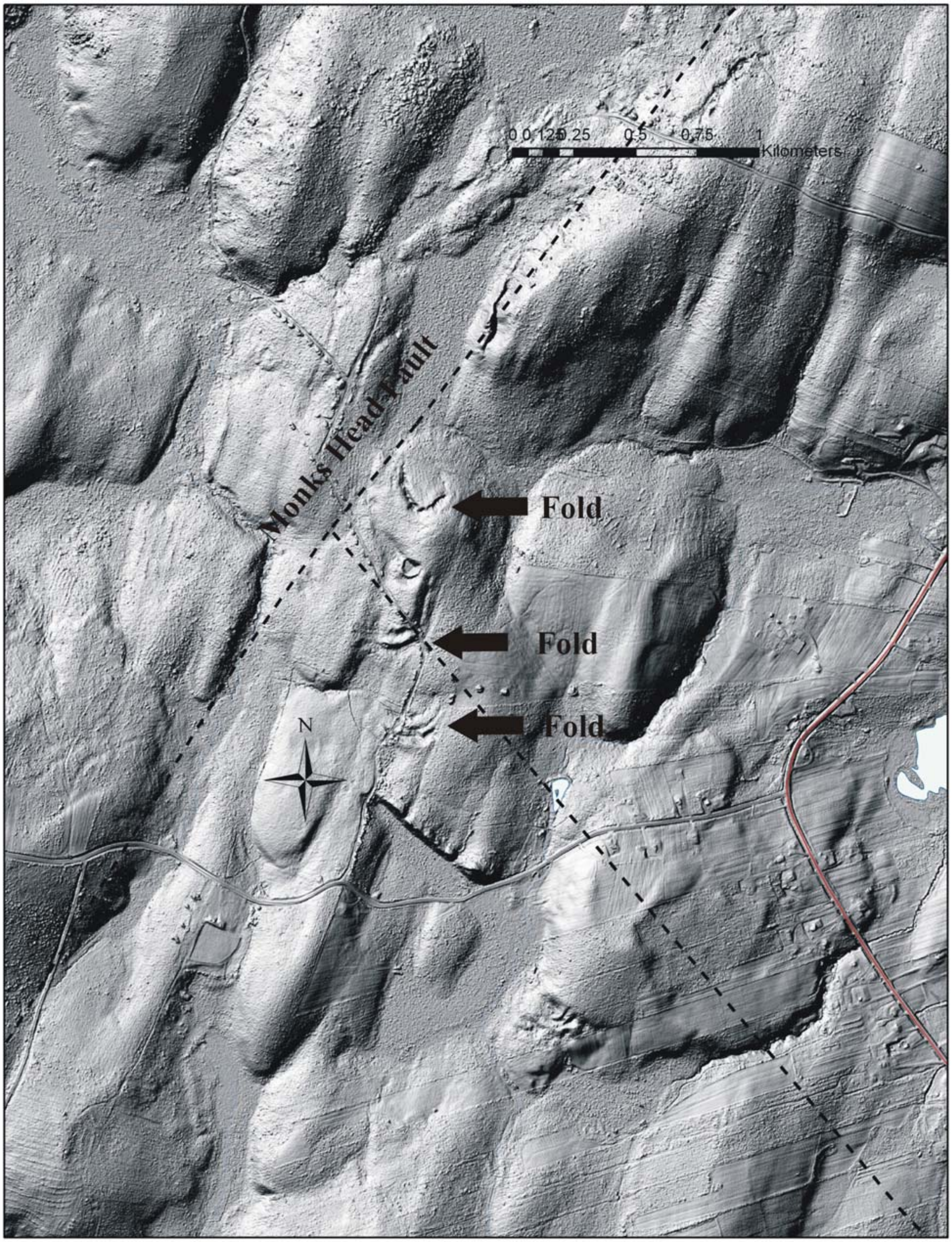

Figure 2. This LiDAR image shows the location of a series of curvilinear sinkholes (located immediately left of the arrows) which define carbonate or evaporate beds within a tight fold structure. This fold was described in Sage (1954) as the Monks Head Anticline.

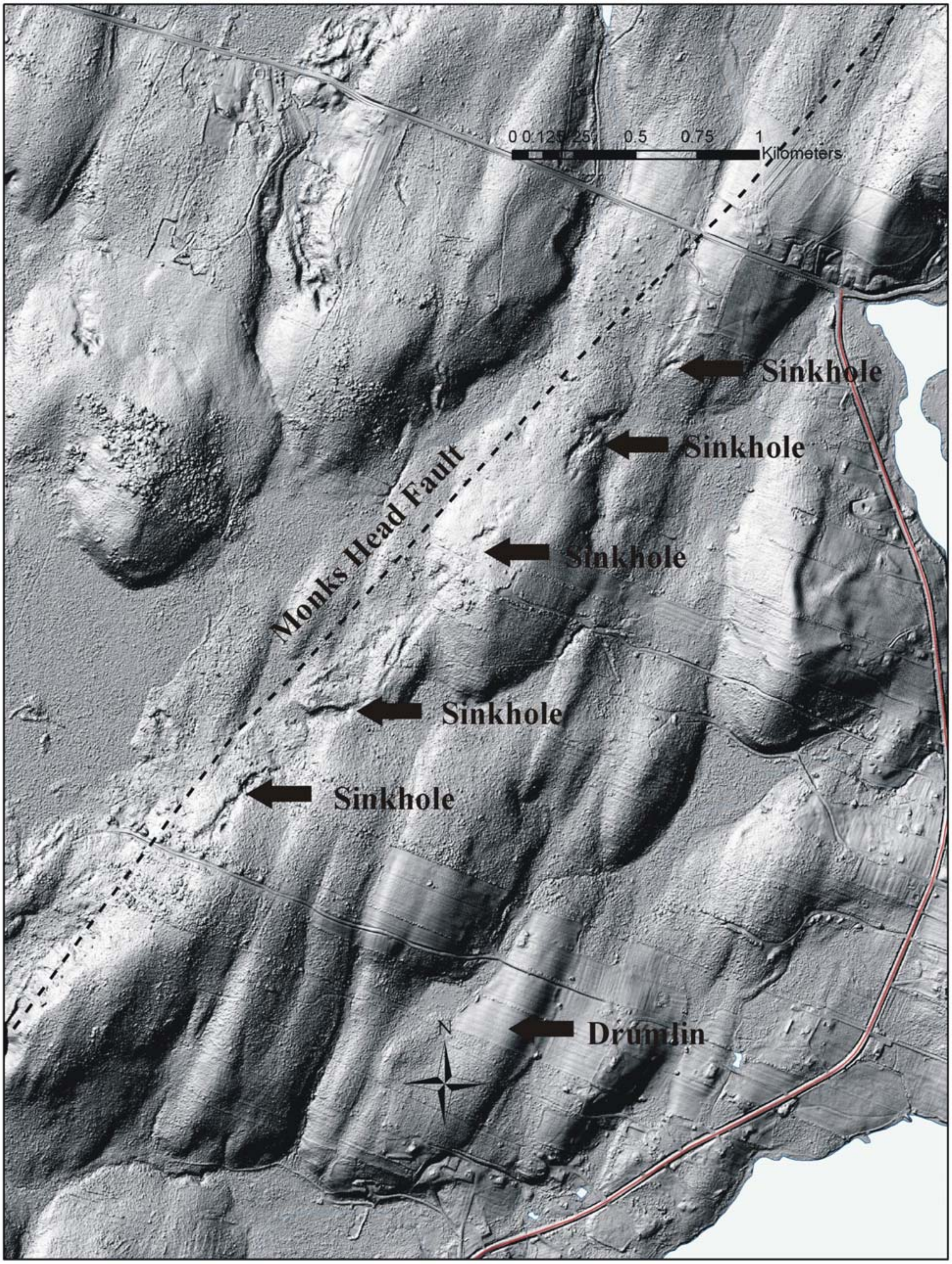

Figure 3. This LiDAR image shows the location of a series of sinkholes which follow the approximate location and orientation of the Monks Head Fault.

structure. These sinkhole features were recognized and mapped by Sage (1954), who suggested the that folded beds form part of the Monks Head Anticline. However, the narrow band of sinkholes that parallels the Monks Head Fault appears to be developed along one limb of the fold structure. Sage showed the axial trace of the Monks Head Anticline passing through Monks Head, but the LiDAR image shows the fold limb defined by the linear line of sinkholes is located well east of Monks Head. Further mapping is required in this area.

Planning restrictions should be placed over the area underlain by Type 2 karst, but its areal extent is reasonably well constrained so the restricted zone will be small. This is in contrast to areas underlain by Type 1 karst developed in the basal Windsor Group (Bridgeville Formation). This karst covers large areas around the east, west and south sides of Antigonish Harbour (Fig. 1). Due to the thick and massive nature of gypsum beds in the Bridgeville Formation the sinkholes found in these areas are deep and pose a considerable risk for development. In 2010, however, a geological interpretation of existing DNR geological datasets using ARCGISR indicated the area underlain by the Bridgeville Formation, and therefore at high risk for sinkhole formation, might be less extensive than previously thought.

Three of the digital layers compiled and overlain in the ARCGISR project are LiDAR, the 1982 (Boehner and Giles) geological map and calculated second derivative aeromagnetic images (King, 2006). Granite intrusions found around the east and south sides of Antigonish Harbour (Fig. 1) show up as strong magnetic anomalies on the King images, while weaker anomalies are found along the east and west sides of the harbour in areas mapped as Bridgeville Formation.

A site visit was made to the granite body mapped in the area south of Dunns Point (Fig. 1). The aeromagnetic image (King, 2006) shows a weak magnetic anomaly associated with this intrusion. A sample collected for petrographic and chemical analyses had low magnetic susceptibility.

The granite exposed at Dunns Point and in the Southside Antigonish Harbour Limestone Quarry formed islands in the Windsor Sea. Fossiliferous limestone was deposited in reefs around the edges of the islands and an algal limestone (Macumber Formation) was deposited as a facies equivalent in deeper water. As the sea shallowed and became more saline, gypsum and salt were deposited on top of the limestone. Gypsum would not have been deposited on the basement highs, however which were higher in elevation than the surrounding sea. In this regard it is interesting to look at Figure 4, which shows a close-up view of an area of Type 1 karst developed along the west side of Antigonish Harbour. Karst is found along both sides of the Lanark Fault (Boehner and Giles, 1982).

By comparing the LiDAR image (Fig. 4) with the aeromagnetic image in Figure 5, it is possible to identify clues to delineate high-risk karst zones. Along the west side of Lanark Fault, no magnetic anomalies are visible, but karst is evident on the LiDAR image and some of the drumlins show signs of collapse into sinkholes. Compare this to the area located east of the Lanark Fault where magnetic anomalies are visible. In this area no karst is visible in the LiDAR image and the drumlins show no signs of sinkhole development. So what are these data telling us?

Although the geological map (Boehner and Giles, 1982) shows both areas as being underlain by Bridgeville Formation (Fig. 1) our research suggests this is likely not the case. The aeromagnetic data indicate the drumlins located east of the fault are underlain by non-soluble basement rocks (granite?). This would explain why karst is not visible in this area. In contrast, no magnetic anomalies are visible west of the fault so the drumlins sit directly on Bridgeville Formation rocks. This would explain why the drumlins in this area show signs of sinkhole development. It should be borne in mind, however that these theoretical observations must be tested by drilling before any conclusions can be reached.

What are the implications for mineral resource exploration and land-use planning if this theory is correct? In areas underlain by Bridgeville Formation the risks are considered high for karst development and restrictions should be placed on any development. Due to water quality issues in gypsum aquifers, accessing groundwater could also

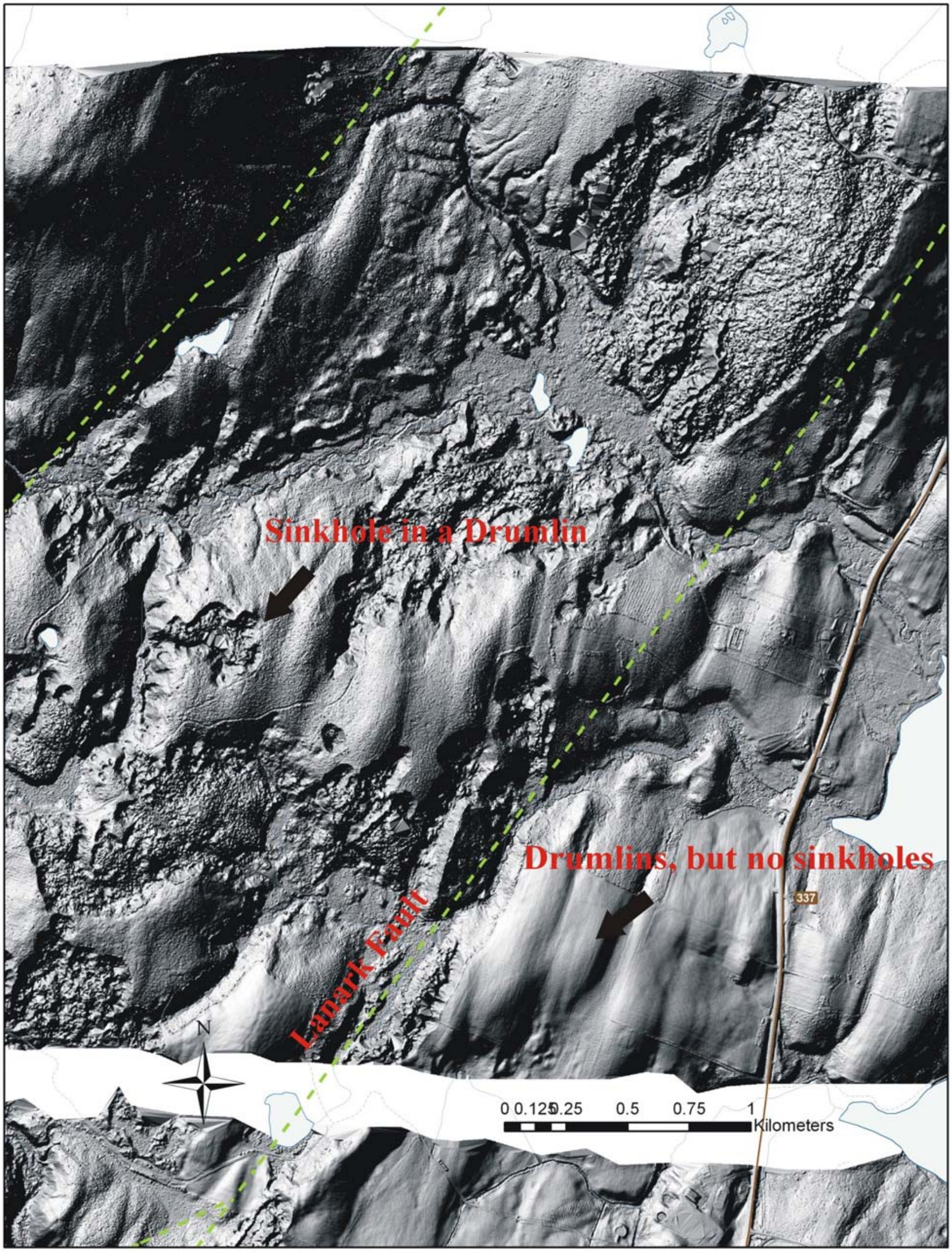

Figure 4. This LiDAR image shows areas where sinkholes are developed in drumlins west of the Lanark Fault, whereas the drumlins located east of the fault appear stable.

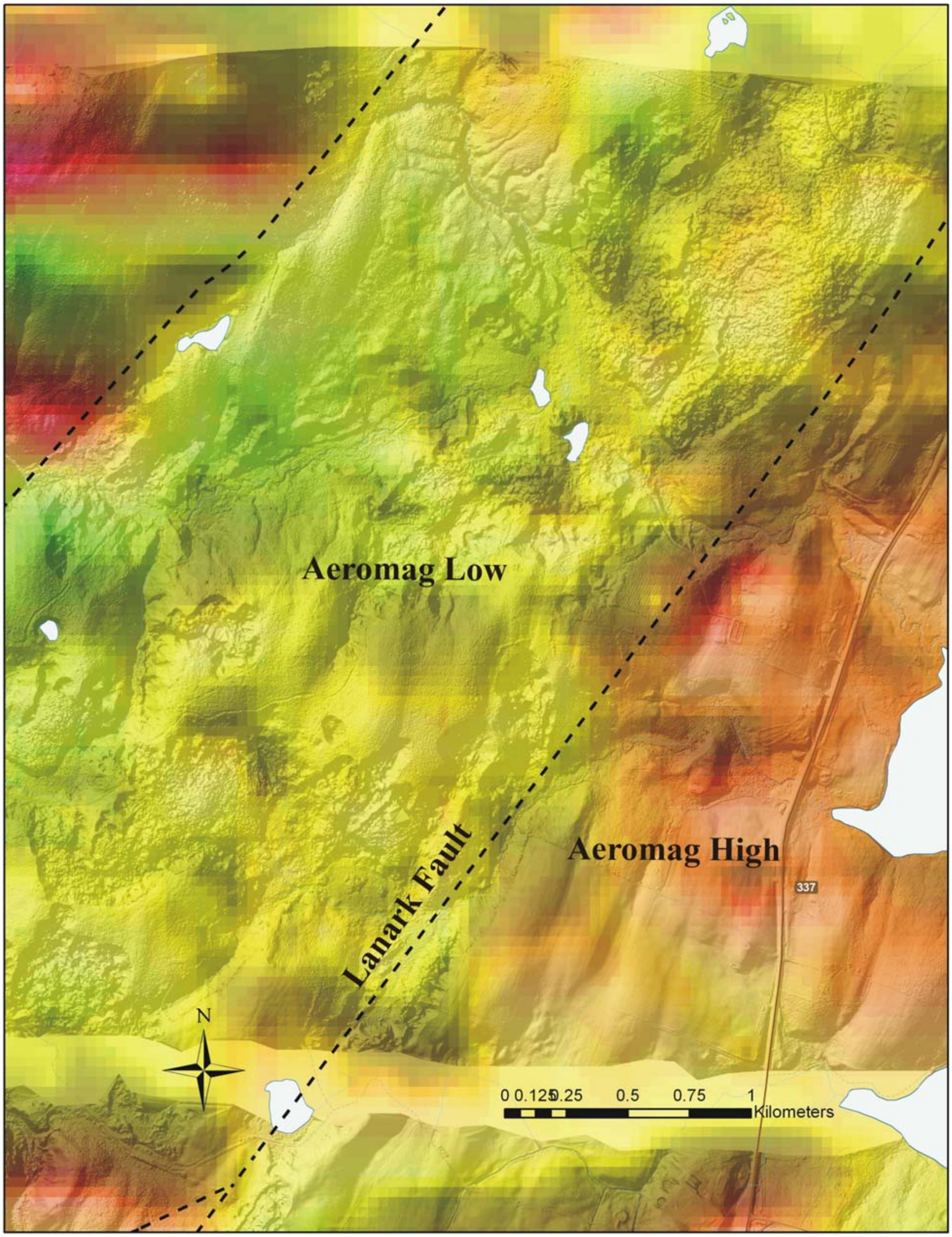

Figure 5. Aeromagnetic data (King, 2006) are overlain on the same LiDAR image shown in Figure 4. Magnetic highs are seen covering the area of drumlins located east of the Lanark Fault. These data indicate that the drumlins are underlain by magnetic basement rocks.

be a problem. In comparison, the areas mapped as Bridgeville Formation but associated with magnetic anomalies could be stable sites for land developments if the drumlins are proven to be sitting on basement. It might also be possible to locate groundwater aquifers in the basement rocks.

Antigonish County planners and council are interested in the results of this geological analysis because they are currently under pressure from developers who want to build subdivisions along the west side of Antigonish Harbour. The municipality is also dealing with requests to build water supply lines to some of the existing subdivisons. In essence, this study could save the county a considerable sum of money. It should be borne in mind, however that this is a theoretical model which can only be tested through a detailed geotechnical assessment.

If this new geological model is proven correct it opens up opportunities for mineral and energy exploration in the Antigonish Basin. The reef structures surrounding the granite basement highs along the south and east sides of Antigonish Harbour have historically been the focus of base metal exploration. The identification of other basement highs could stimulate base metal exploration in the associated reefs. Highpurity limestone quarried in the South Side Antigonish Harbour Quarry could also be present on or adjacent to other magnetically defined basement highs. Use of LiDAR to outline areas of gypsum karst will assist with the delineation of gypsum resources. The LiDAR DEM can also be used in conjunction with well water data from the DNR well water database to estimate overburden thicknesses. This could help reduce costly diamond-drilling programs used in mineral exploration surveys, and subsequent exploration and mining costs. Through use of these combined data sets areas of thick overburden could be avoided.

Geohazard risk assessment maps and a GIS database are being prepared, with a targeted release in the spring of 2011.

LiDAR Digital Elevation Model and Flood Risk Model

Tim Webster of the Applied Geomatics Research Group and his assistants completed the LiDAR processing for the central Antigonish County data set and produced a new Digital Elevation Model in 2010. The group subsequently used the DEM to produce a flood risk model for the study area. This product was completed and given to the project partners and Eastern District Planning Commission.

Coastal Zone Risk Assessment

Multiple data sets are required to undertake a complete coastal erosion risk assessment. Some examples are bathymetry, slope maps, bedrock and surficial geological maps, maps showing the geological composition of the coastal materials, maps showing locations of built infrastructure and armoring, and historic erosion rate maps produced by scanning and ortho-rectifying old aerial photographs. Local historians or longtime coastal dwellers can also play a critical role in the risk analyses by capturing changes in the coastal environment in photographic images.

Field data required for the risk analyses in central Antigonish County were captured by Dan Utting and Philip Finck in 2009. The historic erosion rate maps produced from scanned aerial photographs were completed by Nathan Crowell of the Applied Geomatics Research Group in 2010. All of the data sets will be compiled in a GIS project and used for the final coastal risk assessment analyses to be completed by the spring of 2011.

Communication

Perhaps the most important component of this project is the transfer or communication of the technical knowledge obtained in the project to the central Antigonish community and landuse planners. The challenge is reporting the data in a form that can be used by the community for making landuse planning decisions. A meeting was held with Eastern District Planning Commission planners and the Central Antigonish County Planning Advisory Committee in September 2010. The community was very interested in the project results. It was agreed that the data will be provided in a GIS format so they can be used in conjunction with the other data sets used in the planning process. It is anticipated that the finished geological products will be transferred to the central Antigonish County planners in the spring of 2011. A successful completion of this project will provide a template for conducting this type of study in other Nova Scotia municipalities.

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