A Pilot Project to Assess Climate Change Risk and Land-use Planning in Central Antigonish County

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Project Overview

Weather has always been a focus of casual conversation in Nova Scotia, but lately discussions on this issue frequently lead to talk of climate change and the impacts it is having, or will have on the province. If climate change prediction models are correct, the province could see many environmental changes in the years ahead, including, but not limited to, an increase in coastal erosion, coastal flooding, and more frequent inland floods or periods of drought. All of the above could have significant negative impacts on municipal and provincial infrastructure, including wharfs, roads, buildings and municipal water and sewage treatment systems. Nova Scotians have joined the voices of other Canadians in expressing their concerns to government regarding climate change and the need to develop and implement adaptation strategies and policies as soon as possible.

An overlooked chapter of the climate change story talks about the role of geology in both the climate change process and the development of adaptation strategies. The climate change connection to geology is apparent to geologists, but most people fail to recognize it. The principal reason for this is a general lack of educational exposure to this science. The vast majority of Nova Scotians will graduate from high school without taking a geology course. This could pose a significant problem for provincial planners who must design a climate change adaptation strategy, because understanding geology is critical for the design and implementation of new policies and action plans.

The Geological Services Division (GSD) of the Nova Scotia Department of Natural Resources (DNR), holders of the provincial geological databases, are making concerted efforts to disseminate this message to provincial and municipal decision makers. One of the groups the division has targeted is land-use planners, because they will develop and implement new land-use policies and regulations, a key component of the climate change adaptation strategy. Unfortunately, what GSD discovered in its educational seminars is a profound exclusion of geology in the land-use planning process for the reasons alluded to above.

After attending a Geological Services Division educational seminar in 2007, John Bain, Eastern District Planning Commission Director, made a decision to include geology in the Central Antigonish County Land-use Plan. The division is working with the commission's planner and the Central Antigonish Area Advisory Committee to develop a methodology to incorporate geology in the planning process. The following discussion outlines the steps required to complete this task. We hope the project's template will be adopted by all provincial planning commissions. In this regard, the final component of the project will be the development of a Letter of Provincial Interest in Geology and Mineral Resources for inclusion in Service Nova Scotia and Municipal Relations Land-use Planning Handbook. If this endeavor is successful, geology will become an integral component of all future land-use plans in Nova Scotia.

Introduction

The Geological Services Division of DNR has the mandate to collect and disseminate geoscience data. Traditionally, the largest client group for these data was the mineral industry, but over the last decade GSD has observed a significant increase in use of geological databases by the environmental consulting industry and the general public. This shift in client base correlates with a growing interest by Nova Scotians in the health of

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the environment and their concerns about the impacts of climate change. The division recently established an Environmental Geology Program to address these client demands and to educate provincial and municipal decision makers about the role of geology in their daily lives.

An educational seminar prepared by GSD staff, called *Geology and Society*, has been presented to a number of municipal councils, planning commissions and other agencies over the last three years. Natural geohazards, such as sinkholes, and the connections between geology, water resources, coastal erosion and mineral resources are some of the issues addressed in this presentation. Two significant areas of concern were identified by GSD during the presentations: (1) <10% of attendees have taken a geology course in their life time and (2) land-use planners do not incorporate geology in their planning decisions.

Climate change related to global warming will affect Nova Scotia over the next century. The Maritime Provinces are projected to experience increases in both temperature and annual rainfall. Seasonal, yearly and local variations in weather patterns will be more evident. Inland areas are expected to be warmer and drier, but changes in coastal areas will be moderated to some degree by the proximity of the ocean. Flooding conditions related to an increase in rainfall may occur more frequently in some areas of the province while drought condition will be an issue in inland areas.

Sea levels are rising in Nova Scotia. This problem is compounded by the fact that portions of the provincial coastline are subsiding after a period of isostatic rebound related to melting of the continental ice sheets. Glacial ice sheets up to 3 km thick, which covered northern regions of North America during the last ice age, depressed the land surface. When the ice melted there was a quick rebound in land elevation followed by a period of slower uplift. As the earth's crust and mantle slowly return to a point of equilibrium, some land surfaces sink while others continue to rise. Nova Scotia is for the most part sinking. When you couple rising sea levels with subsiding land you get a coast line that is vulnerable to both flooding and erosion. This issue is of growing concern, because in the last few years Nova Scotia has seen a significant increase in coastal development, especially in rural communities located near the city of Halifax.

The province's geological databases will become extremely important in the future as the province develops new policies required to adapt to climate change. A brief overview of the connections between climate change, land-use planning and the province's underlying geology is provided in the following section of the report.

Coastal Erosion

Perhaps the climate change issue of greatest concern in Nova Scotia is the significant potential for an increase in rates of coastal erosion related to sea-level rise and more frequent storm events. Coastal geology, including the distribution of both bedrock and surficial units, controls the rate and degree of coastal erosion. In areas where the coast is bounded by hard bedrock, such as granite or basalt, there is minimal coastal erosion, but these areas represent only a small fraction of the total coastline. An example of this coastline type is found at Peggys Cove, where granite is exposed along the shore. In other areas of the province, such as central Antigonish County, the coast is composed of soft, easily eroded rocks or glacial till. This shoreline is highly vulnerable to coastal erosion, and the risks associated with development along this coast will increase with rising sea levels and more frequent storm events, but it is not all bad news. In these high-risk areas the easily eroded headlands produce an abundance of sediment, which migrates to the beautiful sand beaches we see along this coast, a real attraction for the tourism industry. Beaches might be at risk in the future, however, when this geological process is disrupted as people start armoring the headlands to protect their land from coastal erosion. Understanding these geological processes is critical for intelligent land-use planning in coastal areas of Nova Scotia. Each permit issued for armoring of coastal areas or wharf construction could affect other areas of the coast. It is extremely important that the issuer of these permits have enough geological education and access to supporting information to assess the risks before approving coastal development permits.

The central Antigonish County planners identified the need to establish coastal setbacks for construction of cottages, homes or commercial developments along the ocean shorelines. Geology,

both bedrock and surficial, should be used as the rationale for the establishment of these setbacks. It will provide the principal legal argument for planners if a developer challenges the setback legislation in court. A short walk along the coastline in central Antigonish County provides the informed observer with all of the visual evidence required to justify coastal setbacks. Houses, cottages and transportation infrastructure are already at risk, and sea-level rise will place them in greater danger.

Coastal Flooding

Sea-level rise and more frequent storm events will lead to coastal flooding in low-lying areas. This flooding could result in considerable damage to municipal and provincial infrastructure if mitigation measures are not taken to reduce the risk. Wind direction, topographic elevation, coastal bathymetry and shape of the coastal inlets all play a role in defining the degree of coastal flooding during a single storm event. With the exception of wind direction, all of the above are controlled, for the most part, by the underlying bedrock or surficial geology.

Inland Flooding Along Rivers

Rivers are dynamic geological systems where the migration of river channels and overbank flooding are natural and cyclic events. Unfortunately flood plains, which were once used exclusively as agricultural lands, have all too often become new sites of residential or commercial development. Extreme storm events and the combination of ice dams and snow melt during spring break-up are recipes for disaster in these developed areas. Communities react by constructing flood levees and rerouting channels, but these actions can lead to more problems if the natural sedimentary processes are not considered in the planning process. Flooding could become a larger issue in the future if the prediction that we will see an increase in frequency of major storm events is proven correct. It is important that planners making land-use decisions in flood plain areas understand some basic concepts of sedimentary geology and geomorphology, or they should consult with a professional geologist or geomorphologist before making planning decisions in these areas.

Groundwater

Geology plays a significant role in defining the quantity and quality of groundwater in both dug and drilled wells. Dug wells tap into groundwater supplies contained in surfical deposits, which in Nova Scotia are primarily of glacial origin. The depositional environment of any single glacial deposit determines the type of material it contains and its potential as a source of groundwater. As an example, glaciolacustrine deposits, formed in glacial lakes, often contain thick sections of massive clay. Anyone looking for a source of groundwater in areas underlain by these low porosity, impermeable deposits will have difficulty finding an adequate supply. Glaciofluvial (meltwater stream) deposits, such as kames and eskers, are just the opposite, their primary constituents are sand and gravel so they are typically excellent aquifers, depending on the saturated thickness of the material. These deposits, however, are often associated with increased vulnerability to contamination from waste disposal or chemical spills. The porous, permeable nature of sand and gravel, features that makes them productive aquifers, also allows for widespread and rapid contaminant transport within the aquifer.

Bedrock geology determines the quality and quantity of water found in a drilled well. Areas underlain by thick sequences of fractured, porous sandstone will likely yield significant quantities of groundwater, but wells drilled in areas underlain by granite will generally have very limited groundwater yields. Using geology maps, combined with available groundwater information, to identify areas of high potential for groundwater supply could save developers and purchasers a lot of time, money and stress. There is little doubt that proper use of geology in the land-use planning process will result in the identification of adequate groundwater aquifers for rural communities. This information will also help ensure that these vital resources are protected from contamination and other abuses.

Geohazards

Acid rock drainage, karst (sinkhole) terrain, slope stability, heavy metals in soils, and abandoned mine workings and tailings are some of the geohazard issues that planners should consider.

Acid rock drainage (ARD) is common in the southern Nova Scotia mainland where it develops when mineralized slates are exposed to oxygen and water. The slates contain disseminated pyrite and pyrrhotite, which oxidize when the slates are exposed to air, resulting in the production of sulphuric acid and iron oxides. The latter give the rocks their reddish-orange colour. Acid rock drainage was first discovered as an environmental issue in Nova Scotia when construction started on the Halifax International Airport in 1957. A significant fish kill occurred in the streams surrounding the construction site. To date, it has cost over 20 million dollars to mitigate ARD at the airport and this number grows annually by a million dollars.

Karst or sinkhole development occurs in limestone and gypsum, two rocks which are common in some areas of Nova Scotia, such as central Antigonish County. These rocks are dissolved by surface water as it percolates down through fractures and voids, and circulating groundwater below the ground surface. Caverns developed in the buried rocks can collapse without warning, causing a sinkhole to appear at surface. Sinkhole development is of most concern when groundwater aquifers are over pumped, or during periods of alternating wet and dry weather, a condition predicted in the future due to climate change.

Slope stability is directly linked to slope angle and height, the composition of underlying materials and in the case of unconsolidated surficial deposits, degree of water saturation. During extreme rainfall events slope stability becomes a significant concern. If weather predictions are correct and climate change leads to more frequent heavy rainfalls, planners should be prepared to deal with this issue. Areas with high potential for this to occur should be identified in land-use planning documents and maps.

In stable climate conditions heavy minerals in rock and soils often reach a point of equilibrium where there is little to no mobilization. However, in unstable climatic conditions where rocks and soils are saturated one week and dry the next there is a higher risk of transport into groundwater systems. Heavy minerals can also be taken up by vegetation, which is in turn ingested by animals, leading to potential toxicity. Areas of concentrated heavy minerals should be identified on land-use planning maps to inform the development of protective covenants that restrict land-use activities.

Abandoned mine workings and tailings are scattered around the province. These mines, which were developed before modern management regulations, are often safety and environmental hazards. On Crown land the province is responsible for ensuring that proper signs and closures are in place, but on private land the land owners are responsible. The locations of known abandoned mines are identified in the Nova Scotia Department of Natural Resources Abandoned Mines Database, which is available for public access on the Mineral Resources Branch online map server. It is important that this data set be included on land-use planning maps so that restrictive covenants can be used to restrict access and development on these sites.

Mineral Resources

Despite the fact they are an essential component of community development, mining and quarrying are contentious issues in some areas of the province. Construction aggregate supplies are critical for any community, whether the stone is for use in concrete, road construction or armoring of vulnerable coastlines. Zoning to protect areas of good quality aggregate will become a significant issue in the future as the price of fuel increases. Transportation from quarry to construction site is often the largest component of the cost per ton of aggregate (Prime and Bonner, 2007). As fuel prices rise, this cost will grow. The volume of aggregate required to construct one kilometre of road is fixed, as are many of the road construction budgets. The kilometres of road a community can afford to construct in any given year are very much dictated by transportation costs. It is critical that land-use planners provide zoning for aggregate quarries in areas close to construction projects, particularly in areas prone to flooding and road washouts where road and bridge repair are common events.

The Geological Services Division has been working on a series of mineral resource potential maps that will identify areas of both historical mineral claim staking, and areas with high mineral potential for metallic mineral, industrial mineral and aggregate deposits. These maps can be used as

a rough guide to identify areas that may see future mineral resource exploration and development.

Mineral staking generally occurs in areas where there are known occurrences of minerals or geochemical anomalies indicating a possible buried mineral source. In the areas where the land is staked for metallic mineral exploration there is a good chance that the soils and bedrock contain anomalous concentrations of heavy metals. The DNR Mineral Occurrences and Geochemical databases are also good sources of information for locating areas of elevated heavy minerals. In these areas developments should have restrictive covenants attached that would require testing of soils, water and bedrock prior to breaking ground. It is, therefore, very important that these areas be identified on planning maps.

Planners should consider the creation of restricted land use and buffer zone development around areas of high mineral potential if the community is open to mine or quarry development as part of their community economic development strategy. If commercial or residential developments infringe on areas with high mineral potential they make it extremely difficult for projects to obtain environmental or operating permits, whether the development is a gold mine or aggregate quarry.

Project Activities in 2008

The main component of field data collection for this project will commence in the summer of 2009, but a reconnaissance air and ground assessment of the coastal geology was undertaken by GSD staff in 2008 (see Utting, 2009). Office database compilation required for some of the proposed products, including the area's mineral inventory, surficial geology, and water resources, was started in 2008 and will continue through the winter months in 2009.

GSD formed a partnership in 2008 with the Applied Geomatics Research Group (AGRG) of the Nova Scotia Community College Centre of Geographic Sciences (COGS) to acquire and process new LiDAR data. This light detection and ranging survey uses lasers to accurately measure distance from the ground source to the airborne sender-receiver unit. The resulting data set is processed to produce a detailed digital elevation model, a sophisticated successor to paper topographic maps. The data set has elevation resolution in the centimeter range.

The survey was flown over the coastal area from Antigonish to the Canso Causeway in December 2008. The digital elevation model will be supplied to GSD in March or April 2009. AGRG will also undertake ortho-rectification of aerial photographs required for historical measurement of coastline erosion rates.

One of the challenges department will face in this project is presentation of the geological data in a map format that provides useful information for people having no prior geological training. This will likely require development of bedrock and surficial geology maps with new legends. Traditional geology maps list the rock units by age and stratigraphic position, but the new maps will likely list and describe rock units by their degree of environmental risk and mineral/aggregate/ groundwater resource potential. Project members will consult with the land-use planning team on a regular basis to obtain assistance with the design of maps and reports.

References

Prime, G. A. and Bonner, F. J. 2007: Bedrock aggregate development potential in Western Halifax Regional Municipality; Nova Scotia Department of Natural Resources, Economic Geology Series ME 2007-1, 56 p.

Utting, D. J. and Gallacher, A. F. 2009: Coastal environments and erosion in southwest St. Georges Bay, Antigonish County; *in* Mineral Resources Branch Report of Activities 2008; Nova Scotia Department of Natural Resources Report ME 2009-1, p. 139-149.