USING GROUND PENETRATING RADAR (GPR) TO IDENTIFY TURTLE NESTS

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ABSTRACT

Many turtle species are considered species at risk in Ontario and Canada. Legislation and policy protects individuals, habitats and nests. Turtles nest in areas with sand and gravel and other loose substrates, with suitable sunlight and good drainage, including roadsides, and other disturbed areas. The presence of nests may pose constraints to construction and operation of roads and other engineering projects in Ontario.

Throughout Ontario, turtles have been observed to nest in the embankments and gravel shoulders of roadways located near wetlands. The ease of access to these nests enables the use of non-destructive technologies, such as Ground Penetrating Radar (GPR), that are capable of locating these nests. During a GPR survey, the radar scans cross subsurface features such as pipes, walls, rocks or void spaces which generate hyperbolic reflections. The turtle nests are essentially void spaces in the gravel shoulder and can be detected using GPR because of the change in the reflected radar signal velocity. Once the data has been collected, it is imported into a data reduction software which digitizes the radar reflections and can also be linked to GPS coordinates. The depth and location of the nests can then be exported into an Excel spreadsheet.

In this paper, we will draw on recent project experiences in Ontario to: describe the process for identifying suitable nesting habitat and finding nests; and regulatory approval requirements, including avoidance, mitigation, and compensation requirements. The paper also provides suggestions for improvements in ground-truthing the collected data in order to refine data processing and identification techniques.

Keywords: - turtles, GPR, non-destructive testing, SAR

1. INTRODUCTION

Many turtle species are considered species at risk in Ontario and Canada. Legislation and policy protects individuals, habitats and nests. Turtles nest in areas with sand and gravel and other loose substrates, with suitable sunlight and good drainage, including roadsides, and other disturbed areas. The presence of nests may pose constraints to construction and operation of roads and other engineering projects in Ontario.

Throughout Ontario, turtles have been observed to nest in the embankments and gravel shoulders of roadways located near wetlands. The ease of access to these nests enables the use of non-destructive technologies, such as ground penetrating radar (GPR), that are capable of locating these nests relatively quickly. GPR is typically used for archaeological surveys or subsurface utility surveys, however the same principles can be applied to detecting turtle nests buried below the surface of a gravel shoulder adjacent to a roadway. During a GPR survey, the radar scans cross subsurface features such as pipes, walls, rocks or void spaces which generate hyperbolic reflections. The turtle nests are essentially void spaces in the gravel shoulder and can be detected using GPR because of the change in the
reflected radar signal velocity. Once the data has been collected, it is imported into a data reduction software which digitizes the radar reflections and can also be linked to GPS coordinates. The depth and location of the nests can then be exported into an Excel spreadsheet.

The next section of this paper will provide some background regarding turtle nesting habits, legislation in Ontario, and typical mitigation measures.

2. BACKGROUND

2.1 Status of Turtles in Ontario

There are ten distinct taxa of turtles that are native in Ontario, including nine distinct species and two subspecies. Eight of the nine species are listed as Species at Risk (SAR) in Canada and Ontario, and are considered rare in Ontario. The turtle species are presented in Table 1 below.

The Committee on the Status of Species at Risk in Canada (COSEWIC) identified declining populations and/or susceptibility to population decline as a threat to all turtle SAR except for Eastern Box Turtle, which is no longer present in Ontario (COSEWIC 2016). Although factors leading to population decline are species specific, some factors listed by COSEWIC are common to many of Ontario’s turtle species, including: habitat loss and fragmentation, population isolation, habitat degradation, late age of reproductive maturity, low reproductive output, low fecundity (reproductive rate), and road mortality. Low reproductive output and low fecundity highlight the importance of nesting success to the sustainability of turtle populations in Ontario.

Turtles lay their eggs in spring and summer months and may return to the same areas for nesting each year. Turtles nest in areas with sand, gravel and other loose substrates, including roadsides and other disturbed areas. Suitable exposure to sunlight and good drainage are essential to nesting success, and turtles may show a preference for sites that are close to overwintering habitat such as ponds, marshes, or other wetlands and waterbodies. The most productive nesting sites are located away from roads, because mortality from vehicle collision and wildlife predation is reduced (OMNR 2000).

2.2 Legal Protection in Ontario

Legal protection for SAR in Canada and Ontario is provided by the federal Species at Risk Act, 2002 (SARA) and provincial Endangered Species Act, 2007 (ESA) respectively. The SARA was created to prevent wildlife species from becoming extirpated (i.e., extinct in Canada), and includes prohibitions against killing, harming, harassing, capturing or taking species at risk or destroying their critical habitats. SARA provides protection to turtles listed in Schedule 1, and their critical habitat, when they are located on federal lands.

The ESA was created to protect SAR and their habitats in Ontario. Species listed as threatened, endangered or extirpated by the Species at Risk in Ontario (SARO) list automatically receive legal protection from harm or harassment and general habitat protection under the ESA, including protection of nesting sites. The ESA applies to public and private lands, and can impose restrictions on development and construction projects in Ontario. Seven of Ontario’s turtles are protected by the SARA, and six are protected by the ESA. The turtle species details are presented below in Table 1.

Nest sites of turtle species that are not protected under the ESA or SARA may be considered Significant Wildlife Habitat (SWH) in Ontario. SWH is protected in Ontario by the Provincial Policy Statement, 2014 (PPS) issued under the provincial Planning Act, 1990 (PA). The PPS protects SWH from development and site alteration that is subject to municipal planning decisions. For development and other construction scenarios where the PPS does not apply, identification of SWH can be used as a tool to identify relative significance of natural heritage features. Nesting areas on road shoulders and embankments are generally not considered SWH (MNRF 2015) due to the high risk of adult and hatchling mortality.
Table 1: Status of Ontario’s Native Turtles

<table>
<thead>
<tr>
<th>Species Number</th>
<th>Common Name</th>
<th>Scientific Name</th>
<th>S-rank</th>
<th>COSSARO</th>
<th>COSEWIC</th>
<th>Protected by the ESA</th>
<th>Protected by the SARA (Schedule 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Eastern Spiny Softshell</td>
<td>Apalone spinifera spinifera</td>
<td>S3</td>
<td>THR</td>
<td>THR</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>2</td>
<td>Snapping Turtle</td>
<td>Chelydra serpentina</td>
<td>S3</td>
<td>SC</td>
<td>SC</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>3</td>
<td>Western Painted Turtle</td>
<td>Chrysemys picta bellii</td>
<td>S4</td>
<td>-</td>
<td>NAR</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>4</td>
<td>Midland Painted Turtle</td>
<td>Chrysemys picta marginata</td>
<td>S5</td>
<td>-</td>
<td>-</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>5</td>
<td>Spotted Turtle</td>
<td>Clemmys guttata</td>
<td>S3</td>
<td>END</td>
<td>END</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>6</td>
<td>Blanding’s Turtle</td>
<td>Emydoida blandingi</td>
<td>S3</td>
<td>THR</td>
<td>THR</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>7</td>
<td>Wood Turtle</td>
<td>Glyptemys insculpta</td>
<td>S2</td>
<td>END</td>
<td>THR</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>8</td>
<td>Northern Map Turtle</td>
<td>Graptemys geographica</td>
<td>S3</td>
<td>SC</td>
<td>SC</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>9</td>
<td>Eastern Musk Turtle</td>
<td>Sternoterus odoratus</td>
<td>S3</td>
<td>THR</td>
<td>THR</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>10</td>
<td>Eastern Box Turtle</td>
<td>Terrapene carolina</td>
<td>SU</td>
<td>EXT</td>
<td>EXT</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

S-rank: Provincial (Ontario) rank
S2: Imperilled—Imperilled in Ontario, very few populations (often 20 or fewer)
S3: Vulnerable—Vulnerable in Ontario, relatively few populations (often 80 or fewer)
S4: Common—Common in Ontario.
S5: Secure—Common, widespread, and abundant in Ontario
SU: Status Unrankable due to lack of information
COSSARO: Committee on the Status of Species at Risk in Ontario
COSEWIC: Committee on the Status of Endangered Wildlife in Canada
SC: Special Concern
THR: Threatened
END: Endangered
EXT: Extirpated
NAR: Not at risk

Turtle nesting sites are difficult to find in the field (OMNR 2000). The Significant Wildlife Habitat Technical Guide (OMNR 2000) and Criteria Schedules (MNRF 2015) describe an approach that includes desktop screening to identify potentially suitable nesting sites, field documentation of soil substrates and vegetation cover, and visual scans to document the presence of nesting turtles or turtle nests. This approach may result in poor detection of nesting sites or individual nests because eggs are buried and covered by mineral soil and may not be visually distinct from the surrounding area.

2.3 Typical Mitigation Measures

Construction or other work can reduce the risk of disturbing turtles and their nests by avoiding the peak active season (i.e., when turtles are not hibernating), which generally corresponds with spring, summer and fall; however, avoidance of the peak active season may not be feasible for many construction projects. If construction proceeds during the peak active season, sediment or other barrier fencing can be used to inhibit the movement of turtles into working areas. To exclude nesting females and nests, barrier fencing can be installed outside the turtle nesting season, which generally corresponds with spring and summer. If work must be initiated during the turtle nesting season, a qualified biologist can visually inspect the site for turtles and/or nests and direct installation of turtle exclusion fencing to avoid interference while maintaining access to wetlands for hatchling turtles. If it is not possible to isolate a nest from the work area, it may be necessary to delay work until it is determined that the nest no longer includes viable eggs (i.e., hatchlings have emerged or eggs were predated), particularly if the nests are protected by the ESA.
Turtle exclusion fencing should meet minimum acceptable standards based on the best available information, including the Best Practices Technical Note – Reptile and Amphibian Exclusion Fencing (OMNR 2013). This approach has been successfully implemented by Stantec on multiple projects, including the Rehabilitation of Highway 24 from Blue Lake Road to Glen Morris Road in the County of Brant as well as the Rehabilitation of Culverts in Southwestern Ontario, Contract 2 (GWP 3040-11-00 and 3032-14-00).

During the Detail Design studies for both of these projects, turtle habitat was identified adjacent to the locations where culvert improvements were required. As a result, exclusionary fencing will be installed, tapering outwards to prevent turtles and other reptile species from entering the specific work areas.

In the case of the Highway 24 project, barrier fencing will also be provided along the corridor to address high instances of turtle road mortality by restricting access to the road and shoulders, where nesting activities could occur. In both cases, construction workers will be trained to search for and identify turtles, and implement appropriate avoidance strategies.

Compensation and overall net benefit plans may also be required as a regulatory requirement, particularly as a condition of authorization under the ESA. A case study in southern Ontario highlights turtle habitat enhancement strategies that exceeded typical mitigation requirements, including consideration of the following: design of multiple turtle passages across a provincial highway, installation of permanent barrier fencing to redirect turtles away from the highway, creation of turtle nesting habitat in a remote location from the highway; removal of suitable turtle nesting substrate along the highway shoulder, and monitoring to measure the effectiveness and use of crossing structures and other enhancements by turtles.

The Detail Design study for the rehabilitation of Highway 24 from Blue Lake Road to Glen Morris Road encompassed an area well known within the scientific community as containing significant turtle nesting and migration activities. High instances of turtle road mortality were historically documented, prompting the project team to consider both temporary mitigation measures to address construction related impacts as well as permanent measures to address these issues.

The project team conducted a literature review, including case studies to identify appropriate culvert conditions to determine type and size that would be most likely to be used by turtle species as crossings and appropriate fencing that would be durable, cost effective and function as intended to exclude turtle and other reptile species.

Specifically, the following permanent mitigation measures were developed as a proactive approach by MTO:

1. Installation of larger culverts where replacement of existing culverts was identified as required. This included providing concrete box culverts 2.4 m wide and 1.8 m high to provide suitable conditions for wildlife crossing under Highway 24. These culvert locations were ranked in order of priority based on proximity to high turtle mortality locations, proximity to SAR records, connectivity to wetlands and other natural areas, distance to nearest suitable turtle wintering area, proximity to other priority crossing structures and opportunities to install funnel fencing without limitations (i.e., driveways).

2. The installation of permanent chain link fencing to produce a funneling effect towards the proposed upsized crossing culverts. Portions of the chain link fence will also serve as barrier fencing to restrict wildlife access to Highway 24 and prevent nesting in the shoulders. The chain link fence was also intended to serve as exclusion fencing during the construction phase, as recommended, where feasible. Fine mesh or solid geotextile material should be installed at the base of the fence to prevent the passage of turtle hatchlings and amphibians in areas of concentration.

3. A location of alternative turtle nesting habitat was proposed to be created away from the highway and behind the permanent barrier fencing on the east side of the highway.

A meeting with the Ministry of Natural Resources and Forestry was undertaken to obtain input regarding the above measures. At this meeting MNRF confirmed support of the proposed measures and that due to MTO’s proactive approach; a permit under the Endangered Species Act would not be required for the project. Subsequently, the
identified measures were incorporated into the contract documents to be implemented when construction is scheduled.

3. USE OF ALTERNATIVE TECHNOLOGIES TO LOCATE TURTLE NESTS

Over the past few decades there has been considerable advancement in technology which has allowed computers and electronics in general to become more portable and to be able to store more data than ever before. GPR is most synonymous with archaeological investigations, however it has become more prevalent in civil engineering applications as the technology has been developed for specific applications including the location of buried utilities and infrastructure, structural concrete assessments (bridge decks, piers, slabs and columns), as well as roadway surveys (pavement layer profiles, sinkholes/voids and frost tapers).

As discussed above, turtle nesting sites are difficult to identify in the field using conventional practices, which involve using a qualified biologist to perform a visual survey and inspect the potential nesting sites. The turtle nests themselves are generally flask-shaped, with the narrowest part at the top and the eggs down below in a wider chamber. The nests are buried below the surface at an unknown depth and are surrounded by gravel, sand and silt materials. The opening at the top of the nest is smaller in diameter than the width of a work boot.

GPR is non-destructive and is based on the reflection/transmission of microwave electromagnetic (EM) energy which responds to different materials governed by two physical properties of the material, electrical conductivity and dielectric constant. For reflections to occur at different material interfaces, there must be a contrast in dielectric value (reflection produced at a boundary where the dielectric changes). The turtle nests introduce a different material type and therefore would have a different dielectric value than the material surrounding it which should be visible in a GPR scan.

The following section will provide some background information on GPR technology.

3.1 GPR Technology – How Does It Work?

A GPR system typically consists of an antenna which contains both a transmitter and a receiver. The antenna emits pulses of microwave EM energy at a specific frequency range (typically between 200 MHz to 2,000 MHz) which is dependent on the type of antenna used. During emission of the EM pulses, the antenna receives reflections of the signal when there is an abrupt change in material dielectric permittivity below the surface (Conyers 2013). Essentially, some of the emitted energy pulses are reflected back to the antenna at subsurface features which could include pipes, rocks, void spaces, and soil strata. The travel time of the pulses emitted from the antenna are recorded by the GPR equipment which can then be imported into software which digitizes the reflections and allows the user to determine the depth of the reflection (ie. material interface). The general principle of GPR data collection is illustrated below in Figure 1 using an example from a typical roadway application.
The quality of the digitized reflections, or resolution, as well as the depth of signal penetration below the surface depend on the frequency of the emitted pulses which are attributed to certain models of antennae. Antennae which operate at lower frequencies (200 MHz to 400 MHz) are able to penetrate deeper into the subsurface (4 m to 9 m), however the resolution of the digitized reflections are much lower than the antennae operating between 1,000 and 2,000 MHz due to the higher amplitude of the emitted waves. The differences in the signal amplitude of various antennae are illustrated in Figure 2 below.
A digital photograph of the cart-mounted GPR equipment is provided below in Figure 3. The pictured system is composed of a Geophysical Survey Systems Inc. (GSSI) 400 MHz ground-coupled antenna and a Trimble GPS system.

Figure 3: GSSI Cart-mounted GPR System – 400 MHz Antenna

4. APPLICATION OF GPR TECHNOLOGY FOR LOCATING BURIED TURTLE NESTS

This section of the paper will describe the methodology and the steps taken to develop and implement a field program for GPR surveys to detect buried turtle nests in the gravel shoulders of a rural road in Ontario.

4.1 Development of Field Program

Several turtle nesting sites were identified in 2014 on a stretch of roadway in Ontario. Since turtles are known to return to the general location of the nesting site each year, the agency responsible for the roadway wanted to try an alternative to the conventional practice of using a biologist to perform a visual survey.

The field investigation program was developed around known nesting sites and would include performing GPR surveys for a distance of 1 km upstream and downstream of the site in an attempt to determine the limits of the nesting areas. The antenna selected for the survey was a 400 MHz ground-coupled antenna which has an effective penetration depth of 4 m below the surface. This antenna was chosen for its portability and maneuverability as it is cart-mounted (similar in size and function to a baby stroller) with three wheels and can be operated by a single technician.

Prior to the field investigation, it was uncertain if the GPR scan would be able to detect an object as small as a turtle nest. As mentioned above, the opening at the top of the nest is typically smaller than the width of a work boot (~10 cm), therefore the investigation program required careful consideration. The effective width of the GPR scan using the 400 MHz is roughly equivalent to the physical width of the antenna itself (approximately 30 cm). However, the effective scan width will shrink with increasing depth. Since the width of the existing shoulder at the project site was approximately 1.0 m in width, it was decided to use an offset of approximately 0.3 m from successive longitudinal scans. Each nesting site would require a total of three passes, with 1 km for each pass, and a total of 6 km of data collection. The general layout of the GPR scan runs are illustrated in Figure 4 below.
Another concern during the planning stages of the project was whether the turtle nests could be distinguished from other subsurface anomalies, voids, etc. Consequently, data was obtained from a previous investigation performed by a qualified biologist in July of 2015. The known location was located at the beginning of our investigation by field technicians using a handheld GPS system and subsequently surveyed with multiple passes of the GPR. This data would be used during post-processing to ground-truth and calibrate all of the GPR data collected at each nesting site.

Lastly, the fieldwork involving all GPR surveys would need to be completed between mid-July and mid-August as this timeline would not interfere with the turtles’ preparation of the nests and laying of the eggs as well as not affecting the emergence of the hatchlings in late summer.

4.2 GPR Survey Results

GPR testing was completed using a GPR system manufactured by GSSI. It consisted of a SIR-4000 data acquisition system, a model 50400S 400-MHz ground coupled antenna, and a wheel-mounted distance measuring instrument (DMI). The unit was also paired with a Trimble Global Positioning System (GPS) system that simultaneously collected GPS data during the GPR scans. All of the turtle nests identified during post-processing of the data could be exported with GPS coordinates to facilitate ease of location and would help identify the limits of the nesting site.

To collect GPR data at the required depth, the antenna was set to collect at 40 nanoseconds, or up to a depth of approximately 1.5 m below ground surface. The transmission rate for the GPR data collection was set to 100 kHz. Data was collected at a scan rate of 50 scans per meter.

A number of ground-truth scans were completed at the confirmed turtle nesting location to provide a base line sample to calibrate the data collected at each nest site. A screen capture of the calibration run showing the confirmed nesting location is presented below in Figure 5.
The buried nest is illustrated in Figure 5 above and is characterized by the hyperbola outlined by the red box in the GPR scan. Hyperbolas typically indicate the presence of a void space below the surface. In this case, the turtle nest was determined to be buried approximately 10 cm below the surface. Another nesting location identified during post-processing of the collected data is shown in Figure 6 below.

The turtle nest illustrated in Figure 6 was identified directly above a Corrugated Steel Pipe (CSP), highlighted by the yellow box, that runs underneath the roadway. The energy pulses emitted by the GPR antenna cannot pass through metal, and thus all of the energy is reflected back to the antenna. The strong hyperbolic reflection and lack of visible data below the peak of the hyperbola is indicative of a large metal object beneath the surface. Culverts require
regular maintenance and depending on their condition, rehabilitation. Depending on the treatment applied at the culvert location, mitigation measures would be required so as not to disturb the nest.

After completing all of the data processing, hundreds of potential turtle nests were identified at each nesting site. The nests were observed to be buried at varying depths ranging from 25 mm to over 300 mm below the surface of the roadway. The locations of the potential turtle nests were exported into an Excel spreadsheet file complete with GPS coordinates, GPR pass number and offset as well as the depth to the top of the nesting chamber. The data was also exported into a Keyhole Markup Language (KML) file which is used to display geographic data in software such as Google Earth of Google Maps. The ability to store the data in a KML file is valuable as the data can be accessed using free software that is easily accessible and facilitates sharing the information among all stakeholders.

4.3 Future Improvements

This paper has shown that locating turtle nests is possible using GPR technology, however a number of improvements are still needed for this technology to be a universally accepted alternative to conventional procedures. While GPR may never completely replace a conventional visual survey in the near future, it has been shown that it can be used to reduce the scope of a visual survey and identify specific locations to focus the investigation. One major issue identified during the case-study of this project which requires further research and examination is; how can we be certain that the identified nest locations are active and the eggs are still present and have not been affected by predation? More ground-truth information is required to discern an old or predated nest and an active one. This ground-truth data can be used to fine-tune the data processing techniques used to recognize active nests.

5. REFERENCES


MNRF, 2015. Significant Wildlife Habitat Criteria Schedules For Ecoregions 3E, 5E, 6E and 7E. Ontario Ministry of Natural Resources and Forestry, Southern Region Resources Section and Northern Region Resources Section. January, 2015
