Ministry of Transportation of Ontario

Highway Infrastructure Innovation Funding Program 2015 to 2019

Specific Topic #14: Beaver Exclusion-Turtle Passage & Reptile Exclusionary Fence Concept Designs: Literature Review and Field Testing

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DRAFT FINAL

Submitted To:	Submitted By:
Natalie Boyd, B.Sc. Team Lead, Ministry of Transportation 301 St. Paul Street, 2nd Floor St. Catharines, ON Tel: 905-704-2213 E-mail: natalie.boyd@ontario.ca	*Kari Gunson, Eco-Kare International; Ryan Danby, Queen's University *Point of Contact: 644 Bethune Street Peterborough, Ontario K9H 4A3 Phone #: 705-933-8430 Email: kegunson@eco-kare.com

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1. Acknowledgements

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- Bob Norrie, Maintenance Coordinator, MTO Northeast Region, Huntsville Area
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- Tom Lumley, Retired Maintenance Superintendent, Northeast Region, Huntsville Area;
- Brenda Carruthers, Retired Team Lead, MTO Environmental Policy Office;
- Jennifer Newman, Senior Policy Analyst, MTO Environmental Policy Office;
- Natalie Boyd, Team Lead, MTO Environmental Policy Office.

Our MTO project manager was Brenda Carruthers, Team Lead, Environmental Policy Office (EPO) who was replaced by Natalie Boyd at EPO in the fall of 2019 when Brenda Carruthers retired. Brenda was instrumental in co-ordinating and reaching out to key stakeholders throughout this project and Natalie Boyd saw this project to completion. Jennifer Newman (Senior Policy Analyst) carefully reviewed the draft report and provided valuable comments.

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2. Executive Summary

Road mortality is a leading cause of decline for many reptile (turtle and snake) species and is a well-documented threat on Ontario's Highways. Safe passages under highways is possible through existing drainage culverts, but exclusionary fence and guide-wall systems are also required to funnel animals to these passages.

The purpose of this research was to assess whether there is an integrated approach to providing both turtle passage and beaver exclusion from drainage culverts on highways managed by the Ministry of Transportation. A second objective was to provide installation techniques for reptile exclusion fence that is able to withstand the harsh conditions of the road environment. These techniques would then be employed as best practices during road construction projects or routinely in road maintenance procedures.

We first conducted a literature review to identify and organize the current state of practice for beaver exclusion techniques from road culverts. We also followed up with several experts, and conducted field reconnaissance to examine beaver exclusion strategies in Ontario. We then examined each technique to assess whether it would allow for both turtle passage and beaver exclusion at drainage culverts. We then performed field testing on selected techniques at two field study sites.

The first trial entailed modifying the openings on exclusion screens to exclude beavers carrying sticks but to allow permeability for turtles. We created openings in mesh screens of 8 inches wide by 4 inches high because mid-sized turtles could pass through but not adult beavers carrying sticks. Our testing showed that exclusionary screens with larger openings (8 inches wide by 4 inches high) does not facilitate passage for all turtles because some turtles may not find the opening in the screen especially when water levels decrease, or larger turtles cannot 'fit' through the opening. Furthermore, beavers are still able to dam against the exclusionary screen with sticks and debris. This would require continual routine maintenance to clear the debris. Therefore, this option was not further tested and is not recommended as a solution.

The second trial entailed a diversionary dam, and a flexible pipe to convey water from the pond into the culvert. The diversionary dam was placed around one culvert entrance at the primary site on Highway 7 and was made from sticks and debris. Several beavers built on this dam and it worked well in dry water years. When water is higher than the dam, animals can easily swim over. The pond-leveler device through the dam allows for water to move through the culvert. Exclusionary fence must be installed on higher ground and a gap provided between the dam

and fence so that animals can access the culvert. Guide-walls are also needed to funnel animals that are moving along the fence to the culvert.

Beavers built-on the diversionary dam in the first year, but were able to swim over the dam in high waters, and there was one attempt to plug the culvert with sticks. Also, a larger dam on the south side of the highway at the southwest fence end impeded water flow through the main culvert This posed a flood risk or roadbed damage due to lack of water flow in the entire system. Therefore, this technique is only recommended when the beaver is damming at or near the culvert and is not damming elsewhere. In addition, there are various other techniques that can be implemented to protect the culvert face, such exclusionary fencing etc. These methods need to be employed with measures such as a 'turtle door or gap' and with guide-walls from exclusionary fence to funnel turtles to the culvert.

Upon consultation with expert, M. Callahan from Beaver Solutions, it was recommended to install a pond-leveler pipe at the main dam on the southwest fence end. The pipe was installed in early 2019 and will likely last 10 years and require minimal maintenance. The pipe proved effective in providing adequate water levels so that the main drainage culvert was not submerged. It would also be possible to lower the pipe in the dam to further decrease water levels.

A new beaver is likely to inhabit the site each year because beavers are trapped or road-killed, therefore each beaver will respond differently to management practices. It is recommended to halt trapping so that the same beaver can adjust and acclimatize to the management practices at the site and in turn, the practices employed can be monitored and adapted.

At the primary site, the MTO upsized the drainage culvert from a 800 mm to a 1200 mm pipe in July 2018. We monitored the culvert in July 2019 when the water levels receded enough to allow for placement of a camera inside the culvert. In 2 months of monitoring with one motion triggered Reconyx camera a Snapping Turtle and a Painted Turtle likely crossed through the culvert. These findings demonstrate success in the turtle passage and beaver exclusion system.

In addition to maintaining turtle passage and beaver exclusion at drainage culverts, a secondary component of our study was to develop techniques for installation of permanent reptile exclusion fence along a highway. A phase I installation proved ineffective because the fence was installed with posts that could not sustain snow removal impacts, the fence sagged and buckled from weight of poured gravel on the bottom lip, and the fence moved apart at joins or seams between 20 m panels. A phase II installation using stronger posts, a 6 inch below-grade installation, and new join techniques at panels has proved successful with no maintenance over

three years. Exclusionary fence is an important component for turtle passage at drainage culverts, and must not have gaps or holes and be continuous along the wetland habitat to prevent undesired road-kill at fence-ends.

This research study proved successful in integrating road ecology mitigation solutions such as crossing structures and exclusionary fence with beaver management techniques at drainage culverts along highways, and allows for the coexistence of beavers and turtles in our wetlands. Next steps are to provide guidelines and protocols, and standard drawings to be used on a case-by-case basis along the MTO highway network. Road culvert sites should be prioritized where there is a known threat of flooding and/or roadbed damage due to high water levels caused by beaver damming and also where SAR turtles and snakes occur.

During road upgrade projects such as culvert replacement projects flow devices and/or culvert protection fence or diversionary dams can be implemented. These devices are then maintained during routine maintenance procedures as currently done in the Huntsville area in MTO Northeastern Region (NER).

On new roads, larger box culverts and bridges are ideal for highways that bisect turtle habitat because beavers are reluctant to dam these structures, flooding is less of a threat, and turtles can easily move through these structures. A challenge will be to educate and train environmental planners, maintenance staff and contractors to be able to identify when, where and how these techniques can be applied. In addition, the road construction process must be flexible to allow the necessary expertise to be sought and utilized during the planning and construction phases of MTO road improvement projects.

3. Introduction

Road mortality is a leading cause of decline for many reptile species and is a well-documented threat on Ontario's Highways (Gibbons et al. 2000). Gunson et al. (2014) observed a total of 219 turtles on the road or road shoulder on Highway 7 and 41 between 2012 and 2015, and 89% of these were road-killed. This and many other Ontario studies (e.g., Ashley & Robinson 1996; MacKinnon et al. 2005; Garrah et al. 2015) that have shown that when an active highway with no mitigation measures bisects an area of high reptile biodiversity and abundance, there is a corresponding high level of reptile road mortality.

Mitigation measures such as wildlife crossing structures and reptile fencing assist in reducing road mortality while providing connectivity between natural habitats bisected by roads (Dodd et al. 2004; Ontario Ministry of Natural Resources and Forestry 2016). The Ministry of Transportation (MTO) is actively involved in implementing mitigation measures to reduce road

mortality for Ontario's Species at Risk reptiles and other wildlife (MTO Traffic Office, 2012; Caverhill et al. 2011; Eco-Kare International 2017a; Ministry of Transportation 2017).

Existing drainage culverts that are suitably sized for openness (e.g., > 1 m in diameter and less than 25 m in length) and that are located in ideal turtle habitat have been shown to be effective for turtle passage (Caverhill et al. 2011; Heaven et al. 2019). When the drainage culvert is not large enough to provide safe passage for turtles these structures may be upsized during routine culvert replacement or road rehabilitation projects. In these cases, it is also recommended to include exclusion fencing along the highway right-of-way as a retro-fit to guide turtles and other smaller animals to the drainage culverts.

Beavers and turtles often co-exist because beavers create and maintain ideal wetland habitat. When wetlands are adjacent to roads, with drainage culverts, beavers often plug drainage culverts to maintain their habitat. Beavers are attracted to drainage culverts for damming because the road itself is behaving as a dam and the culvert is a 'hole' allowing water flow that a beaver wants to 'plug'. When these culverts are 'plugged' they no longer provide water flow, and during high rain-fall events the road bed may be damaged and/or the road flooded.

Currently, in Ontario and elsewhere, road maintenance agencies often exclude beavers from the inside of the culvert by placing metal screens on culvert ends (Photo 1). While these screens may be effective at keeping beavers out of culverts, beavers will still block or dam water flow through the screens with sticks and debris, requiring continual clearing and maintenance for the road agency (Photo 2). Furthermore, these screens will obstruct passage for turtles, some snakes and other aquatic wildlife including fish. These screens may also pose a safety hazard causing mortality for turtles that get stuck between the wire mesh holes.

Photo 1: Metal screen placed in front of 800 mm drainage culvert at the study site.	Photo 2: Metal screen (left) plugged with debris and sticks by a beaver preventing water flow

Effectiveness of drainage culverts for turtle passage is greatly enhanced when animals are funneled or guided to culvert passages under a road with exclusionary fence/wall system. This is accomplished with exclusion fence or barrier walls (Ontario Ministry of Natural Resources 2013; Ontario Ministry of Natural Resources and Forestry 2016). Design considerations for fence barriers, often vary on a site-by-site basis and is challenging to install because the road – wetland interface is often sloped and wet. Often, wash-outs can create holes under barrier walls where wildlife can move underneath, or snow removal activities can damage structural integrity creating a need for continual and costly maintenance.

This project, although only funded with the Highway Infrastructure Innovations Funding Program (HIIFP) for three years, spanned five years. An extension was granted from the MTO (Environmental Policy Office) due to a planned culvert replacement project in the study area and as a result our research was postponed in 2017. The culvert replacement was then delayed until July 2018. This replacement culvert likely improved the potential for turtle passage under the highway but still required a beaver-exclusion, turtle passage system to remain functional.

4. Objectives

The objectives of this study were to provide the MTO with recommendations on the following:

(1) Provide options for maintaining permeable drainage culverts for wildlife, specifically turtles along roads, while deterring beavers from damming culverts;
    a. Trial selected options at drainage culverts at sites where turtles and beavers occurred;
(2) Provide options for exclusionary fences and guide-walls that are able to withstand the harsh road-wetland interface, and snow removal activities, and;
    a. Trial selected options at sites with drainage culverts in number 1 above.

5. Literature Review Findings

To achieve Objective 1, we first conducted a literature and expert review that focused on beaver exclusion techniques at drainage culverts along roads (Appendix B). We then examined these techniques to evaluate specific modifications that would prevent beaver damming as well as allow turtle passage.

The literature review documented a variety of measures that were implemented for beaver exclusion devices at drainage culverts from North America (Appendix B). These techniques varied from using devices at the culvert entrances such as simple beaver screens, cone-shaped and cylindrical extension cages, or diversionary/barrier fencing. Other techniques, included using pond-leveler pipes at diversionary dams (intentionally created for beavers away from culvert entrances) or using pond-leveler pipes at upstream or downstream dams already built by beavers (Appendix B).

There was no documented literature on techniques used and their effectiveness at providing both beaver exclusion as well as providing turtle passage at culverts. Therefore, the research team trialed several options at two similar study sites from 2015 to 2019 to examine Objective 1. In addition, at one of these sites the research team trialed several methods for installation of permanent exclusion fence that will require minimal maintenance but also integrate beaver exclusion – turtle passage techniques employed in Objective 1.

6. Field Investigations

Two sites were selected for field investigations where previous research has shown that the highway bisected ideal beaver and turtle wetland habitat and road-killed animals overall were higher than expected (hotspots). Both sites had existing smaller drainage culverts (800 mm) with beaver exclusion screens made from metal. Both sites also had exclusion fencing recently installed at road-kill hotspots to guide animals to the drainage culverts. Trials and lessons learned are outlined from 2015 to 2019.

The first site was on Highway 7 in MTO East Region (ER) where a previous monitoring study (HIIFP Project #2012-18; Gunson et al. 2014) showed a high incidence of turtles being killed on the highway on an approximately 500 m section of highway (Figure 1).

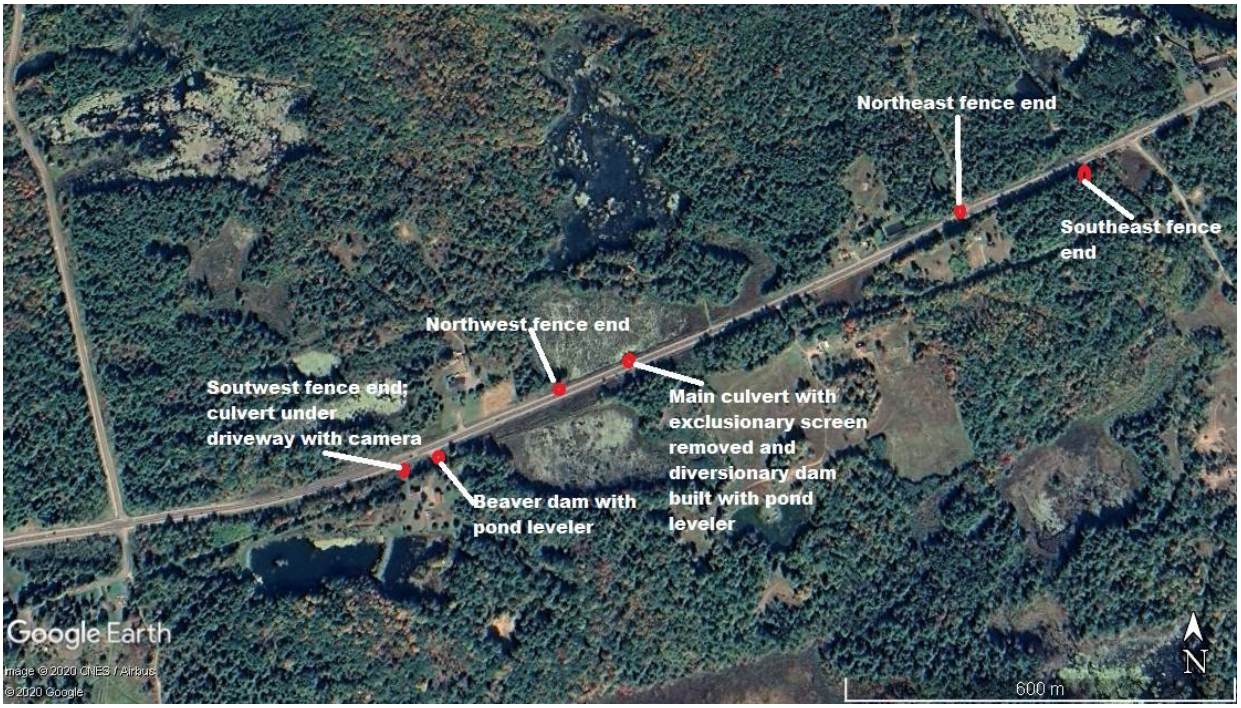

Figure 1: Location on Highway 7 where exclusion fencing was installed and where field testing was conducted at drainage culverts and at the beaver dam south of the highway.

The second site was in MTO West Region on Highway 6 in the Bruce Peninsula where a previous study documented a high incidence of snakes and turtles being killed on the highway (Eco-Kare International 2015). The majority of the field work was conducted at the Highway 7 site because of the nearness of the site to where the researchers resided.

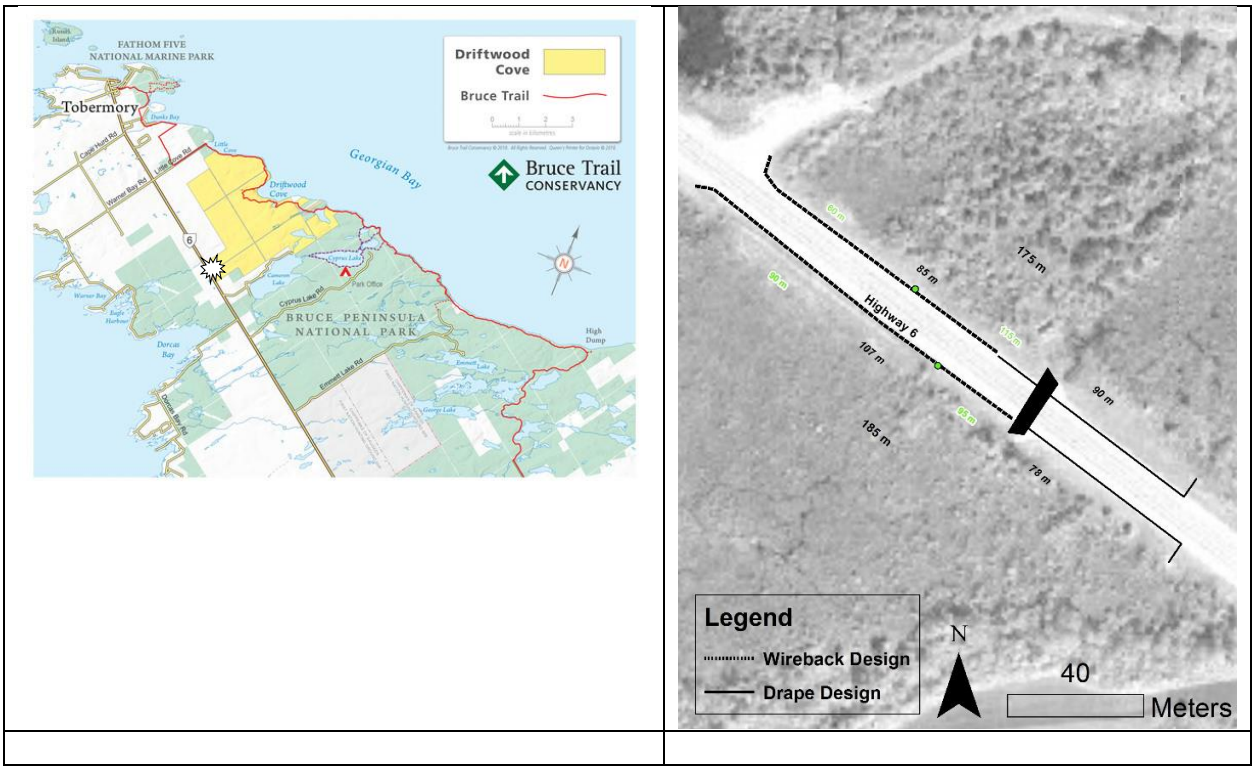

Figure 2: Location (✳) marked on Highway 6 (left) where temporary exclusion fencing was installed at a drainage culvert (as part of another project) with a beaver exclusion screen on the north side (black polygon) and where initial field testing was conducted (right).

Exclusionary screen modification

The first modification to beaver exclusion at culverts entailed cutting a larger mesh opening in the exclusion screen that would allow mid-sized Snapping Turtles and most Painted Turtles but not adult beavers through. The opening size that was tested was 8 inches wide by 4 inches high. The average skull size of a beaver is approximately 4.5 inches wide and tall. In addition, it was thought that beavers would not be able to both swim and carry their sticks through the opening. The modified exclusion screen was tested on Highway 7 and Highway 6.

On Highway 6, we replaced a beaver exclusion metal screen on the east side of the drainage culvert with a wire screen with a mesh size of 8 inches wide by 4 inches high (Photo 3, right). We then monitored the drainage culvert with a PC800 motion activated Reconyx camera from July 15th 2015 to October 13th, 2015 to determine what animals would pass through the screen into the drainage culvert. Water levels varied between 10 and 30 cm during the study and no debris blocked the entrance of the culvert with the screen.

On the east side of the culvert (with screen) snakes (12 Eastern Gartersnakes, 7 Ribbonsnakes, and 1 Eastern Smooth Greensnake, Photo 4) and frogs (Photo 7) were able to enter into the

culvert. Some mammals were able to enter such as a River Otter (Photo 3) but not larger mammals such as a Raccoon (Photo 6). One mid-sized Snapping Turtle was not able to enter into the culvert (Photo 3, left).

Photo 3. Exclusionary wire screen on the east side of the drainage culvert entrance with larger mesh size at the culvert opening (right) and pictures of Snapping Turtle trying to enter culvert but turning around (left).

Photo 4. Smooth Greensnake, Aug 11th, 2015

Photo 5. Otter tail exiting east side of culvert, Oct 7th, 2015

Photo 6. Raccoon attempting to enter screened culvert entrance, Oct 11th, 2015

Photo 7. Green frog sitting on rock ramp at east culvert entrance, Jul 31st, 2015

On Highway 7, a metal exclusion screen with a 'hole' cut in the bottom (8 inches wide x 4 inches high, Photo 8) was placed at the drainage culvert at the southwest fence end along Highway 7 (see Figure 2). The culvert was monitored with a motion activated Reconyx camera (PC800) that was placed at the roof of the culvert at one end from September 6th to October 23rd, 2015. There was about 1 – 5 cm of water flow through this culvert during the monitoring period. Water flow was impeded by a beaver dam along the highway upstream about 25 meters.

There was a diversity of small mammals that were able to pass through the hole at the bottom of the wire mesh screen. These animals ranged from Muskrat (*Ondatra zibethicus*), Meadow Vole (*Microtus pennsylvanicus*), American Mink (*Neovison vison*), and Deer Mouse (*Peromyscus maniculatus*). The largest animal to pass through was a Raccoon and one River Otter did not find the larger opening and turned around (Photo 9). No turtles were found at the culvert. There were two snakes that passed into the culvert: An Eastern Garter snake and a Northern Watersnake (*Nerodia sipedon*) (Photos 10 & 11).

Photo 8. Metal screen with opening at bottom of the southwest drainage culvert for animals to pass under the driverway

Photo 9. River Otter unable to find gap through the screen at the southwest drainag culvert, Sep 20th, 2015

Photo 10: Eastern Gartersnake passing through hole in exclusion screen

Photo 11: Northern Watersnake passing through hole in exclusion screen

The results from this monitoring showed that a larger opening (8 inches wide by 4 inches high) in an exclusionary screen would allow some animals to enter a drainage culvert but not all animals. For example, a Snapping Turtle (*Chelydra serpentina*) wider than 8 inches, and a Raccoon (*Procyon lotor*) were not able to go through the larger opening at the Highway 6 site. At the Highway 7 site a River Otter (*Lontra canadensis*) looked as though it could not find the gap in the bottom of the screen (Photo 9).

A primary objective of drainage culverts with exclusionary fencing is to allow safe passage of animals under the highway. Exclusionary screens prevent beaver access, but also excludes

turtles, and other larger animals. Modified exclusionary screens with a larger mesh opening have several limitations. Use by aquatic wildlife is dependent on water levels, the ability of animals to find the opening, and the size of the opening because larger animals cannot 'fit' through the opening. Furthermore, although this did not happen in our trials, beavers can still use sticks and debris to dam the screen with these opening. This would require routine maintenance to clear the debris. Therefore, this option was not further tested and is not recommended as a solution for beaver exclusion and turtle passage at culverts.

Diversionary dam & pond-leveler at culvert entrance

As a second trial, a diversionary dam was built on October 9th 2015 around the north culvert entrance in the middle of the fenced area on Highway 7 and was monitored until 2018 (see Figure 1). The idea was that a beaver would find it easier to build on a diversionary dam made from upright sticks than to go around this to build on or dam the culvert. The dam was built by placing and hammering in vertical sticks upright in an arch around the culvert entrance which were stabilized with mud and sticks (Photo 12). A gap was left between the diversionary dam and the exclusionary fence to allow wildlife to move into the culvert (Photo 13).

The site was monitored to assess wildlife activity, water levels and flow, and beaver activity at the diversionary dam about one time per month from October 2015 to 2018. After installation, woody debris and mud accumulated at the diversionary dam. The bulk of materials were added to the dam between November 6th, 2015 and December 25th, 2015 (Photo 14). This suggests that the beaver preferred to dam the diversionary dam rather than the culvert entrance. However, it was noted that the gap for wildlife movement to the culvert was now blocked by debris and mud from the beaver, and water flow through the dam into the culvert was not occurring (see below).

Photo 12: Construction of a diversionary dam around the north culvert entrance on Highway 7

Photo 14: Side-view of dam set-up where beavers used sticks and mud to close the gap between exclusionary fence and the diversionary dam.

Photo 13: Gap between dam and exclusion fence where a turtle (pasted into photo) could access the culvert, later beavers closed this gap with sticks and mud (Photo 14).

A pond-leveler pipe was added through the dam to maintain water flow from the wetland through the culvert (June 3rd, 2016). The pond-leveler pipe was a 10-metre long section of 6" diameter black Polyethylene Corrugated Pipe (PCP) placed approximately two feet into the culvert inlet and secured with plastic ties to a metal rod that was hammered into the stream bed at the inlet (Photo 15). The pipe then extended through the dam and about 10 m into the wetland into a metal protective cage (Photo 16-18).

The end of the PVC pipe was anchored to the metal cage using plastic ties. The purpose of the cage was to prevent the end of the pipe from being plugged by a beaver or from pond debris. The metal cage was constructed by wrapping a galvanized cattle panel (4 feet by 8 feet with a 6 inch mesh opening) into a cylinder and using malleable plastic-covered metal ties to secure ends. A single circular piece of panelling was cut for the top of the cage, with the overhang wires of both the cylindrical and side panelling being bent and tied together with malleable metal wires.

	
Photo 15: Culvert with two metal t-posts in front of inlet, with pipe anchored on to one (right) post for stability.	Photo 16: The pipe extended outwards, passing through diversionary dam on west side of culvert, extended westwards, parallel to highway.

	
Photo 17: Implementation of cage with pipe into wetland.	Photo 18: Cage anchored into wetland floor with pipe inserted in a hole at the side.

Two Reconyx cameras (PC800) set for motion detection only, were set-up at each side of the culvert facing towards the dam to monitor beaver and turtle activity at the diversionary dam and pond-leveler pipe from June 3rd to September 29th, 2016 (Photos 18 & 19). At the onset of monitoring, sticks were removed and a rock ramp was built to water level so that turtles following along the exclusion fence could access the culvert.

Photo 19: Camera (red box) at east side of culvert facing east side of diversionary dam. Red arrow indicates placement of second camera.

Photo 20: Camera (red box) at west side of culvert facing west side of diversionary dam.

There was a progressive accumulation of debris and mud at the rock ramp between the dam and exclusionary fence on both sides of the culvert (Photos 21 to 26). It was assumed that the debris (rocks and logs) were moved here by beavers although surprisingly no beavers moving materials were not captured on the cameras. This may because beavers likely built-up the dam during night hours and the motion detection distance is limited, especially if the beavers work in the water. One Painted Turtle on July 23rd, 2016 was observed climbing over the stick debris on the west side and may have entered the enclosure from moving through the drainage culvert.

Photo 21: Initial set-up of Reconyx cameras, view of gap between diversionary dam and culvert on west side on 3-Jun-2016.

Photo 22: Initial debris accumulation and water level rise on 11-Jun-2016.

Photo 23: Debris build-up on 06-Jul-16.

Photo 24: Additional log at far right side on 27-Sep-16.

Photo 25: Stick debris on east side of diversionary dam on 10-Jul-16.

Photo 26: Stick debris on east side of diversionary dam with additional sticks on 05-Aug-16.

We continued monitoring and adapting the system in 2017. In the spring, water levels were high (100 cm in April and 125 cm in July), almost entirely submerging the diversionary dam, culvert and exclusionary fence. On July 10th, 2017, the research team moved the wildlife exclusion fencing back about 1 m to higher ground (Photo 27). On an August 12th site visit, the culvert north entrance had been plugged with sticks, presumably by a beaver. The sticks were removed and silt fencing was added as an east and west structure to guide wildlife from the exclusion fence to the culvert (Photo 28). Two metal t-posts were placed at the culvert entrance to deter beavers from entering the culvert.

This improved functionality of the system because the exclusion fence was no longer submerged, and turtles following the exclusion fence would now be directed to the culvert. A gap between the drift fence and diversionary dam was on higher ground and beavers would likely not close this gap because they typically do not carry debris/sticks out of water to dam areas (Mike Callahan, personal communication).

Photo 27: Moving the exclusionary fence to higher ground on the north side of the main drainage on 10-July-2017.

Photo 28: Silt fencing used to guide turtles to culvert on 12-Aug-2017.

Two motion activated Reconyx cameras (PC800) were set-up at the east and west side of the culvert (Photos 29 & 30). By the end of August, it appeared that a beaver had breached the dam in the middle at a low point (Photos 31 & 32) and the gap was closed with logs. The beaver breached the dam again and was captured on camera on two occasions attempting to climb over the exclusionary guide walls. In doing so, the beaver did not plug the culvert or build further on the dam. Muskrats, mink, raccoons, moles, mice and chipmunks were also captured moving along the guide-wall but no turtles.

Photo 29: Monitoring camera set-up on west side of culvert on 12-Aug-2017.

Photo 30: Monitoring camera (red box) set-up on east side of culvert on 12-Aug-2017.

Photo 31: Secured diversionary dam on 12-Aug-2017.

Photo 32: Breached dam presumably by a beaver on 31-Aug-2017.

	
Photo 33: Beaver trying to climb silt fence on wetland (safe-side) side of culvert on 23-Aug-2017.	Photo 34: Beaver trying to climb silt fence on 05-Sep-2017.

The diversionary dam was successful in drier years (2015 & 2016), but was breached by a different beaver in 2017 during high water levels. It was assumed that the beaver in 2017 was new to the area because trapping occurs every winter (personal communication, Brad Donaldson, Carillion, Retired maintenance patrol, Madoc Patrol Yard; presently replaced by Richard McCullough, Ercom Services). This beaver was able to swim over the diversionary dam and plug the culvert. Perhaps, if the dam was more exposed the beaver would have worked on the diversionary dam.

When water levels receded, likely the same beaver as above, breached the exposed diversionary dam but did not dam the culvert. The photos showed the beaver navigating the exclusionary silt fence (Photo 33). The beaver may not have plugged the drainage culvert because the large dam on the south side of the highway was sufficient to provide the desired water depth.

The diversionary dam and pond-leveler combination was effective but was breached at one point during high water levels, therefore it requires maintenance and monitoring. The addition of two poles or posts at the culvert will help to deter beavers from plugging the culvert. At this site the diversionary dam and pond-leveler combination was not effective because water was still dammed by a beaver downstream southwest of the culvert, therefore there was no water flow. This technique is only recommended when the beavers have not dammed elsewhere along the roadbed to prevent water flow. However, it can be complementary to other techniques used (see below). Road-side wildlife exclusionary fencing must be on high land to

provide a gap between the culvert entrance and exclusionary fencing so turtles can access the culvert. Guide fencing will guide turtles that move along the fence to the culvert for safe passage.

Pond-leveler at downstream dam

During the literature review it was found that pond-leveler devices or 'beaver deceivers' have been installed by the MTO NER in Ontario. A field meeting was conducted with Bob Norrie (Maintenance Coordinator, MTO NER, Huntsville Area) on May 5th, 2016 to view an example of a pond-leveler device employed at a secondary road on Highway 69 at the Musquash River (Photos 51-54). Furthermore, an email discussion (July 2019) and teleconference call (July 23rd, 2019) was held with retired senior policy analyst, Brenda Carruthers (Team Lead MTO Environmental Policy Office, now retired); Natalie Boyd (new Team Lead in the Environmental Policy Office (absent from teleconference); Jennifer Newman (Senior Policy Analyst, MTO Environmental Policy Office); Kari Gunson Principal, Eco-Kare International); Bob Norrie; and James Hamilton (Maintenance Superintendent, MTO NER, Huntsville Area). The objectives of these consultations were to determine when, how, where and the success of the pond-leveler pipe systems used by the MTO NER.

Photo 51: Aerial view of secondary road with culvert providing water flow of stream into river (red arrow), a beaver had dammed the flow at the east end of the red arrow to create a beaver pond (right).

Photo 52: Beaver pond on east side of secondary road.

Photo 53: Pond-leveler pipe enters into drainage culvert runs along channel through dam and into wetland and is protected by a cage.	Photo 54: Black pipe extending inside culvert.

In addition, the project team consulted with Mike Callahan from Beaver Solutions who conducted a site visit in July 2018. M. Callahan recommended installing a pond-leveler pipe at the large beaver dam on the southwest side of the exclusionary fence approximately 10 m upstream from the southwest culvert and to monitor beaver activity (Figure 3). This was discussed with the project team, MTO ER and the policy office, as well as MTO ER maintenance office in Madoc at a site visit on October 17th, 2018.

On May 3rd, 2019, a pond-leveler pipe at the large beaver dam was carefully installed using the design and direction developed by beaver solutions (see video at https://www.youtube.com/watch?v=LVfpRBzk5PM, Figure 3, Photos 35-38). Two 6-foot lengths of 12 inch (250 mm) dual-walled BOSS 2000 High Density Polyethylene Pipe were joined with a coupler and installed through the dam. Steel fence sheets sometimes referred to as cattle fencing panels (6 gauge) 4 feet by 8 feet with a 6-inch mesh opening were used to construct a 5-foot diameter cage around the inflow that was placed in about 1.5 metres of water. The outflow pipe was installed at the highest point of the dam and the bottom of the pipe was about 9 inches (22.9 cm) below the upstream water level.

Water was flowing vigorously out of the pipe immediately after set-up (Photo 39) and continued flowing between June 12th and July 4th, 2019 (Photo 40). The water receded immediately upstream of the dam about 4-5 inches. Afterwards it stayed approximately the same level.

Water levels were recorded at both the north and south sides of the main drainage culvert two times in May, one time in June, two times in July, and one time in August. The new drainage culvert was never submerged in water and water levels declined at the main culvert about 6 cm while the water was running out of the pond-leveler. Water levels dropped approximately 17 cm from May to August at the north side of the culvert. The additional reduction of water (11 cm) at the main culvert was likely due to reduced precipitation and hot temperatures.

Two road-killed beavers were seen on Highway 7 during the project, one on April 14th, 2017 and another on June 6th, 2019 near the exclusion fence. This is evidence that beavers may not be able to escape from the exclusion fence and additional jump-outs or escape opportunities may be required to alleviate road-kill.

A live beaver was seen on site during the pond-leveler pipe installation in May 2019. Another live beaver was found on camera moving through the southwest drainage culvert on June 13th, 2019. It is unknown if there was any further beaver activity in the area. The beavers seen in the

area on June 13th, 2019 did not build on the diversionary dam at the main culvert of the larger dam where the pond-leveler was installed.

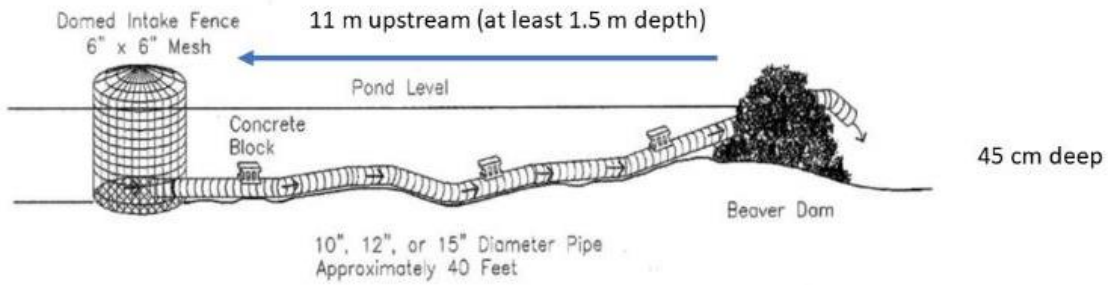

Figure 3: A schematic of the pond-leveler system installed at the large beaver dam near the southwest drainage culvert. Adapted from Beaver Solutions.

Photo 35: A live beaver (top) going through culvert under driveway near dam; dead intact beaver (bottom) found along south side of exclusion fencing in May 2019.

Photo 36: 6-foot 250 mm HDPE Pipe transported and assembled into protective cage on site.

Photo 37: View upstream of the large beaver dam in a channel that flows to the southwest drainage culvert.

Photo 38: Placing the pipe into the beaver dam.

Photo 39: Water flow out of the pipe on initial set-up.

Photo 40: No water flow from pipe on July 4th, 2019.

The pond-leveler system was relatively easy to install after reviewing guidance from the Beaver Institute and obtaining the supplies. Water levels were reduced to the level of the pipe in the dam (about 6 inches). One live Beaver was observed at the site on June 13th, 2019 10 m

downstream of the pond-leveler but there was no evidence of beaver damming on the site. Therefore, it is assumed that the beaver occupying this site was content with the wetland water depth. If a further reduction in water level is required the pipe could be moved lower in the dam. It is recommended to reduce water levels up to a maximum of 12 inches from the upstream beaver pond because beavers are likely to tolerate this and not build a dam at another location (M. Callahan, personal communication).

New upsized culvert monitoring on Highway 7

At the Highway 7 site, a new upsized culvert (1200 mm) replaced the old 800 mm culvert in July 2018 as part of a culvert replacement project with the MTO. The upsized culvert was installed because the culvert was being replaced as part of a road upgrade project, and this site had previously been identified as a turtle crossing hotspot (Gunson et al. 2014). This new culvert is believed to improve the likelihood of turtle crossings under the highway.

During the second phase of exclusion fence installation, reptile exclusion fence (see below) was pulled back from the culvert to higher ground to prevent submergence of the exclusion fence in spring during higher waters (Photos 41 & 42). Permanent guide-walls were then built that extended from the exclusionary fence to each south and north drainage culvert entrance in June and July 2019 (Photos 43 & 44). These guide-walls are intended to direct turtles to the drainage culvert when walking along the exclusion fence and are extremely important, otherwise turtles and other wildlife may walk by the drainage culvert.

The amount of time animals move along exclusionary fence should be minimized. Previous research has shown that animals may be exposed to a fatality when moving along exclusionary fencing due to over-heating. In addition, if holes or fence gaps are present, animals will cross the road and be exposed to road-kill. These unnecessary fatalities can be prevented by providing shade structures such as shrubs along the safe-side of the fence, and ensuring there is adequate safe crossing opportunities such as culverts with guide-fencing (Peaden et al. 2017; Boyle et al. 2019).

Photo 41: Exclusion fencing pulled 1 metre above south main culvert on higher ground

Photo 42: Exclusion fencing pulled 1 metre above north main culvert on higher ground

Photo 43: Guide-wall fencing extending from fence to north main culvert entrance on 13-Jun-19.

Photo 44: Guide-wall fencing extending from fence to south main entrance on 08-Jul-19

One motion triggered Reconyx camera (Hyperfire 2 HP2X) was used for monitoring on the north side of the culvert from July 8th, 2019 to September 20th, 2019. Monitoring was initiated when water levels receded enough to allow a camera to be placed on-top of the culvert, above water. Rocks were placed on-top of each other inside the culvert up to the high level of water which forced animals entering into the culvert to swim up into the camera field of view (Photo 45 top).

Among other aquatic mammals such as Muskrats, a Painted Turtle (Photo 45 bottom) and a Snapping Turtle (Photo 46) were documented using the main drainage culvert. Although only captured on one side of the culvert, the turtles were not seen turning around and are therefore likely complete passages (Eco-Kare International 2020). These two turtle passages highly support the success of the beaver-exclusion, turtle passage system as well as the new upsized culvert. If monitoring had been done in June, it is likely many more turtles would have been captured. Furthermore, it is likely that some turtles were missed because motion detection cameras are not ideal for cold-blooded animals and time lapse is ideal (Eco-Kare International 2020).

	
Photo 45: Placement of camera in main culvert with rocks piled up to water height July 8th, 2019 (top); Painted Turtle passing under the camera field-of-view on the north side of the main drainage culvert on 29-Jul-19, at 13:09 PM (below).	Photo 46: Snapping Turtle passing under the camera field of view on the north side of the main drainage culvert on 26-Jul-19 at 12:26 PM.

Permanent reptile exclusion fence

Temporary reptile exclusion fencing was installed on Highway 7 in 2012 and 2013 (Gunson et al. 2014) and was upgraded with 875 m of permanent Animex fencing in October 2015 with jump-outs (see location in Figure 1;Phase I). This was the first large-scale installation of Animex fencing in Ontario, Canada. The following lists key deficiencies noted in the fence during and after installation of phase I:

- Cable ties were used to fasten posts to fence material; this technique failed because the ties expanded and snapped under extreme heat (>40^{o} C);
- 4 cm wide t-post made from recycled plastic failed (bent or broke) during the 2015-2016 winter season from snow removal with plows;
- Heavy loads of gravel on the road-side of the fence had caused sagging and buckling of the fence;
- High amounts of snow and ice had caused the fence to separate at joins and/or sag;
- Portions of the bottom lip were no longer buried at wash-outs and at uneven terrain, and;
- High water levels at the drainage culvert completely submerged the fence on the south side.

In early 2016, about 12 hours of maintenance was conducted to replace broken posts, bury the bottom lip, and re-connect the seams between 20 m panels that had come apart. Exclusion fence placement and subsequent maintenance proved successful because only one dead Blanding's Turtle was found 10 m from the southeast fence-end during road surveys in June 2016 as part of a concurrent MTO research project (Eco-Kare International 2017a).

In 2017, no fence maintenance or any formal on-road surveys were conducted. One survey was completed by counting the number of dead on road (dor) turtles along the fence on July 10th, 2017. Five Painted Turtles, 1 Snapping Turtle, and 2 Watersnakes were found within 100 m of the drainage culvert. The turtles likely swam over the south side of the exclusionary fence because the fence was entirely submerged (+10 cm) at the drainage culvert. There were an additional 6 Painted Turtles where there was fencing on only one side of the highway at the west fence-end. In addition, there was 1 Painted Turtle and 1 Snapping Turtle at the east fence end.

In August 2016, it was decided that the entire fence would be replaced (Phase II), with a new below-grade installation with specialized joins between rolls of materials, (see https://s3-eu-west-1.amazonaws.com/assets-animexfencing-com/documents/PDFs/Animex-Roadside-Embankment-Installation-Guide.pdf; Photos 47-50). Furthermore, stronger and larger posts (5 cm wide) were used and attached to the fence by placing posts through holes drilled with a hole saw. Phase II installation began in August 2016 (100 m) and continued again in October 2018 (430 m). The remaining 36% of the phase I exclusion fence remains to be replaced on the south side of the highway.

There were no new jump-outs or escape opportunities installed because about 75% of the fence height was below-grade and about 20-30 cm was above-grade. It is assumed that most small mammals and turtles could scale the 20-30 cm above-grade fencing. However, two dead beavers were found along-side the exclusion fence in 2017 and in 2019 (Photo 35). It is unknown whether these animals were road-killed or died of other causes.

It is recommended to monitor this site to evaluate whether more animals are road-killed as a result of being trapped between the exclusion fence. In addition, jump-outs can be installed from woody debris piled up on the road-side of the fence to provide escape opportunities from the road-side of the fence. Jump-outs should be located at fence-ends or where the exclusion fence is a barrier to animal movement on the road-side (Photo 48). Alternatively, fine gravel or small rocks and dirt can be added to the back-side of the fence to make it level with the road-side slope.

In May 2019, 2 technicians spent 2 hours providing maintenance on the remaining phase I fence to ensure functionality during the 2019 warm season. Phase II fence installation and placement has adequately addressed all the deficiencies noted in Phase I and no maintenance has been required for the replaced Phase II fence in 2017, 2018, and in 2019.

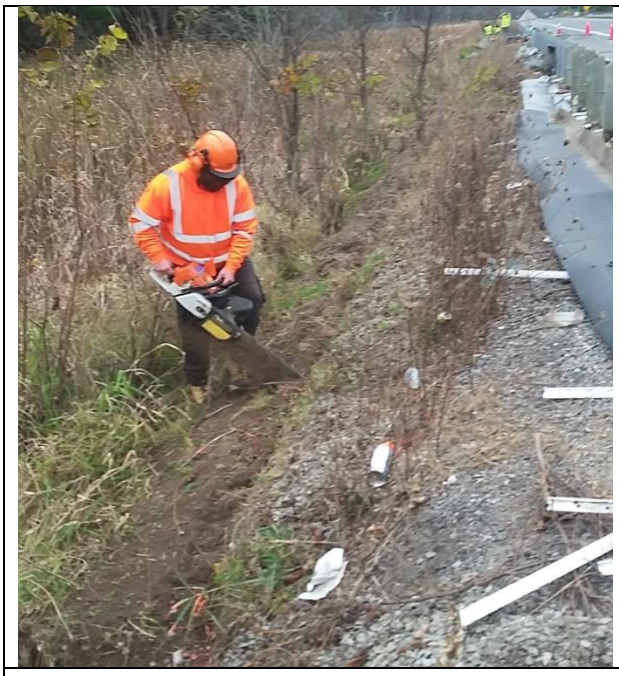	
Photo 47: Preparation of ground at road slope for below-grade installation of exclusion fence, 23-Oct-18	Photo 48: Example of a jump-out with wood pieces stacked and stabilized with sand bags in Presqu'ile Provincial Park.

	
Photo 49: Viewing exclusion fence (Animex) from inside with larger stronger posts attached through the top lip of the fence 26-April-2019; no maintenance required after installation in October 2018.	Photo 50: Viewing exclusion fence from top showing an approximate 30 cm below-grade installation (26-April-2019).

7. Conclusions and Recommendations

This was the first attempt, that we are aware of, to integrate road ecology mitigative measures (underpass and exclusion fence system) with techniques for mitigating human/beaver conflicts in a suburban environment. These integrated techniques require co-ordination between several disciplines and stakeholders, and are extremely important to consider at wetland habitat bisected by roads and occupied by beavers and turtles. Furthermore, because much of these measures are experimental and being trialed in new locations, the importance of adaptive management is essential to maintain, improve and learn from the system and prevent unnecessary wildlife mortality.

Therefore, it is recommended to continue monitoring the Highway 7 site to assess long-term functionality of the pond leveler system with new beavers in the area. Monitoring should include:

- Evaluate how beavers respond to the water levels at the site in 2020;
- Although not a necessary part of this system the diversionary dam should be monitored to assess its functionality for future applications, the main drainage culvert should be

protected from beaver access by including posts (1 x 1 by 7 feet long snow plow marker posts or t-posts) at both the inlet and outlet;
- Replace the remaining Phase I (36%) of Animex exclusion fencing to Phase II installation methods and extend the northwest fence end to be in-line with the southwest fence end and add jump-outs at fence ends;
- Evaluate how well Phase II fence stands up to snow, ice and changing hydrology;
- Monitor the site for road-kill, beaver activity, hydrology, pond-leveler system maintenance and modifications, and turtle use at the up-sized culvert, and;
- Educate the local residents about the pond-leveler system and its success so that trapping is discouraged at the site on privately owned property and/or by the MTO maintenance contractors; it is essential to have the same resident beaver at the site to acclimatize to the existing water levels with the new pond-leveler pipe.

In addition, to monitoring Highway 7, it is recommended to install pond-leveler pipes as routine maintenance procedures, and in road upgrade projects with the MTO. These measures have been shown to be an effective tool in preventing beavers from damming hydraulic flow in road culverts in this study and others.

A compilation by Boyles & Savitzky (2009) showed that the use of pond-leveler pipes installed at 39 of 40 sites were functioning properly and meeting management objectives in Virginia state. The costs to install and maintain flow devices were significantly lower (6.9 times) than preventative road maintenance, damage repairs, and/or population control costs, prior to flow device installation. Often beaver dams are removed and this is a costly management tool and has potential to cause indirect property damages to private property and infrastructure.

An additional environmental benefit of pond-leveler pipes is that beavers continue to exist and construct wetlands resulting in 'no net loss' of wetland habitat. This is extremely beneficial in in regions such as the Mixedwood Plains of Southern Ontario where wetland conservation is a primary goal of the Provincial Government (see A Wetland Conservation Strategy for Ontario 2017-2030).

Other effective tools are oversizing culverts (Jensen et al. 2001), or providing more culverts (Hawley-Yan 2016) to discourage beaver plugging activity. Beavers are more reluctant to dam larger culverts such as box culverts or bridges because the water flow is less constricted (Jensen et al. 2001). Larger culverts are also preferred for creation of fish habitat and turtle passage and are easier to clean when beavers dam inside. If beavers dam elsewhere away from larger culverts, a pond-leveler system is easy and cost-effective to implement and maintain.

Presently, pond-leveler systems are installed routinely along the highway network to manage road bed damage at culverts in the Huntsville area within the MTO Northeastern Region (NER). (Appendix A). There are approximately 50-70 deceivers (pond-levelers) protecting culverts of an estimated 3,100 (2%) of the culverts in the Huntsville Area (Bob Norrie, MTO NER Maintenance

Coordinator). These installations have decreased the use of other exclusionary methods such as beaver cones, posts, and screens at culverts.

The maintenance department installs pond-leveler pipes when there is a threat of highway flooding and these are maintained by the maintenance contractor. The protocols are written up in the CDMC (Contractor Directed Maintenance Contract) in the Maintenance Standard Specification Section for Roadside Maintenance (Appendix A). Beaver pond-levelers are installed in the region and contractors must inspect, maintain and repair devices to minimize impacts to the highway infrastructure. Inspection results are recorded on a Beaver Pond-leveler Inspection form and submitted to the Contract Administrator each month.

It is recommended to devise Best Management Practices for design specifications that includes drawings for specific scenarios based on protocols in MTO NER and elsewhere. A process for implementing these measures can be modelled after that established in MTO NER. In addition, other opportunities for implementation into existing roads and during culvert replacement projects should be investigated. Workshops could be provided to educate and train practitioners about how to implement these measures. Additional to guidelines, the Environmental Policy Office in coordination with Maintenance and Highway Design can investigate using Special Provisions and Standard Drawings for wider application into road upgrade projects.

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Appendix A: Pond-leveler pipe installation guidelines

MAINTENANCE STANDARD SPECIFICATION
4001 – Roadside Maintenance

Ontario

APPENDICES

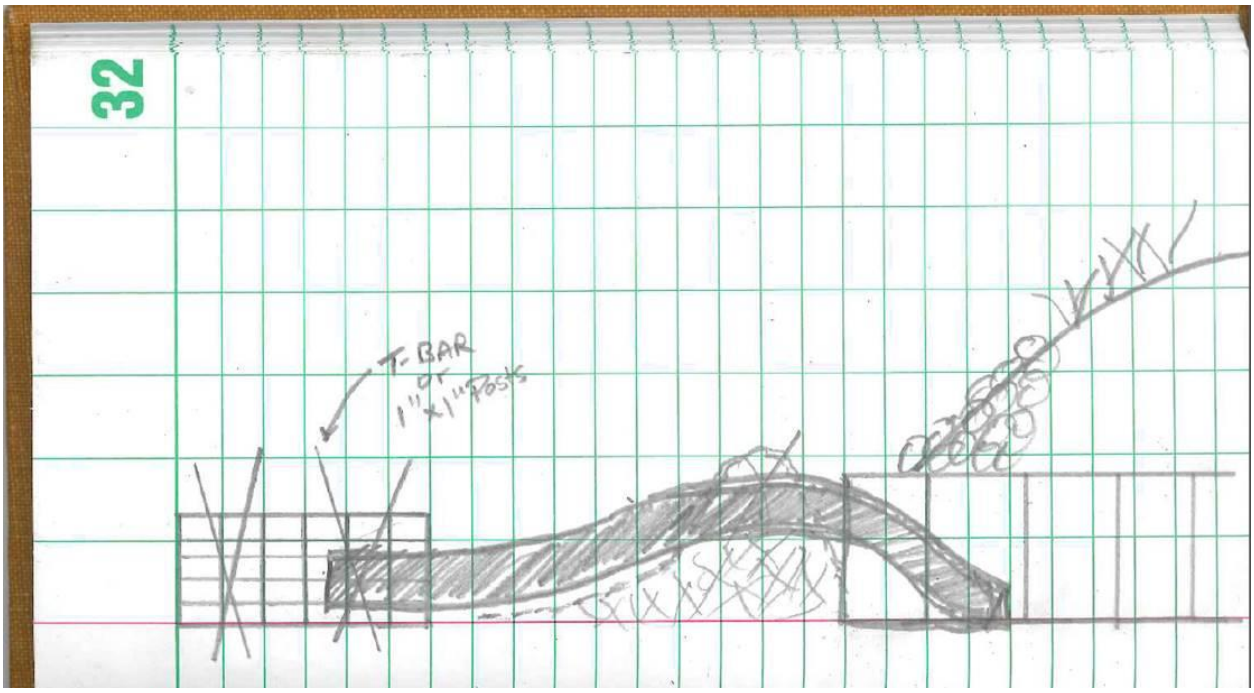
APPENDIX 4001A – CONTRACT SPECIFIC ADDITIONS AND AMENDMENTS

MSS4001 Roadside Maintenance is amended as follows:

Subsection 4001.04.05.01 is amended by the addition of the following:

h) Beaver Pond Levellers

The Contractor shall be complete all work on all Beaver Pond Levellers identified Schedule B – Beaver Pond Levellers. The work at each site shall include: monthly inspection, cleaning away collected debris, and repairing deteriorated components and complete systems as necessary to control the pond water level from impacting the highway infrastructure. The inspection results are to be recorded on the Beaver Pond Leveller Inspection Form in Appendix 4001B – Forms, and submitted to the Contract Administrator by the 15th of the following month.



Flexible Pond-leveler Pipe Installation Guidelines developed by retired Maintenance Superintendent, Tom Lumley, Received 10-February-2017

Flexible Pond Leveler pipes do not need to be sized like culverts to handle catastrophic storm events because heavy storm runoff will simply flow over the top of the dam.

Following the storm the pipe will return the pond to the normal level. Some mild pond fluctuations are possible following very wet periods, but since the dam height is controlled by the pipe the pond size remains controlled at a safe level.

When installing a pipe system it is very important to lower a pond only enough to protect our interests. The more a pond is lowered the more likely it is beavers will build a new dam downstream to render the pipe ineffective. Lowering a beaver pond by up to 450mm is generally not a problem.

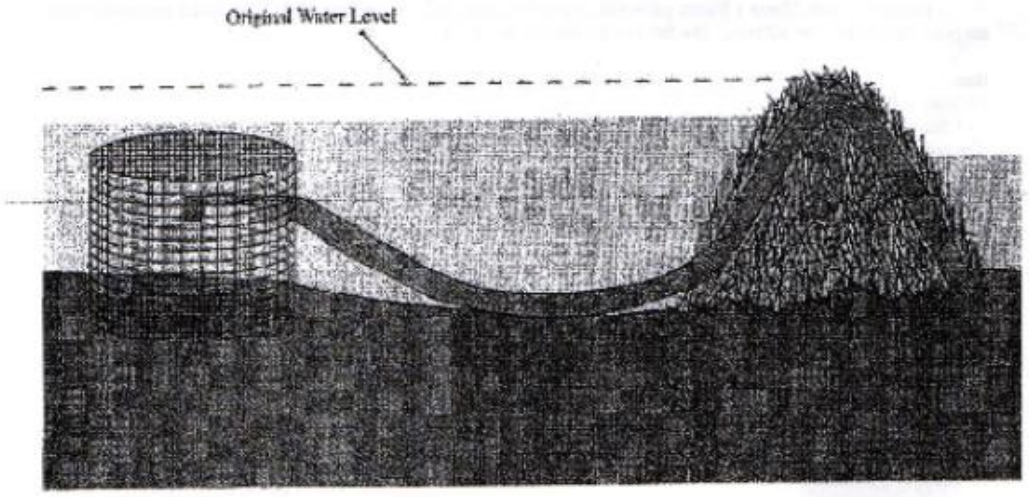
Whenever a pond must be lowered by more than 450mm, a single round of trapping may be necessary prior to the flow device installation. When new beavers without the memory of the higher water level relocate to this area they are more likely to tolerate the smaller pond so repeat trapping will not be needed.

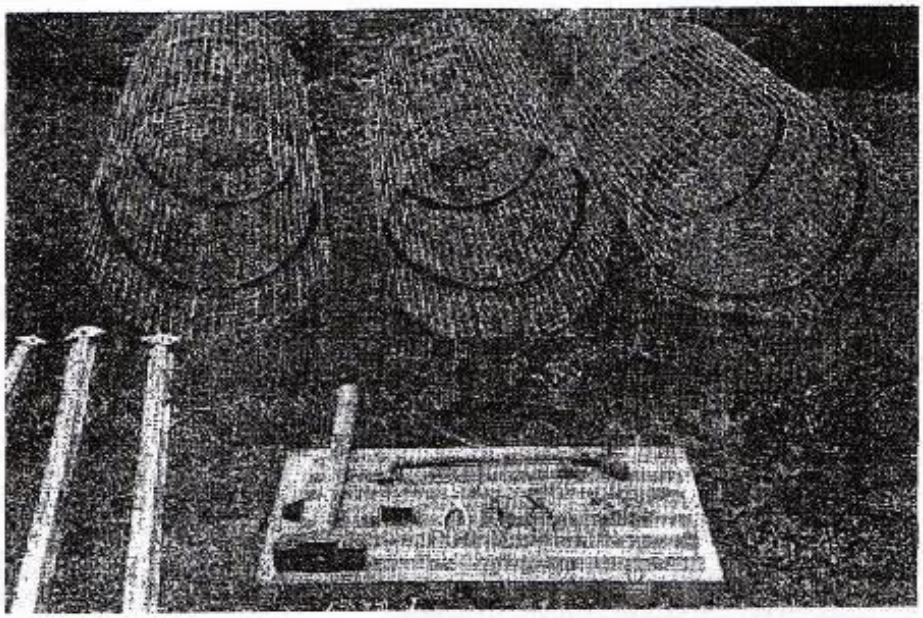
Most Flexible Pond Leveler failures are due to new downstream damming in response to a dramatic lowering of the water level.

The leveler is designed to minimize current flow similar to a storm water management pond riser pipe and the sound of flowing water. These two features are the most important stimuli that beaver respond to when building or repairing dams. When properly installed, this device will help reduce land flooding, plugged road culverts and water control structures on ponds and small marshes.

The design is limited to stream flows of about 10 cubic meter per second (cms) or less. Streams subject to periodic flash flooding or exceeding 10cms are not suited for this style of leveler. The cost of this leveler is about $1550.00 for materials and 8 hours in labor for construction and installation.

Typically, pipes consist of flexible corrugated plastic pipes inserted through the dam to allow water to flow. The upstream end of the pipe is protected with large wire mesh to keep beavers from plugging the pipe.





Materials Needed

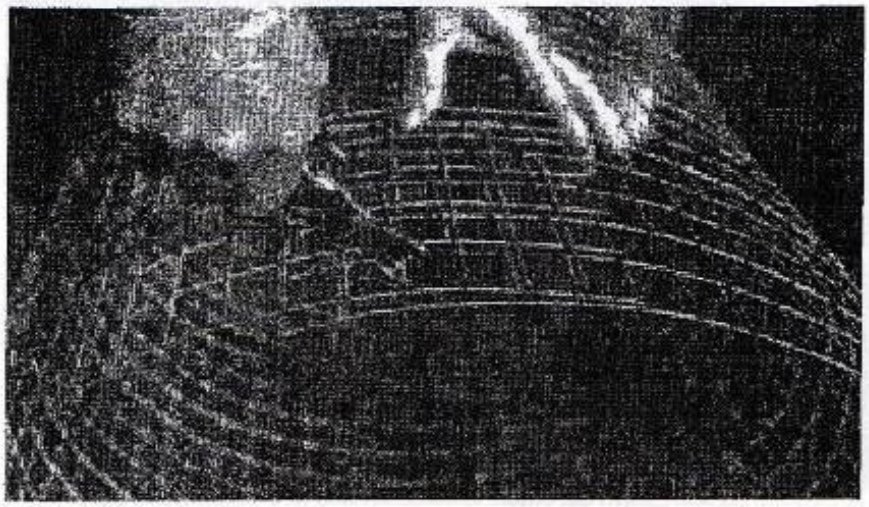
Beaver pond levelers are basically a wire fence cylinder installed as a riser in the pond with a 300mm outlet subdrain pipe cut to length. They can be made of fence with mesh size less than 150mm x 150mm as well. This design works best with 25mm x 50mm galvanized fence reinforced tie strapped against 3-1.5m t-bars hammered into the pond bottom by over 600mm. The following materials and tools.

Item
3 – 2.4m T-Bar fence posts
1 - 1.5m high section of galvanized highway fence cut to a length of 2.4m
10m sections of 300mm subdrain plastic pipe
6m length of 50mm nylon rope
6 - Concrete cement anchor blocks
50 - Hog Rings
8m - #12 Galvanized Wire
25 plastic tie straps

Standard
Corrugated

Tools
Standard Pliers
Hog, Ring Pliers (Optional)
Side Cutting Pliers
Post Maul or Fence Post Driver
Hand Saw

Construction

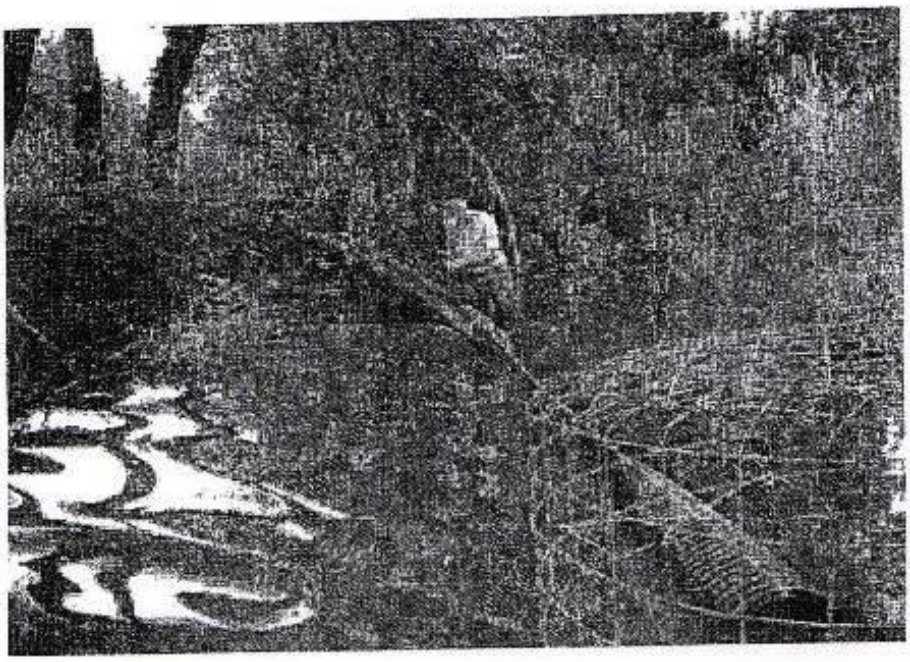


Construct one wire cylinder at the proper length require to act as a storm water management pond riser. approximately 800mm in diameter by overlapping the cut end 150mm and fastening with hog rings or twisted wire.

It is a rather simple matter to build this type of beaver pond leveler. One person alone with all materials and tools available can construct a 800mm x 1.5m leveler in about 2 hours

Close off one end of a 800mm diameter wire cylinder by curving back from the end along four (4) lines about 300mm.. Fold the cut ends in and secure with bog rings or wire.

At this point you are ready to transport to the beaver dam site. You can either join the three (3) wire cylinders together to create one, or you can transport them separately and connect them at the beaver dam location.



Installation

Either dig out the beaver pond base by hand to a depth of 450mm or stake in the base of the riser with T-Bars and tie strap the riser to the vertical t-bars. A complete installation at one site takes about 2 - 3 hours, depending on the size and construction of the riser and 300mm outlet subdrain pipe. One person could install this type of leveler, but when working around water a buddy system is required to ensure OSH compliance.

Maintenance

Most of the existing beaver pond levelers in use today require periodic maintenance. To keep this leveler operating at optimal efficiency you should inspect it at least a couple time a months and clean away collected debris along the length of the upstream end. Following spring break up you should also inspect the installation and make appropriate repairs or replacement. Because of rusting problems, this particular leveler will only last about 3 - 4 years in place. After this time a new leveler will need to be installed.

Tony Lansing

Appendix B: Literature Review