An Analysis of the Efficacy and Comparative Costs of Using Flow Devices to Resolve Conflicts with North American Beavers Along Roadways in the Coastal Plain of Virginia

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Abstract: Road damage caused by beavers is a costly problem for transportation departments in the U.S. Population control and dam destruction are the most widely used methods to reduce road damage caused by beavers, but the benefits of such measures in some situations are often very short-term. At chronic damage sites, it may be more effective and cost-beneficial to use flow devices to protect road structures and critical areas adjacent to roads. To determine the potential benefits of using flow devices at chronic beaver damage sites, from June 2004 to March 2006 we installed 40 flow devices at 21 sites identified by transportation department personnel as chronic damage sites in Virginia's Coastal Plain. Following installations, study sites were monitored to determine flow device performance and any required maintenance and repairs. Between March 2006 and August 2007, transportation department personnel were surveyed to collect data on flow device efficacy and comparative costs. As of August 2007, transportation department personnel indicated that 39 of the 40 flow devices installed were functioning properly and meeting management objectives. The costs to install and maintain flow devices were significantly lower than preventative road maintenance, damage repairs, and/or population control costs at these sites prior to flow device installations. Prior to flow device installations, the transportation department saved \$0.39 for every \$1.00 spent per year on preventative maintenance, road repairs, and beaver population control. Following flow device installations, the transportation department saved \$8.37 for every \$1.00 spent to install, monitor, and maintain flow devices. Given the demonstrated low costs to build and maintain flow devices, transportation agencies may substantially reduce road maintenance costs by installing and maintaining flow devices at chronic beaver damage sites.

Key Words: beaver, Beaver Deceivers™, *Castor canadensis*, Castor Masters™, economics, flow devices, Round Fences™, water flow control devices

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INTRODUCTION

The recovery of the North American beaver (*Castor canadensis*) is one of the conservation movement's greatest success stories, but the re-colonization of a massive historical range that is now widely inhabited by humans has led to inevitable conflicts. Beavers fell trees and shrubs and impound waters that flood agricultural lands, timberlands, structures, buildings and roads. Arner and Dubose (1979) estimated that economic losses attributed to beaver activity exceeded \$4 billion in the southeastern U.S. over the previous 40 years, and Miller (1983) estimated that annual damage was between \$75 and \$100 million in the U.S.

Road damage caused by beavers is a costly problem for many transportation departments in the U.S. Beaver damming behavior is believed to be stimulated by the sound and feel of running water. As water flows through narrow channels and/or road culverts, especially metal culverts, which resonate the sound of flowing water, beavers respond by damming channels and culverts, impounding water against roadbeds, and ultimately causing roads to flood and/or wash out (Langlois and Decker 1997). Plugged culverts are difficult, dangerous, and expensive to clear, and over time if they remain "plugged," saturated roadbeds settle, become unstable, and potholes form. Eventually, the road may wash out altogether, resulting in expensive, time-consuming road repairs (Jensen et al. 1999).

Trapping and dam destruction are widely considered the most effective and economical methods for reducing and eliminating road damage caused by beavers. In cases where it is unlikely that immigrants will re-occupy trapped sites, removing beavers and dams may be the most cost-effective approach to mitigating beaver damage. However, in areas with dense concentrations of beavers, dams are quickly re-built due to rapid beaver immigration and re-colonization. For example, Houston et al. (1995) reported that beavers in a bottomland forest in southwest Tennessee immediately and repeatedly re-colonized idle colony sites following eradication, because the area still maintained preferred habitat. Removing or breaching dams is also an immediate but temporary solution to flooding problems caused by beaver. Demolishing dams, with explosives or by hand, is dangerous, expensive (Arner 1964), and futile, as beavers usually rebuild the dams within days (Miller 1977). In situations where removing beavers and dams provides only short-term solutions to problems associated with beaver activity, it may be more effective and affordable for transportation departments to identify chronic beaver damage sites and take proactive measures to protect road culverts and critical areas adjacent to roads.

The installation and maintenance of water flow control devices, designed to prevent problems associated with beaver damming activity, is an alternative that is potentially a more efficient and cost-effective approach to managing beaver conflict along roadways than the expense of annual beaver population control, repeated road maintenance and repairs, and damage to property and buildings due to flooding and washouts. Over the years, state, federal, and tribal agencies have developed, described, and installed several types of effective water flow control devices (Arner 1964; Laramie 1963; Lisle 1996, 2001; Roblee 1987; Wood et. al 1994). This includes the Penobscot Indian Nation Department of Natural Resources in Old Town, ME, which initiated a program in the 1990s to develop and install water flow control devices on tribal lands to prevent road damage caused by beaver activity and to create and enhance wildlife habitat (Lisle 1999). The results of these efforts led to the development of innovative flow device concepts known as Beaver Deceivers™, Castor Masters™, and Round Fences™.

There are generally two categories of beaver damage sites: 1) narrow outlets, such as road culverts, that direct water through a manmade barrier (e.g., an embankment or roadbed), and 2) beaver dams that are not attached to manmade structures. To prevent beavers from damming road culverts, the Penobscot Nation created the Beaver Deceiver™, a rugged, wooden-framed fence constructed of braced wooden posts and 4-gauge steel mesh fencing installed on the upstream end of road culverts. Because beaver damming behavior is stimulated by the sound and feel of running water, Beaver Deceivers™ are designed to not only deny beaver access to culverts, but to reduce or eliminate the "feel" of running water by spreading stream flow over a long perimeter. The perimeter of a Beaver Deceiver™ frame typically ranges from 40 to 120 ft and generally increases with stream and culvert size.

Beaver Deceivers™ are also strategically shaped to discourage damming behavior; their frames may be square, rectangular or pentagonal, but trapezoidal designs, 4-sided with 2 parallel sides and 2 non-parallel sides, tend to be the most effective. From the road, trapezoid-shape Beaver Deceivers™ resemble upside-down triangles. Once in place, beavers may swim around the Beaver Deceiver™ and attempt to dam the corners of the fence closest to the culvert due to visual, auditory, and tactile cues (e.g., the sight, sound, and feel of water running through a metal culvert). The sides of the fence direct beavers away from the upstream side of the culvert at an unusual angle, and as the beavers work to dam the area, the fence side forces them away from the culvert opening, discouraging damming behavior.

To address flooding problems that occur with beaver build dams that are not attached to manmade structures, the Penobscot Nation invented the Castor Master™, a pipe system that is used with a filter called the Round Fence™ to control water flow through an existing beaver dam (Lisle 2003). A Castor Master™ consists of one or several 12-in × 20-ft polyethylene pipes submerged and placed through an existing beaver dam, with the upstream and downstream sides of the pipes protected with filters. Round Fences™ are filters made of 4-gauge steel mesh fencing, typically between 2 to 4 ft height and 4 to 8 ft in diameter. Filters such as Round Fences™ prevent beavers and debris from plugging the pipe directing water through the dam, and they disperse flowing water over a broad area so that it is difficult for beavers to detect (Lisle 2003).

Beaver Deceivers™, Castor Masters™, and Round Fences™ have been used successfully to reduce and prevent damage to roads and other manmade structures at numerous beaver damage sites in the U.S., but few studies have been conducted to determine the effectiveness and cost benefits of using these devices. Over a period of 7 years, Lisle (1999 and unpubl. data) significantly reduced and/or eliminated preventative maintenance at 20 damage sites in Maine near un-trapped beaver colonies, where beavers frequently plugged culverts and flooded roads. In another study, Callahan (2003) reported that of 277 conflict sites, beaver damming was effectively controlled at 83% of sites where devices similar to a Caster Masters™ and Round Fences™ were installed, and at 95% of sites where devices similar to a Beaver Deceivers™ were installed. The purpose of this study was to evaluate the efficacy and cost-effectiveness of using Beaver Deceivers™, Castor Masters™, and Round Fences™ to resolve conflicts with beavers on roadways in the Commonwealth of Virginia.

METHODS

Study Area

Our study was conducted at chronic beaver damage sites along roadways in 7 counties within the 3 Virginia Department of Transportation (VDOT) districts located in the Coastal Plain of Virginia. VDOT districts in the Coastal Plain of Virginia were selected for this study because of the high number of reported beaver damage sites compared with Piedmont, Blue Ridge, Ridge and Valley, and Appalachian Plateau Districts (USDA-WS 2002, 2003, 2004, 2005), and to evaluate the premise that flow devices are effective in streams with higher gradients (e.g., Piedmont and Mountain regions) but are less effective in streams with low gradients (e.g., Coastal Plain).

Site Selection

To maintain objectivity, VDOT environmental and maintenance personnel from 3 districts with counties located in the Coastal Plain of Virginia– Hampton Roads, Fredericksburg and Richmond– selected chronic beaver damage sites, which were defined as sites where removing beavers and/or dams did not significantly reduce and/or prevent road maintenance, road repairs or beaver population control costs attributed to beaver activity along roadways. A total of 14 sites were initially selected for flow device installations: 4 in the Hampton Roads District, 5 in the Fredericksburg District, and 5 in the Richmond District.

In November 2005, we used data provided by USDA-Wildlife Services (USDA-WS) to identify and select 7 additional chronic beaver damage sites where maintenance records showed that beaver population control activities and/or preventative maintenance had been conducted more than once over a 5-year period. We ranked the sites by frequency of required population control and/or preventative maintenance (i.e., a damage site where population control activities were conducted 5 times in 5 years was given priority over a site that had been trapped twice) and then treated the sites by installing a total of 7 flow devices.

Flow Device Installation

Selected beaver damage sites generally consisted of plugged culverts and/or high water resulting from free-standing beaver dams located upstream and/or downstream of affected roads. Between June 2004 and November 2005, with the assistance of the principal investigator and several undergraduate students, wildlife biologist and flow device consultant Skip Lisle designed, constructed, and installed 33 flow devices at 14 study sites. Between November 2005 and March 2006, Mr. Lisle installed 7 flow devices at an additional 7 study sites. Beaver Deceivers™ were recommended primarily for treating plugged road culverts, and Castor Masters™ were installed to lower high water impounded by free-standing dams. In some cases, Castor Masters™ were installed with Beaver Deceivers™ to enhance flow efficiency.

Monitoring and Maintenance

Following installations, study sites were monitored by principal investigators and/or VDOT personnel and inspected at least once every 4 months to determine if the flow devices were functioning properly, to note any specific damage to the device or changes in the landscape, and if necessary, to remove any accumulated debris obstructing the Beaver Deceivers™ and/or Round Fences™. Any time spent manually removing debris from the site was recorded as less than 15 minutes, less than 30 minutes, less than 45 minutes, or less 60 minutes. If time spent cleaning the device exceeded 60 minutes, actual time cleaning the device was recorded.

Table 1. Data from surveys conducted with Virginia Department of Transportation personnel and adjacent landowners before flow device installations at 14 beaver damage study sites in the Coastal Plain of Virginia. For each site, individuals surveyed reported whether flooding occurred prior to flow device installations (yes [Y] and no [N]), and the costs per year for maintenance, road repairs and beaver removal due to beaver activity.

Study Sites	Prior Flooding	Maintenance Cost/Yr	Repair Costs/Yr	Beaver Removal Costs/Yr
Lake Cohoon	Y	$43,500.00		$1,891.44
Kingsale Swamp	Y	$6,000.00		$1,891.44
Corrowaugh Swamp (South)	Y	$7,000.00		$763.25
Corrowaugh Swamp (North)	Y	$7,000.00		$799.05
Craney Creek	Y	$5,600.00	$1,000.00	
Briary Swamp	Y	$10,800.00	$300.00	
Pope's Creek (South)	Y	$21,600.00	$132,500.00	$117.89
Pope's Creek (North)	Y	$21,600.00		
Newtons Pond	Y	$400.00		
Winterpock Creek	Y	$11,000.00		
Swift Creek	Y	$4,000.00	$10,000.00	$506.32
Blackwater Swamp	Y	$3,600.00		
Second Swamp	Y	$4,800.00		
Indian Swamp	Y	$3,000.00	$1,200.00	
Totals		**$149,900.00**	**$145,000.00**	**$5,969.40**

Surveys

We surveyed VDOT personnel from all 3 cooperating districts, as well as several landowners with property adjacent to study sites, to gather general data on what, if any, effect flow device installations had on previous flooding frequency, road maintenance, repair, or beaver management costs. Information recorded included when the devices were installed, the status of the flow devices (including any flooding, road maintenance and/or repairs, beaver damage/population control activities, and any efforts made by VDOT and/or the landowner to maintain the devices following installation), and whether management objectives for the study site had been met.

Comparative Cost Analysis

A cost-benefit ratio formula utilized by USDA-WS (2003) to compare beaver management expenditures to VDOT resources saved was used to test the differences in the costs to manage beavers and repairs roads before and after the installation of flow devices at 14 of the 21 selected study sites. (Comparative cost data collected for the 7 beaver damage sites treated between November 2005 and March 2006 has not yet been analyzed). For the purposes of this study, the estimated cost-benefit will be considered favorable if the ratio of expenditures to resources saved is greater than 1 to 2, or for $1 spent on beaver management activities or road repairs, $2 in VDOT resources are saved.

RESULTS

VDOT Personnel and Landowner Surveys

VDOT personnel and landowners reported that flooding occurred and preventative maintenance was conducted at all 14 sites prior to installation of flow devices at a total cost of $149,900.00 for preventative maintenance, or an average cost of $10,707 per site (Table 1). Beaver population control activities were conducted at 10 of 14 sites prior to installations at an average cost of $5,969 per year, or $994.90 per site, at the 6 sites where VDOT paid for beaver population control activities (Table 1). Following preventative maintenance and beaver population control efforts, all of the study sites were re-occupied by beavers. VDOT personnel and landowners also reported that road repairs attributed to beaver-related damage were carried out at 5 sites prior to installations at a total cost of $145,000 and an average cost of $29,000 per site.

From June 2004 to November 2005, 33 flow devices– 18 Beaver Deceivers™ and 15 Castor Masters™– were installed at 14 beaver damage sites in 7 counties in 3 VDOT districts in the Coastal Plain of Virginia. Installation costs per site ranged from $1,359 to $5,572 at an average cost of $3,160 per site and a total cost of $44,245 for installations at all 14 study sites (Table 2). Total installation time ranged from 10 to 50 hours with a total of 390 hours and an average installation time of 28 hours per site. The total costs for labor at these 14 study sites was $39,000 or $2,786 per site, and the total costs for materials was $5,244.52 or $374.61 per site.

Flow device maintenance time ranged from 1.0 to 4.75 hours per year and required a total of 19.75 hours per year, or 1.4 hours per site, and at $14.00 an hour, cost a total of $276.50 or $19.75 per site (Table 2). At the time that VDOT personnel and landowner surveys were conducted in April 2006, length of time following installations ranged from 6 months to 22 months with an average length of time following installations of 15 months per site.

After flow device installations, VDOT personnel and

Table 2. Data from surveys conducted with Virginia Department of Transportation personnel and adjacent landowners following flow device installations at 14 beaver damage study sites in the Coastal Plain of Virginia. For each site, individuals surveyed reported whether flooding occurred following flow device installations (yes [Y] and no [N]), the total cost for materials and labor to install flow devices, maintenance costs per year following installations.

Study Site	Current Flooding	Installation Costs	Maintenance Costs/Yr*
Lake Cohoon	N	$2,371.05	$17.50
Kingsale Swamp	N	$1,825.32	$31.50
Corrowaugh Swamp (S)	N	$1,340.13	$14.00
Corrowaugh Swamp(N)	N	$1,359.41	$14.00
Craney Creek	N	$3,829.81	$14.00
Briary Swamp	N	$3,329.79	$14.00
Pope's Creek (S)	N	$5,571.76	$14.00
Pope's Creek (N)	N	$3,882.31	$14.00
Newtons Pond	N	$2,800.55	$14.00
Winterpock Creek	N	$4,464.43	$21.00
Swift Creek	N	$1,752.28	$14.00
Blackwater Swamp	N	$4,841.68	$14.00
Second Swamp	N	$2,344.70	$14.00
Indian Swamp	N	$4,531.30	$66.50
Total		**$44,244.52**	**$276.50**

* based on an average wage of $14.00/hour

landowners reported that the study sites had not flooded, that road maintenance, flow device maintenance, and beaver population control activities had not been required or conducted, and that overall they were satisfied with the performance of the flow devices (Table 2). VDOT personnel surveys were also conducted for the 7 beaver damage sites treated from November 2005 and March 2006. As stated previously, comparative cost data collected for these sites has not yet been analyzed, but the preliminary efficacy results show that 6 of the 7 devices are functioning properly and meeting VDOT management objectives (Table 3).

Comparative Cost Analysis

Prior to flow device installations, the estimated beaver management costs at the first 14 study sites, including preventative maintenance and population control activities, was $155,869 and the estimated beaver damage repair cost was $145,000, for a total cost to VDOT of $300,869 per year (Table 4). Following flow device installations, the estimated beaver management costs, including flow device installations and maintenance costs, was $44,526, and the estimated beaver damage repair cost was $0 for a total cost to VDOT of $44,526 per year (Table 4). The resources saved were estimated at $71,639, based on calculations in USDA-WS (2003) (Table 4). We assumed that the same resources were saved after installation of flow devices. The total resources saved prior to flow device installations included resources saved ($71,639) in addition to funds VDOT saved by not installing flow devices ($44,526), for a total resources saved of $116,165.

Table 3. Data from surveys conducted with Virginia Department of Transportation personnel and adjacent landowners before flow device installations at 7 beaver damage study sites in the Coastal Plain of Virginia. For each site, individuals surveyed reported whether flooding occurred prior to and following flow device installations (yes [Y] and no [N]).

Study Sites	Prior Flooding	Current Flooding
Mill Creek	Y	N
Monroe Bay	Y	Y
Jones Hole Swamp (A)	Y	N
Jones Hole Swamp (B)	Y	N
Miles Creek	Y	N
John H. Kerr Reservoir	Y	N
Proctors Creek	Y	N

Table 4. The ratio of total resources saved to total costs per year for beaver management and damage repairs before and with the installation of flow devices at 14 beaver damage sites in the Coastal Plain of Virginia. Total costs are the sum of beaver management costs (preventative maintenance and/or flow device installations and beaver population control activities), and beaver damage repair (funds used to repair roads). Total resources saved before flow devices is the sum of potential resources saved and the total costs with flow devices. The total resources saved with flow devices is the sum of potential resources saved and the total costs before flow devices.

Beaver Management Costs/Yr.	Before Flow Devies	With Flow Devices
Beaver management	$155,869.00	$44,526.00
Beaver damage repair	$145,000.00	$0.00
Total costs	**$300,869.00**	**$44,526.00**
Potential resources saved*	$71,639.00	$71,639.00
Total resources saved	**$116,165.00**	**$372,508.00**
Total resources saved/ Total costs	**$0.39**	**$8.37**

* based on data published by USDA-Wildlife Services (2003)

Total resources saved following flow device installations included resources saved ($71,639) in addition to funds VDOT saved in beaver management costs ($155,869) and road repair costs ($145,000) saved by installing flow devices, for a total resources saved of $372,508.

The cost-benefit ratio at these 14 study sites (total costs divided by total resources saved) prior to flow device installations was 1 to 0.39, or $0.39 in resources saved for every $1 VDOT spent. Following flow device installations, the estimated cost-benefit ratio was 1 to 8.37, or for every $1 spent, VDOT saved $8.37.

DISCUSSION

The results of our study show that flow devices such as Beaver Deceivers™, Castor Masters™, and Round Fences™ can be efficient, cost-beneficial tools for resolving conflicts with beavers along roadways in the Coastal Plain of Virginia. To date, based on the most current survey information, all 33 devices installed at 14 beaver damage sites from June 2004 to November 2005, including 18 Beaver Deceivers™ and 15 Castor Masters™, are functioning properly and are meeting VDOT and landowner beaver management objectives. Of the 7 devices installed at 7 chronic damage sites from November 2005 to March 2006, 6 are functioning properly.

These results concur with data published by Callahan (2005), who reported an 87% success rate using Flexible Pond Levelers (devices with designs similar to Castor Masters™) at 156 beaver damage sites in New York and Massachusetts, and a 97% success rate using upright trapezoidal or rectangular culvert fences (devices similar to Beaver Deceivers™) at 227 sites in the same geographic region. Several factors may have contributed to the slightly higher flow device success rates in our study, the most influential of which may have been our study's relatively small sample size (21 sites) compared to Callahan's study (383 sites). Climate, weather, topographic, and landscape differences may also have contributed to differences in success rates, since our study was conducted in the Coastal Plain of Virginia and Callahan's devices were installed throughout New England. Nonetheless, the flow device success rates reported in both studies were significantly higher than rates reported by other researchers who conducted similar studies on other flow device designs (Nolte et al. 2001, Hamelin and Lamendola 2001).

Although Callahan reported high flow device success rates, flow devices did fail at a small percentage of sites for a variety of reasons. At 383 sites managed with flow devices from November 1998 to February 2005, pond leveler failure rate was 13.5%, while culvert fence failure rate was only 3.1%. Pond levelers generally failed due to the construction of new dams downstream by beavers (11 sites or 7.1%), insufficient pipe capacity (6 sites or 3.8%), lack of maintenance (2 sites or 1.3%), and dammed fencing (2 sites or 1.3%). Culvert fences failed due to lack of maintenance (4 sites or 1.8%), dammed fencing (2 sites or 0.9%), and vandalism (1 site or 0.4%). Other factors that contributed to failure included inexperienced installers, poor site selection, and/or flow device design (Callahan 2003). Results of a previous study conducted by Callahan (2003) also showed that when flow devices did fail, they failed within the first 2 to 12 months following installation, but as of 2003, 221 successful devices in Callahan's study had been in place longer than 12 months.

The results of our study also demonstrated that the flow devices we used can be extremely cost-beneficial due to relatively low installation and maintenance costs compared to the time and expense of repeated road maintenance, repair of road damage, and annual beaver population control required for other flow device designs. The comparative cost analysis revealed that for every $1 VDOT spent on preventive maintenance, road repairs, and beaver population control activities at the 14 study sites prior to the installation our flow devices, the agency saved $0.39 in resources; whereas, after installing and maintaining our flow devices, VDOT saved $8.37 for every $1 spent, for a total of $372,508 of resources saved per year (Table 4). Additionally, the cost-benefit comparison represents both actual damages that occurred at a site 12 months prior to installations and potential damages expected to occur within 12 months without flow device installations. Since the predicted life expectancy for each successful device is at least 10 years (Callahan 2005), with an average maintenance cost of $19.75 at each site per year compared to $21,490.64 per site per year for maintenance, repairs, and beaver population control prior to the installation of our flow devices, we believe the value of resources saved by installing flow devices at these sites will continue to increase over time.

During the course of our study, we also discovered several benefits to using flow devices that are difficult to quantify, but nonetheless significant. For instance, opening blocked culverts– manually, or by using heavy equipment– is an expensive, arduous, and potentially dangerous endeavor, compared to the routine maintenance required for Beaver Deceivers™. VDOT personnel noted that culverts are often damaged in the process of clearing with heavy equipment, decreasing the life expectancy of these road structures and forcing the transportation department to replace them more frequently.

Moreover, clearing a culvert manually generally involves having one or more people inside the culvert disassembling the dam using their hands or hand tools (a cultivator, for instance) to remove the blockage piece by piece, until the pressure of the dammed-up water finally pushes the remainder of the dam out the downstream side of the culvert. Under these circumstances, the dam could easily give way while a worker is in the culvert and could lead to serious, life-threatening injuries. Compared to clearing a plugged culvert, routine maintenance on a Beaver Deceiver™ is relatively easy and safe, as it simply requires removing any leaves, sticks, twigs, or branches that have accumulated on the upstream side of the receiver fence once or twice a year. Maintenance workers are never subject to the risk of an unpredicted release of large volumes of dammed water.

One potential concern for us when using flow devices to manage beavers near roadways is the development of new conflict sites following installations. In 2003, Callahan published data showing that of the 177 beaver colonies present where flow devices were installed in New England between 1998 and 2003, there were 277 conflict sites, or an average of 1.56 conflict sites per beaver colony. Since data published 2 years later in 2005 showed the average conflict sites per colony remained constant, Callahan concluded that by using flow devices to treat a small number of critical beaver conflict sites, a large watershed can be managed without contributing to the development of new problem sites or removing beavers from the community.

In the future, to test Callahan's findings, it may be beneficial to generate data on the ratio of beaver conflict sites per colony at our study sites in Virginia. In the meantime, to assist transportation agencies in the decision-making process for selecting chronic beaver damage management sites for flow device installation, we intend to develop a projected cost-benefit analysis model based on current and future collected comparative cost data. We also plan to create guidelines for identifying chronic damage sites where flow device use is both preferable and feasible, and the criteria necessary for designing and installing the devices.

As stated previously, Callahan's data indicated that there are sites where flow device installations are not workable, but it would be helpful to determine what, if anything, these sites have in common so that wildlife damage control managers can make educated decisions on the most effective, cost-beneficial strategies for beaver conflict resolution at particular damage sites. We also know, for instance, that a Beaver Deceiver™ frame is typically trapezoid-shaped and that the perimeter ranges from 40 to 120 feet and generally increases with stream and culvert size, but specific standard dimensions and instructions should be developed for transportation departments and wildlife damage control operators to use when designing, installing, monitoring, and maintaining these devices.

Given the demonstrated low costs to install and maintain flow devices compared to the high costs of preventative maintenance, road repairs, and beaver population control activities, a compelling case can be made to install flow devices in freestanding dams near roads or to protect culverts that beavers could potentially plug. Nevertheless, a more prudent approach may be for transportation agencies to install flow devices at sites that have the largest impact on road maintenance and beaver management budgets.

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