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Edge Drain Performance

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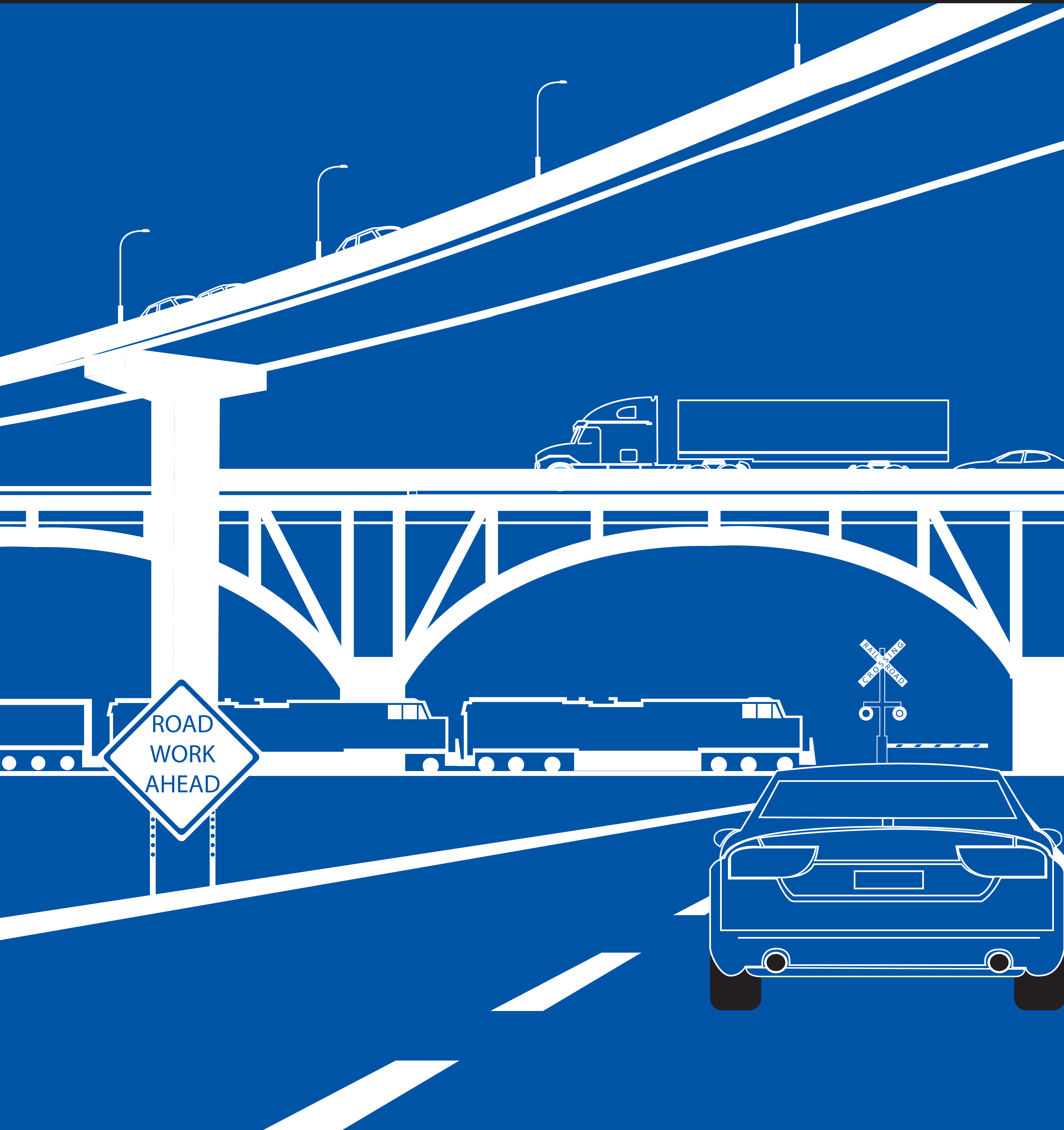

Kentucky Transportation Center
College of Engineering, University of Kentucky, Lexington, Kentucky

in cooperation with
Kentucky Transportation Cabinet
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Research Report
KTC-19-21/SPR18-557-1F

Edge Drain Performance

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Edge drain systems are used on new highway construction projects and rehabilitation projects to reduce the moisture content of the pavement block and subgrade. Maintaining dry conditions in and around these components increases the subgrade strength and extends a pavement's surface life. Edge drain systems can only operate effectively, however, if the entire subsurface drainage system functions properly. While many studies have demonstrated the benefits of edge drain systems, no comprehensive investigation of their performance has been undertaken in the state of Kentucky in over 20 years. After the Kentucky Transportation Cabinet (KYTC) identified problems with an edge drainage system along a segment of Interstate 275 in Kenton County, the agency commissioned researchers at the Kentucky Transportation Center (KTC) to evaluate the performance of edge drains on roadway segments that will be resurfaced in the coming years. Researchers comprehensively inspected 10 roadway segments, assessing several components of their edge drain systems. For edge drain systems with headwalls, researchers found that all headwalls (n =126) were in good condition and free of structural issues. Roughly 29% of the outfall waterways prevented the flow of water from the headwall, while 65% of the outlet waterways were blocked to some extent by gravel, mud, silt, or other debris, and 61% of the outlet pipes were obstructed. Of the edge drain systems draining to catch basin inserts or ditch bottom inlets (n = 110), outfall waterways were clear on 97% of the systems, but just 14% of the edge drains were unobstructed. Based on inspections, edge drain systems were classified as good, compromised, or undetermined (the final designation being used if conditions prevented a full inspection) and identified a probable failure mode. Approximate 75% of the problems found during inspections were related to maintenance, with the remainder the product of construction activities. To preserve edge drains in a functional condition, post-installation inspections should be conducted, and yearly inspections and cleanings of headwalls and outlet pipes completed. Other methods for outletting water (e.g., dry wells) can also be explored.</td></tr>
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1. Introduction

Edge drains remove water that has infiltrated the pavement block. For an edge drain to work effectively, the entire subsurface drainage system, which includes the drainage blanket, perforated drainage conduit, aggregate trench, outlet pipe, and headwall, must be functioning properly.

In the years since the Kentucky Transportation Cabinet (KYTC) began requiring the installation of edge drains, specifications for run length, drain geometry, materials, and the use of drainage blankets have undergone revisions. Edge drains are included in new construction projects as well as rehabilitation projects, where the existing road base is augmented to establish positive drainage toward the edge drain to effectively convey the water from beneath the pavement.

Post-installation inspections of edge drain systems are required to verify they have been installed properly and were not damaged during construction. The inspection also helps ensure the grade of the pipe is maintained so that it allows water to flow through the edge drain to the outlet. Over time, the outlet waterway, outlet pipe, or the perforated edge drain requires maintenance to keep the system free of silt, grass, debris, rodent nests, and other materials that can impede the flow of water from the edge drain system.

Previous Kentucky Transportation Center (KTC) investigations have demonstrated the benefits of edge drain systems. However, a comprehensive evaluation of edge drain system performance has not been conducted in over 20 years. KYTC personnel have recently voiced concerns about the long-term performance of edge drains. One investigation of edge drain performance along I-275 in Kenton County revealed that 26 of the 32 headwalls were so blocked or overgrown with vegetation that the perforated edge drain could not be inspected. Additionally, 65 of the 72 edge drains that outlet to a catch basin insert (CBI) or ditch bottom inlet (DBI) were blocked or crushed. Responding to the problems observed with edge drains, this research evaluates the performance of edge drain systems in Kentucky and classifies their failure mode; this information will help the Cabinet determine where improvements are needed.

2. Previous Research

Kentucky has used some variation of an underdrain system to remove water from the pavement block since the 1970s. The materials and construction methods used to fabricate these systems, however, have changed. In the early 1970s aggregate-filled trenches were first used to collect and convey the water away from the pavement block. The mid-1970s witnessed the introduction of perforated pipe, while panel drain systems were first used in the 1980s — use of the latter has since been discontinued.

Since the mid-1980s, KTC has evaluated pavement issues and edge drain performance. In 1984, KTC studied the pavement drainage on I-64 in Rowan and Carter Counties. Problems with the surface started appearing less than a month after the project was completed. The site did not have edge drains installed. Researchers discovered that due to the composition and orientation of the underlying rock strata, ground water was flowing through the rock and into the pavement. Researchers suggested installing a subsurface drainage system to mitigate the problem.

A 1988 investigation into a premature pavement failure on the Pennyrile Parkway in Webster County revealed the panel drains had been crushed and crimped the during installation and that the outlet pipes and headwalls may have been installed with an improper slope. These problems led to edge drain being completely ineffective, allowing water to remain in the pavement block and degrade the performance of the pavement.

A 1994 KTC investigation on the use of drainage blankets found that the edge drain systems then currently in place were poorly designed and often not maintained properly. Specifically, the research team observed siltation or vegetation in headwalls, damage to outlet pipes, or ponding due to headwalls being placed at the elevation of the ditch line.

A 1996 KTC project examined water and fines coming to the surface of the pavement on I-64 in Fayette, Scott, and Woodford Counties. This problem was the result of edge drains not being constructed properly in sags, debris in the headwalls blocking outlet pipes, headwalls tilted backward, and the panel drains being damaged during construction. Infrared scans confirmed water was trapped in the broken concrete and the asphalt concrete (AC) overlay. Asphalt cores indicated the presence of asphalt stripping.

From 1991 to 1995, the Center conducted a study on edge drains and pavement performance. The study confirmed the existence of construction and maintenance issues that compromise the effectiveness of edge drain systems, as noted in previous reports described above. During construction approximately 20 to 30 percent of the outlet pipes were crushed, numerous pipes contained sags, and round pipe was crushed when the sand backfill was not densified appropriately before construction traffic was allowed over the pipe. An evaluation of the headwalls revealed maintenance was also an issue — 46% of the headwalls were clear, 31% were partially covered, and 11% were plugged. The study generated several other key findings. The No. 2 stone placed around headwalls reduce the amount of vegetation that accumulates around them. Sand backfill effectively filters out some fine material from broken concrete, preventing the clogging of the geotextile. Edge drains help reduce the moisture in the subgrade by as much as 28%; falling weight deflectometer (FWD) analysis demonstrated that removing the water from the subgrade increases the subgrade strength. An Rideability Index (RI) data analysis illustrated that edge drains can increase pavement life by seven years before the critical RI is reached.

3. Project Selection

KYTC provided a list of 61 roadway sections throughout the state that are slated for resurfacing over the next few years. KTC researchers used this list to identify the projects evaluated in this study. A review of archived construction documents for all projects found only 10 projects had edge drain systems installed. Table 1 lists the selected projects with county, route, mile point, installation year and age of edge drain. Project 7 — I-275 in Kenton Country — is also included on the list because an inspection of that roadway section prompted this research study. The original research plan called for inspecting and recording video of approximately 60,000 linear feet of edge drain.

Table 1 Project List

Project	District	County	Route	From	To	Installation Year	Age
1	5	JEFFERSON	KY1934	4.444	9.742	1982	36
2	6	BOONE	I-75	169.439	183.08	1983	35
3	6	KENTON	KY0017	16.2	18.4	1984	34
4	2	HANCOCK	US0060	1.933	9.4	1985	33
5	5	JEFFERSON	KY0864	7.111	11.438	1985	33
6	5	JEFFERSON	KY1932	3.21	3.8	1990	28
7	6	KENTON	I-275	82.5	1.05	1994	24
8	6	KENTON	KY0236	2.131	2.622	1995	23
9	5	JEFFERSON	I-265	23.127	34.708	1997	21
10	12	PIKE	US0119	10.4	12.4	2000	18
11	4	GRAYSON	WK-9001	108	111.25	2005	13

4. Inspection Procedure

An edge drain system with a headwall consists of the mainline perforated edge drain, non-perforated outlet pipe, headwall with outlet waterway (trough), and the outfall waterway. If an edge drain drains to a CBI or

DBI the system consists of the mainline perforated edge drain and the outfall waterway. Each inspection started at the outfall waterway and worked upstream to the mainline edge drain. For systems with headwalls, the conditions of the outfall waterway, outlet waterway, pipe, headwall, and the rodent screen were appraised. Next, the edge drain was inspected using a push camera with color display. Video recordings were stored on an SD card and uploaded to ArcGIS Online. If portions of the system were blocked, preventing video inspection, an attempt was made to clean out the system so video inspection could proceed. Researchers used an iPad and the Survey 123 app to record the condition of each component; a picture of the outlet structure and drainage way was also captured. Results were uploaded to ArcGIS Online and stored with the associated edge drain inspection video.

5. Edge Drain Component Results

5.1 Draining to Headwalls

Six components of each edge drain system with a headwall were evaluated:

- Headwall condition,
- Outfall waterway,
- Outlet waterway,
- Outlet pipe,
- Rodent screen, and
- Perforated pipe.

All 126 headwalls inspected by KTC were in good condition and did not have any structural problems (e.g., cracks, damage), nor did they show signs of settlement. 71% of the outfall waterways were clear. The remaining 29% exhibited issues that prohibited the flow of water from the headwall (Figures 1 and 2). 65% of the outlet waterways or the trough of headwalls suffered from blockages. Most blockages were due to grass growing in the trough, but gravel, mud, silt and other debris were observed in outlet waterways as well (Figures 3 to 5). Due to blockages at outfalls and outlet waterways, 61% of the outlet pipes were blocked. These blockages impeded the video inspection of perforated pipes. Due to blockages, of the 126 perforated edge drains, only 57% underwent video inspection. Of the 72 that were inspected 37% were clear, 6% were blocked with mud/gravel/debris, and 14% were crushed/ damaged.

With respect to the presence and condition of rodent screens, 75% of the 126 headwalls had them installed 18% lacked them, while on 6% they were present but not functioning due to the screens being rusted through (Figure 9).

5.2 Draining to CBI or DBI

Researchers evaluated two components of edge drains that drain to CBIs or DBIs: 1) Outfall, which in is the bottom phase of the CBI or the DBI, and 2) Perforated pipe. If an outfall is filled with mud, rock, or debris, these materials can prevent the edge drain from functioning correctly.

110 edge drain systems investigated by KTC researchers drain to a CBI or DBI. Outfall waterways were blocked on just 3%, indicating the vast majority of the boxes were clean. However, only 16 of the edge drains were clear and 7 of the drains had been crushed; 86 were blocked with gravel or mud at or just past the outlet, and the condition of one other edge drain could not be determined because the drain outlet was located at the bottom of a deep box which the research team could not access.

5.3 Failure Modes

The condition of each edge drain system was coded based on inspection results. Researchers devised a three-tier classification system for condition ratings (Table 2).

Table 2 Classification System Used to Code Edge Drain System Condition

Condition	Description
Good	System is functioning as intended and no problems identified with system components.
Compromised	Problems identified with one or more system components.
Undetermined	Conditions encountered which prevented inspection.

Although the number of systems researchers were unable to determine the condition of was small, there were instances when conditions could not be determined due to the presence of a T-Junction instead of a Y-Junction in the pipe or where the grate on the drop box or curb box was welded onto the frame.

After rating the condition of each system, researchers identified a failure mode based on the prevailing aspects of the system that were used to justify the assigned the condition rating. Table 6 summarizes the rating and failure modes for edge drains with headwalls for each project. Table 7 lists rating and failure modes for edge drains that drain to CBIs or DBIs. Table 8 highlights the combined overall rating and failure mode for all types by project.

Approximately 75% of the issues were maintenance related and approximately 25% of the issues were construction related. However, these results are skew toward maintenance because a large portion of the edge drains pipes could not be inspected due to the maintenance-related issues.

6. Summary

Edge drains help reduce moisture in the pavement block and subgrade. Drier conditions help increase the subgrade strength and lengthen a pavement's service life. Previous investigations undertaken by KTC researchers in the 1990s revealed that 42% of the problems associated with edge drain performance were maintenance related. Now — 25 years later — that figure stands at 76%. Nonetheless construction issues are still evident, however, it was difficult to quantify how frequently they occur due to the conditions of outfall and outlets, which prohibited adequate inspection of the edge drains. But revisions to construction methods and inspections standards made over the years cannot be discounted.

Construction and maintenance issues with edge drain systems have been an ongoing challenge for several decades. While edge drain systems confer obvious benefits, to ensure they perform at an optimal level it is critical that the systems be constructed properly and undergo maintenance on a regular basis.

7. Recommendations

- Continue to perform post-installation inspection of edge drains.
- Perform a yearly inspection and cleaning of the headwalls and outlet pipes
- Consider alternative methods to outlet water (e.g., a dry well).
- Limit the use of T-Junctions.

Table 3 Edge Drain System Component Performance Summary (Does not Include I-275)

		Headwall		CBI or DBI		Both	
	Count	126		110		236	
	Footage	9,909		2,452		12,361	
Headwall Condition	Good	126	100%				
	Poor	0	0%				
Outfall Waterway Condition	Clear	90	71%	107	97%	197	83%
	Blocked	36	29%	3	3%	39	17%
Outlet Waterway Condition	Clear	44	35%				
	Blocked	82	65%				
Outlet Pipe Condition	Clear	49	39%				
	Partially Blocked	34	27%				
	Fully Blocked	43	34%				
Rodent Screen	Present	95	75%				
	Not Present	23	18%				
	Present/Not Functioning	8	6%				
Perforated Pipe Condition	Clear	47	37%	16	15%	63	27%
	Blocked	7	6%	86	78%	93	39%
	Crushed/Other	18	14%	7	6%	25	11%
	Could Not Determine	54	43%	1	1%	55	23%

Table 4 Perforated Pipe Performance Summary (I-275 Only)

		Headwall		CBI or DBI		Both	
	Count	32		72		104	
	Footage	58		756		814	
Perforated Pipe Condition	Clear	0	0%	1	1%	1	1%
	Blocked	3	9%	48	67%	51	49%
	Crushed/Other	3	9%	17	24%	20	19%
	Could Not Determine	26	81%	6	8%	32	31%

Table 5 Perforated Pipe Performance (All Projects)

		Headwall		CBI or DBI		Both	
	Count	158		182		340	
	Footage	9,967		3,208		13,175	
Perforated Pipe Condition	Clear	47	30%	17	9%	64	19%
	Blocked	10	6%	134	74%	144	42%
	Crushed/Other	21	13%	24	13%	45	13%
	Could Not Determine	80	51%	7	4%	87	26%

Table 6 Edge Drain System Rating and Failure Mode (Headwalls)

			System Condition						Failure Mode			
Project	Age	Count	Good		Compromised		Could Not Determine		Maintenance Related		Construction Related	
2	35	31	8	26%	21	68%	2	6%	20	87%	3	13%
4	33	24	0	0%	24	100%	0	0%	18	75%	6	25%
6	28	6	0	0%	4	67%	2	33%	2	33%	4	67%
7	24	32	0	0%	30	94%	2	6%	24	75%	8	25%
9	21	33	20	61%	11	33%	2	6%	7	54%	6	46%
10	18	2	0	0%	2	100%	0	0%	1	50%	1	50%
11	13	30	19	63%	10	33%	1	3%	9	82%	2	18%
	Total All	158	47	30%	102	65%	9	6%	81	73%	30	27%
	Total w/o I-275	126	47	37%	72	57%	7	6%	57	72%	22	28%

Table 7 Edge Drain System Rating and Failure Mode (CBI or DBI)

			System Condition						Failure Mode			
Project	Age	Count	Good		Compromised		Could Not Determine		Maintenance Related		Construction Related	
1	36	31	2	6%	29	94%	0	0%	26	90%	3	10%
3	34	8	4	50%	4	50%	0	0%	3	75%	1	25%
5	33	33	1	3%	32	97%	0	0%	27	84%	5	16%
6	28	12	0	0%	12	100%	0	0%	8	67%	4	33%
7	24	72	1	1%	62	86%	9	13%	51	72%	20	28%
8	23	11	8	73%	3	27%	0	0%	3	100%	0	0%
10	18	15	1	7%	13	87%	1	7%	11	79%	3	21%
	Total All	182	17	9%	155	85%	10	5%	129	78%	36	22%
	Total w/o I-275	110	16	15%	93	85%	1	1%	78	83%	16	17%

Table 8 Overall Edge Drain System Rating and Failure Mode (Headwall and CBI or DBI)

			System Condition						Failure Mode			
Project	Age	Count	Good		Compromised		Could Not Determine		Maintenance Related		Construction Related	
1	36	31	2	6%	29	94%	0	0%	26	90%	3	10%
2	35	31	8	26%	21	68%	2	6%	20	87%	3	13%
3	34	8	4	50%	4	50%	0	0%	3	75%	1	25%
4	33	24	0	0%	24	100%	0	0%	18	75%	6	25%
5	33	33	1	3%	32	97%	0	0%	27	84%	5	16%
6	28	18	0	0%	16	89%	2	11%	10	56%	8	44%
7	24	104	1	1%	92	88%	11	11%	75	73%	28	27%
8	23	11	8	73%	3	27%	0	0%	3	100%	0	0%
9	21	33	20	61%	11	33%	2	6%	7	54%	6	46%
10	18	17	1	6%	15	88%	1	6%	12	75%	4	25%
11	13	30	19	63%	10	33%	1	3%	9	82%	2	18%
	Total All	340	64	19%	257	76%	19	6%	210	76%	66	24%
	Total w/o I-275	236	63	27%	165	70%	8	3%	135	78%	38	22%

Figure 1 Outfall Waterway Obstructed by Vegetative Growth

Figure 2 Outfall Waterway Obstructed by Debris

Figure 3 Outlet Waterway Blocked by Gravel

Figure 4 Outlet Waterway Blocked by Vegetative Growth

Figure 5 Waterway Completely Inundated

Figure 6 Waterway Completely Inundated

Figure 7 Outlet Waterway and Outfall Waterway Holding Water

Figure 8 Blocked Outlet Pipe

Figure 9 Rodent Screen Rusted Through