In-Depth Hydrologic Assessment
Cape Fear Survey Area

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SARP

A detailed assessment of hydrologic barriers in the Hood Creek watershed of the Cape Fear River Basin was completed. This effort included field surveys and data collection according to the tidal barrier assessment method, and a desktop analysis of drainage density and capacity. The results have been combined to develop a prioritized summary of recommended retrofit actions in the watershed.

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Introduction

The Cape Fear is the largest river system in North Carolina, encompassing over 9,000 square miles of drainage area and over 6,500 miles of stream. Human activities along the river and in floodplain areas have created substantial hydrologic barriers through the installation of roads, culverts, levees, and mill dams. Kris Bass Engineering was contracted by the Southeast Aquatic Resources Partnership (SARP) to survey fish barriers in the lower Cape Fear watershed using methodology developed for tidal barrier assessment. These surveys involve a combination of field collected data and desktop analysis. The Hood Creek watershed was chosen for additional analysis assist with prioritizing potential retrofit projects. This report includes details on data collected, analysis completed, and recommendations that can be used to match potential projects with specific goals.

Field Data Collection

A total of 50 barriers were surveyed in the Cape Fear basin. Parameters such as culvert and channel dimensions, substrate type, culvert perch, vegetation density and several others were input into the Survey123 app and uploaded to SARP's online web map. Barriers were then automatically ranked using a weighted formula and assigned a barrier severity score, which can be used to determine the most impassable crossings.

Of the 50 barriers surveyed, 2 were ranked a severe barrier, 6 a moderate barrier, 19 a minor barrier, and 23 an insignificant barrier by the SARP formula.

The Hood Creek watershed was chosen for an in-depth study assessing the passability and hydrology of each barrier and suggesting potential improvements to restore the flow regime to a more natural state (Figure 1). Nineteen culverts were surveyed within the Hood Creek watershed, as shown in Table 1.

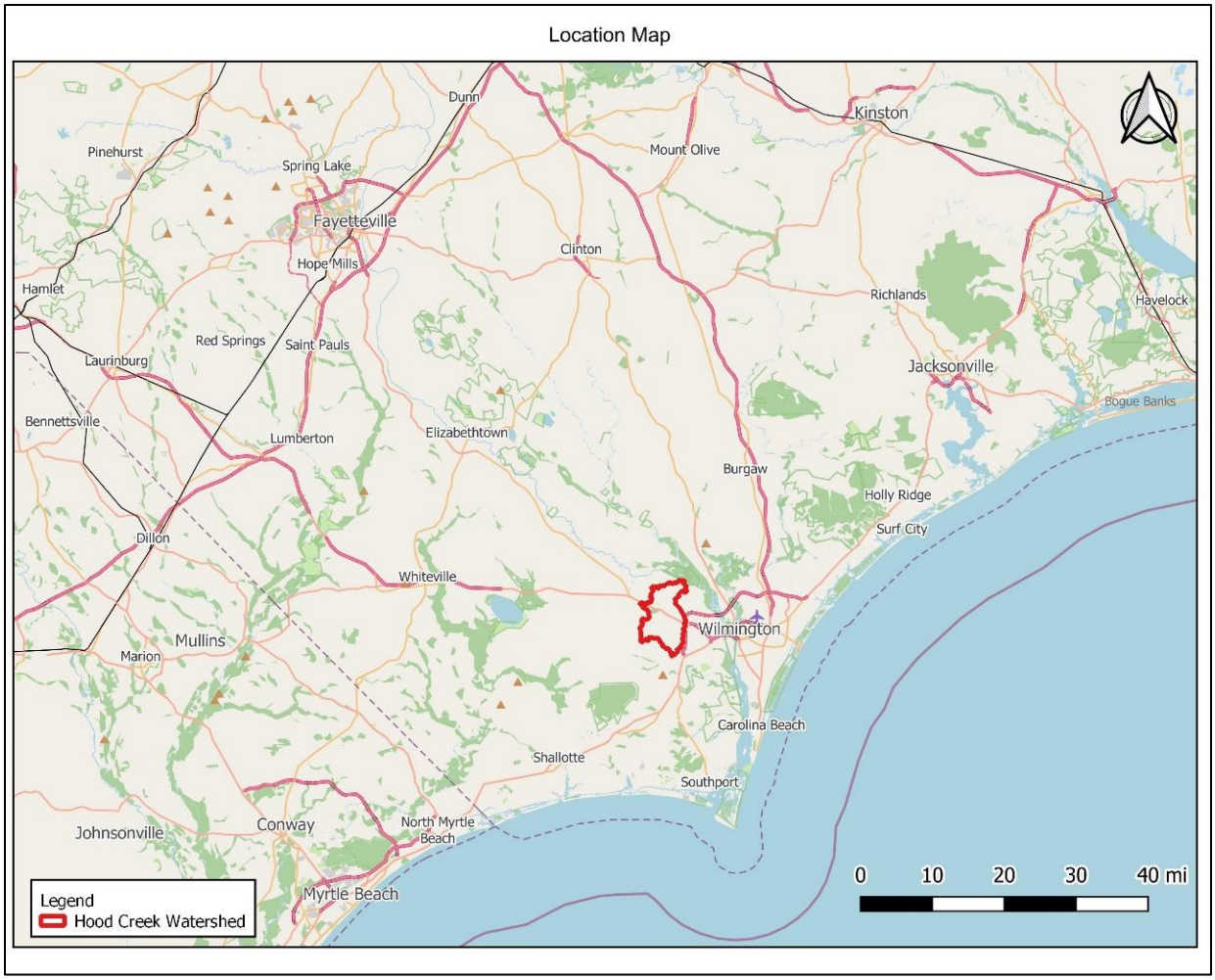


Figure 1. The Hood Creek watershed is located in the Cape Fear Basin in Brunswick County, NC.

Table 1. Surveyed barriers in the Hood Creek watershed within the Cape Fear River basin, NC.

ID	Crossing Type	SARP Score	SARP Category	# Structures	Material	Condition	Width	Bankfull Width	Road Type	Lat/Long
CPF133	Culvert	0.7325	Minor	1	Concrete	OK	2.5	8	Paved	34.30915 -78.14675
CPF138	Culvert	0.6116	Minor	3*	Metal	Failing	2.5	6.5	Unpaved	34.27637 -78.13794
CPF248	Culvert	0.8309	Insignificant	1	Metal	Failing	4	4.5	Paved	34.23961 -78.14272
CPF350	Culvert	0.7999	Minor	2	Metal	Poor	7	20.5	Paved	34.32022 -78.11768
CPF354	Culvert	0.7503	Minor	1	Concrete	Poor	2	6	Paved	34.30805 -78.14913
CPF356	Culvert	0.6926	Minor	1	Concrete	OK	1.5	3.5	Paved	34.30630 -78.15027
CPF358	Culvert	0.5000	Moderate	1	Metal	Poor	6.2	12.75	Paved	34.31700 -78.11935
CPF360	Culvert	0.8040	Insignificant	2	Metal	OK	8	15.6	Paved	34.29271 -78.14177
CPF362	Culvert	0.7911	Minor	1	Metal	OK	6	14.55	Paved	34.29059 -78.14935
CPF366	Culvert	0.7111	Minor	2	Concrete	OK	2.5	10	Paved	34.26516 -78.14543
CPF368	Culvert	0.9517	Insignificant	2	Concrete	OK	2.5	3.75	Paved	34.26512 -78.14247
UC 1	Culvert	0.7865	Minor	3	Metal	Failing	5	17.1	Paved	34.23797 -78.11519
UC 2	Culvert	0	Severe	1	Concrete	Poor	3.5	99.0 (floodplain)	Paved	34.25241 -78.11200
UC 3	Culvert	0.8718	Insignificant	1	Metal	OK	5	18.1	Paved	34.24994 -78.11919
UC 4	Bridge	0.7852	Minor	1	Combo	OK	90	32.0	Paved	34.25159 -78.12988
UC 5	Culvert	0.5	Moderate	1	Concrete	Poor	1.5	6.1	Paved	34.27254 -78.14451
UC 6	Culvert	0.8581	Insignificant	1	Metal	Poor	2.5	16.5	Paved	34.25667 -78.13763
UC 7	Culvert	0.8	Insignificant	1	Concrete	Failing	2	6.5	Paved	34.23526 -78.14068
UC 8	Culvert	0.5	Moderate	1	Concrete	OK	3.6	8.9	Paved	34.28394 -78.15292

*One of the three culverts at CPF138 was almost entirely buried and could not be surveyed.

Barrier Assessment

A hydrologic assessment using desktop GIS was performed on each of the 19 barriers surveyed in the Hood Creek watershed. In addition, 140 unsurveyed barriers in the watershed were identified on both public and private land (Figure 2). Watershed and connectivity analyses were performed in the focus area to determine the potential upstream effects of removing barriers to fish passage (Table 2).

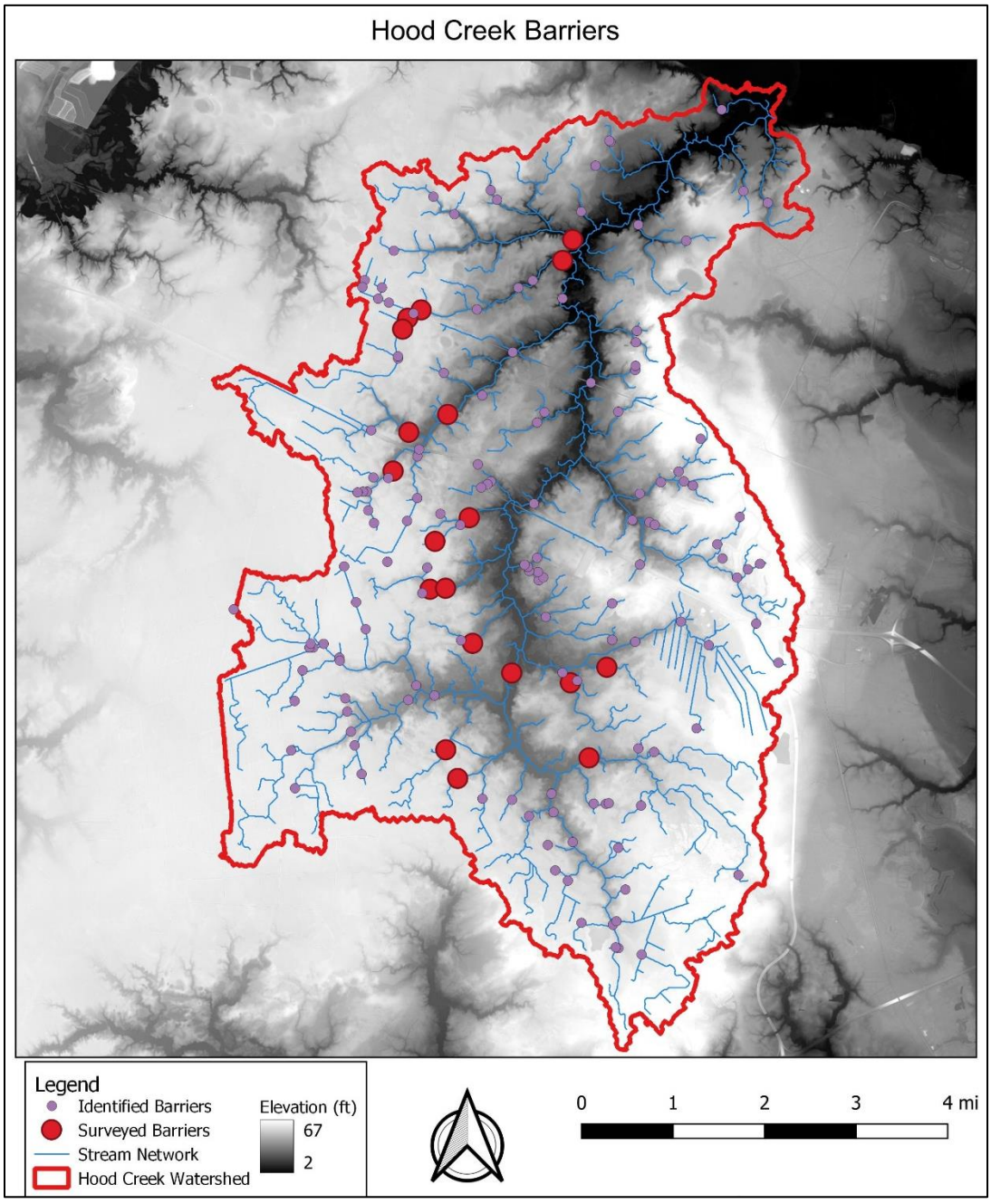


Figure 2. Identified and surveyed barriers in the Hood Creek watershed in the Cape Fear River basin, NC.

Stream networks, watershed areas and unobstructed upstream stream distances are shown in the table below for surveyed barriers in the Hood Creek Watershed.

Table 2. Watershed characteristics of surveyed barriers in the Hood Creek watershed.

ID	Crossing Type	# Structures	Condition	SARP Category	US Stream Length (ft)	US Stream Length (w/o barrier)	Watershed Area (ac)	Road Type	Lat/Long
CPF133	Culvert	1	OK	Minor	22,942	2,036	599	Paved	34.30915 -78.14675
CPF138	Culvert	3	Failing	Minor	6,726	2,700	169	Unpaved	34.27637 -78.13794
CPF248	Culvert	1	Failing	Insignificant	9,331	9,331	286	Paved	34.23961 -78.14272
CPF350	Culvert	2	Poor	Minor	54,772	39,178	1,689	Paved	34.32022 -78.11768
CPF354	Culvert	1	Poor	Minor	13,772	708	389	Paved	34.30805 -78.14913
CPF356	Culvert	1	OK	Minor	13,008	13,008	373	Paved	34.30630 -78.15027
CPF358	Culvert	1	Poor	Moderate	41,610	2,410	1,117	Paved	34.31700 -78.11935
CPF360	Culvert	2	OK	Insignificant	43,301	9,803	1,981	Paved	34.29271 -78.14177
CPF362	Culvert	1	OK	Minor	28,735	7,675	785	Paved	34.29059 -78.14935
CPF366	Culvert	2	OK	Minor	7,625	7,078	283	Paved	34.26516 -78.14543
CPF368	Culvert	2	OK	Insignificant	9,125	1,375	329	Paved	34.26512 -78.14247
UC 1	Culvert	3	Failing	Minor	57,567	39,276	1,622	Paved	34.23797 -78.11519
UC 2	Culvert	1	Poor	Severe	4,142	4,142	133	Paved	34.25241 -78.11200
UC 3	Culvert	1	OK	Insignificant	12,155	12,155	286	Paved	34.24994 -78.11919
UC 4	Bridge	1	OK	Minor	358,580	50,728	9,665	Paved	34.25159 -78.12988
UC 5	Culvert	1	Poor	Moderate	781	781	31	Paved	34.27254 -78.14451
UC 6	Culvert	1	Poor	Insignificant	3,434	822	106	Paved	34.25667 -78.13763
UC 7	Culvert	1	Failing	Insignificant	2,706	2,706	100	Paved	34.23526 -78.14068
UC 8	Culvert	1	OK	Moderate	16,578	3,720	448	Paved	34.28394 -78.15292

Culvert Capacity Analysis

Surveyed culverts in the Hood Creek watershed were analyzed for flow capacity using the HY-8 culvert design tool developed by the Federal Highway Administration. Recurrence interval storm flows were calculated using rural peak-flow equations for the southeastern US region developed by USGS. Culvert modeling accounts for backwater effects due to channel dimensions, but does not consider tidal flooding. Peak flows for storms corresponding to 2-, 5-, 10-, 25-, 50-, 100-, 200-, and 500-year recurrence intervals were modeled (Table 3).

Table 3. Watershed characteristics and modeled culvert capacities in the Hood Creek watershed.

ID	Crossing Type	# Structures	SARP Category	Condition	Width	Bankfull Width	Road Type	Max. Storm Capacity
CPF133	Culvert	1	Minor	OK	2.5	8	Paved	< 2-year
CPF138	Culvert	3	Minor	Failing	2.5	6.5	Unpaved	2-year
CPF248	Culvert	1	Insignificant	Failing	4	4.5	Paved	2-year
CPF350	Culvert	2	Minor	Poor	7	20.5	Paved	100-year
CPF354	Culvert	1	Minor	Poor	2	6	Paved	< 2-year
CPF356	Culvert	1	Minor	OK	1.5	3.5	Paved	< 2-year
CPF358	Culvert	1	Moderate	Poor	6.2	12.75	Paved	10-year
CPF360	Culvert	2	Insignificant	OK	8	15.6	Paved	10-year
CPF362	Culvert	1	Minor	OK	6	14.55	Paved	10-year
CPF366	Culvert	2	Minor	OK	2.5	10	Paved	5-year
CPF368	Culvert	2	Insignificant	OK	2.5	3.75	Paved	2-year
UC 1	Culvert	3	Minor	Failing	5	17.1	Paved	25-year
UC 2	Culvert	1	Severe	Poor	3.5	99.0 (floodplain)	Paved	2-year
UC 3	Culvert	1	Insignificant	OK	5	18.1	Paved	10-year
UC 4	Bridge	1	Minor	OK	90	32.0	Paved	N/A
UC 5	Culvert	1	Moderate	Poor	1.5	6.1	Paved	2-year
UC 6	Culvert	1	Insignificant	Poor	2.5	16.5	Paved	2-year
UC 7	Culvert	1	Insignificant	Failing	2	6.5	Paved	2-year
UC 8	Culvert	1	Moderate	OK	3.6	8.9	Paved	2-year

Culverts were analyzed for the maximum passable storm interval flow before water overtopped the road. One crossing, a bridge, was omitted from the analysis. The most recent version of the NCDOT Guidelines for Hydraulic Design states that culverts under minor arterials, collectors and local roads should be designed at a minimum to the 25-year recurrence interval storm, and culverts under major arterials should be designed at a minimum to the 50-year recurrence interval storm. When compared to the current standard, only 2 of the 18 analyzed culverts (CPF350 and UC 1) meet this design criteria. Based on these capacity estimates, nearly all culverts in this watershed would benefit from a level of service upgrade. As a result, addressing culverts on more traveled roads may be a way of prioritizing retrofits. If upgrades can be combined with passability improvements, the completed projects will have multiple co-benefits.

Prioritization and Recommendations

Each surveyed crossing was visually assessed for fish passage, structural condition and obstructions to flow. A general description of each crossing follows, noting areas of deficiency and suggesting possible methods of repair. These potential repairs are summarized in Table 4, below. Detailed descriptions of each crossing, including photographs, are included in Appendix A.

Table 4. Summary of potential repairs for surveyed barriers in the Hood Creek watershed in the Cape Fear River basin, NC.

ID	Crossing Type	Max. Storm Capacity	Meets DOT Capacity Criteria	Potential Repairs
CPF133	Culvert	< 2-year	No	Regrade downstream channel
CPF138	Culvert	2-year	No	Remove debris, eliminate culvert perch, replace culverts
CPF248	Culvert	2-year	No	Repair erosion, replace culvert
CPF350	Culvert	100-year	Yes	Remove debris, repair headwall
CPF354	Culvert	< 2-year	No	Remove debris regularly
CPF356	Culvert	< 2-year	No	Remove debris regularly
CPF358	Culvert	10-year	No	Assess headwall, remove grate, clear debris
CPF360	Culvert	10-year	No	Remove fallen log
CPF362	Culvert	10-year	No	N/A
CPF366	Culvert	5-year	No	Remove fallen log, monitor upstream flooding
CPF368	Culvert	2-year	No	Repair erosion, monitor upstream flooding
UC 1	Culvert	25-year	Yes	Repair significant erosion
UC 2	Culvert	2-year	No	Remove gravel obstruction, repair or replace culvert
UC 3	Culvert	10-year	No	Remove beaver dam
UC 4	Bridge	N/A	N/A	N/A
UC 5	Culvert	2-year	No	Remove debris regularly
UC 6	Culvert	2-year	No	Regrade downstream channel, replace culvert
UC 7	Culvert	2-year	No	Repair significant erosion, replace culvert
UC 8	Culvert	2-year	No	Remove sediment, re-arrange rock, stabilize banks

Surveyed crossings were prioritized by several different factors, including flow capacity, structural condition, watershed characteristics, fish passage and road traffic (Table 5). A ranking of 1 indicates a greater deficiency (in the case of flow capacity, structural condition and fish passage) or larger affected area (in the case of watershed size/stream connectivity or road traffic). With consideration to each of these areas, crossings were then sorted into tiers representing overall project priority. The results of this approach can be used to prioritize retrofits based on overall benefits or to target projects based on more specific goals. For example, projects in the first tier will provide the best benefits in multiple areas, but there are different projects that might be pursued if fish passage or capacity improvements are prioritized.

Table 5. Prioritized culvert repairs in the Hood Creek watershed in the Cape Fear River basin, NC.

ID	Flow Capacity	Watershed Size/Stream Connectivity	Structural Condition	Fish Passage	Road Traffic	Overall Tier
CPF248	1	2	1	3	1	1
CPF358	2	1	2	2	1	1
UC 2	1	3	1	1	2	1
UC 7	1	3	1	1	1	1
CPF133	1	2	3	1	2	2
CPF138	1	3	1	1	3	2
CPF368	1	2	2	2	2	2
UC 1	3	1	1	3	1	2
UC 3	2	2	2	1	2	2
UC 6	1	3	2	1	2	2
UC 8	1	2	2	1	3	2
CPF350	3	1	2	3	1	3
CPF354	1	3	2	2	2	3
CPF366	1	2	3	2	1	3
UC 5	1	3	2	2	1	3
CPF356	1	3	3	2	2	4
CPF360	2	1	3	3	2	4
CPF362	2	2	3	3	1	4
UC 4	3	1	3	3	2	4

Summary

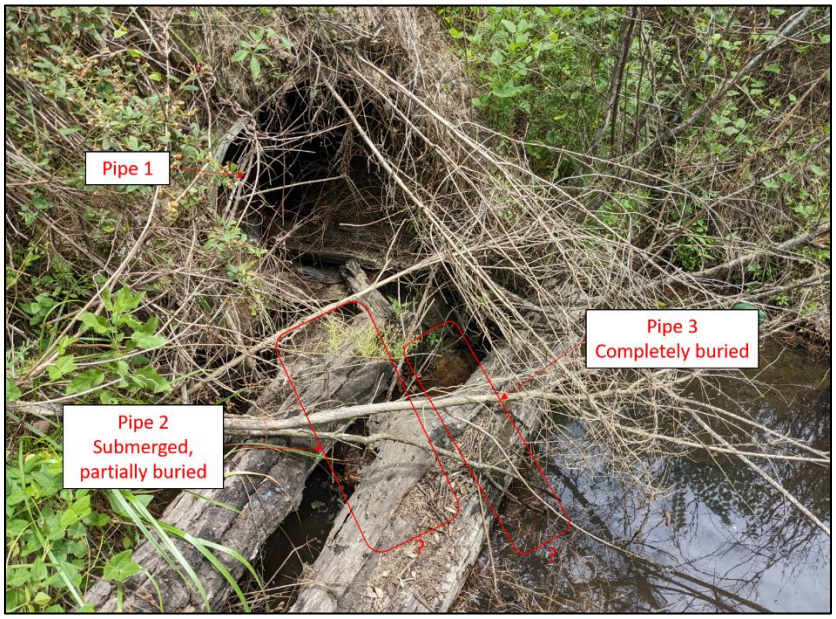
Fifty barriers in the lower Cape Fear watershed were surveyed using SARP Tidal methodology. Nineteen of these barriers were in the Hood Creek watershed, where a detailed analysis was performed. Results show that many barriers could be retrofitted to benefit aquatic species, and almost all need additional capacity for storm flows. By ranking deficiencies in several categories, potential projects can be matched with specific goals, or grouped into tiers based on overall benefits.

Appendix A – Detailed Barrier Descriptions

CPF133

CPF133 is a single 30” RCP in an intermittent or ephemeral channel. Though the channel was dry while the survey occurred, the outlet pool still retained water. Many small fish were observed in the pool, which seemed likely to dry up in a few days. The outlet pipe was slightly perched, and a utility pipe ran perpendicular to the stream channel directly downstream of the pipe. This crossing is the most downstream of a group of three culverts, with CPF354 and CPF356, located within a ½ mile of each other. Though the utility pipe presents a challenge, the downstream channel could be regraded and pipe buried to allow passage upstream.

CPF138



CPF138 is a group of three culverts in poor shape. One CMP was perched significantly above the water both upstream and downstream, and appeared to rarely receive flow. Two further pipes were submerged below the water and debris, and the inlet openings were buried in the stream bed. Slight flow was observed downstream, suggesting that some water is passing through the buried pipes. However, it seems unlikely that fish passage is possible except in high flow events. The road above these culverts is not paved, however it appears to be the only point of access to several houses beyond the culvert crossing. If access issues can be resolved, these culverts could be replaced with a larger culvert or small bridge to improve passage.

CPF248

CPF248 is a single CMP in failing condition. The culvert is rusted through in several areas and erosion above the pipe is approaching the road. This erosion should be repaired to preserve the integrity of the road. Removal and replacement of the current culvert with a larger barrel size could help to prevent further erosion in the future.

CPF350

This crossing is two CMP with a headwall made of concrete bags. A metal grate is present in front of one culvert barrel on the downstream side. The purpose of this grate is unclear, but potential beaver activity has formed a debris blockage on the downstream side of the grate. Fish passage appeared unimpeded in

the open culvert. To improve passage in the grated culvert barrel, debris should be removed regularly. The stability of the headwall should also be assessed, as several of the concrete bags were separated and falling from the wall on the downstream side.

CPF354

CPF354 is a small CMP in what appeared to be an ephemeral stream channel. The upstream side of the culvert was close to being covered by weedy vegetation. This area could be cleared regularly and monitored during and after storms to ensure that flow is not obstructed.

CPF356

This culvert is also a small CMP in an ephemeral channel. It is the most upstream of a cluster of culverts, with CPF133 and CPF354, that only occasionally receive flow. This area could be monitored following storms to ensure that debris build-up does not obstruct flow.

CPF358

CPF358 is a single CMP with a metal grate on the outlet. The headwall is made of concrete bags and is visibly leaning on the downstream side. A small wooden structure was present on the downstream side, possibly to reinforce the wall. The spacing on the outlet grate may impede passage of some larger fish as well as attract debris. The stability of the headwall should be assessed at this crossing. The metal grate on the downstream side could be removed or debris cleared regularly to improve fish passage.

CPF360

This crossing has two culvert barrels in an aluminum headwall. The culvert and surrounding stream are located under a power corridor. The area appeared stable with no signs of erosion or functional issues, and major debris build-up was not observed. A large log had fallen near the inlet of one of the culvert barrels and could be removed to prevent future debris accumulation in that area. Fish passage did not appear to be restricted by this culvert in most flow conditions.

CPF362

CPF362 is a single CMP barrel with a headwall. The culvert appeared to be in fine shape and no major erosion or functional issues were observed. There was no debris build-up surrounding the culvert, and fish passage did not appear to be restricted during normal flow conditions.

CPF366

This crossing is two RCP with a small braided channel upstream. A fallen tree trunk blocks most of the upstream channel and potentially impedes fish passage. Other than the tree, no debris or other obstructions were observed. This area could be monitored following storms to determine the extent of any upstream flooding.

CPF368

This crossing is two RCP culverts located approximately 1,000 ft downstream of CPF366. Significant erosion was observed on the upstream side of the crossing. A neighbor informed us that during previous hurricanes, water had ponded upstream of the culverts up to the house and shed on their property. This area could be monitored during and following storms to determine the extent of upstream ponding, and to assess the need for larger culverts.

Unnumbered Crossing 1

This crossing is three CMP in failing condition. Woody debris accumulation was observed on top of the culvert outlet pipes, suggesting that flow may overtop the pipes on occasion. Significant erosion was also observed above the culverts. A layer of matting was present above the inlet side, but it appeared that some of the soil under the matting had washed away leaving an empty space behind the inlet headwall. This area should be further assessed for stability and repaired as necessary.

Unnumbered Crossing 2

This crossing is a single small RCP that has a recent repair of the slope and road above the pipe. Both sides of the pipe appeared to be sloped upward, so it is possible that the pipe is separated somewhere

under the road. A gravel dam was present downstream of the crossing, possibly left over from the road repair. This gravel is obstructing flow and could be removed.

Unnumbered Crossing 3

The CMP at this crossing is in passable condition, however there is a beaver dam located roughly 100 ft upstream of the pipe. The dam was holding water several feet above the stream bed in July 2022 and preventing fish passage. This dam could be removed and area monitored for further beaver activity to improve fish passage.

Unnumbered Crossing 4

Fish passage and flow capacity did not appear to be a problem at this bridge.

Unnumbered Crossing 5

This small RCP appears to be in an ephemeral channel. No flow was observed in early July 2022 when the crossing was assessed. However, a sediment and debris blockage upstream likely obstructs storm drainage during rainfall. This area could be kept clear of obstructions to improve the flow capacity of the culvert.

Unnumbered Crossing 6

This CMP is perched nearly a foot from the water surface and is in poor condition. Though the channel upstream is relatively small, erosion around the outlet pipe suggests that this area occasionally receives

high flow. This area could be regraded to remove the outlet perch or the pipe, which is old and rusting, could be replaced and set lower in the channel to improve passage.

Unnumbered Crossing 7

The single RCP at this crossing is in failing condition, and more than one of the pipe joints have separated and fallen into the channel. There is also significant erosion above the pipe on the inlet side. The channel appeared ephemeral, but the outlet pool was still holding water when observed in July 2022. This pipe could be replaced and side slopes regraded before erosion in this area begins to threaten the road.

Unnumbered Crossing 8

This crossing is an RCP with attached flared end sections in a residential area. Badly eroding banks appear to be contributing to the heavy sediment load entering the inlet (pictured above). Rip-rap armoring in the downstream channel also appears to restrict fish passage. This rock could be rearranged or removed to enhance fish passage. Upstream channel banks could also be stabilized to reduce the incoming sediment and prevent build-up in the structure.

Other Notable Crossings

Although not located within the Hood Creek watershed, a few other culverts stood out as potentially beneficial projects to both fish passage and hydrology.

CPF86

This crossing is two RCP under an unpaved road adjacent to a gated horse pasture. The two culverts are perched roughly a foot above the water, preventing upstream passage except for during storms. An unpaved road makes culvert replacement less difficult than if pavement had to be disturbed.

CPF88

This crossing is two RCP, both slightly perched on the outlet side. These culverts appear to be located on an old/abandoned subdivision plot where paved roads have been constructed but no houses were ever built. The crossing may be easier to improve than other culverts because there is no traffic over the site.