Fish Passage Status of Road-Stream Crossings on Selected National Forests in the Southern Region, 2005

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Table of Contents

List of Figures 2

List of Tables 4

Background 5
Methods 6
  Data Collection 6
  Data Analysis 7
Results 8
Discussion 9
  Regional Analysis 9
  Current Limitations and Future Improvements 10
Literature Cited 13
Acknowledgements 15

Appendix A: Results for the George Washington-Jefferson National Forest 28

Appendix B: Results for the Daniel Boone National Forest 47

Appendix C: Results for the Ozark-St. Francis National Forest 63

Appendix D: Results for the National Forests in Alabama 76

List of Figures

Figure 1. National Forests where road-stream crossing inventories were conducted in 2005 16
Figure 2. Common road-stream crossing structure shapes. 17
Figure 3. Survey points used to calculate culvert characteristics 18
Figure 4. Coarse Filter A 19
Figure 5. Coarse Filter B 20
Figure 6. Coarse Filter C 21
Figure 7. Results of coarse filter A for crossings (all Forests combined) in 2005. 22
Figure 8. Results of coarse filter B for crossings (all Forests combined) in 2005. 22
Figure 9. Results of coarse filter C for crossings (all Forests combined) in 2005. 22
Figure 10. Results of coarse filter A for crossings (by Forest) in 2005 23
Figure 11. Results of coarse filter B for crossings (by Forest) in 2005 23
Figure 12. Results of coarse filter C for crossings (by Forest) in 2005. 23
Figure 13. Results of coarse filter A for each crossing type (all Forests combined) in 2005. 24
Figure 14. Results of coarse filter B for each crossing type (all Forests combined) in 2005 24
Figure 15. Results of coarse filter C for each crossing type (all Forests combined) in 2005 24
Figure 16. Crossing width to bankfull channel width ratios (by Forest) in 2005 25

Appendix A
Figure A1. GWJNF Ranger Districts surveyed in 2005 30
Figure A2. Results of coarse filter A for crossings on the GWJNF in 2005 31
Figure A3. Results of coarse filter B for crossings on the GWJNF in 2005. 31
Figure A4. Results of coarse filter C for crossings on the GWJNF in 2005. 31
Figure A5. Results of coarse filter A for each crossing type on the GWJNF in 2005. 32
Figure A6. Results of coarse filter B for each crossing type on the GWJNF in 2005 32
Figure A7. Results of coarse filter C for each crossing type on the GWJNF in 2005 32
Figure A8. Crossing width to bankfull channel width ratios on the GWJNF in 2005. 33
Figure A9. Map of impassable, passable, and indeterminate crossings on the GWJNF 34

Appendix B
Figure B1. DBNF Ranger Districts surveyed in 2005.. 49
Figure B2. Results of coarse filter A for crossings on the DBNF in 2005 50
Figure B3. Results of coarse filter B for crossings on the DBNF in 2005. 50
Figure B4. Results of coarse filter C for crossings on the DBNF in 2005. 50
Figure B5. Results of coarse filter A for each crossing type on the DBNF in 2005.. 51
Figure B6. Results of coarse filter B for each crossing type on the DBNF in 2005.. 51
Figure B7. Results of coarse filter C for each crossing type on the DBNF in 2005. 51
Figure B8. Crossing width to bankfull channel width ratios on the DBNF in 2005. 52
Figure B9. Map of impassable, passable, and indeterminate crossings on the DBNF 53

Appendix C
Figure C1. OSFNF Ranger Districts surveyed in 2005 65
Figure C2. Results of coarse filter A for crossings on the OSFNF in 2005. 66
Figure C3. Results of coarse filter B for crossings on the OSFNF in 2005. 66
Figure C4. Results of coarse filter C for crossings on the OSFNF in 2005 66
Figure C5. Results of coarse filter A for each crossing type on the OSFNF in 2005.. 67
Figure C6. Results of coarse filter B for each crossing type on the OSFNF in 2005. 67
Figure C7. Results of coarse filter C for each crossing type on the OSFNF in 2005.. 67
Figure C8. Crossing width to bankfull channel width ratios on the OSFNF in 2005 68

List of Figures, continued…

Figure C9. Map of impassable, passable, and indeterminate crossings on the OSFNF 69

Appendix D

Figure D1. NFAL Ranger Districts surveyed in 2005. 78
Figure D2. Results of coarse filter A for crossings on the NFAL in 2005..... 79
Figure D3. Results of coarse filter B for crossings on the NFAL in 2005..... 79
Figure D4. Results of coarse filter C for crossings on the NFAL in 2005..... 79
Figure D5. Results of coarse filter A for each crossing type on the NFAL in 2005.. 80
Figure D6. Results of coarse filter B for each crossing type on the NFAL in 2005. 80
Figure D7. Results of coarse filter C for each crossing type on the NFAL in 2005.. 80
Figure D8. Crossing width to bankfull channel width ratios on the NFAL in 2005 81
Figure D9. Map of impassable, passable, and indeterminate crossings on the BHNF. 82
Figure D10. Map of impassable, passable, and indeterminate crossings on the TNF..... 83

List of Tables

Table 1. Crossings documented and not surveyed by Forest in 2005. 26
Table 2. Results of coarse filters A, B, and C for crossings (by Forest and Forests combined) in 2005... 26
Table 3. Crossings impassable at outlet drop, slope, and slope x length (all Forests combined). 27
Table 4. Results of the coarse filters for each crossing type (all Forest combined) in 2005..... 27

Appendix A
Table A1. Crossings documented and not surveyed on the GWJNF in 2005. 35
Table A2. Results of coarse filters A, B, and C for crossings on the GWJNF in 2005. 35
Table A3. Location of surveyed crossings on the GWJNF in 2005..... 36
Table A4. Results the of coarse filters for individual crossings on the GWJNF in 2005. 40
Table A5. Description of surveyed crossings on the GWJNF in 2005 43

Appendix B
Table B1. Crossings documented and not surveyed on the DBNF in 2005. 54
Table B2. Results of coarse filters A, B, and C for crossings on the DBNF in 2005. 54
Table B3. Location of surveyed crossings on the DBNF in 2005 55
Table B4. Results the of coarse filters for individual crossings on the DBNF in 2005. 58
Table B5. Description of surveyed crossings on the DBNF in 2005. 60

Appendix C
Table C1. Crossings documented and not surveyed on the OSFNF in 2005 70
Table C2. Results of coarse filters A, B, and C for crossings on the OSFNF in 2005..... 70
Table C3. Location of surveyed crossings on the OSFNF in 2005. 71
Table C4. Results the of coarse filters for individual crossings on the OSFNF in 2005. 73
Table C5. Description of surveyed crossings on the OSFNF in 2005 74

Appendix D
Table D1. Crossings documented and not surveyed on the NFAL in 2005. 84
Table D2. Results of coarse filters A, B, and C for crossings on the NFAL in 2005. 84
Table D3. Location of surveyed crossings on the NFAL in 2005 85
Table D4. Results the of coarse filters for individual crossings on the NFAL in 2005. 88
Table D5. Description of surveyed crossings on the NFAL in 2005 90

Background

The United States has >6.2 million km of public roads (National Research Council 1997), that directly impact 20% of its land surface (Forman 2000). There are an estimated 1.4 million road-stream crossings in the United States and over 50,000 on National Forest managed lands in the eastern U.S. (M. Hudy, U.S. Forest Service, unpublished data), each of which represents a potential impediment or barrier to movement of fish and other aquatic organisms. The ability of animals to move freely through stream networks is an important aspect of a species' long-term viability (Fausch et al. 2002). In particular fish movement in streams prevents population fragmentation (Winston et al. 1991), allows for population recovery following disturbance (Detenbeck et al. 1992; Roghair and Dolloff 2005), and provides access to critical spawning habitats (Fausch and Young 1995). Early work examining effects of road-stream crossings on fish movement occurred primarily in the western U.S. and focused on anadromous Pacific salmon. Effects of road-stream crossings on stream-resident fishes in the eastern U.S. have received less attention, in part because resident fishes were regarded as sedentary (Gerking 1959). Recent research and re-examination of historic movement studies (Gowan et al. 1994) on a wide range of stream-resident fish species (Albanese et al. 2003; Schmetterling and Adams 2004; Warren and Pardew 1998) has shown that so called resident species exhibit greater frequency and magnitude of movement than previously was thought. For land managers, this new understanding of fishes ability and propensity to move has significant implications. Road-stream crossings must be managed to permit both downstream and upstream passage of aquatic animals.

In 2003 and 2004 the U.S. Forest Service Southern and Eastern Regions and the San Dimas Technology and Development Center (SDTDC) hosted several fish passage assessment and remediation workshops. The National Inventory and Assessment Procedure (NIAP) (Clarkin et al. 2003), developed by SDTDC, presented at these workshops provided a framework for collecting field data, but the assessment models, designed for fish species endemic to the western U.S., were not directly applicable to species in the eastern U.S. The southeastern U.S. has over 560 freshwater fish species in over 28 families encompassing a wide range of swimming and leaping abilities (Warren et al. 2000). Development of species-specific passage models was considered impractical and lack of data on leaping and swimming ability for most eastern fish species limited the usefulness of previously developed passage software such as FishXing (Love et al. 1999).

In 2003, graduate students and biologists of the U.S. Forest Service Aquatic Ecology Unit – East at James Madison University began to develop several simple models that would allow managers to quickly assess the passage status of a crossing for groups of fish with similar swimming abilities. Three 'coarse screening filters' were developed: Filter A for species with strong leaping and swimming abilities; Filter B for species with moderate leaping and swimming abilities; and Filter C for species with weak

leaping and swimming abilities. Movement data on a broad cross section of eastern stream fishes showed that the coarse filters provided a reasonable estimate of the likelihood of a particular crossing presenting a barrier to upstream passage (Coffman 2005).

In 2005 the Southern Region elected to allocate 10% of its Roads and Trails (TRTR) funds to inventory road-stream crossings in the George Washington-Jefferson (GWJNF), Daniel Boone (DBNF), Ozark-St. Francis (OSFNF), Bankhead (BNF) and Talladega (TNF) National Forests (Figure 1). To insure a quality product with consistent data collection and analysis the Region partnered with the Southern Research Station, Center for Aquatic Technology Transfer (CATT) to design an inventory and assessment program for road-stream crossings. The CATT designed an inventory program based on the NIAP, deployed field crews to collect data, and then classified each crossing as passable, impassable or indeterminate for each of the three coarse filters described above. This report summarizes the results of road-stream crossing inventories and data analysis performed by the CATT in 2005.

Methods

Data Collection

Dimensions, shape (Figure 2), and condition of road-stream crossing structures and data pertaining to the adjacent stream channel were recorded for each site following the (NIAP) (Clarkin et al. 2003). A CST/berger SAL series automatic level with 32x magnification mounted on a tripod and a 25-foot stadia rod graduated in tenths of feet were used to measure the elevation of the crossing structure inlet and outlet, tailwater control, and the water surface (Figure 3). A measuring tape marked in hundredths of a foot was used to measure the distance between the crossings inlet and outlet. Bankfull channel width was measured at three locations upstream of the crossing and three downstream where natural channel geometry was intact (i.e. outside of the influence of the crossing structure). Photographs of the inlet and outlet were taken and each site was sketched on paper. Condition of the crossing structure was recorded and any natural barriers (e.g.. waterfalls) immediately upstream or downstream were documented. Natural stream substrate covering the bottom of the crossing structure was recorded as present continuous throughout the structure, present discontinuous, or not present. Substrate had to cover 100% of the structure bottom for a crossing to receive a present continuous throughout the structure designation. Crossing location was documented but the structure was not surveyed if there was inadequate habitat upstream of the crossing to support fish, or if the crossing structure was a bridge or natural ford. Bridges and natural fords were assumed to always provide adequate upstream fish passage. Crossing locations that could not be reached because of inaccessible or closed roads, private property issues, or locked gates were also documented.

Data Analysis

The elevation and distance measurements for the crossing inlet, crossing outlet, tailwater control, and water surface were used to calculate residual inlet depth, outlet drop, outlet perch, slope, and slope x length values for each crossing (Figure 3). Residual inlet depth was calculated as

$$P_3 - P_1,$$

where P_3 is the tailwater control elevation of the outlet pool and P_1 is the crossing inlet elevation. Residual inlet depth values greater than zero indicate the structure is completely backwatered, allowing fish passage. Outlet drop was calculated as

$$P_2 - P_3,$$

where P_2 is the crossing outlet elevation and P_3 is the tailwater control elevation of the outlet pool. Outlet perch was calculated as

$$P_2 - Ws,$$

where P_2 is the crossing outlet elevation and Ws is the water surface elevation immediately downstream of the outlet. Outlet perch is used in place of outlet drop when a tailwater control is not present and outlet drop cannot be calculated. Excessive outlet drop or outlet perch values indicate the presence of jump barriers. Slope was calculated as

$$(P_{1elev} - P_{2elev}) / (P_{1dist} - P_{2dist}) * 100,$$

where P_{1elev} is the crossing inlet elevation, P_{2elev} is the crossing outlet elevation, P_{1dist} is the crossing inlet distance, and P_{2dist} is the crossing outlet distance. Steep slope is an indicator of velocity barriers. Slope x length was calculated as

$$[(P_{1elev} - P_{2elev}) / (P_{1dist} - P_{2dist}) * 100] * (P_{1dist} - P_{2dist}),$$

where P_{1elev} is the crossing inlet elevation, P_{2elev} is the crossing outlet elevation, P_{1dist} is the crossing inlet distance, and P_{2dist} is the crossing outlet distance. High slope x length values indicate an exhaustion barrier.

Residual inlet depth, outlet drop, outlet perch, slope, and slope x length values for each crossing were applied to each of three regional coarse filters (Figures 4 – 6) to determine upstream passage status. Threshold values for each parameter differ by filter and were set according to published swimming and leaping abilities of representative species in each filter group, and relationships among crossing dimensions, species presence/absence data, and movement data (Coffman 2005). Filter A (Figure 4) classifies crossings for species with strong swimming and leaping abilities, such as the adult brook trout (*Savelinus fontinalis*). Filter B (Figure 5) classifies crossings for species with moderate swimming and leaping abilities such as juvenile trout or species in the minnow family (Cyprinidae). Filter C (Figure 6) classifies crossings for weak swimmers and leapers, such as species in the darter (Percidae) and sculpin (Cottidae) families. Crossings are classified as passable, impassable, or indeterminate for each of the

three filters. Biological sampling or computer modeling is required to determine passage status for crossings classified as indeterminate.

Sites with more than one crossing structure (e.g. culverted site with multiple pipes) were occasionally encountered during the surveys. At these sites each individual structure was classified, which could result in a single site having multiple classifications for a given filter. Under those circumstances the location was classified based on the structure that received the best passage rating. For example, in a crossing location with two circular culverts where one was classified as impassable and one indeterminate by Filter B, the location would receive an overall classification of indeterminate rather than impassable.

The ratio of culvert width to bankfull channel width was also calculated for each site. The ratio was calculated as

$$CW / BCW,$$

where CW is the maximum width or diameter of the crossing structure and BCW is the average of all six (three upstream and three downstream) bankfull channel width measurements. A ratio of 1.0 or greater indicates that the crossing structure is equal to or greater than the width of the bankfull channel. Fords, vented fords, and sites with multiple crossing structures were eliminated from the analysis.

Results

We visited a total of 1337 road-stream crossings in 2005 and completed surveys at 297 sites (Table 1). Filter A (strong swimmers and leapers) classified 22% (n=64) of crossings as impassable, 30% (n=89) as passable, and 48% (n=144) as indeterminate (Figure 7, Table 2). Filter B (moderate swimmers and leapers) classified 63% (n=188) of crossings as impassable, 15% (n=45) as passable, and 22% (n=64) as indeterminate (Figure 8, Table 2). Filter C (weak swimmers and leapers) classified 81% (n=239), of crossings as impassable, 12% (n=36) as passable, and 7% (n=22) as indeterminate (Figure 9, Table 2). The GWJNF had the highest percentage of impassable sites for both Filter A and B, and the DBNF had the highest percentage of impassable sites for Filter C. All Forests had greater than 55% of sites for Filter B and greater than 75% of sites for Filter C classified as impassable (Figures 10-12, Table 2). Excessive outlet drops accounted for 61% of the impassable sites for Filter A, 74% for Filter B, and 85% for Filter C (Table 3).

The majority of crossings were either circular culverts (n=145) or pipe arches (n=88), while box culverts (n=18), vented fords (n=10), concrete slab fords (n=28), and open bottom arches (n=8) were less frequently encountered. Filter A classified 25% of circular culverts and 24% of pipe arch crossings as impassable (Figure 13, Table 4). The proportion of circular culverts and pipe arches classified impassable increased from Filter A to Filters B and C. Filter B classified 70% of circular culverts and 67% of pipe

arch crossings as impassable (Figure 14, Table 4). Filter C classified 89% of circular culverts and 78% of pipe arches as impassable (Figure 15, Table 4). All three filters classified 100% of the open bottom arches as passable (Table 4).

Greater than 90% of all crossings (excluding fords, vented fords, and multiple structure crossings) had crossing to channel width ratios less than 1.0 (i.e. crossing width was less than the bankfull channel width). The mean crossing width to channel width ratio (n=177) was 0.54 (SD=0.23) (Figure 16). Only 11 crossings were greater than or equal to the mean bankfull channel width (i.e. crossing width to channel width ratio was greater than or equal to 1.0).

Discussion

Regional Analysis

Crossings that prevent upstream fish passage are a common feature of stream networks on all the Forests we surveyed. Considering all Forests, no more than 17% of crossings were passable for all three filters highlighting the potential severity of stream fragmentation. Outlet drop triggered passage failure at the majority of impassable sites for all three filters, but it was not the only factor that prevented movement at many sites. Over 40% of sites classified as impassable due to excessive outlet drop would also have failed due to either excessive slope or slope x length values. Even if fish had managed to find a way to leap into these crossing structures they likely would have faced water velocities that exceeded their swimming abilities or a combination of water velocity and pipe length that would have exhausted them before they could exit the upstream end of the structure. These conditions are created when crossing structures do not mimic natural channel characteristics such as bankfull channel width, slope, and substrate. The result is increased water velocity within the structure and scouring immediately downstream creating an outlet drop, or perch (Castro 2003). This effect is exaggerated in high gradient streams which may explain why the GWJNF, which had the highest gradient streams for Forests inventoried in 2005, also had the highest proportion of sites that failed for Filters A and B. Streams in the other Forests visited were primarily low gradient and failure for Filter A in these streams indicated an extreme passage problem.

The high proportion of impassable sites for Filters B and C is particularly troubling. Minnow and darter species, the majority of which fall within Filters B and C represent >70% of the freshwater fish diversity in the Southeast (Warren et al. 2000) and occur on every Forest in the Southern Region. These fishes also represent 65% of the imperiled fish taxa in the Southeast (Warren et al. 2000). Our results suggest that these species face barriers to movement at 60% - 80% of road-stream crossings on National Forest managed lands in the Southern Region. The fragmentation caused by these barriers likely contributes to species imperilment, and the high number of impassable sites adds to the challenge of restoring connectivity (Walsh et al. 1995).

All crossing types blocked upstream fish passage to some degree with the exception of open bottom arches. Open bottom arches typically had crossing to channel width ratios close to 1.0 and always had natural stream substrate throughout the crossing, providing favorable conditions for upstream fish passage. However, open bottom arches are expensive compared to other crossing types (Murphy and Pyles 1989), which may explain why we encountered relatively few of these structures. Other than open bottom arches, box culverts and vented fords had the smallest percentage of impassable sites, but sample size for these types was low in 2005. Pipe arches and circular culverts were the most frequently encountered crossing type. Pipe arches and circular culverts dominate the road-stream crossing landscape because they are the most readily available and cost effective to install, but as our results demonstrate, they can create passage problems when stream hydrology and biological factors are not carefully considered prior to installation (Baker and Votapka 1990).

Current Limitations and Future Improvements

The coarse filters presented here apply to several general categories of fish including strong swimmers and leapers (Filter A), moderate swimmers and leapers (Filter B), and weak swimmers and leapers (Filter C). We assigned adult trout to represent Filter A, minnows and young trout to represent Filter B, and darters and sculpins to represent Filter C, however there are a range of swimming and leaping abilities represented within each family. For example, passage of some minnow species may actually be best assessed by Filter A whereas others may fit better in Filter C. Still other families or species, such as those that are strong swimmers but weak to moderate leapers may require the creation of additional filters to correctly classify their passage status. Currently, few data are available regarding swimming and leaping ability of non-game fish species in the Southeast making it difficult to refine or expand the existing filters. Members of the sucker (Catostomidae), catfish (Ictuluridae) and sunfish (Centrarchidae) families may fit into such filters, but clearly more research is needed.

Results provided by the existing filters include a sometimes large area of indeterminate passage status. Crossings enter this "gray area" when they pass for outlet drop and slope but do not pass or fail for slope x length. The range of values that leads to an indeterminate classification for slope x length can be quite large, particularly for Filter A leaving a large portion of sites essentially unclassified. The slope x length value represents the relative level of exhaustion a fish would experience by trying to swim through a pipe of a certain slope for a given distance. Because few empirical data exist for species exhaustion rates the filters were designed to be conservative at this step. Biological sampling can provide important information for evaluating fish passage at sites classified indeterminate and generally with little expense relative to the cost of replacing a crossing structure. Mark-recapture sampling designs can vary in complexity and effort depending on project goals (Warren and Pardew 1998) and provide direct evidence of fish passage without the assumptions of fish passage models. The mark recapture design can

be as simple as marking and releasing a sample of fish downstream of a crossing, and then sampling for marked fish about the crossing on subsequent sampling trips. Collection of marked fish above the crossing would indicate that crossing is passable for the species in question. More elaborate designs to detect if movement through the crossing is the same or similar to movement through the unobstructed natural stream channel can also be implemented (Coffman 2005). The use of mark-recapture studies at indeterminate sites would not only allow managers to classify these sites as passable or impassable, but would also provide data necessary to refine the filter thresholds and shrink the gray areas.

We could not perform surveys at nearly 4 out of every 5 sites we visited in summer 2005. Many sites were natural fords or bridges, which we do not survey or were on closed roads, behind private gates, etc. Our efficiency could be vastly improved with better pre-visit preparation. Early notification of the Forests selected for crossing assessments would give Forest personnel the time necessary to prepare for the assessment. This preparation should include watershed selection using existing databases, recent aerial photography, maps and local knowledge to eliminate crossings that do not require surveys (i.e. natural fords, bridges, and closed roads). Specific crossings scheduled to be surveyed that are behind locked gates or require passing through private property to access could be identified and the necessary steps taken to ensure efficient use of the field crews. Maps denoting crossings to be surveyed and sites to avoid can allow the field crews to coordinate an efficient strategy to complete the surveys. Because time and resources for assessment and remediation are limited, prioritization is crucial to the assessment program.

The Forests have opportunities to improve fish passage at road-stream crossings both during routine maintenance when crossing structures reach the end of their serviceable life, and when funding becomes available to replace crossings outside of the regular maintenance schedule. Managers should always consult with their biologists and hydrologists to determine whether routine replacements should include aquatic organism passage considerations. Selection of sites for replacement outside of the routine maintenance schedule can be more challenging. Currently, Forests can use the information from our surveys to locate impassable crossings that are candidates for replacement; however the number of impassable crossings per Forest makes selecting sites an overwhelming task. Survey results only provide passage status and exclude many other factors that should be considered when prioritizing crossings for replacement. Information such as miles of habitat upstream of a crossing, cost of replacement, species presence, and species status (i.e. threatened, endangered, exotic invasive) need to be included in the decision process. Given the large number of impassable sites, using criteria such as these to prioritize sites for remediation can be time consuming and overwhelming.

Decision support systems (DSS) can be designed to assist managers faced with complex prioritization problems such as these. For example, in the case of the crossing assessment project a DSS

could be designed that would allow Forests to prioritize watersheds for assessment based on characteristics such as number of stream crossings, percent Forest ownership, or presence of endangered species within the watershed. Crossings within the prioritized watersheds that do not pose a threat to fish passage (i.e. bridges and natural fords) could be eliminated from the surveys prior to field crew visits saving valuable time. Once inventories are completed the DSS could be used to prioritize impassable sites for replacement based on factors such as the quantity and quality of habitat that could be opened upstream of a crossing. A DSS could be a powerful tool, helping Forests focus assessment efforts and make justifiable fish passage remediation decisions allowing them to more efficiently and effectively compete for funding.

The results of culvert inventories performed in the Southern Region in summer 2005 demonstrate the impact of road-stream crossings on aquatic organism passage in southern streams. Future inventories in the Region will expand the baseline data necessary to meet legislative provisions, prioritize crossings for replacements, and compete for remediation funds.

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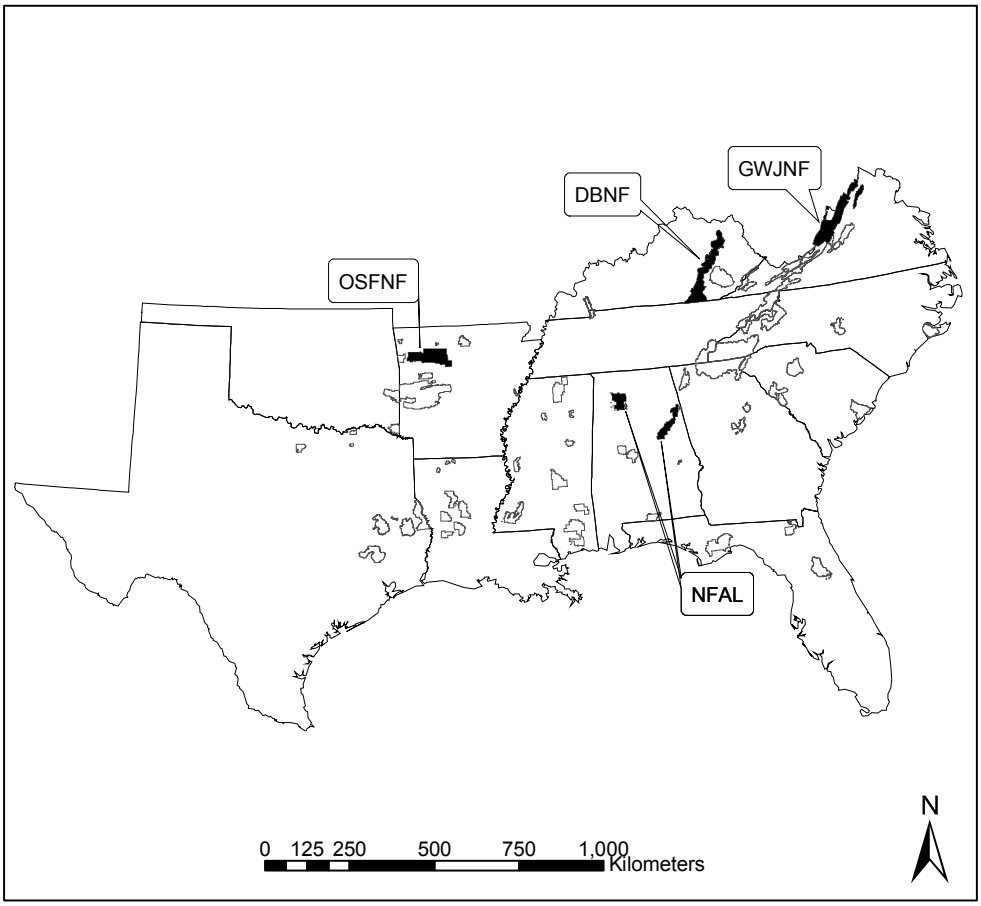

Figure 1. National Forests managed lands in the Southern Region. Crossing assessments were conducted during summer 2005 in areas shaded black. GWJNF= George Washington-Jefferson National Forest, DBNF= Daniel Boone National Forest, OSFNF= Ozark-St. Francis National Forest, NFAL= National Forests in Alabama (Bankhead NF, western; Talladega NF, eastern).

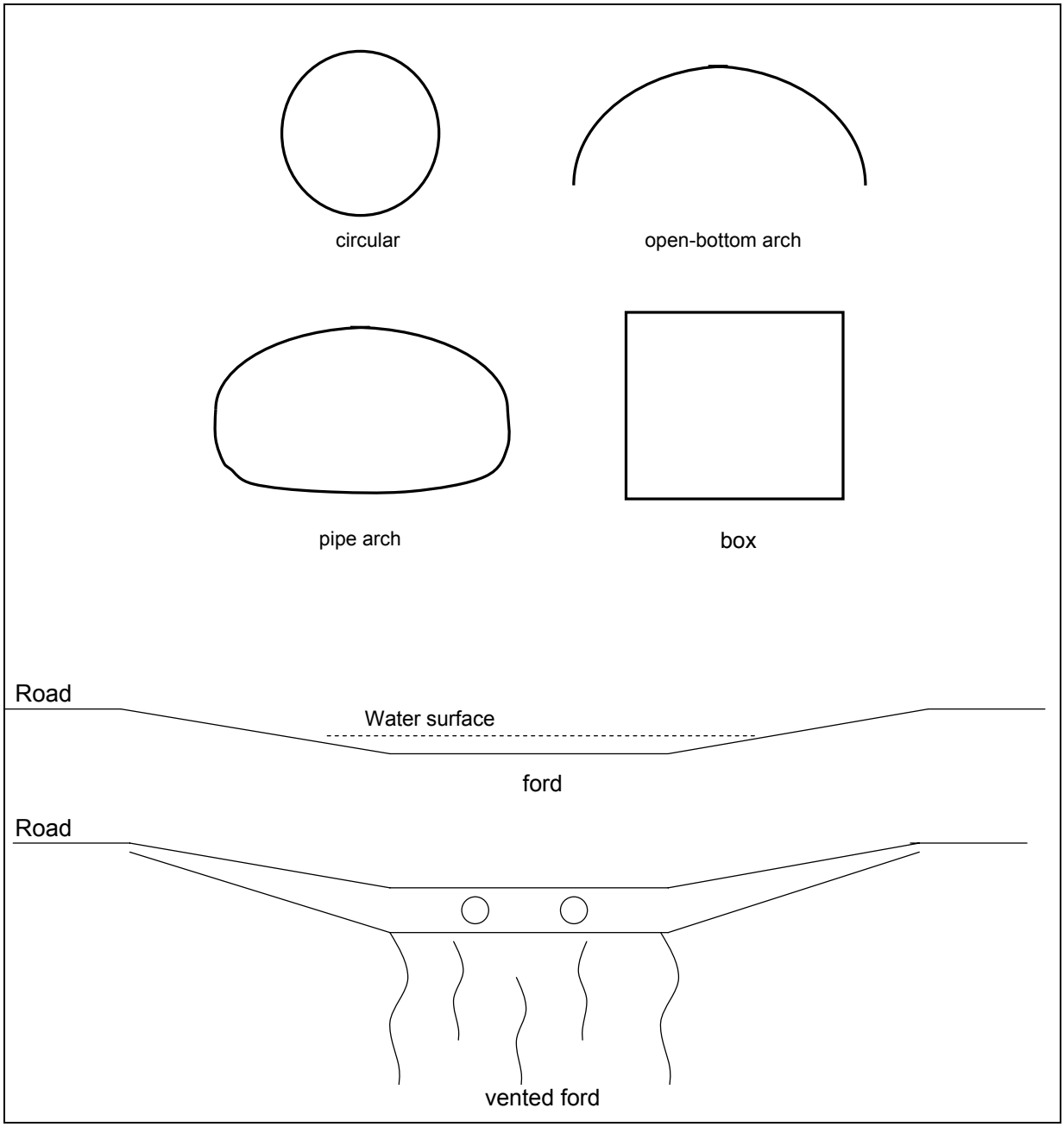

Figure 2. Common crossing shapes encountered during road-stream crossing inventories conducted in the Southern Region, summer 2005.

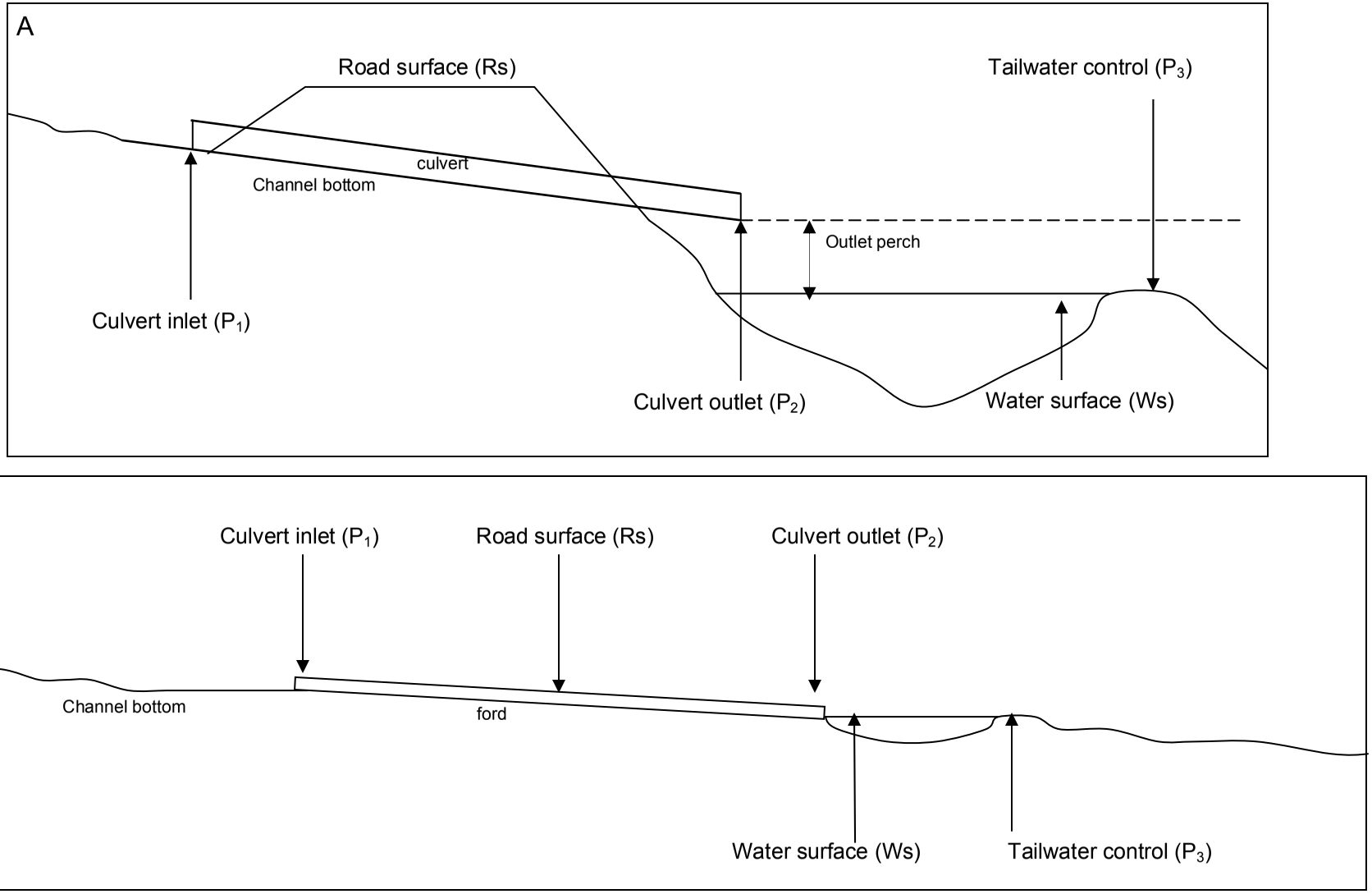

Figure 3. Survey points measured on culverts (A) and unvented fords (B) to calculate parameters used in coarse filters for upstream fish passage Adapted from Clarkin et al. 2003. Parameters are calculated as follows: Residual Inlet depth= $P_3 - P_1$, Outlet drop= $P_2 - P_3$, Outlet perch= $P_2 -$ Ws, Slope= $(P_{1elev} - P_{2elev}) / (P_{1dist} - P_{2dist}) * 100$, Slope x Length= $[(P_{1elev} - P_{2elev}) / (P_{1dist} - P_{2dist}) * 100] * (P_{1dist} - P_{2dist})$.

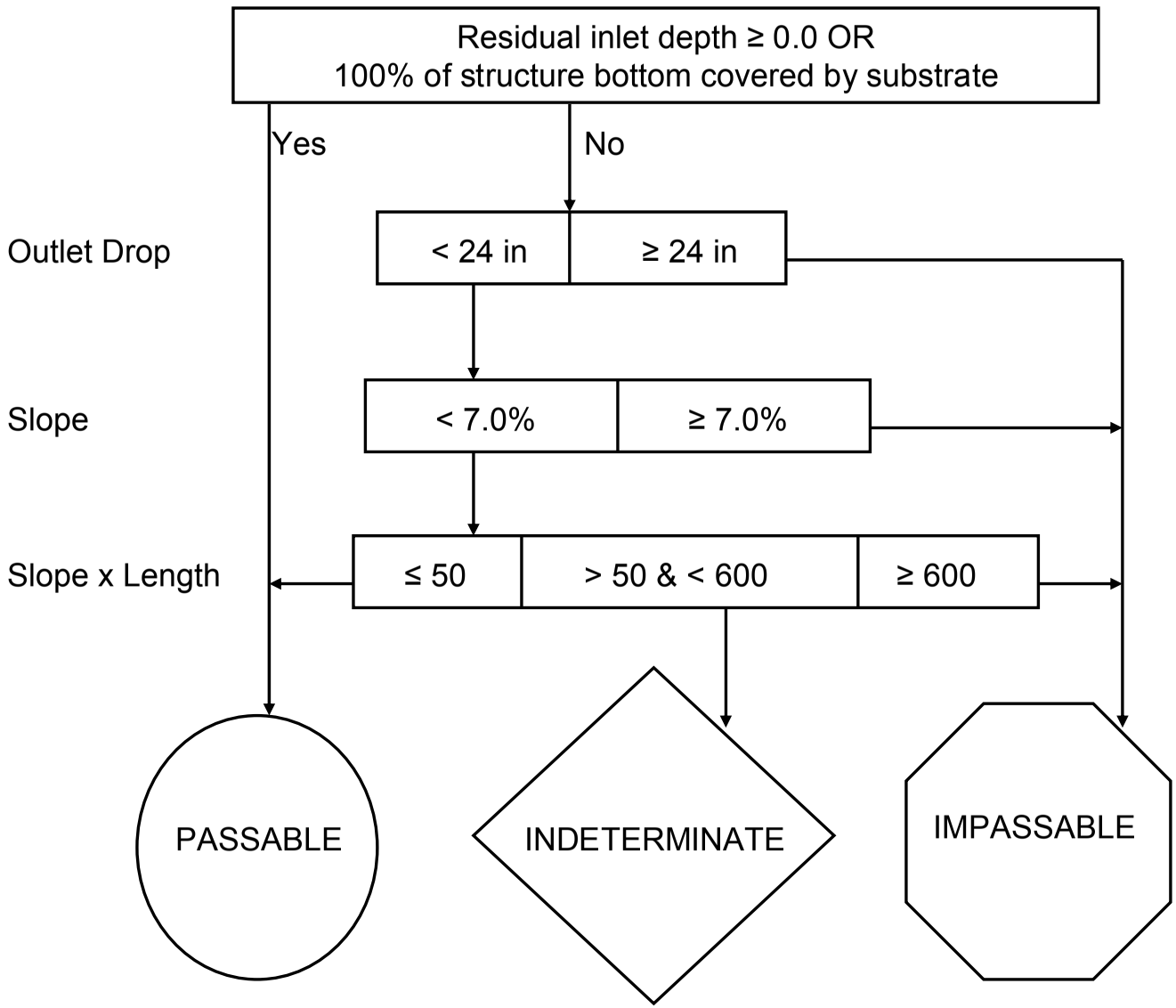

Figure 4. Coarse Filter A: Predictive model used to determine upstream passage for fish with swimming and leaping abilities similar to adult trout. A residual inlet depth ≥ 0.0 (Figure 2) indicates structure is fully backwatered. An outlet perch of 14 in. was used when outlet drop could not be calculated (Coffman 2005).

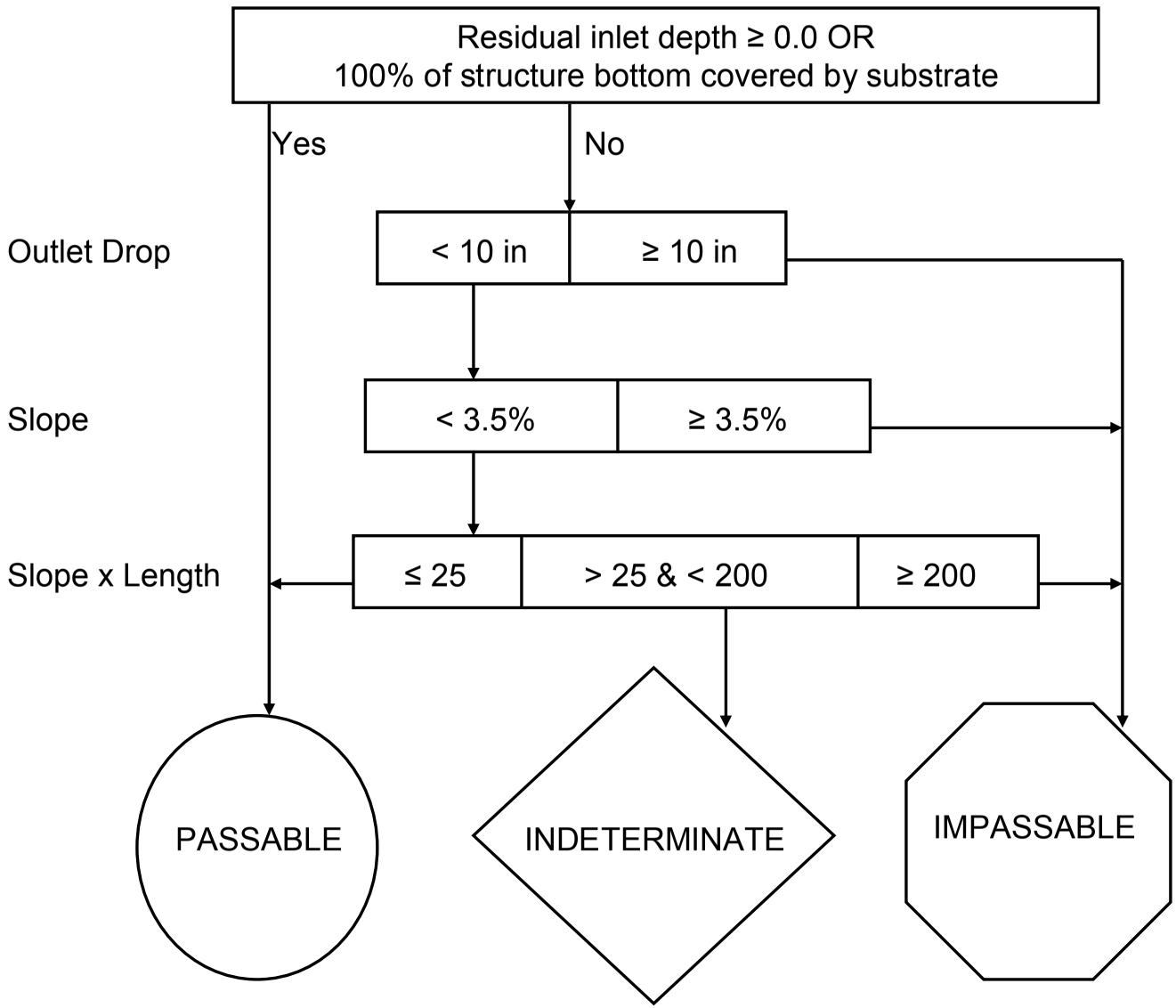

Figure 5. Coarse Filter B: Predictive model used to determine upstream passage for fish with swimming and leaping abilities similar to minnows and juvenile trout. A residual inlet depth ≥ 0.0 (Figure 2) indicates pipe is fully backwatered. An outlet perch of 5 in. was used when outlet drop could not be calculated (Coffman 2005).

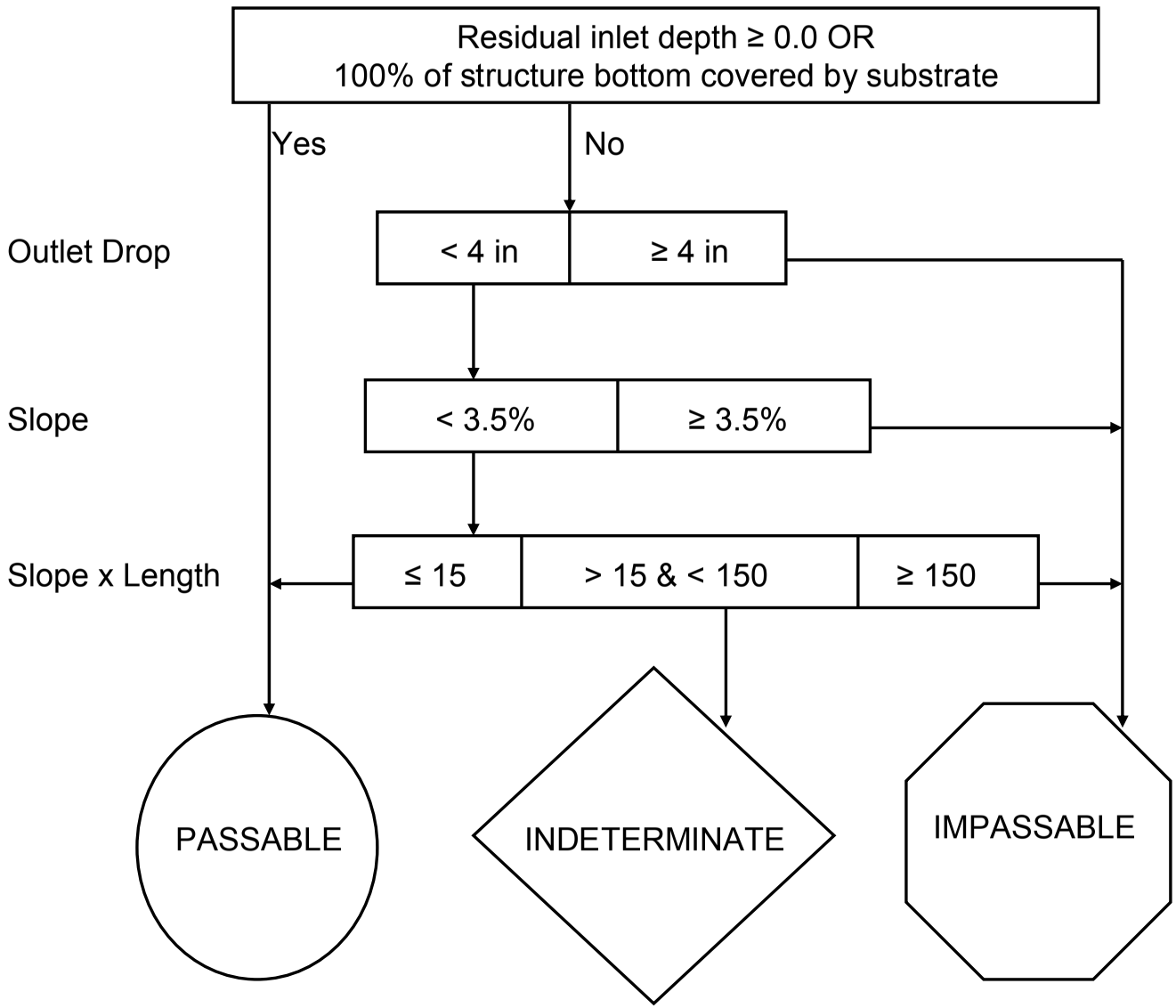

Figure 6. Coarse Filter C: Predictive model used to determine upstream passage for fish with swimming and leaping abilities similar to darters and sculpins. A residual inlet depth ≥ 0.0 (Figure 2) indicates pipe is fully backwatered. An outlet perch of 2 in. was used when outlet drop could not be calculated (Coffman 2005).

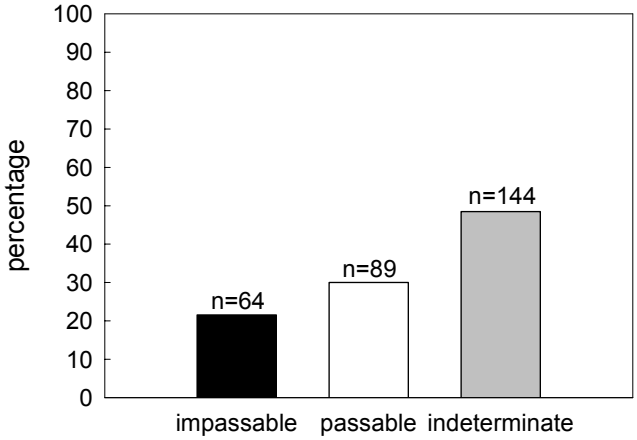

Figure 7. Percentage of crossings classified as impassable, passable, or indeterminate by Filter A; Southern Region (all Forests combined), summer 2005 (N=297).

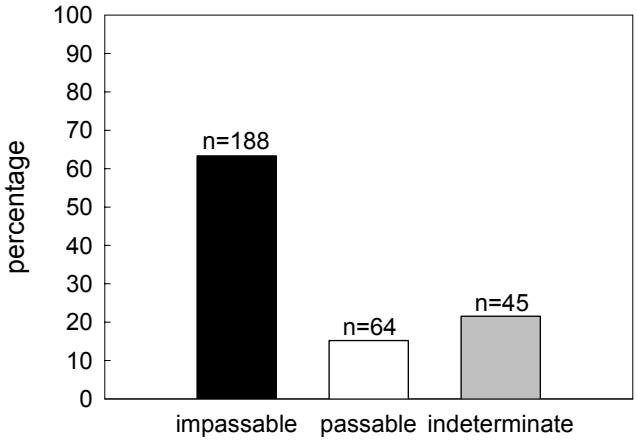

Figure 8. Percentage of crossings classified as impassable, passable, or indeterminate by Filter B; Southern Region (all Forests combined), summer 2005 (N=297).

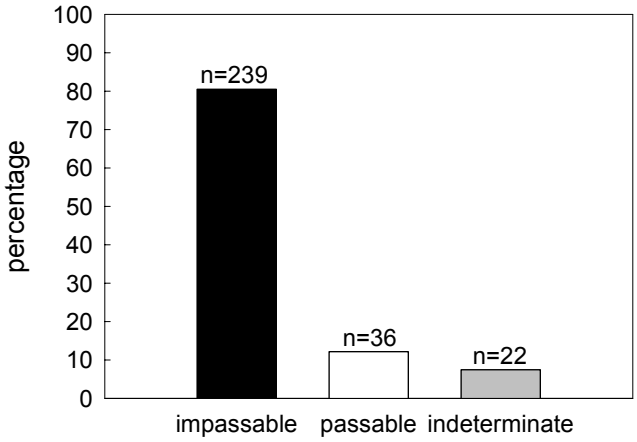

Figure 9. Percentage of crossings classified as impassable, passable, or indeterminate by Filter C; Southern Region (all Forests combined), summer 2005 (N=297).

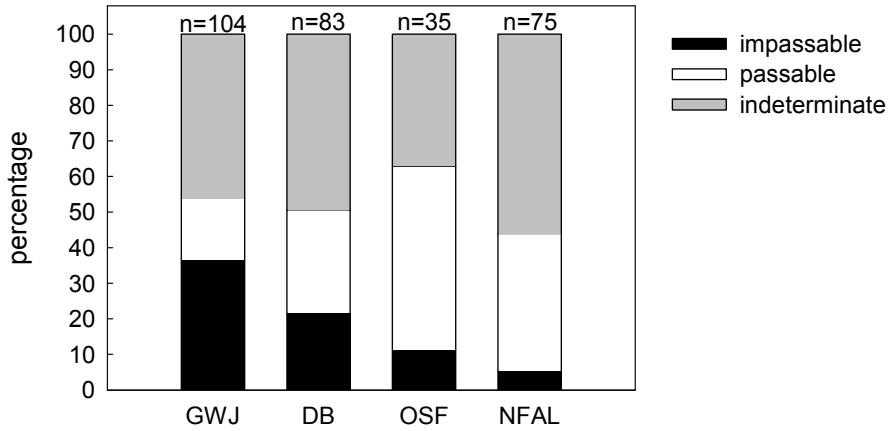

Figure 10. Percentage of crossings classified as impassable, passable, or indeterminate by Filter A; Southern Region (by Forest) summer 2005. GWJ=George Washington-Jefferson, DB=Daniel Boone, OSF=Ozark-St. Francis, and NFAL=National Forests in Alabama.

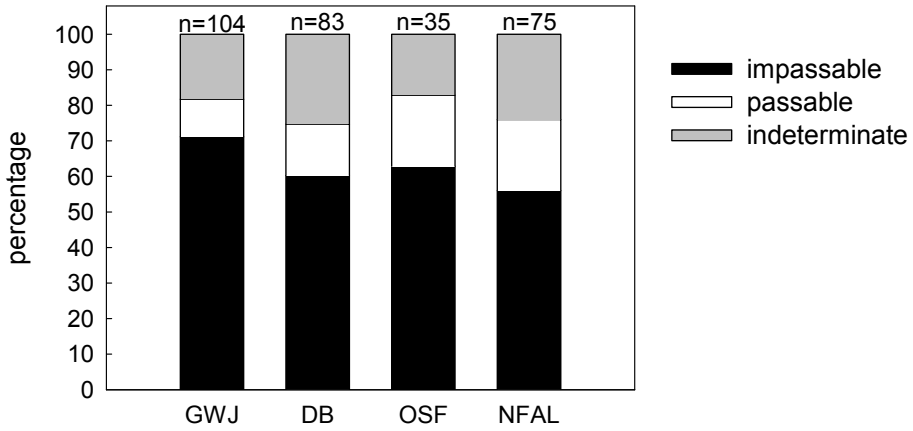

Figure 11. Percentage of crossings classified as impassable, passable, or indeterminate by Filter B; Southern Region (by Forest) summer 2005. GWJ=George Washington-Jefferson, DB=Daniel Boone, OSF=Ozark-St. Francis, and NFAL=National Forests in Alabama.

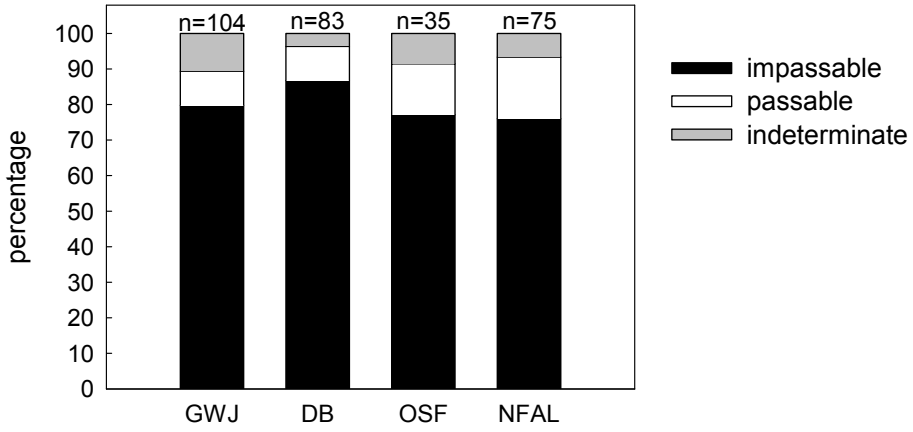

Figure 12. Percentage of crossings classified as impassable, passable, or indeterminate by Filter C; Southern Region (by Forest) summer 2005. GWJ=George Washington/ Jefferson, DB=Daniel Boone, OSF=Ozark/ St. Francis, and NFAL=National Forests in Alabama.

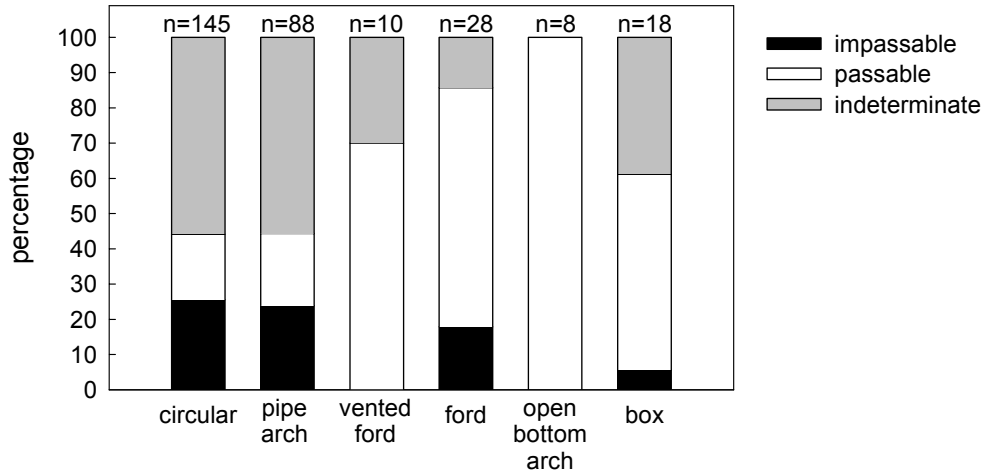

Figure 13. Percentage of each crossing type classified as impassable, passable, or indeterminate by Filter A; Southern Region (all Forests combined) summer 2005.

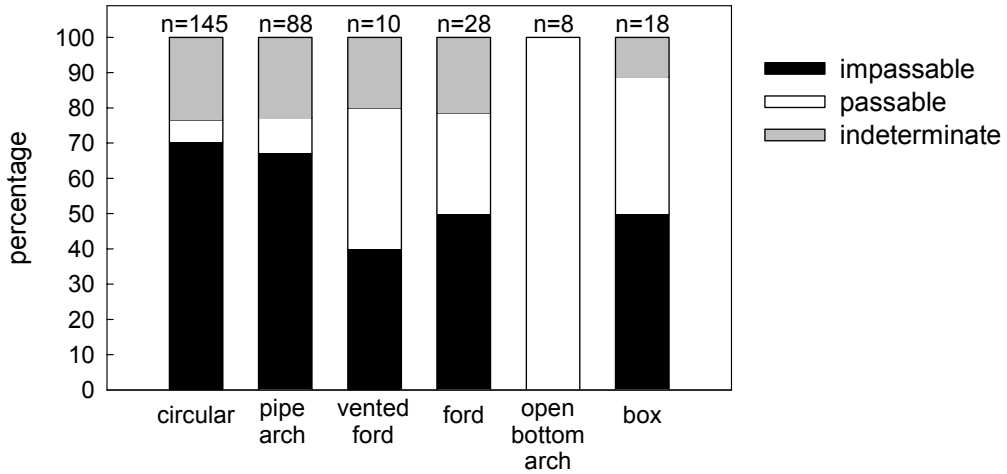

Figure 14. Percentage of each crossing type classified as impassable, passable, or indeterminate by Filter B; Southern Region (all Forests combined) summer 2005.

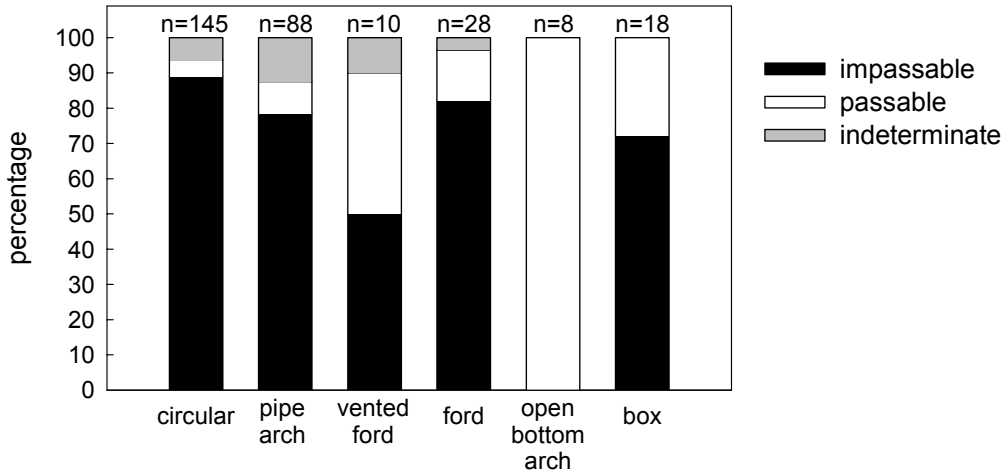

Figure 15. Percentage of each crossing type classified as impassable, passable, or indeterminate by Filter C; Southern Region (all Forests combined) summer 2005.

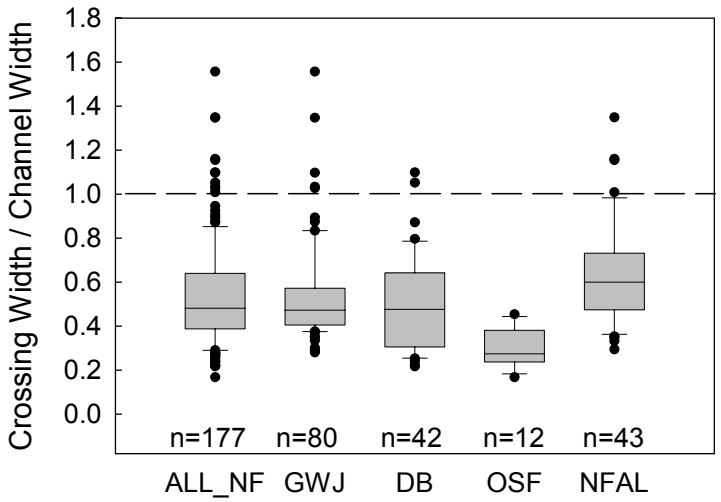

Figure 16. Crossing width to bankfull channel width ratio for crossings surveyed in summer 2005 (excluding fords, vented fords, and multiple structure crossings). A ratio of 1.0 (dashed line) or greater indicates the crossing structure opening is greater than or equal to the bankfull channel width. ALL_NF=Forests combined, GWJ=George Washington-Jefferson, DB=Daniel Boone, OSF=Ozark-St. Francis, and NFAL=National Forests in Alabama. The top and bottom of the boxes represent the 25th and 75th percentiles, the bar in the center of each box represents the median, whiskers represent the 10th and 90th percentiles, and closed circles represent the entire range of the data.

Table 1. Number of crossings documented (Total crossings documented) and number not surveyed (Crossings not surveyed) on Forests visited in summer 2005. Reasons for not surveying a documented site include: no suitable fish habitat upstream of crossing (NH); no access to site due to closed roads or private gates (NA); crossing was a natural ford (NF); crossing was a bridge (BR).

Forest	Total crossing documented	Crossing not surveyed (n, [%])				
		NH	NA	NF	BR	Total not surveyed
GWJNF	258	80 (52)	51 (33)	23 (15)	0 (0)	154 (60)
DBNF	206	28 (23)	61 (50)	21 (17)	13 (10)	123 (60)
OSFNF	724	85 (12)	396 (57)	191 (28)	17 (3)	689 (95)
NFAL	149	17 (23)	35 (47)	6 (8)	16 (22)	74 (50)
Total	1337	210 (20)	543 (52)	241 (23)	46 (4)	1040 (78)

Table 2. Number of crossings surveyed (Total surveyed) with coarse filter results for Forests visited in summer 2005. Coarse filter results are presented for Filter A, Filter B, and Filter C (see filter descriptions, Fig 3 – 5).

Forest	Total surveyed	Coarse filter results								
		Impassable (n, [%])			Passable (n, [%])			Indeterminate (n, [%])		
		A	B	C	A	B	C	A	B	C
GWJNF	104	38 (37)	74 (71)	83 (80)	18 (17)	11 (11)	10 (9)	48 (46)	19 (18)	11 (11)
DBNF	83	18 (22)	50 (60)	72 (87)	24 (29)	12 (14)	8 (10)	41 (49)	21 (25)	3 (4)
OSFNF	35	4 (11)	22 (63)	27 (77)	18 (51)	7 (20)	5 (14)	13 (37)	6 (17)	3 (9)
NFAL	75	4 (5)	42 (56)	57 (76)	29 (39)	15 (20)	13 (17)	42 (56)	18 (24)	5 (7)
Total	297	64 (22)	188 (63)	239 (81)	89 (30)	45 (15)	36 (12)	144 (49)	64 (22)	22 (7)

Table 3. Number of crossings (percentage in parentheses) classified as impassable due to excessive outlet drop, excessive slope, or excessive slope x length values for each coarse filter; Southern Region (all Forests combined), summer 2005.

	Filter A	Filter B	Filter C
Outlet drop	39 (61)	139 (74)	203 (85)
Slope	24 (37)	47 (25)	33 (14)
Slope*Length	1 (2)	2 (1)	3 (1)
Total	64 (22)	188 (63)	239 (81)

Table 4. Number of each crossing type (percentage in parentheses) classified as impassable, passable, or indeterminate for each coarse filter; Southern Region (all Forests combined) during summer 2005.

Classification	crossing type	Filter A	Filter B	Filter C
Impassable	circular	37 (25)	102 (70)	129 (89)
	pipe arch	21 (24)	59 (67)	69 (78)
	vented ford	0 (0)	4 (40)	5 (50)
	ford	5 (18)	14 (50)	23 (82)
	open bottom arch	0 (0)	0 (0)	0 (0)
	box	1 (6)	9 (50)	13 (72)
Passable	circular	27 (19)	9 (6)	7 (5)
	pipe arch	18 (20)	9 (10)	8 (9)
	vented ford	7 (70)	4 (40)	4 (40)
	ford	19 (68)	8 (29)	4 (14)
	open bottom arch	8 (100)	8 (100)	8 (100)
	box	10 (55)	7 (39)	5 (28)
Indeterminate	circular	81 (56)	34 (24)	9 (6)
	pipe arch	49 (56)	20 (23)	11 (13)
	vented ford	3 (30)	2 (20)	1 (10)
	ford	4 (14)	6 (21)	1 (4)
	open bottom arch	0 (0)	0 (0)	0 (0)
	box	7 (39)	2 (11)	0 (0)

Appendix A: Results for the George Washington-Jefferson National Forest

We visited 258 crossings on the Deerfield, Warm Springs, James River, and New River Valley Ranger Districts in 2005 (Figure A1, Table A1) and completed surveys on 40% (n=104) (Table A2). Filter A (strong swimmers and leapers) classified 37% (n=38) of crossings as impassable, 17% (n=18) as passable, and 46% (n=48) as indeterminate (Figure A2, Table A2). Filter B (moderate swimmers and leapers) classified 71% (n=74) of crossings as impassable, 11% (n=11) as passable, and 18% (n=19) as indeterminate (Figure A3, Table A2). Filter C (weak swimmers and leapers) classified 80% (n=83) of crossings as impassable, 9% (n=10) as passable, and 11% (n=11) as indeterminate (Figure A4, Table A2). Characteristics and filter classifications for each crossing are presented in Tables A3-A5.

The majority of the crossings surveyed were either circular culverts (n=46) or pipe arches (n=52), while open bottom arches (n=5), fords (n=1), vented fords (n=0), and box culverts (n=0) were less frequently encountered. Filter A classified 39% of circular culverts and 38% of pipe arch crossings as impassable (Figure A5). Filter B classified 80% of circular culverts and 71% of pipe arch crossings as impassable (Figure A6). Filter C classified 91% of circular culverts and 79% of pipe arch crossings as impassable (Figure A7). The 5 open bottom arches and 1 ford surveyed were passable for all 3 filters. The mean crossing width to channel width ratio for surveyed structures (excluding fords and multiple structure crossings) (n=80) was 0.54 (SD=0.22), and five crossings were greater than or equal to the mean bankfull channel width, three of which were open bottom arches (Figure A8).

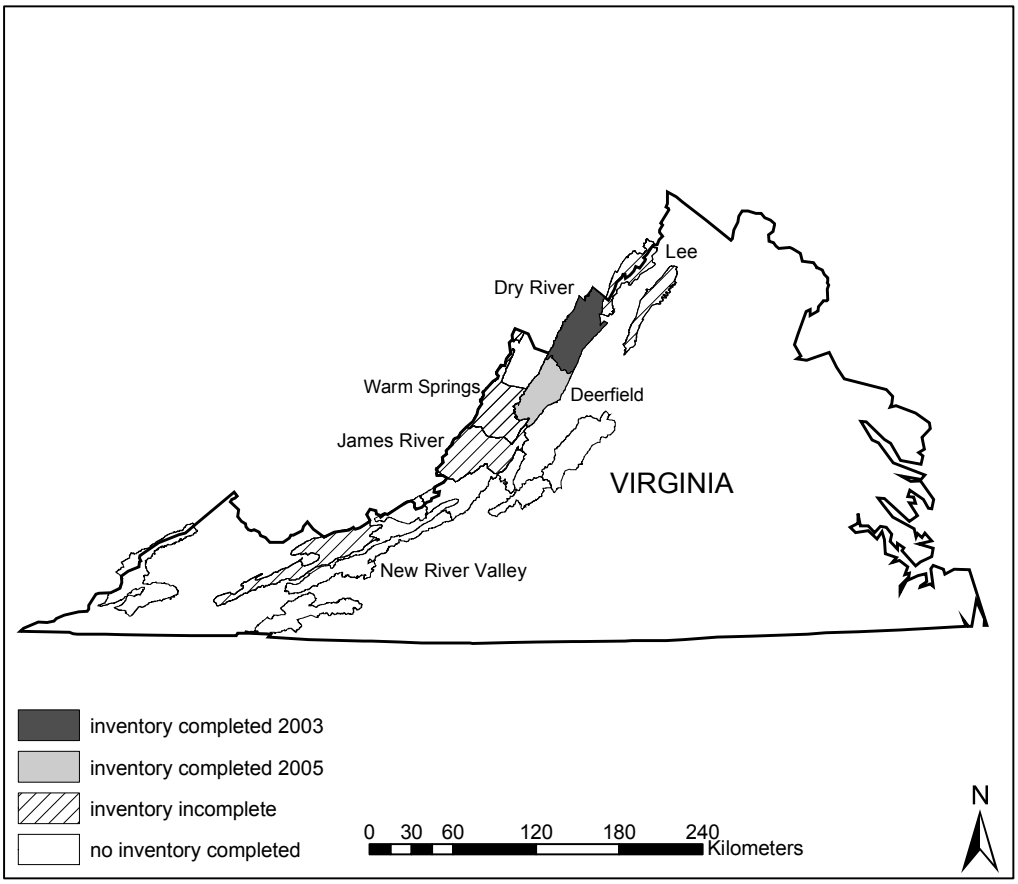

Figure A1. Ranger Districts on the George Washington-Jefferson National Forest road-stream crossing surveys were conducted. Results of inventories conducted by Fish and Aquatic Ecology Unit - East on Dry River and Lee Ranger Districts in 2003 presented in a separate report.

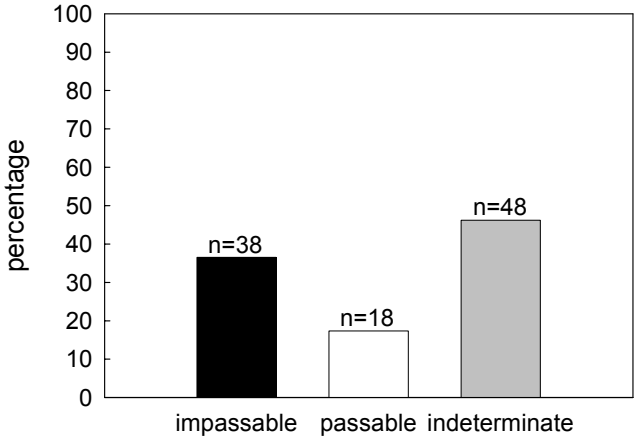

Figure A2. Percentage of crossings classified as impassable, passable, or indeterminate by Filter A; George Washington-Jefferson National Forest, summer 2005 (n=104).

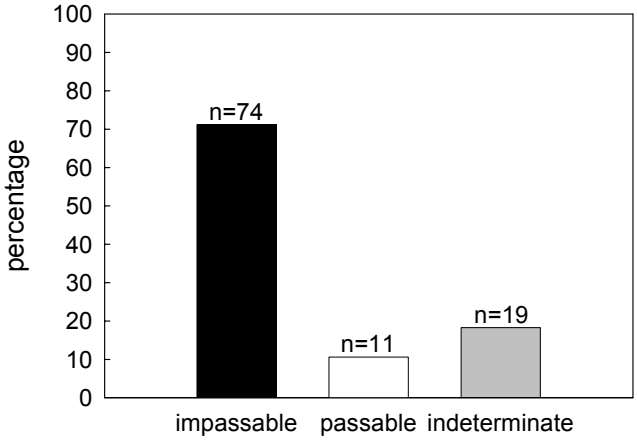

Figure A3. Percentage of crossings classified as impassable, passable, or indeterminate by Filter B; George Washington-Jefferson National Forest, summer 2005 (n=104).

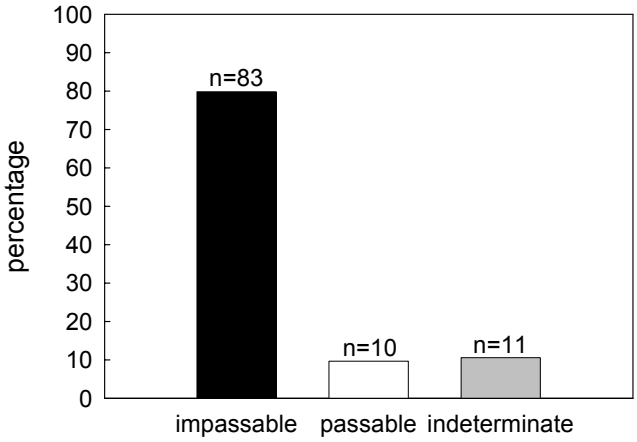

Figure A4. Percentage of crossings classified as impassable, passable, or indeterminate by Filter C; George Washington-Jefferson National Forest, summer 2005 (n=104).

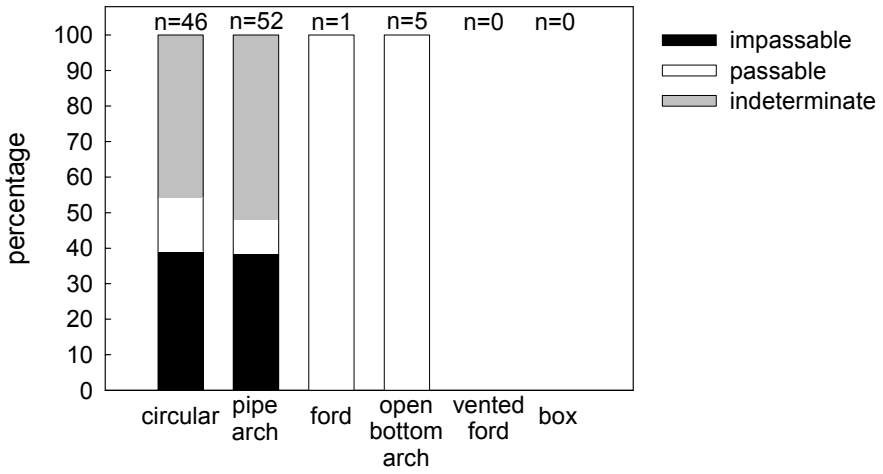

Figure A5. Percentage of each crossing type classified as impassable, passable, or indeterminate by Filter A; George Washington-Jefferson National Forest, summer 2005 (N=104).

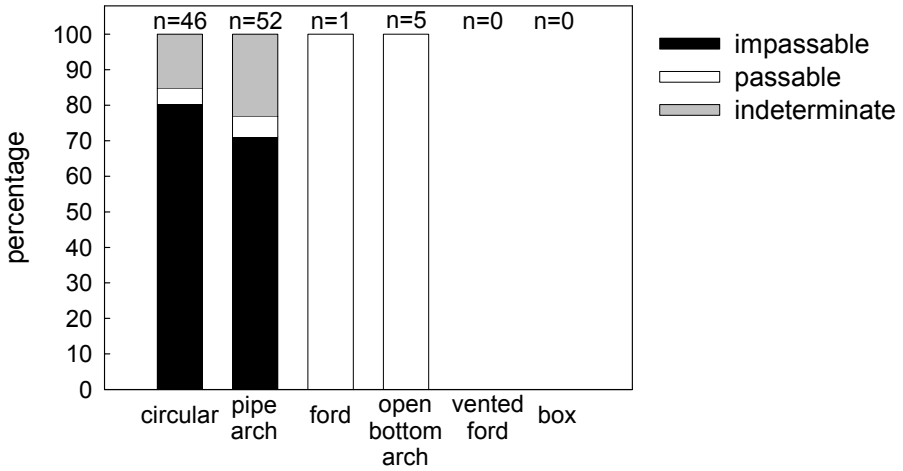

Figure A6. Percentage of each crossing type classified as impassable, passable, or indeterminate by Filter B; George Washington-Jefferson National Forest, summer 2005 (N=104).

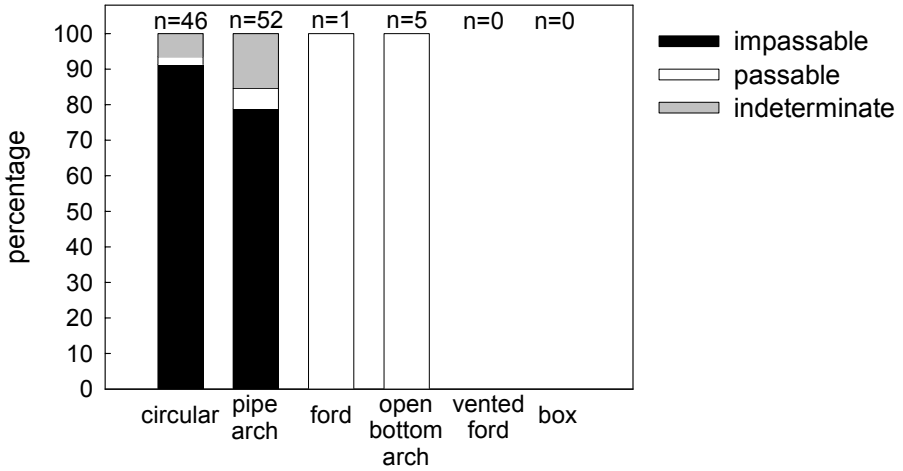

Figure A7. Percentage of each crossing type classified as impassable, passable, or indeterminate by Filter C; George Washington-Jefferson National Forest, summer 2005 (N=104).

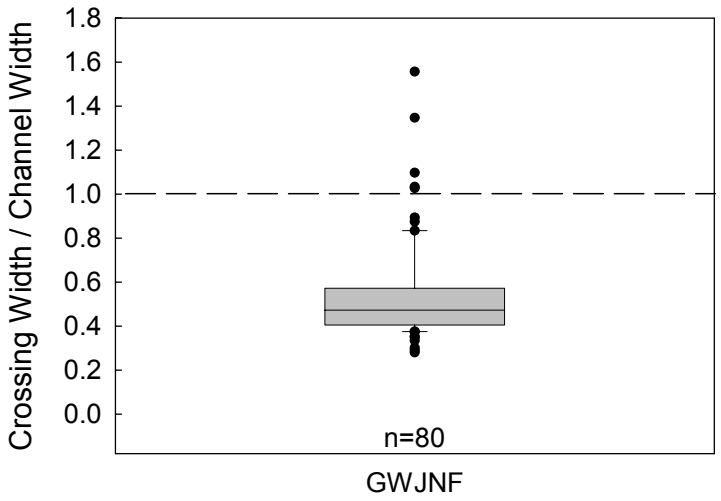

Figure A8. Crossing width to bankfull channel width ratio for crossings surveyed in summer 2005 on the George Washington-Jefferson National Forest (excluding fords, vented fords, and multiple structure crossings). A ratio of 1.0 (dashed line) or greater indicates the crossing structure opening is greater than or equal to the bankfull channel width. The top and bottom of the boxes represent the 25th and 75th percentiles, the bar in the center of each box represents the median, whiskers represent the 10th and 90th percentiles, and closed circles represent the entire range of the data.

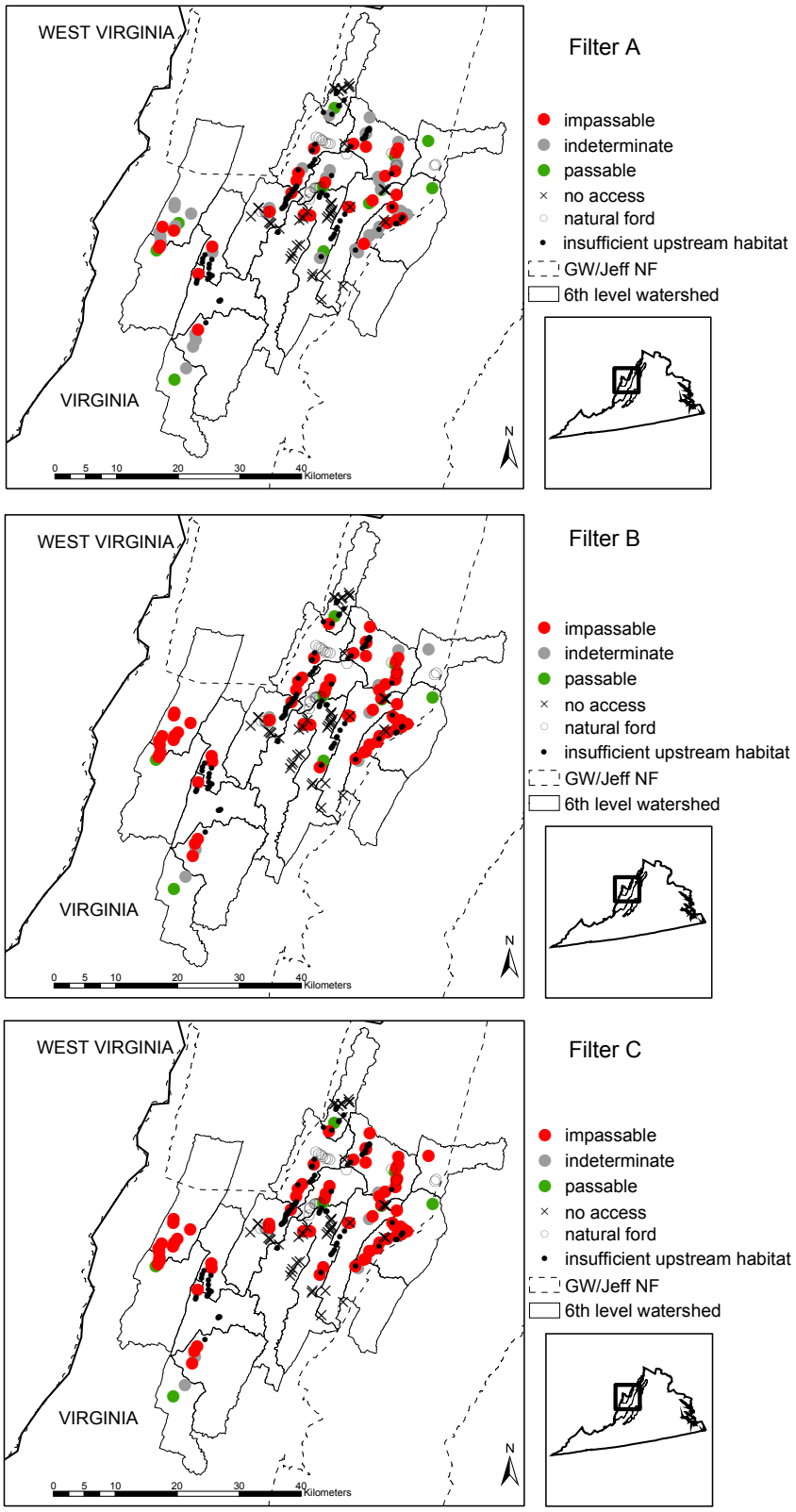

Figure A9. Location of crossings classified for fish passage by coarse filters A, B, and C within 6th level watersheds, and crossings not surveyed on the George Washington-Jefferson National Forest, summer 2005.

Table A1. Number of crossings documented (Total crossings documented) and not surveyed (crossings not surveyed) on the GWJNF in summer 2005. Reasons for not surveying a documented site include: no suitable fish habitat upstream of crossing (NH); no access to site due to closed roads or private gates (NA); crossing was a natural ford (NF); crossing was a bridge (BR).

Forest	Total crossing documented	Crossings not surveyed (n, [%])				
		NH	NA	NF	BR	Total not surveyed
GWJNF	258	80 (52)	51 (33)	23 (15)	0 (0)	154 (60)

Table A2. Number of crossings surveyed (Total surveyed) with coarse filter results for the GWJNF in summer 2005. Coarse filter results are presented for Filter A, Filter B, and Filter C (see filter descriptions, Fig 3 – 5).

Forest	Total surveyed	Coarse filter results								
		Impassable (n, [%])			Passable (n, [%])			Indeterminate (n, [%])		
		A	B	C	A	B	C	A	B	C
GWJNF	104	38 (37)	74 (71)	83 (80)	18 (17)	11 (11)	10 (10)	48 (46)	19 (18)	10 (11)

Table A3. Location of crossings surveyed on the George Washington-Jefferson National Forest during the summer of 2005. Site ID consists of the Forest abbreviation (GWJ), road the crossing is on (1576), and the distance (miles) from the junction road (0.4).

Site ID	Pipe #	District	Junction Road	Stream Name	Quad	6th Level Watershed
GWJ1576-0.4	1	Deerfield	61	Clayton Mill Spring Creek	Deerfield	020802020105
GWJ255-0.9	1	Deerfield	173	Holloway Draft	Deerfield	020802020103
GWJ255-0.9	2	Deerfield	173	Holloway Draft	Deerfield	020802020103
GWJ255-4.5	1	Deerfield	629	Rock lick	Deerfield	020802020103
GWJ255-4.6	1	Deerfield	629	Rock lick	Deerfield	020802020103
GWJ255-4.6	2	Deerfield	629	Rock lick	Deerfield	020802020103
GWJ381-0.1	1	Deerfield	82	Fridley Branch	Elliot Knob	020802020105
GWJ381-0.1	2	Deerfield	82	Fridley Branch	Elliot Knob	020802020105
GWJ381-3.6	1	Deerfield	82	Scott Hollow	Deerfield	020802020105
GWJ381-4.65	1	Deerfield	82	UT Kiser Hollow	Deerfield	020802020105
GWJ382-1.2	1	Deerfield	82	Archer Run	Augusta Springs	020802020201
GWJ382-2.3	1	Deerfield	82	Gum Lick Hollow	Augusta Springs	020802020201
GWJ382-4.3	1	Deerfield	82	Kennedy Draft	Augusta Springs	020802020201
GWJ382-5.5	1	Deerfield	82	Taylor Hollow	Craigsville	020802020201
GWJ382-6.5	1	Deerfield	82	Staples Hollow	Craigsville	020802020201
GWJ382-7.1	1	Deerfield	82	Stouples Hollow	Craigsville	020802020201
GWJ382-7.15	1	Deerfield	82	Stouples Hollow	Craigsville	020802020201
GWJ382-9.6	1	Deerfield	82	Wallace Draft	Craigsville	020802020201
GWJ382-9.9	1	Deerfield	82	Wallace Draft	Craigsville	020802020201
GWJ383h-.001	1	Deerfield	42	Fall Branch	Elliot Knob	020802020201
GWJ383h-.001	2	Deerfield	42	Fall Branch	Elliot Knob	020802020201
GWJ387-0.05	1	Deerfield	61	Little Mill Creek	Green Valley	020802020106
GWJ393-0.2	1	Deerfield	173	Left Fork Halloway Draft	Deerfield	020802020103
GWJ394-0.39	1	Deerfield	627	Rail Hollow	Williamsville	020802010701
GWJ394-0.4	1	Deerfield	627	Rail Hollow	Williamsville	020802010701

Table continued next page…

Site ID	Pipe #	District	Junction Road	Stream Name	Quad	6th Level Watershed
GWJ394-0.8	1	Deerfield	627	Rail Hollow	Williamsville	020802010701
GWJ394-10.7	1	Deerfield	627	Wide Hollow	Williamsville	020802010603
GWJ394-10.71	1	Deerfield	627	Wide Hollow	Williamsville	020802010603
GWJ394-12.1	1	Deerfield	627	Brushy Fork	Williamsville	020802010603
GWJ394-6.9	1	Deerfield	627	Marshall Draft	Williamsville	020802010701
GWJ394-9.4	1	Deerfield	627	Hulit Draft	Williamsville	020802010603
GWJ394b-0.8	1	Deerfield	394	House Run	Deerfield	020802010603
GWJ394y-0.01	1	Deerfield	394	Rail Hollow	Williamsville	020802010701
GWJ394z-.01	1	Deerfield	394	Rail Hollow	Williamsville	020802010701
GWJ395-1.3	1	Deerfield	616	Clover Lick Hollow	McDowell	020802010602
GWJ395-3.5	1	Deerfield	616	Jerry's Hollow	McDowell	020802010602
GWJ399-1.0	1	Deerfield	600	Jerkemtite Branch	Deerfield	020802020104
GWJ399b-0.8	1	Deerfield	399	Tom Lee Draft	Deerfield	020802020104
GWJ399b-1.6	1	Deerfield	399	Frames Draft	Deerfield	020802020104
GWJ399b-3.9	1	Deerfield	399	Stoney Lick	Deerfield	020802020104
GWJ433-1.3	1	Deerfield	629	Buck Lick Run	Williamsville	020802010704
GWJ433-2.35	1	Deerfield	629	Buck Lick Run	Williamsville	020802010704
GWJ433-2.4	1	Deerfield	629	Rock Lick Run	Williamsville	020802010704
GWJ61-0.8	1	Deerfield	600	Clayton Mill Spring Creek	Deerfield	020802020105
GWJ61-6.3	1	Deerfield	600	Little Mill Creek	Green Valley	020802020106
GWJ61-6.3	2	Deerfield	600	Little Mill Creek	Green Valley	020802020106
GWJ627-4.4	1	Deerfield	629	Scotchtown Draft	Williamsville	020802010701
GWJ687-0.09	1	Deerfield	1133	Ramsey Draft	Craigsville	020802020202
GWJ687-0.5	1	Deerfield	382	Ramsey Draft	Craigsville	020802020202
GWJ688-2.2	1	Deerfield	42	East Dry Branch	Elliot Knob	020700050102
GWJ688-2.2	2	Deerfield	42	East Dry Branch	Elliot Knob	020700050102
GWJ688-2.2	3	Deerfield	42	East Dry Branch	Elliot Knob	020700050102
GWJ77-0.25	1	Deerfield	688	West Dry Branch	Elliot Knob	020802020103

Table continued next page…

Site ID	Pipe #	District	Junction Road	Stream Name	Quad	6th Level Watershed
GWJ77-1.0	1	Deerfield	688	Laurel Branch	Elliot Knob	020802020103
GWJ77-1.65	1	Deerfield	688	White Rock Branch	Elliot Knob	020802020103
GWJ77-1.65	2	Deerfield	688	White Rock Branch	Elliot Knob	020802020103
GWJ77-1.9	1	Deerfield	688	S Fork White Rock Branch	Elliot Knob	020802020103
GWJ77-2.9	1	Deerfield	688	Steel Lick Draft	Elliot Knob	020802020103
GWJ77-2.9	2	Deerfield	688	Steel Lick Draft	Elliot Knob	020802020103
GWJ77-3.2	1	Deerfield	688	Charlie Lick Branch	Elliot Knob	020802020103
GWJ77-3.8	1	Deerfield	688	Still Run	Elliot Knob	020802020103
GWJ77-5.6	1	Deerfield	688	UT Daddy Run	Elliot Knob	020802020103
GWJ77-6.2	1	Deerfield	688	Staples Run	Deerfield	020802020103
GWJ77-6.8	1	Deerfield	688	Corbett Branch	Deerfield	020802020103
GWJ81-2.4	1	Deerfield	688	Hodges Draft	McDowell	020802020103
GWJ82-0.1	1	Deerfield	382	Hite Hollow	Augusta Springs	020802020201
GWJ82-0.5	1	Deerfield	382	Hite Hollow	Augusta Springs	020802020201
GWJ82-1.0	1	Deerfield	382	Hite Hollow	Augusta Springs	020802020201
GWJ82-1.6	1	Deerfield	382	Hite Hollow	Augusta Springs	020802020201
GWJ82-1.9	1	Deerfield	382	Hite Hollow	Augusta Springs	020802020201
GWJ82-5.39	1	Deerfield	382	Fridleys Branch	Elliot Knob	020802020105
GWJ82-7.5	1	Deerfield	382	Fridleys Branch	Deerfield	020802020105
GWJ125-6.95	1	Warm Springs	606	Smith Creek	Healing Springs	020802010506
GWJ125-9.1	1	Warm Springs	606	Left Prong Wilson Creek	Healing Springs	020802010506
GWJ1747-0.02	1	Warm Springs	220	Rocky Run	Burnsville	020802010102
GWJ194-4.8	1	Warm Springs	629	Stouts Creek	Healing Springs	020802010801
GWJ194-5.6	1	Warm Springs	629	Stouts Creek	Healing Springs	020802010801
GWJ194-6.7	1	Warm Springs	629	Wilson Creek	Healing Springs	020802010801
GWJ194-6.7	2	Warm Springs	629	Wilson Creek	Healing Springs	020802010801
GWJ194-7.6	1	Warm Springs	629	Porter's Mill Creek	Healing Springs	020802010801
GWJ241-10.0	1	Warm Springs	621	Ned Hollow	Sunrise	020802010102

Table continued next page…

Site ID	Pipe #	District	Junction Road	Stream Name	Quad	6th Level Watershed
GWJ241-3.6	1	Warm Springs	621	Limeklin Run	Warm Springs	020802010103
GWJ241-3.9	1	Warm Springs	621	UT Limekiln Run	Sunrise	020802010103
GWJ241-4.0	1	Warm Springs	621	UT Limekiln Run	Sunrise	020802010103
GWJ241-4.0	2	Warm Springs	621	UT Limekiln Run	Sunrise	020802010103
GWJ241-4.3	1	Warm Springs	621	UT Limekiln Run	Sunrise	020802010103
GWJ241-4.5	1	Warm Springs	621	Limeklin Run	Sunrise	020802010103
GWJ241-4.9	1	Warm Springs	621	Kelley Run	Sunrise	020802010102
GWJ241-6.0	1	Warm Springs	621	Kelley Run	Sunrise	020802010102
GWJ241-6.7	1	Warm Springs	621	Kelley Run	Sunrise	020802010102
GWJ241-9.0	1	Warm Springs	621	UT Jackson River	Sunrise	020802010102
GWJ241-9.3	1	Warm Springs	621	Birch Run	Sunrise	020802010102
GWJ241-9.6	1	Warm Springs	621	UT Jackson River	Sunrise	020802010102
GWJ358-1.3	1	Warm Springs	gate	Jordan Run	Bath Alum	020802010703
GWJ401-1.4	1	Warm Springs	623	Cave Run	Sunrise	020802010102
GWJ401-1.7	1	Warm Springs	623	Cave Run	Sunrise	020802010102
GWJ465-1.3	1	Warm Springs	609	Dry Run	Bath Alum	020802010702
GWJ465-2.3	1	Warm Springs	609	Cub Run	Bath Alum	020802010702
GWJ603trail	1	Warm Springs	621	Ned Hollow	Sunrise	020802010102
GWJ10570-2.6	1	NewRiver	734	Laurel Creek	Interior	050500020304
GWJ613-0.4	1	NewRiver	635	White Rock Branch	Interior	050500020305
GWJ613-0.4	2	NewRiver	635	White Rock Branch	Interior	050500020305
GWJ125-1.3	1	James River	625	Pounding Mill Creek	Covington	020802010504
GWJ587-0.4	1	James River	606	Smith Creek	Clifton Forge	020802010507

Table A4. Coarse filter A, B, and C, classifications for crossings surveyed on the George Washington-Jefferson National Forest, summer 2005.

Site ID	Pipe #	Filter A	Filter B	Filter C
GWJ1576-0.4	1	impassable	impassable	impassable
GWJ255-0.9	1	impassable	impassable	impassable
GWJ255-0.9	2	impassable	impassable	impassable
GWJ255-4.5	1	indeterminate	impassable	impassable
GWJ255-4.6	1	indeterminate	impassable	impassable
GWJ255-4.6	2	impassable	impassable	impassable
GWJ381-0.1	1	passable	indeterminate	indeterminate
GWJ381-0.1	2	passable	passable	passable
GWJ381-3.6	1	impassable	impassable	impassable
GWJ381-4.65	1	passable	indeterminate	indeterminate
GWJ382-1.2	1	impassable	impassable	impassable
GWJ382-2.3	1	impassable	impassable	impassable
GWJ382-4.3	1	impassable	impassable	impassable
GWJ382-5.5	1	indeterminate	impassable	impassable
GWJ382-6.5	1	indeterminate	impassable	impassable
GWJ382-7.1	1	indeterminate	impassable	impassable
GWJ382-7.15	1	indeterminate	impassable	impassable
GWJ382-9.6	1	indeterminate	impassable	impassable
GWJ382-9.9	1	impassable	impassable	impassable
GWJ383h-.001	1	indeterminate	indeterminate	indeterminate
GWJ383h-.001	2	passable	passable	passable
GWJ387-0.05	1	indeterminate	impassable	impassable
GWJ393-0.2	1	impassable	impassable	impassable
GWJ394-0.39	1	indeterminate	impassable	impassable
GWJ394-0.4	1	indeterminate	indeterminate	impassable
GWJ394-0.8	1	indeterminate	indeterminate	impassable
GWJ394-10.7	1	impassable	impassable	impassable
GWJ394-10.71	1	impassable	impassable	impassable
GWJ394-12.1	1	indeterminate	impassable	impassable
GWJ394-6.9	1	impassable	impassable	impassable
GWJ394-9.4	1	impassable	impassable	impassable
GWJ394b-0.8	1	impassable	impassable	impassable
GWJ394y-0.01	1	impassable	impassable	impassable
GWJ394z-.01	1	passable	passable	passable
GWJ395-1.3	1	indeterminate	impassable	impassable
GWJ395-3.5	1	passable	passable	passable
GWJ399-1.0	1	passable	passable	passable
GWJ399b-0.8	1	impassable	impassable	impassable
GWJ399b-1.6	1	indeterminate	impassable	impassable

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Site ID	Pipe #	Filter A	Filter B	Filter C
GWJ399b-3.9	1	indeterminate	impassable	impassable
GWJ433-1.3	1	impassable	impassable	impassable
GWJ433-2.35	1	impassable	impassable	impassable
GWJ433-2.4	1	indeterminate	impassable	impassable
GWJ61-0.8	1	impassable	impassable	impassable
GWJ61-6.3	1	passable	passable	impassable
GWJ61-6.3	2	passable	indeterminate	impassable
GWJ627-4.4	1	indeterminate	indeterminate	indeterminate
GWJ687-0.09	1	indeterminate	impassable	impassable
GWJ687-0.5	1	indeterminate	indeterminate	indeterminate
GWJ688-2.2	1	passable	impassable	impassable
GWJ688-2.2	2	indeterminate	indeterminate	impassable
GWJ688-2.2	3	passable	indeterminate	impassable
GWJ77-0.25	1	indeterminate	indeterminate	impassable
GWJ77-1.0	1	impassable	impassable	impassable
GWJ77-1.65	1	impassable	impassable	impassable
GWJ77-1.65	2	impassable	impassable	impassable
GWJ77-1.9	1	passable	passable	passable
GWJ77-2.9	1	indeterminate	impassable	impassable
GWJ77-2.9	2	indeterminate	impassable	impassable
GWJ77-3.2	1	indeterminate	indeterminate	impassable
GWJ77-3.8	1	impassable	impassable	impassable
GWJ77-5.6	1	impassable	impassable	impassable
GWJ77-6.2	1	indeterminate	indeterminate	indeterminate
GWJ77-6.8	1	indeterminate	impassable	impassable
GWJ81-2.4	1	indeterminate	impassable	impassable
GWJ82-0.1	1	indeterminate	impassable	impassable
GWJ82-0.5	1	indeterminate	impassable	impassable
GWJ82-1.0	1	indeterminate	impassable	impassable
GWJ82-1.6	1	indeterminate	impassable	impassable
GWJ82-1.9	1	impassable	impassable	impassable
GWJ82-5.39	1	impassable	impassable	impassable
GWJ82-7.5	1	indeterminate	impassable	impassable
GWJ125-6.95	1	passable	passable	passable
GWJ125-9.1	1	indeterminate	indeterminate	indeterminate
GWJ1747-.02	1	indeterminate	impassable	impassable
GWJ194-4.8	1	impassable	impassable	impassable
GWJ194-5.6	1	indeterminate	impassable	impassable
GWJ194-6.7	1	indeterminate	indeterminate	indeterminate
GWJ194-6.7	2	indeterminate	indeterminate	indeterminate
GWJ194-7.6	1	indeterminate	impassable	impassable

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Site ID	Pipe #	Filter A	Filter B	Filter C
GWJ241-10	1	passable	impassable	impassable
GWJ241-3.6	1	passable	passable	passable
GWJ241-3.9	1	impassable	impassable	impassable
GWJ241-4.0	1	impassable	impassable	impassable
GWJ241-4.0	2	impassable	impassable	impassable
GWJ241-4.3	1	indeterminate	impassable	impassable
GWJ241-4.5	1	indeterminate	indeterminate	impassable
GWJ241-4.9	1	indeterminate	impassable	impassable
GWJ241-6.0	1	indeterminate	impassable	impassable
GWJ241-6.7	1	impassable	impassable	impassable
GWJ241-9.0	1	impassable	impassable	impassable
GWJ241-9.3	1	indeterminate	indeterminate	indeterminate
GWJ241-9.6	1	indeterminate	impassable	impassable
GWJ358-1.3	1	impassable	impassable	impassable
GWJ401-1.4	1	indeterminate	impassable	impassable
GWJ401-1.7	1	indeterminate	impassable	impassable
GWJ465-1.3	1	impassable	impassable	impassable
GWJ465-2.3	1	indeterminate	impassable	impassable
GWJ603trail	1	passable	indeterminate	indeterminate
GWJ10570-2.6	1	impassable	impassable	impassable
GWJ613-0.4	1	impassable	impassable	impassable
GWJ613-0.4	2	impassable	impassable	impassable
GWJ125-1.3	1	passable	passable	passable
GWJ587-0.4	1	passable	passable	passable

Table A5. Description of crossings surveyed on the George Washington-Jefferson National Forest, summer 2005. Shape abbreviations: C= circular, PA= pipe arch, OBA= open bottom arch, and F= ford. Channel width is the mean bankfull channel width. N= no natural substrate, N (discontin)= discontinuous substrate, Y= continuous natural substrate. An NA (not applicable) indicates outlet drop (no outlet pool or tailwater control) or outlet perch (stream dry) could not be calculated. Negative outlet drop or perch values indicate a submerged outlet (structure partially backwatered). Residual inlet depth values ≥ 0.0 indicate the structure is fully backwatered.

Site ID	Pipe #	Shape	Pipe Condition	Mean Channel Width (ft)	Continuous Substrate in Structure	Pipe slope (%)	Pipe Width: Channel Width ratio	Outlet Drop (in)	Outlet Perch (in)	Residual Inlet Depth (in)	Pipe Length (ft)	Slope (%) * Length (ft)
GWJ1576-0.4	1	C	fair	7.1	N	11.00	0.42	14.40	12.84	0.00	33.1	364.0
GWJ255-0.9	1	PA	poor	13.7	N (discontin)	2.17	0.48	32.46	16.86	0.00	48.1	104.5
GWJ255-0.9	2	PA	poor	13.7	N (discontin)	2.07	0.48	32.58	16.98	0.00	48.1	99.5
GWJ255-4.5	1	C	poor	8.5	N	4.22	0.53	12.60	9.96	0.00	36.0	152.0
GWJ255-4.6	1	PA	poor	11.3	N	4.14	0.46	23.58	8.34	0.00	34.4	142.5
GWJ255-4.6	2	PA	poor	11.3	N	6.60	0.46	24.12	8.88	0.00	34.4	227.0
GWJ381-0.1	1	PA	good	20.0	N (discontin)	1.21	0.33	-0.12	-3.36	0.00	36.5	44.0
GWJ381-0.1	2	PA	good	20.0	Y	0.56	0.33	2.64	-0.60	0.00	36.5	20.5
GWJ381-3.6	1	PA	poor	16.1	Y	7.72	0.28	-0.72	NA	0.00	23.0	177.5
GWJ381-4.65	1	PA	good	13.3	N	1.96	0.47	-1.02	-1.80	0.00	25.0	49.0
GWJ382-1.2	1	C	poor	9.7	N (discontin)	2.51	0.38	38.88	NA	0.00	78.2	196.0
GWJ382-2.3	1	PA	poor	11.1	N	2.78	0.51	32.64	NA	0.00	59.0	164.0
GWJ382-4.3	1	PA	good	19.3	N	3.27	0.50	24.24	30.90	0.00	52.8	172.5
GWJ382-5.5	1	PA	good	13.1	N	5.02	0.57	18.12	14.76	0.00	48.5	243.5
GWJ382-6.5	1	PA	good	11.8	N	5.01	0.57	13.32	NA	0.00	42.7	214.0
GWJ382-7.1	1	C	good	13.6	N	4.07	0.39	22.80	NA	0.00	48.7	198.0
GWJ382-7.15	1	C	good	10.5	N	3.45	0.48	11.28	12.36	0.00	69.5	240.0
GWJ382-9.6	1	C	good	14.3	N	4.34	0.35	7.32	NA	0.00	45.0	195.5
GWJ382-9.9	1	C	good	11.7	N	1.70	0.38	80.52	NA	0.00	45.0	76.5
GWJ383h-.001	1	PA	fair	16.0	N (discontin)	2.29	0.38	3.84	-0.06	0.00	33.0	75.5
GWJ383h-.001	2	PA	fair	16.0	Y	1.52	0.38	1.20	-2.70	0.00	33.0	50.0
GWJ387-0.05	1	PA	good	12.6	N	3.49	0.83	14.04	-0.72	0.00	35.0	122.0
GWJ393-0.2	1	C	good	11.4	N	7.59	0.39	16.86	NA	0.00	38.0	288.5

Table continued next page…

Site ID	Pipe #	Shape	Pipe Condition	Mean Channel Width (ft)	Continuous Substrate in Structure	Pipe slope (%)	Pipe Width: Channel Width ratio	Outlet Drop (in)	Outlet Perch (in)	Residual Inlet Depth (in)	Pipe Length (ft)	Slope (%) * Length (ft)
GWJ394-0.39	1	C	fair	7.4	N	4.86	0.40	5.34	NA	0.00	77.3	375.5
GWJ394-0.4	1	C	fair	10.1	N	1.45	0.40	9.12	NA	0.00	80.4	116.4
GWJ394-0.8	1	PA	poor	14.8	N	1.94	0.39	8.10	6.78	0.00	59.5	115.5
GWJ394-10.7	1	PA	fair	9.5	N	7.78	0.40	-14.88	NA	0.00	67.5	525.0
GWJ394-10.71	1	C	good	11.5	N	5.12	0.44	25.92	NA	0.00	64.3	329.0
GWJ394-12.1	1	C	good	10.8	N	5.68	0.43	23.88	25.44	0.00	76.0	432.0
GWJ394-6.9	1	C	good	12.2	N	7.77	0.41	13.14	13.14	0.00	101.0	785.0
GWJ394-9.4	1	C	good	10.3	N	6.44	0.44	37.80	42.72	0.00	64.8	417.0
GWJ394b-0.8	1	C	good	10.9	N	3.79	0.46	24.78	NA	0.00	49.0	185.5
GWJ394y-0.01	1	C	poor	8.5	N	8.05	0.35	6.24	NA	0.00	23.3	187.5
GWJ394z-0.01	1	C	poor	10.8	N (discontin)	0.67	0.37	-3.48	NA	5.28	22.5	15.0
GWJ395-1.3	1	C	good	12.6	N	3.80	0.40	7.92	6.60	0.00	44.0	167.0
GWJ395-3.5	1	OBA	good	18.7	Y	0.82	0.53	-4.20	-4.80	0.24	40.0	33.0
GWJ399-1.0	1	F	good	19.7	N	0.28	NA	3.36	1.08	0.00	21.6	6.0
GWJ399b-0.8	1	PA	good	11.3	N	4.99	0.42	27.12	12.18	0.00	35.7	178.0
GWJ399b-1.6	1	PA	good	14.2	N	3.78	0.48	-8.64	-8.64	0.00	44.9	169.5
GWJ399b-3.9	1	C	fair	14.6	N	2.82	0.55	18.84	15.12	0.00	55.7	157.0
GWJ433-1.3	1	PA	good	14.1	N	4.70	0.51	25.08	24.36	0.00	36.6	172.0
GWJ433-2.35	1	C	fair	8.6	N	7.10	0.49	50.52	NA	0.00	34.7	246.5
GWJ433-2.4	1	C	poor	10.4	N (discontin)	5.45	0.40	20.22	NA	0.00	38.5	210.0
GWJ61-0.8	1	C	good	7.1	N (discontin)	9.80	0.56	NA	1.00	0.00	24.5	241.0
GWJ61-6.3	1	C	poor	10.9	N (discontin)	0.46	0.37	9.42	5.94	0.00	24.9	11.5
GWJ61-6.3	2	C	poor	10.9	N (discontin)	1.04	0.37	8.52	5.04	0.00	24.9	26.0
GWJ627-4.4	1	PA	poor	13.5	N	3.05	0.33	-4.68	-30.12	0.00	40.3	123.0
GWJ687-0.09	1	C	good	13.3	N	5.72	0.30	-0.96	NA	0.00	30.0	171.5
GWJ687-0.5	1	C	fair	10.3	N	2.87	0.39	-2.76	NA	0.00	50.2	144.0
GWJ688-2.2	1	C	good	19.5	N	1.63	0.12	13.44	6.24	0.00	30.0	49.0
GWJ688-2.2	2	C	good	19.5	N	2.23	0.10	4.80	-2.40	0.00	30.0	67.0

Table continued next page…

Site ID	Pipe #	Shape	Pipe Condition	Mean Channel Width (ft)	Continuous Substrate in Structure	Pipe slope (%)	Pipe Width: Channel Width ratio	Outlet Drop (in)	Outlet Perch (in)	Residual Inlet Depth (in)	Pipe Length (ft)	Slope (%) * Length (ft)
GWJ688-2.2	3	C	good	19.5	N	1.00	0.10	9.00	1.80	0.00	30.0	30.0
GWJ77-0.25	1	PA	good	11.5	N	3.10	0.66	7.44	-3.60	0.00	49.0	152.0
GWJ77-1.0	1	PA	good	14.4	N (discontin)	2.20	0.55	54.54	47.82	0.00	49.8	109.5
GWJ77-1.65	1	PA	good	17.8	N	2.61	0.34	37.08	NA	0.00	36.0	94.0
GWJ77-1.65	2	PA	good	17.8	N	2.44	0.34	36.96	NA	0.00	36.0	88.0
GWJ77-1.9	1	OBA	good	17.0	Y	0.50	0.59	-2.04	-0.36	0.12	32.0	16.0
GWJ77-2.9	1	C	good	16.4	N	2.48	0.24	19.08	NA	0.00	43.5	108.0
GWJ77-2.9	2	C	good	16.4	N	3.01	0.24	12.72	NA	0.00	41.0	123.5
GWJ77-3.2	1	PA	good	13.2	N	3.40	0.72	9.84	3.60	0.00	35.0	119.0
GWJ77-3.8	1	PA	poor	11.9	N	8.02	0.63	53.88	52.44	0.00	39.8	319.0
GWJ77-5.6	1	PA	poor	8.3	Y	12.30	0.48	30.72	27.24	0.00	23.0	283.0
GWJ77-6.2	1	C	fair	8.9	N	2.13	0.45	2.40	NA	0.00	40.0	85.0
GWJ77-6.8	1	PA	good	13.5	N (discontin)	1.87	0.89	16.20	15.60	0.00	54.0	101.0
GWJ81-2.4	1	PA	good	11.5	N	5.33	0.44	16.80	15.84	0.00	40.0	213.0
GWJ82-0.1	1	PA	good	22.0	N	3.59	0.52	-6.66	-13.62	0.00	51.7	185.5
GWJ82-0.5	1	PA	poor	12.7	N (discontin)	3.82	0.38	7.20	2.16	0.00	20.4	78.0
GWJ82-1.0	1	PA	fair	18.7	N	3.72	0.38	2.40	-2.88	0.00	26.1	97.0
GWJ82-1.6	1	PA	good	15.3	N	3.36	0.58	10.44	6.72	0.00	32.0	107.5
GWJ82-1.9	1	C	good	10.2	N	7.73	0.44	19.68	17.04	0.00	44.5	344.0
GWJ82-5.39	1	PA	good	11.6	N	12.13	0.52	33.84	43.80	0.00	42.2	512.0
GWJ82-7.5	1	PA	good	14.9	N (discontin)	4.47	0.57	-6.06	-11.94	0.00	33.9	151.5
GWJ125-6.95	1	OBA	good	11.3	Y	1.83	1.56	3.72	-3.00	0.00	47.0	86.0
GWJ125-9.1	1	PA	good	23.5	N	2.63	0.66	-2.28	-10.92	0.00	30.0	79.0
GWJ1747-0.02	1	PA	fair	15.6	N	2.85	0.42	11.76	7.68	0.00	36.2	103.0
GWJ194-4.8	1	C	good	7.0	N	5.47	0.57	NA	22.32	0.00	45.0	246.0
GWJ194-5.6	1	PA	good	10.6	N	5.68	0.47	12.30	10.50	0.00	36.0	204.5
GWJ194-6.7	1	PA	good	13.0	N	2.30	0.54	NA	-4.44	0.00	33.0	76.0
GWJ194-6.7	2	PA	good	13.0	N (discontin)	1.70	0.54	NA	-0.24	0.00	33.0	56.0

Table continued next page…

Site ID	Pipe #	Shape	Pipe Condition	Mean Channel Width (ft)	Continuous Substrate in Structure	Pipe slope (%)	Pipe Width: Channel Width ratio	Outlet Drop (in)	Outlet Perch (in)	Residual Inlet Depth (in)	Pipe Length (ft)	Slope (%) * Length (ft)
GWJ194-7.6	1	PA	good	7.2	N	6.69	0.83	4.32	7.08	0.00	42.0	281.0
GWJ241-10.0	1	C	good	13.0	N	0.95	0.46	15.72	15.60	0.00	40.2	38.0
GWJ241-3.6	1	PA	poor	8.5	N (discontin)	0.25	0.41	0.12	-0.96	0.00	27.61	7.0
GWJ241-3.9	1	PA	fair	5.4	N	7.38	0.54	2.64	-0.12	0.00	26.0	192.0
GWJ241-4.0	1	PA	good	7.8	N	6.79	0.60	24.12	18.36	0.00	29.9	203.0
GWJ241-4.0	2	PA	good	7.8	N	6.86	0.60	25.32	19.56	0.00	29.9	205.0
GWJ241-4.3	1	PA	good	4.7	N	5.76	1.03	1.32	0.00	0.00	26.2	151.0
GWJ241-4.5	1	PA	good	6.1	N	3.00	0.87	4.92	3.00	0.00	30.0	90.0
GWJ241-4.9	1	C	good	6.6	N	6.19	0.70	5.76	3.72	0.00	38.1	236.0
GWJ241-6.0	1	C	fair	4.5	N	4.95	1.03	12.12	9.96	0.00	38.0	188.0
GWJ241-6.7	1	C	good	6.6	N	7.43	0.60	12.00	6.84	0.00	33.1	246.0
GWJ241-9.0	1	C	good	6.1	N	11.74	0.77	20.40	18.00	0.00	36.3	426.0
GWJ241-9.3	1	PA	good	12.8	N	1.90	0.45	NA	-6.12	0.00	35.8	68.0
GWJ241-9.6	1	C	good	6.1	N	4.97	0.41	14.88	15.24	0.00	31.6	157.0
GWJ358-1.3	1	C	good	7.7	N	11.83	0.39	24.72	22.68	0.00	37.2	440.0
GWJ401-1.4	1	C	good	10.6	N (discontin)	4.67	0.47	23.76	20.40	0.00	32.0	149.5
GWJ401-1.7	1	C	good	8.7	N	6.63	0.46	9.24	9.06	0.00	29.5	195.5
GWJ465-1.3	1	C	good	10.4	N	7.53	0.29	6.72	NA	0.00	36.0	271.0
GWJ465-2.3	1	PA	good	11.1	N	4.54	0.69	20.76	16.56	0.00	38.8	176.0
GWJ603trail	1	C	good	7.4	N	2.39	0.41	0.60	-0.18	0.00	19.9	47.5
GWJ10570-2.6	1	C	good	14.7	N	3.12	0.52	32.52	32.52	0.00	50.5	157.5
GWJ613-0.4	1	PA	good	8.3	N	5.34	0.78	27.36	21.84	0.00	58.0	310.0
GWJ613-0.4	2	PA	good	8.3	N	5.07	0.78	30.00	24.48	0.00	58.0	294.0
GWJ125-1.3	1	OBA	good	17.1	Y	7.36	1.35	-5.88	-8.04	30.60	28.0	206.0
GWJ587-0.4	1	OBA	good	25.5	Y	0.29	1.10	7.68	-2.28	0.00	42.0	12.0

Appendix B: Results for the Daniel Boone National Forest

We visited 206 crossings on the Stearns, Somerset, and London Ranger Districts in 2005 (Figure B1, Table B1) and completed surveys on 40% (n=83) (Table B2). Filter A (strong swimmers and leapers) classified 22% (n=18) of crossings as impassable, 29% (n=24) as passable, and 49% (n=41) as indeterminate (Figure B2, Table B2). Filter B (moderate swimmers and leapers) classified 60% (n=50) of crossings as impassable, 15% (n=12) as passable, and 25% (n=21) as indeterminate (Figure B3, Table B2). Filter C (weak swimmers and leapers) classified 87% of crossings (n=72) as impassable, 10% (n=8) as passable, and 3% (n=3) as indeterminate (Figure B4, Table B2). Characteristics and filter classifications for each crossing are presented in Tables B3-B5.

The majority of the crossings were circular culverts (n=52) while fords (n=18), pipe arches (n=12), open bottom arches (n=1), vented fords (n=0), and box culverts (n=0) were less frequently encountered. Filter A classified 29% of circular culverts, 17% of fords, and 0% of pipe arches as impassable (Figure B5). Filter B classified 65% of circular culverts, 58% of pipe arches, and 50% of fords as impassable (Figure B6). Filter C classified 91% of pipe arches , 90% of circular culverts, and 78% of fords as impassable (Figure B7). The mean crossings width to channel width ratio (excluding fords and multiple structure crossings) (n=42) was 0.49 (SD=0.21), and only two crossings were greater than or equal to the mean bankfull channel width (Figure B8).

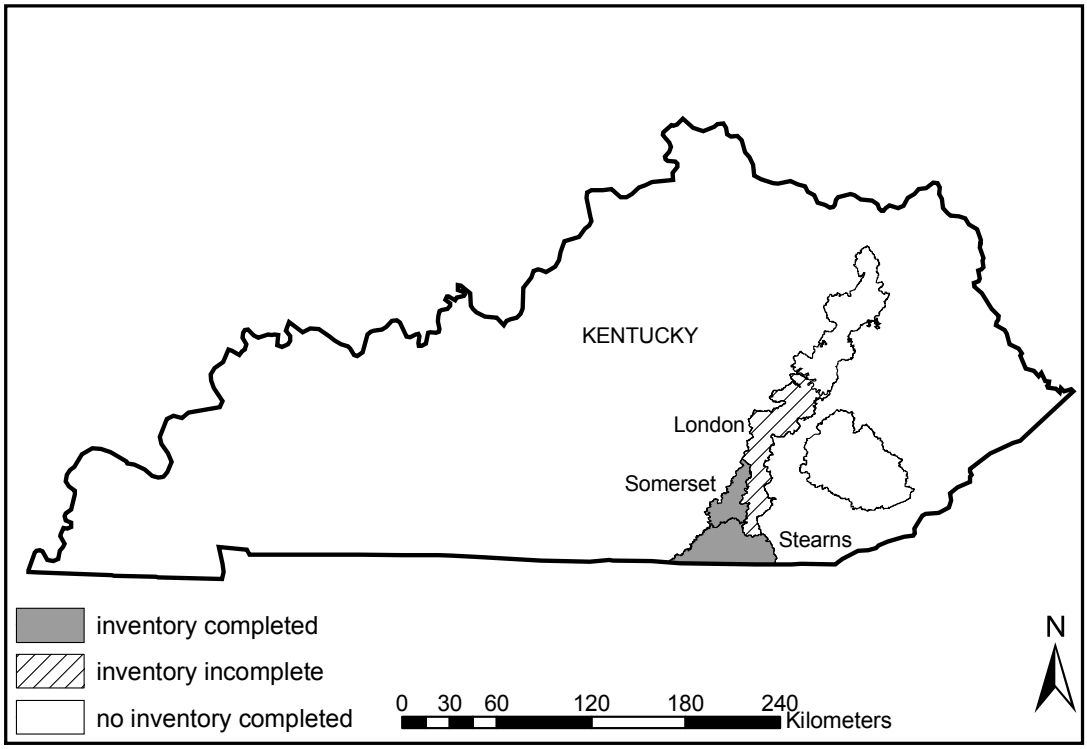

Figure B1. Ranger Districts on the Daniel Boone National Forest road-stream crossing surveys were conducted, summer 2005.

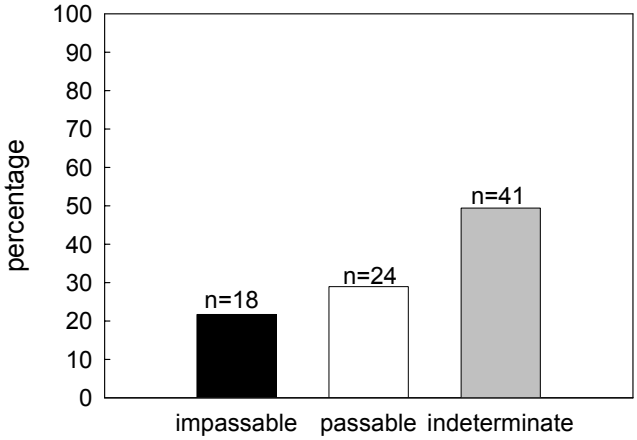

Figure B2. Percentage of crossings classified as impassable, passable, or indeterminate by Filter A; Daniel Boone National Forest, summer 2005 (N=83).

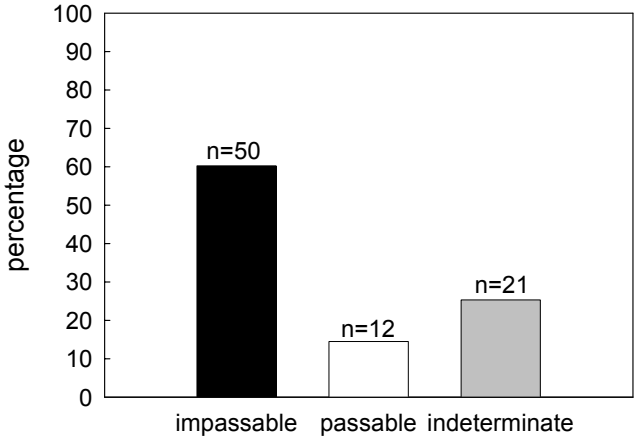

Figure B3. Percentage of crossings classified as impassable, passable, or indeterminate by Filter B; Daniel Boone National Forest, summer 2005 (N=83).

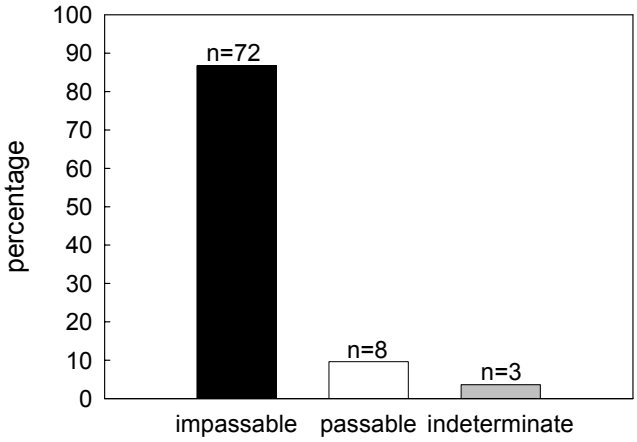

Figure B4. Percentage of crossings classified as impassable, passable, or indeterminate by Filter C; Daniel Boone National Forest, summer 2005 (N=83).

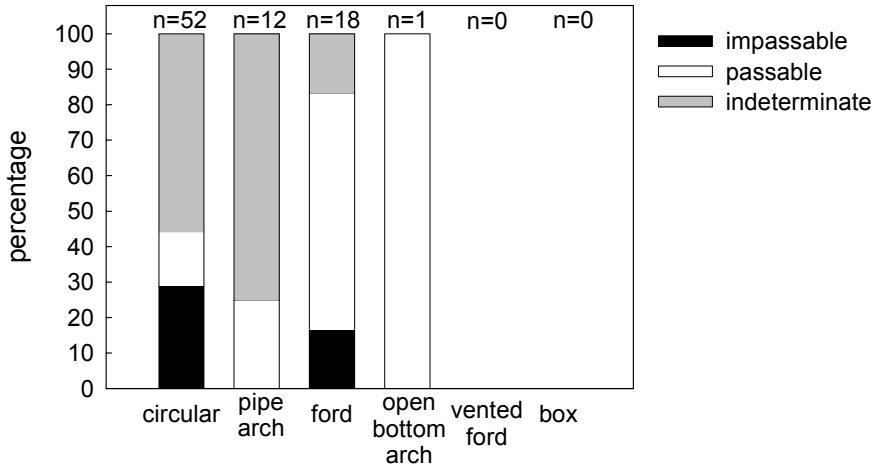

Figure B5. Percentage of each crossing type classified as impassable, passable, or indeterminate for Filter A; Daniel Boone National Forest, summer 2005 (N=83).

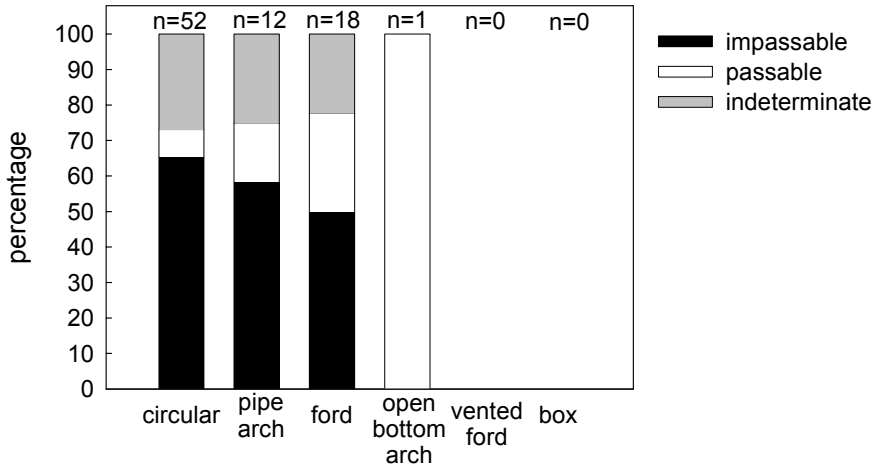

Figure B6. Percentage of each crossing type classified as impassable, passable, or indeterminate for Filter B; Daniel Boone National Forest, summer 2005 (N=83).

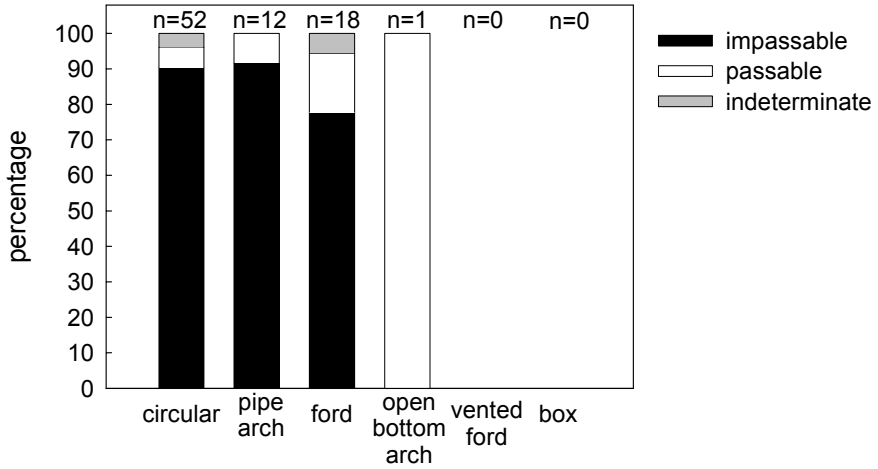

Figure B7. Percentage of each crossing type classified as impassable, passable, or indeterminate for Filter C; Daniel Boone National Forest, summer 2005 (N=83).

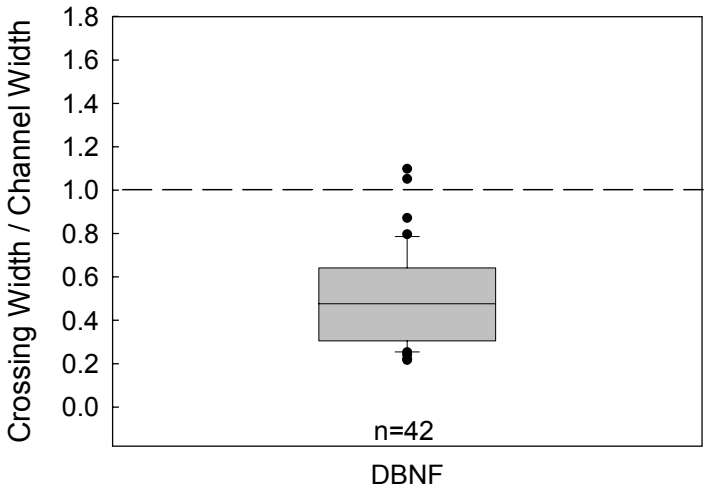

Figure B8. Crossing width to bankfull channel width ratio for crossings surveyed in summer 2005 on the Daniel Boone National Forest (excluding fords, vented fords and multiple structure crossings). A ratio of 1.0 (dashed line) or greater indicates the crossing structure opening is greater than or equal to the bankfull channel width. The top and bottom of the boxes represent the 25th and 75th percentiles, the bar in the center of each box represents the median, whiskers represent the 10th and 90th percentiles, and closed circles represent the entire range of the data.

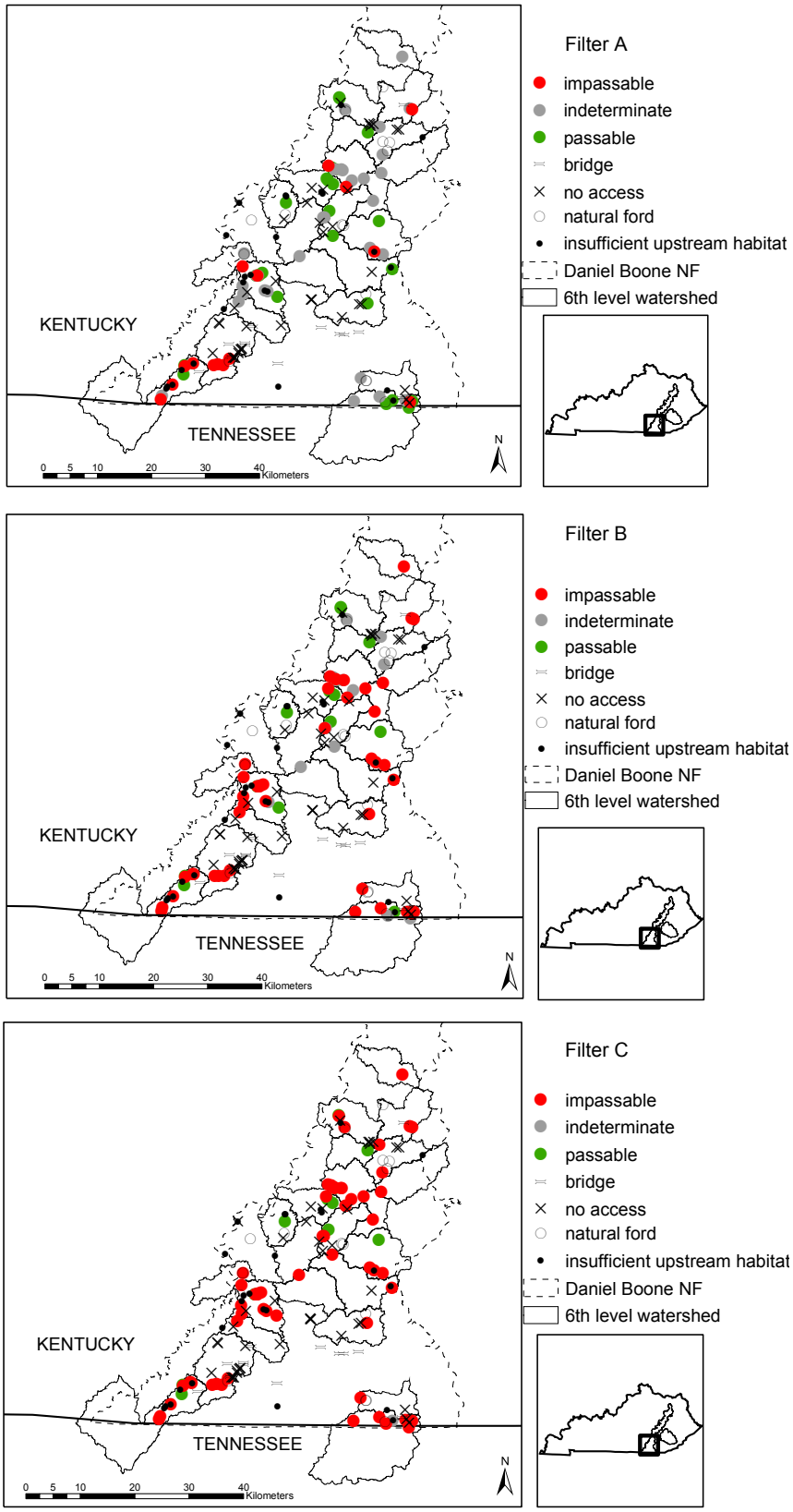

Figure B9. Location of crossings classified for fish passage by coarse filters A, B, and C within 6th level watersheds, and crossings not surveyed on the Daniel Boone National Forest, summer 2005.

Table B1. Number of crossings documented (Total crossings documented) and not surveyed (Crossings not surveyed) on the DBNF in summer 2005. Reasons for not surveying a documented site include: no suitable fish habitat upstream of crossing (NH); no access to site due to closed roads or private gates (NA); crossing was a natural ford (NF); crossing was a bridge (BR).

Forest	Total crossings documented	Crossings not surveyed (n, [%])				
		NH	NA	NF	BR	Total not surveyed
DBNF	206	28 (23)	61 (50)	21 (17)	13 (10)	123 (60)

Table B2. Number of crossings surveyed (Total surveyed) with coarse filter results for the DBNF in summer 2005. Coarse filter results are presented for Filter A, Filter B, and Filter C (see filter descriptions, Fig 3 – 5).

Forest	Total surveyed	Coarse filter results								
		Impassable (n, [%])			Passable (n, [%])			Indeterminate (n, [%])		
		A	B	C	A	B	C	A	B	C
DBNF	83	18 (22)	50 (60)	72 (87)	24 (29)	12 (14)	8 (10)	41 (49)	21 (25)	3 (4)

Table B3. Location of crossings surveyed on the Daniel Boone National Forest during the summer of 2005. Site ID consists of the Forest abbreviation (DB), road the crossing is on (119b), and the distance (miles) from the junction road (0.8).

Site ID	Pipe #	District	Junction Road	Stream Name	Quad	6th level watershed
DB100-1.5	1	London	1277	UT Cumberland River	Sawyer	051301011405
DB119b-0.8	1	London	119	Lick Branch	Ano	051301020507
DB119b-0.8	2	London	119	Lick Branch	Ano	051301020507
DB119b-0.8	3	London	119	Lick Branch	Ano	051301020507
DB131-0.3	1	London	3497	Rock Creek	Sawyer	051301020509
DB132-0.5	1	London	1193	UT Sam's Branch Laurel River Lk	Sawyer	051301011309
DB193-1.8	1	London	1277	Bark Camp Branch	Sawyer	051301011404
DB195-1.1	1	London	88	North Fork Gulf Branch	Cumberland Falls	051301011404
DB195-1.9	1	London	88	Hogbed Branch	Cumberland Falls	051301011404
DB195-3.3	1	London	88	South Fork	Cumberland Falls	051301011404
DB4094-0.6	1	London	4094 road sign	UT Hawk Creek	Bernstadt	051301020502
DB4133-0.49	1	London	766	UT Pound Branch	Ano	051301020508
DB4252-0.5	1	London	539	Amos Falls Branch	Cumberland Falls	051301011403
DB4252-0.5	2	London	539	Amos Falls Branch	Cumberland Falls	051301011403
DB534-xx	1	London	NA	Cane Creek	Cumberland Falls	051301011206
DB615-0.9	1	London	131	UT Ned Branch	Sawyer	051301020509
DB626-0.3	1	London	3497 (gate)	Dutch Brook	Sawyer	051301020509
DB741-0.3	1	London	781	UT Sinking Creek	London SW	051301020505
DB781-0.01	1	London	741	UT Sinking Creek	London SW	051301020505
DB119-3.7	1	Somerset	56	UT Storm Branch	Ano	051301020508
DB272-1.3	1	Somerset	122a	Big Lick	Hail	051301030202
DB272-1.7	1	Somerset	122a	Big Lick	Hail	051301030202
DB272-2.5	1	Somerset	122a	Big Lick	Sawyer	051301030202
DB46-0.6	1	Somerset	3257	Dry Branch	Hail	051301030201
DB5057-0.2	1	Somerset	750	UT Lick Creek	Ano	051301020506
DB5057-0.25	1	Somerset	750	UT Lick Creek	Ano	051301020506
DB5057-1.8	1	Somerset	750	Gwen's Branch	Ano	051301020506
DB5057-1.8	2	Somerset	750	Gwen's Branch	Ano	051301020506
DB5138-0.6	1	Somerset	122a	UT Bear Creek	Hail	051301020509
DB5138-1.0	1	Somerset	122a	Cub Creek	Hail	051301020509

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Site ID	Pipe #	District	Junction Road	Stream Name	Quad	6th level watershed
DB5138-1.5	1	Somerset	122a	Bear Creek	Hail	051301020509
DB5138-1.5	2	Somerset	122a	Bear Creek	Hail	051301020509
DB5138-1.6	1	Somerset	122a	UT Bear Creek	Hail	051301020509
DB5138-1.6	2	Somerset	122a	UT Bear Creek	Hail	051301020509
DB5138-1.61	1	Somerset	122a	Bear Creek	Hail	051301020509
DB5138-2.1	1	Somerset	122a	UT Bear Creek	Sawyer	051301020509
DB5138-2.1	2	Somerset	122a	UT Bear Creek	Sawyer	051301020509
DB5138-2.5	1	Somerset	122a	Bear Creek	Hail	051301020509
DB5165-0.3	1	Somerset	50	UT Cave Creek	Hail	051301030203
DB5183-0.2	1	Somerset	5181	Pink Branch	Hail	051301011406
DB5195-.09	1	Somerset	46	UT Dry Branch	Hail	051301030201
DB5234-0.4	1	Somerset	817	UT Eagle Creek	Hail	051301011403
DB5267-0.25	1	Somerset	927	UT Stanley Branch	Nevelsville	051301040703
DB5270-0.4	1	Somerset	927	Lick Branch	Nevelsville	051301040607
DB5279-0.8	1	Somerset	646a	Straight Creek	Nevelsville	051301040607
DB5279-1.2	1	Somerset	646a	Fox Den Hollow	Nevelsville	051301040607
DB5279-1.4	1	Somerset	646a	Straight Creek	Nevelsville	051301040607
DB5279-1.45	1	Somerset	646a	Straight Creek	Nevelsville	051301040607
DB5279-1.5	1	Somerset	646a	UT Straight Creek	Nevelsville	051301040607
DB5279-1.7	1	Somerset	646a	UT Straight Creek	Nevelsville	051301040607
DB5279-1.75	1	Somerset	646a	Straight Creek	Nevelsville	051301040607
DB137-0.05	1	Stearns	564	UT Rock Creek	Bell Farm	051301040408
DB137-0.8	1	Stearns	TN line on 137	Big Branch	Barthell SW	051301040408
DB137-1.2	1	Stearns	TN line on 137	Buffalo Branch	Barthell SW	051301040408
DB137-2.9	1	Stearns	TN line on 137	UT Rock Trace	Bell Farm	051301040408
DB137-2.9	2	Stearns	TN line on 137	UT Rock Trace	Bell Farm	051301040408
DB137x 0.01	1	Stearns	137	Rock Creek	Bell Farm	051301040408
DB492-2.3	1	Stearns	1470	Lot Hollow	Ketchen	051301011001
DB492-5.8	1	Stearns	1470	UT Rock Creek	Ketchen	051301011001
DB492-7.1	1	Stearns	1470	Rock Creek	Ketchen	051301011001
DB492-8.0	1	Stearns	1470	Shutin Branch	Ketchen	051301011001
DB498-0.9	1	Stearns	1470	Riggs Branch	Holly Hill	051301011002
DB502-0.6	1	Stearns	6274	UT Capuchin Creek	Jellico West	051301011001

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Site ID	Pipe #	District	Junction Road	Stream Name	Quad	6th level watershed
DB502-1.7	1	Stearns	492	UT Capuchin Creek	Jellico West	051301011001
DB564-0.1	1	Stearns	566	UT Rock Creek	Bell Farm	051301040408
DB564-1.3	1	Stearns	566	UT Rock Creek	Bell Farm	051301040408
DB564-1.3	2	Stearns	566	UT Rock Creek	Bell Farm	051301040408
DB566-0.05	1	Stearns	564	UT Rock Creek	Bell Farm	051301040408
DB566-2.4	1	Stearns	1363	UT Rock Creek	Barthell	051301040409
DB566-3.5	1	Stearns	1363	UT Rock Creek	Barthell	051301040409
DB566-4.6	1	Stearns	1363	UT Fidelity Locker	Barthell	051301040409
DB566-5.0	1	Stearns	1363	UT Rock Creek	Bell Farm	051301040409
DB6020-0.3	1	Stearns	90	Kilburn Fork	Wiborg	051301011402
DB6020-0.3	2	Stearns	90	Kilburn Fork	Wiborg	051301011402
DB6061-3.2	1	Stearns	1651	UT Big Creek	Wiborg	051301040607
DB6274-0.2	1	Stearns	502	UT Capuchin Creek	Jellico West	051301011001
DB6274-0.4	1	Stearns	6274	UT Capuchin Creek	Jellico West	051301011001
DB650-3.1	1	Stearns	69	Stallion Fork	Nevelsville	051301040606
DB663a-0.0	1	Stearns	663	Big North Fork	Nevelsville	051301040607
DB663a-0.5	1	Stearns	663	Big North Fork	Nevelsville	051301040607
DB663a-0.5	2	Stearns	663	Big North Fork	Nevelsville	051301040607
DB68-2.1	1	Stearns	651	Bridge Hollow	Nevelsville	051301040607
DB68-3.6	1	Stearns	651	Steven's Branch	Nevelsville	051301040607

Table B4. Coarse filter A, B, and C, classifications for crossings surveyed on the Daniel Boone National Forest, summer 2005.

Site ID	Pipe #	Filter A	Filter B	Filter C
DB100-1.5	1	indeterminate	impassable	impassable
DB119b-0.8	1	indeterminate	indeterminate	indeterminate
DB119b-0.8	2	indeterminate	indeterminate	indeterminate
DB119b-0.8	3	passable	passable	impassable
DB131-0.3	1	indeterminate	impassable	impassable
DB132-0.5	1	indeterminate	impassable	impassable
DB193-1.8	1	passable	passable	passable
DB195-1.1	1	indeterminate	impassable	impassable
DB195-1.9	1	impassable	impassable	impassable
DB195-3.3	1	indeterminate	impassable	impassable
DB4094-0.6	1	indeterminate	impassable	impassable
DB4133-0.49	1	indeterminate	indeterminate	impassable
DB4252-0.5	1	passable	impassable	impassable
DB4252-0.5	2	passable	impassable	impassable
DB534-xx	1	passable	impassable	impassable
DB615-0.9	1	indeterminate	indeterminate	impassable
DB626-0.3	1	impassable	impassable	impassable
DB741-0.3	1	indeterminate	impassable	impassable
DB781-0.01	1	impassable	impassable	impassable
DB119-3.7	1	indeterminate	indeterminate	impassable
DB272-1.3	1	passable	impassable	impassable
DB272-1.7	1	passable	passable	passable
DB272-2.5	1	indeterminate	indeterminate	impassable
DB46-0.6	1	indeterminate	indeterminate	impassable
DB5057-0.2	1	passable	passable	passable
DB5057-0.25	1	passable	passable	impassable
DB5057-1.8	1	indeterminate	indeterminate	impassable
DB5057-1.8	2	indeterminate	indeterminate	impassable
DB5138-0.6	1	impassable	impassable	impassable
DB5138-1.0	1	passable	indeterminate	impassable
DB5138-1.5	1	indeterminate	impassable	impassable
DB5138-1.5	2	indeterminate	impassable	impassable
DB5138-1.6	1	indeterminate	indeterminate	impassable
DB5138-1.6	2	indeterminate	indeterminate	impassable
DB5138-1.61	1	passable	passable	passable
DB5138-2.1	1	indeterminate	indeterminate	impassable
DB5138-2.1	2	indeterminate	indeterminate	impassable
DB5138-2.5	1	indeterminate	impassable	impassable
DB5165-0.3	1	passable	passable	passable
DB5183-0.2	1	passable	passable	passable
DB5195-.09	1	indeterminate	impassable	impassable
DB5234-0.4	1	passable	indeterminate	impassable
DB5267-0.25	1	indeterminate	impassable	impassable
DB5270-0.4	1	impassable	impassable	impassable
DB5279-0.8	1	passable	impassable	impassable

table continued next page…

Site ID	Pipe #	Filter A	Filter B	Filter C
DB5279-1.2	1	passable	indeterminate	impassable
DB5279-1.4	1	passable	impassable	impassable
DB5279-1.45	1	indeterminate	indeterminate	impassable
DB5279-1.5	1	impassable	impassable	impassable
DB5279-1.7	1	indeterminate	impassable	impassable
DB5279-1.75	1	passable	passable	passable
DB137-0.05	1	impassable	impassable	impassable
DB137-0.8	1	impassable	impassable	impassable
DB137-1.2	1	indeterminate	impassable	impassable
DB137-2.9	1	impassable	impassable	impassable
DB137-2.9	2	impassable	impassable	impassable
DB137x 0.01	1	passable	passable	passable
DB492-2.3	1	indeterminate	impassable	impassable
DB492-5.8	1	indeterminate	impassable	impassable
DB492-7.1	1	passable	indeterminate	impassable
DB492-8.0	1	passable	passable	indeterminate
DB498-0.9	1	indeterminate	impassable	impassable
DB502-0.6	1	indeterminate	impassable	impassable
DB502-1.7	1	passable	indeterminate	impassable
DB564-0.1	1	indeterminate	impassable	impassable
DB564-1.3	1	impassable	impassable	impassable
DB564-1.3	2	impassable	impassable	impassable
DB566-0.05	1	impassable	impassable	impassable
DB566-2.4	1	impassable	impassable	impassable
DB566-3.5	1	impassable	impassable	impassable
DB566-4.6	1	impassable	impassable	impassable
DB566-5.0	1	impassable	impassable	impassable
DB6020-0.3	1	indeterminate	impassable	impassable
DB6020-0.3	2	indeterminate	indeterminate	impassable
DB6061-3.2	1	passable	passable	impassable
DB6274-0.2	1	impassable	impassable	impassable
DB6274-0.4	1	passable	impassable	impassable
DB650-3.1	1	indeterminate	impassable	impassable
DB663a-0.0	1	indeterminate	impassable	impassable
DB663a-0.5	1	indeterminate	impassable	impassable
DB663a-0.5	2	indeterminate	indeterminate	impassable
DB68-2.1	1	indeterminate	impassable	impassable
DB68-3.6	1	indeterminate	impassable	impassable

Table B5. Description of crossings surveyed on the Daniel Boone National Forest, summer 2005. Shape abbreviations: C= circular, PA= pipe arch, OBA= open bottom arch, and F= ford. Channel width is the mean bankfull channel width. N= no natural substrate, N (discontin)= discontinuous substrate, Y= continuous natural substrate. An NA (not applicable) indicates outlet drop (no outlet pool or tailwater control) or outlet perch (stream dry) could not be calculated. Negative outlet drop or perch values indicate a submerged outlet (structure partially backwatered). Residual inlet depth values ≥ 0.0 indicate the structure is fully backwatered.

Site ID	Pipe #	Shape	Pipe Condition	Mean Channel Width (ft)	Continuous Substrate in Structure	Pipe slope (%)	Pipe Width: Channel Width ratio	Outlet Drop (in)	Outlet Perch (in)	Residual Inlet Depth (in)	Pipe Length (ft)	Slope (%) * Length (ft)
DB100-1.5	1	C	poor	5.2	N	2.96	0.87	13.62	NA	0.00	46.7	138.0
DB119b-0.8	1	C	poor	17.7	N (discontin)	1.93	0.25	2.64	2.28	0.00	34.2	66.0
DB119b-0.8	2	C	poor	17.7	N (discontin)	1.86	0.25	2.28	1.92	0.00	35.5	66.0
DB119b-0.8	3	C	fair	17.7	N (discontin)	0.60	0.25	5.34	4.98	0.00	34.3	20.5
DB131-0.3	1	C	good	7.4	N	3.15	0.48	11.52	NA	0.00	83.8	264.0
DB132-0.5	1	PA	poor	12.7	N	1.98	0.35	15.60	16.56	0.00	59.7	118.0
DB193-1.8	1	OBA	good	32.2	Y	3.51	0.65	-30.72	-41.76	0.24	72.3	254.0
DB195-1.1	1	PA	good	23.4	N	1.46	0.56	18.90	15.18	0.00	76.4	111.5
DB195-1.9	1	C	fair	14.0	N	3.72	0.36	32.40	29.16	0.00	93.0	346.0
DB195-3.3	1	PA	fair	17.2	N	1.31	0.70	11.40	3.60	0.00	66.6	87.0
DB4094-0.6	1	C	good	18.2	N	2.66	0.22	14.04	15.72	0.00	29.7	79.0
DB4133-0.49	1	PA	fair	7.3	N	1.70	0.59	9.24	7.50	0.00	35.2	60.0
DB4252-0.5	1	C	poor	10.6	N	0.67	0.47	12.84	10.44	0.00	46.0	31.0
DB4252-0.5	2	C	poor	10.6	N	0.60	0.47	13.20	10.80	0.00	44.4	26.5
DB534-xx	1	F	good	11.0	N (discontin)	1.60	0.00	NA	12.42	0.00	17.8	28.5
DB615-0.9	1	C	fair	6.4	N	2.98	0.39	6.96	8.88	0.00	24.8	74.0
DB626-0.3	1	C	good	13.2	N	9.68	0.30	17.40	NA	0.00	72.3	700.0
DB741-0.3	1	C	good	7.9	N	4.46	0.25	2.28	-2.16	0.00	24.9	111.0
DB781-0.01	1	C	fair	8.9	N	3.10	0.34	44.76	38.04	0.00	62.9	195.0
DB119-3.7	1	C	fair	10.2	N	1.39	0.54	9.60	13.14	0.00	80.1	111.0
DB272-1.3	1	PA	fair	16.8	N	0.56	0.68	11.64	21.00	0.00	47.9	27.0
DB272-1.7	1	PA	good	16.4	Y	0.18	0.76	-4.68	NA	3.84	39.4	7.0
DB272-2.5	1	PA	poor	21.5	N	1.34	0.58	-2.76	-1.32	0.00	116.6	156.0
DB46-0.6	1	PA	poor	5.5	N	2.28	1.10	6.96	NA	0.00	42.6	97.0
DB5057-0.2	1	C	good	9.7	Y	0.64	0.31	-2.52	-3.78	4.2	22.0	14.0
DB5057-0.25	1	PA	fair	12.6	N	1.06	0.35	8.58	NA	0.00	21.6	23.0

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Site ID	Pipe #	Shape	Pipe Condition	Mean Channel Width (ft)	Continuous Substrate in Structure	Pipe slope (%)	Pipe Width: Channel Width ratio	Outlet Drop (in)	Outlet Perch (in)	Residual Inlet Depth (in)	Pipe Length (ft)	Slope (%) * Length (ft)
DB5057-1.8	1	C	good	10.1	N	1.90	0.25	7.56	NA	0.00	31.0	59.0
DB5057-1.8	2	C	good	10.1	N	2.70	0.20	5.46	NA	0.00	31.5	85.0
DB5138-0.6	1	C	fair	9.6	N	8.05	0.26	53.52	52.56	0.00	39.9	321.0
DB5138-1.0	1	F	poor	17.3	N (discontin)	2.29	0.00	4.92	1.32	0.00	15.7	36.0
DB5138-1.5	1	C	good	19.9	N	2.10	0.20	11.28	8.28	0.00	41.4	87.0
DB5138-1.5	2	C	good	19.9	N	1.61	0.20	14.52	11.52	0.00	40.4	65.0
DB5138-1.6	1	C	fair	10.3	N	2.81	0.24	7.92	6.36	0.00	22.4	63.0
DB5138-1.6	2	C	fair	10.3	N	2.23	0.24	6.24	4.68	0.00	22.4	50.0
DB5138-1.61	1	F	poor	19.2	N (discontin)	0.79	0.00	NA	-3.24	0.00	15.2	12.0
DB5138-2.1	1	C	poor	9.7	N	3.23	0.31	5.64	4.08	0.00	30.0	97.0
DB5138-2.1	2	C	poor	9.7	N	3.47	0.31	4.68	3.12	0.00	30.0	104.0
DB5138-2.5	1	C	fair	11.1	N	4.00	0.27	2.52	2.40	0.00	39.5	158.0
DB5165-0.3	1	C	poor	9.6	N	0.10	0.42	3.72	NA	0.00	19.9	2.0
DB5183-0.2	1	C	bad	8.4	N	0.10	0.30	-2.28	-2.76	2.04	19.8	2.0
DB5195-.09	1	PA	poor	7.9	N	5.40	0.51	1.32	NA	0.00	21.3	115.0
DB5234-0.4	1	C	fair	4.3	N	2.55	1.05	7.86	7.56	0.00	11.4	29.0
DB5267-0.25	1	C	fair	6.3	N	4.51	0.48	-0.36	-1.44	0.00	27.3	123.0
DB5270-0.4	1	C	poor	12.5	N	0.46	0.24	34.68	32.76	0.00	18.5	8.5
DB5279-0.8	1	F	good	18.2	N (discontin)	0.65	0.00	15.96	14.52	0.00	15.5	10.0
DB5279-1.2	1	F	good	8.6	N (discontin)	1.43	0.00	9.72	8.40	0.00	22.3	32.0
DB5279-1.4	1	F	good	21.3	N (discontin)	2.87	0.00	15.66	10.68	0.00	17.0	48.0
DB5279-1.45	1	F	good	19.4	N	1.83	0.00	9.24	7.80	0.00	28.0	51.0
DB5279-1.5	1	F	good	8.8	N (discontin)	8.34	0.00	18.12	NA	0.00	15.7	233.0
DB5279-1.7	1	F	good	19.1	N (discontin)	4.19	0.00	14.04	12.00	0.00	15.5	65.0
DB5279-1.75	1	F	good	16.3	N (discontin)	0.09	0.00	1.74	NA	0.00	16.0	1.5
DB137-0.05	1	C	good	10.6	N	6.46	0.57	11.28	NA	0.00	115.9	749.0
DB137-0.8	1	F	good	13.2	N (discontin)	8.02	0.00	16.20	6.24	0.00	8.1	65.0
DB137-1.2	1	F	good	14.8	N	6.93	0.00	5.52	-1.56	0.00	14.0	97.0
DB137-2.9	1	C	poor	7.1	N	9.49	0.28	1.08	NA	0.00	25.4	241.0
DB137-2.9	2	C	poor	7.1	N	7.14	0.28	-1.20	NA	0.00	25.2	180.0

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Site ID	Pipe #	Shape	Pipe Condition	Mean Channel Width (ft)	Continuous Substrate in Structure	Pipe slope (%)	Pipe Width: Channel Width ratio	Outlet Drop (in)	Outlet Perch (in)	Residual Inlet Depth (in)	Pipe Length (ft)	Slope (%) * Length (ft)
DB137x 0.01	1	F	good	36.8	N (discontin)	0.50	0.00	0.96	0.24	0.00	14.0	7.0
DB492-2.3	1	C	good	8.2	N	4.47	0.31	7.26	4.14	0.00	-29.2	130.5
DB492-5.8	1	C	good	9.5	N	5.15	0.26	-0.06	-0.54	0.00	20.5	105.5
DB492-7.1	1	F	poor	25.5	N (discontin)	2.89	0.00	5.76	10.08	0.00	14.2	41.0
DB492-8.0	1	F	good	15.8	N (discontin)	1.63	0.00	0.48	2.28	0.00	14.1	23.0
DB498-0.9	1	PA	poor	6.1	N	4.00	0.49	10.92	9.84	0.00	41.8	167.0
DB502-0.6	1	C	poor	16.2	N	3.54	0.22	-2.28	-2.28	0.00	48.0	170.0
DB502-1.7	1	C	fair	14.8	N (discontin)	1.08	0.31	6.00	5.52	0.00	30.6	33.0
DB564-0.1	1	C	fair	9.0	N	6.11	0.44	7.14	6.84	0.00	40.0	244.5
DB564-1.3	1	C	poor	12.3	N	8.68	0.16	-0.12	NA	0.00	71.8	623.0
DB564-1.3	2	C	poor	12.3	N	8.68	0.16	-1.68	NA	0.00	71.8	623.0
DB566-0.05	1	C	good	6.3	N	1.87	0.80	36.30	29.88	0.00	41.5	77.5
DB566-2.4	1	C	poor	6.1	N	12.37	0.66	-2.40	NA	0.00	33.5	414.5
DB566-3.5	1	C	fair	9.0	N	7.48	0.28	12.66	NA	0.00	32.6	244.0
DB566-4.6	1	C	fair	10.5	N	8.42	0.38	69.24	67.86	0.00	26.0	219.0
DB566-5.0	1	C	good	12.3	N	4.12	0.36	49.92	13.44	0.00	21.0	86.5
DB6020-0.3	1	C	poor	13.4	N	3.75	0.30	4.92	1.02	0.00	60.0	225.0
DB6020-0.3	2	C	poor	13.4	N (discontin)	3.08	0.30	9.3	5.40	0.00	60.0	185.0
DB6061-3.2	1	F	good	7.0	N	1.19	0.00	9.36	9.12	0.00	13.4	16.0
DB6274-0.2	1	F	good	5.4	N	7.19	0.00	2.16	NA	0.00	18.8	135.0
DB6274-0.4	1	F	good	11.3	N	0.37	0.00	13.56	16.26	0.00	18.8	7.0
DB650-3.1	1	PA	good	11.9	N	3.48	0.59	7.80	18.36	0.00	83.6	291.0
DB663a-0.0	1	C	fair	9.5	N	5.29	0.53	18.96	NA	0.00	56.8	300.5
DB663a-0.5	1	C	poor	12.3	N	6.38	0.43	-3.96	-2.04	0.00	51.7	330.0
DB663a-0.5	2	C	poor	12.3	N	2.92	0.43	7.80	9.72	0.00	51.7	151.0
DB68-2.1	1	C	poor	9.1	N (discontin)	1.10	0.64	21.96	21.24	0.00	64.3	71.0
DB68-3.6	1	C	fair	8.9	N	5.95	0.68	10.92	11.04	0.00	54.8	326.0

Appendix C: Results for the Ozark-St. Francis National Forest

We visited 724 crossings on the Boston Mountain, Pleasant Hill, Buffalo, and Bayou Ranger Districts in 2005 (Figure C1, Table C1) and completed surveys on 5% (n=35) (Table C2). Filter A (strong swimmers and leapers) classified 12% (n=4) of crossings as impassable, 51% (n=18) as passable, and 37% (n=13) as indeterminate (Figure C2, Table C2). Filter B (moderate swimmers and leapers) classified 63% (n=22) of crossings as impassable, 20% (n=7) as passable, and 17% (n=6) as indeterminate (Figure C3, Table C2). Filter C (weak swimmers and leapers) classified 77% (n=27) of crossing as impassable, 14% (n=5) as passable, and 9% (n=3) as indeterminate (Figure C4, Table C2). Characteristics and filter classifications for each crossing are presented in Tables C3-C5.

The number of each crossing types surveyed was evenly distributed among circular culverts (n=8), fords (n=9), vented fords (n=7), and box culverts (n=8). In addition surveyed pipe arches (n=3) and open bottom arches (n=0) were less frequently encountered. Filter A classified 25% of circular culverts and 22% of fords as impassable (Figure C5). Filter B classified 100% of pipe arches, 63% of circular culverts and box culverts, 57% of vented fords, and 56% of fords as impassable (Figure C6). Filter C classified 100% of pipe arches and vented fords, 75% of circular culverts, 63% of box culverts, and 57% of vented fords as impassable (Figure C7). The mean crossing width to channel width ratio (excluding fords, vented fords, and multiple structure crossings) (n=12) was 0.30 (SD=0.08), and no crossings were greater than or equal to the bankfull channel width (i.e. crossing width to channel width ration was greater than or equal to 1.0) (Figure C8).

Figure C1. Ranger Districts on the Ozark St. Francis National Forest road-stream crossing surveys were conducted, summer 2005.

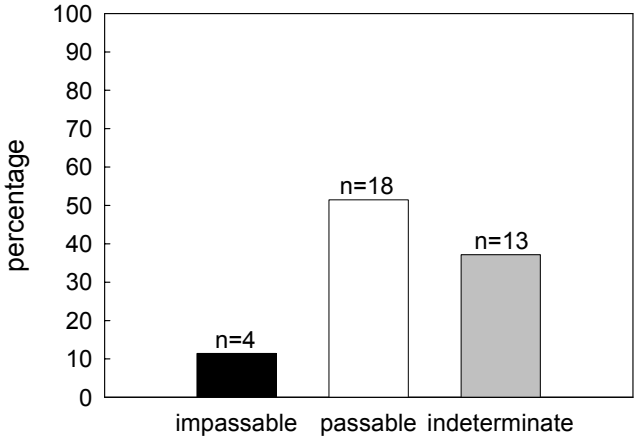

Figure C2. Percentage of crossings classified as impassable, passable, or indeterminate for Filter A; Ozark-St. Francis National Forest, summer 2005 (N=35).

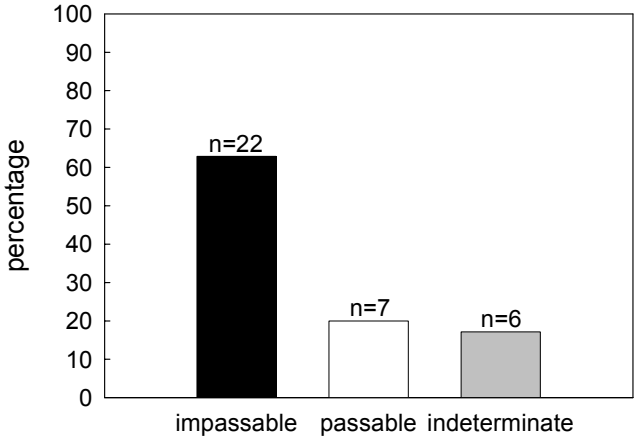

Figure C3. Percentage of crossings classified as impassable, passable, or indeterminate for Filter B; Ozark-St. Francis National Forest, summer 2005 (N=35).

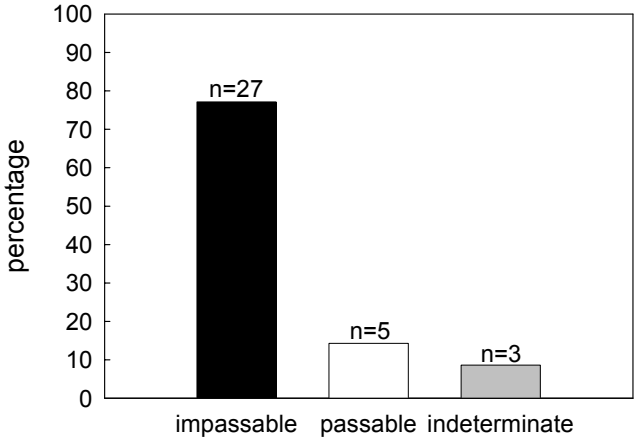

Figure C4. Percentage of crossings classified as impassable, passable, or indeterminate for Filter C; Ozark-St. Francis National Forest, summer 2005 (N=35).

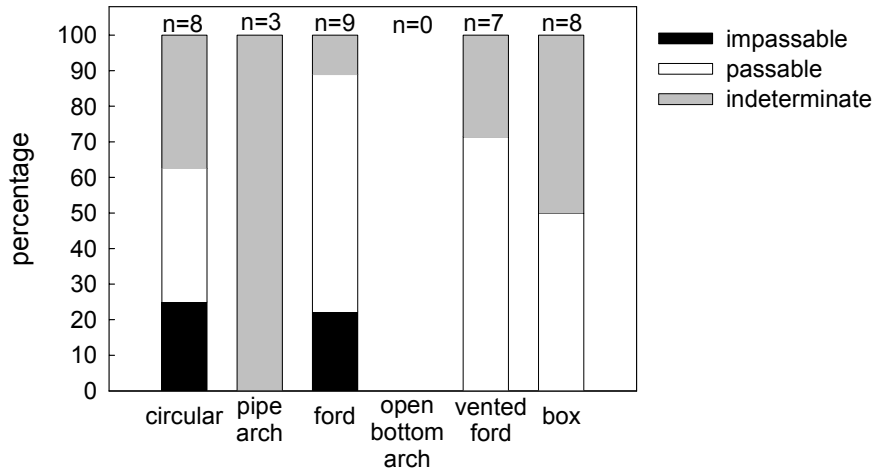

Figure C5. Percentage of each crossing type classified as impassable, passable, or indeterminate for Filter A; Ozark-St. Francis National Forest, summer 2005 (N=35).

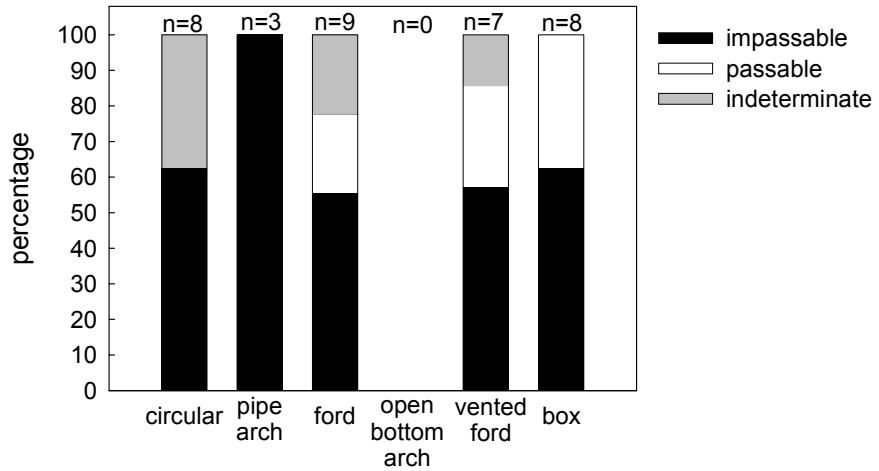

Figure C6. Percentage of each crossing type classified as impassable, passable, or indeterminate for Filter B; Ozark-St. Francis National Forest, summer 2005 (N=35).

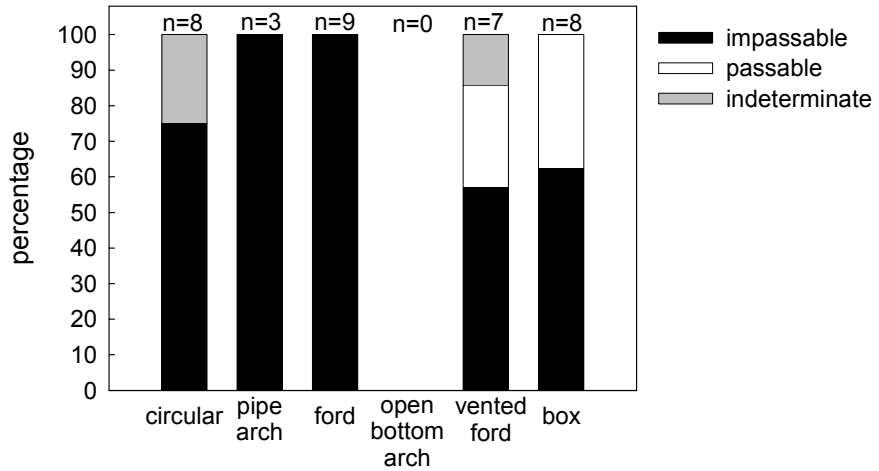

Figure C7. Percentage of each crossing type classified as impassable, passable, or indeterminate for Filter C; Ozark-St. Francis National Forest, summer 2005 (N=35).

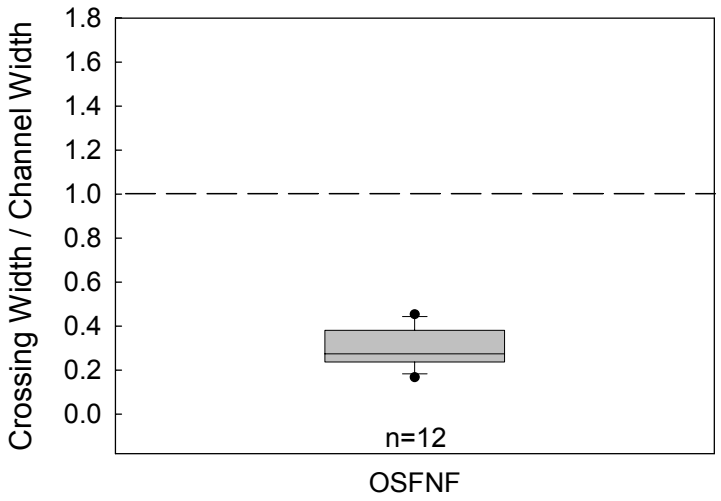

Figure C8. Crossing width to bankfull channel width ratio for crossings surveyed in summer 2005 on the Ozark-St. Francis National Forest (excluding fords, vented fords, and multiple structure crossings). A ratio of 1.0 (dashed line) or greater indicates the crossing structure opening is greater than or equal to the bankfull channel width. The top and bottom of the boxes represent the 25th and 75th percentiles, the bar in the center of each box represents the median, whiskers represent the 10th and 90th percentiles, and closed circles represent the entire range of the data.

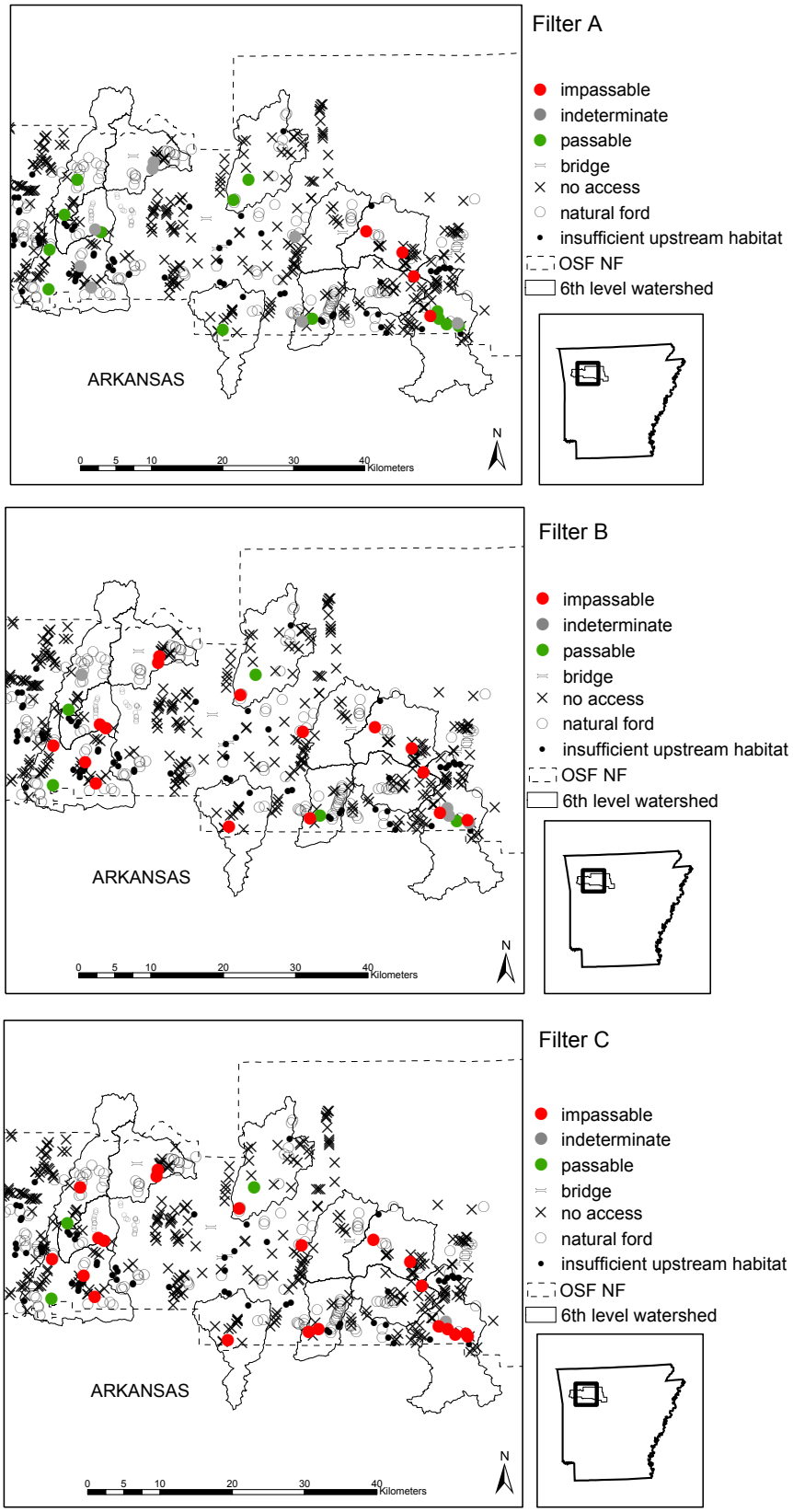

Figure C9. Location of crossings classified for fish passage by coarse filters A, B, and C within 6th level watersheds, and crossings not surveyed on the Ozark St. Francis National Forest, summer 2005.

Table C1. Number of crossings documented (Total crossing documented) and not surveyed (Crossings not surveyed) on the OSFNF in summer 2005. Reasons for not surveying a documented site include: no suitable fish habitat upstream of crossing (NH); no access to site due to closed roads or private gates (NA); crossing was a natural ford (NF); crossing was a bridge (BR).

Forest	Total crossings documented	Crossings not surveyed (n, [%])				
		NH	NA	NF	BR	Total not surveyed
OSFNF	724	85 (12)	396 (57)	191 (28)	17 (3)	689 (95)

Table C2. Number of crossings surveyed (Total surveyed) with coarse filter results for the OSFNF in summer 2005. Coarse filter results are presented for Filter A, Filter B, and Filter C (see filter descriptions, Fig 3 – 5).

Forest	Total surveyed	Coarse filter results								
		Impassable (n, [%])			Passable (n, [%])			Indeterminate (n, [%])		
		A	B	C	A	B	C	A	B	C
OSFNF	35	4 (12)	22 (63)	27 (77)	18 (51)	7 (20)	5 (14)	13 (37)	6 (17)	3 (9)

Table C3. Location of crossings surveyed on the Ozark St. Francis National Forest during the summer of 2005. Site ID consists of the Forest abbreviation (OSF), road the crossing is on (1538), and the distance (miles) from the junction road (0.8).

Site ID	Pipe #	District	Junction Road	Stream Name	Quad	6th Level Watershed
OSF113-0.1	1	Bayou	123	UT Little Piney Creek	Hagarville	111102020804
OSF113-0.1	2	Bayou	123	UT Little Piney Creek	Hagarville	111102020804
OSF113-0.7	1	Bayou	123	UT Little Piney Creek	Hagarville	111102020804
OSF1813-0.05	1	Bayou	113	Little Sulphur Creek	Hagarville	111102020804
OSF1813-1.3	1	Bayou	113	UT Toms Branch	Hagarville	111102020804
OSF1813-1.6	1	Bayou	113	Toms Branch	Hagarville	111102020804
OSF1003-7.4	1	Boston Mtn	23	Spirits Creek	Bidville	111102010704
OSF1501-2.4	1	Boston Mtn	23	Big Eddy Hollow	Cass	111102010704
OSF1501-2.4	2	Boston Mtn	23	Big Eddy Hollow	Cass	111102010704
OSF1509-0.4	1	Boston Mtn	79	UT Mill Creek	St. Paul	110100010103
OSF1520-0.4	1	Boston Mtn	1520 road sign off 112	Fane Creek	Cass	111102010705
OSF1520-0.4	2	Boston Mtn	1520 road sign off 112	Fane Creek	Cass	111102010705
OSF1520-0.4	3	Boston Mtn	1520 road sign off 112	Fane Creek	Cass	111102010705
OSF1520-0.4	4	Boston Mtn	1520 road sign off 112	Fane Creek	Cass	111102010705
OSF1520-1.0	1	Boston Mtn	1520 road sign off 112	Cove Creek	Cass	111102010705
OSF1520-7.2	1	Boston Mtn	1520 road sign off 112	UT Mill Creek	Bidville	110100010103
OSF1520-7.2	2	Boston Mtn	1520 road sign off 112	UT Mill Creek	Bidville	110100010103
OSF1521-0.8	1	Boston Mtn	23	Cripple Branch	Cass	111102010704
OSF1405-0.8	1	Pleasant Hill	57	UT Piney Creek	Rosetta	111102020801
OSF1405-1.6	1	Pleasant Hill	21	Clifty Hollow	Ozone	111102020801
OSF1409-0.9	1	Pleasant Hill	57	UT Piney Creek	Rosetta	111102020802
OSF1422-1.3	1	Pleasant Hill	182	Dry Sprada Creek	Harmony	111102020501
OSF1422-2.7	1	Pleasant Hill	182	UT Sprada Creek	Harmony	111102020501
OSF1426-0.3	1	Pleasant Hill	123	UT Little Piney Creek	Hagarville	111102020804
OSF1538-0.5	1	Pleasant Hill	502	Lumpkin Creek	Pettigrew	110100010102

Table continued next page…

Site ID	Pipe #	District	Junction Road	Stream Name	Quad	6th Level Watershed
OSF1538-1.0	1	Pleasant Hill	502	UT Lumpkin Creek	Pettigrew	110100010102
OSF1538-1.2	1	Pleasant Hill	502	Lumpkin Creek	Pettigrew	110100010102
OSF283-1.7	1	Pleasant Hill	164	Horsehead Creek	Hunt	111102020601
OSF353-0.2	1	Pleasant Hill	406	Little Mulberry Creek	Boston	111102010601
OSF36-0.3	1	Pleasant Hill	1425 A	UT Mulberry Creek	Oark	111102010604
OSF36-0.3	2	Pleasant Hill	1425 A	UT Mulberry Creek	Oark	111102010604
OSF407-0.1	1	Pleasant Hill	5151(409)	UT Mulberry Creek	Oark	111102010601
OSF5151-2.5	1	Pleasant Hill	407	Eldridge Hollow	Boston	111102010601
OSF5151-2.5	2	Pleasant Hill	407	Eldridge Hollow	Boston	111102010601
OSF5151-2.5	3	Pleasant Hill	407	Eldridge Hollow	Boston	111102010601

Table C4. Coarse filters A, B, and C, classifications for surveyed crossings on the Ozark-St. Francis National Forest, summer 2005.

Site ID	Pipe #	Filter A	Filter B	Filter C
OSF113-0.1	1	passable	indeterminate	indeterminate
OSF113-0.1	2	passable	indeterminate	indeterminate
OSF113-0.7	1	passable	indeterminate	impassable
OSF1813-0.05	1	passable	passable	impassable
OSF1813-1.3	1	indeterminate	impassable	impassable
OSF1813-1.6	1	passable	indeterminate	impassable
OSF1003-7.4	1	passable	impassable	impassable
OSF1501-2.4	1	indeterminate	impassable	impassable
OSF1501-2.4	2	indeterminate	impassable	impassable
OSF1509-0.4	1	passable	indeterminate	impassable
OSF1520-0.4	1	indeterminate	impassable	impassable
OSF1520-0.4	2	passable	impassable	impassable
OSF1520-0.4	3	passable	impassable	impassable
OSF1520-0.4	4	indeterminate	impassable	impassable
OSF1520-1.0	1	indeterminate	impassable	impassable
OSF1520-7.2	1	passable	passable	passable
OSF1520-7.2	2	passable	passable	passable
OSF1521-0.8	1	indeterminate	impassable	impassable
OSF1405-0.8	1	impassable	impassable	impassable
OSF1405-1.6	1	impassable	impassable	impassable
OSF1409-0.9	1	impassable	impassable	impassable
OSF1422-1.3	1	passable	passable	impassable
OSF1422-2.7	1	indeterminate	impassable	impassable
OSF1426-0.3	1	impassable	impassable	impassable
OSF1538-0.5	1	indeterminate	impassable	impassable
OSF1538-1.0	1	indeterminate	impassable	impassable
OSF1538-1.2	1	indeterminate	impassable	impassable
OSF283-1.7	1	passable	impassable	impassable
OSF353-0.2	1	passable	passable	passable
OSF36-0.3	1	indeterminate	impassable	impassable
OSF36-0.3	2	indeterminate	impassable	impassable
OSF407-0.1	1	passable	impassable	impassable
OSF5151-2.5	1	passable	passable	passable
OSF5151-2.5	2	passable	passable	Passable
OSF5151-2.5	3	passable	indeterminate	Indeterminate

Table C5. Description of crossings surveyed on the Ozark St. Francis National Forest, summer 2005. Shape abbreviations: C= circular, PA= pipe arch, OBA= open bottom arch, V= vented ford, B= box, and F= ford. Channel width is the mean bankfull channel width. N= no natural substrate, N (discontin)= discontinuous substrate, Y= continuous natural substrate. An NA (not applicable) indicates outlet drop (no outlet pool or tailwater control) or outlet perch (stream dry) could not be calculated. Negative outlet drop or perch values indicate a submerged outlet (structure partially backwatered). Residual inlet depth values ≥ 0.0 indicate the structure is fully backwatered.

Site ID	Pipe #	Shape	Pipe Condition	Mean Channel Width (ft)	Continuous Substrate in Structure	Pipe slope (%)	Pipe Width: Channel Width ratio	Outlet Drop (in)	Outlet Perch (in)	Residual Inlet Depth (in)	Pipe Length (ft)	Slope (%) * Length (ft)
OSF113-0.1	1	C	good	16.0	N	1.75	0.17	0.48	75.36	0.00	20.0	35.0
OSF113-0.1	2	C	good	16.0	N	1.80	0.17	1.20	76.08	0.00	20.0	36.0
OSF113-0.7	1	C	good	15.0	N	1.64	0.17	4.56	NA	0.00	24.4	40.0
OSF1813-.05	1	F	good	23.4	N	1.92	NA	NA	2.34	0.00	12.0	23.0
OSF1813-1.3	1	C	good	12.9	N	3.86	0.27	11.88	NA	0.00	36.8	142.0
OSF1813-1.6	1	F	good	19.2	N	1.97	NA	NA	2.40	0.00	15.0	29.5
OSF1003-7.4	1	B	good	28.8	N	0.88	0.26	22.32	17.76	0.00	13.0	11.5
OSF1501-2.4	1	B	good	29.7	N (discontin)	3.03	0.52	17.70	NA	0.00	63.3	192.0
OSF1501-2.4	2	B	good	29.7	N (discontin)	4.93	0.52	3.84	NA	0.00	63.3	312.0
OSF1509-0.4	1	F	good	13.8	N	3.00	NA	7.38	6.90	0.00	14.5	43.5
OSF1520-0.4	1	VF	fair	50.8	N	2.16	NA	18.24	11.70	0.00	24.1	52.0
OSF1520-0.4	2	VF	fair	50.8	N	1.49	NA	19.50	12.96	0.00	24.1	36.0
OSF1520-0.4	3	VF	fair	50.8	N	1.87	NA	19.68	13.14	0.00	24.1	45.0
OSF1520-0.4	4	VF	fair	50.8	N	2.72	NA	18.54	12.00	0.00	24.1	65.5
OSF1520-1.0	1	F	good	47.0	N	6.79	NA	-1.74	-2.16	0.00	16.8	114.0
OSF1520-7.2	1	B	poor	13.8	Y	5.52	0.29	-8.40	NA	0.00	20.0	110.5
OSF1520-7.2	2	B	poor	13.8	Y	0.65	0.29	3.30	NA	0.00	20.0	13.0
OSF1521-0.8	1	C	fair	19.0	N	1.65	0.42	11.88	8.88	0.00	42.3	70.0
OSF1405-0.8	1	C	fair	22.7	N	7.00	0.22	39.96	NA	0.00	40.0	280.0
OSF1405-1.6	1	F	fair	35.1	N	7.17	NA	12.00	NA	0.00	20.5	147.0
OSF1409-0.9	1	F	good	19.7	N	0.33	NA	40.56	27.42	0.00	12.2	4.0
OSF1422-1.3	1	F	good	26.1	N	0.32	NA	4.56	NA	0.00	20.0	6.5

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Site ID	Pipe #	Shape	Pipe Condition	Mean Channel Width (ft)	Continuous Substrate in Structure	Pipe slope (%)	Pipe Width: Channel Width ratio	Outlet Drop (in)	Outlet Perch (in)	Residual Inlet Depth (in)	Pipe Length (ft)	Slope (%) * Length (ft)
OSF1422-2.7	1	C	poor	17.4	N	4.01	0.32	21.06	18.60	0.00	28.2	113.0
OSF1426-0.3	1	C	fair	8.8	N	5.12	0.45	27.18	NA	0.00	36.7	188.0
OSF1538-0.5	1	PA	fair	17.3	N	4.00	0.29	9.42	5.28	0.00	39.5	158.0
OSF1538-1.0	1	PA	fair	11.4	N	6.41	0.40	23.40	21.60	0.00	29.0	186.0
OSF1538-1.2	1	PA	fair	18.4	N	4.75	0.28	10.56	22.80	0.00	32.0	152.0
OSF283-1.7	1	F	good	45.6	N	0.55	NA	17.46	13.26	0.00	15.4	8.5
OSF353-0.2	1	B	fair	74.7	Y	7.64	NA	-3.48	-12.24	0.00	14.0	107.0
OSF36-0.3	1	B	fair	16.9	N	4.12	0.24	22.44	NA	0.00	45.4	187.0
OSF36-0.3	2	B	fair	16.9	N	4.26	0.24	21.96	NA	0.00	45.4	193.5
OSF407-0.1	1	F	fair	26.5	N	1.68	NA	12.90	18.48	0.00	14.0	23.5
OSF5151-2.5	1	VF	good	24.7	N	0.05	0.05	2.88	-2.28	0.00	40.4	2.0
OSF5151-2.5	2	VF	good	24.7	Y	0.52	0.05	4.20	-0.96	0.00	40.4	21.0
OSF5151-2.5	3	VF	good	24.7	N	0.69	0.05	1.68	-3.48	0.00	40.4	28.0

Appendix D: Results for the National Forests in Alabama

We visited a total of 149 culverts on the Bankhead, Shoals Creek, and Talladega Ranger Districts in 2005 (Figure D1, Table D1) and completed surveys on 50% (n=75) of the 149 crossings (Table D2). Filter A (strong swimmers and leapers) classified 5% (n=4) of crossings as impassable, 39% (n=29) as passable, and 56% (n=42) as indeterminate (Figure D2, Table D2). Filter B (moderate swimmers and leapers) classified 56% (n=42) of crossings as impassable, 20% (n=15) as passable, and 24% (n=18) as indeterminate (Figure D3, Table D2). Filter C (weak swimmers and leapers) classified 76% (n=57) of crossings as impassable, 17% (n=13) as passable, and 7% (n=5) as indeterminate (Figure D4, Table D2). Characteristics and filter classifications for each crossing are presented in Tables D3-D5.

The majority of the crossings were either circular culverts (n=39) or pipe arches (n=21), while box culverts (n=10), vented fords (n=3), and open bottom arches (n=2) were less frequently encountered. Filter A classified 10% of box culverts, 5% of circular culverts and 4% of pipe arches impassable (Figure D5). Filter B classified 67% of circular culverts, 57% of pipe arches, and 40% of box culverts impassable (Figure D6). Filter C classified 87% of circular culverts, 80% of box culverts, 67% of pipe arches, and 33% of vented fords impassable (Figure D7). The open bottom arches surveyed were passable for all 3 filters.

The mean crossings width to channel width ratio for surveyed structures (excluding fords and vented fords) (n=43) was 0.65 (SD=0.34), and four crossings were greater than or equal to the mean bankfull channel width (i.e. crossing width to channel width ration was greater than or equal to 1.0) (Figure D8).

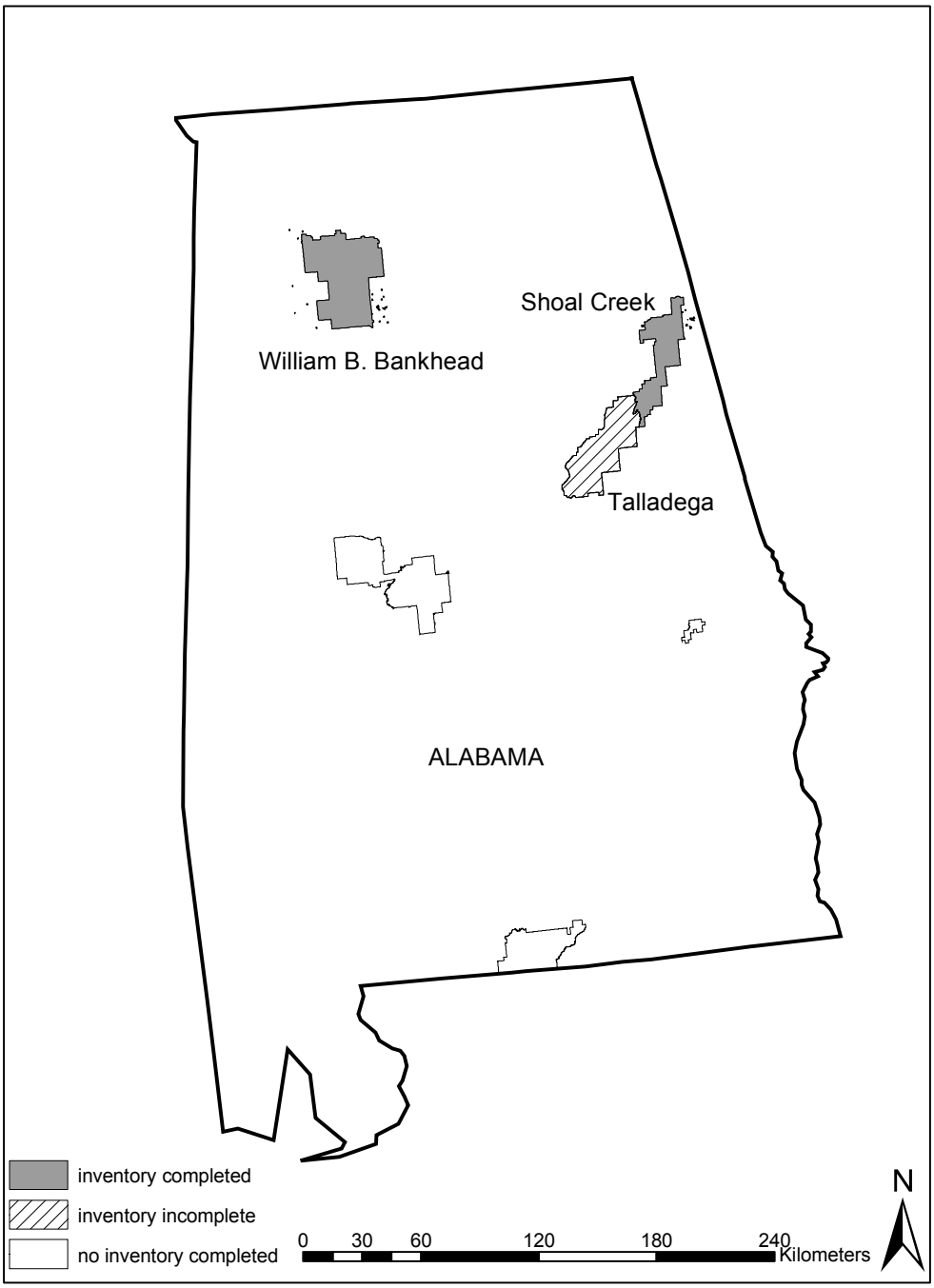

Figure D1. Ranger Districts on the National Forests in Alabama road-stream crossing surveys were conducted, summer 2005.

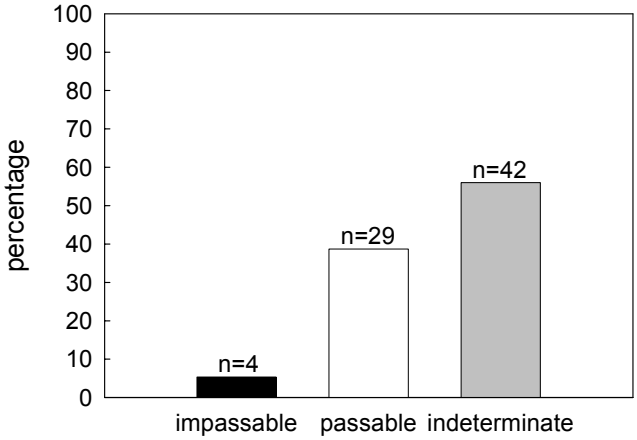

Figure D2. Percentage of crossings classified as impassable, passable, or indeterminate for Filter A; National Forests in Alabama (Bankhead and Talladega NFs), summer 2005 (N=75).

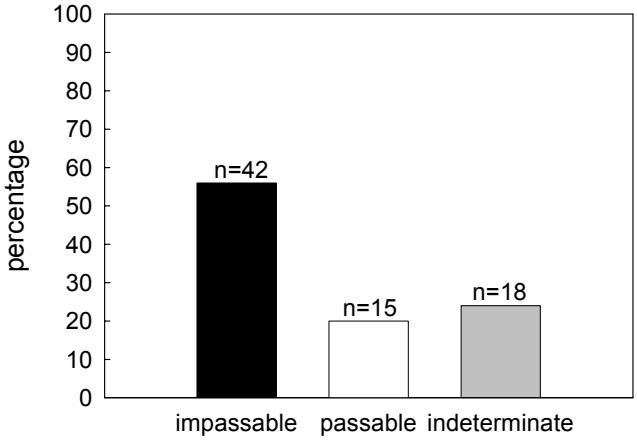

Figure D3. Percentage of crossings classified as impassable, passable, or indeterminate for Filter B; National Forests in Alabama (Bankhead and Talladega NFs), summer 2005 (N=75).

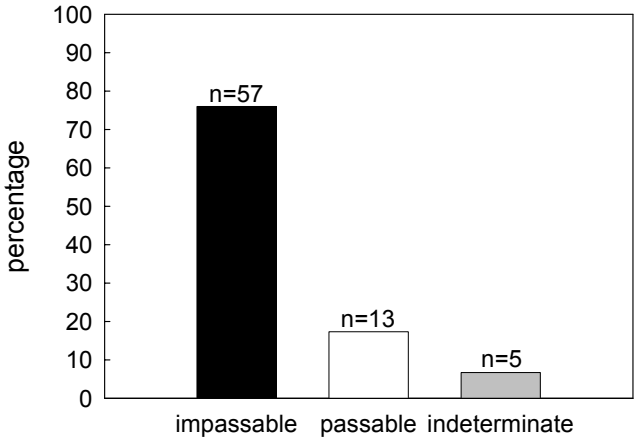

Figure D4. Percentage of crossings classified as impassable, passable, or indeterminate for Filter C; National Forests in Alabama (Bankhead and Talladega NFs), summer 2005 (N=75).

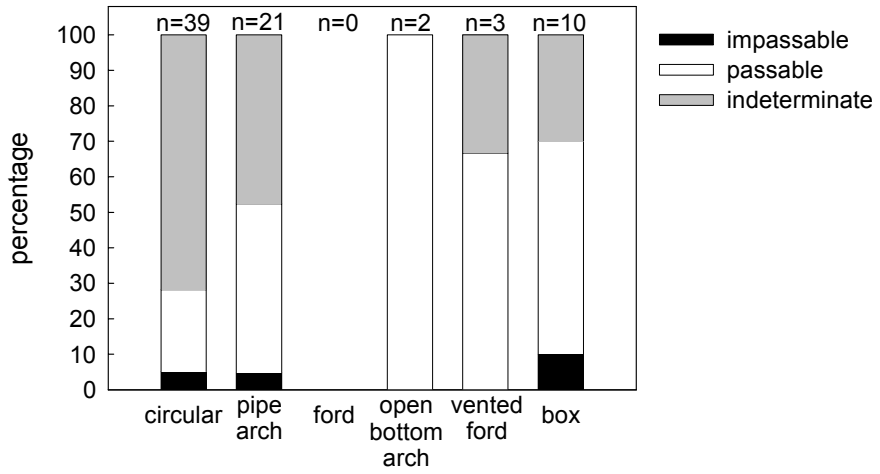

Figure D5. Percentage of each crossing type classified as impassable, passable, or indeterminate for Filter A; National Forests in Alabama (Bankhead and Talladega NFs), summer 2005 (N=75).

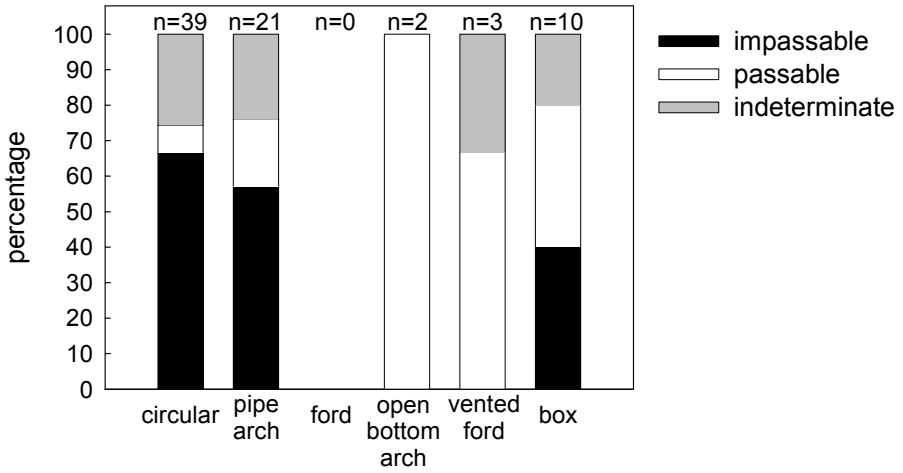

Figure D6. Percentage of each crossing type classified as impassable, passable, or indeterminate for Filter B; National Forests in Alabama (Bankhead and Talladega NFs), summer 2005 (N=75).

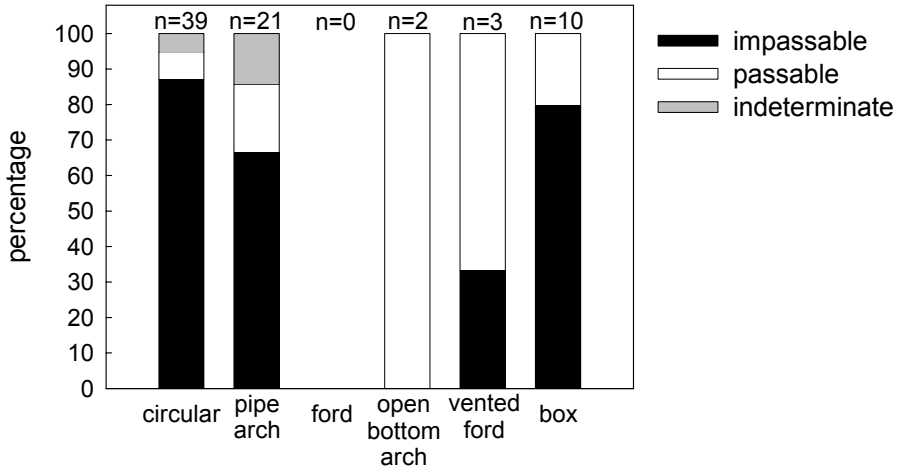

Figure D7. Percentage of each crossing type classified as impassable, passable, or indeterminate for Filter C; National Forests in Alabama (Bankhead and Talladega NFs), summer 2005 (N=75).

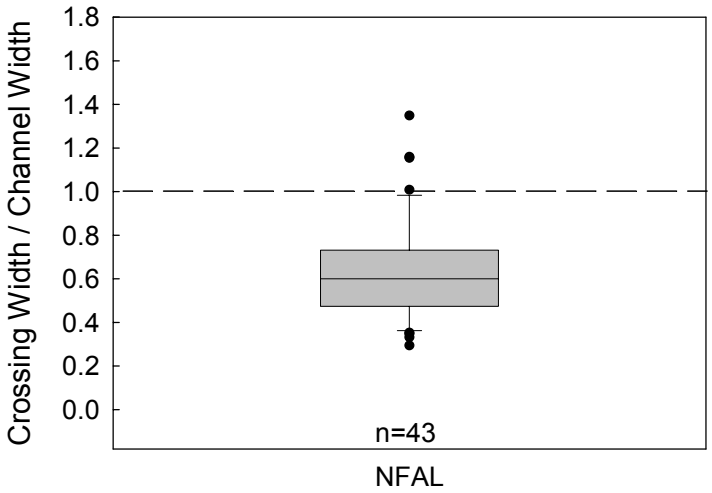

Figure D8. Crossing width to bankfull channel width ratio for crossings surveyed in summer 2005 on the National Forests in Alabama (Bankhead and Talladega NFs) (excluding fords, vented fords, and multiple structure crossings). A ratio of 1.0 (dashed line) or greater indicates the crossing structure opening is greater than or equal to the bankfull channel width. The top and bottom of the boxes represent the 25th and 75th percentiles, the bar in the center of each box represents the median, whiskers represent the 10th and 90th percentiles, and closed circles represent the entire range of the data.

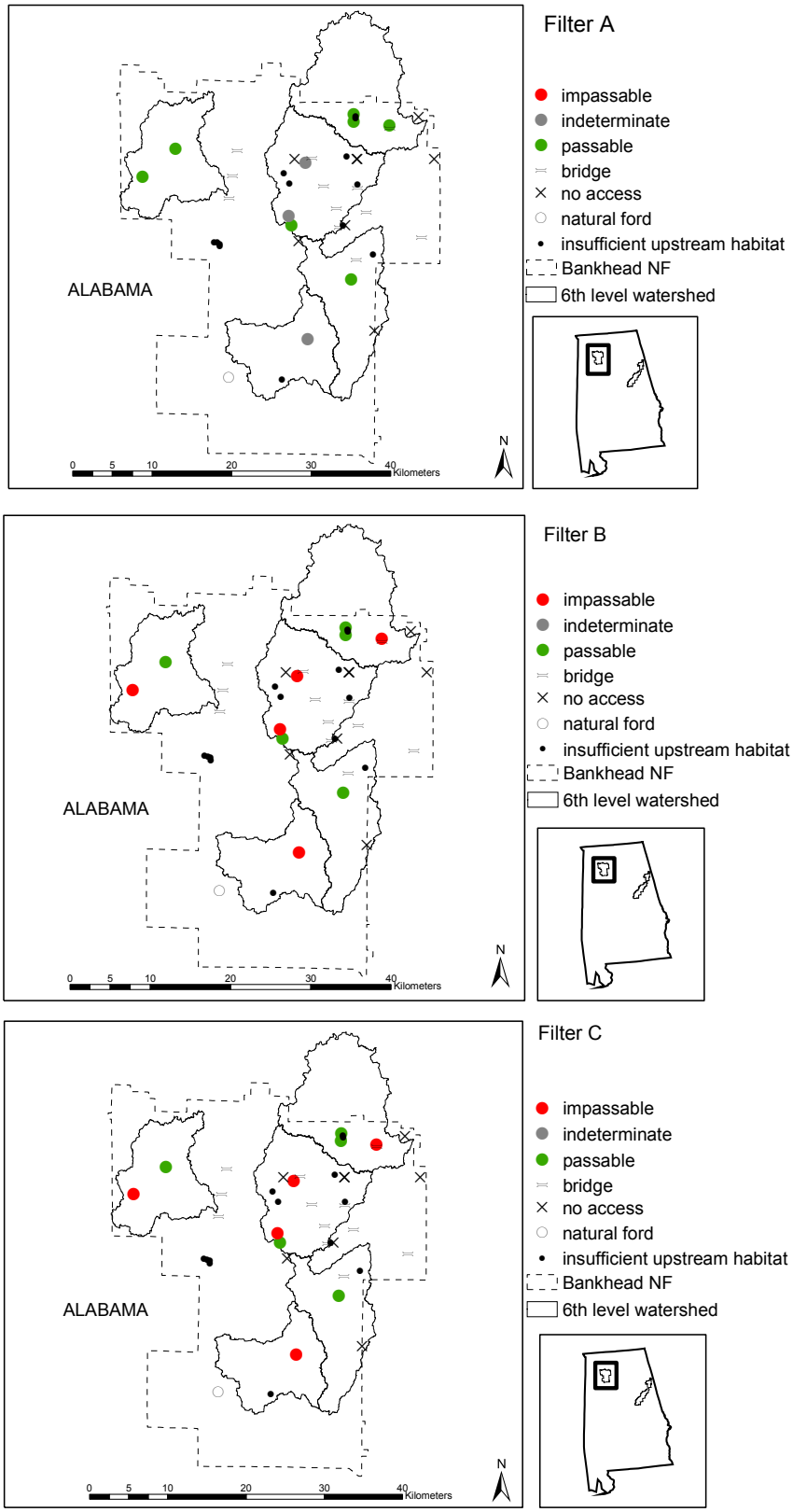

Figure D9. Location of crossings classified for fish passage by coarse filters A, B, and C within 6th level watersheds, and crossings not surveyed on the Bankhead National Forest in Alabama, summer 2005.

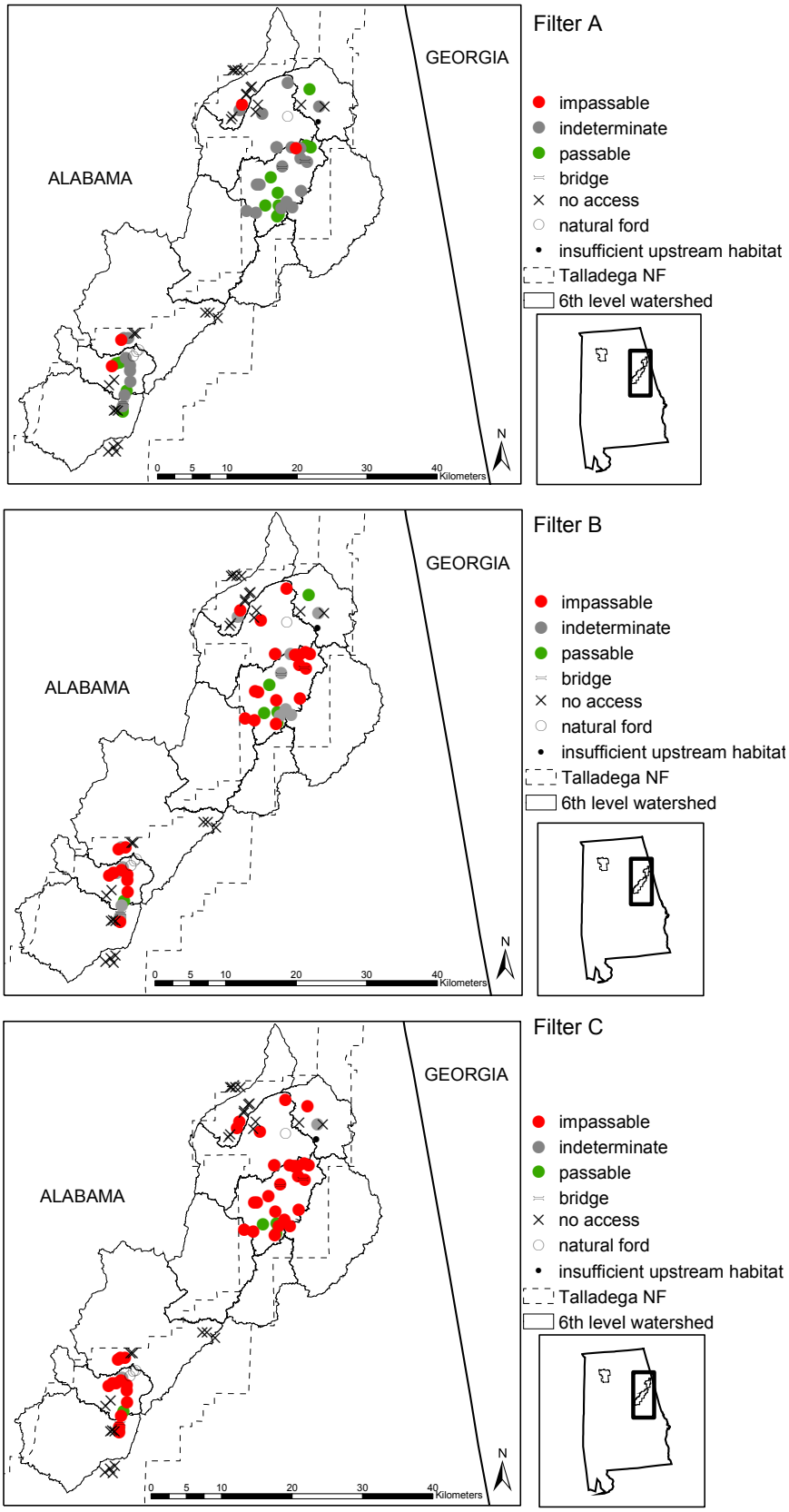

Figure D10. Location of crossings classified for fish passage by coarse filters A, B, and C within 6th level watersheds, and crossings not surveyed on the Talladega National Forest in Alabama, summer 2005.

Table D1. Number of crossings documented (Total crossings documented) and not surveyed (Crossings not surveyed) on the National Forests in Alabama (Bankhead and Talladega NFs) summer 2005. Reasons for not surveying a documented site include: no suitable fish habitat upstream of crossing (NH); no access to site due to closed roads or private gates (NA); crossing was a natural ford (NF); crossing was a bridge (BR).

Forest	Total crossings documented	Crossings not surveyed (n, [%])				
		NH	NA	NF	BR	Total not surveyed
NFAL	149	17 (23)	35 (47)	6 (8)	16 (22)	74 (50)

Table D2. Number of crossings surveyed (Total surveyed) with coarse filter results for the National Forests in Alabama (Bankhead and Talladega NFs) summer 2005. Coarse filter results are presented for Filter A, Filter B, and Filter C (see filter descriptions, Fig 3 – 5).

Forest	Total surveyed	Coarse filter results								
		Impassable (n, [%])			Passable (n, [%])			Indeterminate (n, [%])		
		A	B	C	A	B	C	A	B	C
NFAL	75	4 (5)	42 (56)	57 (76)	29 (39)	15 (20)	13 (17)	42 (56)	18 (24)	5 (7)

Table D3. Location of crossings surveyed on the National Forests in Alabama (Bankhead and Talladega NFs), summer of 2005. Site ID consists of the Forest abbreviation (BH), road the crossing is on (118A), and the distance (miles) from the junction road (0.3).

Site ID	Pipe #	District	Junction Road	Stream Name	Quad	6th Level Watershed
BH118A-0.3	1	Bankhead	118	Alford Spring	Houston	031601100105
BH160-0.9	1	Bankhead	160	Glover Creek	Addison	031601100203
BH160-0.9	2	Bankhead	160	Glover Creek	Addison	031601100203
BH204A-1.0	1	Bankhead	210	Basin Creek	Kinlock Spring	031601100101
BH204A-1.0	2	Bankhead	210	Basin Creek	Kinlock Spring	031601100101
BH204A-1.0	3	Bankhead	210	Basin Creek	Kinlock Spring	031601100101
BH208-4.0	1	Bankhead	203	Trib. Thompson Creek	Bee Branch	031601100101
BH248-0.35	1	Bankhead	63	Collier Creek Trib.	Grayson	031601100201
BH250-0.3	1	Bankhead	63	Collier Creek Trib.	Grayson	031601100201
BH254-0.45	1	Bankhead	246	Brushy Creek Trib.	Grayson	031601100201
BH254-0.45	2	Bankhead	246	Brushy Creek Trib.	Grayson	031601100201
BH264-1.5	1	Bankhead	49	Lee Creek	Upshaw	060300021005
BH264-1.5	2	Bankhead	49	Lee Creek	Upshaw	060300021005
BH264-2.15	1	Bankhead	249	Gillespie Creek	Oakville	060300021005
BH268-2.0	1	Bankhead	49	Trib. West Flint Creek	Upshaw	060300021005
BH268-2.0	2	Bankhead	49	Trib. West Flint Creek	Upshaw	060300021005
TNF500-0.7	1	Shoals Creek	553	Trib. Shoal Creek	Piedmont SE	031501060602
TNF500-1.2	1	Shoals Creek	55	Trib.Mary's Creek	Piedmont SE	031501050901
TNF500-1.3	1	Shoals Creek	500	Trib. Coleman Lake	Piedmont SE	031501060602
TNF500-1.4	1	Shoals Creek	553	Trib. Shoal Creek	Piedmont SE	031501060602
TNF500-1.7	1	Shoals Creek	553	Trib. Shoal Creek	Piedmont SE	031501060602
TNF500-11.2	1	Shoals Creek	281	Trib. Sweetwater Lake	Piedmont SE	031501060602
TNF500-2.2	1	Shoals Creek	change pavement to gravel	S. Fork Terrapin Creek	Piedmont SE	031501050901
TNF500-2.3	1	Shoals Creek	532	Trib. Shoal Creek	Piedmont SE	031501060602
TNF500-5.6	1	Shoals Creek	281	Trib. Highrock Lake	Heflin	031501060602
TNF500-5.8	1	Shoals Creek	281	Trib. Highrock Lake	Heflin	031501060602
TNF500-6.5	1	Shoals Creek	281	Trib. Highrock Lake	Heflin	031501060602
TNF500-6.5	2	Shoals Creek	281	Trib. Highrock Lake	Heflin	031501060602
TNF500-6.5	3	Shoals Creek	281	Trib. Highrock Lake	Heflin	031501060602
TNF500-6.8	1	Shoals Creek	281	Trib. Highrock Lake	Heflin	031501060602
TNF500-6.8	2	Shoals Creek	281	Trib. Highrock Lake	Heflin	031501060602

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Site ID	Pipe #	District	Junction Road	Stream Name	Quad	6th Level Watershed
TNF500-6.8	3	Shoals Creek	281	Trib. Highrock Lake	Heflin	031501060602
TNF500-8.2	1	Shoals Creek	281	Trib. Shoal Creek	Heflin	031501060602
TNF500-8.2	2	Shoals Creek	281	Trib. Shoal Creek	Heflin	031501060602
TNF500k-3.1	1	Shoals Creek	500	Dry Creek	Piedmont SE	031501060601
TNF522-0.5	1	Shoals Creek	522	Trib. Shoal Creek	Choccolocco	031501060602
TNF522-1.5	1	Shoals Creek	531	Trib. Choccolocco Creek	Choccolocco	031501060603
TNF529-1.2	1	Shoals Creek	500	Trib. Whitesides Mills Lake	Heflin	031501060602
TNF529-2.6	1	Shoals Creek	500	Trib. Whitesides Mills Lake	Choccolocco	031501060602
TNF529-2.6	2	Shoals Creek	500	Trib. Whitesides Mills Lake	Choccolocco	031501060602
TNF529-2.9	1	Shoals Creek	500	Trib. Whitesides Mills Lake	Choccolocco	031501060602
TNF531-0.2	1	Shoals Creek	548	Trib. Henry Creek	Heflin	031501080404
TNF531-1.1	1	Shoals Creek	500	Trib. Highrock Lake	Heflin	031501060602
TNF531-1.5	1	Shoals Creek	500	Trib. Highrock Lake	Heflin	031501060602
TNF531-1.5	2	Shoals Creek	500	Trib. Highrock Lake	Heflin	031501060602
TNF531-1.5	3	Shoals Creek	500	Trib. Highrock Lake	Heflin	031501060602
TNF532-0.9	1	Shoals Creek	500	Trib. Choccolocco Creek	Piedmont SE	031501060601
TNF532-1.0	1	Shoals Creek	500	Trib. Choccolocco Creek	Piedmont SE	031501060601
TNF548-0.2	1	Shoals Creek	500	Shoal Creek	Piedmont SE	031501060602
TNF548-0.2	2	Shoals Creek	500	Shoal Creek	Piedmont SE	031501060602
TNF548-2.7	1	Shoals Creek	531	Trib. Shoal Creek	Heflin	031501060602
TNF548-2.7	2	Shoals Creek	531	Trib. Shoal Creek	Heflin	031501060602
TNF553-1.9	1	Shoals Creek	500	Trib. Shoal Creek	Piedmont SE	031501060602
TNF553c-0.3	1	Shoals Creek	500	Trib. Shoal Creek	Piedmont SE	031501060602
TNF558a-0.9	1	Shoals Creek	570	Trib. Nances Creek	Jacksonville E	031501050905
TNF534r-0.1	1	Shoals Creek	55	Trib. Choccolocco Creek	Piedmont SE	031501060601
TNF600-0.9	1	Shoals Creek	385	Trib. Cheaha Creek	Cheaha Mt.	031501060608
TNF600-1.1	1	Shoals Creek	385	Trib. Cheaha Creek	Cheaha Mt.	031501060608
TNF570-0.1	1	Shoals Creek	change pavement to gravel	Trib. Nances Creek	Jacksonville E	031501050905
TNF486-0.7	1	Talladega	651	Trib. Salt Creek	Oxford	031501060606
TNF486-1.1	1	Talladega	651	Trib. Salt Creek	Oxford	031501060606
TNF486-1.1	2	Talladega	651	Trib. Salt Creek	Oxford	031501060606
TNF486-1.5	1	Talladega	651	Trib. Salt Creek	Oxford	031501060606
TNF486-1.9	1	Talladega	651	Trib. Salt Creek	Oxford	031501060606

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Site ID	Pipe #	District	Junction Road	Stream Name	Quad	6th Level Watershed
TNF486-1.9	2	Talladega	651	Trib. Salt Creek	Oxford	031501060606
TNF486-2.4	1	Talladega	651	Trib. Salt Creek	Oxford	031501060606
TNF600-1.5	1	Talladega	385	Cheaha Creek Trib.	Cheaha Mt.	031501060608
TNF643-0.7	1	Talladega	651	Trib. Dry Branch	Oxford	031501060604
TNF643-1.1	1	Talladega	651	Trib. Dry Branch	Oxford	031501060604
TNF643-1.3	1	Talladega	651	Trib. Dry Branch	Oxford	031501060604
TNF651-0.9	1	Talladega	CR 42	Trib. Salt Creek	Oxford	031501060606
TNF651-1.4	1	Talladega	CR 42	Salt Creek Trib.	Oxford	031501060606
TNF651-2.5	1	Talladega	CR 42	Dry Creek Trib.	Cheaha Mt.	031501060606
TNF651-3.2	1	Talladega	CR 42	Trib. Cheaha Creek	Cheaha Mt.	031501060606
TNF651-3.9	1	Talladega	CR 42	Dry Creek Trib.	Cheaha Mt.	031501060606

Table D4. Coarse filters A, B, and C, classifications for surveyed crossings on the National Forest in Alabama (Bankhead and Talladega NFs), summer 2005.

Site ID	Pipe #	Filter A	Filter B	Filter C
BH118A-0.3	1	indeterminate	impassable	impassable
BH160-0.9	1	indeterminate	indeterminate	indeterminate
BH160-0.9	2	passable	passable	passable
BH204A-1.0	1	passable	impassable	impassable
BH204A-1.0	2	passable	impassable	impassable
BH204A-1.0	3	passable	impassable	impassable
BH208-4.0	1	passable	passable	passable
BH248-0.35	1	indeterminate	impassable	impassable
BH250-0.3	1	passable	passable	passable
BH254-0.45	1	indeterminate	impassable	impassable
BH254-0.45	2	indeterminate	impassable	impassable
BH264-1.5	1	passable	passable	passable
BH264-1.5	2	passable	passable	passable
BH264-2.15	1	passable	passable	passable
BH268-2.0	1	passable	impassable	impassable
BH268-2.0	2	indeterminate	impassable	impassable
TNF500-0.7	1	indeterminate	indeterminate	impassable
TNF500-1.2	1	indeterminate	indeterminate	indeterminate
TNF500-1.3	1	impassable	impassable	impassable
TNF500-1.4	1	indeterminate	impassable	impassable
TNF500-1.7	1	indeterminate	impassable	impassable
TNF500-11.2	1	indeterminate	indeterminate	impassable
TNF500-2.2	1	passable	passable	impassable
TNF500-2.3	1	passable	impassable	impassable
TNF500-5.6	1	passable	impassable	impassable
TNF500-5.8	1	passable	passable	passable
TNF500-6.5	1	indeterminate	indeterminate	impassable
TNF500-6.5	2	indeterminate	indeterminate	impassable
TNF500-6.5	3	indeterminate	indeterminate	impassable
TNF500-6.8	1	passable	passable	passable
TNF500-6.8	2	passable	indeterminate	indeterminate
TNF500-6.8	3	passable	passable	passable
TNF500-8.2	1	passable	impassable	impassable
TNF500-8.2	2	indeterminate	impassable	impassable
TNF500k-3.1	1	indeterminate	impassable	impassable
TNF522-0.5	1	indeterminate	impassable	impassable
TNF522-1.5	1	indeterminate	impassable	impassable
TNF529-1.2	1	passable	passable	impassable
TNF529-2.6	1	indeterminate	impassable	impassable
TNF529-2.6	2	indeterminate	impassable	impassable
TNF529-2.9	1	indeterminate	impassable	impassable
TNF531-0.2	1	indeterminate	indeterminate	impassable
TNF531-1.1	1	indeterminate	indeterminate	impassable
TNF531-1.5	1	indeterminate	indeterminate	impassable
TNF531-1.5	2	passable	passable	passable

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Site ID	Pipe #	Filter A	Filter B	Filter C
TNF531-1.5	2	passable	passable	passable
TNF531-1.5	3	passable	passable	passable
TNF532-0.9	1	indeterminate	indeterminate	indeterminate
TNF532-1.0	1	indeterminate	impassable	impassable
TNF548-0.2	1	indeterminate	impassable	impassable
TNF548-0.2	2	passable	impassable	impassable
TNF548-2.7	1	indeterminate	impassable	impassable
TNF548-2.7	2	indeterminate	impassable	impassable
TNF553-1.9	1	indeterminate	impassable	impassable
TNF553c-0.3	1	indeterminate	impassable	impassable
TNF558a-0.9	1	indeterminate	indeterminate	impassable
TNF534r-0.1	1	indeterminate	impassable	impassable
TNF600-0.9	1	indeterminate	indeterminate	impassable
TNF600-1.1	1	passable	passable	passable
TNF570-0.1	1	impassable	impassable	impassable
TNF486-0.7	1	indeterminate	indeterminate	indeterminate
TNF486-1.1	1	passable	impassable	impassable
TNF486-1.1	2	passable	impassable	impassable
TNF486-1.5	1	passable	indeterminate	impassable
TNF486-1.9	1	passable	impassable	impassable
TNF486-1.9	2	indeterminate	impassable	impassable
TNF486-2.4	1	impassable	impassable	impassable
TNF600-1.5	1	passable	impassable	impassable
TNF643-0.7	1	indeterminate	impassable	impassable
TNF643-1.1	1	indeterminate	indeterminate	impassable
TNF643-1.3	1	impassable	impassable	impassable
TNF651-0.9	1	indeterminate	impassable	impassable
TNF651-1.4	1	indeterminate	impassable	impassable
TNF651-2.5	1	indeterminate	impassable	impassable
TNF651-3.2	1	passable	passable	passable
TNF651-3.9	1	indeterminate	indeterminate	impassable

Table D5. Description of crossings surveyed on the National Forests in Alabama (Bankhead and Talladega NFs) summer 2005. Shape abbreviations: C= circular, PA= pipe arch, OBA= open bottom arch, and F= ford. Channel width is the mean bankfull channel width. N= no natural substrate, N (discontin)= discontinuous substrate, Y= continuous natural substrate. An NA (not applicable) indicates outlet drop (no outlet pool or tailwater control) or outlet perch (stream dry) could not be calculated. Negative outlet drop or perch values indicate a submerged outlet (structure partially backwatered). Residual inlet depth values ≥ 0.0 indicate the structure is fully backwatered.

Site ID	Pipe #	Shape	Pipe Condition	Mean Channel Width (ft)	Continuous Substrate in Structure	Pipe slope (%)	Pipe Width: Channel Width ratio	Outlet Drop (in)	Outlet Perch (in)	Residual Inlet Depth (in)	Pipe Length (ft)	Slope (%) * Length (ft)
BH118A-0.3	1	C	fair	6.0	N	0.93	0.92	17.76	12.96	0.00	80.0	74.0
BH160-0.9	1	PA	fair	23.7	N	3.02	0.30	-9.36	6.36	0.00	28.5	86.0
BH160-0.9	2	PA	fair	23.7	N	0.72	0.27	-2.52	13.20	5.16	30.4	22.0
BH204A-1.0	1	PA	good	15.6	N	1.00	0.45	16.08	7.08	0.00	33.0	33.0
BH204A-1.0	2	PA	good	15.6	N	0.79	0.45	16.32	7.32	0.00	33.0	26.0
BH204A-1.0	3	PA	good	15.6	N	0.73	0.45	16.44	7.44	0.00	33.0	24.0
BH208-4.0	1	OBA	good	5.9	Y	0.00	1.35	4.20	-1.20	0.00	21.0	0.0
BH248-0.35	1	C	fair	4.2	N	2.93	0.94	14.40	13.80	0.00	41.0	120.0
BH250-0.3	1	C	good	3.5	Y	5.20	1.16	3.60	-6.60	0.00	63.5	330.0
BH254-0.45	1	C	poor	8.8	N	1.88	0.51	18.00	12.60	0.00	32.0	60.0
BH254-0.45	2	C	poor	8.8	N	2.50	0.51	16.80	11.40	0.00	32.0	80.0
BH264-1.5	1	C	good	17.1	N	1.33	0.20	-14.28	-22.20	19.08	30.0	40.0
BH264-1.5	2	C	good	17.1	N	0.47	0.20	-8.40	-16.32	10.08	30.0	14.0
BH264-2.15	1	PA	poor	16.7	N	3.00	0.35	NA	-24.00	0.96	21.0	63.0
BH268-2.0	1	PA	fair	4.6	N	1.13	1.17	16.68	8.88	0.00	32.0	36.0
BH268-2.0	2	PA	fair	4.6	N	1.91	1.17	17.76	9.96	0.00	27.0	51.5
TNF500-0.7	1	C	fair	6.2	N	1.88	0.73	4.20	2.88	0.00	66.5	125.0
TNF500-1.2	1	C	good	7.8	N	1.94	0.38	2.16	0.60	0.00	35.0	68.0
TNF500-1.3	1	C	fair	4.5	N	0.88	1.01	25.44	21.84	0.00	81.4	72.0
TNF500-1.4	1	C	fair	5.3	N	1.24	0.79	13.92	6.12	0.00	80.9	100.0
TNF500-1.7	1	C	fair	4.3	N	2.12	1.15	3.00	4.08	0.00	112.8	239.0
TNF500-11.2	1	C	fair	4.5	N	1.94	0.55	4.68	1.68	0.00	33.0	64.0

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Site ID	Pipe #	Shape	Pipe Condition	Mean Channel Width (ft)	Continuous Substrate in Structure	Pipe slope (%)	Pipe Width: Channel Width ratio	Outlet Drop (in)	Outlet Perch (in)	Residual Inlet Depth (in)	Pipe Length (ft)	Slope (%) * Length (ft)
TNF500-2.2	1	B	excellent	14.2	N	0.02	0.35	6.66	-0.54	0.00	24.0	0.5
TNF500-2.3	1	C	good	5.7	N	0.64	0.71	15.36	26.04	0.00	73.0	47.0
TNF500-5.6	1	B	good	11.1	N	0.19	0.90	12.48	9.12	0.00	31.7	6.0
TNF500-5.8	1	B	good	11.8	N	1.45	0.68	-13.20	-16.44	9.72	20.0	29.0
TNF500-6.5	1	C	good	6.3	N	2.03	0.40	5.04	1.68	0.00	39.0	79.0
TNF500-6.5	2	C	good	6.3	N	3.31	0.40	5.88	2.52	0.00	39.0	129.0
TNF500-6.5	3	C	good	6.3	N	2.85	0.40	5.04	1.68	0.00	39.0	111.0
TNF500-6.8	1	PA	fair	13.7	Y	0.08	0.40	NA	-2.64	0.00	26.4	2.0
TNF500-6.8	2	PA	fair	13.7	N (discontin)	1.33	0.40	NA	-4.44	0.00	26.4	35.0
TNF500-6.8	3	PA	fair	13.7	Y	0.30	0.40	NA	2.64	0.00	26.4	8.0
TNF500-8.2	1	C	poor	7.4	N	0.81	0.34	17.28	15.36	0.00	37.0	30.0
TNF500-8.2	2	C	poor	7.4	N	1.82	0.34	14.40	12.48	0.00	37.0	67.5.
TNF500k-3.1	1	C	good	9.6	N	5.59	0.73	13.20	11.52	0.00	34.0	190.0
TNF522-0.5	1	C	poor	6.1	N (discontin)	3.59	0.41	-3.12	-4.38	0.00	57.0	204.5
TNF522-1.5	1	C	good	5.5	N	3.74	0.73	13.20	10.32	0.00	49.6	185.5
TNF529-1.2	1	B	good	12.5	N	0.40	0.80	5.64	0.48	0.00	16.3	6.5
TNF529-2.6	1	C	good	14.4	N (discontin)	1.45	0.38	18.48	13.08	0.00	48.2	70.0
TNF529-2.6	2	C	good	14.4	N	1.36	0.38	18.66	13.26	0.00	48.2	65.5
TNF529-2.9	1	C	good	8.0	N	2.05	0.63	12.84	10.08	0.00	48.3	99.0
TNF531-0.2	1	PA	good	8.3	N	1.63	0.67	7.68	-1.20	0.00	41.0	67.0
TNF531-1.1	1	PA	fair	11.7	N	0.92	0.47	9.96	7.08	0.00	147.5	136.0
TNF531-1.5	1	VF	good	28.3	N	2.81	0.18	-2.88	-23.52	0.00	60.1	169.0
TNF531-1.5	2	VF	good	28.3	Y	0.35	0.18	-6.84	-27.48	4.32	60.1	21.0
TNF531-1.5	3	VF	good	28.3	N	0.62	0.18	-5.52	-26.16	9.96	60.1	37.0
TNF532-0.9	1	PA	good	8.5	N	2.74	0.59	3.24	0.72	0.00	31.7	87.0

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Site ID	Pipe #	Shape	Pipe Condition	Mean Channel Width (ft)	Continuous Substrate in Structure	Pipe slope (%)	Pipe Width: Channel Width ratio	Outlet Drop (in)	Outlet Perch (in)	Residual Inlet Depth (in)	Pipe Length (ft)	Slope (%) * Length (ft)
TNF532-1.0	1	C	good	5.6	N	3.92	0.53	3.72	0.96	0.00	31.1	122.0
TNF548-0.2	1	PA	fair	10.8	N	2.17	0.56	11.16	3.36	0.00	35.0	76.0
TNF548-0.2	2	PA	fair	10.8	N	0.60	0.56	17.16	9.36	0.00	35.0	21.0
TNF548-2.7	1	PA	good	10.3	N	3.60	0.53	0.36	-3.72	0.00	53.0	191.0
TNF548-2.7	2	PA	good	10.3	N	1.19	0.53	19.08	15.00	0.00	53.0	63.0
TNF553-1.9	1	B	fair	16.7	N	2.67	0.60	14.88	10.68	0.00	30.7	82.0
TNF553c-0.3	1	C	fair	6.6	N	4.81	0.38	-3.60	-5.94	0.00	32.2	155.0
TNF558a-0.9	1	C	poor	7.1	N	2.85	0.56	6.60	4.56	0.00	65.0	185.0
TNF534r-0.1	1	C	poor	7.8	N	6.06	0.64	-2.76	-6.24	0.00	39.8	241.0
TNF600-0.9	1	B	good	10.7	N	2.62	0.56	7.08	15.00	0.00	24.0	63.0
TNF600-1.1	1	B	good	7.1	Y	1.00	0.85	-0.60	-0.72	0.00	8.0	8.0
TNF570-0.1	1	PA	good	7.9	N	1.49	0.38	27.66	25.02	0.00	30.5	45.5
TNF486-0.7	1	C	good	6.0	N	3.16	0.33	3.60	0.12	0.00	25.0	79.0
TNF486-1.1	1	C	poor	4.5	N	1.71	0.44	21.60	6.24	0.00	24.5	42.0
TNF486-1.1	2	C	poor	4.5	N	2.02	0.44	19.68	4.32	0.00	24.5	49.5
TNF486-1.5	1	C	fair	6.8	N (discontin)	1.63	0.29	9.24	NA	0.00	24.5	40.0
TNF486-1.9	1	C	good	7.4	N	0.40	0.34	18.72	17.52	0.00	24.7	10.0
TNF486-1.9	2	C	good	7.4	N	3.28	0.34	14.76	13.56	0.00	24.7	81.0
TNF486-2.4	1	C	fair	4.3	N	7.14	0.59	-4.32	-4.92	0.00	21.0	150.0
TNF600-1.5	1	B	good	7.1	N	1.88	0.56	14.40	11.76	0.00	24.0	45.0
TNF643-0.7	1	PA	poor	9.1	N	3.39	0.64	15.18	14.28	0.00	60.5	205.0
TNF643-1.1	1	B	good	13.9	N	0.88	0.43	8.28	4.92	0.00	56.8	50.0
TNF643-1.3	1	B	good	14.7	N	7.17	0.54	-9.96	-10.92	0.00	29.0	208.0
TNF651-0.9	1	C	good	5.5	N	3.64	0.73	3.12	0.00	0.00	42.0	153.0
TNF651-1.4	1	PA	poor	14.0	N	2.75	0.64	10.32	5.04	0.00	48.3	133.0

Table continued next page…

Site ID	Pipe #	Shape	Pipe Condition	Mean Channel Width (ft)	Continuous Substrate in Structure	Pipe slope (%)	Pipe Width: Channel Width ratio	Outlet Drop (in)	Outlet Perch (in)	Residual Inlet Depth (in)	Pipe Length (ft)	Slope (%) * Length (ft)
TNF651-2.5	1	C	good	7.2	N	5.68	0.56	15.24	12.6	0.00	37.0	210.0
TNF651-3.2	1	OBA	good	22.8	Y	4.15	0.47	-3.24	-8.76	0.00	108.7	451.0
TNF651-3.9	1	C	good	3.9	N (discontin)	2.62	0.52	8.40	6.36	0.00	24.0	63.0