No. 142, Original

In the

Supreme Court of the United States

STATE OF FLORIDA,

Plaintiff,

v.

STATE OF GEORGIA,

Defendant.

Before the Special Master

Hon. Ralph I. Lancaster

UPDATED PRE-FILED DIRECT TESTIMONY OF FLORIDA WITNESS J. DAVID ALLAN, PH.D

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INTRODUCTION

1. My name is J. David Allan. I have a Ph.D in biology, and have worked in the field of river ecology for over 45 years. I am a professor emeritus at, and former dean of, the School of Natural Resources and Environment at the University of Michigan. Scientists in my field are in broad consensus that long term changes in river flow can radically alter a natural system, leading to severe ecological damage as biological communities and ecosystem functions are altered, often irreversibly. Commonly, native plant and animal species are replaced by other species more tolerant of degraded habitat conditions, the complex food web becomes simplified and less resilient, and the changes to the supply of nutrients can pollute or starve inter-connected ecosystems. This is sadly not a new phenomenon: this scenario has played out with terrible and permanent results in the United States and around the world as a result of water resource use and pollution. Well-known examples include the Colorado River, the Murray-Darling in Australia, and numerous rivers throughout the United States and Europe.

2. In my field, experts use analytical tools to assess these types of risks, including assessing how frequently reduced river flows are stressing natural populations of aquatic and terrestrial life. We use these tools to predict long-term impacts. I develop and use those tools here and focus on four exemplary "target" populations in the Apalachicola River and Floodplain which represent a variety of species, habitats, and ecological requirements—mussels, fish, the Gulf sturgeon, and the swamp trees in the floodplain forest. Because of their variety, I consider these four populations to be surrogates for harm to the hundreds of other unique and in some cases endangered plant and animal species reliant upon flow in the Apalachicola River and floodplain. If harmful events to these target populations occur with increasing frequency, we can accurately predict a likelihood of significant long term harmful change to a system, permanently and

fundamentally altering its ecology. Here, the metrics for these target populations produced dramatic results. Without a remedy in the near term, it is highly likely that the system will face fundamental long term and potentially irreversible damage.

3. Specifically, based on my review of all the relevant Apalachicola-specific historic records, literature, and data, I conclude the following:

a. The Apalachicola River is a national treasure. There are few remaining rivers in the United States that rival the Apalachicola in diversity of species of all kinds—invertebrates, fish, amphibians, reptiles, birds, and mammals. The River has historically been a highly productive system that has suffered and continues to face significant risk as a result of flow reductions.

b. There is indisputable evidence of significant increases in harm to various populations, including mussels, fish, and trees of the floodplain forest over the past decades as flows in the Apalachicola River have decreased. As the objective data show, low flows are now more common than ever, causing harm to many species in the River basin as their habitats dry up. (*See* Figure 1 (mussel flats), Figure 3

Figure 1 - Mussel flats in the main channel become exposed at low flows, stranding and killing many mussels. This is a photo of Kentucky Landing in 2006, when flows were about 6,000 cfs. This is a true and accurate copy of a photo I used in my expert report (FX-790, Fig. 8C). This kind of photograph is regularly relied upon by experts in my field, and I reviewed and relied upon this photograph in forming my opinions in this case.

(slough), Figure 4 (trees))

c. As I explain below, I used specific "metrics" for sample or target species, or groups of species, to evaluate harm to the ecosystem as a whole. Those metrics show that harm has significantly increased over time. (*See* metric example graph, Figure 2) An increase in flows reaching the Apalachicola could meaningfully mitigate this harm, and halt the process that is currently leading to permanent damage to the system, as shown in my metrics, which are explained below.

d. Even relatively modest increases in flows—on the order of 300 to 500 cfs during key periods of the year—could reduce harm to the ecosystem and halt the cycle that is leading to irreversible harm. Greater increases could make even more dramatic improvements.

e. Species of fish and mussels in Georgia's Flint River Basin have also suffered harm because of reduced flows, and would also benefit from increases in flow in the Flint River Basin. Because some species of fish pass through the Woodruff dam to Florida, increases in fish population in the Flint River Basin would also directly benefit Florida.

f. If flows continue to hit extreme lows, as they have in 2012, or reach even lower levels as consumption increases, the Apalachicola River ecosystem faces extreme risk, and is likely to pass a point after which it cannot recover.

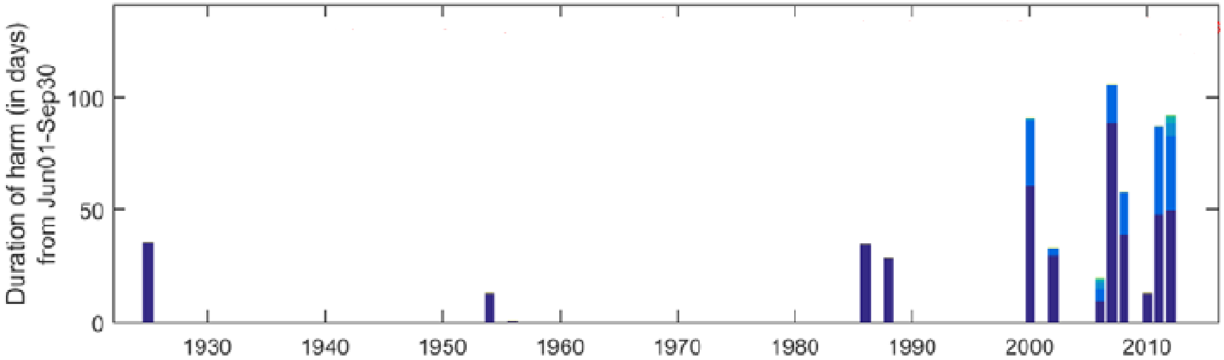
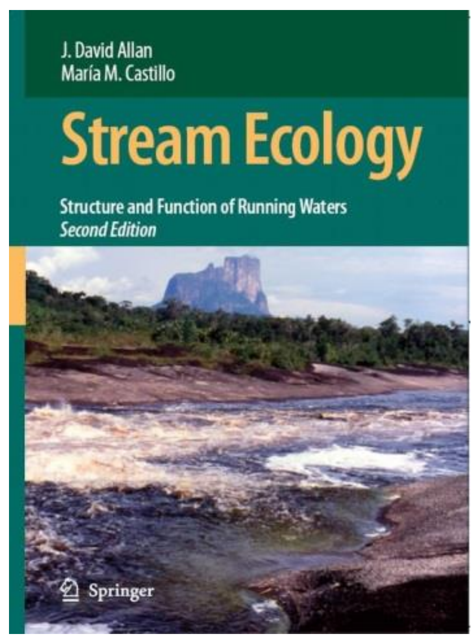


Figure 2 - A graph of one of the harm metrics showing how harm to mussels in Swift Slough has increased over time; as flows have become dramatically lower, harm has increased in recent years. The metric is explained in more detail in Section III below. This is a true and accurate copy of a chart reflecting my harm metrics against the record of historical flow. It was created under my supervision, using scientifically valid methodology, for use in my expert report (FX-790, App'x D.III.A.3.a).

PROFESSIONAL BACKGROUND

4. I am currently a professor emeritus in the School of Natural Resources & Environment at the University of Michigan. I was an Associate Dean at the School from 2007 to 2011, and Interim Dean for two years during that period. Since completing my Ph.D. in 1971, I have over 45 years of experience as a researcher, university professor and consultant to governmental agencies and non-governmental organizations. I am a recognized expert on all aspects of river ecology, having published the principal textbook in this field—*Stream Ecology: Structure and Function of Running Waters*. I also co-led and co-authored the most widely cited paper in the literature on the environmental flow needs



of rivers, *The Natural Flow Regime: A Paradigm for River Conservation and Restoration*, and also the most widely cited paper in the literature on river restoration, *Synthesizing U.S. River Restoration Efforts*.

5. I have extensive experience in the practical application of ecological principles to river ecology and management. I frequently advise a variety of organizations and governments on these issues. I have consulted for EPA on the development of metrics to assess human impact on aquatic ecosystems, and most recently served on a sub-committee of EPA's Science Advisory Board regarding the jurisdictional extent of the Clean Water Act. I have advised local watershed organizations and major non-governmental agencies, including The Nature Conservancy and American Rivers, and have served on their boards. At present I am a member of the Great Lakes Advisory Board (an advisor to the EPA Administrator on Great Lakes restoration), and the Science Advisory Board of the International Joint Commission (created by the U.S and Canada to regulate shared water uses and recommend solutions to transboundary issues).

6. My work has involved field studies of rivers and streams throughout North America and elsewhere, including biological sampling and measurement of water quality and physical habitat. I have specific technical expertise in the development and application of biological metrics to assess the ecological condition of rivers and streams. I have published extensively in scientific journals (over 120 peer reviewed publications and two books).

I. OVERVIEW OF THE ECOLOGICAL SIGNIFICANCE OF THE APALACHICOLA RIVER AND FLOODPLAIN

A. *Definitions*

7. For ease of understanding, I want to explain several terms that I will be using throughout my testimony:

Figure 3 – Top: Swift Slough during low flows in May 2012 (around 5,300 cfs). The slough dries up, stranding mussels (as seen at the bottom of the picture) and stressing or killing fish.
Bottom: Low-flow conditions in a tupelo swamp near Iamonia Lake in 1993. Without sufficient flow, the swamp is not inundated, and swamp tree species cannot germinate and grow. These are true and accurate copies of photos I used in my expert report (FX-790, Fig. 11D, Fig.6H). This kind of photograph is regularly relied upon by experts in my field, and I reviewed and relied upon these photographs in forming my opinions in this case.

a. **Microhabitat:** Habitat is the natural environment in which an aquatic or terrestrial organism lives. Microhabitats are the localized, small-scale habitats where environmental conditions meet the requirements of some particular set of species, and each microhabitat type will differ in which species are present. Microhabitats range in size from a few centimeters to tens of meters, and are characterized by a particular combination of depth, current speed and bottom substrate (such as sand, gravel or bedrock), the presence of tree roots or a fallen tree, the extent of shade or exposure to sun, etc.

b. **Floodplain:** This is typically the area adjacent to a river that is inundated during periods of high discharge. As is typically the case in the Apalachicola, water flows out of the main channel through sloughs and side channels, even at lower flows, into the floodplain and inundates low-lying areas. During wet months (roughly January through May), more and more of these channels become connected as flows increase and river level rises. The

Apalachicola floodplain is 1 to 5 miles wide, and becomes wider near the lower end of the River as it naturally "fans out" in the flatter lands near the coast.

c. **Slough** (pronounced *slew*)**:** These channels are typical in low-lying, swampy areas, branching off from the main channel of the River and becoming connected to the River as flows rise. They are low areas of soft, muddy ground within the floodplain that allow water to enter the floodplain when the river level rises. Each slough has its own "connecting flow," the level at which water can enter the slough through an opening in the River bank. Sloughs are important habitat for mussels and fish, as well as swamp trees, because they substantially increase the volume of habitat and spread water throughout the floodplain.

d. **Channel margin:** The channel margin is the interface between river and land. It may be gradual or steep, and the location of the channel margin moves up and down in elevation with water level. The channel margin is thus a specific microhabitat category. In some locations, the channel margin is characterized by a very gradual slope and undulating topography, creating "channel flats" that organisms may colonize at certain flows, only to become trapped and exposed by even small reductions in River flow when flow is already naturally low.

e. **Woody debris:** Submerged wood including logs, sticks, branches, and other wood that falls into streams and the River. Because it provides food, shelter, and allows water to pool behind it, woody debris is one type of microhabitat.

f. **Assemblage:** A group of species together. For instance, the "mussel assemblage" is all of the different mussel species in the Apalachicola River considered as a whole and the fish assemblage is various fish species in the Apalachicola River considered as a whole.

Figure 4 – On the left, a tupelo swamp in 1978, with sparse ground cover. On the right, a hydrologically altered swamp with dense ground cover in 2006. When flows decrease swamps no longer are inundated, allowing grasses and other plants to establish, crowd out swamp tree seedlings and thus change the swamp forest, eventually causing its replacement by non-swamp species. These are true and accurate copies of photos I used in my expert report (FX-790, Fig. 25). This kind of photograph is regularly relied upon by experts in my field, and I reviewed and relied upon these photographs in forming my opinions in this case.

g. **Food web:** The way in which all species – from microscopic bacteria, fungi and plants, through invertebrates and fish, to birds and mammals – are connected together, based upon what eats what. At the base of the food web are those species that do not need to feed on other living things to survive; primarily plants, from microscopic algae to trees, which grow using nutrients in the water or soil and sunlight. Microbes, including fungi and bacteria, also lie near the base of the food web, converting decaying plant and animal matter into microbial biomass.

The food web then follows which species eat the species at the base of the food web. If one part of the food web is harmed, other parts of the food web will also experience harm as their food source is affected.

h. **Algae:** Algae are microscopic plants which use dissolved nutrients present in the water, combined with sunlight, to grow. They form the base of the food web. When water becomes stagnant, algae can accumulate and through a process of microbial breakdown at night reduce dissolved oxygen, causing harm to species trapped in the stagnant water.

i. **Microbes:** Microbes including bacteria and fungi that gain nourishment from decaying organic matter, mainly dead plant material.

j. **Detritus:** Dead organic matter, mainly leaves and other plant material, that is an energy source for microbes. Microbes and detritus together are an important energy source to many invertebrates, including mussels.

k. **River reach:** These are sections of the River. A river is divided into sections based on characteristics such as slope, bed sediments, and the topography of the river bank. Different river reaches typically have characteristic biological assemblages. The River also has a "tidal reach," the lower portion of the River that is influenced by the tides as water from the ocean is pushed in and out. The lowest River reach includes the River's **distributaries**, a network of small channels that split off from the main channel and drain into Apalachicola Bay.

l. **Salinity:** A measure of how much salt is in the water, usually measured in parts per thousand (ppt). River water is freshwater, and so has a salinity of 0 ppt. However, in the lowest reaches of the River, as the elevation of the River is almost the same as the Bay, salt water extends some distance into the tidal reach. This "saltwater incursion" is greatest at lower river discharge, and because saltwater is denser than freshwater, salinities are highest near the river bed.

m. **Federally listed species:** This term denotes species that are protected under the federal Endangered Species Act. Species can be listed as "threatened" or "endangered." There are legal penalties for harming these species and impacts on those species must be addressed in the planning of federal actions. (*See* Biological Opinion, USFWS 2012, (JX-72)) The Apalachicola River and Floodplain are key habitat for at least four federally listed species, some of which are specifically discussed in my testimony. But threatened and endangered species are not the sole focus of riverine health; impacts on all species and the natural system must be addressed.

n. **Cubic feet per second (cfs):** This is one of the common metrics to measure the volume of flow in a river. The United States Geological Survey (USGS) maintains river gages in various locations to measure this volume, and periodically evaluates gage accuracy. In the Apalachicola River, the main gage I use is at Chattahoochee, Florida, immediately below the Jim Woodruff Dam. Flow in the River at that gage can vary widely, from flows over 100,000 cfs during flood times to flows of 5,000 cfs during the lowest flow times.

B. *Ecological Characteristics of the Apalachicola River and Floodplain*

8. I consider the Apalachicola River and Floodplain to be worthy of special consideration for its many unique characteristics, complex ecology, and biological richness. Flowing 106 miles from the confluence of the Chattahoochee and Flint Rivers to Apalachicola Bay, it is the

largest river in Florida by discharge. The Apalachicola River floodplain is the largest river floodplain in Florida, and having minimal development, it remains one of the most intact forested floodplains in the contiguous United States. I understand Ted Hoehn, a biologist at the Florida Fish and Wildlife Conservation Commission, will testify in detail about the natural beauty of the River and its importance to Florida as a unique and pristine ecosystem. In my testimony, I will highlight some of the features of the River that Mr. Hoehn testifies about, but I will primarily focus on the "target" assemblages for my metrics and on the wide variety of academic research and reports available on the River.

9. The Apalachicola River floodplain ranges from 1 to 5 miles in width and includes considerably well over than 100,000 acres of wetlands, more than 90% of which are wetland forests, with most of the remainder being tidal marshes near the mouth of the River. Floodplain habitats range from sloughs and lakes to swamps and forests.

10. The River has distinct sections or reaches, including an upper, middle and lower riverine reach, and an upper, middle and lower tidal reach. The length of floodplain sloughs, streams and lakes is over 400 miles, approximately four times greater than the main channel length of 106 miles. As explained in Section II, below, the floodplain is of incredible biological importance, and sufficient flows are critical for the ecology of the River that uses the floodplain.

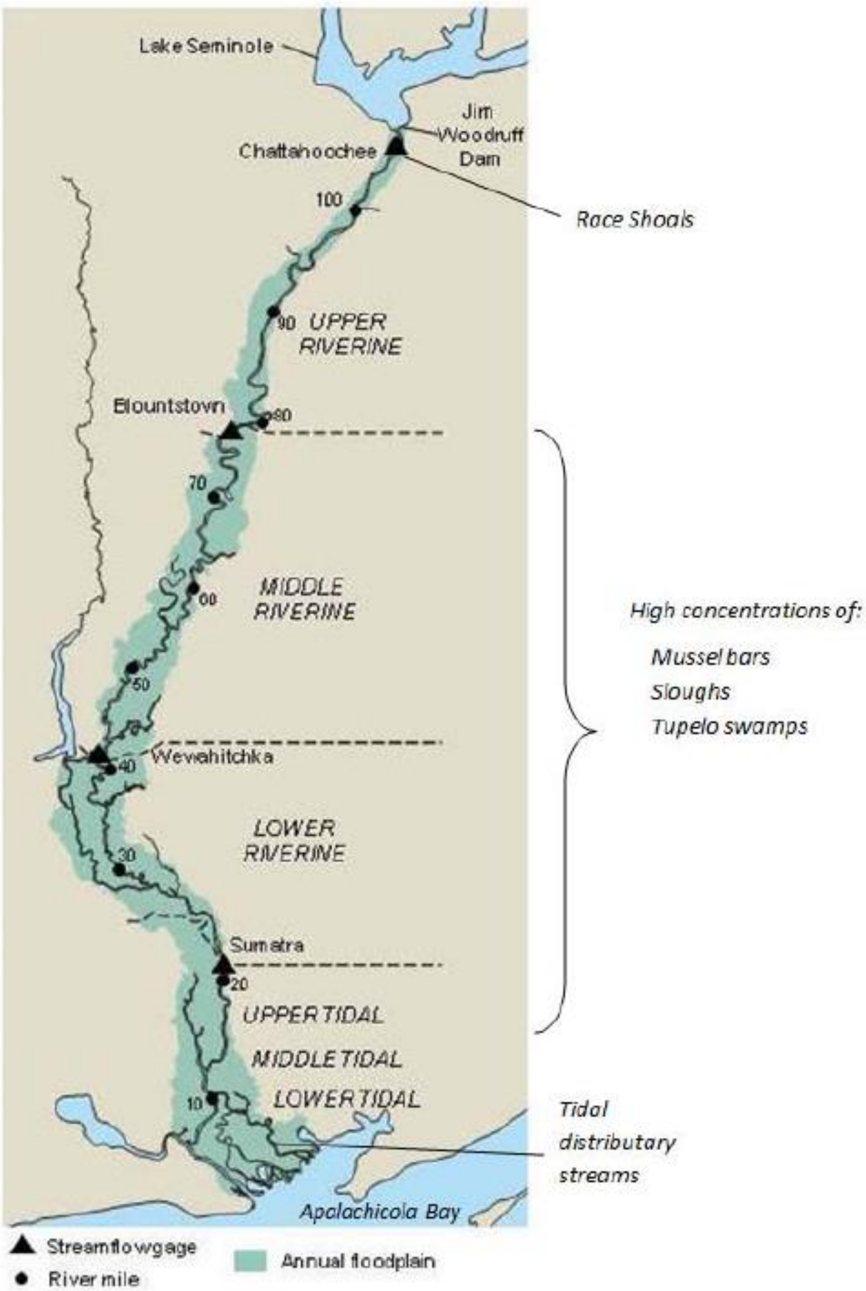


Figure 5– Major reaches of Apalachicola River and location of biological habitats harmed by upstream depletions. This is a true and accurate copy of a figure I used in my expert report (FX-790, Fig. 1). This figure was copied and modified under my supervision from an official USGS publication, Light et al. 2006 (GX-88).

11. At a very local level, microhabitats in the River (bank margins, pools, submerged wood, locations of different current speeds) become exposed or remain wetted depending on river flows, and are very sensitive to even modest changes in water levels.

12. The freshwater fish assemblage of the River and Floodplain is one of the most diverse in all of Florida, with a total of 142 freshwater and estuarine fish species in the Apalachicola River including popular sport fish and the federally listed Gulf Sturgeon (*Acipenser oxyrinchus desotoi*). At least 99 of those species have been found in the nontidal reach of the River, over 80% of which are known to occur in floodplain habitats at some point in their life cycle. (*See* Figure 6)

Figure 6 – Photos of larval fish caught in sloughs. This is a true and accurate copy of a figure I used in my expert report (FX-790, Fig. 16C). It was taken from an official USGS publication, Walsh et al. 2006. This is the kind of publication that experts in my field regularly rely upon, and I reviewed and relied upon this publication in forming my opinions in this case.

13. Historically the River has supported one of the most intact and diverse freshwater mussel assemblages in North America. The Apalachicola River presently contains 26 mussel species, of the 28 mussel species historically known to occur in the River. Three are federally listed: fat

threeridge, *Amblema neislerii* (endangered) (*see* Figure 7); purple bankclimber, *Elliptoideus sloatianus* (threatened); and Chipola slabshell, *Elliptio chipolaensis* (threatened).

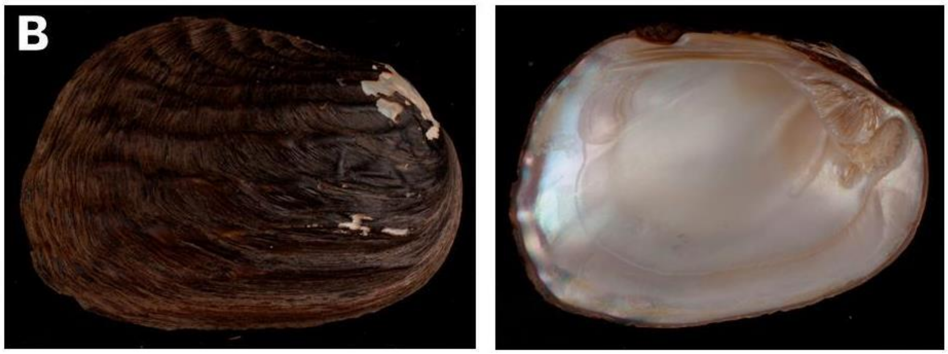


Figure 7 – An FWC archival picture of the outside and inside of a fat threeridge mussel shell. These are true and accurate copies of photos I used in my expert report (FX-790, Fig. 7B). This kind of photograph is regularly relied upon by experts in my field, and I reviewed and relied upon these photographs in forming my opinions in this case.

14. The River has supported the federally listed threatened Gulf sturgeon (*Acipenser oxyrinchus desotoi*) (*see* Figure 8), which also is the only known host species for the larvae (known as glochidia) of the threatened purple bankclimber mussel. The Gulf sturgeon has a migratory life cycle, meaning that adults spawn in the upper reaches of the River in spring and newly hatched larvae drift downriver to the vicinity of the upper tidal reach, where they spend up to two years developing into juvenile sturgeon with sufficient tolerance to higher levels of salinity to enable them to move into Gulf waters.

Figure 8 – An adult Gulf sturgeon, surveyed during a recent (2013-2015) sturgeon research project in Florida panhandle rivers. This picture is a true and accurate copy of a photo used in a presentation by University of Georgia professors, supported by USFWS, Georgia DNR, and Florida FWC (FX-384).

15. The Apalachicola River system has historically supported one of the most intact forested floodplains in the southeastern United States. (*See* Figure 9) The tupelo-cypress swamp forest is an important feature of the ecosystem. It is characterized by two dominant and important trees – the tupelo and cypress. But it also includes at least 54 other tree species and a total of 342 plant species within three major forest types. The lowest forests, continuously flooded for 4-9 months each year, are dominated by wet-site species, the most important of which are water tupelo, Ogeechee tupelo and bald cypress. The Ogeechee tupelo is the source of tupelo honey, the state honey of Florida, and supports a local honey industry. These low, wet-site species forests are those that are most susceptible to harm from low flows and are the focus of my analysis here. Low bottomland hardwood forests, growing on low ridges and flats where flooding occurs 2-4

months each year, are dominated by water hickory, overcup oak and swamp laurel oak. High bottomland hardwoods – including sweetgum, hackberry and water oak – grow on higher ridges and levees inundated for 2-6 weeks each year.

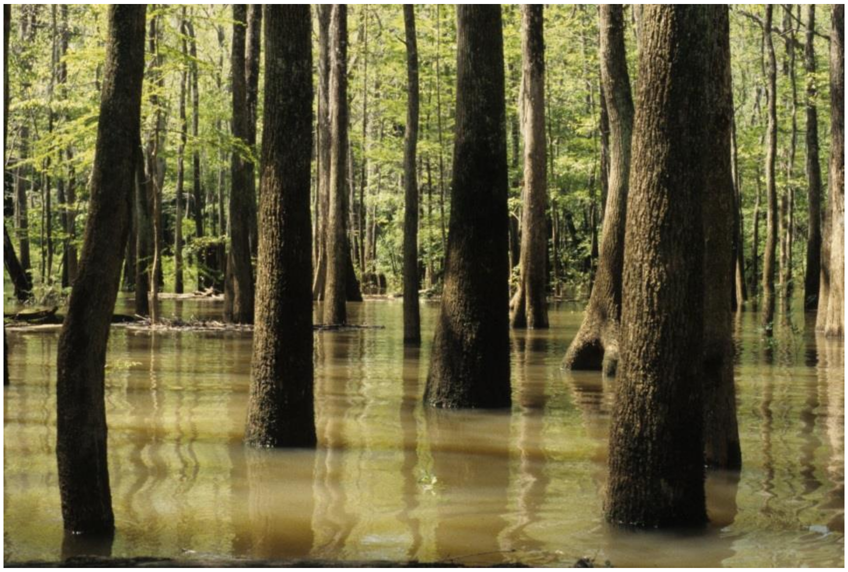


Figure 9 – Inundated tupelo-cypress swamp (near Flat Creek, 1994). This photograph is a true and accurate copy of a photo published in an official USGS report, Light et al. 1998.

16. Over 500 species of benthic (bottom-dwelling) macroinvertebrates (including mussels, aquatic insects and crustaceans) have been found in the Apalachicola River and floodplain. (*See* Appendix III of FDEP 2013, List of Flow-Dependent Species (JX-88)) Of these, 112 species have been identified as dependent on flowing waters and I am confident that hundreds more likely are affected by reduced water levels, particularly the dewatering of swamps and sloughs. The total number of flow-dependent freshwater invertebrate species is unknown to those who study the Apalachicola River and floodplain because comprehensive surveys of these species have not been conducted.

17. Finally, the River is also home to a high species diversity of reptiles and amphibians (including turtles and water snakes) in the U.S. and Canada. (UNESCO Biosphere Description

(FX-154)) This is one of the reasons why the Apalachicola River and Bay have been designated as a United Nations Biosphere Reserve. The River basin is also home to a variety of birds, as well as mammals such as beavers and otters. (Edmiston 2008 (JX-29)) All of these species are part of the riverine food web and are affected at some level when flows decline.

18. All of the biological resources of the River and Floodplain I have described are inextricably linked with the physical features of the River. The frequency, magnitude and duration of flows throughout the year, and especially flow conditions that occur during dry periods of episodically dry years, all affect the many species of plants and animals in the River basin. A large body of ecological literature explains how the ecology and biological richness of rivers and their floodplains depend on the flow regime that the ecosystem has historically experienced. My expert report cites and relies upon the scholarly literature in this field, including a widely-cited paper on the flow needs of freshwater ecosystems which I co-authored.

19. There is more than ample historical evidence of the biological richness of the Apalachicola River and Floodplain, and in my testimony I will explain how decreased flow has impacted the appropriate frequency, magnitude and duration of flows needed to sustain habitats and organisms. I note that I will use a variety of species assemblages as representative of the overall health of the River ecosystem. This is a methodology frequently employed in my field to assess ecosystem health.

II. IMPORTANCE OF FLOW TO HABITATS, ORGANISMS AND THE ECOSYSTEMS OF RIVER AND FLOODPLAIN

A. *Habitats of the Apalachicola River and Floodplain*

20. A three-dimensional view of the River and Floodplain (Figure 10) illustrates the importance of the enormous range of aquatic habitats that occur throughout the network of sloughs and the floodplain surrounding the River, which are critically important to the plants and

animals (the "biota"). These habitats are important both on larger scales (for instance, all the mussel flats in the main channel are important habitat that is inundated by flow) and smaller scales (for instance, a patch of woody debris in a slough that is inundated by flow).

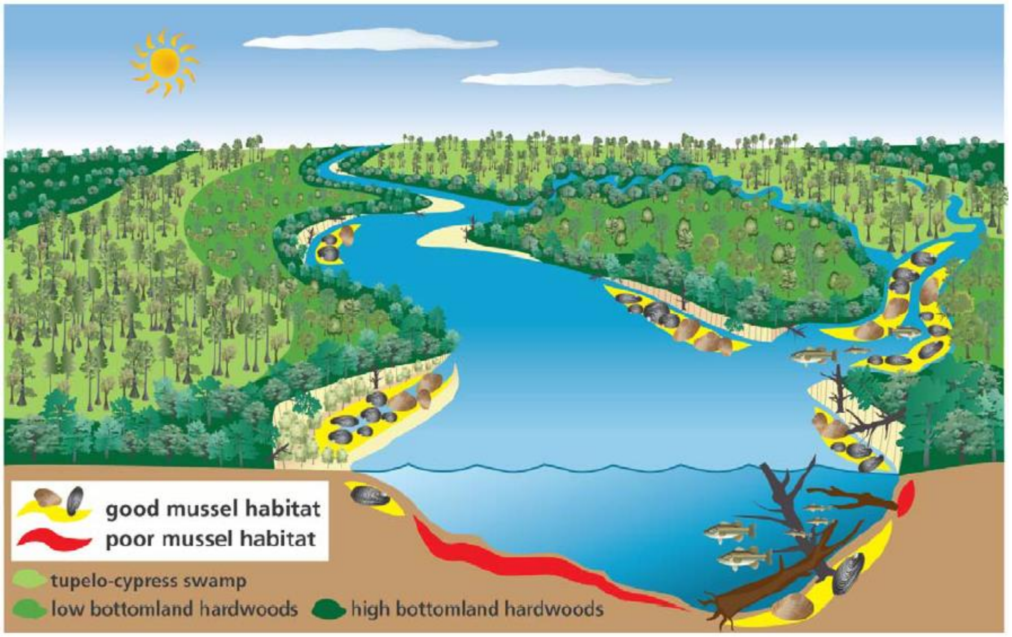


Figure 10 – A three-dimensional conceptualization of the Apalachicola River, including the network of sloughs and the floodplain that are critically important for the biota. Conditions typical of the River's middle and lower reaches are depicted. Note that the channel banks support high bottomland hardwoods and seasonal high flows rarely overtop the river banks. Tupelo-cypress swamps are located some distance from the channel margins, and their seasonal cycle of inundation is driven by water entering the swamp via sloughs at moderate and lower flows. The yellow areas are good mussel habitat, including main channel flats and sheltered locations behind woody debris in the main channel, and in many locations throughout sloughs. This is a true and accurate copy of a figure that was created under my supervision for use in my expert report, reflecting a stylized but representative portion of the River and which was prepared using generally scientifically accepted principles and methodology. (FX-790, Fig. 4).

21. Within the River, populations of mussels and fish utilize channel margins, sloughs, and microhabitat features such as submerged wood (*see* Figure 10). Channel margins typically experience less shear stress—that is, the force of moving water—from the current than the main channel because the current is slower along channel margins. Shear stress is the force of moving

water on objects such as a stone or a mussel shell on the stream bed. At higher current speeds, shear stress will cause such an object to move, skipping along the bottom or swept away in suspension. Because of lower current velocity and shear stress, channel margins are preferred habitat for many mussel species, including the fat threeridge, where they are less likely to be swept away by the moving water. In addition, mussels frequently colonize flat areas and backwaters along channel margins, where mussels are vulnerable to stranding when water levels decline. (Figure 11; *see* Gangloff 2012 (FX-389); EnviroScience 2006a (FX-388)).

Figure 11 – A flat area near the main channel margin of the River in late August 2016, in the middle reach. The picture shows many dead mussels which had become exposed as water levels dropped and exposed the flat. This is a true and accurate copy of a picture in Ted Hoehn's files (FX-823r).

22. In contrast, the bed of the main channel typically is poor habitat for mussels and other invertebrates. The combination of fine (and therefore easily scoured) substrate, fast current and seasonal flooding results in unstable conditions and downstream displacement of mussels.

Populations inhabiting main channel locations typically are found behind sand buildups on the inside of river bends where the current is slower, known as point bars; or sheltered in the vicinity of half-buried root wads and similar depositional habitat, i.e., habitats with slower currents where materials settle rather than get swept away.

23. The network of sloughs that receive river water at low and medium flows provides important habitat for fish, mussels and other invertebrates, and are critical to sustaining swamp habitat and vegetation. River water readily enters into sloughs when water levels are high enough, but flow into sloughs declines with falling river levels. (*See* Figure 12)

Figure 12 – Two sloughs in the middle reach of the River that experienced disconnection from the main River in recent months. Left (FX-812m): Hog Slough in early August 2016. Low flows have exposed woody debris and stranded mussels. Right (FX-820o): Dog Slough in late August 2016. The disconnection results in pools of stagnant water, which can trap fish and mussels present in the slough. These are true and accurate copies of pictures in Ted Hoehn's files.

24. Sloughs vary greatly in habitat features including size and depth, substrate diversity such as presence of gravel vs. sand or mud, shallow vs. deep pools, and in their exposure to sunlight vs. shade. Sloughs typically contain much more woody debris than main channels because of greater inputs of material (i.e., wood from the dense forest surrounding the sloughs), and fewer flushing flows (i.e., there is less and slower-flowing water in sloughs, so debris is not as readily

flushed out). Woody debris is itself habitat for organisms that use it as a feeding position or shelter from current; it also enhances habitat variability because depressions in the substrate form downstream of any obstruction to flow. (*See* Figure 12)

Figure 13 – A hummock with tupelo and other trees growing on it near Brickyard Transect (the upper tidal reach of the River), in 1980. This photograph was published in an official USGS report, Leitman et al. 1984.

25. As illustrated in the three-dimensional view of the River and Floodplain above (Figure 10), channel banks support high bottomland hardwoods because the River overtops its banks only at high flows. In contrast, the tupelo-cypress swamps for which this area is famed occur at some distance laterally from the channel margins—areas that are lower in elevation that are reached more easily by water flowing into the floodplain via sloughs. (*See* Figure 14) The seasonal cycle of inundation that maintains the swamp forest is driven by water entering via sloughs at moderate and lower flows. Within the swamp forest there is a wide variety of habitat for many species, since there are elevated mounds above the swamp floor (often the result of fallen wood or tree stumps), known as hummocks within the forest that provide uneven terrain and variations in microhabitat. (*See* Figure 13) The forest also provides patches of sun or shade that affect the rate of drying of habitat.

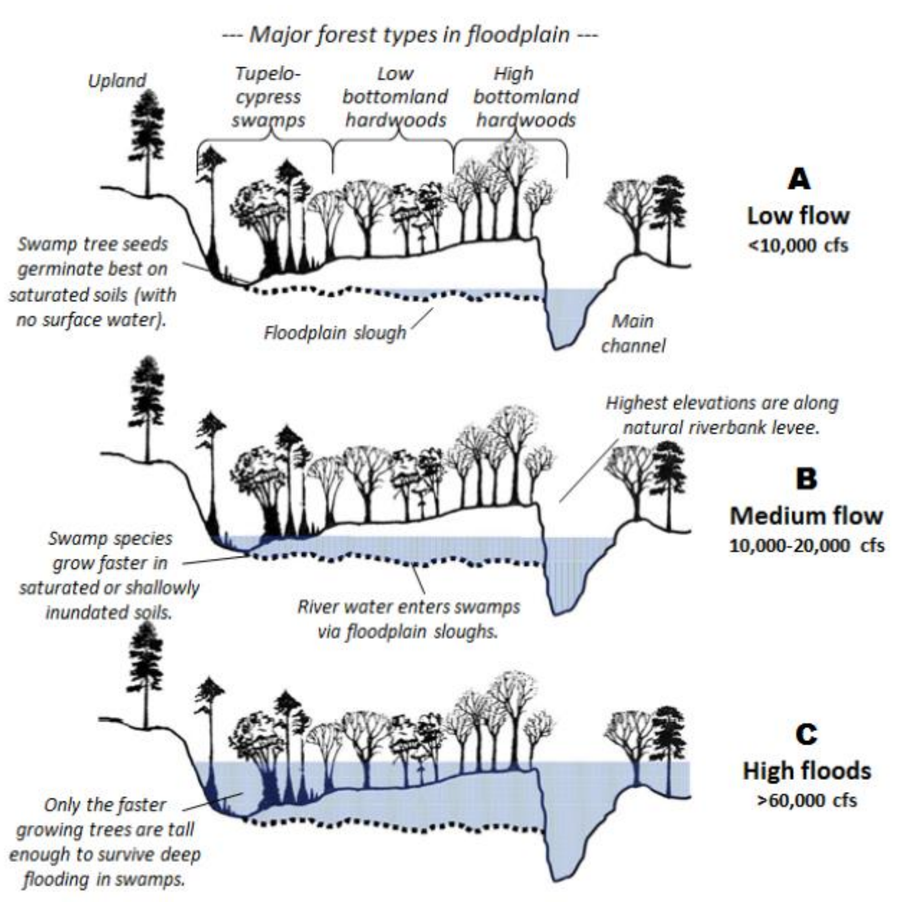


Figure 14 – This figure shows how variation in floodplain elevations and water level at which the River connects to sloughs affects the three major forest types of the Apalachicola River floodplain (tupelo-cypress swamps, low bottomland hardwoods, and high bottomland hardwoods). The caption to Figure 10 explains these types in more detail. This is a true and accurate copy of a chart that I used in my expert report (FX-790, Fig. 23). It was modified under my supervision, using generally scientifically accepted principles and methodology, from a figure published in an officially published USGS report, Light et al. 2006 (Fig. 3) (GX-88).

26. Because microhabitat is so important and so varied (*see* Figure 15), even modest increases in flow can have disproportionately large impacts on the extent of suitable habitat and survival of organisms. As an example of this impact, an increase in flow in the range of 300-500 cfs at the Wewahitchka gage when flows are 6,000 cfs, is estimated to raise water levels in many sloughs by 3 to 5 inches, which would significantly increase the extent of suitable habitat and survival of organisms. (*See* Stage-Discharge Chart (FX-661))

Figure 15 – Cypress roots on the River bank during low flow (2001). These roots provide excellent microhabitat for mussels and fish, but only if the water is high enough to cover them. This is a demonstrative photograph provided by Helen Light.

27. One example of the significant harm that happens when flows become very low dates back to 2006. Thousands of mussels in Swift Slough became stranded and died in 2006, when the Apalachicola River flows fell to 6,000 cfs and caused the slough to become disconnected for an extended period. (*See* EnviroScience 2006b, (FX-387)) Ultimately, over 95% of the estimated 18,000 endangered fat threeridge mussels within Swift Slough eventually perished. However, some mussels persisted in a few important microhabitats within Swift Slough where groundwater input and shade provided cover until flow returned. This shows the importance of

inundation of microhabitats and variation in flow—even if increases are modest— to ensure microhabitats remains inundated.

B. *The Food Web of the Apalachicola River and Floodplain*

28. The food web of the Apalachicola River and Floodplain is complex. All organisms are linked together through how they feed on each other. Food is energy, and energy moves from plants (including algae and decaying plant matter known as organic detritus) through links in the food web to larger species, ultimately supporting the River's fishes, amphibians, reptiles, birds and mammals. The entire River ecosystem is governed by the interactions between its living (the biota) and non-living (physical-chemical) components such as dissolved nitrogen in the water. The physical-chemical environment is highly influenced by flow conditions.

29. Sloughs (when connected) and floodplain lakes are locations of high biological activity, where algal production can flourish wherever there is adequate light. High levels of algal production can be beneficial to the entire food web, but when current flows slow or cease, overproduction of algae can result in serious declines in dissolved oxygen due to microbial breakdown of algal biomass. (*See* Figure 19 and accompanying text) Sloughs, since they are smaller and surrounded by trees, also receive more falling leaves and other plant matter, which bacteria process into food that can be eaten by other species, including many invertebrates that are in turn food for juvenile fish. As such, adequate River flows are necessary to ensure slough connectivity, which in turn enables critical ecosystem processes that support the riverine food web, and especially allows sloughs to serve as a nursery for many species of fish.

30. In summary, connectivity between the varied habitats of the Apalachicola River, sloughs and floodplain is essential to food web interactions and ecosystem function. First, much of the overall biological productivity occurs within the network of sloughs and the floodplain forest.

These are locations with the greatest amount of plant litter and algae production, basic sources of food for the food web. They also contain abundant stable habitat such as woody debris, and the slower flowing current means they provide good habitat for mussels and fish, including abundant food sources, moderate flows, and varied microhabitats. Second, receding floodwaters transport organic detritus and nutrients into the main channel and to locations downriver, benefiting receiving ecosystems. Reduced flows thus shrink the extent of biologically productive habitat—that is, lower flows reduce the areas where food can be optimally produced, resulting in less available food and therefore lower population densities, with attendant risk of species loss. Low flows reduce the extent of productive area, and so undermine the integrity of the ecosystem, i.e., the ability of all parts of the ecosystem to function properly and interdependently.

III. MY ANALYTICAL TOOLS, METRICS OF HARM, SHOW THAT HARM HAS INCREASED DRAMATICALLY IN RECENT PERIODS

31. In this Section III of my testimony, I quantitatively evaluate harm to the riverine ecosystem using a series of metrics for four exemplary biological target populations or species, including four federally listed threatened and endangered species, and applying them to the historical and modeled flow record. First, I will discuss the methodology that underlies the metrics. Second, I illustrate how a series of selected metrics demonstrates harm to the target species. Third, I apply my metrics to quantify harm that the Apalachicola River has suffered historically. In Section IV, I will discuss how my metrics show that a remedy can stabilize the ecosystem and allow it to meaningfully improve ecologically.

32. As an initial matter, I note that flows have fallen precipitously in recent decades. For instance, Dr. Hornberger has found that the number of days with flow below 6,000 cfs has increased dramatically in the past decades, as has the number of consecutive days below that

threshold. As Figure 16 shows, the average number of days with flows below 6,000 cfs in the 49-year period between 1921 and 1970 was 5.2 days. In contrast, the average number of days with flows below 6,000 cfs in the 10-year period between 2003 and 2013 was 71 days. In 2012 alone, more than 130 days fell below 6,000 cfs. As I explain in more detail below, at 6,000 cfs many sloughs become disconnected, causing the stranding of mussels and trapping of fish in stagnant pools of water, which causes severe stress and ultimately mortality as mussels are exposed to desiccation and predation, and fish die as the dissolved oxygen in the water is depleted. Similarly, at those low flows, channel margins and flats become exposed, stranding more mussels. The metrics described in this section quantify in more detail how harm occurs at different thresholds and durations; all of the metrics show a similar dramatic increase in the harm the River ecology has suffered as flows have decreased.

AVERAGE NUMBER OF DAYS WITH FLOW BELOW INDICATED THRESHOLD AT CHATTAHOOCHEE GAGE				
Threshold Discharge	**1921-1970**	**1970-2013**	**1992-2013**	**2003-2013**
6,000 cfs	5.2	29.8	50.6	71.0
5,500 cfs	2.6	19.0	32.7	54.0

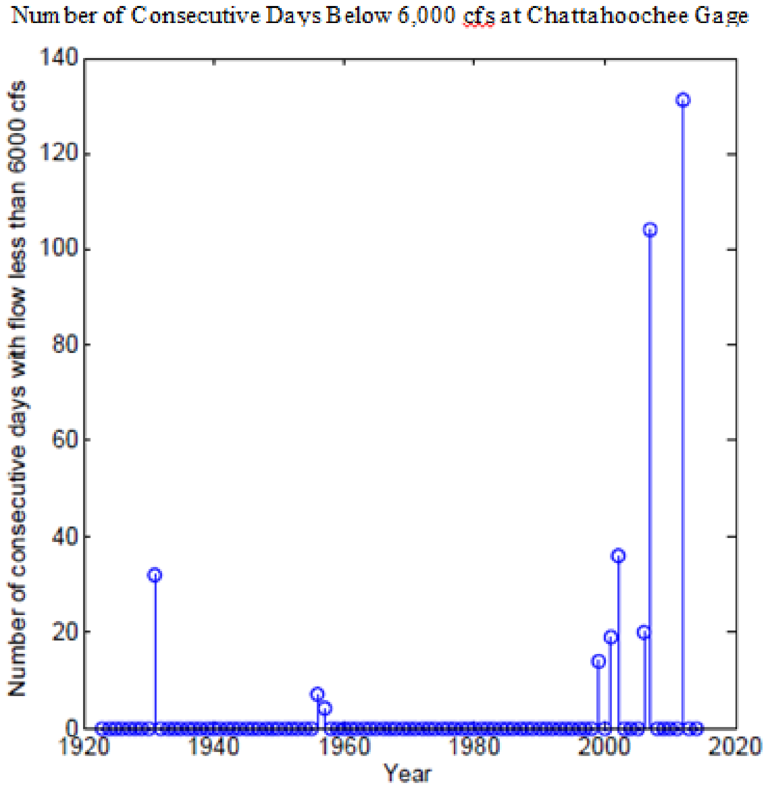


Figure 16 – This figure shows the increase in the number of consecutive days below 6,000 cfs at the Chattahoochee Gage. The graph shows there has been a dramatic increase in extended low-flow periods since the late 1990s. This figure is a true and accurate excerpt from Table 4 and Figure 8 from Dr. Hornberger's report, which I relied upon in forming my opinions (FX-785).

A. *Explanation of Harm Metrics Methodology*

33. While the River naturally alters its physical shape over time, there is no doubt that lower flows have serious impacts on the ecosystem. I have developed specific flow metrics for several targeted assemblages based on the River's current state to quantify these impacts. However, these metrics are also relevant to assessing how low flows would have caused harm in the past,

and how low flows will cause harm in the future. More specifically, although the River flow necessary to fill certain specific sloughs with water may change somewhat over time, there are many sloughs in the floodplain. Similarly, while channel margins and adjacent flat areas may shift somewhat, there are many areas that become exposed at low flows. Therefore, the metrics I employ in this Section will always be relevant to the slough network and the main channel as a whole.

34. A "metric" is a tool to evaluate harm to some biological target or assemblage in response to changes in River flow. It can be applied to both the actual historical flow record as well as modeled flow records. This allows me to understand how harm has changed over time, and how harm would decrease if there were less Georgia consumption. A metric measures harm by defining "harm events" based on specific flows. So, for each metric, I used available evidence to establish: (1) a **flow threshold** at which significant harm occurs (e.g., 5,700 cfs is a flow level that disconnects certain sloughs); (2) **a certain length of time** after which significant harm occurs (e.g., 30 continuous days of flows below the threshold); and (3) **a particular time frame** during which significant harm occurs (e.g., June through September).

35. There can be multiple "harm events" in a year—for instance, if flows increase above 5,700 cfs for a week, and then fall below that threshold again. One "harm event" can also last longer than the minimum time necessary: for instance, if flows stay below 5,700 cfs for far more than 30 continuous days. The more "events" occur and the longer they last, the more devastating the harm becomes. In my metric results, therefore, I present the estimated change in harm in two ways: first, as a change in the *number of years* in which there is at least one significant harm event as defined by the metric. Second, I also describe harm as the *total number of days* that my

metrics are met or exceeded. A reduction in either the number of years or the number of days, or both, is a clear reduction in harm.

36. Using the best available information, including site-specific evidence, and following a rigorous scientific approach, I developed a series of metrics to assess the impacts of low-flow levels to four biologically-important species or groups of species (assemblages) which occur in the Apalachicola River and Floodplain: mussels, fish, the floodplain forest trees, and the Gulf sturgeon as an individual species. In doing so I utilized my personal experience with the development and application of ecological metrics and my familiarity with the extensive literature on ecological indicators to ensure that the metrics used follow accepted practice. Because these four targeted groups represent different species assemblages, habitats and ecological requirements, I consider the evidence characteristic of the entire ecosystem of the Apalachicola River and Floodplain.

37. I describe the results of my comparison of various flow conditions, as applied to a subset of all my metrics, in Section III.C below. These selected metrics illustrate results from a variety of different scenarios, pulled from the full suite of metrics in my expert report, all of which point towards the same conclusion. Ultimately, I find that harm to the organisms, habitats and ecosystems of the Apalachicola River and Floodplain has increased significantly as flows have declined in the Apalachicola River over the historical record, which Dr. Hornberger has tied to Georgia consumption (*See* Dr. Hornberger Testimony and Expert Report (FX-785)). This is an ominous signal as to what could happen in the future without a remedy: the Apalachicola River could be permanently harmed. With a remedy, however, the ecosystem can be stabilized and would significantly improve.

B. *Description of Each Metric Presented in This Testimony*

38. Before I describe the results of my metrics, it is helpful for me to explain why I chose each target assemblage or species for a metric, and describe why the flow threshold, duration, and season I selected for each metric represent harm to that target.

1. Metrics for Mussels in the Main Channel and Sloughs

39. I use the **mussel assemblage** as a biological target because the Apalachicola River supports one of the most intact and diverse freshwater mussel assemblages in North America, with 26 species occupying a range of habitats, including three federally listed species and four that have been petitioned for listing. While threatened and endangered species have been the most studied, it is appropriate to focus on the assemblage of all mussel species as a whole—particularly since the Apalachicola is a biodiversity hotspot for freshwater mussels.

40. Low flows are harmful to mussels for a number of reasons, including some that are a consequence of their unique life cycle. As filter feeders, mussels require sufficient flows to provide current across their gills to supply oxygen and suspended food particles that they filter. Flowing water is also important for reproduction, as mussels in their immature parasitic stage, called glochidia, must attach to a fish host for nourishment and dispersal, and to eventually transform into a juvenile. The majority of mussel species inhabiting the Apalachicola River are flowing water species that require host fish species generally adapted to flowing water and riverine habitats. As such, the health of the fish population is of critical importance to the health of the mussel population.

41. Low flows also result in mussel mortality as declining water levels leave individuals trapped in shallow, isolated pools or completely dewatered, causing exposure, desiccation and increased vulnerability to predators. Mortality also results when sloughs become disconnected

and water ceases to flow and becomes stagnant, resulting in low dissolved oxygen concentrations and elevated water temperatures. Some impacts from decreased flows are more subtle. For example, mussels can be stressed by needing to expend energy to move in an attempt to escape stranding as water levels decline and water temperature warms. Stressful conditions and elevated energy expenditures can cause increased risk of mortality. (*See* Kaeser & Herrington 2011, (FX-390))

Figure 17 – Mussel exposure and desiccation along main channel margins during low flow. Thousands of mussels died in the summer of 2006 because they were unable to travel long distances across open flats to reach deeper water in the main channel. The river flow at which water levels drop below the elevation of open flats varies from site to site. Maximum mussel mortality occurred when flow dropped to about 8,000 cfs (recorded at the Chattahoochee gage) at the site in the two upper photos, and about 6,000 cfs at the site in the lower photo. Mortality also occurred in isolated pools and shallow water along the river edge, presumably because of high water temperatures, low dissolved oxygen, and the prolonged stress of migrating. These are true and accurate

copies of photos I used in my expert report (FX-790, Fig. 8). This kind of photograph is regularly relied upon by experts in my field, and I reviewed and relied upon these photographs in forming my opinions in this case.

42. The majority of research on freshwater mussels within the Apalachicola River system has been performed in relation to listed species. (EnviroScience 2006a, (FX-388); EnviroScience 2006b, (FX-387); Biological Opinion, USFWS 2012, (JX-72)) Surveys focused on threatened and endangered species in the Apalachicola River and sloughs typically locate multiple species, and conditions that result in mortality of protected species such as the fat threeridge are highly likely to affect other mussel species as well. Because the fat threeridge has received the most study, I use evidence from these studies to develop my metrics of harm. Individual mussel species vary in how vulnerable they are to stranding and mortality due to drying of mussel tissue (known as "desiccation") in de-watered locations, because of differences in size and thickness of shell, their mobility and burrowing ability, and preferred habitat. The fat threeridge is intermediate among mussel species of the Apalachicola River and Floodplain in many of the traits that influence vulnerability to stranding and desiccation. Thus, I consider harm metrics based on the well-studied fat threeridge to be representative of the mussel assemblage as a whole.

43. While my metrics for mussels identify a flow threshold for the purpose of applying the hydrologic scenarios developed by Dr. Hornberger, I note that harm can occur at flows above the identified threshold, and increase in severity as flows drop below the identified threshold. As the U.S. Fish and Wildlife Service's 2012 Biological Opinion (JX-72)) and 2015 Draft Fish and Wildlife Coordination Act Report (DFWCAR) (JX-122)) make clear, and as was maintained in the 2016 Biological Opinion (JX-168), stranding of mussels occurs at all flow levels below 10,000 cfs, depending on the location in the River, and becomes common at flows below 6,000

cfs. This is because habitat conditions (bank slope, topography of flats along channel margins, etc.) vary from place to place. In addition, mussels can move up in bank elevation during higher flows, only to become trapped as flows decline. Mussels on flats (locations adjacent to the main channel banks where mussels colonize and may become stranded as water levels recede) and in sloughs (which become dewatered or stagnant when flow levels decline, trapping mussels) are especially vulnerable. Figure 17, above, provides a visual representation of flats, and Figure 18, below, documents exposure of mussels in sloughs.

44. In this testimony, I am presenting two metrics of harm: one metric of harm to mussels occupying main channel margins, and one metric of harm to mussels in sloughs. For the metric of harm to mussels occupying main channel margins, I selected a low-flow threshold of **6,000 cfs**. This is a conservative threshold, because reductions at flows below 10,000 cfs will also harm mussels in the main channel, as described above. At the 6,000 cfs level, there is severe mussel mortality from exposure leading to stranding, heat stress, and predation. (*See* Figure 17) This harm occurs once mussels have been exposed for at least **7 continuous days** during the warm period between **June 1 and September 30.**

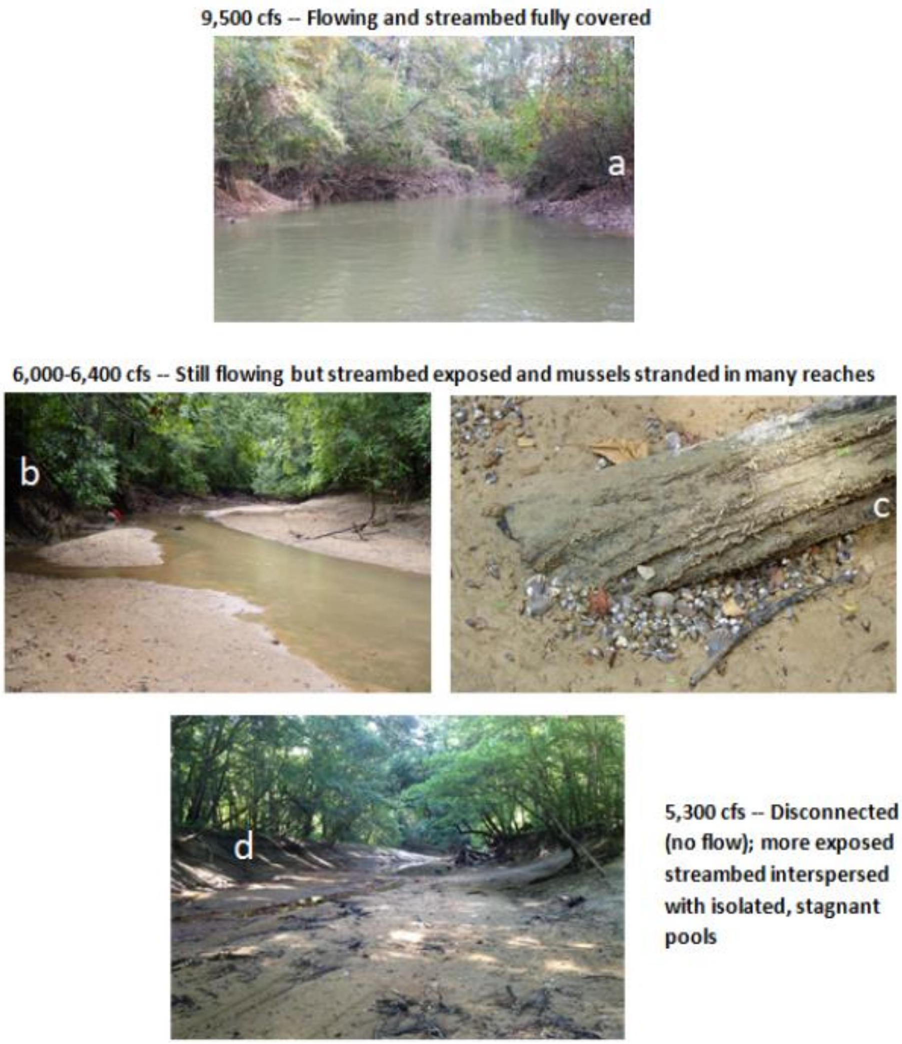


Figure 18 –Streambed exposure in Swift Slough under different flow conditions in 2006 (a-c) and 2012 (d). When flows fall into the range of 6,000 to 6,400 cfs (at the Chattahoochee gage) for more than 30 days in the summer, 20-25% mortality of fat threeridge can occur. When the slough is completely disconnected (under 5,700 cfs) for months, mortality can exceed 95% and recovery in subsequent years can be slow. These are true and accurate copies of photos I used in my expert report (FX-790, Fig. 11). This kind of photograph is regularly relied upon by experts in my field, and I reviewed and relied upon these photographs in forming my opinions in this case.

45. Second, I developed a metric to represent harmful conditions experienced by mussels occupying sloughs, a number of which have been documented to support substantial mussel populations. In this testimony, I highlight a representative small slough, Swift Slough, in the

middle reach of the River (*see* map, Figure 5). At low flows, this slough transitions from riverine to harmful stagnant pond-like conditions. When that occurs, the stagnant water warms, causing dissolved oxygen levels to decline, and exposure to predators increases. Swift Slough becomes disconnected from the River at 5,700 cfs, thus harm occurs when flows are at or below **5,700 cfs** for **30 continuous days** during the warm period between **June 1 and September 30**. My report presents site-specific evidence showing that this harm has already occurred. (*See, e.g.*, EnviroScience 2006b (FX-387)) My metric is conservative; that is, I would expect to observe harm to mussels even when flows reach these thresholds for less than 30 days, or at higher flows when some other sloughs are already disconnected. Figure 18 shows that mortality at Swift Slough starts occurring at a threshold of 6,000-6,400 cfs, higher than my more conservative threshold of 5,700 cfs. As a result, I would expect my conservative metrics to underestimate harm rather than overestimate it. The same is true for the other metrics I have chosen in my opinions presented here.

2. <u>Metric for Fish in Sloughs</u>

46. I use the **freshwater fish assemblage** of the Apalachicola River–Floodplain system as a biological target because it is one of the most diverse of all Florida rivers. At least 99 species occur in the nontidal reach, over 80 of which are known to occur in floodplain habitats at some point in their life cycle and of which at least 45 species use the Apalachicola River floodplain for spawning and nursery habitats.

47. Inundated floodplain habitats provide critical spawning and rearing habitats for many large-river fishes. Flow connectivity, that is, having flows at high enough levels to have water flow from the main channel into the floodplain through the network of sloughs and side channels, is important throughout spring and summer. Reductions in connectivity reduce the

size of fish year classes (that is, the total amount of young fish that are produced by adult spawning in a given year), because adult fish lose access to the floodplain habitat, allowing fewer fish to spawn there, and because fewer young fish survive. Fish born in sloughs and the floodplain may die if the slough is not reconnected, and those that do survive have less habitat. Sloughs are critically important as spawning and nursery habitat, which is demonstrated by the many thousands of larval fishes of at least 45 species collected in light trap studies by the Florida Department of Environmental Protection. Reductions in size of fish year classes in successive years due to low flows can seriously impair fish populations as a whole. Floodplain habitats also are heavily used for foraging by many popular sport fish such as largemouth bass and several sunfishes. Therefore, the U.S. Fish and Wildlife Service has found floodplain connectivity to be an important factor for Apalachicola River fish. (DFWCAR (JX-122)) Nearly all fish species identified as potential host fishes for mussel glochidia (and thus critical to mussel species survival) are known to utilize floodplain habitats.

48. Low-flow conditions harm fish populations by reducing the total extent of aquatic habitat. Stream banks are important fish habitat because they have more riparian vegetation and woody debris than the bottom of the streambed. Complex vegetative structure supports abundant food for fish, because many invertebrates live in the stream bank plants; it also provides protected areas for fish to hide from predators and build nests for spawning. The total length of stream banks that are key habitat is known as “stream length”; the longer the stream length, the more habitat for fish. The length of floodplain sloughs, streams and lakes in the Apalachicola River floodplain is over 400 miles, approximately four times greater than the main channel length of 106 miles.

49. Reductions in flow cause direct mortality to individuals in the fish assemblage and impair population recruitment (i.e., how many fish are born). At low flows, floodplain sloughs and lakes become disconnected from the main river channel; these sloughs and lakes then switch from flow-through to stagnant, pond-like conditions. A lack of flow quickly leads to a decline in dissolved oxygen concentrations, which are especially harmful to fish in floodplain habitats during summer. The reason for this decline is that, (1) in stagnant waters, high temperatures and increased microbial activity reduce dissolved oxygen levels, and (2) flowing water naturally is oxygenated, and continually replenishes dissolved oxygen levels. In the absence of flow, dissolved oxygen in sloughs can rapidly drop to levels that cause significant fish mortality.

50. Analyses of fish collection data by the Florida Fish and Wildlife Commission clearly show a direct relationship between fish recruitment and flow. This is caused by diminished spawning and rearing habitat as well as direct mortality resulting from reduced levels of dissolved oxygen in critical habitats. (FWC Fish Analyses Spreadsheet (FX-385))

51. While my expert report evaluates multiple metrics that all show harm to fish using various floodplain habitats, in this testimony I focus on the harm to fish in small sloughs. As discussed above, sloughs provide critical larval fish habitat. When small sloughs become disconnected, as explained above, fish experience harm because of rapidly declining dissolved oxygen. Note that even fish in sloughs that remain connected at this flow level can experience significant harm as flow stagnates and oxygen levels decline, as shown and described in Figure 19. For this metric, while there are many different sloughs with different connecting flow levels, I selected Swift Slough as a representative example. Swift Slough becomes disconnected at approximately **5,700 cfs**. Significant harm from reduced dissolved oxygen occurs after **5 days of continuous disconnection**, during the warm summer months of **June to September**. And, the

longer the disconnection lasts, the more significant the harm becomes as fish that are initially able to seek out refuge will increasingly suffer harm as more time passes.

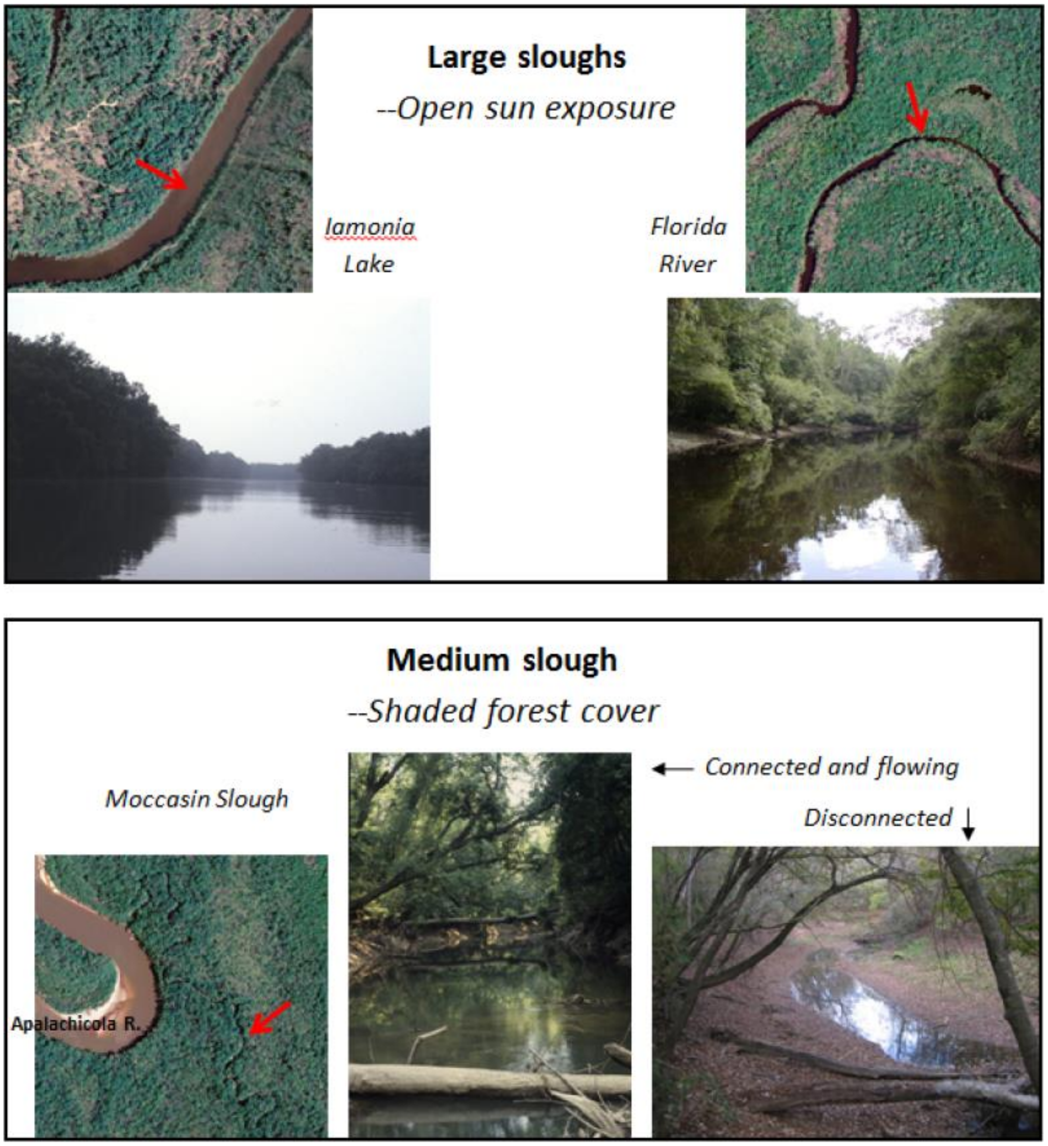


Figure 19 – Open sun exposure of large sloughs compared to shaded forest cover of medium sloughs. The amount of sunlight reaching the water surface strongly affects dissolved oxygen concentrations in sloughs if they are not flowing. Still water in sloughs open to sun exposure (large sloughs) will have large diurnal fluctuations in dissolved oxygen concentrations with daytime highs and nighttime lows, because sunlight fuels algal photosynthesis (oxygen production) during the day, followed by those algae dying and being consumed by microbes (respiration and oxygen consumption) at night. These fluctuations are harmful to fish, mussels, and other species. There is less diurnal fluctuation of dissolved oxygen in small and medium sloughs (because they receive less direct sunlight), but when they become disconnected, there is

little to no inflow of new, oxygenated water, and eventually dissolved oxygen reaches deadly levels as fish and mussels use up the oxygen. These are true and accurate copies of photos I used in my expert report (FX-790, Fig. 17). The aerial photographs are available from the official Florida land boundary information system, at www.labins.org. Fig. 17A (middle left) was published in an official USGS report, Light et al. 1998; Fig. 17B (middle right) was published in an official report for Florida, ESA PWA and Light 2012; Figure 17C (bottom center) was published in an official USGS report, Light et al. 2006. This kind of photograph is regularly relied upon by experts in my field, and I reviewed and relied upon these photographs in forming my opinions in this case.

3. Metric for Young of Year Gulf Sturgeon

52. I use the **Gulf sturgeon** (*Acipenser oxyrinchus desotoi*) as a biological target because it is a federally listed threatened species (listed in 1991) that is dependent upon coastal rivers of the Gulf of Mexico for its reproductive success. The U.S. Fish and Wildlife Service has designated the entire Apalachicola River as critical habitat that is essential for the conservation of this species. In addition, the Gulf sturgeon is the most probable host for the threatened purple bankclimber mussel (*Elliptoideus sloatianus*), the first known case of a federally protected fish serving as host for a federally protected mussel.

53. I focus here on the survival of young-of-year sturgeon (i.e., fish under one year old). Since survival of these young-of-year fish is important to the population, it is also important to the recovery of this listed species. Young-of-year sturgeon hatch from eggs spawned just below Woodruff Dam in April and drift and migrate downstream about 95 miles to the tidal reach of the River where they reside in low-salinity locations. Juveniles spend up to two years in fresh water, often migrating to estuarine waters but remaining at low salinities. (*See* Figure 20 comparing juvenile and adult sturgeon) Research in the Suwannee River, also in Florida, has established that early (up to 6 months of age) young-of-year cannot tolerate salinities above about 10 parts per thousand (ppt). Long-term survival of the Gulf sturgeon in the Apalachicola system depends on adequate nursery habitat for early young-of-year.

Figure 20 – Left: A juvenile (~1 year old) Gulf sturgeon, being measured for authorized research purposes during a 2013-2015 sturgeon research project. Young-of-year are much smaller still, and require sufficient feeding habitat available for enough of their growth period in their first year of life to reach this size. Right: A full-grown Gulf sturgeon sampled in the Suwannee River in 1973. The left picture is taken from FX-384, a presentation by University of Georgia professors, supported by USFWS, Georgia DNR, and Florida FWC. The right picture is taken from FX-383, an official Florida government report on the conservation of Gulf Sturgeon.

54. Young-of-year sturgeon feed mainly on bottom-dwelling ("benthic") invertebrates, and the brackish waters of the lower Apalachicola River have abundant benthic invertebrate food items relative to locations of higher salinity. Because fresh water is less dense than salt water, surface waters of the lower distributaries tend to be less saline, and bottom water more so. Higher flows will 'push' the freshwater farther down river and mix surface with bottom water, resulting in a larger area with the right salinity for young-of-year sturgeon to feed in. Lower flows result in less mixing of surface and bottom waters – in addition to higher salinities overall

– and thus a smaller area with optimal salinity in which the juvenile sturgeon can feed. The net effect is that decreased flows deny young-of-year sturgeon access to the most beneficial feeding habitat by increasing salinity at the River bottom in brackish water reaches, primarily the lower distributaries (*see* map, Figure 5).

55. During the mid-summer months, flows in the Apalachicola River of at least **7,000 cfs** are needed to provide low salinity conditions (less than 10 ppt) in bottom waters of the distributaries of the Apalachicola delta. Young-of-year sturgeon are most vulnerable for the first six months of their lives. Hence I identify **May to September**, the months immediately after spawning, as the critical time period. Because early young-of-year sturgeon must feed most of the time in order to grow and survive their first year, flows below 7,000 cfs for more than **60 days** (**total**, not continuous) of the 153-day period between May 1 and September 30 would restrict early young-of-year sturgeon from obtaining adequate feeding opportunities. As the total number of days when flows are below 7,000 cfs increases, access to feeding grounds in distributaries for young-of-year and other juvenile sturgeon is further restricted; this metric therefore represents significant harm as feeding opportunity is lost for well over a third of the critical growth period.

4. Metric for Swamp Trees in the Floodplain Forest

56. I use the **Apalachicola floodplain forest**, especially its tupelo-cypress swamps, as a biological target because this is one of the most intact floodplains in the southeastern United States. The importance of the floodplain forest is widely acknowledged. It provides essential habitat for many species of fish, reptiles, amphibians, and mussels. Changes in tree species are widely recognized as an indicator of change in the floodplain, and the Apalachicola floodplain forest has been extensively researched.

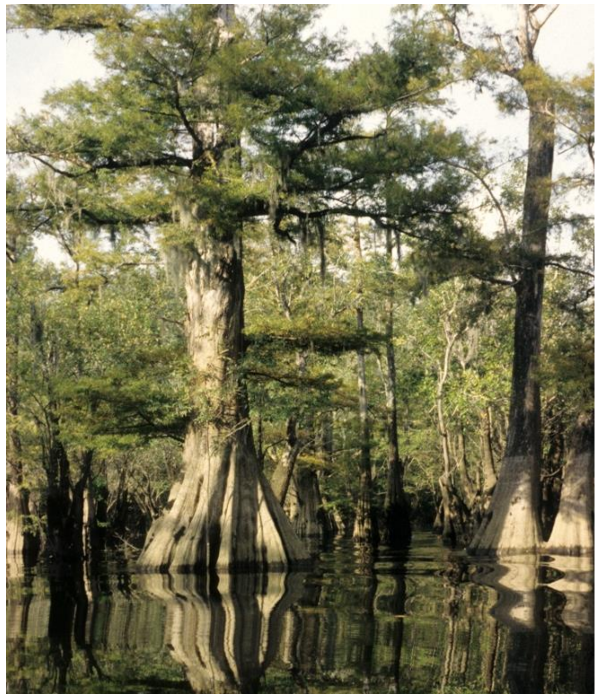


Figure 21 – A large cypress tree growing in a large slough in the middle reach of the River (Outside Lake), in 1995. This photograph was published in an official USGS report, Light et al. 1998.

57. Three major forest types grow at different elevations of the floodplain: tupelo-cypress swamps at the lowest and wettest sites, low bottomland hardwoods at intermediate elevations, and high bottomland hardwoods at higher elevations. The tupelo-cypress swamp forest includes at least 35 species, some of which also occur in low and high bottomland forests. The total number of tree species in the Apalachicola River floodplain has not been definitively determined but exceeds 50 species at a minimum. The most important swamp species include water tupelo (*Nyssa aquatica*), Ogeechee tupelo (*Nyssa ogeche*), bald cypress (*Taxodium distichum*) and Carolina ash (*Fraxinus caroliniana*). (*See* Figure 21)

58. Swamp species germinate in low-flow season when soils are exposed, because tree seeds will not germinate underwater. After germination, swamp species require saturated or shallowly

inundated soils during the growing season for rapid height growth of seedlings and saplings—dry soils stunt their growth. During flood season in subsequent years, swamps are flooded more deeply and more often than bottomland hardwood forests. Taller saplings will survive subsequent flooding, whereas shorter saplings (such as stunted swamp species and most bottomland hardwoods) will die if overtopped by flood waters for prolonged periods. (*See* Figure 14)

59. As conditions become drier in the Apalachicola River and Floodplain, a series of changes ensue, to the detriment of the Apalachicola swamp forest. Ground cover plants such as perennial grasses become established, competing with tree seedlings for light and moisture. Fewer trees surviving to canopy height result in less shade, allowing more sunlight to reach the forest floor. This further encourages growth of ground-cover vegetation, while the thicker ground cover makes it more difficult for tree seedlings to become established. Figure 4 (pictures with historical comparisons) above provides images comparing typical sparse swamp groundcover with thick perennial grasses that establish in drier conditions.

60. Forest composition of these Apalachicola Floodplain swamps is changing in large part due to reduced river flows occurring throughout the life span of swamp trees. As fewer trees survive to reach canopy height, reduced shade and increased sunlight encourage the establishment and growth of bottomland hardwood species. The density of swamp species has decreased over time, as documented in surveys conducted in the 1970s and repeated in 2004.

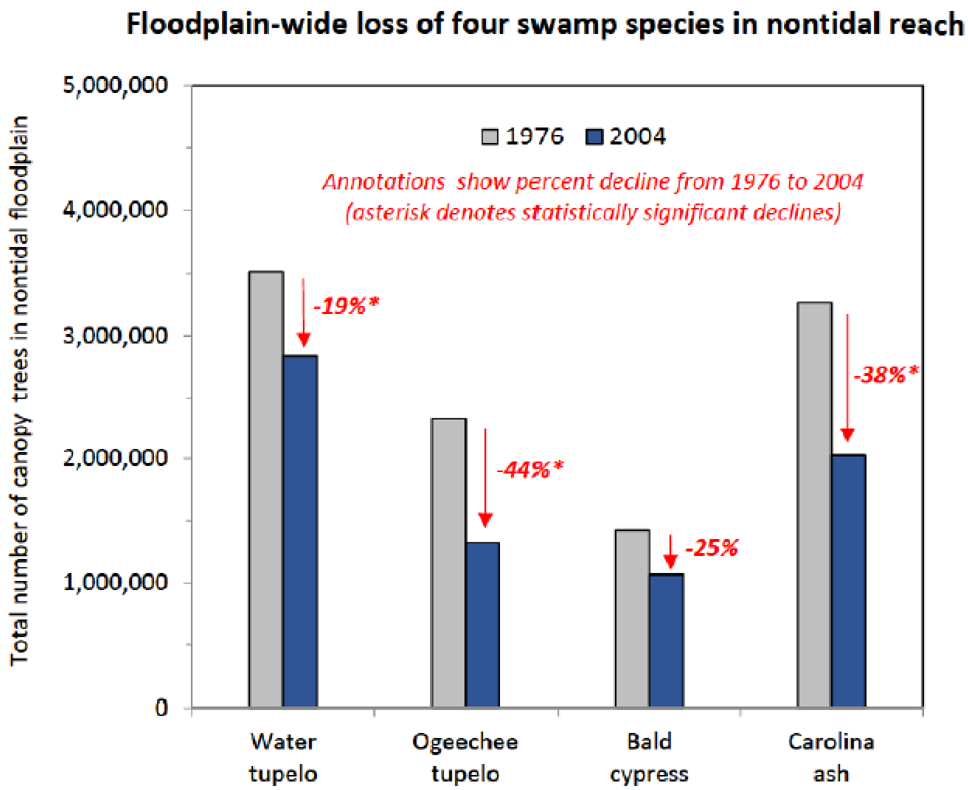


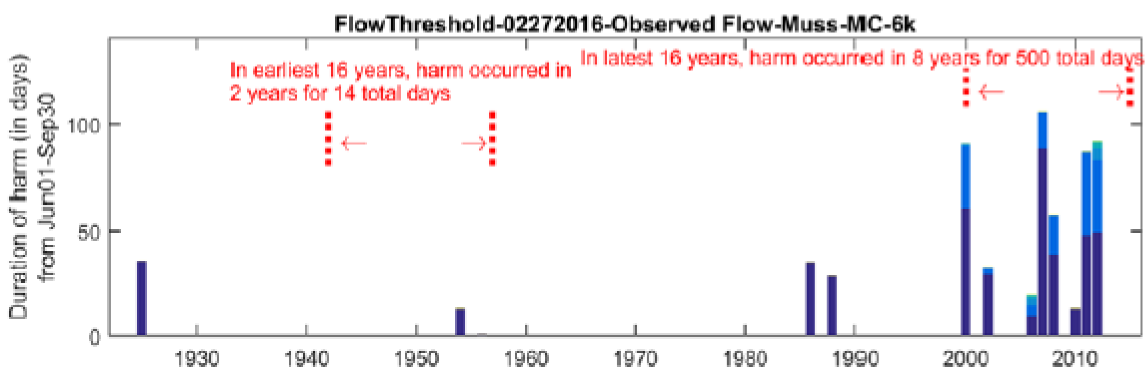
Figure 22 – Graph showing the significant decline in swamp tree species from 1976 to 2004. There were 4.3 million fewer canopy trees in 2004 than 1976 in the nontidal floodplain, 3.3 million of which were the four species in this graph. The reduction in tupelo trees is especially concerning because they are the principal source of the prized tupelo honey. Note that this figure is taken from a 2008 USGS report; more recent sampling is not available. However, continuous decreases in flow over the last decade (especially the significant and extended low-flow periods in 2007-2008 and 2011-2012) have most likely continued to harm the floodplain forest, which consists of trees that have lived for decades if not over a hundred years. This is a true and accurate copy of a chart created under my supervision, using scientifically valid methodology, that I used in my expert report (FX-790, Fig. 27). It graphically reflects data contained in an officially published USGS report, Light et al. 2008 (Table 10 and accompanying text) (FX-870).

61. Harm occurs when tupelo-cypress swamps of the middle and lower riverine reaches as well as upper tidal reach of the Apalachicola River receive no floodwater inundation for long periods during the growing season, resulting in stunting or mortality of seedlings. For my metric, I selected the flow threshold of **14,100 cfs**, the level at which the lowest 10% of tupelo-cypress swamps is inundated, and a level below which the majority of the forest is harmed. The

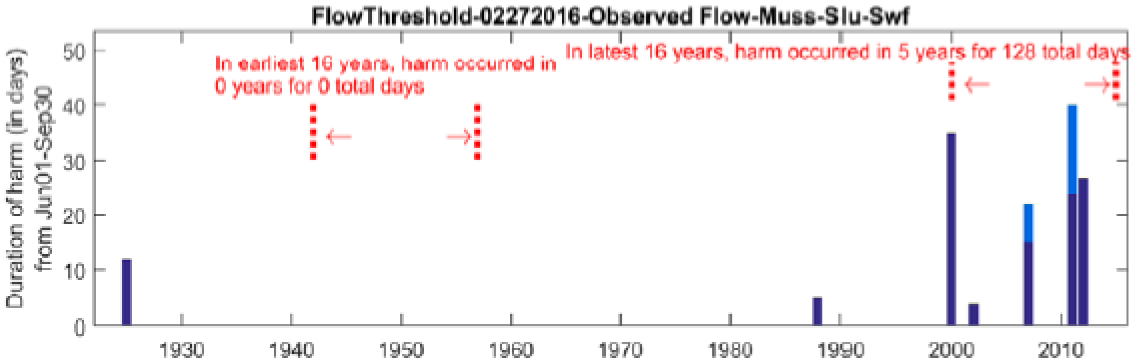
relevant period is **March 20 through September 22**, the peak growing season for seedlings. I expect harmful conditions to occur when no inundation occurs for half of the spring-summer growing season **(90 consecutive days**) for each extent of area potentially flooded. Additional days that lack inundation further increase the harm, as seedlings' ability to grow diminishes completely as drier conditions persist.

C. *Metric Comparison of Historical Conditions with Current Conditions*

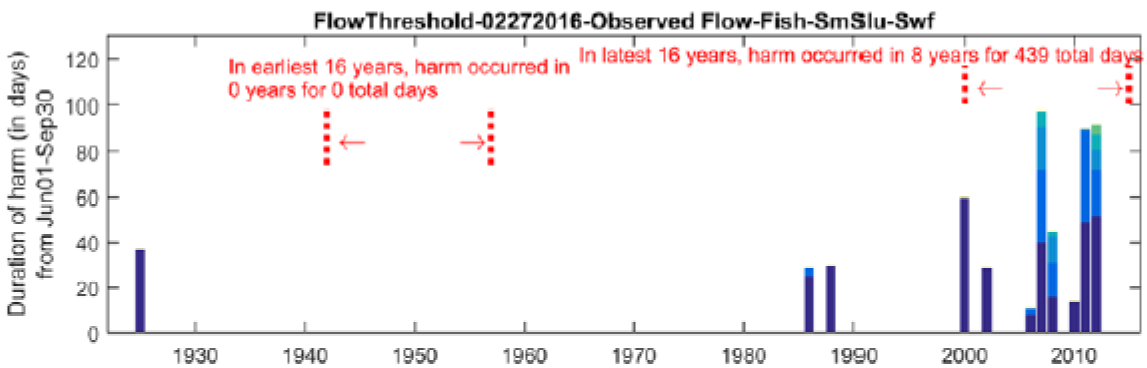
62. My metrics, plotted over the entire historical record, show a consistent increase in harm over time to each target assemblage or species. The following graphs show which years harm occurred. In some years, the harm threshold was exceeded more than once, as shown by the different shading of vertical bars. The height of each bar denotes the total days of harm for a given year. Both the number of events and total days of harm have increased dramatically in the past decades, concurrent with an increase in Georgia consumption. (*See* Dr. Hornberger Testimony and Expert Report (FX-785)) In many historical years prior to 1980, there was no harm at all, as shown by the lack of bars representing harm. (Figure 23)



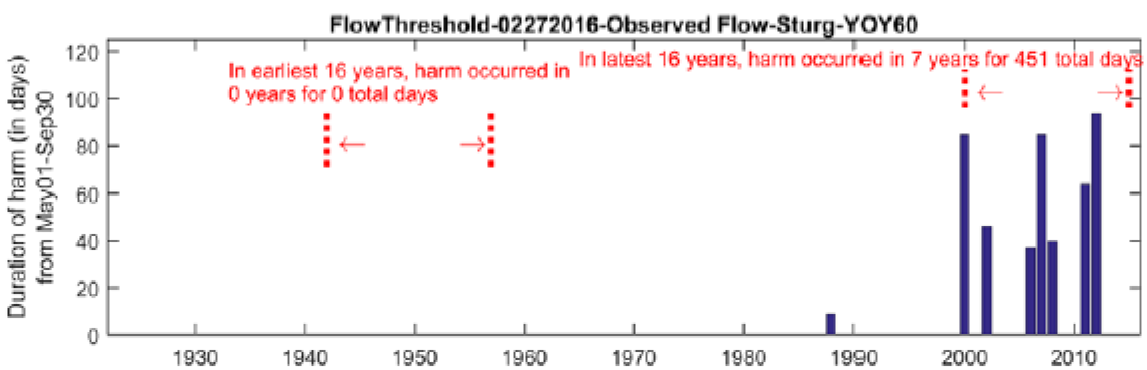
Historical Harm to Mussels in the Main Channel based on flows falling below the 6,000 cfs threshold. The date on each graph specifies when the analysis was finalized.



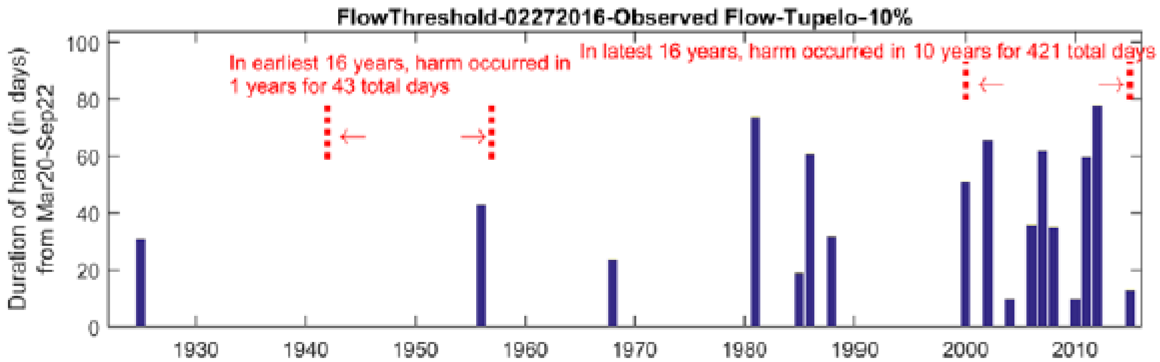
Historical Harm to Mussels in Swift Slough, based on flows falling below the 5,700 cfs threshold.



Historical Harm to Fish in Swift Slough, based on flows falling below the 5,700 cfs threshold.



Historical Harm to Young of Year Sturgeon, based on flows falling below the 7,000 cfs threshold.



Historical Harm to Swamp Trees in the Floodplain Forest, based on flows falling below the 14,000 cfs threshold.

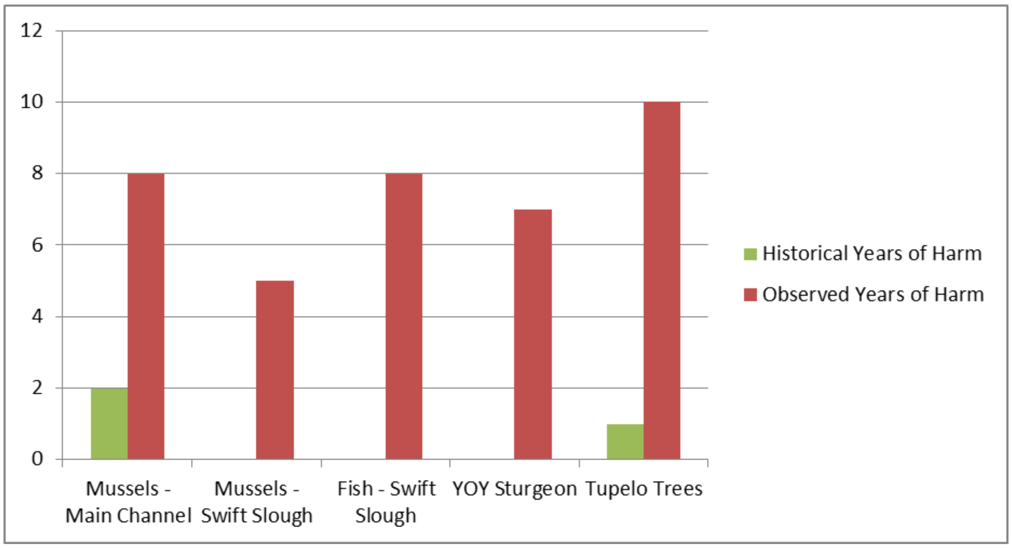
Figure 23 – Harm metric results. The above charts are all true and accurate copies of charts that were created under my supervision using scientifically valid methodology for use in my expert report, based on my metrics and the historical flow record (FX-790, App'x D.III).

63. To quantify the increase in harm, I compared the harm that occurred for a specific 16-year historic period (1942-1957) with a roughly similar pattern of precipitation as the most recent 16-year period (2000-2015). I selected the most recent 16 years (rather than a longer period) because it avoids complications associated with artificial flow pulses (known as "navigation windows") that occurred prior to 2000 when water was periodically released from the upstream dams to aid navigation (i.e., barges) between the Apalachicola Bay and Gulf of Mexico and locations upstream in Georgia. I selected the early period of 16 years to reflect a period that had similar precipitation patterns as the most recent 16 years, including a significant drought. As the graphs below show, harm has increased significantly in this period – for many species, the earlier period experienced *no harm* at all, yet recent periods see a significant amount of harm (*see* Figure 24). For example:

- The mussels in the main channel experienced a significant increase in harm, with harm years increasing four-fold to 8 years of harm, and days of harm increasing from less than 50 to 500.

- Floodplain trees experienced an increase of 9 years in which harm events occurred, a nine-fold increase, with almost 400 more days of harm.
- Mussels and fish in Swift Slough and young-of-year sturgeon experienced a change from no harm to frequent harm typical of each of these selected metrics.

Comparison of Historic and Recent Harm (Years)



Comparison of Historic and Recent Harm (Days)

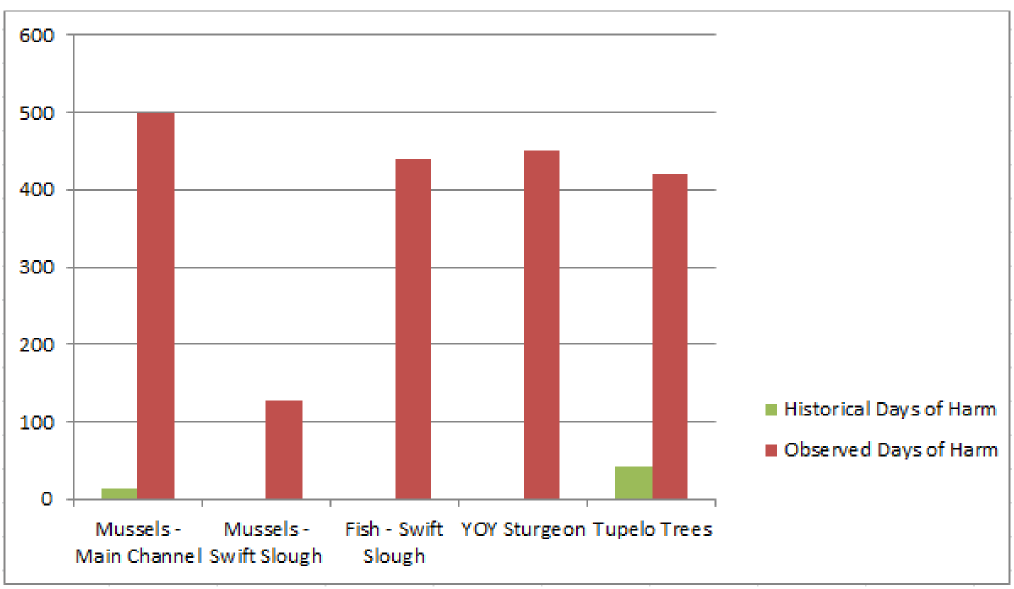


Figure 24 - Charts showing the significant difference between harm observed in recent years 2000-2015 (in red) and in the historical comparison period 1942-1957 (in green). These graphs graphically represent data presented in my expert report (FX-790, Tables 4-7) and were created under my supervision for use in this testimony.

D. *Combining Modeling and Metrics Shows That Georgia Consumption Is Responsible for a Significant Amount of Harm*

64. To isolate the harmful impact of Georgia's consumption on the River from any other factors, I combine my metrics with a modeled flow record created by Dr. George Hornberger, who explains his modeling work in his pre-filed direct testimony. The modeled flow record is an "unimpacted" record, which means a simulated situation with no Georgia water consumption. For this evaluation, I select the latest 16 years available in Dr. Hornberger's modeling (1997-2012), in part to avoid as much as possible any impacts from navigation windows, and to compare harm under the "unimpacted" scenario to harm that is demonstrated from the observed record for those same years. Those results (*see* Figure 25) show that there would be a substantial decrease in harm without Georgia consumption; for some metrics, there would be no harm without Georgia consumption. As examples:

- The mussels in the main channel would experience 75% fewer years and 98% fewer total days of harm without Georgia's consumption.
- The mussels in Swift Slough would experience no harm without Georgia's consumption.
- The fish in Swift Slough would experience 75% fewer years and 98.8% fewer total days of harm without Georgia's consumption.
- The young-of-year sturgeon would experience no harm without Georgia's consumption.

- The floodplain trees would experience 60% fewer years and 68.9% fewer total days of harm without Georgia's consumption.

Comparison of Actual Harm and Harm Without Georgia Consumption (Years)

Comparison of Actual Harm and Harm Without Georgia Consumption (Days)

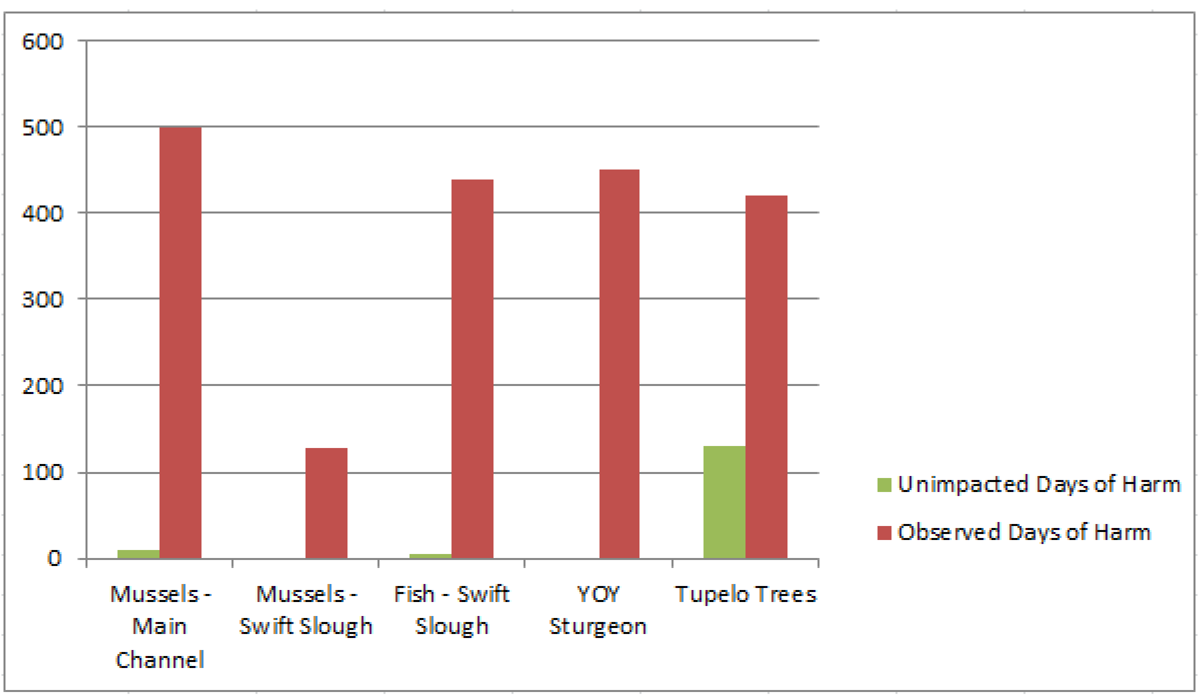


Figure 25 - Charts showing comparison for the actual harm for the selected metrics (in red) and modeled harm in the absence of Georgia consumption (in green). These graphs graphically represent data presented in my expert report (FX-790, Tables 4-7) and were created under my supervision for use in my testimony.

IV. ONE REMEDY SCENARIO: THE APALACHICOLA RIVER AND FLOODPLAIN NEED RESTORED FLOWS TO AVOID PERMANENT HARM

65. In my opinion, there is clear scientific evidence that the River has been significantly harmed. In this Section, I explain how a reduction in consumption will prevent the harm from becoming even worse. A remedy will also allow the ecosystem to stabilize, avoiding long periods of significant harm, and will facilitate the preservation of the River's ecology. This is true especially as compared to a future with increased Georgia consumption, which could cause permanent ecological harm to the River. First, I will discuss how even relatively modest increases in flow as a result of a remedy that caps Georgia consumption can improve the River's state by inundating more microhabitat. Second, I will illustrate with my metrics and one of Dr. Hornberger's modeled scenarios that a remedy can have significant and meaningful impacts.

A. *The Importance of Microhabitat and the Positive Impact of Modest Increments in Flow*

66. Incremental changes in river flow can profoundly affect the area of inundated habitat along channel margins, in sloughs and within the flooded forest. Much variability in extent of suitable habitat results from topographic variation, the positioning of habitat units such as submerged wood, the depressions that form downstream of any obstruction to flow, the different slopes of channel margins, hummocks within the forest, patches of sun or shade that affect rate of drying of habitat, and so on. (*See* Figure 13, Figure 15, Figure 26)

67. Because of this variation in microhabitat conditions, modest increases in flow can have disproportionately larger impacts on the extent of suitable habitat and survival of organisms. As

an example, an increase in flow in the range of 300-500 cfs at the Wewahitchka gage, when flows are 6,000 cfs, would raise water levels in many sloughs by 3 to 5 inches and will connect a number of disconnected sloughs, allowing flow to enter critical habitats within the sloughs and the Floodplain. (*See* Stage-Discharge Chart (FX-661)) This would significantly increase the extent of suitable habitat and survival of organisms.

68. Studies of mussel mortality during extreme low-flow episodes clearly show that survival or death depends on very minor differences in microhabitat among locations. (*See* EnviroScience 2006a (FX-388); EnviroScience 2006b (FX-387)) My report (FX-790) and Figures 15, 18, and 26 in my testimony contain numerous photographs illustrating this microhabitat variability. Field studies find high spatial variability in mortality among sites. Frequently, mussels located near springs or in flowing sections of stream survived drought conditions better than those found in shallow, isolated beds along stream margins, or in stagnant pools.

(Left) Main channel of the Apalachicola River at ~RM 57.8, illustrating the very gradual slopes typical of the middle reach of the river. FWC collected mussels here on 08-21-2015. (Photo 6A)

(Right) Mussels collected along the main-channel margin at the site pictured in 6A. Fat threeridge are shown in left two rows, with several other common species to the right. (Photo 6B)

(Left) View from downstream of backwater site, RM 44.3, 10-27-2005. (Photo 6C)

(Left) A small subset of the mussels found at the site shown in Photo 6C. Fat threeridge are at lower left, purple bankclimber upper left, and six other non-listed species are to the top and right. (Photo 6D)

(Right) Swift Slough, 7-12-06. At low flows, small changes in flow and water level cause the area of wetted stream habitat to shrink or expand dramatically, and the small side-channel at left to receive flow or be cut off. (Photo 6E)

(Left) Swift Slough 7-19-06. Mussels trapped in the small pool at left have no escape. Note the extensive woody debris. When submerged, shallow depressions are scoured by flow at the downstream of each piece of wood, algae and biofilms develop on wood surface, filter-feeding insects use submerged wood as "perches" and fish use it as shelter. (Photo 6F)

(Left) Kennedy Creek, 11-15-2001. Mussel mortality in a pool isolated by low flows. A field biologist is holding dead washboard mussels. Kennedy Creek joins the Apalachicola at River Mile 26, well downriver of most channel erosion. (Photo 6G)

(Left) Low flow conditions in a tupelo-cypress swamp in a small tributary of Iamonia Lake in the middle riverine reach. Sloughs are important to swamps because they carry water from the main channel to the interior of the floodplain through breaks in the riverbank levee. Low flow in the main channel reduces the amount of water getting to swamps, which lowers recruitment success for swamp species. (Photo 6H)

(Right) The raised mound of land in the center of the photo at right is a tree hummock surrounded by mud flats that are frequently inundated. Hummocks are very common in tidal freshwater swamps of the Apalachicola River and other coastal rivers. A long-term reduction in flows causes drier hydrologic conditions on tops and sides of hummocks; this causes a decline in swamp species due to competition from bottomland hardwoods. (Photo 6I)

Figure 26 – Distinct microhabitats occur throughout the River and floodplain and are important to the biota. Examples include main channel margins, which vary in slope and are the preferred microhabitat of many mussel species; side-pools and woody debris that are submerged at all but the lowest flows, and which are important to mussels, aquatic insects, and fish; and the lowest elevations of the floodplain which are the last to drain as floodwaters recede, where swamp species seedlings may become established and grow if the

floodplain receives the right amount of water, and where larval fish may find refuge or perish depending on flow. The pictures of mussels were taken during authorized field research by the Florida and federal governments in 2001 (6G), 2005 (6C, 6D), 2006 (6E, 6F), and 2015 (6A, 6B). Dead mussels were found as such in the field; no live mussels were taken from the sites. These photos are true and accurate copies of photos I used in my report (FX-790, Fig. 6). This kind of photograph is regularly relied upon by experts in my field, and I reviewed and relied upon these photographs in forming my opinions in this case.

69. Similarly, fish habitat is intimately connected to specific local features including channel margins, woody debris, bottom substrate, current and water depth. As water levels decline, the area of inundated habitat shrinks. Local conditions are highly variable due to differences in shade, pool depth, input of spring water and other variables. Again, modest increases in river flow can have disproportionately greater impacts on the recruitment of juvenile fish into the population and survival of adult fish, as they can make the difference between stagnant or flowing water in some sloughs.

70. As described more fully in my report (FX-790, p. 33-34), these microhabitats are incredibly important to the survival of individuals and populations. The harmful impacts of microhabitat loss become especially severe under low-flow conditions, as more and more habitat is lost. To the degree possible, the loss of microhabitat as harm is reflected in my biological metrics. Much of the evidence used in my metric development shows harm resulting from common-sense observations: exposed dead mussels are seen along sloughs that are nearly or completely dry, important habitat elements like woody debris are no longer submerged, only a small fraction of the forest is flooded and accessible to spawning fish, and the forest itself obviously is changing in character. Often, the margin between inundated or exposed habitat and between survival and death is small, and even modest increases in flow can yield disproportionate benefits to the ecosystem and improve the functioning of the food web as a whole. However, it is impossible to capture all of the loss of microhabitat, since there is so much

variability throughout the river. Therefore, my metrics only show a portion of the remedial effects that can be achieved with even a modest increase in river flow.

B. *My Metrics Show That a Cap on Georgia Consumption Will Help Stabilize the Ecosystem and Avoid Additional Harm that Will Occur in the Future*

71. Application of my metrics demonstrates that the habitats, organisms and ecosystems of the Apalachicola River and Floodplain have been seriously harmed by reduced water levels. I believe that actions are needed to ensure adequate flows not only to stabilize the system and prevent harm from worsening, but also to ameliorate harm that already has occurred and to help the system recover.

72. The present system is severely stressed. Although the River and Floodplain may be capable of recovery at this point, especially over an extended time period with healthy flows, *continued stress is likely to push the system to the point of irreversible harm*. This is particularly evident in the floodplain forest, where longitudinal studies show its forest ecosystems to be in transition. (*See* Figure 22) As I explained above, the decline in flow is causing the forest to lose its swamp trees and is shifting forest composition to different tree species. This forest land cannot recover in any short-term period – indeed, decades could be required to try to reverse the harm that has already been done. Should upstream depletions continue and flows decrease even more, permanent, irreversible harm to the River becomes even more likely and the likelihood of ever restoring the ecosystem becomes much more remote.

73. By combining my metrics with a scenario of Dr. Hornberger's under which upstream depletions continue to grow as projected under one scenario (the "future scenario"), I find that harm would become even more severe in the future. In contrast, by combining my metrics with one of Dr. Hornberger's very conservative "remedy scenarios," in which Georgia reduces its water use relative to the present-day condition, I can assess how a possible remedy can stabilize

the system and then result in the reduction in harm that can be achieved by even modest increases in flow that can range from a few hundred to as much as 1,000 cfs or more in summer months. (Hornberger Report, Appendix B (FX-785)) Using a less conservative remedy scenario that results in greater flows would provide an even greater positive impact on the Riverine ecosystem.

74. As with my "unimpacted" analysis, I use the latest 16 available years in Dr. Hornberger's modeling (1997-2012) as a baseline to compare what flows would have been like with a remedy and with increased future consumption. The following chart (Figure 27) shows the improvements that my metrics show would result from a remedy compared to the increase in harm that would result from future uncapped increases in consumption:

"Target" Species	**<u>Decreases</u> in Harm with a Remedy Scenario Capping Georgia Consumption as Compared to a Future with Increased Consumption**
Mussels (in main channel)	37.5% (years) decrease in harm 97.1% (days) decrease in harm
Mussels (in Swift Slough)	100% (years) decrease in harm 100% (days) decrease in harm
Fish (in Swift Slough)	66.7% (years) decrease in harm 98.0% (days) decrease in harm
Sturgeon	28.6% (years) decrease in harm 49.7% (days) decrease in harm
Floodplain Trees	11.1% (years) decrease in harm 3.7% (days) decrease in harm

Figure 27 – Chart showing improvement in the metrics, showing both improvement in "harm years" (as described above, these are years in which there are harm events at all) and "harm days" (as described above, this is the amount of days exceeding the metric harm thresholds). This chart numerically reflects data, based on my metrics and future and remedy scenarios, contained in my original report. It was created under my supervision using scientifically valid methods for use in my testimony. (FX-790, Tables 4-7, data on p. 83-84)

V. IMPROVED FLOWS IN GEORGIA'S RIVERS WILL ALSO BENEFIT STRESSED ENVIRONMENTS IN GEORGIA

75. Improved flows will not only aid species in the Apalachicola River, but also aid riverine species (including threatened and endangered mussels) in the Flint River in Georgia, as well as fish populations shared by both states. The Flint and Chattahoochee Rivers are the sources of the Apalachicola, and these rivers also have experienced extreme low flows in recent years, especially the lower Flint where most of the agricultural withdrawals are taking place (Hornberger Expert Report (FX-785); Flewelling Expert Report (FX-786)). Thus, an increase in flows in the rivers reaching the Apalachicola would unquestionably benefit river ecosystems in Georgia.

76. The Flint River Basin in particular is of significance because of its extensive high-quality habitat and well-documented biological diversity. The Flint River is important habitat for three species of anadromous fishes that historically or currently spawn in its waters. The Flint River has high physical habitat diversity including shoals, boulder-strewn rapids and varying gradient. The river and tributary streams of the lower Flint River Basin historically had a diverse mussel fauna, including at least 14 genera and 29 species, six of which were endemic to the larger Flint River Basin, although only 22 native bivalve species persist today. (*See* Golladay et al. 2004 (FX-396))

77. The impacts of reduced flows in the lower Flint River have stimulated numerous biological studies over the past two decades, and demonstrated far-reaching effects of low flows on the ecosystem's condition and biota. (*E.g.*, Golladay et al. 2004 (FX-396); *see* Figure 28) For example, measurement of substrate elevation profiles in Ichawaynochaway Creek in conjunction with water elevation-discharge relationships and historic discharge records dating back to the 1930s showed that substantial habitat loss today is attributable to current water

consumption. (McCormick & Baron (FX-50)) Shoals and coarse woody material are two ecologically important stream habitats that are affected by flow reductions in the Flint tributary creeks such as Ichawaynochaway. The McCormick & Baron study found that most shoal habitat that remained wet during extreme droughts in the past now dries under similar climate conditions today, a strong indication that withdrawals are causing the Creek to be drier than ever.

Figure 28 – A photograph taken by researchers at the J.W. Jones Center in Spring Creek, another important tributary to the Flint River, in June 2000. This shows that the Creek had virtually run dry except for a stagnant pool from which the researchers collected mussels (in the red bag). This is a true and accurate copy of a picture that was sent to Florida during the course of discovery (FX-254e), and that was described by Paula Gagnon in her accompanying declaration. (FX-255)

78. Mussels have been extensively studied in the lower Flint River and found to be negatively affected by low flows. One study estimated that mussels were on average four times less likely to be present following severe drought, and the effects were more pronounced in smaller streams. (Shea et al. 2013 (FX-398)) Studies done during droughts showed that mussels

in the lower Flint River decreased significantly in non-flowing streams including in 2000, and associate the decline with combined effect of drought and water consumption in Georgia. (Golladay & Hicks 2003 (FX-49n)) Subsequent surveys up until as recently as 2014 have found that mussels continue to be on the decline in the Flint River as a result of extended droughts and water withdrawals, with smaller populations making it more difficult for mussels to recover. (Smith et al. 2015 (FX-51))

79. Three species of anadromous fishes – Alabama shad (*Alosa alabamae*), Gulf striped bass (*Moxone saxatilis*) and Gulf sturgeon (*Acipiter oxyrinchus desotoi*) – are important migratory species of the Apalachicola-Chattahoochee-Flint (ACF) River system. Despite the presence of the Woodruff Dam, migratory species still connect these waters, and multi-state management agreements document efforts to recover these populations and re-establish important linkages between the Flint River Basin and Apalachicola River.

80. In sum, the Flint River Basin is a valuable freshwater ecosystem, known especially for its habitat, mussels and migratory fishes. A remedy that would prevent further decline in flows and would improve water levels in the Flint River Basin (especially during dry periods in dry years) would not only help Florida, but would also benefit the ecosystems and species in the Flint River Basin – some of which are connected directly to Florida's populations. Both states thus stand to gain ecologically from a remedy.

VI. MY BIOLOGICAL METRICS ASSESS HARM CAUSED BY GEORGIA'S CONSUMPTION, NOT CHANNEL CHANGES

81. I understand that Georgia has argued that historical harm to the River was also caused by the U.S. Army Corps of Engineers' navigation activities, such as dredging of the River. My report acknowledges and takes into consideration changes in the Apalachicola River channel that have occurred over the past 50 or more years. Construction of the Jim Woodruff Lock and Dam,

as well as navigational projects by the Army Corps of Engineers, have resulted in channel changes that had at least the temporary effect of making the River, generally speaking, deeper and/or wider. These processes are collectively termed “channel erosion.”

82. This channel erosion resulted from actions that were largely intended to benefit navigation to Georgia river ports such as Columbus and Bainbridge (Kondolf Expert Report (FX-796)). As described in Dr. Kondolf’s testimony, Florida has historically objected to the navigational work by the Corps. A decade ago, Florida declined to permit any further dredging in the River. I understand that there has been no significant dredging for over 15 years in the key parts of the River. I have reviewed and agree with Dr. Kondolf’s conclusion that since the cessation of dredging, the River channel morphology has stabilized and in some areas the morphology is recovering. This means that the channel itself is recovering from prior dredging, not that the ecosystem is recovering. Florida’s actions to halt navigational activity complement Florida’s other active preservation work, including spending millions of dollars in land purchases to preserve the ecosystem (Testimony of J. Steverson).

83. While I acknowledge that historical events have influenced the channel in the past, I do not believe it is possible to know with any reliability at this point in time what precise flow thresholds were necessary to connect every slough at every portion of the River some 50 or more years ago. But that is not necessary to my opinions. A variety of sloughs have always connected at differing flow levels, and there is no dispute that less of the floodplain is inundated in recent years that at any time in past history. Moreover, as explained by Dr. Kondolf, the upper, middle and lower tidal areas were not impacted by channel erosion; the effects of the navigational activities there have disappeared, and lower flows in this reach cause immediate significant declines in water levels. The tidal areas – which contain large amounts of swamp trees and

associated habitat for fish and sturgeon – are included in the harm metrics I evaluate here for tupelo and sturgeon, and in the fish metrics I evaluated in my report. Those metrics are therefore unaffected by channel erosion.

84. Most importantly, I link my biological metrics to Dr. Hornberger's hydrologic analyses. Doing so provides a scientifically sound way to isolate the effects of flow from the effects of channel change. All the analyses I perform using Dr. Hornberger's modeled flows use my metrics to compare harm that occurs today with the present channel and flow, to the harm that would occur, with the present channel, if Georgia's upstream consumption was different. Removing Georgia's consumption (the unimpacted comparison), while keeping the channel constant, invariably results in a significant decrease in harm. My metrics, combined with Dr. Hornberger's hydrologic analysis, isolate the effects of changes in flow as a result of Georgia consumption from the effects of altered channel morphology, and show that changes in flow have a significant impact on the River ecology.

85. Because it is possible to isolate the effects of Georgia's consumption from altered channel morphology, I do not believe channel erosion is relevant in assessing harm to the River that results from Georgia's consumption, nor is it relevant to understanding how a remedy will help the ecosystem. The River is more stressed now than ever in its history, and even modest increases in flow will help Florida preserve and recover parts of the Apalachicola River ecosystem.

VII. RESPONSES TO GEORGIA'S EXPERT-- DR. CHARLES MENZIE

86. As part of my preparation of this testimony, I reviewed the report of Georgia's ecological expert, Dr. Charles Menzie. Since I understand his pre-filed testimony will not be available until

after I present my testimony, I wanted to respond to concerns he has raised, and emphasize some of our points of agreement.

87. First, Dr. Menzie acknowledges in his report that under low-flow conditions, the inflow elevations of sloughs can be above river level, preventing water from entering sloughs and thereby inundating the swamp and bottomland forests. Thus, we are in agreement on that requirement of flow for inundation.

88. Dr. Menzie also acknowledges the importance of the floodplain. His report states, "Because the forest communities of the floodplain provide essential habitat to support other aquatic resources, such as fish, reptiles, amphibians, and mussels, the species composition of trees in the Apalachicola River floodplain was used as an indicator of change in the floodplain." Dr. Menzie further notes that "[t]he selection of trees as an indicator is supported by extensive research conducted in the Apalachicola River floodplain, the distribution of the resource along the entire extent of the non-tidal river, the long lifespans of tree species, as well as the ecological and economic significance of floodplain tree species." Indeed, Dr. Menzie also agrees that there is evidence of a significant decline in the densities of tree species that are characteristic of swamps throughout the non-tidal floodplain, and of a successional shift through the floodplain forest habitats to species that are more typical of the next-drier habitat.

89. Dr. Menzie stated that he does not think there is population-level harm to species in the Apalachicola River basin, because species have continued to exist. I think this approach is incorrect. It is important to note that population harm is the outcome of direct mortality of individuals and reduction in quality and in area of suitable habitat, all of which contribute to declines in population abundance. It is overly narrow to equate biological harm with jeopardy of

extinction, as Dr. Menzie did in his report. Under Dr. Menzie's approach, there can *only* be harm if there is a threat of populations going extinct.

90. Dr. Menzie cites a finding by the U.S. Fish and Wildlife Service (USFWS) under the Endangered Species Act that certain actions, unrelated to Georgia's water consumption, will not threaten extinction of certain mussel species. (USFWS 2012 Biological Opinion (JX-72); 2016 Biological Opinion (JX-168)) However, Dr. Menzie ignores the substantial harm that the USFWS found in its report. The report finds that harm will still occur to mussels once flow drops below 10,000 cfs, and estimates that thousands of mussels will die at low flow.

91. Moreover, in its report created pursuant to the Fish and Wildlife Coordination Act, the USFWS identified the harm caused by increasingly lower flows, and the need for higher flow levels to sustain the health of the Apalachicola ecosystem. (*See* DFWCAR (JX-122)) Any mortality of mussels as a result of low flows reduces the ability of the population to recover and thrive, and harms Florida's efforts to protect and preserve these mussels, even if a small subset of mussels could survive at low flows and avoid complete extinction.

92. Finally, focusing on "jeopardy" alone limits the discussion to only the handful of species listed under the Endangered Species Act, and fails to take into account the connectedness and importance of all species in the ecosystem and the importance of flow to their environment.

CONCLUSIONS

93. The Apalachicola River and Floodplain are a national treasure, valuable for their high level of biodiversity, productivity and natural ecological processes. I have found that adequate flow from upstream is essential, particularly during droughts, to maintain river-floodplain connectivity and support biological communities throughout the Apalachicola riverine corridor.

94. The evidence presented in my report and above testimony strongly documents harm to the Apalachicola River and Floodplain ecosystem over recent decades as a result of the diminished flows from upstream. This evidence rests on two separate analyses: (1) I constructed a series of carefully researched and ecologically meaningful metrics of harm for four important features of the ecosystem (mussel assemblage, fish assemblage, Gulf sturgeon and tupelo-cypress swamps), based on evidence of flow thresholds, duration and seasonal timing at which harmful conditions occur; and (2) drawing on hydrologic analyses and modeling presented by Dr. Hornberger, I showed how harm has increased over the historical record, how harm would be reduced under one potential remedy and how it would increase under a future of greater water withdrawals.

95. It is important to recognize that the exact metrics selected here (as well as the additional metrics I evaluated in my report), while amply justified by known harmful conditions, events and other evidence, are representative of harm that would occur at both higher and lower thresholds. Other species and ecosystem components undoubtedly are likewise harmed by flow depletions, but data are unavailable to quantify all such cases. Moreover, the harm described is consistent with extensive ecological knowledge of the habitat and microhabitat needs of many different species, and the sensitivity of habitat conditions to even small changes in flow and water level during low-flow seasons and years.

96. For a broad range of features and their associated metrics, harmful flow conditions in the Apalachicola River and its Floodplain are occurring more often under the current, impacted flows than occurred in the past and would occur in the absence of upstream depletions. Projecting the extent of harm into the future indicates that harmful conditions will worsen over

the coming decades if the flow depletions are not reduced. Even modest amounts of additional flow would benefit the ecosystem.

ATTACHMENT – LIST OF EXHIBITS CITED

- JX-29: This is a true and accurate copy of an official 2008 Apalachicola National Estuarine Research Reserve (ANERR) report by Lee Edmiston, titled *A River Meets the Bay: A Characterization of the Apalachicola River and Bay System*, available online at http://www.dep.state.fl.us/coastal/downloads/management_plans/A_River_Meets_the_Bay.pdf. This work contains biological data and summaries typically relied upon by biologists, and I relied upon this document to further inform my opinions.
- JX-72: This is a true and accurate copy of the 2012 Biological Opinion published by USFWS and available online at https://www.fws.gov/southeast/news/2012/pdf/woodruffBOFinal.pdf. Experts in my field regularly rely on such government reports containing biological data, and I relied upon it to inform my opinions.
- JX-88: This is a true and accurate copy of a spreadsheet titled *Appendix III.B.* created by FDEP in 2013 as part of official comments to the U.S. Army Corps of Engineers, as produced to Georgia by Florida. It reflects biological data that biologists typically rely on, and I relied upon it to inform my opinions.
- JX-122: This is a true and accurate copy of the official Draft Fish and Wildlife Coordination Report by the United States Fish and Wildlife Service (USFWS), dated July 2015, as provided to both Florida and Georgia. Experts in my field regularly rely on such government reports containing biological data, and I relied upon it to inform my opinions.
- FX-49n: This is a true and accurate copy of a document titled *Mussel Population Surveys and Estimation of Potential Stream Withdrawals at Selected Sites in the Lower Flint*

River Basin, identified in Woody Hicks' March 3, 2016 declaration (FX-49) as a June 2003 report with mussel survey data created for the Georgia Department of Natural Resources, Environmental Protection Division by the Joseph W. Jones Ecological Research Center. Experts in my field regularly rely on such government reports containing biological data, and I relied upon it to further inform my opinions.

- FX-51: This is a true and accurate copy of an article titled *Stream Habitat and Mussel Populations Adjacent to AAWCM Sites in the Lower Flint River Basin*, authored by Nathalie Smith and others, published in the *Proceedings of the 2015 Georgia Water Resources Conferences*, a type of publication regularly relied upon by experts in my field. This article is publicly available, and I relied upon it to further inform my opinions.
- FX-50: This is a true and accurate copy of an article titled *Effects of Reduced Summertime Stream Flows on Instream Habitat in the Lower Flint River Basin, Georgia, USA*, authored by Paul McCormick and Lisa Cowart Baron, published in the *Proceedings of the 2015 Georgia Water Resources Conferences*, a type of publication regularly relied upon by experts in my field. This article is publicly available, and I relied upon it to inform my opinions.
- FX-154: This is a true and accurate copy of the official United Nations Educational, Scientific, and Cultural Organization (UNESCO) website listing of the Central Gulf Coast Plain Biosphere, which encompasses the Apalachicola River, located at http://www.unesco.org/mabdb/br/brdir/directory/biores.asp?mode=all&code=USA+37. I reviewed and relied upon this information to further inform my opinions.
- FX-254e: Described in text.

- FX-255: This is a true and accurate copy of a March 28, 2016 declaration filed by Paula Gagnon of the Jones Center, describing, among other images, the image contained in FX-254e. I relied upon this declaration to identify what FX-254e shows.
- FX-383: This is a true and accurate copy of an official 2001 Florida Fish and Wildlife Conservation Commission (FWC) report titled *State of Florida Conservation Plan for Gulf Sturgeon* (Acipenser oxyrinchus desotoi), as produced to Georgia by Florida. This work contains basic biological information typically relied upon by biologists, and I relied upon this document to further inform my opinions.
- FX-384: This is a true and accurate copy of a 2015 presentation titled *Assessing Juvenile Gulf Sturgeon Recruitment in the Apalachicola River, FL*, by Andrew Marbury and Doug Peterson of the University of Georgia, supported by USFWS, the Georgia Department of Natural Resources (DNR), and the Florida Fish and Wildlife Conservation Commission (FWC). It was provided to both Florida and Georgia at a joint meeting in 2015. This work presents research typically relied upon by biologists, and I relied upon this document to extract images and to further inform my opinions.
- FX-385: This is a true and accurate copy of a spreadsheet created by FWC in 2015, as produced to Georgia by Florida. This spreadsheet contains data regularly relied upon by biologists, and I relied upon this document to inform my opinions.
- FX-387: This is a true and accurate copy of an official report titled *Swift Slough Population (Abundance) Estimate for the federally endangered* Amblema neislerii *(Fat Threeridge) and federally threatened* Elliptoideus sloatianus *(Purple Bankclimber)*, prepared for the Florida Department of Environmental Protection (FDEP) by EnviroScience, Inc. in 2006, as produced to Georgia by Florida. It contains biological

data typically relied upon by biologists, and I relied upon this document to inform my opinions.

- FX-388: This is a true and accurate copy of an official report titled *Freshwater Mussel and Habitat Surveys of the Apalachicola River, Chipola River and Selected Sloughs/Tributaries*, prepared for the Florida Department of Environmental Protection (FDEP) by EnviroScience, Inc. in 2006, as produced to Georgia by Florida. It contains biological data typically relied upon by biologists, and I relied upon this document to inform my opinions.
- FX-389: This is a true and accurate copy of an official report titled *Population size and depth distribution of three federally-protected mussels in the Apalachicola and Lower Chipola rivers*, prepared for the U.S. Army Corps of Engineers by Dr. Michael Gangloff in 2012, as produced to Georgia by Florida. It contains biological data typically relied upon by biologists, and I relied upon this document to inform my opinions.
- FX-390: This is a true and accurate copy of an official USFWS report titled *An investigation of movement, exposure, and mortality of fat threeridge mussels* (Amblema neislerii) *at Apalachicola and Chipola River sites*, prepared by Adam J. Kaeser and Karen Herrington, as produced to Georgia by Florida. It contains biological data typically relied upon by biologists, and I relied upon this document to inform my opinions.
- FX-396: This is a true and accurate copy of an article authored by Stephen Golladay and others titled *Response of freshwater mussel assemblages* (Bivalvia: Unionidae) *to a record drought in the Gulf Coastal Plain of southwestern Georgia*, published in 2004 in the *Journal of the North American Benthological Society*, a journal regularly relied upon

by biologists. This article is publicly available, and I relied upon it to inform my opinions.

- FX-398: This is a true and accurate copy of an article authored by Colin Shea and others titled *Evaluating the influence of land use, drought and reach isolation on the occurrence of freshwater mussel species in the lower Flint River Basin, Georgia (U.S.A.)*, published in 2013 in the journal *Freshwater Biology*, a journal regularly relied upon by biologists. This article is publicly available, and I relied upon it to inform my opinions.
- FX-661: This is a true and accurate copy of a river stage chart created by United States Geological Survey (USGS) scientist Helen Light in 2014, produced to Georgia by Florida, based upon official USGS publications. Such data is regularly relied upon by riverine biologists, and I relied upon it to inform my opinions.
- FX-785: This is a true and accurate copy of Dr. George Hornberger's expert report as submitted by Florida to Georgia on February 29, 2016. Riverine biologists frequently cooperate with and rely upon hydrologists, and I relied upon Dr. Hornberger's work to inform my opinions.
- FX-786: This is a true and accurate copy of Dr. Sam Flewelling's expert report as submitted by Florida to Georgia on February 29, 2016. Riverine biologists frequently cooperate with and rely upon hydrologists, and I relied upon Dr. Flewelling's work to inform my opinions.
- FX-790: This is a true and accurate copy of the expert report that I prepared for this case, as submitted by Florida to Georgia on February 29, 2016.
- FX-796: This is a true and accurate copy of Dr. G. Mathias Kondolf's expert report as submitted by Florida to Georgia on February 29, 2016. Riverine biologists frequently

cooperate with and rely upon geomorphologists, and I relied upon Dr. Kondolf's work to inform my opinions.

- FX-812m: Described in text.
- FX-820o: Described in text.
- FX-823r: Described in text.
- JX-168: This is a true and accurate copy of the 2016 Biological Opinion published by USFWS and available online at https://www.fws.gov/panamacity/resources/USFWSBiologicalOpinionforACFWaterControlManual2016.pdf, publicly released in October 2016. Experts in my field regularly rely on such government reports containing biological data, and I reviewed it recently to confirm my opinions.