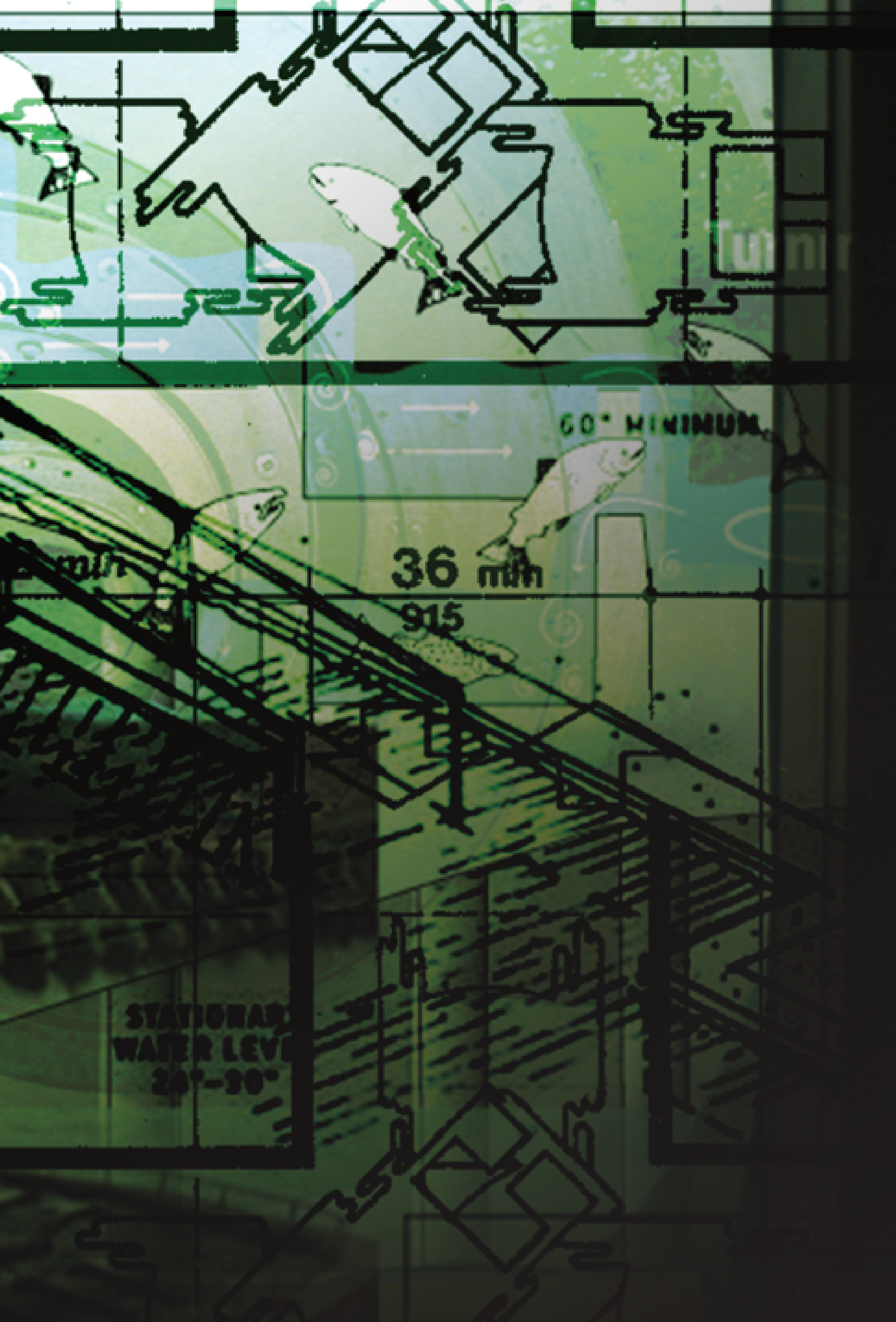

# OVER THE DAM

a multifunctional dam
designed for multiple species

by matthew blansit
**Auburn University**
master of landscape
architecture 2014

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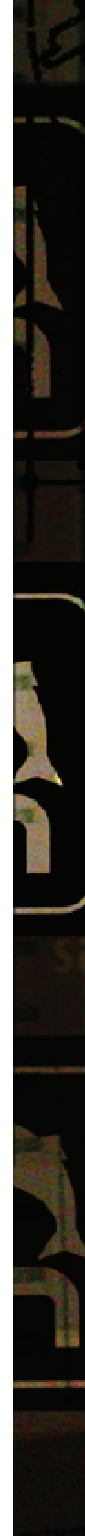


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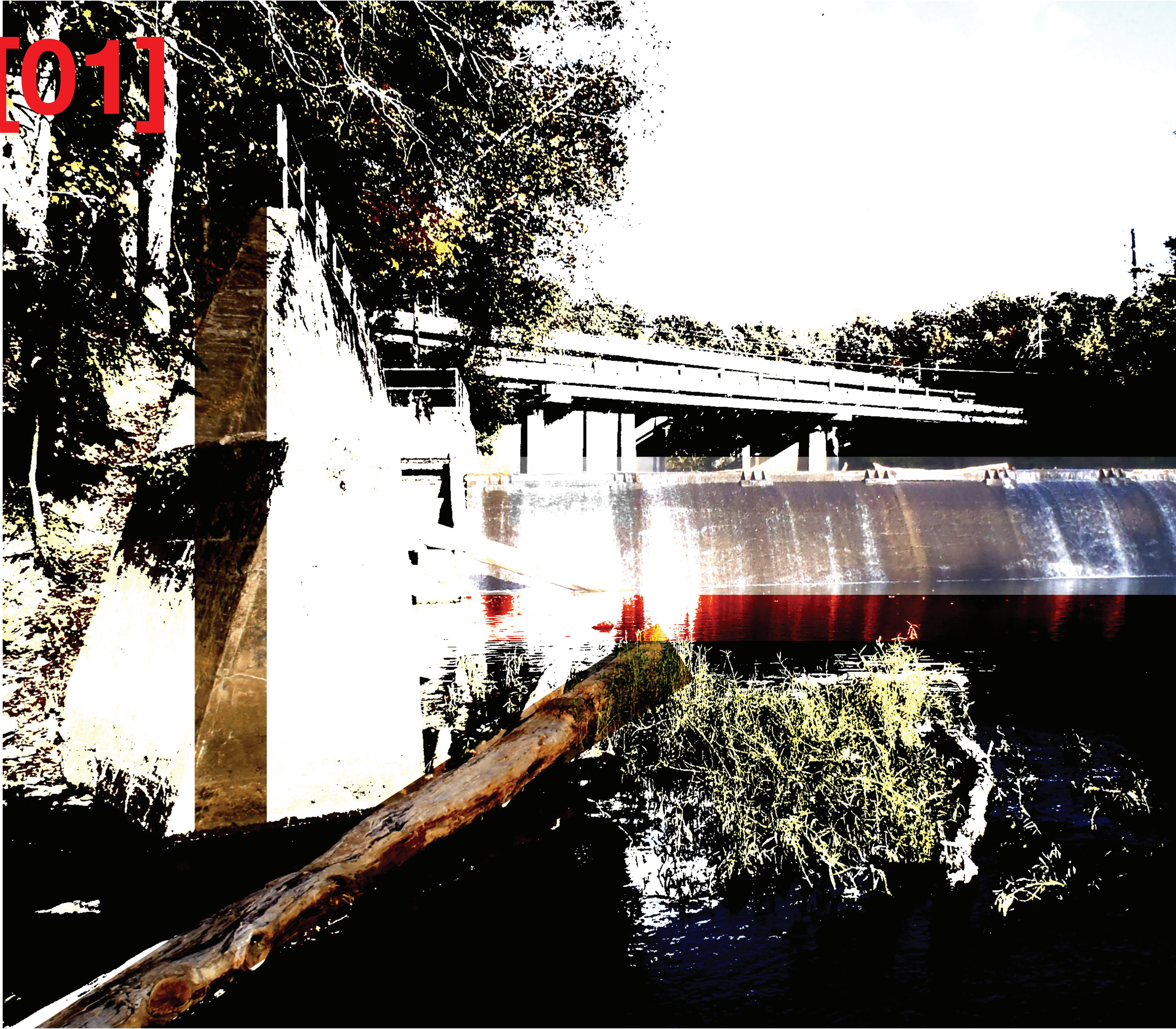
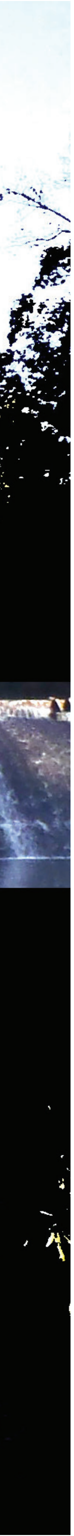




# ABSTRACT

Strong infrastructure makes a strong city, and advances in infrastructure are linked to the success of any civilization throughout history. Bridges, dams, roads, sewer systems, food sources, energy, and communication networks are all parts of what makes modern societies thrive, but many times these advances for human gain comes at an ecologic cost. Habitat fragmentation, changes in ecologic function, water flow disturbances, and hazardous materials can greatly change the make up of our surrounding ecosystems, which in turn harms the health of our communities. Balancing the health benefits for human needs and non-human needs could be the next advance in our infrastructural systems that can allow both to thrive.

The Nature Conservancy and the World Wildlife Foundation have recognized ecologic hotspots around the world as places of high biodiversity. These organizations claim that connecting these hotspots is essential to maintain global biodiversity as well as healthy human populations.

The Cahaba River in Central Alabama has more species of fish in one mile than any other river in the world and is considered an ecologic hotspot. Much of this can be attributed to its long stretch of free flowing waters, unimpeded by dams, but there are dams that segment the river isolating populations of fish, mussels, and snails, which weakens their gene pool and puts these species at risk of extinction. However, one of these dams is essential to the city of Birmingham’s fresh water supply.

This thesis researches the possibilities of multifunctional infrastructure that can benefit multiple species on the Cahaba River. This allows the dam to continue functioning as a dam, while providing improved habitat for multiple species, allows the river to continue flowing, and provides a place where humans can actively and passively interact with the ecology of the river.

# INFRASTRUCTURE'S EFFECTS ON ECOLOGY

## the one-sided relationship

Most creatures attempt to make their surroundings more favorable for their survival. Ants form colonies, birds build nests, foxes make dens, and beavers build dams. Humans are a species that has been able to manipulate its environment so much that survival is not on the forefront of minds for people that live in modern cities. These infrastructural advances allow populations to have a reliable source of water, heat, electricity, connections to food supplies from around the world, and dispose of waste.

The greatest civilizations developed some of the most impressive infrastructures, which allowed them to grow faster than their contemporaries. India constructed dams to cool climates and preserve water resources. China created terraced farms to grow large quantities of food in unforgiving terrain. Rome built highways and aqueducts allowing supplies, troops, and water to move easily throughout the empire. Today, modern countries have super highways, railroads, mega hydroelectric dams, bridges, grids of electricity, pipe networks of gas and oil, sewage lines, water conveyance systems, and water treatment facilities making the basic needs of survival for their citizens easy to attain. The hypothesis put forth by Abraham Maslow of a "Hierarchy of Needs" is generally accepted. It states that when the basic needs of food, water, shelter, and safety are met people are able to concentrate on more complicated matters and populations can increase.

As populations increase, greater stress is put on the resources to ensure the population's survival, which leads to either searches for more and/or better resources, or a more efficient use of the existing resources. The former is usually the case. That can mean more mines, larger dams, or greater deforestation to supply the growing needs of the growing population. As long as the population continues to grow and there is only a search for more resources, the cycle will continue.

The effects on the surrounding ecosystems are often habitat fragmentation, contamination of existing resources, and habitat alteration, all of which lead to great density, more edge conditions, and competition for space and resources. The stress felt by the species of the effected systems may suffer from weaker gene pools leading to greater risk of diseases, larger risk of invasive species taking over, or starvation. Many species are put at risk of extinction.

Alabama is home to one of the largest man-made mass extinctions. Before the rivers of Alabama were dammed, they were home to the largest populations of freshwater mussels and snails, many different species of fish, and some of the largest shoals in the America. The dams flooded many of the shoals to make rivers navigable to boat traffic, produce hydroelectricity, and control flooding. It is estimated that these dams wiped out half of the species of mussels and snails that were found in the Alabama River basin (Master, Flack, & Stein, 1998). The migrating fish are now cut off from their traditional breeding grounds. To complicate the matter further, industrialization has caused toxins to build up in the sediment halted by the dams.

But many of the dams are needed in order for humans to thrive and maintain the standard of living to which we have become accustomed. This brings up the ethics question of how much can we place our needs above ecologic health? Obviously, to harm ourselves it not self-serving, but at some point we begin to harm ourselves by taking more than we need. The line to be walked could grow to a path if we are able to find more sustainable ways to gather the resources we need in a less destructive way than we have in the past. These investigations will be examining one such way through the infrastructure of low-head dams acting.

# NOVEL ECOLOGIES

wild new encounters

Novel Ecologies are the systems that result from disturbances, such as natural disasters or human implementations, where two or more organisms that had no previous relations are introduced to each other. Some examples are a prairie growing in the clearing of a forest taken down by fire or tornados, moss on newly exposed rock that had been covered by a glacier, cracks in the pavement where ants and weeds take over, birds and rats living in the rafters of houses, or rivers turned to lakes by dams.

Strict preservationists fight novel ecologies because they view any change to the current ecology as a destruction of the fragile systems of unique specialist species, which is a sin. The concept of novel ecologies acknowledges that life will go on, as it always has, even with the loss of species. Any niche that becomes vacant will be filled by another species, native or exotic, supporting the notion of surrogate species.

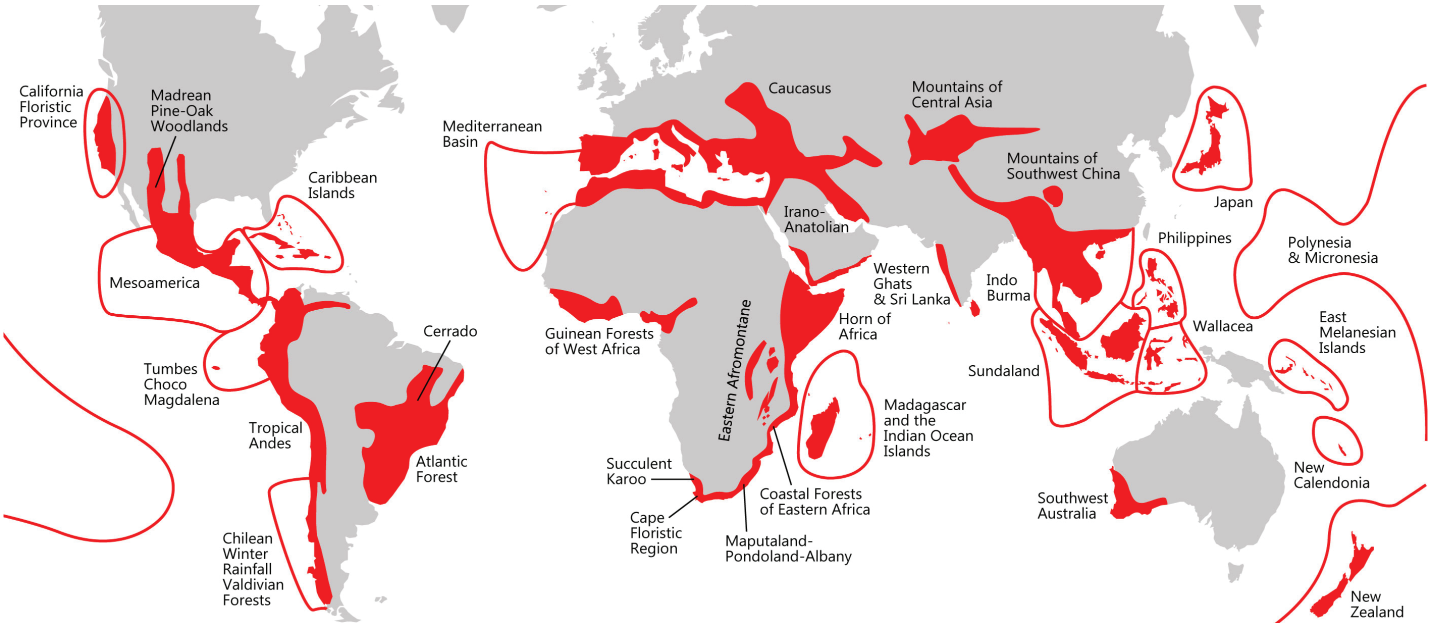
In the grand scheme of things, a novel ecology is just a perception of time. However, as designers, we design for the here and now, while harkening back to the past and looking towards the future. We can utilize the concept of novel ecologies when we consider the effects a design intervention might have on the niches in the surrounding ecosystems. Designing with ecological functions and building surrogate habitats can be a way to move the infrastructural designs that we live with today. In doing so, I believe that this knowledge does not give us free license to throw out any responsibility of how our designs affect their surroundings, but it does empower us to design for species. By creating or emphasizing niches for specific species, we open the door directly for those species and indirectly for the other species that are associated with them.

# ECOLOGICAL HOTSPOTS
## the rare places

The freshwater systems of the United States are home to some of the greatest biodiversity in the entire world. The number of freshwater mussels, snails, crayfish, stoneflies, mayflies, and caddisflies are the highest in the world according to the Nature Conservancy, but many of these species are at risk of extinction (Master, Flack, & Stein, 1998). Much of the threat to the freshwater habitats comes from human activities: dam construction, water withdrawals, point source and non-point source pollution, heavy agriculture, sprawling cities, and introduction of non-native species. Shrinking suitable habitats have become targets for conservation groups and environmental agencies to protect. A British ecologist, Norman Myers, developed the term biodiversity hotspot to classify these disappearing habitats, which "hold especially high numbers of endemic species, yet their combined area of remaining habitat covers only 2.3 percent of the Earth's land surface. Each hotspot faces extreme threats and has already lost at least 70 percent of its original natural vegetation. Over 50 percent of the world's plant species and 42 percent of all terrestrial vertebrate species are endemic to the 34 biodiversity hotspots" (Myers, Mittermeier, Mittermeier, Fonseca, & Kent, 2000).

This theory has been adopted and expanded by groups such as the Nature Conservancy, World Wildlife Fund, and Conservation International. Landscape architect Richard Weller believes that his discipline should be leading the campaign of what to do with these hotspots that have been identified. He claims that cities cannot exist without forests, and as the world has become more globalized in commerce, communications, and culture, we should also think of a global forest. This concept looks at the worldwide need to have forests for global health and maintain biodiversity and developing conservation implementations that acknowledge the growth and needs of human and non-human populations (Weller & Hands, 2014). Weller is still investigating the multitude of possibilities and implications of actions that could be done with his students at the University of Pennsylvania, focusing in many cases how to connect and integrate the expansion of forests into cities and cities into forests while still protecting the integrity of the biodiversity hotspots.

The hotspots that have been identified by Myers, and studied by Weller, are terrestrial ecologies that are mainly tropical and subtropical forests, but the Nature Conservancy (TNC) has expanded the framework to include aquatic habitats. Through large efforts and samplings TNC has developed a worldwide inventory of aquatic biodiversity hotspots. In order to be considered a hotspot, the river system must be home to at least ten imperiled species, and "have the greatest total diversity of species, or … the greatest number of species at




**Map of Ecological Hotspots**

Ecologists have identified these terrestrial Ecological Hotspots throughout the world. Many of them are being threatened by human expansion. Landscape architects, like Richard Weller, are investigating ways to incorporate habitat improvements with human development and experimenting with ways to connect ecological hotspots through human expansion. This thesis examines how those concepts can be applied to riparian environments.

*Image from Conservation International*

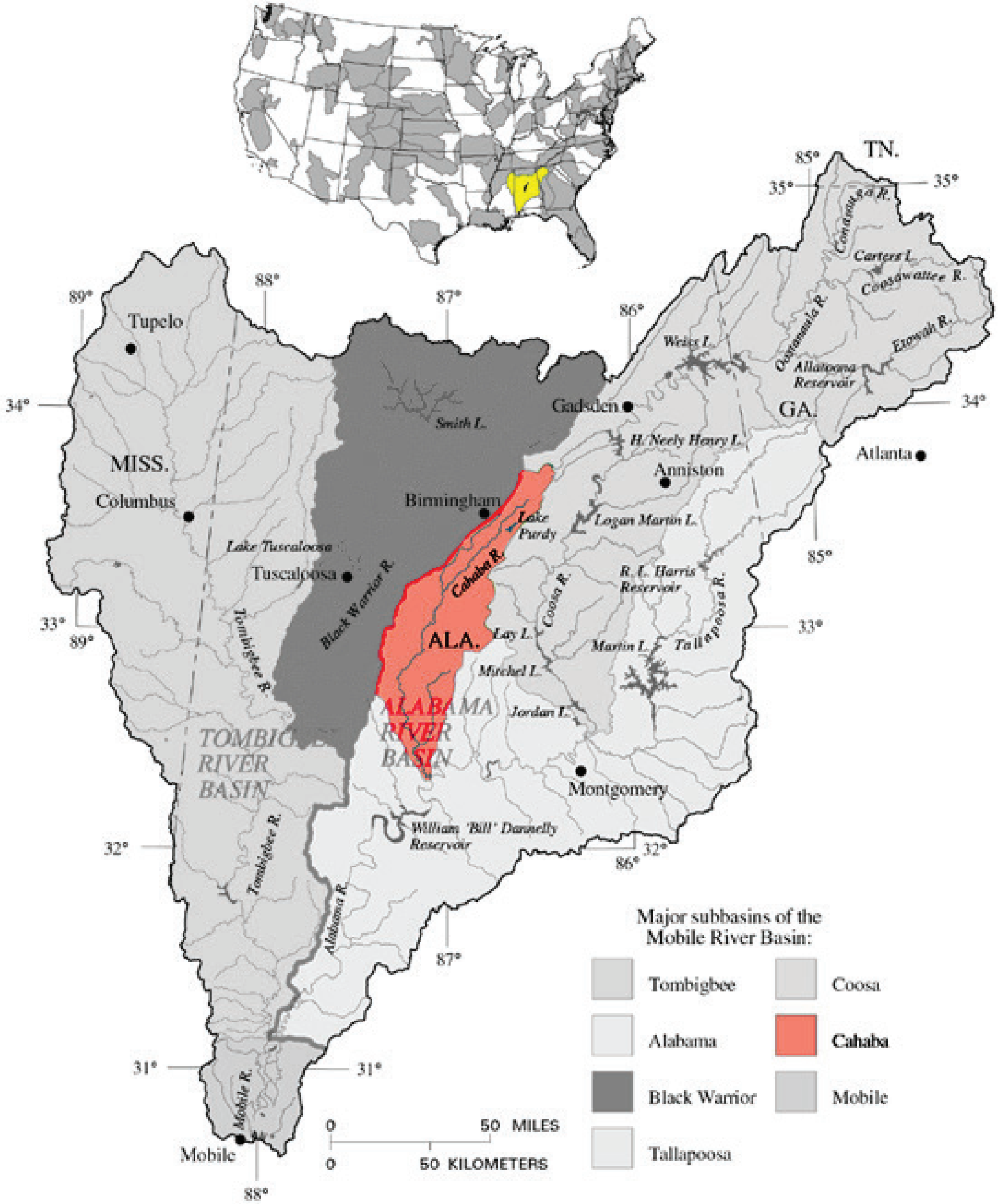
risk" (Master et al., 1998). Small watersheds identify these hotspots, so that conservation plans can be implemented and assessed at a manageable scale.

It is important to identify hotspots for a multitude of reasons, including resource protection, biodiversity conservation, food security, medical research, recreation, and flood control. Managing the health of hotspots is a challenging and sometimes divisive task that can manifest through public policies, bills, local volunteer efforts, enforcing stricter construction practices, updating wastewater treatment practices, creating multifunctional infrastructure, or designing interventions like stream bank restoration. But trying to tackle everything at once can be overwhelming especially when the goal is to reach a baseline standard from a past time. Lowering the levels of pollutants discharged in a river is a desirable outcome and something to strive for, but sometimes focusing strategic interventions can be more beneficial in the long run of conservation goals.

Many issues being faced in the watersheds are ones that have not been previously experienced and have no precedent, so there is going to be a lot of firsts if anything is to be done. A large effort across many disciplines will have to take place, analyzing key points within the hotspots: rare species areas, infrastructure, human populations, recreation areas, wastewater treatment, land use, water quality, etc. Taking this information in is when the experimentation begins. Should infrastructure stay or go? Should policies be implemented? How do you inform the public? Should disturbances be spread throughout in smaller doses or should they be concentrated to just one area? These are decisions that can be hypothesized and tested in models and labs but only truly known when implemented. And at some point we are just going to have to build it because the risk of doing nothing will become greater than the risk of doing something. Connection between hotspots might be an answer, but not the only answer. The complexities of the growing, globalizing human populations continue to increase. Maybe we should look at how we can incorporate the ecological processes into our own connections and movements as we continue to grow.

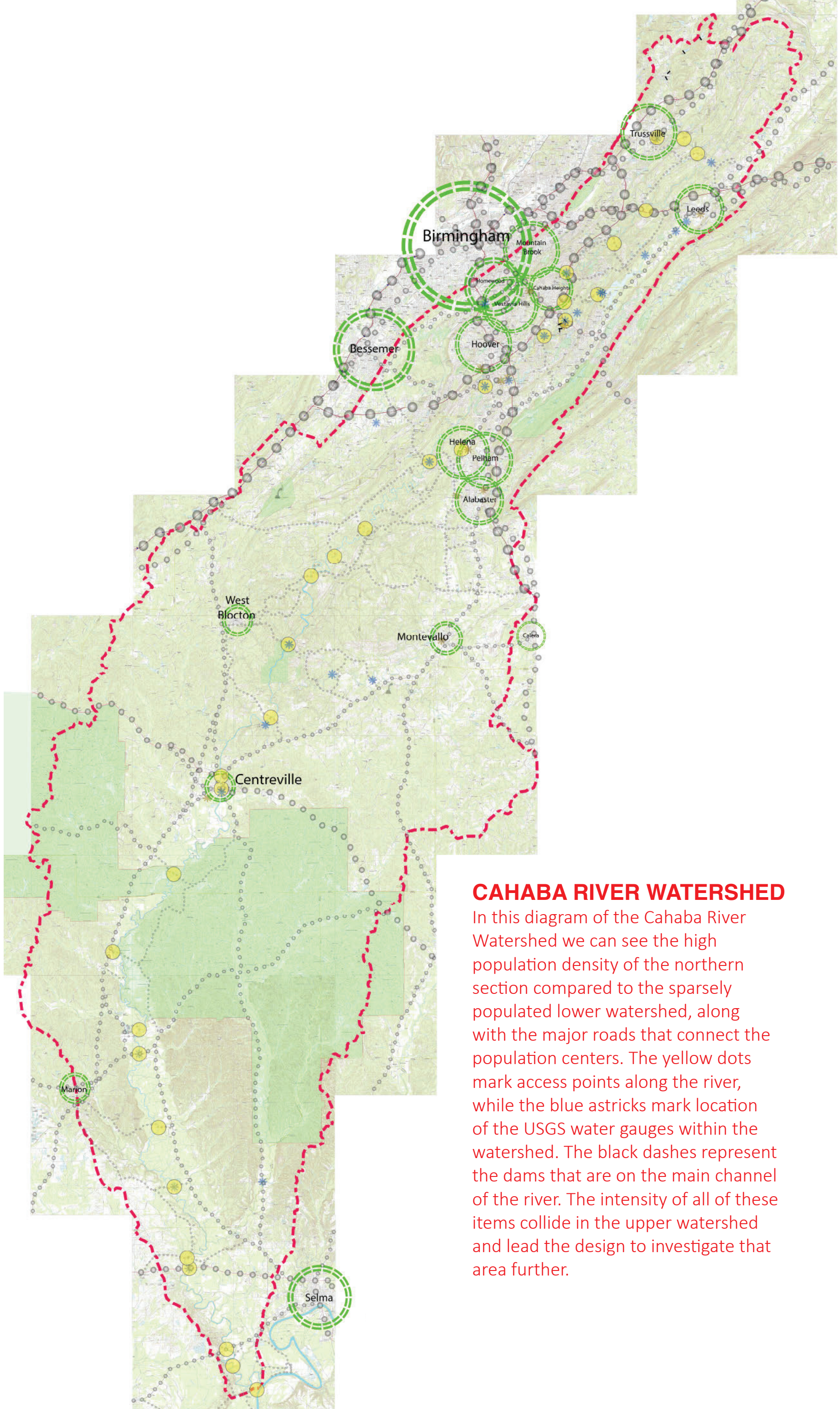
# CAHABA RIVER

## the ecologic treasure in the heart of Alabama




Many times we think that diverse ecologies are located far away from us, in the wilder lands. In the state of Alabama, that is not the case. Near the population hub of Birmingham, a ecologically diverse river runs right by the backyards, shopping centers, and main thoroughfares for a large portion of the population, yet is isolated and threatened by current human activities. Thus, lending itself to be a perfect test site to see how we may design to mutually benefit the needs of humans and non-humans.

The Cahaba River is a 200-mile long river located in the center of the Alabama-Mobile River watershed in the Southeastern United States. Its headwaters are found in the foothills of the Appalachian Mountains just to the north and east of Birmingham.  The watershed itself is not very large compared to the neighboring Black Warrior and

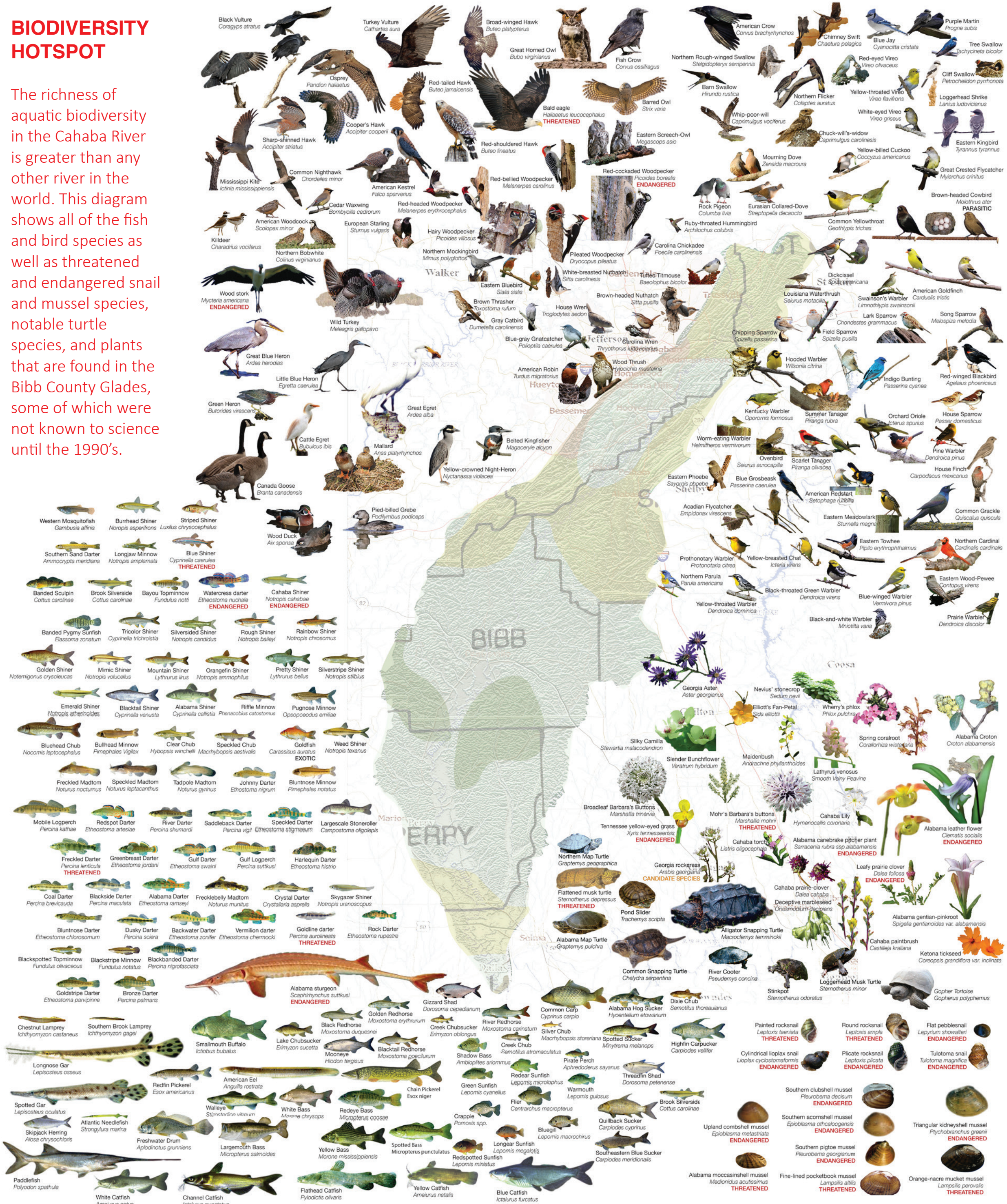



## CAHABA RIVER WATERSHED

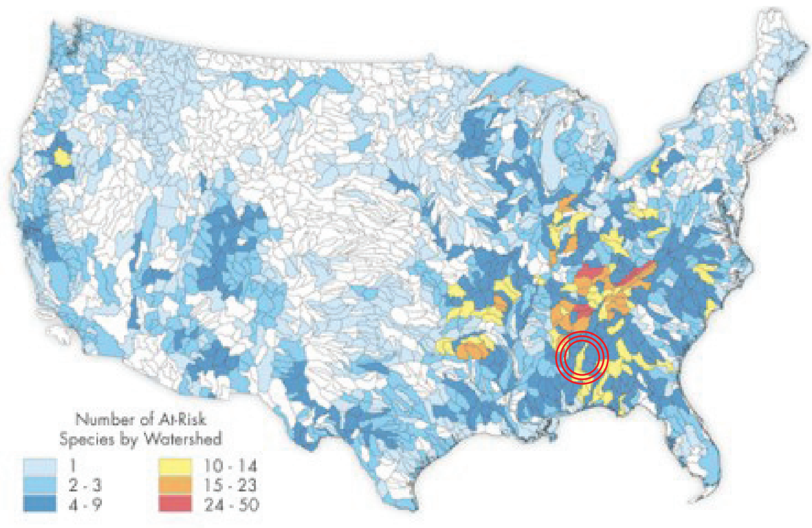
In this diagram of the Cahaba River Watershed we can see the high population density of the northern section compared to the sparsely populated lower watershed, along with the major roads that connect the population centers. The yellow dots mark access points along the river, while the blue astricks mark location of the USGS water gauges within the watershed. The black dashes represent the dams that are on the main channel of the river. The intensity of all of these items collide in the upper watershed and lead the design to investigate that area further.

# BIODIVERSITY HOTSPOT

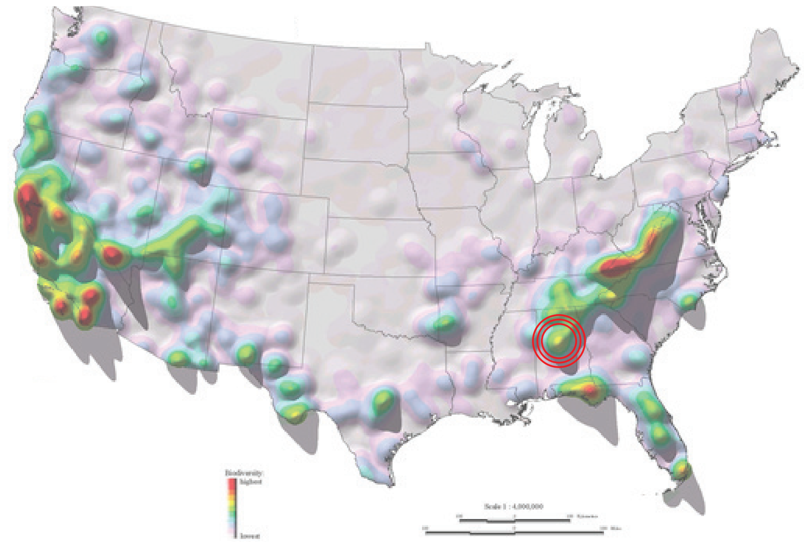
The richness of aquatic biodiversity in the Cahaba River is greater than any other river in the world. This diagram shows all of the fish and bird species as well as threatened and endangered snail and mussel species, notable turtle species, and plants that are found in the Bibb County Glades, some of which were not known to science until the 1990's.



**Hotspots for At-Risk Fish and Mussel Species**




**Hotspots for Biodiversity**



These maps from the Nature Conservancy show the number of at-risk species that can be found in a watershed (left) and aquatic biodiversity hotspots (right). The maps give a different perspective on where biodiversity occurs compared to the map from Conservation International page 11.

Coosa Rivers, but it is ecologically and geologically diverse.

The geologic regions feeding the river include the Alabama Ridge and Valley, the Fall Line Hills, and the East Gulf Coastal Plains. Rich deposits of coal, iron, and dolomite can be found in the Ridge and Valley region of the Upper Cahaba, while the rich soils of the Black Belt are found in the Lower Cahaba.

Ecologically, the Cahaba River is boasted as being the most biodiverse river of its size in the world (Master, Flack, & Stein, 1998). More species of fish can be found in one mile of the Cahaba than any other river. To date, 131 species of fish have been identified, along with numerous freshwater mussels and snails. Sixty-nine of these species are endemic to the watershed, including ten that are on the threatened and endangered species lists qualifying it to be an ecological hotspot according to the Nature Conservancy. The Cahaba River is also home to many plants that are not found anywhere else and were not known until the early 1990's. One of the most famous of the unique plants is the Spider Shoals Lily (Hymenocallis coronaria), or as Alabamans like to call it, the Cahaba Lily, which blooms from "Mother's Day to Father's Day, peaking around Memorial Day" (Ragland, 2013).

This large amount of biodiversity can be attributed to the rivers many shoals and its lack of dams. The Cahaba River has the longest stretch of free flowing water unlike the other rivers in Alabama. At the end of the 19th century the Army Corps of Engineers (USACE) studied the river to evaluate if it was suitable for dams that would increase navigability for commercial boats and/or produce hydroelectricity. They concluded:

Owing to the low-water discharge of this river and the fact that the portion under consideration offers location for a


Passengers moving around a steamboat docked at the former state capital of Cahawba during the Antebellum era.


The old Pumphouse that has supplied water from the Cahaba River to the city of Birmingham since the late 1870's.

power dam very much inferior to a location above Centerville it is in my opinion, not practicable to coordinate any water-power development with the improvement of the river and, in this manner reduce-the cost of improvement within the limits of an expenditure considered justified by the interests of navigation. This river is, in my opinion, unworthy of improvement by the General Government at the present time. (Dickinson, 1910)

The decision of the USACE to not dam the Cahaba River has allowed it to retain its biodiversity and thrive while the rivers around it became impounded and imperiled.

Although, the watershed has historically been sparsely inhabited, the Cahaba River Watershed is rich in cultural heritage. It acted as a boundary for the North and South Creek Indian Nations and provided little desire for the white settlers that moved in due to its unfavorable terrain. Though the first state capitol was founded in 1825 at the confluence of the Cahaba and Alabama Rivers, a key point for cotton farmers shipping their crop downriver to Mobile. At that time Cahawba (as they spelled it then) was the wealthiest and one of the most populous towns in the state. Five years later, though, the capitol was moved to Tuscaloosa, and eventually to its current location of Montgomery. After the capitol was moved, the population began to slowly dwindle until the Civil War when the Confederate Army established one of the largest prisoner-of-war camps in the cotton warehouses of the town (Bryant, 1990). In 1865, towards the end of the war, the former capitol experienced the largest flood to happen since it was inhabited. The entire town was under water and prisoners were hanging in the rafters of the warehouses to stay dry. After this event the town was abandoned.

In the late 1870's, after the Civil War, 140 miles upriver the city of Birmingham was booming with the iron industry and needed a reliable source of clean drinking water for its citizens. Since the streams of Birmingham proper were being used by the industries the Birmingham Water Works Board decided to pump water from the Cahaba River over Red Mountain for the city's consumption. A 15-foot tall dam was constructed at mile 148 to redirect water from the Cahaba and Little Cahaba Rivers three miles upstream to the fresh water intake. This process has been in place since the mid-1880's and is still used today


Siltation entering the river from a tributary in the upper watershed.


The famous Cahaba Lillies in bloom on the shoals of the Cahaba River. Over siltation can smother the bulbs of the lillies preventing them from blooming.

providing water to the majority of the Metro-Birmingham area.

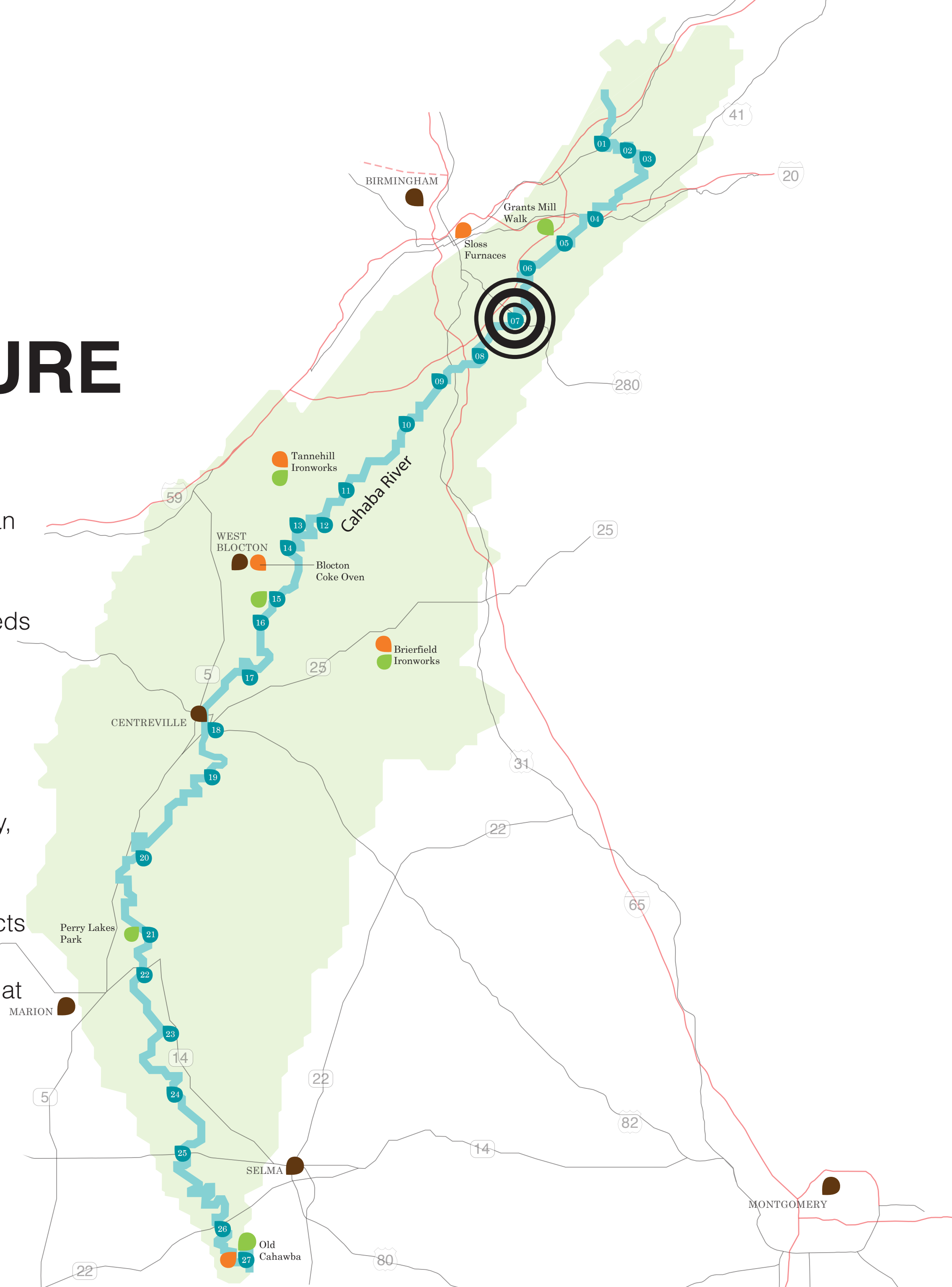
As Birmingham continued to grow, its footprint crossed into the Upper Cahaba Watershed. Within the past few decades the construction of large neighborhood developments, shopping centers, medical facilities, and office complexes have increased the amount of impermeable surfaces, and contributed to what the Cahaba River Society (CRS) and Alabama Department of Environmental Management (ADEM) says is the main threat to the watershed: sediment (ADEM, 2013). This sediment can harm the development and well being of the many unique aquatic species found in the Cahaba River by smothering them or altering their habitats, increase stress on infrastructure like dams and bridges, increase scour of the rivers banks, creating more sediment and incising the river channel, and clog pipes, drains, and water intakes damaging water treatment systems (Master et al., 1998).

The Cahaba River is also the recipient of a great deal of effluent wastewater from the surrounding communities. During the dry seasons ADEM estimates that up 90% of the Cahaba's water has run through a wastewater treatment facility (ADEM, 2006). That can cause a large amount of nutrients, like nitrates and phosphorus, in the waterway. Phosphorus has been identified as a leading contributor to harmful algae growth that can lower dissolved oxygen (DO) levels, block sunlight to critical aquatic plants, and smother plants and animals found on the river bottom. Lowering the phosphorus levels in the Cahaba Watershed is a key focus for conservation efforts of the river.

Because the Cahaba River goes mainly unseen by the residents of its watershed, in fact most of the people I have talked to during my visits did not know it was there, these issues of sediment and nutrient loading continue to progress. Many conservation efforts aim to curb the amount of pollutants that go into the river, but this is merely like putting a bandage on a broken arm. Revealing to the public the effects of what they are doing, most of them unknowingly, can help to change the minds of the people. Providing a chance for an intimate experience with the water system in which they live; that can change behaviors of communities.

# [02]

# LIFE THROUGH INFRASTRUCTURE

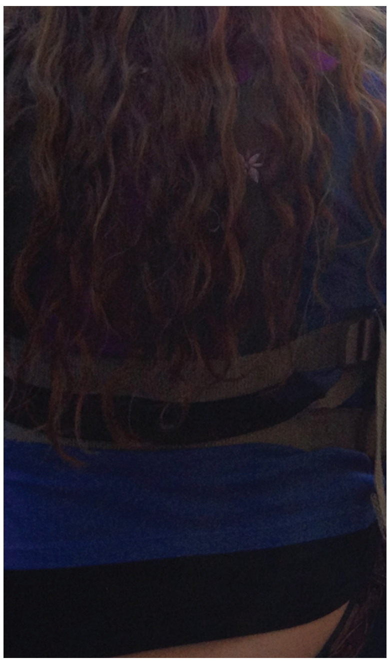


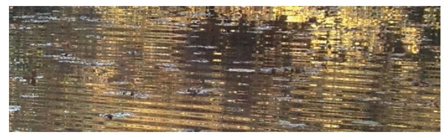

This thesis is set to test how Birmingham's public water supply dam on the Cahaba River can be multifunctional, where it acknowledges and serves the needs of the human population, while also being intentionally designed to meet the needs of the surrounding ecosystem. If we can begin to see how infrastructure can be implemented to serve and connected humans and non-humans then we may improve the health of both. The intensely biodiverse Cahaba River is considered an ecological hotspot by the Nature Conservancy, and much of this is due to its lack of dams. By investigating ecological hotspots, which are traditionally sensitive areas, we may see the effects of interventions more readily and establish what may be considered common denominators of what makes a successful design.

The dam that this thesis investigates is the main barrier of the entire watershed, severing the ranges of aquatic species, thus, isolating populations that have been declining since its implementation. However, this 15-foot dam has

## SITE OVERVIEW

At the point where US-280 crosses the Cahaba River there is the largest impoundment on the river. The public water supply dam, owned by the Birmingham Water Works Board, is 15' tall, 20' deep, and spans the river 150' across. The dam redirects the flows of the Cahaba and Little Cahaba River upstream about three miles to the public water intake, which has been in operation since the mid-1880's. This site is a popular place for fishing, relaxing, and small boat launching. The pool on the upstream side never drops too low, thanks to releases from Lake Purdy on the Little Cahaba River, so that Birmingham will always have water. Thus, even when the water is low everywhere else on the river, this spot is able to be paddled, which educational and recreational groups, like the Cahaba River Society, the Nature Conservancy, and the Birmingham Canoe Club use to their benefit. The current popular canoe launch site is located on river left, just upstream from the US-280 Bridge. A parking lot is located on the opposite side of the river on the downstream side of the US-280 Bridge, which is where most of the fishers park. Both sites are accessible only by Cahaba River Road.





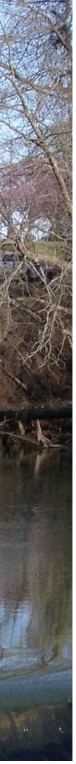
## ABOVE THE DAM

Above the dam is about three miles of flat water that can be paddled up to Sicard Hollow Road. Only a quarter of a mile upstream from the dam is the confluence of the Cahaba and Little Cahaba Rivers. The Little Cahaba River is connected to Lake Purdy, which keeps the public water supply pool at sufficient levels. Large mussels, many fish, snails, and other wildlife can be found paddling up the Little Cahaba River. One must travel to the moving water section of the Cahaba River to find the mussels and snails. The Birmingham Water Works Board owns most of the land surrounding these two rivers creating a buffer to help protect the public water supplies quality from any contamination giving the area a wild feel even though on the other side of the hills are commercial and residential developments bustling with traffic.

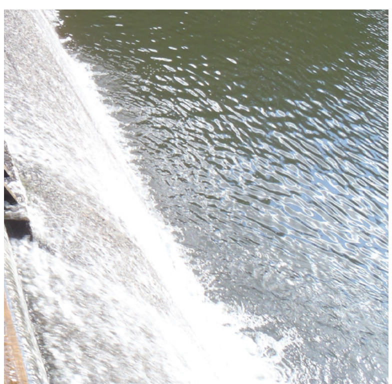
been in place below the confluence of the Cahaba and Little Cahaba Rivers since the 1880's allowing a shallow, soft bottom lake ecosystem to develop over the past 120+ years. Over that period of time novel ecologies have formed and taken hold. Lake species like the largemouth bass, chain pickerel, and sunfish have established themselves here calling it home for generations. The sediment built up on the bottom has changed the benthic layer altering the habitat of mussels, snails, and insect larvae that previously lived there. Now, catfish, turtles, and other bottom feeding species scavenge through the silt to find their meals. It now becomes difficult to place the value of one ecosystem over another. The build up of sediment and chemicals in the sediment is not the fault of the dam or the species that live in the lake system. Rather, it is a result of what is happening up stream from the dam and the dam is merely a revealer of the pollution that is entering the waterway, a symptom but not the illness.

## AT THE DAM

The dam is a large concrete structure spanning the width of the river. There is a defunct fish ladder on the river-right side of the dam along with a large retaining wall stabilizing the bank. At the top of the dam are several cuts that focus the water's flow at lower levels. The water cascades over the top and slopes down to the river below creating a dangerous hydraulic hole that holds onto objects that get caught in its trap.



I propose that dams, especially low-head dams, can act as more than just water stoppers. Ecosystems above and below the dam do not have to be cut off from one another, habitats and ecotones can be created, and opportunities for recreation, education, research, and human interaction can be imbedded in the design of the infrastructure. The interaction between reintroduced species that used to move freely up and down the river and the species that currently occupy the area offers the chance of an even more complex ecology, potentially increasing the biodiversity more. Or it could go the other way by introducing a species that is more dominant and aggressive than other species, thus overtaking the existing fauna. The ability to observe, record, and display such ecological exchanges with infrastructure is not common. By allowing this dam to connect the ecosystems and to reveal the ecological symptoms at the dam, we can begin to rethink the role that our infrastructure plays and how it can be more multifunctional and mutually beneficial to its



environment.

In order to focus the ecological design we will focus on five species to be "target species" for design. The habitats will be designed to the specifics of these target species more than other species, however, this does not mean that other species will be left without any habitat or excluded from the design. Many animals would be indirectly designed for because of their association or similar needs as the target species. In fact, the target species may not inhabit the intervention at all, but if there are all of the parts that also meet other species needs then the niche will be occupied.

Therefore, the factors that go into choosing a target species include habitat preferences, food types, predators, and ecologic services. Since it rare to find one-to-one

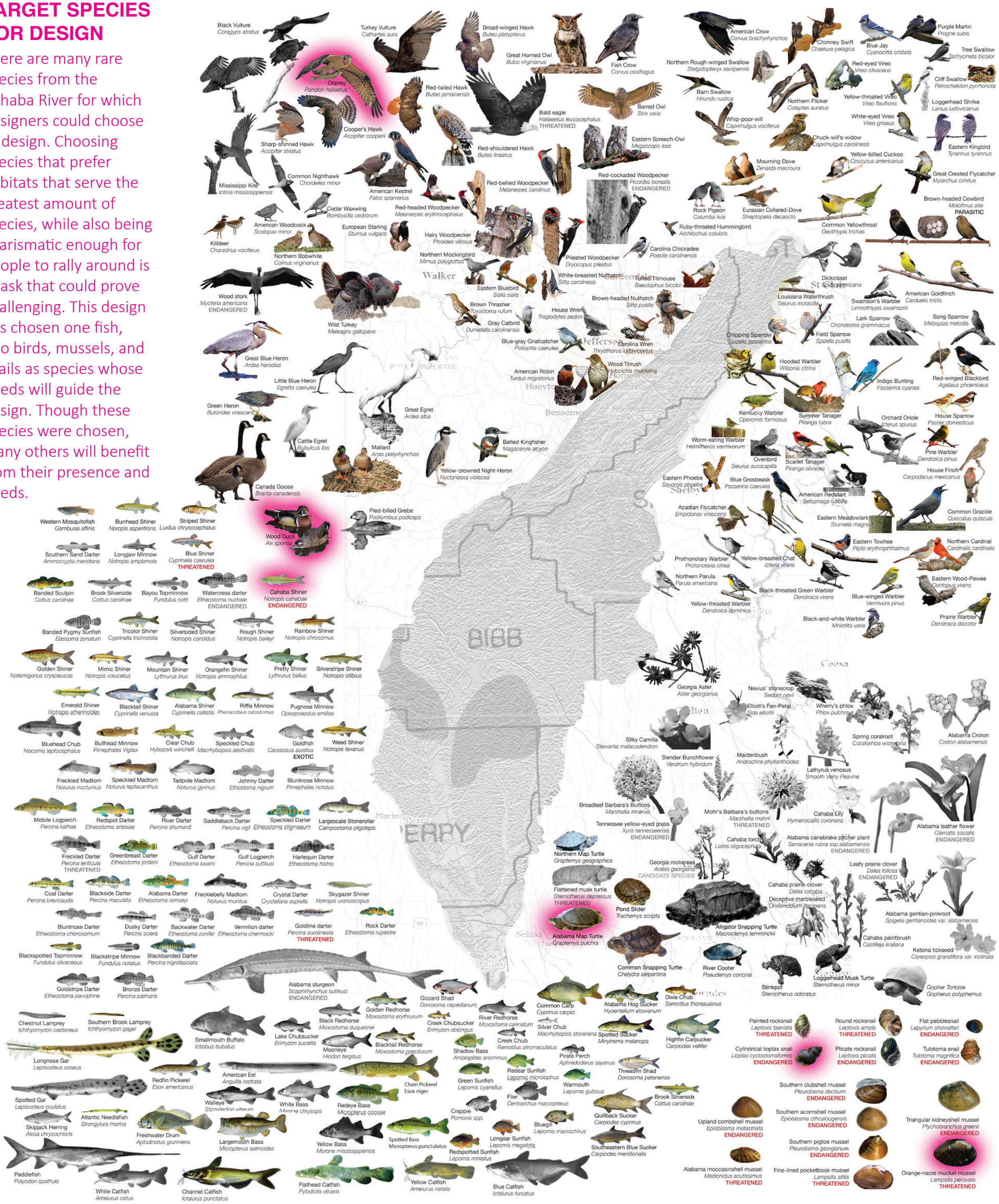
## BELOW THE DAM

Below the dam is an island of sediment that finds its rest after crashing over the dam. Trees and other riparian vegetation have taken root stabilizing the island. Scour from high waters is washing away the bank on river-right cutting behind the retaining wall, while the exposed rock face on the opposite side of the river is resisting the persistent attack of the river. Also on river-left is a pipe carrying runoff from the roadways with an opening that empties on the downstream side of the dam.

The area around the island and the eroding bank are the more popular and easily accessible fishing spots.

# TARGET SPECIES FOR DESIGN

There are many rare species from the Cahaba River for which designers could choose to design. Choosing species that prefer habitats that serve the greatest amount of species, while also being charismatic enough for people to rally around is a task that could prove challenging. This design has chosen one fish, two birds, mussels, and snails as species whose needs will guide the design. Though these species were chosen, many others will benefit from their presence and needs.



relationships between predators and prey, then if we design for one species' food source to be present that other species, which also eat that food source, will also be present. And not all species live in unique shelters; therefore, some species that were not explicitly designed for will occupy the habitats created in this design. Thus, by designing for one species, we design for many species, allowing the opportunity for greater biodiversity at this site.

**how can Birmingham's public water supply dam be multifunctional, allowing the Cahaba River to act as a connected river, providing habitat, and creating educational and recreational opportunities, while still supplying the city with water?**

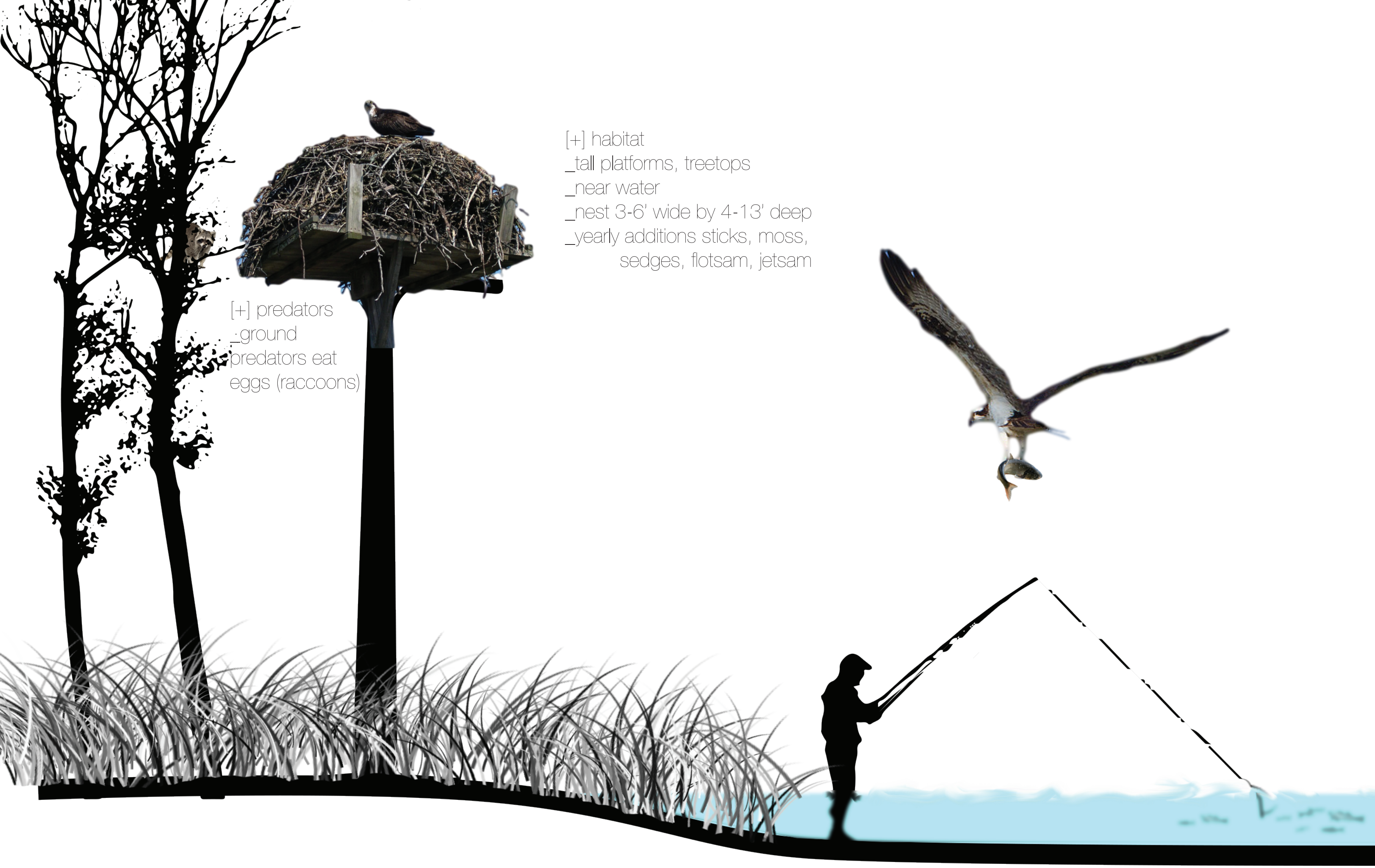
Now the dam is serving with two designed functions. To answer the thesis question more fully let us examine the functions that the dam can perform to be educational and recreational.  The species for which we are designing allows these spaces of the dam to be ecological classrooms and data collection sites. With fish moving through the ladder we can count the number of successful passes and record the video of the process, which can then be displayed on a large LED billboard to reach out the general public that cross the river each day on their commute. Connecting to the public at large can establish a collective identity of the residents of the area and develop interest in the happenings of the river. More public attention generates public concern. The dam can also offer more intimate encounters between people and habitats by making habitats accessible.  These opportunities for experiential education create places where people can establish personal connections to a river. The deeper the connections a place or object, the greater advocacy it will garner.

As we move forward in this section, through the design development, we will unpack the process of species selections and what the selected species bring to the design, as well as the development of the principles that framed this design. Each iteration will be judged based on how well they meet these six guidelines:

1. **The dam must still function as the dam**
2. **The river must be able to flow in order to connect the ecosystems above and below the dam.**
3. **Improved habitat must be incorporated into each part of the intervention**
4. **There must be opportunities for human interactions with each part of the interventions**
5. **There must be educational opportunities within the design**

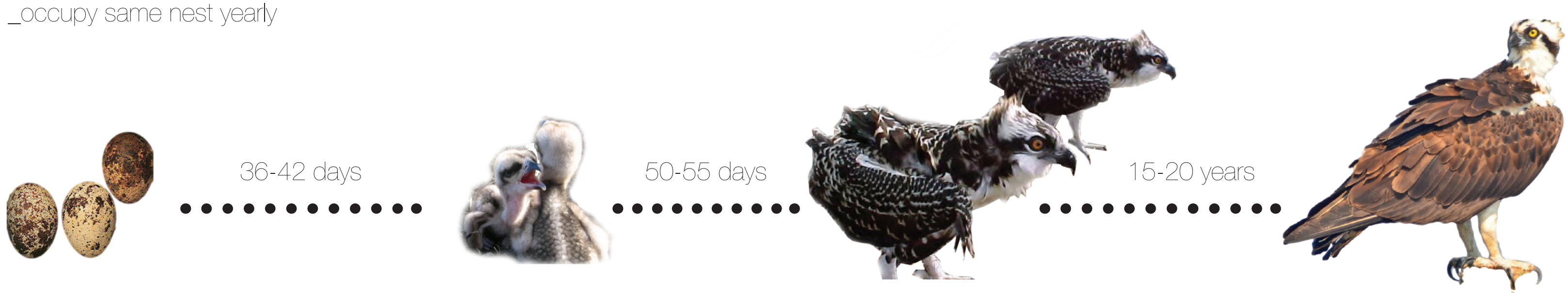
## dam target species profile

# OSPREY *Pandion haliaetus*

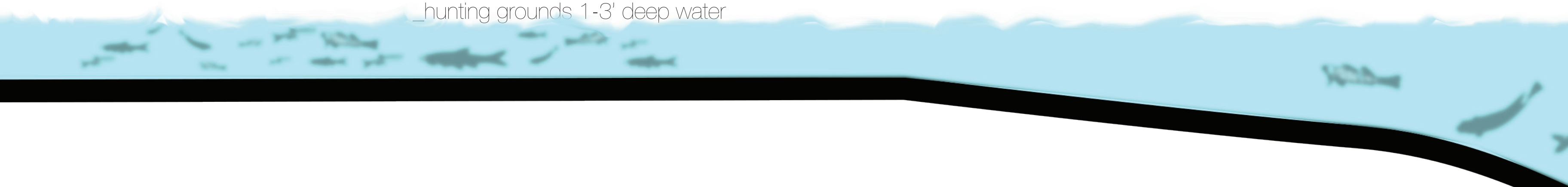


Osprey, unlike other birds of prey, have a diet of live fish making them very common along shores and waterways. Their nests made of large sticks are found high up in places that are hard for predatory mammals to get to in, for example, dead trees, telephone poles, or on platforms placed by conservation agencies. They do well around humans and prefer shallow water hunting because they can only dive a few feet into the water. These migratory birds range from the Artic Circle in Canada and Alaska down to Patagonia of Chile and Argentina, though some find permanent homes along the Gulf of Mexico Coast and Baja California. Really they will nest anywhere that there is an adequate supply of fish within 12 miles and has a long enough ice-free season to allow their young to fledge.
Osprey pairs will often use the same nest year after year building upon the existing structure of large sticks, algae, moss, bark, flotsam, jetsam, vines, sod, and grasses. The nests can grow to be six feet in diameter, and thirteen feet deep! These largely solitary birds are protective of their surrounding area, especially from other Osprey, and need open spaces to approach their nest with their fresh catches (Cornell University, n.d.).

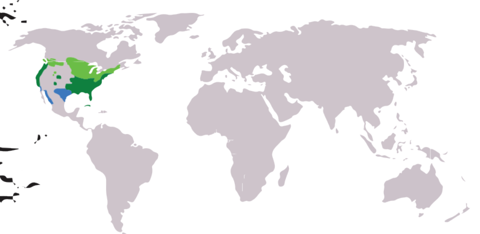
[+] reproduction
_life partners
_1-4 eggs per clutch
_1 brood per year
_occupy same nest yearly



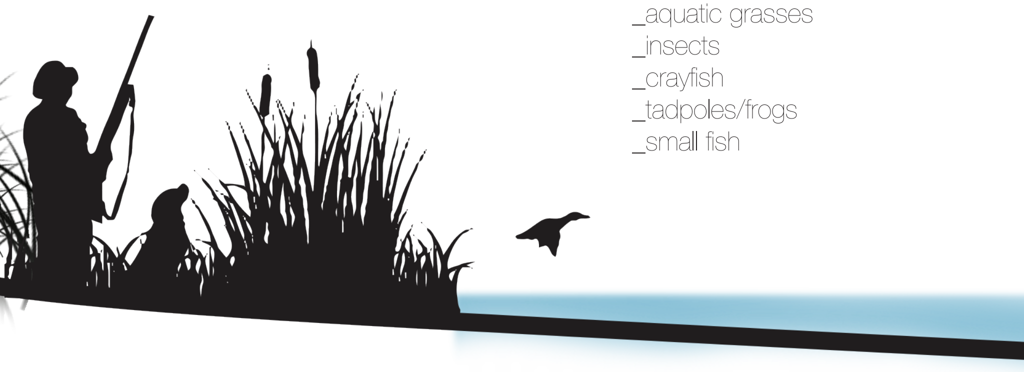

[+] food
_99% fish
_scavenge in dire times
_hunting grounds 1-3' deep water



# WOOD DUCK *Aix sponsa*



[+] predators
_fox
_raccoon
_owl
_hawk
_snake
_hunter
_largemouth bass
_channel catfish



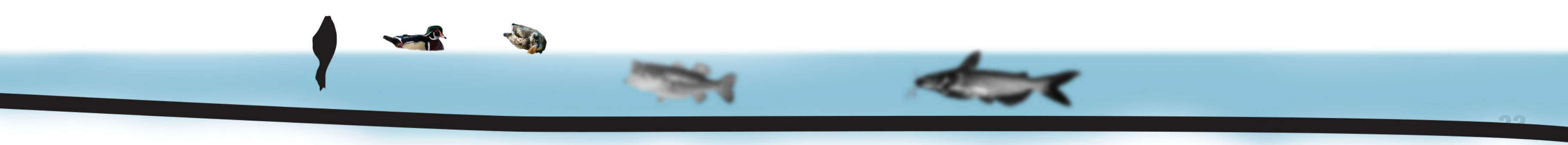
[+] habitat
_cavities in trees or boxes
_near water
_2-60' high

[+] food
_seeds
_berries
_aquatic grasses
_insects
_crayfish
_tadpoles/frogs
_small fish

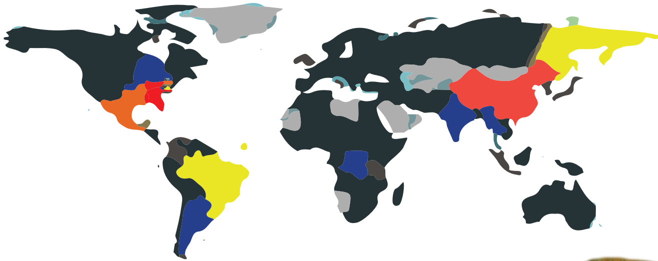
The Wood Duck is a beautifully plumed bird that makes its home in cavities of trees. Conservation efforts to improve population numbers of the ducks found that they will also occupy wood boxes or other artificial structures that are similar to their tree cavity homes. These homes are near or above the waters found in bottomland forests, swamps, marshes, beaver ponds, and streams of all sizes, ranging 2-60' high with openings 2-24" wide and cavities 2-15' deep. They prefer to forage for seeds, fruits, insects, snails, and crayfish, both on water and land, where there is some vegetative cover.

Wood Ducks generally pair up around January and begin breeding in the springtime. These non-territorial birds lay about 10 eggs per clutch, however, a female may find herself talking care of even more ducklings because another female has "egg-dumped" in her nest. "Intraspecific brood parasitism" is common among Wood Ducks, believing to happen in as many as half of the nests.

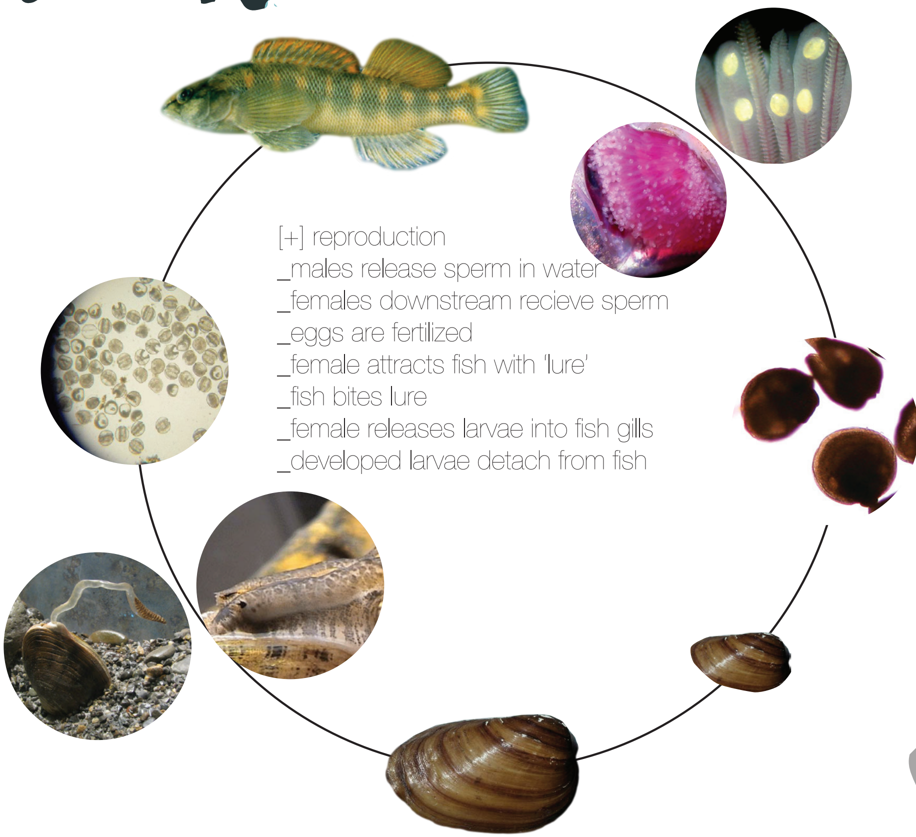

[+] reproduction
_yearly breeding pairs
_10-26 eggs per clutch
_1-2 broods per year



## dam target species profile
# MUSSELS

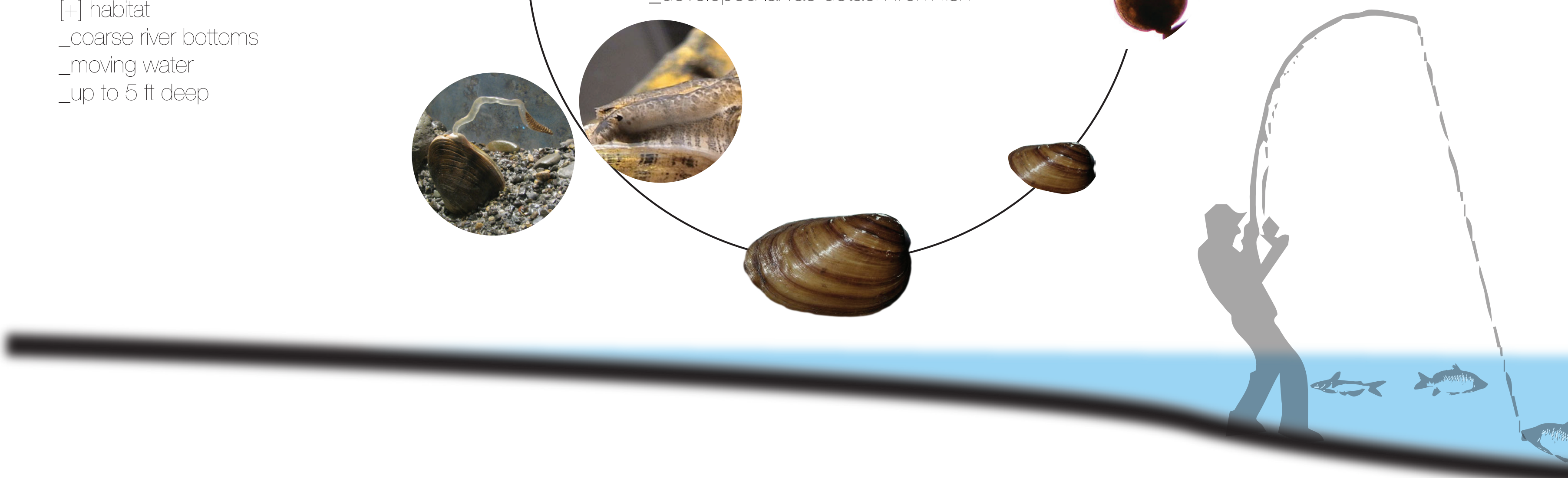


[+] habitat
_coarse river bottoms
_moving water
_up to 5 ft deep



[+] reproduction
_males release sperm in water
_females downstream recieve sperm
_eggs are fertilized
_female attracts fish with 'lure'
_fish bites lure
_female releases larvae into fish gills
_developed larvae detach from fish

[+] food
_algea
_detritus
_plankton
_bacteria



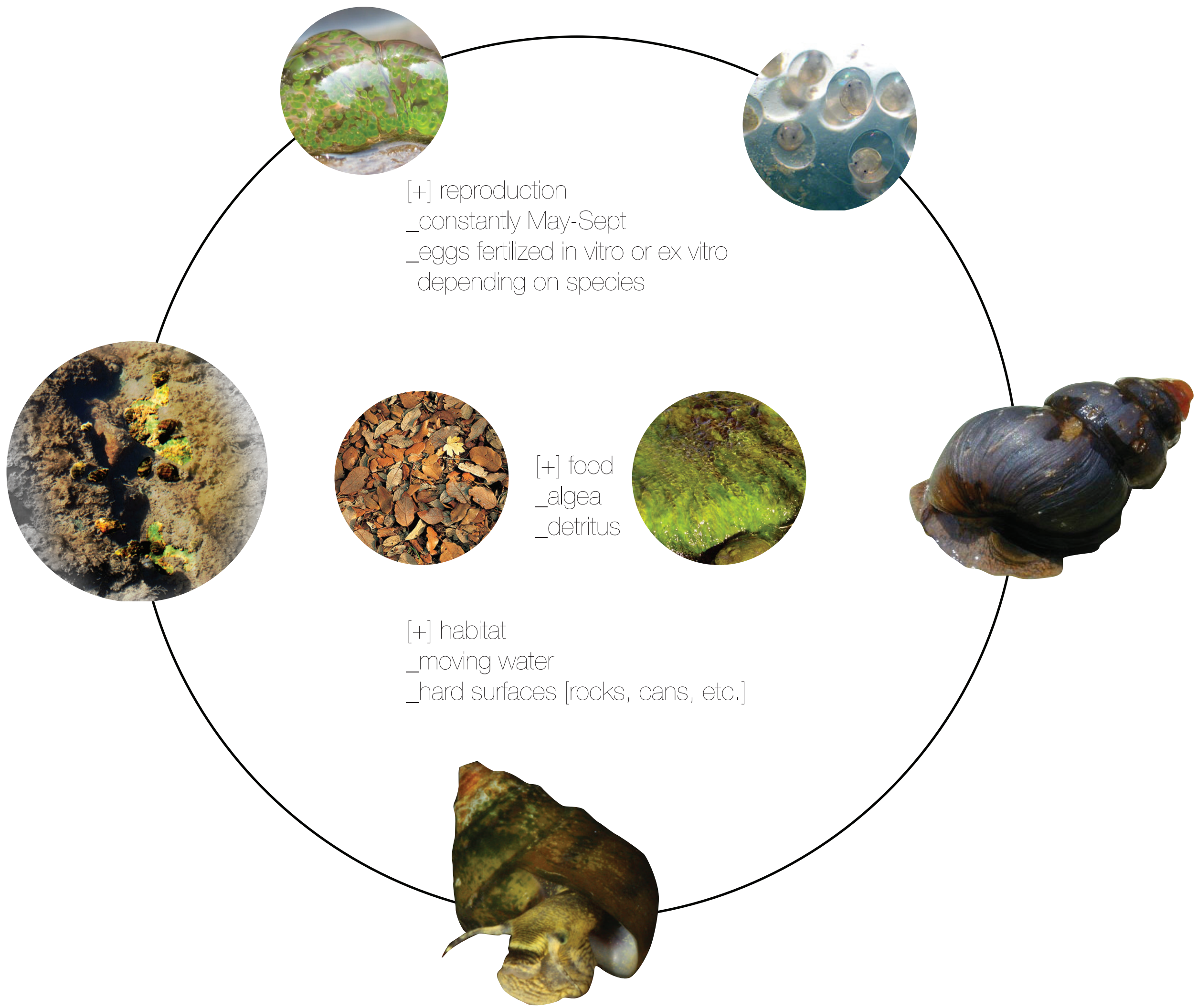
Mussels are bivalve mollusks that prefer gravel bottoms of streams and rivers with good water quality and a stable stream channel of free flowing water. They live off of algae, tiny plants and animals like plankton, and bacteria that they filter from the water. An average Alabama Moccasin Shell Mussel can filter one gallon of water per hour and live up to 50 years. That is near a half of a million gallons of water filtered in a lifetime by just one mussel. Alabama's rivers used to be extremely abundant in freshwater mussels, but since the construction of the dams, many species have gone extinct for a couple of reasons. One is habitat alteration. Mussels that were upstream of the dam became smothered by sediment halted by the dam or had their water flow slowed to an unsuitable rate and could not get enough food or oxygen to survive. Another reason is that they could not distribute their eggs like they previously had.

The lifecycle of a mussel begins as an egg. The female will attract fish to her with a lure that looks like some sort of prey like a minnow, worm, or crayfish. They attacking fish will instead get a mouthful of mussel larvae that attach themselves to the gills of the fish. The larvae will live in the gills of the fish until they have reached a certain size when they detach. This is how they distribute their population throughout a river system.

Mussels are a food source for many animals including fish, turtles, muskrats, raccoons, and otters, but some of the main killers of mussels are dams, pollutants, and channel alterations, like dredging (Aycock, 2010).

[+] predators
_fox
_human
_largemouth bass
_channel catfish
_birds
_ducks
_turtles
_geese
_otters

# dam target species profile
# SNAILS



[+] predators
_fox
_raccoon
_aquatic fowl
_humans
_largemouth bass
_channel catfish
_otters
_muskrats
_turtles
_beaver
_frogs

Freshwater snails are an important food source for many of the animals in the Cahaba River Watershed and play a crucial role of scraping algae from surfaces and processing detritus like dead trees and leaves. The presence, or lack thereof, of snails can be an indicator of the water quality in a river or stream. Within the Mobile River Basin, which includes the Cahaba River, 18% of the freshwater snail species native to North America can be found. At some places in the Cahaba River there are more than 50 snails in one square foot.

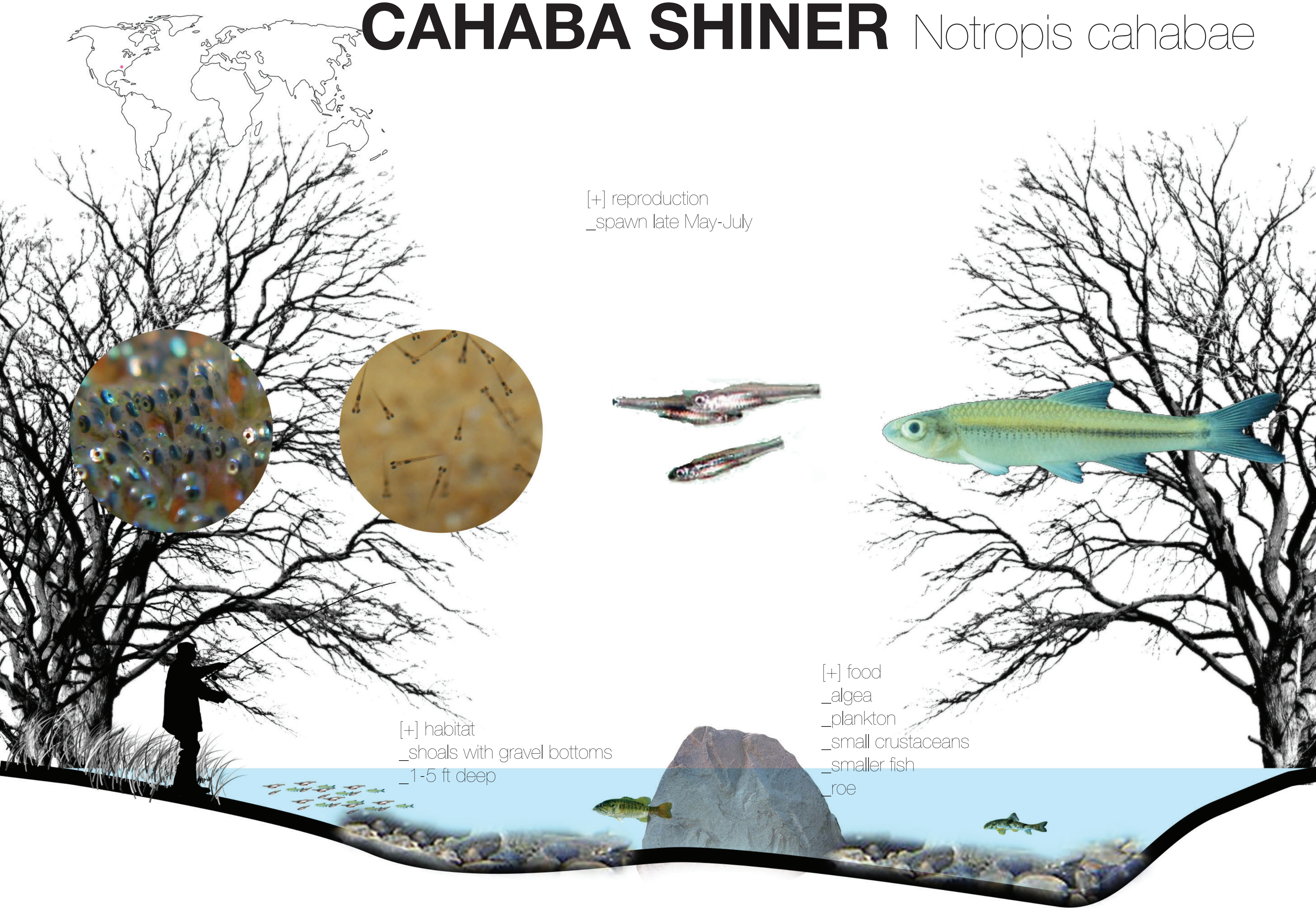
Snails reproduce almost continuously from late spring to early fall, so long as there is an abundant food source, which is why they are so prolific.

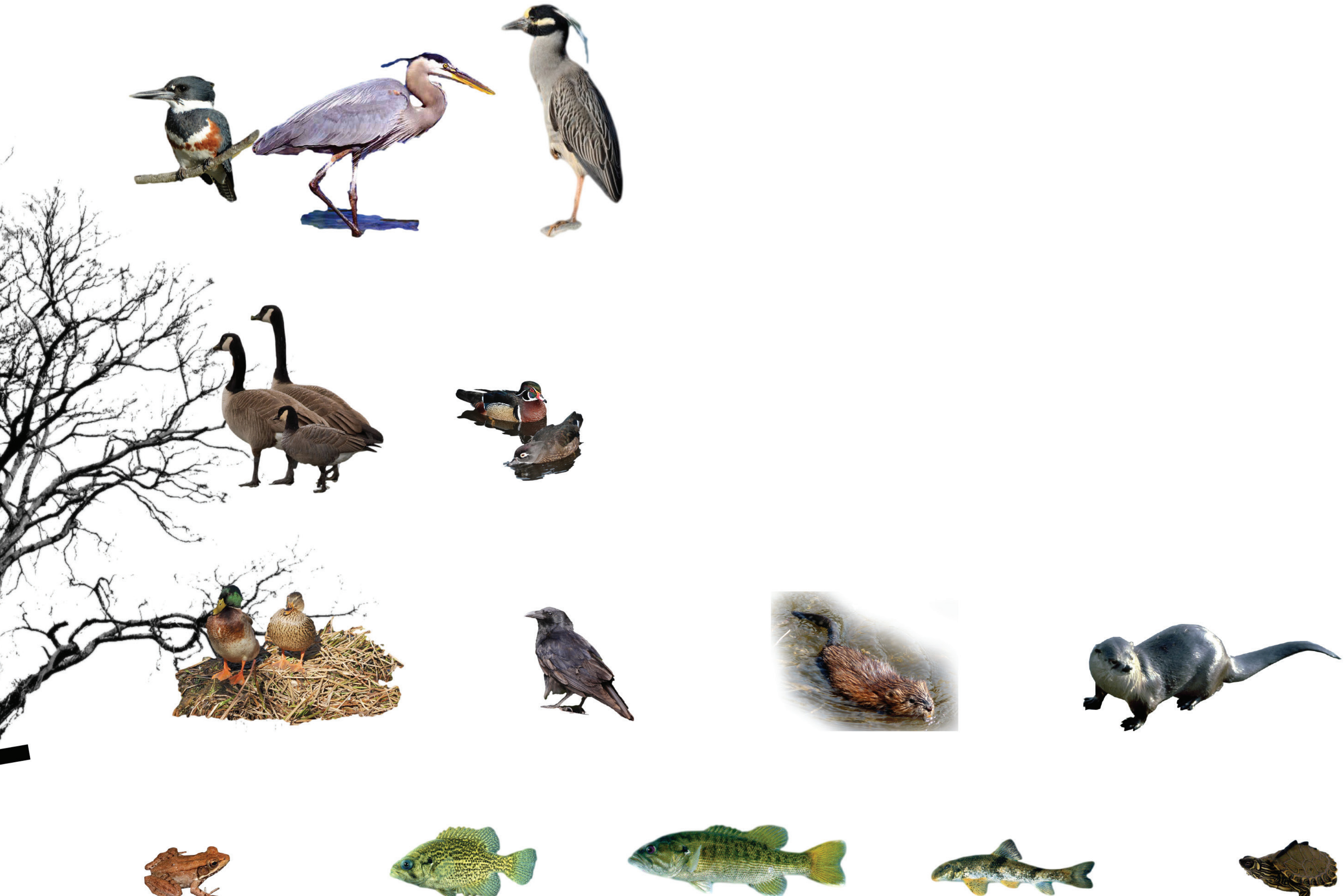
There are several species of snail that are of special concern because of their uniqueness and sensitivity to environmental changes, one of which is the Cylindrical Lioplax (Lioplax cyclostomaformis).

This is the only known species of lioplax to occur in the United States and it is currently only known to be found in the Cahaba River, though it used to be more widely distributed throughout the Mobile River Basin (Johnson, 2009).

# target species profile

# CAHABA SHINER *Notropis cahabae*

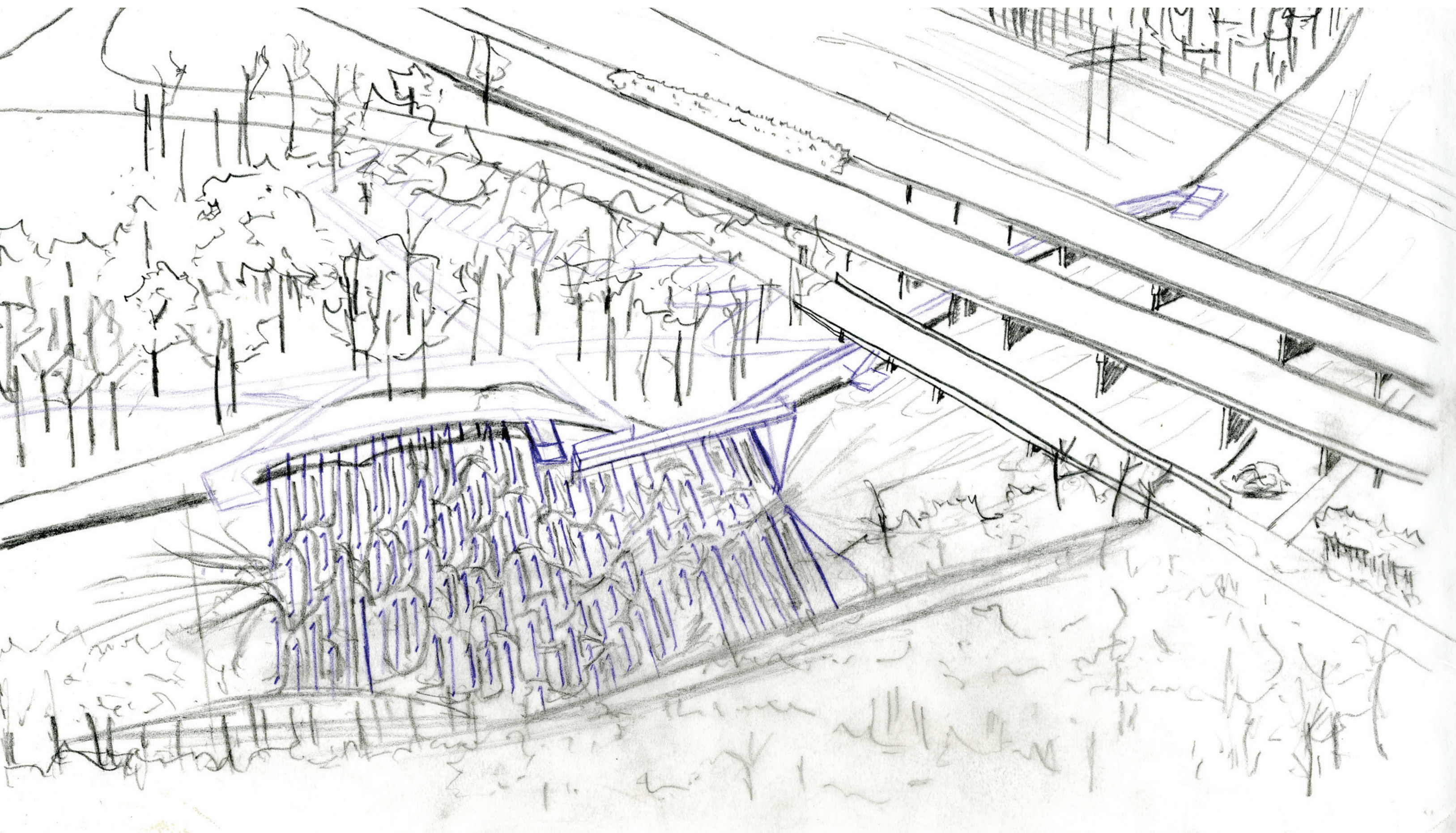


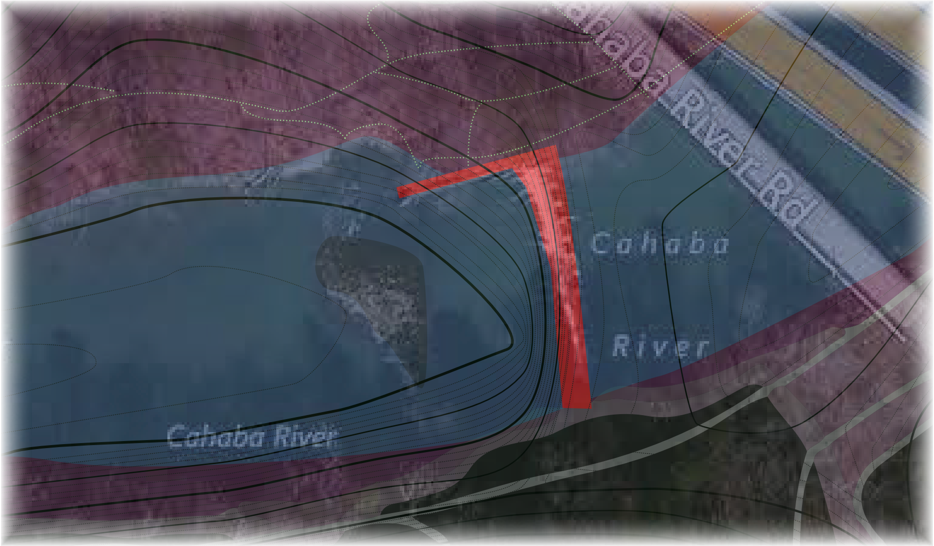


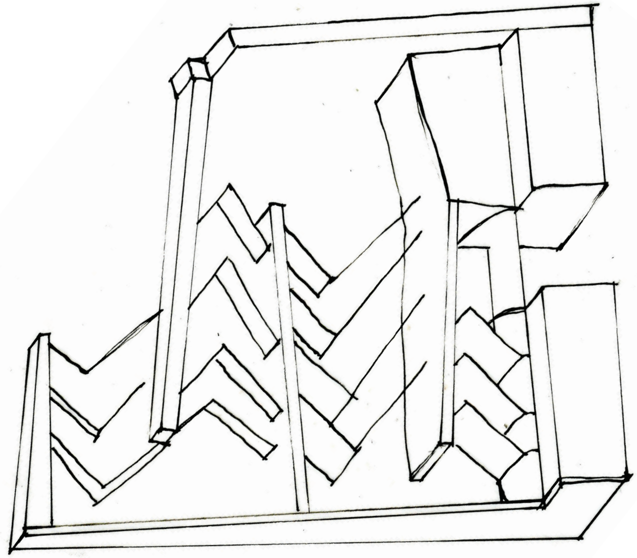
# [03]
# OVER THIS DAM

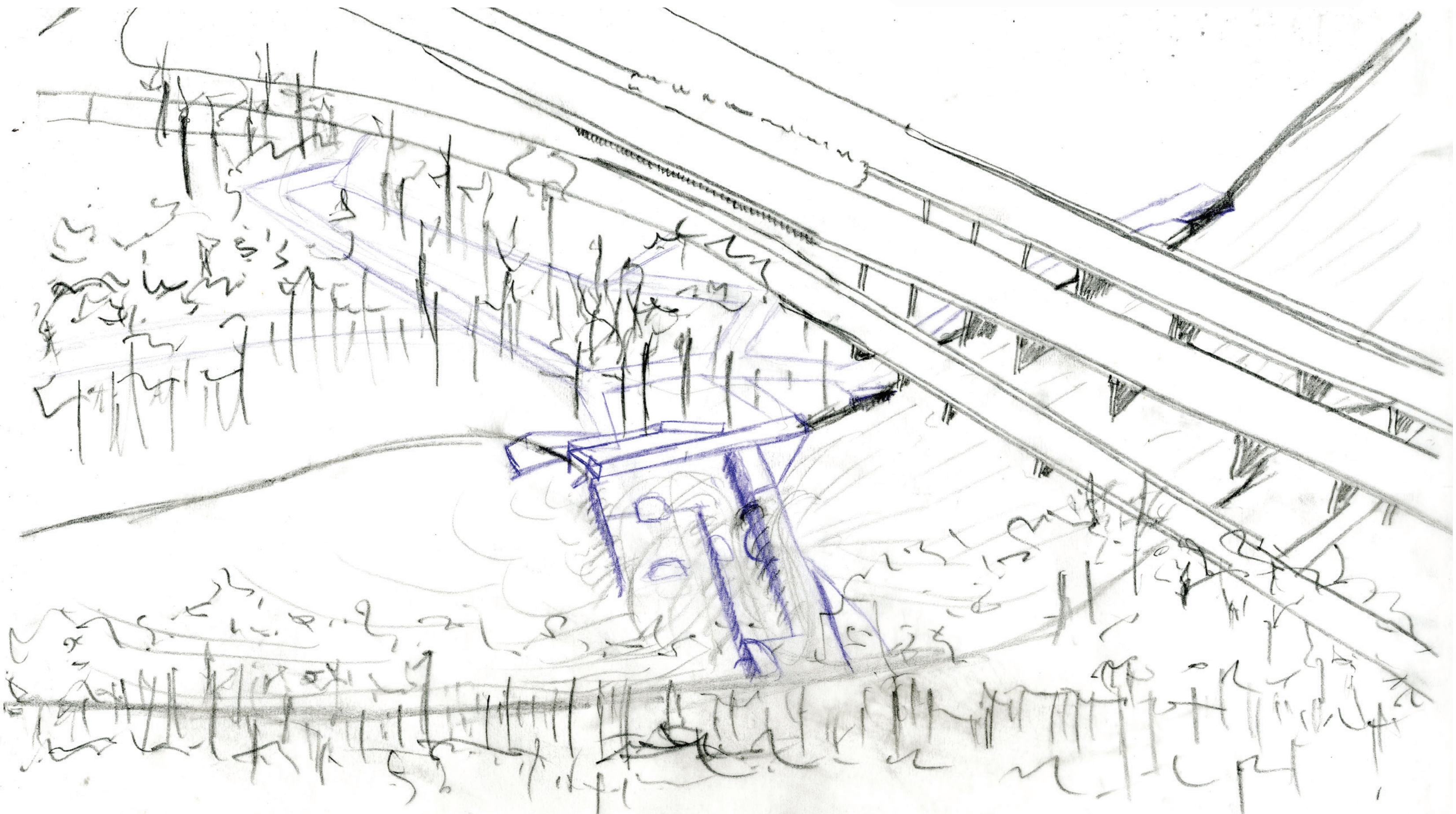
These initial investigations examined how to get over the dam, essentially creating fish ladders that spanned the length of the river. The first design passes were done in plan, which did not allow the change of elevation to be experienced through the illustrations.

Thus, a bird's eye perspective helped to understand the drawings further. Though they did not address the issues of habitat improvement or the human experience, they did heavily influence the design of the fish ramp/whitewater course.




River Rd
Cahaba
River
Cahaba River





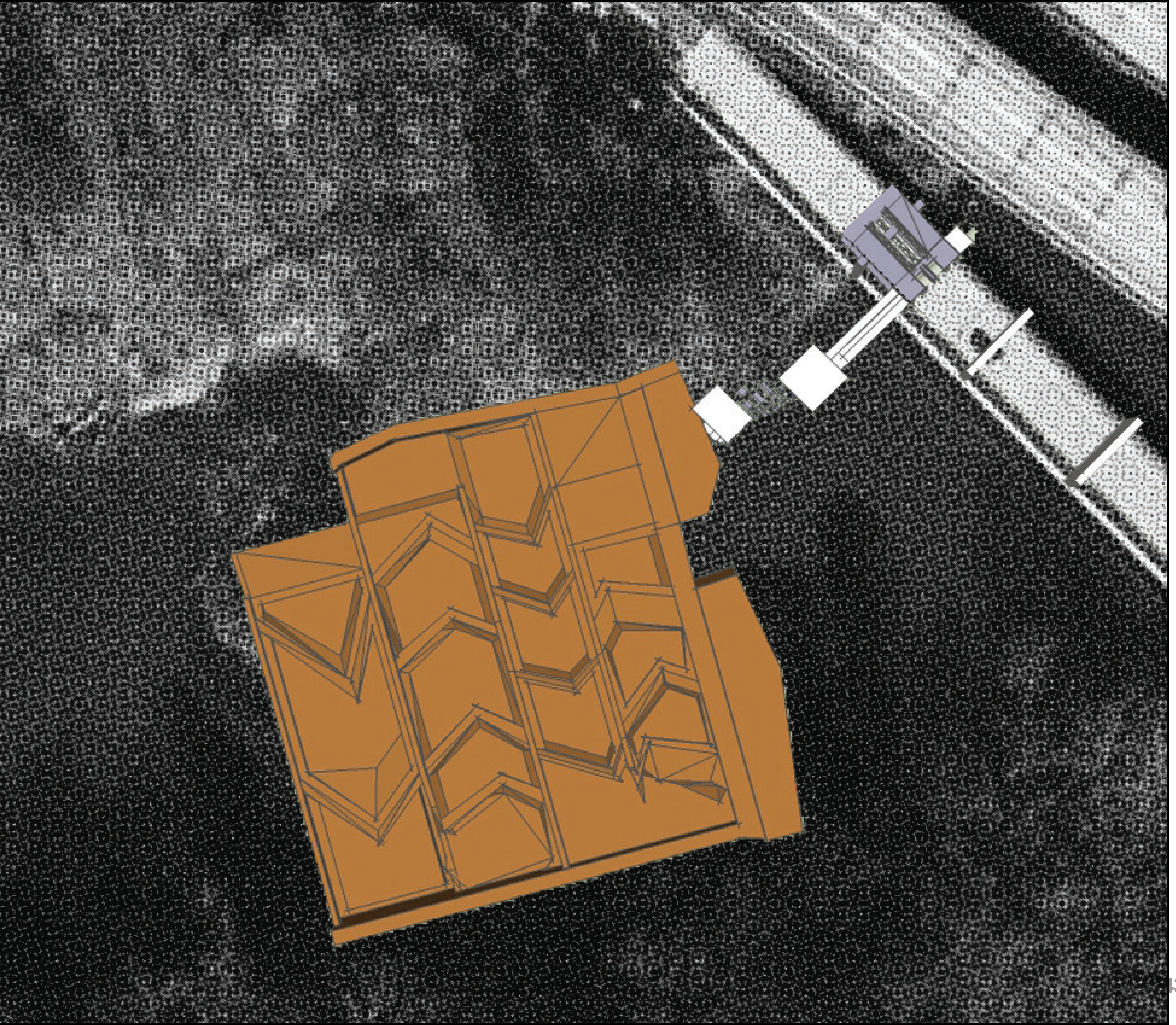
# DAM MULTIFUNTIONAL

As this design idea progressed to be more multifunctional it became more apparent that it also had to be multilayered. Designing above and below the water surface and those interactions was became the driver for how to represent the design.

This design test focused on creating opportunities for human-nature interaction, and integrating habitats for specific species into the infrastructure's design.

There are several key features of habitat in this design appearing at the dock under the bridge, in the poles between the dock and the dam, and on the fish ladder below the dam.

Accessible points for humans within this design occur at the dock under the bridge, on the upstream side of the dam, and on the fish ramp. The dock has two gangway's leading down to a floating platform with two boat slips for kayak and canoe launching. Eighteen inches below the surface of the water there are 2" aluminum pipes supporting a screen. Aluminum is a surface that is ideal for many species of snails to harvest food, while the screen can capture sediment during storm events allowing the coarser sediment to remain while the finer sediment sifts out, thus creating an ideal habitat for many of the freshwater mussels that filter and clean the water. The mussels and snails are popular food choices for many birds, mammals, predatory fish, and turtles. The birds are able to perch on the railings and bridge above, while the fish hide in the shadows beneath the dock, and the turtles and mammals can rest on either side of the dock on the platforms that are just at the water's surface. All the while, student groups of all abilities may have an experiential, hands-on learning about the preferable ecology of mussels and snails by jumping in and exploring. The dock is designed to meet ADA standards at the lowest pool level that Birmingham Water Works Board allows and has taken key features from several of the Nation Parks Service's (NPS) Logical Lasting Launches guidebook (Wolf,



2004).

Stairs off of the upstream side of the dam provides access and a path of step pillars, some submerged, some not, that connects to the dock. These steps act as research tools, sampling water quality, sediment contents, and recording surrounding wildlife. These results are relayed back to the USGS database and can be visibly seen by the LED fiber-optic lights on the stepping pads of the pillars. The brighter the lights are is responsive to the amount of wildlife that is around. These pillars capture limbs and debris coming down river, which can offer habitat and hunting ground for many fish, turtles, birds, and snails, and the platforms offer sunning areas for turtles and ducks. The steps may also offer a place to play for kids and spots for fishers to move off of the bank.

Out of those pillars rise two taller pillars above the bridges with platforms on the top. The taller of the two is meant to attract osprey while the shorter can be a perch for many species of birds. Inside the pillars are designed to be wood duck habitat, though there are many tree-burrowing species that may occupy the cavities. These poles are able to grab the attention of motorists passing by on US-280 or Cahaba River Road, since the river itself is hardly visible while crossing these bridges.

The water flowing over the dam will be focused to a 20' opening that leads to the fish ladder. This ladder is based off of the previous design test, which is a ramp with three switchbacks, pools at the transition point for each switchback, and 1' steps to allow fish to pass each obstacle and rest,

A view from the osprey's perspective looking over the fish ramp. It's nest sits atop the highest pole giving it the protection and vantage point that it seeks in a home. Inside the pole that supports the platform are hollowed out cavities designed for wood duck inhabitation, similar to the boxes that conservation groups build in wetland areas. The fish ramp offers habitat for species that prefer swift moving water with coarse river bottoms and eddys to provide resting stops. This habitat also attracts the whitewater boaters that dare to navigate the rapids and eddys that occur at higher waters. The ability to move over the dam connects the upstream lake with the downstream river and provides the opportunity for species that were once disconnected to reunite.

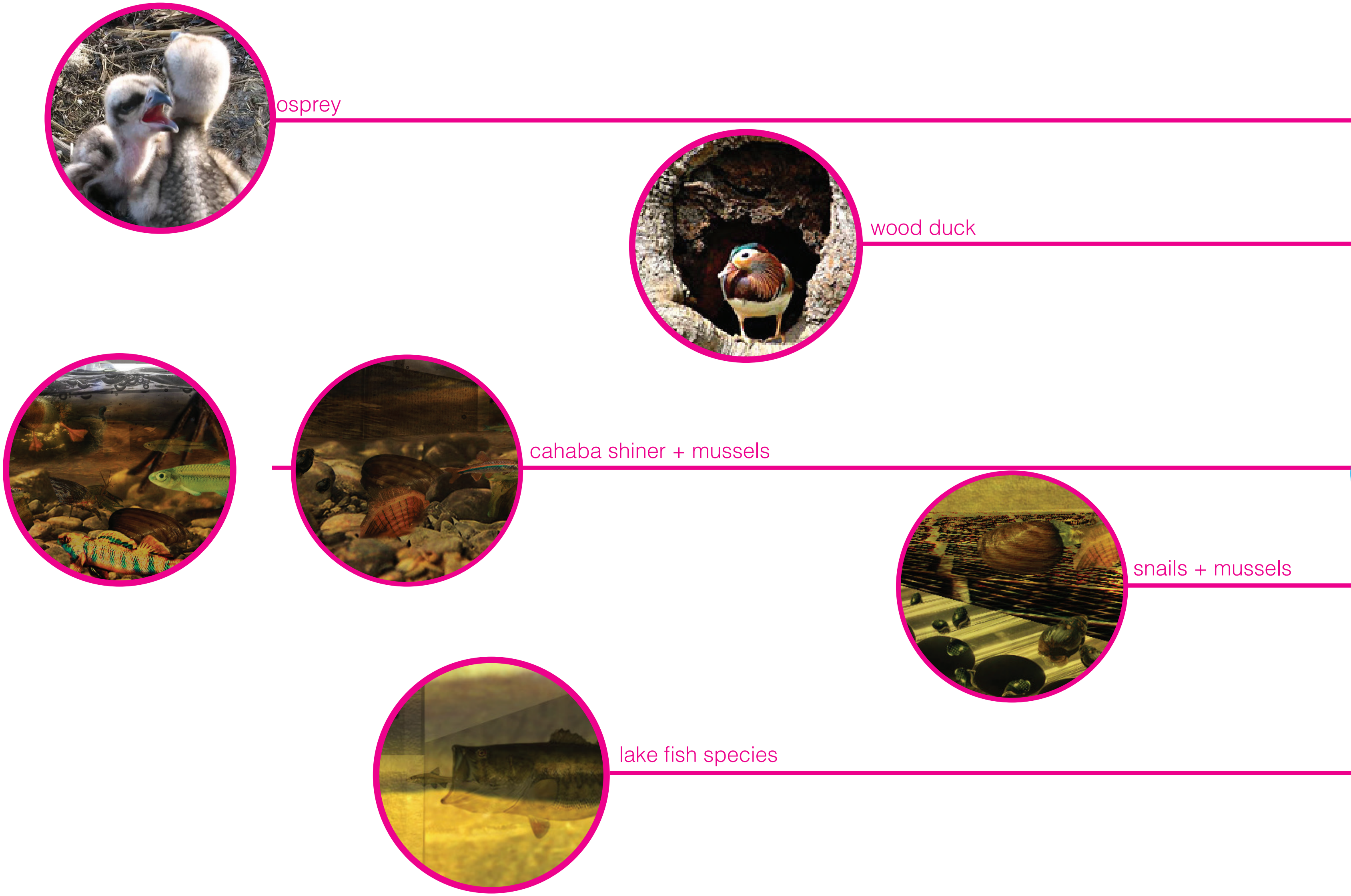
while also offering a way for paddlers to pass over the dam without having to portage their boat. Motorboats were intentionally left out of the equation for several reasons: 1) motorboats are illegal on this stretch of river due to safety concerns of someone harming the public water intake three miles upstream; 2) this is a public water reservoir and having gas and/or oil spills are a risk that can be reduced by prohibiting motorboat traffic on the river; 3) the river varies between 75-150' wide and is 16.5' deep at the deepest part which is not ideal for motorboats.

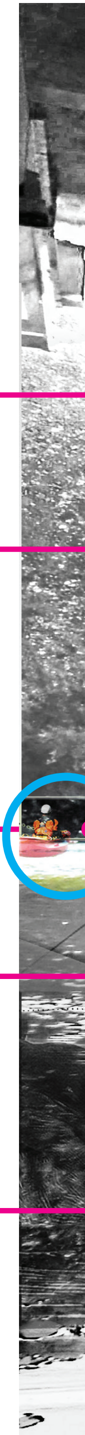
Each drop is about 1' but the pools range from 1-3'deep and 20-40' wide allowing for various fish, mussel, and snail species that prefer swift water habitats, such as our target species of the Cahaba Shiner, Cylindrical lioplax, and orange-nacre mussel.

This design meets all of the qualifications to be considered multifunctional infrastructure designed for multiple species. However, it seems like it could be more integrated, because it is so spread out.

Under the water at the entrance to the fish ladder from the lake is a shallow, swift water ecosystem with coarse gravel bottom that is supportive of many species that live  in the Cahaba River, including the Cahaba Shiner, mussels, and snails. These species and their close relatives are near the base of the food chain that supports the whole ecosystem.

# habitats + interactions



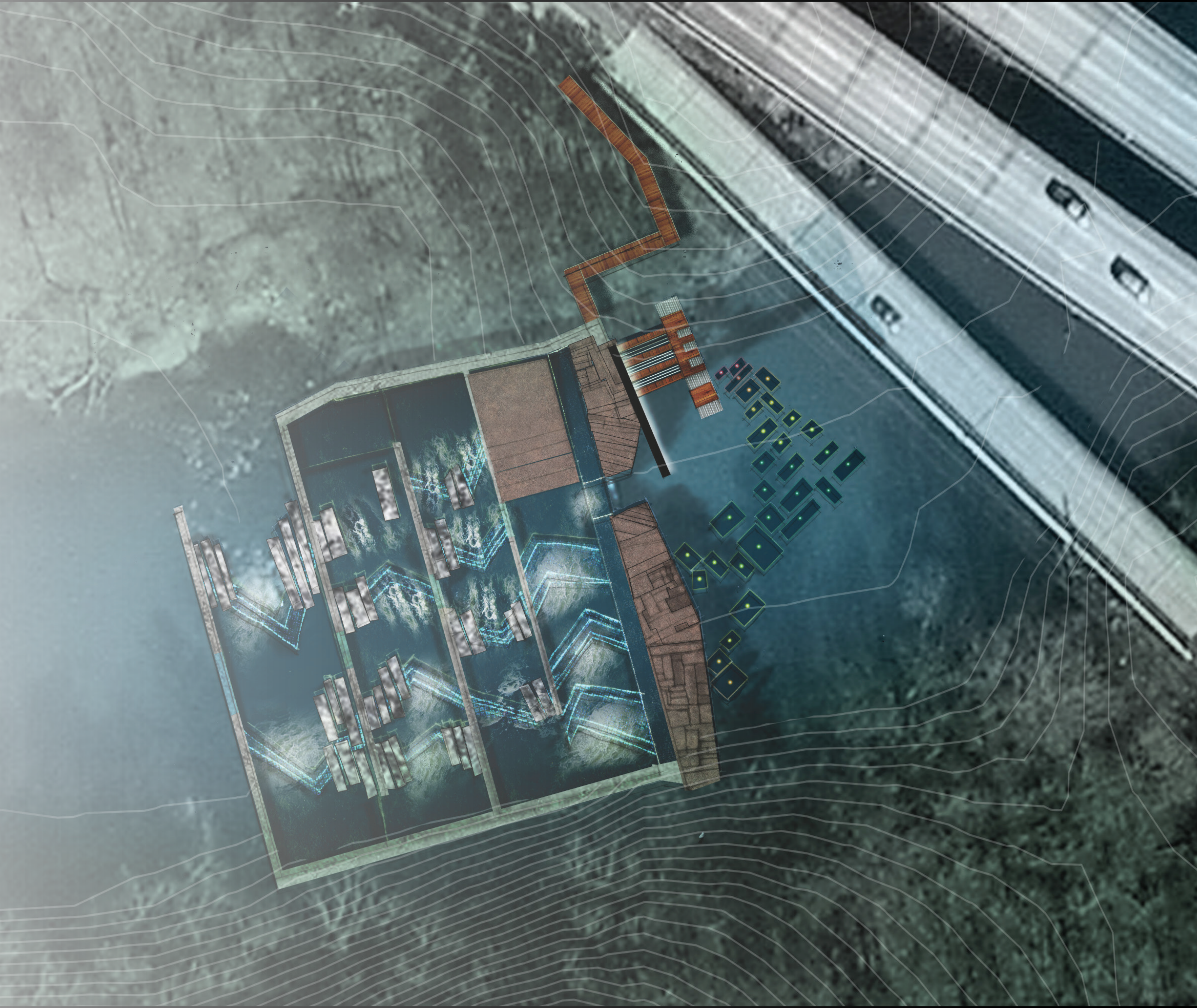
# DAM CONVERGENCE

Consolidating the interventions strictly around the dam, this design tests how many uses can be integrated into the infrastructure of the dam, creating the multifunctional infrastructure for multiple species that this thesis is exploring. Inspired by the previous designs submerged steps throughout the water, this design created steps along the upstream extension of the dam to allow access to the water's edge and the banks at various water levels, while providing hiding places for the aquatic fauna.

From these steps one is extruded high above the others with a large LED billboard attached to it to display information of what is occurring at the site, from the activities of the wildlife to the quality and quantity of water, pollutants, and sediment at the dam. At the top of this pole is the habitat designed for the Osprey. A camera is placed for the observation of the Osprey nest to be displayed on the LED billboard. In the pole are the cavities designed for wood ducks or whatever species may choose to occupy that vacancy. Again cameras observing those nests are set up to observe the happenings of the nests to be displayed on the billboard. The corners of the pole are lined with LED lights that glow with colors of red, yellow, or green to display the quality of the water passing over the dam, and the height of the water passing over the dam. Displaying this information to the commuters passing over the bridge is a way to pass on the happenings of the river to the hurried public, especially during Birmingham's slow and heavy rush hour traffic.

The dock from the previous design has been moved and modified a touch. Consolidating it to the dam provides access to the water for persons with limited mobility, canoeists and kayakers, and addition learning and research areas for students, instructors, and researchers. There are now three boat slips with three boat slides, and a platform to the side.

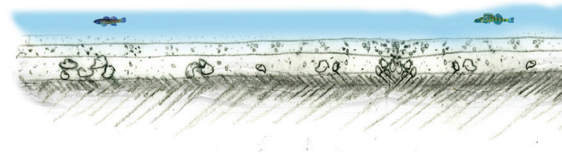
The habitats designed for the mussels and snails

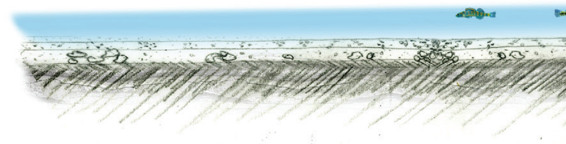


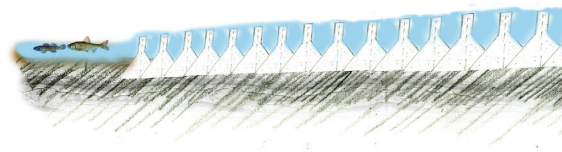
still remain from the previous design below the surface of the dock, except they will now be facing a more direct flow due to the nearly 90° pivot of the dock.

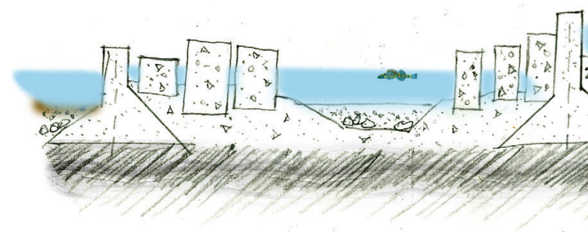
The spillway/fish ladder/whitewater course of the dam has been modified to respond to the findings from the Fish Ladder Study mentioned in the precedent case studies with protruding rocks and resting pools for the fish to make their way over the dam, while keeping in mind the whitewater boaters who wish to move down the river without exiting their boats. Each drop is 1’ and the average slope is 1’:20’ creating a course that is manageable for most fish and boaters at the average water level, but intensifying as the water rises. In the event of a storm there are cuts in the walls to allow the water to cascade down more easily than following the course, which takes pressure off of the edges of the infrastructure and focuses the energy to the bulk of its mass.

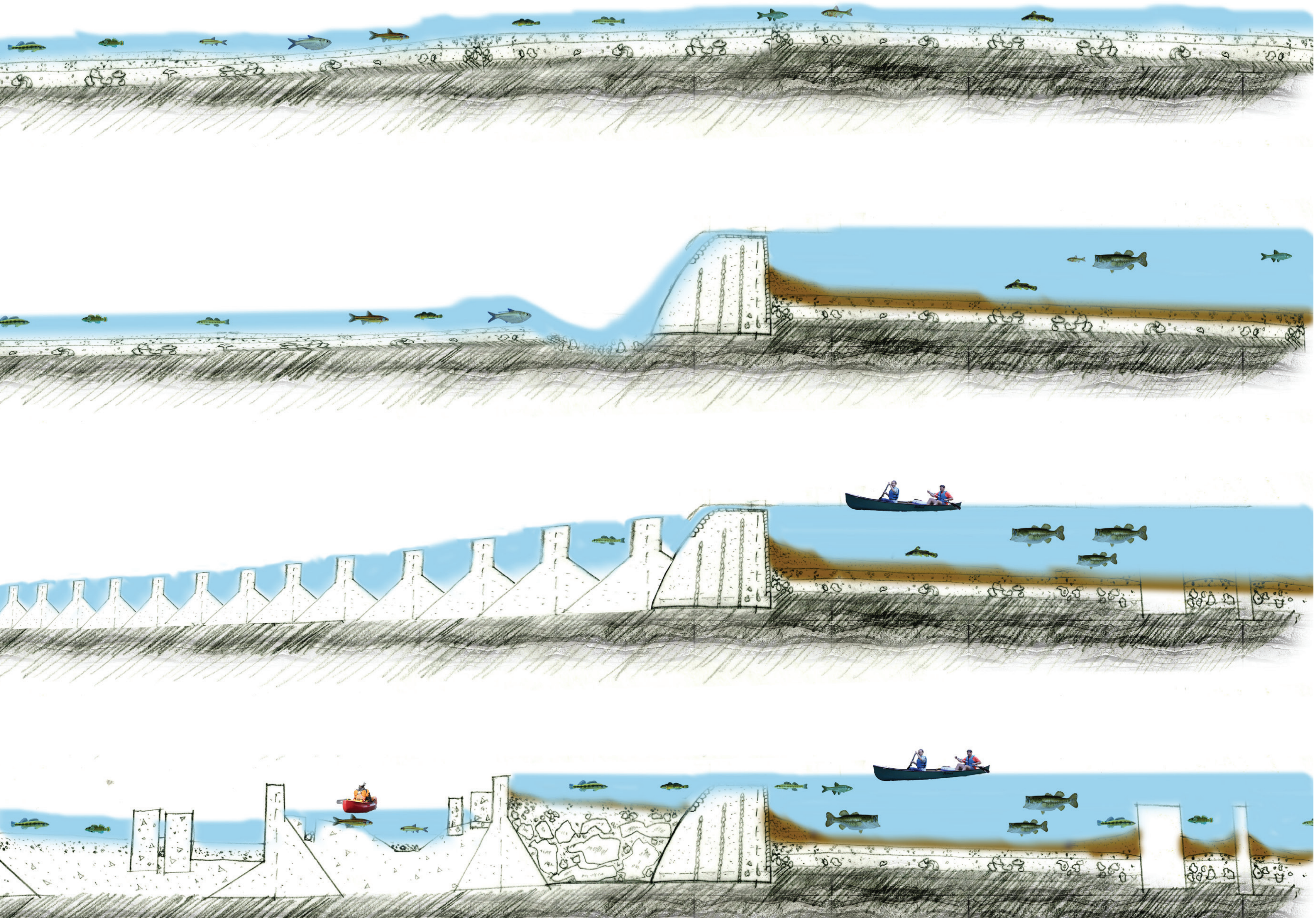
For research purposes at the peak of each rapid there is a counter and camera tracking the number and types of aquatic life that cross it. This data is collected by the USGS and displayed on the LED billboard. The knowledge gained from this can increase our understanding of the influence of this installment of infrastructure on the river’s ecosystem.





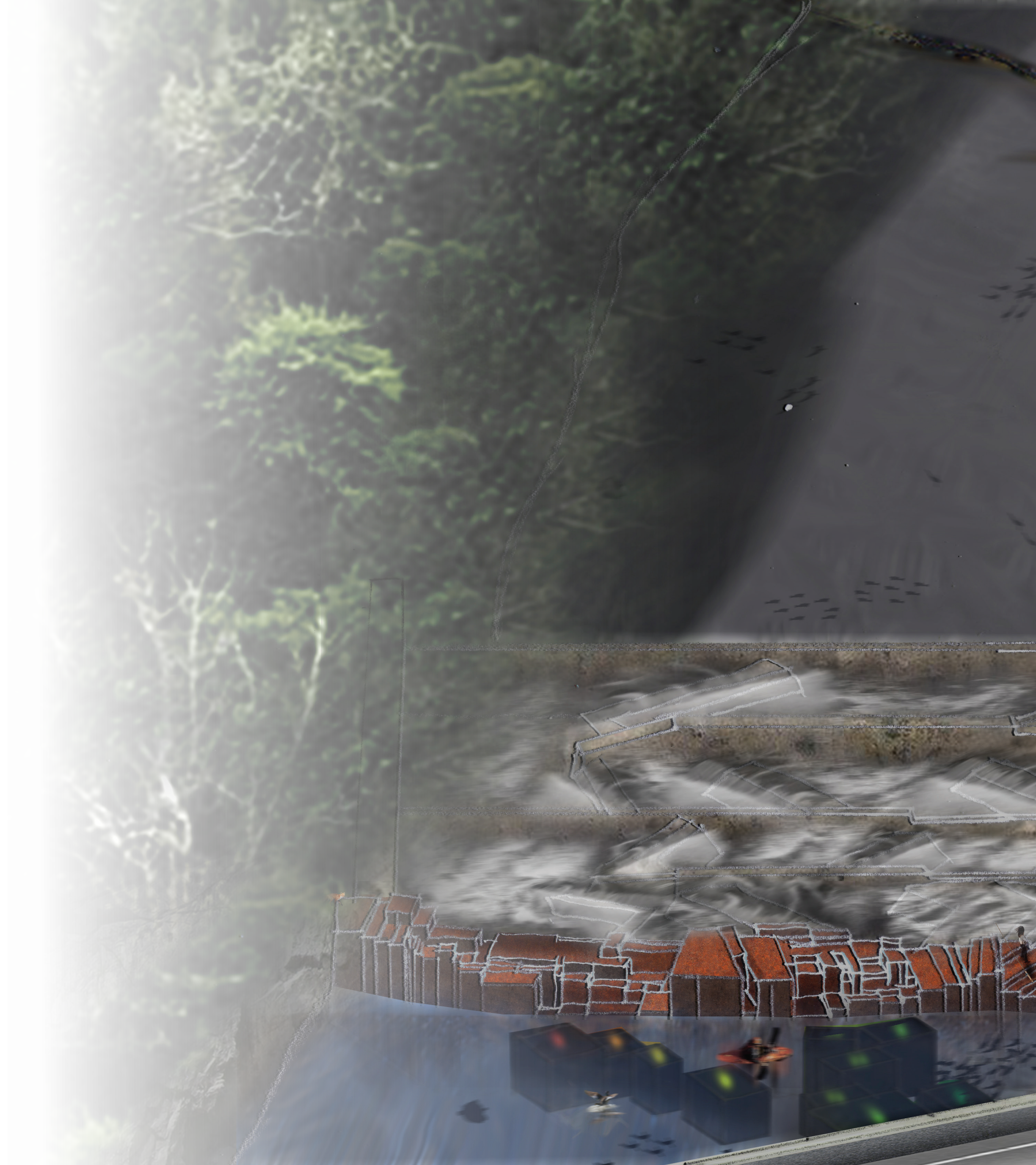


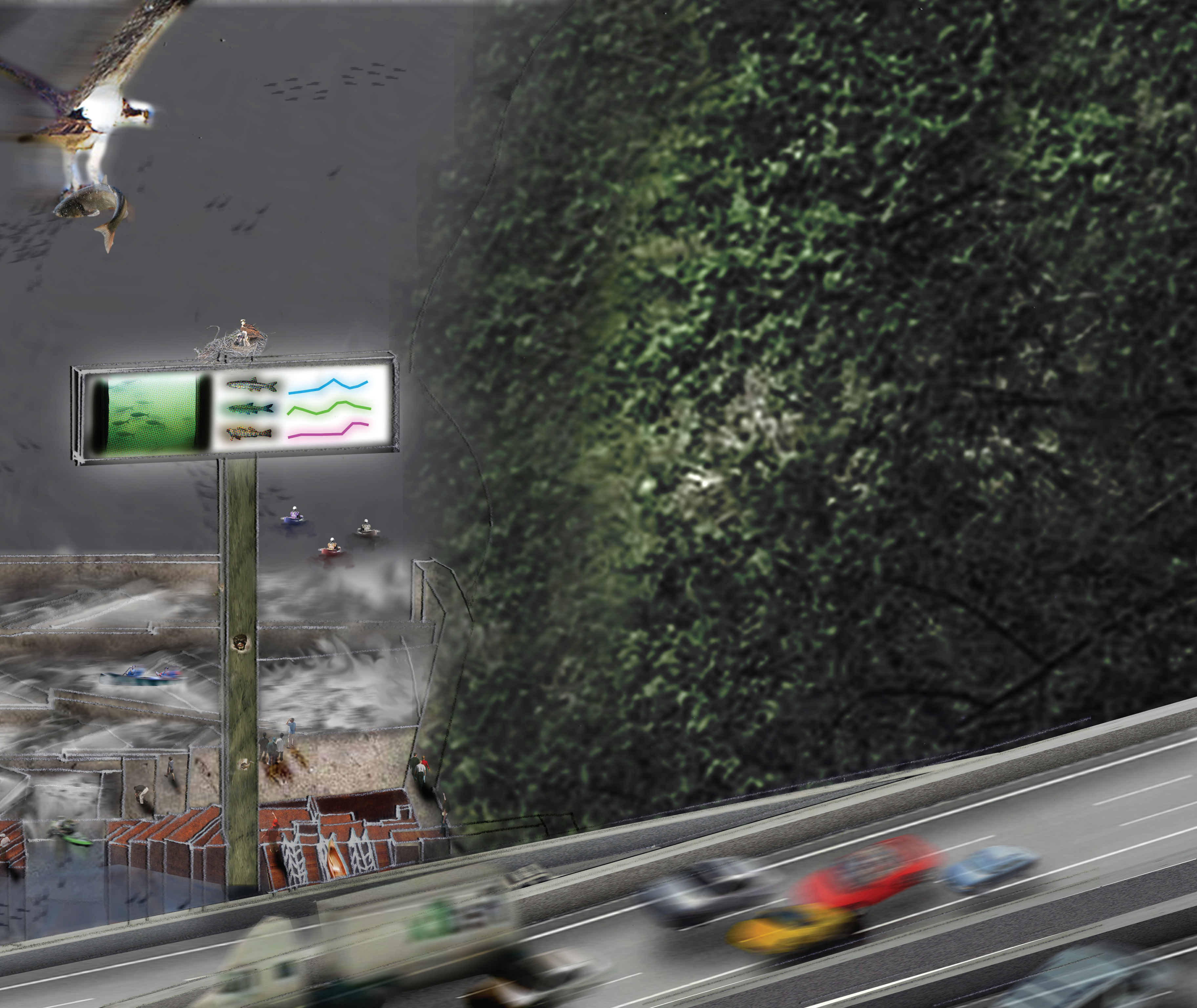


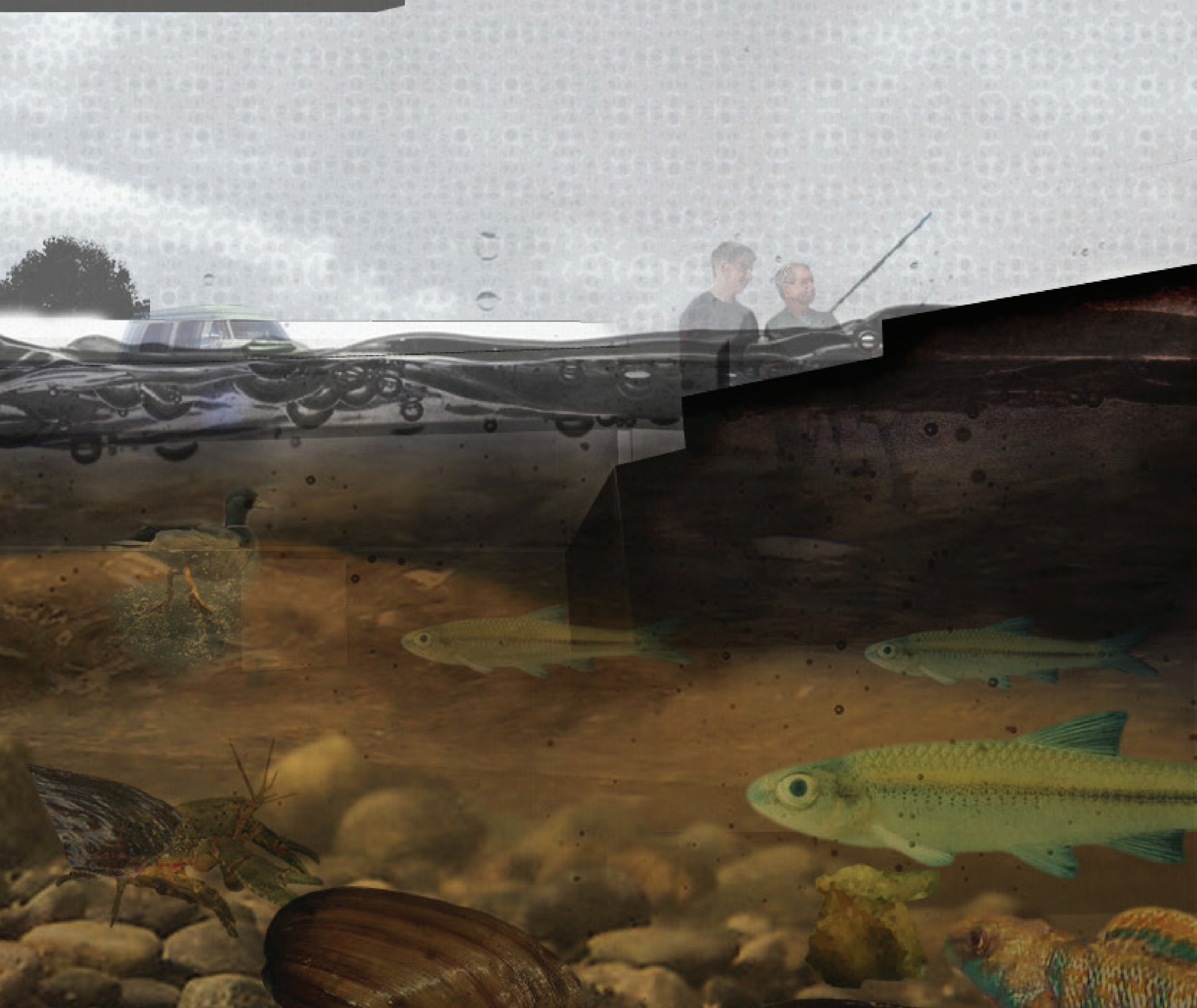


Dams dramatically effect riparian ecosystems by halting the flow, collecting silty sediment, changing the chemistry of the water, and changing the way of life for humans and non-humans that live there. These sections show how the river would be like without a dam, the current situation, an early design idea, and the final fish ramp design.

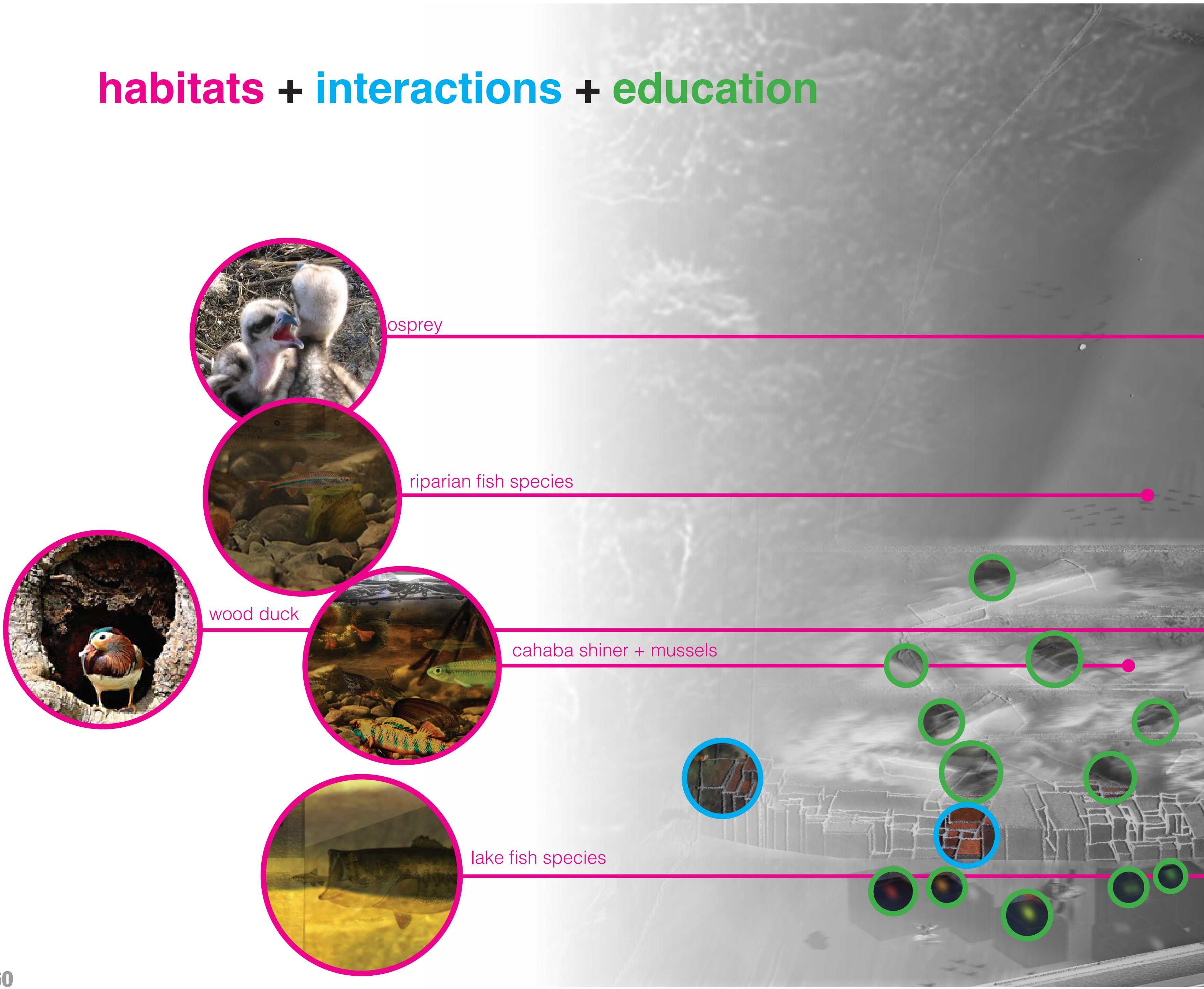
From the osprey's point of view over the fish ramp we can see the water cascading down offering a passage over the dam for aquatic species. At each drop there is a device that counts the fish that cross it to get a perspective on how successful the intervention is in connecting the ecosystems and to collect data to display on the LED billboard. The billboard, located just below the osprey nest platform, displays live streaming data for any driver that can spare a glance during their commute to and from Birmingham.
On the lake side of the dam there are pillars that have been installed to act as habitat, data collectors, platforms for wading fishermen, and baffles to calm sediment. These pillars provide real time data of how many fish are near by and display that with a red, yellow, or green light.
The dam provides access to the water with its stepped platforms and a ramp that leads to a floating dock.

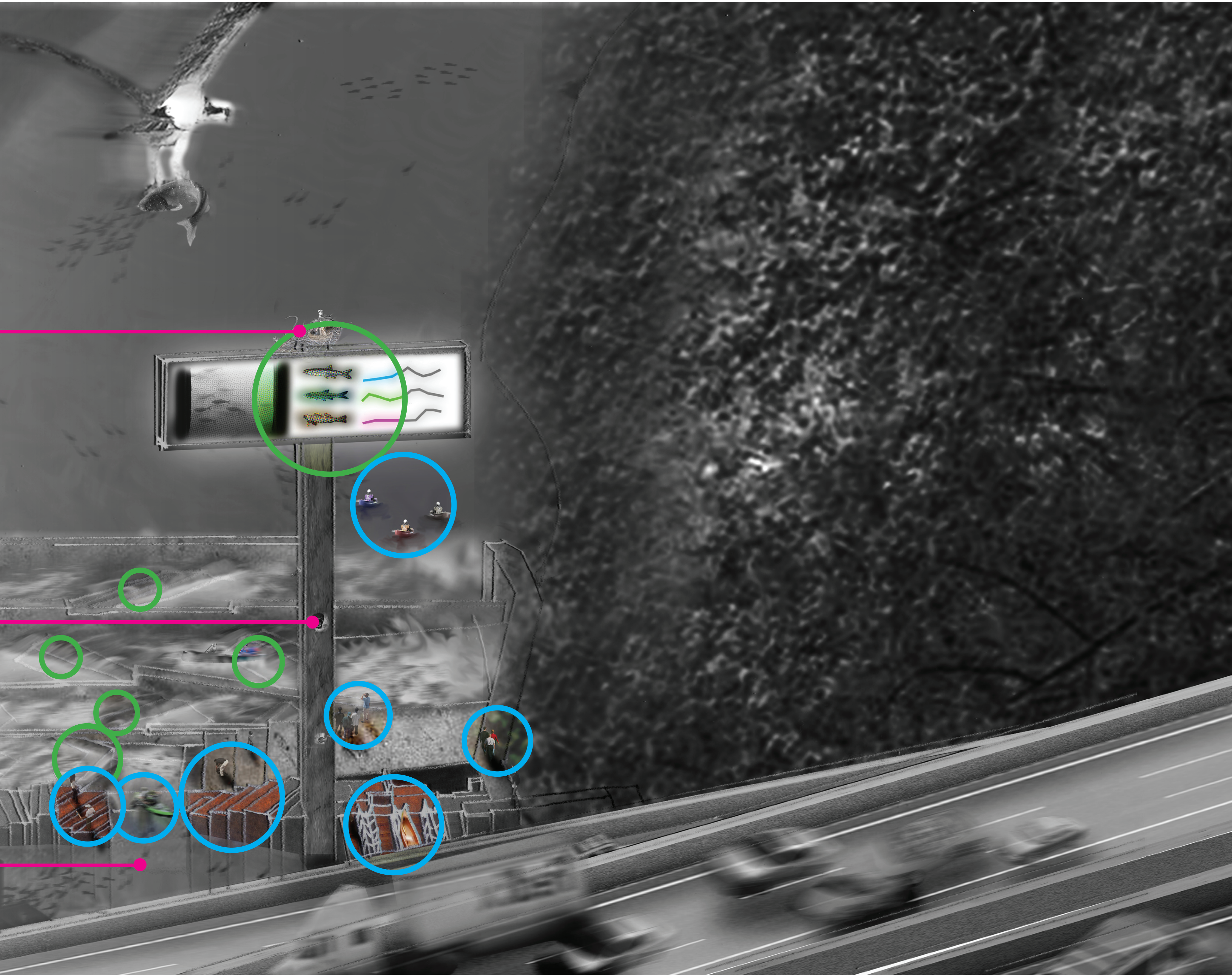






# habitats + interactions + education





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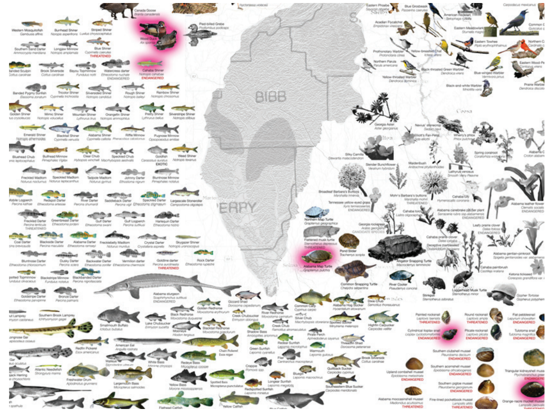
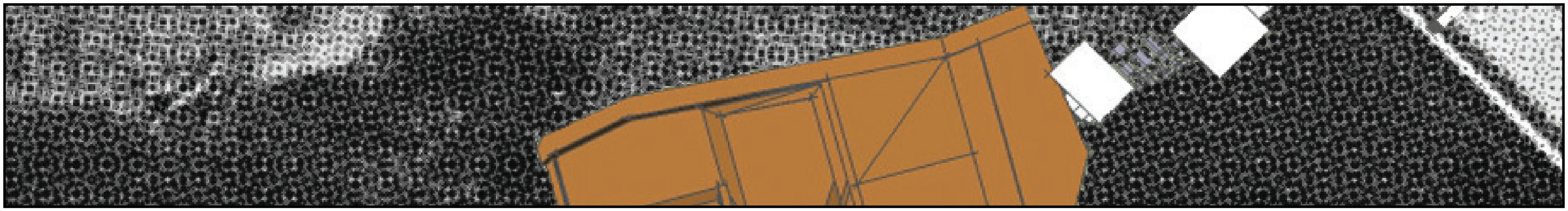
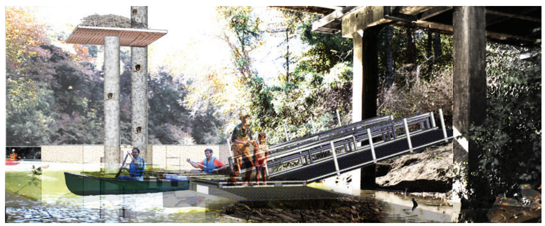
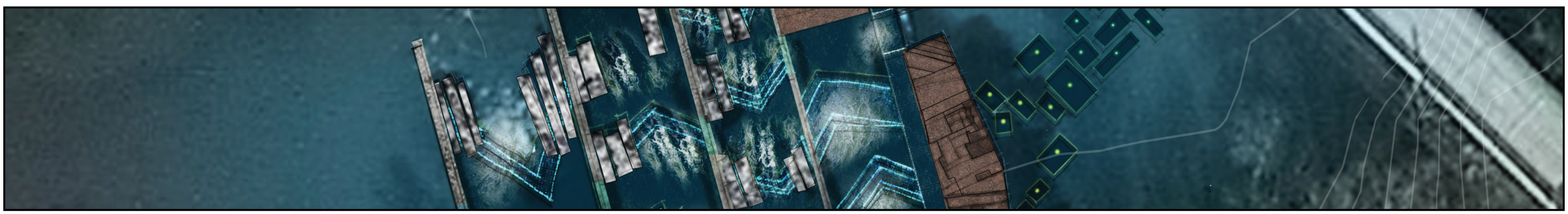
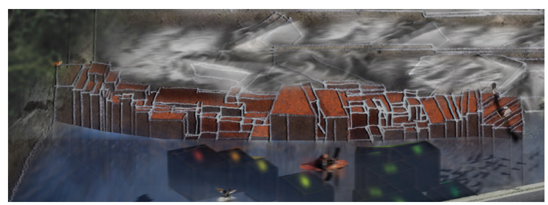


# DAM REFLECTIONS







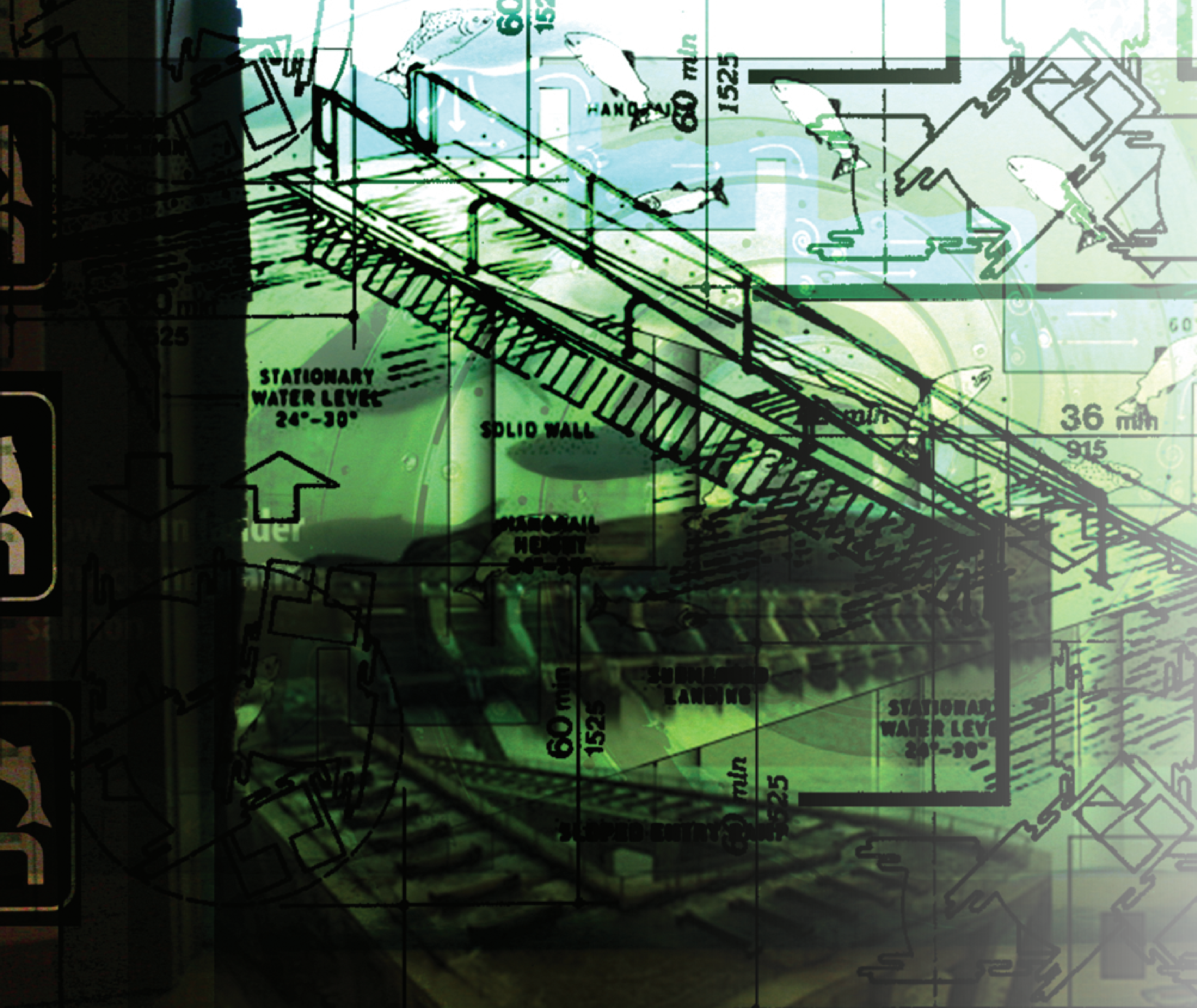


A wise man once told me, “Never pack anything that cannot serve less than three purposes.” I believe that this principle should be applied to our infrastructure as well. The tests from this thesis demonstrate how a low-head dam that is critical infrastructure can be more than just a safeguard of a water supply. It can be a research center, a habitat, a classroom, a fishing hole, a connection, a park, or an information distribution medium. It can enhance the learning of an elementary school student, expand the knowledge of the scientific community, engage the attention of the rush hour commuter, establish a connection between ecosystems, strengthen the populations of rare aquatic species, and emphasis the importance of the resources on which we depend.

To integrate infrastructure so that it acts as a catalyst of connection between ecological hotspots and establishes a way for humans to connect with the ecology was the aim of this thesis.  To continue the research we might look at how the dam and bridge could be the same structure, or how removing the dam and having a decentralized water supply might affect the landscape of the Metro-Birmingham area and the ecology of the Cahaba River Watershed. We might also look at other scales of intervention, like dams on the Alabama River or those found in the headwaters of the watershed.

These design tests limited themselves by not challenging the final design of the fish ramp. It remained within a box of which two sides were established by the existing dam and a retaining wall. It also could have investigated designs that targeted other species and tested its success based on those designs. The results that were described in the drawings were very ideological and only seemed to be quasi-rooted in reality. Long term maintenance, especially after storm damage could be a major issue with this structure. Could the walls survive the beating from debris coming down river during the major storm events? These are all shortcomings from this design test, but the design idea I think is the key to come out of these investigations.

For this design idea to move even further we must expand these ideas to other forms of infrastructure: bridges, electric power lines, pipelines, interstates, light poles, billboards, and other objects that dominate the landscapes spanning many of the modern countries.  The more integrated our infrastructure can be with its surroundings, the healthier ecologic and civic communities can be.


STATIONARY
WATER LEVEL
24"-30"
SOLID WALL
60 min
1525
36 min
915
SUBMERGED
LANDING
SLOPED ENTRY RAMP

However, increased stress and pressure on critical infrastructure which requires more engineering, species could be introduced to new diseases, species could be wiped out by predators that were previously unknown are all limitations that could be found in making infrastructure and habitat multifunctional. Plus, this is a huge multimillion-dollar project, what if it does not do anything but cascade water? No species use it and nobody visits? These are all concerns that we must deal with in many of the innovative designs that have happened, are happening, and will happen. Often times, things do not change until the pain of staying the same becomes greater the pain of change. In this case, I do not see an absolute immediate need for this type of intervention at this place. But I believe that the type of dams we build in the future need to be more conscious of the environment that they are entering. Though it seems that in America more dams are coming down then going up, so we might also learn from the lessons of how a river reclaims itself. In many of the Asian countries, like India and China, dams are springing up in large numbers. The effects are already taking a toll on historic civilizations, civic relations, and the critical environment. These new dams could be the testing ground for new ideas that combine environmental and municipal functions, instead of doing things the way they have been for years only bigger.

As landscape architects, we need to be advocates to look at all sides of the issues concerning dams. Integrating functions of such critical infrastructure as dams is not a small task and it will concern involving more disciplines working on the same project, which is why it probably has not been done in the past. But as the world becomes more globalized and complex, it seems that disciplines should be doing the same through collaboration rather than insulating themselves. Landscape architects can facilitate this by educating and training their students on how to utilize and lead multidisciplined teams. This can be done through competitions, studios, or seminar classes.

As that wise man from the introduction of this section said, so must we do. In our training, education, practice, and designs, do not do anything that serves just one function, one person, or one service. Design wisely to server the greatest good.

# [05]

## DAM APPENDIX

## connecting hotspots through infrastructure removal

# MARVEL SLAB DAM

## cahaba river, al

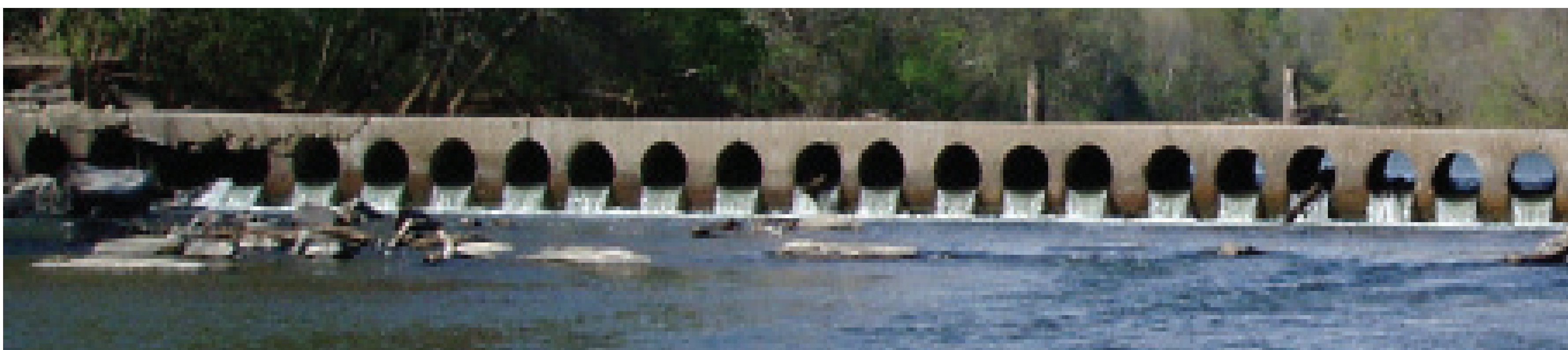
Marvel Slab Dam was built on the Cahaba River in Central Alabama in the early 1960's for a resource extraction company that needed to connect its operations on the east and west side of the river. Measuring 24' wide, 6' tall, and 210' across the river, this dam stopped the current allowing only what could fit through the 46 culverts that were 3' wide.

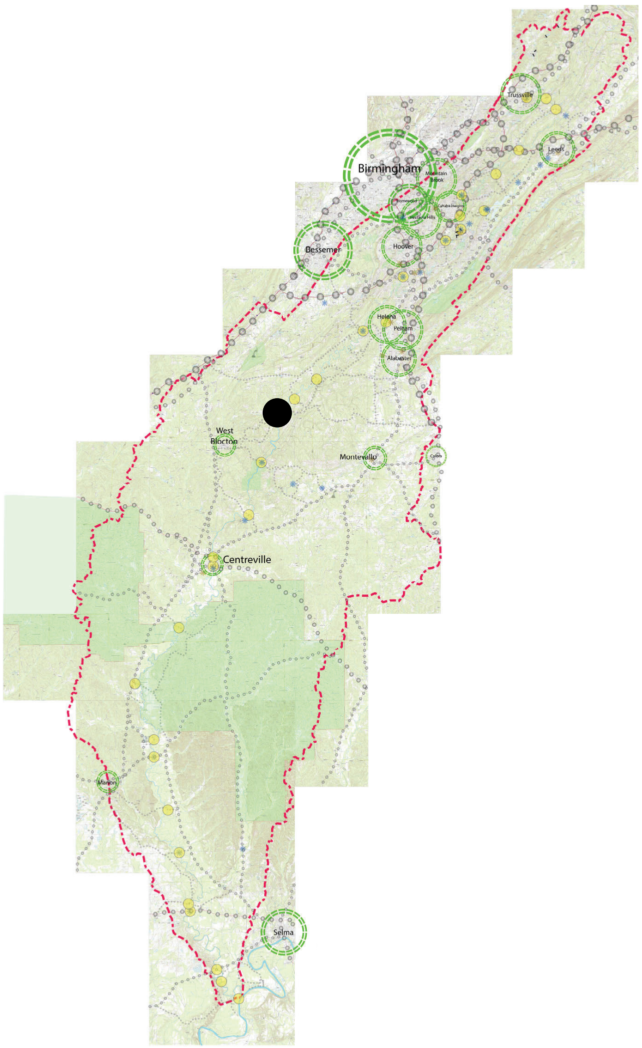
The dam eased operations and gave locals a new place to cross the river. However, it cut off species populations above and below the dam, slowed flow of river above the dam covering the shoals collecting pollutants, thus lowering the numbers of snails, mussels, and fish species. It also impeded recreational boat traffic.

In the 1990's plans began of what to do about the dam since it had not been in service since the 1980's. The Nature Conservancy, Cahaba River Society, State of Alabama, and Army Corps of Engineers devised a plan to remove the dam to allow the river to freely flow again.

In 2004, they demolished the dam and have created an access site for recreational use. Since then, species that had not been seen in the area for decades are returning and the isolated species area able to reconnect strengthening the gene pool. Studies are ongoing to examine the effects of this reconnection of the river.

The study of the Marvel Slab Dam demonstrates an option that is becoming more popular throughout the world of conservation: removing non-critical infrastructure to reestablish connections between ecosystems. However, it remains to be seen of what to do about critical infrastructure impeding natural connections, and how to integrate the human experience within the design.






| SLAB SITE | Summer 2005 | Fall 2005 | Spring 2006 |
|---|---|---|---|
| Cahaba Shiners | 0 | 7 | 7 |
| Goldline Darters | 1 | 4 | 9 |
| Coal Darters | 1 | 1 | 13 |
| Total | 2 | 12 | 29 |
| NEWLY EXPOSED | | | |
| Cahaba Shiners | 0 | 0 | 5 |
| Goldline Darters | 0 | 0 | 0 |
| Coal Darters | 1 | 0 | 8 |
| Total | 1 | 0 | 13 |

# experimenting with fish ladder design strategies

# FISH LADDER STUDY

## turner falls, ma

Alex Haro, Abigail Franklin, Theodore Castro-Santos, and John Noreika from the U.S. Geological Survey's S.O. Conte Andadromous Fish Research Laboratory in Turner Falls, MA studied the success rate of migratory fish of the northeastern U.S. passing different designs of fish ladders. They studied and compared two already built fish ladders and the success rate of fish to pass them, one in the East River, Guilford, CT, and the other in Town Brook, Plymouth, MA. The study's objectives were:

1. Evaluate passage performance of alewife and blueback herring in an existing nature-like fishway site at Town Brook in Plymouth, Massachusetts.

2. Evaluate passage performance of alewife in an existing spillway bypass channel with nature-like fishway features site at the East River, Guilford, Connecticut.

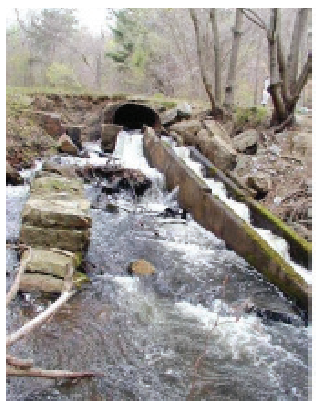
3. Evaluate two full-scale prototype nature-like fishway designs (perturbation boulder and rock weir; each 10 ft width) in the Conte Anadromous Fish Research Laboratory (CAFRL) flume complex under varying flow depths or a variety of test species, including American shad, alewife, blueback herring, white sucker, and other species, over two study years (Haro, Franklin, Castro-Santos, & Noreika, 2008).

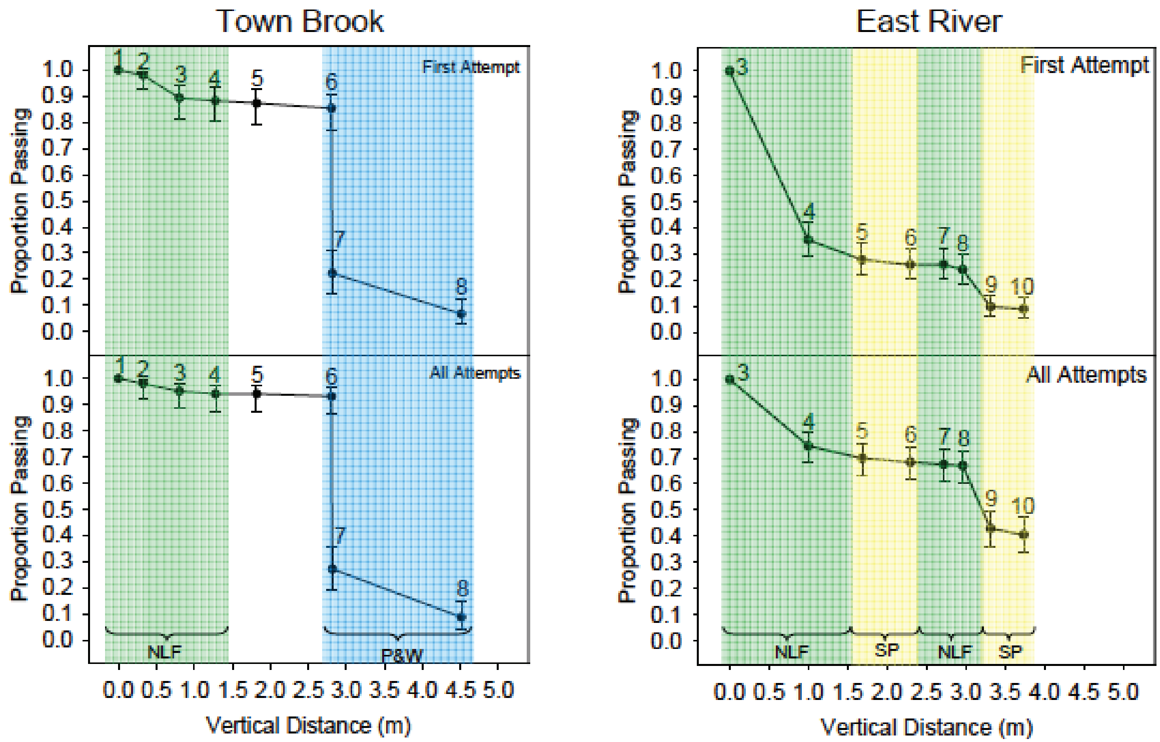
Antennas were placed at each level of the ladders, which measured when a fish crossed the path. The scientists were


Below Middle: Steep pass fish ladder design with sensors.

Below Left: Broken down fish ladder before reconstructions.

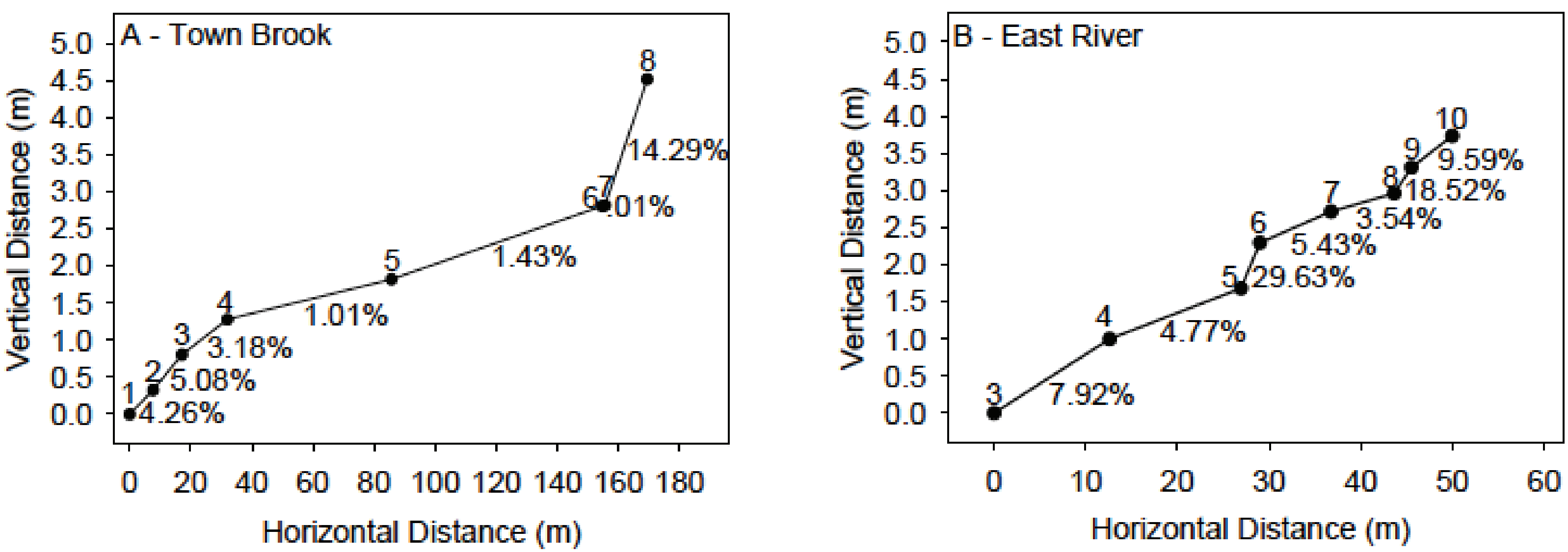
Below Right: Natural-like fish ladder design with sensors above the surface that cross the stream.






Left: The results of the fish successfully passing over the fish ladders by percentage over vertical distance. Our dam is 15' tall (~4.5 meters).
NLF-Nature Like Fish Ladder
P&W- Pool and Weir
SP- Steep Pass

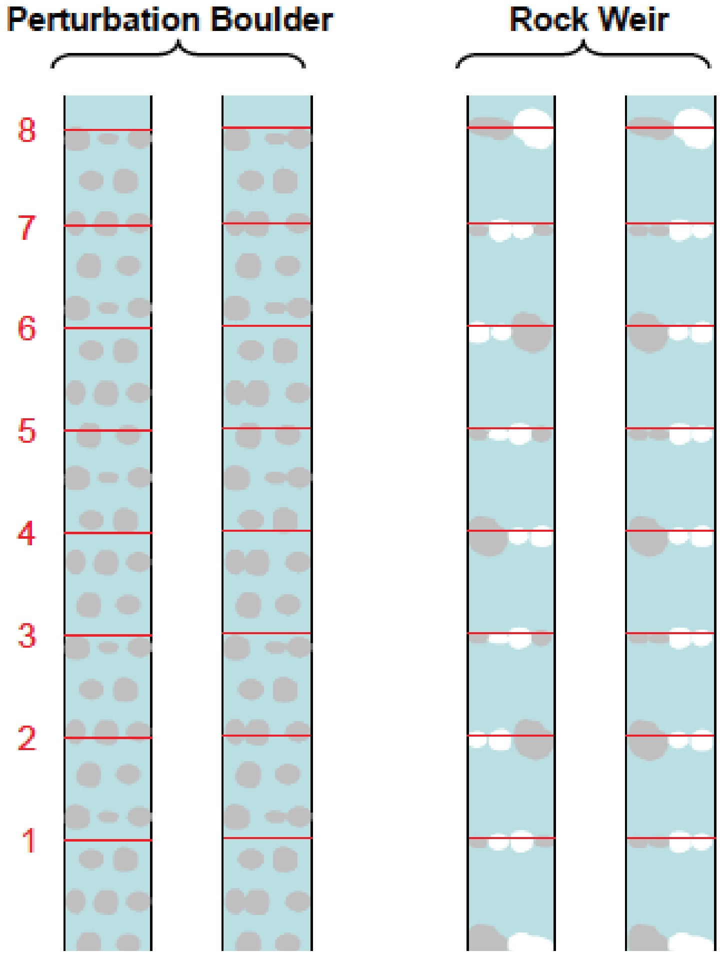
Below: The slope of each section between the measuring devices. Our target slope is 5% (1:20)



then able to analyze the number of fish crossing the antennas at each stage to gain an idea of how many fish were able to make it to each level and about how much time it took the fish to make it through the obstacles. These findings are shown in the line graphs.

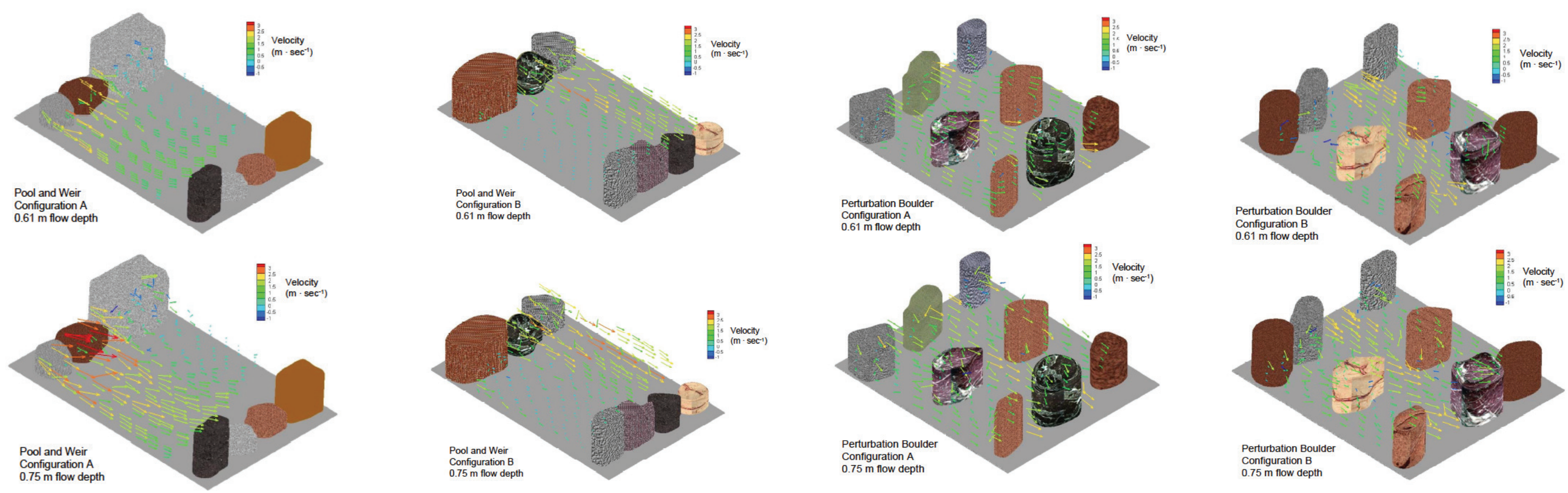
The scientists were then able to construct two artificial fish passages in their labs for more controlled testing. It was found that the design that had protruding rocks creating eddies was generally more successful that the other design.

This gives ideas into how to design fish ladders but it does not address how to integrate human interactions and uses into the fish ladders as well.



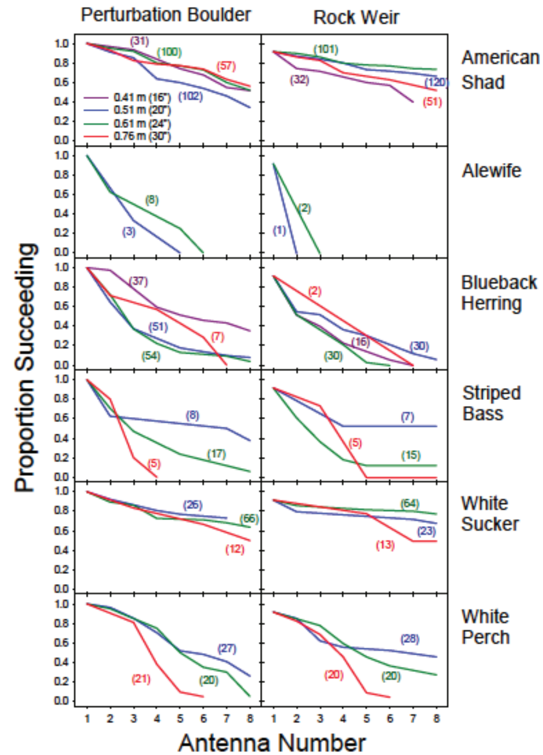

Right: Design plans of four different test courses that were run in the laboratory. Results are on the opposite page.

Below are the computer generated models of the water's flow through different rock configuations with red being the fastest current and dark blue being the slowest. The designs are considered least successful to most successful moving left to right.



Test tracks with the pertrubation boulders on the left and the rock weirs on the right.

Test tracks with the water flowing.




Average results from tests where each color represents different velocities of water.

## infrastructure as habitat

# AUSTIN BAT BRIDGE

## austin, tx

The city of Austin, Texas was surprised when a colony of Mexican Free-tail Bats moved into the newly reconstructed Congress Street Bridge in 1980. As it turns out the engineers that designed the bridge created an ideal roosting spot for the bats on their annual migration to give birth.

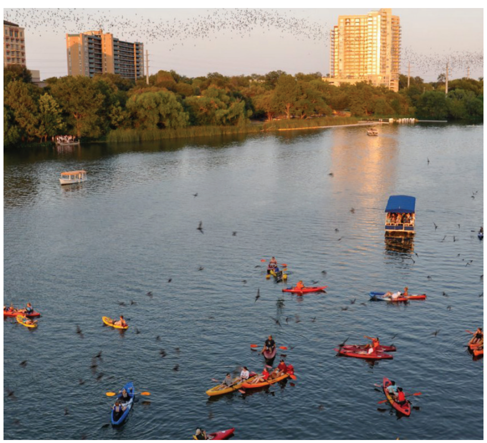
As the population of bats grew to the hundreds of thousands many citizens feared the new inhabitants of the bridge would harm the surrounding community, the integrity of the bridge, and the water quality of the lake below. Through studies and public education, the bats began to be accepted and are now celebrated by the citizens of Austin with bat festivals, nightly bat viewing, and bat cruises on the lake. Austin even has a sculpture of a bat downtown and is heralded as being the bat capitol of the U.S. (Moran & Sceurman, n.d.).

This accidental design has inspired the Texas Department of Transportation to consider retrofitting other bridges as the projects became available (TxDOT, n.d.). We can learn how a bridge can be multifunctional and designed to serve more than just a span over an obstacle, and offer something to the environment and culture of the community.

What if this success could be spread to other animals and other types of infrastructure? Are there other ways to incorporate human interaction or experiences with the environmental processes that are happening around the infrastructure?


Austin, TX


Welcome To The World's Largest Urban Bat
Bat Conservation International
www.batcon.org



# bibliography

Aaserude, R., & Orsborn, J. (1982). *New Concepts in Fish Ladder Design, Volume II of IV: Results of Laboratory and Field Reserch on New Concepts in Weir and Pool Fishways* (Final Report No. 198201400) (p. 175).

ADEM. (2006, September). *Nutrient Total Maximum Daily Loads for the Cahaba River Watershed*. Alabama Department of Environmental Management.

ADEM. (2011). *Alabama Nonpoint Source Management Program.* Alabama Department of Environmental Management.

ADEM. (2013, August 8). *Upper Cahaba River Watershed Final TMDL Document: Siltation/Habitat Alteration*. Alabama Department of Environmental Management.

Agostinho, A. A., Pelicice, F. M., Petry, A. C., Gomes, L. C., & Julio, Jr., H. F. (2007). *Fish diversity in the upper Parana River basin: habitats, fisheries, management and conservation*. Aquatic Ecosystem Health & Management, 10(2), 174–186.

Andersen, A. N., Fisher, A., Hoffmann, B., Read, J. L., & Richards, R. (2004). *Use of terrestrail invertebrates for biodiversity monitoring in Australian rangelands, with particular reference to ants*. Austral Ecology, 29, 87–92.

Aycock, R. (2010). *Critical Habitat for Freshwater Mussels in the Mobile River Basin*. US Fish and Wildlife Service.

Barlow Rogers, E. (2001). *Landscape Design: A cultural and architectural history*. New York: Harry Abrams.

Barnett, R. (2013). *Emergence in Landscape Architecture*. London: Routledge.

Bennett, M., & Howell, J. H. (2006). *Fish Diversity and Conservation in the Mobile Basin in Alabama: An Overview with Case Studies* (p. 6). Mobile River Basin, Alabama: The University of Alabama.

Bryant, W. O. (1990). *Cahaba Prison and the Sultana Disaster*. Tuscaloosa: University of Alabama Press.

census.gov. (2010). *U.S. Decennial Census*. U.S. Department of Commerce.

Chamness, M. A. (2009). *Evaluation of a Fish Passage Site in the Walla Walla River Basin* (No. 2007-396-00) (p. 16). Richland, WA: Pacific Northwest National Laboratory.

Chiu, G., Guttorp, P., Westveld, A., Khan, S., & Liang, J. (n.d.). *Latent Health Factor Index: A statistical modeling approach for ecological health assessment*. Environmetrics, 22, 243–255. doi:10.1002/env. 1055

Cloas, F., Baudoin, J.-M., Danger, M., Usseglio-Polatera, P., Wagner, P., & Devin, S. (2013). *Synergistic impacts of sediment contamination and dam presence on river functioning*. Freshwater Biology, 58, 320–336.

Cornell University. (n.d.). All About Birds: The Cornell Lab of Ornithology.

CRBCWP. (2002). *Cahaba River Basin Management Plan.* Cahaba River Basin Clean Water Partnership.

Cubanova, L., & Rumann, J. (2009, September 1). *Whitewater Course Design in Slovakia.* Presented at the International Symposium on Water Management and Hydraulic Engineering, Ohrid, Macedonia.

Dickinson, J. M. (1910, February 17). *Cahaba River, Alabama.* US Government.

Doyle, C. (2010, August 3). *Benchmark Study Values Adventure Tourism Market at $89 Billion*. Xola Press Release. Retrieved from http://www.xolaconsulting.com/pr-2010-08-Benchmark-Study-Values-Adventure-Tourism-Market-89-Billion.php

DRBC, Delaware River Basin Commission. (1961). *Delaware River Basin Compact.*

Echols, S., & Pennypacker, E. (2008). *From Storm Water Management to Artful Rainwater Design.* Landscape Journal, 27(2), 268–90.

Ferguson, B. K. (1999). *The Alluvial History and Environmental Legacy of the Abandoned Scull Shoals Mill.* Landscape Journal, 18(2), 147–56.

Freeman, P. (2013, October 5). *Cahaba River Field Visit with Cahaba River Society and The Nature Conservancy*.

Freeman, P., & Stout, B. (2004). *Marvel Slab Dam Removal.* Powerpoint, Cahaba River.

FTC&H, F., Thompson, Carr, & Huber, Inc. (2009). *Green Grand Rapids Special Study Grand River Whitewater Park Preferred Alternative* (Study No. G080058) (p. 69). City of Grand Rapids.

GAO, (US General Accounting Office). (1981, February 20). *Federal Interstate Compact Comissions: Useful Mechanisms for Planning and Managing River Basin Operations.* Congress of the United States.

Gentzler, K., & Hines, J. (2006). *Delaware, Susquehanna, and Potomac: Three Federal Compact Commissions of the Northeast United States. In Interstate Water Allocation in Alabama, Florida, and Georgia: New Issues, New Methods, New Models* (pp. 78–101). Gainesville: University of Florida Press.

Ghosh, S. K., & Ponniah, A. G. (2008). *Freshwater fish habitat science and management in India.* Aquatic Ecosystem Health & Management, 11(3), 272–288.

Hands, D. E., & Brown, R. D. (2002). *Enhancing Visual Preferecne of Ecological Rehabilitation Site. Landscape and Urban Planning*, 58, 57–70.

Haro, A., Franklin, A., Castro-Santos, T., & Noreika, J. (2008). *Design and Evaluation of Nature-Like Fishways for Passage of Northeastern Diadromous Fishes* (p. 35). S.O. Conte Andadromous Fish Research Laboratory: USGS.

Horner, R., Lim, H., & Burges, S. (2002, November). *Hydrologic Monitoring of the Seattle Ultra-Urban Stormwater Management Projects*. University of Washington, Department of Civil and Environmental Engineering.

Hulse, D., Eilers, J., Freemark, K., Hummon, C., & White, D. (2000). *Planning Alternative Future Landscapes in Oregon: Evaluating effects on water quality and biodiversity.* Landscape Journal, 19(1-2), 1–19.

Jackson, J. B. (1984). *Discovering the Vernacular Landscape*. New Haven: Yale University Press.

Johnson, P. D. (2009). *Sustaining America's Aquatic Biodiversity: Freshwater Snail Biodiversity and Conservation.* Virginia Polytechnic Institute and State University.

Kilbane, S. (2013). *Green Infrastructure: Planning a National Green Network for Australia.* Journal of Landscape Architecture, 8(1), 64–73. doi:10.1080/18626033.2013.798930

Kingsford, R. T. (2003). *Ecological Impacts and Institutional and Economic drivers for water resource development-- a case study of the Murrumbidgee River, Australia*. Aquatic Ecosystem Health & Management, 6(1), 69–79. doi:10.1080/14634980390151583

Lewis, L. Y. (2006). *Interstate River Compacts of the West. In Interstate Water Allocation in Alabama, Florida, and Georgia: New Issues, New Methods, New Models* (pp. 102–130). Gainesville: University of Florida Press.

Master, L., Flack, S., & Stein, B. (1998). *Rivers of Life: critical watersheds for protecting freshwater biodiversity*. Arlington, Virginia: The Nature Conservancy.

Mayden, R. L., & Kuhajda, B. R. (1989). *Systematics of Notropis cahabae, a new cyprinid fish endemic to the Cahaba River of the Mobile Basin.* Bull Alabama Museum of Nature History, 9, 1–16.

Mettee, M. F., O'Neil, P. E., & Pierson, J. M. (1996). *Fishes of Alabama* (First.). Oxmoor House.

Moran, M., & Sceurman, M. (n.d.). *Austin's Congress Avenue Bat Attacks.* Weird U.S. Retrieved from http://weirdus.com/states/texas/bizarre_beasts/congress_avenue_bats/index.php

Mueller, M., Pander, J., & Geist, J. (2011). *The effects of weirs on structural stream habitat and biological communities.* Journal of Applied Science, 48, 1450–1461.

Myers, N., Mittermeier, R., Mittermeier, C., Fonseca, G., & Kent, J. (2000). *Biodiversity hotspots for conservation priorities.* Nature, 403, 853–858.
Nichols, H. (2014). *The Cahaba River.* Documentary. Retrieved from https://www.youtube.com/watch?v=USAaPrCJhAE
Norlund, B., Swenson, L., Jundt, M., Meyer, E., Carlon, S., & Johnson, J. (2008). *Anadromous Salmonid Passage Facility Design*. Northwest Region: National Marine Fisheries Service.
O'Dee, S. H., & Watters, G. T. (1998). *New or confirmed host identifications for ten freshwater mussels.* Conservation, Captive Care, and Propagation of Freshwater Mussels Symposium, 77–82.
Patz, J. A., Daszak, P., Tabor, G. M., Aguirre, A. A., Pearl, M., Epstein, J., … Bradley, D. J. (2004). *Unhealthy Landscapes: Policy Recommendations on Land Use Change and Infectious Desease Emergence.* Environmental Health Perspectives, 112(10), 1092–1098.
Peters, P. M., Heath, E., Lewallen, A., & Leonard, P. (2005, October). *The Upper Cahaba Watershed Greenprint*. EDAW Inc.
PWD. (2011, June 1). *Green City, Clean Waters.* Philadelphia Water District.
Ragland, C. (2013, October 25). *Conversation with Talladega National Forest Service Ranger.*
Robinson, W. H., Ivey, J. B., & Billingsley, G. A. (1953). *Water Supply of the Birmingham Area Alabama* (No. Geological Survey Circular 254) (p. 60). Birmingham, AL: US Department of the Interior.
Stremke, S., Van Kann, F., & Koh, J. (2012). *Integrated Visions (Part I): Methodological Framework for Long-term Regional Design*. European Planning Studies, 20(2), 305–319.
Sudorova, J., & Harfst, J. (2011). *Integrative Approaches for Post-Mining Development* (Thematic Report). ReSource.
TxDOT. (n.d.). *Bats "N" Bridges.* Texas Department of Transportation.
USACE. (2004). *Environmental Assessment Fairmount Dam Fish Ladder Project* (Environmental Assessment) (p. 57). Philadelphia, PA: US Army Corps of Engineers.
USEPA Region 4. (2003). *Cahaba River: Biological and Water Quality Studies, Birminham, Alabama*, March/April, July and September, 2002. USEPA Region 4, Science and Ecological Support Division, Athens, GA.
Van Lear, D. H., Carroll, W. D., Kapeluck, P. R., & Johnson, R. (2005). *History and restoration of the longleaf pine-grassland ecosystem: Implications of species at risk.* Elsevier.
Wagner, M., & Hoogeveen, N. (2010). *Developing Water Trails in Iowa*. Iowa State University.
Weller, R., & Hands, T. (2014). *Building the Global Forest.* Scenario Journal, 4(Winter).
Willis, M. (2004, April 27). *Fish Ladders.* Powerpoint.
Wolf, A. T. (2006). *International Water Agreements: Implications for the ACT and ACF*. In Interstate Water Allocation in Alabama, Florida, and Georgia: New Issues, New Methods, New Models (pp. 131–156). Gainesville: University of Florida Press.
Wolf, C. (2004). *Logical Lasting Launches: Design Guidance for Canoe and Kayak Launches* (p. 117). National Parks Service.
Yager, K., & Matheny, J. *Tennessee Adventure Tourism and Rural Development Act of 2011*. , 11 11 § 1 1–4 (2011).
Zeller, J. (2013a, September 11). *Paddling and People with Disabilities*. Powerpoint presented at the Universal Design for Water Access, Smithfield, VA.
Zeller, J. (2013b, September 11). *Universal Design of Launches/Landings for Carry-down Craft.* Powerpoint presented at the Universal Design for Water Access, Smithfield, VA.

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Savage, M. (2007, November 23). Ancient dam creating a lake to cool the Summer Palace. Flickr. Photography. Retrieved from https://www.flickr.com/photos/56796376@N00/2178574447
p. 6 Chinese Terrace
mcrosswg. (2012, April 10). Culture of China- Terrace Farming. edublogs. Blog. Retrieved from http://mcrosswg.edublogs.org/2012/04/10/culture-of-china-terrace-farming/
p. 6 Roman Road
PhR61. (2007, April 15). Roman Road in Timgad. Flickr. Photography. Retrieved from http://en.wikipedia.org/wiki/File:Timgad_rue.jpg
samuraishawn. (2006, May 30). Bats Build Barracks Under Bridge. MetBlogs. Retrieved from http://houston.metblogs.com/2006/05/30/bats-build-barracks-under-bridge/
p. 6 Roman Aquaduct
B., D. (2012, September 17). The Roman Aqueduct: Who Knew Plumbing Could Be So Beautiful. Okeanos Aquascaping. Company Website. Retrieved from http://www.okeanosgroup.com/blog/aquatic-architecture-2/the-roman-aqueduct-who-knew-plumbing-could-be-so-beautiful/
p. 7 Highway
Glenn, A. (2013, February 6). Worst Cities for Drivers: Los Angeles. esurance blog. Insurance. Retrieved from http://blog.esurance.com/worst-cities-for-drivers-los-angeles/#.Uz4z2sd042w
p. 7 Train
grumpyoldman. (2008, June 11). Railroad Forums. railroad.net. Forum. Retrieved from http://www.railroad.net/forums/viewtopic.php?t=30689&start=60
p. 7 Hoover Dam
Murphy, T. (2011, December 20). How Much Dam Energy Can We Get? Do the Math. Educational. Retrieved from https://physics.ucsd.edu/do-the-math/2011/12/how-much-dam-energy-can-we-get/
p. 7 Power Grid
Spector, D. (2013, December 3). Green Energy Could Crash The US Power Grid. Business Insider. News. Retrieved from http://www.businessinsider.com/green-energy-isnt-compatible-with-us-power-grid-2013-12
p. 9 Highline
Sternfeld, J. (2000, May). High Line. High Line. Retrieved from http://www.thehighline.org/galleries/images/joel-sternfeld
p. 11 Biodiversity Hotspots
Biodiversity. (2005, February). Conservation International. Retrieved from www.conservation.org
p. 15 Endangered Mussels
Master, L., Flack, S., & Stein, B. (1998). Rivers of Life: critical watersheds for protecting freshwater biodiversity. Arlington, Virginia: The Nature Conservancy.
p. 15 Ecological Hotspots
Master, L., Flack, S., & Stein, B. (1998). Rivers of Life: critical watersheds for

protecting freshwater biodiversity. Arlington, Virginia: The Nature Conservancy.
p. 16 Old Cahawba
Keith, T. (2010). Day-Tripping at Old Cahaba. Monkey Planet. Travel. Retrieved from http://www.monkeyplanet.com/articles/cahawba.htm
p. 16 Cahaba Pumphouse
Badham, T. (2014, January). Willis J. Milner and the Water Works Tunnel. JCHA Newsletter. Retrieved from http://www.jeffcohistory.com/newsletter_Jan_14_pg2.html
p. 17 Siltation in River
Brooke, N. (2007). Legal Docket- Spring 2007. Black Warrior River Keeper. Retrieved from http://www.blackwarriorriver.org/legal docket/legal_docket_spring2007.htm
p. 17 Cahaba Lillies
Holmes, C. (2011). Cahaba Lilies in May. Retrieved from http://floraphile.blogspot.com/2012/03/great-georgia-aster-hunt-part-2.html
p. 18 Cahaba Blueway
Alabama Innovation Engine. (2013). Cahaba River Blueway Access Points.
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Retrieved from bing.com
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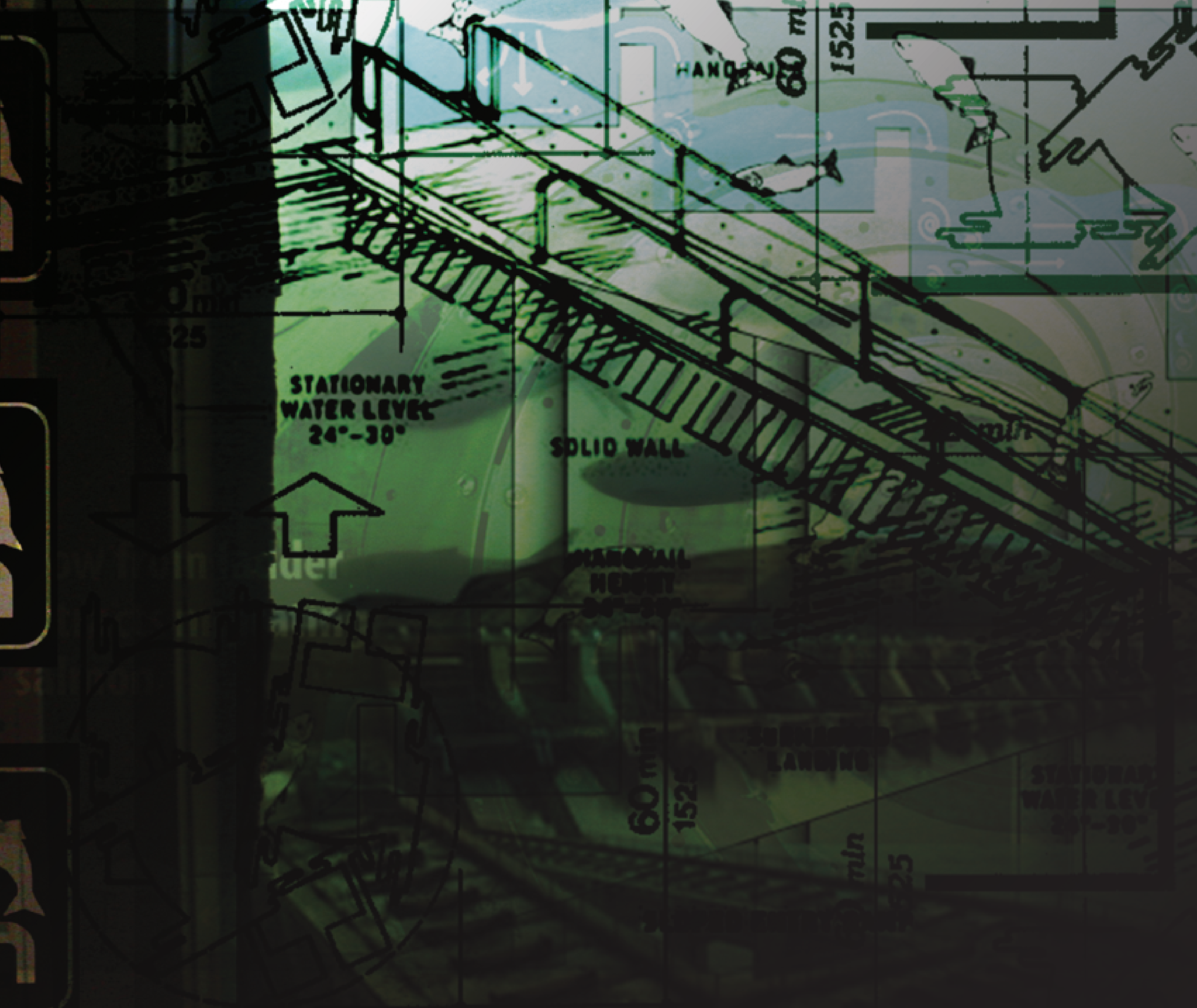
Retrieved from bing.com
p. 66 Marvel Slab Dam
Freeman, P., & Stout, B. (2004). Marvel Slab Dam Removal. Powerpoint, Cahaba River.
p. 67 Marvel Slab Before and After
Freeman, P., & Stout, B. (2004). Marvel Slab Dam Removal. Powerpoint, Cahaba River.
p. 67 Marvel Slab Downstream Side
Freeman, P., & Stout, B. (2004). Marvel Slab Dam Removal. Powerpoint, Cahaba River.
p. 67 Marvel Slab Upstream Side
Freeman, P., & Stout, B. (2004). Marvel Slab Dam Removal. Powerpoint, Cahaba River.
p. 68 Bing Map
Retrieved from bing.com
p. 68 Photos of Fish Ladders
Haro, A., Franklin, A., Castro-Santos, T., & Noreika, J. (2008). Design and Evaluation of Nature-Like Fishways for Passage of Northeastern Diadromous Fishes (p. 35). S.O. Conte Andadromous Fish Research Laboratory: USGS.
p. 69 Graphs of Fish Success
Haro, A., Franklin, A., Castro-Santos, T., & Noreika, J. (2008). Design and Evaluation of Nature-Like Fishways for Passage of Northeastern Diadromous Fishes (p. 35). S.O. Conte Andadromous Fish Research Laboratory: USGS.
p. 69 Graphs of Fish Ladder Slope
Haro, A., Franklin, A., Castro-Santos, T., & Noreika, J. (2008). Design and Evaluation of Nature-Like Fishways for Passage of Northeastern Diadromous Fishes (p. 35). S.O. Conte Andadromous Fish Research Laboratory: USGS.
p. 70 Plan of Test Runs
Haro, A., Franklin, A., Castro-Santos, T., & Noreika, J. (2008). Design and Evaluation of Nature-Like Fishways for Passage of Northeastern Diadromous Fishes (p. 35). S.O. Conte Andadromous Fish Research Laboratory: USGS.
p. 70 Diagram of Water Flow through Different Rock Formations
Haro, A., Franklin, A., Castro-Santos, T., & Noreika, J. (2008). Design and Evaluation of Nature-Like Fishways for Passage of Northeastern Diadromous Fishes (p. 35). S.O. Conte Andadromous Fish Research Laboratory: USGS.
p. 71 Fish Ladder Designs without watier
Haro, A., Franklin, A., Castro-Santos, T., & Noreika, J. (2008). Design and Evaluation of Nature-Like Fishways for Passage of Northeastern Diadromous Fishes (p. 35). S.O. Conte Andadromous Fish Research Laboratory: USGS.
p. 71 Fish Ladder Designs with water
Haro, A., Franklin, A., Castro-Santos, T., & Noreika, J. (2008). Design and Evaluation of Nature-Like Fishways for Passage of Northeastern Diadromous Fishes (p. 35). S.O. Conte Andadromous Fish Research Laboratory: USGS.
p. 71 Graph of fish succuess
Haro, A., Franklin, A., Castro-Santos, T., & Noreika, J. (2008). Design and Evaluation of Nature-Like Fishways for Passage of Northeastern Diadromous Fishes (p. 35). S.O. Conte Andadromous Fish Research Laboratory: USGS.
p. 73 Bing Maps
p. 73 Austin Bat Bridge Festival
Clarke, J. (2012, June 24). Furry Aviators. John Clarke Writer. Blog. Retrieved from http://johnclarkeonline.com/2012/06/24/furry-aviators-%E2%80%93-bats/
p. 73 Austin Bat Scupture
Paris and John. (2008, February 6). POTD: Austin Bat Sculpture. Texas Tripper. Retrieved from http://www.texastripper.com/blog/2008/02/potd-austin-bat-sculpture.html
p. 73 Austin Bat Bridge at Dusk
Endval, B. (2003, September 21). Austin Bat Bridge Sign. Miscellaneous San Antonio pictures and the Bat Bridge in Austin. Retrieved from http://www.angelfire.com/tv2/endval/fifth/fifth.html
p. 73 Under the Austin Bat Bridge
Ambition, D. (2009, September 14). OMG Bats Under the Bridge. Flickr. Photography. Retrieved from https://www.flickr.com/photos bigkitty/3934737709/
p. 73 Bats Under the Bridge
White, R. (2011, August 27). We're Going "Batty" in Austin. The Original Weather Blog. Blog. Retrieved from http://originalweatherblog.blogspot.com/2011/08/were-going-batty-in-austin.html
p. 73 Cloud of Bats
Miehls, A. (2011, August 27). Congress Bridge Bat Migration. Photography V. School. Retrieved from https://www.msu.edu/~jaegeran/Andrea_Miehls_Photography_MS5.html
p 73 Kayakers watching Bats
Lynn, A. (August 4, 2014q). Bats on the Water. The Adventures of Team Danger. Blog. Retrieved from http://theadventuresofteamdanger.blogspot.com/2013/08/bats-on-water.html


1525
STATIONARY
WATER LEVEL
24°-30°
SOLID WALL
60
1525