**20 Years of Water**

**Visualizing Alabama’s List of Impaired Waters.**

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**Abstract:**

Alabama’s climate and geographic history makes it one of the most ecologically diverse states in the United States. At the same time, a history of industrial accidents and abuse has led to disasters that have harmed everything from ponds to populations of cities to coastlines. Since 1998 stricter water monitoring policies have been mandated to attempt to control the human and environmental harm caused by pollutants. This project seeks to analyze the progress that has been made during the past 20 years of water quality testing. Data from the Alabama Department of Environmental Management (ADEM) is used to visualize the scope of water contamination in each river basin by size, cause, and source.

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**Personal anecdote:**

I spent most of my summers as a child escaping the hustle and bustle of New York City to a place known as Embry Bend road. Embry Bend sits just north of Lincoln Alabama and its name relates to the pattern of twists and turns the small dirt road takes as it shadows the Coosa River. This was a place where people seemed to live in order to distance themselves from society and embrace a more bucolic lifestyle. It was routine for me to arrive and be tasked with cleaning the modestly sized pool in the back of the house which often resembled more of an overgrown pond. Each summer I would open the pool shed, cautious of black widow spiders and other vibrant insects, turn on the motor, and begin the process of removing the algae, frogs, and fish from the pool. Unbeknownst to me as a child, this pool was a living example of the remarkable capabilities of Alabama wildlife; a window by which we can begin to comprehend the natural cycle of life that predates us as humans.

**Introduction:**

Millions of years ago, in a time now titled “The Ice Age”, the earth underwent a series of drastic geological and biological changes imposed by the formation of glaciers. Much of life as we know it was covered by thick sheets of ice that made survival impossible. Moving forward to the end of the ice age, a period about 10 to 18 thousand years ago, North America was primarily covered by the Pleistocene glacier. Fossil records indicate that many species were lost in this final freeze that reached all the way down to lower latitudes. While much of this part of the planet was tucked away in unhospitable ice, a region of North America now known as the state of Alabama survived and prospered (Raines, 2020). Located at a latitude of 30 degrees north, the upper border of Alabama contains deep valleys that progress southbound into meadows and forests. Temperatures remained stable in these areas and allowed for evolution to continue uninterrupted while the rest of the country was forced to restart the process thousands of years later. Ben Raines’ book “Saving America’s Amazon” serves as a major inspiration for this work. In it he reports that scientists at Archbold Biological Station believe the Red Hill region of the state represents a biological oasis with hundreds of unknown species. Many of these species have been continuing their life cycles unhindered by the environment around them. The result of this uninhibited growth is an incredibly diverse population of plants and animals. For example, Alabama contains more than one-third of all freshwater fish species in the United States, Canada, and Mexico. To put these numbers in perspective, we can compare Alabama’s 450 fish species to Colorado, a much larger state, which only has 55 species (Raines, 2020). Fossils dating back millions of years are continually discovered as well as types of salamanders that have been around way before humans walked the earth. As we come to appreciate these facts, we must also examine our human impact on the region and the relatively short, but troubling, history of industrial development that has stained “America’s Amazon”.

In more recent years, Alabama has been labeled as an extinction capital of the United States, with close to 130 species endangered or threatened species. What was once a bustling biological hotspot for species divergence has become an unfortunate example of the costs we pay for unabated industrial growth. Even more frustrating is the lengths that corporations have taken to undermine scientific and journalistic reporting on the subject matter. Raines notes in the preface to his book that he has witnessed the systematic dismantling of news sources in the state and has been spied on in his own home by the largest corporation in the world. The strategy to intimidate and de-platform journalists has created an uncomfortable situation where many of the environmental transgressions go unreported. Although it is easy to assign blame to the multi-billion-dollar companies because of their catastrophes of epic proportion, we must also realize that this pattern of abuse occurs at various levels throughout the state. Much of the quality testing has been relegated to underfunded state agencies or private enterprises whose motives are moved more by their bottom line than by ethical justice.

This project seeks to report on biodiversity and industrial impact and present it in a format that allows for easy comprehension of statewide patterns. Water is used as a unifying theme between these subjects since Alabama’s waters have been crucial for the record aquatic biodiversity in the region and have been impacted by industrial accidents. Water quality reports from the Alabama Department of Environmental Management are used to visualize the state’s progress for the past 20 years. While it is worth noting that the political atmosphere in the state has played a major part, this paper avoids accusations or discussion in the realm of politics. Simply put the goal is to present the data that has been buried in government reports and suppressed by corporate interests. I hope readers of this paper and viewers of the project will walk away with an understanding of the problem that nature faces in a state that is often overlooked and mistreated.

**Context and Goals:**

The goal of this project is to present the rich biodiversity of Alabama as well as the impact of industrial actions in the area. Water quality is the metric that is used for most comparisons because organisms rely on this to function and most industries produce aquatic contaminants. This paper will first outline the scope of biodiversity and its importance and then the industrial accidents within the state. Alabama department of environmental management 303(d) impaired water body data is introduced to draw a connection between the two. D3.js and Vue.js introduce modern visualization tools to data that has traditionally resided in portable document format (PDF) tables. Much of the analysis is done by aggregating data by major watershed. Sources and contaminants are assessed for each river basin region to create a general understanding of the threat that each of the areas may be under. The acquired data is from the past two decades of active monitoring so changes over time are of particular interest.

**Biodiversity and Endangered Species in Alabama**

In 1973 the Endangered Species Act was signed into law to protect critically imperiled species from extinction because of economic growth and development untampered by adequate concern and conservation (16 U.S.C.A. §§ 1531 et seq). Its purpose was to prevent extinctions and to help recover species to a point where they need not be protected by law. The U.S. Fish and Wildlife Service and National Marine Fisheries Service were given the responsibility of enforcement. In 2016 one of the nations most comprehensive species surveys was conducted in order to gather data regarding the prevalence of the species listed as protected under this law. The results of the survey reported that, within Alabama, there were 105 endangered and threatened animal species believed to occur in the state. In addition, there were 22 and endangered plant species for a grand total of 127 total endangerments (U.S. Fish and Wildlife, 2016). This ranked the state as number two within the continental united states with the state of California taking the trophy for first place at 305. It is worth noting that the landmass area of AL at 53,419 square miles is not even one-third the size of CA at 163,696 square miles. By comparison, CA is the third largest state while AL is the 28th largest state.

According to NatureServe’s States of the Union: Ranking America’s, AL ranked fifth in species diversity, fourth in species risk, and second in species extinctions Biodiversity (Stein, 2002). The report continues “The condition of nature in America reflects an interplay between natural history and human history. And it is the breadth and intensity of this interaction that tends to define a geography of risk for a wild species”. Habitat destruction and degradation are the leading threats to U.S. biodiversity. For this paper, the focus is on two main areas biodiversity which are impacted by aquatic habitat quality: Fish and Macroinvertebrates. Both measures serve as an entry point to our impact on the environment and the potential for human health concerns.

**Fish Inventory and Analysis**

Perhaps one of the best indicators of Alabama’s surprising biodiversity is the number of freshwater fish species. Sitting at 450, the state ranks higher than any other state or province in north America (Mettee, Maurice F. “Fishes of Alabama.”). Much of this diversity is a result of the temperate climate and large river networks throughout the state. Heavy rainfall and wetland areas are responsible for an average discharge of .94 million gallons of water per square mile, which is nearly greater than the Mississippi river basin and Columbia river basin combined (Raines, 2020). Furthermore, the regions history during the ice age of rising and lowering sea levels allowed numerous species to relocate to certain basins deep within the state. This tremendous fish diversity is integral to the aquatic environments they reside in, human food availability, and economic impact of commercial fishing. Changes in fish diversity often reflect changes in their environment and this has been the subject of several studies in the past couple decades. Scientists have tried to understand both changes in diversity patterns and how these might be used to understand micro and macro ecosystems.

“Man’s activities have had a profound, and usually negative, influence on freshwater fishes from the smallest streams to the largest rivers” wrote James R. Karr in 1981. His research at the time sought to distinguish measures of water quality and aquatic biota. Karr maintained that fish serve as the primary taxon for biological monitoring as opposed to algae and invertebrates for several reasons. They represent a variety of trophic levels, they have stable spawning rates, occupy diverse large-scale habitats, and have long life spans. Additionally, fish require little training to identify and can easily be captured and released. His research sought to answer the question of how researchers could take advantage of pre-existing population and community data to conduct future studies of ecosystem integrity.

Karr proposed a system of collecting fish community attributes to evaluate the quality of an ecosystem, not just chemical tests for its waters. This construct was called the index of biological integrity (IBI). The IBI was designed to include 12 measures in three categories: Species Composition, Trophic Composition, and Fish Abundance and Condition (Karr, 1986). Water bodies would be sampled for fish and compared to what might be expected from a similar geographic region. His rational for the method was that it preserved the data obtained during the labor-intensive collection phase and allowed for trends to be drawn from large sample areas over time (Karr, 1986). The IBI tool has been researched since its inception and become widely accepted as a means of defining the health of biotic systems and classifying pollution issues.

In 2004 the Geological Survey of America, Alabama Department of Environmental Management, Wildlife and Freshwaters Fisheries Division of the Alabama Department of Conservation and Natural Resources initiated an 8-year research plan to calibrate the IBI for the state of Alabama. The goal was to incorporate biological monitoring into chemical monitoring that existed. Five geographic regions comprising the entire state were sampled during the time period and species data was collected for each. Like previous research using the IBI model, this study found a IBI scores to be related to increased levels of watershed disturbance and habitat degradation. The results for the southern region of Alabama showed that 34 percent of sites were in the good to excellent IBI range, 35 percent were fair, and 31 percent were very poor to poor (Berry H. 2011). Nearly one third of these waterways were in a category indicating low biodiversity, higher proportions of tolerant species, and out of balance trophic levels.

Other research has tried to understand species shifts and declines in a larger context. These studies of species diversity change over time have been limited largely because of the long-time monitoring that is required at specific locations. In 2009 researchers at Auburn University conducted a longitudinal study of fish assemblages based on available data from 1970, and 1995, and 2005 (Johnston, C.E. and Maceina, M.J. 2009). The team sampled species from three streams in the Chattahoochee River drainage and found strong evidence for assemblage changes and species declines. They note that at all but one of their sampling sites saw assemblage shifts during the 35-year study period. When they looked at the species that had declined the data suggested that cosmopolitan species, those that are found universally, had replaced endemic, those confined to a specific geography, species. This was in support of a study conducted by Scott & Helfman in 2001 where the researchers found cosmopolitan and tolerant species replacing endemic species in the southern Appalachian mountain region.

Heavy metals in aquatic biota have also been of particular interest for researchers of aquatic conservation. Fish tissue sampling has become common for human health reasons and as a means of understanding species declines. It has been shown that these metals, biproducts of certain industries, can bioaccumulate and bio magnify in food chains (U.S. EPA, 2000). Fish that exist in contaminated waters slowly accumulate these particles through absorption in their gills and their growth, development, and survival is affected. The effects of these metals have been shown to cause disruption of the ecological balance of river waters in high concentrations (Afshan et al, 2014). The individual toxic effects of heavy metals such as mercury, lead, thallium, zinc, copper, and cadmium on fish populations has been well documented (Namakwa, 2019). In addition to the direct impact on these populations, anything further down the food chain inherits these metals that have bound to the flesh of the fish. Fish tissue sampling has become an important part of understanding water qualities and protecting ecosystems and human populations.

Research has also focused on physical impairments to aquatic ecosystems. Dams have played a large role in compromising aquatic biodiversity. In 2013 the World Wildlife Fund published a report titled “Seven Sins of Dam Building”. Coincidently, out of a global selection of dams, Alabama Power’s series of seven dams along the Coosa river is listed as a case study for the third sin: Neglecting Biodiversity. The damming of the river, beginning in 1914 with the Lay dam, is described as causing “one of the largest extinction rates in North America during the 20th century, with the extinction or extirpation of nearly 40 freshwater species” (WWF, 2013). Dams play a disruptive role in the migratory patterns of fish species that need to travel to spawning grounds. They are also guilty of fragmenting terrestrial connectivity and causing habitat loss by inundation (WWF, 2013).

Alabama power’s Coosa dams span 224 miles, and their effects are most easily seen in the example of the critically endangered Alabama sturgeon. The sturgeon feeds in the ocean and coastal deltas but embarks on a lengthy upstream journey each spawning season. Dams have blocked migratory paths of the Alabama sturgeon to the point that the fish have been documented ramming their noses into the walls of dams until they bleed and die (Raines, 2020). In 2000, the fish was listed as critically endangered thanks to lawsuits by environmental lawyer Ray Vaughan who expressed concern with the fact that state agencies believed habitat protection measures would curtail or halt the maintenance dredging that keeps barges from running aground (Vaughan, 1995). State opposition to the lawsuit raised the questioned that, if a fish is not commercially viable, why protect it?

**Macroinvertebrate sampling**

Macroinvertebrates have also become known as a solid indicator of water quality as well as overall ecosystem health and diversity. Benthic macroinvertebrates are small animals that live or lay eggs in the bottom of rivers and streams. Examples include snails, stonefly larvae, dragonflies, worms, beetles, and some moths. As their name would suggest, they lack a backbone and are large enough to be seen by the human eye. Presence of these organisms is essential to a functioning ecosystem because they consume organic matter such as algae which in turn keeps water oxygen levels safe for other organisms. They hold an important position in the food chain that links plants to larger invertebrate species such as fish.

Macroinvertebrate diversity is a good indicator of aquatic ecosystem health for a few reasons. First, they have a wide species range with varying ranges of pollution tolerance. Second, they are relatively easy to collect since populations are usually abundant. Third, they have limited mobility, so they are unable to escape from stressors in their environment. Finally, they have a lifespan typically of about 6 to 12 months which allows researchers to gather longitudinal data regarding a specific ecosystem. If the presence of macroinvertebrates disappears from one testing period to another there is usually reason for more investigation of the area for possible contaminants. Healthy aquatic conditions support a wider variety of taxa for both fish and macroinvertebrates.

**3. Industry**

Alabama’s recent economy has been fueled by its manufacturing industry which maintains a lead over any other sector (Statistica, 2021). Historically the economy was dominated by the agricultural sector. Prior to the abolition of slavery in the United States, cotton fields served as a key resource for the region. Moving into the 20th century coal and timber evolved to be the primary moving force of the economy. Manufacturing production picked up in the 20th century when the state welcomed one of the world’s most infamous agrochemical companies, Monsanto. The industrial surge was boosted further during WWII as chemical and aviation plants opened. Many of these plants were powered by an increasing number of hydraulic dams such as the Lay dam. Manufacturing continued to be largest sector of the economy when a major U.S. automotive boom occurred in the 1990s. Since then, several companies such as Honda, Hyundai, Toyota, Mazda, and Mercedes-Benz have established large production facilities in the state.

**Monsanto DDT and PCBs:**

Unfortunately, a booming business climate has brought with it a grim history of environmental disasters. Perhaps the most notorious was the 1929 to 1971 Monsanto polychlorinated biphenyls (PCBs) plant located in Anniston Alabama (Anniston Community Health Survey, 2015). The company become the city’s largest employer by producing these toxic chemicals. PCBs were pervasive throughout the 20th century as a class of chemicals that usually took the form of insulated materials. Other uses included: fireproofing, paint, ink, varnishes, and chewing gum (Swann Use Codes, 1935).

DDT was made in abundance for several years to create a host of products ranging from everyday insecticides to Agent Orange, a chemical used by the U.S. military to clear foliage during the Vietnam War. The chemical came into the spotlight in part due to Rachel Carson’s “Silent Spring”, a publication outlining the adverse effects of DDT. While considered controversial at the time, this prompted research on the chemical. Eventually in 1972 the EPA, formerly U.S. department of agriculture, issued a ban on the use of DDT because of its detrimental effects to the environment and humans (EPA, 1972). Around the same time Monsanto stopped producing PCBs and sold their plant to another company.

Years after the plant moved, the residents of Aniston, primarily an African American, began experiencing severe health complications. Cognitive issues, cancers, and lung issues in the city became the center of scientific attention. As it turns out, Monsanto’s factories had been dumping their waste PCBs into the river unnoticed for four decades and the presence of the material had been poisoning people on unheard of scale. Residents of the city were experiencing the side effects of years of PCB contamination in the air, water, and food supply (Markowitz, 2018). In 1979 the production of PCBs was banned due to research suggesting them to be highly toxic. To make matters worse the chemicals do not break down in the environment which means cleanup operations must be physical (removal of contaminated sediment) and laborious.

PCB contamination exists as a remnant from a specific period of history but lawsuits involving Monsanto’s role in this environmental hazard continue into the present. In 2001 and 2003, the company settled lawsuits relating to their role in the problem and paid $700 million in clean up and relief fees (The New York Times, 2003). In 2020, Monsanto was again forced to pay to resolve a lawsuit involving the sale of PCBs despite having knowledge that the chemicals were toxic to humans and wildlife (The District of Columbia v. Monsanto Co., Solutia, INC, 2020). Cleanup of Anniston remains in effect to this day and water quality testing is done for residual PCBs.

**Alabama Power Plant Barry Coal Ash:**

Alabama Power’s dams have been subject to criticism in the past but recent activism has focused on the heavy metal contamination caused by their coal power plants. Locations such as the Barry Power Plant have come under increasing scrutiny for having, among other things, 800% the legal limit of arsenic in the surrounding groundwater (Alabama Power, 2018). This is largely due to the presence of on-site coal ash pits containing 21 million tons of toxic material. Coal ash is a byproduct of burning coal for power and is mainly comprised of mercury, chromium, arsenic, and lead.

At the Barry Power Plant, coal ash is stored in an unlined pit surrounded on three sides by parts of the Mobile River. During flood seasons or hurricanes, parts of the river can come within feet of the toxic stores, but spills are not the only concern. Since the pit is unlined, the metals can slowly travel through the soil to reach nearby waters. Alabama Power has recently opted to invest billions of dollars into cleanup and remedy efforts, but critics say they are failing to address the issue (Pillion, 2020). The company’s cleanup method would focus on a cap-in-place draining the coal ponds of water and then covering them with a waterproof liner. The Mobile Baykeeper organization writes that this waste should instead be recycled or moved upland into lined landfills. Customers of Alabama Power have already begun to see price hikes in their electricity bills to cover the cap-in place strategy even though its success remains heavily disputed by more than 35 water and wildlife organizations and the lead coal fired Electric Utility Trade Association (Mobile Baykeeper, 2019).

**Food Processing Plants and E. coli:**

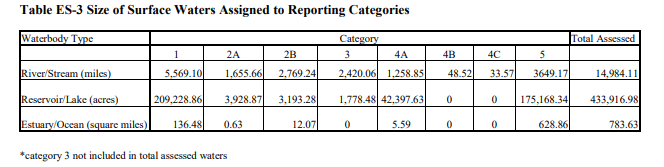
Other disasters have involved more organic contaminants. In 2011 a food processing facility operated by American Proteins Inc accidentally released 1.6 million gallons of wastewater into the Mulberry Fork river of the Black Warrior river basin (Sack, 2016). In 2016 the facility released 900 gallons of acid which resulted in the deaths of an estimated 40,000 fish. By 2019, under new management by Tyson Farms, the same facility released another 220,000 gallons of anaerobic wastewater into the Mulberry Fork killing 175,000 fish. In a letter to the residents of Hanceville and the surrounding areas, senior vice president of Tyson explains that the fish deaths were the result of oxygen level decreases and not man-made chemicals (Parks, 2019). ADEM monitored the area for 5 days following the spill and found e. coli levels over 30 times the state level considered safe for swimming and contact (Black Warrior Riverkeeper, 2020).

In 2020 the Alabama Attorney General sued Tyson Farms on behalf of ADEM for the alleged “unpermitted discharges of wastewater and/or partially treated wastewater” that caused “depressed levels of dissolved oxygen and elevated levels of pathogens” (The State of Alabama v. Tyson Farms, Inc, 2020). The complaint claims that the company engaged in “negligent and wanton conduct by causing a public nuisance, committing a trespass to State land, and by committing a trespass to chattel, resulting in the death of various species of fish and wildlife.”

**Water Quality**

In 1948 the Federal Water Pollution Control Act was enacted. After the creation of the Environmental Protection Agency in 1970, the act was expanded in 1972 with several amendments and titled the Clean Water Act (33 U.S.C. §1251 et seq.1972). By 1982 the state of Alabama established the Alabama Environmental Management Commission and Alabama Department of Environment Management (ADEM). The agencies mission statement is to assure for all citizens of the State a safe, healthful, and productive environment. ADEM is responsible for administering all federal environmental laws including, but not limited to, the Clean Water and Safe Drinking Water acts. In 1998 the state began conducting biennial water quality reports which would be submitted to the United States Environmental Protection Agency.

State waters in these reports are divided into unique waterbodies using the high-resolution National Hydrography Dataset and assigned a unique assessment unit ID. These waterbodies are then classified into five categories which indicate their status. Category 1 refers to any water that is maintaining applicable water quality standards. Category 2 contains waters where readily available data meets the State’s requirements however there is insufficient data to conclude that all quality standards are met. Generally, these waters become subject for increased monitoring and data collection. Category 3 waters do not have any data or information necessary to make an assessment. Categories 4a, 4b, and 4c include waters where standards are not met but there is no required establishment of Total Maximum Daily Loads for pollutants. In the case of 4b, this may mean that other control mechanism for pollutants need to be researched or are necessary. For 4c waters the impairment is not caused by a man-made pollutant defined in section 502(6) of the Clean Water Act: spoil, solid waste, incinerator residue, sewerage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked equipment, rock, sand, cellar dirt, and industrial/ municipal, agricultural waste”. This may include natural pollutants including, but not limited to, invasive species of plants and animals. The fifth and final category is where waters that have been impaired by an identified pollutant are placed. Categories four and five are of particular interest for this report as they are the most compromised and are listed on what is known as the 303(d) list. As of 2020, a summary of the Size of surface waters assigned to these categories can be seen in the table below which is taken from the most recent ADEM report (ADEM, 2020).



**The 303(d) list:**

Section 303(d) of the Clean Water Act requires that each state identify those waters that do not currently support designated uses. Each waterbody in the state has its chemical, physical, and biological data measured in order to produce a comprehensive assessment. The methodology for this can be found at: <http://www.adem.alabama.gov/programs/water/wquality/2018WAM.pdf>. The 303(d) list contains the following information: waterbody name, county, cause of impairment, source of pollutant, size of impaired segment, and location of waterbody. For this paper, the information is grouped according to the 16 major watersheds (table 2) that exist in Alabama. The biennial reports highlight new waterbodies that are added each year as well as corrections to causes and sources.

**River and Stream Monitoring Program:**

It is evident that there has been an increase in concern for aquatic ecosystems within Alabama but the degree to which it has helped the historically unfortunate situation remains unknown. From 2005 to 2016 the ADEM published annual River and Stream Monitoring summaries. Each year several watersheds are selected for enhanced sampling. The objectives of the project were to assess biological integrity of monitoring sites and estimate overall water quality within each river basin. Monthly water chemistry data is collected for these sites and overall habitat assessments are made. These assessments include percentage scores for Instream Habitat Quality, Sediment Deposition, Sinuosity, Bank and Vegetative Stability, and Riparian Buffer. The scores are averaged and then classified based on habitat condition compared to least impaired waters in the ecoregion.

These reports also include ADEMs Multi-habitat Bioassessment methodology (WMB-I) to sample macroinvertebrate communities. Measures include taxonomic richness, community composition, and community tolerance to assess the health of the macroinvertebrate community. These metrics are rated from 0-100 and then averaged together to judge the condition of the community. Aided by macroinvertebrate and fish bioassessment data, as well as non-point source water monitoring, Alabama has set in motion an effort to document the states impaired waters.

**Data:**

**Alabama Department of Environmental Management – Water Quality Reports**

The ADEM conducts a biennial water quality survey which is published publicly online in a PDF report. Reports for the past 20 years, beginning 2000, were downloaded. Water quality tables for the 303(d) list of affected waters were extracted from PDF to CSV. CSV tables were manually checked for formatting. Individual reports were aggregated to create a single file with a new ‘ReportYear’ column using Microsoft Excel. The CSV file was loaded into D3, a JavaScript based data visualization library. The file contains the following columns: AssessmentUnitID, WaterbodyName, Type, RiverBasin, County, Uses, Causes, Sources, Size, UnitType, DownstreamUpstreamLocations, YearListed, and Priority.

Example row: *“ AL03150201-0104-302,Three Mile Branch,R,Alabama,Montgomery,Fish & Wildlife,Pathogens (E. coli),Urban development,7.65,miles,"Lower Wetumpka Road /its source",2010,L ”*

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**Visualization methods and design decisions.**

The final project makes use of Vue CLI to deliver a single page web application. The webpage is designed to follow a narrative that summarizes the topics discussed in this paper and provides rationale for the visualizations. Viewers are introduced to the surprising biodiversity at the start, then presented a brief history of industrial accidents that have compromised aquatic environments, and finally shown a summary of water quality data from the 303(d) initiative. There are roughly 7 sections outlined as follows:

1. 20 Years of Water.
2. A lush habitat
3. A troubling history
4. The river basins of Alabama
5. First Visualization: The Size of the problem
6. Second Visualization: Sources and Causes of Impairment
7. The Riverkeepers

**1. 20 Years of Water.**

The title frame has an important role of setting the scene for the narrative. Since the glacial history of Alabama is relevant to the biodiversity the state experiences today, an image of mountains with snowcapped tips melting down into water is used for the background. A white SVG wave is placed at the bottom of this image, near the water, to introduce the theme of moving water. The white wave, in conjunction with the white app background, creates the allusion of water that has just dripped. The setup for dripping water is relevant to the history of melting glaciers that has impacted Alabama’s biodiversity and is used later as a means of progressing time through scrolling.

**2. A Lush Habitat.**

In the next section, an ariel photo of the Black Warrior river taken by river keeper Nelson Brooke is used to show the lush habitat present today. Text is used to briefly outline the history of the region and present a fact about the species of fish found in Alabama. A white drop of water is used as a device to connect the first ‘ancient history’ section to the second section ‘present day’ section.

**3. A Troubling History.**

The third section introduces three industrial actions that have compromised the waters of Alabama: Lay dam construction, Monsanto’s PCB factory, and Alabama power coal ash pits. Each of these micro stories have a key image that is placed within the bounds of a water droplet shape. They are arranged in chronological order from left to right. The image droplets are used to allude to the fact that the water that has melted down from the glaciers has also been influenced by these events.

**4. The River Basins of Alabama.**

The final history and context segment includes references to the data that will be used for the visualizations that follow. A blue and green gradient wave is used as a background image here to represent a river. All the falling droplets above this segment are meant to collect here in the present river basins of Alabama. A map of these basins is shown to introduce the geographic organization of the state waters.

**5. First Visualization: The Size of the Problem.**

In the first visualization, water bodies are grouped by major river basin region and the total size of impairment is calculated for each. The information present here is the total length of impaired waters for each basin, the percentage contribution to this total for each cause of impairment, and the rough location of each basin. The total value number is calculated by summing all the values of the causes of impairment. A problem with this method is that some locations contained more than one cause of impairment, leading to duplications in the number of contaminated miles for a particular water body. A JavaScript function was written to sum the total impaired miles by “unique unit ID” however this eliminated cases where the different mileages were reported for different causes at the same unit ID. Ultimately a decision was made to use the original calculations because they were truthful about the individual measurements of the causes. Additionally, there are no comparisons to a total number of possible river miles, so this value does not inflate any ratios. This will likely be an area to return to for additional consideration.

The shape of the visualization takes on the form of an abstracted horizontal bar chart with each river basin being represented by a different set of bars. The rivers are arranged with inline-block positioning so that after a certain length two rivers could fit on the same screen y-space. This was done to condense the overall size of the visualization and help aid with the comparison of two regions. The length of each river basin section is scaled to the sum of impaired water bodies within that basin. The shape of each river basin segment is determined by two wave-like SVG’s on the top and bottom of each segment. The top SVG is animated as to further pursue the device of moving water. These SVGs abstract away the horizontal bar chart nature of this visualization and create forms that are more consistent with the themes of water and rivers.

Colored rectangles populate the region between the top and bottom curved SVG shapes. This is meant to create the appearance of a river being made up of several parts. These parts, or bars, are representative of the causes of impairment for each region. The bars sum to 100% of the total impairment and are sized according to the contribution of each impairment. Each cause of impairment is colored according to four color groups: Greens for organics, Reds for metals, Purples for complex chemicals, and oranges for terrestrial causes. A modal legend of these causes is placed on the right side of the screen. Hover functionality is present on both the central river visualizations and the modal. A user may hover over a cause on the legend to make a warning sign appear next to any river basin where this cause is located. This helps understand the scope of each cause on a statewide level and can help identify the presence of causes over time.

Time, an important piece of this project, is controlled by users through the buttons found on the left side modal. The primary content of this modal is a collection of SVG paths that make up the state of Alabama. Each path is the outline of a major river basin. They are filled according to a white to blue to black gradient, with darker colors indicating regions that rank higher in the total number of impaired miles for the central visualization. It is important to note that this is an intentional generalization of the geographic locations for these basins. By using rough geographic boundaries, the project can more easily identify statewide patterns. These boundaries also provide unfamiliar users an easy way of referencing an otherwise complicated set of names and coordinates.

**6. Second Visualization: Causes and Sources of Impairment.**

The second visualization is intended to be aesthetically different than the rest of the wave-like forms found earlier in the webpage. A rigid grid layout with a left side panel is used to create the abstract form of a factory. An SVG cartoon image of factories is placed at the top of the left section to symbolize smoke and guide viewers towards this aesthetic shift.

A small multiple of bar charts is used to visualize the causes and sources of impairment seen in the first visualization. This section provides the raw number values for the lengths of impairments found in the first visualization and is a more traditional representation of the data. Small multiples are used to for quick comparisons between basins and to consolidate information. One of the goals for this project was to condense 16 regions, and 20 years of data, into a single view window and small multiples proved to be an effective tool. The unfortunate side effect of this organization was small axis label text. A hover tooltip was created as a quick, incomplete, solution to the problem. The visualizations were tested with no axis labels however the visuals in this situation seemed to be missing something. Axis label text and the hover tooltip are areas to be revisited for visual clarity.

Hovering over a bar activates the left side component containing all the sources of the hovered cause. Some examples of sources in the data include: Agricultural, Municipal, Industrial, Urban Runoff/storm sewers, and surface mining – abandoned. The list of sources is stacked on top of each other, and the size of each box is scaled according to size impairment from each source. The boxes for the side panel are scaled so that they are representative of the height of the small multiple bar that is selected.

Source names were complicated to deal with and a large part of this was due to the nature of the data and its collection. Since the 303(d) lists are complied from non-point source testing data, its difficult to match an exact source to a particular cause. Sources are often listed as a combination of multiple factors like Agriculture and Municipal. Additionally, this data column seemed to contain the most misspellings, missing punctuation, and lack of standardization among testing years. This was partially rectified during the data cleaning stage of the project however there are still cases where misspellings and spacings separate values that should otherwise be grouped together. A decision was made to leave the sources grouped together as they appear in the data to avoid making inaccurate assumptions. For example, with non-point source testing it is impossible to say what portion of “7 miles of mercury” with the source “Agriculture/Municipal” is agriculture versus municipal.

**7. The Riverkeepers**

The final section of the webpage offers additional information regarding the Riverkeeper organizations that study and monitor the waters of Alabama. Since most of this project establishes the presence of impaired waters, it is necessary to offer informational resources to learn more about what is being done to protect them. The Riverkeepers often run their own, more detailed studies, to keep check on the results presented by ADEM. In many cases these organizations have filed lawsuits against the ADEM and the EPA to maintain transparency and accountability (Black Warrior Riverkeeper, Inc v. Alabama Department of Environmental Management and Shepherd Bend LLC, 2008). Since this project has relied on ADEM reporting it is subject to any errors and biases reported by the state government. For example, in 2019 the Black Warrior Riverkeepers sued the EPA to maintain two waterbodies on the 303(d) list that had be removed by ADEM without proper evidence of applicable water quality standards (Black Warrior Riverkeeper, Inc v. U.S. Environmental Protection Agency, 2019). In a public memo, Black Warrior Riverkeepers’ leader and spokesperson writes “It is a shame that the state of Alabama ignores pollution problems just so a few polluters can make more money” (Brooke, 2019).

**Conclusion**

This goal of this project was to highlight the threat to our nations biodiversity by exploring state reported water quality. A large part of the visualizations involved the aggregation of data sources from different report years, a process that revealed the complexities of this kind of work. Inconsistencies in reporting of causes and sources were found in the 303(d) data. When the data was originally compiled there were over 150 listed causes of impairment. This was due to a mix of scientific nomenclature and everyday language, misspellings, and unique unclear listings (ex: ‘color’ listed as a cause of impairment). This list of 150 was ultimately consolidated to 44 unique causes however further research on the chemicals that appeared might allow for further organization. It should be noted that inconsistencies emerged because of different river basin reasons seeming to have different listing methodologies. The same complications arose when analyzing the sources of contamination. While these problems lead to complications with the data cleaning process, they should not affect the overall validity of the project. If we want to use this type of data to spread information and inform public opinion, proper standardization of collection and data entry would be beneficial.

The visualizations themselves could benefit from additional national and statewide context. Working with 303(d) only gives attention to the most critically threatened waterways. In the future it would be helpful to incorporate more statewide water data to compare impaired waters to non-impaired waters. Furthermore, it would be interesting to include the geographic locations of the sites that are used to collect data reported in the 303(d) lists. This might, however, transform the project to target a more specific and informed audience. The project could also benefit from a more detailed statistical analysis. Regression models of changes over time for specific causes in each river basin would help indicate general trends for the regions and highlight specific threats that each may be affected by.

Overall, this project is successful in accomplishing its goals of visualizing Alabama’s history of impaired waters on a statewide level. I hope that this work will provide people with both an overview of the problem and a curiosity for learning more about the region. A history of environmental abuse plagues the state and knowledge of this is critical for protecting it in the future. If we remember that Alabama is home to an impressively diverse population of plants, fish, and animals, we can begin to take steps to make sure they are not forgotten moving into the 21st century.

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Table 1: Example 303(d) PDF Report:

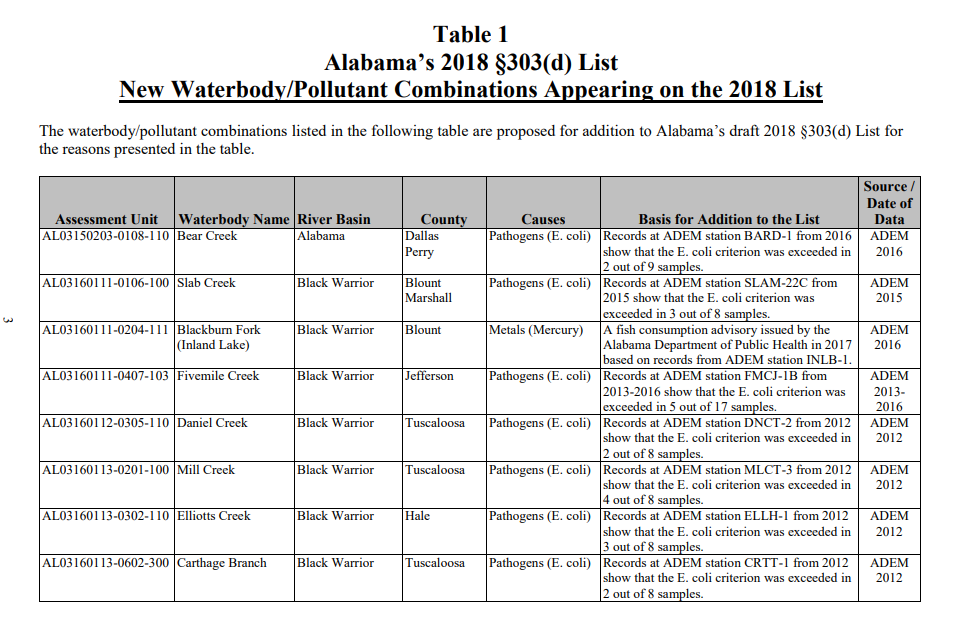


Table 2: River Basins of Alabama:

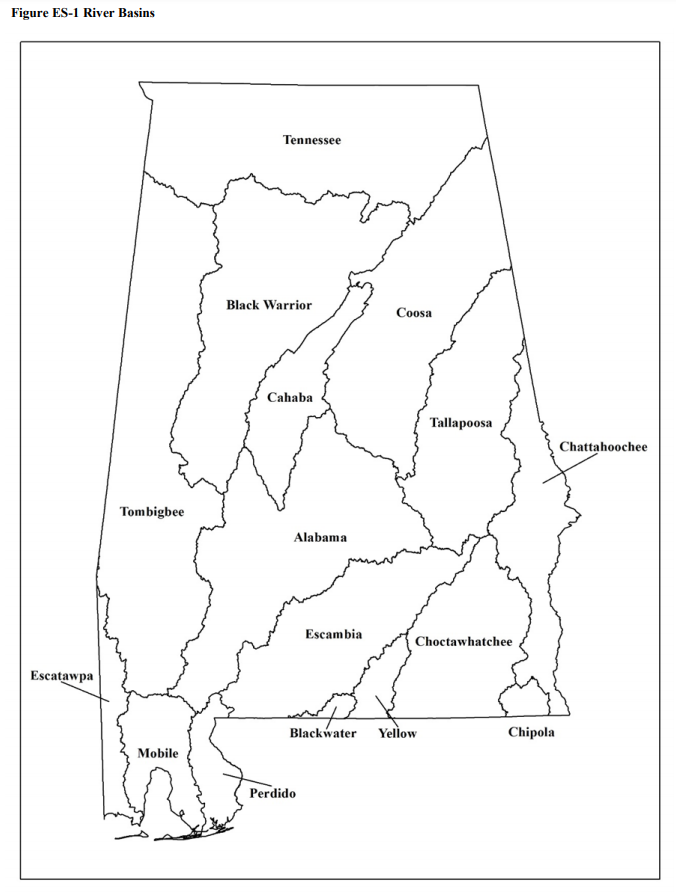
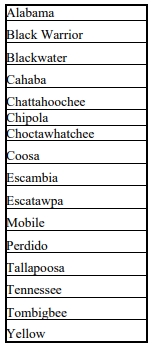


Table 3: Example water quality data provided by ADEM

