MEADOW CREEK WATER QUALITY MANAGEMENT PLAN

THE SCARS OF INDUSTRY: A LOOK INTO THE WATER CRISIS OF THE NAVAJO NATION

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By
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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Technical progress made through industrialization and urban expansion within the United States has come at a very high environmental cost. The spread of cities has drastically changed the hydrologic landscape thereby increasing stormwater runoff. This increase in water quantity has led to the degradation of many streams through erosion and increased pollutant loads. Additionally, hazardous industrial practices leading up to the 21st century, such as uranium mining, have had lasting impacts on the quality of water in many areas. This is a threat to both the environment and communities who rely on these polluted sources for drinking water.

From 2012 to 2013, one of the largest urban stream restoration projects in the United States was completed on Meadow Creek (City of Charlottesville, 2013). While many stream restoration projects are beneficial for an initial period of time, a large majority of these projects have proven ineffective long term. Currently, there are three main methods for stream restoration: restoration of channel morphology, restoration of ecological function, and restoration beyond the channel (Palmer, Hondula, & Koch, 2014, p. 249-253). Most projects have restored the design of the channel itself, such as reshaping it with boulders or wood to hold more water. This method does not address the source of the excess stormwater reaching the stream, often leading to its ultimate failure. In order to ensure the long-term restoration of a stream, best management practices must be implemented at the source of urban runoff. Another concern with the United States' water is groundwater contamination. The Navajo Nation is experiencing a water crisis due to the uranium pollution of groundwater from improper management of abandoned mines. Within the Navajo Nation today, there are at least 1,000 abandoned mines, exposing many communities to hazardous pollutants such as uranium and arsenic (Panikkar & Brugge, 2007, p. 122). These two water-related concerns need to be addressed. This technical research and loosely coupled STS research look to provide greater understanding of the social,

economic, and hydrologic factors that affect water quality management within the United States, and provide a framework for how to go about addressing them.

MEADOW CREEK WATER QUALITY MANAGEMENT PLAN

Based on data provided by the City of Charlottesville, Meadow Creek receives water from the northern half of Charlottesville, which composes a 5,800 acre drainage basin. Stormwater runoff comes from a variety of sources, including neighborhoods, schools, and shopping centers along U.S. Route 29. Prior to stream restoration in 2012, Meadow Creek was listed as an "impaired waterway" by the Virginia Department of Environmental Quality, mostly due to excessive sedimentation from stream bank erosion (City of Charlottesville, 2013). The restoration effort focused upon 9,000 linear feet of Meadow Creek, which extended from Hydraulic Road to Greenbrier Park, and was a collaborative project completed by the City of Charlottesville, Rivanna Water and Sewer Authority (RWSA), and The Nature Conservancy, funded by the Virginia Aquatic Resources Trust Fund. The restoration involved the realignment of the stream channel, the addition of meanders and in-stream habitat structures, removing invasive species, and enhancing the riparian buffer by planting native plants and trees. To ensure the protection of this work, construction easements were put in place along the area (City of Charlottesville, 2013).

Since uncontrolled stormwater runoff is a major source of river degradation, this runoff most likely heavily contributed to the excessive sedimentation that impaired Meadow Creek (Palmer et. al, 2014, p. 253). On top of this, nonpoint source water quality degradation in rivers and receiving bodies is a major issue in urban systems throughout the United States (Gallo et. al, 2020, p. 1). Increased pollutant loads and percent imperviousness vary in relation to land use. Watershed land uses with a higher imperviousness tend to contribute more to water quality

degradation (Gallo et. al, 2020, p. 1). The land use data for the City of Charlottesville is shown in Figure 1 below. A large percentage of the city is composed of developed land of high and medium level intensity. These highly impervious surfaces lead to a larger volume of water

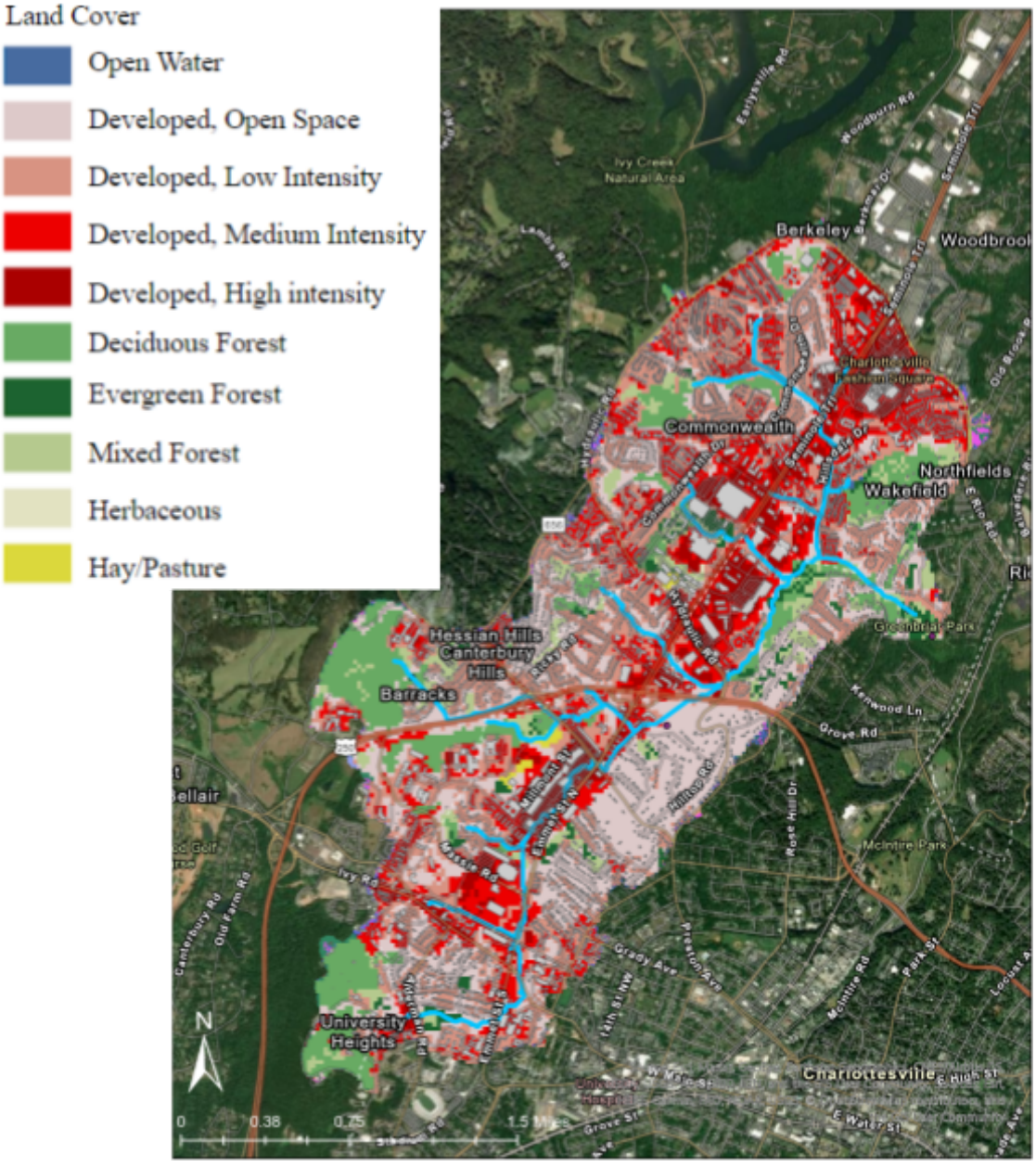

Figure 1: Current Charlottesville Land Use. This figure displays a map of the city of Charlottesville with a corresponding land use layer. Charlottesville contains large quantities of developed areas that have impervious surfaces. (Stephens, 2020).

being carried away as runoff. This increases the concentration of deposited pollutants carried to streams.

Under the guidance of Environmental and Water Resources Engineer Teresa Culver, Environmental Systems and the Environment Ph.D candidate Robert Herbst, Water Resources Engineer Don Rissmeyer, and postdoctoral research associate Kazi Tamaddun, Civil Engineers Emma Stephens, Zavier Richards, Lindsey Stegenga, and I will be conducting a multi-objective watershed analysis, where the objectives are to assess stream ecology, determine environmental impacts of the stream restoration, identify local stormwater hotspots, and propose an equitable green infrastructure plan. The Meadow Creek Capstone Project aims to address the negative environmental impacts of previous and existing development while accounting for the perceived negative impacts of future development, including degradation of water quality and the associated stream ecosystem. Furthermore, the project will expand beyond promoting the well-established technology of green infrastructure by incorporating key socioeconomic issues of green infrastructure implementation, such as the lack of incorporation of disadvantaged communities in planning and the relationship between public and private entities.

SOCIO-ECONOMIC CONSIDERATIONS

Oftentimes, green infrastructure projects are implemented to maximize environmental benefits with minimal regard for the social benefits and who could benefit from these projects the most - particularly disadvantaged communities. Studies have been conducted in Philadelphia related to the inequitable distribution of green infrastructure. The city has mandated the implementation of green infrastructure projects for private developers but this mandate does not influence where the projects are built. The authors state that “strategic public sector investment is

needed to establish a more equitable distribution," (Mandarano & Meenar, 2017, p. 1348). It is crucial that we consider the social aspects when choosing locations for these technologies because private-sector companies most often will not. Additionally, one of the primary challenges with supporting Philadelphia's 3,000-mile pipe network with green infrastructure is building the municipal, commercial, and residential partnerships necessary to make a new system work. From the planning stage through the construction and maintenance stage, these projects require coordination among schools, businesses, nonprofits, politicians, residents, developers, and landowners in order to avoid overflows (Sellers, 2020). In framing the problem and its solution, communication is key. One of the missing links identified in the project network is communication between the designers and low-income neighborhoods. This has led to slower acceptance of free rain barrels and planters (Sellers, 2020). Education and advocacy in these areas are key in ensuring the success of the overall project.

MEADOW CREEK DATA ANALYSIS AND MODELING

A large portion of this project is related to data analysis and modeling. To assess stream ecology, students will be participating in field work. This field work will primarily include downloading data from sensors at stations along Meadow Creek and obtaining data through water testing. This data will then be used to determine the current health of the stream. Additionally, students will be identifying stormwater hotspots throughout the watershed. The location of these hotspots provide potential sites for the implementation of best management practices (BMPs) to manage stormwater and pollutant loads entering Meadow Creek. Another important aspect of BMP selection will be the use of ArcGIS to determine land use, population data, slopes, and other information related to our study area. Data from this software will aid in developing a multi-criteria BMP selection procedure. Based on a similar study conducted by

Young et al. (2010), the criteria we have chosen to select a BMP will be contributing drainage area, impervious percentage, aesthetic benefit, safety and nuisance liability, implementation cost, annual operation and maintenance cost, peak runoff rate reduction, relative total suspended solids (TSS) removal, and relative total phosphorus (TP) removal (p. 58). Similarly, SWMM-CAT will be utilized to determine future climate and land use impacts to the watershed. Based on these results, a best management plan will be developed for the Meadow Creek watershed to meet the ecological, hydrologic and hydraulic, social, and economic objectives outlined by the team. Along with this plan, the team will identify avenues for potential funding and develop a funding proposal by quantifying social and economic benefits and ecosystem services. Currently, we are planning to write a technical proposal for a BMP implementation plan for the City of Charlottesville by the conclusion of this project.

THE SCARS OF INDUSTRY: A LOOK INTO THE NAVAJO NATION WATER CRISIS

Water quality and quantity are a large concern within the Navajo Nation in the American Southwest. The water sources within these tribal communities have been vulnerable to arsenic and uranium contamination due to the geologic characteristics of the region, lack of proper infrastructure and regulation, low socioeconomic status of the Navajos, and the region's previous involvement in the uranium mining industry (Credo et al., 2019, p. 7). The soil composition in the American Southwest contains sandstone and limestone bedrock with iron-oxide and iron-sulfide minerals along with an abundance of uranium. For this reason from 1944 to 1986 the Navajo Nation was the largest producer of domestic uranium ore in the United States for use in nuclear weaponry (Credo et al., 2019, p. 1). Despite the passage of the Comprehensive Environmental Response, Compensation, and Liability Act in 1980, which addresses sites highly contaminated by hazardous materials, uranium mines in these areas have remained largely

untouched. The exposed surfaces of the mine come in contact with rainwater, causing them to infiltrate into groundwater sources. To make matters worse, 30% of Navajo people get their drinking water from unregulated sources, as they are often the closest (Credo et al., 2019, p. 7). These two issues could in part be because the Navajo are a sovereign nation. Past plans to try to address this water crisis have proven ineffective, and research of the area is scarce. While the extent of health threats from these mining practices on these communities is still largely unknown, numerous studies have linked uranium mining to kidney diseases (Panikkar & Brugge, 2007, p. 138). This radioactive contamination can also lead to pancreatic, bladder, reproductive organ cancers, and can even be deadly (Tsosie, 2015, p. 220). This is especially an issue for the Navajo people, as close familial ties to the land and cultural significance of the earth keep them from leaving these dangerous conditions. On top of this, typical water use practices such as the construction of dams have been destructive to the ecological functions of rivers that these people rely on, making it a very controversial topic today (Groenfeldt, 2019, p. 15). In response to this, the main research question that I aim to answer over the course of this project is: how can we combine the traditional ecological knowledge of the Indigenous Peoples with more modern water treatment technology?

There are several water resources challenges that this research question encompasses. The challenges that I will be addressing in my STS research paper include the pitfalls of previous restoration efforts, tribal water rights, lack of access to water, the effects of excessive use of water on water quantities on the reservation, water contamination from mining and other human activities, and how climate change and drought will amplify these existing water challenges. Chief et al. (2016) emphasize in their research that the integration of Western and indigenous sciences in a way that is beneficial to both of their knowledge systems is crucial to water

resource management (p. 1). In recent history, tribal water rights have been circumvented by the United States government through a variety of tactics. An example of this can be seen in the early justification of uranium mining. The United States government claimed that uranium mining was crucial to maintaining national security during wartime. As a result, certain information about the mines was kept classified, and the federal government maintained sovereignty over this land use (Tsosie, 2015, p. 213). The core problems related to the Navajo Nation water crisis are outlined in Figure 2 below. My analysis of this topic will require me to gain a greater understanding of the severity of contaminated groundwater sources, lack of water infrastructure in the Southwest, the disregard of cultural significance of water and land in previous design, and the extent of tribal water rights.

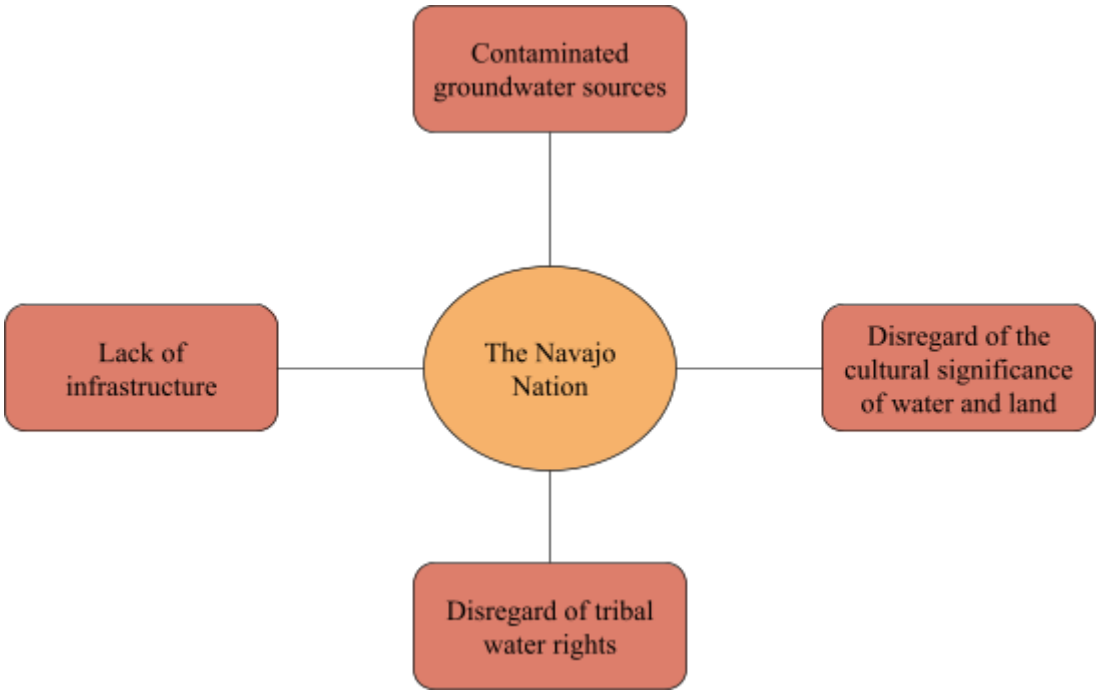

Figure 2: Indigenous Water Resources: This figure displays the Navajo Nation as a core social group and this community's close relationship to several key water resource problems. (Adapted by Caroline Marquis (2020) from Carlson 2009)

Actor-Network Theory developed in 1986 by Bruno Latour, Michael Callon, and John Law has many applications in the development of a successful water resource management plan for the Navajo Nation Water Crisis. As shown in the Figure 3 on the following page, there are four primary actors: uranium mining, the US government, the Navajo Nation, and engineers/researchers. The booming industry of uranium mining in the latter half of the 20th century exposed dangerous pollutants within the soil to the elements, resulting in infiltration and contamination of groundwater sources. Additionally, unregulated water sources throughout Arizona and Utah are outside of the boundaries for management by both the Arizona Department of Water Resources and the Navajo Nation Department of Water Resources (Credo et al., 2019, p. 3). Both US and Navajo governmental agencies must interact to address issues such as these. Engineers and researchers continue to study this region and can provide important data and technical perspectives on addressing this water resource problem. Climate change is an externality, or a factor that is influencing this water crisis outside of the original scope of the issue. Analysis of summertime droughts from 1901 to 2010 utilizing the Palmer Drought Severity Index (PDSI) reveals that 2001 to 2010 produced the second largest area affected by drought (Nania et al., 2014, p. 43). This occurrence of drought could result from increased temperature. As these droughts persist, they can result in decreases in streamflow, deficits in soil moisture, and lowering of groundwater tables, thus accentuating this water scarcity further.

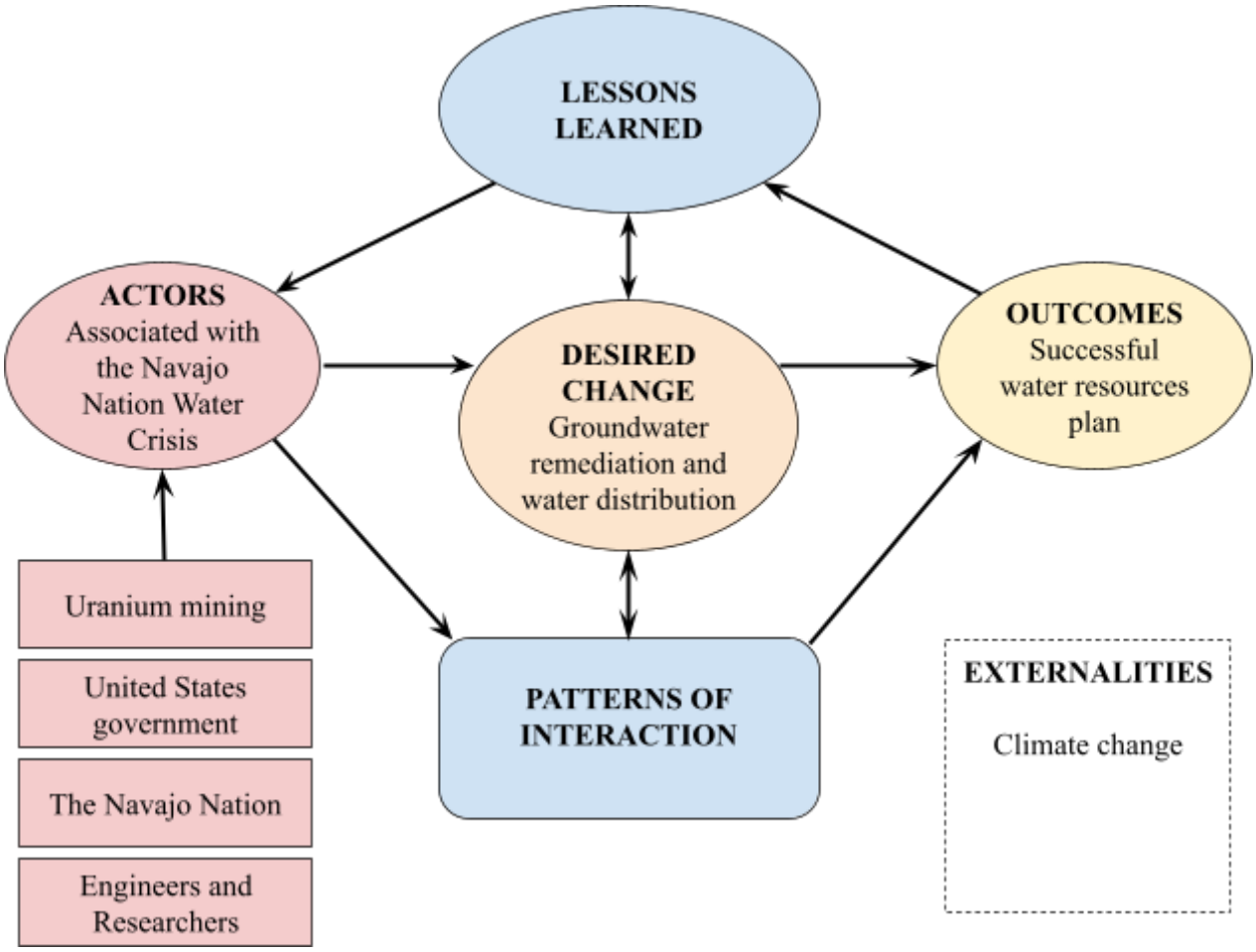

Figure 3: Application of Actor-Network Theory in Navajo Nation Water Crisis: This figure displays that in order to accomplish a successful water resources plan, all actors involved with the design challenge must interact and learn from one another. (Adapted by Caroline Marquis (2020) from Sellamuttu, de Silva, Khoa, & Samarakoon 2008)

The STS portion of this thesis will be a scholarly article that provides an analysis of water quality and quantity measures through an environmental and social justice perspective, forming a judgement through this perspective, and making recommendations based on that judgement. To draft this article, research will be conducted into specific case studies of water projects within the Navajo Nation. Insights will be drawn from the failures and successes of these projects and

combined with personal socio-technical expertise applicable to the issue to complete a well-informed analysis and recommendation for an engineering solution.

MOVING TOWARDS BETTER WATER RESOURCES PRACTICES

Urbanization and industrialization have led to many environmental and socioeconomic problems around water quality and quantity. Engineering solutions of the past have often not fully addressed these problems. This technical research and loosely coupled STS research both aim to explore these design problems and develop more effective design solutions. While the latter focuses more on water quality, the former will be more centered around stormwater management.

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