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**Climate Change Vulnerability Assessment of Navajo Nation Water Resources in the San Juan River Basin, NM: Utilizing Traditional Navajo Ecological Knowledge**

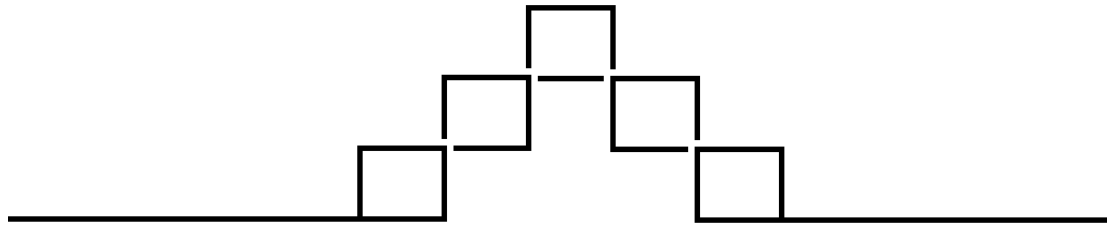
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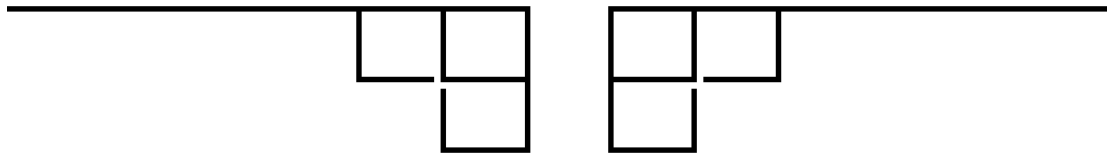


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**Climate Change Vulnerability Assessment of Navajo Nation  
Water Resources in the San Juan River Basin, NM:  
Utilizing Traditional Navajo Ecological Knowledge**



**by**

**Kirena Elana Yanibaa Tsosie**

Committee

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A Professional Project Proposal Submitted in Partial Fulfillment of the Requirements

for the Degree of

**Master of Water Resources**

Water Resources Program

The University of New Mexico

Albuquerque, New Mexico

Summer 2020

## Committee Approval

The Master of Water Resources Professional Project of Kirena Elana Yanibaa Tsosie,  
entitled Climate Change Vulnerability Assessment of Navajo Nation Water Resources  
in the San Juan River Basin, NM: Utilizing Traditional Navajo Ecological Knowledge,  
is approved by the committee.

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Chair

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Date

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## **1. Abstract**

The Navajo Nation consists of 110 chapters, local government subdivisions, organized into five regional agencies. Over half of the Navajo Nation chapters have traditional names in the Navajo language that describe a local water source including springs, washes, rivers, ponds, and reservoirs. Therefore, traditional Navajo names consist of Traditional Navajo Ecological Knowledge (TNEK) and can assist in documenting water sources that can be further assessed for vulnerability and sensitivity to climate change. There are 52 Navajo Nation chapters located in the San Juan River Basin and 28 chapters have water related names. Water sources associated with place names will also be evaluated for risks from industrial development. Water is sacred to the Navajo people and provides a strong sense of identity, kinship, and livelihood to Navajo communities. To ensure profiled water sources are protected and community values upheld, documentation of the water sources will be constructed to conceal the true location as advised by community leaders. Water sources identified from TNEK will be mapped to allow for a better comprehension of the vast available water that is present on Navajo land, which can then be used in future environmental assessments or impact studies. Environmental assessments will need to take into consideration the impacts industrial development has on natural resources, in addition, implementing action to protect highly vulnerable water sources. This project generates a valuable source of knowledge through reclaiming Navajo place names, preserving TNEK, and building resilient ecological communities on Navajo land in the face of a changing climate.

### **Key Science Themes:**

Sustainable Water Resources, Mapping and Predicting Changes in Ecosystems, and Enhancing the Resilience of Indigenous, Rural and Vulnerable Communities.

## **2. Executive Summary**

This report summarizes water resources in the San Juan River Basin, located in the northwestern part of New Mexico in the United States and identifies the potential risks climate change and industrial resource extraction have on documented water resources. The Navajo Nation is targeted in energy resource exploration and extraction, with the negative impacts of this industrial development heavily affecting the safety and health of Navajo communities (Tauli-Corpuz, 2017). As New Mexico's climate shifts to a drier and hotter environment, securing clean water will become increasingly difficult (Garfin et. al., 2013). Water is essential for Navajo communities and is intimately interwoven in Navajo worldview through mythology, epistemology, and philosophy. Using traditional Navajo Nation chapter names in the Navajo language, Traditional Navajo Ecological Knowledge (TNEK) can assist in identifying vulnerable water resources in the Navajo Nation. Highly vulnerable water resources need to be protected in an effort to sustain important ecological communities on Navajo land in order to remain adaptive to climate variability.

Furthermore, the beginning of sections 3, 4, 5, and 6 will consist of short summaries of the Navajo worldview. This vulnerability assessment of Navajo Nation water resources will be holistic in nature, including Navajo epistemology and philosophy of the four directions and their representations. In doing so, it is hoped to increase awareness, admiration, and perspective of the Navajo culture that can develop a deeper understanding of New Mexico's water resources.

## **3. Introduction**

A Navajo home or hogan has the door built facing the East, to receive blessings and to greet Father Sun as he rises over the horizon bringing light, warmth, and energy to Mother Earth. In the East is the sacred mountain Sis Naajini, also known as Blanca Peak. The mountain represents nitsáhákees (thoughts), the dawn and white shell symbolizing positive thinking and intelligence. When a hogan is built there are four main cardinal poles that are the foundation of the hogan, not just for structural support but are considered necessary for survival and continuation of life. The first pole is respectfully placed in the East representing nitsáhákees because before a hogan is built



there needs to be thoughts to build and maintain a home considering the weather, land, water, plants, and animals (Hubbard, 1977).

### 3.1 Overview of the Navajo Nation

The Navajo Nation is over 27,000 square miles that spans from northwestern New Mexico, with three “satellite” areas in central New Mexico, to northeastern Arizona and southeastern Utah. It is located within the southcentral portion of the Colorado Plateau and encompasses parts of the San Juan River Basin, as well as parts of the Little Colorado River Basin (Figure 1). A chapter is the most local form of government in the Navajo Nation; chapters have communal meeting places called chapter houses where Navajo residents conduct Navajo Nation elections, community meetings and community programs. There are currently 110 local chapters, each with their own chapter house, that are grouped into five agencies within the Navajo Nation, including Eastern (Crownpoint), Fort Defiance, Western (Tuba City), Northern (Shiprock), and Central (Chinle) Agencies. The Navajo Nation includes many cultural resources such as sacred sites, ancient architecture, and traditional ecological knowledge.

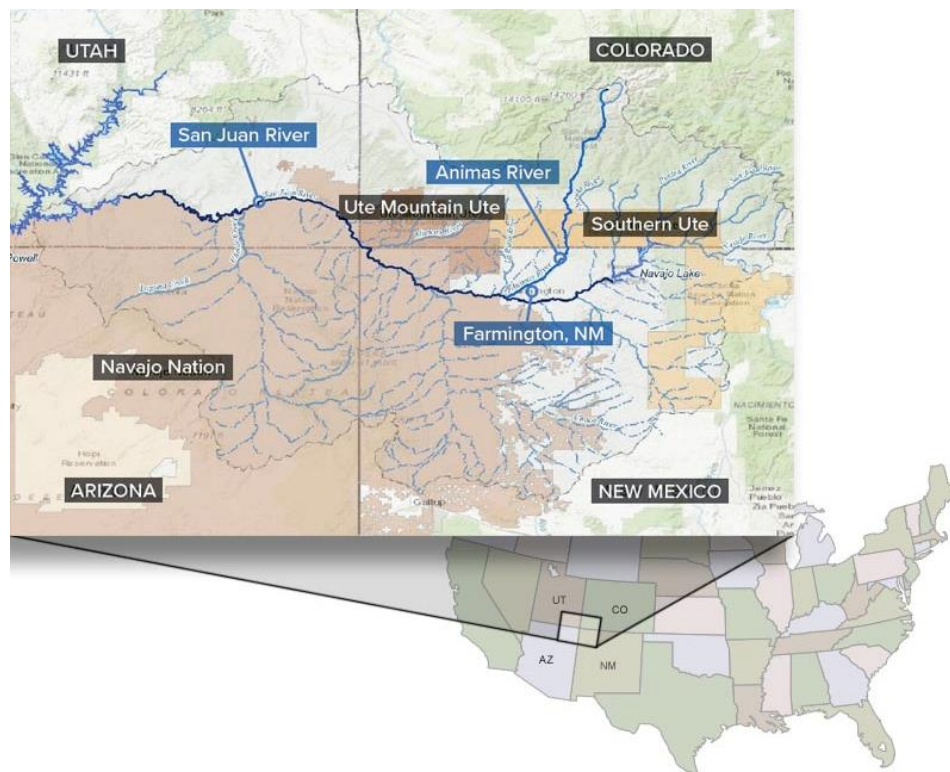


Figure 1: The San Juan River Basin; Highlighting the San Juan River and Indigenous reservations including the Navajo Nation, located in the Four Corners area of the U.S. Southwest (EPA, 2020).

### **3.2 History of the Navajo People**

Tribal Indian policy and law were designed for Indigenous people to fail, to be expendable and to be eliminated (Means, 1989). In 1864, about 11,500 Navajo people were forcibly removed from their homelands and marched 400 miles to a desolate reservation at Fort Sumner, called Hwéedli in the Navajo language meaning the place of great suffering (Kappler, 1904). Four years later, in 1868, the Navajo negotiated with the United States (U.S.) government and gained permission to return to their homelands becoming the only Indigenous Nation to use a treaty to escape removal (Kappler, 1904). However, the Navajo Reservation represents only a portion of the original Navajo homeland which extends from the sacred mountains Blanca Peak, CO, Mount Taylor, NM, the San Francisco Peaks, AZ, and Hesperus Peak, CO. Hwéedli was the start of environmental and social injustices for the Navajo people (Lenzen, 2019). Over the next hundred years, the aggressive and callous assimilation of Navajo children was a tremendous tragedy suffered by Navajo families resulting in the loss of culture, teachings, practices, language, identity, and values (Tapahonso, 2016).

In 1923, the formation of the Navajo Tribal Council was entrenched by the U.S. government, along with direct participation from oil companies, for the singular intent of signing mineral leases with no consideration for the destruction it would bring to the health of Navajo communities (Lewis et. al., 2017) (McBride, 2017). Since the Navajo Tribal Council's inception, the Navajo Nation has been the target of mineral leasing allowing uranium, coal, and oil and gas extraction on Navajo land without ensuring that tribal needs were met (Grogan, 2011). Injustices endured by Navajo communities have had significant impacts on the socio-economical, environmental, and cultural resources that has continued for generations (Tapahonso, 2016) (Lewis et. al., 2017). The U.S. government recognizes the tribal sovereignty of Indigenous people but has restricted tribal self-determination through colonial legal systems. Tribal sovereignty is inherent and predates the U.S. which only understands delegated sovereignty that is controlling, contradicting and assuming over Indigenous rights (Diver, 2018). Extractive industries have taken advantage of tribal natural resources through systematic manipulation of Indian law and government that sets them in positions of power over Indigenous communities (McBride, 2017).

For hundreds of years, the U.S. government has reduced tribal land size, settled it, privatized it, polluted it and placed difficult restrictions that has assured the Navajo Nation can wield its power to buy and sell coal mines before it can guarantee housing and water for its people (Sage, 2017). Repressive Western practices and ideologies have produced a legacy of misappropriation, commoditization, and mismanagement of Indigenous resources (Smith, 1999). Since colonial contact, Navajo epistemology has been subjugated, rejected, and debased by Western society resulting in research exploiting Navajo communities only to benefit Western science and producing unethical representations of Indigenous people (Manuelito, 2006) (FNIGC, 2019).

### **3.3 Overview of the San Juan Basin**

The San Juan River Basin (SJRB) is about 21,600 square miles and occupies the eastern third of the Navajo Nation of the Colorado Plateau (Levings et. al., 1996). Distinctive landscape features are mesas, canyons, mountains, and volcanic necks (Levings et. al., 1996). Majority of the distinctive landscape features are sacred places for the Navajo People including Shiprock, Huerfano Mountain, and the San Juan River. The San Juan River is one of the largest tributaries of the Colorado River and bisects the Navajo Nation. The most significant cultural site on public land in New Mexico is Chaco Canyon or Chaco Culture National Historical Park. Chaco Canyon is a United Nations Educational, Scientific, and Cultural Organization (UNESCO) World Heritage Site, National Historical Park and Dark Sky Park in the center of the SJRB. The massive structures of Chaco Canyon are internationally recognized architectural and engineering wonders built a millennium ago by Indigenous people who become proficient in architecture, agriculture, astronomy, and arts. Chaco is the core of a much larger Ancestral Puebloan civilization, known as the Greater Chaco, that extends and connects for hundreds of miles by a web of ancient roads (H.R., 2019)

### **3.4 Scope of the Document**

This report summarizes recent climate, hydrologic and industrial development changes within the SJRB and water resources within the Navajo Nation that are at risk. There is no shortage of water in the desert because everything is in Hózhó or balance unless a city is established without considering the harmony of the ecosystem (Shirley & Jojola, 2013). Indigenous people understand this and have gained ecological knowledge, wisdom, and practices

that continue on that balance by establishing K'é or kinship with the water. K'é refers to the establishment of familial and clan relationships, while Hózhó refers to the balance and harmony within the chaos of life. It is difficult to define Navajo words because they encompass a deeper and more complex concept than its simple English translation (Manuelito, 2006). Using the Navajo language and traditional names to document ecological knowledge allows for a broader record of the historical climate that will assist in climate change adaptation planning efforts.

Industrial scale natural resources extraction is a constant threat to Navajo communities, groundwater resources, and the natural ecosystem with the drastically increasing development in oil and gas (BMMR, 1983) (Lewis et. al., 2017). When Navajo water sources are not protected, there is and has been an increased threat of losing these water sources to contamination, drought, or extractive industries. When the water is gone, the name will be lost, the people will leave, and we will lose our knowledge and language. Rediscovering traditional Navajo practices and language could be a way for families to heal from past traumas, improve their lifestyles, and reconnect to the sacredness of water. In this way Navajo culture can be preserved and Navajo water sources protected.

### **Research Questions:**

1. How many Navajo Nation Chapters consist of water related names based on traditional Navajo place names?
2. How many documented water resources are groundwater or surface water resources?
3. How vulnerable are documented water resources to climate change and industrial resource extraction?

### **4. Climate of the San Juan River Basin**

Father Sun continues his journey rising higher in the sky to lighten it to a light blue. The sacred mountain to the South is Tsoodzil (Mount Taylor). The mountain represents nahat'á (plans), the day, and turquoise symbolizing health and positive learning. The second pole is respectfully place in the South representing nahat'á because organized thoughts become plans for the building of the hogan. Plans are carried out with good health and allow positive learning to take place to develop valuable skills. Skills are used to achieve plans while protecting and acting

as a shield against poverty, laziness, sickness, and starvation. Planning with patience and compassion takes time so that the socio-economic, environmental, and cultural considerations are addressed in a respectful way (Hubbard, 1977).

#### **4.1 Current Climate and Hydrologic Changes**

Navajo Nation lands range from arid to semi-arid, with total annual precipitation in semi-arid regions receiving between ten inches to sixteen inches or more and total annual precipitation in arid regions averaging seven inches (Nania & Cozzetto et. al., 2014). Precipitation has a seasonal and spatial distribution with spring snowmelt runoff and late summer monsoon rainfall providing the majority of the vital water for agricultural and ecological systems. Deficiency in precipitation can lead to drought and can last from weeks to decades, resulting in declines in streamflow, deficits in soil moisture, and declining of groundwater tables (Nania & Cozzetto et. al., 2014). During the past 2,000 years, drought events have been more severe and longer lasting than droughts observed since 1901 (Hoerling et. al., 2013). Although the Navajo Nation has experienced severe droughts between 1900-2008, due to natural climate variability, recent drought events have been more severe and longer (Faulstich et. al., 2013).

Groundwater resources are the only source of water in most of the SJRB for municipal, industrial, domestic, and stock purposes, while the limited surface water has been fully appropriated (Levings et. al., 1996). The Navajo Nation relies heavily on groundwater for municipal, domestic and businesses, including Coconino, Dakota, Navajo, Mesa Verde, Morrison aquifers, and numerous alluvial aquifers (NDWR, 2011). Throughout the Southwest region, hydrologic changes being observed are declines in mountain snowpack, more winter precipitation falling as rain rather than snow, and earlier snowmelt (Garfin et. al., 2013). Navajo elders maintain majority of TNEK and have observed for decades the changes in the decline of water availability and water quality. Current science now vindicates the observations of Navajo elders in that significant declines have occurred in over thirty surface water features, declines in snowpack, the disappearance of water sources, and declines in water quality due to declining recharge and overutilization (Redsteer et. al., 2013b).

## **4.2 Projected Climate and Hydrologic Changes**

Many of the climate changes currently being observed are expected to sustain and are likely to intensify in the future. In New Mexico, average annual temperature has increased by about 2° Fahrenheit (F) since the 1970s, annual summer monsoon rainfall is highly variable and uncertain for future needs, snowpack accumulation is projected to decrease, and drought intensity and wildfire severity are projected to increase (Frankson et. al., 2017). Within the Navajo Nation projected changes in climate by the end of the century are annual temperatures increasing from 3°F to 12°F which will be new historic highs, annual precipitation decreasing slightly while snow water will decrease greatly and the extremes of year-to-year precipitation (floods and droughts) are projected to increase (Dettinger & Albano, 2015). The Navajo Nation recognizes the need to distinguish between chronic water shortages and droughts to better assess and alleviate water shortage events. Severe droughts have significant impacts on vulnerable communities, such as the Navajo people, health, livelihood and TNEK (Cozzetto et. al., 2013).

Changes in precipitation and increased temperatures brought on by climate change will reduce water availability and quality (Nania & Cozzetto et. al., 2014). In the Navajo Nation rising temperatures may cause more winter precipitation falling as rain rather than snow, lower spring snowpack, earlier snowmelt, and snowpack being increasingly confined to smaller, higher elevation areas (Cayan et. al., 2013). Snow stores water and gradually releases freshwater into streams, rivers, and lakes sustaining life throughout the dry summer season. Warmer temperatures and reduced period of snow cover could mean a longer and dryer summer seasons that might led to lower soil moisture by early summer, decreases in runoff, decreases in Colorado River flows, and increased evapotranspiration, which could lead to groundwater salinization (Nania & Cozzetto et. al., 2014). Current and future ecosystems will experience more stress for water availability which will pose a major challenge to New Mexico's environmental, agricultural, and human systems.

## **4.3 Increase in Oil and Gas Development**

New technological advancements in subterranean drilling has evolved the extractive process for natural resources, which has secured more energy production and led to a frenzy of rapid oil and gas development in the SJRB. The primary federal agency that holds federal mineral lease sales is the Bureau of Land Management (BLM) including the San Juan Basin in

the northwest corner and the Permian Basin in the southeast and are the two most prolific oil and gas basins in the U.S. (BLM, 2020). A total of 37,307 wells have been drilled within the SJRB through August 2017 with the BLM projecting 3,200 new oil and gas wells for the period 2018-2037 (Crocker & Glover, 2018). There was 1,367 reported oil and gas spills in 2018, averaging nearly four spills daily, with 106 spills in the San Juan Basin and 1,261 in the Permian Basin (BLM, 2019). In addition to the threat of spills impacting water resources, hydraulic fracturing of the 3,200 new wells will require an estimated 60 million barrels or 2.5 billion gallons of water (Crocker & Glover, 2018).

Environmental injustices occur in areas with unconventional development of oil and gas, the most common method being hydraulic fracturing or fracking, and vulnerable communities. Fracking wells are disproportionately located in poor rural communities and are exposed significantly higher to pollution from such wells, just as within Pennsylvania's Marcellus Shale (Ogneva-Himmelberger & Huang, 2015). Vulnerable communities near areas of oil and gas development with unconventional wells will suffer the potential detrimental health impacts of air and water pollution that other urban rich communities will not. For the first time, long-term impacts of oil and gas drilling have been linked to negative effects on per capita income, crime rates and educational attainment when fossil fuel development plays a role in local economics (Headwaters Economics, 2014). The environmental damages can be costly and irreversible, in addition to huge socio-economic impacts that have yet to be studied.

#### **4.4 Political Climate of Oil and Gas Development**

The BLM sold mineral leases on land in the SJRB for natural resource exploration and extraction despite protests from the local community, including tribal and non-tribal community members. In 2014, BLM estimated nearly 4,000 fracking wells would be developed in the region, where more than 91% of the available land being leased for oil and gas drilling, without any consideration to the impacts to water supplies, community health, air quality, climate, and cultural integrity of the landscape (Brown, 2019). Since December 2018, advocates have delivered over 50,000 protests in opposition to BLM's three recent lease sales covering 142,000 acres with a record-breaking 33,000 protests opposing the March 28, 2019 online action (Sobel, 2019). The BLM has implemented multiple strategies to obstruct public opposition such as no longer accepting emailed letters (only mailed or hand deliver), shorting the protest period from

30-days to 10-days, switching to online auctions from oral auctions, and operating during the 35-day government shutdown of 2018-2019.

On May 7, 2019, the U.S. Court of Appeals for the Tenth Circuit held that the BLM illegally approved oil and gas drilling including fracking in the Greater Chaco region of the SJRB (Diné Citizens Against Ruining the Environment (CARE) v. BLM, 2019). The Tenth Circuit held the BLM failed to comply with federal law by failing to account for the cumulative impacts of fracking and failure to consider the cumulative impact of water use associated with drilling 3,960 new oil and gas wells (Diné Citizens Against Ruining the Environment (CARE) v. BLM, 2019). In doing so, BLM violated the National Environmental Policy Act (NEPA) by failing to conduct a proper analysis of cumulative impacts that are too speculative or hypothetical to meaningfully contribute to NEPA. In addition the State Land Office Executive Order No. 2019-002, established a four-year moratorium on new oil and gas mineral leasing of state trust lands within ten miles around Chaco Culture National Historical Park while engaging with tribal members to “enable the State Land Office to explore other land uses that are more consistent with the protection and preservation of the landscape” (Sobel, 2019).

## **5. Navajo Nation Chapters in the San Juan Basin**

Father Sun lowers from the sky creating beautiful, bright colors as he retires for the day. In the West is the sacred mountain Dook’o’ooslííd (San Francisco Peaks). The mountain represents ‘iiná (life), the dusk, and abalone shell that symbolizes physical strength and resilience. The third pole is respectfully placed in the West representing ‘iiná because living in the hogan must be done according to thoughts and plans to enjoy life. The hogan is where respect for kinship is taught and is continually emphasized. The Navajo people have K’é (kinship) with Mother Water, Father Sun, Mother Earth, and Father Sky. Water can create, teach, and sustain life, strengthening communities and ecosystems. Physically strong communities and ecosystems are resilient enough to protect traditional values, practices, and teachings (Hubbard, 1977).

### **5.1 Analyzing Navajo Nation Chapters in the SJRB**

TNEK was obtained from traditional place names in the Navajo language of Navajo Nation chapters. Traditional Navajo chapter names were retrieved from the Navajo Times,



*Exploring the Navajo Nation Chapter by Chapter* series from 2017 written by Cindy Yurth. All 110 Navajo Nation chapters had their traditional Navajo names evaluated for their affinity to water sources, tree formations, rock formations, or non-environmental relations. In cases where chapters had more than one name for the area, older names were selected over newer names. In other cases where the age of the name was not specified, water related names took priority, following tree related names and finally rock related names. It was imperative to consider the story and origin of traditional Navajo place names; in these instances, the names related to a water source without using the word water. For example, the Naschitti Chapter's traditional name is Nahashch'idí meaning badger. This place name is considered water related because the origin of the name tells a badger that was digging near the wash and uncovered a spring of pure, fresh water. Water related names include springs, wells, washes, rivers, ponds, lakes, reservoirs, rain, and tree and rock formations that indicate water sources. Tree related names include tree formations and plants. Rock related names include rock formations, mesas, mountains, canyons, and landscape features. Non-environmental related names include settler names, animals, man-made structures, ancient man-made structures, and minerals.

Navajo Nation chapters within the SJRB with water related names were further analyzed to determine the type of water source as surface water or groundwater. Chapters on the border of New Mexico and Arizona were considered in the SJRB by estimating chapter boundaries to have majority of land in the New Mexico state. In total all 31 chapters from the Eastern (Crownpoint) Agency, 13 chapters from the Northern (Shiprock) Agency and 8 chapters from the Fort Defiance Agency were evaluated. 28 out of 52 Navajo Nation chapters in the SJRB have water related names. Surface water is any body of water above ground, including washes, rivers, ponds, lakes, and reservoirs. Surface water resources will be classified into three types of surface water: perennial, ephemeral, and man-made (NGS, 2019). Perennial sources of water are permanent, persisting throughout the year and is replenished with groundwater when there is little precipitation which includes rivers, ponds, and lakes. Ephemeral sources of water are semi-permanent and includes washes. Man-made surface water is found in artificial structures, such as reservoirs (NGS, 2019). Wells and springs were classified as groundwater resources, since a spring is groundwater becoming surface water (NGWA, 1999). ArcGIS was utilized to map water resources using custom Google pins and included Navajo Nation boundaries. To ensure the

sacredness of the water resources and community confidentially, chapter houses were used instead of the water resource location.

## 5.2 Methodology for Vulnerability Assessment

The 28 Navajo Nation chapters were assessed for climate change and industrial development vulnerability based on location and drought. Vulnerability is defined as the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes (IPCC, 2001). Exposure is the degree of stress placed upon a water resource due to changing climate conditions or increased climate variability (IPCC, 2001). For this study, exposure is measured in relation to oil and gas resource extraction based on distance. Water sources 0-9.9 miles have high exposure, 10-19.9 miles have medium exposure and >20 miles have low exposure from the nearest oil and gas well (Figure 2a). A 10-mile buffer around cultural sites is the same distance established around Chaco Canyon to protect it from oil and gas extraction (S. 1079/H.R. 2181, 2019). Sensitivity is the degree to which a water resource is affected by or is responsive to climate changes and variability (IPCC, 2001). Water sources that have dried up have high sensitivity, drying up have medium sensitivity, unaffected have low sensitivity due to drought. Combining the exposure and sensitivity analysis can determine the potential impact on water resources.

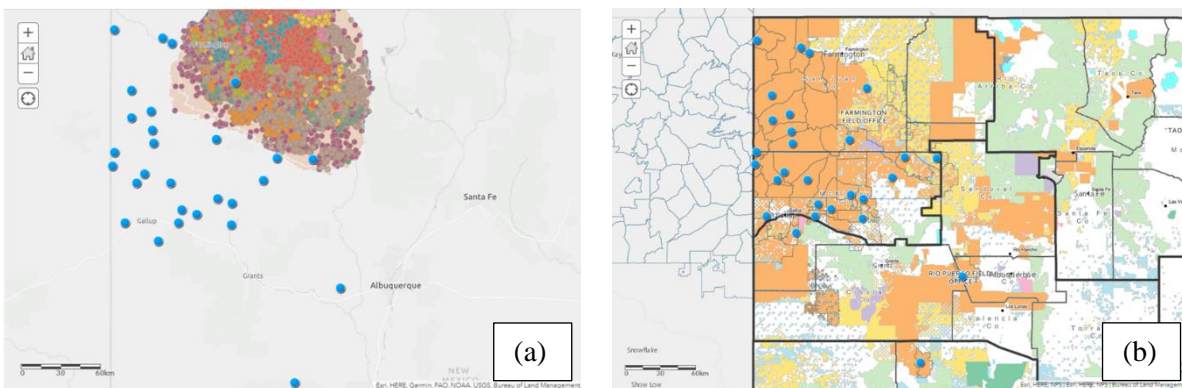


Figure 2: ArcGIS Maps; Used to assess vulnerability by measuring distance to oil and gas wells for exposure(a) and by estimating land use for the environmental dimension of adaptive capacity (b).

Adaptive capacity is the ability of a water resource to adjust to climate change as a means to moderate potential damages or to cope with the consequences (IPCC, 2001). A holistic view of adaptation from a river basin perspective involves adaptive capacity indicators that stem from the three dimensions of a sustainable state; social, economic, and environmental (Pandey et al,

2009). The quantification of adaptive capacity for this study uses educational attainment (25 years or over) of a high school diploma or higher (1= 21%- 40%, 2= 41%- 60%, 3= 61%- 80%) to determine the social dimension, individuals below the poverty level (1= 61%- 80%, 2= 41%- 60%, 3= 21%- 40%) to determine the economic dimension, and land use (1= >50% checkerboard land, 2= <50% checkerboard land, 3= no checkerboard land) to determine the environmental dimension (US Census, 2000)(Figure 2). Lower values reflect lower adaptive capacity while higher values reflect higher adaptive capacity. Vulnerability is deduced by the equation,  $Vulnerability = Exposure + Sensitivity - Adaptive\ Capacity$ .

### **5.3 Climate Change Vulnerability Assessment**

Vulnerability assessments are an important first step to understanding the vulnerabilities that exist in the Navajo Nation and to effectively reduce vulnerability through Indigenous planning. Highly vulnerable water resources are located near checkerboard land where oil and gas extractive activities occur. Over half of the Navajo Nation chapters have water related names that correlate to a water source (Table 1). 28 Navajo Nation chapters in the SJRB have a water related name that correlates to 27 groundwater and surface water resources (Figure 3). Tse Daak'aan/ Hogback Chapter and San Juan Chapter in the Northern Agency both describe the San Juan River. Majority of the water resources are springs, however, the springs identified are only a small portion of nearly 1,000 springs on the Navajo and Hopi reservations excluding 846 drilled wells and 537 dug wells (Cooley et. al., 1969). The overharvesting of groundwater for extractive industries has huge implications for water demand in the future, groundwater recovery for the SJRB to a steady state could be 6,600 to 10,600 years after the cessation of dewatering (USGS, 2013). Navajo communities are disproportionately vulnerable to impacts of climate change and have tribe-specific vulnerability factors such as socioeconomical, political, infrastructural, environmental, spiritual, and cultural (Cozzetto et. al., 2013). Vulnerable communities also represent futurity risks that could result in loss of culture, ecosystem, or community (Figure 4)(Table 2). Indigenous planning represents both an approach to community planning and ideological movement that incorporates traditional knowledge and cultural identity, positioning Indigenous communities with traditional planning approaches that adapt with change making them more culturally resilient (Jojola, 2008). Climate change adaptation planning is an opportunity to adapt to climate change while considering community and ecosystem values.


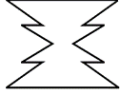
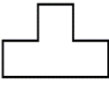

					Total
	Water Related Name	Tree Related Name	Rock Related Name	Non-Environmental Related Name	Total
Eastern Agency	15	5	7	4	31
Fort Defiance Agency	15	3	4	5	27
Western Agency	10	2	2	4	18
Northern Agency	9	3	6	2	20
Central Agency	9	0	4	1	14
TOTAL	58	13	23	16	110

Table 1: Assessment of Traditional Navajo Place Names; kinship to water sources, tree formations, rock formations, or non-environmental elements for all 110 Navajo Nation chapters.

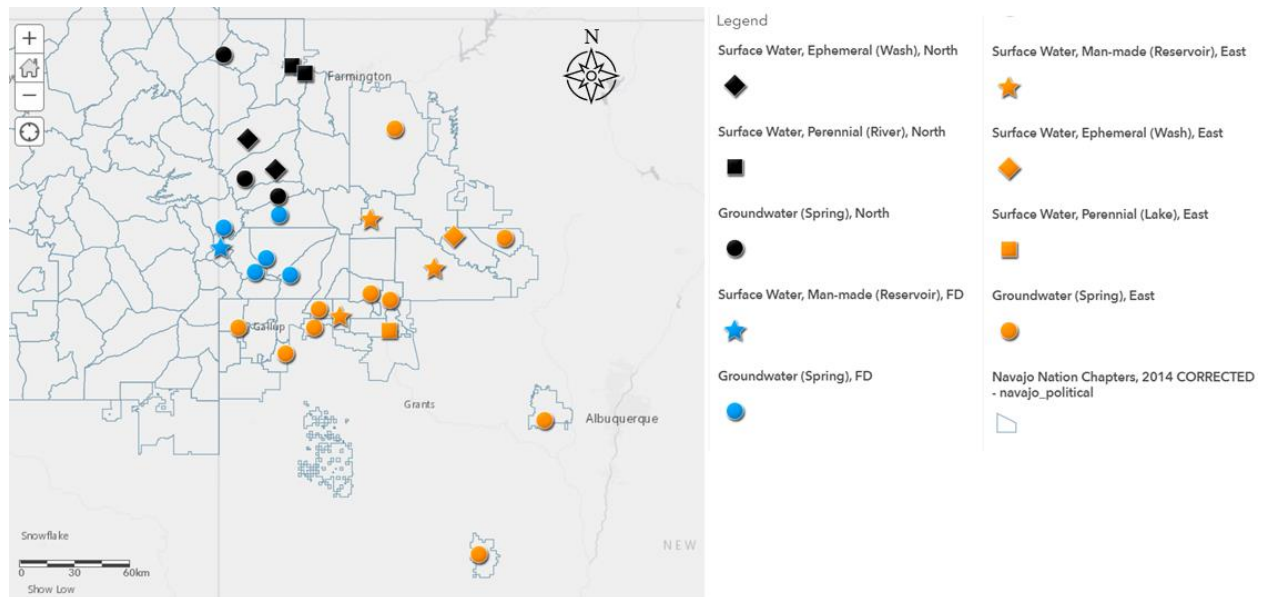


Figure 3: Water Related Names; Navajo Nation chapters in the SJRB correlating to groundwater, surface water (perennial), surface water (ephemeral), and surface water (man-made) mapped through ArcGIS using Navajo Nation chapter boundaries.

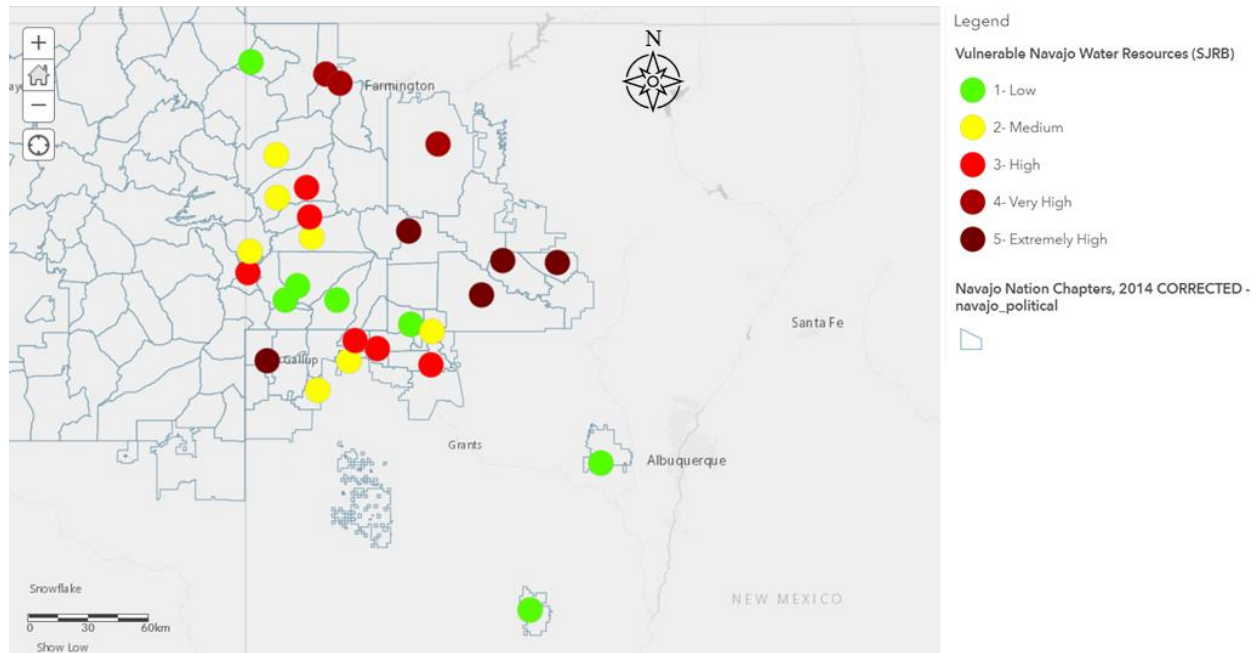


Figure 4: Futurity Risk Map; Vulnerable Navajo water resources in the SJRB based on the climate change vulnerability assessment through ArcGIS using Navajo Nation chapter boundaries.

Agency	Chapter Name	Water Source	Type	Vulnerability	Agency	Chapter Name	Water Source	Type	Vulnerability
Eastern Agency	Lake Valley/ Be'ak'id Halgai, "Flat Lake".	Reservoir	Surface Water, Man-made	Extremely High	Fort Defiance Agency	Bread Spring/ Bááh Háálj, "Bread Flowing Out".	Spring	Ground water	Medium
Eastern Agency	Ojo Encino/ Tsé Ch'izhi Bii' Tó, "Water among some rough rocks".	Spring	Ground water	Extremely High	Eastern Agency	Crystal/ Tó Nilt's'íli, "Crystal Clear Water".	Spring	Ground water	Medium
Eastern Agency	Pueblo Pintado/ Nahodeeshgiizh Ch'inilj, "Flowing Out from the Gap".	Wash	Surface Water, Ephemeral	Extremely High	Northern Agency	Iyanbito/ Ayáni Bito', "Buffalo Spring".	Spring	Ground water	Medium
Eastern Agency	Tsayatoh/ Tséyaa Tó, "Water Under the Rock".	Spring	Ground water	Extremely High	Eastern Agency	Little Water/ Tó 'Alch'ídi, "Little Water".	Spring	Ground water	Medium
Eastern Agency	White Horse Lake/ Ljítgai Bito', "White Horse Lake".	Reservoir	Surface Water, Man-made	Extremely High	Eastern Agency	Naschitti/ Nahashch'ídi, "Badger".	Spring	Ground water	Medium
Eastern Agency	Huerfano/ Hanaa'dli, "Water Coming Up".	Spring	Ground water	Very High	Northern Agency	Toadlena.Two Grey Hills/ Tó Háálj, "Where the Water Flows Out".	Spring	Ground water	Medium
Northern Agency	San Juan/ Tooh, "San Juan River".	River	Surface Water, Perennial	Very High	Fort Defiance Agency	Tse Alnaozt'i'i/ Sanostee/ Tsé Alnaozt'i'i, "Criss Crossing Rock Formation".	Wash	Surface Water, Ephemeral	Medium
Northern Agency	Hogback/ Tsé Daak'áan or Tsé Tahí Kaa, "Rock Uplift" or "Rock Eroded by Water".	River	Surface Water, Perennial	Very High	Fort Defiance Agency	Alamo/ T'iis Tsoh Sikaad, "Big Cottonwood Tree".	Spring	Ground water	Low
Eastern Agency	Casamero Lake/ Tséyah Tó Alk'oli, "Water Waves Among the Rock".	Lake	Surface Water, Perennial	High	Eastern Agency	Beclabito/ Bitl'ááh Bito', "Water Underneath".	Spring	Ground water	Low
Eastern Agency	Mariano Lake/ Be'ak'id Hóteeli, "Wide Lake".	Reservoir	Surface Water, Man-made	High	Eastern Agency	Coyote Canyon/ Ma'ii Tééhítlzhí, "Coyote Fell in the Watering Hole".	Spring	Ground water	Low
Northern Agency	Newcomb/ T'iis Nideeshgiizh, "Cottonwoods Spreading Out from the Wash".	Wash	Surface Water, Ephemeral	High	Eastern Agency	Crownpoint/ T'iists'óóz Nideeshgiizh, "Skinny Tree Canyon".	Spring	Ground water	Low
Eastern Agency	Pinedale/ Tó Bééhwiisgáni, "Hardened Mud Around the Water".	Well	Ground water	High	Northern Agency	Mexican Spring/ Naakai Bito'í, "Mexican Springs".	Spring	Ground water	Low
Fort Defiance Agency	Red Lake/ Be'ak'id Halchii', "Among the Red Lake".	Reservoir	Surface Water, Man-made	High	Fort Defiance Agency	Tohajileeh/ Tó Hajileehí, "Where They Pull the Water Up and It Keeps Refilling Itself".	Spring	Ground water	Low
Northern Agency	Sheep Springs/ Tó Lítósi, "Yellow Springs".	Spring	Ground water	High	Fort Defiance Agency	Tohatchi/ Tó Haach'i', "One Who Digs for Water".	Spring	Ground water	Low

Table 2: Climate Change Vulnerability Assessment; Navajo Nation water resources in the SJRB.

## **5.4 Building Resiliency in Navajo Nation**

Centuries of imperialistic treatment by the U.S. government has rendered the Navajo people, and other Indigenous Tribes, dependent upon directives that have been destructive to their lives (Manuelito, 2006). Due to Western systems of governance, education and management being foreign and incompatible to the traditional practices of Navajo communities. Despite the unyielding social, environmental, and political forces that have attempted to limit inherent powers of tribal self-government, Indigenous communities developed a multidisciplinary approach to deal with complex set of issues, laws, and regulations toward tribal community development (Jojola, 2008). Five steps to reduce vulnerability and build resilience include conducting a vulnerability assessment, incorporating uncertainty into resilience planning; engaging socially marginalized groups in decision making; monitoring, evaluating, and learning; and scaling adaptation plans (Chaudhury, 2017).

## **6. Development of Climate Adaptation Strategies**

Father Moon now journeys in the sky, allowing life to rest and stars to wake, forming constellations the provide guidance, principles, and values for living. The sacred mountain to the North is Dibé Nitsaa (Hesperus Peak). The mountain represents siihasin (hope), the night, and jet that symbolizes self-awareness and protection. The fourth pole is respectfully placed in the North representing siihasin because hope for a better life is to think and plan for the future. This embodies the teaching that only when one thought, planned, lived, and faced the future following values, would one have health and wisdom. By living in Hózhó (balance) with all living things, including water, hope grows and feeds positivity in every aspect of life. That is why we must live in Hózhó with constant self-awareness of our impact on Mother Earth to protect the knowledge, wisdom, and values of Navajo teachings. Rapid development without respectful thoughts or considerate planning is bad for life and could result in no hope for the future (Hubbard, 1977).

### **6.1 Navajo Knowledge Systems**

Western science is still predominantly Eurocentric, so the dynamic nature of Indigenous knowledge is difficult to integrate into definite Western resource management systems (Casimirri, 2003). Historically community-based research has led to Indigenous knowledge

being recorded from communities and retold through the biased narrative of a non-Indigenous researcher that misappropriates that knowledge (Smith, 1999). Current research is based on the supremacy of Western ways of knowing and systems that can be very disempowering to Indigenous knowledge (Casimirri, 2003). The focus on extracting TNEK from community-based research not only marginalizes Indigenous knowledge but distracts from the existence and efficacy of Indigenous systems of land management and the development of including Indigenous peoples and TNEK holders as decision makers (Casimirri, 2003). Decolonizing science will allow the non-Western methods of TNEK to be integrated into U.S. science and resource management.

TNEK defined as shared Indigenous knowledge, wisdom, of the surrounding ecosystem and climate processes that has been gained through hundreds of years of scientific and engineering experiences. TNEK exists within a web of Indigenous knowledge and “is more than just information; its transfer into knowledge happens within a different context, informed by a fundamentally different world view and therefore consists not only of ‘ecological data’ but also spirituality, values, normative rules and cultural practices” (Casimirri, 2003). Indigenous standards are distinct from other communities because they are motivated by traditional community values, including ceremonial uses (Diver, 2018). K’é and Hózhó are essential to an individual’s inner peace because they are the basis for the Navajo value system that drives behavior and establishes culture. K’é with the surrounding water, trees, and rocks supported an ecosystem to be in Hózhó (Figure 5). Navajo values allowed for a large range of families to have access to and manage water resources in a way that was sustainable for the whole community.

Navajo worldview has been neglected in many ways including the concept of self-determination. This has resulted in the current legislative and executive leadership of the Navajo Nation being partly to blame for the unsustainability of Navajo Nation governmental operations and practices (O.N.G.D.C.N.G.D, 2019). The Navajo Sustainability Policy of 2019 provides the framework for integrating Navajo values and philosophies into sustainable policies such as the Navajo Fundamental Laws that maintain balance, sustainability and cooperation among Tribal people, non-Tribal people and the natural world (N.N.C. Coun. Res. 2002). The Navajo Fundamental Laws are described as the following: Diyin Bitsáádeę Beenahaz’áanii (Laws Originating from the Creator or Traditional Law), Diyin Dine’é Bitsáádeę Beenahaz’áanii (Laws

Originating from the Holy People or Customary Law), Nahasdzáán dóó Yádiłhił Bitsʼaądeę Beenahaz’áanii (Mother Earth and Father Sky’s Law or Natural Law) and Diyin Nohookáá Diné Bi Beenahaz’áanii (Laws Originating from the Earth-Surface People or Common Law) (N.N.C. Coun. Res. 2002). With any sovereign power also comes the right and responsibility to protect and govern all aspects of the nation’s data and is a crucial step toward realizing full self-government of Indigenous Nations (FNIGC, 2019).

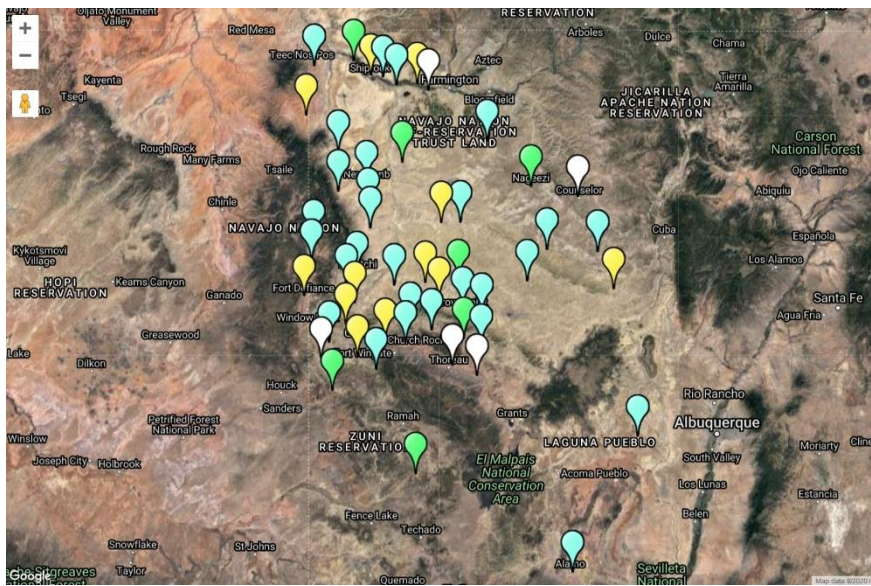


Figure 5: Navajo Nation Chapters Kinship; Traditional Navajo place name and its kinship to water (blue pins), tree (green pins), rock (yellow pins), and non-environmental (white pins) using Google Tour Builder in the SJRB.

## 6.2 Holistic Adaptation Planning

New Mexico has tamed large bodies of surface water that include rivers, lakes, and reservoirs. Water in New Mexico and in the southwest of the U.S. consist of supplementary small bodies of water, springs and wells that rely on groundwater. Natural springs and rivers are sacred spaces in Navajo tradition, culture, and livelihood. Overharvesting of water for resource extraction is detrimental to Navajo community health and way of life (Cozzetto et. al., 2013). It is hoped that these documented water resources will be considered as the Navajo Nation and State of New Mexico continues to engage in adaptation planning in response to climate change and industrial development. The Navajo Nation governs its people under Western operations and practices that do not benefit Navajo communities. Navajo leadership must reconceptualize self-



determination based on Navajo epistemologies for the future survival of Navajo communities (Manuelito, 2006). Community involvement in decision making can build capacity for resiliency for tribal communities addressing climate change through planning and management processes. Indigenous Nation’s right to data sovereignty allows Indigenous peoples to protect, maintain, and develop their cultural heritage, traditional knowledge, and cultural expressions (FNIGC, 2019).

Incorporating risks from oil and gas development into climate change adaptation planning for state and tribal government policies should be a high priority due to the current impacts of climate change and the increasing uncertainty for the future. Community based adaptation places people at the center of adaption and minimizes vulnerability while building resilience (Chaudhury, 2017). Engaging communities on the potential negative impacts of drought and pollution will identify adaptive needs while empowering vulnerable communities to decide how to build their own adaptive capacity. The vulnerability assessment addresses areas to focus allocation of resources as well as incorporating TNEK from the local community to develop efficient adaptive planning that benefits ecosystem health and community health (Figure 6). Good adaptation practices to reduce vulnerability and build resilience require collaboration among multiple partners at various scales; therefore, partnership is key to successful community-based adaptation planning (Chaudhury, 2017).

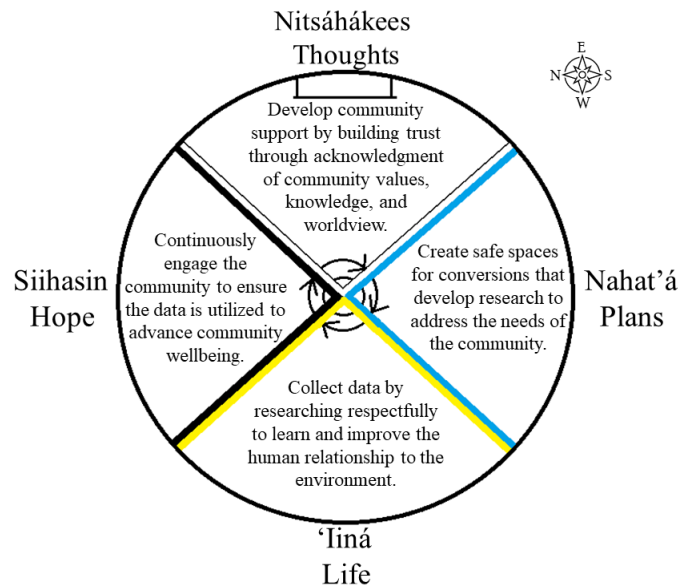


Figure 6: Community-Based Research Learning Model; Applying the four directional Navajo values.

### **6.3 Future Work**

Western practices imposed on the Navajo people have neglected Navajo epistemologies of land and water resource management that applies to the development as individuals and as communities resulting in the loss of culture, teaching, values and language (Manuelito, 2006). The Navajo Nation needs additional climate change vulnerability assessments to gather credible scientific information to efficiently engage adaptation planners to protect and preserve water resources from drought and pollution. The development of climate change adaptation strategies that utilizes TNEK into watershed-based management plans and environmental assessments could result in prioritizing conservation and protection of water resources. Understanding community values and creating a strong culture of research is being thoughtful, appreciative, and respectful of the needs of the community and will likely result in cooperation and support of research projects (Tobias, 2000). Future work should include community-based environmental violence assessment and resources for healing.

### **6.4 Conclusion**

Indigenous nations were born from ashes, matured through blood stained treaties, laws and policies and expected to perish in the shadows of the blinding, bulging American cities. The U.S. government underestimated the resilience of Indigenous people, who have remained grounded warriors that continue to fight for Indigenous rights, way of life and access to natural resources. This report provides a summary of the projected changes in climate for the SJRB and how increasing development of the oil and gas industries will exacerbate the issues. Water resources identified through TNEK emphasizes the importance of securing water quality and understanding the worldview of Indigenous peoples like the Navajo. Navajo families will continue to be disconnected from water resulting in fragmentation, degradation, and loss of connection to protect, preserve, and conserve water resources. The integration of Navajo epistemologies, values and philosophies have significant implications for the Navajo Nation's self-determination, sovereignty, and regaining more authority over natural and cultural resource management. Redefining policies that affect Navajo communities with Navajo values will aid in future sustainable community development; it is a way for families to heal from past traumas, improve their lifestyles, and reconnect with the sacredness of nature.

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