White Mountain Apache Reservation of Arizona
Water Conveyance & Storage

York College of Pennsylvania
Engineering Program

Client: Cheryl Pailzote
Team Members: Nathan Chandler, Lucas Ensor (P.M.), Brett Hackett

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Introduction

The site for the water conveyance and storage project is located on the White Mountain Apache Reservation located in eastern Arizona. The reservation is the home of the White Mountain Apache Tribe. Cheryl Pailzote, a member of the White Mountain Apache Tribe, is the on-site project contact . The student engineering team that will be working on this project includes three members, Nathan Chandler, Lucas Ensor, and Brett Hackett who is serving as project manager. The Highland Support Project (HSP) is non-governmental organization that is also involved with the project. The contact for HSP is Ben Blevins

Project Overview

The White Mountain Apache Reservation is a Native American reservation in eastern Arizona, Figure 1, and is the current and ancestral home of the White Mountain Apache Tribe (WMAT). The WMAT have their own laws and ordinances known as their Tribal Codes. This code includes an Environmental Code, Game and Fish Code, Health and Safety Code, Housing and Construction Code, Labor Code, Land Code, and Land Restoration Code. The Tribe also has an Environmental Protection Office with a Water Quality Regulatory Program with its own separate ordinance.

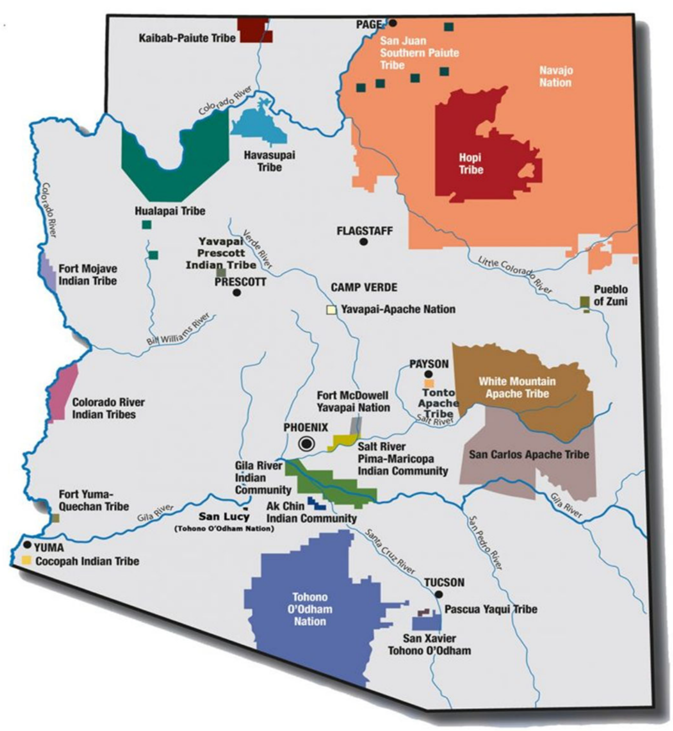

Figure 1: Location of the White Mountain Apache Tribe

The WMAT Water and Hydrology Resources partnered with Natural Resources Conservation Services, known as The People's Farm, to restore health among the Tribe's members through agriculture. The reservation includes approximately 1.6 million acres and has a population of about 16,000 people (White Mountain Apace Tribe 2021). During the last two decades, the area has experienced periods of water shortages, declining water quality, and loss of water sources. The goal of this project is to support local sustainable farming by improving access to water, thereby increasing the production of healthy crops in order to guarantee food security, sovereignty, and the establishment of water rights.

The project site is located in Whiteriver, Arizona, East of River Road as shown in Figure 2. The site is approximately 5 acres and can be easily accessed from River Road that runs parallel to the site's southern boundary. The topography of the site is fairly flat. Nearby water sources include public water mains and the White River which runs parallel to the River Road, on the west side of the site.

Figure 2: Project Site - Whiteriver AZ (Google Maps 2021)

Existing Conditions

Topography

The site lies about 25 yards east of the White River and about 200 yards west of numerous large hills. The topography on the site is rather flat. A map of the topography in the vicinity of the site is shown in Figure 3.

Figure 3: Topography of area in vicinity of project site

Geology

The site's geological survey, located in the blue box shown in Figure 4, shows that there is a great distribution of different types of rock and sediment. The colors and units on this map represent different types of rock types. Thick lines indicate faults and thin lines indicate depositional or intrusive contacts (Add Citation). The site contains and is surrounded by the following units:

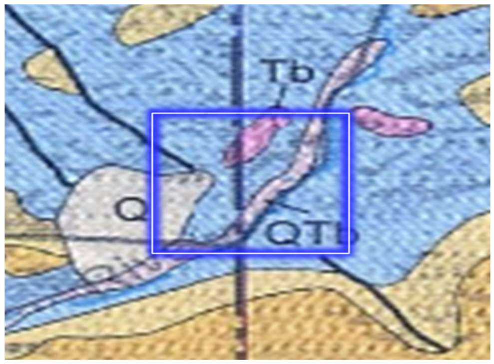

Figure 4: Geological Survey Map

- Q - Quaternary Surficial Deposits, Undivided (0-2 Ma.)
    - Unconsolidated to strongly consolidated alluvial and eolian deposits. This unit includes: coarse, poorly sorted alluvial-fan and terrace deposits on middle and upper piedmonts and along large drainages; sand, silt and clay on alluvial plains and playas; and wind-blown sand deposits
- QTb - Holocene to Middle Pliocene Basaltic Rocks (0-4 Ma.)
    - Mostly dark-colored basaltic lava and cinders young enough that some original volcanic landforms are still apparent. Includes a small amount of andesite, sacite, and rhyolite.
- Tb - Late to Middle Miocene Basaltic Rocks (8-16 Ma.)
    - Mostly dark, mesa-forming basalt deposited as lava flows. Rocks of this unit were not tilted by middle Tertiary normal faulting.
- Tso - Oligocene to Paleocene Sedimentary Rocks (30-65 Ma.)
    - Light-colored, weakly to moderately consolidated conglomerate and sandstone deposited largely or entirely before middle Tertiary volcanism and extensional faulting. Sediments of this map unit are commonly referred to as "rim gravels" because they now rest on or near the Mogollon Rim, which is the southwestern edge of the Colorado Plateau.
- PP - Permian to Pennsylvania Sedimentary Rocks (280-310 Ma.)
    - Interbedded sandstone, shale, and limestone usually characterized by ledgy outcrops.

Geotechnical

The site's soil is classified as Tours fine sandy loam with an AASHTO classification of A-4. With a K-factor of 0.28, the soil is only moderately erodible. The soil's hydrologic soil group is C, meaning that it has a slower infiltration rate (Add Citation).

Climate

The U.S. Climate Data uses a weather station in Whiteriver, Arizona located at Longitude: -109.986 and Latitude: 33.8106. The data reported is from 1981-2010. Figure 3 shows that Whiteriver has a high of 90 degrees Fahrenheit and a low of 24 degrees Fahrenheit. There is a high of 3.62 inches of precipitation and a low of 0.59 inches of precipitation, and the average annual precipitation is 20.16 inches (Add Citation).

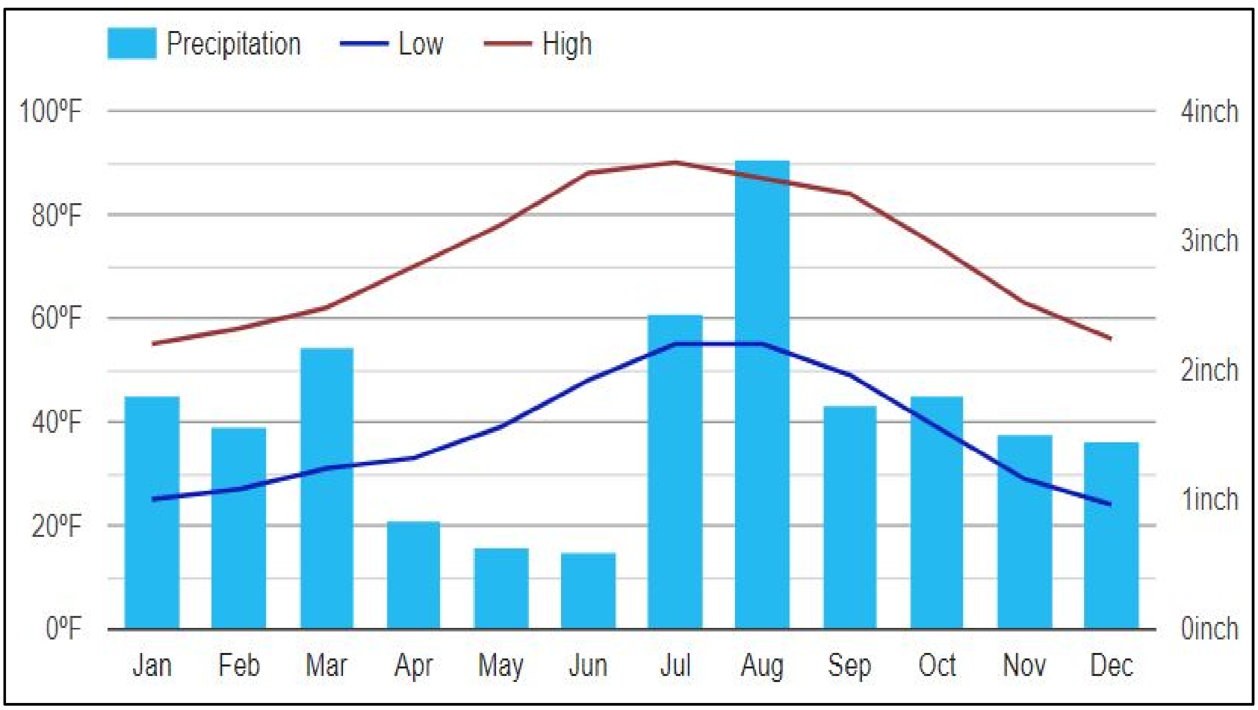

Figure 5: High and Low Temperature Including Precipitation

Figures 5 through 9 were acquired from WeatherSpark. Figure 5 shows the average temperatures in Whiteriver, Arizona. The highest temperature is 87 degrees Fahrenheit and the lowest temperature is 27 degrees Fahrenheit. The hot season is about 3.5 months long lasting from late-May to mid-September. The cold season is about 3 months long lasting from mid-to-late-November to late-February. The moderate season lasts for a total of 5.5 months from late-February to late-May and from mid-

September to mid-to-late-November. The temperature rarely goes higher than 87 degrees Fahrenheit and lower than 27 degrees Fahrenheit.

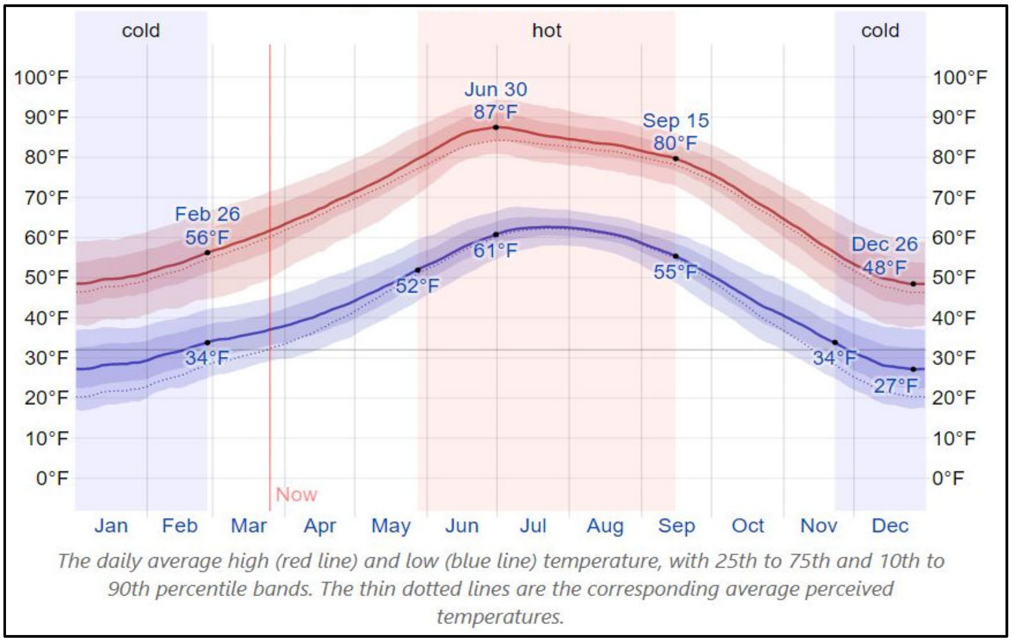

Figure 6: Average High and Low Temperatures

Figures 7 and 8 shows the average highest precipitation of rainfall and liquid-equivalent snowfall of 27.3 inches and the lowest precipitation of 2.8 inches, and an average annual rainfall of 12.7 inches. The rainy period (wet season) of the year lasts for 9.5 months from late-June to early-April. The rainless period (dry season) lasts for 2.5 months from early-April to late-June. The snowy period lasts for less than two months from mid-December to early-February.

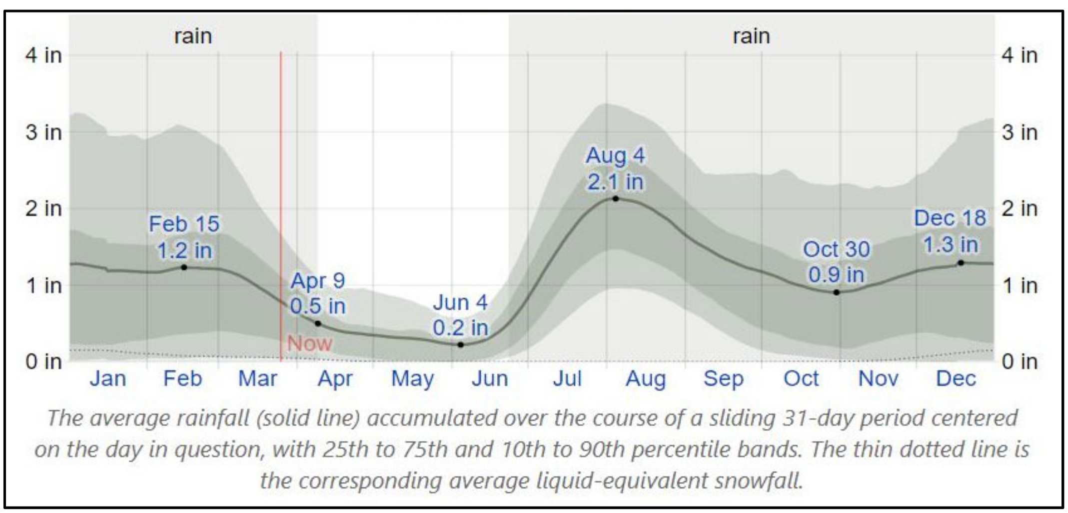

Figure 7: Average Monthly Rainfall

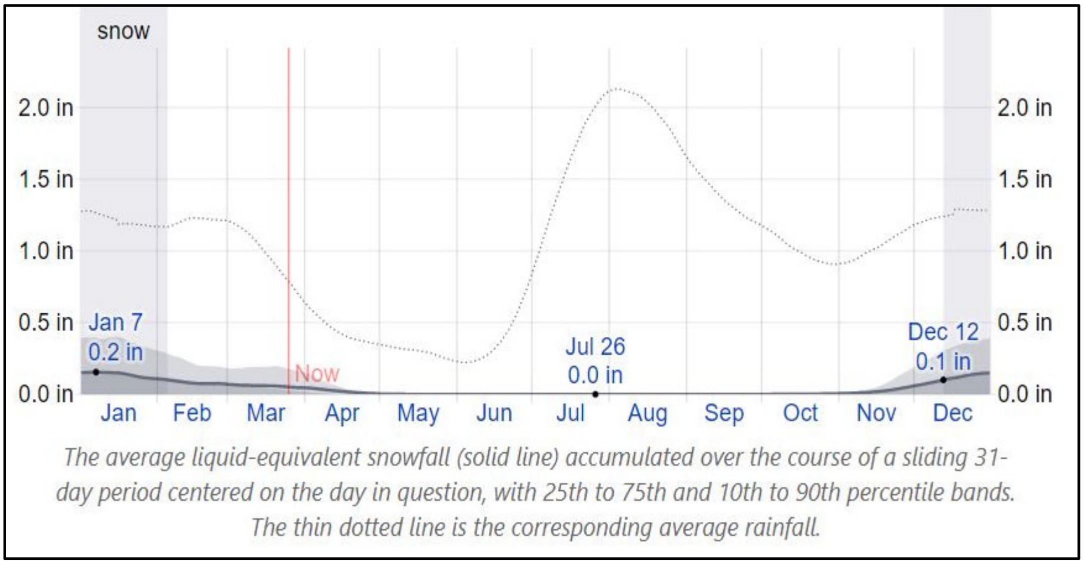

Figure 8: Average Liquid-Equivalent Monthly Snowfall

The growing season is the longest continuous period of non-freezing temperatures (≥ 32°F) in the year. Figure 7 shows the growing season in Whiteriver, Arizona is from mid-to-late-March to mid-November. The growing season lasts approximately 8 months within each calendar year.

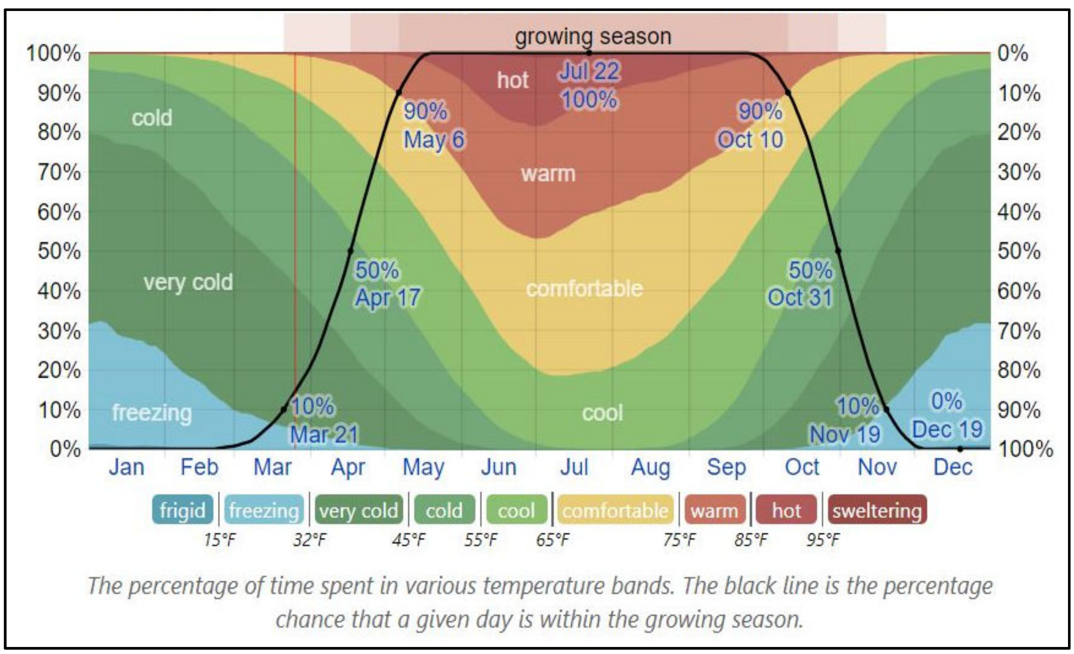

Figure 9: Growing Season

Local Demographics

The town has a population of 4,280 with a land area of 15.67 square miles (10,028.8 acres), and a water area of 0.11 square miles (70.4 acres). The elevation of Whiteriver is approximately 5,246 feet. Whiteriver has a population density of 273 meaning a person for about 2.34 acres of area. The Tribe sees their land and surrounding environment as very valuable and important to protect and preserve, they do not and will not build large residential communities for large populations in their cities and towns. (Add Citation).

The diversity index in Whiteriver is 9 meaning the town is not very diverse. The diversity index is a scale of 0 to 100 that represents the likelihood that two persons, chosen at random from the same area, belong to different races or ethnic groups. If an area's entire population belongs to one race and one ethnic group, then the area has a very diversity index (Home Town Locator 2020). The low diversity index for this area is expected since the project site is located in a town that is located within the White Mountain Apache Reservation. This location is not only the current home of the White Mountain Apache Tribe but has also been the ancestral home of the tribe for centuries (WMAT 2021).

Whiteriver has 1,093 total housing units. 482 are owner occupied, 557 are renter occupied, and 54 are vacant units. Whiteriver has 1,039 total households with an average household size of 4.09. Therefore, there are 844 family households with the average family size being 4. The population grew 0.41% per year from 2010-2020 and is projected to grow 0.44% per year the next 5 years. The households grew 0.31% per year from 2010-2020 and are projected to grow 0.38% per year the next 5 years. The total families grew 0.29% per year from 2010-2020 and is projected to grow 0.38% per year for the next 5 years. The owner occupied housing units are projected to grow 0.37% per year over the next 5 years. The slight increase in population, family, and housing will add to the existing demand for more sustainable agricultural products. Thus, the availability of water and the ability to get it to the agricultural sites will need addressed (Add Citation).

Design Requirements

The purpose of this project is to promote the White Mountain Apache Tribe's return to their agricultural roots and to address the problem of access to water for crop irrigation purposes. This project will research, analyze, and recommend the most efficient way to transport and store water on the site. The scope will include the design of a water conveyance (transport) and storage system to include sizing of any pipes, pumps, lagoons, tanks, and\or cisterns to deliver water to the site and store it for agriculture irrigation purposes. Current options that need to be researched include; pumping from a groundwater source, pumping from a river source, diversion from a river source, canal restoration, rain harvesting, retention ponds, below grade cisterns, water storage tanks, and water bladders. The design alternatives that are being considered will be explained more depth in the following sections of this report.

Design Criteria

The WMAT Water Rights Quantification Agreement confirmed by the United States Congress in the Claims Resolution Act of 2010 authorized and directed the Bureau of Reclamation to construct the WMAT Rural Water System to divert, store, and distribute water from the North Fork of the White River. Section 403(c) of the Act designated the Bureau of Reclamation as the lead Federal agency with respect to ensuring compliance with applicable environmental laws and regulations associated with the implementation. The action would include construction and operation of the WMAT Rural Water System, including a dam, storage, reservoir, pumping plant, treatment facilities, and a distribution system to provide water to communities. After the 3-year period, the WMAT would take ownership, operation, and maintenance of the system. The Bureau of Indian Affairs is also a cooperating agency on the project because of its statutory responsibility regarding Indian Trust Assets (add citation).

Environmental Code

Section 1.1 of the WMAT Environmental Code states the purpose is to maintain a clean, healthy, and safe environment on the Reservation. Chapter Three is the Water Quality Protection. Section 3.1 states the Tribe is authorized and recognizes Section 518 of the Clean Water Act, 33 U.S.C. 1377. The purpose is to; 1) promote the health of tribal waters and the people, plants, and wildlife that depends on them through holistic management and sustainable use, 2) designate the existing and attainable uses for which the surface water of the Tribe shall be protected, 3) prescribe water quality standards to sustain the designated uses, and 4) assure that degradation of existing water quality does not occur. Waters which are not in immediate hydrologic connection with other surface or subsurface waters, such as some stock tanks, constructed wetlands, and treatment lagoons are excluded. Artificially created conveyance systems such as irrigation ditches are also excluded. The standards do apply to the receiving bodies of water impacted by the effluent from such sources. The specified criteria apply to substances attributable to point source discharges, nonpoint sources, or instream activities. The criteria shall not apply to natural phenomena not brought about by human activity. The Tribe's Environmental Planning Office (EPO) shall work in cooperation with other Tribal entities, the U.S. Environmental Protection Agency (EPA) and other appropriate agencies to implement this ordinance. Section 3.2 is the anti-degradation policy. Existing instream water uses and the level of water quality necessary to protect the existing uses shall be maintained and protected. There are several numeric standards that shall not be exceeded, these values are different to protect; irrigation, domestic/industrial water supply, groundwater recharge, livestock and wildlife, primary contact, ceremonial primary contact, and the gathering of plants. Also, actions that disrespect waters of religious significance are prohibited (add citation).

The White Mountain Apache Tribal Plan and Project Review (TPPR) carries out the policies of the Tribal Council concerning the Tribe's natural resource base. This code shall govern and is applicable to any project which impacts Tribal lands or the natural resources within the Reservation. Section 4.8 is the review process; 1) Submittal to TPPR Coordinator, 2) TPPR Panel Review, 3) Tribal Council Decision. Any person, prior to undertaking a project governed by this Code, shall first submit a written proposal and comply with the review process and requirements. Section 4.12 states the exempt activities for the Code; decisions by Board concerning applications for grazing land and farm land assignments (add citation).

Government Code

Section 5.6 states any non-member conducting any study, surveying or mapping of the land, water resources, soil, geology, topography, forest, grazing lands, atmosphere, fish and wildlife, minerals, culture or people without prior consent and approval shall constitute grounds for the immediate removal and exclusion of said person from the exterior boundaries of the Reservation (add citation).

Health and Safety Code

Section 3.1 states no person shall willfully poison or pollute any spring, well, stream, river, reservoir, or other water. Section 3.3 states no person shall deposit on any of the water or the rivers, streams and ditches any sawdust, pulp, oils, rubbish, filth, or poisonous or deleterious substance which affects the health of persons, fish, or livestock, or render said waters unpalatable, distasteful, or unsafe. Section 4.1 states no person shall unlawfully interfere with, befoul, obstruct or tend to obstruct, or render dangerous for passage a stream, canal ditch, mill-race or basin, or a public park, square, street, alley, bridge, culvert, causeway or highway (add citation).

Housing and Construction Code

Section 1.1 states the policy of having and complying with a Uniform Housing Code. Section 1.2 adopts the 2006 International Building Code of the International Code Council and any amendments. Section 2.1 states the policy of having and complying with a Uniform Plumbing Code. Section 2.2 adopts the 2006 International Plumbing Code of the International Code Council. Section 3.1 states the policy of having and complying with a Uniform Housing Code. Section 3.2 adopts the 2006 International Residential Code of the International Code Council. Section 4.1 states the policy of having and complying with a Uniform Electrical Code. Section 4.2 adopts the 2008 National Electric Code of the National Fire Protection Association. Section 5.1 states the policy of having and complying with a Fire Prevention Code. Section 5.2 adopts the 2006 International Fire Code of the International Code Council. Section 7.1 states the policy of having and complying with a Uniform Mechanical Code. Section 7.2 adopts the 2006 International Mechanical Code of the International Code Council (add citation).

Land Code

Section 1.2 states the purpose is to formalize the assignment and usage of lands for farming and other beneficial purposes, preserve the land and other resources of the Reservation through proper use and management (add citation).

Land Restoration Code

Section 1.1 states the purpose is to implement Resolution No. 11-95-354 "to return tribal ecosystems to a condition that better reflects their condition prior to suffering damage from the mismanagement and to fund the education of Tribal members in disciplines related to natural resource management." Section 1.2 gives authority to the White Mountain Apache Tribal Council. Section 4.1 states all projects at minimum shall include the following: consistency with Tribal cultural values and concerns, consistency with Tribal ecosystem goals and objectives, compliance with applicable environmental natural resource and other laws, measurable results using reasonable measures and standards, efficient means for achieving goals, long-term sustainability, an itemized budget and plan of work, and provisions for a final report to the Board evaluating the project. Each proposal shall be submitted to the Land Restoration Projects Coordinator for review and approval (add citation).

Design Alternatives under Consideration

Rainwater Harvesting

One of the alternatives under consideration is rainwater harvesting. This method of capturing and storing water involves tying roof drains to a barrel, cistern or storage tank in order to collect rainwater, which can be saved to use at a later time. one-inch of rain can produce 0.623 gallons of water per square foot of rooftop, given by the following equation:

1 SF roof * 1 in rain * (1 ft / 12 in) * (7.481 gal / 1 CF) = 0.623 gal / in rain / SF roof

This site features two buildings which could both be set up to harvest rainwater. The northern building has approximately 1,721 square feet of rooftop and the southern building has approximately 1,392 square feet of rooftop, which means that these buildings could produce 1,072 and 867 gallons of water for one inch of rain . On a yearly basis, a rain harvesting system could collect 13,614 gallons from the northern building and 11,010 gallons from the southern building. More research would be needed to adjust these water totals based on the efficiency of the collection system, evaporation, temperature, and wind.

Figure 10: Northern building roof area


Figure 11: Southern building roof area

The stored water may be distributed either by gravity or pumping depending on the elevation and distance of the storage device relative to the area intended for distribution. More research will be needed to determine the topography of the site.

Irrigation Canals

Irrigation by divergence of surface water through restored irrigation canals is another design alternative under consideration for this project. This design alternative may be feasible due to the location of the existing canals in the area. In this system, water from the river and runoff from the mountains is diverted into canals and transported to the agricultural land. Some advantages of this design include; utilizing the existing canal system, low environment impact, low capital costs, and no energy required to transport the water (no pumping). Some disadvantages of this design include; restoration costs, maintenance time and labor, and quality control checks (tend to be labor intensive), inefficient application of water to crops compared to other alternatives, and the need to use the field space for additional conveyance and storage of water. Fields may need to be well graded in order to allow a gravity system to be utilized. The construction of head gates to control the volume of water will also likely be needed.

Pumping from White River

Another option for the site is to pump water from the White River located approximately 80 feet west of the project site. The system will have to pump enough water a distance of more than 400 feet to the crops. Pump sizing will be determined in the preliminary design phase. Pumping from the White River may be the hardest design alternative due to since the water will need to be pumped beneath or above the public right of way, River Road. The existing road will also have to be closed for a period of time to allow the construction of the piping system. Possible energy sources also need to be researched to provide power options for the pump(s). However, one advantage of this alternative is that this method would provide a dependable source of water, on demand, for agricultural purposes.

Groundwater

A fourth option for the site would be to construct a well and pump the groundwater directly to the crops or to a conveyance system. The feasibility of installing a well will need to be researched by determining the geology and depth to the groundwater aquifer and the location of the well, if feasible. Once a well is installed, water can then be pumped up and distributed to the crops. Well sizing and pumping requirements will be determined in the preliminary phase of the project. Advantages include needing construction only on the project site. . Disadvantages include the cost of having to test to find an adequate well depth and installing the well and pump system.

Recommendations

At this time, the project team believes the most feasible options of the design alternatives discussed are rainwater harvesting, restoring the existing irrigation canals, or installing a well and utilizing groundwater. It is our opinion that pumping from White River to the site would likely be very difficult and expensive for a single site, as this could require tearing out and replacing pavement in order to lay pipe, or implementing a complex structure to allow pipes to run overhead. Rainwater harvesting and groundwater would be the least expensive options and may be the easiest to implement on site since both designs do not impact surrounding properties. Restoring the irrigation canal system would be significantly more expensive but it could help other members of the tribal community access water for agriculture purposes but more research is needed to determine the scale and feasibility of restoring the canal or canal sections.

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