Evaluation of
Navajo Nation’s
Hydroclimate Network: Issues and Insights

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Project Funding

The Arizona Water Institute (AWI) has been formed to unite the work of Arizona’s three universities to focus on water education, research, community assistance and economic development in Arizona and in arid regions across the world.

http://www.azwaterinstitute.org/
Background

- Navajo Nation Department of Water Resources (NNDWR) operates 209 hydroclimate gages in several environmental networks – since 1984.
- The networks include stream gages, automated weather stations, snow courses, recording and non-recording precipitation gauges.
- Many federal and state agencies, as well as mining companies collect data in Navajo Nation or nearby.
- NDWR data collection requires more manpower than resources will accommodate; nevertheless, these hydroclimatic data can provide valuable information for drought and floodplain management, and to ensure public safety.
• On-reservation population is more than 183,000
• 25-40% haul water for domestic use
• Uses: livestock, traditional agriculture, forestry, recreation, public drinking systems

Challenges

The arid environment of the southern Colorado Plateau subjects Navajo Nation to high inter-annual precipitation variability. The region is prone to multi-year drought, flash floods, and low groundwater recharge rates.
This series of U.S. Drought Monitor "snapshots" illustrates Navajo Nation's vulnerability to drought, during the last 5 years.
Overview

• Project initiated in January 2007
• Goals
  • Evaluate NNDWR hydroclimate network
  • Provide science-based recommendations for reducing network redundancy
  • Examine potential for data exchange
  • Determine instrumentation and communication needs and possible solutions
Strategy

• Site visits
• Interviews
• Data Analysis
• Workshop
Data Analysis

- Precipitation gauges – “rain cans”
- Automated Weather Station Density
- Streamflow
- Instrumentation issues
- Alternative networks: Northern Arizona Mesonet
Workshop

• October 9, 2007
• Information exchange
• Data network development
Key Assumptions

- Limited budget for system overhaul; no major increases expected
- There is no ideal network, unless guided by specific uses
- Maximize uses for each station
- Maximize spatial distribution, uniform coverage
- Fewer good data are better than many poor data
Snow and Streamflow Data Issues

- Snow course data collection adheres to USDA-NRCS standards
- Most streamflow data are collected monthly
  - Two gages are operated in conjunction with USGS
  - Peak flood flows are not collected
- Sometimes there are lags in re-calculating streamflow rating curves
  - Due to lack of adequate manpower, stream channels are not maintained well enough to ensure consistent ratings
- Most stream gages are located in the central part of Navajo Nation
Weather Data Issues

- Historic non-recording rain gauge data, collected between the beginning of the last week of one month and the end of the first week of the following month, does not correspond to the calendar month system used by other agencies.
- Before 2000, many rainfall stations had sporadic collection, resulting in many missing data.
- Automated weather stations are not recalibrated annually.
- Station densities are higher near the Chuska Mountains and Defiance Plateau than elsewhere throughout Navajo Nation.
Hydroclimatic Network Overview

The following slides illustrate the distribution of Navajo Department of Water Resources hydroclimatic stations and gauges, as well as the distribution of stations used by other agencies for hydroclimatic data collection.
Hydroclimatic Network Issues

The following slides illustrate data collection and particular issues of concern.
Fluted Rock Snow Course

Snow data are collected according to USDA-NRCS standards. (Note low snow levels during winter 2006-07)

January 4, 2007

Photo: G. Garfin
Recording Rain Gauge
(known as a “rain can”)

January 4, 2007

Photo: G. Garfin
Recording rain gauge data can provide hourly-to-daily time resolution; however, digitizing the data is human resource intensive.
Sheep Springs Automated Weather Station

Automated stations are well sited and provide excellent time resolution. However, equipment needs updating, and telemetry is lacking.

January 5, 2007

Photo: G. Garfin
Sheep Springs Automated Weather Station

Tipping bucket gauge

Non-recording “rain can”

January 5, 2007
Safety of Dams automated stations provide real-time data for protecting lives and property. Where gaged stream channels have been maintained, long-term data can supply hydrographs for flood prediction.

Photo: G. Garfin
June 6, 2007
**Kinlichee Creek**

The Kinlichee Creek, anchored to a bridge, gage has good control, and the channel is reasonably maintained. The stage-discharge relationship is excellent.

January 5, 2007

Analysis: Aregai Tecle, NAU
Note how stream braiding during low flows results in a probable underestimate of flow.

Analysis: Aregai Tecle, NAU
The Chinle Creek gage suffers from stream braiding, sediment accumulation, and stream side vegetation growth. The stream-discharge relationship shows little correlation.

Analysis: Aregai Tecle, NAU
Uneven rain gauge (rain can) station density

Nation-wide: 1 gauge / 281 mi²
Western region ~ 1 gauge / 475 mi²
Mountain region ~ 1 gauge / 127 mi²
Eastern region ~ 1 gauge / 264 mi²

Analysis: Nancy Selover, ASU
NN Rainfall Data Issues

• Head to head comparison of Navajo to NWS COOP network rainfall is difficult as only 3 high quality stations are essentially co-located
  – Many Navajo stations are co-located with discontinued NWS COOP sites
  – Missing data limit evaluations
• Solution:
  – Compare NN Network with NWS COOP Network for 2001-2006 (few missing data), rather than trying to compare all the stations with a single nearest neighbor
Annual precipitation, summed over the Navajo Nation collection periods.

If months of Navajo precipitation were missing, the corresponding COOP data were not included.

These two sites, although relatively close, have entirely different terrain and exposures. Poor correspondence.

Analysis: Nancy Selover, ASU
Fairly good correspondence at annual time scales (above). Monthly and seasonal data analyses (below) shows relatively low correlation for these nearby sites.

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Utility of rain can network data

• Map A shows winter 2002 precipitation using data interpolated from NWS COOP stations only
• Map B shows an inset of winter 2002 precipitation using data interpolated from NNDWR rain cans only – note the improved spatial variability in the Chuska Mountains and the northwestern Nation
• Map C shows winter 2002 precipitation using all data

Analysis: Nancy Selover, ASU
Potential reductions in the rain can network

- Map A shows rain cans (red stars), and stations from several other precipitation networks.
- Map B shows the potential for rain can reduction, by removal of rain cans within 15 km (~10 mi.) of other networks.
- Map C shows further reductions, if NWS cooperators could be established in each Navajo Nation Chapter (red dots).

Analysis: Nancy Selover, ASU
Conclusions:

• The best COOP – Navajo precipitation pair had only 50% of the variation of the COOP data explained by the Navajo data on a monthly basis. This points out the importance of good station siting conditions.

• The NNDWR precipitation data already collected are useful only at seasonal or annual timescales, which are sufficient for drought monitoring – provided that data continuity is maintained. Since only 3 stations have significantly more than 5 years of data with 25% or less missing data per year, long-term climate study is not possible.

• The data do fill significant holes in the COOP network, so a dense precipitation network would benefit both the Navajo Nation and the surrounding communities.

• There are sufficient stations from other networks to remove over half the WMB precipitation gauges, and if NWS COOP sites could be established in each of the Nation’s Chapters, the entire network could be replaced, removing the burden of monthly data collection, QA/QC, and data reduction.

Analysis: Nancy Selover, ASU
Archived digitized data are available for only a few of the automated weather stations.

Analysis: Nancy Selover, ASU
Extending the Navajo Automated Weather Station Network

- Navajo Nation operated stations are concentrated in the center of the Reservation.
- If non-Navajo stations (COOP and Northern Arizona Mesonet) are included, spatial coverage is fairly good at a maximum distance between stations of 50 km.
- We identified five regions which have no stations within the 50 km maximum distance.
- These regions could be covered with the addition of six weather stations at reasonably easy to visit sites.
- We were able to determine the location and ownership of cell towers nearest each proposed station.
- We were not able to calculate a cost to visiting sites due to the lack of available road data with usable impedance (difficulty of travel) values.

Analysis: Paul Heinrich, NAU
• Extending the Navajo Automated Weather Station Network:

Map A: Existing automated stations with 50 km (~30 mi.) buffers
Map B: Automated station gaps

New station sites were selected based on ease of access and proximity to telecommunications

Analysis: Paul Heinrich, NAU
Navajo Nation, Northern AZ Mesonet, NWS COOP Weather Stations, and Sites for New Automated Stations to fill in significant gaps

Analysis: Paul Heinrich, NAU
Northern Arizona Mesonet

- The Northern Arizona Mesonet (NAM) is a network of wireless, solar-powered weather stations located throughout northeastern Arizona
  - thirteen measured and calculated parameters are automatically uploaded to a web server every 2 minutes
- NAM is a partnership between Northern Arizona University, Navajo Nation Schools, and the National Weather Service
- NAM provides one opportunity for enhancing automated hydroclimate data flow for Navajo Nation

NAM URL:  http://www.cens.nau.edu/~nauws/nam.html
NAM Project leaders:  Diana Anderson, (NAU), Mike Staudenmaier (NWS), Carol Haden (NAU)
Northern Arizona Mesonet

- **Wireless Davis Vantage Pro 2** with Solar Power
- **Sensors**
  - Anemometer, barometer, tipping rain gauge, radiation shield with temperature and humidity sensor
- **Display interface**
  - Weatherlink*, PCLink for Windows*, and Virtual Weather Station*

*This does not constitute endorsement of equipment or software*

NAM Project leaders: Diana Anderson, (NAU), Mike Staudenmaier (NWS), Carol Haden (NAU)
**NAM Stations**

**Flagstaff Stations:**
- Aspen Trail Subdivision
- Coconino High School
- DeMiguel Elementary School
- Flagstaff Arts and Leadership Academy
- Flagstaff High School*
- Flagstaff Middle School
- Northern Arizona University
- Sinagua High School

**NE Arizona Stations:**
- Doney Park
- Hopi Jr/Sr High School (Keams Canyon)*
- Leupp Schools Incorporated
- National Weather Service Office (Bellemont)
- Page Middle School**
- Red Mesa High School (Teec Nos Pos)
- Rocky Ridge Boarding School**
- Tuba City Junior High
- Shonto Boarding School**

*No current web access to data
**Station not up yet, planned station

**NAM URL:** [http://www.cens.nau.edu/~nauws/nam.html](http://www.cens.nau.edu/~nauws/nam.html)

NAM Project leaders: Diana Anderson, (NAU), Mike Staudenmaier (NWS), Carol Haden (NAU)
Navajo Nation
Hydroclimate Data Workshop

- Motivation: maximize NNDWR resources by partnering with other regional networks
  - catalog regional data collection efforts

- Workshop
  - October 9, 2007 – Northern Arizona University, Flagstaff, Arizona
Regional Data Collection
Bold = workshop participant

Hopi Tribe
Zuni Tribe
U.S. Geological Survey
National Weather Service
Northern Arizona University
Peabody Energy
Bureau of Land Management
BHP Billiton
Arizona Department of Transportation
New Mexico Department of Transportation
Utah Department of Transportation
USDA-Natural Resources Conservation Service
Arizona ALERT Flood Warning System
National Park Service
Navajo Agricultural Products Industry
Navajo Nation Department of Water Resources
New Mexico State University
Workshop

KEY OUTCOMES

- establishment of data uses, needs, and partnership opportunities
- information exchange
- means to facilitate communication between regional data collection agencies
KEY RECOMMENDATIONS

■ VISION

  • Master Plan
    - short- & long-term plans based on current and anticipated available technologies
    - revise often to reflect changing needs & technologies
    - most important: clearly articulate regional needs

■ OPPORTUNITIES

  • Leveraging Resources
    - multi-agency partnerships: new stations & equipment
    - e.g., UDOT-Navajo Nation, Hopi Tribe-Navajo Nation

Analysis: Andrew Ellis, ASU
KEY RECOMMENDATIONS (continued)

- OPPORTUNITIES (continued)
  - Pilot Projects
    - use pilot research programs to build/enhance the network
    - Northern Arizona Mesonet
  - Volunteers
    - augment existing network through volunteer sites – “spotters”
    - user ownership is a strong motivator
  - NWS Cooperative Observer Network
    - some Navajo Nation sites incorporated into NWS COOP network
    - careful selection
    - data called-in to NWS Flagstaff

Analysis: Andrew Ellis, ASU
KEY RECOMMENDATIONS (continued)

- OPPORTUNITIES (continued)
  - Research, Modeling, & Monitoring
    - develop a heavily instrumented reference CO Plateau watershed
    - sited in Navajo Nation; research & developing prediction
    - fill-in existing network gaps; resources for enhancing automation
  - Data Access and Facilitation
    - data exchange – use existing efforts: MesoWest, AHIS, CUAHSI

Analysis: Andrew Ellis, ASU
KEY RECOMMENDATIONS (continued)

■ BARRIERS

• Automation & Electronic Communication
  - lack of automation hampers network enhancement & data exchange
  - overcome automation issue:
    a) select a few existing sites for automation and expand incrementally
    b) use established internet connectivity (e.g., chapter houses) or Law Enforcement Telecommunication System (LETS)

• Funding
  - no secure funding options identified

Analysis: Andrew Ellis, ASU
KEY RECOMMENDATIONS (continued)

■ TECHNICAL NEEDS

• Real Time Data
  - top priority for hydroclimate applications
  - frequency of 5-min to 1-hr useful for operations (e.g., flooding)
  - aggregate data for more coarse monitoring (e.g., drought)

• Drought
  - high priority
  - drought forecasting; groundwater recharge

• Data Accuracy
  - barrier to successful application
  - heated tipping-bucket precipitation gauge

Analysis: Andrew Ellis, ASU
Workshop

Follow-up

- catalog of data collection efforts in the region
- explore use of LETS by Navajo Nation
- invitation-only email forum
- creation of working group – in association with new AWI project (Tecle)

Implications

- great enthusiasm from regional organizations
- maintain engagement – aim for formal partnerships
- invest in enhanced automation
- develop a master plan

Analysis: Andrew Ellis, ASU
Key Conclusions

• Limited data quantity and quality
  • Lack of continuity; data collection timing does not coincide with calendar dates; lack of sufficient site maintenance and rating curve re-calculation influences streamflow data; lack of station calibration influences weather data
• Data value – OK for qualified baseline assessment and to serve as a spatial supplement
  • Seasonal time scales (OK for drought…if data continuity is maintained)
• Master planning will guide station (re)location
Recommendations

- Develop a master plan
  - Due to quality control issues, precipitation gages cannot be selected based on data quality; thus, gage selection must be guided by specific data needs
- Enhance data communication
  - Telemetry, digital data download
- Leverage existing networks
- Fill-in spatial gaps
- Enlist cooperators
  - Phone or use Internet to convey data to NWS
Recommendations

• Use interpolated products for climate monitoring
• Shift streamflow resources toward gage maintenance and data communication
• Communicate through data sharing networks
• Enhance staff training