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A Dynamic Water Budget Model of Nambe Pueblo

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Introduction

Nambe Pueblo is in the process of ascertaining future water needs and management practices for agricultural, domestic, recreational, industrial and commercial uses.

Current water use at Nambe Pueblo includes water diverted from the Rio Nambe for irrigated agriculture and ground-water diversion for domestic use and livestock watering. The Rio Nambe is a perennial stream that originates in the Sangre de Cristo Range east of the pueblo.

A US Bureau of Reclamation (USBR) dam on the Rio Nambe stores water in Nambe Reservoir upstream of the Nambe Pueblo village and farmlands. This reservoir is within pueblo boundaries and supplies irrigation water for the Nambe, San Ildefonso, and Pojoaque Pueblos as well as the Pojoaque Valley Irrigation District (PVID). Nambe Pueblo also stores water in the reservoir to maintain a recreational pool for fishing and camping.

Here we present work on a water budget model based on the system dynamics (SD) approach that allows stakeholders to easily explore "what if" water management and use scenarios through a user-friendly interface and succinct graphical output. In this presentation recent work on reservoir operations are emphasized. Accurately simulating reservoir operations is crucial to capturing the dynamics and interrelationships of agricultural use and water storage by Nambe Pueblo under varying climatic conditions.

Objectives

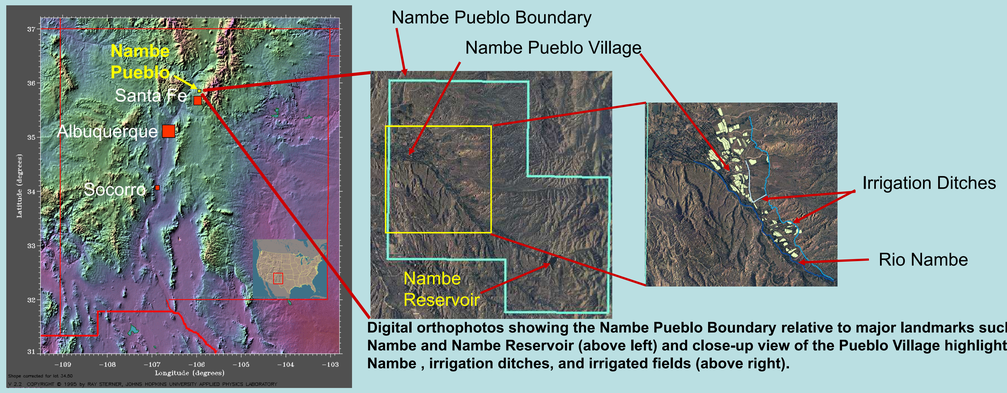
1) To develop a physically based dynamic water budget model that captures the interrelationships between water use and hydrologic processes and can be used by Nambe Pueblo to explore the outcomes of various water management and use scenarios under a suite of user selected hydrological conditions and social demands.

2) To directly involve Nambe Pueblo members in the structuring, conceptualization, quantification, and calibration of the model with the objective to help the stakeholder understand the principles on which the model is based.

3) To identify data gaps and uncertainty that limits modeling of the physical hydrological system in its entirety and to develop workarounds where necessary to capture essential water budget dynamics.

4) To develop an interface that captures the real day to day agricultural operations of the pueblo (diversion rates, irrigation schedules, and efficiencies) and other water uses under a spectrum of user selected water supply conditions.

Location and Overview of Nambe Pueblo Lands



Digital orthophotos showing the Nambe Pueblo Boundary relative to major landmarks such as the Rio Nambe and Nambe Reservoir (above left) and close-up view of the Pueblo Village highlighting the Rio Nambe , irrigation ditches, and irrigated fields (above right).

New Mexico Location Map for Nambe Pueblo

Nambe Pueblo Water Supply

Surface Water:

Rio Nambe

- The drainage area above Nambe Reservoir is 36 mi^2 and varies in elevation from 6800 ft at the dam to 12620 ft at the western most ridge of the north-south trending Sangre de Cristo Range

Nambe Reservoir

- Storage capacity is approximately 1900 ac-ft with an active storage of 1600 ac-ft
- The reservoir usually spills in response to spring run-off
- Supplies 1,030 ac-ft/yr of supplemental water for 2768 acres of irrigated land
- A portion of the water released from the Nambe Reservoir (33.92%) is shared among the Pueblos in the area (Nambe 14.38%, Pojoaque 1.73%, and San Ildefonso 17.81%) and non-Indian users served by Pojoaque Valley Irrigation District (PVID) 66.08%
- Nambe Pueblo irrigates approximately 190 acres and maintains a recreational pool at Nambe Reservoir with their share of the water
- Dam Releases are managed by PVID
- Release schedules are negotiated in meetings between PVID and the three Pueblos and are based on current water-supply conditions and water-supply outlook for the year

Ground-Water

- Most ground-water is supplied by a IHS managed well that taps the regional aquifer
- Diverted ground-water is used primarily for domestic purposes
- Ground-water is also likely diverted for domestic use by a few smaller domestic wells

Current Nambe Pueblo Water Use

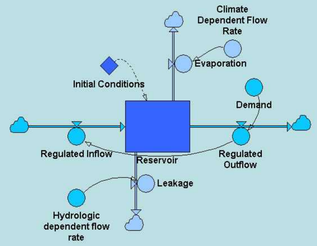
- Irrigation: pasture grass, alfalfa, orchards, gardens
- Livestock: cattle, horses and buffalo
- Domestic use
- Maintenance of a recreational pool at the reservoir

Potential Nambe Pueblo Future Water Uses

- Increased Domestic Use
- Industrial and Commercial Development
- Leasing of water

System Dynamics Modeling Basics

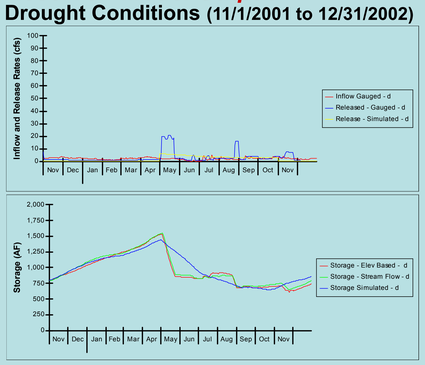
- Provides framework for managing multiple interactive time dependent sub-systems
- Quantification of feed-back, time delays, and coupling between subsystems
- Focuses on broad structure rather than details of any particular system or sector
- Models developed on a PC based software (Powersim Studio®) with interface icons (radio buttons for alternative management strategies, slider bars for variables), fast run times (seconds to minutes), and integrated output allow for efficient scenario testing.



Example of typical symbolism use in Powersims Studio®. Circles represent flow variables, blocks represent reservoirs where flows accumulate, thick arrows indicate direction of flow, diamonds represent constants, and thin arrows indicate connections between constants, variables and reservoirs. Variables can reference databases or contain equations that reference connected variables

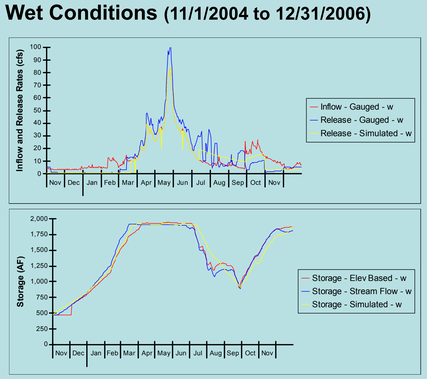
Reservoir Model Output

Drought Conditions (11/1/2001 to 12/31/2002)



Plots showing gauged and simulated inflow and release rates (above top) and storage (bottom) during a period of severe drought.

Wet Conditions (11/1/2004 to 12/31/2006)



Plots showing gauged and simulated inflow and release rates (above top) and storage (bottom) during a moderately wet period.

Reservoir Operations

Non-irrigation Season - November 1 to April 30

- Minimum release of 0.5 cfs to maintain flow in Nambe falls and storage inflow in excess of 0.5 cfs until elevation 6825.6 feet is reached, then releases are matched to inflow

Irrigation season - May 1 to October 31

- Storage and release on demand as agreed upon by PVID and the Pueblos during a pre-irrigation season meeting
- Magnitude of releases are dependent water supply outlook (snow pack)
- Release schedules are updated throughout the irrigation season as conditions change
- Natural inflow up to and including 10 cfs are passed through for use by the pueblos
- If downstream demand is greater than 10 cfs, then inflows above demand will be stored

Reservoir Operations Model

Model Basics

- Model time step is one day and simulation time is 13 months starting November 1.
- Inflow and elevation data is from the USGS
- Surface area and volume is tracked through a USBR area/capacity curve
- Precipitation is added to the reservoir volume (USBR Water Accounting Reports)
- Open water evaporation is calculated through reference evapotranspiration (ET) (Hargreaves ET model)

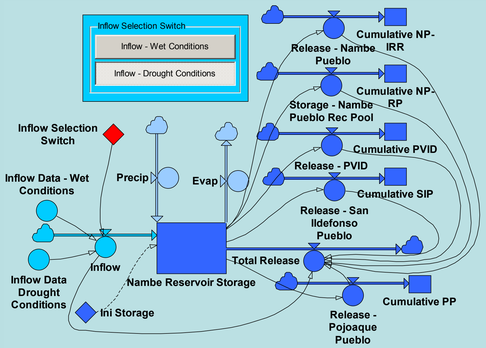


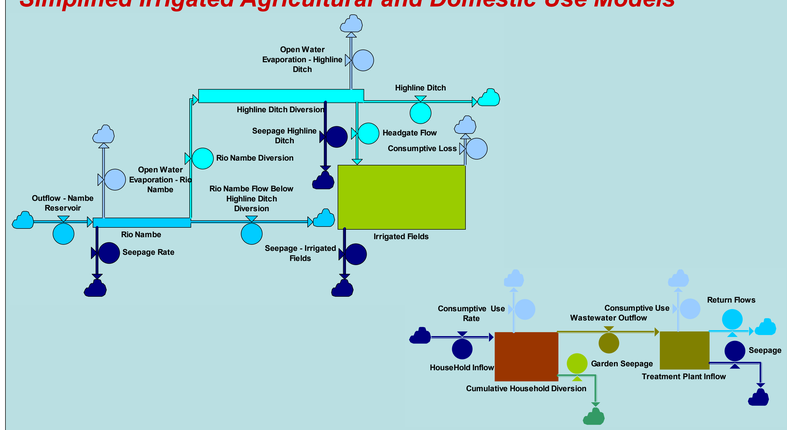
Diagram showing the basic components of the reservoir operations model

- Release rates are dependent on current storage and expected inflow into the reservoir
- Outflow is divided among PVID and the Pueblos in proportion to their water rights

Model Calibration

- Simulations were ran for two years of sharply contrasting water supply conditions in the Rio Nambe catchment basin and when both USGS inflow and release data were available: November 2001 to December 2002 and November 2004 to December 2005
- Simulated daily reservoir storage was compared to actual daily reservoir storage
  - Actual reservoir storage was obtained by applying USBR rating curves to USGS measured elevation data
- Open water evaporation was calibrated to USBR monthly surface water loss data published in the Water Accounting Reports
- Variables adjusted during reservoir storage calibration include the following
  - Reservoir inflow - required minor adjustment to match November through April filling rates when the off season releases were fairly constant
  - Expected inflow into the reservoir – expected inflow was taken as a percentage of the existing reservoir storage
  - Off season release – often the off season release is greater than the minimum of the 0.5 cfs given in the USBR SOP

Simplified Irrigated Agricultural and Domestic Use Models



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