Dniester River Basin Reservoir Simulation Model

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Outline

• Review of risk management framework for water resources adaptation to climate change
  – Results from workshop in Kiev December 2013
• HEC ResSim (reservoir simulation) model for Dniester River basin
• Review of reservoir management
• Results of initial reservoir simulations for different scenarios
• Discussion of possible next steps
Purpose

• Develop a risk assessment of the performance of water resources management under the threat of future climate changes and variability using a ‘bottom-up’ approach.

• A bottom-up approach is a stakeholder driven process to assess vulnerability rather than a reliance on predictive models of the future.
Review of Kiev Workshop

- Sectoral workshop held on 12 December 2013 in Kiev with experts and stakeholders from the Dniester basin.
- Three critical water resources sectors were selected for evaluation: flood risk management, ecosystems, and agriculture.
- Purpose was to begin development of a ‘bottom-up’ risk assessment of water resources management in the Dniester River basin under threat of future climate changes.
Flood Risk Management

• Metrics used to evaluate flood impacts and flood risk management: number (presence of) human deaths, economic costs of the flood damage including costs required to repair damaged infrastructure, and economic losses associated with the loss of crops.

• Possibility of reducing flood risk by restoring natural features of channels and floodplains, but limited due to high population and infrastructure density in floodplains.

• Role of Dniester River reservoirs: balance need for storing flood waters with the need for water supply during dry periods.
Ecosystems

• A great deal of ecological degradation has already occurred, and is continuing, on the tributaries of the upper watershed and lower estuary. Other anthropogenic impacts may be far greater than climate change effects.

• Objectives were identified: biodiversity; conservation of ecosystems with all components; optimization of water use; increasing ecosystem productivity; and improving sanitary and toxicological characteristics of the water environment.
Agriculture

• There is strong dependence between irrigation and crop yields. In Moldova, farmers need irrigation to grow vegetables and grapes.
• Climate is not the only factor causing changes in agriculture. There are socioeconomic changes underway as significant as climate.
• Objectives for agriculture sector are 1) agricultural productivity; 2) quality of yield; and 3) the environment (avoid adverse environmental impacts). Economic factors are most important.
Workshop Summary

• Participants expressed the need to balance flood storage with other demands for reservoir storage, such as water supply and hydropower.
• Need for reservoir storage for agricultural water supply may increase as irrigation infrastructure is repaired and if dry periods become more frequent.
• Reservoirs can be managed to provide flows to better support aquatic and riparian ecosystems.
• Based on feedback from workshop participants in later sessions, AGWA team would develop a model of the main stem Dniester River reservoirs to test reservoir management alternatives under a range of climate conditions.
Reservoir System Simulation (HEC-ResSim) software developed by the U.S. Army Corps of Engineers Hydrologic Engineering Center (HEC) is used to model reservoir operations at one or more reservoirs for a variety of operational goals and constraints. Software is free and available for download at http://www.hec.usace.army.mil/software/hec-ressim/.

Free distribution allows model to be shared widely among users.
Dniester River ResSim Model
Reservoir Morphology

Three levels define reservoir storage – More uncertain than bathymetric survey.
Reservoir Rule Curves and Storage Allocation

Allocation of Reservoir Storage Space

Shasta Reservoir, California, USA

New Bullards Bar Reservoir, California, USA

Less Precipitation

More Precipitation

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Dniestrovsky Reservoir Guide Curves

Reservoir Guide Curve in Old Reservoir Manual

Revised Reservoir Guide Curve with More Conservation
Tradeoff between conflicting objectives

Tradeoff between Hydropower and Flood Risk

Flooding (cms-maximum flow at Mogyliv-Podilskyi)

Hydropower (MW)
Dubasari and Buffer Guide Curves

Dubasari

Buffer
Reservoir releases can be made to meet downstream objectives, such as a minimum flow to meet a water supply need downstream or a maximum flow to prevent flood damages.
Hydropower Production

• Hydropower scheduling to meet power demands
  – Month of year: more power for heating in winter, air conditioning in summer?
  – Day of week: less power on weekends
  – Hour of day: time of peak demand
• We assumed constant schedule
Other Reservoir Operations

• Operate reservoirs as a system rather than as individual projects.
  – Balance conservation and flood storage among multiple reservoirs to better achieve objectives.
  – We simulated both tandem and individual operations.

• Ecosystem flows: provide more “naturalized” flows to support downstream riparian ecosystems.

• Use of hydrologic forecasts for reservoir management – early reservoir release based on flood forecasts.
Information Needs

• Hydrology & Hydraulics
  – Tributary data
  – Routing information
• Hydropower
  – Operating plans (seasonal and daily variations)
  – Function for power generation (i.e., elevation vs. outflows)
• Reservoirs
  – Better guide curves (particularly for Dubassari)
  – Any downstream requirements
• Consequences
  – Water supply demands for agricultural, industrial, municipal
    • Existing and Projected for Moldova
    • Projected for Ukraine
  – Flood damage curves downstream
Results

Performance Metrics

• Reliability for agricultural, municipal and industrial demands
• Reliability for ecological flows
• Maximum flood at Mogyliv-Podilskyi
• Hydropower production

Scenarios

• Climate
  – Observed flows from 1946 to 2010
  – Reduced inflows by 10% and 20%
  – Increased inflows by 10% and 20%

• Operations
  – Independent
  – Tandem
Peak Flow (cms) at Mogyliv Podilsky

- Observed Inflows
- 10% Increase
- 20% Increase

- Independent Operations
- Tandem Operations
Agriculture, Municipal, and Industrial Diversion Reliability (%)
Downstream Ecological Flow Reliability (%)
Hydropower:
Average Energy Production per Day (MWh)

Hydropower scheduling to meet power demands
- Month of year: more power for heating in winter, air conditioning in summer?
- Day of week: less power on weekends
- Hour of day: time of peak demand
1. Use scenarios to outline possible vulnerability domain

2. Link to climate conditions

3. Determine plausibility of scenarios

1. Downscale multiple model projections

2. Generate a few water supply series

3. Find whether system is vulnerable for these series

Tested vulnerability domain

1. Use scenarios to outline possible vulnerability domain

Source: Brown and Werick (2011): A decision analytic approach to managing climate risks. JAWRA
Multi-Factor Risk Assessments

Agricultural Reliability (%): Independent Operations

Agricultural Reliability (%): Tandem Operations

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Future Analyses

• Additional scenarios
  – Sedimentation in the reservoirs
  – Increased demands
  – More realistic climate change

• Different operating rules and scenarios
  – Updated guide curves
  – Updated hydropower operating rules
  – Updated downstream control points (flood control, agriculture, municipal/industrial)

• More sophisticated risk assessment
  – i.e., flood stage vs. damage curves to estimate consequences

Suggestions from participants?
Information Needs

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Proposed Next Step: Follow-on Workshop in Fall 2014

- **Overview of ResSIM Software Program**
  - More in-depth introduction to program by HEC employees

- **Verification of Dniester River Model**
  - Open up the model and verify our assumptions with participants

- **Climate Change Adaptation Exercises w/ Decision Scaling**
  - Stress the system and identify vulnerabilities under climate change
  - Outline adaptation approaches using reservoir operations
Thank you!

Questions?

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