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A Multi-Agent Approach for Water-Power Resilience Modeling:
A Western Irrigation District Jeopardized by Drought

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Background

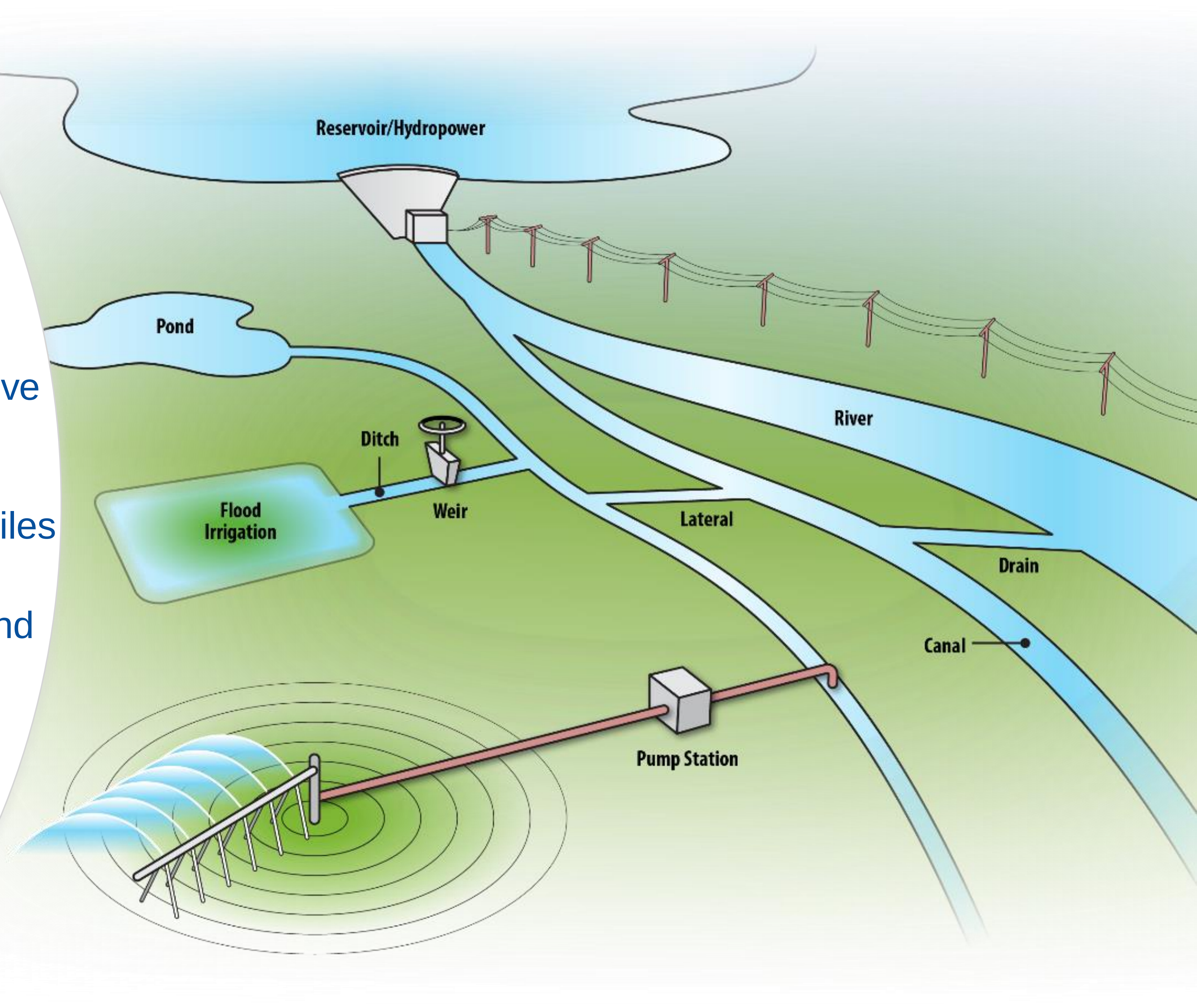
- Climate change and regional droughts pose an existential threat to many western farmers
  - Geographic redistribution of precipitation
  - Increased evaporation from reservoirs, canals, and fields
  - Changes in timing of seasonal and historic weather patterns

- Irrigation Districts
  - Own water rights, diversion facilities/infrastructure
  - Distribute water to district members

- Case-study Irrigation District
  - Features of multiple irrigation districts conglomerated to single model
  - Designed to operate like a real irrigation district

Case-Study Irrigation District

- Reservoir – 95,000 Acre-feet active storage
- Major Canals & Laterals – 120 miles
- 100,000 acres of irrigated farmland
- Several pumps
- Energy mix – local hydropower, wind, external purchased fossil fuel



Methodology

- Rule-based water/power resource management system
- Multi-agent system model
  - System components modeled as agents, which interact with each other based on pre-defined rules
- Water system components
  - Reservoir, canals, laterals, pumps, water demand
- Power system components
  - Generation sources, distribution components, power demand
- Crop yield – UN FAO crop coefficient method

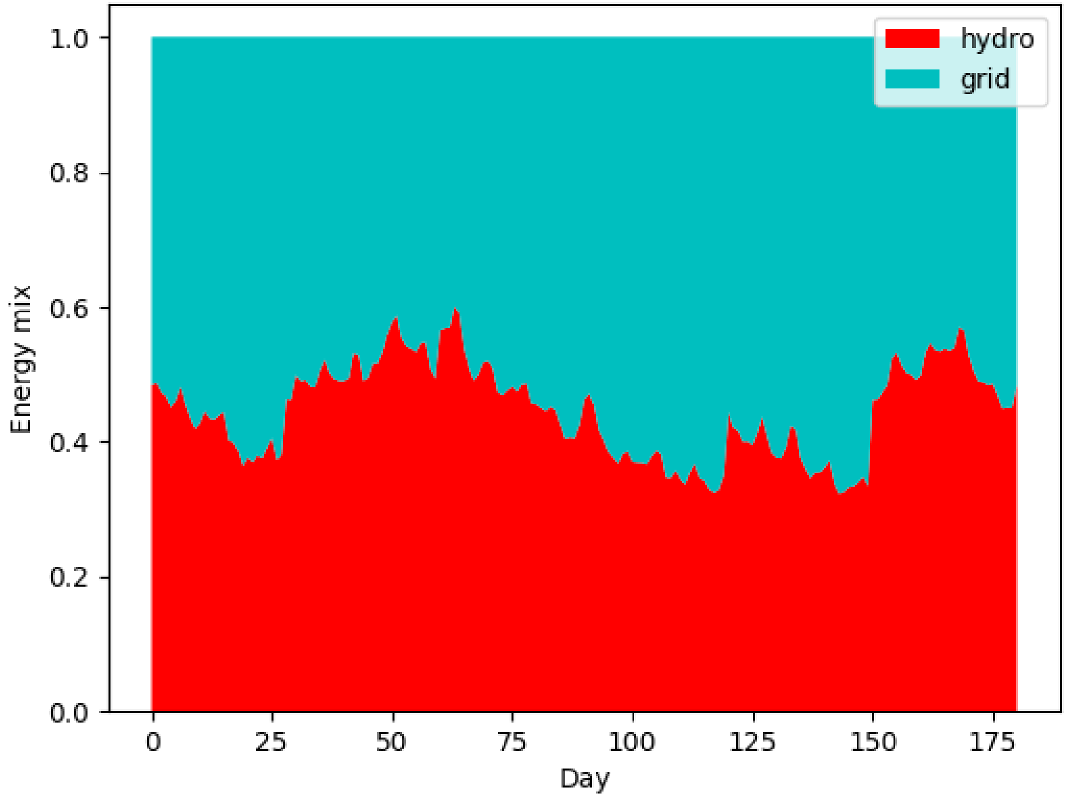
Performance (Hypothetical Baseline)

- Provides a comparison for scenarios

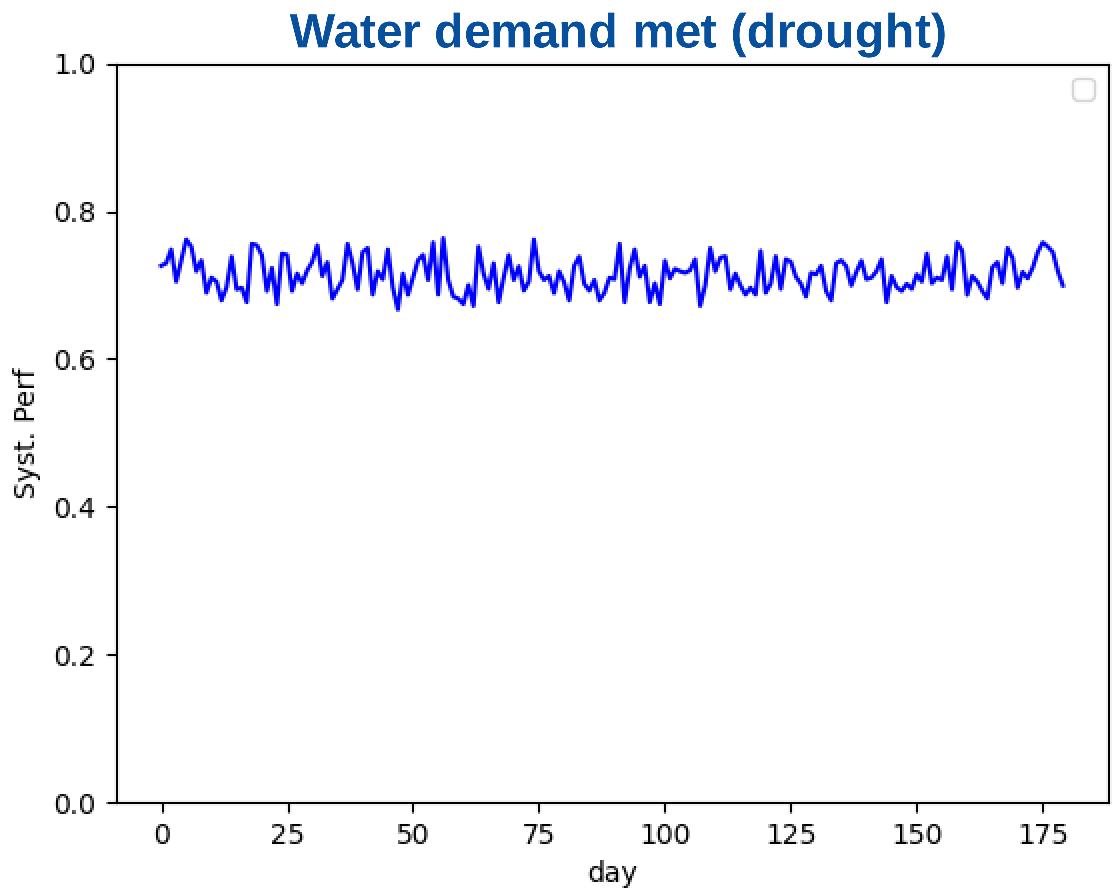
- Conditions:
  - Current climatic conditions
  - No drought

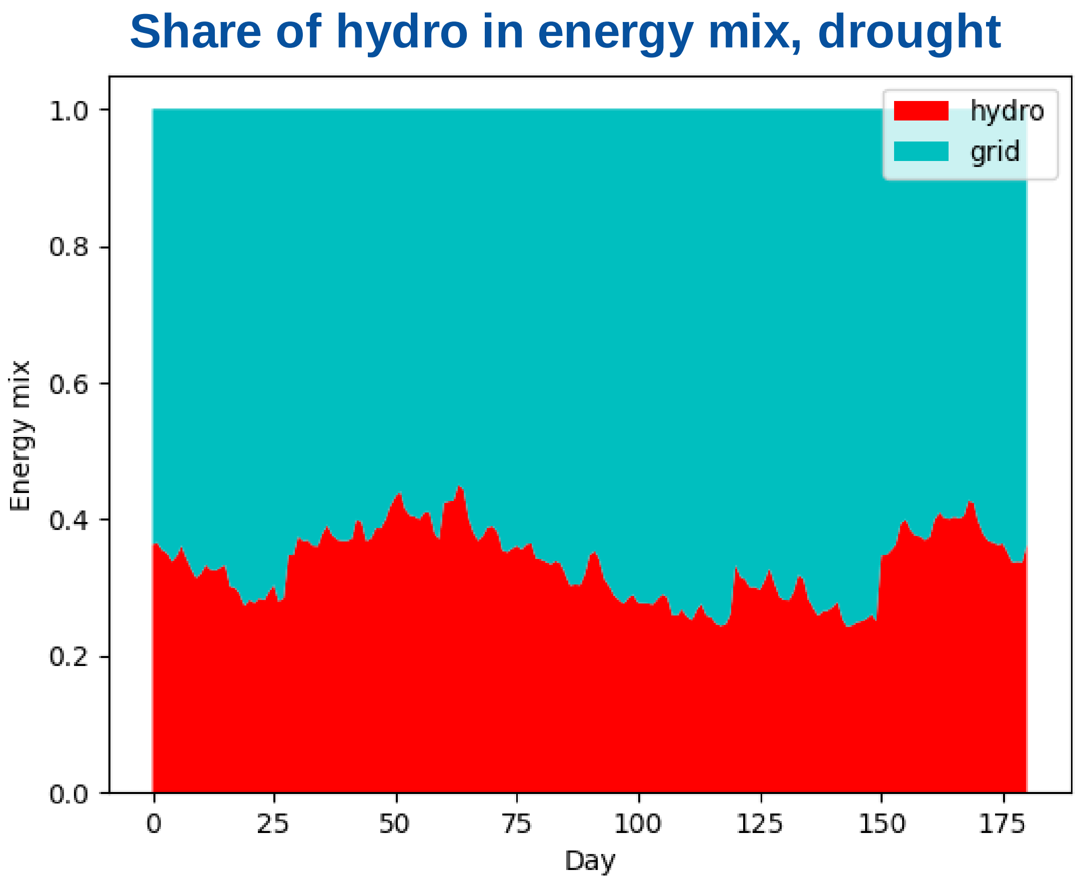
- Results:
  - All water demand met
  - Farmers have typical yield
  - Hydro composes 45% of energy mix

Share of hydro in energy mix, baseline



Performance under Drought (80% of average flows)





- Water demand met: 72%
- Farmers' annual yield: 87%

- Energy Mix: 33.5% hydro

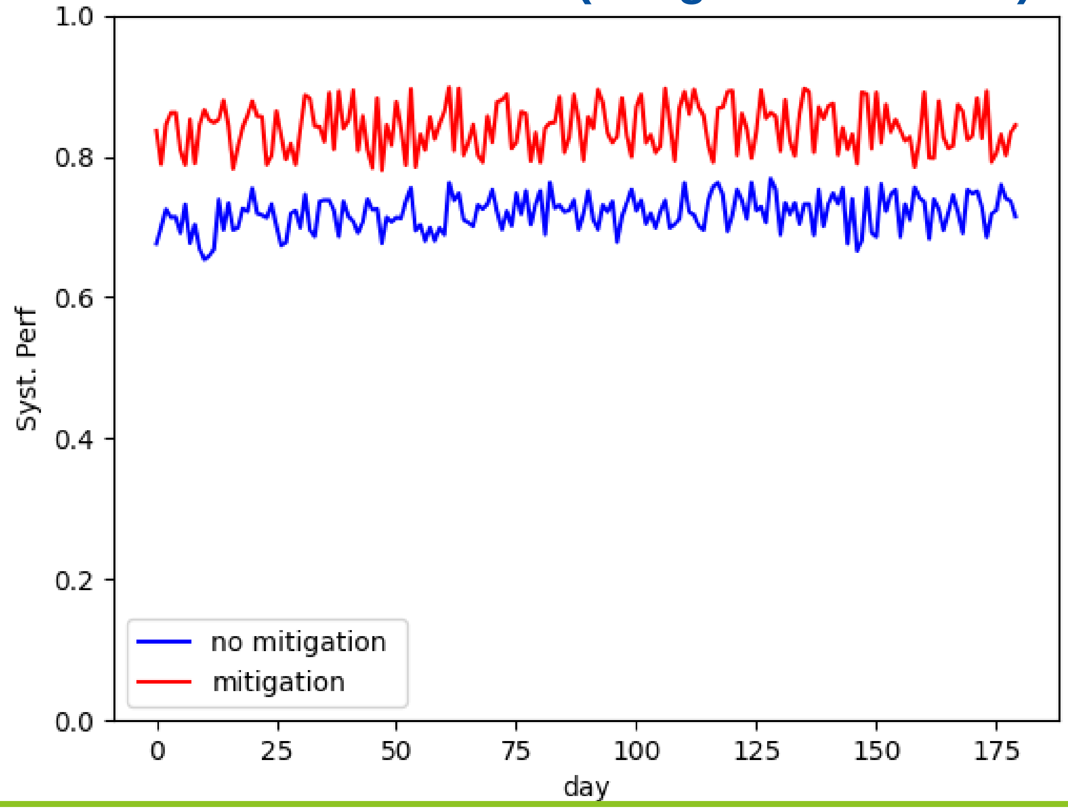
Irrigation Modernization efforts

- On-going, multi-faceted effort to revitalize US irrigation infrastructure
- Reduce water loss to seepage and evaporation, reduce energy usage of pumps, reclaim energy through hydro
- Examples include installation of
  - In-conduit hydropower
  - Pressurized pipes
  - Drip irrigation

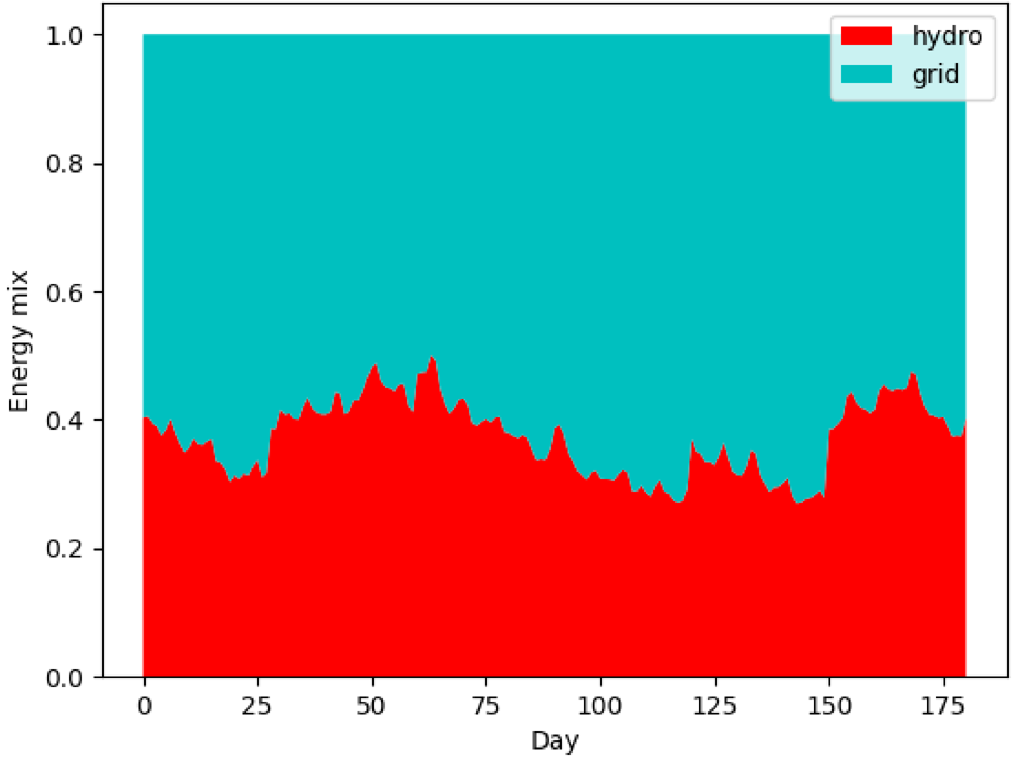
Photo credit: INL

Performance with Irrigation Modernization (drought)

Water demand met (mitigation vs none)



Share of hydro in energy mix, mitigation



- Water demand met: 84% (+12%)
- Farmers' annual yield: 91% (+4%)
- 272,000 Ac-ft of water saved

- Energy Mix: 37.3% hydro (+3.8%)

Conclusion

- Climate and drought problems aren’t going away any time soon
- Treat the “symptoms” while waiting for systemic root-cause solutions
- Irrigation modernization solutions are demonstrated as effective
- Cost and engineering analysis is required (these infrastructure upgrades can be expensive, see IrrigationViz tool[1] for detailed cost-benefit analysis)

1. irrigationviz.pnnl.gov

Future work

- Include temperature effects on crop yield and increasing evaporation
- Analyze other mitigation measures (in-conduit hydro, optimized scheduling)
- Capture cost and preliminary engineering analysis (IrrigationViz)
- Conduct additional real-world case studies for validation and impact

Acknowledgements

- DOE – Water-Power Technologies Office
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- Team –
  - Dr. Lionel Toba (lead modeler)
  - Shiloh Elliot (GIS and Data analyst)
  - Tim McJunkin (PI)
  - Thomas Mosier (WPTO Relationship Manager)

Questions

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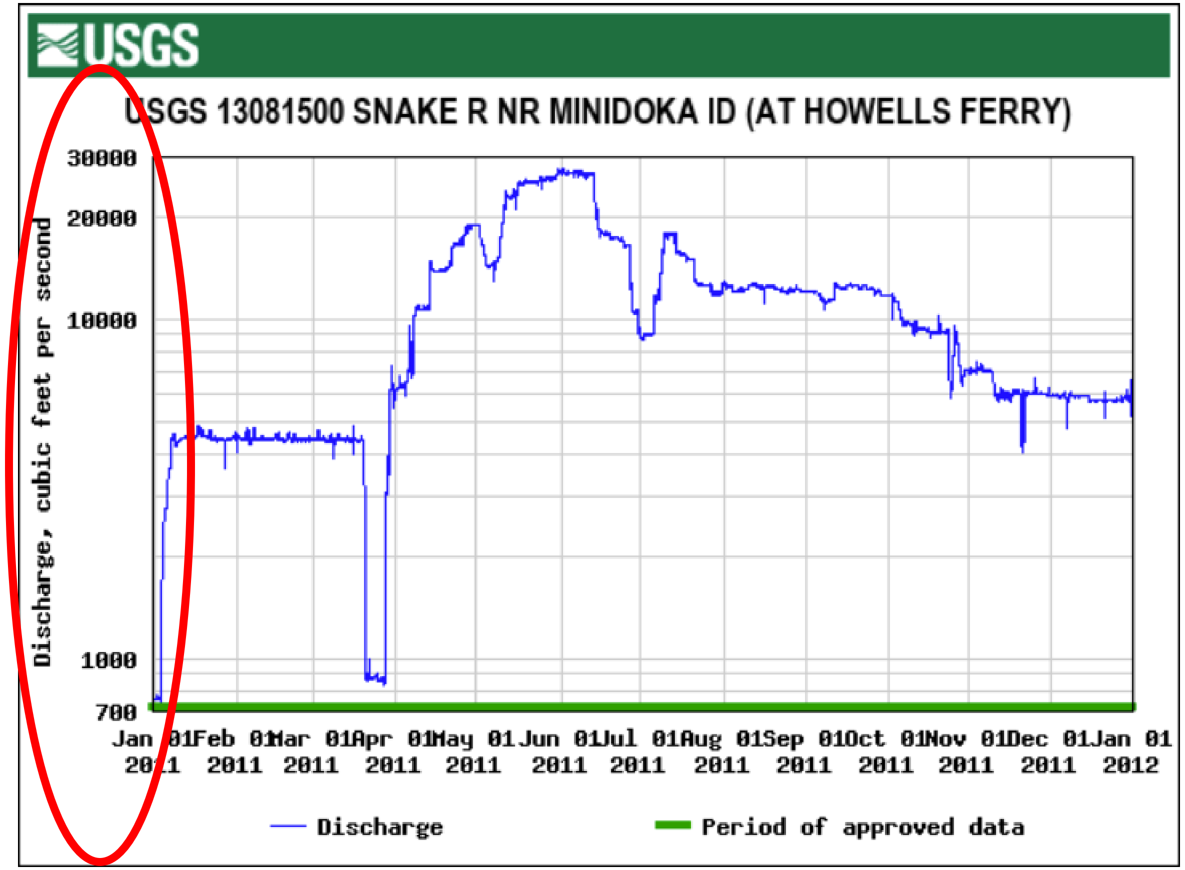
Citation for similar model:

Toba, Ange-Lionel, Liam Boire, and Timothy McJunkin. 2021. "Integrated Water-Power System Resilience Analysis in a Southeastern Idaho Irrigation District: Minidoka Case Study" *Sustainability* 13, no. 19: 10906. https://doi.org/10.3390/su131910906

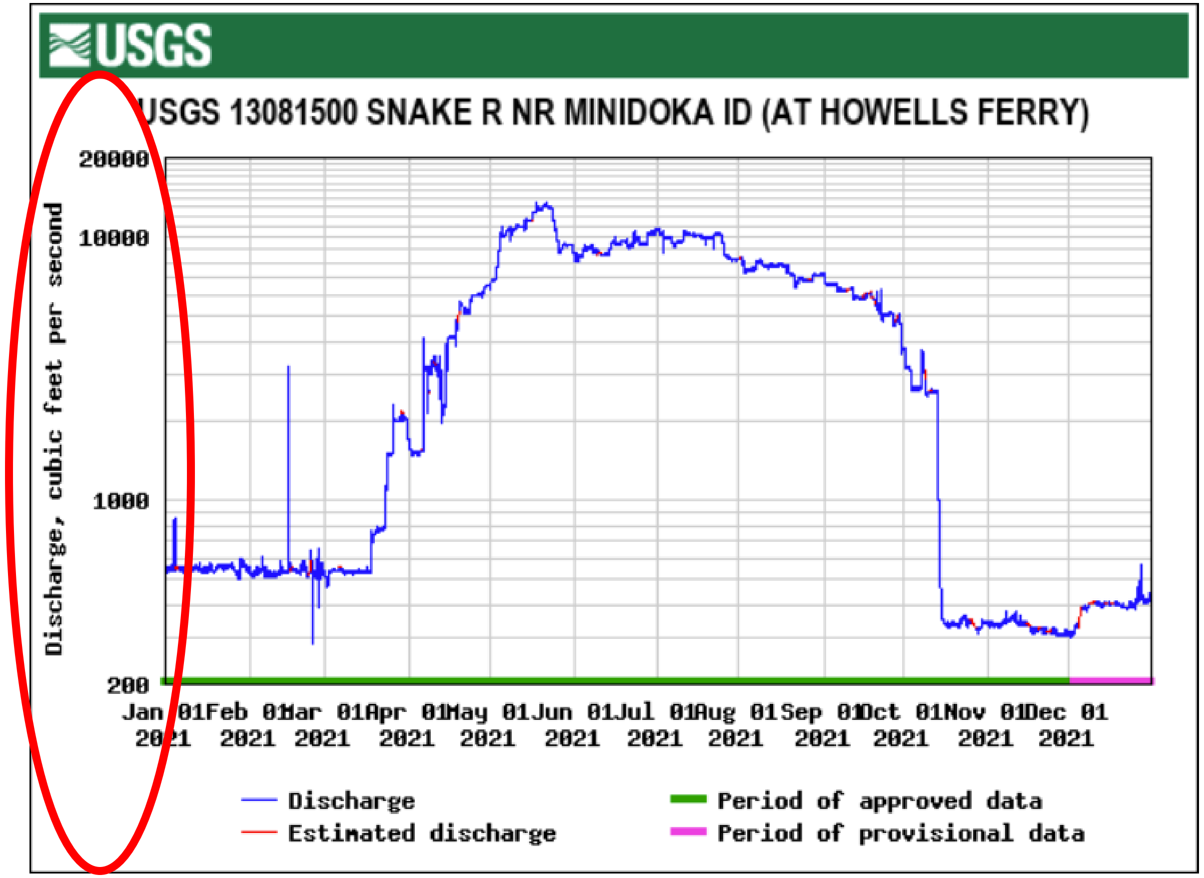
14. Discharge
15. Simulation Process Overview
16. UML diagram
17. Data inputs table

Backup Slides

Example of Discharge (Typical vs Drought)



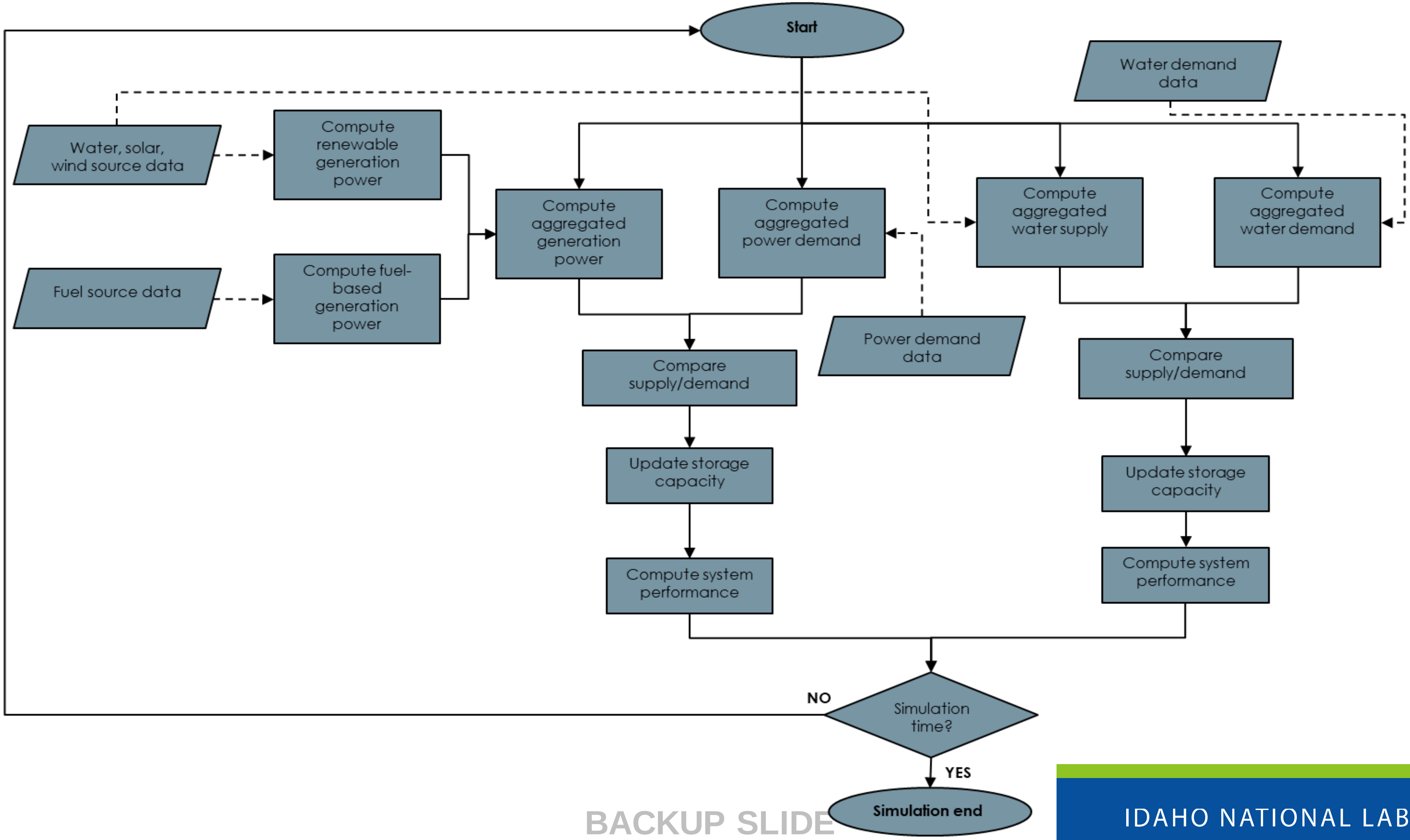
("Typical")



(Drought)

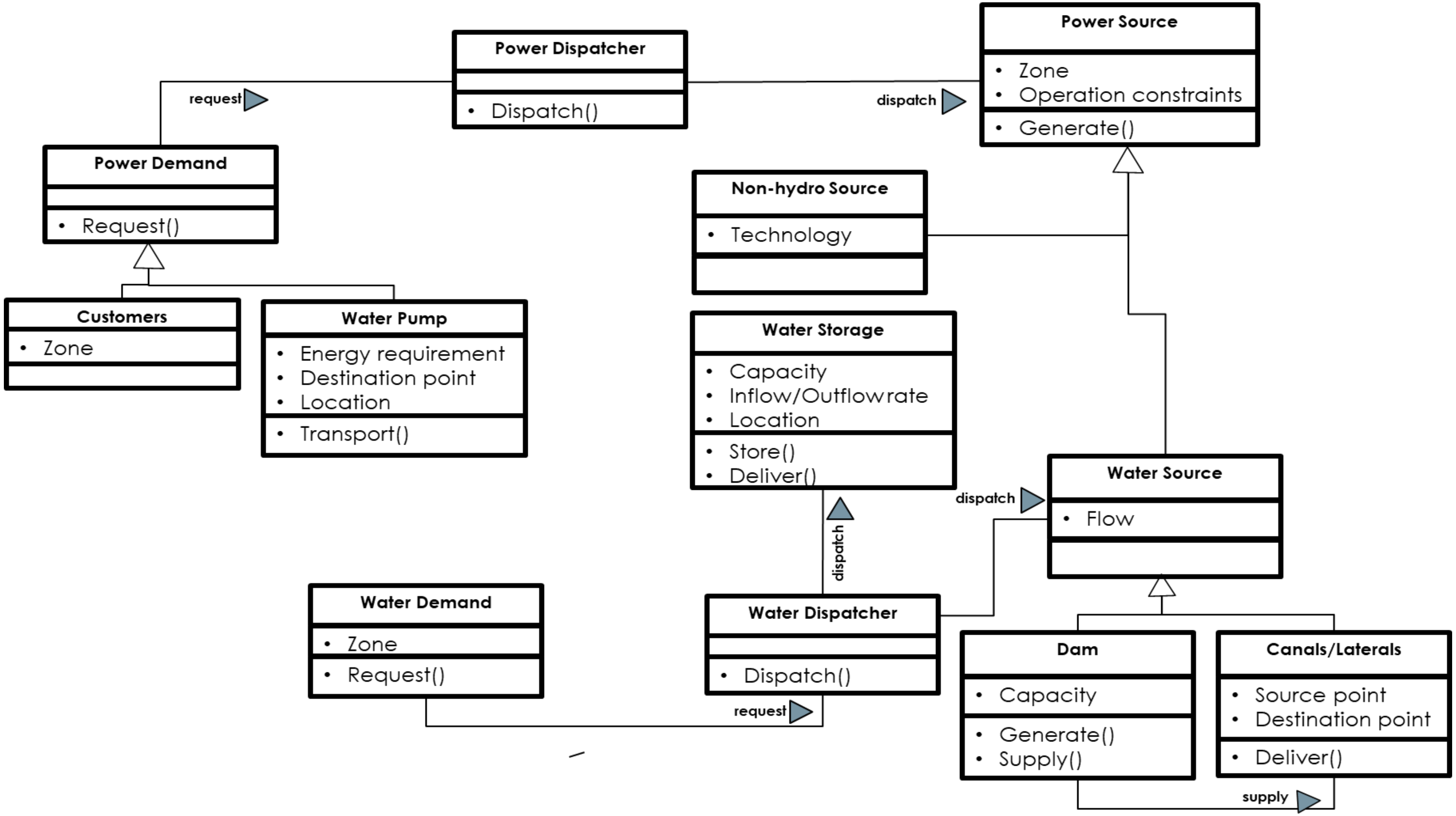
BACKUP SLIDE

Simulation Process Overview



BACKUP SLIDE

UML Diagram



BACKUP SLIDE

Data Inputs

Data Input	Definition
Water and power demand database	Data about the water and power demand per geographical zone and season. Demand data are determined as explained below.
Water and power source database	Data about the water and power sources per geographical zone and type. Data include factors specific to sources (water flow, dam heads, power mix, etc.)
Water pump database	Data about pumps energy requirement and location from example irrigation districts
Wind database	Data about wind speed, locations, and wind turbines

BACKUP SLIDE