Exploring Policy Changes Using RiverWare© and Multi-Objective Optimization

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P W R E

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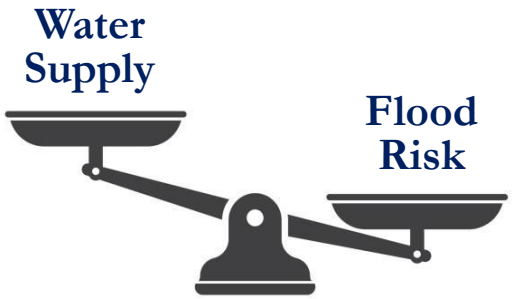
RiverWare

Introduction

- Problems faced by water resource managers regularly necessitate decisions that balance the **tradeoffs** between multiple, often competing objectives.

- How do you balance…?



Introduction

- Technical, data driven methods allow water managers to make well-informed decisions to these types of complex problems.
- In particular, the RiverWare modeling platform offers a uniquely **flexible** and **thorough** modelling framework by which water managers can analyze complex issues.

Truckee Basin WMOP

- Truckee Basin Water Management Options Pilot Study (WMOP):
  - Precision Water Resources Engineering (PWRE) has worked alongside the organizations listed below to develop flexible reservoir flood control regulation criteria without increasing downstream flood risk in the Truckee River Basin.
  - The updated regulation criteria was designed to use Forecast Informed Reservoir Operations (FIRO)

BUREAU OF RECLAMATION

TRUCKEE MEADOWS WATER AUTHORITY

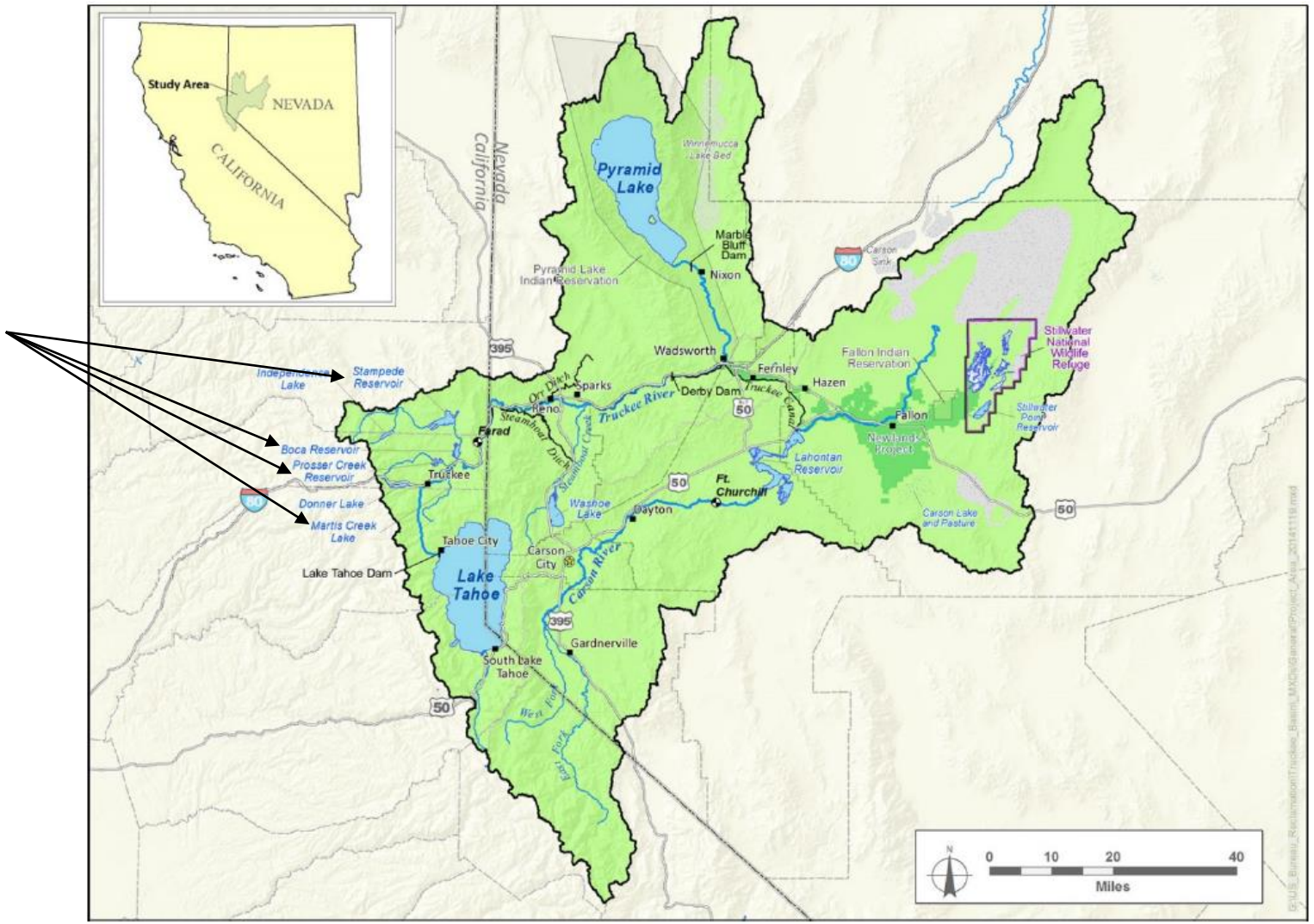
Federal Water Master

DEPARTMENT OF WATER RESOURCES · STATE OF CALIFORNIA

PYRAMID LAKE PAIUTE TRIBE

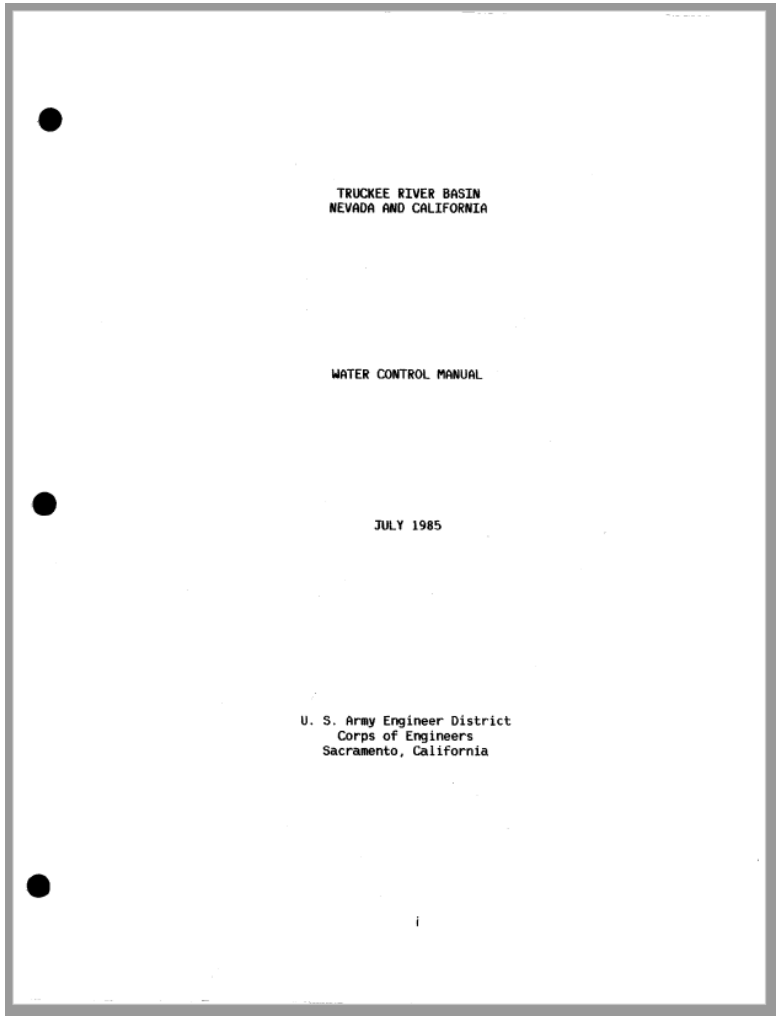
Truckee Basin Overview

- Six upper basin reservoirs in Sierra Mountains
- Flood Control Reservoirs
  - Prosser, Boca, Stampede and Martis Reservoirs
- Reno/Sparks Metropolitan
  - Need for adequate flood protection
  - Need for water supply
- Environmental concerns:
  - Downstream of reservoirs
  - Lower River



WMOP: Defining the Problem

- Current governing flood control regulation criteria: **Water Control Manual (WCM)**
  - adopted in 1985 based on technology, techniques and data from prior decades.
  - Great advancements in river forecasting technology and gaging throughout the basin have been made since its adoption.
- Stakeholders would like to evaluate whether the WCM regulation criteria is overly conservative, resulting in negative impacts to water supply and environmental flows.



TRUCKEE RIVER BASIN
NEVADA AND CALIFORNIA

WATER CONTROL MANUAL

JULY 1985

U. S. Army Engineer District
Corps of Engineers
Sacramento, California

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WMOP: Defining the Problem

- The WMOP aims to answer the following question:

What set of regulation criteria for flood control in the Truckee Basin would optimally:

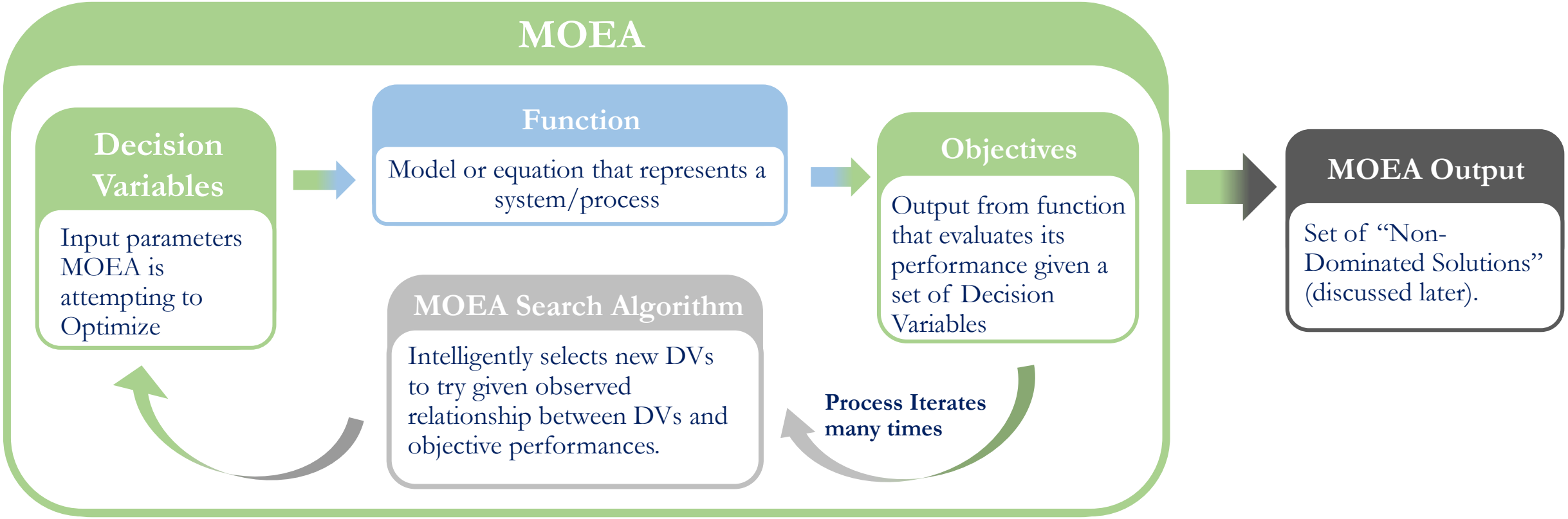
- **Maximize Water Supply**
- **Reduce Flood Damages**
- **Enhance Environmental Flows**
- **Remain flexible to future improvements in technology**

PWRE spearheaded the technical effort of utilizing a **Multi-Objective Evolutionary Algorithm (MOEA)** with **RiverWare** to help address this problem.

MOEA Overview

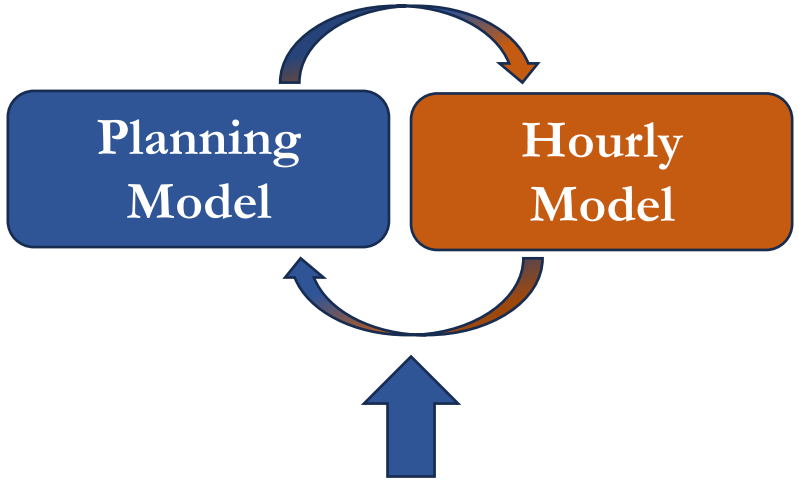
- MOEAs provide an innovative, robust decision-making framework to water managers that allows them to efficiently understand and quantify the tradeoffs between competing objectives.
- Through analysis of these tradeoffs, water managers can maximize benefit / minimize risk in their decisions.

MOEA Overview



WMOP: Function

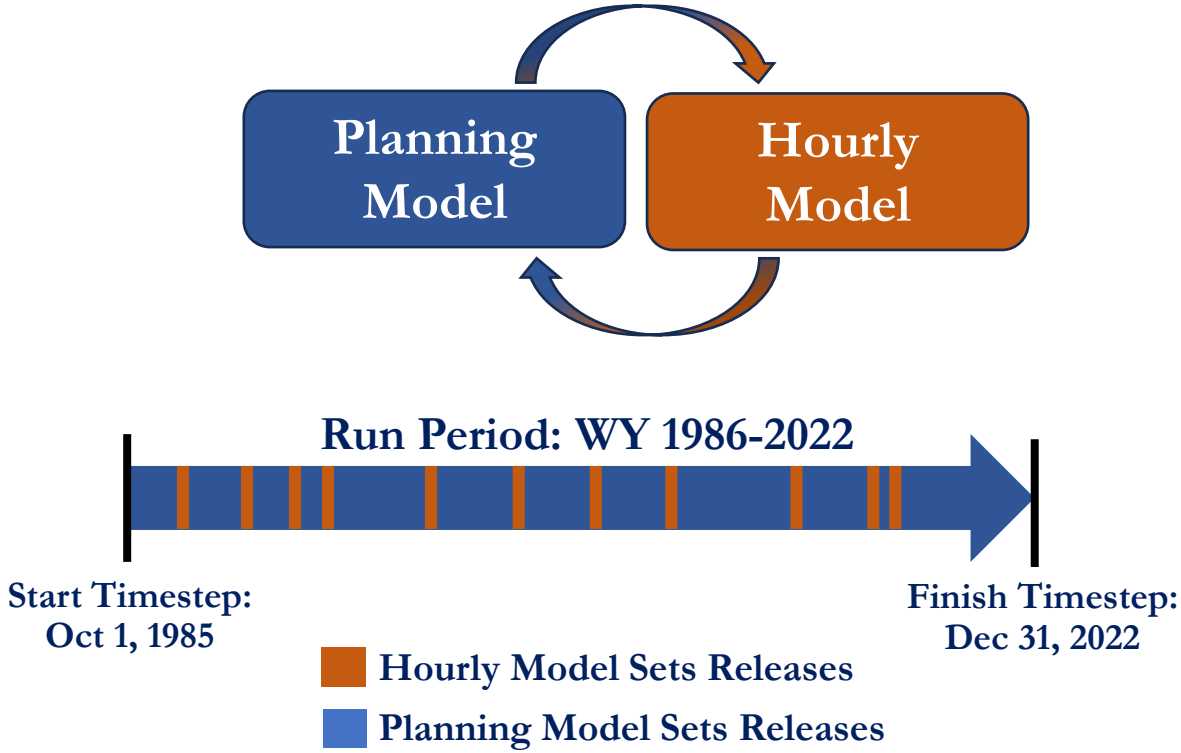
- Two RiverWare models used in tandem to model Truckee Basin:
  - The *Truckee River Operating Agreement (TROA) Planning RiverWare Model* (**Planning Model**)
    - Daily timestep
    - Evaluates water supply and environmental flow objectives
  - The *Truckee River (TR) Hourly RiverWare Model* (**Hourly Model**):
    - Hourly Timestep
    - Evaluates flood objectives



Historical Hydrology Data, WY 1986-2022

WMOP: Function

- Reservoir Releases/Operations set by
  - **Planning Model** during non-flood events.
  - **Hourly Model** during flood events.
- Necessary information (i.e., initial pool elevations, reservoir releases, etc.) communicated between the two models.
- **RiverWare** made this functionality possible through rule fired DMIs



WMOP: Objectives

- Inherent tradeoff between water supply and flood risk:
  - Regulation geared only towards water supply would keep reservoirs in the system full.
  - Regulation geared only towards reducing flood risk would keep reservoirs empty

Objectives

- Maximize Water Supply
- Reduce Flood Risk
- Enhance Environmental Flows

RiverWare provides a convenient framework to quantify these objectives using RiverWare Policy Language (RPL) and expression slots.

MOEA provides a convenient framework to optimize the **tradeoff** between these objectives.

WMOP: Decision Variables

- The Decision Variables in the WMOP:
  1. Represent flood control regulation alternatives.
  2. Parameterize the calculation of flood space requirements using Forecast Informed Reservoir Operations (FIRO) on ensemble hydrologic forecasts.

Decision Variables

- Parameterization of flood space requirements using FIRO

RiverWare provides a convenient framework to parameterize alternative flood control regulation criteria using RPL.

MOEA provides a convenient framework to optimize the configuration of this parameterization.

WMOP: MOEA Search Algorithm

- Python-based NSGA-II algorithm for the used for WMOP.
- The Borg-RW platform was considered and tested.
  - Borg-RW required model runs to be in series.
  - NSGA-II was selected because it allowed for parallel model runs

MOEA Search Algorithm
NSGA-II

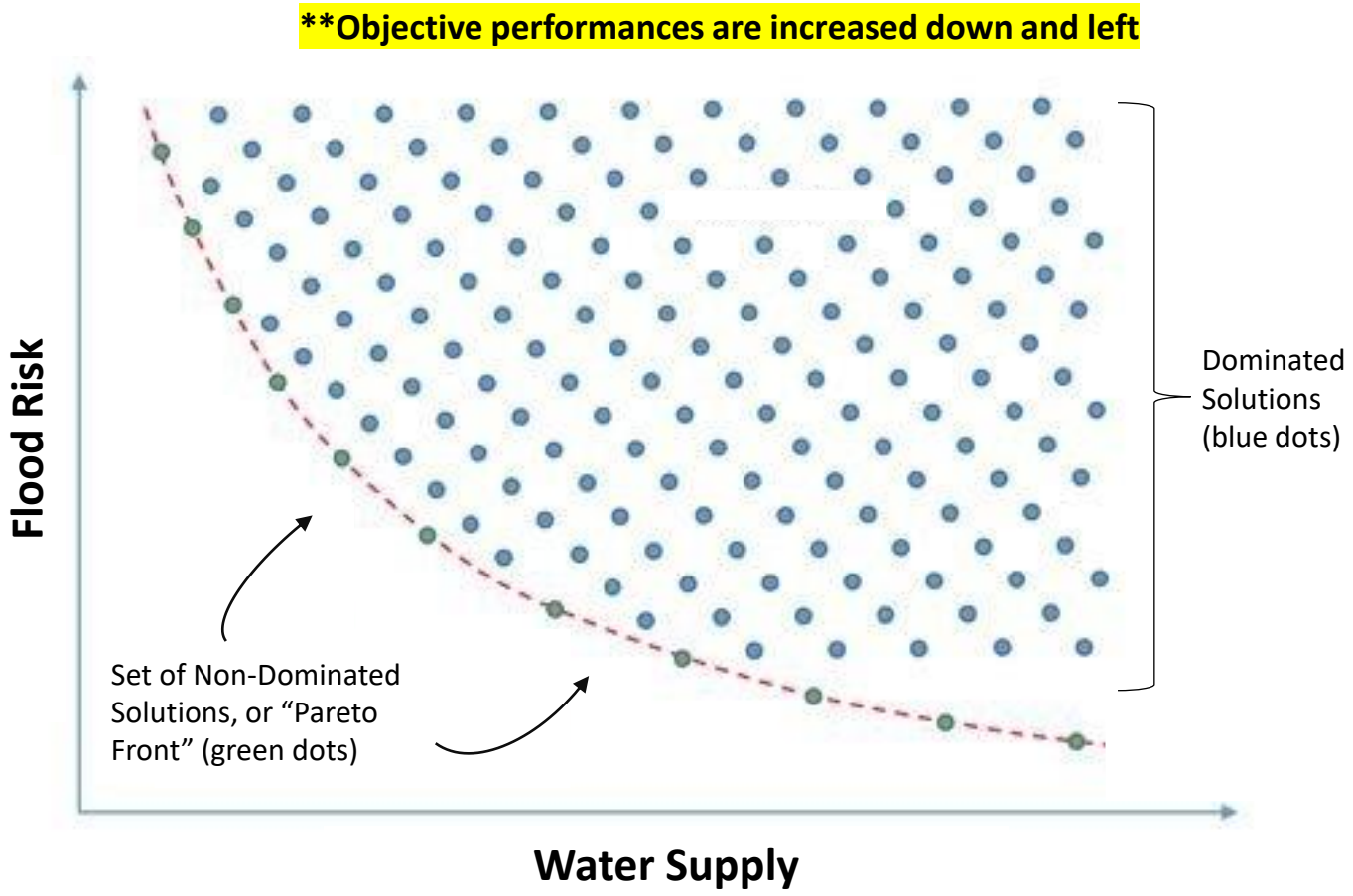
	Number of Model Runs
BorgRW	134
NSGA-II	2,957

MOEA Run Length: 4 weeks
Model Run Length: 3.5 hours

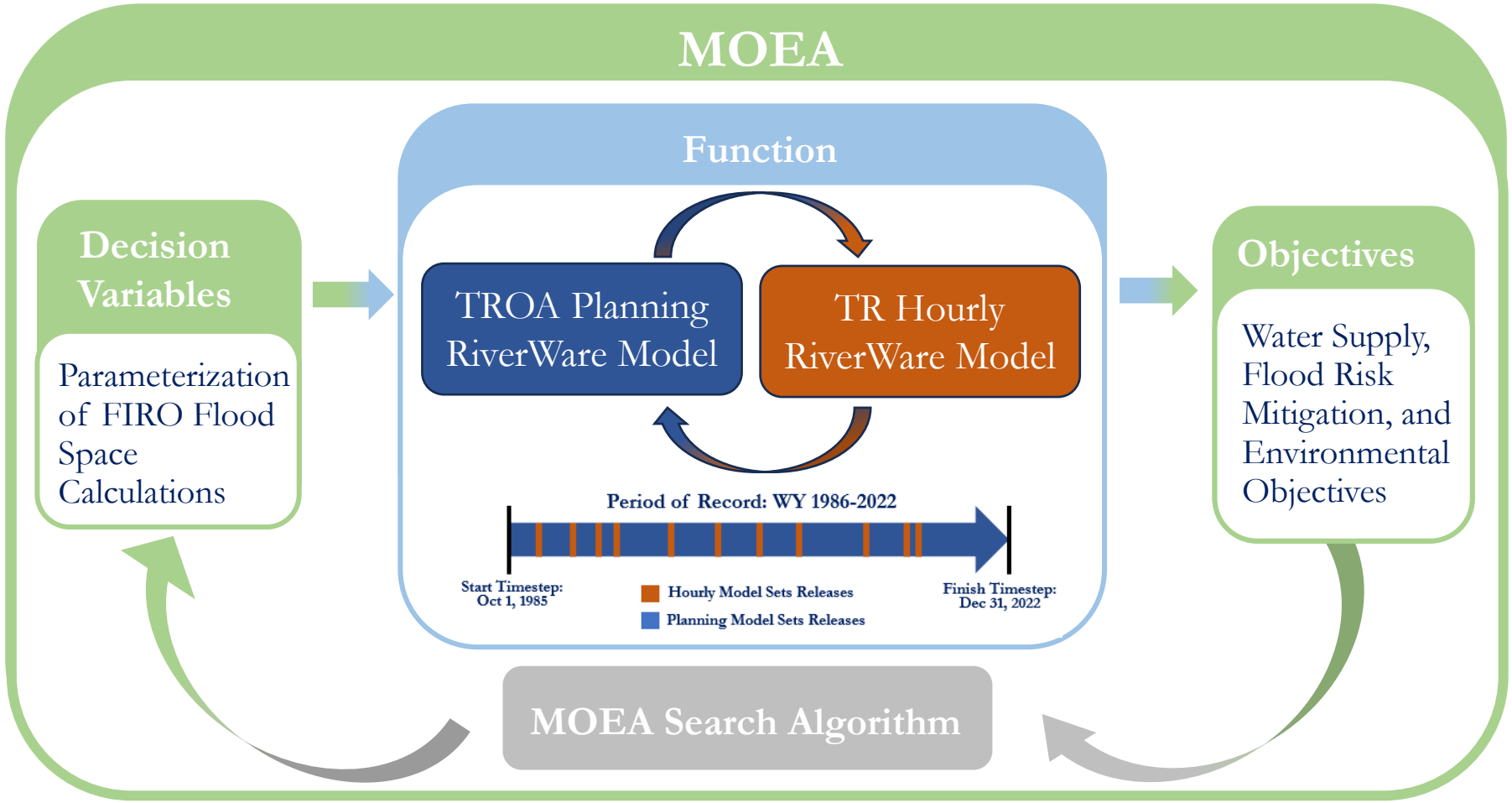
Running **RiverWare** in headless mode with RiverWare Command Language (RCL) made the implementation of a Python based MOEA with RiverWare possible.

MOEA Theoretical Example: Output

- Red dashed line/green dots represent tradeoff between two competing objectives (i.e., Water Supply and Flood Risk)
- MOEA identifies and quantifies the green dots (non-dominated solutions) which are objectively superior to the blue ones (dominated solutions).
- Stakeholders select the green dot based on how they **uniquely/subjectively value**, for example, improvements to flood risk mitigation and water supply.



WMOP Technical Infrastructure



Run Summary:

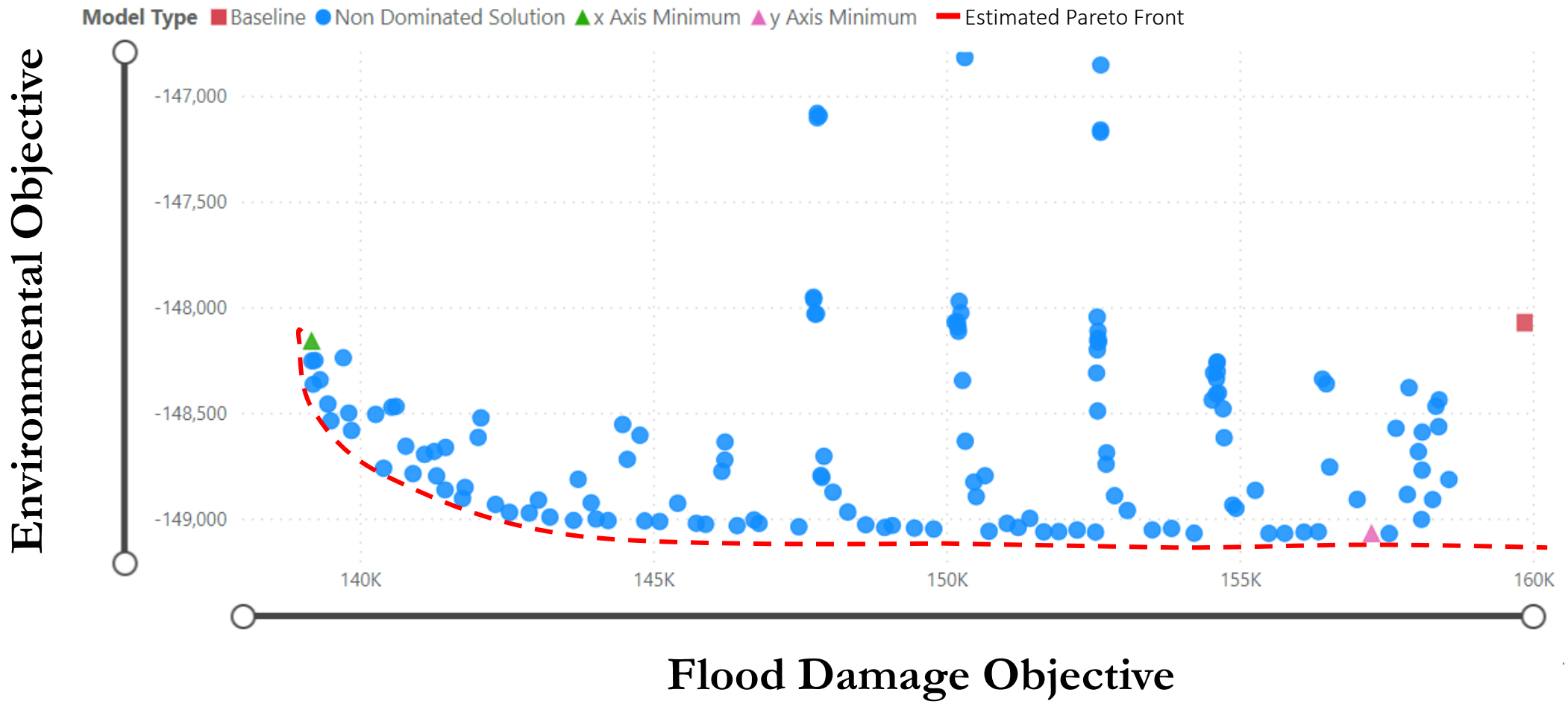
- 21 per Planning Model Run
- 65,000 + RiverWare Runs

MOEA Output

150 "Non-Dominated Solutions".

WMOP Results

*Down and left represents better objective scores



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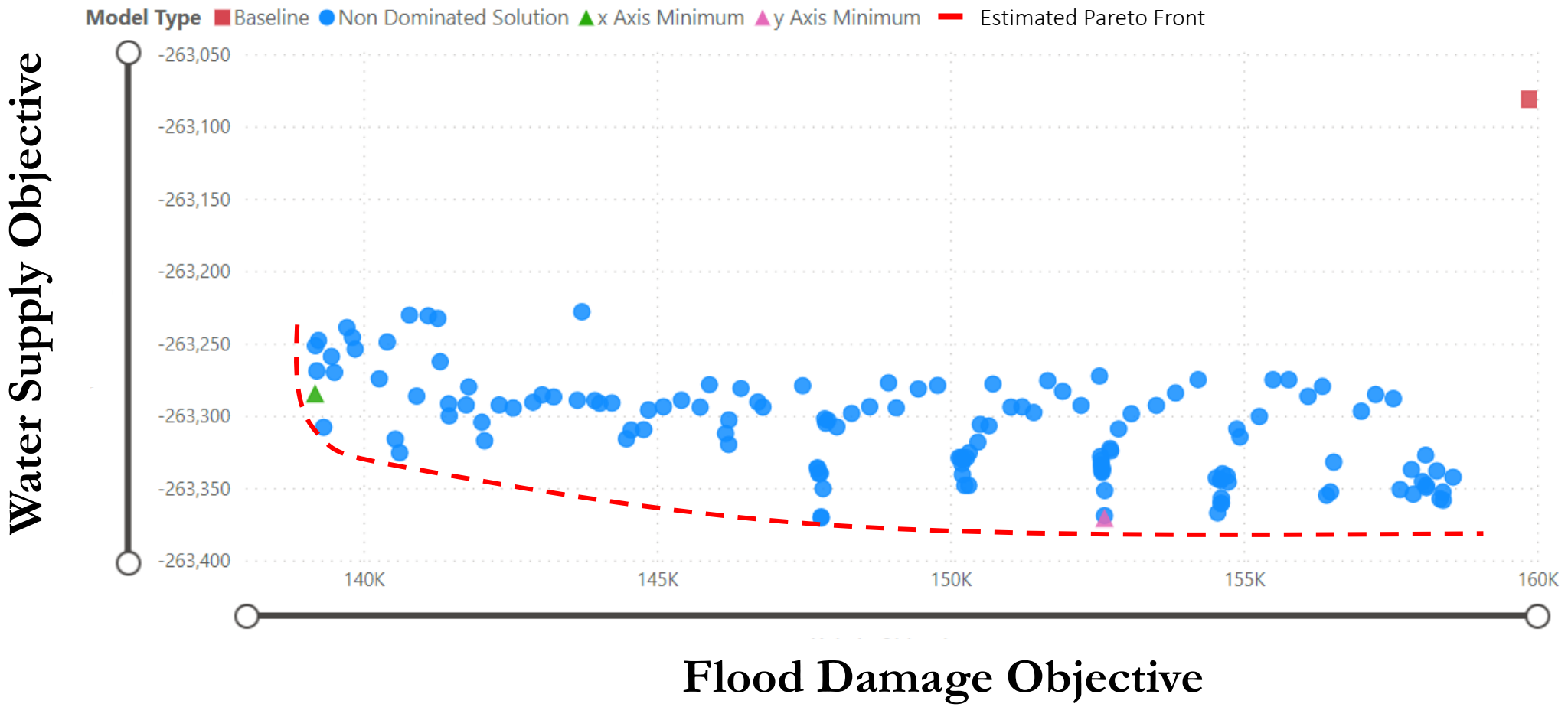


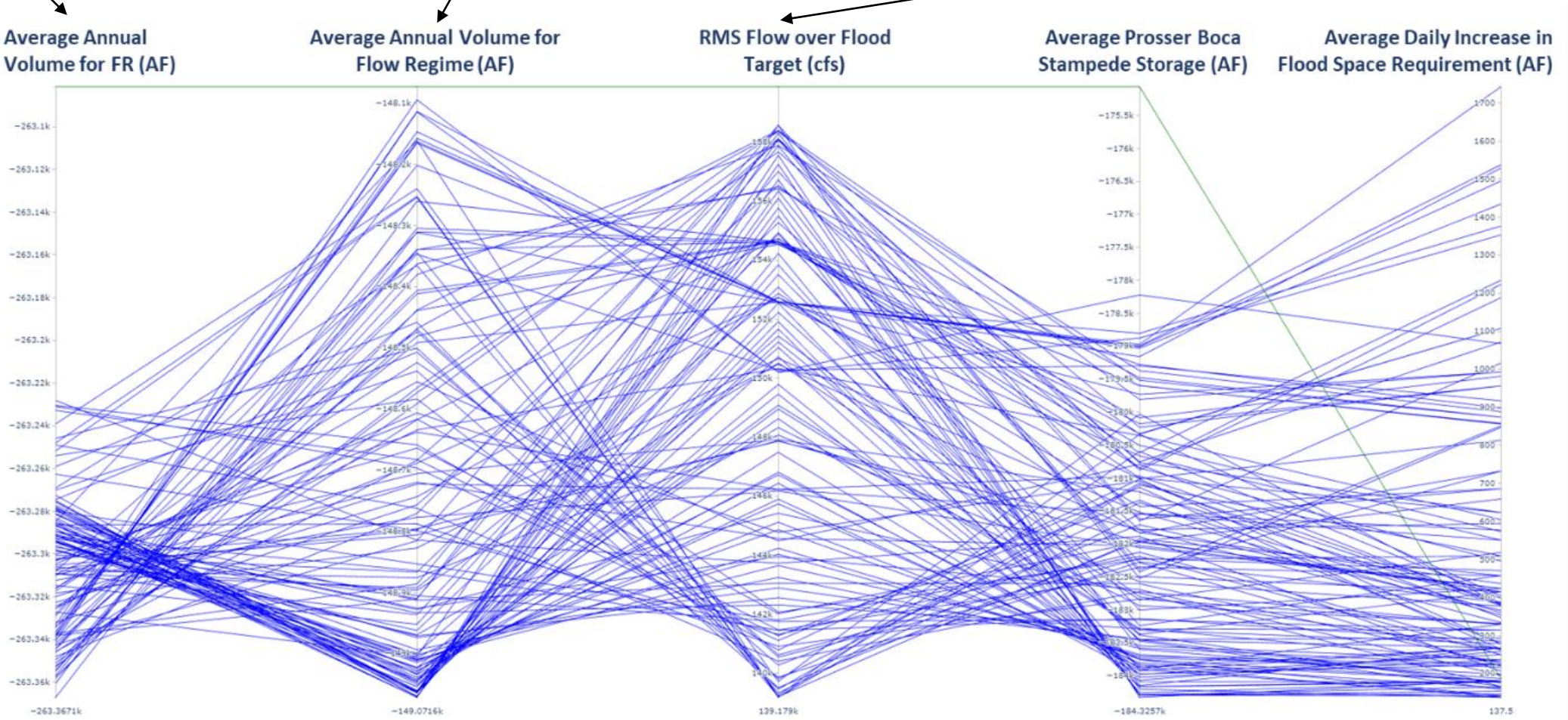
WMOP Results

Water Supply Objective

Environmental Objective

Flood Damage Objective

*Down represents better objective scores



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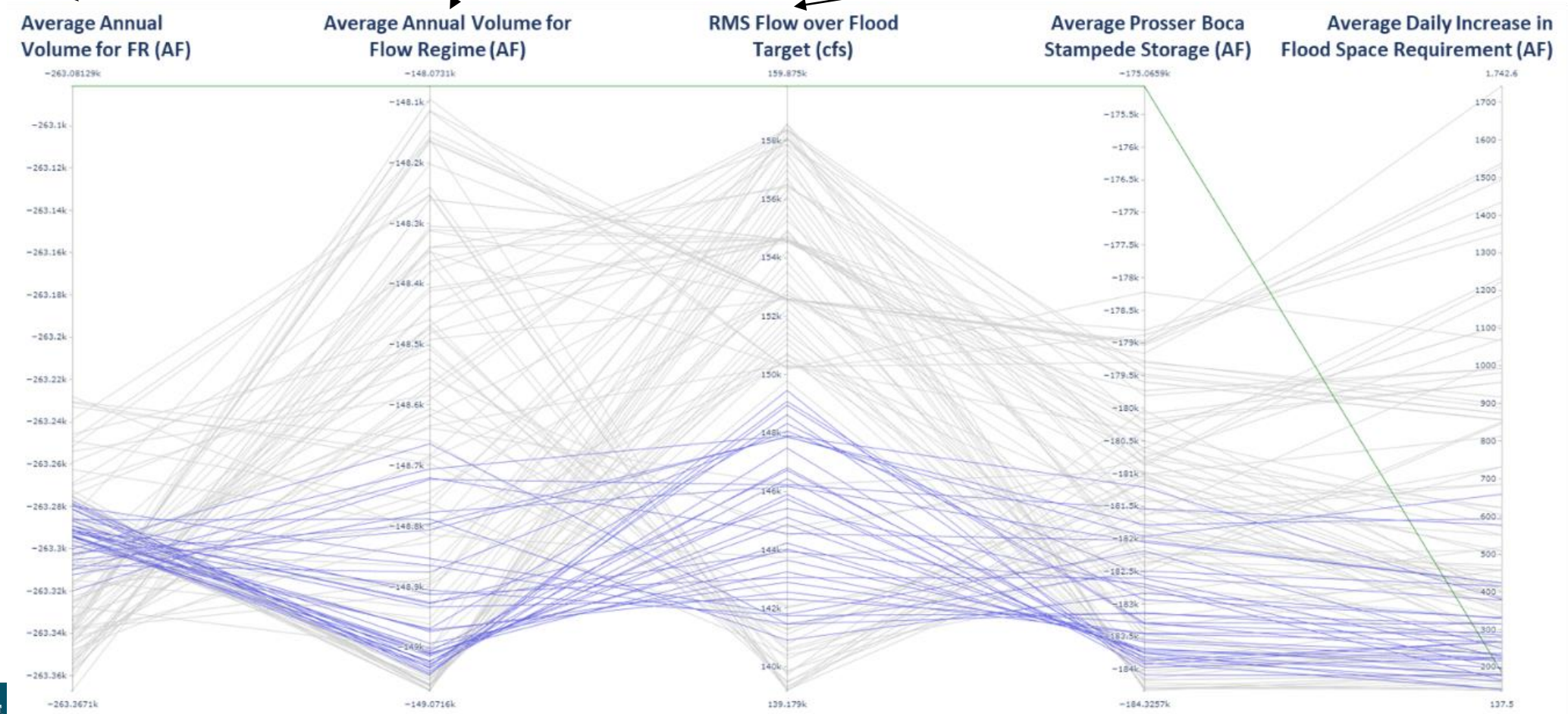

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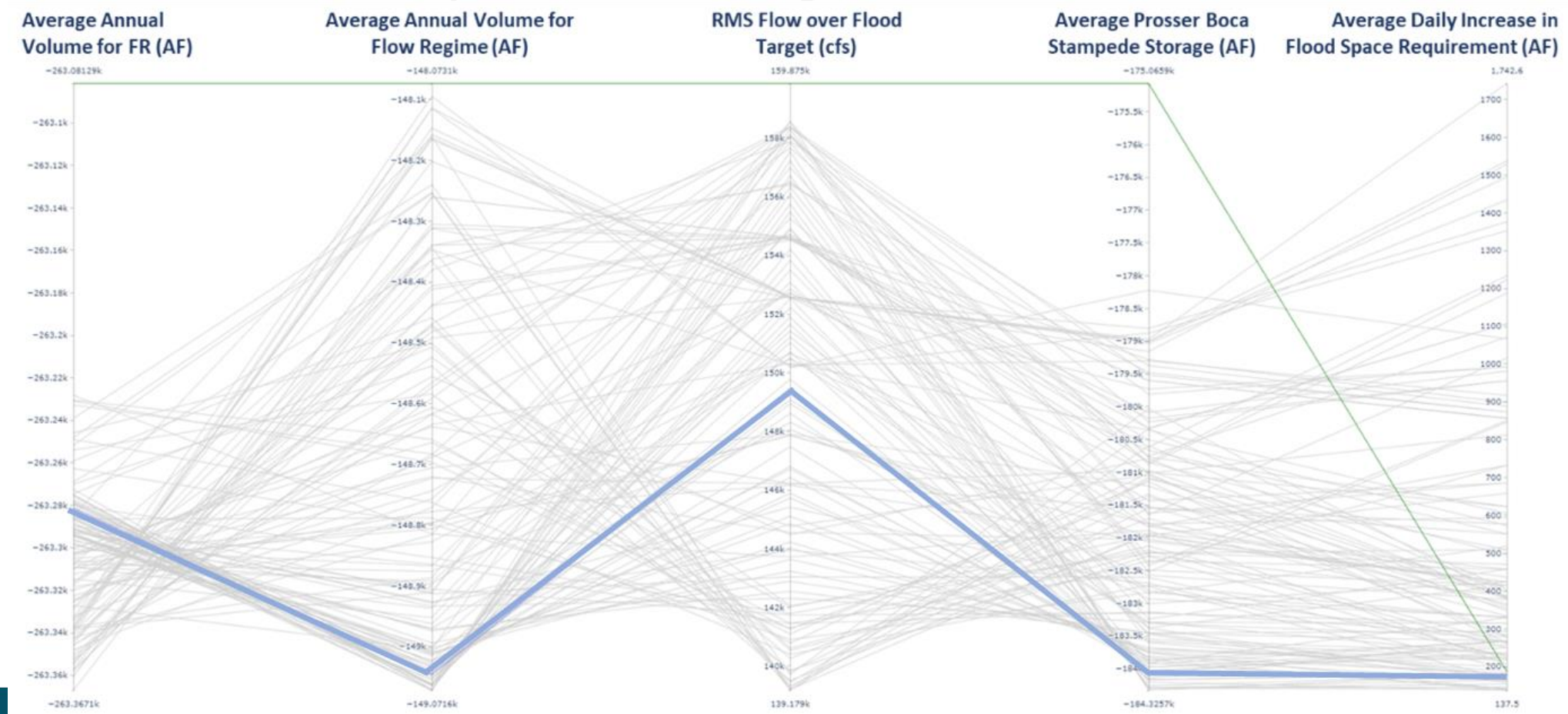

Conclusion

- RiverWare's ***flexibility*** allowed:
  - (1) complex policy to be reduced to a few parameters that served as decision variables in the MOEA.
  - (2) interactions with powerful, external, open-source programs like Python.
- RiverWare's ***thoroughness*** allowed:
  - (1) Water supply *and* flood modeling to work in tandem in the Truckee Basin.
  - (2) Truckee stakeholders to analyze the information they needed to determine proposed revisions to the *Water Control Manual*.
- Stakeholders have arrived at a Preferred Alternative to the WCM that utilizes FIRO operations to maximize/balance water supply/environmental/flood control benefits.
  - The project is currently being written into a *Viability Assessment* that will be given to USACE

Thank you!

Caleb Erkman,

Federal Water Master

Katherine Gwynn & Todd Vandegrift

PWRE

BUREAU OF RECLAMATION

Lahontan Basin Area Office, Bureau of Reclamation

A very special thanks to Truckee Meadows Water Authority for the opportunity to be a part of the WMOP Project!

TRUCKEE MEADOWS WATER AUTHORITY