New York City's Operations Support Tool (OST)

Adao Matonse, Ph.D. and Thomas Murphy, P.E.

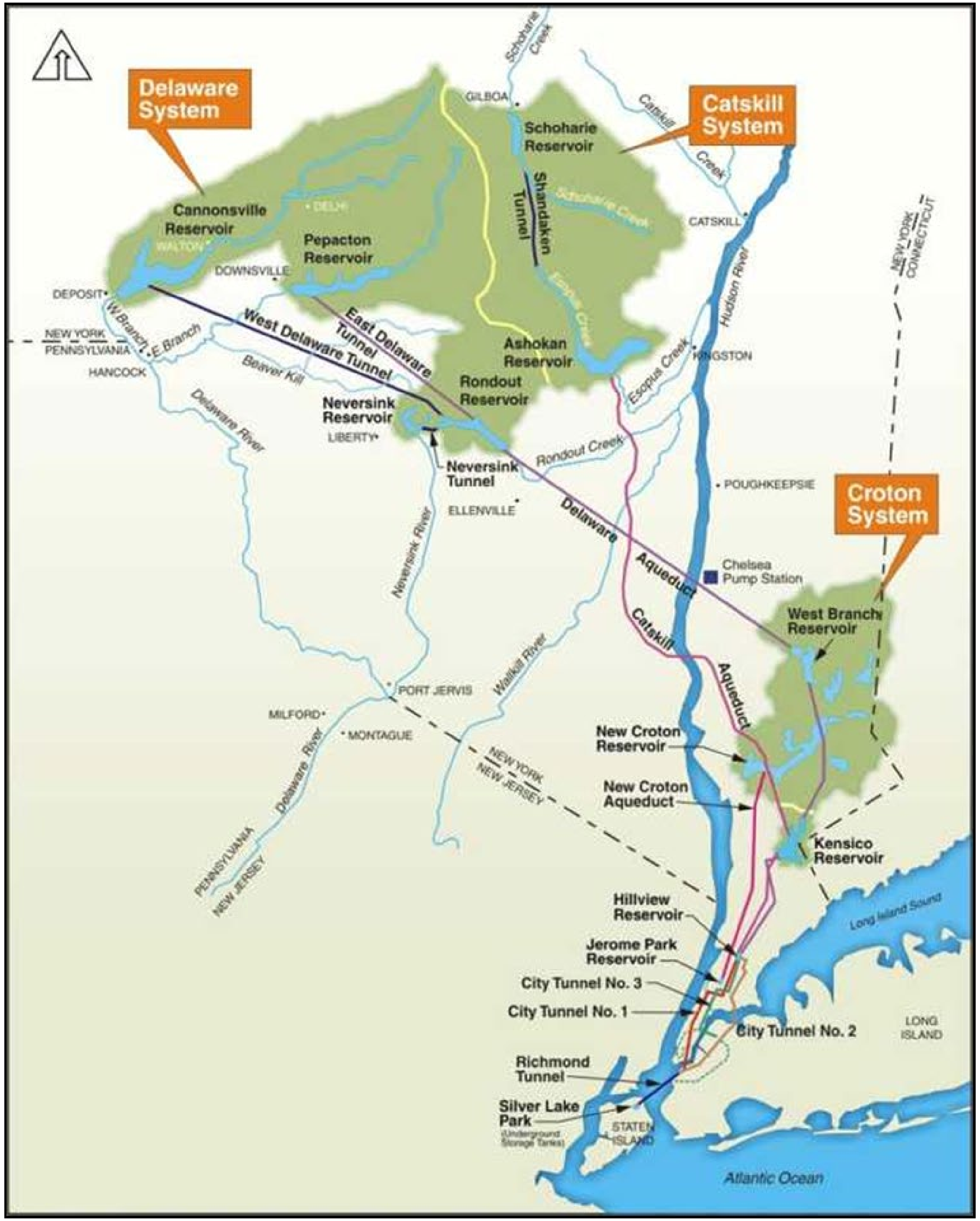
Presented at the *ACF Stakeholders virtual meeting*

October 20, 2021

NYC Environmental Protection

Presentation Outline

- Overview - NYC Water Supply
- Background, FFMP
    - 1954 Supreme Court Decree
    - Terms of the Decree
    - Things get interesting
    - Finding Answers
    - Limitations
    - A new way of doing business
- NYC OST
    - Challenges with complex systems
    - What led to OST creation?
    - What is OST?
    - How do we apply OST?
    - Forecast informed operations and the FFMP
- Would we recommend a similar tool for a complex system and why?

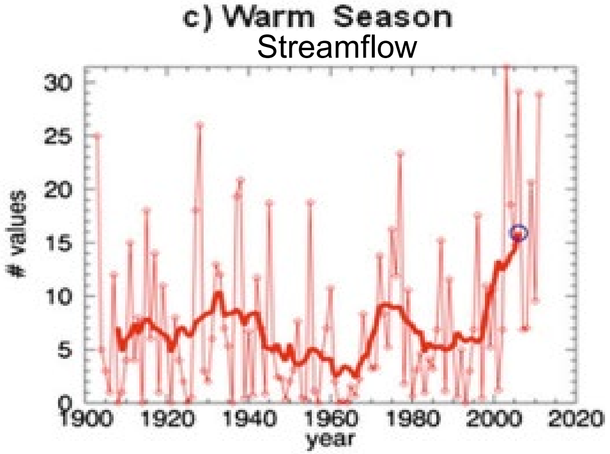


NYC Water Supply

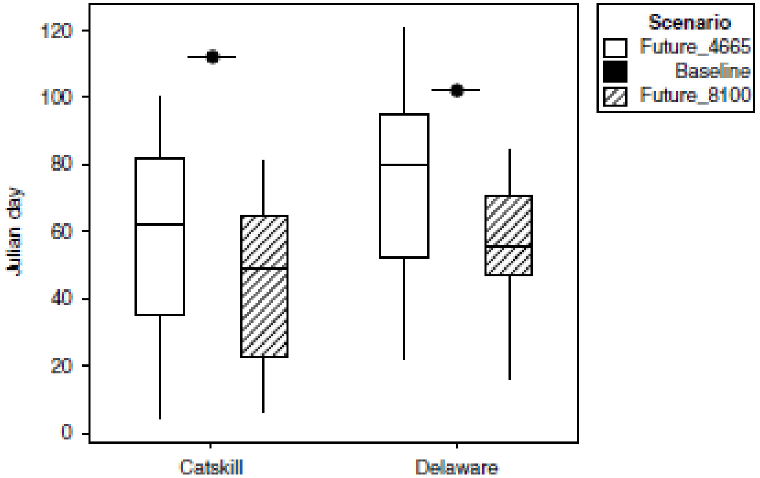
- Three sub-systems
- Protect our 2,000 square mile watershed, including 19 reservoirs and three controlled lakes
- Deliver 1.1 billion gallons of water to 9.8 million New Yorkers
- 570 BG storage capacity
- Managed by NYC DEP

Multiple Objectives

- Supply reliability
- Drinking water quality regulations
- EPA Filtration Avoidance Determination (FAD)
- Tail water fisheries
- Ecological flows
- Spill mitigation
- Long-term supply/demand
- Climate change impact
- Extreme hydrological events frequency
- Operating costs
- Regulated releases and diversions
    - 2017 Flexible Flow Management Program (FFMP)



Southern NYS
95th percentile 4-day streamflow, yearly and 11-year running mean (bold)



First Julian day reservoir system pass 90% storage

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Background FFMP

Thomas Murphy, P.E.

SPECIAL ADVISOR TO BWS

https://webapps.usgs.gov/odrm/ffmp/flexible-flow-management-program

https://www.state.nj.us/drbc/

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1954 Supreme Court Decree

- The Decree underlies all operations in the Delaware River Basin
- Parties to the Decree are the City of New York and New York State (defendants) and the state of New Jersey (complainant) and the states of Pennsylvania and Delaware (interveners)
- In the 1920's New York City and the states of New York, New Jersey and Pennsylvania were interested in developing the basin for water supply
    - Negotiations to reach an agreement for coordinated development were unsuccessful

1954 Supreme Court Decree (cont.)

- Initial litigation: In 1928 NYC, which is outside the basin, needing to increase its water supply began moving to develop the Delaware
  - In 1930 New Jersey went to the Supreme Court to prevent that
  - This resulted in the 1931 Supreme Court Decree
    - NYC allowed to divert 440 mgd from the Neversink Reservoir on the Neversink River and the Papacton Reservoir on the East Branch
- In 1952 NYC sought to increase the water it could divert from the basin
  - This resulted in a return to the Court
  - An amended Decree was agreed to by the Parties

Terms of the Decree

- After the Cannonsville Reservoir, on the West Branch, became operational the City was allowed to divert 800 mgd
- The City is required to make compensating releases to maintain a minimum flow target of 1750 cfs on the Delaware at Montague NJ
- An Excess Release Quantity was established to be released from the City’s reservoirs each year
- The City was required to build and operate a WWTP at Port Jervis NY
- New Jersey was allowed to divert up to 100 mdg from the Delaware
- To oversee the terms of the Decree a Delaware River Master was appointed by the Chief Hydraulic Engineer of the U.S. Geological Survey

Things Get Interesting

- The Decree made no provision for a drought more severe than the drought of record at that time
- In the 1960’s a multi-year drought became the new drought of record and operations needed to change
    - Cutbacks to diversions and flow targets during drought needed to be negotiated
- In addition, there was growing pressures for additional releases for other issues not addressed in the Decree.
    - Cold water fishery
    - Flooding
    - Recreation

Finding Answers

- The Decree Parties addressed these issues on an ad hoc basis through unanimous agreement
  - Delaware River Basin Commission dockets
  - The negotiation process was time consuming and at times contentious
- A better way of managing basin operations was needed
  - Something that could be in place over a long period and not require renegotiating every year or so
  - Stakeholder acceptance
  - NYC retain control of its water supply and its rights under the Decree

Limitations

- The City's position had always been to operate conservatively to protect water supply
  - The next drought can start tomorrow
  - The Delaware system provides about 60% of the City's water
  - Best quality water
- There are limits to what the City's reservoirs can do
  - Single purpose design; water supply, not flood control
- The City doesn't use all its Delaware 800 mgd but will someday
  - No interest in giving it away and then fight to get it back when it is needed

A New Way of Doing Business

- The City's approach to water supply protection began to change with improved forecasting and better operations modeling
- Goal: Develop a program that can release more water for other needs and refills the reservoirs by June 1
- To do that the Operations Support Tool considers demand forecasts, NWS ensemble forecasts, streamflow data and near real-time water quality and system status
- The City demonstrated OST reliability and the Parties negotiated and adopted the FFMP:
    - When more water is available, more water is released
    - Conversely when less water is available, less water is released

NYC OST

Adao Matonse, Ph.D.

DEPUTY CHIEF, OPERATIONS MODELING & ANALYSIS

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Multiple Objectives

- Supply reliability
- Drinking water quality regulations
- EPA Filtration Avoidance Determination (FAD)
- Tail water fisheries
- Ecological flows
- Spill mitigation
- Long-term supply/demand
- Climate change impact
- Extreme events frequency
- Operating costs
- Regulated releases and diversions
  - 2017 Flexible Flow Management Program (FFMP)

The Challenge

- How to integrate all these objectives and optimize operations?
- How to evaluate system performance?

Models can help!

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Why OST?

The Catskill System

- Prone to elevated turbidity
- During high flow events
- System designed to provide settling for turbidity

Ashokan Reservoir

Why OST (cont.)?

EPA Filtration Avoidance Determination (FAD)

Under the **Safe Drinking Water Act (SDWA) – 1986**

- **"For a drinking water system to qualify for FA under the Surface Water Treatment Rule (SWTR) the system cannot be the source of a waterborne disease outbreak, must meet source water quality limits for coliform and turbidity …"**

DEP strategy to Better control turbidity

- A System-wide Operations Support Tool
- An Interconnection of Catskill Aqueduct at the Delaware Aqueduct Shaft 4
- Structural improvements to the Catskill Aqueduct stop-shutter facilities

What is OST?

A software that allows to evaluate all aspects of NYC Water Supply system

Key Elements

- Inflows
- Demands
- Physical Data
  - Storage - elevation curves
  - Spillway rating curves
  - Head - discharge functions
  - Reservoir storage zones
  - Aqueducts capacity
- Operating Rules
  - Stream releases
  - Reservoir balancing
  - Operating preferences

- Daily time step
- Simulates entire system and Delaware down basin points

- **Main components**
  1. Near-real-time data
  2. Quantity & operations model: OASIS
  3. Quality model: CE-QUAL-W2
  4. Inflow forecasts

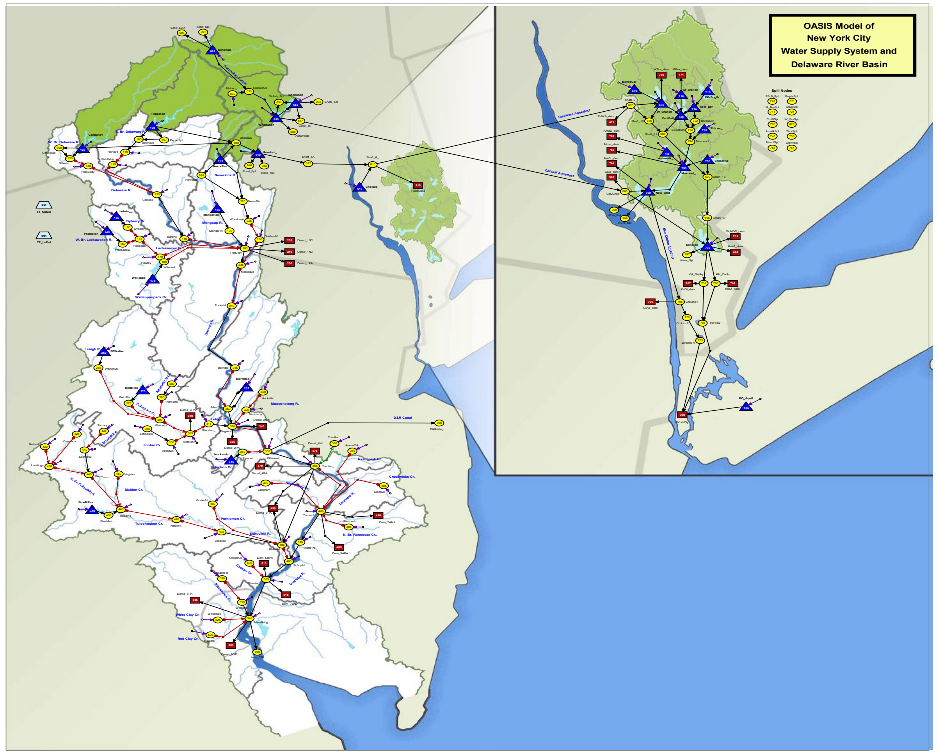
Near-real-time data

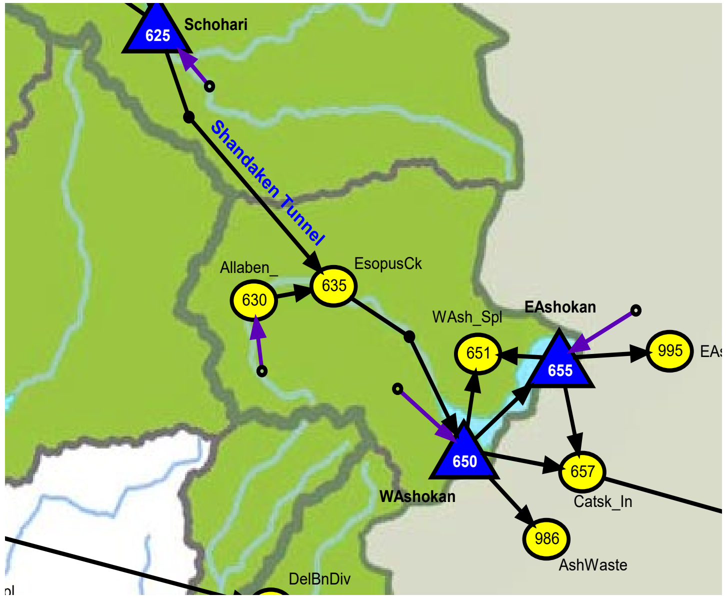
- Data Sources
  - DEP
  - USGS
  - NWS
  - Hydropower operators
- Data Use
  - Model initialization
  - Situational awareness
  - End-user access
  - Data analysis

	# of sites	# of signals
Reservoir Operations	66	474
USGS Streamgages	85	98
Meteorological Stations		
Reservoir Buoy	2	15
Ops Precip	16	28
Snow Core	82	79
Snow Pillow	12	132
Full Station	26	275
Water Quality Sites		
Aqueduct	13	109
Reservoir - Discrete Depth	10	46
Reservoir - AutoProfiling Buoy	8	80
Reservoir - Manual Profile	40	400
Stream - AutoSampling	8	41
	> 350	> 1,700

Quantity & Operations
OASIS Model

OASIS GUI Schematic





NODES

625

Reservoir

767

Demand

630

Junction

ARCS

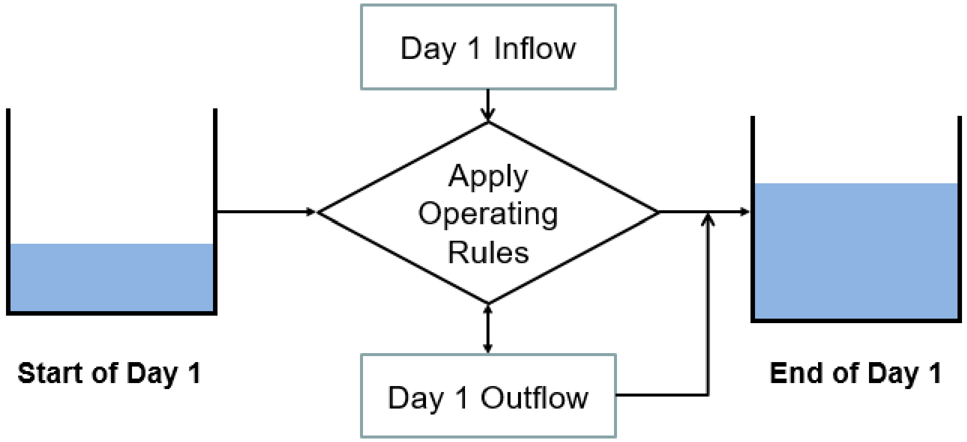
OASIS - Operational Analysis and Simulation of Integrated Systems

Quantity & Operations
OASIS Model (cont.)

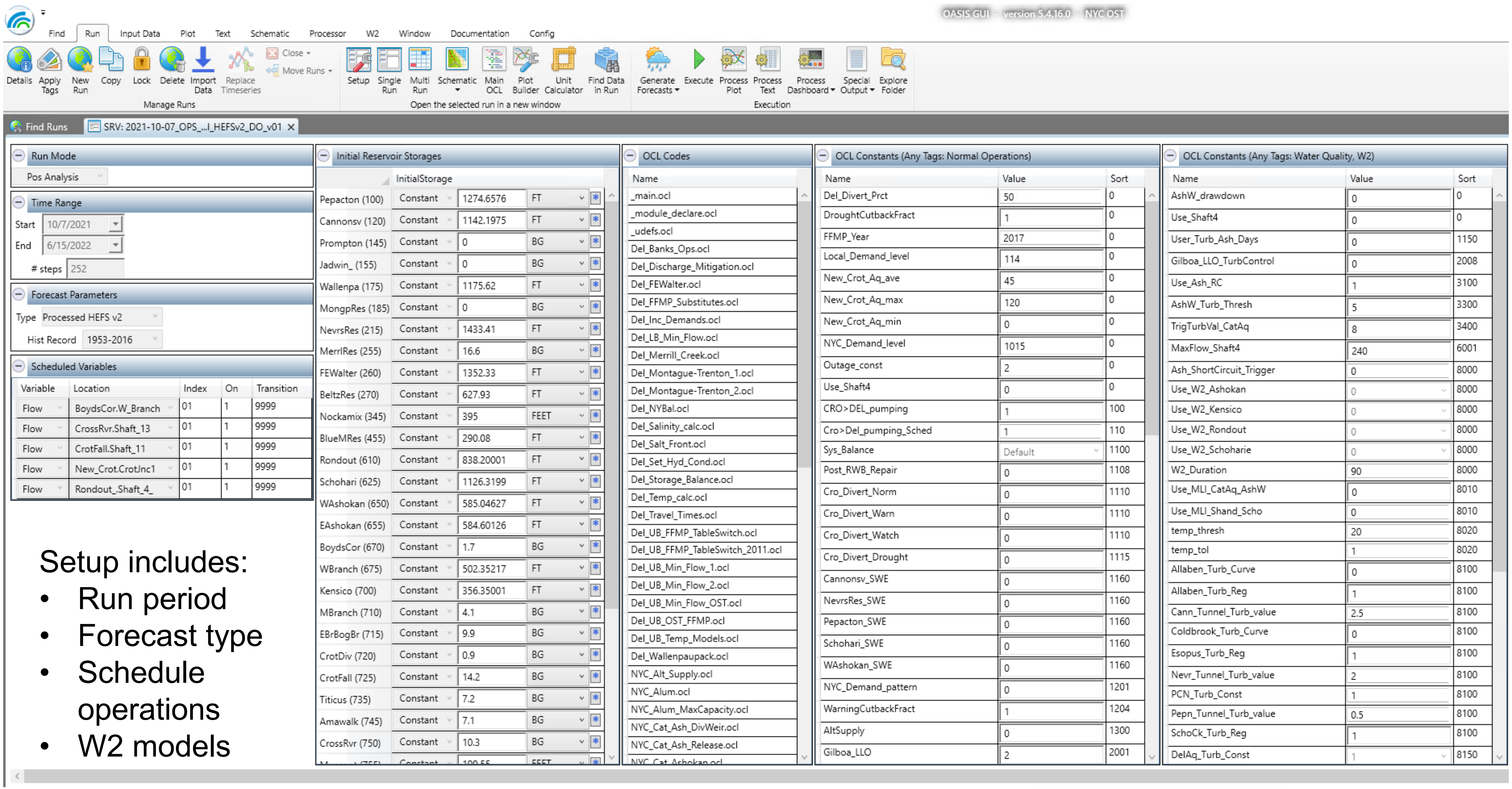
- A software by Hydrologics Inc.
- Simulates routing of water
  - Applying operating rules
  - Weights set order of priority
  - Linear Programing (LP)

- Utilizes an Operations Control Language (OCL)
- Generalized program
- Data-driven

- On each simulation day
  - Reservoirs receive inflow
  - Demand nodes draw water from the system
  - Feedback with WQ models



Run Setup - OASIS GUI



Setup includes:

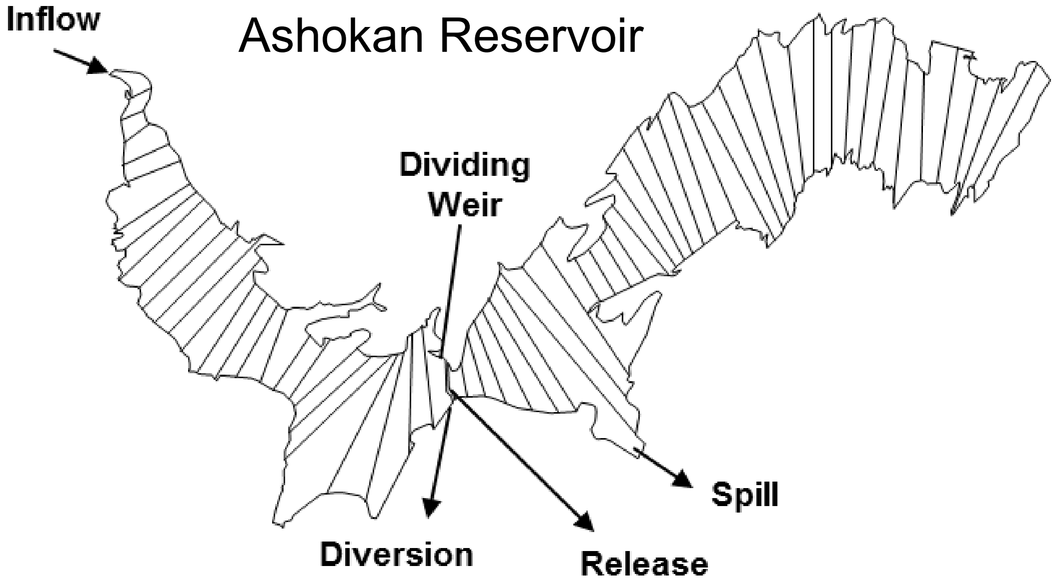
- Run period
- Forecast type
- Schedule operations
- W2 models

Water Quality Model
CE-Qual-W2 (W2)

- Public-domain model
  www.ce.pdx.edu/w2

- 2D (longitudinal/vertical) hydrodynamic and water quality model

- Current Outputs daily turbidity and temperature

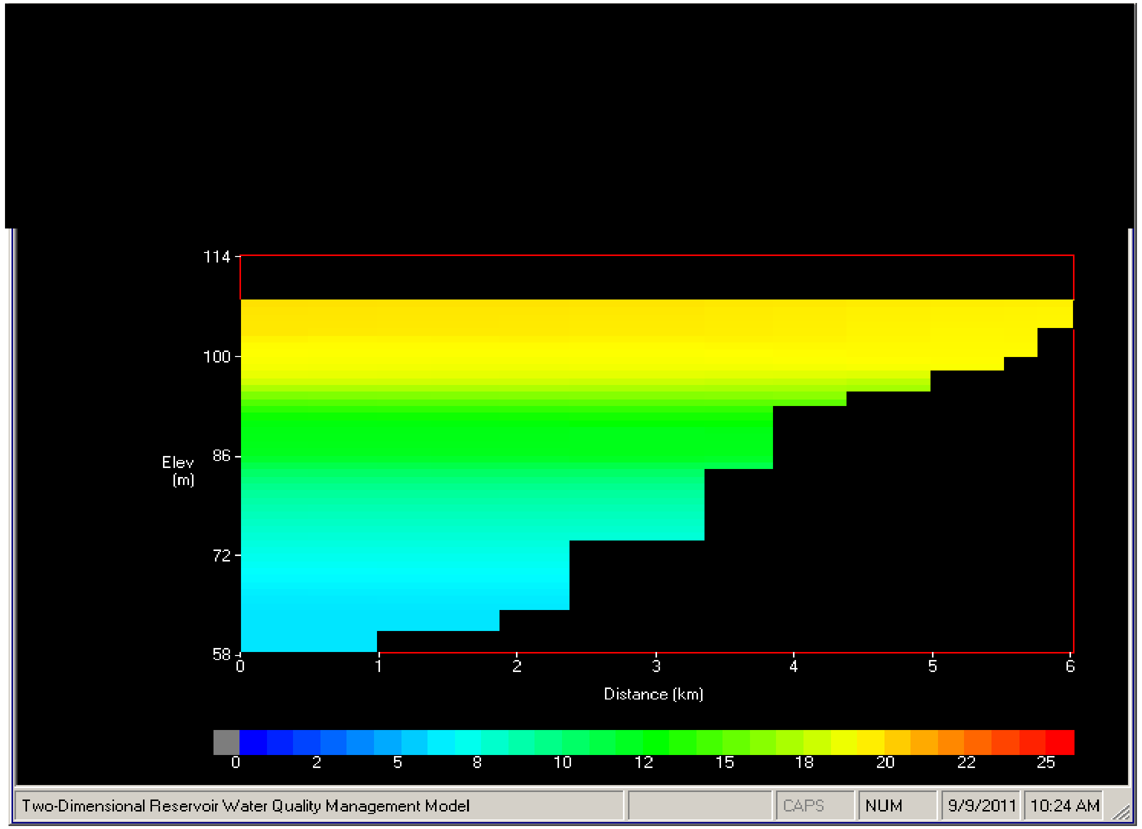


- Current OST W2 models:
  - Schoharie
  - Ashokan
  - Kensico
  - Rondout

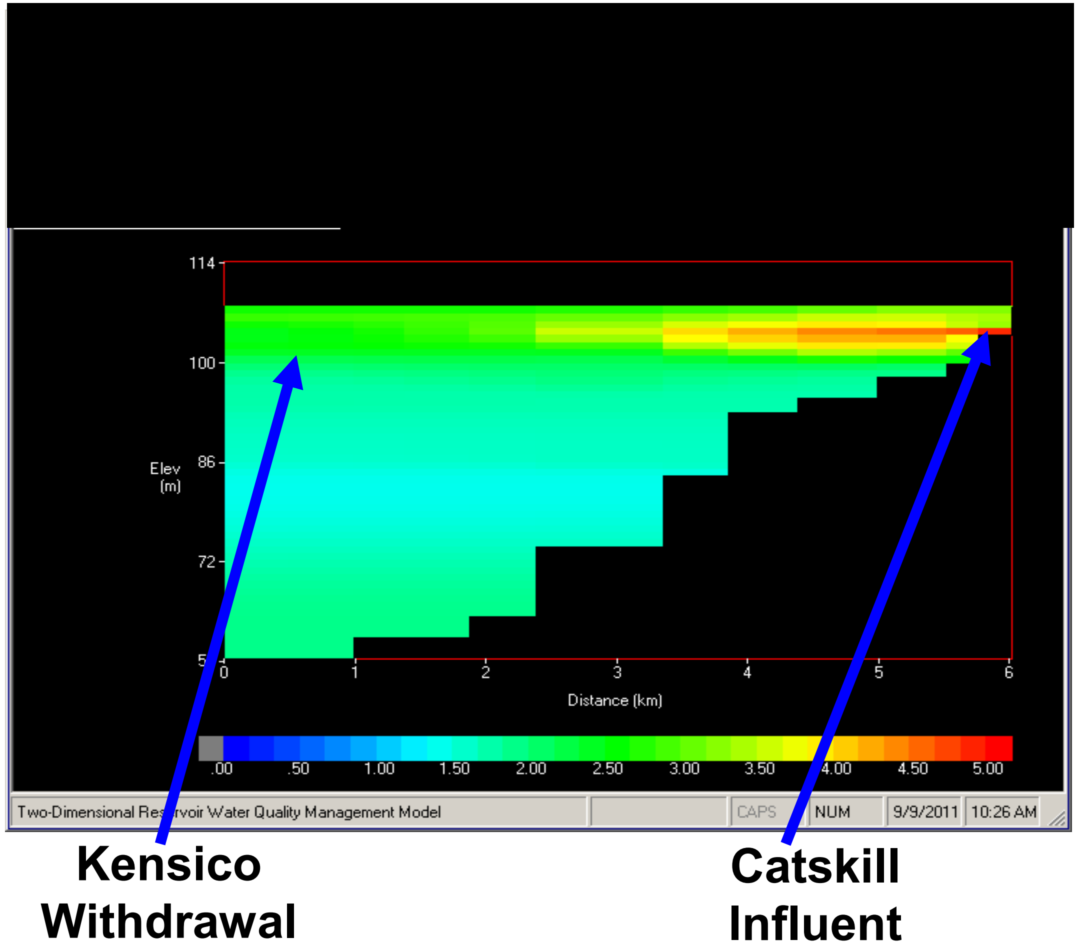
- In development
  - Pepacton
  - Cannonsville
  - Neversink

Water Quality Model
CE-Qual-W2 (W2)

Temperature profile



Turbidity profile



Inflow Forecasts

NATIONAL WEATHER SERVICE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Available in OST

- Historical non conditional
- Hirsch
- Enhanced Hirsch
- AHPS
- HEFS

Current HEFS forecasts are based on GEFSv10 (2014)

- HEFS – Hydrologic Ensemble Forecast Service
- GEFS – Global Ensemble Forecast System
- NWS HEFS national rollout in 2017
- DEP funded accelerated development

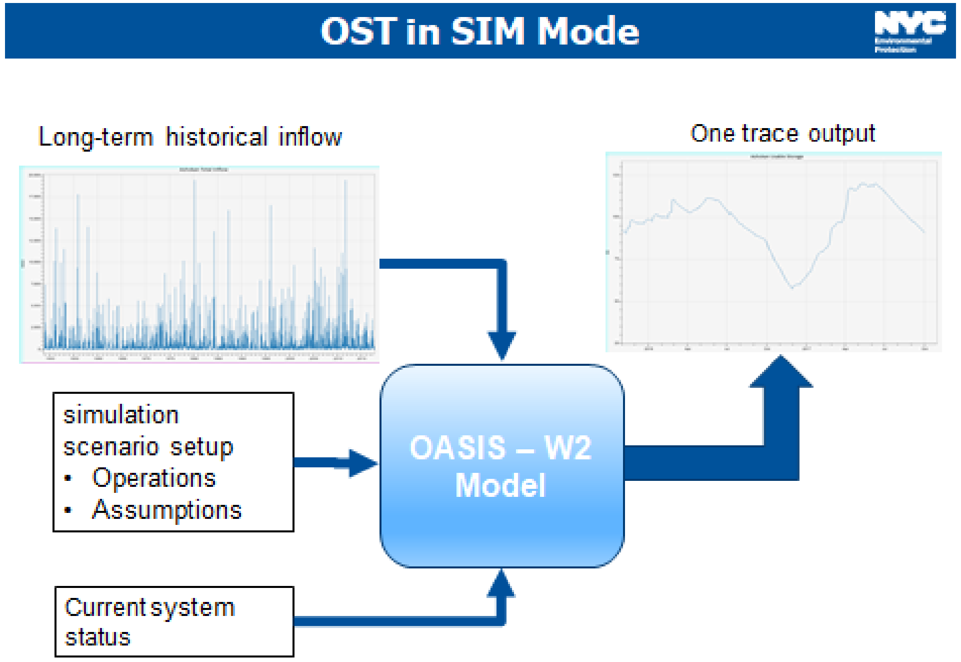
NWS Delivered first GEFSv12 product for OST Sites

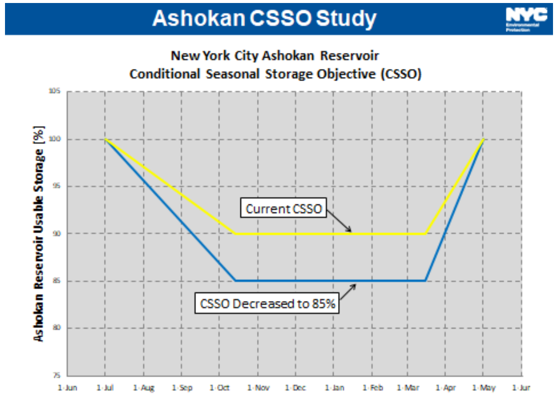
- Improved forecast skill
- Added more ensemble traces (38 to 60)

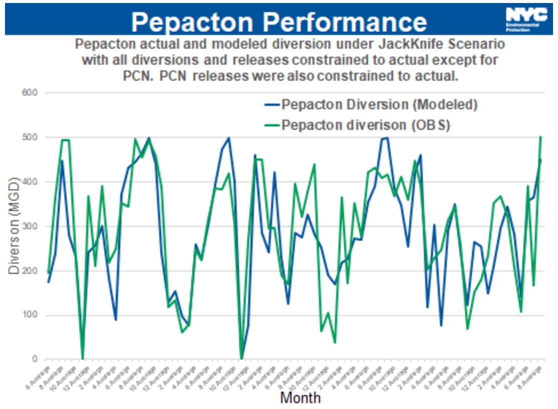
How do we Apply OST?

- **Three run modes are available**
  - Each run mode has specific
    - characteristics and application
    - Input data
    - Output format and interpretation

- **Simulation mode (Sim)**
  - A long-term model run
  - Multiple years
  - Used for planning and climate change assessment
  - Other examples of application
    - Support new rules development
    - Safe Yield studies
    - CSSO studies
    - Model performance studies



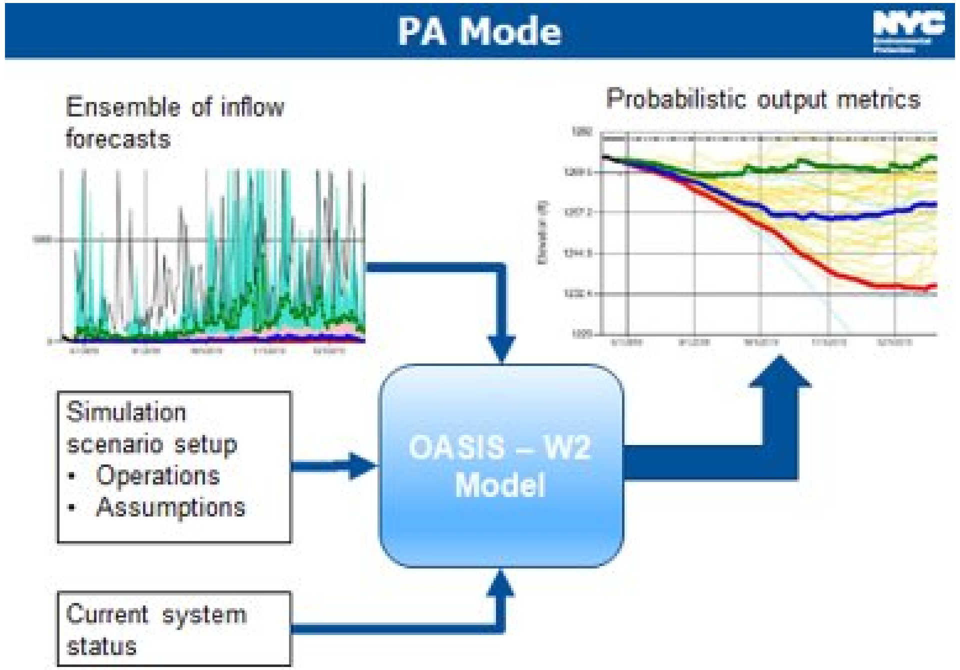


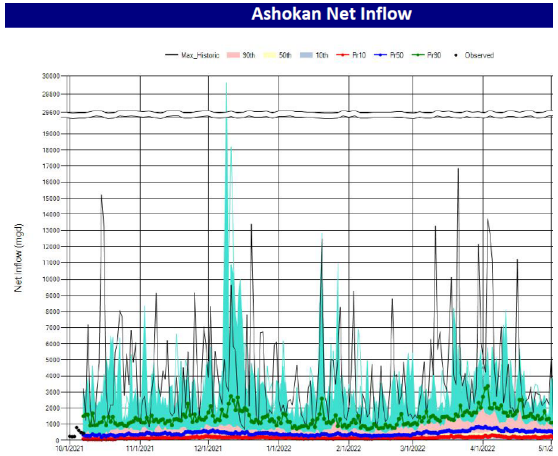


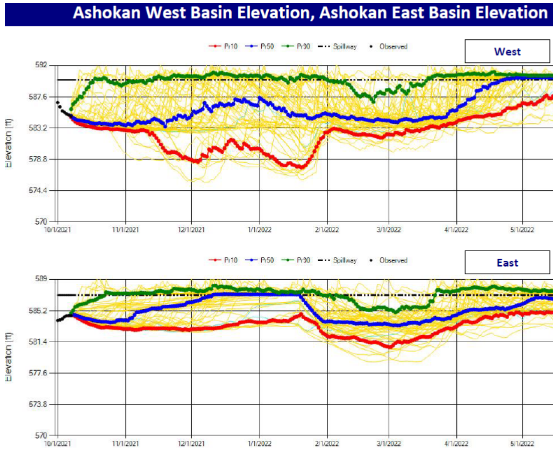
How do we Apply OST (cont.)?

- Positional Analysis (PA)
  - A short-term model run using multiple traces
  - Supports daily operations
    - Open run
    - Current Operations run
    - Test alternatives
  - Infrastructure

    shutdown support

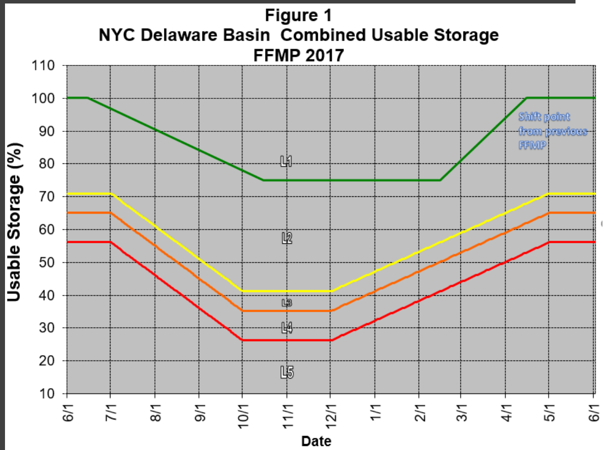






Forecast Informed Operations and the FFMP

- OST-2017 FFMP Release Summary
- OST-2017 FFMP Discharge Mitigation
- Customized OST outputs
- Published monthly



OST-2017 FFMP Release Summary
Decision Day: 8/17/2021

General Release Mass Balance

Combined Pepacton, Cannonsville, and Neversink (PCN) Storage:	250,483	MG
+ PCN Inflow Forecast Accumulated to Jun 1:	396,716	MG
- Expected PCN Diverson Accumulated to Jun 1:	153,939	MG
-Jun 1 Storage Target:	267,460	MG
= Available Release Quantity Accumulated to Jun 1:	225,800	MG

Available Release Quantity Evenly Distributed to June 1

Available Release Quantity Accumulated to Jun 1:	225,800	MG
/ Number of Days to Distribute Release Quantity:	288	days
Current PCN Release Target:	784	mgd
Current PCN Release Target:	1,213	cfs

Current Storage Zone for Schedule Selection

	Usable Storage	Usable Storage + Snow Storage	Zone
PCN	93.7%	*	
Pepacton	94.7%	*	L1-b
Cannonsville	91.4%	*	L1-c
Neversink	95.4%	*	L1-b

*Not applicable (snow storage is included in the forecast)

Use Release Target and Storage Zone to Select Release Schedule

Storage Zone, Summer (cfs)

	Pepacton L1-b	Cannonsville L1-c	Neversink L1-b	PCN
Table-4a	300	215	150	665
Table-4b	300	300	150	750
Table-4c	300	350	150	800
Table-4d	300	400	150	850
Table-4e	300	450	150	900
Table-4f	300	500	150	950
Table-4g	300	550	150	1000

Selected Schedule:Table(s) 4g

Mid-month release summary

OST-2017 FFMP Release Summary
Decision Day: 8/17/2021

General Release Mass Balance		
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Reservoir inflow accumulated through Jun 1 is used to calculate NYC Delaware basin reservoirs mass balance

Mid-month release summary

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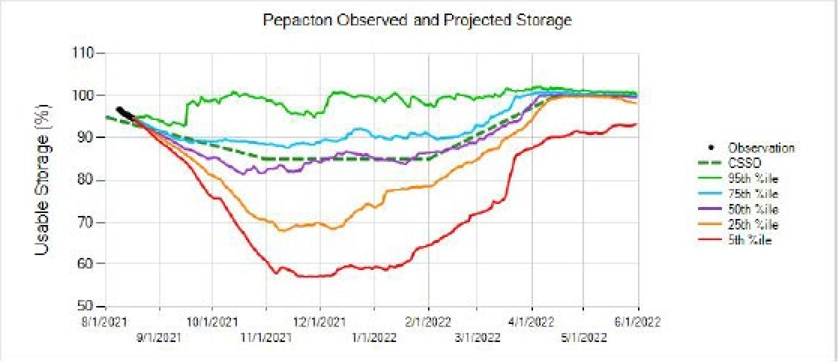
Selected Schedule:Table(s) 4g

Mass balance is used to determine the release quantity from three NYC reservoirs to the Delaware River Basin

OST-2017 FFMP Discharge Mitigation

OST-2017 FFMP Summary Page
Decision Day: 8/17/2021

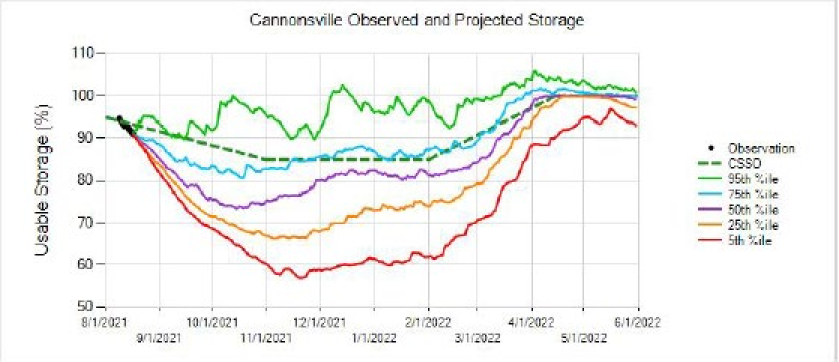


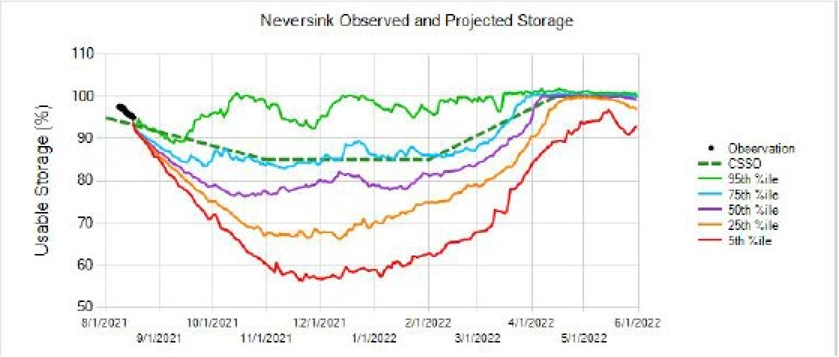
OST-2017 FFMP Discharge Mitigation
Decision Day: 8/17/2021

Discharge Mitigation Mass Balance		
Current PCN Usable Storage:	250,483	MG
+ Current PCN Snow Storage:	*	MG
+ PCN Inflow Forecast Accumulated 7 Days:	3,304	MG
- OST-FFMP Minimum Releases Accumulated 7 Days:	4,524	MG
- Expected PCN Diversion Accumulated 7 Days:	5,697	MG
- PCN Conditional Storage Objective:	247,545	MG
= Estimated 7 Day PCN Excess over CSSO:	**	MG

*Not applicable (snow storage is included in the forecast)

CSSO: Conditional Seasonal Storage Objective





Would we recommend other complex systems to implement a similar tool and why?

- **Hydrological forecast is uncertain**
- **Ensemble forecasts**

Led to a shift in the way we operate the system

- From deterministic to risk-based

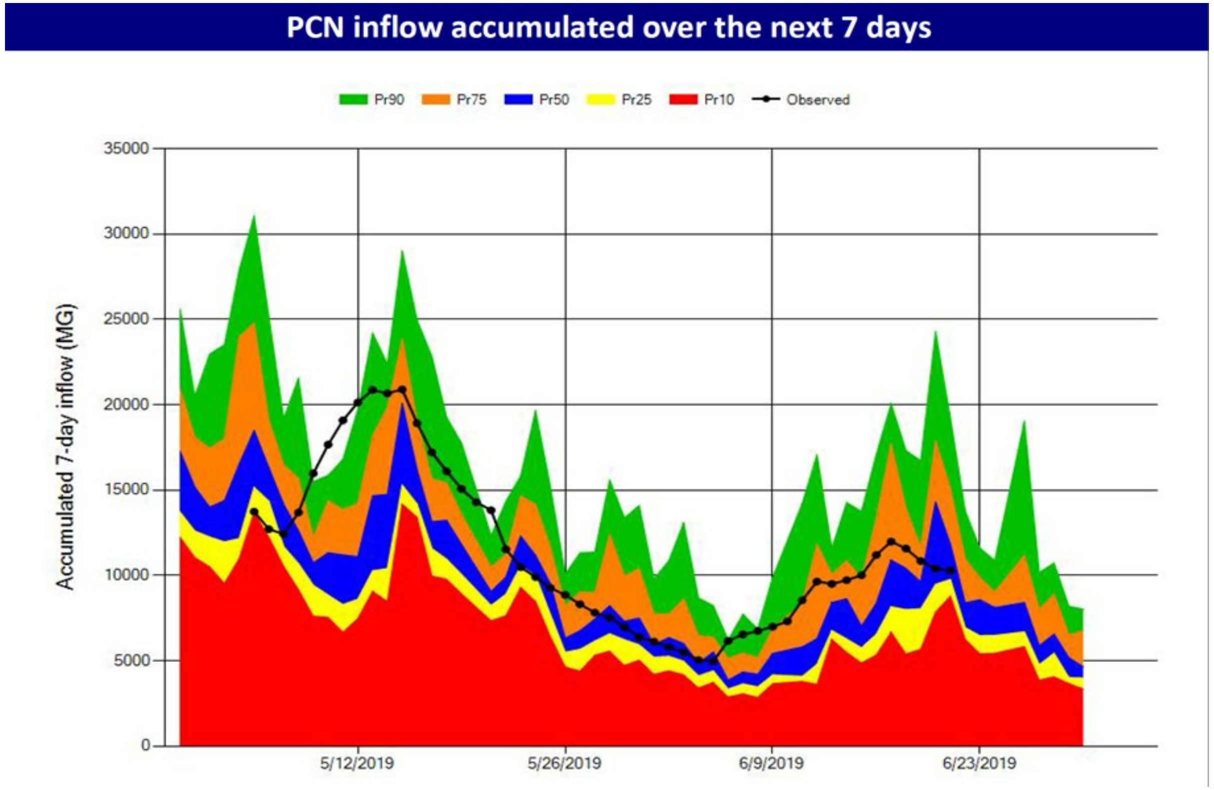
Initially challenging and difficult

- How to interpret model results
- How to display model output
- A learning process

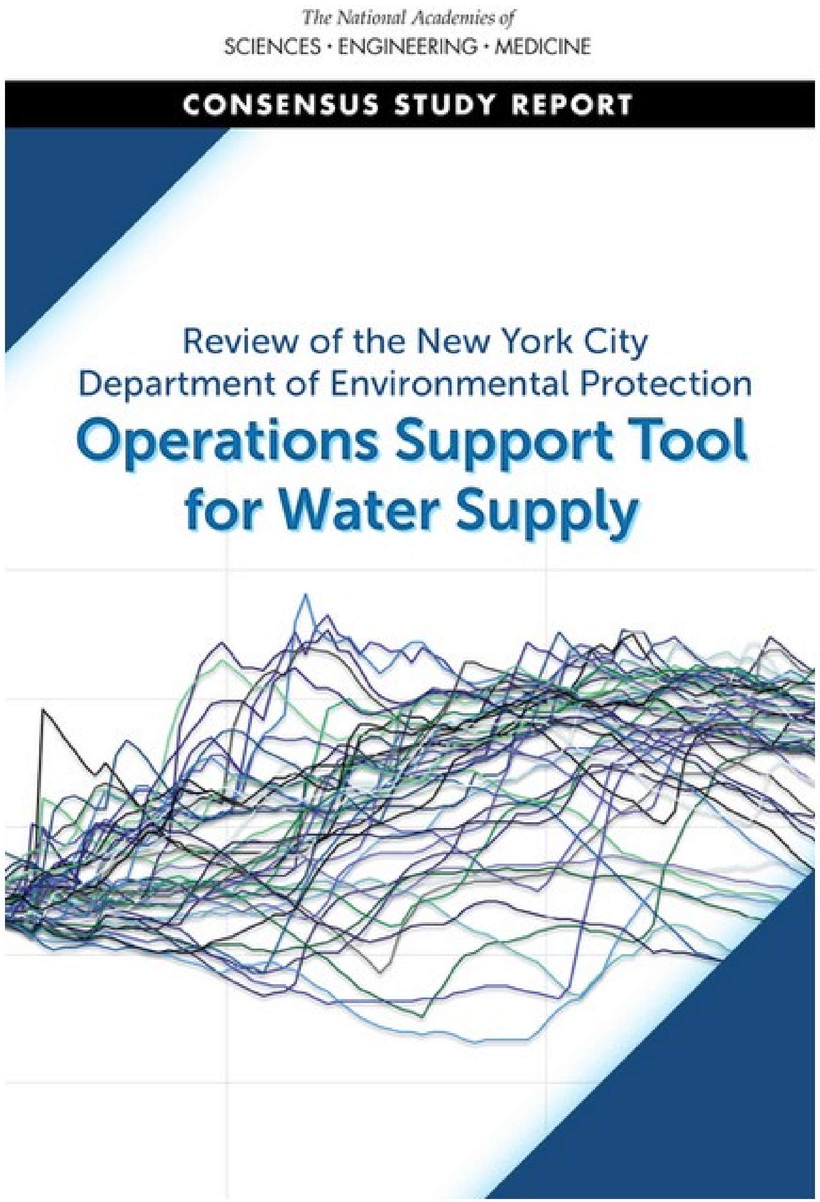
It is a dynamic process

- Streamflow forecast performance changes frequently

Now that we have started using the new approach, it would be even more difficult to operate our system without it !



OST Review by the NASEM Expert Panel



"One of the most advanced and complex support tools for water supply operations of its kind in the world."
(NASEM)

Thank You!

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Special Advisor to BWS

NYC Environmental Protection