New York City's Operations Support Tool (OST)

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Presentation Outline

- Overview NYC Water Supply
- Background, FFMP
 - o 1954 Supreme Court Decree
 - Terms of the Decree
 - Things get interesting
 - Finding Answers
 - o 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
 ⁴ Program (FFMP)



25

20

15

10

1900

values



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

First Julian day reservoir system pass 90% storage



Delaware

Scenario

Future 4668

Future 8100

Baseli

Background FFMP

Thomas Murphy, P.E.

SPECIAL ADVISOR TO BWS





Dashboard Data About ODRM FFMP Publications 🐔

OFFICE OF THE DELAWARE RIVER MASTER

Flexible Flow Management Program



https://webapps.usgs.gov/odrm/ffm p/flexible-flow-managementprogram





Delaware River Basin Commission DELAWARE • NEW JERSEY PENNSYLVANIA • NEW YORK UNITED STATES OF AMERICA



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
 - $\circ \text{Flooding}$
 - \circ 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
 - $_{\odot}$ The Delaware system provides about 60% of the City's water $_{\odot}$ 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
 - \odot Conversely when less water is available, less water is released

NYC OST

Adao Matonse, Ph.D. DEPUTY CHIEF, OPERATIONS MODELING & ANALYSIS



NATIONAL WEATHER SERVICE



RIVERSIDE global science solutions



Multiple Objectives

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- EPA Filtration Avoidance Determination (FAD)
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- Operating costs
- Regulated releases and diversions
 - $_{\odot}$ 2017 Flexible Flow Management
 - ¹⁴ Program (FFMP)

The Challenge

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

Models can help!



Why OST?

The Catskill System

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





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
 - $\circ~$ Head discharge functions
 - Reservoir storage zones
 - Aqueducts capacity
- Operating Rules
 - \circ Stream releases
 - Reservoir balancing
 - \circ 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



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
 - \circ Reservoirs receive inflow
 - Demand nodes draw water from the system
 - $\circ~$ Feedback with WQ models



Run Setup - OASIS GUI

Find Run Input Data Plot Text Schematic P	Processor W2	Window	Documentation	Config			OASI	5 GUI - version 5.4,16.0 -	NYC OST			
Details Apply New Copy Lock Delete Import Replace Data Timeseries	uns + Setup Sin Ri	ngle Multi Schr un Run	ematic Main CL Bi elected run in a n	Plot Unit uilder Calculator	Find Da in Run	ta Generate Execute Process Process Pro Forecasts *	xcess Special Explore poard • Output • Folder					
Find Runs FIND RUNS SRV: 2021-10-07_OPSI_HEFSv2_DO_v01 ×		opentites										
Run Mode	Initial Reserv	voir Storages				⊖ OCL Codes	OCL Constants (Any Tags: Norr	nal Operations)		OCL Constants (Any Tags: Water Q	uality, W2)	
Pos Analysis 🔍		InitialStorage				Name	Name	Value	Sort	Name	Value	Sort
Time Range	Pepacton (100)	Constant v	1274.6576	FT v	* ^	_main.ocl	Del_Divert_Prct	50	0 /	AshW_drawdown	0	0 ^
Start 10/7/2021 V	Cannonsv (120)	Constant v	1142.1975	FT v	*	_module_declare.ocl	DroughtCutbackFract	1	0	Use_Shaft4	0	0
End 6/15/2022	Prompton (145)	Constant v	0	BG v	*	_udets.ocl	FFMP_Year	2017	0	User_Turb_Ash_Days	0	1150
# share 252	Jadwin (155)	Constant v	0	BG v	*	Del Discharge Mitigation oc	Local_Demand_level	114	0	Gilboa_LLO_TurbControl	0	2008
# steps 232	Wallenna (175)	Constant ~	1175.62	FT v	*	Del FEWalter.ocl	New_Crot_Aq_ave	45	0	Use_Ash_RC	1	3100
Forecast Parameters	MongpRos (195)	Constant ~	0	BG v	*	Del_FFMP_Substitutes.ocl	New_Crot_Aq_max	120	0	AshW Turb Thresh	5	3300
Type Processed HEFS v2 V	Mongpites (165)	Constant	1422.41	ET V		Del_Inc_Demands.ocl	New_Crot_Aq_min	0	0	TrigTurbVal CatAg	0	3400
Hist Record 1953-2016 V	Nevrskes (215)	Constant	1455,41			Del_LB_Min_Flow.ocl	NYC_Demand_level	1015	0	MayElow Shaft/	0	6001
Scheduled Variables	MerriRes (255)	Constant	16.6	BG °		Del_Merrill_Creek.ocl	Outage const	2	0	Ash ChartCircuit Trianan	240	- 0000
Variable Location Index On Transition	FEWalter (260)	Constant ~	1352.33	FI V	*	Del_Montague-Trenton_1.ocl	Use Shaft4	0	0	Asn_shortcircuit_ingger	0	- 0000
Flaw X RaydsCar W Pranch V 01 1 9999	BeltzRes (270)	Constant ~	627.93	FT ~	*	Del_Montague-Trenton_2.ocl	CPO>DEL numering		100	Use_W2_Asnokan	0	0000
Flow CrocePur Shoft 12 01 1 9999	Nockamix (345)	Constant 🗸	395	FEET ~	*	Del Salinity calcoci	Creat Del compiling	1	110	Use_W2_Kensico	0	0000
Flow CrotFall Shaft 11 01 1 9999	BlueMRes (455)	Constant ~	290.08	FT v	*	Del_Salt_Front.ocl	Cro>Del_pumping_sched	1	1100	Use_w2_Kondout	0	0000
Flow X New Crat Cratical X 01 1 9999	Rondout (610)	Constant 🗸	838.20001	FT v	*	Del_Set_Hyd_Cond.ocl	Sys_balance	Default	1100	Use_wz_schonarie	0	0000
Flow X Deadeut Shaft 4 X 01 1 9999	Schohari (625)	Constant 🗸	1126.3199	FT v	*	Del_Storage_Balance.ocl	Post_KWB_Kepair	0	1108	W2_Duration	90	
riow Rondout_snart_4_ of 1 5555	WAshokan (650)	Constant V	585.04627	FT v	*	Del_Temp_calc.ocl	Cro_Divert_Norm	0	1110		0	0010
	FAshokan (655)	Constant V	584,60126	FT v	*	Del_Travel_Times.ocl	Cro_Divert_Warn	0	1110	Use_MLI_Shand_Scho	0	
	BoudsCor (670)	Constant V	17	BG Y	*	Del_UB_FFMP_TableSwitch.ocl	Cro_Divert_Watch	0	1110	temp_thresh	20	= 8020
Setup includes:	WPranch (675)	Constant V	502 25217	ET V		Del UB Min Flow 1 oc	Cro_Divert_Drought	0	1115	Allahan Turh Cunio		
	wbranch (675)	Constant	302.53217	FT		Del UB Min Flow 2.ocl	Cannonsv_SWE	0	1160	Allaben_Turb_Curve	0	0100
Run period	Kensico (700)	Constant	356.35001	FI *		Del_UB_Min_Flow_OST.ocl	NevrsRes_SWE	0	1160	Allaben_Turb_Reg	1	8100
	MBranch (710)	Constant ~	4.1	BG V	*	Del_UB_OST_FFMP.ocl	Pepacton_SWE	0	1160	Cann_Tunnel_Turb_value	2.5	8100
 Forecast type 	EBrBogBr (715)	Constant v	9.9	BG v	*	Del_UB_Temp_Models.ocl	Schohari_SWE	0	1160	Coldbrook_Turb_Curve	0	8100
	CrotDiv (720)	Constant v	0.9	BG v	*	Del_Wallenpaupack.ocl	WAshokan SWE	0	1160	Esopus_Turb_Reg	1	8100
 Schedule 	CrotFall (725)	Constant v	14.2	BG v	*	NYC_Alt_Supply.ocl	NYC Demand pattern		1201	Nevr_Tunnel_Turb_value	2	8100
operations	Titicus (735)	Constant v	7.2	BG v	*	NYC_Alum.ocl	WarningCuthackEract		1204	PCN_Turb_Const	1	8100
operations	Amawalk (745)	Constant v	7.1	BG v	*	NYC Cat Ash DivWeir.ocl	AltComple	1	1204	Pepn_Tunnel_Turb_value	0.5	8100
 W2 models 	CrossRvr (750)	Constant v	10.3	BG v	*	NYC_Cat_Ash_Release.ocl	AltSupply	0	1300	SchoCk_Turb_Reg	1	8100
	14 1755	Constant	100.55	EEET V	×	NVC Cat Ashokan ocl	Gilboa_LLO	2	2001	DelAq_Turb_Const	1	8150 🗸

Water Quality Model CE-Qual-W2 (W2)

- Public-domain model <u>www.ce.pdx.edu/w2</u>
- 2D (longitudinal/vertical) hydrodynamic and water quality model
- Current Outputs daily turbidity and temperature
- Current OST W2 models:
 Schoharie
 Ashokan
 - \circ Kensico
 - \circ Rondout

- In development
 - Pepacton
 - o Cannonsville
 - Neversink



Water Quality Model CE-Qual-W2 (W2)

Temperature profile

Turbidity profile

Influent



Withdrawal

Inflow Forecasts



Available in OST

- Historical non conditional
- Hirsch
- Enhanced Hirsch
- AHPSHEFS

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



OST in SIM Mode

110



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
 - o 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	Cannonsville	Neversink	PCN
	L1-b	L1-c	L1-b	
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 Bal	ance			
	Combined Pepacton, Cannonsville, and Neversink (PCN) Storage:	250,483	MG	
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Available Release Quantity Evenly Distributed to June 1							
	225,800	MG					
	288	days					
	Current PCN Release Target:	784	mgd				
	Current PCN Release Target:	1.213	cfs				

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

Mid-month release summary

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			
	*N	lot applicable (snow storage is	included in the forecast)				
Use Release Target and Storage Zone to Select Release Schedule							
		Storage Zone, Summ	her				
		(cfs)					
	Pepacton	Cannonsville	Neversink	PCN			
	L1-b	L1-c	L1-b				
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

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

The National Academies of SCIENCES • ENGINEERING • MEDICINE

CONSENSUS STUDY REPORT

Review of the New York City Department of Environmental Protection **Operations Support Tool** for Water Supply



"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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