Disinfection Byproducts (DBPs) in the NYC Water Supply System in the aftermath of Tropical Storms Irene and Lee

Rich Van Dreason

NYC Department of Environmental Protection

Watershed Technical Conference, West Point , NY

September 13-14, 2012

Acknowledgments

- Lin Lu and Aspa Capetanakis
- Salome Freud, Carla Glaser, Yves Mikol
- Laurie Machung, Steve Schindler
- Gerry Marzec, Tracy Lawrence

Flooding from Irene and Lee

A home on County Route 145 in Middleburgh
Timesunion

rBdge in Windham on Sunday, Aug. 28, 2011

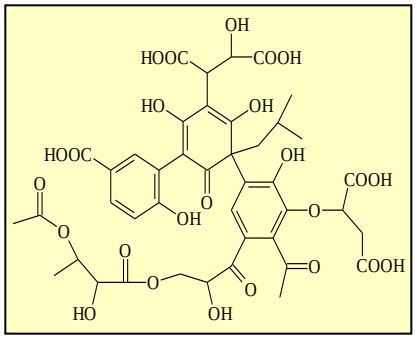
greenlaw.blogs.law.pace.edu

Irene/Lee Water Quality Impacts

Significant increases

- ❖Fecal coliforms
- ❖Turbidity
- ❖Disinfection byproducts

Introduction



+ Cl_2 → **Disinfection byproducts**

- DBPs are organic compounds formed when organic material in water reacts with a disinfectant (e.g. chlorine)
- DEP monitors two DBP classes
  - Trihalomethane (TTHM)
    - TTHM sum of 4 compounds; chloroform most important
  - Haloacetic acids (HAA5)
    - HAA5 sum of 5 compounds; di and trichloroacetic acid most important
- Some DBPs considered probable/possible carcinogens

Reasons for Concern

- 2011 DBPs very high post tropical storms
  - 52% (23/44) samples > MCL value for HAA5 (60 µg/L) in September and October
  - 45% (17/38) samples > MCL value for THMs (80 µg/L) in October and November
  - Never out of compliance in 2011!
- Regulations more stringent in 2012
  - Stage 1 rule compliance based on a system-wide running annual average of quarterly samples
  - Stage 2 rule compliance based on site specific running annual average of quarterly samples
  - Compliance now must be met at each sampling location rather than an average across the entire system

Factors affecting DBP formation

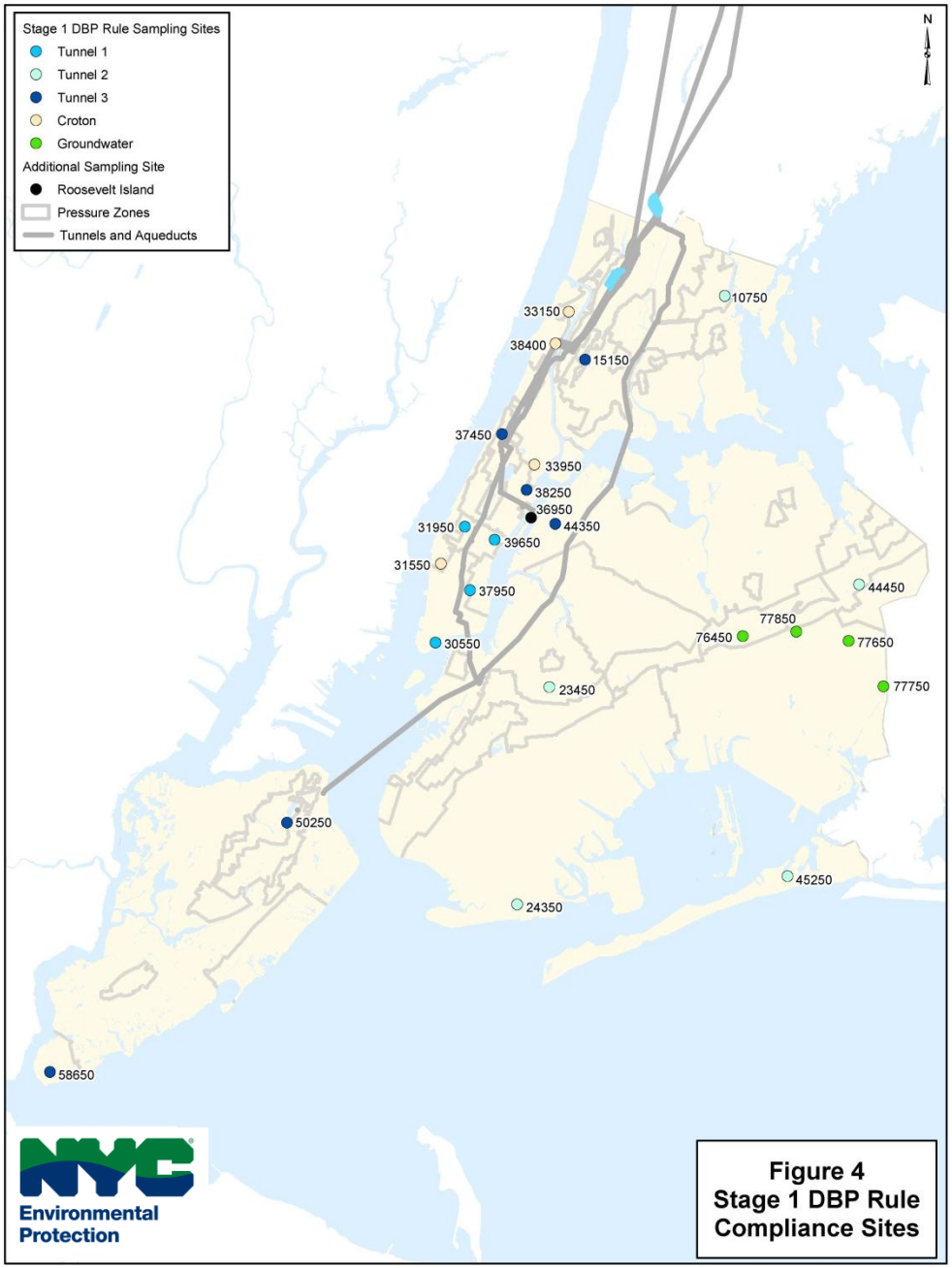
- Quantity of Natural Organic Matter (NOM)
  - TOC, DOC, UV254 common surrogates
- Temperature
  - Rx rates generally increase with temperature
  - At < 10°C, temperature does not effect THM concentrations
- Water age/reaction time with chlorine
- Chlorine dose
- pH
  - More basic conditions favor THM formation.
    - 25 to 50% more THMs will form at pH 7.8 than at pH 7.5.
  - More acidic conditions favor HAA formation.

Objectives of Presentation

- Determine which factors <u>may</u> have contributed to DBP increase post Irene and Lee
  - Increased organic carbon from flooding
  - Necessary reliance on higher DOC source waters
  - Chlorination of West Branch effluent
  - Water temperature
  - Water age/reaction time with chlorine
  - Distribution treatment changes (e.g. pH, chlorination)

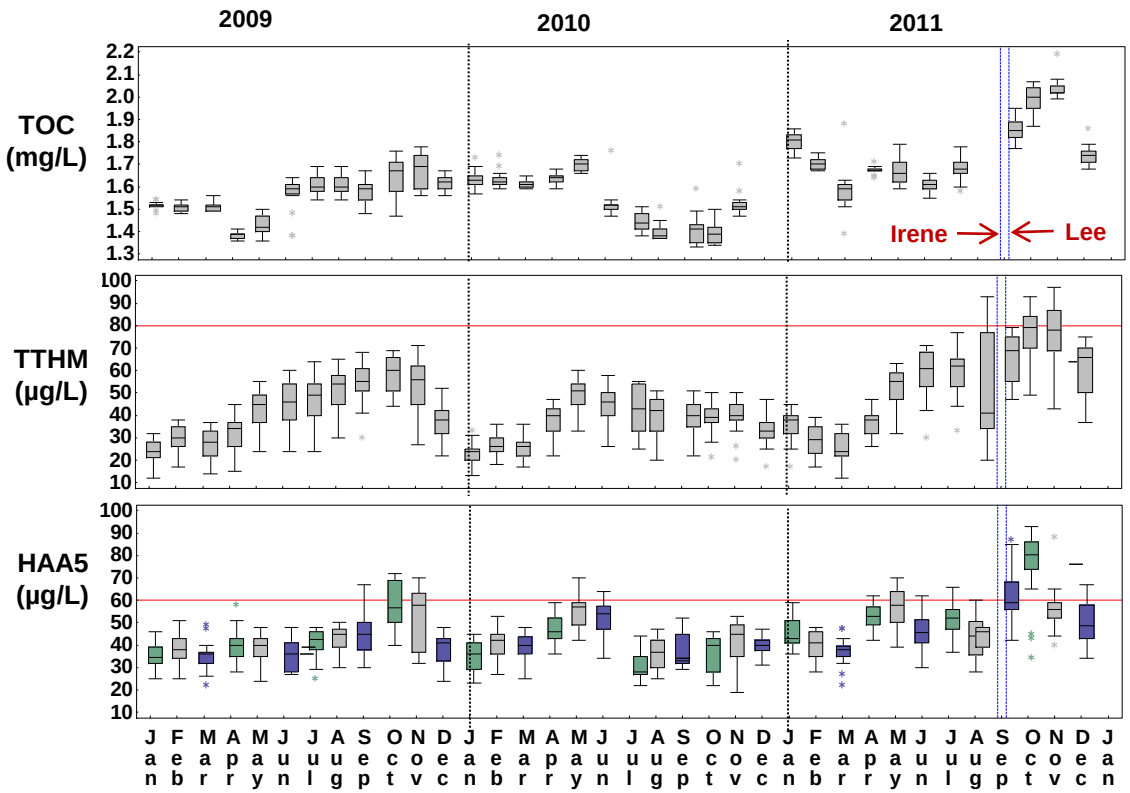
Relative importance not addressed !

Distribution Stage 1 DBP Compliance Sites



- Compliance THMs and HAAs sampled quarterly (Feb., May, Aug., Nov.)
- Extra THMs collected in noncompliance months as directed by NYSDOH
- Different HAA sites (40) are also sampled in noncompliance months.
- Sampling conducted on at least four distribution sites per tunnel/system one of which represents the maximum residence time in the system
- Croton system off since 2008; Croton sites receive Tunnel 1 water

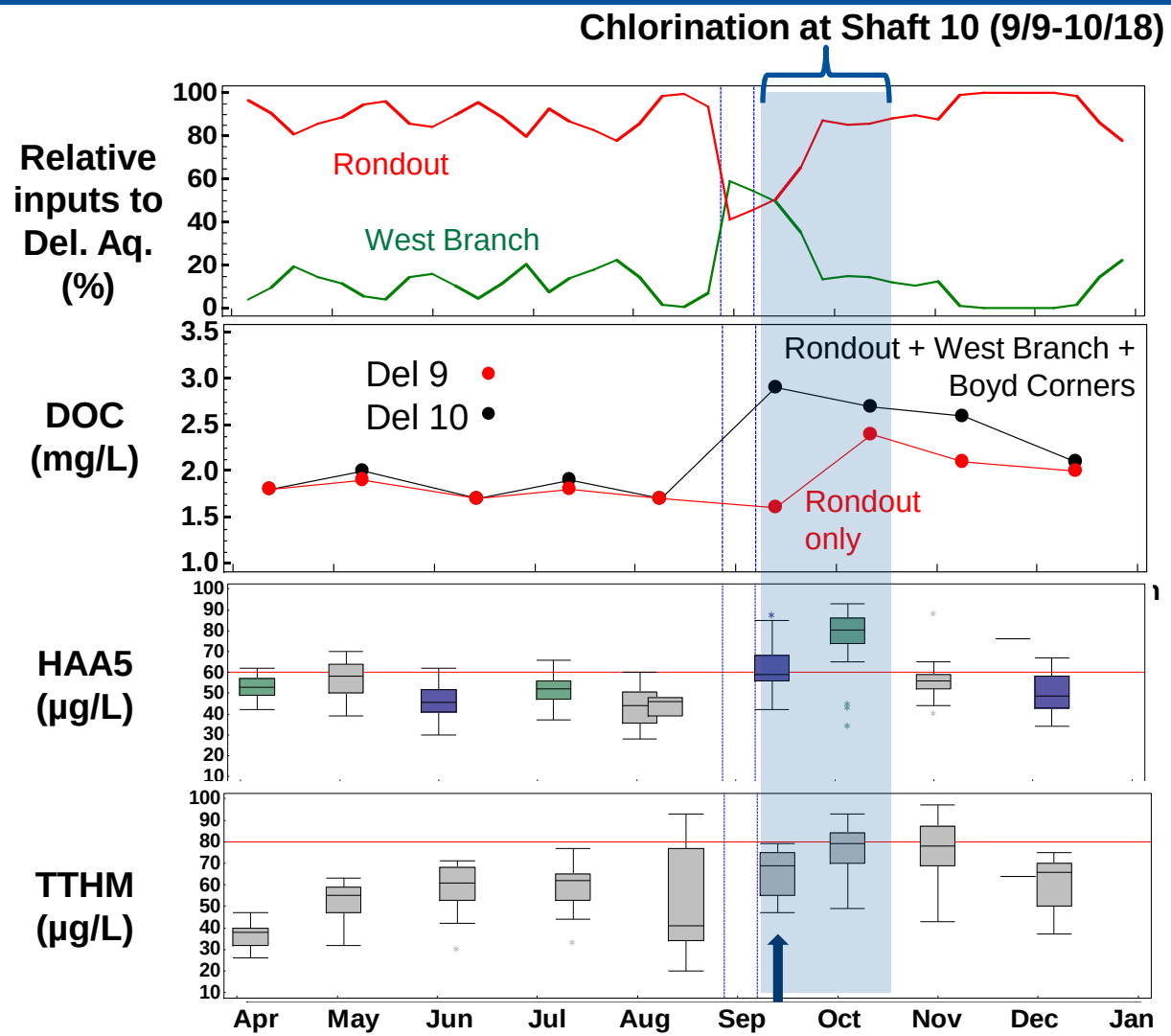
Organic Carbon and Disinfection Byproducts



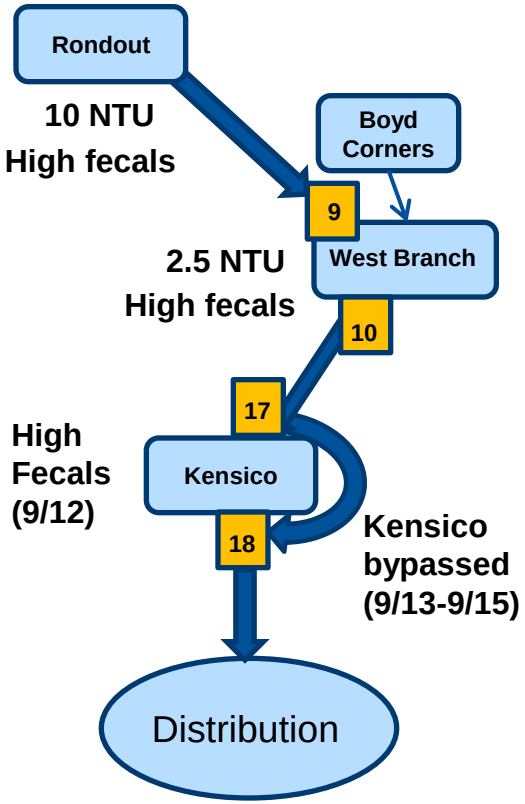
- Different colored boxes represent different sites each sampled quarterly

- TOC elevated 20% in 2011
  - Largely controlled by storms:
    - Oct and Dec 2010
    - Wet spring 2011 (13 in.)
    - Aug 14-15 (2-5 in.)
    - Irene 8/27, Lee 9/4-7 (15-20 in.)
      - Accounts for 12 of the 20% increase
- DBPs strongly correlated to TOC post Irene and Lee
- THMs up 34%; HAAs up 25%
- Increased TOC may also be from reliance on higher TOC source waters post Irene.

Reliance on West Branch/Boyd Corners



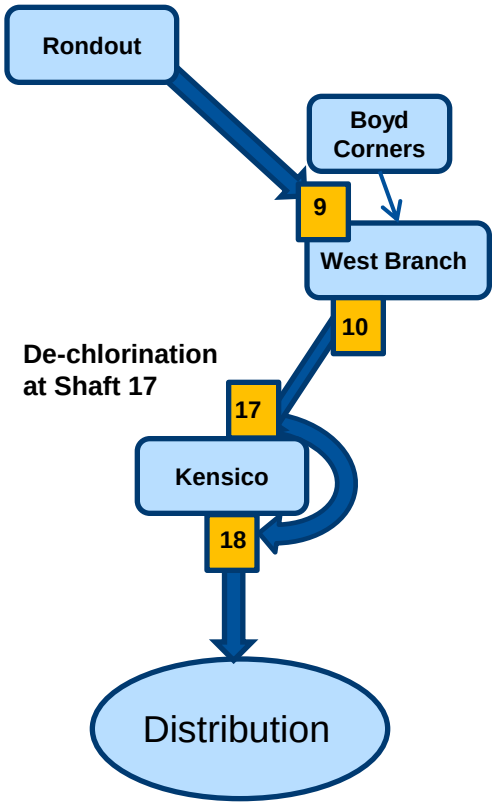
Post Irene Water Quality in Delaware Aqueduct



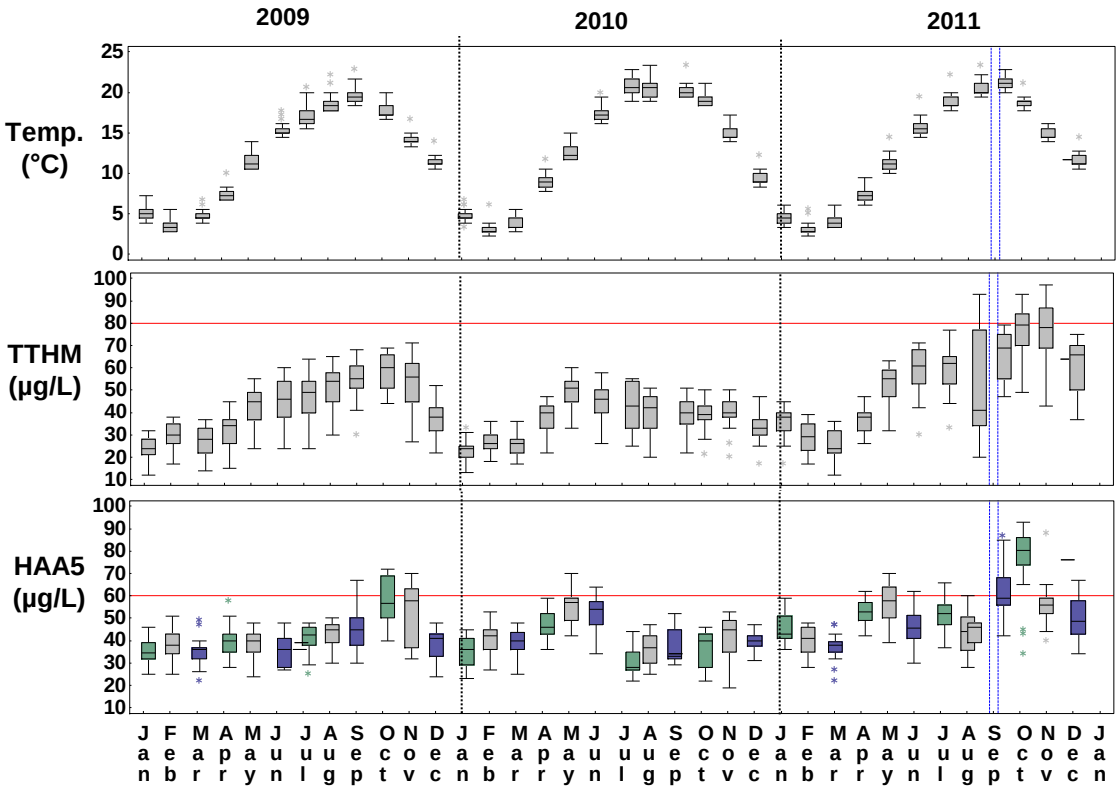
Increased reliance on West Branch/Boyd Corners + **Chlorination at Shaft 10** → **Elevated DBPs ?**

Chlorination at Shaft10 and DBP Formation in Kensico

- No DBP samples collected in Kensico
- DBP formation likely occurred
  - Elevated DOC from West Branch/Boyd Corners (3 mg L^{-1})
  - Contact time (7 hrs.) and chlorine dose (5 lbs./MG) sufficient to create some DBPs.
  - Water temperature increased during West Branch/Boyd Corners drawdown (18 to 21° C)
  - HAAs very persistent
    - Not volatile
    - Not susceptible to microbial or photo degradation
- DBP reduction factors
  - THMs highly volatile
  - Dilution with Kensico



Temperature and Disinfection Byproducts



- DBP reaction rates increase with temperature
- Irene & Lee occurred at the peak temperature of the year
- Water temperature 0.6° Celsius warmer than average July-December 2011

Distribution factors and THMs

Water age/contact time with chlorine

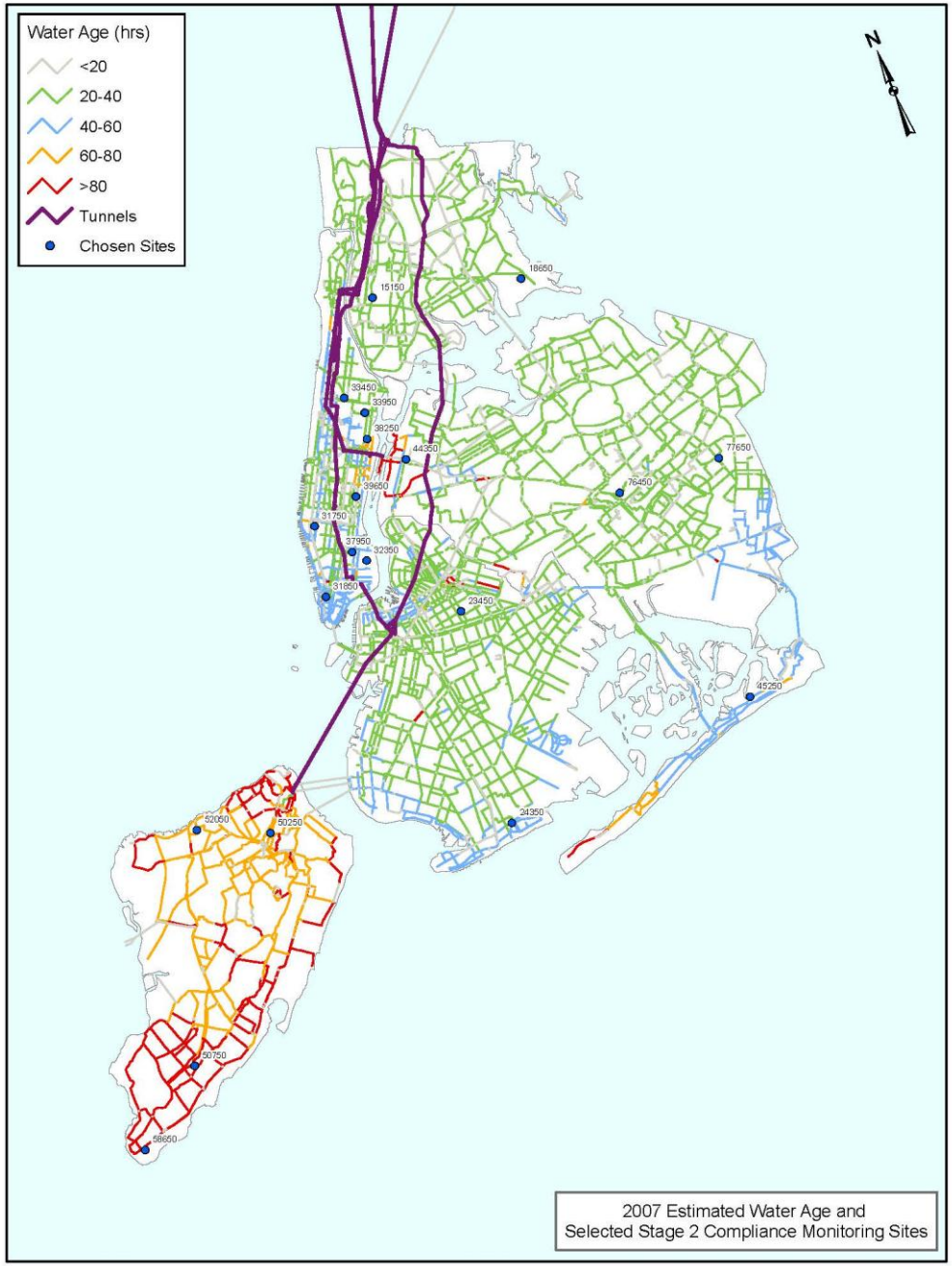
Chlorination

pH

THMs only

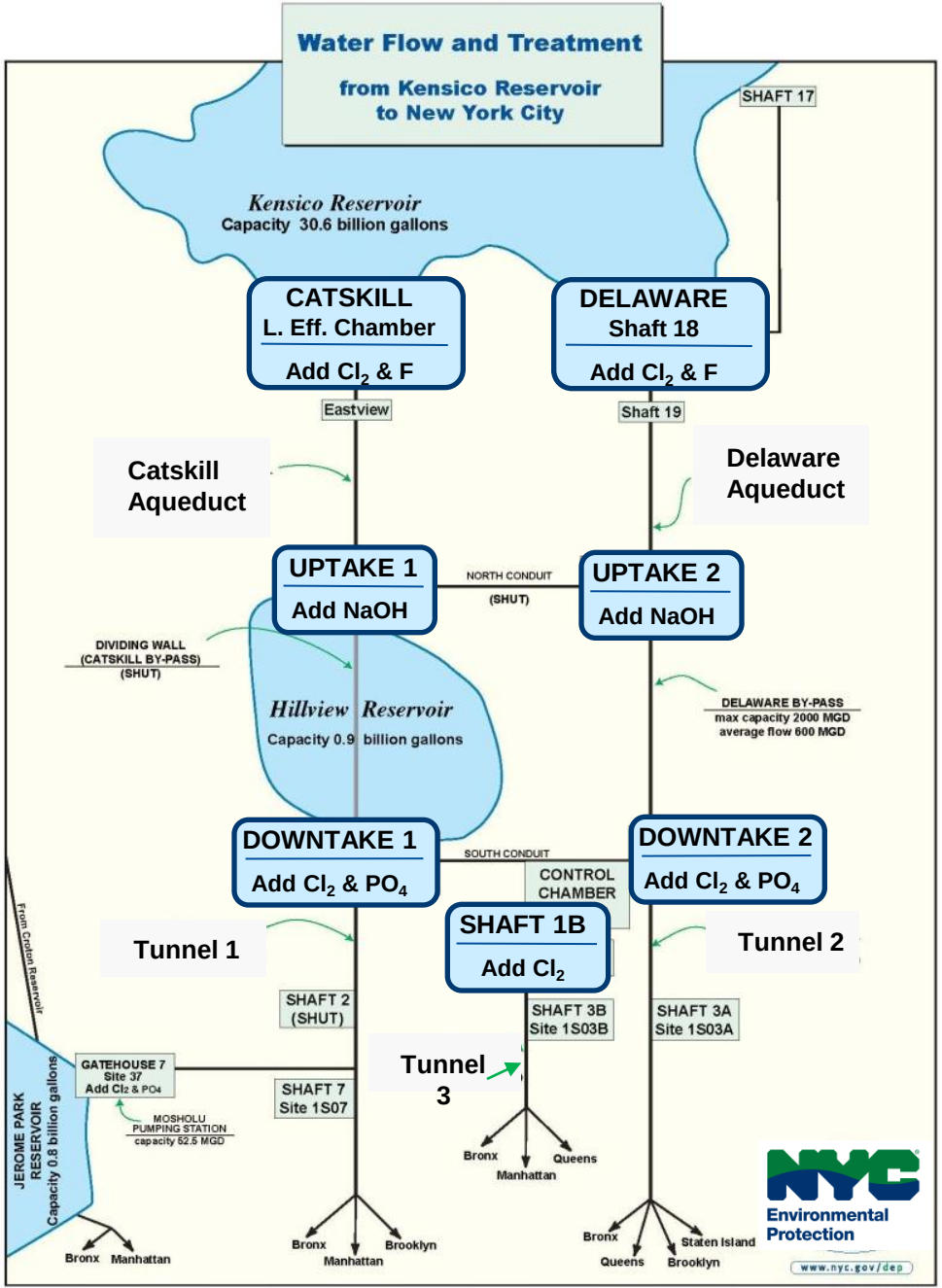
Location of treatment facilities

Water age and THMs



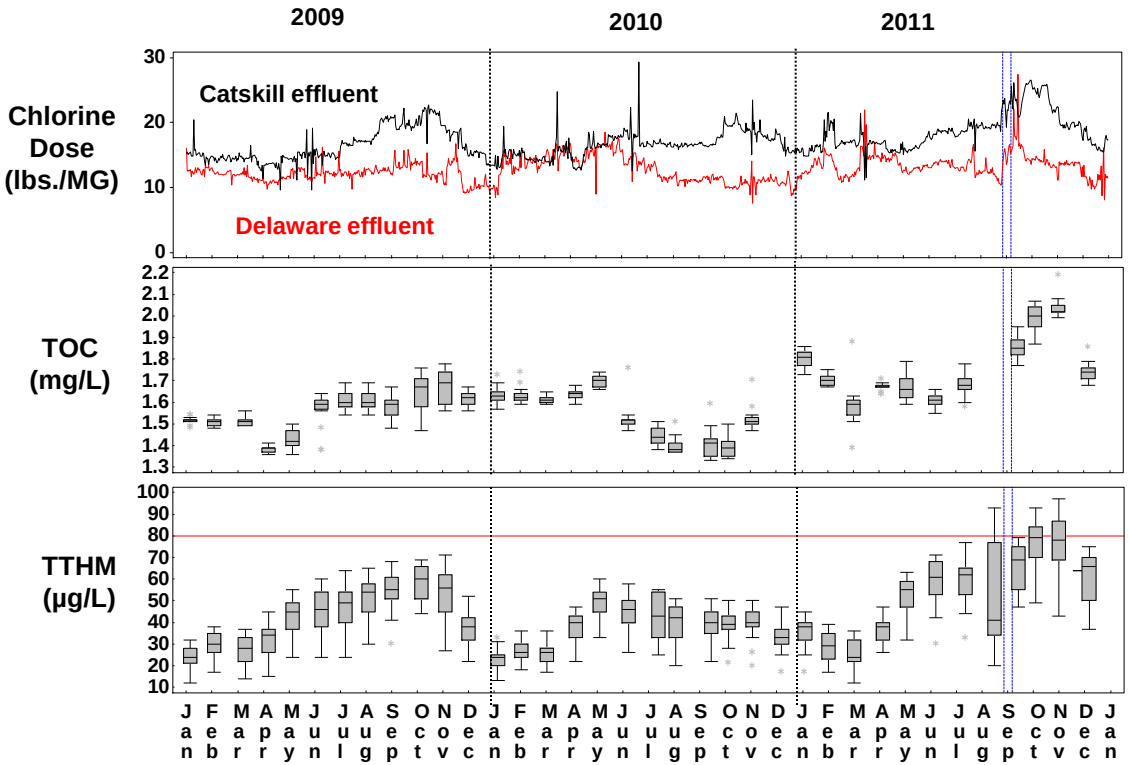
- THMs increase with increased water age/contact time with chlorine
- <u>No</u> change in water age before and after storms (Salome Freud, Chief of Distribution Water Quality Operations, personal communication)
- Water age did <u>not</u> factor in DBP increase post Irene and Lee

Water treatment from Kensico Reservoir to NYC



- Water chlorinated initially at Kensico effluents
- Sodium hydroxide added at Uptakes 1 & 2
- Second chlorination at Downtake 1 & 2
- Downtake 1 ➡ Tunnel 1
- Downtake 2 ➡ Tunnel 2
- A 50/50 blend of Tunnels 1 & 2 ➡ Tunnel 3
- Tunnel 3 chlorinated at Shaft 1B with sodium hypochlorite

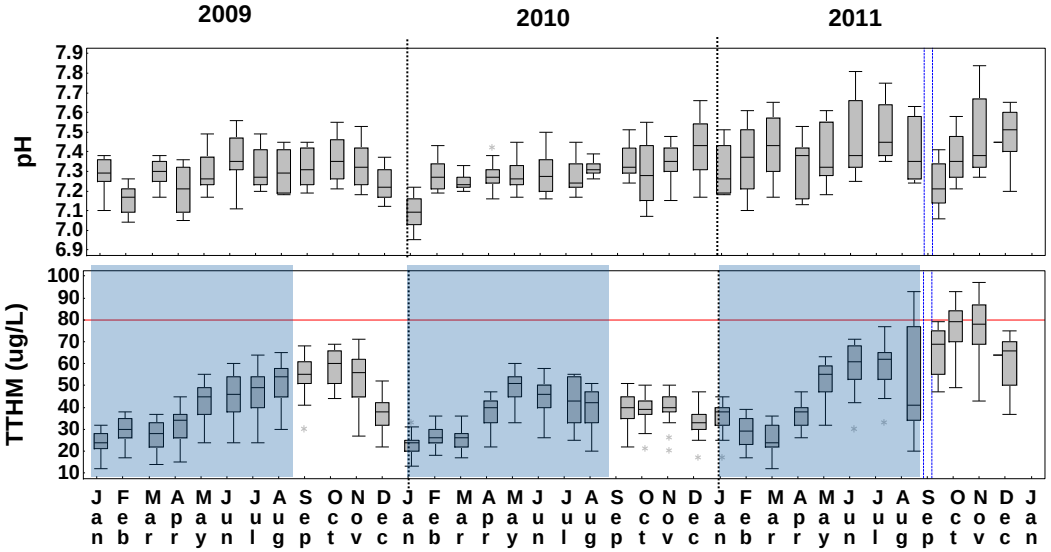
Distribution chlorination and THMs



- Chlorine dose increased in response to increased TOC from Irene/Lee

More Chlorine + More TOC → More THMs

Distribution pH and THMs



- ❖ 2011 pH high versus 2009-10 pH
  - Copper/lead rule violation in 2010-addressed by raising pH
  - In 2011, Tunnel 1&2 sites increased by 0.1 pH units; tunnel 3 sites increased more (0.2-0.3 units) due to hypochlorite usage
  - Jan-Aug 2011 THM up 18% at Tunnel 1 sites,16% at Tunnel 2 sites and 27% at Tunnel 3 sites compared to 2009-2010.
  - pH increase may be an important factor explaining the 34% THM increase in 2011

- ❖ THMs are very sensitive to pH increases
  - Past bench tests indicate up to 50% increase in THMs with a pH change from 7.5 to 7.8-no change in HAAs (JV 2008)
- ❖ Pre- and post-storm pH similar except for September
  - pH post storm probably <u>not</u> associated with THM increase

Summary

- **Factors coinciding with elevated DBPs in 2011**
  - Elevated organic carbon
    - Multiple storms
    - Necessary reliance on higher organic carbon source water (i.e. West Branch/Boyd Corners)
  - Chlorination of West Branch effluent (9/9-10/18)
    - Coincides with highest HAAs in distribution (10/4)
  - Storms occurred at peak water temperature
  - Increased chlorine dose at Kensico effluents
  - Elevated 2011 pH especially at Tunnel 3 sites (0.3 pH units)
    - May have contributed to THM (but not HAA) increase
- **Nonfactors**
  - Water age-similar pre/post storms

DEP Strategy to Reduce Disinfection Byproducts

- Operationally select water with lower organic material
  - DOC/UV254 sampling increased to weekly at all reservoir keypoints
  - Investigate use of on-line organic carbon monitoring instruments
  - Goal: incorporate into DEP Operations Support Tool (OST)
- Reduce chlorine dose by utilizing UV for disinfection
- Investigate adjustments in distribution to reduce water age/contact time
- Increase reliance on Croton water after Croton filtration plant is operational (2014)