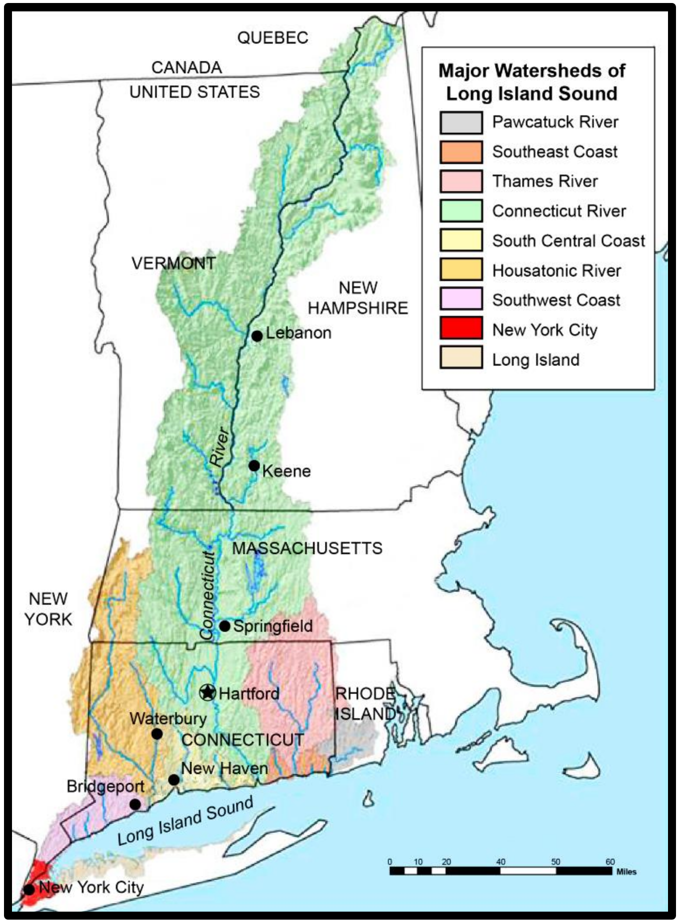


Low Cost BNR Retrofits in the Upper LIS Watershed

NEIWPCC Webinar, September 3, 2015

Jeanette Brown, President, JJ Environmental
Emily Bird, Environmental Analyst, NEIWPCC

Long Island Sound Study
A Partnership to Restore and Protect the Sound

NEIWPCC
New England Interstate Water Pollution Control Commission

TODAY'S PRESENTERS

Emily Bird

- Environmental Analyst in NEIWPCC Water Quality Division
- Project manager at NEIWPCC for:
  - TMDLs
  - Long Island Sound
  - Peconic Estuary
- Coordinates the five-state/EPA/NEIWPCC workgroup tasked with reevaluating the Long Island Sound TMDL
- Project manager for this study

TODAY'S PRESENTERS

Jeanette Brown

- President of JJ Environmental and a Research Assistant Professor at Manhattan College
- Areas of expertise:
  - Biological nutrient removal,
  - Plant operations
  - Biosolids management
- Past-president of the Water Environment Federation
- PE, BCEE, Diplomat-American Academy of Water Resource Engineers

Presentation Outline

- Project Background & Purpose
- Scope of Work
- Methodology
- Summary of Results

Introduction: The Long Island Sound

- Estuaries of National Significance
- Home to the National Estuary Program, Long Island Sound Study

The Problem

Eutrophication, or critically low DO influenced by multiple factors:

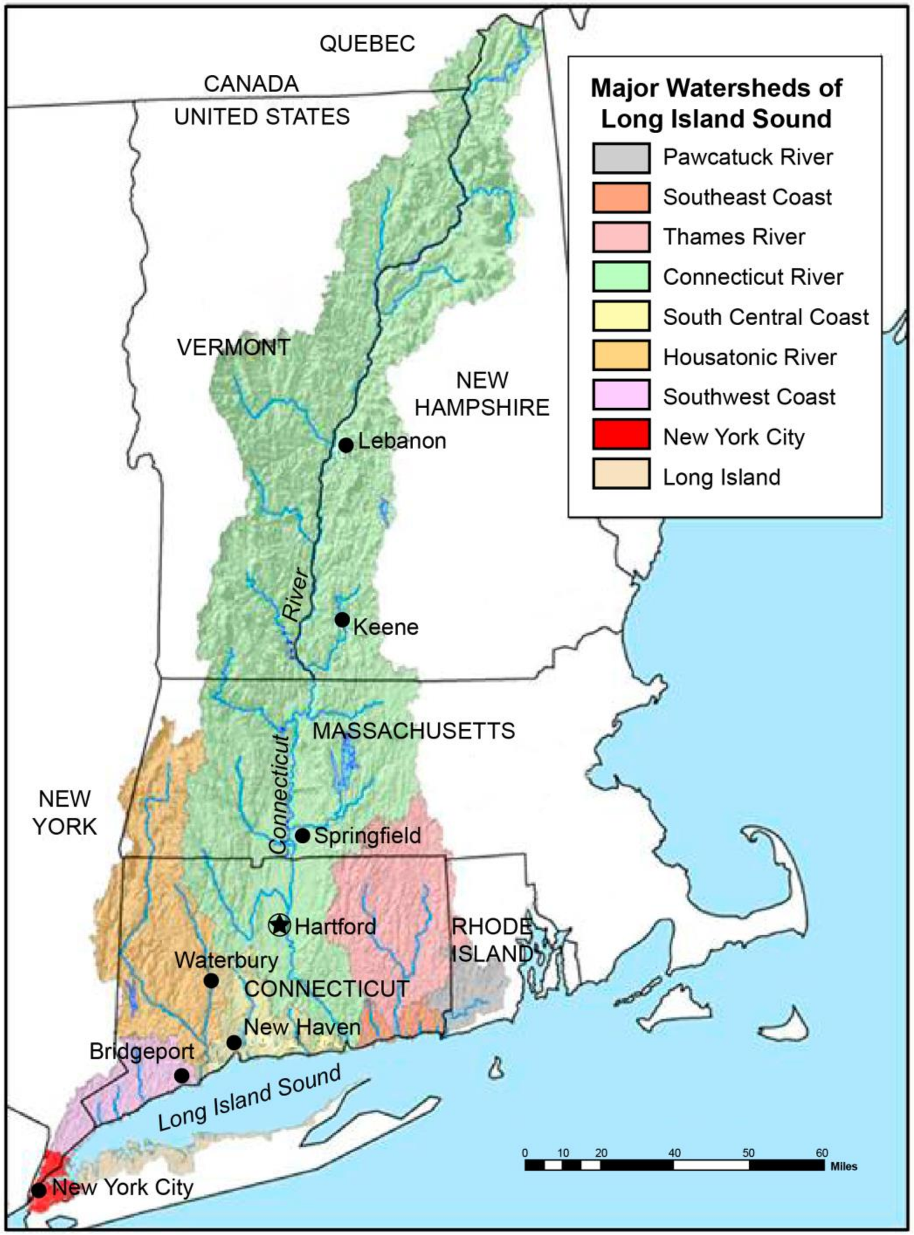
- Geography
- Weather patterns
- **Nutrient loading**

2001 LIS TMDL for Dissolved Oxygen

- Developed by CTDEEP & NYSDEC
- Approved by EPA in 2001

Nitrogen Load Reduction Targets

58.5% reduction for all in-basin sources achieved via WLAs & LAs:	
In-Basin WWTP WLAs	Range from 58.5% to 86% reduction
In-Basin LA	10% reduction for SW and NPS
Upper Basin WLA	25% reduction for point source wastewater
Upper Basin LA	10% reduction for SW and NPS
Atmospheric Deposition	18% reduction expected (not required by TMDL) from implementation of 1990 CAAA



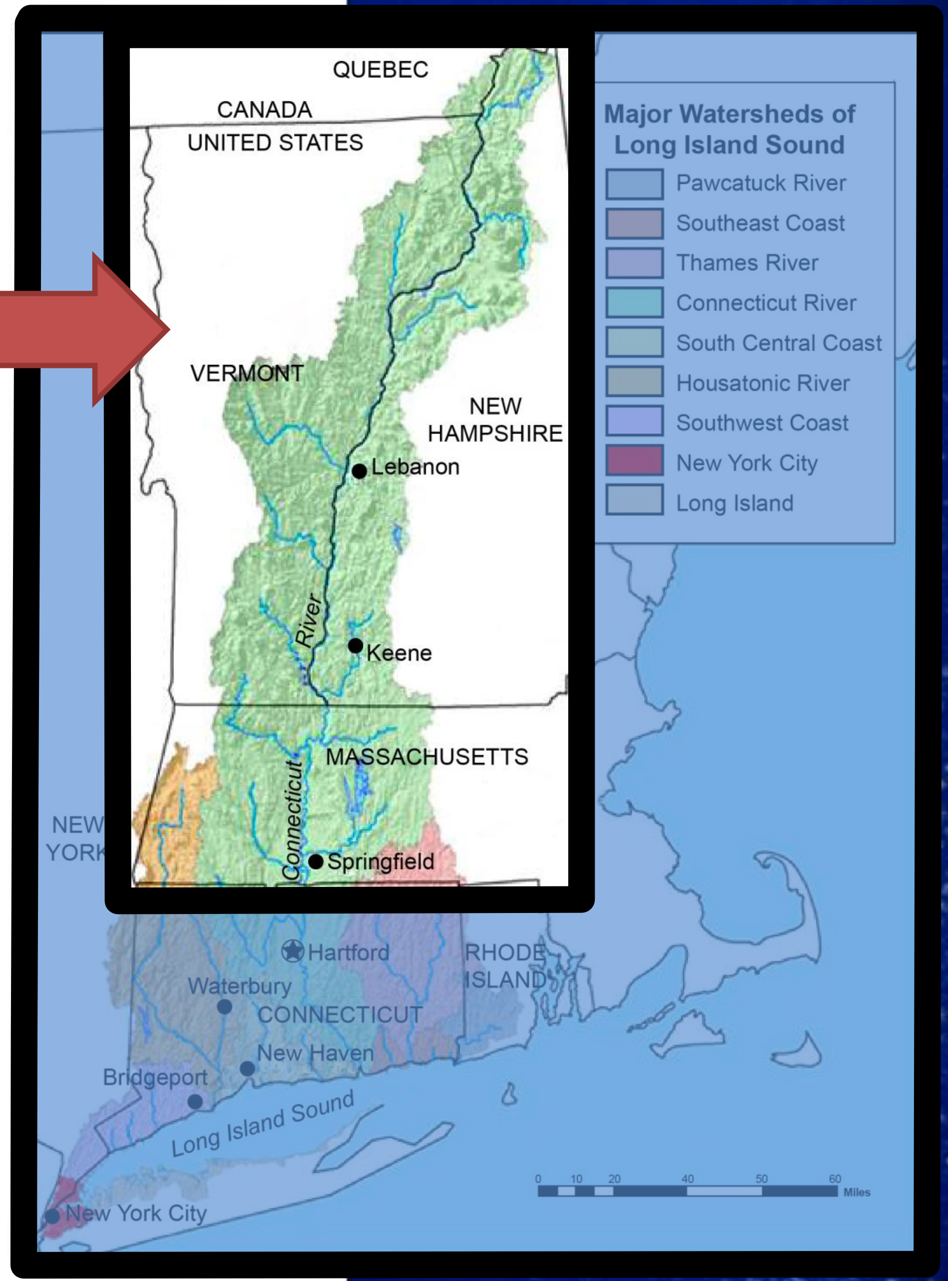
Major Watersheds of Long Island Sound
Pawcatuck River
Southeast Coast
Thames River
Connecticut River
South Central Coast
Housatonic River
Southwest Coast
New York City
Long Island
QUEBEC
CANADA
UNITED STATES
VERMONT
NEW HAMPSHIRE
Lebanon
Keene
River
Connecticut
MASSACHUSETTS
NEW YORK
Springfield
Hartford
RHODE ISLAND
Waterbury
CONNECTICUT
New Haven
Bridgeport
Long Island Sound
New York City
0 10 20 40 50 60
Miles

Upper Basin

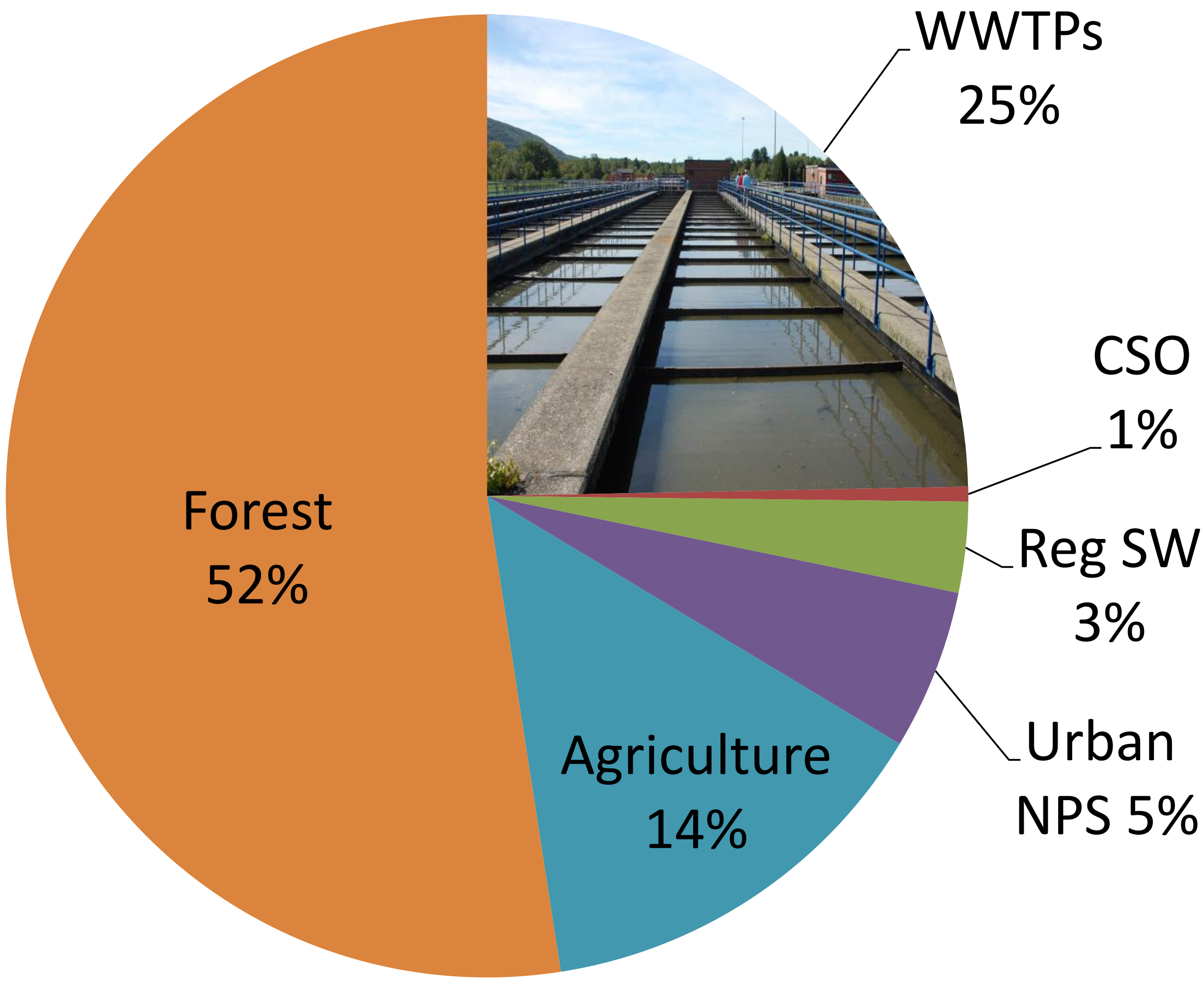
QUEBEC
CANADA
UNITED STATES
VERMONT
NEW HAMPSHIRE
Lebanon
Keene
Connecticut River
MASSACHUSETTS
Springfield
NEW YORK
Hartford
Waterbury
CONNECTICUT
RHODE ISLAND
New Haven
Bridgeport
Long Island Sound
New York City
Major Watersheds of Long Island Sound
Pawcatuck River
Southeast Coast
Thames River
Connecticut River
South Central Coast
Housatonic River
Southwest Coast
New York City
Long Island
0 10 20 40 50 60 Miles

Upper Basin Load

Estimated 19% of N load delivered to LIS is from upper basin



Upper Basin Load by Source



LIS TMDL Need for Revision

- Reassess reduction goal periodically
- Models predict current TMDL reductions (without treatment alternatives) will not meet DO standards

LIS TMDL Revision Workgroup

- Five-state effort with EPA and NEIWPCC
- Currently reevaluating the TMDL effort

Low Cost Retrofit Purpose

- Ensure upper basin reductions are:
  - Cost-effective, and
  - Would improve DO in LIS
- Provide technical assistance
- ID opportunities for low cost N removal

NEIWPCC's Role

- Administer funding
- Coordinate between project partners (MA, NH, VT, EPA), Contractor (JJ Environmental), and Contract Laboratory (Chemserve)
- Provide regular updates to LIS TMDL Workgroup

Low Cost Retrofit Project

- Evaluate treatment plants for biological nitrogen removal
- Determine mass of N reductions
- Ensure reductions are:
  - Cost-effective, and
  - Would improve DO in LIS

Biological Nitrogen Removal (BNR)

- BNR is a two step process
  - Nitrification (sufficient oxygen, sufficient alkalinity and aerobic volume)

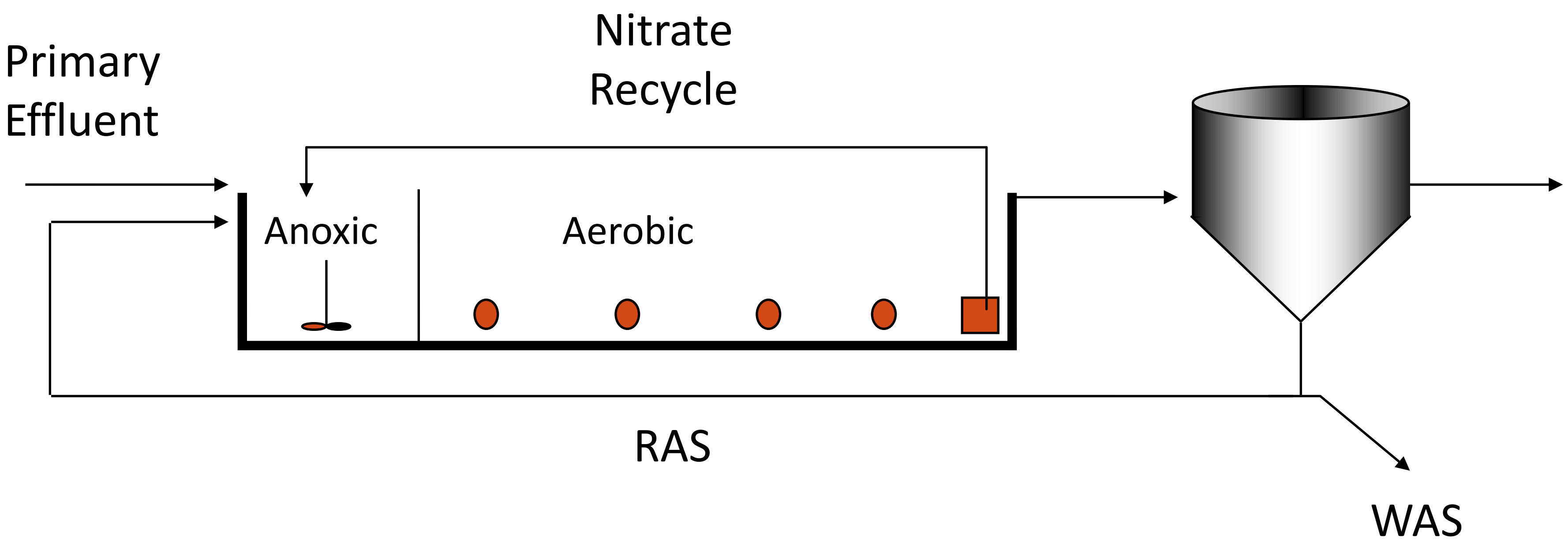
$$2NH_4^+ + 3O_2 \rightarrow 2NO_2^- + 4H^+ + 2H_2O$$

$$2NO_2^- + O_2 \rightarrow 2NO_3^-$$

  - Denitrification (need sufficient carbon)

$$2NO_3^- + 10e^- + 12H^+ \rightarrow N_2 + 6H_20$$

Typical BNR Plant Design (MLE Process)



Cyclic Operation BNR

- Another way is to turn aerators on and off at various intervals to create aerobic and anoxic zones
  - Need to ensure equipment allows for that
  - Some gear boxes cannot sustain this type of operation
  - More effected by seasonal changes

Project Team

- Emily Bird, Project Manager, NEIWPCC
- Jeanette Brown, President JJ Environmental, LLC
  - Passaro Engineering
  - Dr. David Stensel, University of Washington
- Project Officer: Leah O'Neill, U.S. EPA Region 1
- Technical Advisory Committee
- Contract Laboratory-Chemserve

Original 29 Treatment Facilities

- Massachusetts (ADF 1.0 to 17.0 MGD)
  - 15 Activated Sludge (14 conventional, one SBR)
  - 1 RBC
  - 2 Trickling Filter-followed by AS
- New Hampshire (ADF 0.3 to 6.0 MGD)
  - 3 Activated Sludge
  - 2 Oxidation Ditch

Original 29 Treatment Facilities

- Vermont (ADF 0.75 to 2.4 MGD)
  - 2 Activated Sludge
  - 3 RBC
  - 1 Oxidation Ditch

Project Tasks

- Major Tasks include:
  - Preparation of Quality Assurance Project Plan (QAPP) and approval by EPA
  - Site visits-comprehensive field investigations
  - Special sampling program
  - Preliminary evaluation and analysis
  - Evaluation of retrofit alternatives through modelling
  - Conceptual design and production of cost estimates based on mass of nitrogen removed
  - Final Report

QAPP

- Quality Assurance Project Plan approval
  - Ensures adherence to objectives
  - Prior to any obtaining any data (primary or secondary)
- QAPP included
  - Project Objectives, Organization, and Responsibilities
  - Data Generation and Acquisition
  - Data Use and Management
  - Records Management
  - QAPP Conformance and Compliance

Site Visits

- Site visit to each of 29 treatment plants (data acquisition)
  - August 20 to October 25
- Met with operators to
  - Asked operators to complete survey form
  - understand process
  - determine if any upgrades were planned
  - determine wet weather, cold weather issues and operating problems
  - toured plant and documented types of equipment, spare tankage, etc.
  - prepared plants for special sampling program

Site Visits-Initial Findings and Observations

- All plants below design flows and loads
- Many plants have unused tankage
  - Some were using only half of the plant capacity
- Two plants are university towns and three in ski areas
  - season flow variations possible
- Some plants nitrifying to some extent
- Some denitrifying either intentionally or inadvertently

Data Gathering-Existing Information

- Existing data collected included:
  - Requested two years' (minimum) operating data and DMR's
    - Two year data set important since it shows variability
  - Drawings of bioreactors and clarifiers, if available,
  - Design information on bioreactors, clarifiers, WAS and RAS pumps, including size, capacity, age
  - Quantity and type of recycle or side-streams returned to head of plant or prior to bioreactors,
  - Documentation of type and age of equipment such as blowers, mechanical aerators, and diffusers

Data Collection-Gaps

- Most plants did not have influent nitrogen data and only a few plants had effluent nitrogen
- In many cases, only one species of nitrogen was available, typically only NH_4-N
  - Major limitation
    - No influent N species data
    - No influent COD data, plus needed sCOD
    - Little or no effluent N species data, needed TKN and sTKN
    - No influent alkalinity data
- Needed all analytes on same set of samples
  - For example, cannot compare BOD from past samples

Special Sampling Program

- NEIWPCC hired a contract laboratory
  - Sample bottles prepared by laboratory with preservatives
  - Instructions given to operators on site visits
    - Refrigeration
    - Chain of Custody
    - Pick-up schedule

Special Sampling Program

- Samples: either influent and final effluent or primary effluent and final effluent depending on plant design
  - Influent or primary effluent after sidestreams
    - Digester supernatant
    - Thickening or dewatering filtrate
    - Other
- Three consecutive days of sampling
  - Analytes included SKN, SCOD, pH, alkalinity, TSS/VSS, NH_4-N, NO_3-N + NO_2-N on each sample.
  - BOD performed by plant on split sample
  - Plants filtered samples for sCOD and soluble Kjeldahl nitrogen
- Results of special sampling as well as the two year data set used to evaluate the plants.

Initial Evaluation

- Data analysis
  - Flows and loads
  - Seasonal variations
  - Growth expectations
  - C/N ratios
- Excel-based computer model
  - Allows quick evaluation

Process Changes

- Looked at the possibility of processes changes only but process changes must be evaluated over long periods of time and take into account seasonal and wet weather issues
  - For example, a change in process requires at least 2 to 3 SRTs to determine an effect
  - Requires a large amount of laboratory testing to verify results and determine what is happening in process
  - Some risk, since it may put the plant in jeopardy of a permit violation

Excel-based Nitrogen Design Model

- Model developed using all standard design equations and kinetic coefficients
- Input: flow, temperature, BOD, sCOD, NH_4-N, TKN
  - Output: aerobic volume, effluent NH_4-N and NO_3-N concentrations
- Used in conjunction with statistical analysis, C:N ratio, and plant data to develop final list of plants for more in-depth study

Plants Selected for Comprehensive Modelling

- Of the 29 plants studied, 20 were selected for comprehensive modelling
  - 5 from Vermont
  - 4 from New Hampshire
  - 11 from Massachusetts
- Plants eliminated:
  - Already doing nitrogen removal
  - Industrial waste input impacts nitrogen removal
  - Too low C:N ratio
  - Problems with nitrification

BioWin Modeling and Second Site-Visit

- Baseline model developed for all plants except RBC facilities
- Preliminary model (Baseline) model developed and calibrated
  - Baseline model reasonably replicated current plant conditions and configured to match the number and dimension of the various unit processes used

BioWin Modeling and Second Site-Visit

- At second site visit
  - Preliminary conceptual Nitrogen removal model presented
    - concepts for N removal discussed at second site visit
    - operator concerns/comments noted
    - obtained most current plant data
- New information entered into model (collected additional year of data)
  - recalibrated

Second Phase BioWin Modeling

- Second Phase
  - Baseline model was re-calibrated using the annual average plant data from 2011 including new data from 2014
  - Correlated as closely as possible to the current effluent BOD, TSS and TN concentrations (Industry standard $\pm$5 to 20%)

Second Phase BioWin Modeling

- Calibration: matched as closely as possible plants process control parameters
  - MLSS concentration
  - RAS flow
  - WAS flow
  - Clarifier Operation

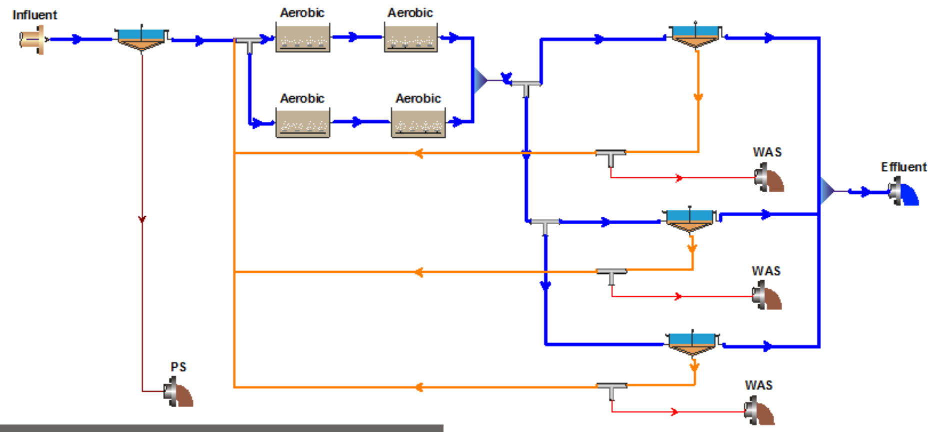
Second Phase BioWin Modeling

- Once calibrated
  - various design alternatives and changes in process control parameters were evaluated
    - Addition of anoxic zones, swing zones
    - Mixers
    - IR pumps
  - configuration with lowest possible effluent total nitrogen concentration called Conceptual Design
  - design tested at winter temperatures and winter temperatures at 80% of design flow

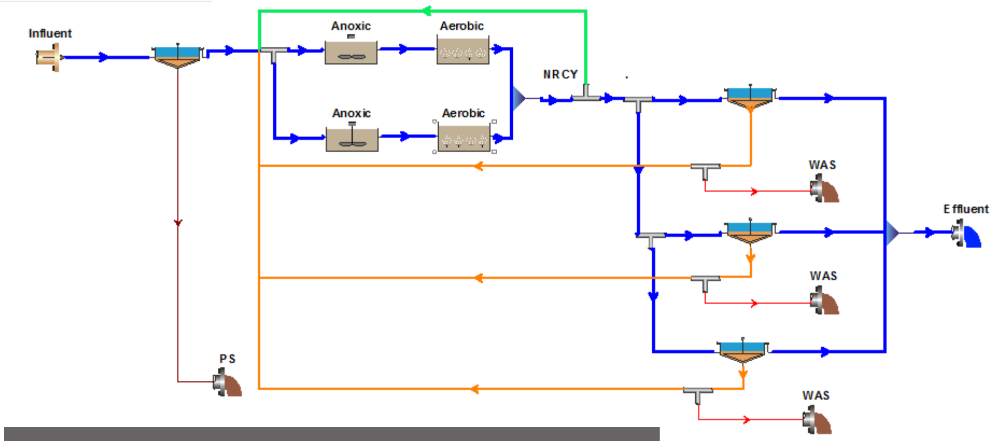
RBC Plants

- Biofilm processes much different than activated sludge
  - Usually get very good nitrification in RBC's and a little denitrification
  - Some success in other areas using recycle
    - Concern is shear forces
- For this project, evaluated excess hydraulic capacity
  - Estimated N removal

Example of BioWin Models



Baseline Model



Conceptual Model

Example BioWin Output

Plant Influent Data			Baseline Model Effluent		Design Model Effluent		Compare Baseline to Model Design	
Parameters	mg/L	lb/d	mg/L	lb/d	mg/L	lb/d	mg/L	lb/d
Volatile suspended solids	257	2745.3	3.85	39.7	4.32	44.5	**-0.47**	**-4.85**
Total suspended solids	286.78	3063.4	4.72	48.6	5.59	57.6	**-0.87**	**-8.97**
Total Kjeldahl Nitrogen	26	267.1	2	21.1	2	24.2	**0**	**-3**
Total Carbonaceous BOD	286	3055.1	1.73	17.9	2.64	27.2	**-0.91**	**-9.30**
Total N	26	267.1	15	156.0	4	41.0	**11**	**115**
pH	7.3	0.0	6.32	0.0	6.60	0.0		
Ammonia N	16.5	176.3	0	1.7	1	7.4	**-1**	**-6**
Nitrate N	0	0.0	13.07	134.6	1.43	14.8	**11.64**	**119.80**
Parameters								
Temperature, °C	16		16		16			
Flow, MGD	1.23		1.23		1.23			

Summary BioWin Output

Current Influent TN, lbs/d	267
Current Effluent TN, lbs/d	156
Current Removal, lbs/d	111
Predicted Effluent TN, lbs/d	41
Predicted Removal, lbs/d	226
Net Change, lbs/d	115
Net Change, lbs/year	41975
Winter Temperature, lbs/year	39481
Winter Temperature/High Flow, lbs/year	37067

Cost Estimation

- Once conceptual design completed
- Cost based on equipment needed to achieve results from the conceptual design model
- Estimates included equipment such as:
  - Mixers
  - Pumps
  - Control panels
  - Baffles
  - Air valves
  - Instruments

Cost of Nitrogen Removal

- Costs normalized to wage rates from Central Valley of Connecticut to allow comparisons from one state to another
- Capital cost was amortized over a 10-year period and a 20-year period at 3% interest
- Estimate of O&M costs (mostly increased electrical costs)
- Total cost for 10 years and 20 years was divided by the estimated pounds of nitrogen removed over that period
- Cost estimates did not include engineering costs, new infrastructure

Cost Estimate Example

NEIWPCC

Low Cost Retrofits for Nitrogen Removal at Wastewater Treatment Plants in the upper Long Island Sound Watershed

COST ESTIMATE

Contractor Name:	JJ Environmental	Date:	1-Jun-14
Address:	17 Archer Lane	Project No.	0302-001
	Darien, Ct 06820	Proposal No.	4
Telephone No:	1-203-309-8768		

		Revisions
SECTION A: CONTRACTOR WORK		
1. Total Contractor Labor	$71,190.66	
2. Total Contractor Material	$118,000.00	
3. Total Contractor Equipment	$26,920.00	
4. Unit Price Costs		
5. Subtotal Contractor Cost	$216,110.66	
6. Contractor Mark-Up 15%	$32,416.60	
7. Contractor Total Section A	$248,527.26	
SECTION B: CONTRACTOR WORK		
8. Names Of Subcontractors		
A. Electrical Subcontractor	$111,258.92	
B. Instrumentation Integrator	$11,914.00	
C.		
D.		
E.		
F.		
9. Total Subcontractor's Proposals (A through F)	$123,172.92	
10. Contractor's Mark-Up On Subs Proposals (5%)	$6,158.65	
11. Subcontractor Total Section B	$129,331.57	
SECTION C: TOTAL CONTRACTED UNIT PRICE COSTS		
SECTION D: CONTRACTOR'S REQUEST		
12. Amount Requested (Total Lines 7 & 11)	**$377,858.83**	

Example $/lb TN removed

Cost Per Pound of Additional Nitrogen Removed as Compared to Capital Improvement Costs	
115	**Delta Pounds N Removed Per day**
41,960	Delta Pounds N Removed 1 Year
419,604	Delta Pounds N Removed 10 Year
839,208	Delta Pounds N Removed 20 Year
377,859	**Capital Cost of Conceptual Design**
$9.01	Cost Per Pound Over 1 Year
$0.90	Cost Per Pound Over 10 Years
$0.45	Cost Per Pound Over 20 Years
Cost Per Pound of Additional Nitrogen Removed Including Interest & Operational Costs	
3.00%	Interest Rate
10	Loan Term in Years
$3,648.63	Monthly Payment (100% Financed)
$437,835.96	Total Cost P & I Over 10 Years
$590,000.00	Additional O&M over term
$1,027,835.96	Total Cost Over 10 Years
$2.45	**Total Cost Per Pound of Additional Nitrogen Removed Over 10 Years**

Cost Per Pound of Additional Nitrogen Removed as Compared to Capital Improvement Costs	
115	**Delta Pounds N Removed Per day**
41,960	Delta Pounds N Removed 1 Year
419,604	Delta Pounds N Removed 10 Year
839,208	Delta Pounds N Removed 20 Year
377,859	**Capital Cost of Conceptual Design**
$9.01	Cost Per Pound Over 1 Year
$0.90	Cost Per Pound Over 10 Years
$0.45	Cost Per Pound Over 20 Years
Cost Per Pound of Additional Nitrogen Removed Including Interest & Operational Costs	
3.00%	Interest Rate
20	Loan Term in Years
$2,095.60	Monthly Payment (100% Financed)
$502,943.04	Total Cost P & I Over 20 Years
$1,180,000.00	Additional O&M over term
$1,682,943.04	Total Cost Over 20 Years
$2.01	**Total Cost Per Pound of Additional Nitrogen Removed Over 20 Years**

Summary of Results-Estimated TN Removal and Cost by State

MA FACILITIES	Design, MGD	ADF, MGD	lbs TN/day	lbs TN/year	Capital Cost, $	Cost/lb (10 yrs)	Cost/lb (20 yrs)
Athol	1.75	0.75	41	15,045	$209,710	$2.27	$1.58
Belchertown	1.00	0.40	0.70	244	$88,514	$170.92	$153.00
Gardner	5.00	2.98	258	94,071	$368,414	$1.05	$0.86
Great Barrington	3.20	1.08	63	23,112	$297,513	$2.91	$2.27
Palmer	5.60	1.47	91	33,215	$320,722	$1.67	$1.19
Pittsfield	17.00	11.94	854	311,853	$745,033	$0.51	$0.40
South Hadley	4.20	2.66	278	101,470	$302,609	$0.51	$0.36
Spencer	1.08	0.78	64	23,269	$352,431	$4.52	$3.78
Warren	1.50	0.31	N/A	N/A	N/A	N/A	N/A
Webster	6.00	2.99	250	91,383	$365,807	$0.87	$0.67
Winchendon	1.10	0.51	30	10,867	$201,739	$5.09	$4.17
TOTAL	**47.43**	**25.87**	**1,930**	**704,529**	**$3,252,492**		

NH FACILITIES	Design, MGD	ADF, MGD	lbs TN/day	lbs TN/year	Capital Cost, $	Cost/lb (10 yrs)	Cost/lb (20 yrs)
Claremont	3.89	1.23	115	41,975	$377,859	$2.45	$2.00
Hanover	2.30	1.25	163	59,550	$401,027	$1.74	$1.40
Hinsdale	0.30	0.25	13	4,954	$98,446	$2.50	$1.52
Littleton	1.50	0.82	N/A	N/A	N/A	N/A	N/A
TOTAL	**7.99**	**3.55**	**291**	**106,479**	**$877,332**		

VT FACILITIES	Design, MGD	ADF, MGD	lbs TN/day	lbs TN/year	Capital Cost, $	Cost/lb (10 yrs)	Cost/lb (20 yrs)
Ludlow	1.05	0.36	18	6,411	$214,780	$4.79	$3.14
Lyndonville	0.75	0.16	N/A	N/A	N/A	N/A	N/A
Springfield	2.40	0.97	74	27,106	$391,634	$4.57	$3.85
St. Johnsbury	1.60	1.00	N/A	N/A	N/A	N/A	N/A
Windsor	1.13	0.27	N/A	N/A	N/A	N/A	N/A
TOTAL	**6.93**	**2.76**	**92**	**33,517**	**$606,414**		

Summary of Results-Estimated TN Removal and Cost by Watershed

FACILITY	RECEIVING WATER	RIVER
Athol, MA	Millers	Connecticut
Belchertown, MA	Lampson Brook	Connecticut
Claremont, NH	Sugar	Connecticut
Gardner, MA	Millers	Connecticut
Hanover, NH	Connecticut	Connecticut
Hinsdale, NH	Ashuelot	Connecticut
Littleton, NH	Ammonoosuc	Connecticut
Ludlow, VT	Black River	Connecticut
Palmer, MA	Chicopee	Connecticut
Lyndonville, VT	Passumpsic	Connecticut
South Hadley, MA	Connecticut	Connecticut
Spencer, MA	Cranberry Brook	Connecticut
Springfield, VT	Black River	Connecticut
St Johnsbury	Passumpsic	Connecticut
Warren, MA	Quaboag	Connecticut
Winchendon, MA	Millers	Connecticut
Windsor, VT	Connecticut	Connecticut
Great Barrington, MA	Housatonic	Housatonic
Pittsfield, MA	Housatonic	Housatonic
Webster, MA	French River	Thames

WATERSHED	Design, MGD	ADF, MGD	lbs TN/day	lbs TN/year	Capital Cost, $
Connecticut River	36.15	16.17	1,146	418,177	$3,327,885
Housatonic River	20.2	13.0	917	334,965	$1,042,546
Thames River	6.00	2.99	250	91,383	$365,807
TOTAL	**62.35**	**32.18**	**2,313**	**844,525**	**$4,736,238**

Training Program and Summary

- As part of this project, two training session were held- one in MA and one in NH/VT region
  - Purpose was to give more in-depth information to operators on
    - Theory of nitrogen removal
    - Process control
- The results of this project show that through some relatively inexpensive capital improvements a significant amount of nitrogen can be removed
  - Advantage of capital improvements is a more robust process that can sustain seasonal changes and ensure permit compliance

CONTACT

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QUESTIONS