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# Ontario Ministry of the Environment
# Sewage Treatment Plant (STP) Studies

Great Lakes Binational Toxics Strategy

Integration Work Group Meeting

December 1, 2010

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# Outline

- 2004/2005 48 STP Survey
  - MOE survey of treatment plants in Ontario
- Literature Review - treatment technologies
  - MOE/CH2MHill review
- 2009 - 2011 Treatment, Chemistry & Toxicity Study
  - MOE/Environment Canada/ University of Windsor/ University of Waterloo study

# 48 STP Survey

- Description:
  - 48 STPs in Ontario monitored from 2004-2005
    - Sites selected represented 70% of Ontario STP discharges
    - Four seasons sampling – “snap shot” of effluent quality
    - 5 different treatment types:
      - Lagoons,
      - Primary (1$^{o}$),
      - Secondary (2$^{o}$),
      - Secondary nitrifying (2$^{o}$N), and
      - Tertiary nitrifying (3$^{o}$N)

# 48 STP Survey

- Chemical analyses:
  - Conventional contaminants: 13 total
    - e.g., CBOD5, TSS, TAN, TKN, TP and COD
  - Non-conventional contaminants (NCCs):
    - metals; phenolics; base neutral extractables; polycyclic aromatic hydrocarbons; chlorobenzenes; organochlorines; halogenated volatiles; non-halogenated volatiles; dioxins and furans; brominated diphenyl ethers; total organic halides and nonyl phenol
  - Total of:
    - 216 chemicals in influent and effluent
    - 156 chemicals in sludge
    - 215 chemicals in leachate

~300,000 data points

- Acute toxicity in 187 effluent samples

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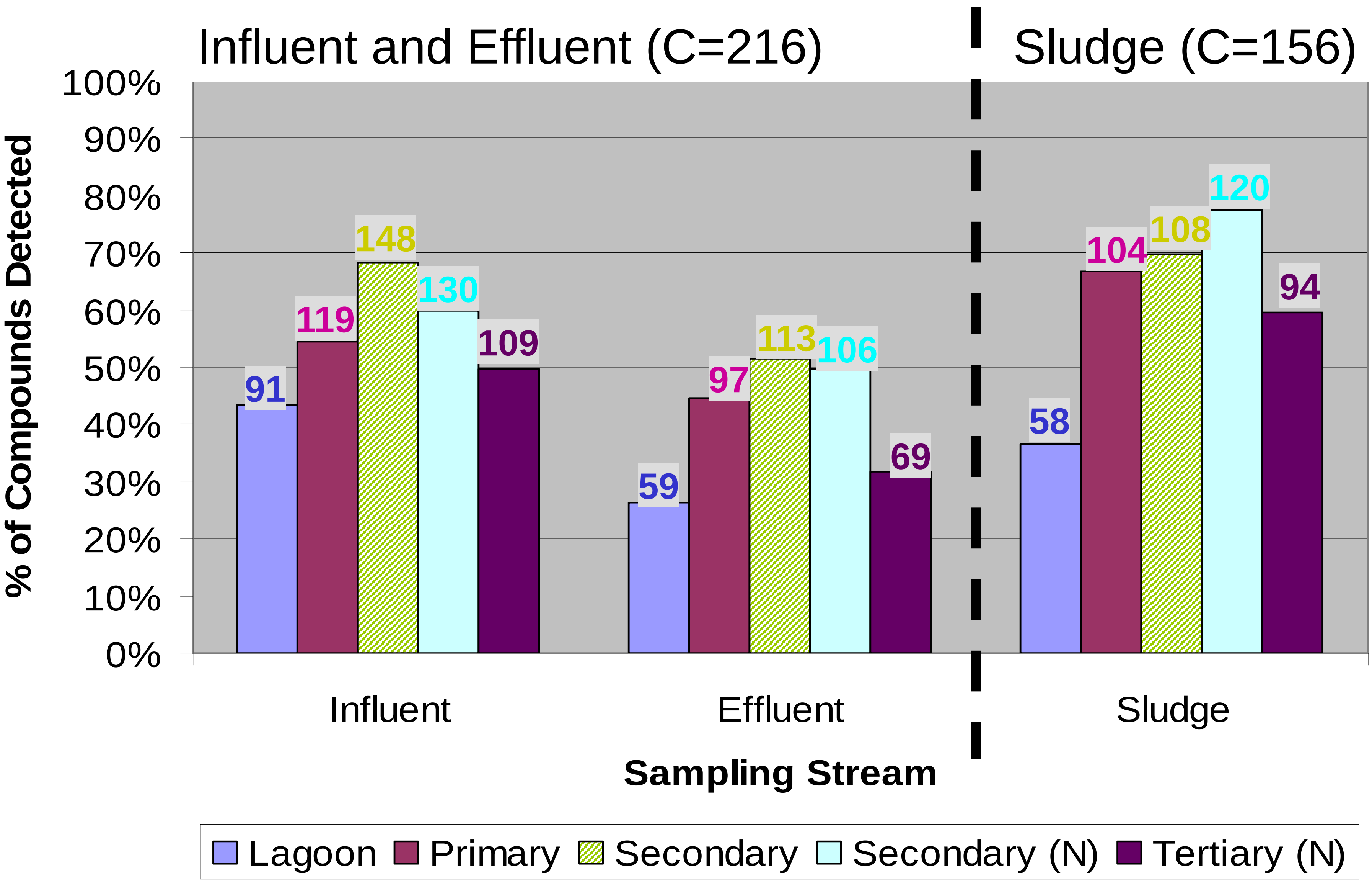
# Compounds Detected



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# Secondary Effluent – Selected Data

| Compound | Units | Mean | Max | % Detection | n |
|---|---|---|---|---|---|
| Mercury | µg/L | 0.016 | 0.48 | 14 | 235 |
| PCBs | ng/L | 3.2 | 47 | 3 | 233 |
| Octachlorodioxin | pg/L | 12 | 300 | 12 | 26 |
| Benzo(a)pyrene | µg/L | 0.02 | 0.6 | 2 | 232 |
| BDE-209 (deca) | ng/L | 14.4 | 160 | 47 | 15 |
| BDE-153 (hexa) | ng/L | 0.673 | 1.4 | 93 | 15 |
| DEHP | µg/L | 1.18 | 16 | 21 | 231 |

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# Secondary Sludge – Selected Data

| Compound | Units | Mean | Max | % Detection | n |
|---|---|---|---|---|---|
| Mercury | µg/L | < 0.05 | < 0.05 | 0 | 99 |
| PCBs | ng/g dw | 465 | 7600 | 98 | 63 |
| Octachlorodioxin | pg/g dw | 559 | 1000 | 100 | 25 |
| Benzo(a)pyrene | ng/g dw | 1304 | 19000 | 100 | 98 |
| BDE-209 (deca) | ng/g dw | 653 | 3700 | 100 | 17 |
| BDE-153 (hexa) | ng/g dw | 95 | 630 | 100 | 17 |

# Acute Toxicity Summary

| Toxicity by Number of Samples | Primary | Lagoon | 2º | 2ºN | 3ºN | Total |
|---|---|---|---|---|---|---|
| # rainbow trout tests | 20 | 11 | 76 | 64 | 16 | 187 |
| # >50% mortality | 8 | 1 | 33 | 0 | 0 | 42 |
| % >50% mortality | 37 | 9 | 43 | 0 | 0 | 22 |
| # *Daphnia magna* tests | 20 | 11 | 76 | 64 | 16 | 187 |
| # >50% mortality | 0 | 0 | 6 | 2 | 0 | 8 |
| % >50% mortality | 0 | 0 | 8 | 3 | 0 | 4 |

- Toxicity:
  - 22% of samples were toxic to rainbow trout; 8% were toxic to *Daphnia magna*
  - Ammonia in effluent was high enough in concentration to account for 94% of the rainbow trout toxicity and approximately 38% of the Daphnia magna toxicity.

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# 48 STP Survey - Key Findings

- Removal of conventionals reflected treatment type – i.e., lowest removals from primary – highest removals from tertiary
- Removal of NCCs was contaminant specific, and influenced by treatment type and operational conditions
- Reduction in acute toxicity generally associated with higher level of treatment

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# Literature Review – NCC Removal by STPs

- Description:
  - A review of the effectiveness of treatment technologies and operational conditions in the reduction of NCCs in municipal effluents.

# Literature Review – Key Findings

- Supported findings of the 48 plant survey
- Treatment technologies for removal of NCCs should be selected based on:
  - Reduction of targeted NCCs
  - Reduction of whole effluent toxicity (WET) (e.g., ozonation may increase the WET while reducing the parent NCCs)
  - Net environmental benefit (e.g., some technologies may require additional energy consumption)

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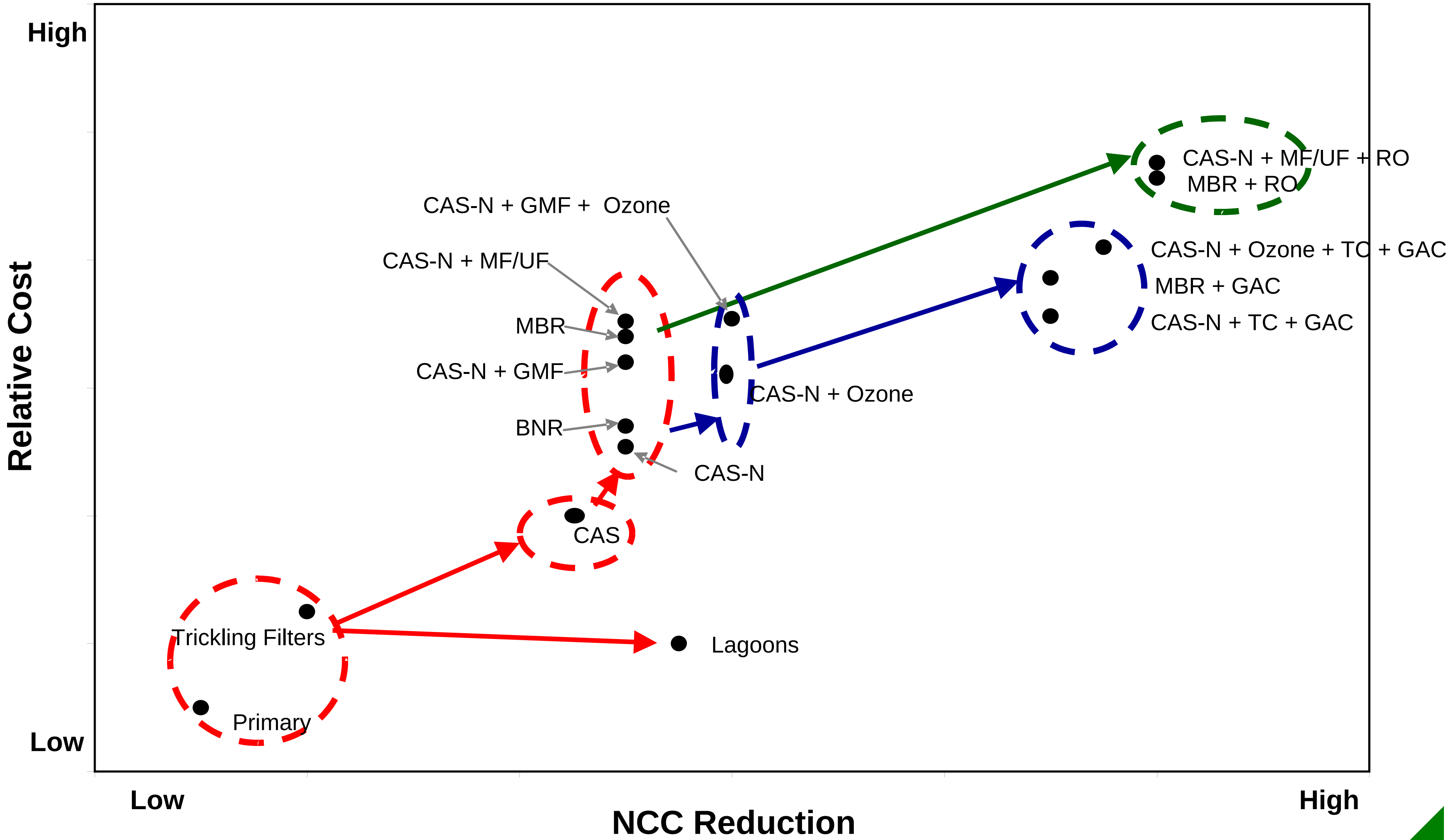
# Relative Technology Ranking



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# Treatment, Chemistry and Toxicity Study

- Description:
  - Pilot- and full-scale study of 2 Ontario STPs
  - Evaluates removal of harmful pollutants (legacy and contaminants of emerging concern) by 6 different sewage treatment technologies
  - Assesses toxicity of STP effluent using whole organism tests (standard tests; life cycle tests) and micro-scale endocrine disruption tests
  - Investigates links between treatment, chemistry and removal of effluent toxicity
  - Baseline study: characterizes conventional activated sludge nitrifying technology without disinfection, chemistry and toxicity.
  - Pilot study: evaluates relative effectiveness of different advanced treatment technologies in removing NCCs and toxicity.

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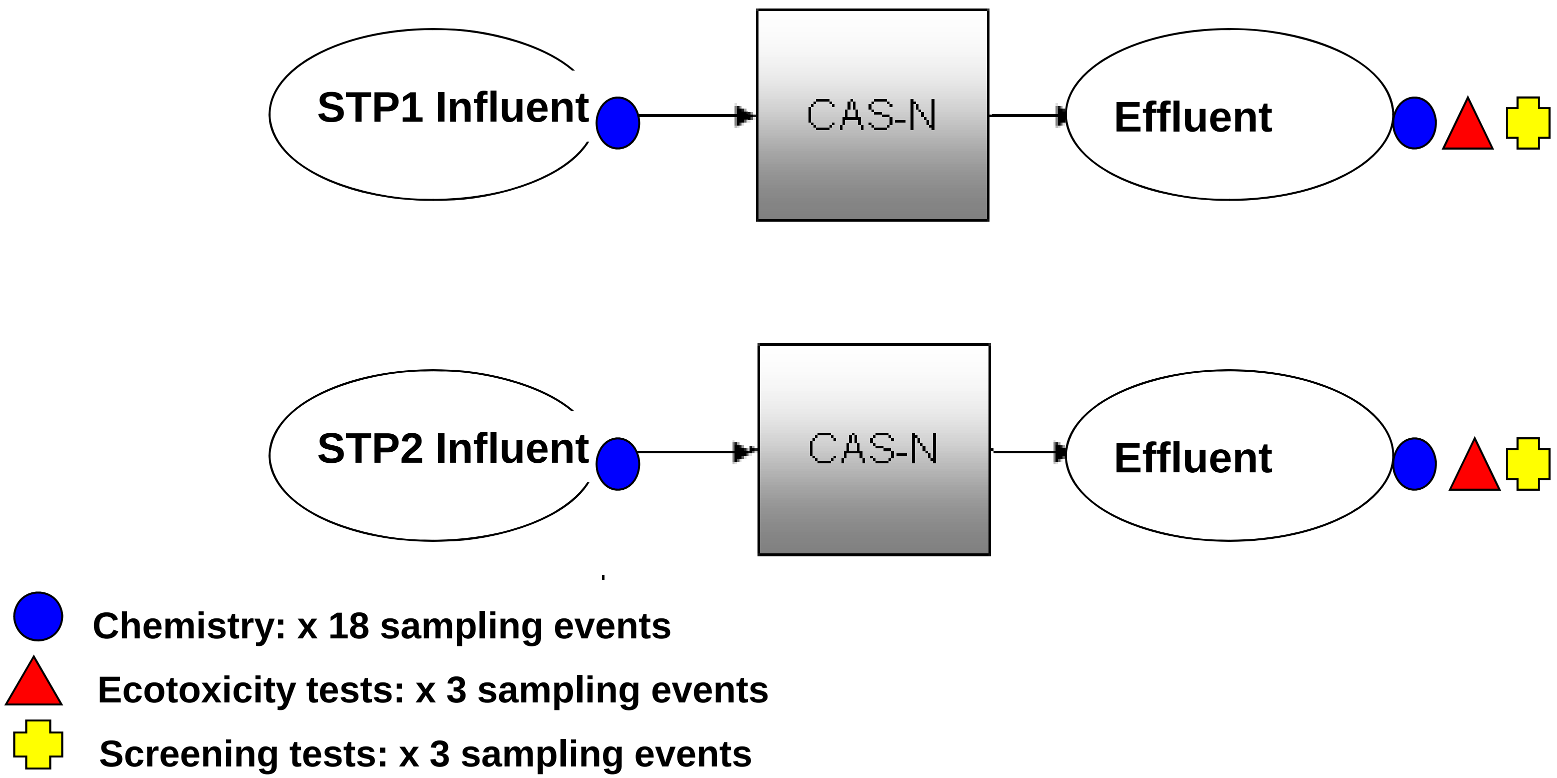
# Project Design – Baseline Study

- Concurrent 6-month background evaluation of two Ontario STPs both operating as nitrifying activated sludge systems without disinfection (UV only in Summer to early Fall)



# Project Design – Baseline Study

- **Chemistry:** Characterized influent and effluent including:
  - TSS, FSS, VSS, DOC, TOC, $CBOD_5$, COD, TKN, TP, $PO_4^-$, TAN, $NO_2^-$, $NO_3^-$
  - Metals, VOCs, alkylphenol polyethoxylates, pharmaceuticals, hormones, industrial organics, halohydrocarbons

- **Ecotoxicity:** Environment Canada standardized test methods for:
  - Rainbow trout acute lethality (96-h)
  - *Daphnia magna* (zooplankton) acute lethality (48-h)
  - Fathead minnow (*Pimephales promelas*) survival, growth (7-d)
  - *Ceriodaphnia dubia* (zooplankton) survival, reproduction (7-d)
  - Duckweed (*Lemna minor*) growth inhibition (7-d)
  - Algae (*Pseudokirchneriella subcapitata*) growth inhibition (72-h)

- ***In vitro* rapid screening tests:**
  - Yeast estrogenic screening (YES) assay
  - Yeast androgenic screening (YAS) assay
  - Thyroid transport receptor ($T_4$/hTTR) binding assay

# Preliminary Findings

- Both STPs performed as fully nitrifying plants:
  - TAN < 5 mg/L, ($NO_2^- + NO_3^-$) > 5 mg/L, TSS < 20 mg/L

- 216 different chemical parameters analyzed in influent and effluent

- Concentrations of metals in effluents varied by compound:
  - Mercury: 0.03 to 0.13 µg/L    Lead: < 0.02 mg/L
  - Strontium: 0.66 to 1.19 mg/L    Barium: 0.02 to 0.04 mg/L

- In both influents and effluents the phenolics, BNEs, PAHs, chlorobenzenes, organochlorines, organic halides, halogenated and non-halogenated volatiles varied but were generally significantly lower in the effluents and mostly found at or below the their respective MDLs in the effluents:
  - 1,3,5-trimethylbenzene: ≤ 0.2 to 19 µg/L, 3-ethyltoluene: ≤ 0.2 to 26 µg/L
  - Chloroform: ≤ 0.2 to 1.1µg/L, 1,2,4-trimethylbenzene: ≤ 0.2 to 68 µg/L
  - Toluene: ≤ 0.2 to 21 µg/L,    p-cresol: ≤ 0.2 to 270 µg/L

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# Preliminary Findings cont'd.

- Bisphenol A and nonylphenol ethoxylates consistently detected in effluents:
  - Bisphenol A: 57 to1672 ng/L
  - 4-nonylphenol: 117 to 215 ng/L
  - 4-NP monoethoxylate: 40 to 54 ng/L
  - 4-NP diethoxylate: 46 to 110 ng/L

- Pharmaceuticals and hormones detected in effluents (ng/L):
  - 17-α-estradiol: 18 to 40
  - 17-β-estradiol ($E_2$): 26 to 35
  - Carbamazepine: 224 to 439
  - Diclofenac: 267 to 315
  - Ciprofloxacin: 97 to 198
  - Naproxen: 79 to 356
  - Gemfibrozil: 39 to 83
  - Clofibric acid: 2 to 12

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* In most cases a reduction from influent concentrations were observed. Notable exception was Carbamazepine

# Preliminary Findings cont'd.

- Ecotoxicity:
  - No short- or longer-term sublethal toxicity of either effluent
- In-vitro Screening Assays:
  - No inhibition of thyroid binding or androgenic effect of either effluent
  - Weak estrogenic effect of STP1, none of STP2

# Next Steps – Parallel Pilot Studies

- Further study at using influent from two full scale plants:
  - P1 is a pilot-scale study with three different treatments
  - P2 is a full/pilot scale study with 4 different treatments
- Comparative analysis of different treatment technologies in use or potential for use in Ontario
- Same suite of chemical analysis, short-term and longer-term ecotoxicity tests, and screening tests for endocrine-disrupting activity. Also:
  - Evaluating sludge from each treatment technology
  - Adding PBDEs to influent, effluent and sludge suite of analysis

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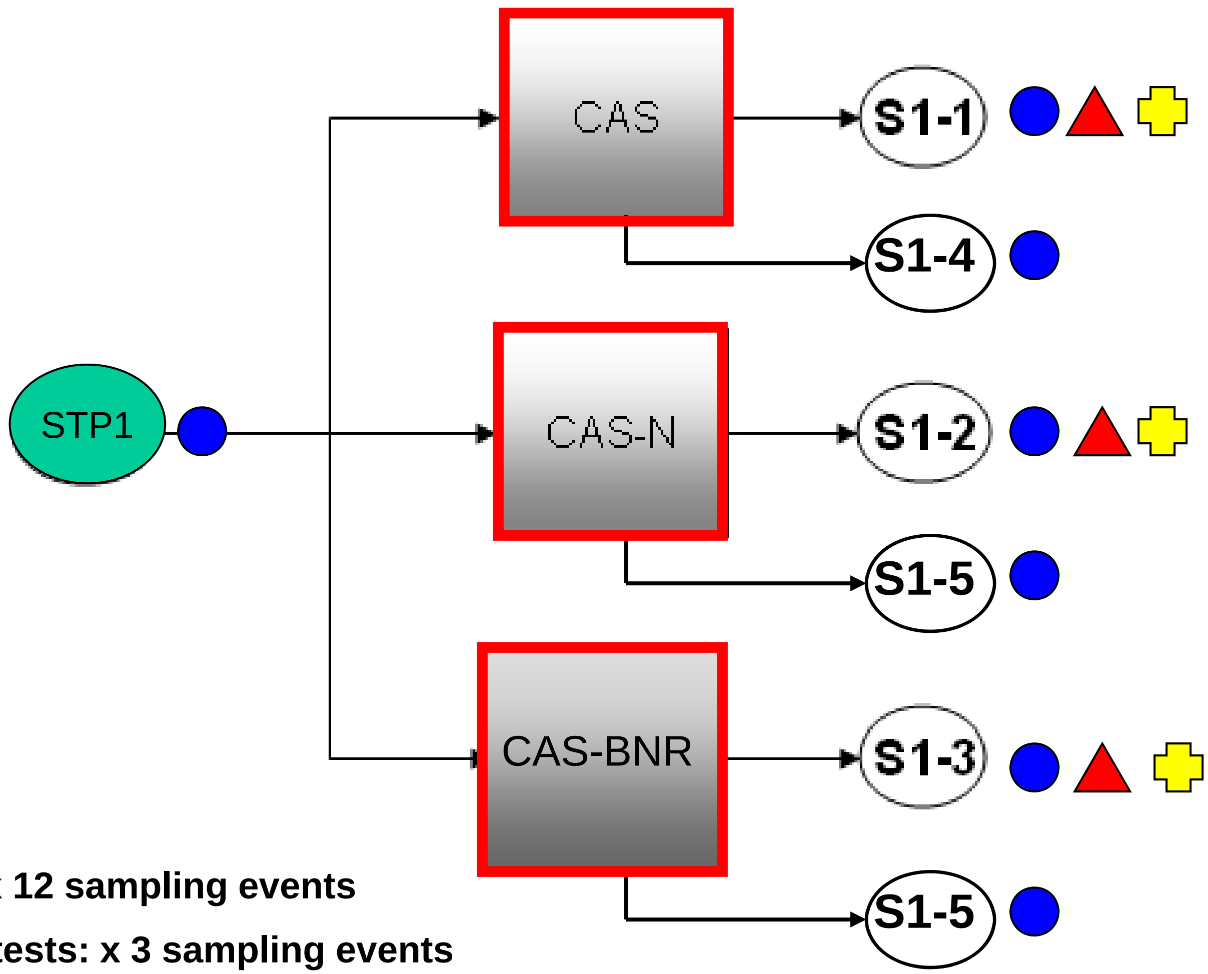
# Next Steps – P1




Pilot plant

Chemistry: x 12 sampling events

Ecotoxicity tests: x 3 sampling events

Biomarker tests: x 3 sampling events

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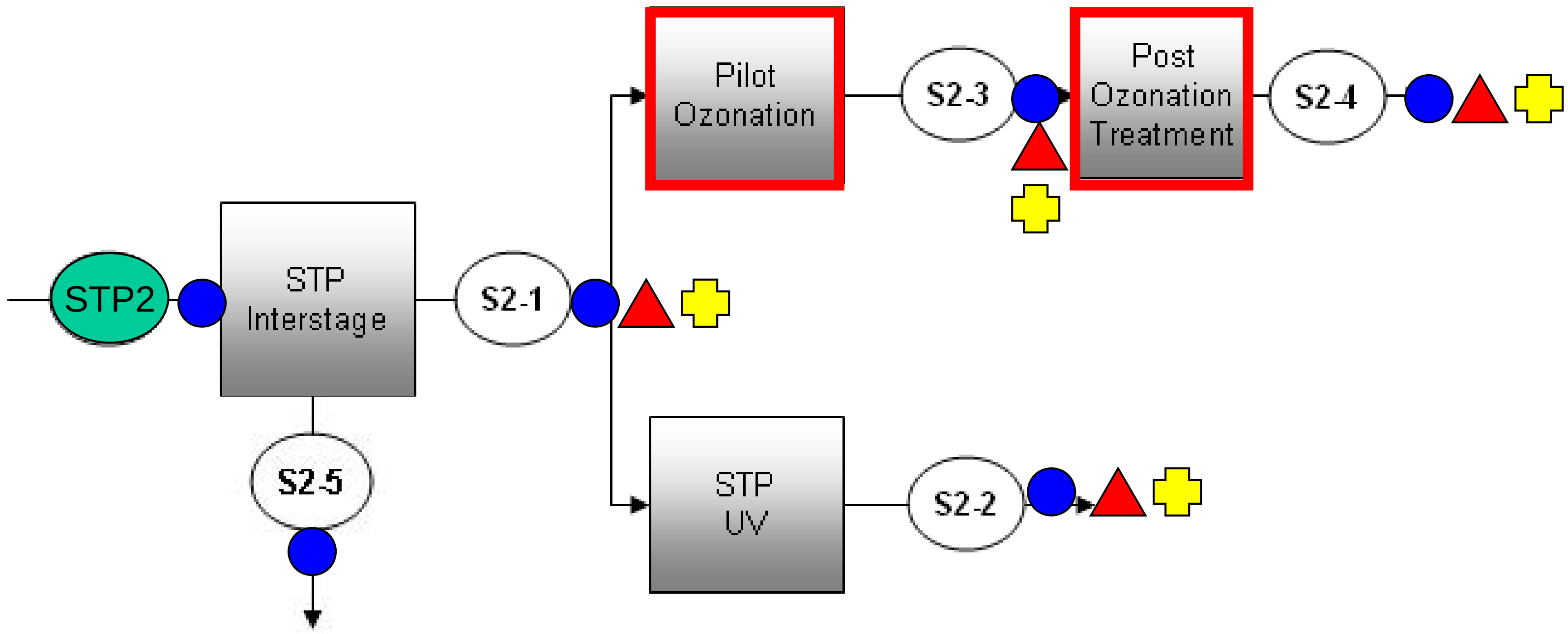
# Next Steps – P2




**Pilot plant**

**Chemistry: x 12 sampling events**

**Ecotoxicity tests: x 3 sampling events**

**Biomarker tests: x 3 sampling events**

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