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# Study on the Effectiveness of Water Treatment Plants in Newfoundland and Labrador

Drinking Water Safety Workshop, Gander, NL
March 24 to 26, 2015

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# Water Treatment Plants in NL

- Overview:
  - 17 WTPs.
  - Two year data collection period:
    - 2010-2012.
  - Sampling locations:
    - Source;
    - WTP outlet;
    - Tap – distribution.
  - Statistical and percent removal analyses.

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# Definitions from the Drinking Water Treatment Standards

## Water Treatment Plant vs. Water Treatment Facility

- WTP: "…plant uses multiple treatment processes for the targeted reduction, increase, removal or inactivation of multiple water quality parameters…".
  - Designed to produce drinking water to meet all required drinking water quality standards and guidelines.

- WTF: "…public drinking water system that has a drinking water treatment process other than chlorine disinfection…".
  - Single treatment process or multiple treatment processes that target specific water quality parameters (e.g., pH adjustment, iron, and manganese removal).
  - A WTP is considered a type of WTF.




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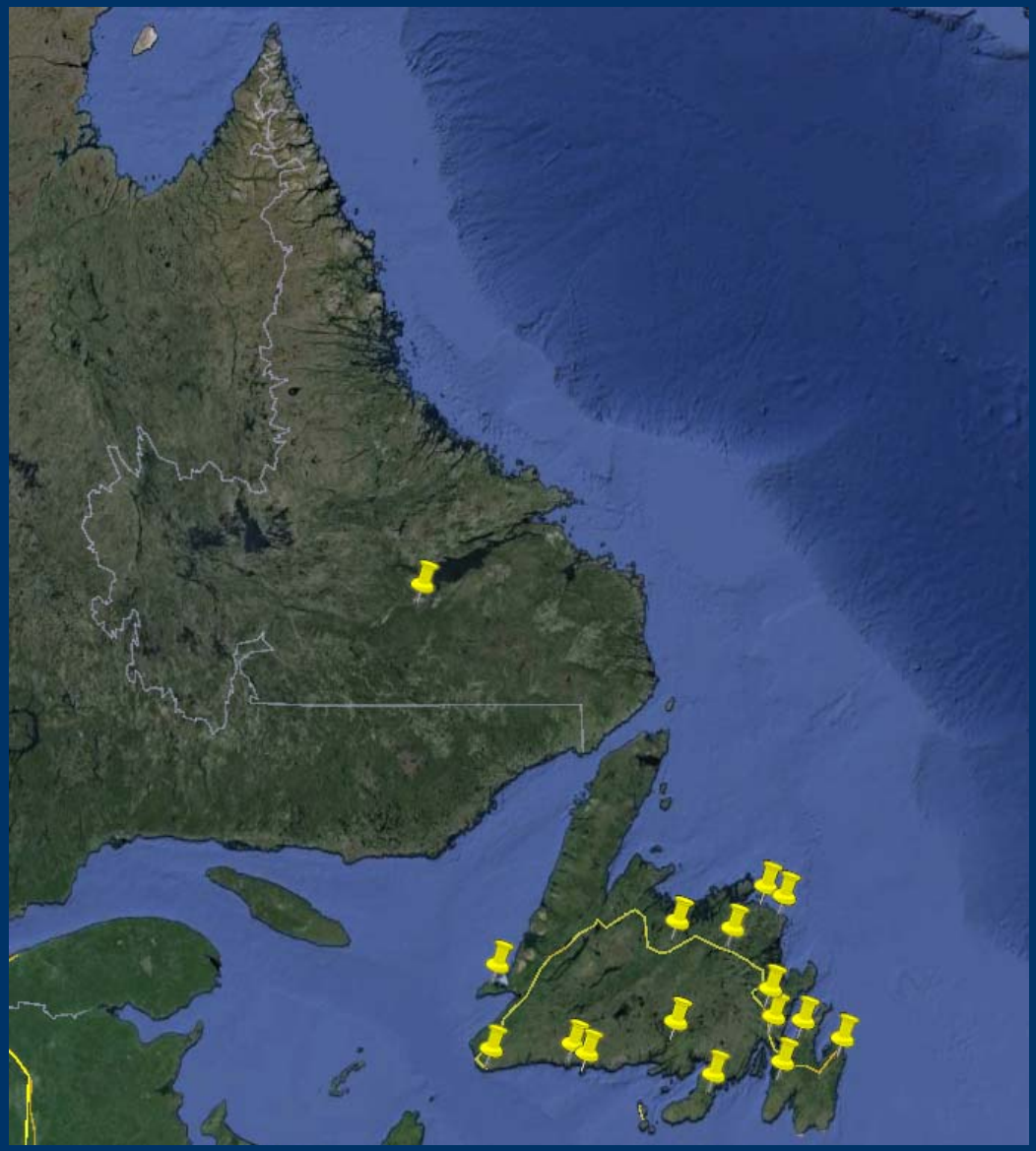
# Water Treatment Plant Locations in Newfoundland and Labrador





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# Water Treatment Plant Types in Newfoundland and Labrador

| Community | Water Treatment Plant Type | Water Supply | Commission Date |
|---|---|---|---|
| Burgeo | | | 2013 |
| Channel - Port au | | | 1988 |
| Clarenville | Conventional | Shoal Harbour River | 2007 |
| Come-by-Ch | | | 2012 |
| Conne Riv | | | 2006 |
| Exploits Regional S | | | 1996 |
| Gander | | | 2006 |
| Happy Valley-Goose Bay | Semi-Conventional | Well Field | 2002 |
| Heart's Delight- | | | 2001 |
| Lourdes | | | 2004 |
| Lumsde | | | 1972 |
| Marystown | Membrane Filtration - MF | Clam Pond | 2012 |
| Musgrave Harbour | Conventional | Rocky Pond | 1998 |
| Placentia | Other – O3 – Direct Filtration | Wyses Pond | 1991 |
| Ramea | Conventional | Northwest Pond | 2002 |
| St. John's – Bay Bulls Big Pond | Conventional – DAF | Bay Bulls Big Pond | 1978 |
| St. John's-Windsor Lake | Membrane Filtration - MF | Windsor Lake | 2007 |

8 Conventional WTPs

2 Semi-Conventional WTPs

4 Membrane Filtration WTPs

3 $O_3$ – Direct Filtration WTPs

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1. **Introduction**
2. WTP Study
   - Why?
   - What?
   - How?
3. Results
4. Challenges
5. Conclusions
6. What's Next?

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# Outline of Presentation

- Study Objective and Background
- Methods
- Results
- System Challenges
- Conclusions
- Path Forward

Shoal Harbour River



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# Study Objective
# Why?

- Objectives:
  - To assess the effectiveness of WTPs and treatment systems in NL:

$$\text{Effectiveness} = \frac{\text{Achieved}}{\text{Desired}}$$

  - Collate an overview background and history of each WTP.
  - Summarize the path forward based on the study results.

- Outcome: report with sub-reports.



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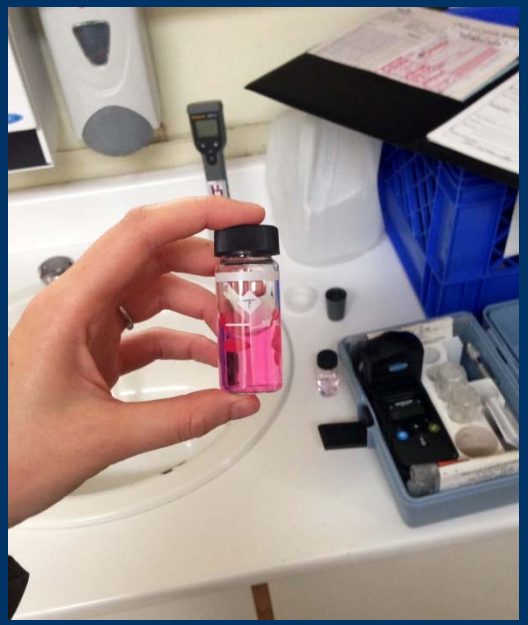
# Study Objective
# What?

- 17 WTPs throughout province of NL.
- Background and history:
  - town, operators, WRMD team members.
- Water quality assessment based on various sampling locations.



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# Study Background
# How?

- Part 1 - Data Collection:
  - 2-yr period (8 seasons):
    - Spring 2010 to Winter 2012.
  - Three site locations:
    - Source: site "0":
      - Raw water (prior to any drinking water treatment process).
    - WTP outlet: site "1":
      - Water subjected to WTP treatment processes.
    - Tap – distribution: site "3":
      - Approximately ¾ of the way through the piping system.


Conne River Supply Intake

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# Study Background
# How?

- Part 2 - Analysis/Methods:
  - Statistical analyses.
  - Seasonal effects.
  - Source vs. WTP (treatment effectiveness).
  - WTP vs. Distribution.
  - % formation of disinfection by-products.



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# Parameters Tested

| **Parameters** |
|---|
| pH |
| Alkalinity |
| Colour |
| Turbidity |
| Dissolved Organic Carbon (DOC) |
| Total Organic Carbon (TOC) |
| Total Dissolved Solids (TDS) |
| Aluminum |
| Iron |
| Manganese |
| Disinfection By-Products (DBPs) – Trihalomethanes (THMs) |
| Disinfection By-Products (DBPs) – Halo Acetic Acids (HAAs) |

# Guidelines Used for this Study



| Parameter | Units | MAC[1] | Other value |
|---|---|---|---|
| **Alkalinity** | mg/L of $CaCO_3$ | None | Preferable operational guideline: 80 to 120<br><br>Considered low if < 30 mg/L. |
| **Aluminum** | mg/L | None | ➢ < 0.1 (operational guideline for conventional treatment plants)<br>➢ < 0.2 (operational guideline for other types of treatment plants) |
| **Colour** | TCU[2] | None | AO[3]: ≤ 15 |
| **Dissolved Organic Carbon (DOC)** | mg/L | None | If average source water DOC < 5.0 mg/L, maximum treated water DOC of 2.0 mg/L.<br><br>If average source water DOC ≥5.0 and < 8.0 mg/L, maximum treated water DOC of 2.5 mg/L.<br><br>If average source water DOC ≥8.0 mg/L, maximum treated water DOC of 3.0 mg/L. |

Alkalinity: operational guidance from Water and Wastewater Plant text for plant operators (2009).

Colour and Aluminum: Canadian Drinking Water Quality Guidelines (2014).

DOC: Drinking Water Treatment Standards for Newfoundland and Labrador (2015).

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# Guidelines used for this study (cont'd)

| Parameter | Units | MAC[1] | Other value |
|---|---|---|---|
| **Haloacetic Acids (HAA)*** | µg/L | 80 | None |
| **Iron** | mg/L | None | AO[3]: ≤ 0.3 |
| **Manganese** | mg/L | None | AO[3]: ≤ 0.05 |
| **pH** | No units | None | 6.5 to 8.5 |
| **Total Dissolved Solids (TDS)** | mg/L | None | AO[3]: ≤ 500 |
| **Total Organic Carbon (TOC)** | mg/L | None | Potentially the same as DOC, used as general guidance. |
| **Trihalomethanes (THMs)*** | µg/L | 100 | None |
| **Turbidity** | NTU[4] | None | Treatment limits for individual filters or units:<br>➢ Conventional and direct filtration: ≤ 0.3 NTU<br>➢ slow sand and diatomaceous earth filtration: ≤ 1.0 NTU<br>➢ membrane filtration: ≤ 0.1 NTU |

TOC: Drinking Water Treatment Standards for Newfoundland and Labrador (2015).

HAAs, THMs, Iron, Manganese, pH, TDS, and Turbidity: Canadian Drinking Water Quality Guidelines (2014).

* The THM and HAA MAC guidelines are based on quarterly averages, not on individual sample concentrations.

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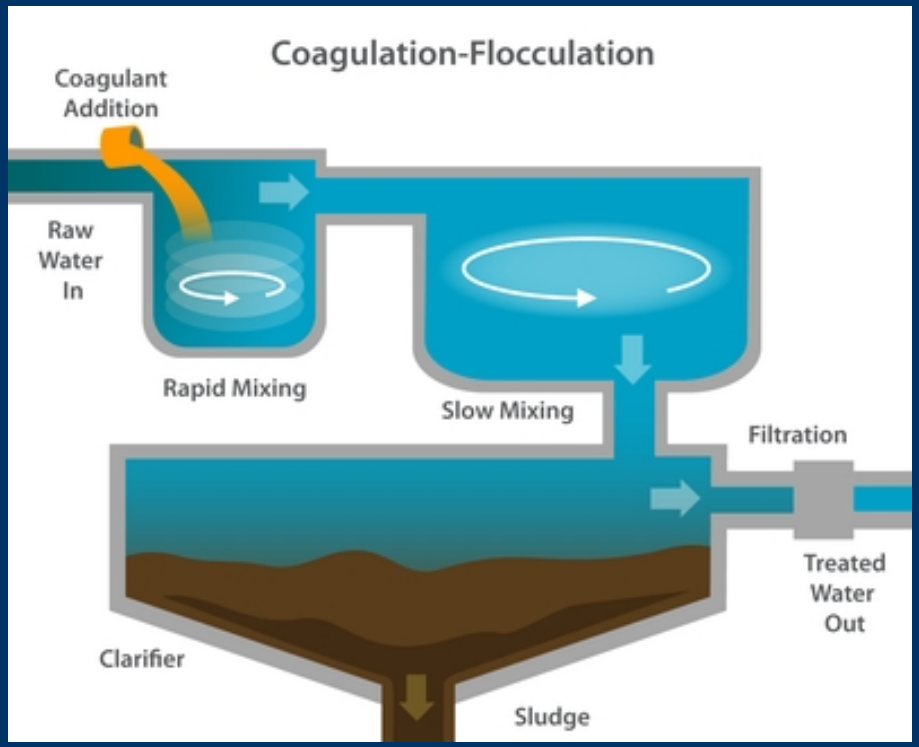
# WTP Technology Types

- Conventional water treatment plant: a series of coagulation, flocculation, sedimentation (or DAF), and media filtration processes used to treat drinking water.



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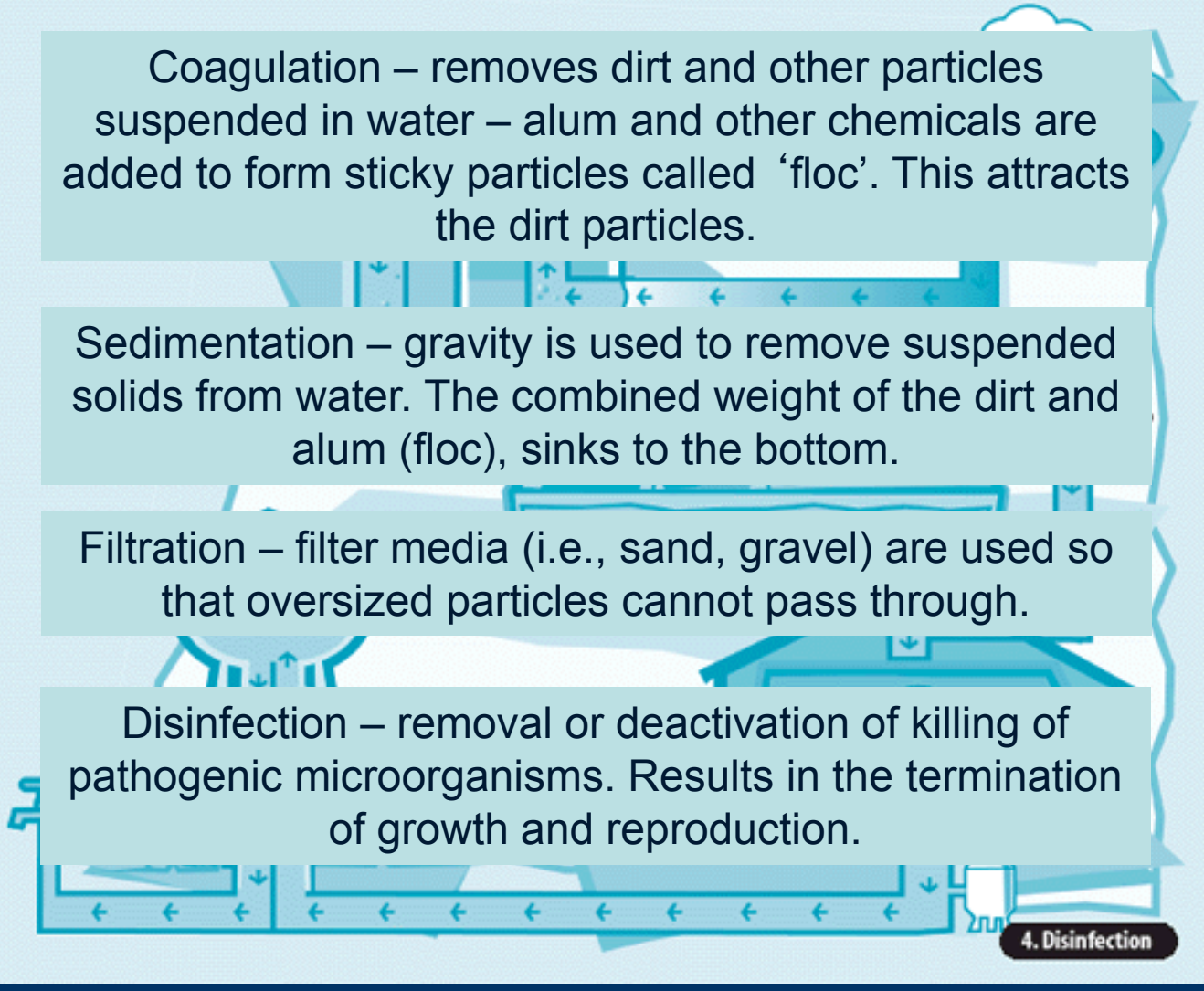
# Conventional WTP Processes

Coagulation – removes dirt and other particles suspended in water – alum and other chemicals are added to form sticky particles called 'floc'. This attracts the dirt particles.

Sedimentation – gravity is used to remove suspended solids from water. The combined weight of the dirt and alum (floc), sinks to the bottom.

Filtration – filter media (i.e., sand, gravel) are used so that oversized particles cannot pass through.

Disinfection – removal or deactivation of killing of pathogenic microorganisms. Results in the termination of growth and reproduction.



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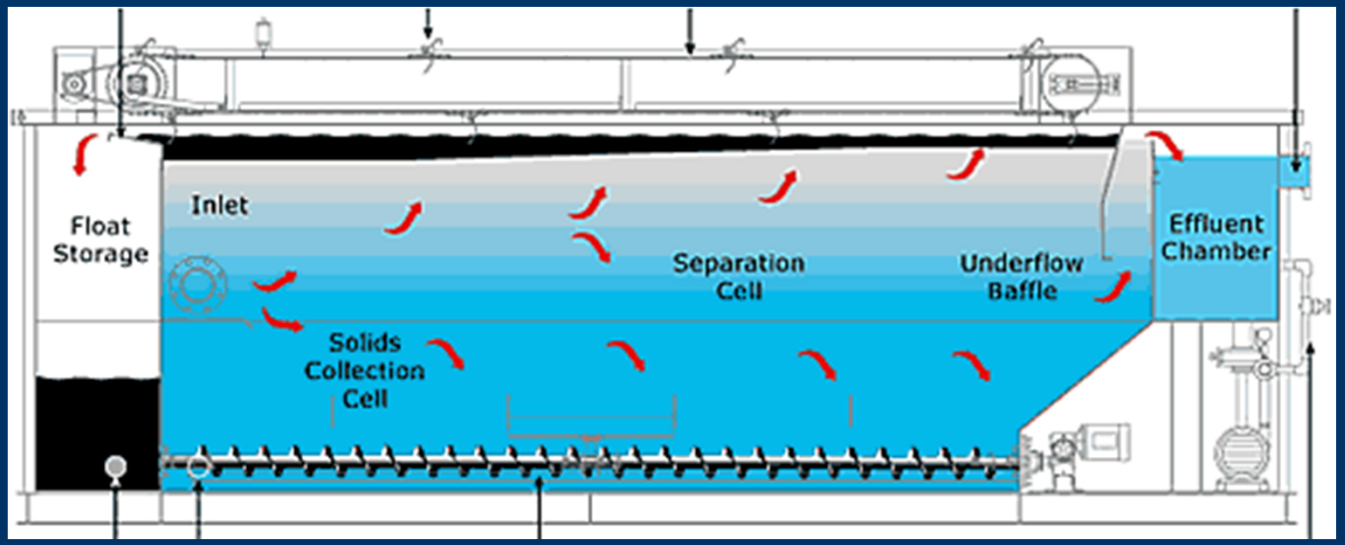
# Dissolved Air Floatation (DAF)

- Removes suspended matter by dissolving air in water under pressure and then releasing the air at atmospheric pressure in a basin.
- The tiny air bubbles adhere to the suspended matter causing it to float to the surface and skimmed from the top.
- DAF is used at BBBP WTP.
- Known to be effective at removing colour.





# WTP Technology Types (cont'd)

- Semi-conventional water treatment plant: they use of some, but not all, components of a conventional water treatment plant (coagulation, flocculation, sedimentation and media filtration) used to treat drinking water.


Lourdes

Happy Valley – Goose Bay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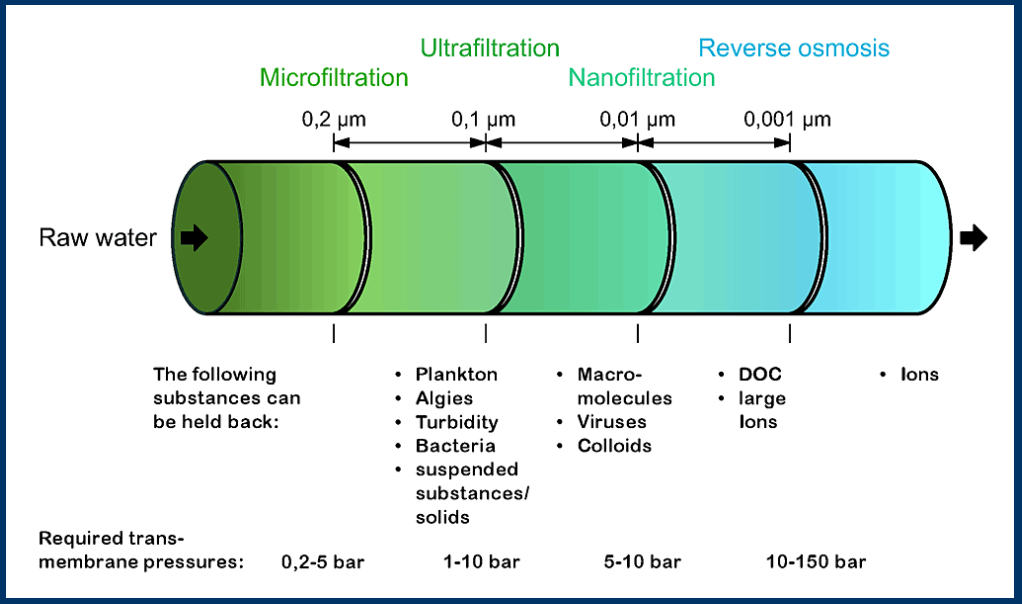
# WTP Technology Types (cont'd)

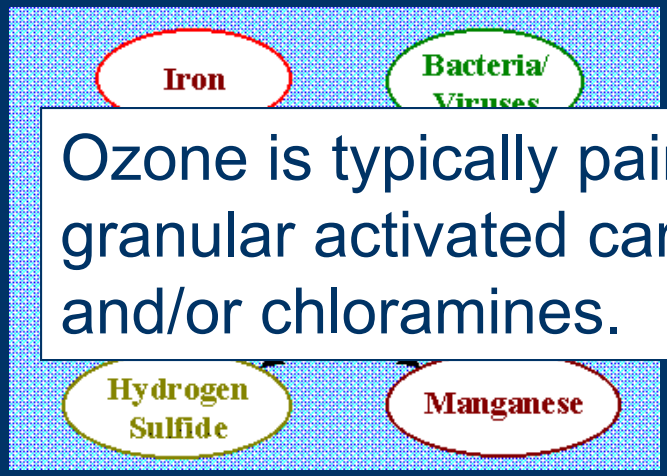
- Membrane water treatment plant: the use of membrane filtration (micro-filtration, ultra-filtration, nano-filtration or reverse osmosis) to treat drinking water and may include upfront treatment such as coagulants, powder activated carbon, or pH adjustment.





# WTP Technology Types (cont'd)

- $O_3$- Direct water treatment plant: a water treatment plant that generates and uses ozone on site to remove water impurities. Ozone exists as a gas at room temperature. Powerful oxidant and capable of oxidizing many organic and inorganic compounds in water. Ozone is commonly used in Europe.

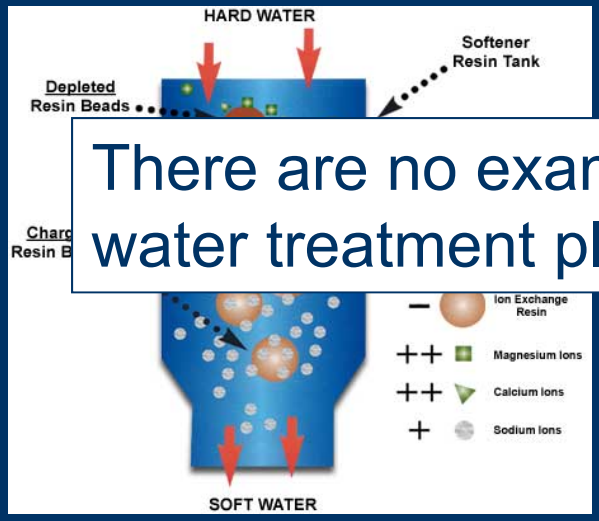



Ozone is typically paired with media filtration, granular activated carbon (GAC) filtration, and/or chloramines.

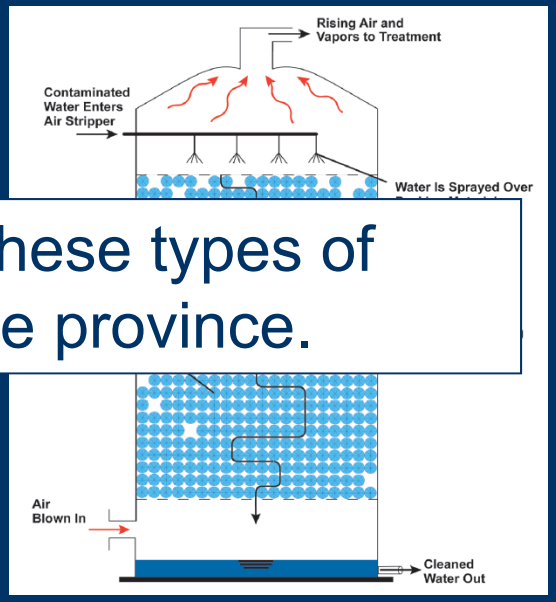


# WTP Technology Types (cont'd)

- Other water treatment plants: this category consists of all other water treatment processes that combine to form a full-scale water treatment plant. This could include but is not limited to: ion exchange, electrodialysis, distillation, and air stripping.




Ion Exchange




Air Stripping

There are no examples of these types of water treatment plants in the province.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# Results – Source to WTP

Alkalinity:

- The quantitative capacity of an aqueous solution to neutralize an acid.
- Affects efficiency of other treatment processes like coagulation.
- Difficult to raise alkalinity even with pH adjustment systems:
  - province-wide;
  - few exceptions, with source water pH already higher.
- Values were often below 30 mg/L.
  - Source average = ~12 mg/L.
  - WTP average = ~18 mg/L.

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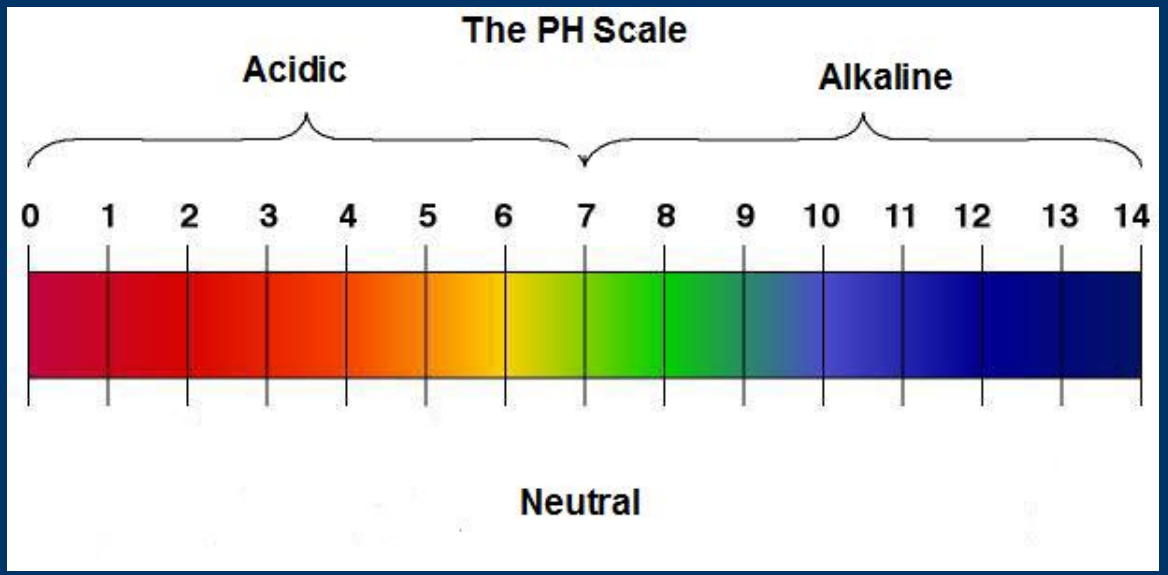
# Results – Source to WTP

pH:

- Soda ash typically showed the ability to raise pH more effectively than lime contactors and caustic soda:
  - Soda ash: average increase in pH ~ 13%;
  - Lime + Caustic soda: average increase in pH ~ 8%.





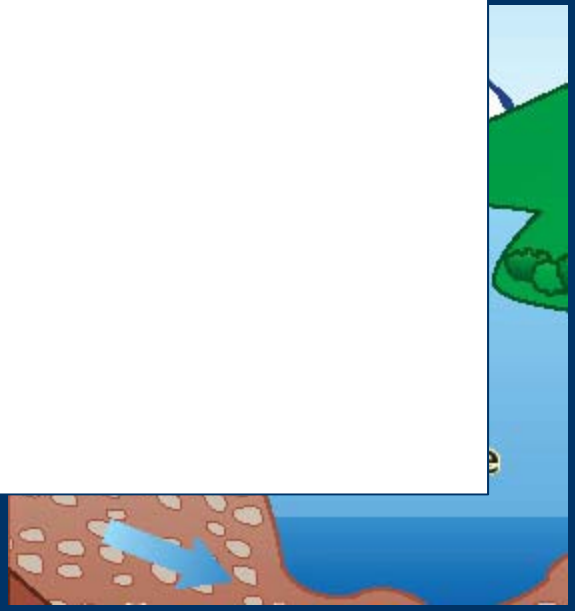
# Results – Source to WTP (cont'd)

Colour:

- Presence of coloured organic substances typically originating in the decay or aqueous extraction of natural

Conventional WTPs were most effective at removing colour:

- @Source:
  - Conventional = 106 TCU
  - Other = 65 TCU
- @WTP outlet:
  - Conventional = 7 TCU
  - Other = 22 TCU



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# Results – Source to WTP (cont'd)

DOC (dissolved organic carbon):

- Subcategory of TOC – organic matter that is able to pass through a 22-um filter.
- DOC is typically removed to minimize the formation of DBPs. Need to see DOC < 2.0 mg/L.
- DOC removal:

Systems effective at removing colour were not necessarily effective at removing DOC/TOC.

- Long chain NOM molecules get broken up, which remove colour.
- However, the molecules may not be removed, leading to no reduction in DOC/TOC.

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# Results – Source to WTP (cont'd)

Iron:

- A naturally occurring element in surface waters.
- It can add taste and colour to water, and cause staining in clothing from laundry and sinks/toilets/bathtubs.
- Iron removal:
  - Conventional WTPs:
    - greater than 75% iron removal.
  - GAC/NF/MF WTPs:
    - less than 10% iron removal.

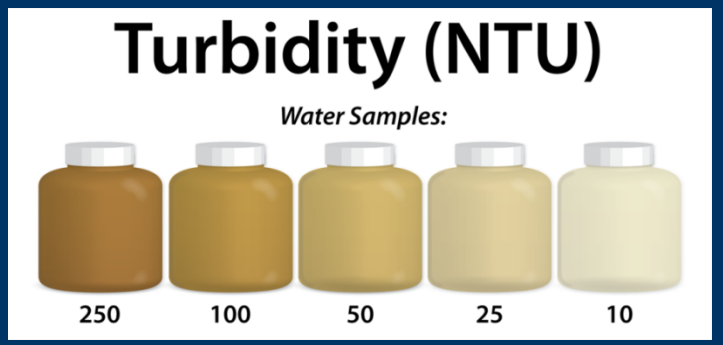


# Results – WTP to Distribution/Tap

Turbidity:

- The cloudiness of water from large numbers of suspended particles, generally invisible to the naked eye.
- Reasons for increase in turbidity:
- Observed high turbidity and slight increase from WTP outlet to tap location:
  - WTP average = ~ 0.56 NTU.
  - Tap average = ~ 0.65 NTU.

Aesthetic Objectives:
- Conventional ≤ 0.3 NTU
- MF/NF ≤ 0.1 NTU



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# Results – WTP to Distribution/Tap (cont'd)

Iron:

- Observed overall increase in iron from WTP to distribution/tap locations.
- Reason for increase in iron:
  - Corrosion and deterioration of iron pipes (cast iron, ductile iron).

Increase in iron from WTP outlet to distribution/tap location (AO: ≤ 0.3 mg/L):

- WTP average = ~ 0.09 mg/L
- Tap average = ~ 0.16 mg/L

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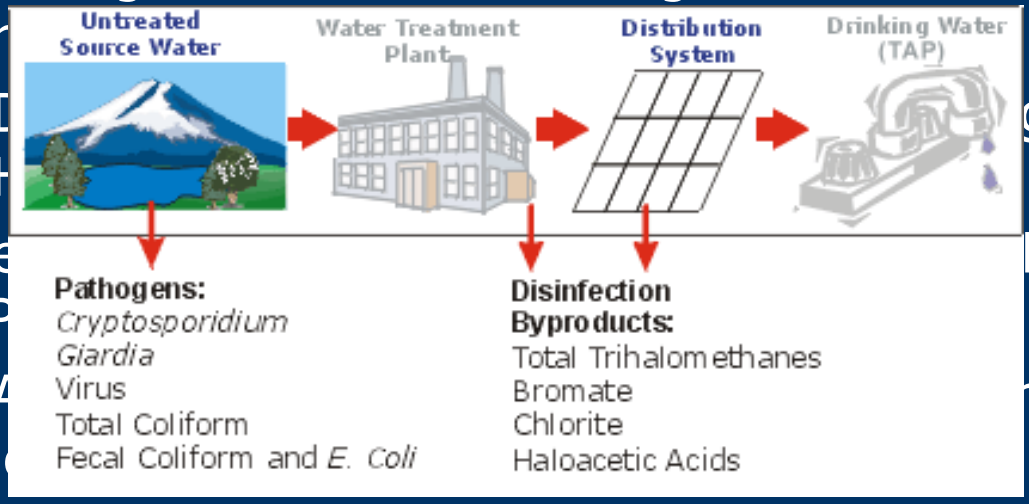
# Results – Disinfection By-Products

- Form when source water containing natural organic matter (NOM) is treated with chlorine.
- 
- 

Impact of residence time either in storage tanks or in the pipes have a significant affect on DBP exceedances.

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Over 100% indicates that the DBPs (THMs and/or HAAs) have decreased from WTP outlet to distribution/tap location.

Below 100% indicates that additional DBPs (THMs and/or HAAs) have formed in the distribution system.

| Water Treatment Plant | Formation at Water Treatment Plant (%) | |
|---|---|---|
| | THMs | HAAs |
| **Bay Bulls Big Pond (St. John's)** | 92.3% | 112.4% |
| **Burgeo** | 18.3% | 230.8% |
| **Channel – Port aux Basques** | 89.7% | 81.0% |
| **Clarenville** | 61.5% | 68.1% |
| **Come by Chance[1]** | n/a | n/a |
| **Conne River[1]** | n/a | n/a |
| **Exploits Regional Service Board** | 52.9% | 66.0% |
| **Gander** | 12.3% | 62.1% |
| **Happy Valley – Goose Bay** | 96.3% | 129.5% |
| **Heart's Delight – Islington** | 76.3% | 66.4% |
| **Lourdes** | 65.4% | 78.4% |
| **Lumsden** | 62.9% | 97.0% |
| **Marystown[1]** | n/a | n/a |
| **Musgrave Harbour** | 75.0% | 101.8% |
| **Placentia** | 78.0% | 274.7% |
| **Ramea** | 83.0% | 79.0% |
| **Windsor Lake (St. John's)** | 83.8% | 107.9% |



# Challenges - Seasonal Changes

Typically Observed:

- Summer samples having the highest DBP concentration levels.
- Seasonal DBPs are linked to seasonal source water quality changes.

| Season | Start | End |
|---|---|---|
| **Winter (1)** | January 15th | March 15th |
| **Spring (2)** | May 16th | June 30th |
| **Summer (3)** | August 1st | September 30th |
| **Fall (4)** | November 1st | December 15th |



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# Challenges - General

General Challenges:

- Difficult to pinpoint source of issues between WTP outlet and tap.
- Operations need to be optimized during summer for NOM removal.

WTP vs. Distribution Systems:

- General decrease in water quality in distribution systems.
- Attempt to rectify with more cleaning/more flushing.

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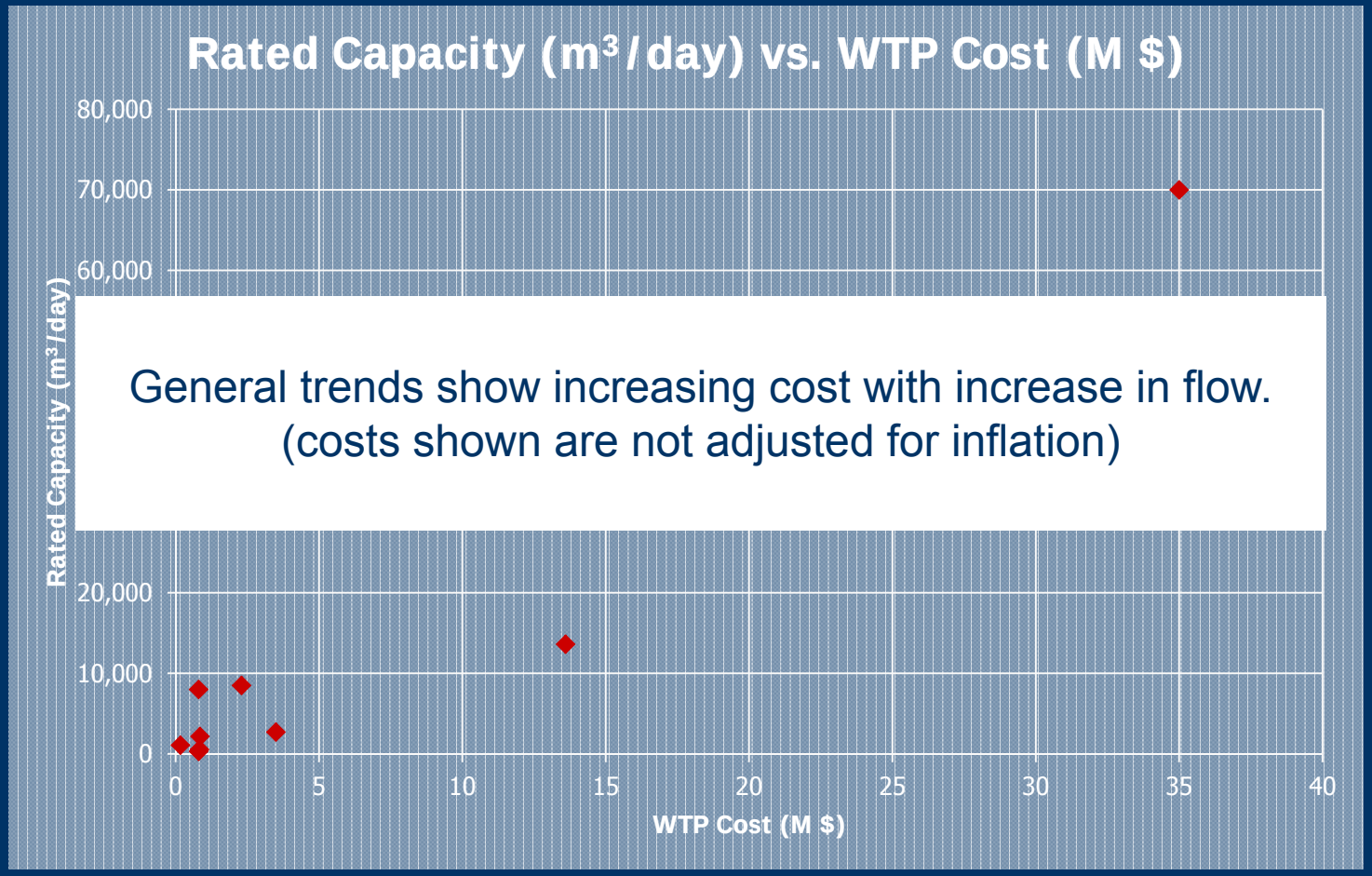
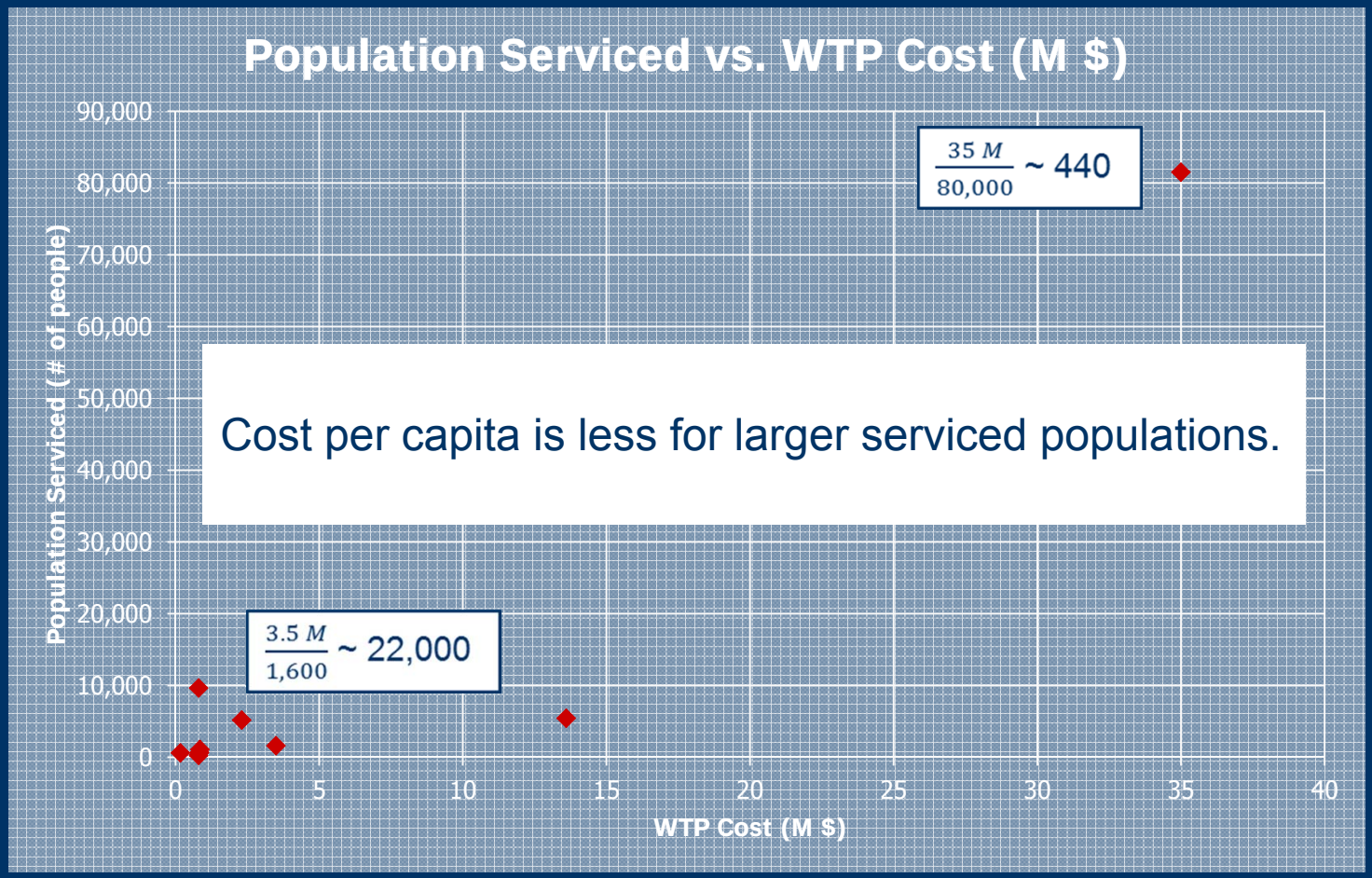
# Challenges: Water Treatment Plant Costs



# Challenges: Water Treatment Plant Costs







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# Conclusions

- Technologies that have demonstrated performance should be given preference for future WTPs.
- There should be increased maintenance and cleaning of water distribution systems.
- WTPs should provide annual reporting to ENVC including information on flows, chemical use, extreme events, water quality, unexpected events, and changes to the WTP.
- WTPs should plan for capital upgrades to meet drinking water requirements as equipment reaches the end of its useful life cycle.



# Conclusions (cont'd)

- Require better log of WTP background and changes to the plants processes:
  - to better reflect changes in system and connected interpretations on water quality data.


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# Path Forward - Opportunities

What's Next?

- Modelling the systems - WatPRO
- New data, especially with changes to WTPs and/or new WTPs commissioned.
- Input from operators? Valuable.
- Operators/Communities to review their individual sub-reports when WTP study is finalized.
- The location of HAA sampling may need to be re-examined for systems with water treatment plants, large systems with a high retention time, or systems with storage tanks located at the start of the system.

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# THANK YOU

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