# Best Management Practices for Controlling DBPs in NL:

## What Works, What Doesn't, and What Could?

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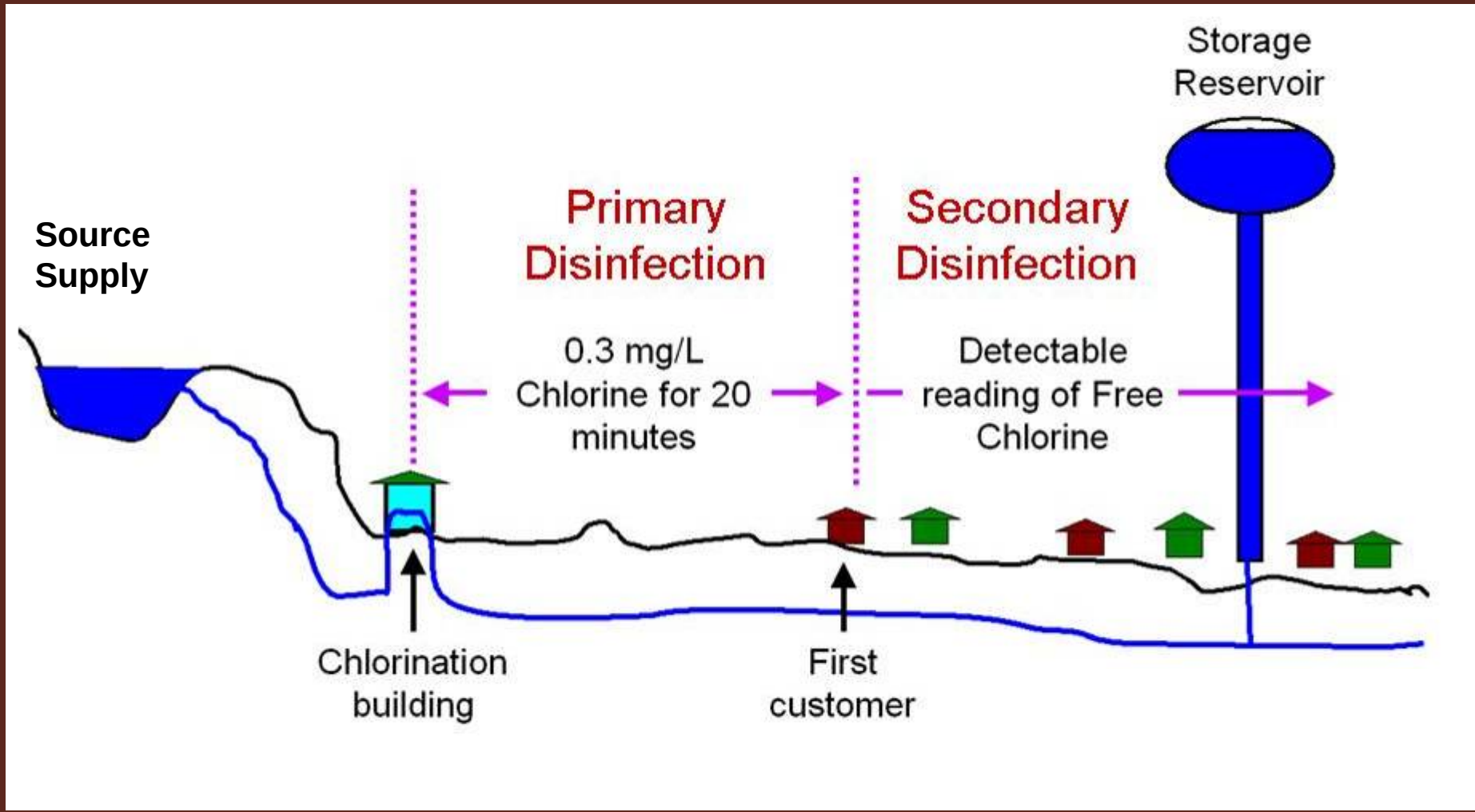
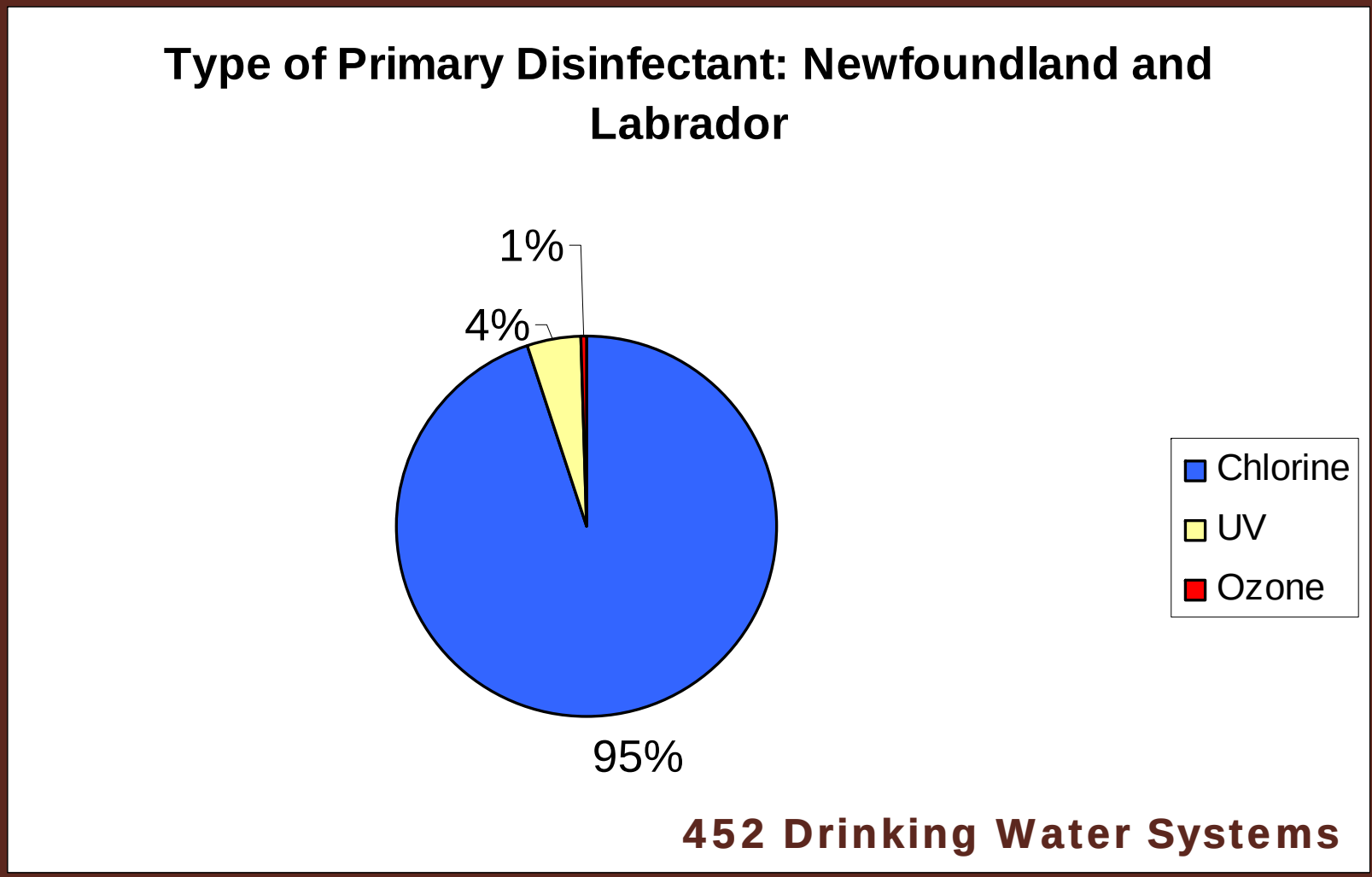
# Typical Water System



# Disinfectant Use



# What Is a DBP?

- [Precursor Material] + [Disinfectant] = [Disinfectant by-product or DBP]

| | | |
|---|---|---|
| Natural Organic Matter | Chlorine | THMs |
| Bromide | Ozone | HAAs |
| Ammonia | $ClO_2$ | HANs |
| Iodide | | Bromate |
| | | Chlorite/Chlorate |
| | | Many Others |

- Other factors that play a role in the formation of DBPs:
  - Water Temperature, pH, Contact Time, Disinfectant Dose

# Toxicological Effects of DBPs

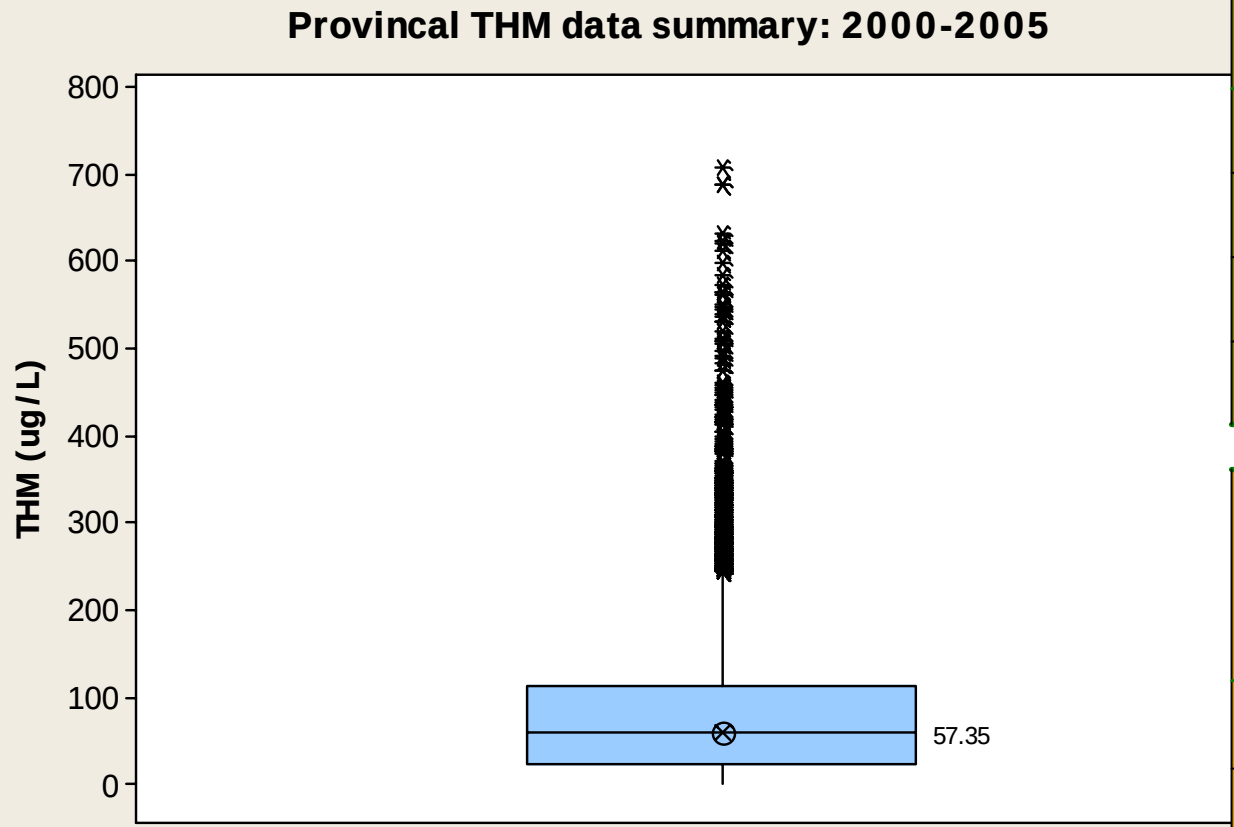
| Class of DBPs | Compound | Rating | Effects |
|---|---|---|---|
| THM | Chloroform | B2 | Cancer, liver, kidney and reproductive effects |
| | Dibromochloromethane | C | Nervous system, liver, kidney and reproductive effects |
| | Bromodichloromethane | B2 | Cancer, liver, kidney and reproductive effects |
| | Bromoform | B2 | Cancer, nervous system, liver and kidney effects |
| HAA | Dichloroacetic acid | B2 | Cancer, reproductive and developmental effects |
| | Trichloracetic acid | C | Liver, kidney, spleen and developmental effects |
| Inorganic compounds | Bromate | B2 | Cancer |
| | Chlorite | D | Developmental and reproductive effects |

# DBP Guidelines and Communities with DBP Issues

| **Compound** | **CCME/ Health Canada (2008)** |
|---|---|
| Total THMs (mg/L) | 0.100 |
| Bromodichloromethane (mg/L) | 0.016 |
| HAA5 (mg/L) | 0.080 |

| DBP Type | Number of Communities with Issues |
|---|---|
| THM | 124 |
| BDCM | 45 |
| HAA (guideline of 0.06 ug/L) | 184 |

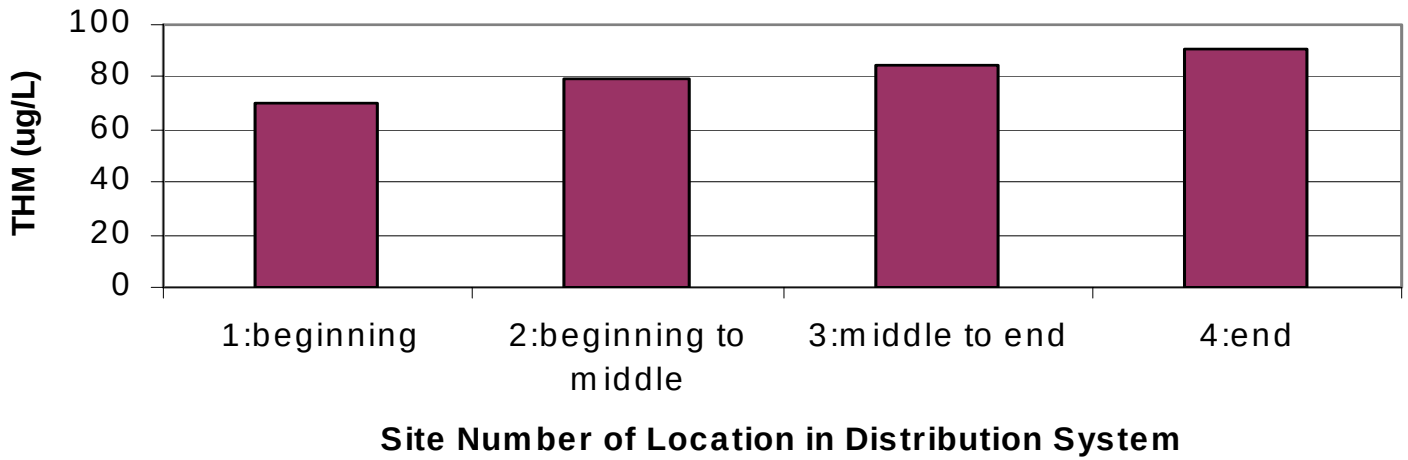
# DBP Behaviour in NL



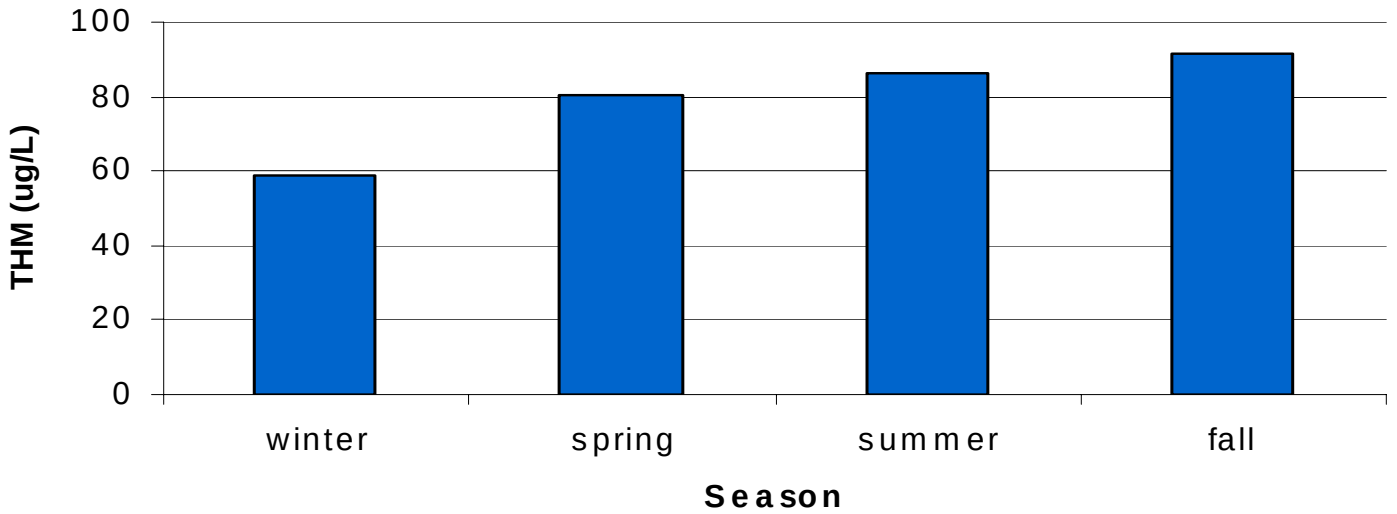

| Region | Maximum THMs (ug/L) |
|---|---|
| Eastern | 573 |
| Central | 688 |
| Western | 740 |
| Labrador | 460 |

| Region | Maximum HAAs, (ug/L) |
|---|---|
| Eastern | 1118 |
| Central | 1114 |
| Western | 2409 |
| Labrador | 712 |

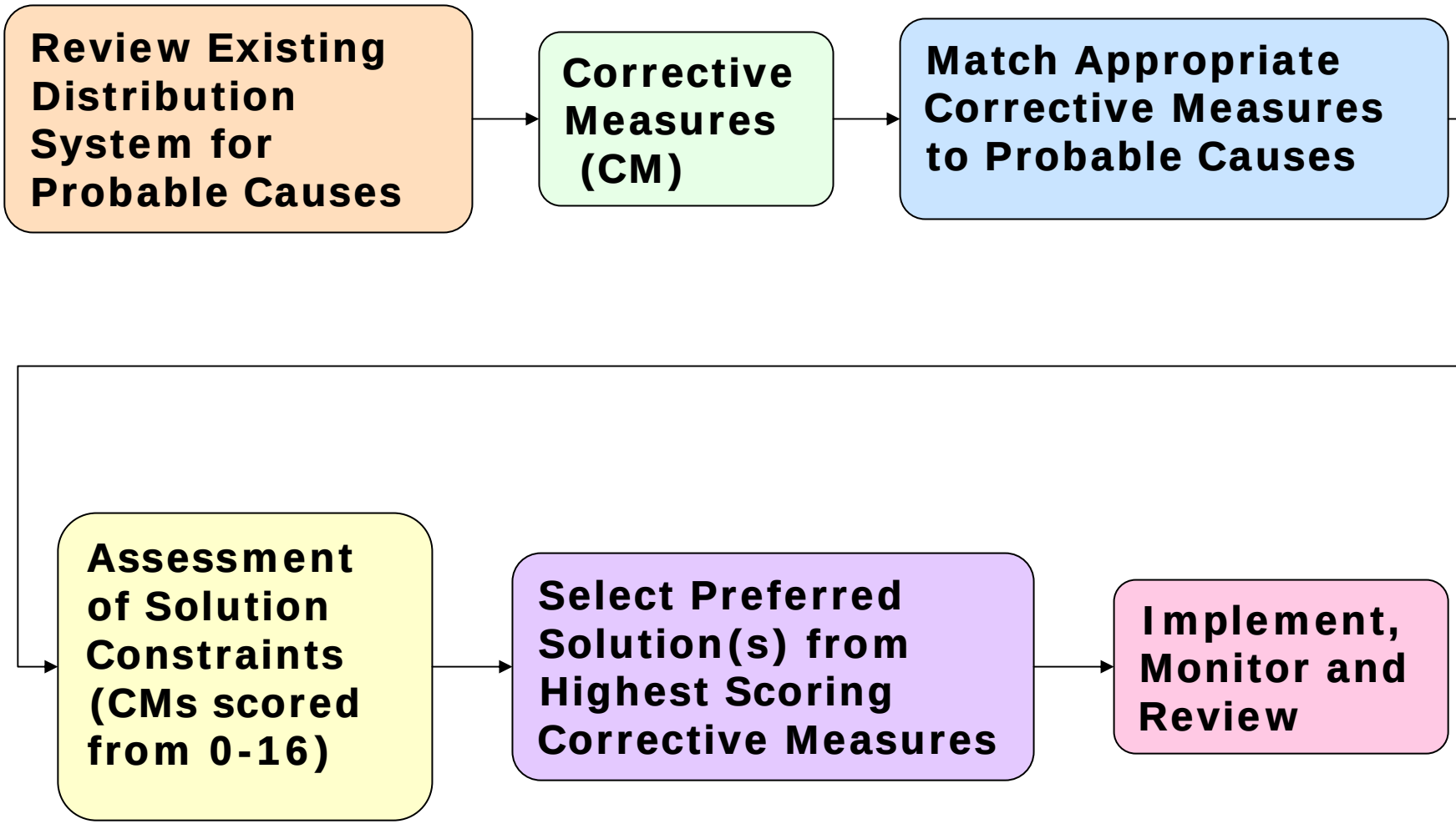
## Average THMs by Location in Distribution System: 2000-2005



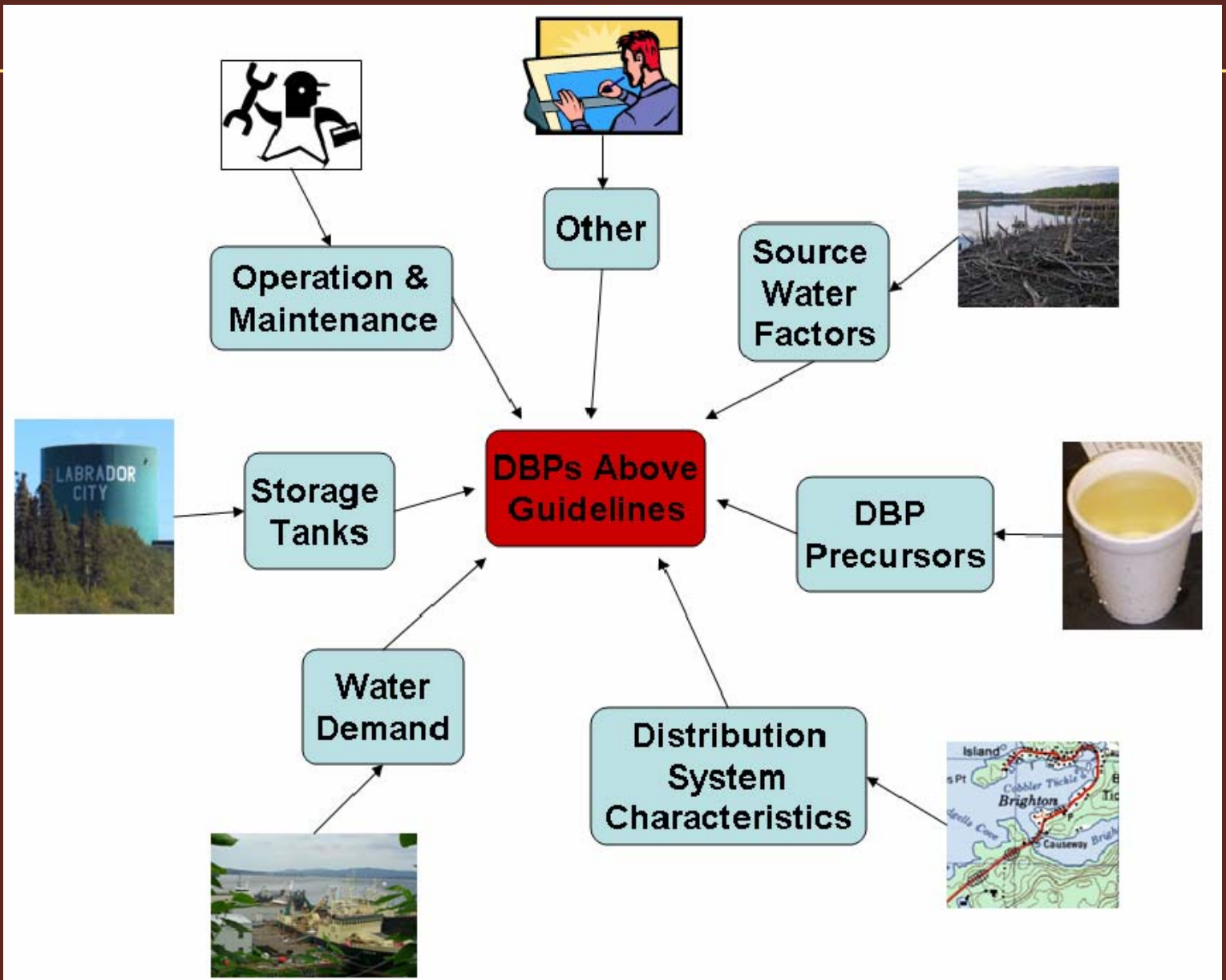

## Seasonal Variation of THMs: 2000-2005



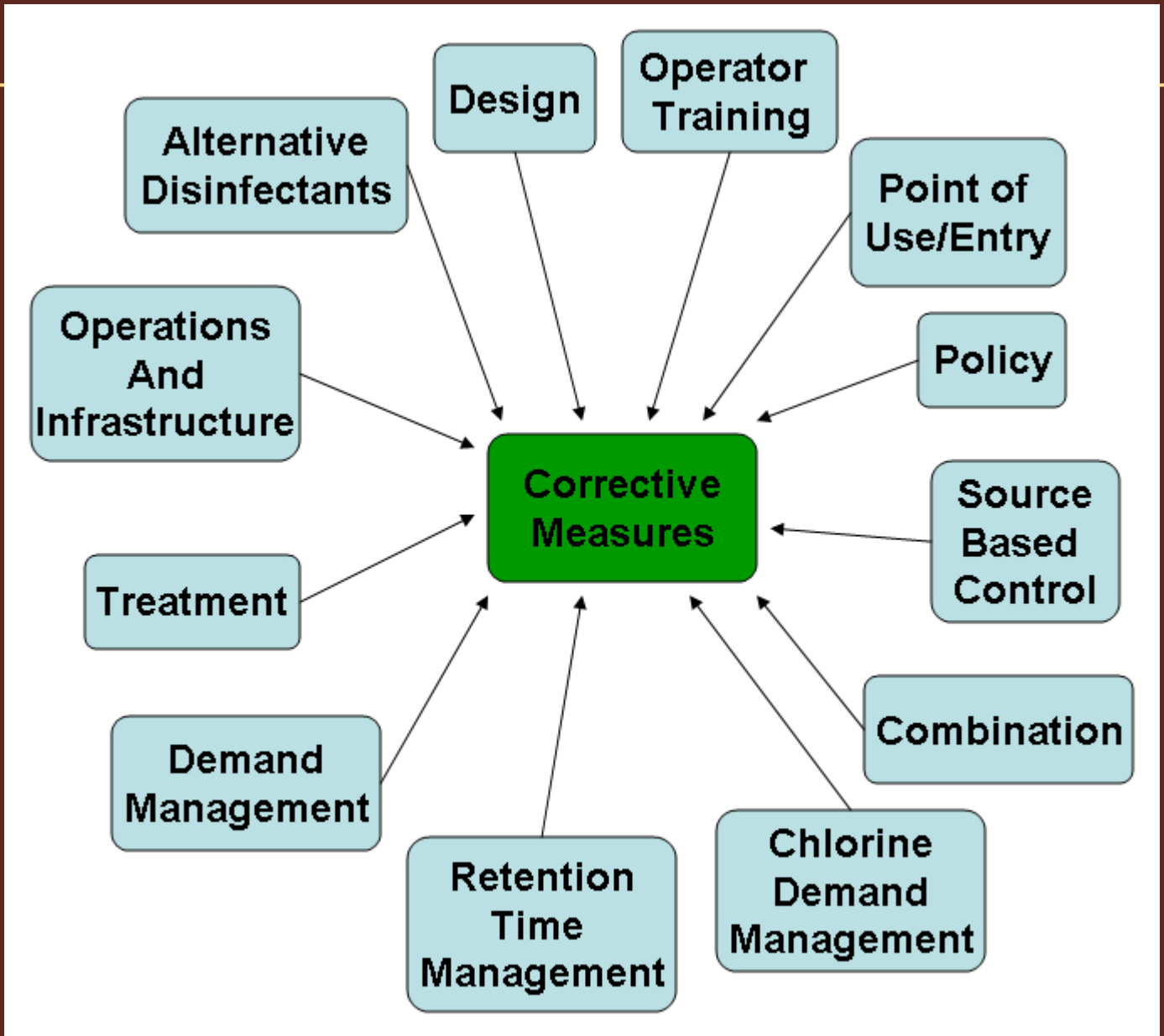
# Decision Making Framework for Selecting DBP Corrective Measures



# Probable Causes



# Corrective Measures



# Corrective Measures- Policy

- Policy for POU/POE treatment- as temporary or emergency measure
- Policy to promote the use of alternative disinfectants- 95% of disinfection systems use chlorine
- Policy to promote PWDUs- Rural Drinking Water Safety Initiative

# Corrective Measures- Source- Watershed Protection

- 259 protected surface water supplies in province
- Protected under Section 39 of the *Water Resource Act*
- All development activity goes through a permitting process
- Most PPWSAs relatively pristine with little development activity
- No significant difference in mean THM levels from protected versus unprotected surface water sources- THM precursors occur naturally

# Corrective Measures- Source- Coastal Influence

- The greater the distance from the coast, the lower the THM average
- Water sources should be sited as far from the coast as possible in locations sheltered from ocean salt-water spray, and prevailing coastal winds

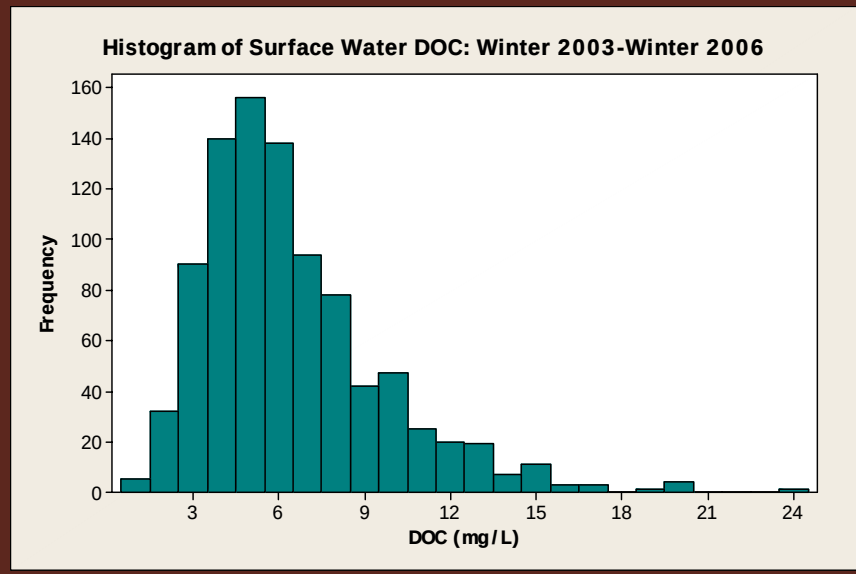
# Corrective Measures- Source- Alternative Water Sources



| Status of Watershed | Mean THM (Standard Deviation) |
|---|---|
| River | 86.6 (± 58.36) |
| Pond | 85.8 (± 65.14) |
| Lake | 73.0 (± 55.29) |
| Brook | 59.6 (± 51.67) |
| Reservoir | 50.9 (± 50.74) |
| Canal | 50.29 |
| Spring | 31.8 (± 4.71) |
| Drilled/ Reservoir | 21.6 |
| Drilled | 15.7 (± 27.7) |
| Dug | 6.73 (± 5.66) |
| Drilled/Dug | 3.06 |

# Corrective Measures- Source- Alternative Water Sources

- DOC is the best available predictor of DBP formation potential
- Pick alternative water sources with DOC < 4.2 mg/L
- DOC high in watersheds with a large percentage of bog, marsh, fens, swamp, open shallow water
- The larger the percent of the watershed classified as exposed (rock, non-vegetated), the lower the THM levels

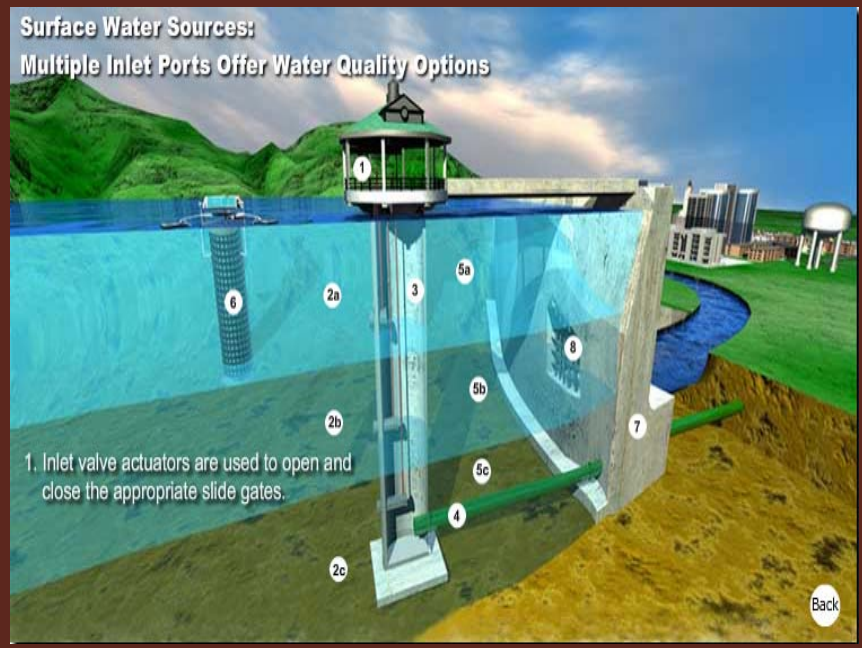


# Corrective Measures- Source- Alternative Water Sources

- Of 309 public surface water supplies, 114 (37%) have dams
- BMPs for reservoir flooding
  - Remove vegetation
- Stop mixing groundwater with surface water
  - DOC from surface water and bromide from groundwater
  - Port au Port West, Port au Choix
- Stephenville THMs > 200 ug/L, after switch to groundwater THMs <20 ug/L

# Corrective Measures- Source- Relocate Intake

- Ideal intake location:
  - Off bottom of waterbody to ensure conduit openings are not clogged by silt, sand, gravel, debris
  - Deep enough to ensure submersion during extreme low water events
- Relocating intake to deeper water can reduce water temperatures and DBP formation
- Optimal intake is one that permits varying the depth of water withdrawal to alternate with seasonal changes



# Corrective Measures- Source

- Shallow ponds with long fetch lengths in the direction of prevailing winds prone to wave generation and agitation of bottom sediments leading to turbidity
  - Cow Head, St. Paul's, Brighton, King's Point
- Horizontal intake filtration berms have a negligible effect on reducing DBP precursors

# Corrective Measures- Chlorine Demand Management- Optimize Dosage

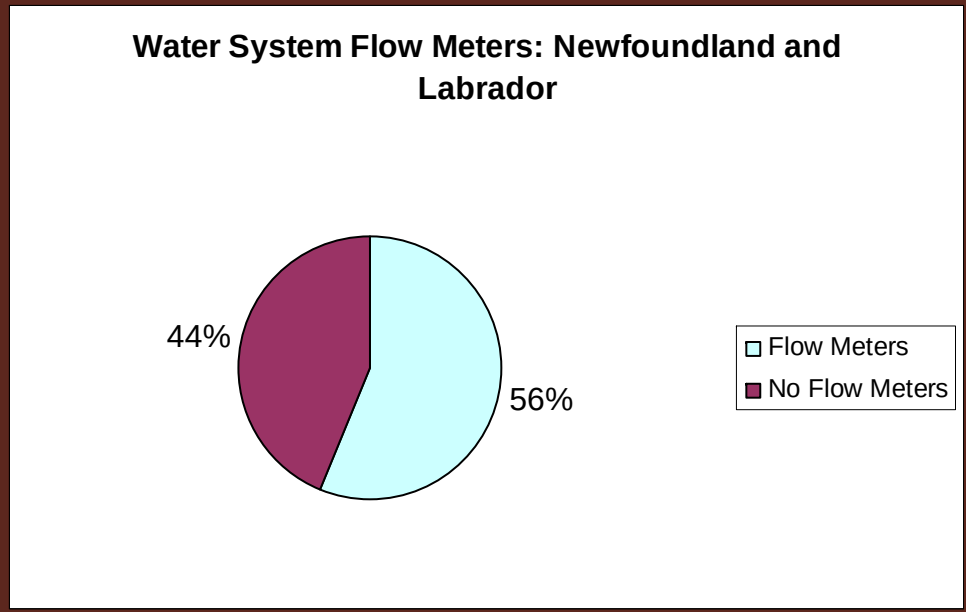
- Chlorine dosage should be kept as low as possible while maintaining required primary and secondary disinfection objectives
- Optimize disinfectant dose
  - Typical chlorine dose is 5 mg/L
  - Chlorine dose is high if over 7 mg/L or over 4 mg/L at first user
- Optimize location of chlorination system
  - Closer to first user- required contact time is 20 minutes
  - Downpipe of tank
- Adjusting chlorine dosage under different seasonal conditions may help reduce the formation of DBPs
  - Summer and fall see peaks in water temperature and DOC

# Corrective Measures- Chlorine Demand Management- Chlorine Boosters

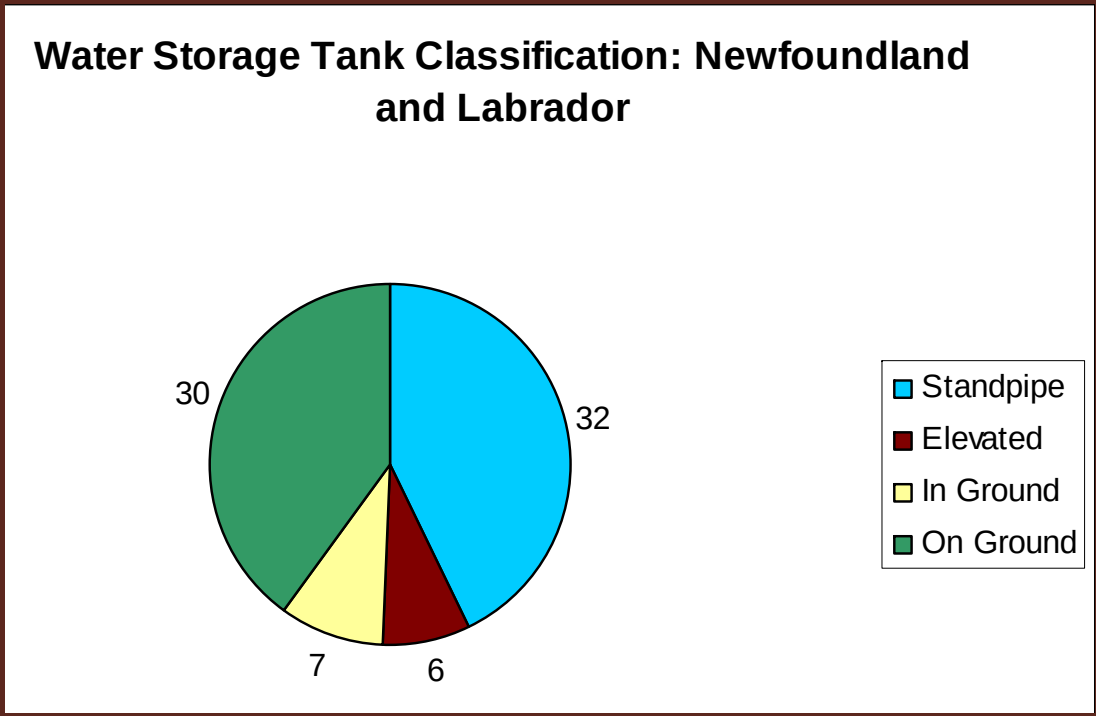
- Booster chlorination strategy involves multiple coordinated doses of chlorine applied throughout the distribution system
  - Maintain chlorine residuals at ends of distribution network
  - Reduce single high chlorine dose
  - Reduce the total amount of chlorine used in the system per day
- 13 communities with chlorine boosters in NL
  - Tend to aggravate THM problem in most cases, however, in some instances appear to have reduced THM levels
  - Depends on operational factors
- Chlorine boosters may reduce DBPs if:
  - Installed at optimal locations
  - If overall chlorine use reduced
  - Chlorine dose is high and/or residuals over 4 mg/L in town

# Corrective Measure- Chlorine Demand Management- Dosage Control

- Majority of systems in NL have manual chlorine control with no working flow meter
- Other chlorine dosage control options:
  - Manual control with a metering device
  - Automatic control with metering device
  - Automatic control with a flow meter and/or chlorine residual analyzer
- Problems of O&M and fluctuating chlorine residuals with Cl residual analyzers
- To control chlorine dosage all towns disinfecting with chlorine should use, at a minimum:
  - flow meter readings
  - manual chlorine residual readings



# Corrective Measures- Retention Time Management



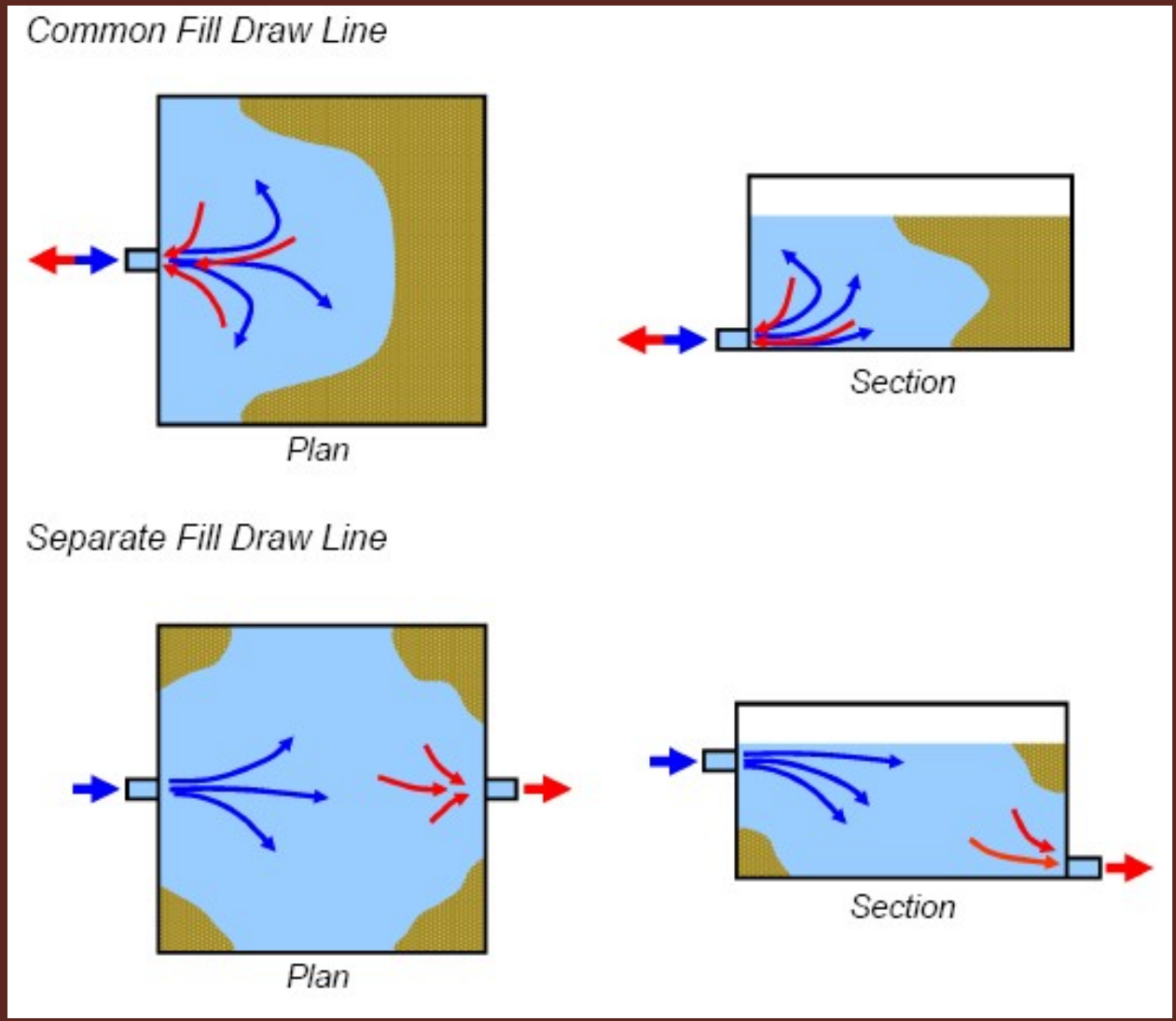

| Presence of Storage Tank | Number of Watersheds | Mean THM (Standard Deviation) |
|---|---|---|
| No Tank | 318 | 62.3 (±59.72) |
| Tank | 69 | 78.4 (±63.59) |

- Problems:
  - Poor mixing of water
  - Dead zones
  - Excessive retention time
  - Lack of water turnover
  - Unnecessary storage

# Corrective Measures- Retention Time Management

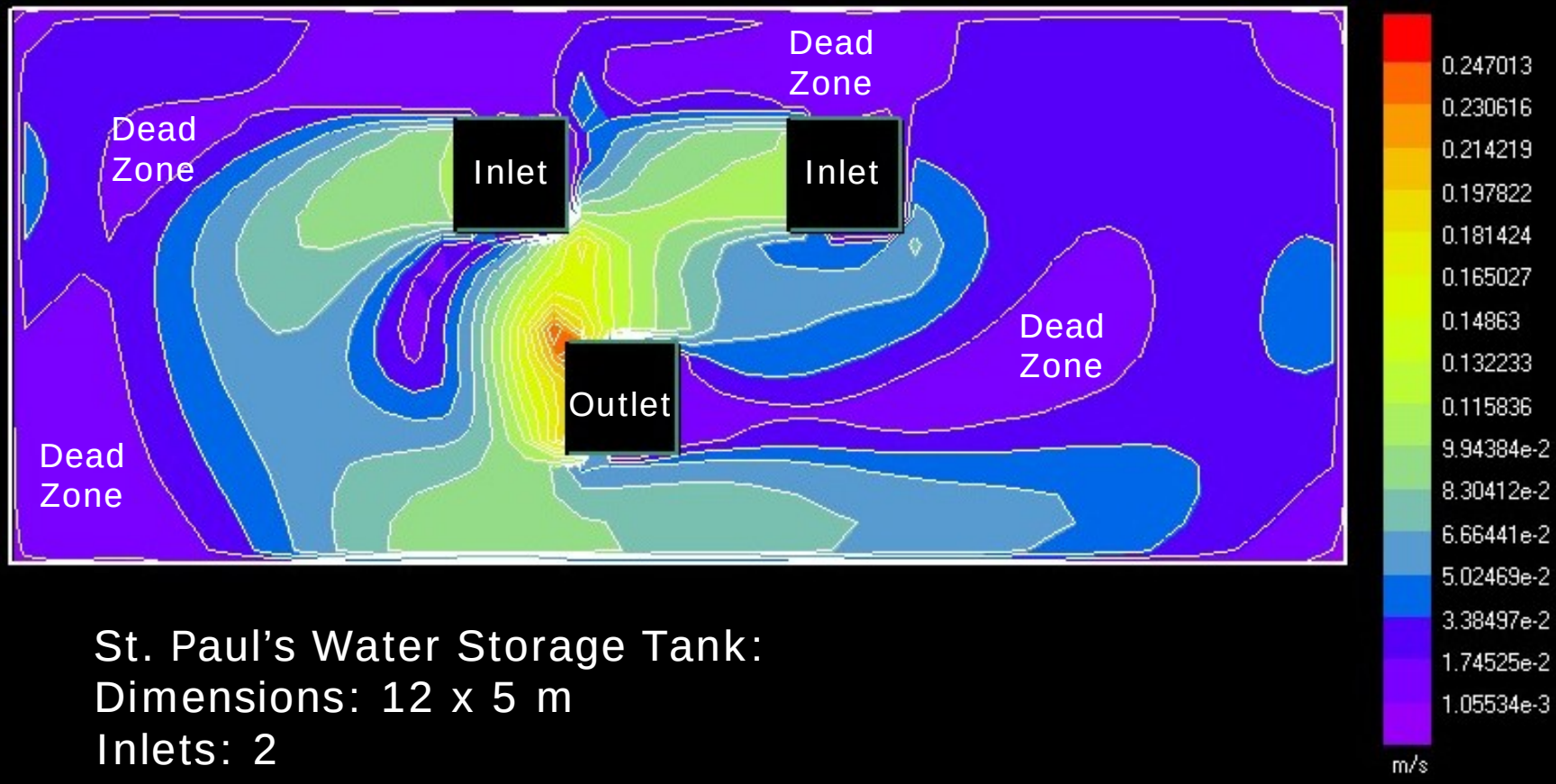
- Optimize tank location and type
  - Beginning of system
  - Elevated storage for pressure issues
- Adjust pump schedules to:
  - Change water level in tank and force turnover of water in tank
  - Increase velocity of inflow into tank- variable speed pumps
  - Reduce the volume of storage required
- Reduce storage capacity
  - Reduce maximum water level in tank
  - Remove storage permanently when no issues with supply or pressure

# Corrective Measures- Retention Time Management- Increase Mixing



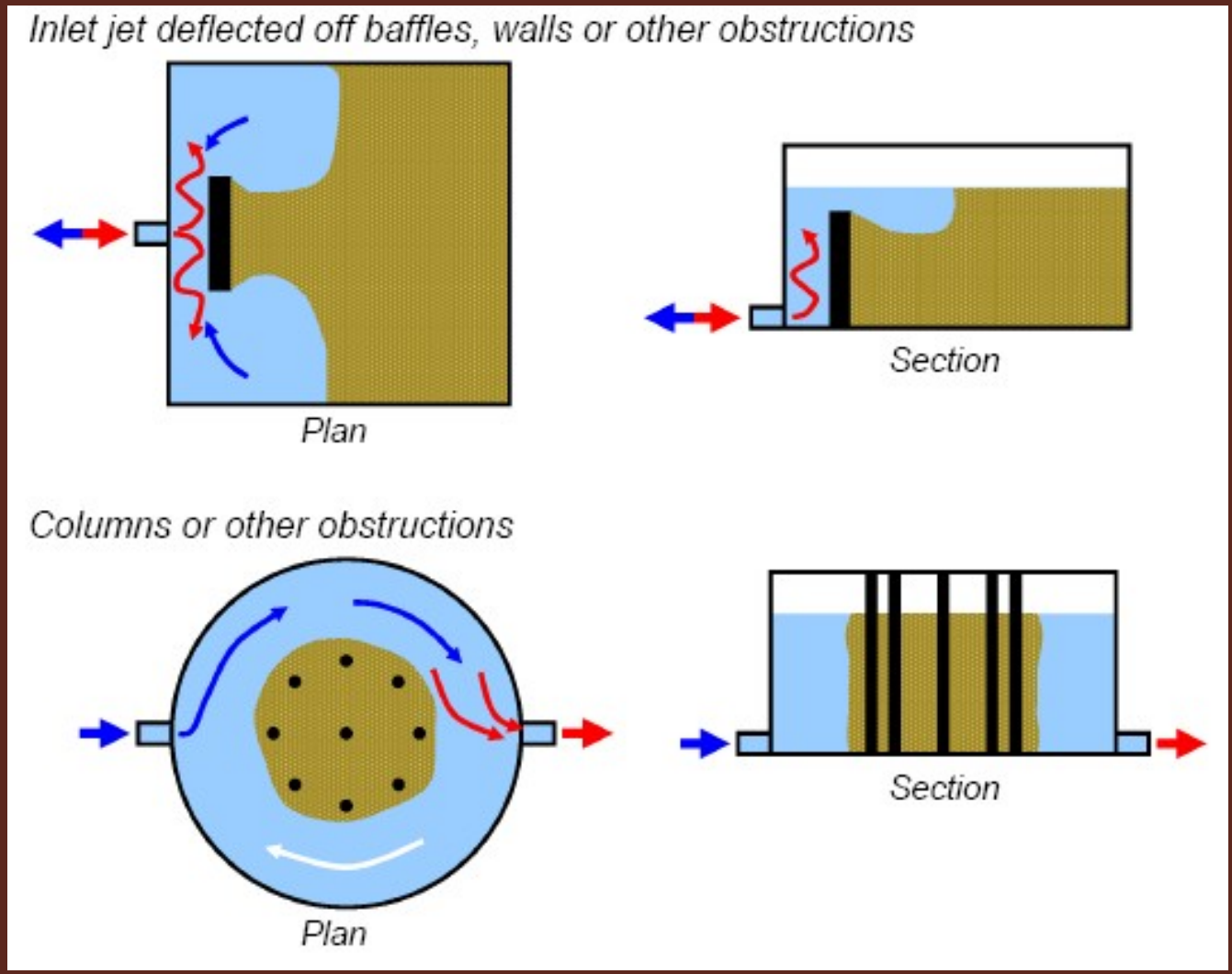

- Replacing a common inlet/outlet with separate pipes
- Increasing the distance between the inlet and outlet

# Corrective Measures- Retention Time Management- CFD Modeling



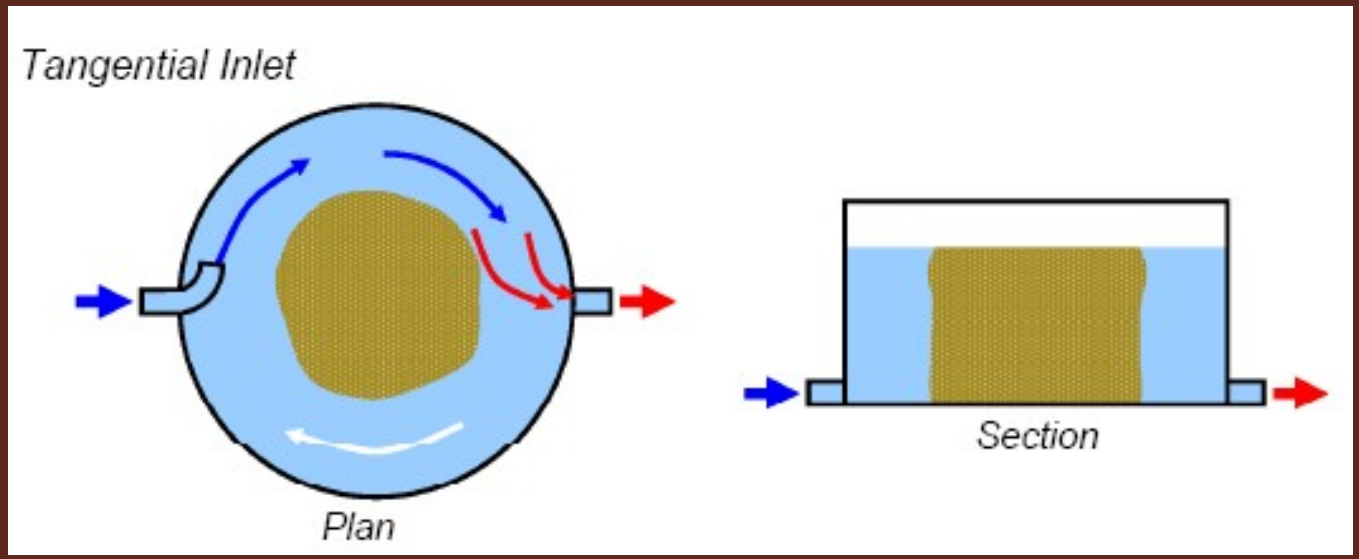

St. Paul's Water Storage Tank:
Dimensions: 12 x 5 m
Inlets: 2
Outlets: 1

# Corrective Measures- Retention Time Management- Increase Mixing

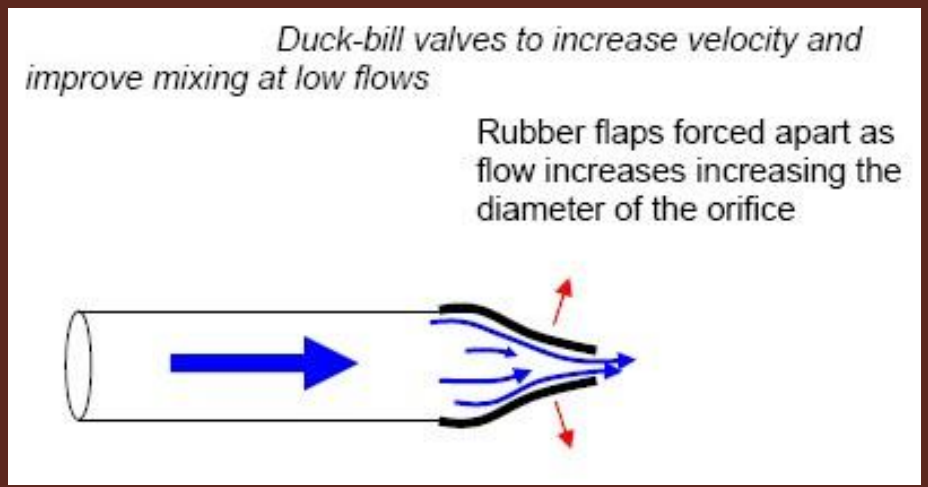


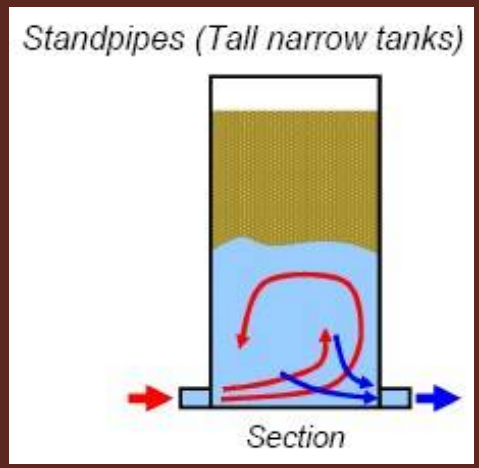

- Install baffles
- Install paddle or impellor devices to improve mixing within the tank

# Corrective Measures- Retention Time Management- Increase Mixing




- Moving the location or orientation of the inlet
- Reducing the diameter of the inlet
- Installing a duckbill valve to increase the velocity of the inlet jet



# Corrective Measures- Retention Time Management- Tank Aeration

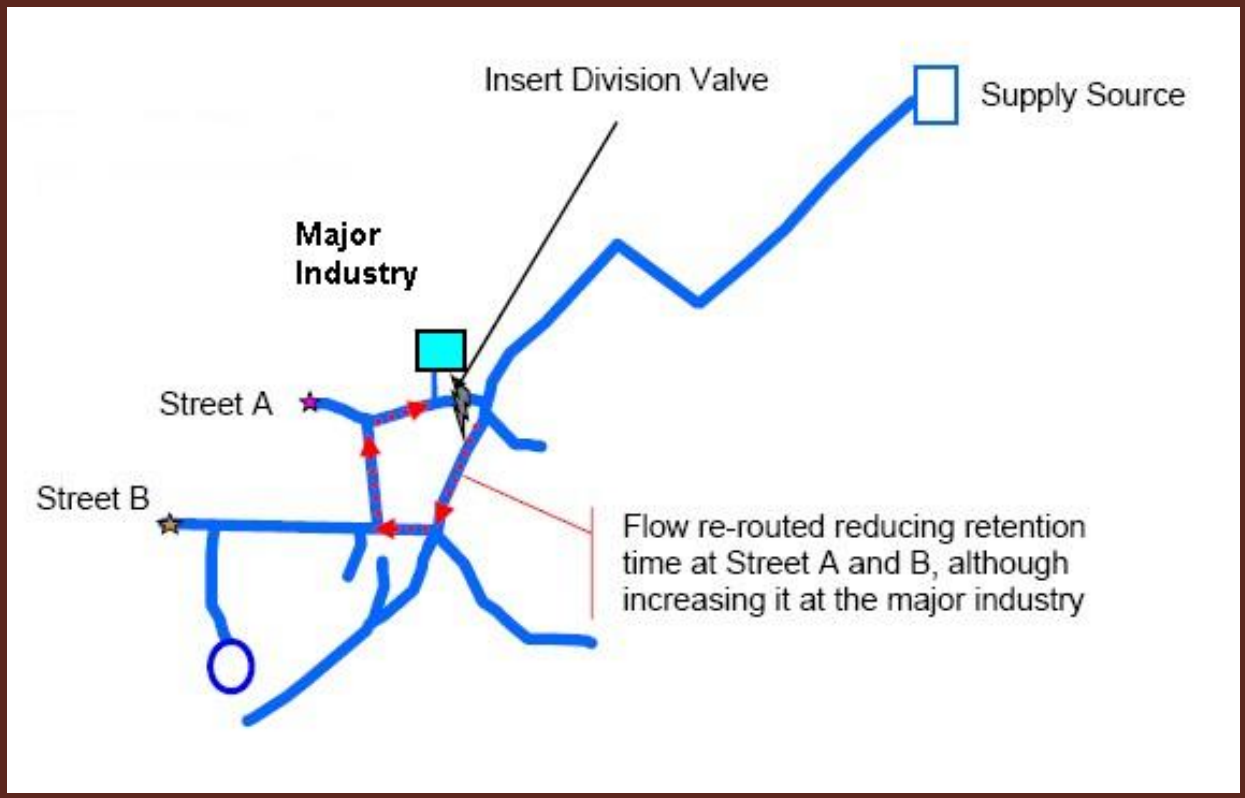
- Aeration is the process by which air is circulated through, mixed with, or dissolved in a liquid substance
- Some DBPs are volatile compounds that can be reduced through aeration
- Reductions of THMs of up to 70%
- Reduction of chlorine residuals

# Corrective Measures- Demand Management- System Flushing

- Flushing of distribution systems can:
  - Remove sediment built up in pipes
  - Reduce water age in dead ends
  - Increase water velocities in sections of pipe
  - Higher disinfectant residuals
- Regular system flushing
  - Automated of manual
- Recommended best management practice & first response measure
- Continuously bleed system at dead ends

- Flushing programs in Burgeo, Gander, and St. Lunaire-Griquet
  - Very turbid water and solid biofilm cake in the flushed effluent
  - Total chlorine dosage dropped after flushing (in one case by 65 percent)
  - free chlorine residuals have improved

# Corrective Measures- Operational and Infrastructural




- Optimize valve placement
- Re-routing of flows through valving
- Pumping to re-circulate water
- Increase demand with new connections

# Corrective Measures- Operational and Infrastructural

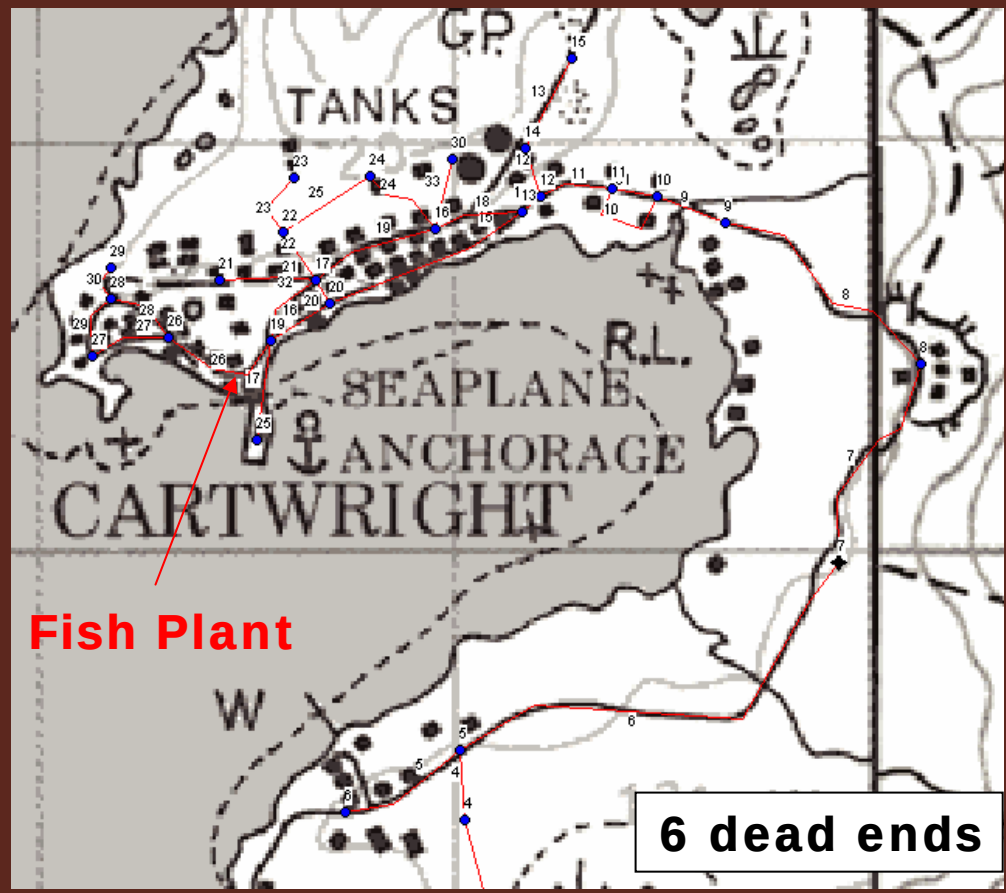
- Abandon or downsize mains to reduce surplus or overall capacity in system
  - Increases water velocity
  - Reduces retention time
- Clean, replace or reline pipe
  - Old pipe > 25 years
  - Cast Iron pipe

Corroded CI Pipe

Corrosion and tuburculation in DI pipe

# Corrective Measures- Operational and Infrastructural

- Loop distribution network
  - Avoid branching
  - Minimize dead ends
  - Long linear systems common
- Upgrade distribution system
  - Reconfigure, replace, abandon pipe
  - New intake
- Large occasional demand on system



# Corrective Measures- Operational and Infrastructural

- System maintenance
  - Flushing, reservoir cleaning, leak detection
  - Swabbing or pigging
  - Pump, valve, hydrant, flow meter maintenance
- Increase capacity of water treatment plant
- Regionalization
  - Regional System- Exploits Region, St. John's
  - Regional Operator- Northern Peninsula

Well Maintained

Poorly Maintained

# Corrective Measures- Alternative Disinfectants

- Alternative disinfectants to chlorine:
  - Less likely or do not form chlorinated DBPs (UV)
  - Chemical destruction of DBP precursors through oxidation (ozone, $ClO_2$, MIOX)
- Alternate disinfectants include:
  - Chloramines, Ozone, $ClO_2$, UV, MIOX
- Disadvantages of alternative disinfectants:
  - More expensive
  - Some may still have to be used in combination with chlorine (UV, ozone)
  - Form non-chlorinated DBPs
    - bromate, chlorite/chlorate, cyanogen chloride, N-Nitrosodimethylamine (NDMA)

# Corrective Measures- Alternative Disinfectants

Ozone- Gander

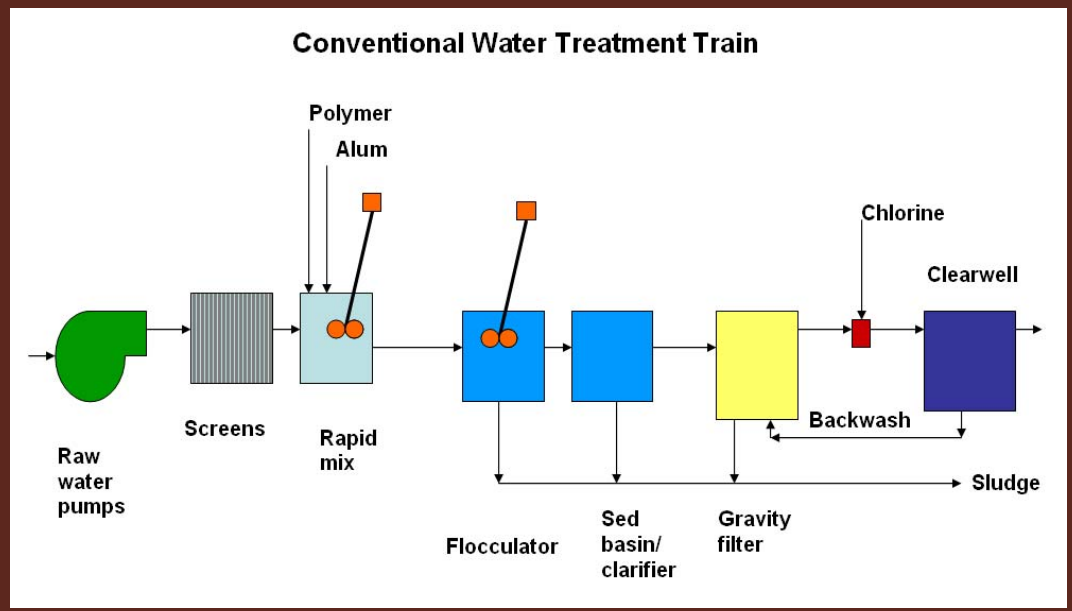
Chloramines- Dunville


UV- Pasadena

MIOX- Heart's Delight-Islington

# Corrective Measures- Treatment- Water Treatment Plants

- Removal of DBP precursors provides the best assurance that DBPs will not form
- A WTP will not reduce DBPs if not designed to remove DBP precursors (NOM) or if the treatment system has not been sized adequately



# Corrective Measures- Treatment- Water Treatment Plants

| **Heart's Delight-Islington** | **Conne River** | **Gander** | **Grand Falls-Windsor** | **Pasadena** |
|---|---|---|---|---|
| pH adjustment | Dual media pre-filters | Pre-filters | Prescreening | Pre-filters |
| Coagulation/ Flocculation | Micro-filtration | Ozonation | Coagulation/ Flocculation | Tread filter |
| Sedimentation | Ultra-filtration | Rapid sand dual media filtration | Sedimentation | UV |
| Filtration | Sodium carbonate addition | Carbon filtration | Rapid sand dual media filters | Chlorination |
| Chlorination | Chlorination | pH adjustment | pH adjustment | |
| | | Chlorination/ Chloramination | Chlorination | |

# Corrective Measures- Treatment- Water Treatment Plants

| **Deer Lake** | **Channel-Port au Basques** | **Happy Valley-Goose Bay** | **Lourdes** | **Ramea** |
|---|---|---|---|---|
| Pre-filters | Prescreening | Permanganate, Alum, Cl Addition | Primary multi-media filtration | Prescreening |
| Thread filter | Coagulation/ Flocculation | Green Sand Filtration | Permanganate Addition | Pre-chlorination |
| UV | Sedimentation | Sedimentation (backwash) | Multi-media filtration | pH adjustment |
| Chlorination | Dual media filtration | Post-Chlorination | Chlorination | Coagulation/ Flocculation |
| | pH adjustment | | | Sedimentation |
| | Chlorination | | | Dual media filtration |
| | | | | Post-chlorination |

# Corrective Measures- Treatment- Filtration

- Types:
  - Granular- sand, gravel
  - Chemical- GAC, greensand
  - Weave-wire screens
  - Polymer membranes with very small pore sizes
- Communities with pre-filters (50-100 µm):
  - Buchans, Embree, Steady Brook, Isle aux Mort, Lewisporte, Port Anson, Seal Cove
- Pre-filtration units alone do not affect THM levels

| Filter Type | Pore Size |
|---|---|
| Screen filters | >10 µm |
| Thread filters | >3 µm |
| Micro-filtration | 0.1-10 µm |
| Ultra-filtration | 0.001-0.1 µm |
| Nano-filtration | 0.0001-0.001 µm |
| Reverse osmosis | <0.0001 µm |

# Corrective Measures- Treatment- pH Adjustment and Iron/Manganese Removal

- THMs increase with increasing pH
- HAAs increase with decreasing pH
- NL surface waters naturally low in pH
- pH adjustment has had little discernable impact on THMs, could have more effect on HAAs
- pH adjustment should always take place post-chlorination
- Fe/Mn common in both surface and groundwater in NL
- Can be responsible for a large portion of chlorine demand
- Removal of Fe/Mn can reduce overall chlorine demand, reduce chlorine dosage required, and potentially reduce DBP levels
  - Long Harbour- THMs reduced by 43%

# Corrective Measures- Treatment- Advanced Treatment

- Removal of NOM
  - Enhanced coagulation (EC)
  - Granular activated carbon (GAC) filters
  - Reverse osmosis or nanofiltration
  - Peroxide addition- to oxidize difficult to treat organics
- Removal of total dissolved solids
  - Reverse osmosis or nano-filtration
  - Electro-dialysis reversal (EDR)
  - Ion exchange (IX)
- MIEX® resin process
- Ceramic membranes
- Ozone and bio-filtration combined
- Filtration using iron-oxide coated media
- Adsorption filters
- Distillation

# Corrective Measures- Treatment- Potable Water Dispensing Units (PWDUs)

- A PWDU is a small scale water treatment system that treats only a fraction of total water demand on a distribution system
- Intended to treat only drinking water portion of total water demand- 5 Liters/person/day
- Water is stored on site at some centralized location for manual collection by users


# Corrective Measures- Point of Use/ Point of Entry Treatment

- Must be ANSI/NSF certified for removal of contaminants of concern
- Consumer is responsible for maintaining the system
- For very small communities that cannot afford any water treatment
- As an interim solution while a more permanent solution is being put in place
- Where DBPs may be high for only limited periods during the year
- For houses located on parts of the distribution system that have extremely high residence times and known DBPs problems

# Corrective Measures- Other

- Improved design of water distribution systems
  - Modeling
- Operator education and training and certification
  - 221 operators in 117 towns or band councils have at least Class I certification for either Water Distribution or Water Treatment
  - Trained operators an essential component of any DBP control methodology
  - Communities should require that their water system operators be certified
- Combination of corrective measures


Atlantic Canada Water And Wastewater
Voluntary Certification Program

*Certificate of Qualification*

THIS IS TO CERTIFY THAT John Q. Operator

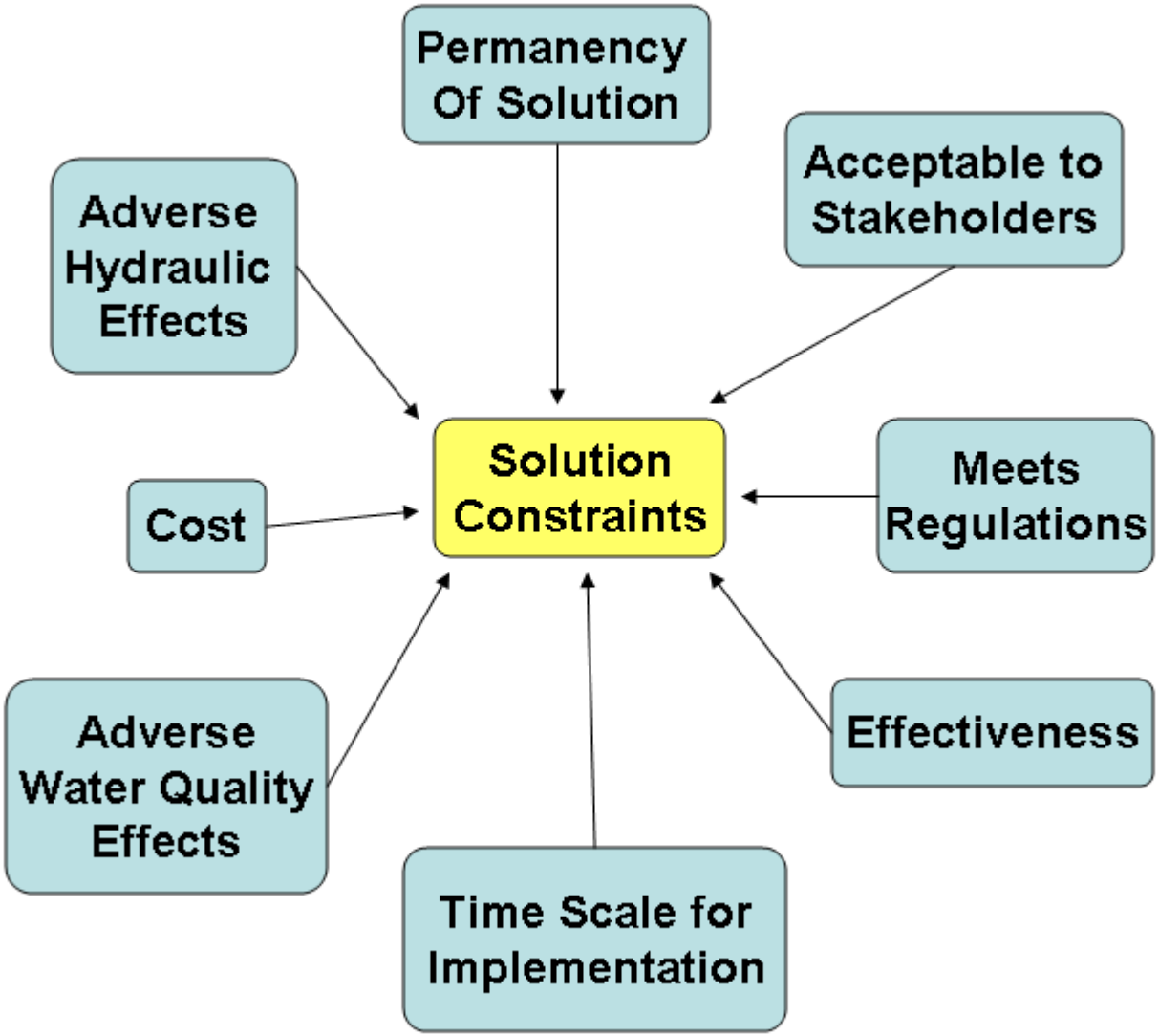
HAS QUALIFIED AS A CLASS II Water Distribution System Operator

IN ACCORDANCE WITH THE GUIDELINES ESTABLISHED BY THE
ATLANTIC CANADA WATER AND WASTEWATER VOLUNTARY CERTIFICATION PROGRAM
IN CO-OPERATION WITH THE ASSOCIATION OF BOARDS OF CERTIFICATION FOR
OPERATING PERSONNEL

DATED AT Corner Brook, NL THIS 8th DAY OF April 20 08

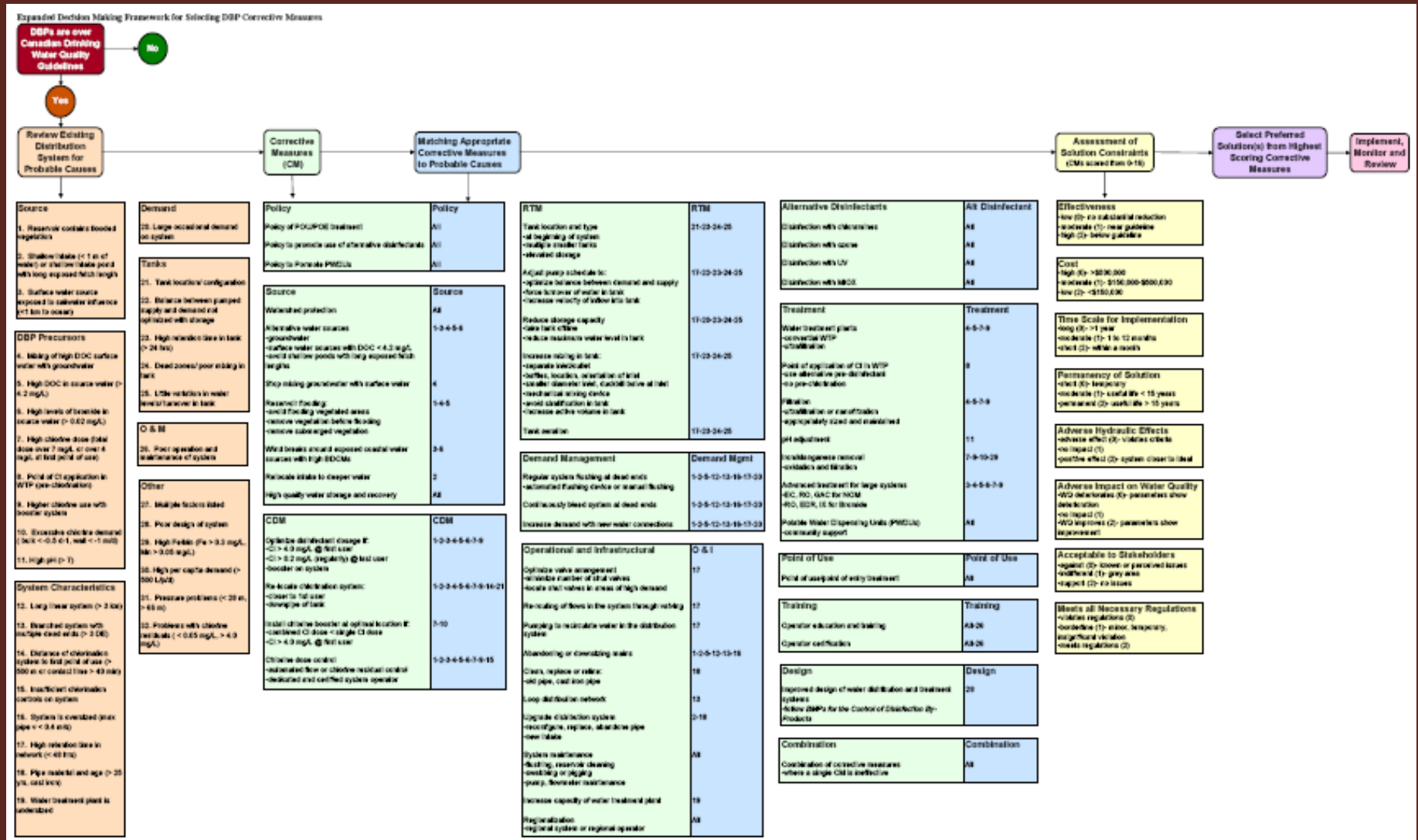
OPERATOR ID NO: 10000 CERTIFICATE NO: NL08-1000U

# Solution Constraints




- To better match corrective measures with the needs of the community

# Integrated Decision Making Framework for Selecting DBP Corrective Measures



# Decision Making Framework and BMPs

- Developed as an iterative process
- Developed based on:
  - known DBP formation behaviour and best management practices used to deal with DBPs in other jurisdictions
  - assessment of DBP characteristics and response to existing corrective measures in NL
  - modeling of water distribution systems with DBP problems in NL

# Three Main Products from BMPs for DBPs Report

1. Best Management Practices for the Control of Disinfection By-Products
2. Decision Making Framework for the Selection of DBP Corrective Measures
3. Checklist of Community Information for DBP Management

- Audience: Government, Towns, Consultants
- Available on Water Resources web site soon

# Key Messages

- The majority of communities with DBP issues are very small and small towns in rural NL
- There is a risk trade-off with water disinfection between microbial pathogens and disinfection by-products
- Corrective measures to address DBP issues must not fix one problem only to create a dozen more
- There is no standard solution that will address the issue of high DBP levels in drinking water for all communities
- Every distribution system is unique and responds differently to different possible corrective measures

# Thank You