Ammonia Criteria Study

Outline

- Background
- History of Ammonia Regulation
- Existing Conditions
- Local Toxicity Testing
- Potential Site-Specific Criteria
- Ammonia Reduction
- Application of Ammonia Criteria
- Potential Ammonia Reduction Strategy

Background

- In 1992, the Clean Environment Commission (CEC) recommended to the Minister of Environment that site-specific studies be undertaken to:
  - Determine both acute and chronic effects of ammonia from wastewater from Water Pollution Control Centre (WPCC) effluents on aquatic life
  - Identify the program to deal with ammonia in wastewater from the WPCC effluents

Background..

- Scientific studies and Engineering studies were conducted by the City of Winnipeg:

Scientific Studies:

– Examined criteria for ammonia to protect aquatic life in Red and Assiniboine Rivers

Engineering Studies:

– Investigated the means and the costs for reducing ammonia in the effluents of the three Water Pollution Control Centres (WPCCs) in Winnipeg

Purpose of Studies

- **Intended to develop scientific information to allow *establishment of locally suitable ammonia control* objectives**

Ammonia Study Team

Tetr*ES* Consultants Inc.

- G. Rempel, M.Sc., P. Eng. - Project Manager
- D. Morgan, Ph.D., P. Eng. -Assistant Project Manager/River Conditions
- J. McKernan, M.Sc. –Toxicity & Resource Harvesting Manager

North South Consultants Inc.

- S. Davies, B.Sc. -Fish Population & Habitat Manager
- M. Lawrence, B.Sc. –Fish Behaviour Manager

Specialists

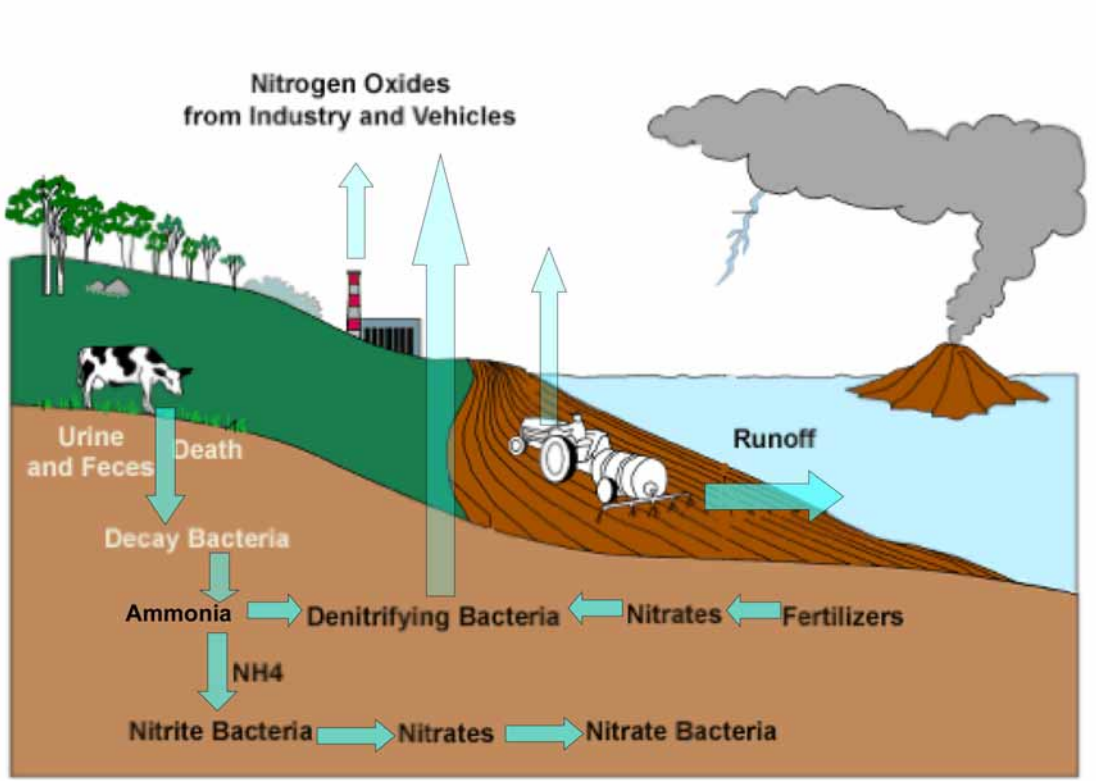
- G. Craig, M.Sc. –Toxicity Special Advisor
- Michael Salazar, M.Sc.- In Situ Mussel Testing

Nitrification Study

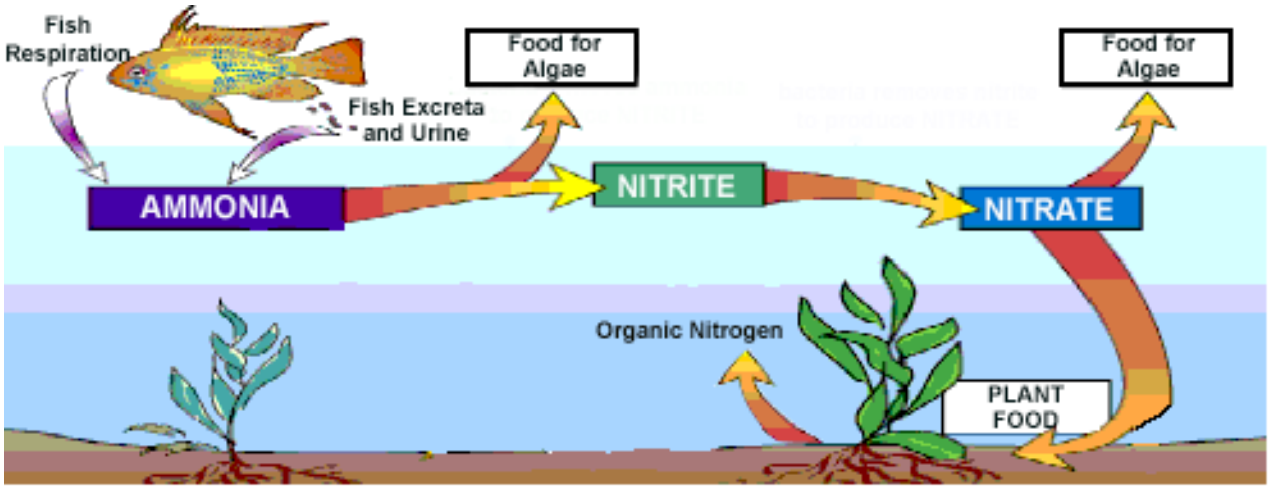
- D. Taniguchi, P.Eng. – Project Manager, EarthTech Canada
- Kim Fries, P.Eng. – Process Engineering, EarthTech Canada
- Albert Li, P.Eng. - Costs, EarthTech Canada
- W. Wilson, P. Eng. - EarthTech Canada

The Nitrogen Cycle

- Human and animal waste contain organic nitrogen and urea
- These materials break down through a natural process known as the nitrogen cycle
- Ammonia is a by-product of this natural cycle



The Ammonia Issue



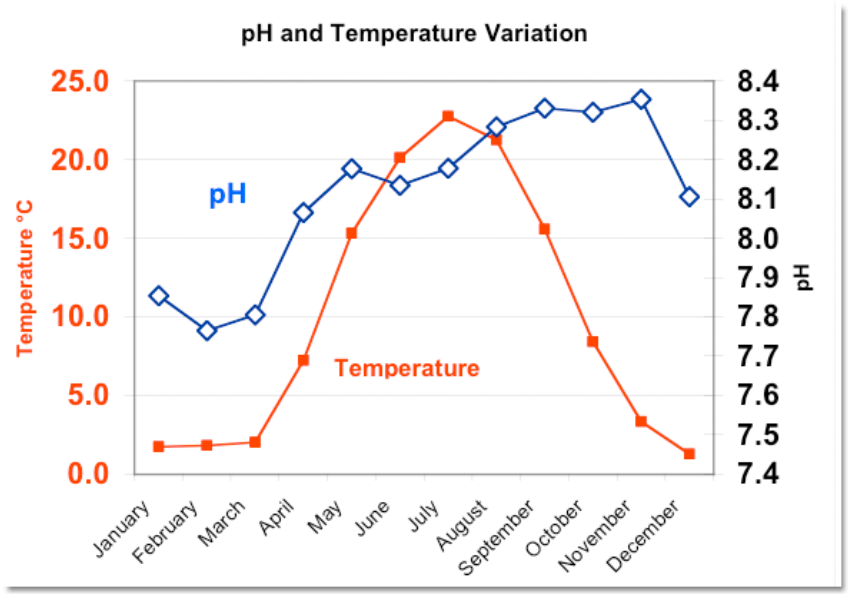
- Ammonia is a component of the nitrogen cycle
- At low levels, ammonia is not toxic to aquatic life and is an integral component of the natural nitrogen cycle
- When present in high concentrations in effluent discharges, ammonia can stress aquatic life in Rivers (chronic effect)
- If ammonia is present in very high concentrations, acute effects - fish kills can occur.

Ammonia Issue in Red and Assiniboine Rivers

- Concern with respect to ammonia relates primarily to potential chronic effects. Examples:
  - Reduction in growth rate of fish
  - Tissue damage
  - Reproductive effects
- Ammonia has no effect on safety of eating fish

Ammonia Exists in Different Forms

- Toxicity of ammonia to aquatic life is mainly attributed to the un-ionized form of ammonia
- Un-ionized ammonia concentrations vary with river temperature and pH
- River water temperature and pH vary with season
- Higher pH & temperature mean more un-ionized ammonia, more concern



Many Sources of Ammonia

- Agricultural Runoff
- Municipal Runoff
- Winnipeg's three WPCCs.
  - All 3 WPCCs use conventional secondary treatment
  - Limited ammonia removal takes place at SEWPCC & NEWPCC

Agricultural Runoff

North End Water Pollution Control Centre

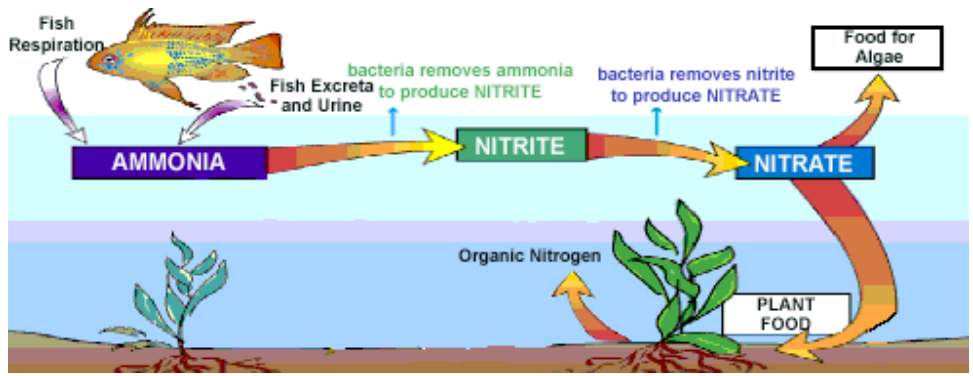
South End Water Pollution Control Centre

West End Water Pollution Control Centre

Ammonia Levels: Existing Conditions

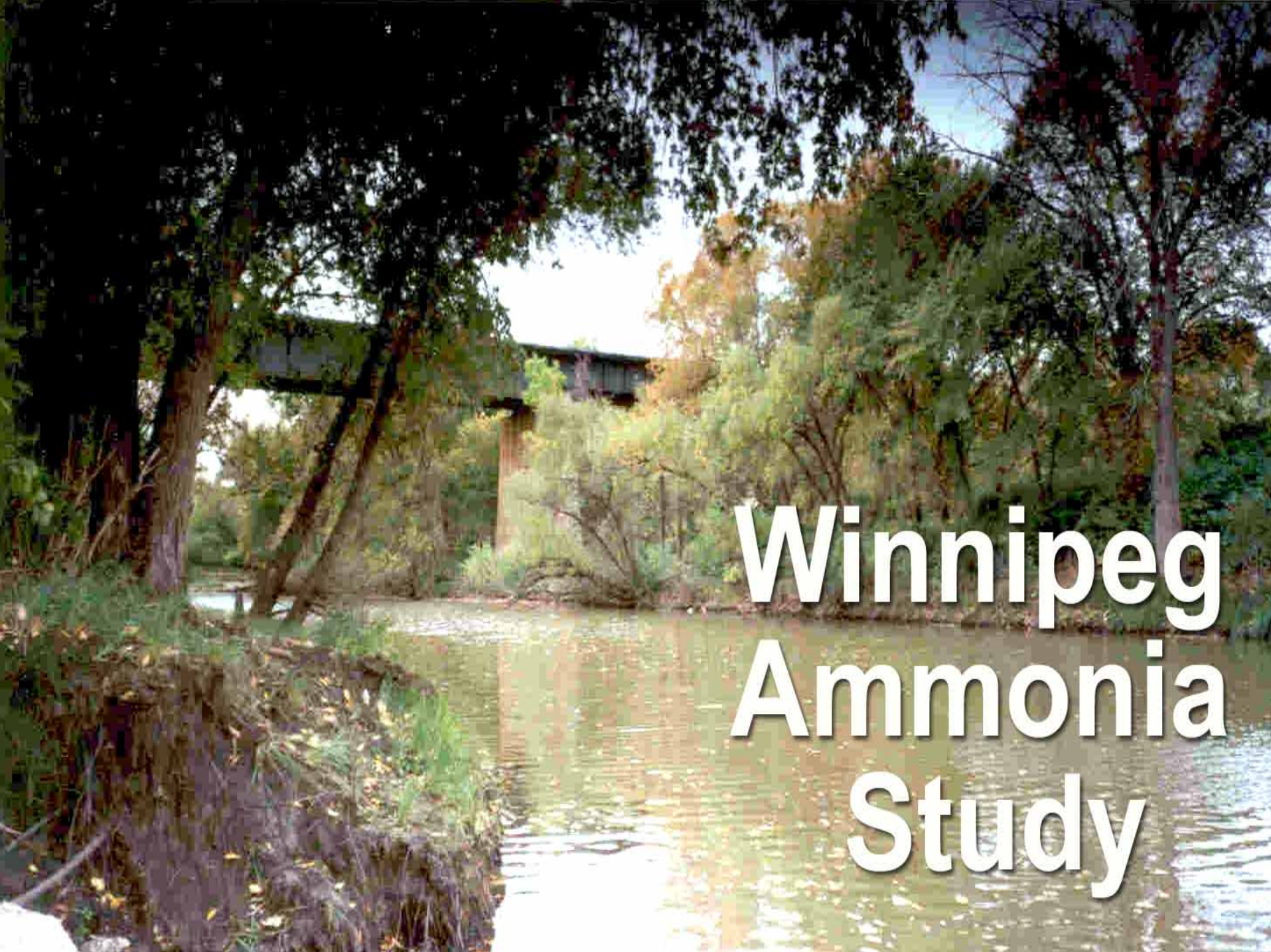
- Due to WPCC effluent discharges, concentrations in the urban reaches of the Rivers occasionally exceed Manitoba Conservation Objectives

- As rivers flow downstream, ammonia levels reduce due to natural conversion processes



Ammonia Levels: Establishing Acceptable Limits

- Scientific rationale for an allowable concentration of ammonia in rivers, that protects aquatic life, has been evolving across North America
- National criteria have been developed including results from tests on fish that do not populate our rivers



Winnipeg Ammonia Study

Ammonia Studies: Winnipeg

- For Winnipeg, the issue is to define appropriate protective criteria for local fish and other organisms in the Red and Assiniboine Rivers.
- Treating ammonia in WPCC effluents is possible
- Ammonia in wastewater can be treated at the WPCCs to a stable form known as nitrate-nitrogen in a biological process called ***Nitrification***, at substantial cost

Main Objectives of Study

- Study the concentrations of ammonia in the Red and Assiniboine Rivers
- Test toxicity of ammonia local aquatic species
- Assess characteristics of the local ecosystem
- Develop alternate site-specific criteria for consideration
- Consider the requirements for additional ammonia reduction at the WPCCs

Consultations with Scientists and Regulators to Date

- Scientific Workshops
  - #1 September 1998
  - #2 February 1999
  - # 3 July 2001
- Individual Scientific Consultations throughout
- Workshop Reports were distributed

List of Scientists Consulted

Provincial

- **A. Derksen –Man. Con.**
- **D. Williamson- Man. Con.**
- **A. Bourne –Man. Con**
- **S. Gurney –Man. Con.**
- **G. Swanson –Man. Cons.**

Federal

- **M. Constable –Env. Canada**
- **F. Gagne –Env. Canada**
- **Uwe Borgman NWRI (Env. Canada)**
- **D. Bodaly -DFO**
- **R. Hesslein -DFO**
- **B. Franzin -DFO**
- **M. Stainton -DFO**
- **B. Scaife –DFO**
- **K. Fisher -DFO**
- **D. Malley –DFO (ret)**
- **L. Lockhart –DFO (ret)**

Academia

- **K. Stewart –U of M**
- **G. Robinson –U of M**
- **L. Graham –U of M**
- **E. Watson –U of M**
- **A. Burton –Wright State U.**

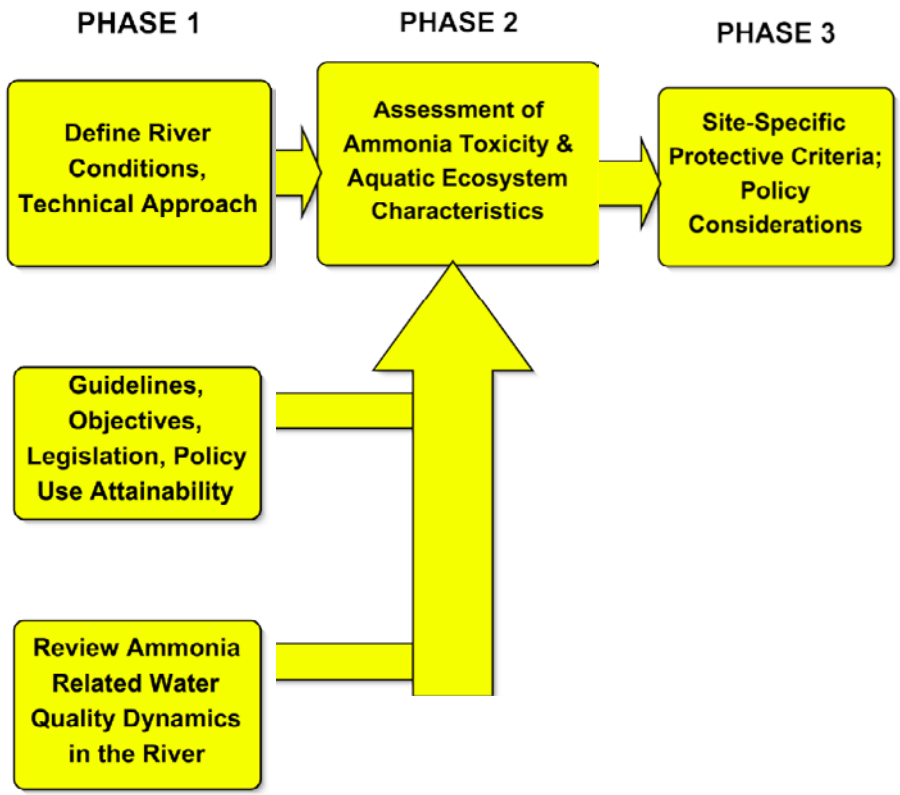
Consultants

- **J. Diamond – Tetra Tech**
- **K. Scheifer -BEAK**
- **Mike & Sandra Salazar-Applied Biomonitoring**
- **EnviroAquatic – (Toxicity Lab)**
- **L. Noval- ESG International**
- **John Monroe – John Monroe & Associates**

3 Main Phases

- **The ammonia study was conducted in three main phases:**

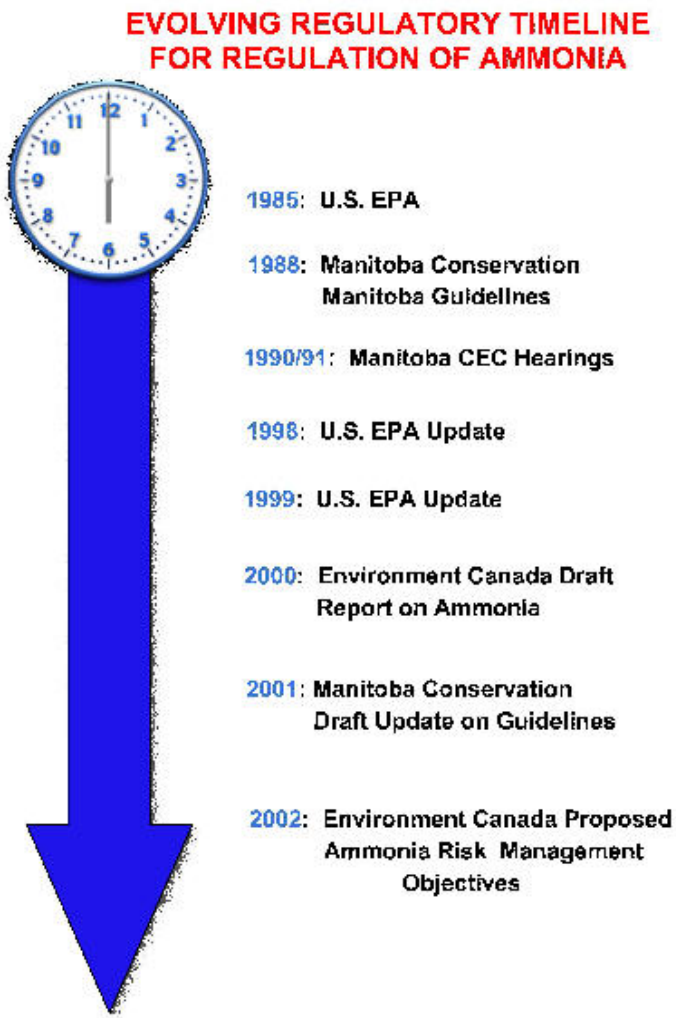
1. Discussion of issues, identifying scope of work, workplan development
2. Integration and execution of scientific and technical activities within workplan
3. Identification of alternative protective criteria for review with Manitoba Conservation



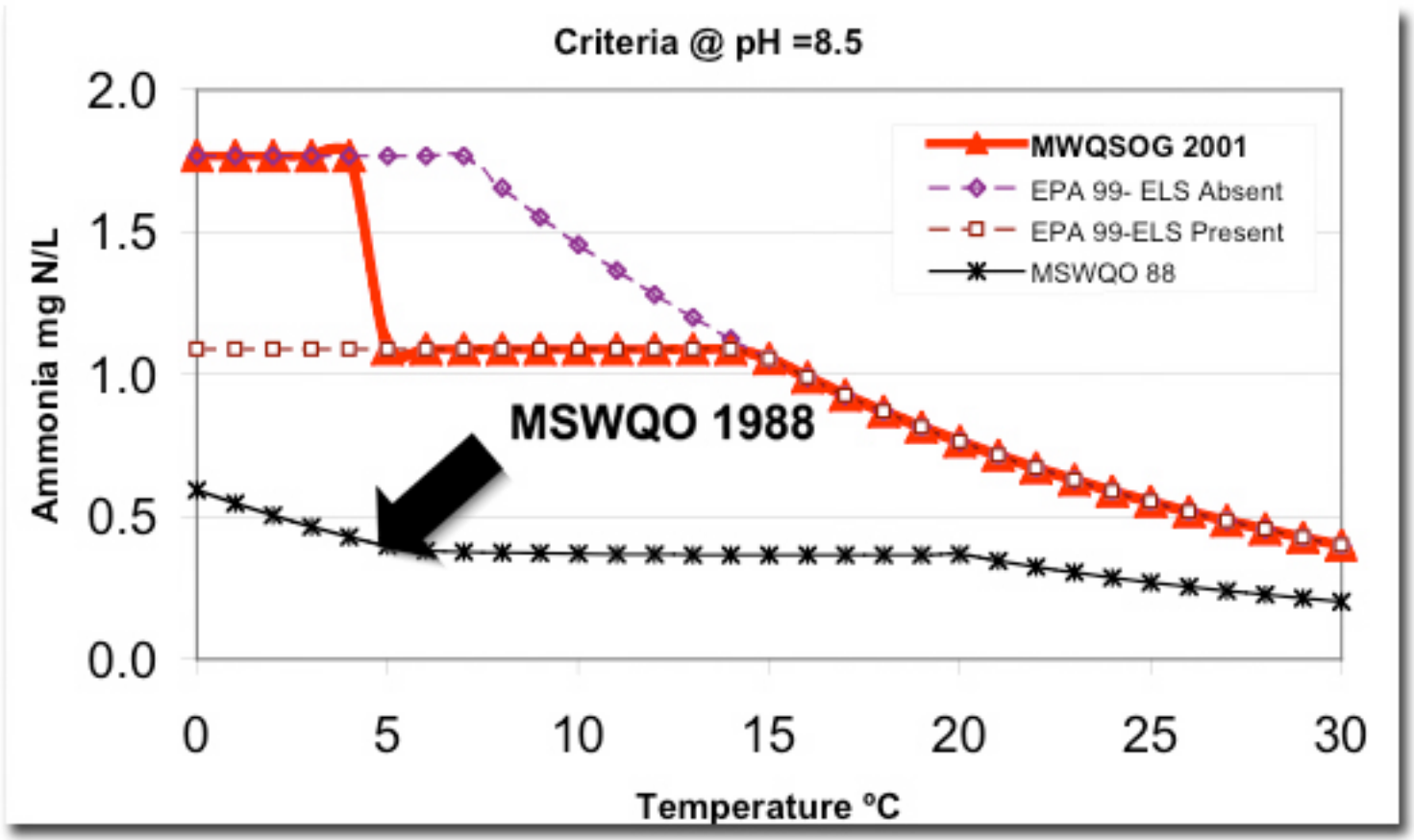
History of Ammonia Regulation

History of Ammonia Regulation

- Regulation of ammonia in the USA and Canada has been complex and ***evolving***
- US Environmental Protection Agency (EPA) lead first research
  - proposed national criteria in 1985, updated using new info 1998, 1999
- Environment Canada
  - 2000 Draft Report
  - 2002 Proposed Objectives
- Manitoba Conservation
  - 1988 Guidelines
  - CEC Hearings
  - Draft Update on Guidelines
  - 2002 MWQSOG Final Draft



Protective Criteria are Evolving



Comparison of Manitoba 2001, EPA 1999 and Manitoba 1988 Chronic Ammonia Criteria

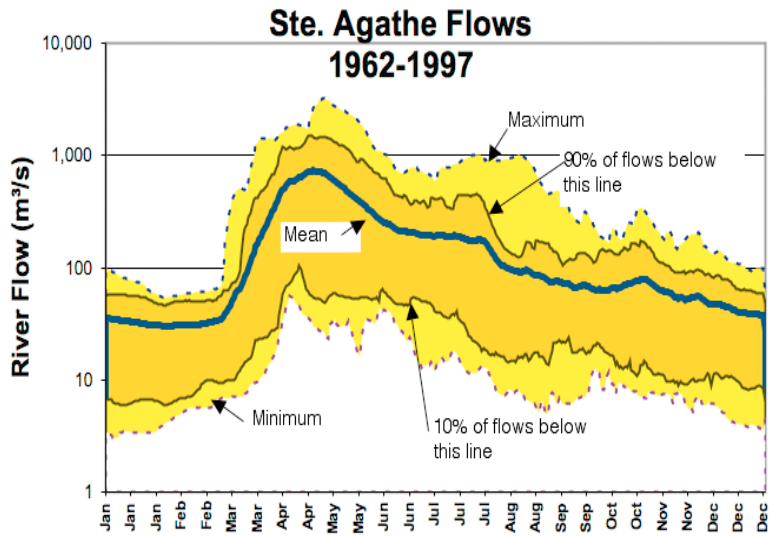

Existing
Conditions

Existing Conditions

- Impacts of ammonia to aquatic species are dependent upon:
  - Loadings
  - River flow
  - Receiving water's pH and temperature
- Ammonia is of greatest concern when river flows are low and pH and temperature are high
  - Creates highest concentration of most toxic form of ammonia, un-ionized ammonia
  - Typically late summer/early fall

River Flows Affect Ammonia Concentration

- Red and Assiniboine Rivers experience wide variations in flows
  - From year to year
  - Seasonally
- Variation in flow can have major influence on ammonia concentration in the Rivers

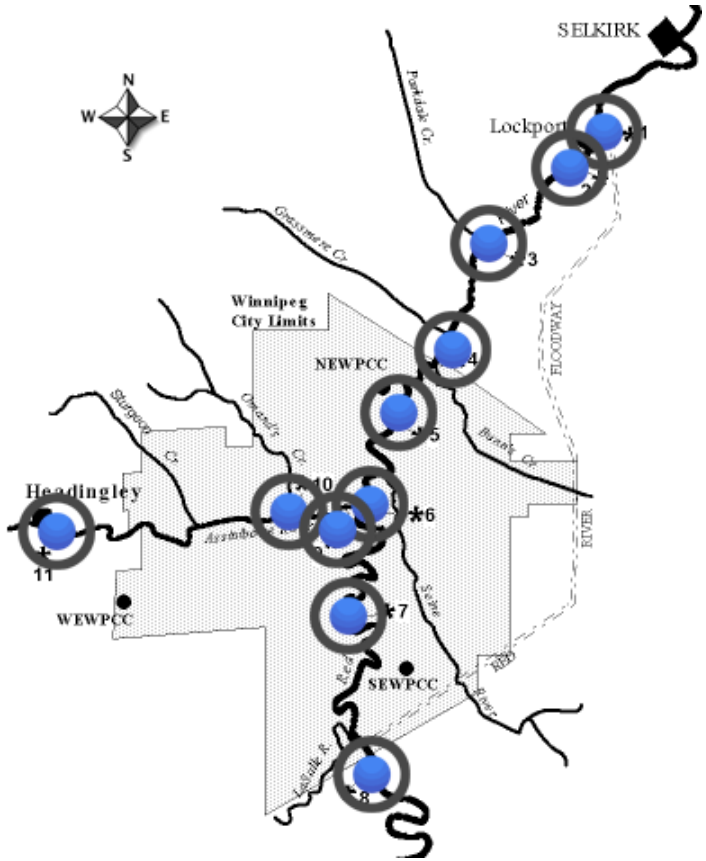


Various Sources of Ammonia

- Ammonia exists in Rivers upstream of Winnipeg boundaries
  - Due to agricultural runoff and other point sources
- Within Winnipeg, Wastewater effluent is discharged to the Rivers from 3 WPCCs
  - Secondary treatment at WPCCs results in limited removal of ammonia
  - At WEWPCC, a polishing ponds step offers significant reduction of ammonia in summer months

Assessing Ammonia Under Varying Conditions

- Assessing conditions:
  - River Design Flows were calculated and models were used
    - Estimated ammonia concentrations in the river under low flows and current WPCC treatment.
    - Models calibrated using 20 years of water quality data from bi-weekly sampling at 11 sampling stations

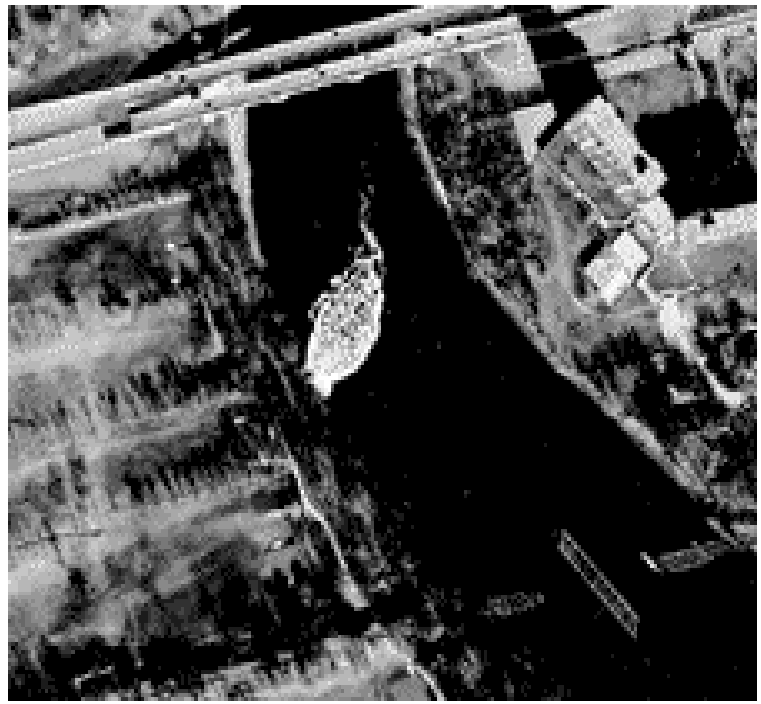


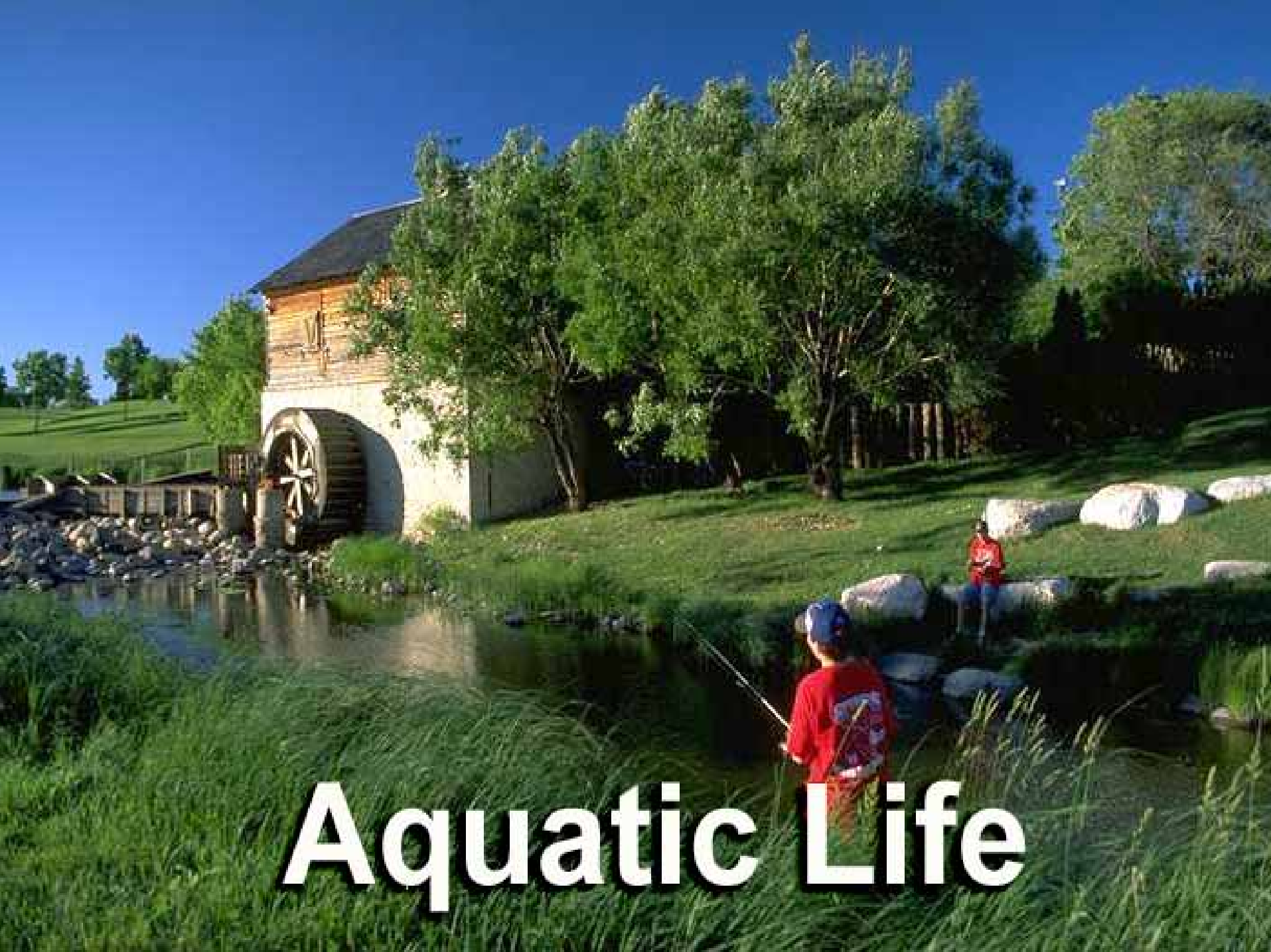
Role of Algae

- Role of algae in the Rivers
  - active in maintaining dissolved oxygen levels
  - Can cause increase in pH levels
- Non-point loadings to Rivers upstream of City stimulate algae growth
  - Growth creates higher pH
  - Higher pH causes more un-ionized ammonia, creating fish toxicity concerns

WPCC Effluent Plumes

- Mixing Zone Analysis and fish behaviour studies were conducted:
  - There is no apparent barrier effect presented by WPCC discharge plumes
  - Fish are not impeded by the plumes
  - Full river mixing occurs during low flow on the Red River
  - Dilution of at least 5 times occurs quickly at all flows, thus quickly reducing ammonia concentrations




Aquatic Life

Diverse Fish Population

- The Red and Assiniboine Rivers support a rich and diverse collection of aquatic species
  - About 35 species of fish captured from the Rivers in the studies
  - Studies examined fish movement in and out of the study area

Fish Species List

Bigmouth buffalo
Black bullhead
Black crappie
Brook stickleback
Brown bullhead
Burbot
Carp
Channel catfish
Emerald shiner
Fathead minnow
Flathead chub
Freshwater drum
Golden redhorse
Goldeye
Johnny Darter
Lake cisco
Mooneye
Northern pike
Quillback
Rock bass
River darter
River shiner
Sauger
Shorthead redhorse
Silver chub
Silver redhorse
Spotfin shiner
Spottail shiner
Stonecat
Tadpole madtom
Trout perch
Walleye
White bass
White sucker
Yellow perch

Fish Movement

- Fish movement studies showed:
  - Fish traveled significant distances in the study area
  - While plumes from WPCCs do not appear to affect fish movements, *some* fish displayed attraction to areas influenced by the plume
    - Northern Pike attracted to the vicinity of the NEWPCC plume during winter
    - Carp attracted to WEWPCC in the fall

Fish Behaviour

- **Fish behaviour was monitored using acoustic tags**
  - Fish were able to pass through NEWPCC area
  - Plumes did not pose barriers to fish movement
  - Tagged fish in general were highly mobile
  - Fish may move in and out of study area on a seasonal basis
  - Exposure of fish to wastewater effluents is generally intermittent

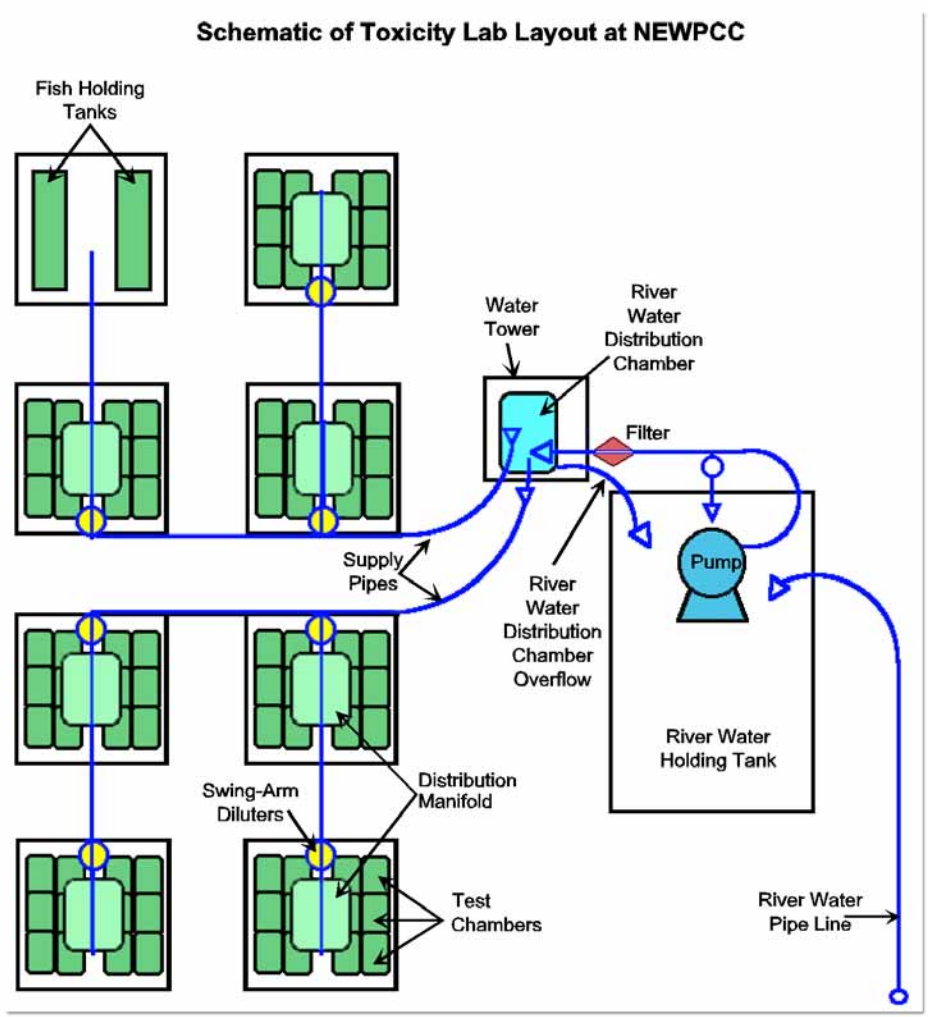

photo: In Fisherman Magazine, Brainerd MN
Local Toxicity Testing

Toxicity Testing

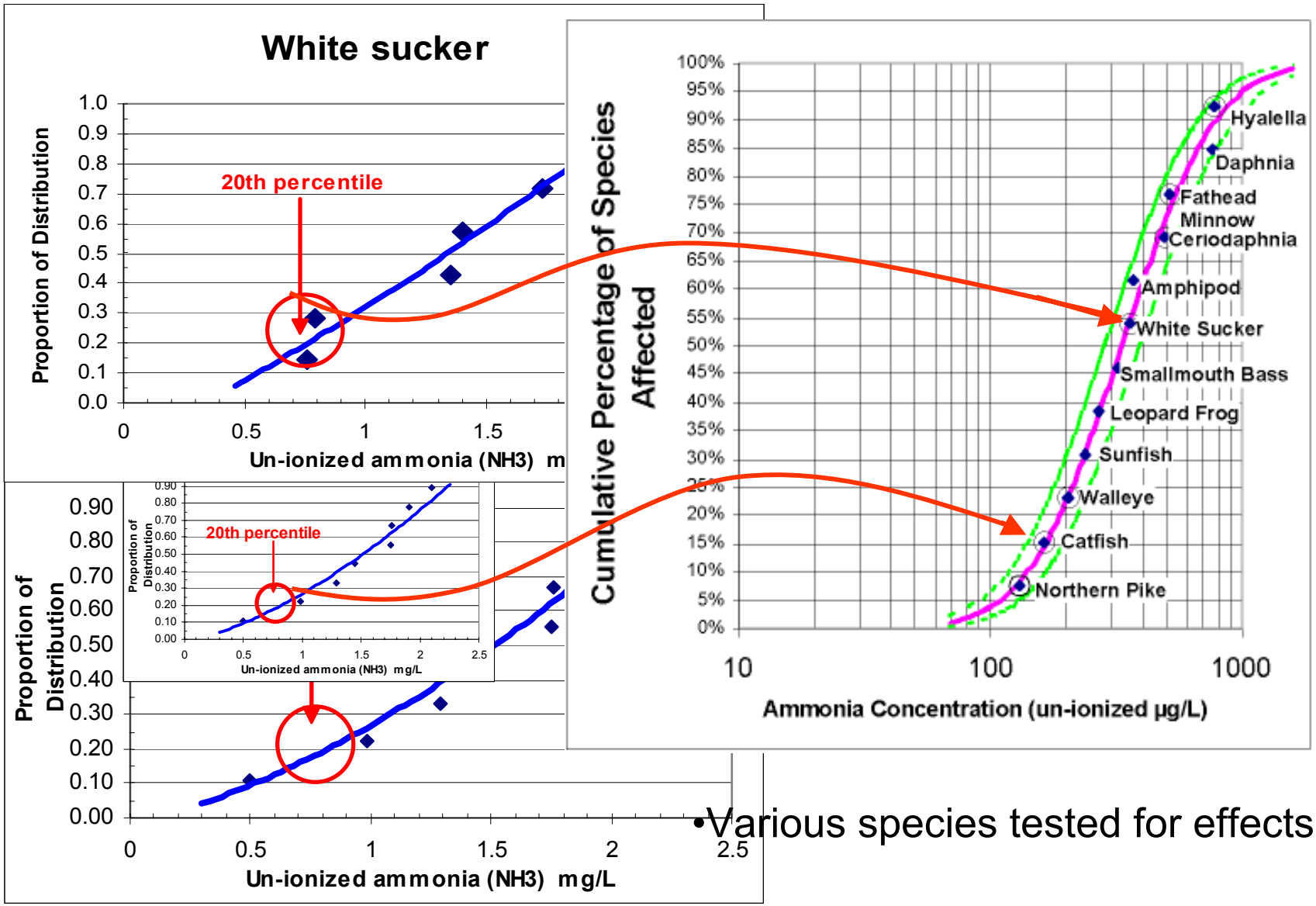
- A key component of the studies was a testing program to establish chronic toxicity of ammonia in representative local species
  - Newly hatched fry which are very sensitive to stress

What did we do?

- River water pumped to laboratory
- Mixed with ammonia to provide a range of concentrations of ammonia to test fish
- Range of local fish species tested
- Fish collected and tested were in an Early Life Stage
  - These protocols allow us to determine the lowest ammonia concentration which may cause limits to growth of adult fish
  - Also ran control (zero ammonia) tanks



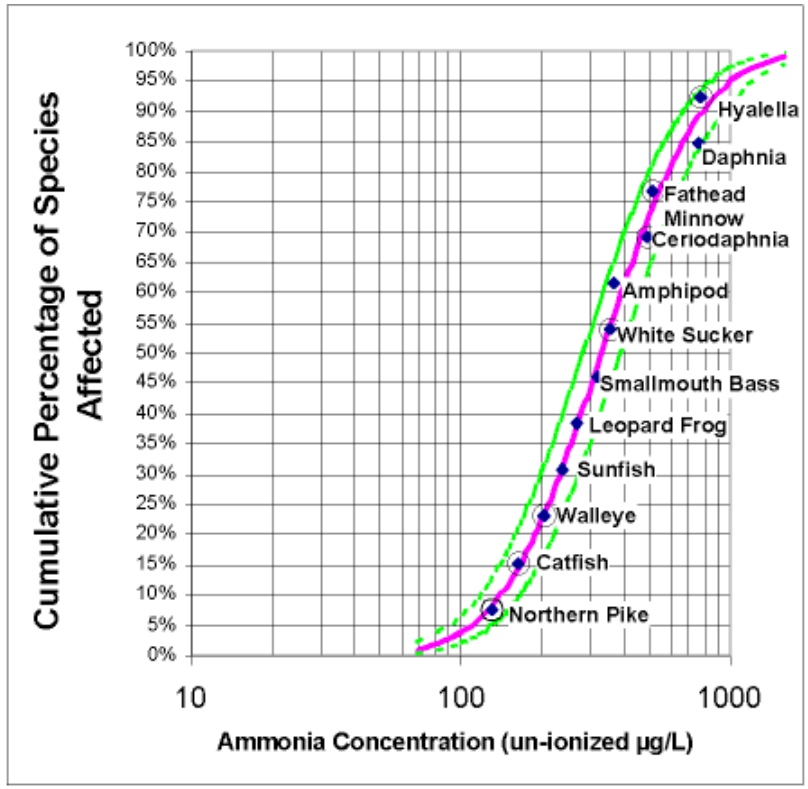
Toxicity Testing EC20



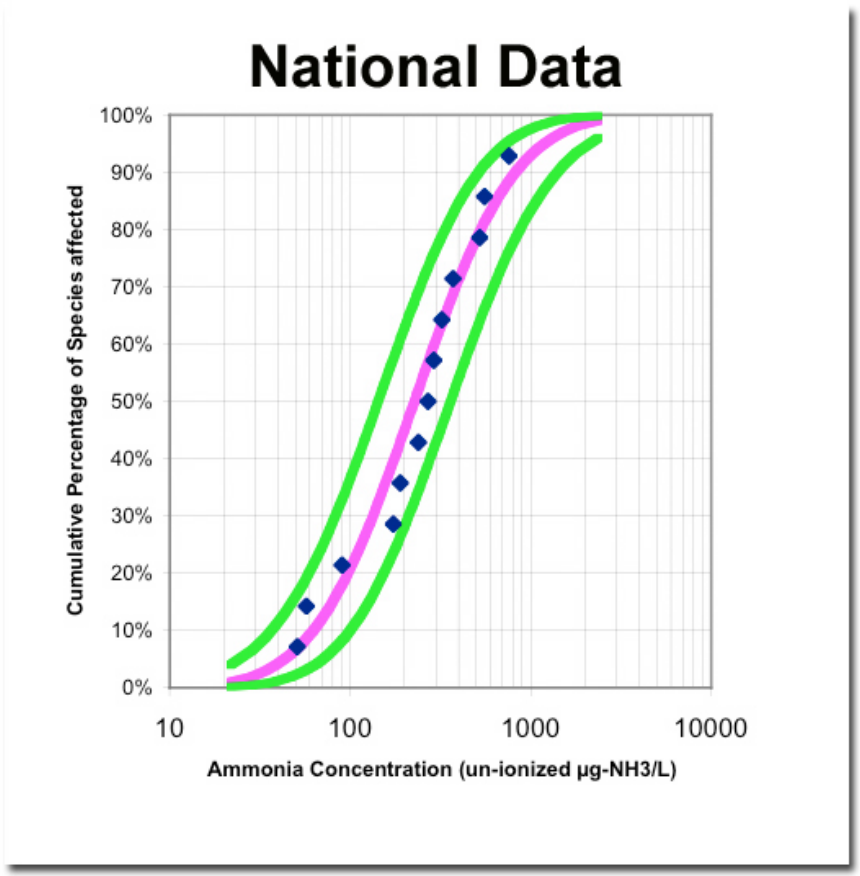
- Various species tested for effects

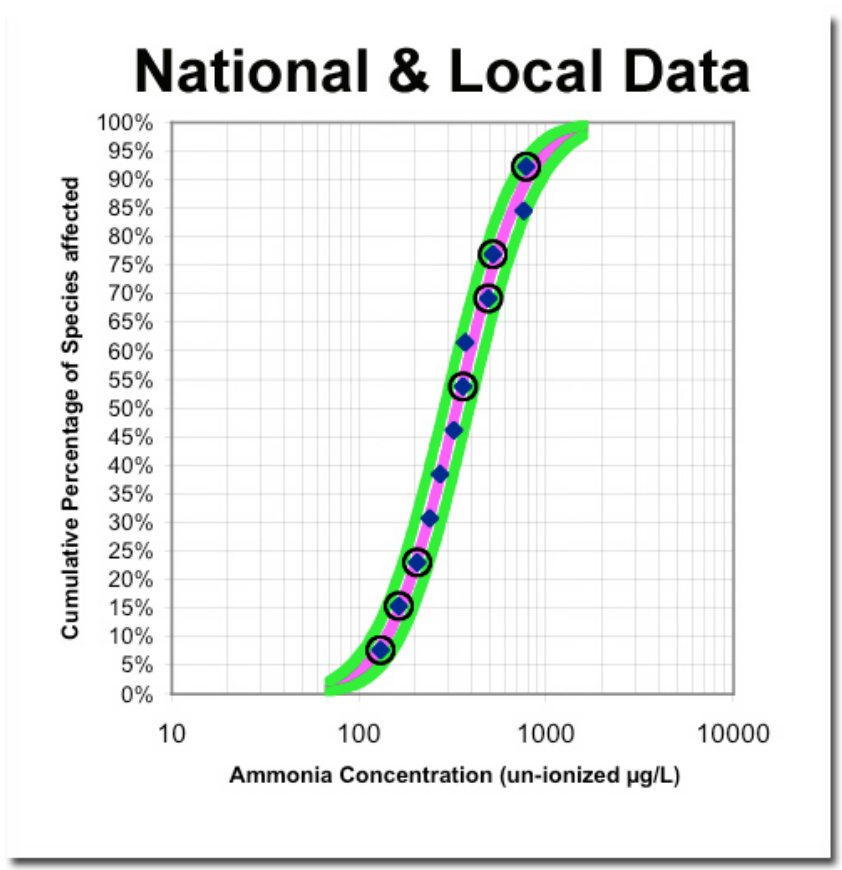
Toxicity Testing

- **26 ammonia toxicity tests conducted:**
  - **Using 11 different local species of aquatic life**
    - **7 fish species**
    - **4 invertebrate species**
  - **Results from 7 chronic exposure tests can be used directly in derivation of local chronic criterion for ammonia**
  - **10 acute toxicity tests were done on 3 fish species**



Study Provided Stronger Scientific Base

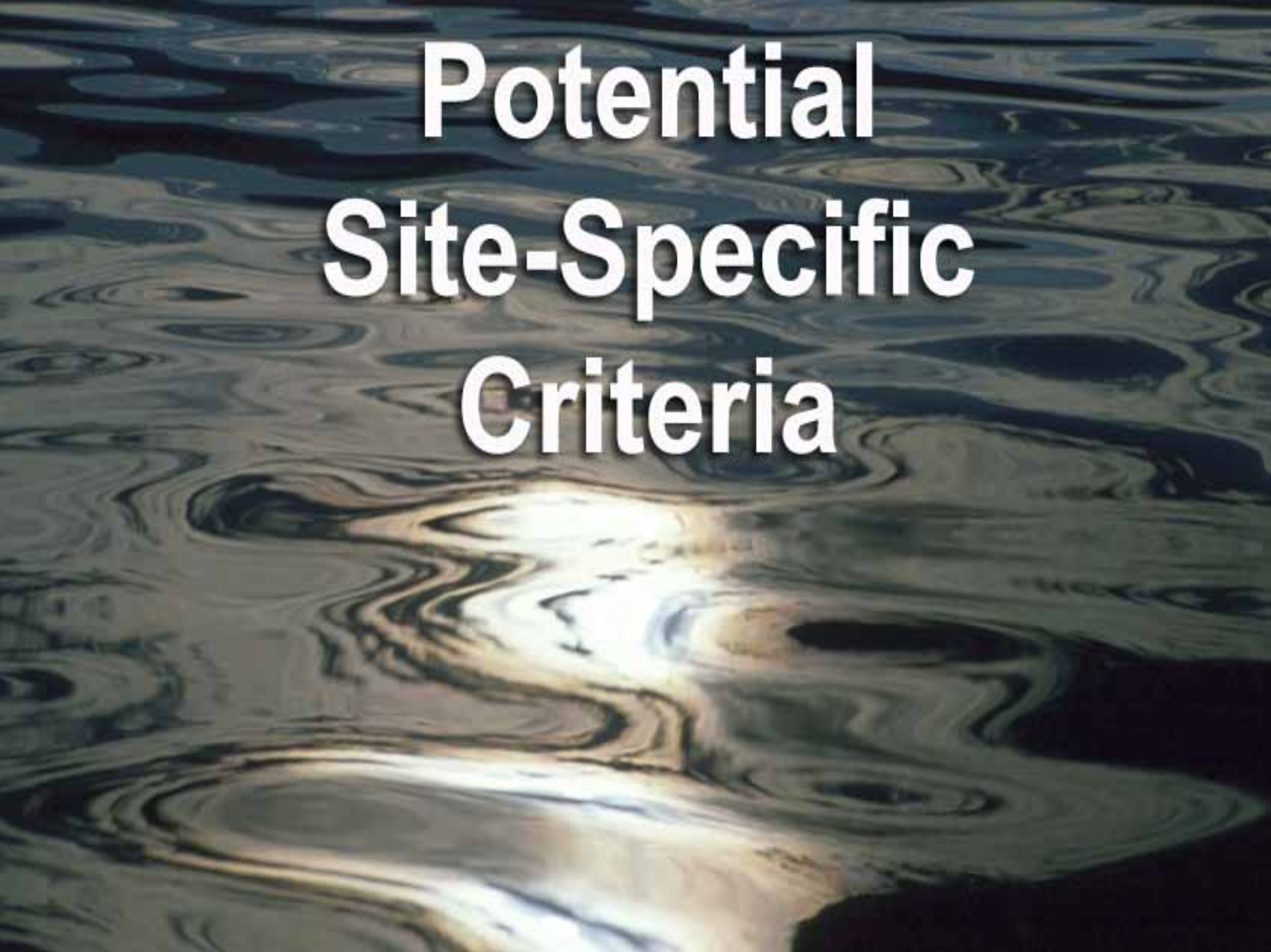




Local Test

Toxicity Testing

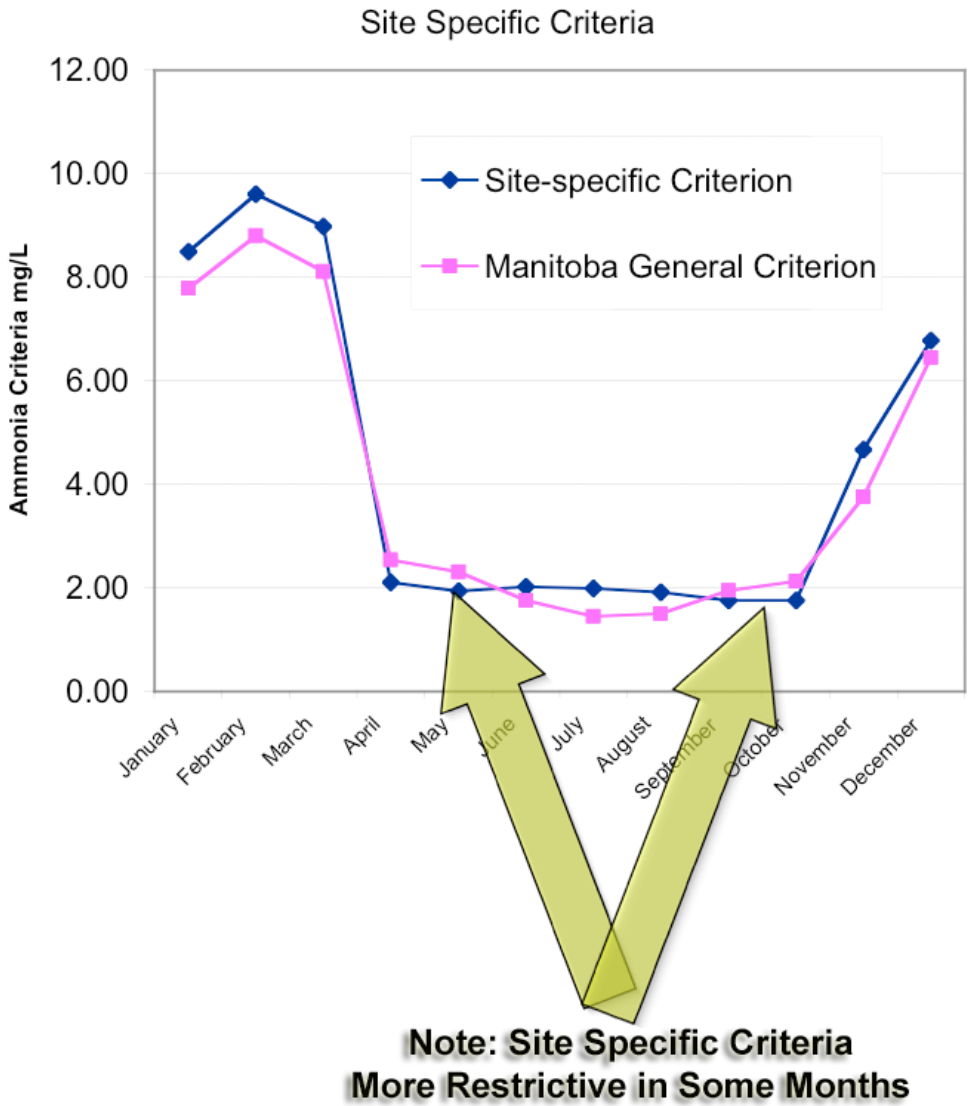
- Integrating local data with existing data significantly improved the scientific foundation to support ammonia regulation for local conditions
- Local scientific review resulted in acceptance of protocols and results
- Recommendation that local results be used in developing site-specific criteria by the Province


Potential
Site-Specific
Criteria

Potential Site-Specific Criteria

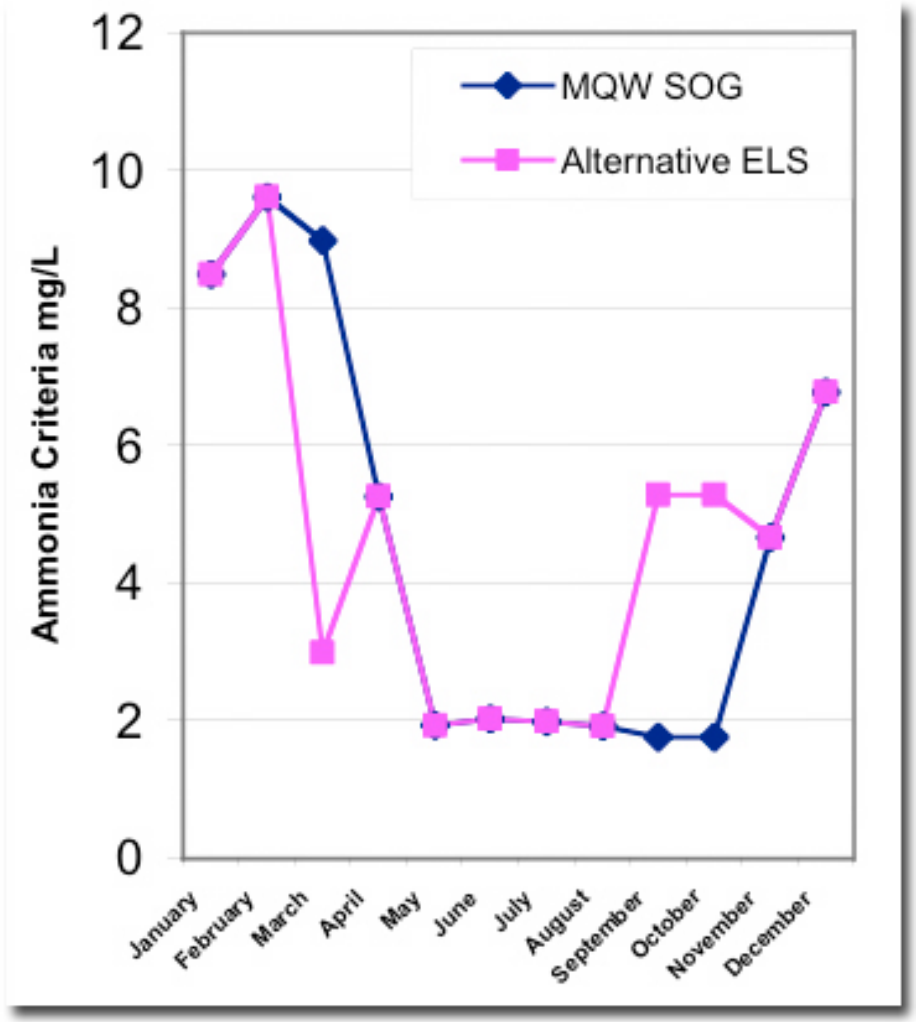
- Protective critieria developed using:
  - relevant public domain data with addition of local test results
  - protocols advocated by EPA (1998/99) and Environment Canada (2000)
  - values derived from a stronger scientific database due to addition of *local* toxicity test results

- Manitoba Conservation used the EPA protocols in the proposed Manitoba Water Quality Guidelines



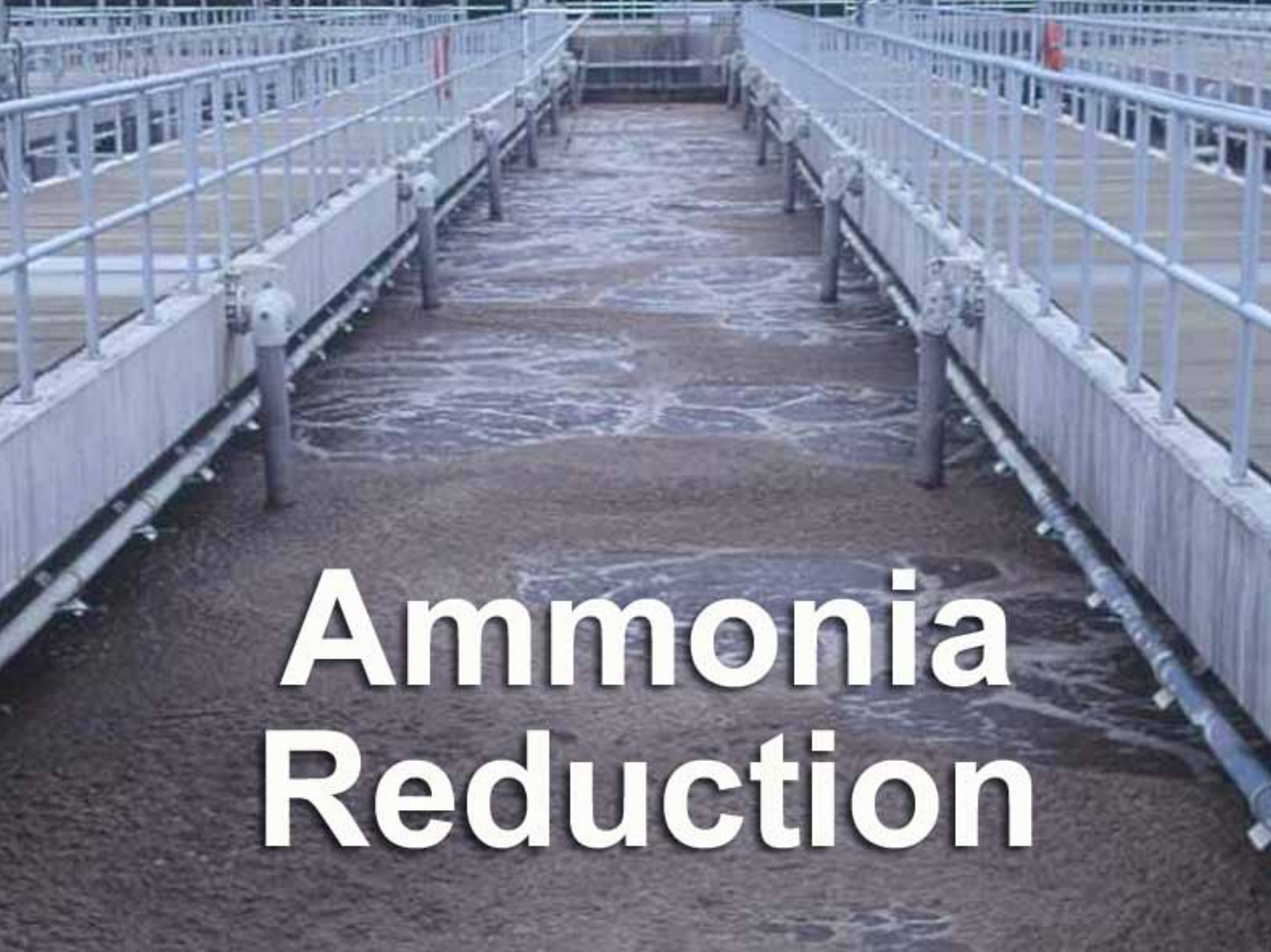
Early Life Stages(ELS)
are more sensitive than other life stages

- When ELS are absent the ammonia criteria is 3x higher than when they are present
- Uncertainty in when ELS occur in spring or fall
- Important to the decision of the level of treatment required



Many Conservative Assumptions in **Development** of Criteria

Conservative assumption	Comment
1.) Fish tested at early life stages	likely 3x more sensitive than juveniles, more when compare to adults
2) Fish and invertebrates tested out of natural environment, (usually in laboratory water) adding additional stress	potential for questionable test to be included in data set, must be cautious
3) Only 20% of test organisms show effects (80% unaffected)	1 in 5 of sensitive individuals from each genus affected
4) Only 5% of species assemblage affected	Only 1 in 20 Species
5) 30 days averaging period assumes fish stationary at position immediately downstream of outfall	fish generally not stationary only spend limited time in once place, unknown safety factor


Ammonia
Reduction

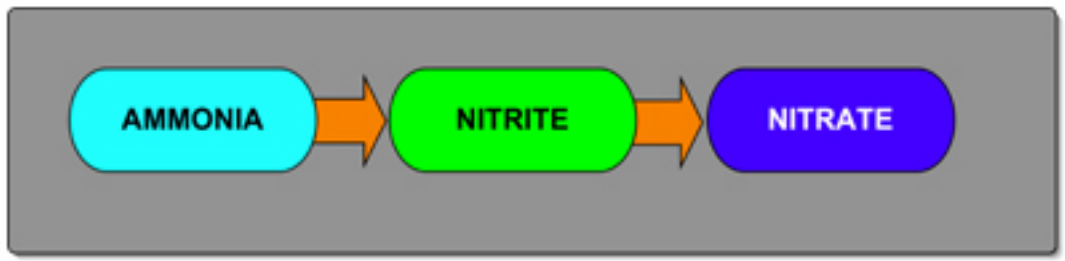
Ammonia Reduction at WPCCs

- Effluent Flows from WPCCs
  - NEWPCC and WEWPCC projected to show little change over the next 40 years
  - SEWPCC flows projected to increase 30% over next 40 years

Ammonia Reduction Process

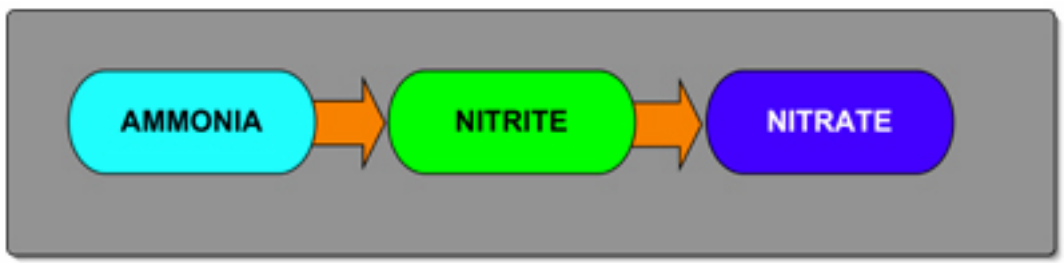
- The process used to remove ammonia is ***nitrification***
  - Converts the ammonia to another form of nitrogen, nitrate, which is not toxic to fish
  - Nitrogen is not removed
  - Similar process also occurs in the river

- The treatment process should convert enough ammonia to reduce the ammonia concentration in the river to non-toxic levels
  - Additional nitrification has little environmental benefit



Ammonia Reduction at WPCCs

- A separate engineering study considered a variety of nitrification options at each of the WPCCs
- Process options were reviewed for ammonia reduction including:
  - Operational improvements
  - A range of added treatment



Costs of Ammonia Reduction

CAPITAL COST ESTIMATES FOR AMMONIA REDUCTION

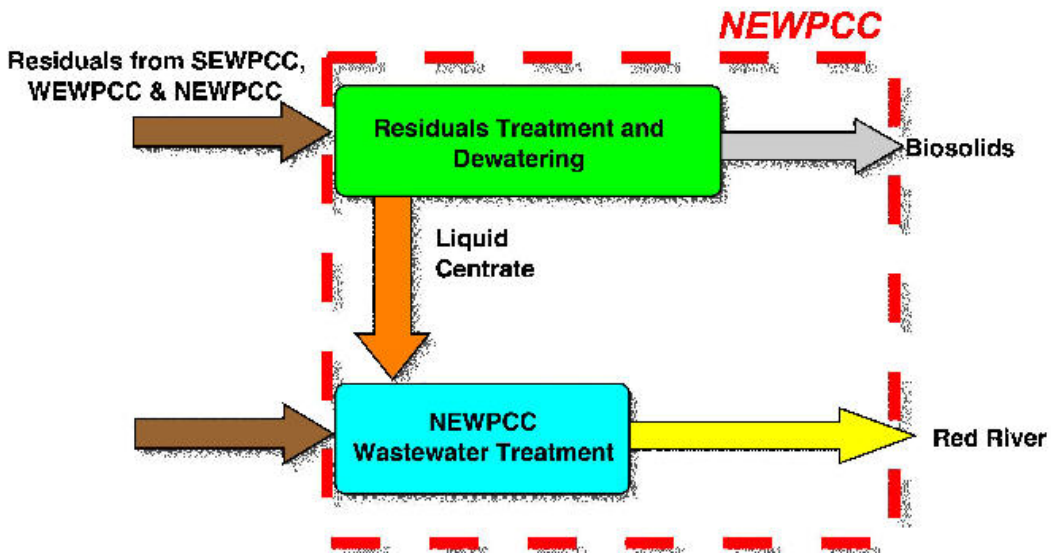
Treatment:	Target NH3 Concentration in Effluent	NEWPCC	SEWPCC	WEWPCC	TOTAL
Best Practicable Level of Control	2	$112	$33	$4	$149
High Level of Control	8	$93	$21	--	$114
Moderate Level of Control	14	$84	$14	--	$98
Centrate Treatment	18	$10	--	--	$10

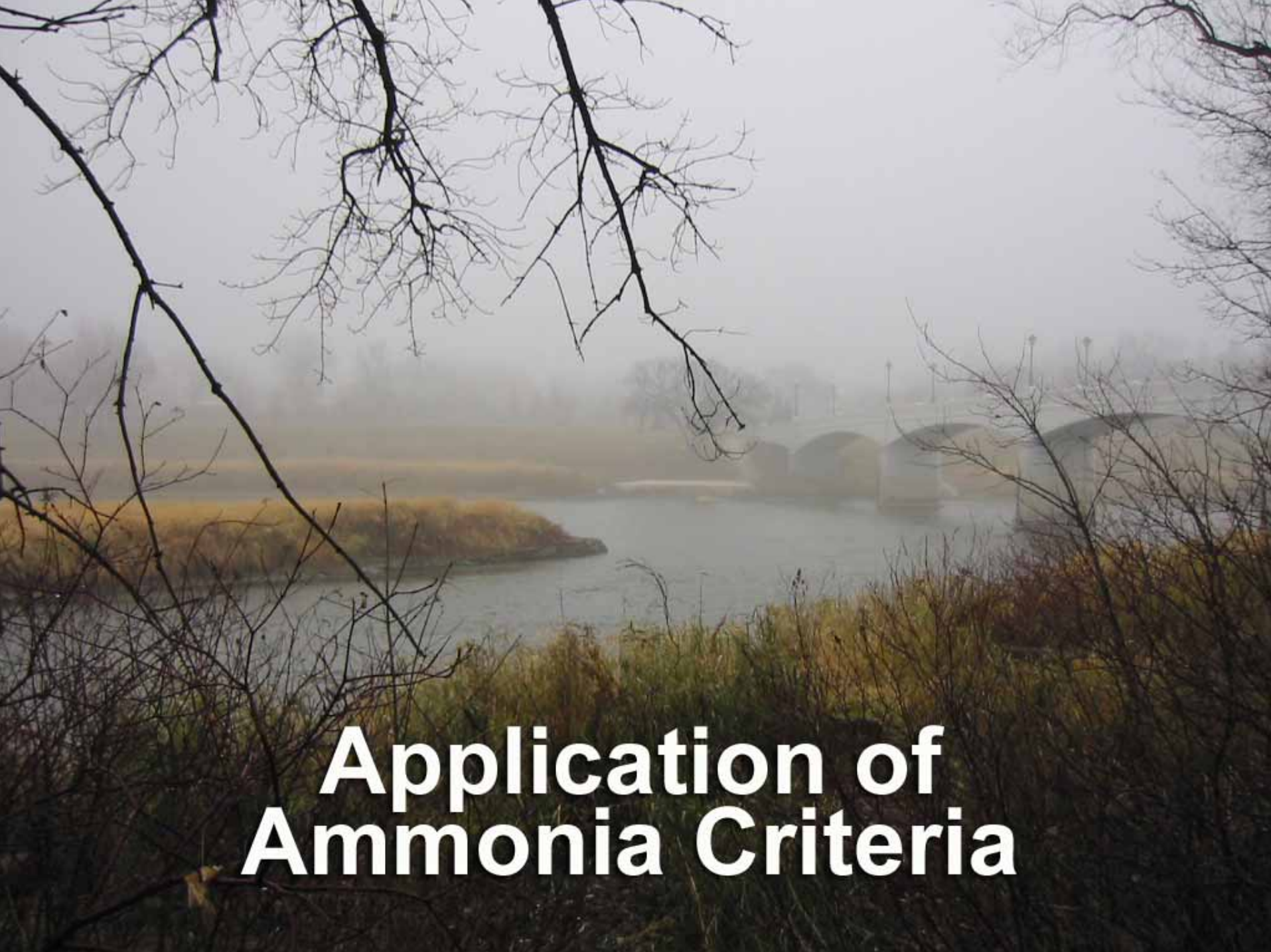
All costs in millions (current $)

Typical ammonia concentration in WPCC effluent = 26 mg/L

Centrate Treatment at NEWPCC

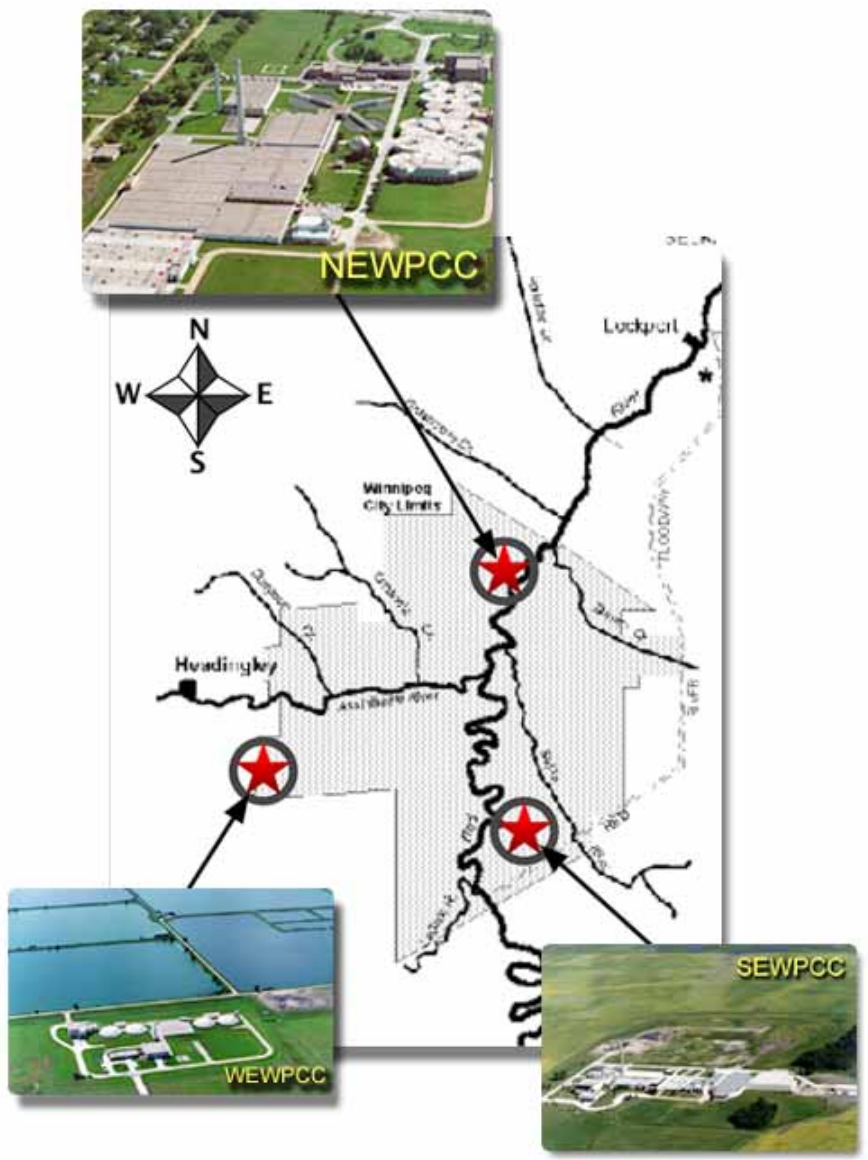
- Ammonia-rich centrate is produced as a by-product of the solids dewatering at the NEWPCC
- Centrate adds 30% to the raw wastewater ammonia concentration at the NEWPCC
- Treatment of this centrate
  - Expected to result in compliance with site-specific criteria
  - Estimated to cost $10 million




Application of
Ammonia Criteria

Application of Criteria

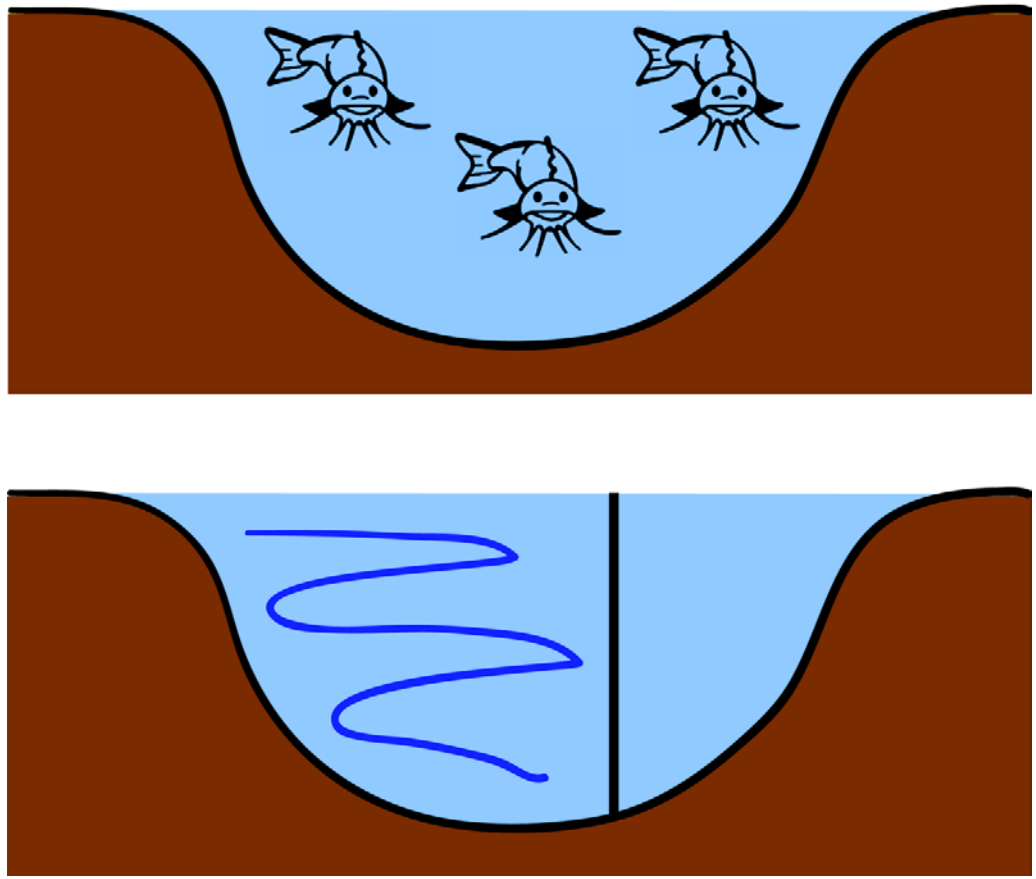
- Determines what concentration of ammonia is allowable at each WPCC to meet the protective ammonia criteria in the river
- This dictates the level of treatment and cost required



Application of Ammonia Criteria

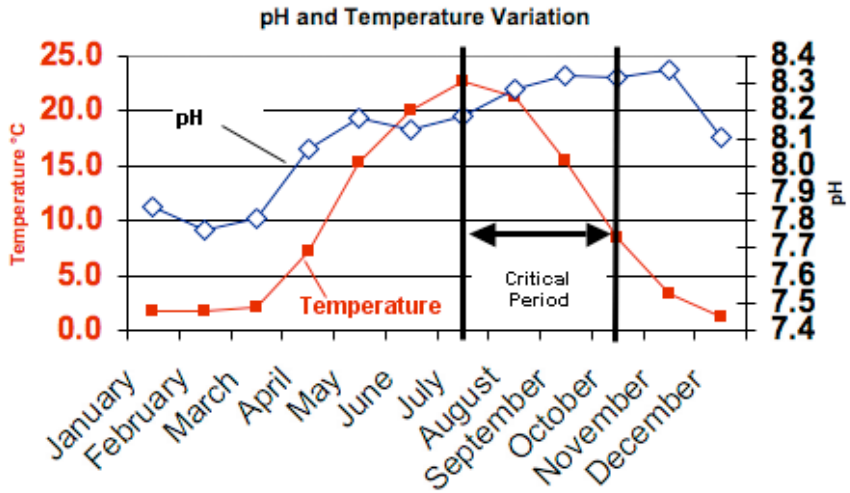
Application involves several important science-based and site-specific considerations

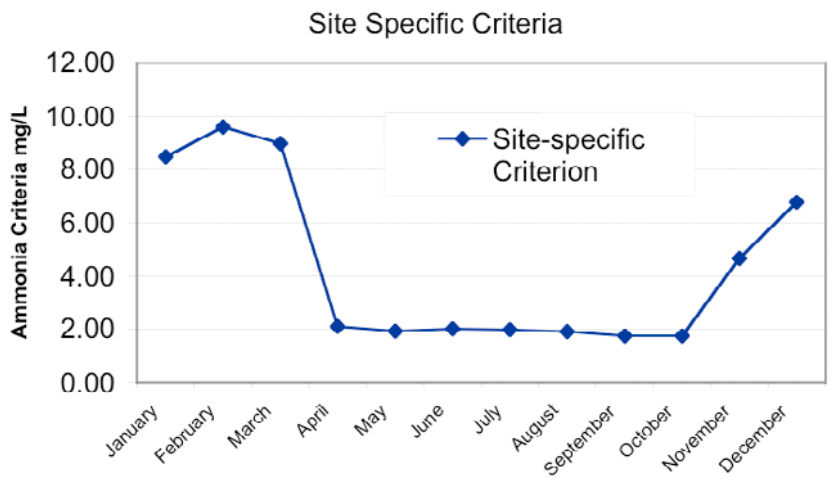
- Allowable ammonia concentration
- Exposure
- Period of Record for Design Flow
- Flow allocation



Duration of Exposure

- Allowable in-stream chronic concentration is expressed as an average over at least 30 days
- Design Flows in combination with monthly pH and temperature is the most effective method to assess compliance with the chronic criteria





How Is Design Flow Selected?

- To predict a Design Flow, one must review a historical flow record

For example, Environment Canada applies a protocol using 30-year running-averages for historical rainfall data

What are the Different Proposals?

- The Province has proposed using a period of record for the Red and Assiniboine Rivers from
  - 1913 to present (89 years)
  - Requires reconstruction of 1913-62 (50 years) flow data (no data at St. Agathe prior to 1962)
  - Reconstruction must account for present reservoir operations in the United States and Manitoba
- The City has proposed:
  - **Actual data** on Red River from 1962 to present (40 years)
  - **Actual data** on Assiniboine River from 1972 to present (30 years) supplemented by reconstruction of only 10 years of data to account for new dams operated by Manitoba

Comparison Of :

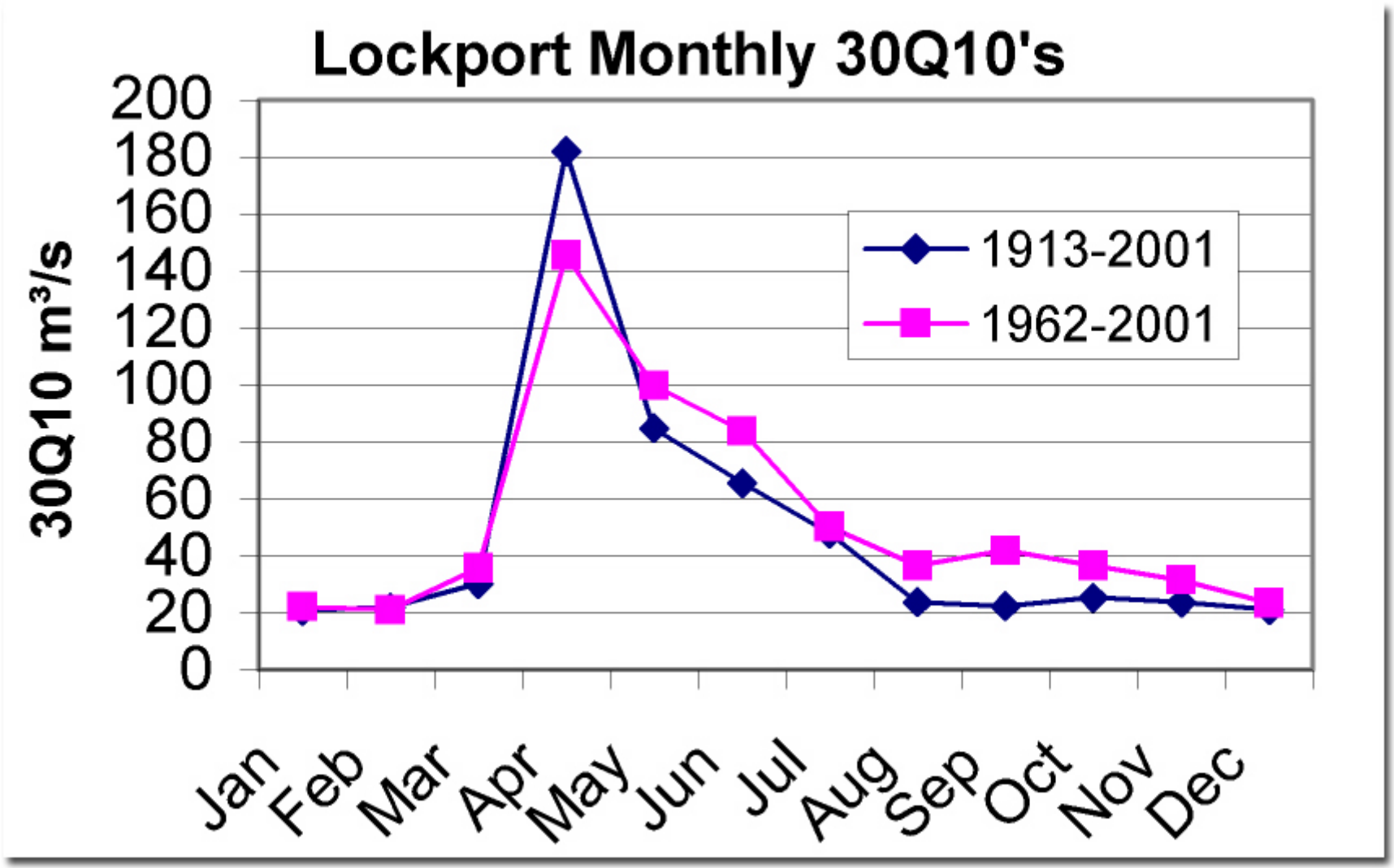
Provincial Approach

- 90 year record consistent with approach used in designing to protect against catastrophic events
  - Flood protection for populated areas
  - Reservoirs for minimum instream flows

City Approach

- Criteria exceedance not catastrophic event
- 90 year record skewed by catastrophic drought of 1930s
- 40 years record consistent with
  - design of treatment plants on Red River in U.S. (40 years)
  - Environment Canada Climatic Normals (30 years)
  - Rules for operating Floodway (about 30 years)
- Accounts better for current and evolving climatic conditions

Comparison of Design Flows at Lockport



Implications of Period of Record

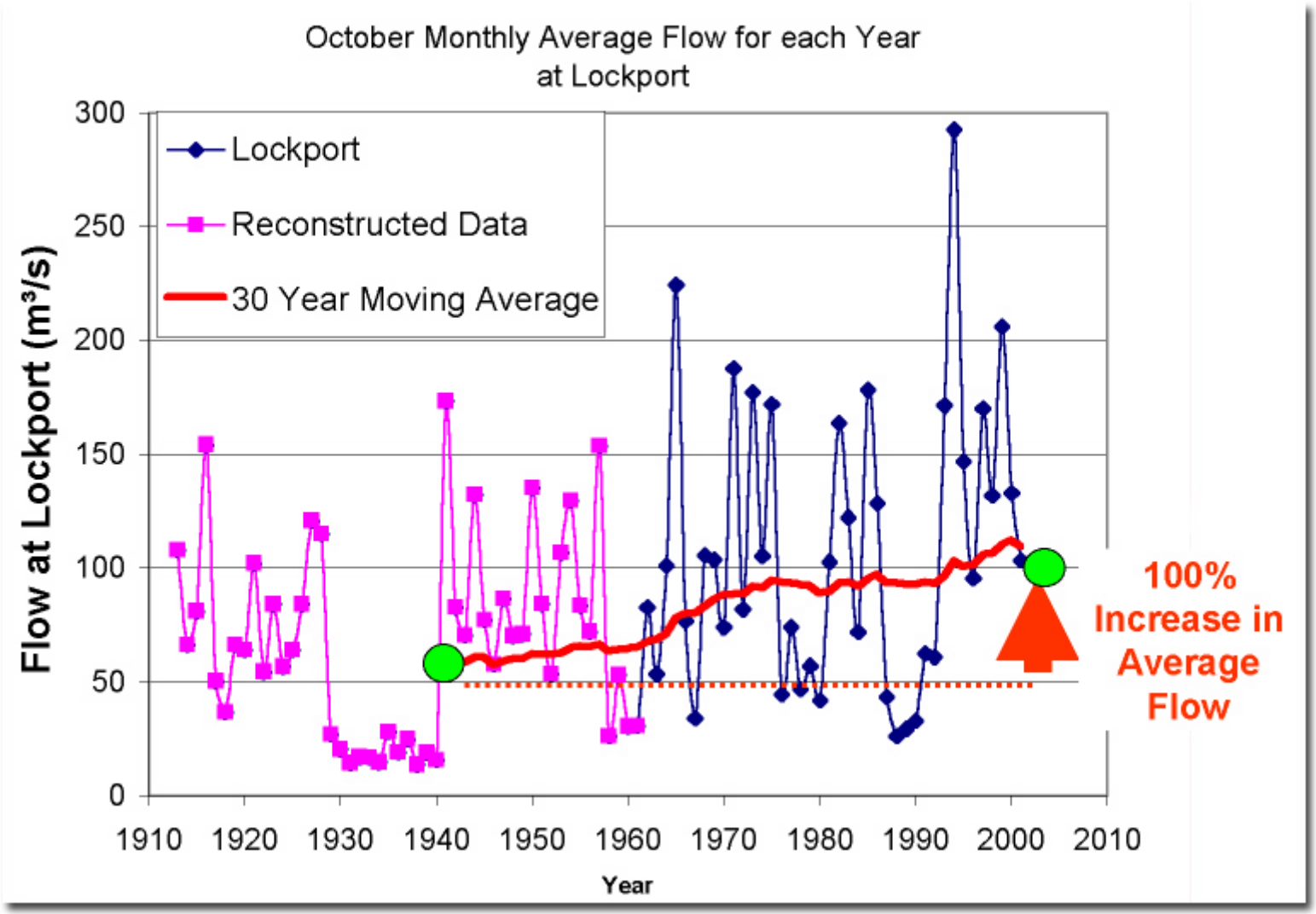
- The **City Proposal** would provide design flows requiring
  - Centrate Treatment at the NEWPCC costing $10 Million
  - No Nitrification at the SEWPCC at least until after a ten year time frame
- The **Provincial Proposal** would provide design flows requiring
  - Centrate Treatment Plus a Level of Treatment at the NEWPCC costing $84 Million
  - Level of Nitrification at the SEWPCC costing $14 Million

The difference is $88 Million

Why the Difference in Design Flows?

- The long-term (1913-2001) and current (1962-2001) period of records provide very different design flows because the river flows changed significantly over the century
- The longer period of record includes the drought of the 1930's

River Flow Have Changed Significantly Over Last Century



Drought (1930's-40's)

- Can be included in Period of Record, using reconstructed data
- Was very extreme event
  - Research states 1 in 300 year event
- Will bias the design flow

Climate Change

- Effects of climate change on flow in the Rivers

  Provincial Proposal

  – To use the period of record from 1913 to 2001 (even adjusted) assumes that there have been no changes in climate since 1913 which could have changed flows

  City Proposal

  – Using 1962 to 2001 would likely be more representative of current climate
  – Use 40 years rolling average in future to account for climate

- Other Guidance
  – *Environment Canada uses 30-year rolling averages as their protocol (City open to this approach)*

City Approach Consistent with Regulatory Experience at Moorhead

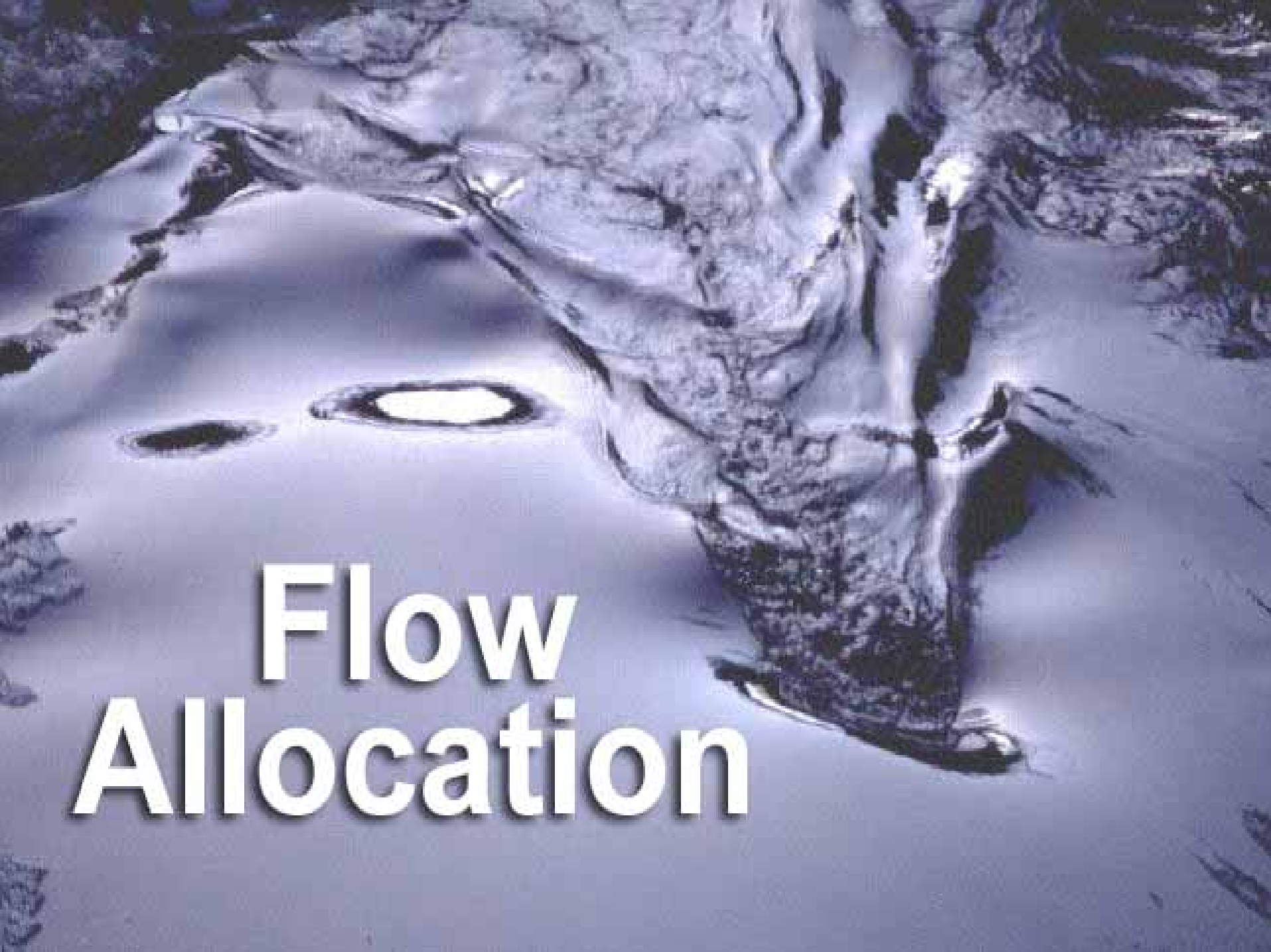
- Moorhead License uses only 1954 to 1994 flow record, although 1901 –1994 data available
  - Unlike Manitoba, Minnesota EPA did not reconstruct pre-reservoir dataset to regulate ammonia

Consistency with Environment Canada Canadian Climate Normals

- Environment Canada uses International Standards: “values of climatic elements averaged over a fixed standard period of years”
- Standard is to use 30 year period and update them every decade
  - in 1990 use 1961-1990
  - in 2000 use 1971-2000

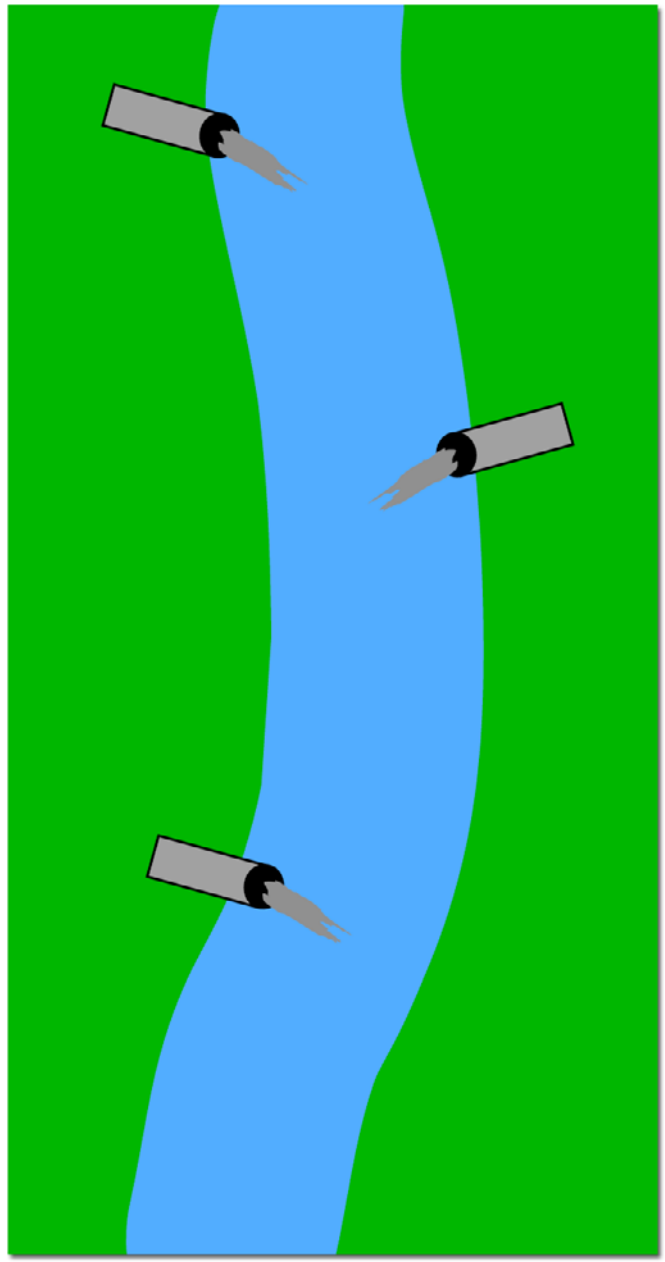
City Design Flows

- The period of record used should best reflect the most likely occurrence of flows for next 10 years
- The 1962 – present flow record best represents the likely flow for the future (consistent with other practices)
- Periodic review of flow record should be used to reflect changing climatic conditions
- Reassessment should occur in 10 years

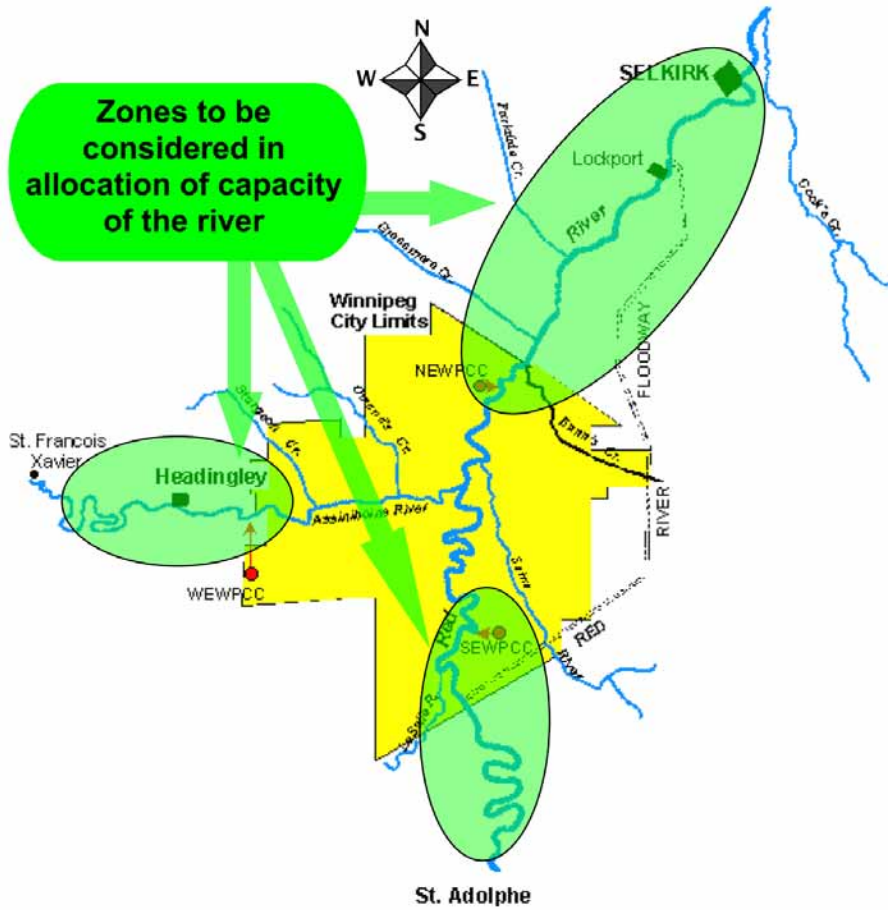

Flow
Allocation

Flow Allocation Considerations

- Multiple discharges in close proximity should not cause criterion to be exceeded at or above design flow
  - Must consider aggregate effect
- Allocation of total assimilative capacity between dischargers is a site-specific decision
  - Important decision for CEC
- Allocation should recognise that ammonia concentration will decrease downstream
  - This will allow capacity for additional discharges to use the river and not cause an ammonia criterion to be exceeded



Allowance for Future Development



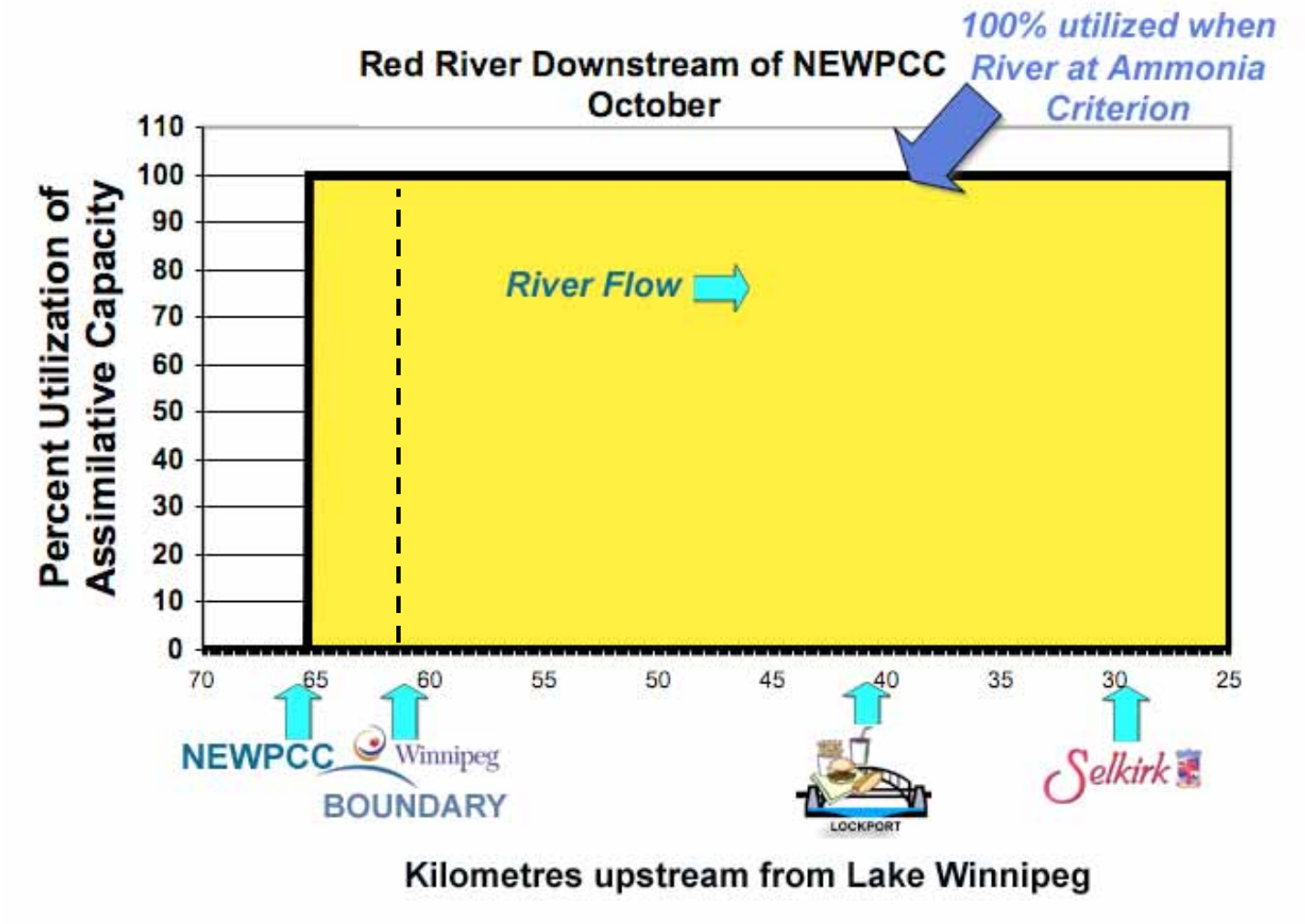
- **Intent of Flow Allocation Policy is not to restrict development outside the City Limits**
- **City Policy limits all wastewater discharges within the City to the three WPCCs**

What are the different proposals?

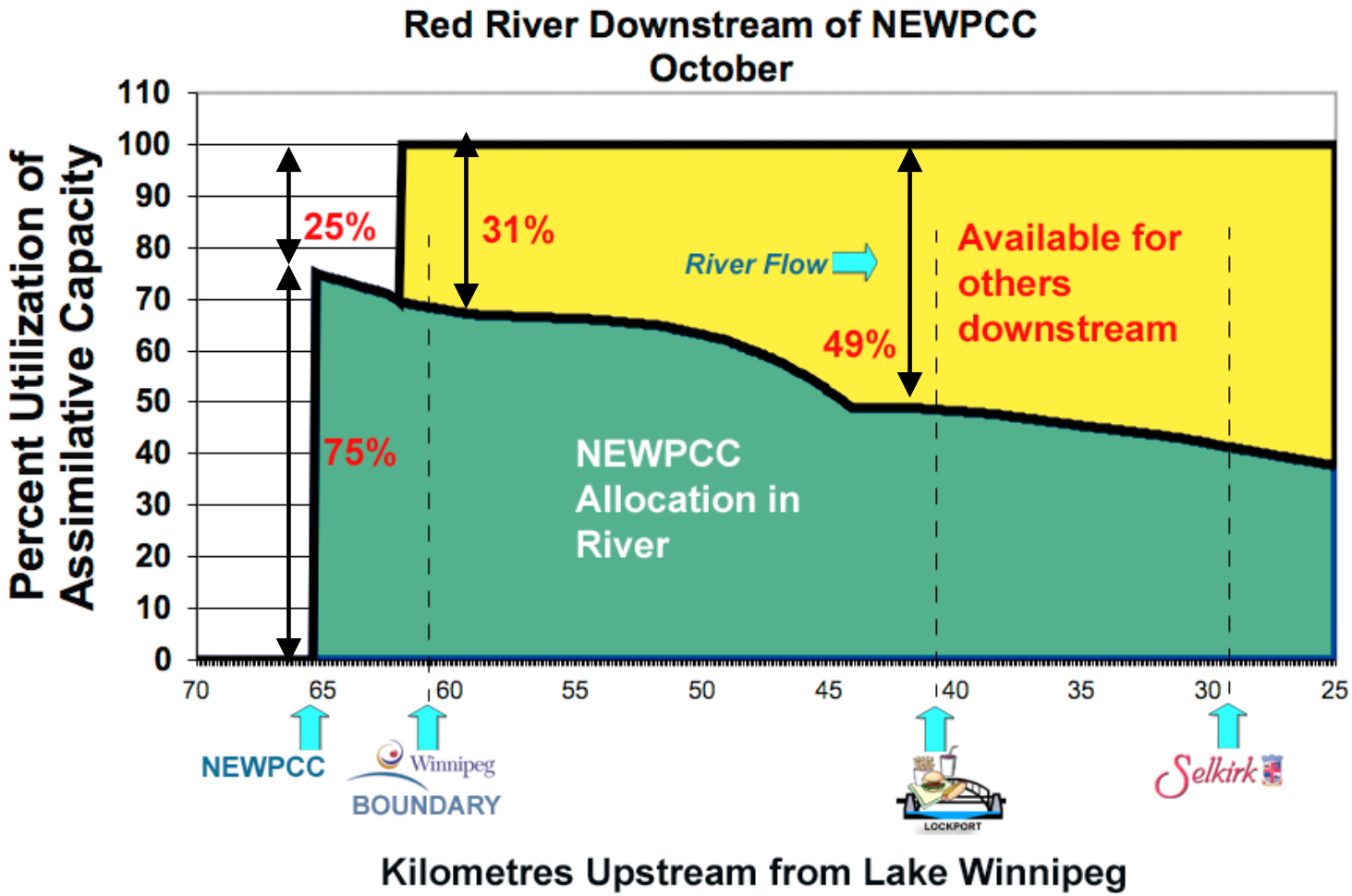
- The Province has proposed allocating only 75% of river flow for each City plant at point of discharge
- The City Proposal would allow for
  - 90% allocation of Red River flow for City WPCCS at the north and south limits of the City and;
  - 75 % allocation on the Assiniboine River at Boundary on West end (i.e at point of discharge of WEWPCC)

Difference is in the Red River flow allocation

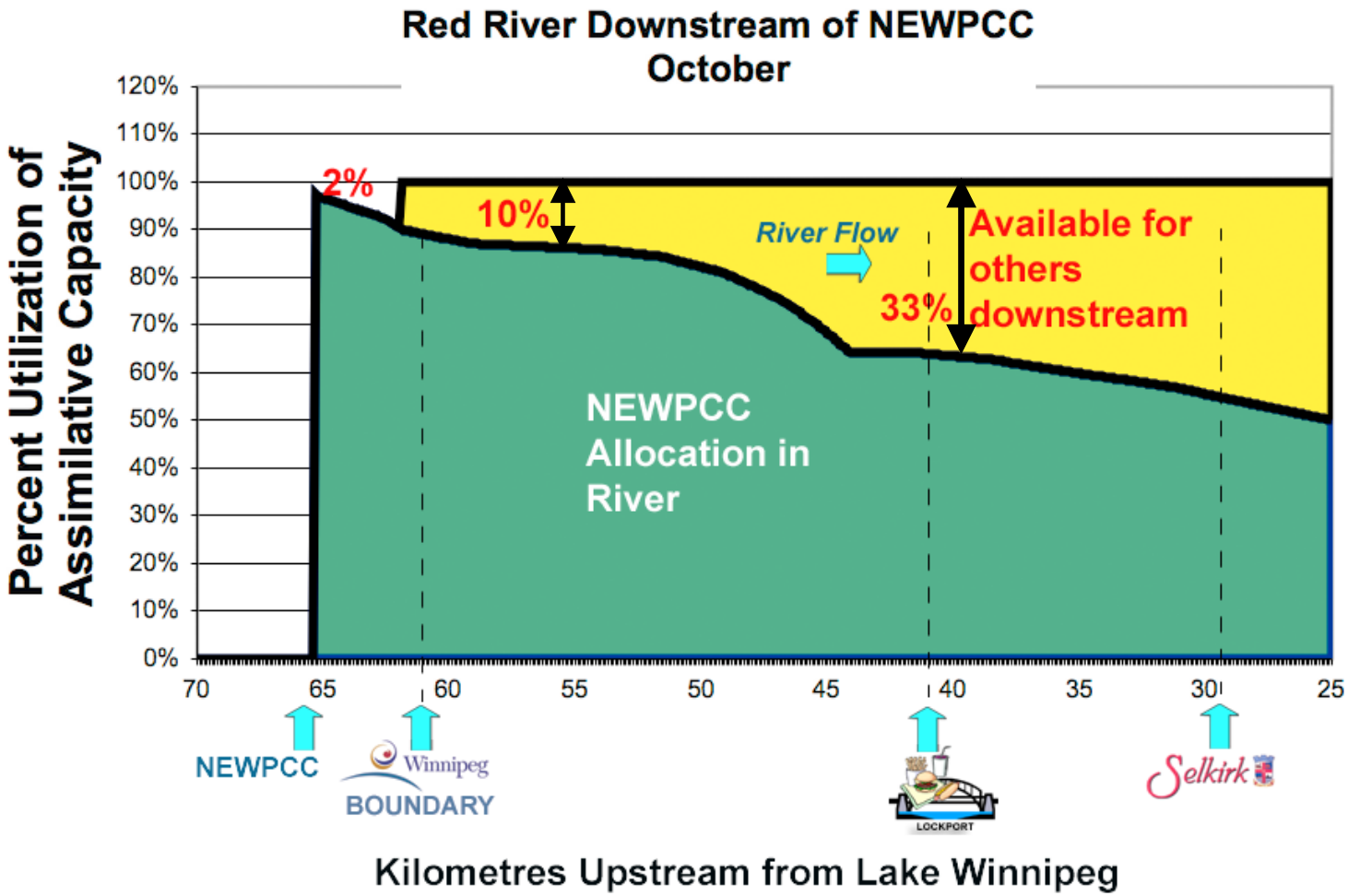
Allocation Must Allow Capacity for Downstream Growth–How much is Needed?



Provincial Proposal



City Proposal



How much Capacity is available each Month?

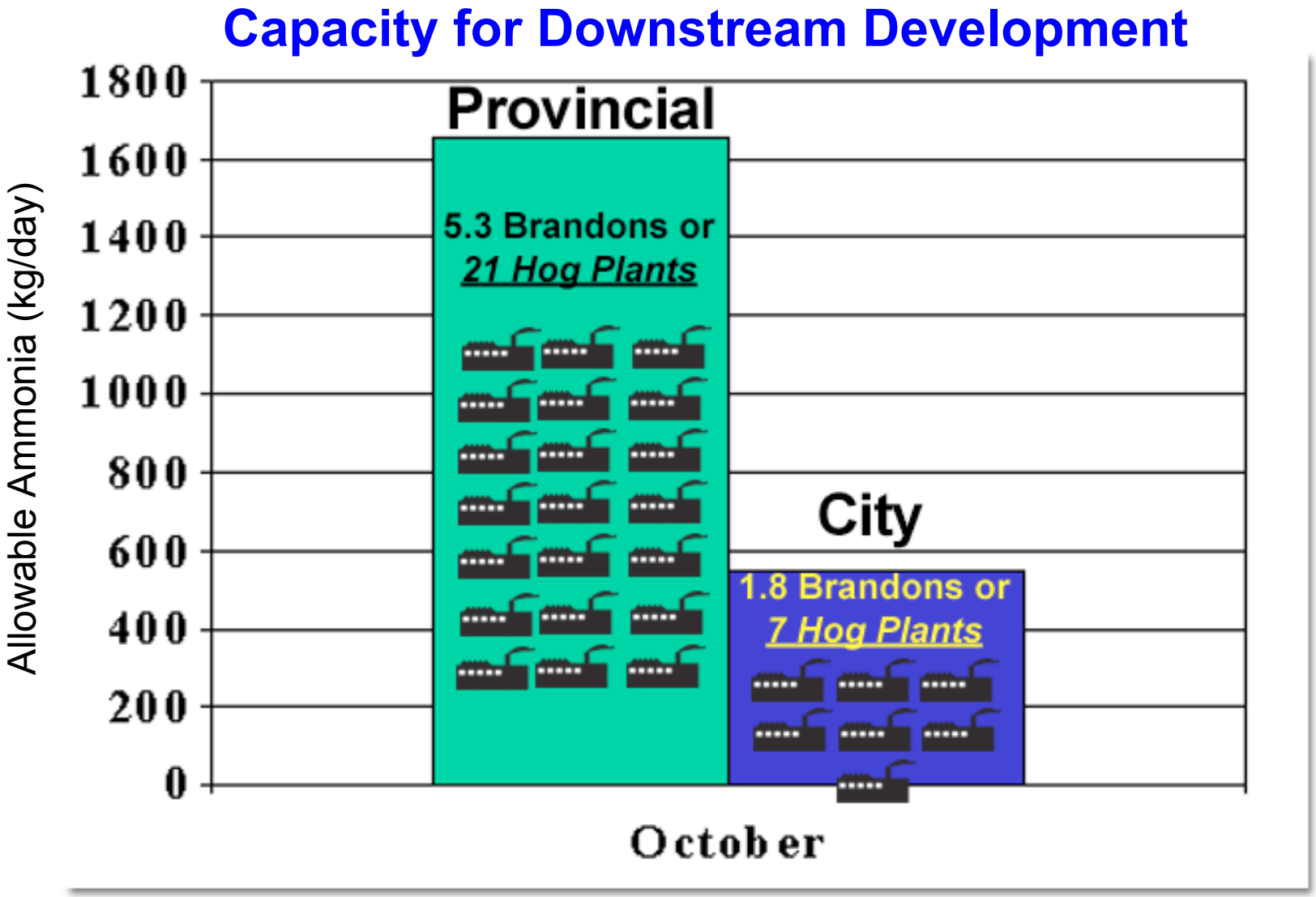
- Each month was checked for design flow conditions to determine critical month
  - October is the critical month

- City Proposal
  - 10% Capacity available in the River is equivalent to 550 kg/day of ammonia in discharge in critical period
- Provincial Proposal
  - 31% Capacity available in the River is equivalent to 1650 kg/day of ammonia in discharge in critical period

How much Development can be considered for each Proposal?

- Comparative examples:
  - Development the size of Brandon (21 ML/D including the Maple Leaf WTP)
  - A hog plant the size of Maple Leaf is 5 ML/d
- Assume equivalent treatment as the NEWPCC

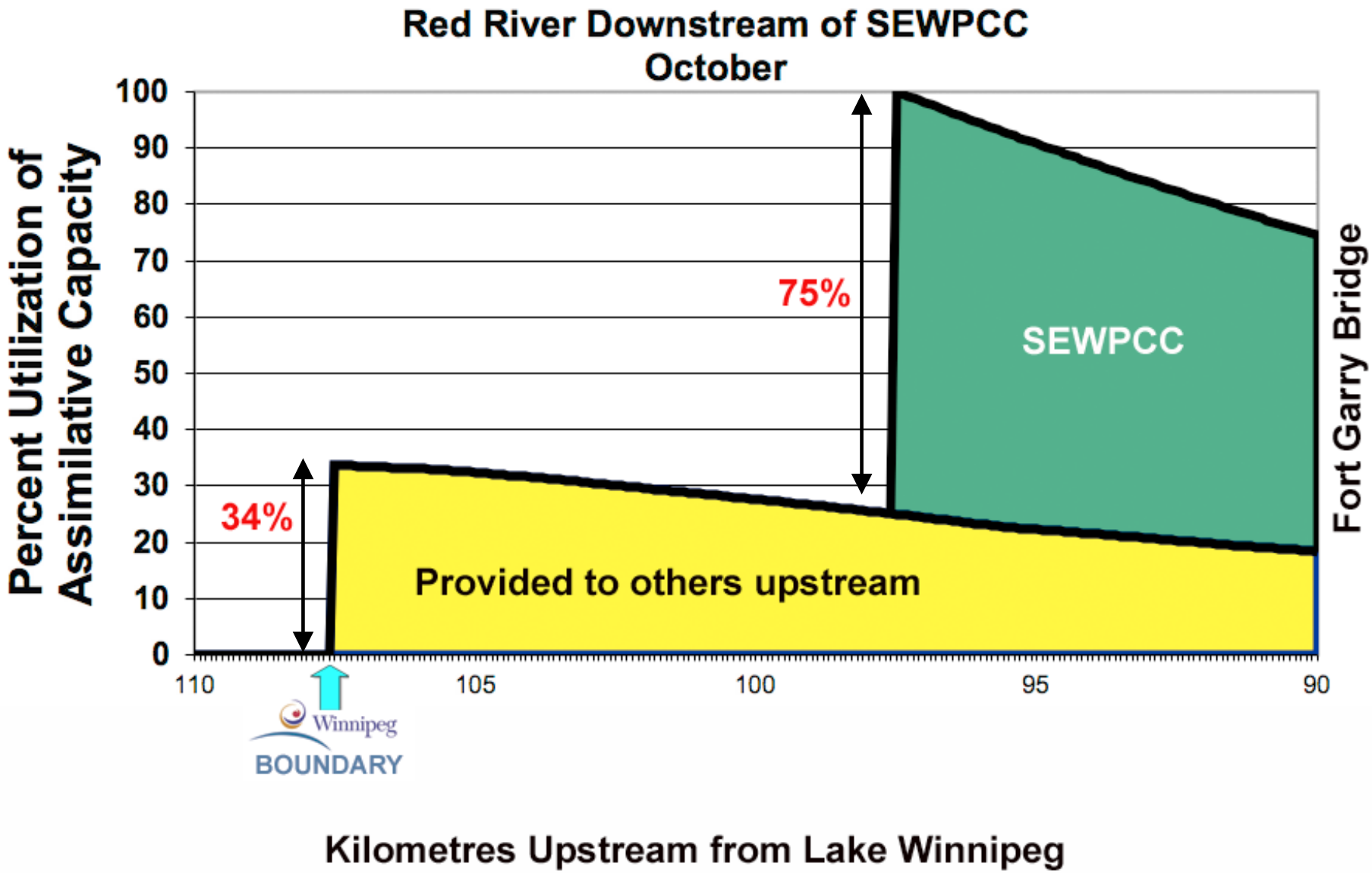
Comparison of City and Provincial Proposals at NEWPCC



City Proposal: No Constraint on ***Reasonable, Well-Managed*** Growth

- City Proposal allows for significant potential for future development at North edge of City
  - Larger than Brandon (including Maple Leaf)
  - 72,000 people
- Further downstream at Lockport, City Proposal allows for
  - 250,000 people
  - 6 Brandon Sized Cities

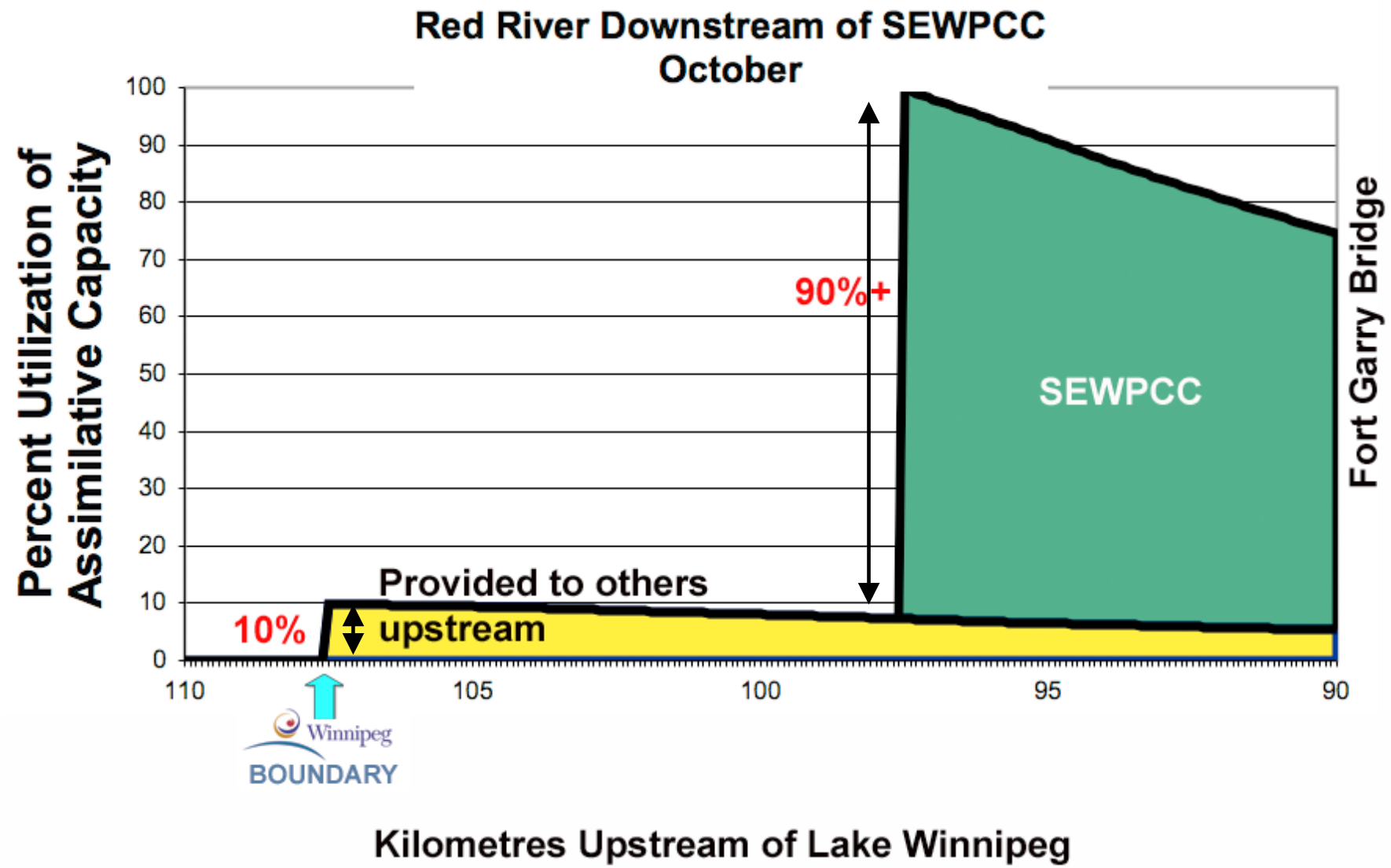
Provincial Proposal at SEWPCC



Provincial Proposal Would allow for:

- A new WPCC of same size as the WEWPCC (serve 87,000 people)
- 87,000 people is equivalent to 6.5 hog plants the size of Maple Leaf at Brandon

City Proposal at SEWPCC



City Proposal has no constraint on reasonable well managed growth

- Allows for new WPCC
- Servicing about 20,000 additional people or 2 hog plants the size of Maple Leaf at Brandon
- Note that this area is just upstream of the floodway and is a high flood risk area
  - Not conducive to major residential or industrial development

WEWPCC

- City could agree with Provincial Proposal on the Assiniboine at WEWPCC of 75% Allocated to WEWPCC
  - WEWPCC services 87,000 people
  - 25% for others would allow 29,000 people immediately upstream

Summary Comparison

- City Proposal has no constraint on reasonable well managed growth in Capital Region
  - Upstream of WEWPCC – 29,000
  - Upstream of SEWPCC – 22,000
  - Down stream of NEWPCC – 72,000
    - 250,000 downstream to Lockport
  - **In Total -120,000 to 300,000 people**
- The provincial proposal provides for more development than is reasonable in the foreseeable future
  - **In Total -300,000 to 400,000 people**

Potential Ammonia Reduction Strategy

Application of Ammonia Criteria

Application involves several important science-based and site-specific considerations

- Allowable ammonia concentration
- Exposure
- Period of Record for Design Flow
- Flow allocation

Issues are complex, some differences in interpretation between City and Manitoba Conservation

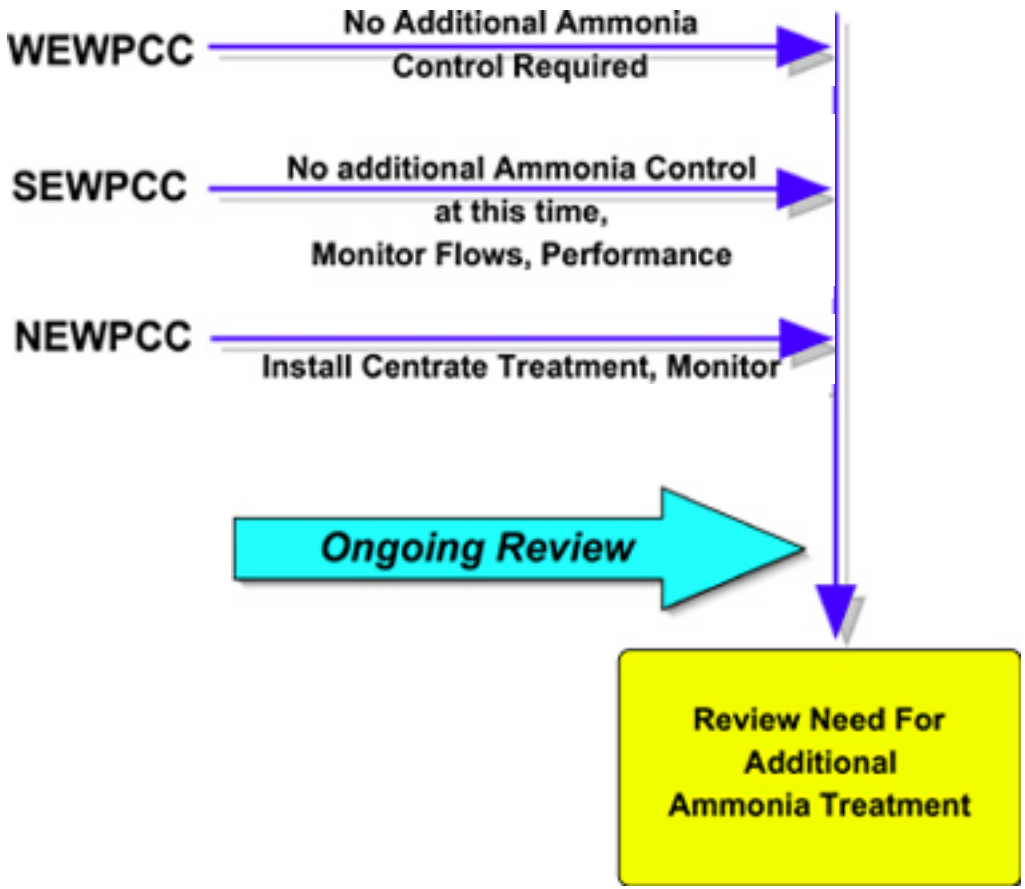
Comparison of Manitoba and City Positions

	Flow Allocation	
	90% Allocation at City Boundary	75% Allocation at Discharge
Current Flow Record 1962-2000	City Proposal $10M	$98M
Long-term Flow Record 1913-2000	$98M	Provincial Proposal $107M

The City believes its program will meet protective criteria, even with many conservative assumptions

Potential Ammonia Reduction Strategy

- **WEWPCC:**
  - –Continued use of polishing ponds
- **SEWPCC:**
  - –Additional ammonia control not needed at present.
  - –As flows increase to plant, ammonia control to be reviewed
- **NEWPCC:**
  - –Ammonia control required to meet proposed criteria
  - –Centrate Treatment should be implemented
  - –Effectiveness should be evaluated after commissioning



Manitoba Conservation and the City should evaluate the strategy within 10 years to determine if additional nitrification is required, adhering to Nutrient Management Strategy

City Strategy Allows Time to Address Differences in Application

- Review of period of record and evolving data set
- License review can allow for re-evaluation of flow allocations (monitor development)

Additional Information

- Conduct monitoring programs and toxicity testing
  - Presence/absence of Early Life Stages

- Develop and conduct water quality monitoring program during times of summer/fall low flows
  - Increase understanding of distribution of ammonia concentrations
  - Natural decay of ammonia in the river
  - Influence of upstream conditions


Thank You