TONGUE RIVER SALINITY TMDL PROJECT

Stakeholder Meeting

October 11, 2016

Miles City

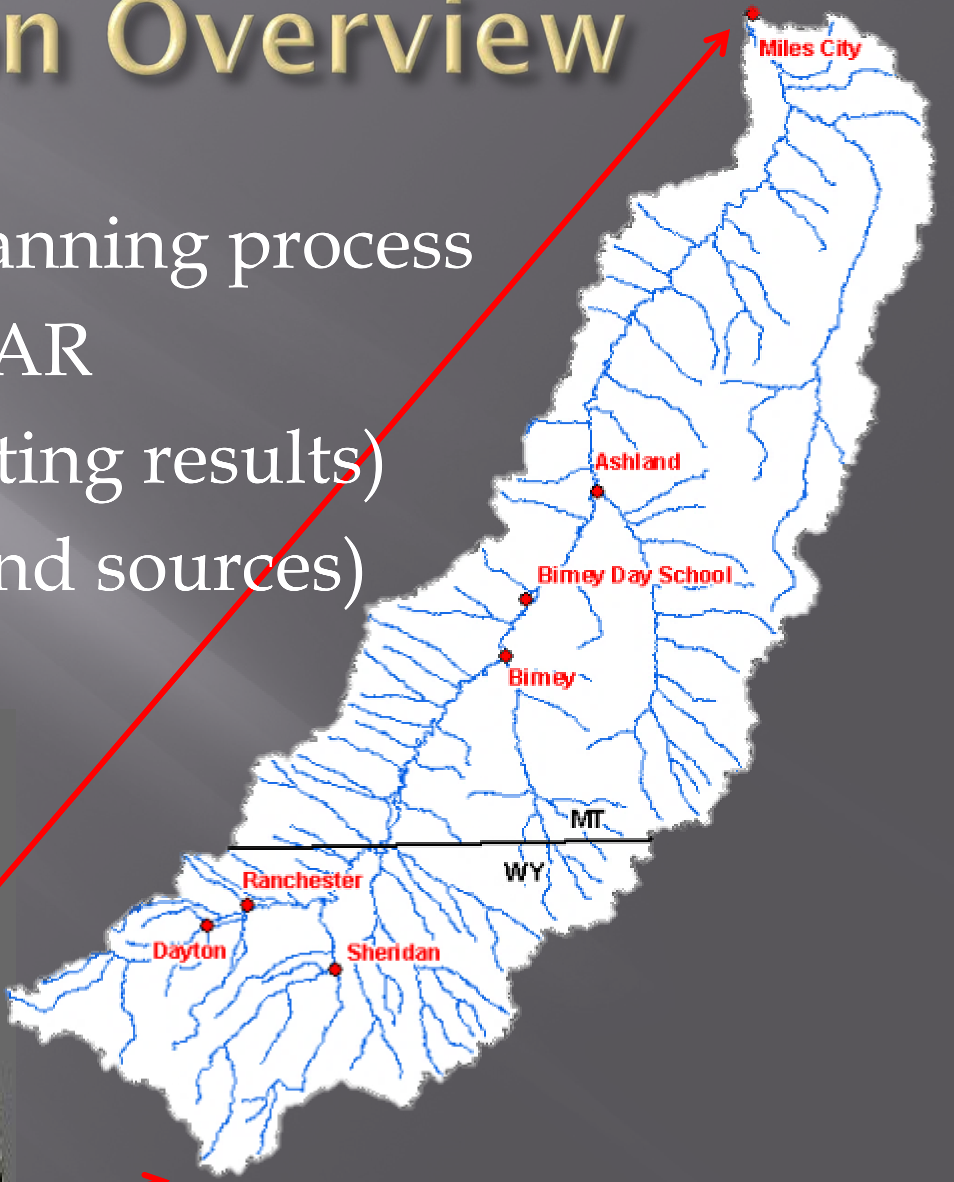
DEQ Montana Department of Environmental Quality

Meeting Purpose

Meet with Tongue River watershed stakeholders to discuss modeling effort and scenario development.

Presentation Overview

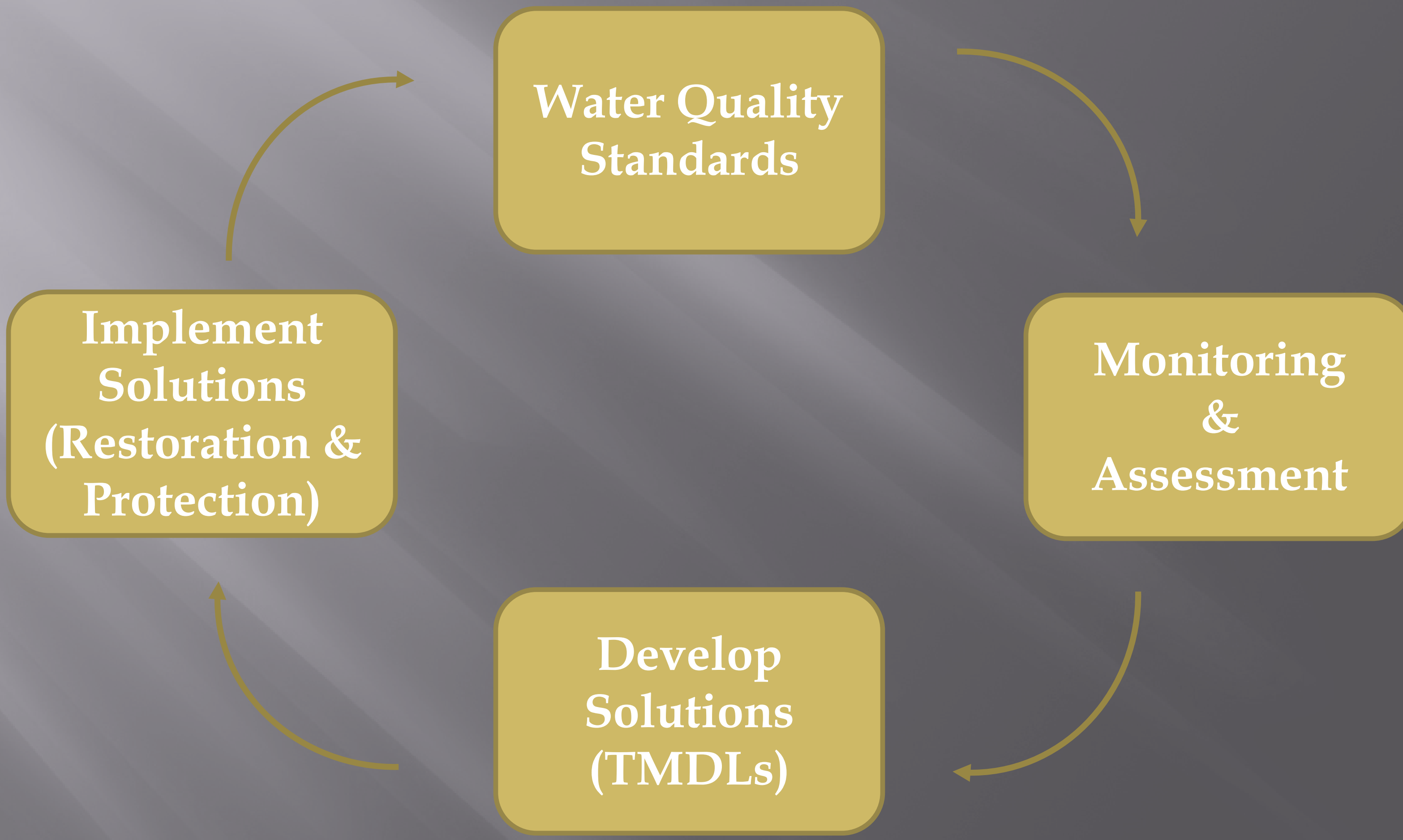
- MT’s water quality planning process
- Review of TDS/EC/SAR
- SWAT Modeling (existing results)
- Scenarios (examples and sources)
- Next Steps



Water Quality Planning Process

- Establish water quality standards
- Sample and evaluate water quality relative to the standards
- **Characterize the problems and develop solutions (Current Project Phase)**
  - Often involves TMDL development
- Implementing solutions and steps toward meeting water quality standards

Water Quality Planning Process



Total Dissolved Solids (TDS)

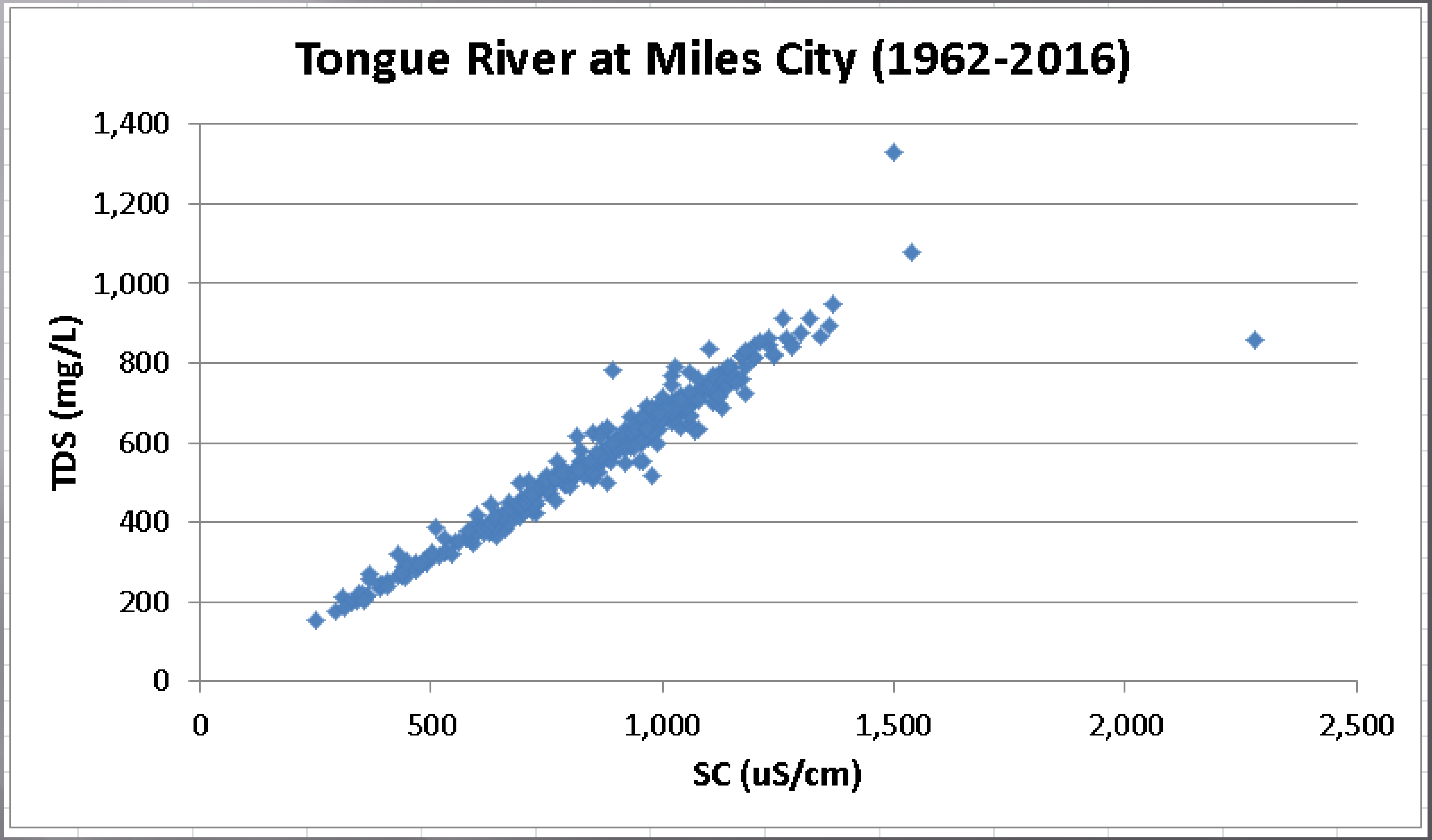
- TDS is a measure of how much material (mass) is dissolved in water.
- Most dissolved solids are inorganic salts, so this value is really just a measure of salinity.
- Units of mass/volume
  - milligrams per liter (mg/L), tons/acre-foot, or parts per million (ppm)
- Most hydrologic models operate on a 'mass-balance' approach, so this is easily incorporated.

Electrical Conductivity

- Electrical conductivity (EC) is a measure of the ability of water to conduct electricity.
  - The more cations (Na^+, Ca^{2+}, Mg^{2+}, etc.) and anions (HCO_3^-, SO_4^{2-}, Cl^-, etc.) that are in the water, the higher the EC.
  - Therefore, EC is a *relative* measure of salinity.
  - EC is temperature dependent
- Specific conductance (SC) is EC corrected to 25ºC.
- EC definition in Montana rules (ARM 17.30.602) matches definition of SC, so

Conductivity = EC = SC

SC and TDS


Tongue River at Miles City (1962-2016)
TDS (mg/L)
1,400
1,200
1,000
800
600
400
200
0
0
500
1,000
1,500
2,000
2,500
SC (uS/cm)

Sodium Adsorption Ratio

- Sodium adsorption ratio (SAR) is the ratio of sodium to calcium and magnesium.
- A high SAR means high amounts of sodium compared to Ca and Mg (and vice versa).
- Unitless
- Concentrations used in calculation are in milliequivalents per liter (meq/L)

$$SAR = \frac{[Na]}{\sqrt{([Ca] + [Mg])/2}}$$

Montana's Water Quality Standards for Salinity in The Tongue River

- Monthly average:
  - March 2 – October 31: 1,000 µS/cm EC, 3.0 SAR
  - November 1 – March 1: 1,500 µS/cm EC, 5.0 SAR
- No sample may exceed:
  - March 2 – October 31: 1,500 µS/cm EC, 4.5 SAR
  - November 1 – March 1: 2,500 µS/cm EC, 7.5 SAR

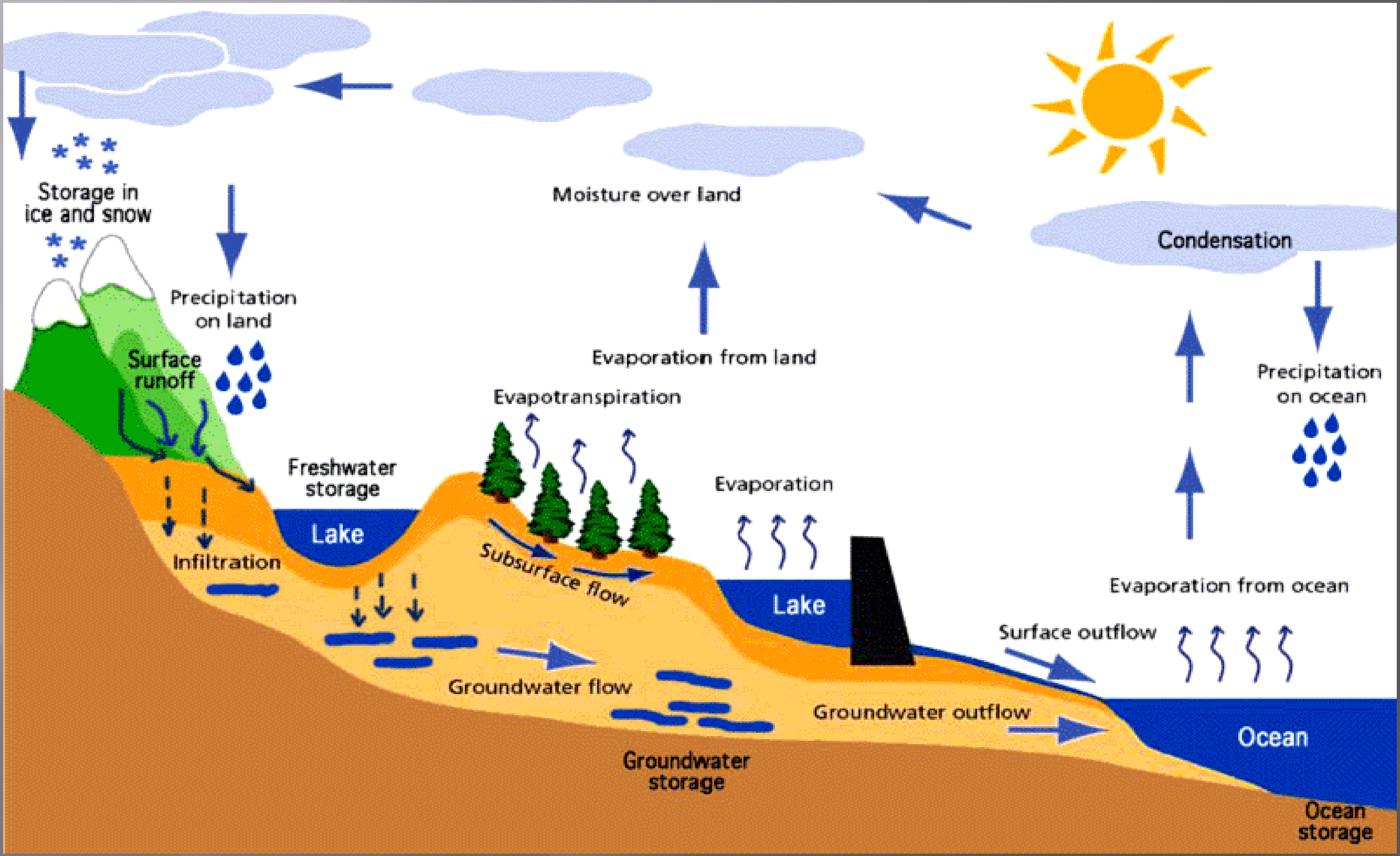
Source: ARM 17.30.670

SWAT Soil & Water Assessment Tool

http://swat.tamu.edu

- Developed by the USDA-ARS and Texas A&M University
- Main focus is as an agricultural model
- Open source, constantly being updated
- Extensive documentation

SWAT: Hydrologic/Water Quality Model



Major Inputs for SWAT

- Climate
  - SWAT uses a daily time step
  - Required climate files include precipitation, temperature, wind speed, relative humidity, and solar radiation data.
- Land Use
- Topography (digital elevation model)
- Soils
- Point Sources/Inflows/Outflows

Salinity Inputs for SWAT

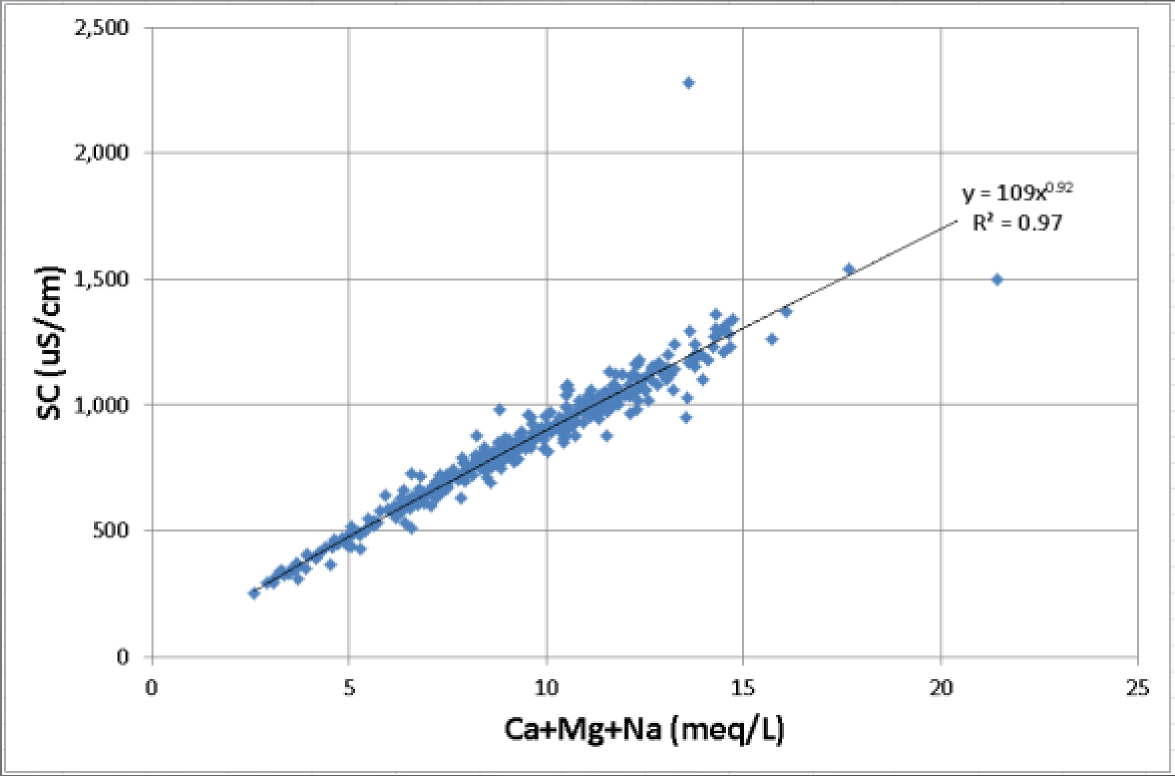
- We can model cations within SWAT
  - Calcium
  - Magnesium
  - Sodium
- Cation concentrations are input by the user
- They can be varied by land use, water source, and month.
- These values were taken from literature sources and previous modeling efforts, and then adjusted slightly during calibration.

Salinity Inputs for SWAT

Land Use	Cation	GROUNDWATER Event Mean Concentration (mg/L)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Pasture	Ca	99	72	63	78	72	79	65	71	63	60	86	82
Forest	Ca	99	72	63	78	72	79	65	71	63	60	86	82
Shrubland	Ca	99	72	63	78	72	79	65	71	63	60	86	82
Irrigated Land	Ca	121	88	77	95	88	97	79	87	77	73	105	100
Pasture	Mg	162	137	108	142	136	153	135	117	144	131	153	141
Forest	Mg	162	137	108	142	136	153	135	117	144	131	153	141
Shrubland	Mg	162	137	108	142	136	153	135	117	144	131	153	141
Irrigated Land	Mg	198	167	132	174	166	187	165	143	176	160	187	172
Pasture	Na	406	410	348	418	441	297	297	297	297	402	428	448
Forest	Na	406	410	348	418	441	297	297	297	297	402	428	448
Shrubland	Na	406	410	348	418	441	297	297	297	297	402	428	448
Irrigated Land	Na	497	501	425	510	538	575	497	536	510	491	523	548

EC/SAR Modeling in SWAT

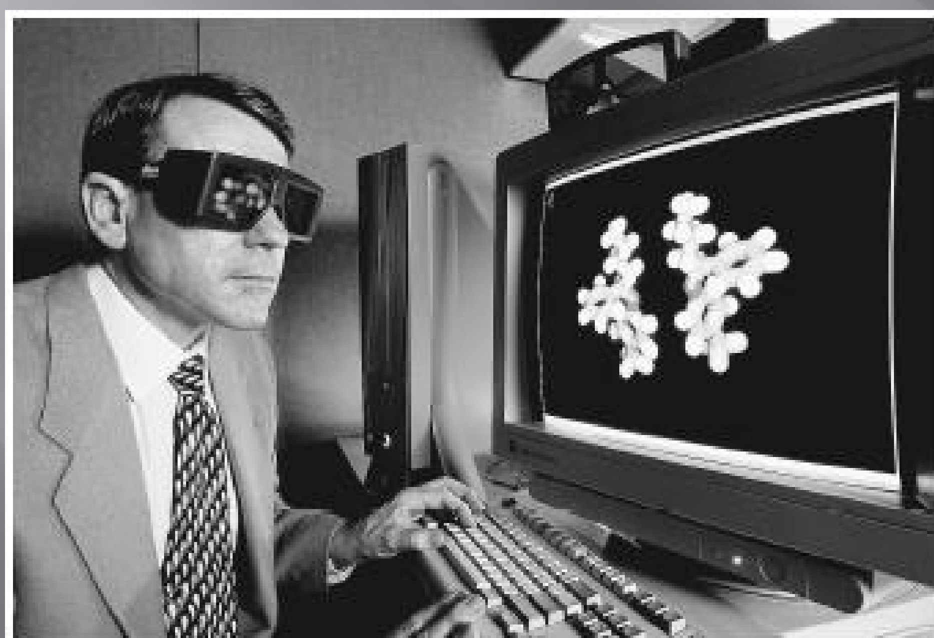
- SAR can be calculated.
- Use observed relationship between cation totals and salinity to determine EC/SC.

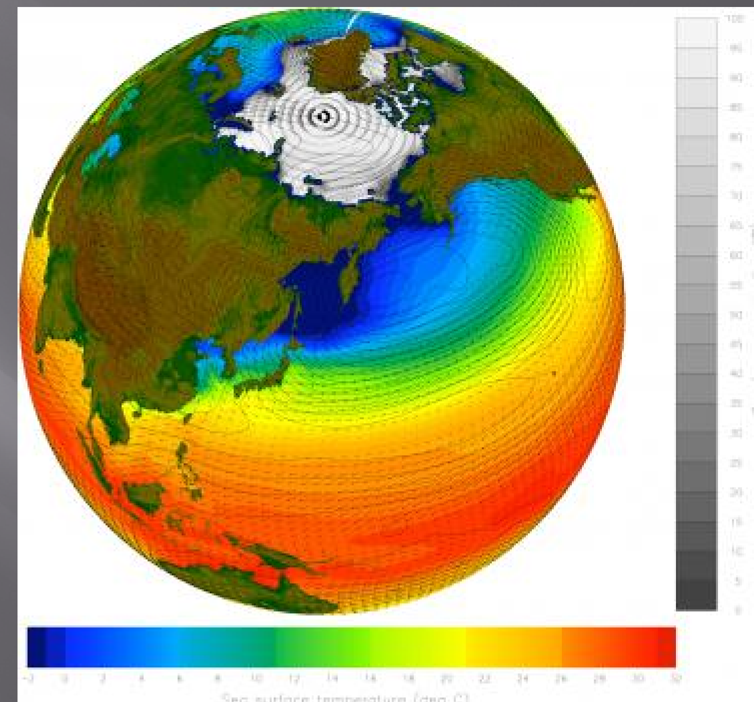


Modeling Summary

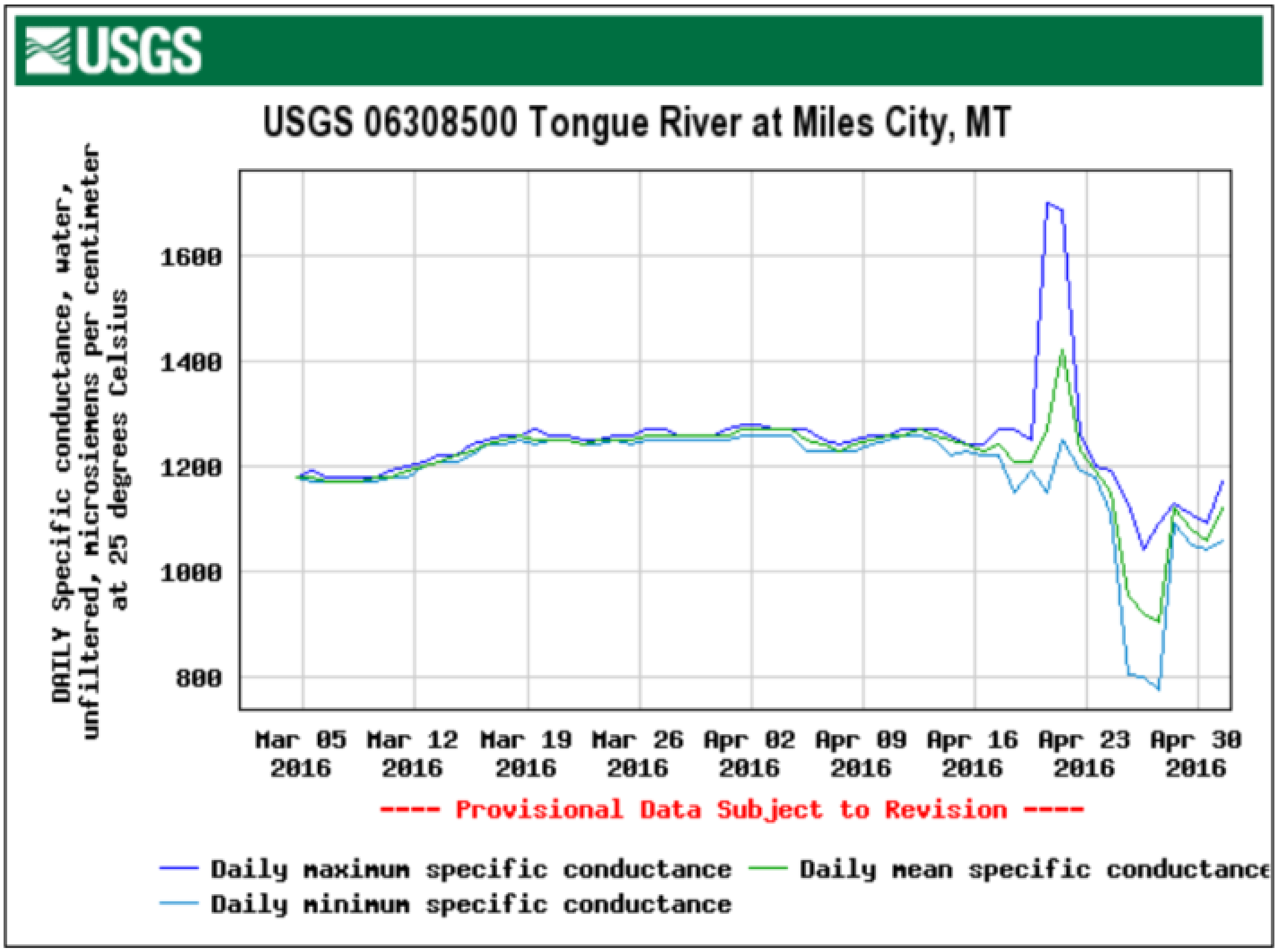
- Model simulates hydrology and major cations.
- Major cations can be correlated to SC, TDS, and SAR.
- Major gaged tributaries (Hanging Woman, Otter, Pumpkin) are modeled as point sources.

Why do we need a computer model?





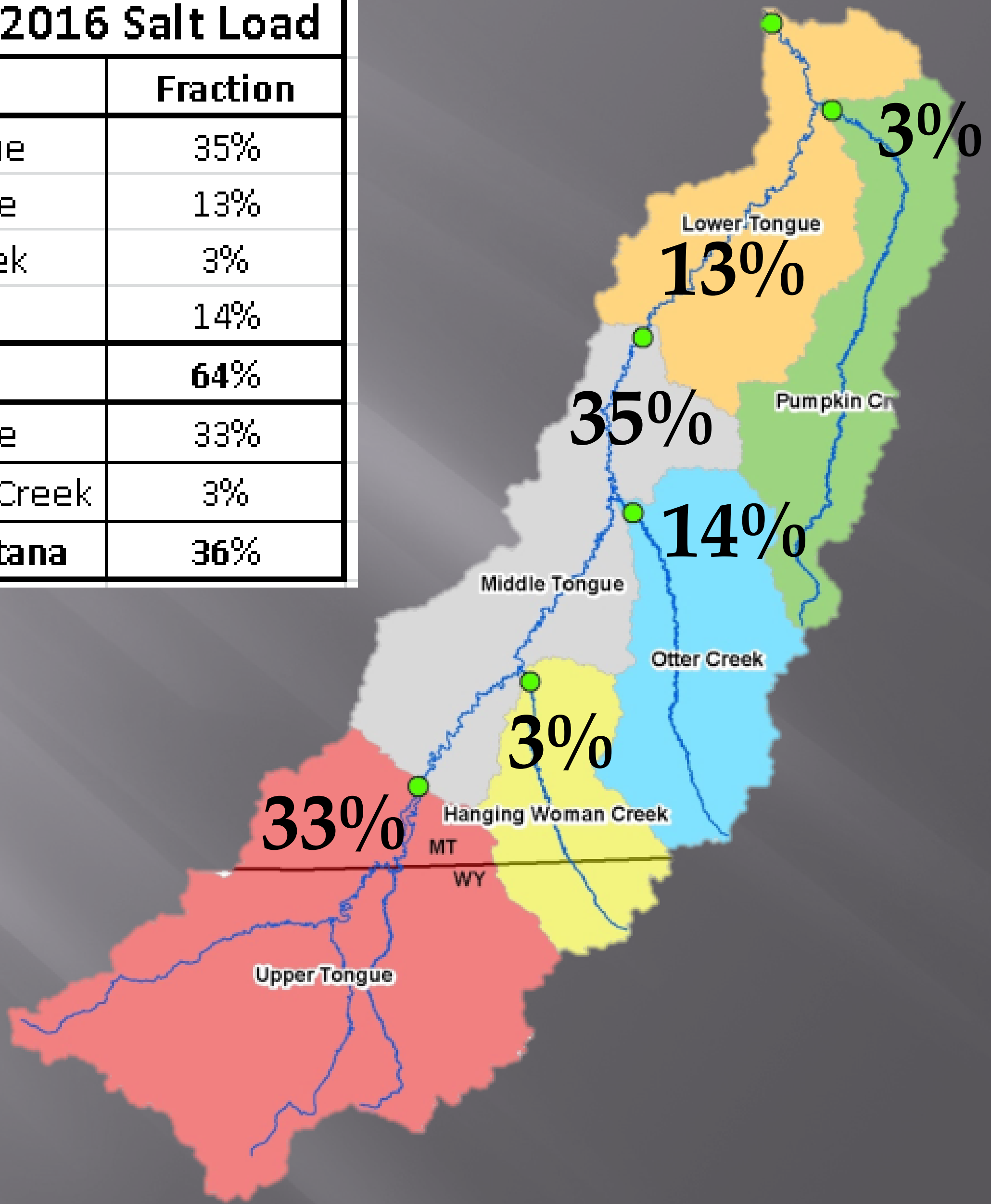
Where is the salt coming from?

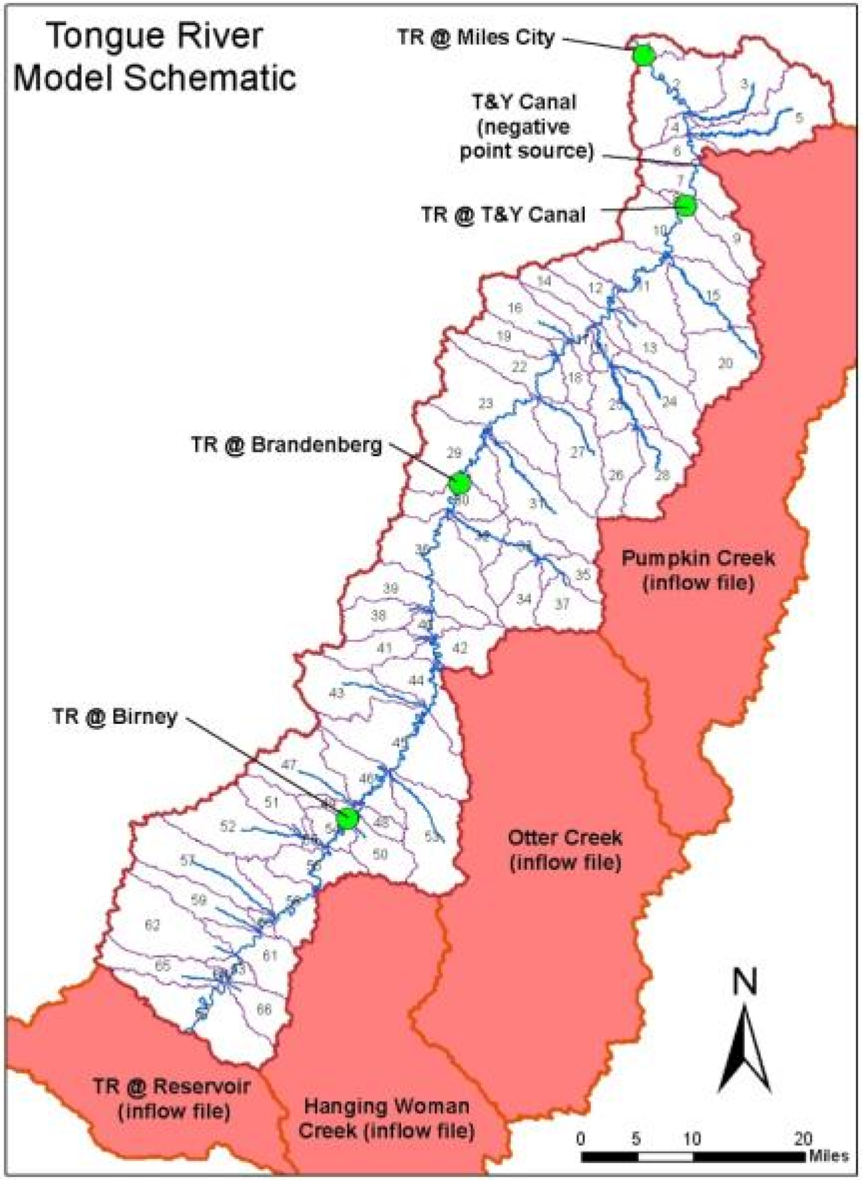


Where is the salt coming from?

- March and April 2016 – above standard
- Gages measuring flow/SC at:
  - Reservoir
  - Brandenburg
  - Miles City
  - Tribs (Hanging Woman, Otter, Pumpkin*)
- Set up a simple mass balance at these sites.

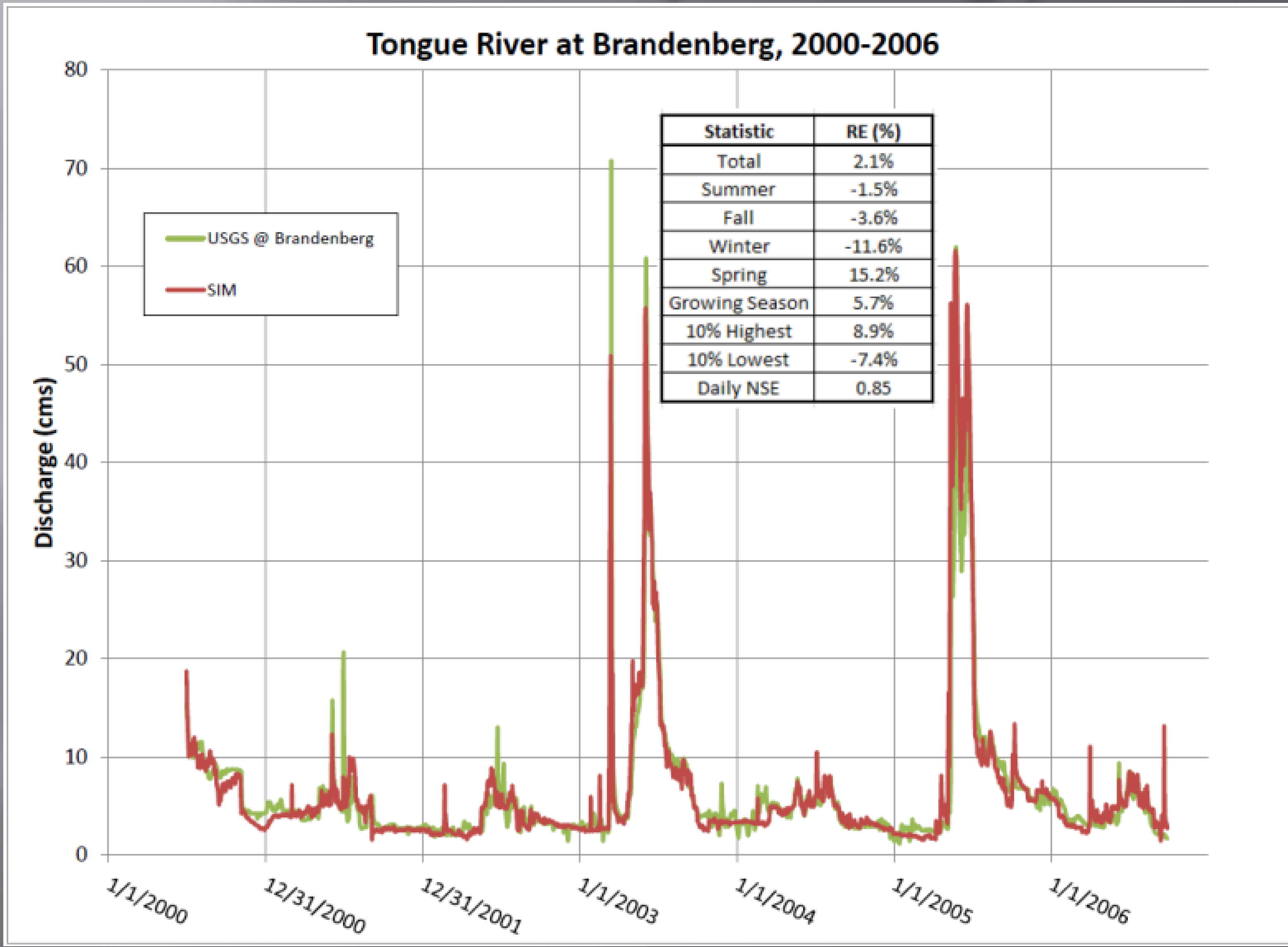
March/April 2016 Salt Load	
Source	**Fraction**
Middle Tongue	35%
Lower Tongue	13%
Pumpkin Creek	3%
Otter Creek	14%
Montana	**64%**
Upper Tongue	33%
Hanging Woman Creek	3%
Wyoming/Montana	**36%**




Tongue River
Model Schematic
TR @ Miles City
T&Y Canal
(negative
point source)
TR @ T&Y Canal
TR @ Brandenberg
TR @ Birney
Pumpkin Creek
(inflow file)
Otter Creek
(inflow file)
TR @ Reservoir
(inflow file)
Hanging Woman
Creek (inflow file)
N
0 5 10 20
Miles

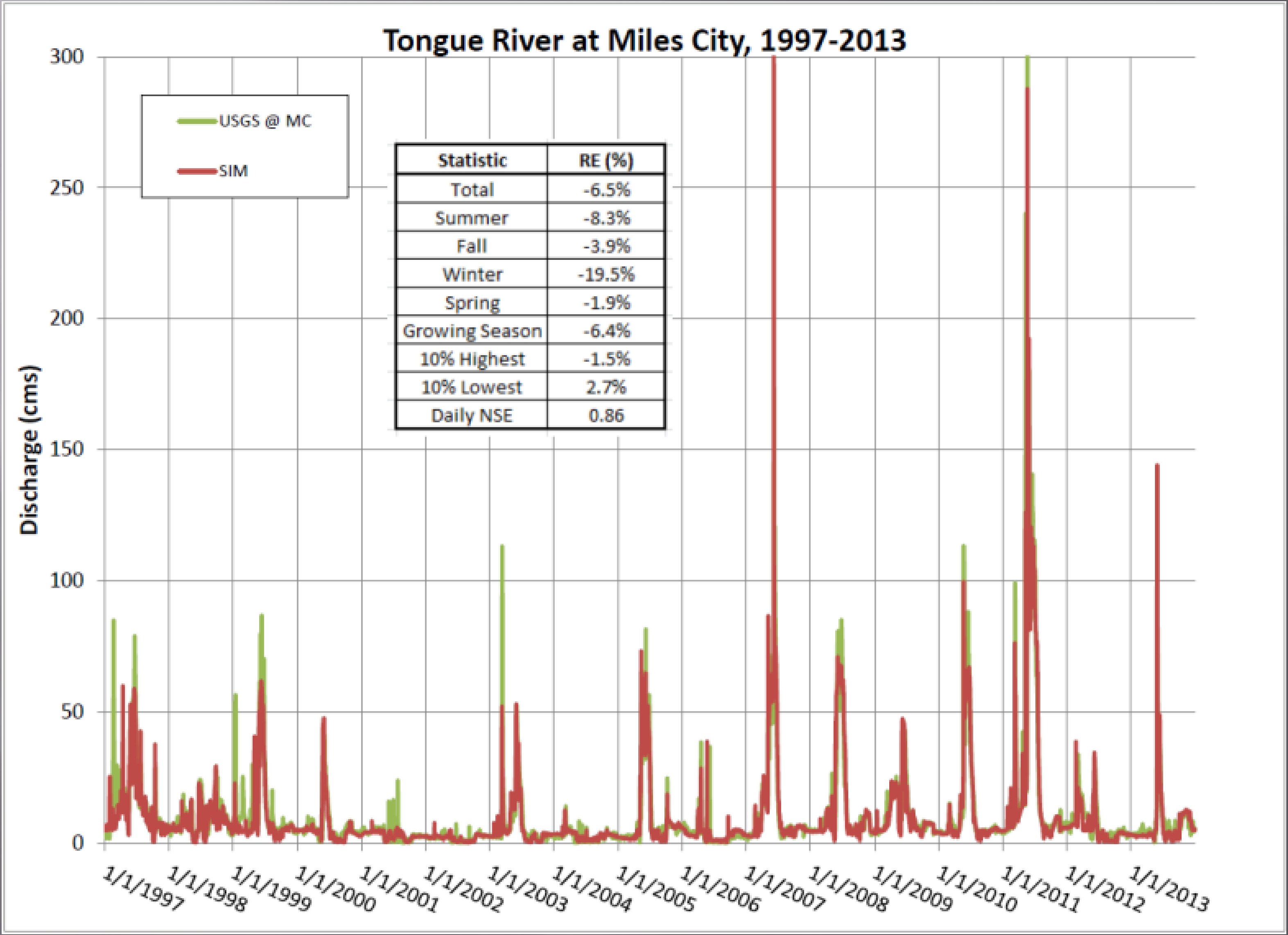
SWAT Model

SWAT - Hydrology



Statistic	RE (%)
Total	2.1%
Summer	-1.5%
Fall	-3.6%
Winter	-11.6%
Spring	15.2%
Growing Season	5.7%
10% Highest	8.9%
10% Lowest	-7.4%
Daily NSE	0.85

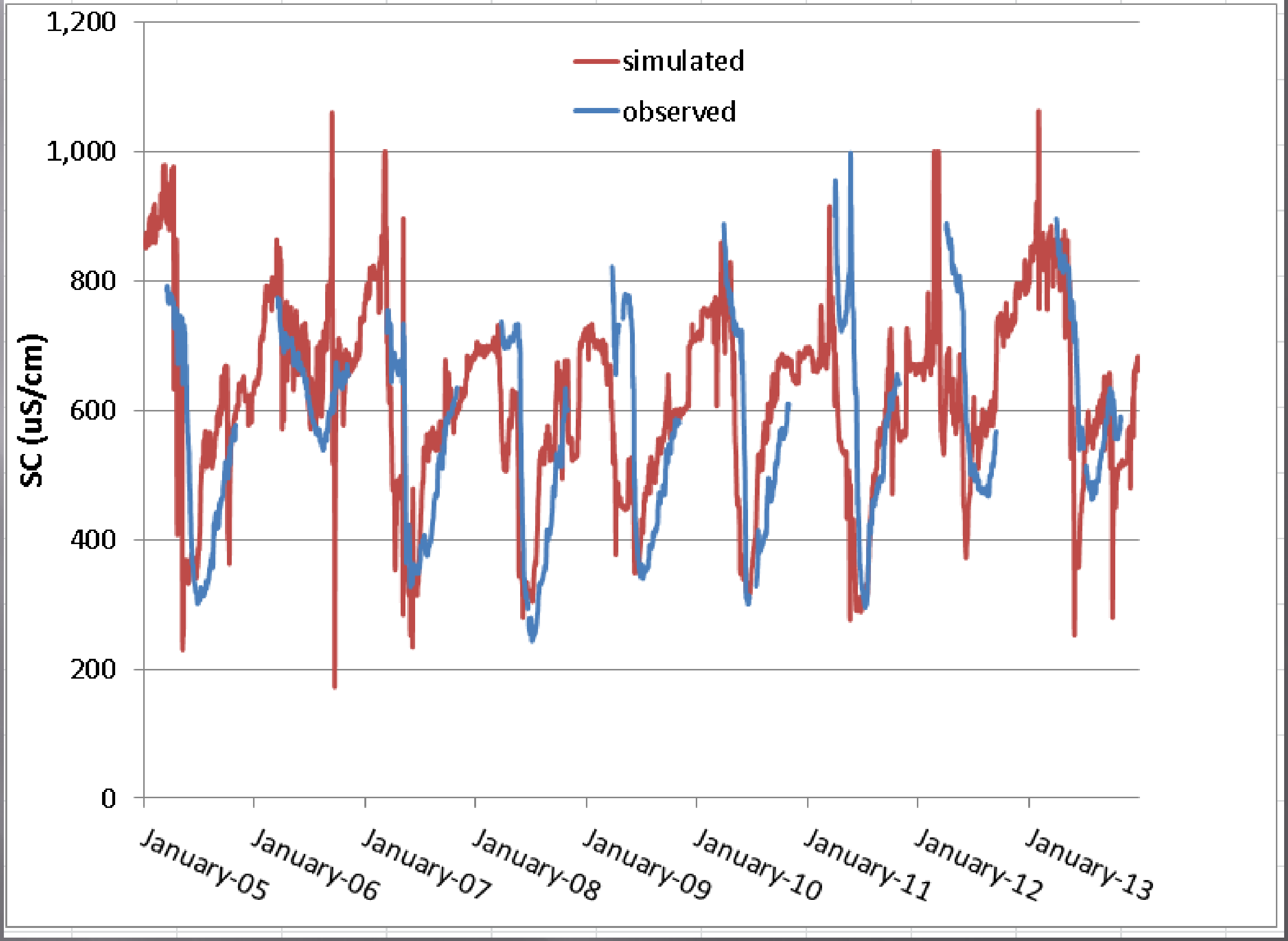
SWAT - Hydrology



Statistic	RE (%)
Total	-6.5%
Summer	-8.3%
Fall	-3.9%
Winter	-19.5%
Spring	-1.9%
Growing Season	-6.4%
10% Highest	-1.5%
10% Lowest	2.7%
Daily NSE	0.86

SWAT – Salinity Calibration

- Tongue River at Birney, 2005-2013



Scenario Development

- We have a model that we believe represents existing conditions, we can go ahead and start playing "what if?" scenarios.
- What if there were no CBM wells in Wyoming?
- What if there were no agriculture in Montana?
- What if Decker didn't have a mixing zone (i.e. discharged at the standard)?
- To do all of this, we need to understand our sources!

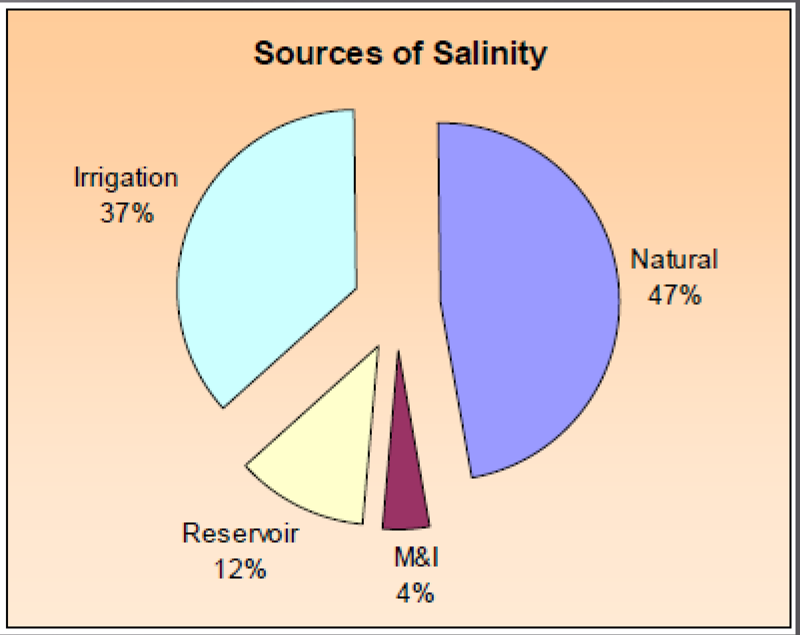
Goal: Achieve our water quality standards!

Source Assessment (Existing Loading)

- Natural
- CBM
- Coal Mines
- Agriculture
- Other (point sources, sediments, seeps/springs, etc.)

The largest contributor of salt in the watershed is nature

- The region's unique geology, size, and climate mean that salts are a natural part of the system.
- Example: Colorado River:
  - 243,000 square miles
  - 5.5 million irrigated acres
  - Drinking water for 37 million people.

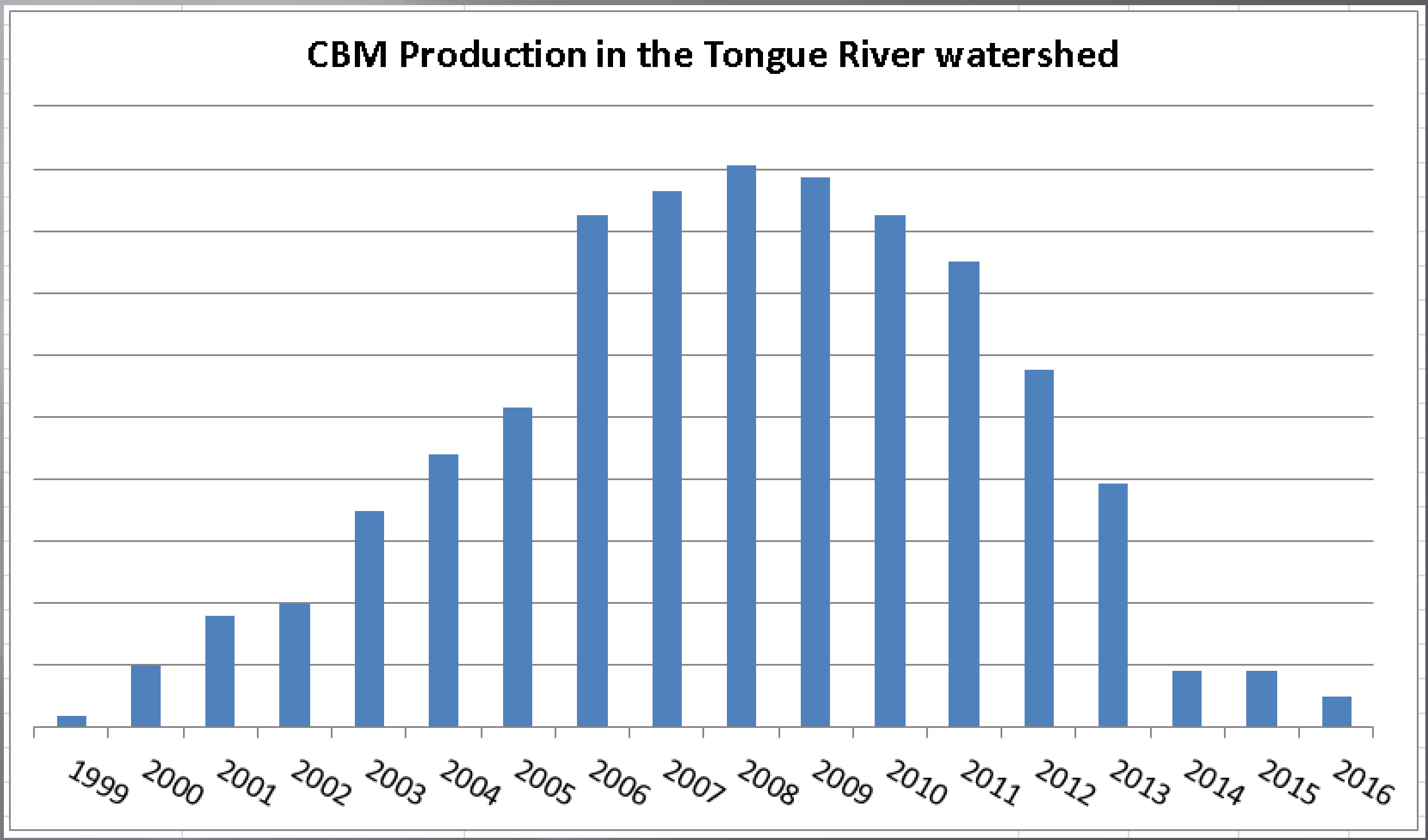


Source: Bureau of Reclamation, 2013

Coal Bed Methane

- Coal bed methane produces water typically higher in EC and SAR than surface water.
- For both Montana and Wyoming, production records (locations, amounts of water, some water quality).
- These are (for the most part) already in the existing model for the years they produced.
- For CBM scenarios, can remove these point sources from the model.

Coal Bed Methane



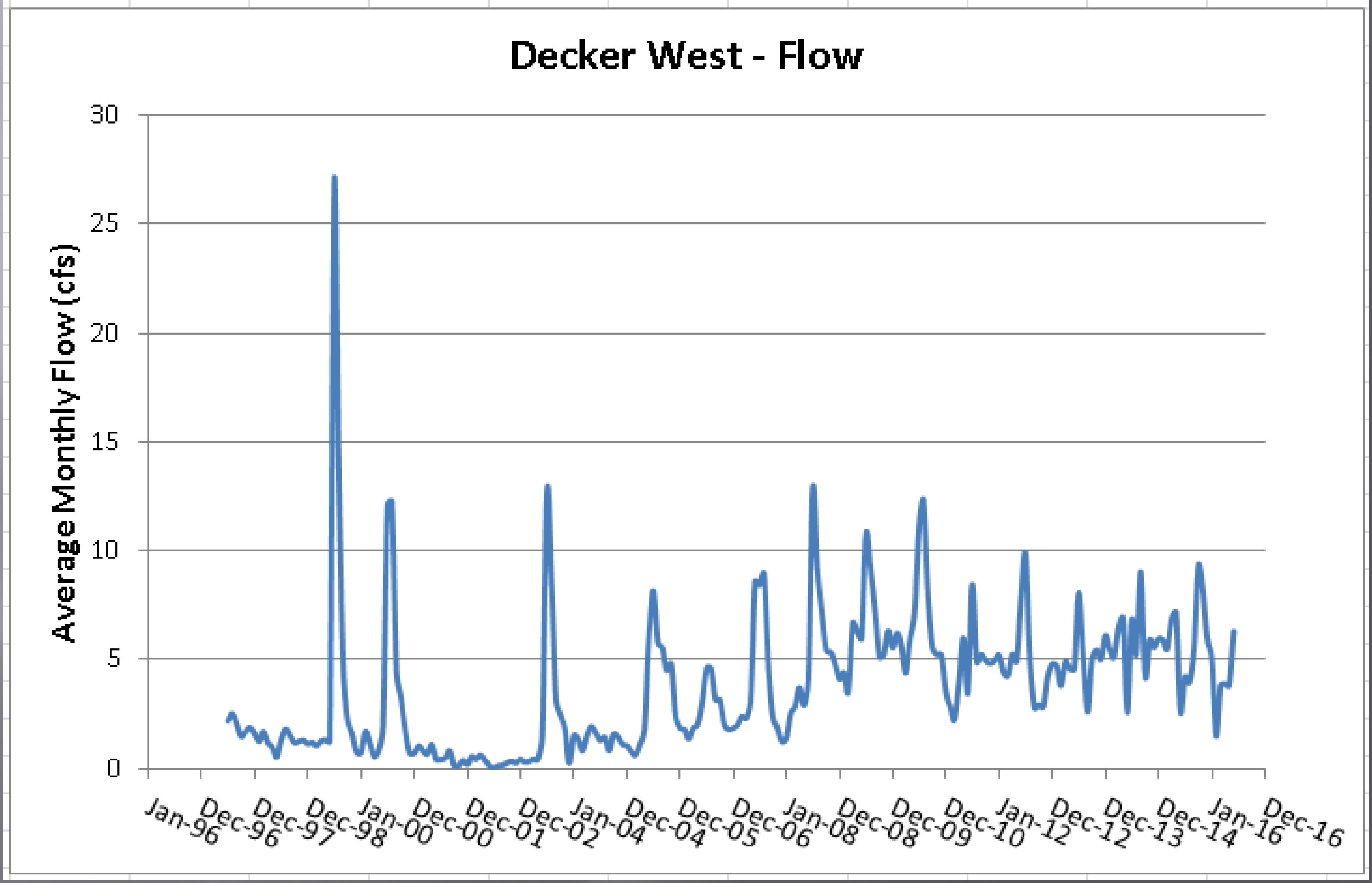
Coal Bed Methane – Potential Scenarios

- Remove all CBM from watershed
- Lower permit limits for CBM in watershed (Montana or Wyoming, or both)
- Increase CBM development in watershed

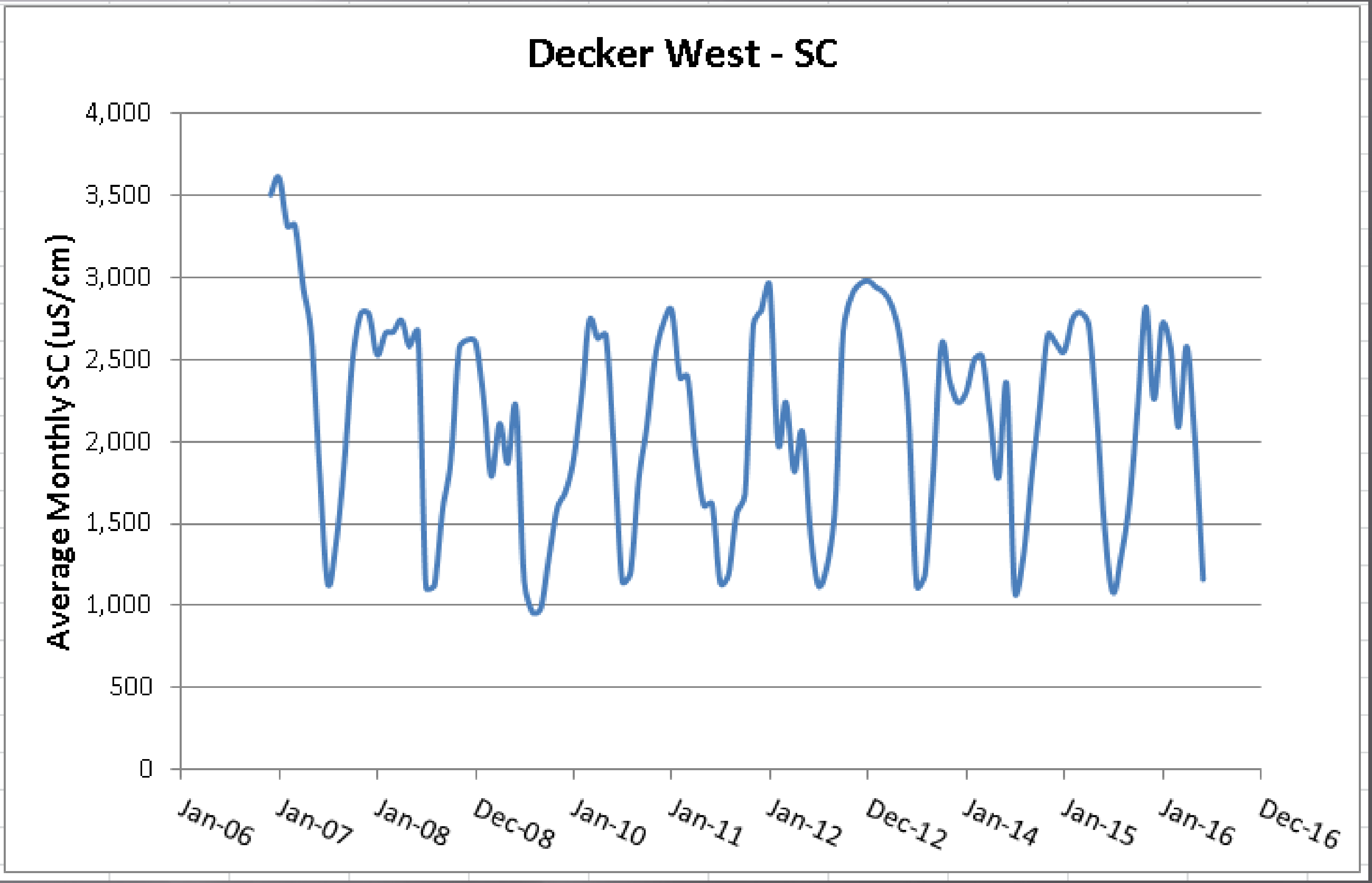
Coal Mines

- Coal mines may dewater by pumping into receiving waters, usually higher EC/SAR values.
- Some coal mines are "dry" and only dewater during extreme runoff events (Spring Creek).
- Some dewater almost constantly (Decker).
- Discharge data including flow, SC, and SAR from 2004-present.
- For coal mine scenarios, we simply remove point source from model.

Coal Mines


Decker West - Flow
Average Monthly Flow (cfs)
30
25
20
15
10
5
0
Jan-96
Dec-96
Dec-97
Dec-98
Jan-00
Dec-00
Dec-01
Dec-02
Jan-04
Dec-04
Dec-05
Dec-06
Jan-08
Dec-08
Dec-09
Dec-10
Jan-12
Dec-12
Dec-13
Dec-14
Jan-16
Dec-16

Coal Mines



Decker West - SC
Average Monthly SC (uS/cm)
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Jan-06
Jan-07
Jan-08
Dec-08
Jan-10
Jan-11
Jan-12
Dec-12
Jan-14
Jan-15
Jan-16
Dec-16

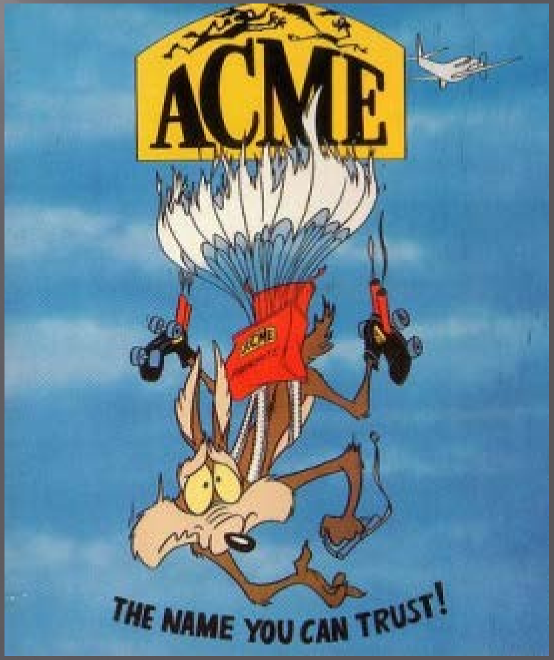
Coal Mines – Potential Scenarios

- Remove all coal mines from watershed
- Lower permit limits for coal mines in watershed (Montana or Wyoming, or both)
- Add a new coal mine point source in watershed

Haerwusu coal mine, China

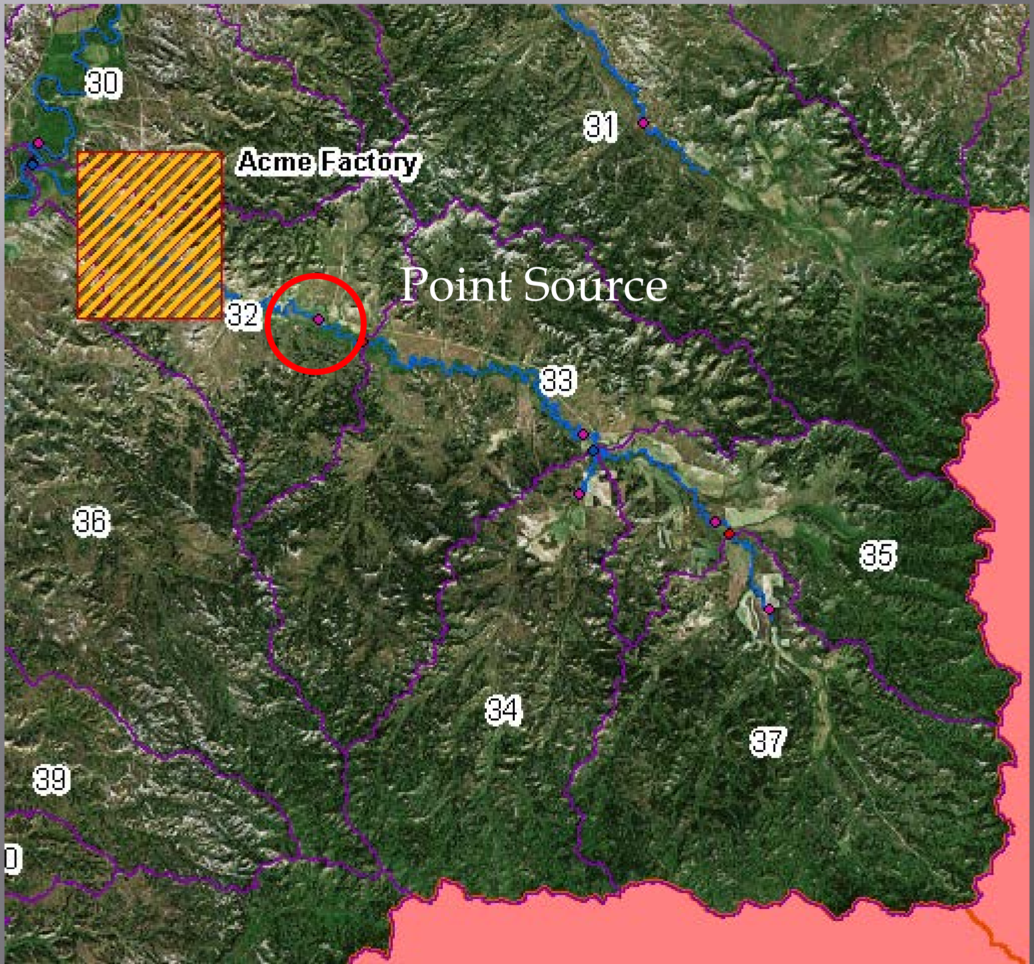
Example: “Acme Factory”

- Opens in 2005.
- Continuous discharge, 10 cfs at 3,000 µS/cm.
- Closes in 2010.



Acme Factory

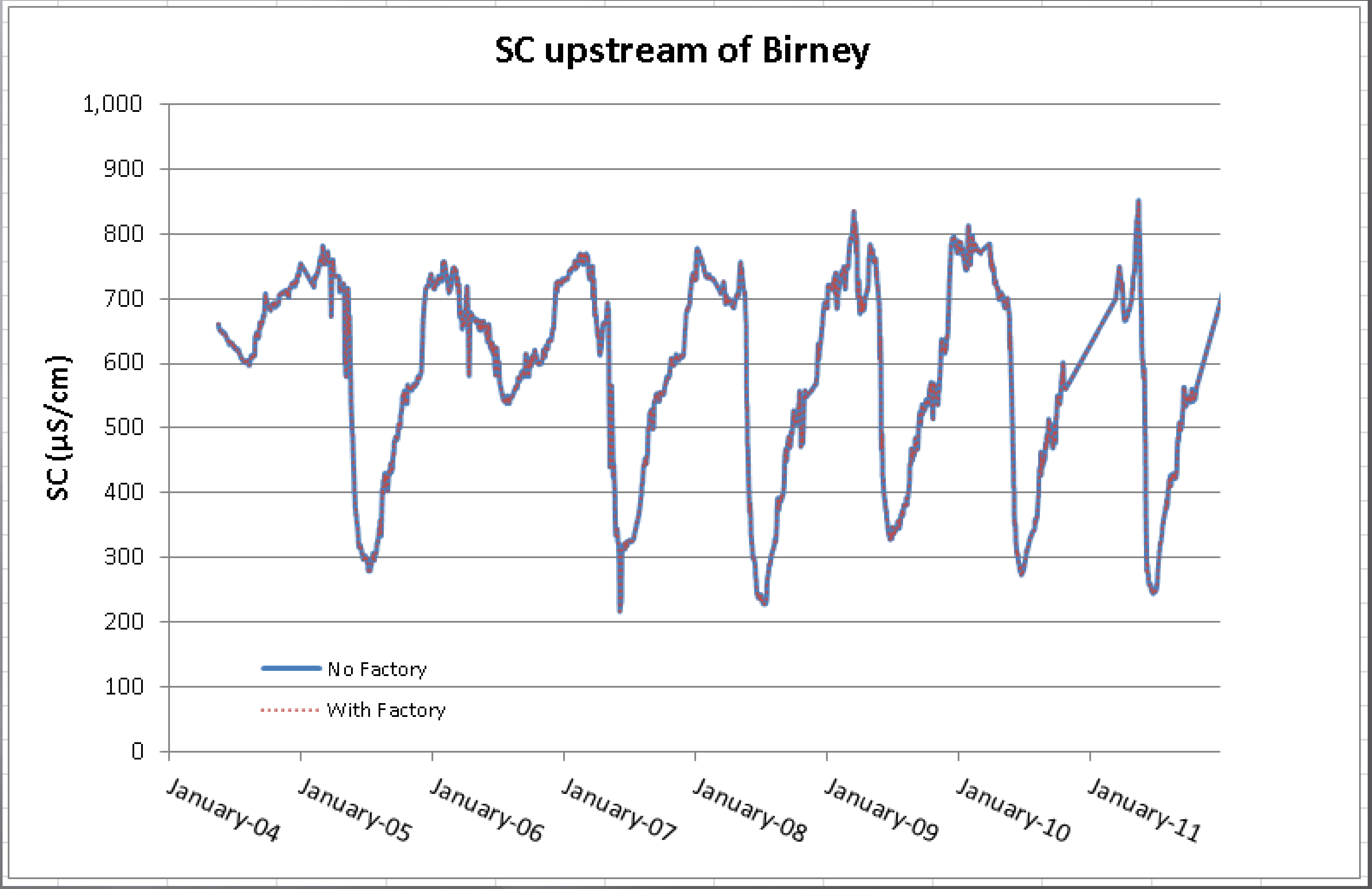
- Add to the model as a point source.



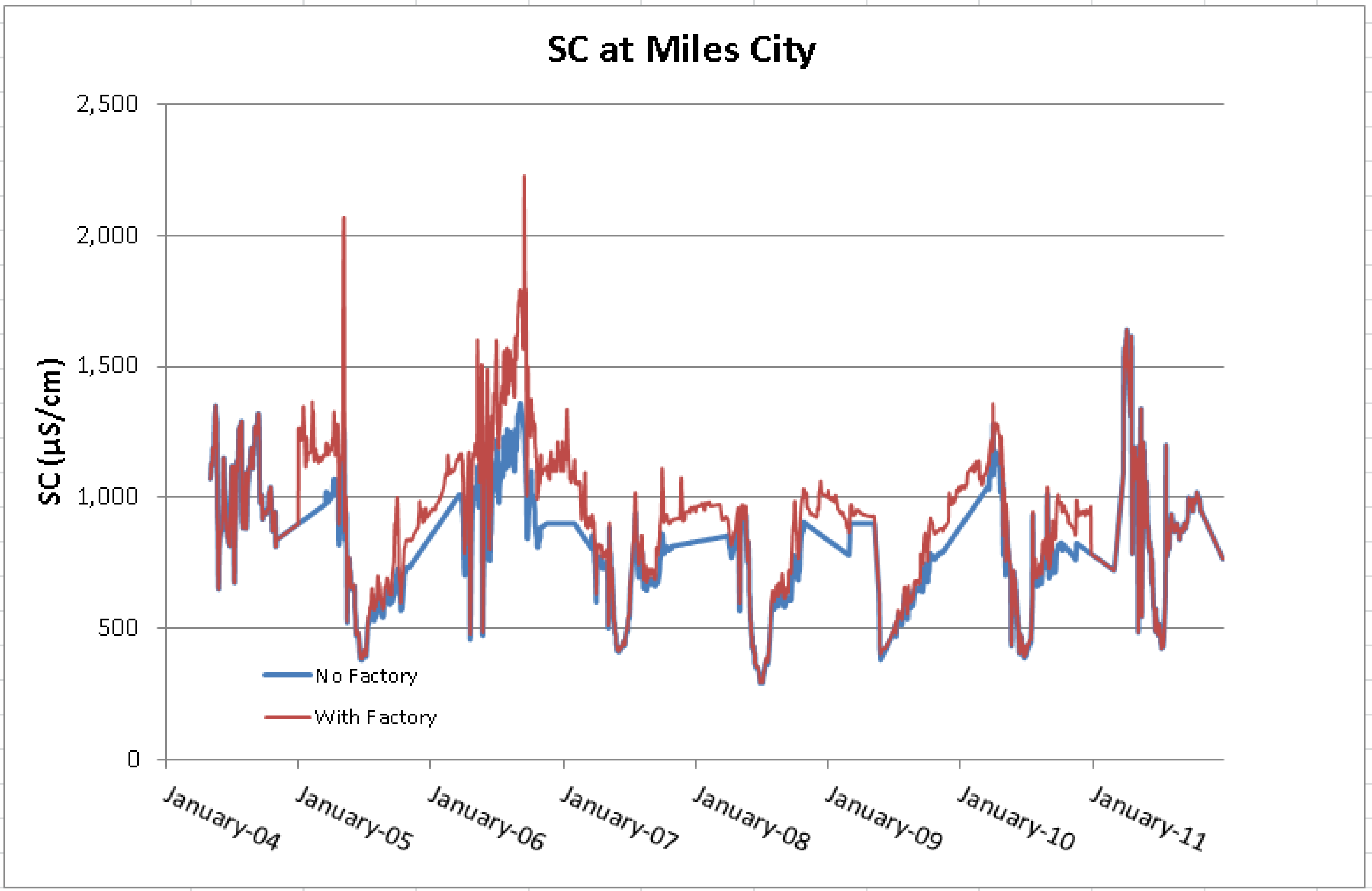
- Convert EC to TDS using previously established relationships
- Convert TDS and flow to kg/day salt
- Input water load and salt into the model

Acme Factory - Results

Acme Factory - Results



Acme Factory - Results



Irrigation

- Irrigation affects salt concentrations in two ways:
  - Flushing naturally occurring salts out of the soil profile and into the stream
  - Plants (evaporation) use water but leave salts, concentrating salts
- End result is higher salt concentrations in irrigation return flows (surface, soil, groundwater).
- We have estimates of irrigated land area, and return flow salt concentrations.
- To remove irrigation:
  - adjust salt concentrations
  - stop applying irrigation water.

Diversions

- Discussed at last meeting – most (all) of these diversions are no longer being used.
- Ditches discussed:
  - 4D Ditch
  - Ball Ranch East Ditch
  - Brown Cattle Co Ditch
  - F.L. Ditch
  - Horton Ditch
  - Quarter Circle U Ditch
  - SH Ditch

Irrigation – Potential Scenarios

- Remove all irrigation from watershed.
- Modify irrigation practices in watershed.
- Increase irrigation in watershed (unused water rights).

Springs/Saline Seeps

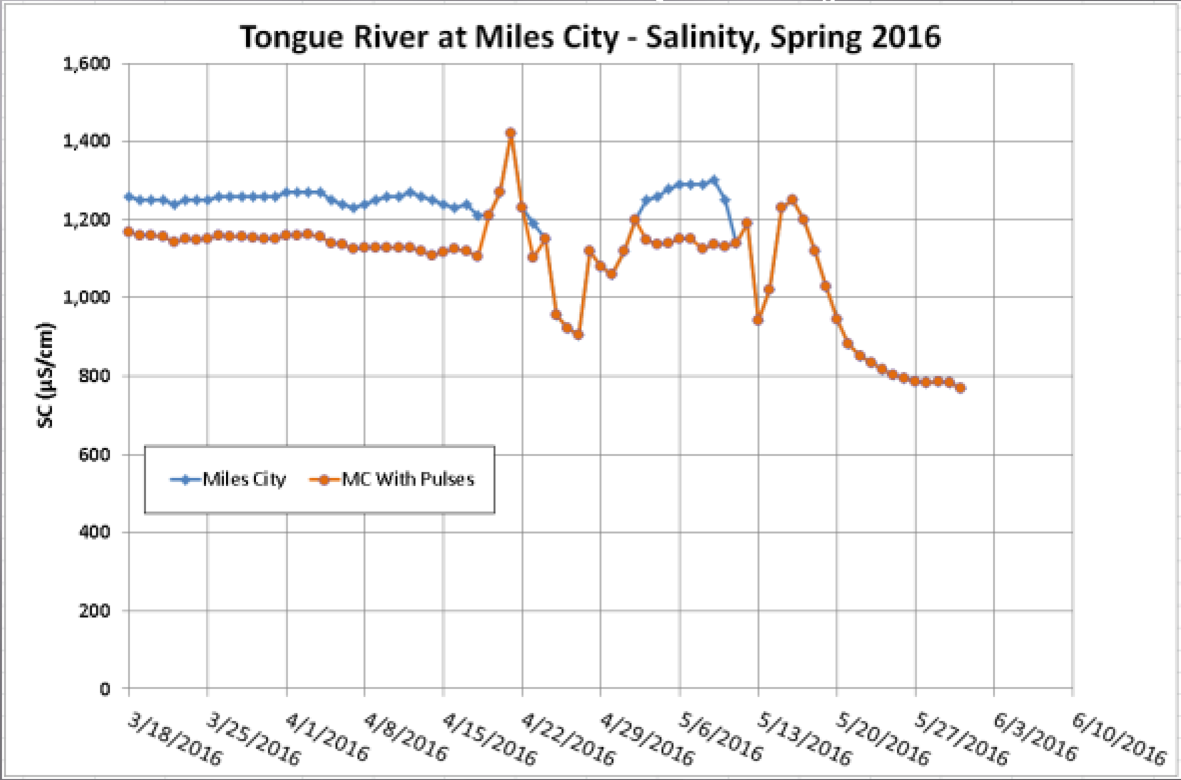
- Springs are common in certain portions of the watershed.
  - Springs are typically saline.
- Saline seeps are often a result of irrigation water infiltrating past the root zone.
- Both of these are small but can have an effect on salinity of streams and rivers.

Livestock

- Livestock have an effect on salt concentrations
  - Cattle tend to increase sediment load along stream channels.
  - Sediments in the Tongue River watershed are high in salts, so any increased sediment load can increase salt load.
- However, in this model we have assumed livestock play a minor role.

Tongue River Reservoir Operations

- TRR is mainly managed for water quantity
- Small changes in operations could have large effects on water quality.

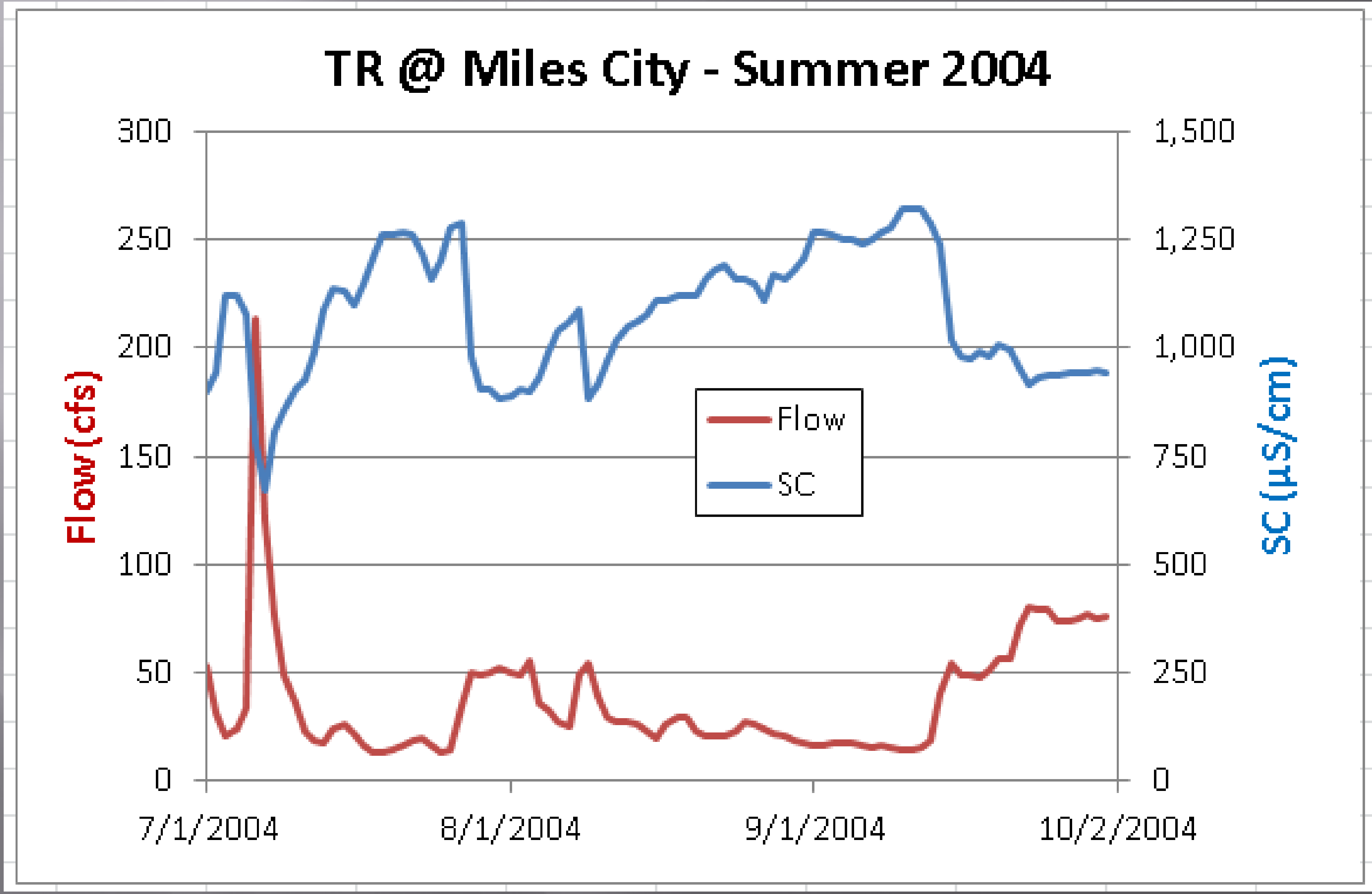


- 25 cfs pulse when flow drops below 125 cfs at MC gage.
- Cost: 2,000 acre-feet of water

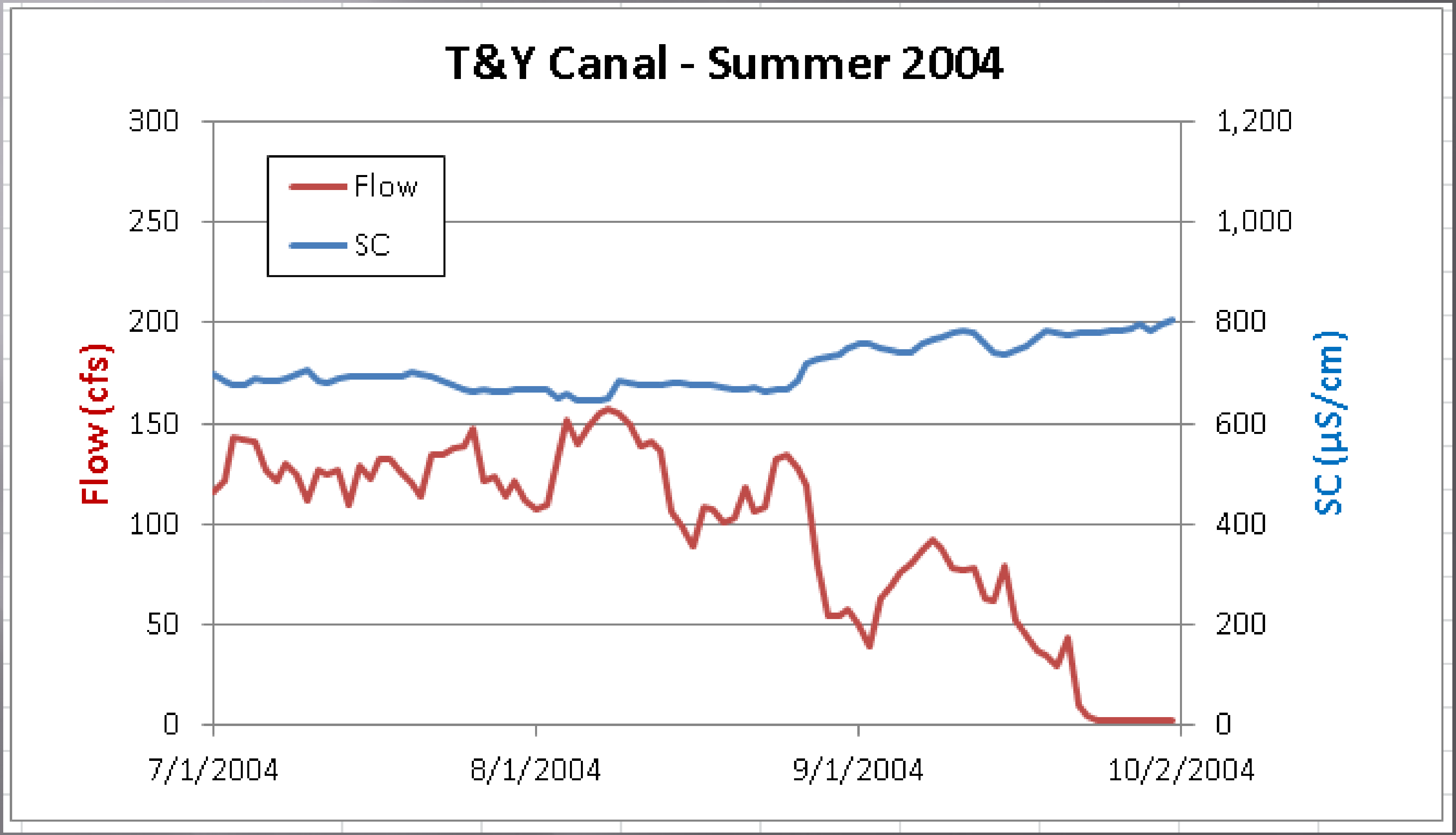
T&Y Canal Operations

- Some summers, T&Y Canal withdraws approximately 80% or more of the flow in the Tongue River.
- The river below T&Y is heavily influenced by Pumpkin Creek/prairie runoff at these times.

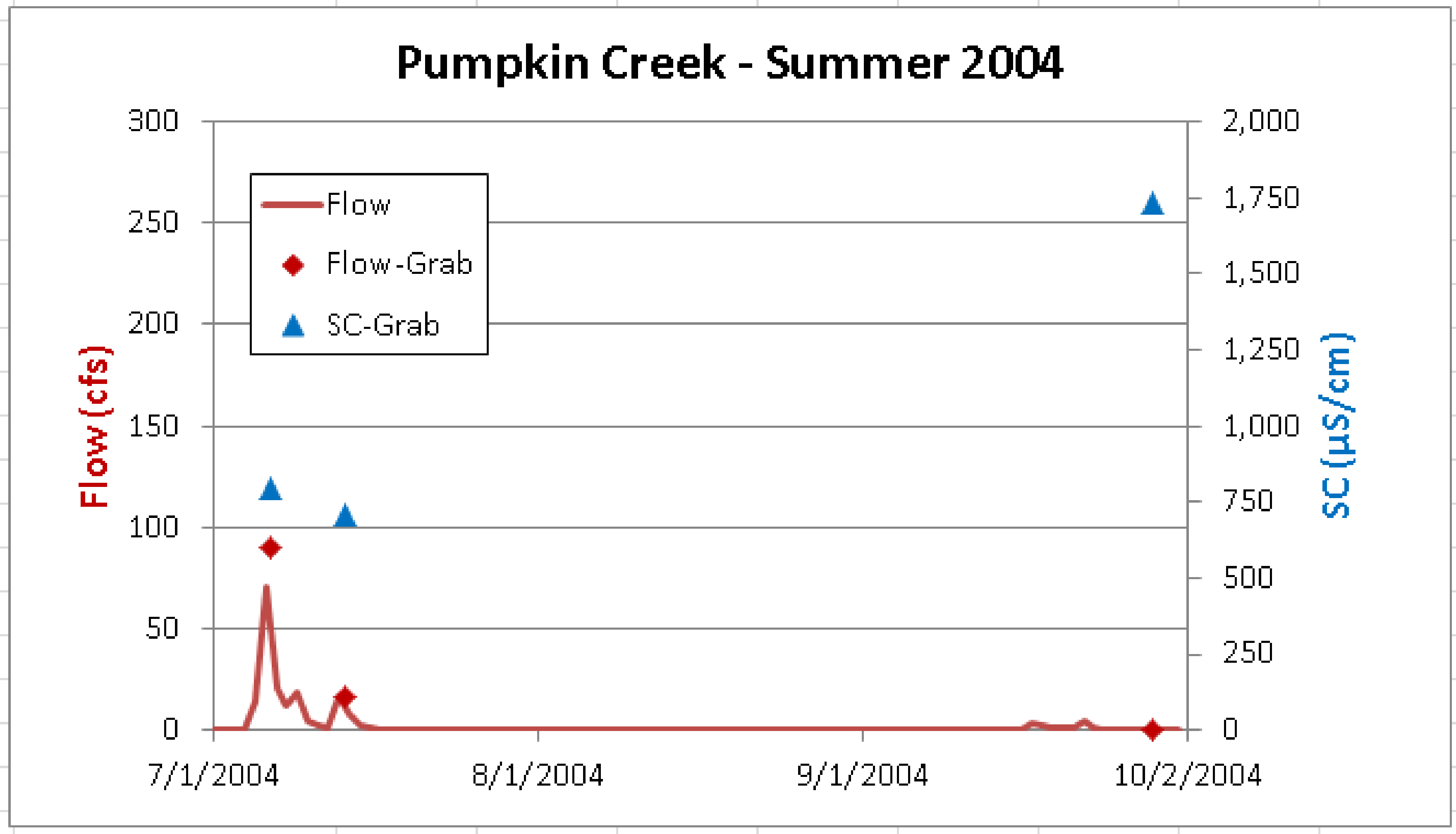
T&Y Canal Operations



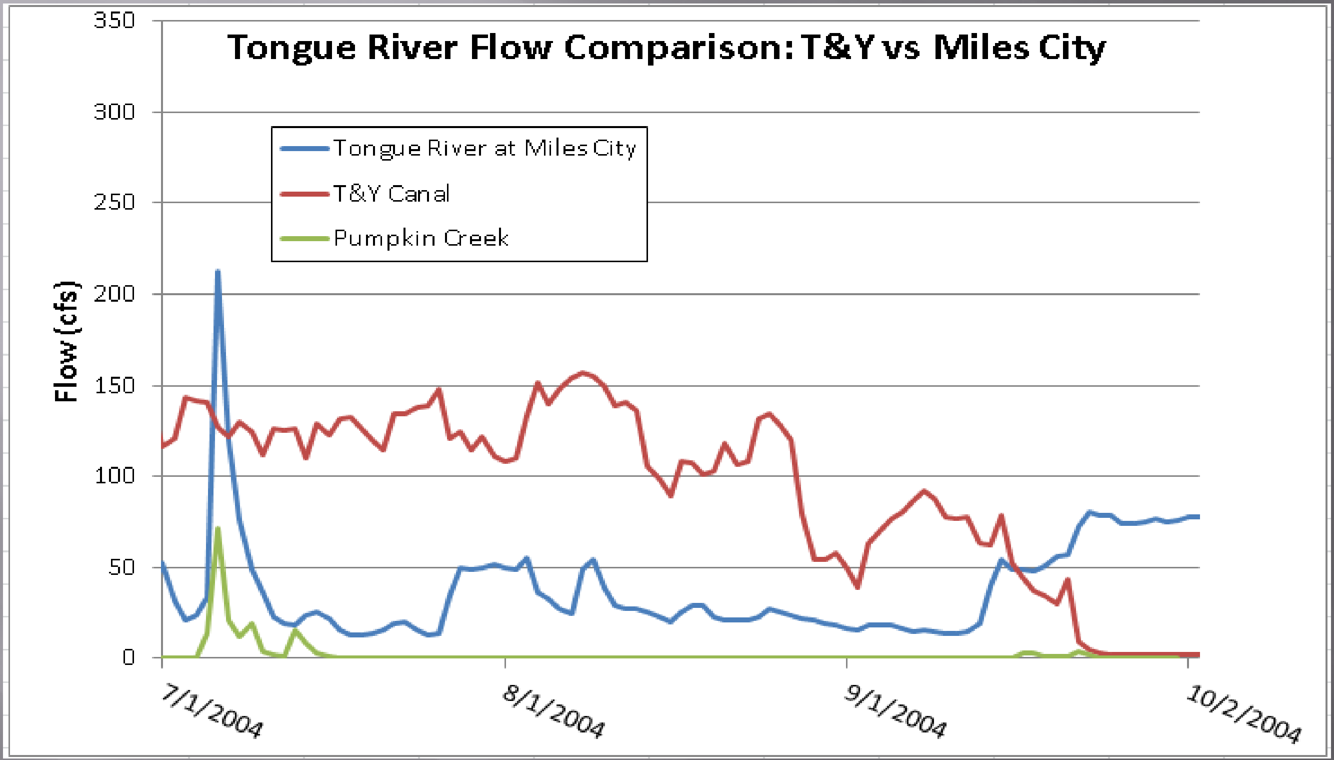
T&Y Canal Operations



T&Y Canal Operations



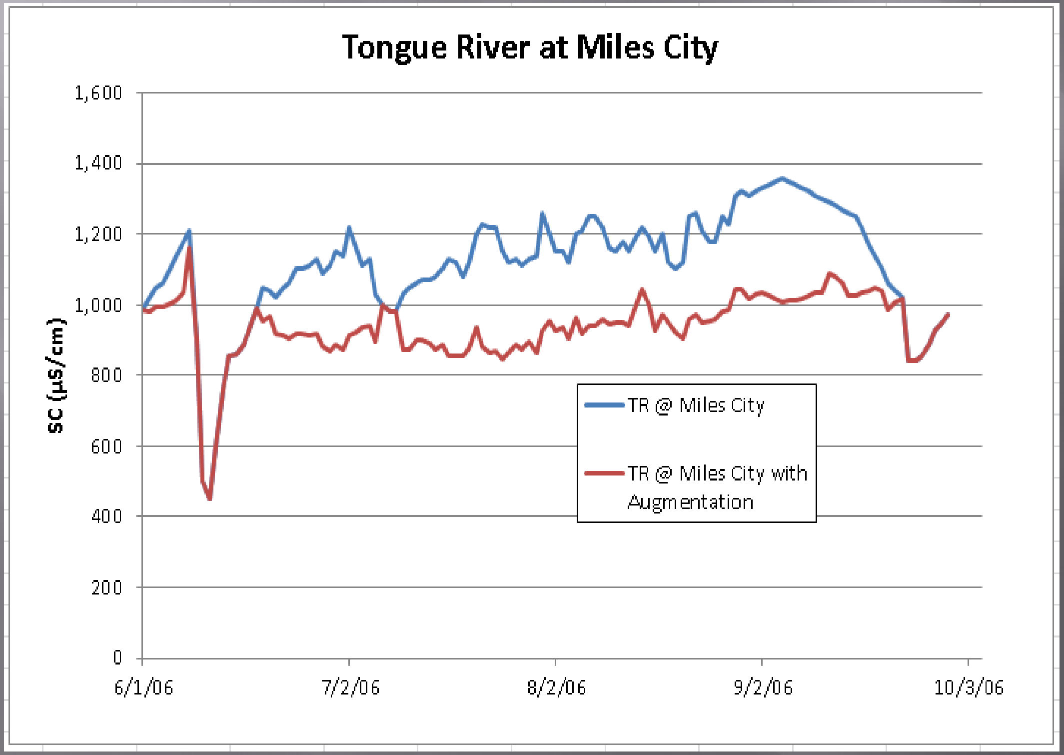
T&Y Canal Operations



- T&Y operations have large effect on lower Tongue

T&Y Canal Operations - Example

- Example: When SC at Miles City exceeds 1,000 µS/cm, reduce T&Y withdrawal by 16% for that day only.



- Reduce daily exceedance by 70%, monthly exceedance from 3 months to none.
- Total reduction: about 14% of T&Y summer withdrawal.

Future Scenario Summary

- Natural/Historical
  - Remove all human sources (dam?)
- Industrial
  - Remove industrial sources (coal mines, CBM, WWTPs, etc.)
  - Modify industrial practices or permit limits
  - Future mines or other activities
- Agricultural
  - Remove agricultural sources
  - Modify agricultural practices
  - Modify TRR dam and T&Y canal operations
- Others?

Next Project Steps

- Run model scenarios
  - **Deadline to submit scenarios: October 31, 2016**
- Discuss results with stakeholders
- Determine solutions/routes for achieving water quality standards

Questions?