Data Collection for QUAL2Kw Model Population and Calibration

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MODEL CALIBRATION BACKGROUND

➢ Purpose: Models attempt to simulate water quality processes in order to support decision making

   "*Essentially, all models are wrong, but some are useful*"
   George E.P. Box

➢ Model Applications

   1) Establishing Numeric Criteria for Water Quality Standards
   2) Water Quality Based Effluent Limits (WQBELs) for Permits
   3) Total Maximum Daily Loads

➢ Model calibration

   • Builds confidence in application of model
   • Calibration involves adjusting rate parameters so that simulation results most closely match observations

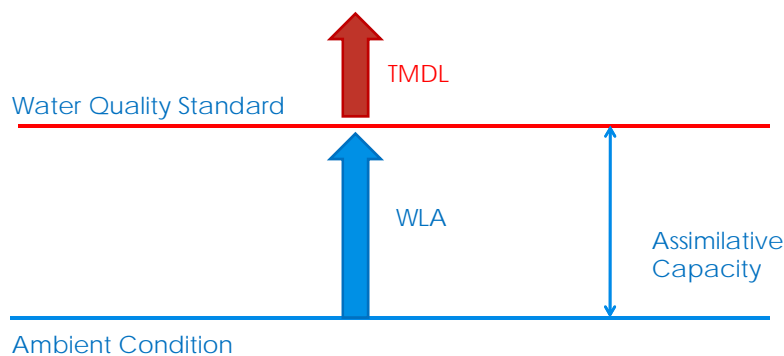# APPLICATION TO NUTRIENT CRITERIA

- UAC R317-2-14 Numeric Criteria for Protection of Aquatic Life
  - Dissolved Oxygen
  - Ammonia (toxicity)
  - Indicators
    - BOD 5 mg/L
    - Total Phosphorus
      0.05 mg/L rivers/streams; 0.025 mg/L lakes/reservoirs
    - Nitrate 4 mg/L
  - pH 6.5 – 9.0
- Ecological and modeling study initiated in 2010 to support development of numeric nutrient criteria
  - Utah State University – Dr. Bethany Neilson
  - Build and calibrate 9 models with POTW discharges

Slide 3

APPLICATION TO WASTELOAD ANALYSES

- Current Dissolved Oxygen Criteria
  - BOD
  - Nutrients: nitrogen and phosphorus
  - DO

TMDL

Water Quality Standard

WLA

Assimilative Capacity
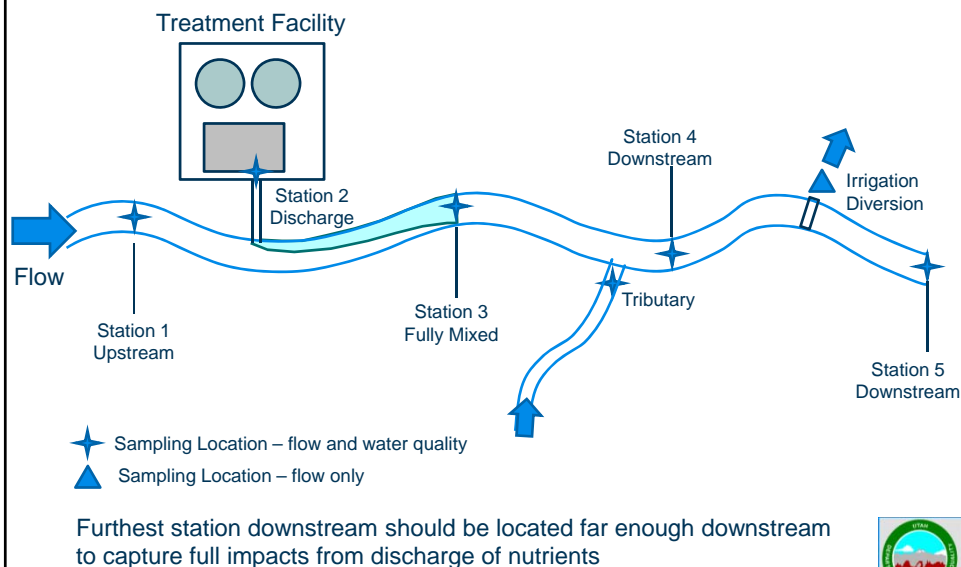
Ambient Condition

Slide 4

DATA COLLECTION FOR QUAL2KW

- Synoptic survey for model calibration
  - Summer critical condition
  - One week deployment of data sondes
  - Collection of physical, chemical, biological and meteorolgical data
- Voluntary support from POTW
  - Additional effluent monitoring
  - Collection of validation data set
- Standard Operating Procedures Manual

Slide 5

SYNOPTIC SURVEY SCHEMATIC

Furthest station downstream should be located far enough downstream to capture full impacts from discharge of nutrients

Slide 6

WATER QUALITY DATA

Grab Samples
- Total Suspended Solids (TSS)
- Volatile Suspended Solids (VSS)
- Chlorophyll a
  - Water Column (Phytoplankton)
  - Benthic (Periphyton)
- Soluble Carbonaceous Biochemical Oxygen Demand (SCBOD)
- Nutrients
  - Total Kjeldahl Nitrogen (TKN)
  - Ammonia
  - Nitrate/Nitrite
  - Total Phosphorus
  - Orthophosphate
- Alkalinity

Data Sondes
- Temperature
- Specific Conductance
- Dissolved Oxygen
- pH
- Chlorophyll a

Slide 7

MODEL INPUT VS. MEASURED

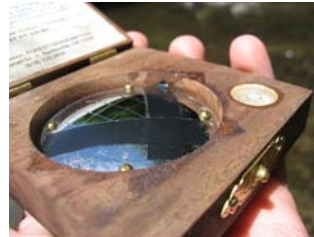| Variable	Symbol	Units*	Measure
Conductivity	s_1, s_2	μmhos	Direct
Inorganic suspended solids	$m_{i,1}, m_{i,2}$	mgD/L	TSS – VSS
Dissolved oxygen	o_1, o_2	mgO_2/L	Direct
Slow-reacting CBOD	$c_{s,1}, c_{s,2}$	mg O_2/L	Direct
Fast-reacting CBOD	$c_{f,1}, c_{f,2}$	mg O_2/L	Direct
Organic nitrogen	$n_{o,1}, n_{o,2}$	μgN/L	TKN – NH4 - Algae
Ammonia nitrogen	$n_{a,1}, n_{a,2}$	μgN/L	Direct
Nitrate nitrogen	$n_{n,1}, n_{n,2}$	μgN/L	Direct
Organic phosphorus	$p_{o,1}, p_{o,2}$	μgP/L	TP – PO4 - Algae
Inorganic phosphorus	$p_{i,1}, p_{i,2}$	μgP/L	Direct
Phytoplankton	$a_{p,1}, a_{p,2}$	μgA/L	Direct
Detritus	$m_{o,1}, m_{o,2}$	mgD/L	VSS - Algae
Pathogen	x_1, x_2	cfu/100 mL	NA
Generic constituent	gen_1, gen_2	user defined	NA
Alkalinity	Alk_1, Alk_2	$mgCaCO_3$/L	Direct
Total inorganic carbon	$c_{T,1}, c_{T,2}$	mole/L	pH
Bottom algae (a_b in the surface water layer)	a_b, a_h	gD/m^2	Direct

Slide 8

4

PHYSICAL DATA

Field Survey
- Flow Rate/Velocity
- Width
- Bank Height
- Side Slope
- Bottom Channel Slope
- Riparian Shading
- Substrate Characterization

Slide 9

METEOROLOGICAL DATA

- Weather Station
  - Air Temperature
  - Dew Point Temperature
  - Wind Speed
  - Solar Radiation
- Photosynthetically Active Radiation

Slide 10

MODEL CALIBRATION

- ➢ Model calibration
  - Adjust model parameters such that simulated results most closely match observed data set
- ➢ Model validation
  - Evaluate model performance using another observed data set without adjusting model parameters
- ➢ Ideally would collect both a calibration and validation data set
  - Due to resource limitations, typically will only have a calibration data set
  - Requesting support from POTWs to collect validation data set
  - May collect validation data set during following permit renewal
- ➢ DWQ maintaining database of model parameters used in calibrated Utah models
  - Reference for building models without calibration data

Slide 11

MODEL CALIBRATION PROCEDURES

1) Estimate whole stream metabolism
   - a) Estimate reaeration, respiration, primary production, net ecosystem metabolism
   - b) Methods: nighttime regression, approximate delta method (peak-lag), dual-probe
2) Manually calibrate hydraulics
   - a) Flow, travel time, velocity, depth, reaeration
3) Determine need for prescribed SOD from whole stream metabolism
4) Autocalibrate model water quality parameters
   - a) Genetic algorithm – 100 populations, 100 generations (1,000 simulations with mutations)
   - b) Acceptable range for parameters from literature and Dr. Chapra

Slide 12

APPLICATION TO WASTELOADS

1) QUAL2Kw applied only to POTWs and nutrient-related discharges to rivers and streams
2) Due to limited resources and short duration of critical period, QUAL2Kw will <u>not</u> be calibrated for all models
3) Prioritization of data collection each year based on several factors:
   - ➢ Size and potential impact of discharge
   - ➢ Beneficial use of the receiving water
   - ➢ Accessibility of site
   - ➢ Difficulty of quantifying inflows and outflows to receiving reach

Slide 13

TREATMENT SURVEY SITES

Stream	Facility	Treatment Type
Box Elder Creek	Brigham City	Oxidation Ditch
Little Bear River	Wellsville	Discharging Lagoon
Malad River	Tremonton	Activated Sludge (STM Aerotor)
Price River	Price	Hybrid – Trickling Filter/Activated Sludge
San Pitch River	Fairview	Membrane Bioreactor
San Pitch River	Moroni	Membrane Bioreactor
Silver Creek	Silver Creek	Oxidation Ditch
Spanish Fork River	Spanish Fork	Hybrid – Parallel Activated Sludge (STM Aerotor) and Trickling Filter
Weber River	Oakley	Membrane Bioreactor

Slide 14

7

QUAL2Kw MODELS

DISCHARGER	RECEIVING WATER	STATUS
South Davis S., Central Valley South Valley, Jordan Basin	Jordan River	TMDL
Provo	Mill Race	Complete – no calibration
Corinne	Bear River	Complete – no calibration
Bear River City	Malad River	Complete – no calibration
EA Miller/Hyrum	Spring Creek	Complete – limited calibration
Brigham City	Box Elder Creek	Preliminary WQBELs
Oakley	Weber River	Complete
Magna	Kersey Creek	Preliminary WQBELs – no calibration
Snyderville Basin	Silver Creek	Calibrated model
Logan	Swift Slough	Preliminary WQBELs
Wellsville	Little Bear River	Calibrated model
Price	Price River	Calibrated model
Spanish Fork	Spanish Fork River	Calibrated model
Tremonton	Malad River	Data Collected
Fairview	San Pitch River	Calibrated model
Moroni	San Pitch River	Calibrated model

Slide 15

RESOURCES

➢ *Wasteload Analysis Guidance Manual*
➢ *QUAL2Kw Data Collection Standard Operating Procedures*
➢ *Whole Stream Metabolism Estimation Guidance Manual*
➢ *USU Nutrient Modeling Report*

➢ Training
  ▪ QUAL2Kw workshop with academic expert?
  ▪ Utah specific WLA training

Slide 16