Demonstration of the Kiliszek Water Quality Indices (KWQI) Model: KWQI Calculation Utilizing Water Quality Data from a Small Agricultural Watershed

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INTRODUCTION

- In 2001, developed UD Experimental Watershed (UDEW)
- Piedmont & Coastal Plain Fall Line delineates 2 sub-watersheds.
- Coastal Plain - Cool Run and its tributaries with head waters on UD research farm.
- Classified as impaired with nutrients, bacteria, sediments and other water quality
- In 2004, The Cool Run Wetland Restoration Project that designed and implemented improved nonpoint source best management practices (BMPs) to protect and restore water quality of the Cool Run and reduce total pollutant loads.
- 2006 to 2011, Cool Run monitored for nutrients, metals, solids and bacteria.
- Assessment of the impact of BMPs on Cool Run water quality
- Resulted in production of vast quantities of water quality monitoring data describing many different parameters.
- 20 parameters * 8 sites * monthly = >4320 quality variables
- Results can detect water quality criteria violations for individual constituents but fails to give a clear, condensed description of the actual stream health.
- Water Quality Indices (WQIs) reduce the massive amounts of data to a single, unit-less, numeric score.
- Researchers use WQIs to study trends in environmental quality
- WQI allow for a summation of parameter effects on the overall changes in stream water quality.

OBJECTIVES

- Develop Water Quality Indices (WQI) using DE criteria.
- Select parameters
- Develop sub-index equations
- Develop model to calculate indices
- Use KWQI Model to assess BMPs Impact on water quality of Cool Run

MODEL DEVELOPMENT

- Microsoft Excel Interface
- 3 main scenarios
- Predefined input parameters
- Predefined parameter sets
- Predefined automatic output data

USES OF MODEL

- Point to point comparison over time
- Trends at individual sites
- Estimation of trends for entire UD farm

AVAILABLE PARAMETERS

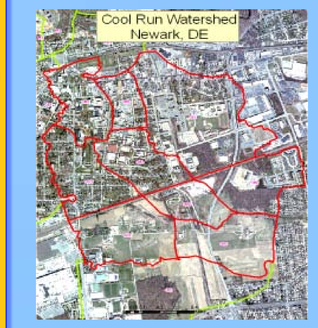
- Nutrients-NH3-N, NO3-N, TN, TP, OP
- Bacteria- Coliform bacteria
- Metals- Al, As, B, Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Se, Zn
- Oxygen demand- BOD, DO
- General Water Characteristics- Chlorophyll a, conductivity, pH, Temperature, TSS, TDS, Turbidity
- Other Chemical Compounds- cyanide, fluoride

PREDEFINED ANALYSIS

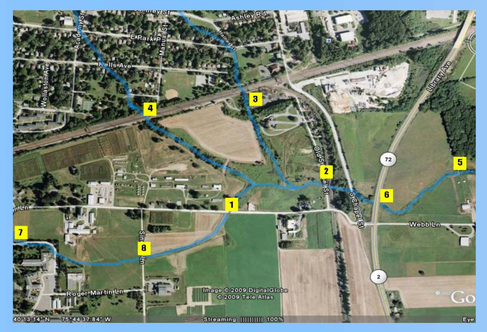
- Selected parameters important to specific BMPs
- Wetlands, Manure collection system, Riparian zones, basins

DEMONSTRATION

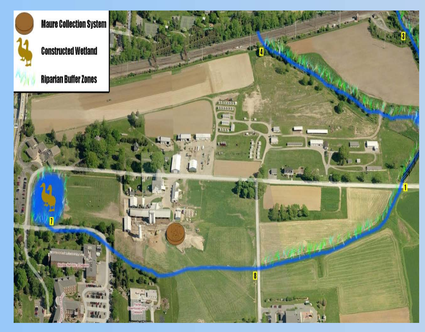
- Assess impact of manure collection system on Cool Run water quality
- Use Kiliszek Model to calculate KWQI
- Assess temporal changes in water quality
- Specifically N, P and bacteria



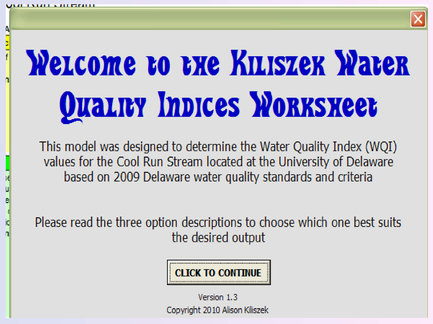
Cool Run Watershed of the White Clay Creek Wild & Scenic River; Christina River Basin; DE River Basin Influenced By Agricultural, Industrial & Urban Activities Headwaters Located Within Research Farm



Cool Run Tributary On The UD Research Farm And Its 8 Sample Sites Monitored 2006 to 2011



BMP Implementation: Wetlands, Stream Exclusion, Manure Collection, Stream Restoration, Stormwater Controls, Riparian Buffer Zones



Option 1 : Single Site Evaluation — **Click to use Option 1: Single Site Evaluation**

This option should be chosen when the evaluation of a single site from a specific sample collection date is desired.

Included in the Output:

List of each paramater concentration including units	Table of Subindex Rating Distribution
List of each paramater used in calculations	Table of KWQI Scale Values
List of each parameter with the Subindex Value	Table of KWQI Rating
List of each parameter with the Subindex Rating	Total KWQI Value
Plot of Subindex Rating Distribution	Total KWQI Rating
Plot of Subindex Values	Total Number of Parameters Used

Option 2 : Side-by-Side Evaluation — **Click to use Option 2: Side-by-Side Evaluation**

This option should be chosen for the following cases:

Case One : This option can be chosen when an upstream site is to be compared to a downstream site using the same parameter set; the percent difference compares the individual parameters.

Case Two : This option can be chosen when the difference over time for the same site is to be evaluated; the percent diference compares the individual parameters.

Included in the Output:

List of each paramater concentration including units	Percent Difference between Data Sets
List of each paramater used in calculations	Table of Subindex Rating Distribution
List of each parameter with the Subindex Value	Table of KWQI Scale Values
List of each parameter with the Subindex Rating	Table of KWQI Rating
Plot of Percent Difference	Total KWQI Value
Plot of Subindex Rating Distribution	Total KWQI Rating
Plot of Subindex Values	Total Number of Parameters Used

Option 3 : Spatial Evaluation — **Click to use Option 3: Spatial Estimation**

This option should be chosen for the following cases:

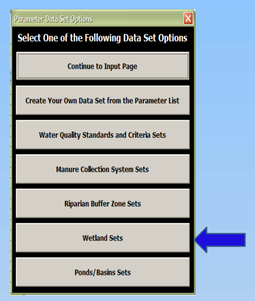
Case One : This option was designed to be used for the evaluation of any combination of the 8 sites. The overall KWQI values for the sites are then entered into a relative spatical plot of the UD NREC. Values for the stream between the sites are then interpolated and entered into the stream path. To have the spatial 3D plot function properly the flow values for Sites 1, 3, and 4 must be entered on the INPUT page. (3D Plot is an estimation of trends and needs Sites 1 - 6 to function properly.)

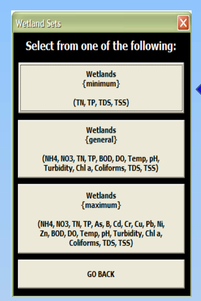
Case Two : This option was designed to be used for the evaluation of up to 8 sets of data using one parameter set. (3D Plot Not Applicable for Case Two)

Included in the Output:

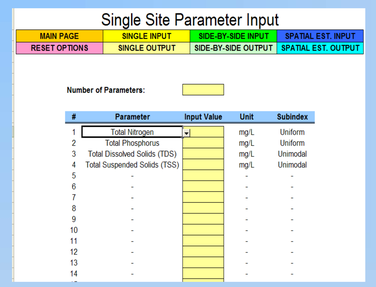
3D Spatial Estimation of WQI throughout the UD Farm	Table of Subindex Rating Distribution
List of each paramater concentration including units	Table of KWQI Scale Values
List of each paramater used in calculations	Table of KWQI Rating
List of each parameter with the Subindex Value	Total KWQI Value
List of each parameter with the Subindex Rating	Total KWQI Rating
Plot of Subindex Rating Distribution	Total Number of Parameters Used

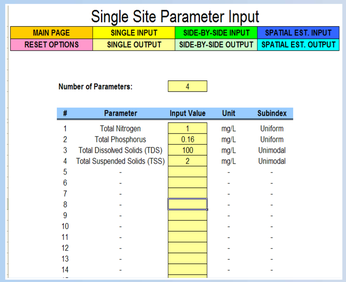
Model: Assessment Options

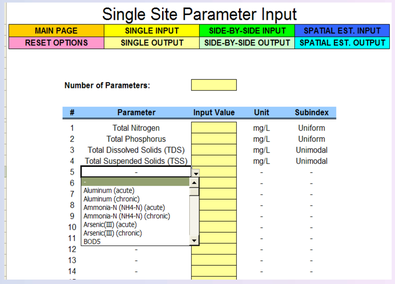




Model: Parameter Selection Wetlands; Minimum



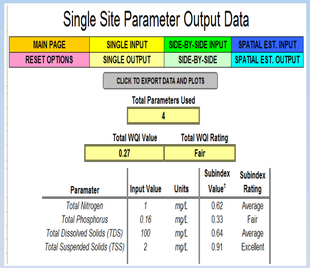


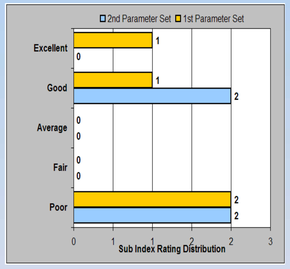


Model: Parameter Data Input TN, TP, TDS, TSS

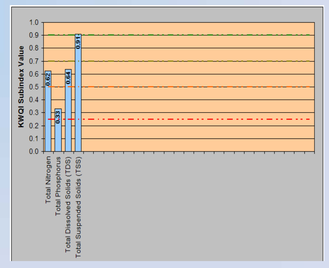
$$I = \left[1 - N + \sum_{i=1}^{N} s_i^{-\log_2(N-1)}\right]^{-1/\log_2(N-1)}$$

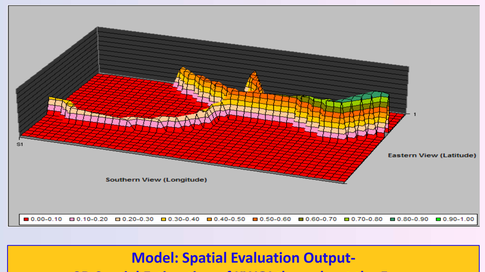
Final KWQI = aggregation of sub-WQI of each water quality parameter





Rating Scale	WQI Rating Scale	Rating Scale	Number per 1st Set	Number per 2nd Set
Poor	0 - 0.25	Poor	2	2
Fair	0.26 - 0.50	Fair	0	0
Average	0.51 - 0.70	Average	0	0
Good	0.71 - 0.90	Good	1	2
Excellent	0.91 - 1.00	Excellent	1	0





Model: Index Calculations

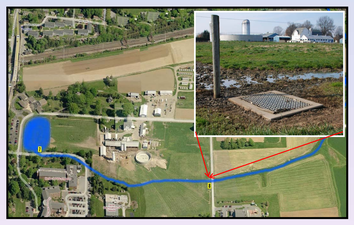
Model: Parameter Data Output

Model: Spatial Evaluation Output- 3D Spatial Estimation of KWQI throughout the Farm

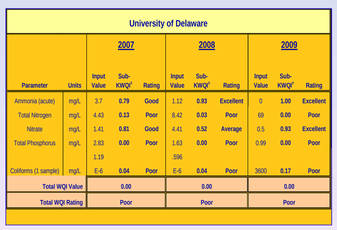
ABSTRACT

Kiliszek and Chirnside (2010) researched previously developed Water Quality Indices (WQI) (Swamee and Tyagi, 2000 & 2007) and the different water quality parameters that were used in developing the equations. Using these as a guideline, changes were made to adapt the WQI to Delaware and United States Environmental Protection Agency (USEPA) standards and criteria. A user-friendly computational interface tool for calculating the KWQI was developed (Kiliszek, 2010).

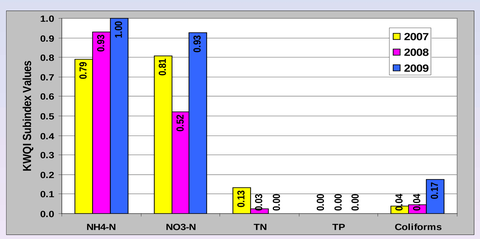
The working model was developed to allow the KWQI to be used for the evaluation of up to eight different parameters sets or to be used to create a spatial distribution of the KWQI values within a watershed. The KWQI model can spatially and temporally define and rate sub-watershed health. This paper demonstrates the Kiliszek model and illustrates how actual water quality monitoring data from a small agricultural watershed is incorporated into the KWQI calculations. Examples of model outputs and graphical interpretation of the data are reviewed.



Site 8



Model Output Using Manure Preset with 5 Variables . Output shows Sub-KWQIs , Final KWQI and Ratings.



Model Output : Plot of Sub-KWQIs for All Variables and Each Year

- [Ammonia] reduced by 1st year-70%
- [Nitrate] reduced by 2nd year- 65%
- Sub-index for TN decreased each year
- Suggests organic N main species of N present at Site 8
- DO, chlorophyll a, and Cu remain above criteria standard
- Most significant change in bacteria
  - First year CFU decreased from ~1.19x106 to 596,740
  - 2nd year CFU ~3,600 for thousand fold reduction
- Improvement in [Total P]
  - 35% decrease since system installed
  - 2.83 mg/l in 2007 to 0.99 mg/l in 2009
  - Continues to receive Sub-KWQI of Poor
  - Criteria standard 0.20 mg/l

Discussion of Output Data

Model Demonstration: Evaluate Manure Collection System Effect on Site8

References

- Kiliszek, A. 2010. "Development and use of water quality indices (WQI) to assess the impact of BMP implementation on water quality in the cool run tributary of the White Cay Creek Watershed." Master of Science Thesis. Department of Bioresources Engineering. University of Delaware.
- Kilisek, A. K. and A. E. M. Chirnside. 2010. "Development and use of water quality indices (WQI) to assess the impact of BMP implementation on water quality in the Cool Run tributary of the White Clay Creek Watershed." Proceedings of the World Environmental & Water Resources Congress, May 16-20, Providence, Rhode Island. Paper No 264.
- Swamee, P. K. and A. Tyagi. 2000. "Describing Water Quality with Aggregate Index." Journal of Environmental Engineering 126(5): 451- 455.
- Swamee, P. K. and A. Tyagi. 2007. "Improved method for aggregation of water quality subindices." Journal of Environmental Engineering 133(2): 220-225.