Report as of FY2006 for 2006NE128B: "Determination of Appropriate Lake Water Quality Expectations in Agriculturally Dominated Ecosystems. Phase 1: Defining Nebraskas Hydroecoregions"

Publications

Project 2006NE128B has resulted in no reported publications as of FY2006.

Report Follows

Project Title: Determination of Appropriate Lake Water Quality Expectations in Agriculturally Dominated Ecosystems. Phase 1: Defining Nebraska's Hydroecoregions

Investigators: Aris Holz (aholz2@unl.edu), John Holz (jholz@unl.edu) and James Merchant (jmerchant1@unl.edu)

Progress Summary: The overall goal of this research is to develop a dynamic strategy for determining appropriate water quality standards for agricultural ecosystems by grouping geographic regions with similar natural landscape characteristics into management groups (termed "hydroecoregions"), using Nebraska as a model. Specifically, we proposed to (a) extract watershed characteristic data from existing HUC's (i.e. hydrologic cataloging units) using the zonal summary in ARCMAP GIS, (b) convert the data file to MS Excel, (c) statistically group (classify) HUC's with similar landscape characteristics into hydroecoregions, and (d) compare these regions to the 65 watersheds that were delineated in our previous lake and reservoir classification project to ensure that they HUC-derived hydroecoregions adequately represent watersheds. The classification results from either of these hydrologic units can be used to create a hydroecoregion map for Nebraska which will facilitate the subsequent modeling efforts to predict nutrient and sediment runoff.

Research progress on this project has exceeded our expectations. Tasks (a) – (c) are completed and task (d) is underway. In addition, one Co-PI (A. Holz) and one M.S. graduate student (A. Zoller) attended an intensive watershed modeling workshop and an appropriate watershed model has been selected for the project. Actual modeling is scheduled to begin in July, 2007. Our successful approach to deriving the hydroecoregions and subsequent modeling will contribute greatly to field of watershed/surface water management and will form the backbone of future research and proposals. We also anticipate at least two manuscripts will be submitted for publication based on our current work alone.

Background. Large inputs of nutrients such as nitrogen and phosphorus to lakes and reservoirs are well known to cause a variety of water quality problems such as excessive vegetation growth, noxious odors, poor water transparency, oxygen depletion, fish kills, reduced recreational value, and reduced property value. In recent decades, substantial progress has been made in improving the quality of U.S. surface waters. Nevertheless, much work remains to be done. It is estimated, for example, that the water quality of more than 75% of Midwestern lakes (both natural and man-made) are still "impaired" by nonpoint sources of silt, organic matter, and nutrients (Duda, 1985). Impairment implies that the existing lake water quality, as measured by some selected criteria (e.g., nitrogen, phosphorus), is lower than a set of target standards that presumably reflect optimal attainable water conditions. The U.S. Environmental Protection Agency (EPA) is charged with establishing national standards and criteria for assessing lake water quality. It is, however, increasingly evident that a single set of national water quality standards that do not take into account regional hydrogeologic and ecological differences will not be viable, since lakes clearly have different inherent capacities to meet such standards (e.g., lakes occurring in the nutrient-rich soils of the Midwest will not have the same characteristics of lakes occurring in nutrient-poor soils of the Northeast).

A more tenable approach is to define different standards (targets) for groups ("classes") of lakes determined to be similar to one another in terms of their potential to attain a certain level of water quality. Standards would then be established independently for lakes in different classes according to a set of "reference" target conditions unique for each class. This approach was used in Nebraska to form lake and reservoir classes using the Ecological Continuum Approach (ECA) that groups lakes by ecological function along a linear continuum (Holz, 2005). All of the parameters that contribute significantly to lake water quality interact similarly within classes defined by the ECA, giving a better indication of potential water quality. However, some lakes may require more action than others to meet water quality benchmarks depending upon their location along the ecological continuum. Lakes within a group may have very different parameter values (e.g., TP, chlorophyll *a*, Secchi depth), but have the same potential to achieve water quality expectations. Once lake classes were identified using the ECA, the USEPA 25^{th} percentile approach was used to identify the best 25% of lakes, which were used to establish nutrient benchmarks (reference conditions) for members of a lake class. This approach is recommended for regions where some lakes are impacted by anthropogenic disturbances (USEPA, 1998). However, the approach may not be optimal in agricultural regions where nearly all lakes are heavily impacted by land-use (Holz, 2005) as the relative contributions of land-use (e.g., agriculture) and natural processes to the lake nutrient concentrations have not been determined and thus make the values highly artificial.

Holz (2005) also tested the effectiveness of watersheds to identify the ECA reservoir classes. Sixty-five watersheds were delineated from the dam of each reservoir using DEM based EDNA datasets (Bulley, in review), and then classified. Reservoir classes were very similar to watershed classes when land-use data was incorporated in the classification (94.4% agreement), however, similarities were not as strong when land-use parameters were left out of the classification (81.4% agreement). The watershed classification alone primarily explained large reservoir classes, but did not do a good job of predicting outlier reservoirs (i.e. those with exceptionally unusual or poor water quality). However, the addition of land-use to the watershed classification explained most of these outlier classes. This indicates watersheds are strongly correlated with reservoir water quality in Nebraska and that land-use clearly impacts water quality in a significant number of reservoirs. Thus, reservoirs appear to be highly impacted by land-use, and ***it is not possible to determine if the benchmark values are appropriate without understanding the natural background reservoir nutrient levels*.** For example, if the high nutrient conditions in Nebraska reservoirs are due mainly to Nebraska's naturally nutrient-rich prairie soils, then the benchmarks are realistic. Conversely, if the high nutrient conditions result from crop production practices, then the values may be too low. The potential regulation of nitrogen and phosphorus containing crop fertilizers and associated impacts on production practices clearly establishes the need for appropriate nutrient criteria as one of the most critical and pervasive issues currently facing the agricultural Midwest.

Research Goal and Objectives. The overall goal of this proposal is to develop a dynamic strategy for grouping geographic regions with similar natural landscape characteristics into management groups (termed "hydroecoregions") by using Nebraska as a model for agricultural ecosystems. Agricultural land-use data will not be used to define the hydroecoregions, resulting in a representation of geographic regions unaltered by anthropogenic disturbances. This strategy will facilitate subsequent research that will build and calibrate integrated models of agricultural watersheds and lake water quality for each hydroecoregion. These models will allow the determination of appropriate water quality expectations under (1) low and no agricultural land-use scenarios (i.e. natural conditions), (2) multiple best management scenarios (i.e. best-attainable conditions), and (3) various economic scenarios (i.e. cost-effective conditions). Here we propose to address the critical first step in determining appropriate water quality expectations: defining hydroecoregions. The specific objectives for this goal are: (1) Extract landscape characteristic data for each appropriate aggregate level (i.e. hydrologic unit). (2) Statistically group aggregate levels with similar landscape characteristics into hydroecoregions. (3) Identify the appropriate aggregate levels for hydroecoregion development.

Approach. We have at UNL a unique contingent of scientists, spanning several disciplines (e.g., limnology, aquatic ecology, geographic information systems, statistical ecology), who are unusually well-prepared to make significant progress towards resolving such problems. The project we propose here will provide the catalyst, critical mass, and resources required to further integrate our ongoing research and, thereby, develop focus and synergism that will result in new and improved approaches to water quality assessment and management. The project will focus on reservoirs located in agriculturally-dominated landscapes, with specific initial focus on Nebraska. Standards are particularly difficult to establish for lakes located in areas highly modified by humans since few, if any, reservoirs represent non-impacted reference conditions. Nebraska has a broad diversity of water resources, environments and landscapes, and is representative of many mid-continent regions of the U.S. Moreover, the state has a rich set of data with which to work.

Our recent $1.22 million EPA STAR project entitled "Development and Implementation of a Comprehensive Lake and Reservoir Classification Strategy for Nebraska as a Model for Agriculturally Dominated Ecosystems" has established UNL as a leader in lake and reservoir classification and we are now in an exceptional position to evaluate the effect of agricultural land use on the water bodies of the Midwest. We have developed an unprecedented water quality database that includes physical, chemical (including nutrients), and biological data for over 400 Nebraska lakes and reservoirs and have acquired state-of-the-art equipment and expertise in water quality monitoring and analysis. Moreover, through our collaboration with UNL's Center for Advanced Land Management Information Technologies (CALMIT), we have developed unique and essential approaches to using geographic information systems (GIS) and remote sensing for water quality characterization, geospatial database development, watershed analysis, spatial modeling and decision support.

We propose to use these databases, tools, and capabilities to develop hydroecoregions within a consistent ecological and hydrological framework. The smallest or fourth level division of USGS hydrologic units (i.e. hydrologic cataloging units or 8-digit HUC) developed by Seaber *et. al.*, (1987), does not conform to the topographic hydrologic boundaries of the terrain (e.g., Omernik, 2003). However, the Nebraska Department of Natural Resources developed 11-digit HUC's to address the limitations of the 8-digit HUC's. We propose to (a) extract watershed characteristic data (e.g., slope, soil erodibility, soil cation exchange capacity, soil clay content, elevation, total precipitation, degree growing days) from these existing 11-digit HUC's using the zonal summary in ARCMAP GIS, (b) convert the data file to MS Excel, (c) statistically group (classify) HUC's with similar landscape characteristics into hydroecoregions, and (d) compare these regions to the 65 watersheds that were delineated in our previous lake and reservoir classification project to ensure that they HUC-derived hydroecoregions adequately represent watersheds. The Pffafstetter hydrologic unit is the second potential grouping unit we propose to investigate. This unit is advantageous as they exist for the continental US and are consistent across state boundaries, which may make this approach more applicable to other areas of the country. However, the 11-digit HUC's are preferable in Nebraska as these units are already used as management tools. Classification results from either of these hydrologic units can be used to create a hydroecoregion map for Nebraska which will facilitate the grouping the 600 or more unclassified reservoirs in the state, as well as subsequent modeling efforts. This map will also aid in identifying the best location for new reservoir construction in order to minimize watershed impacts on water quality.

Research Progress (Year 1). GIS watershed characterization work has been completed using 8-digit Hydrologic Unit Codes (HUCs). Initial analysis on available watershed GIS datasets proved U.S. Geological Survey (USGS) 8-digit HUCs was a more complete and accurate portrayal of Nebraska watersheds when compared to Nebraska Department of Natural Resources (NE DNR) 11-digit HUC GIS dataset. Hence, the USGS 8-digit HUC dataset was used for the watershed characterization.

First, the data was downloaded and clipped to the Nebraska state boundary. From this, individual HUCs were extracted and projected. In all, there are eighty-six 8-digit HUCs that partially or completely underlie the Nebraska State boundary (Figure 1). Next, national GIS datasets of elevation, slope, soils, and 1992 land cover were downloaded from appropriate agencies' websites and clipped to the Nebraska boundary. Raw data from NE weather stations was obtained and converted into a GIS layer.

All datasets were checked for completeness, accuracy, and consistency before being projected into the NE Stateplane coordinate system. Weighted-average calculations were performed on soils data layers in order to display three-dimensional information in a two-dimensional map.

Computer programs were written to extract slope, elevation, land use, growing degree, precipitation, soil chemistry, and soil erodability data to individual HUC boundaries. It is interesting to note the 2001 National Land Cover Dataset (NLCD) was released for download during this process (Figure 1). This data was also downloaded, projected, and extracted to HUC boundaries in addition to 1992 land cover data.

Finally, the GIS summary statistics tool was utilized to calculate an area-weighted average of each parameter (excluding land use) within individual HUC boundaries. The summarized GIS data was converted into a Microsoft Excel format to show the soils, weather, topography, and land use statistics for each of the 86 HUCs (Figure 2). Next, the summary statistics tool was used to calculate categorical land use percents of each watershed for 1992 and 2001, and values converted into Excel format.

Much work was done in initial hydrologic model research, with actual modeling scheduled to begin in July, 2007. It was determined that a GIS-based sediment delivery ratio model will be built to simulate sediment-bound contaminant transport to reservoirs at the base of a watershed. After the model is calibrated and validated to existing data, model scenarios will be run to simulate natural, best-attainable, and cost-effective scenarios according to varied land use parameters.

Timeline: (1) Extract landscape characteristic data for each aggregate level (March-Aug, 2006); (2) Statistically group aggregate levels with similar landscape characteristics into hydroecoregions (Sept-Nov, 2006); (3) Identify the appropriate aggregate levels for hydroecoregion development (Dec-Feb, 2007).

Anticipated Outcomes. Through this proposal we will strengthen our posture at UNL as an international center-of-excellence in water quality assessment, and the application of advanced geospatial information technologies in water science and management, and, thus, enhance our competitive stature with respect to generation of external funding. In the process of implementing this proposal we will develop methods that will serve to enhance natural resource management, sustainable agriculture and environmental quality in Nebraska and other agricultural regions. We will work closely with the EPA, Nebraska Department of Environmental Quality, agricultural and environmental non-government agencies, and other partners to ensure that the fruits of our research are brought to bear, in the earliest possible timeframe, on what is arguably one of the highest priority issues which currently challenges these organizations. The Nebraska Department of Environmental Quality (NDEQ) has adopted the nutrient benchmarks (as determined by our ECA lake classification research) for the lakes and reservoirs of the state and other agencies from states in the region are interested in applying this approach. We anticipate that these real outcomes and benefits will continue.

Extramural Funding Opportunities. In early October 2005, J. Holz met with program officers from EPA and USDA regarding their interest in our on-going research interests in determining appropriate water quality expectations in agricultural regions. Both agencies expressed significant interest in the project and we specifically intend to apply for a USDA Integrated Programs grant to define reference conditions by modeling the hydroecoregions developed in this proposal.

References

Bulley, H.N.N., J.M. Merchant, D.B. Marx, J.C. Holz, A.A. Holz. A GIS-based approach to watershed classification for Nebraska reservoirs. Journal of American Water Resources Association (in review).

Duda, A. 1985. Environmental and economic damage caused by sediment from agricultural nonpoint sources. Water Resources Bulletin 21:225-234.

Holz, A. 2005. Lake and reservoir classification in agriculturally dominated ecosystems. A dissertation, University of Nebraska, Lincoln, NE.

Omernik, J.M. 2003. The misuse of hydrologic unit maps for extrapolation, reporting and ecosystem management. Journal of the American Water Resources Association. 39:563–573.

Seaber, P.R., F. P Kapinos, and G. L. Knapp. 1987. Hydrologic Unit Maps. Water Supply Paper 2294. United States Geological Survey, Denver, Colorado.

USEPA. 1998. Technical guidance document: Lake and reservoir bioassessment and biocriteria. EPA 841-B-98-007. U.S. Environmental Protection Agency, Office of Water, Washington D.C.

Figure 1: Map layout of Nebraska 8-digit Hydrologic Unit Code Boundaries and 2001 National Land Cover

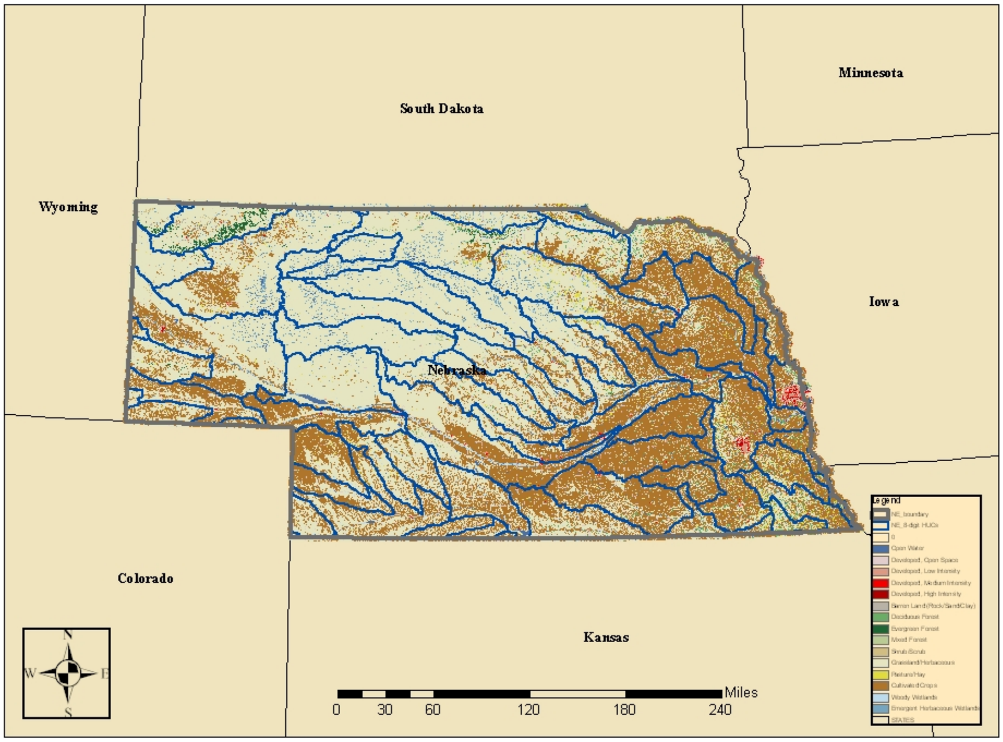

Figure 2: Summary statistics for individual HUC topography, soil, and climate characteristics

HUC number	mean_elev (feet)	Mean_Slope (degree	Soil CEC-mean	Soil CACO3-mean	Permeability-mean	Slope-mean	KFACT	Annual preci	growing degree-mean
1012010	1141.48	2.77	26.93	1.78	0.08	13.10	0.38	17.0	4796.45
1012010	1227.08	2.46	16.95	1.64	1.31	11.26	0.33	15.4	4459.87
1014020	1156.84	4.40	11.37	1.77	1.70	15.53	0.30	16.7	4697.71
1014020	973.38	1.52	4.19	0.40	11.93	14.50	0.15	18.7	4798.82
1015000	516.39	2.50	19.76	5.81	2.14	11.07	0.32	22.9	5047.13
1015000	1395.61	1.04	7.99	0.90	4.16	12.82	0.23	15.6	4524.52
1015000	1178.99	2.61	6.52	0.79	7.53	10.60	0.22	17.0	4723.35
1015000	838.41	2.27	5.18	0.41	10.76	14.19	0.16	20.8	4957.22
1015000	1030.56	2.37	3.41	0.16	12.26	18.04	0.15	19.0	4810.98
1015000	682.26	3.33	8.72	0.87	8.55	8.96	0.20	21.7	4826.01
1015000	549.42	1.61	12.50	1.00	7.30	7.71	0.23	23.0	5170.07
1017010	453.96	2.00	16.56	2.72	2.42	8.79	0.32	24.8	5333.11
1018000	1223.18	1.74	5.62	1.09	6.78	8.82	0.23	16.4	5068.94
1018001	1313.98	2.11	3.30	1.25	3.77	7.44	0.31	15.0	4844.25
1018001	1377.47	3.97	6.70	1.44	4.01	7.93	0.26	16.1	4844.31
1018001	1050.23	2.40	4.01	0.36	10.50	13.83	0.18	18.6	5125.44
1019001	1232.38	1.85	8.31	0.31	2.13	5.07	0.29	18.4	5346.89
1019001	1550.84	1.35	10.58	1.57	1.67	8.19	0.28	17.0	4461.99
1019001	1367.62	0.98	8.94	0.67	1.70	4.28	0.30	17.4	4830.90
1019001	1473.27	1.74	11.85	0.99	1.44	4.72	0.30	16.6	4579.98
1019001	1027.83	1.74	6.36	0.51	3.62	5.62	0.29	18.1	5259.97
1020010	799.81	0.93	5.05	0.29	4.61	8.25	0.29	22.3	5291.97
1020010	693.33	1.62	4.30	0.10	1.82	8.08	0.35	24.1	5284.88
1020010	528.34	0.37	5.11	0.26	3.81	3.74	0.28	26.4	5604.55
1020020	482.55	0.83	17.97	1.23	1.45	4.75	0.32	27.7	5425.58
1020020	359.96	1.10	22.01	1.19	1.87	4.97	0.28	30.1	5577.03
1020020	395.24	2.16	21.95	0.02	1.02	5.37	0.33	29.2	5674.59
1021000	1066.77	3.63	3.57	0.19	12.32	14.55	0.15	19.8	4886.96
1021000	1045.14	4.17	3.38	0.11	12.65	17.32	0.15	20.0	4981.08
1021000	710.51	1.60	4.43	0.10	4.84	12.70	0.30	23.8	5142.05
1021000	803.42	2.52	3.76	0.07	4.92	12.84	0.30	22.9	5115.45
1021000	768.02	1.65	3.72	0.01	4.16	14.37	0.32	23.6	5042.53
1021000	912.10	2.10	3.60	0.14	12.21	15.89	0.15	21.6	5022.71
1021000	654.13	1.91	4.94	0.07	2.67	11.12	0.34	24.0	5191.46
1021000	783.63	1.20	3.54	0.12	12.45	17.33	0.15	23.0	5114.22
1021000	570.94	1.81	9.15	0.70	4.99	6.84	0.28	25.9	5269.58
1021001	645.80	1.02	6.56	0.44	8.58	10.43	0.22	24.4	5088.09
1022000	636.19	0.79	6.88	0.34	9.81	6.40	0.19	23.6	5050.91
1022000	528.16	0.87	11.46	0.72	6.21	4.39	0.25	25.2	5237.82
1022000	447.81	1.73	18.01	0.76	1.95	4.86	0.32	28.0	5327.38
1022000	454.73	1.80	19.51	0.37	1.33	5.19	0.33	27.3	5322.04
1023000	368.05	2.96	27.44	4.78	1.08	7.82	0.31	28.1	5462.73
1023000	351.94	2.38	21.67	2.25	1.34	7.16	0.30	29.1	5616.76
1024000	342.01	2.59	22.02	1.69	1.11	5.79	0.32	32.3	5681.10
1024000	273.84	0.04	28.31	14.45	1.60	1.05	0.27	33.0	5878.25
1024000	303.22	2.74	24.07	6.06	1.29	9.15	0.29	33.4	5935.33
1024000	350.46	1.39	18.11	0.07	0.70	4.61	0.35	31.7	5772.81
1024000	369.15	1.64	20.23	1.03	0.64	5.76	0.36	32.9	5894.40
1024000	354.05	0.97	18.80	0.37	0.68	5.17	0.35	32.6	5873.46
1025000	1028.54	1.53	3.38	0.60	3.51	3.82	0.31	17.0	5679.94
1025000	1030.34	0.79	5.61	0.22	8.11	8.54	0.19	17.8	5605.52
1025000	922.78	0.58	5.89	0.79	6.28	4.23	0.23	19.0	5680.67
1025000	886.84	1.64	4.40	0.19	2.53	6.08	0.33	20.4	5550.04

1025000	978.42	0.83	7.93	0.30	2.84	4.52	0.31	19.0	5404.42
1025000	1019.10	0.86	8.54	0.30	5.16	5.47	0.26	18.5	5267.65
1025000	915.09	1.13	4.35	0.11	4.93	9.16	0.28	19.9	5321.36
1025000	858.90	1.69	2.65	0.00	3.89	13.64	0.33	20.7	5333.22
1025000	716.27	1.03	2.04	0.04	1.42	8.98	0.35	22.5	5616.98
1025001	678.73	1.90	3.96	0.02	1.32	8.11	0.35	23.0	5954.91
1025001	737.16	2.61	3.38	0.03	1.30	8.68	0.36	22.4	5890.85
1025001	651.02	1.45	1.42	0.10	1.32	6.97	0.34	23.0	5843.24
1025001	603.00	1.08	7.31	0.34	1.57	6.29	0.34	25.4	5615.88
1026001	635.05	3.06	3.81	1.91	1.30	9.22	0.33	25.0	5760.72
1027020	506.37	0.66	7.00	0.00	1.31	1.42	0.33	27.5	5615.68
1027020	428.30	0.60	22.93	0.02	0.94	3.48	0.35	30.1	5782.40
1027020	520.80	1.13	12.93	0.00	1.31	1.85	0.34	27.1	5584.83
1027020	467.75	1.34	33.34	0.00	1.21	4.54	0.34	28.7	5724.92
1027020	416.03	1.11	19.91	0.00	0.62	4.21	0.37	31.3	5789.87
1027020	547.39	0.96	22.74	0.02	1.46	4.15	0.35	27.2	5638.44
1027020	446.15	0.80	29.95	0.34	1.18	5.29	0.34	29.9	5839.74