Nebraska Water Resources Center
Annual Technical Report
FY 2009

Introduction

Dr. Kyle D. Hoagland served as director of the University of Nebraska Water Center through August of 2009. Dr. Bruce I. Dvorak took over as Interim Director as of Sept. 2009. Lorrie Benson, J.D. serves as the assistant director. Steve Ress and Tricia Liedle continue as communications specialist and program specialist, respectively. The Water Center staff also includes Rachael Herpel as our water outreach specialist and Duane Mohlman as our data assistance coordinator. Patricia Jarecke served as the administrative assistant through September 2009 and Michal Jess served as Associate Director through August 2009.

The Water Center is currently housed as part of the School of Natural Resources, located in Hardin Hall (3310 Holdrege, Lincoln, NE 68583-0979). The campus-wide Water Resources Research Initiative (WRRI) completed its sixth year and has provided limited operating funding. The annual Water Law, Policy, and Science conference, "Blue Gold: When Water Meets Money" was held on April 29-30, 2009, with featured outside speakers Ari Michelsen, Chris Goemans, James Boyd, Garth Taylor, Ellen Hanak, David Brookshire, Michael Hanemann, Noel Gollehon, and Anne MacKinnon. Also, the Water Center helped the UNL Office of Research host the first annual Water for Food conference in 2009.

The Water Center has also continued to assist with development of the UNL water portal (water.unl.edu) and we maintain the NIWR website (snr.unl.edu/niwr) through the Water Center. Along with these websites, we continue to focus on the Water Center’s home website (http://watercenter.unl.edu).

Research Program Introduction

For the 2010 fiscal year, four research seed grants were chosen to receive funding through the USGS 104(b) program. Areas chosen for funding were: (1) mitigate and treat antibiotic residues and antibiotic resistance genes in soil and water; (2) develop a wireless underground sensor networks for irrigation management; (3) investigating a new and potentially critical Cyanobacterial toxin in midwestern reservoirs; and (4) develop a groundwater recharge forecasting method for episodic recharge responses to weather events.

Several major water events were conducted and/or sponsored by the UNL Water Center this year, including the annual summer water tour of the Northern California's Bay-Delta. The annual Water Colloquium took place in October. Also held was a Water Quality Summit meeting.

The Water Sciences Laboratory continues as a core facility to assist water science faculty. Analyses and the number of faculty utilizing this cutting-edge analytical facility continued to grow. Once again, analyses were conducted for several other universities, state and federal agencies, as well as for private companies and individuals, but the focus remains on UNL faculty.

Most recently, UNL is in the process of forming a Global Water for Food Institute, with an emphasis on agricultural water management, based primarily on private fund contributions; the founding donation of $50 million was announced in April of 2010.

Cooperative Agreement No. 07HQAG0004 Incorporating Remote Sensing Information into the US Drought Monitor

Basic Information

Title:	Cooperative Agreement No. 07HQAG0004 Incorporating Remote Sensing Information into the US Drought Monitor
Project Number:	2006NE163S
Start Date:	4/1/2007
End Date:	12/31/2010
Funding Source:	Supplemental
Congressional District:	1
Research Category:	Climate and Hydrologic Processes
Focus Category:	None, None, None
Descriptors:	drought, drought monitoring, remote sensing, soil moisture
Principal Investigators:	Mark D Svoboda

Publications

1. Nghiem, et al. (authors from JPL, USGS, NDMC, NOAA PSD, DFO, and others), "Pattern and Frequency of Soil Moisture Variability over the Continental United States," manuscript in revision, 52 pp., 2009.
2. Nghiem, S. V., D. Balk, E. Rodriguez, G. Neumann, A. Sorichetta, C. Small, and C. D. Elvidge, 2009. Observations of Urban and Suburban Environments with Global Satellite Scatterometer Data, ISPRS Journal of Photogrammetry and Remote Sensing, 64, 367-380.
3. Nghiem, S. V., and G. Neumann, "Remote Sensing of the Global Environment with Satellite Scatterometry," keynote paper in Microwave Remote Sensing of the Atmosphere and Environment VI, ed A. Valinia, P. H. Hildebrand, and S. Uratsuka, Proc. of SPIE, Vol. 7154, 715402, doi:10.1117/12.804462, 11 pages, 2008.
4. Nghiem, S. V., "Satellite Remote Sensing of Soil Moisture for Drought Applications," invited paper, National Integrated Drought Information System Knowledge Assessment Workshop – Contribution of Satellite Remote Sensing to Drought Monitoring, Boulder, Colorado, USA, 6-7 February 2008.
5. Nghiem, S. V., G. R. Brakenridge, and G. Neumann, "Drought, wetland, and Flood Monitoring with Satellite Scatterometer," EOS Trans, AGU, 88(23), Jt. Assem. Suppl., Abst. U53B-05, May 2007.
6. Nghiem, S. V., G. R. Brakenridge, D. Cline, M. Dettinger, R. M. Dole, P. R. Houser, G. Neumann, E. G. Njoku, D. K. Perovich, K. Steffen, M. Sturm, J. Verdin, D. A. Wilhite, S. H. Yueh, and T. Zhang, "Global Observations of Land Surface Water with Satellite Active and Passive Microwave Sensors," Satellite Observations of the Global Water Cycle, Irvine, California, 7-9 March 2007.
7. Brakenridge, G. R., S. V. Nghiem, E. Anderson, and R. Mic, "Orbital Microwave Measurement of River Discharge and Ice Status," Water Resources Research, Vol. 43, W04405, doi:10.1029/2006WR005238, 2007.
8. Gu, Y., J.F. Brown, W. van Leewen, B.C. Reed, and T. Miura, 2009. Phenologic classification of the United States: a framework for extending a multi-sensor time series for vegetation drought monitoring, In Proceedings of the Annual Meeting of the Association of American Geographers, Las Vegas, Nevada.

National Drought Monitoring System for Drought Early Warning Using Hydrologic and Ecologic Observations from NASA Satellite Data

Investigators: S. V. Nghiem (JPL, PI), J. P. Verdin (USGS, Lead Co-I), D. A. Wilhite (National Drought Mitigation Center or NDMC), R. Dole (NOAA Physical Science Division), D. LeComte (NOAA Climate Prediction Center), G. R. Brakenridge (Dartmouth College), E. G. Njoku (JPL)

Collaborators and NDMC PIs: Mark Svoboda (NDMC, Lead PI), Brian Wardlow (NDMC), Tsegaye Tadesse (NDMC), and Brian Fuchs (NDMC)

INTRODUCTION AND PROBLEM

The National Drought Mitigation Center (NDMC) is a partner with the NASA's Jet Propulsion Laboratory (JPL), the U.S. Geological Survey's Center for Earth Resources Observation and Science (USGS/EROS), NOAA's Physical Science Division (PSD) and Climate Prediction Center (CPC) along with Dartmouth College in the project entitled "National Drought Monitoring System for Drought Early Warning Using Hydrologic and Ecologic Observations from NASA Satellite Data".

The objective of this project is to assimilate hydrologic and ecologic observations from NASA Earth satellite sensors, including the Advanced Microwave Scanning Radiometer - Earth Observing System (AMSR-E), the QuikSCAT/SeaWinds Scatterometer (QSCAT), and the Moderate Resolution Imaging Spectroradiometer (MODIS), into a national drought monitoring system, specifically the United States Drought Monitor (USDM), an existing national decision support tool used for drought monitoring and drought early warning. The lead Principal Investigator for the partnership is Son Nghiem from the Jet Propulsion Laboratory (JPL). The 3-year project is scheduled to last through September 30, 2010.

The NDMC team members include Mark Svoboda, Dr. Brian Wardlow, Dr. Tsegaye Tadesse, and Brian Fuchs at the University of Nebraska-Lincoln, who will work to establish and carry out the scientific program as proposed in the project plan. The NDMC tasks for Year 3 of this project are outlined in the following section.

The role of the NDMC is to serve as the lead integrator for incorporation of products derived from NASA satellite data (including ASMR, QuikSCAT, and MODIS vegetation index (VI) data) into an improved operational U.S. Drought Monitor (USDM) system. The NDMC is responsible for working with USDM authors to establish: 1) input data requirements and formats, 2) system requirements for the USDM to assimilate new remote sensing data, and 3) processing requirements to improve USDM outputs. The NDMC will also work with USDM authors and project partners to benchmark new USDM results against the results from current USDM approach, which uses non-NASA data inputs, to assess improvements. In addition, the NDMC will develop a centralized web location for USDM authors and project partners to access the

NASA satellite data-derived products and the USDM deliverables produced using the new remote sensing data sets.

Several limitations in the current U.S. drought monitoring effort have been identified: (1) the coarse level of spatial detail at which analyses are performed and results delivered and (2) the lack of detailed, accurate, and objective data sources especially where current networks of weather stations are sparse in the public lands of the West. These represent the two largest impediments to early detection of drought and its impacts at the county or sub-county level, which is where key drought decision making takes place.

JPL has the lead in the development of drought monitoring products from AMSR-E and QSCAT. The role of USGS/EROS is the development of systems for production of time-series vegetation index (VI) imagery from MODIS data, and delivery of VI products to USDM authors and the drought community in general. The NDMC plays the role of lead integrator for an improved operational USDM system. The NDMC is also responsible for ingesting NASA results from JPL and USGS into the existing USDM system for drought decision support, and performing benchmark analyses.

RESEARCH PROGRAM, OBJECTIVES AND METHODOLOGIES

With the granting of our request for a no-cost extension through December 31, 2010, the NDMC will continue to work on the Year 3 tasks below as we sunset this project. We house and continue to maintain the project web site at: drought.unl.edu/nasa. The Year 3 tasks include:

1. **Continue guidance to establish data and processing requirements for the remote sensing products generated by the project participants for integration into the operational USDM system.** As products developed using the initial set of requirements become available, the NDMC will work with the USDM authors to ensure they meet their operational needs. If needed, the initial requirements will be adjusted and/or modified for effective integration of the data into the USDM system.

2. **Develop a centralized web location for USDM authors and project participants to access the NASA satellite-derived products**. The NDMC-NASA Partnership website (URL: http://drought.unl.edu/nasa) developed and hosted by the NDMC for project-related information will be used as the central access point for the remote sensing-derived products generated for the advanced USDM prototype system. A 'Data' section will be added to the website and adapted according to the deliverables provided by the project participants. In addition, these data products will also be posted in the USDM Authors' Community within the National Integrated Drought Information System's (NIDIS) U.S. Drought Portal (www.drought.gov) for authors to visualize the information in an interactive map viewer. A demonstration of the advanced USDM system will be conducted once the feed is established and automated from CPC to NIDIS.

3. **Coordinate with USDM authors to implement remote sensing data product ingestion into an advanced USDM prototype environment.** The NDMC will work with USDM authors to describe the informational content of each project deliverable as it

becomes available and assist them with the evaluation/integration of this information into the USDM development process.

4. **Benchmark existing and new USDM results to evaluate the improvements in the USDM map results produced using the advanced USDM prototype system.** The NDMC will work with the USDM authors to assess the enhancements provided by the remote sensing products in the development of the USDM maps. Each product will be evaluated independently in the improved USDM prototype by comparing the new USDM map results with those produced with the existing USDM process. The evaluation of the products will be dependent on them being delivered in a timely fashion in Year 3 to allow adequate time to investigate their utility and potential contribution within the USDM map development process. Examples of the improvements made in the USDM maps with a specific remote sensing-based product will be documented.

5. **Participate in a demonstration of the improved USDM prototype and distribute the improved drought products over the Internet to users via the NDMC web site**. Once activities 1 through 4 are completed, the NDMC will coordinate with project participants and USDM authors to communicate the improved USDM prototype at professional meetings and in the peer-reviewed literature to demonstrate the utility of remote sensing-based products derived from NASA satellite observations. The improved USDM drought products and supporting information will be made available to the general public via the NDMC-NASA Partnership website.

6. **Initiate the implementation of the prototype approach operationally at the end of Year 3**. The implementation of such an approach will be dependent on the timely delivery of data products early in Year 3 in order to complete activities 1-5, which is required in advance of developing the operational phase of this project.

YEAR 3 PROGRESS

JPL:

- Providing QuikSCAT soil moisture change (SMC) data for drought applications: data for entire CONUS, daily data production, nearly daily of CONUS, and automated routine upload processor is ready. Procedure for PSD to get AMSR-E soil moisture data.

- Resolution benchmarking: SMC data gridded at ¼ degree in latitude and longitude, resolving county scale per Nyquist scale requirement estimated at 27 km.

- Prototyping: Working with the team to develop SMC prototypes with different color protocols, file format, and drought contour overlay options.

- Demonstration of improvement (all) – JPL automated SMC data upload to NOAA Physical Science Division.

- Incorporating latest satellite algorithm improvements and advanced NASA products/results for drought monitoring: Improving SMC algorithms and products, initiating and testing new QS products for drought monitoring/forecast.

USGS:

- MODIS Vegetation Indices ingested into a drought model called the Vegetation Drought Response Index (VegDRI) was produced in an operational fashion during 2009 at USGS EROS.
- Evaluation of those vegetation products is ongoing. One evaluation method focused on a data intercomparison involving several different drought indicators including the U.S. Drought Monitor.
- Highest correlations were found between the VegDRI and the Palmer Drought Severity Index.
- Results were then presented at the Fall 2009 American Geophysical Union. Full operational delivery of VegDRI will occur early in 2010.

NDMC:

- Worked with JPL and NOAA-PSD on feedback of the QuikSCAT derived SMC product (e.g., legend, incorporation of DM vector overlays, cartographic color scheme, and temporal updating) for presentation of case study results (by Son Nghiem) at the U.S. Drought Monitor (USDM) Forum in Austin, TX. (Oct. 7-8, 2009)
- NDMC presented on VegDRI and the enhanced DM/DSS mock-up at the U.S. Drought Monitor Forum in Austin, TX. Another NDMC presentation discussed research efforts with regards to U.S. and North American drought monitoring and its potential ties to the NIDIS, Global Earth Observation System of Systems (GEOSS), and the North American Drought Monitor, which lack sufficient observed observations and is ready to evaluate new remotely sensed data and derivative products (Oct. 2009 – Wardlow, Fuchs, and Svoboda)
- Initial stage of preparing individual book chapters for VegDRI and SMC approaches for a new book entitled 'Remote Sensing of Drought: Innovative Monitoring Approaches' being prepared for CRC Press (co-editors: Brian Wardlow - NDMC, Jim Verdin – USGS & NIDIS, and Martha Anderson – USDA ARS) (May – Sept., 2009 – Wardlow)
- Research efforts with regards to U.S. and North American drought monitoring and potential ties to NIDIS, Global Earth Observation System of Systems (GEOSS), and the North American Drought Monitor, which lack sufficient observed observations and is ready to evaluate new remotely sensed data and derivative products. (ongoing)
- Provided guidance/feedback on initial JPL and NOAA PSD derivative products involving the QuikSCAT SMC. Provided information on DM ranking percentile criteria, color scheme, and USDM operational methods, color scheme, delta maps, and temporal production needs that will be applied to the SMC product.
- Work being done between the NDMC, PSD, and NIDIS Portal Team for setting up operational integration of the Soil Moisture Change (SMC) product into the NIDIS Drought Monitor Author Community and/or GIS Map Viewer on the Portal (drought.gov).

- NDMC maintains an operational email list server to facilitate communication amongst all project participants (nasadrought@unl.edu) (ongoing).
- NDMC will continue to update, enhance and maintain a project web site (http://www.drought.unl.edu/nasa/index.html) for project communication and to facilitate the integration of NASA Earth Science data into the USDM (ongoing).

NOAA PSD:

- Acquiring and assembling NASA QuikSCAT/SMC data set Obtained results for VegDRI and the enhanced DM/DSS mock-up.
- Acquiring and assembling AWDN Nebraska in-situ soil moisture data set.
- Establishing semi-automatic daily updates for SMC data stream.
- Establish weekly updates of SMC consumer imagery, including SMC weekly derivatives.
- Developing software for detail correlation of high resolution satellite data with in-situ data.

DFO:

- Testing MODIS Rapid Response Subset-based water classification algorithms (mainly using bands 1,2,7 geotiff files).
- Implemented test drought displays, 10 deg x 10 deg land areas for 48 states and Alaska. Basic approach involves comparison of MODIS-imaged normal surface water conditions to present MODIS-imaged surface water.
- Acquisition of imagery, processing water classification, GIS vectorization, and quality control of "normal surface water" (mean conditions) map layers, based on MODIS subset data, 2007-present. First area to be completed includes California and Nevada.
- Development of HTML displays importing the latest Drought Monitor display, thence allowing directed, clickable access to MODIS-based Surface Water Drought displays, an also AMSR-E surface water sites.

NOAA CPC (non-cost collaborator):

- Review of current procedures for production of Drought Outlooks, including principal input for short-term and long-term forecasts.
- Identifying candidates for drought monitor and forecast: multi-model LDAS, soil moisture anomaly, historical PDI data, etc.
- Potential utilization of soil moisture change data to identify recent trends (non-stationary) for applications to drought forecast.
- Advising the team on drought forecast/outlook issues.

NIWR-USGS STUDENT INTERNSHIP PROGRAM

Not applicable

STUDENT SUPPORT

Not applicable

NOTABLE AWARDS AND ACHIEVEMENTS

Not applicable

PUBLICATIONS AND PRESENTATIONS IN 2009

Brown, J.F., Miura, T., Gu, Y., Jenkerson, C., and Wardlow, B., "Utilizing a multi-sensor satellite time series in real-time drought monitoring across the United States", *In* Proceedings of the 2009 Joint Assembly of the American Geophysical Union, May, 2009, Toronto, Canada. [Presentation].

Gu, Y., Brown, J.F., van Leewen, W., Reed, B.C., and Miura, T., "Phenologic classification of the United States: a framework for extending a multi-sensor time series for vegetation drought monitoring," *In* Proceedings of the Annual Meeting of the Association of American Geographers, March, 2009, Las Vegas, Nevada. [Presentation].

Gu, Y., Brown, J.F., Miura, T., van Leewen, W., and Reed, B.C., "Phenological classification of the United States: a geographic framework for extending multi-sensor time series data," manuscript in preparation.

JPL Photo Journal, "Rapid Dry-Up of Rainwater on Land Surface Leading to the Santa Barbara Wildfire," *Internet article* http://photojournal.jpl.nasa.gov/catalog/PIA12006, Jet Propulsion Laboratory, Pasadena, California, 8 May 2009.

NDMC et al., Initial stage of preparing individual book chapters for VegDRI and SMC approaches for a new book entitled 'Remote Sensing of Drought: Innovative Monitoring Approaches' being prepared for CRC Press (May – Sept., 2009 – Wardlow).

NDMC presented VegDRI at the US/Canada Bi-lateral GEO Workshop hosted by the National Science Foundation (NSF) in Arlington, VA. (Oct. 2009 – Wardlow).

Nghiem, S. V., D. Balk, E. Rodriguez, G. Neumann, A. Sorichetta, C. Small, and C. D. Elvidge, "Observations of Urban and Suburban Environments with Global Satellite Scatterometer Data," *ISPRS Journal of Photogrammetry and Remote Sensing*, 64, 367-380, doi:10.1016/j.isprsjprs.2009.01.004, 2009.

Nghiem, et al. (authors from JPL, USGS, NDMC, NOAA PSD, DFO, and others), "Pattern and Frequency of Soil Moisture Variability over the Continental United States," *manuscript* in revision, 52 pp., 2009.

Nghiem, S. V., "NASA Satellite Data for Applications to Early Warning of Droughts across the World – Examples for Africa," *Inter-Regional Workshop on Indices and Early Warning Systems for Drought*, Lincoln, Nebraska, 8-11 December 2010.

Nghiem, S. V., "Satellite Observation of Soil Moisture Change and Applications to Drought Monitoring," *6th U.S. Drought Monitor Forum*, Lower Colorado River Authority, Redbud Center, Austin, Texas, 7-8 October 2009.

Nghiem, S. V., "Geophysical Information from NASA Satellite Scatterometry – Western U.S. and California," *ESRI International User Conference*, San Diego Convention Center, San Diego, California, 13-17 July 2009.

How Water Resources Limit and/or Promote Residential Housing Developments in Douglas County

Basic Information

Title:	How Water Resources Limit and/or Promote Residential Housing Developments in Douglas County
Project Number:	2008NE164B
Start Date:	3/1/2008
End Date:	3/15/2010
Funding Source:	104B
Congressional District:	2
Research Category:	Social Sciences
Focus Category:	Economics, Floods, Management and Planning
Descriptors:	floodplains property values, dam construction lakeview amentities
Principal Investigators:	Steven Shultz

Publications

1. Shultz, S, and N. Schmitz, 2008.. Viewshed Analyses to Measure the Impact of Lake Views on Urban Residential Property Values. The Appraisal Journal: 76(3): 224-232.
2. How Water Resources Limit and/or promote Residential Housing Developments in Douglas County. 2008. Shultz and Schmitz. http://unorealestate.org/pdf/UNO_Water_Report.pdf

Final Project Report

U.S. Geological Survey 104 B Program (through the NU Water Center)
March 30, 2010

How Water Resources Limit and/or Promote Residential Housing Developments in Douglas County

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Douglas County, NE Board of Commissioners

Any and all claims and statements made in this report along with any potential omissions or errors are the sole responsibility of the authors

Executive Summary

Objectives:

This research quantifies the relationships between water resources and residential property values in the Greater Omaha metropolitan area by measuring the impact of:

1. 100-year floodplain designations on residential housing prices to evaluate potential economic benefits of flood mitigation projects.

2. Man-made lakes on nearby residential property prices to identify strategies to maximize public benefits.

3. Alternative types of open space/low impact development (LID) subdivision designs on residential property values. This will help both the public and private sector better understand and promote successful and profitable LID subdivisions.

These analyses are expected to be of interest to both policy makers and resource managers in their ongoing efforts to design and implement cost-effective flood mitigation and stormwater water management projects in Douglas County.

Approaches:

The methodological approach of this study relied on empirical real estate transaction data that was referenced within a geographical information system (GIS) in order to quantify site-specific relationships between water resources and property values. In particular, hedonic price models (also known as ‘mass appraisal’ models) were estimated along with comparisons of the sale prices of residential lots. Earlier phases of this research have already been accepted for publication in peer-reviewed professional journals.

Results 1: Floodplain Impacts and Residential Property Values

Hedonic price models indicate that homes within Douglas-Papio Creek floodplains100-year floodplains have sold for 3.9% less than otherwise similar but non-floodplain homes

over the 1996 to 2007 time period. Based on these hedonic price impacts in conjunction with the estimated market value of all 1,123 Douglas-Papio floodplain homes, a hypothetical set of upstream flood mitigation projects which would remove all of these homes from the floodplain, would generate $5.3 million in increased property values.

Alternatively, potential flood mitigation benefits were also calculated based on the estimated cost of flood insurance premiums: $11.9 million for all Douglas-Papio floodplain homes versus $360,000 for only the homes designated to be in the newly revised floodplain in 2008 (based on 'grandfathered' non-floodplain insurance rates which are about 75% cheaper than typical 100-year floodplain rates).

These property valuation estimates related to floodplain status, could potentially be used by Douglas County for evaluating the economic feasibility of proposed flood mitigation projects in the Papio Creek Watershed. In particular, if it is known how proposed flood mitigation projects impact downstream floodplains (i.e. the number of homes removed from the 100-year floodplain), then either expected property value increases or avoided flood insurance could be considered as flood mitigation benefits. For example, depending on the likely effectiveness of a flood mitigation project, and the type of benefits deemed most appropriate for comparison, a range of possible economic benefits associated with future (hypothetical) Douglas-Papio Creek flood mitigation projects emerges: The low end of the range is $36,000 in benefits associated with a scenario of only 10% of homes being removed from the Douglas-Papio Creek floodplains, and considering only new insurance costs to homes placed in the floodplain in 2008-09. The high end of the range is $11.9 million based on avoided flood insurance when 100% of Douglas-Papio Creek residential properties are removed from the floodplain. This information could potentially be used in conjunction with results of hydrologic-based feasibility studies (by others) to evaluate the economic feasibility of proposed flood mitigation projects in Douglas and/or Washington County. However, two other key property types should be included in such analyses: Commercial property which is likely more valuable than residential property within these floodplains, and undeveloped land which would likely increase in value if it is removed from the 100-year floodplain.

Results 2: Amenity Values Created by Lakes

Hedonic valuation models of residential housing sales along with comparative lot sale analyses have demonstrated that substantial increases in residential property values have resulted from the construction of four different man-made lakes in the Omaha area. Lake views increase housing values by between 7% and 18% at the four different lakes and has created $26.7 million in increased housing values. Both view and access premiums are paid by home and/or lot buyers and based on the analyses of lot sales at two lakes, most of these premiums appear to be captured by landowners and/or developers at the time the lakes are first constructed. It is also evident that increased levels of exclusivity increase the premiums that homebuyers are willing to pay for both lake views and access.

An analysis of 'Dam Site 13' (the most recently constructed Omaha lake and the first 'public-private lake construction partnership'), demonstrated that the private sector partner contributed $1.6 million to the cost of lake construction and in return, is *expected* to generate an additional $7.7 million from incrementally higher lot sale values associated with view and access premiums. This corresponds to a discounted rate of return of 437% or, 87% annually for five years. These are *preliminary* estimates of potential profit levels and continued research on this topic is warranted particularly since it is suspected that part of the lot values in this subdivision may be due to proximity to a school and/or a very high quality subdivision design.

It was concluded that future public-private lake construction partnerships should more closely evaluate whether contributions from private developers are sufficient in relation to the increased profit levels associated with lake views and/or access that they are likely to capture. Alternatively, the design of future lakes should have more public recreation and buffer areas that improve both access and lake water quality in order to guarantee the public fully captures lake amenity values that are created through the use of public funds.

Results 3: LID Subdivision Design and Property Values

A set of 14 different hedonic valuation models were estimated across 326 different subdivisions in the western and southwestern (suburban) portions of Douglas County in

order to quantify how different types of open space characteristics, which are considered a proxy for alternative LID designs, impact residential property values. From this it was concluded that homeowners:

- Are willing to pay more for a home near open space if the open space is owned and/or managed by private versus a public entity.
- Prefer open space that is dominated by trees and mowed grasses over non-mowed areas, or open spaces with recreation (sports) facilities.
- Prefer open space with trails.
- Are willing to pay 1.1% more for clustered open space (LID) designs, and, 2.74% more for open (contiguous) open space (LID) designs than they would for conventional sub-division designs.

These research results should be useful to both public planners and private developers in the design and implementation of open space and LID subdivision designs within residential subdivisions. In particular, price premiums associated with alternative open space or LID subdivision designs can now be compared to their implementation costs and relative effectiveness for stormwater management.

Where These Research Methodologies Have Already Been Peer Reviewed

Shultz, S. and N. Schmitz. 2008 (forthcoming). Augmenting Housing Sales Data to Improve Hedonic Estimates of Golf Course Frontage. ***Journal of Real Estate Research.***

Shultz, S, and N. Schmitz, 2008. Viewshed Analyses to Measure the Impact of Lake Views on Urban Residential Property Values. ***The Appraisal Journal* (Summer, 2008).**

Shultz, S. and P. Fridgen. 2001. "Floodplains and housing values: Implications for flood mitigation projects". ***Journal of the American Water Resources Association*** 37(3)

Shultz, S. and D. King. 2001. "The use of census data for hedonic price estimates of open space amenities and land uses". ***Journal of Real Estate and Finance Economics*** 22(1)

Suggested Follow-Up Research

The original study objectives specified in the contract between UNO, Douglas County, and the NU Water Center, are considered to have been met by this Final Project Report. However, the UNO research team plans to conduct follow-up research on the various

suggested future research topics listed below (categorized by floodplain, lake amenities, and LID research themes). No additional funds are being requested from the sponsors for this continued research, and the resulting research results will be considered 'supplemental reports' and distributed to the Douglas County Board and the NU Water Center when they are completed (likely in the next 6 to 12 months).

Floodplain-Property Value Research

1) Conduct comparable sales based appraisal analyses.
2) Evaluate strategies to improve flood insurance cost estimates.
3) Conduct surveys of floodplain property owners.
4) Estimate the impact of floodplain status of commercial properties and for undeveloped land.
5) Determine total (residential, commercial and vacant) property values and related flood mitigation benefits in the Douglas-Papio floodplains

Lake-View Amenities

1) Conduct a hedonic analysis of sold lots at Standing Bear, and Zorinsky to better measure view and access values that were captured by developers
2) Continue to collect and monitor both lot and housing sales at Dam Site 13 to see if view and access premiums change over time
3) Conduct surveys of homebuyers at Dam Site 13 and nearby subdivisions to identify factors that may have influenced their purchase decisions and in particular, to assess the importance of lake views, access and other factors.

LID/Open Space Amenities

1) Replicate the open space hedonic price models using lot sales. This would potentially be more helpful for residential housing developers to identify different profit levels associated with different open space designs

2) Survey homebuyers to elicit their perceptions of and preferences for different open space amenities. This could potentially confirm many of the conclusions reached in this study based on observed property sales data

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The Impact of Floodplains on Residential Property Values

Background

The hedonic valuation method is a widely accepted approach to quantify the determinants of property values and for measuring the marginal contribution of environmental amenities (or disamenities). It relies on multiple regression where the dependent variable (usually housing price) is specified to be a function of structural housing characteristics, lot characteristics, neighborhood effects, transaction details (including time of sale), and environmental conditions. When the hedonic approach is used to quantify how floodplains impact residential property values, a dichotomous ('dummy') variable usually represents whether a property (usually a building) is located in the floodplain.

There are several reasons why it is important to quantify the relationship between 100-year floodplain status and property values. First, homeowners, appraisers and tax assessors regularly need such information to better understand how floodplain status affects the market value of residential properties. Second, such information can be used to help quantify the economic benefits associated with flood mitigation projects which are proposed to remove particular residential properties from the 100-year floodplain. Finally, an improved understanding of the relationship between floodplains and property values could potentially be used to determine how much individual floodplain property owners should contribute to the cost of specific mitigation projects which will potentially remove their properties from the floodplain and hence increase their property values.

It is expected that the development and refinement of methodologies to quantify the impact of floodplains on property values is particularly relevant in the Greater Omaha metropolitan area where 100-year floodplain maps have recently been re-drawn by the Papio-Missouri Natural Resource District (PMNRD) and the Federal Emergency Management Agency (FEMA). These new floodplain maps will become official by the end of 2008 or early 2009. The construction of new homes is not permitted in the 100-year floodplain but existing homes in these high flood-risk areas are usually permitted to

remain in existence and can be re-sold as long as their floodplain status is disclosed to potential homebuyers. Also, flood insurance administered by the National Flood Insurance Program (NFIP) is required for such homes by mortgage lenders. Preliminary estimates by the PMNRD indicated that there are about 2,600 properties in the 100-year floodplain (Douglas and Sarpy counties) and that approximately 700 to 900 of these properties have been designated to be included in the 100-year floodplain as a result of the new (2008-09) floodplain maps (PMNRD Spectrum Newsletter, Summer, 2007).

The impact of floodplain location on property values in Omaha has to date not been formally studied. In fact, the closest known location of a published hedonic floodplain study is Fargo, North Dakota, where it was determined that homes in the 100-year floodplain lowered home values by between 8.8% and 10.2% (Shultz and Fridgen, 2001). Another study in a suburban watershed in St. Louis, MO, measured a 4.7% floodplain impact on housing prices (Qui, Prato and Boehm, 2006). Negligible floodplain impacts have been noted in other regions, particularly in areas with high profile and recent flood events have not occurred and/or where homebuyers are not fully informed of the floodplain status of their homes prior to purchases (Chivers and Flores, 2002).

Study Objectives

1) Quantify Floodplain Impacts on Property Values

A hedonic price model is estimated to quantify the determinants of housing prices with a particular focus on the marginal impact of 100-year floodplain status. The study sample is a two-mile buffer around the Big, Little, and West reaches of the Papio Creek within Douglas County (hereafter referred to as the 'Douglas-Papio Creeks'). This study area was chosen since the Douglas-Papio Creeks contain the highest relative concentrations of floodplain properties in Douglas County, and because the Papio Creeks are the focus of several recently proposed flood mitigation projects.

2) Determine the Market Values of Floodplain Properties

Using Douglas County tax assessment records and GIS-based analyses of housing structures within FEMA D-Firm floodplain maps the market value of all residential

properties within the current and proposed (2008-09) Douglas-Papio Creek floodplains are estimated. This is based on ratios between assessed and sale values and site specific determinations of the floodplain status of individual homes.

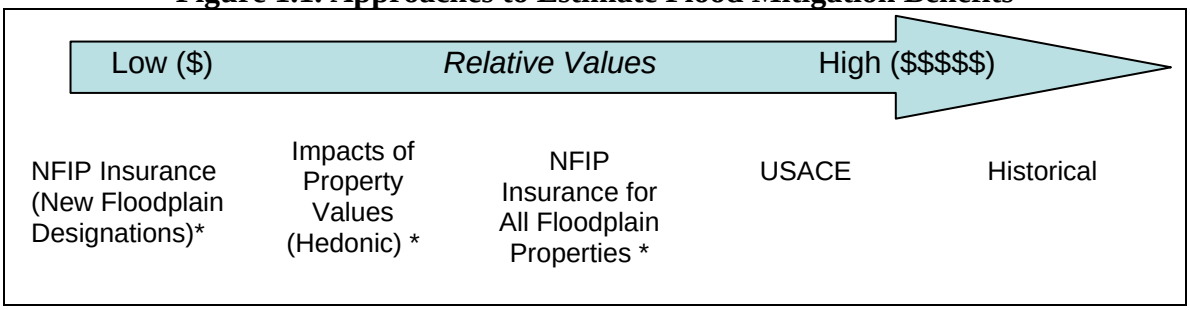
3) Estimating Potential Flood Mitigation Benefits

Here the potential economic benefits associated with flood mitigation projects that eliminate the 100-year floodplain status of residential properties in the Douglas-Papio Creek floodplains are calculated based on alternative criteria: a) Observed marginal impacts of floodplain location on property values; b) Flood insurance premium costs associated with all residential floodplain properties; and c) Flood insurance premiums costs only for homes designated to be in the new (2008-2009) 100-year floodplain.

In addition to identifying potential property value losses associated with floodplains, this research effort will demonstrate an approach for calculating the potential financial benefits which individual property owners could capture as a result of flood mitigation projects. This in turn could become a mechanism for objectively calculating special assessment taxes on these property owners who would directly benefit from specific flood mitigation projects and hence reduce the financial burden of such projects on taxpayers who will not receive any direct flood mitigation benefits.

It should be noted that there are other approaches used by policy makers to quantify flood mitigation benefits that were not evaluated by this present research. These include quantifying actual flood damage after specific flood events (i.e. historical flood data), and/or the standard USACE approach to quantifying potential flood damages which involves determining the value of first floor residential structures and a fixed amount of personal contents measured as percentage of structural value that would be potentially damaged during a 100-year flood events. The relative values of estimated flood mitigation benefits associated with each approach are shown in Figure 1.1. Insurance cost savings for homes determined to be in the 100-year floodplain after an earlier home purchase generate the lowest expected economic values, while observed historical flood damages are expected to generate the highest values flood mitigation benefits.

Figure 1.1. Approaches to Estimate Flood Mitigation Benefits



** Indicates approaches/values quantified by this present study*

The selection of a particular type of flood mitigation benefit for use in a cost-benefit analysis (CBA) of a specific flood mitigation project depends on which approach or value is most suitable from the dual perspectives of: 1) Reliability of data and estimation approaches (usually a function of available data); 2) Who is expected to received flood mitigation benefits (i.e. from whose perspective is the CBA being analyzed)?

For example, from the federal government's perspective, the use of the standard USACE inventory-based approach is likely the most appropriate as it accounts for damages from a wide societal perspective. In cases where extensive flood damage has occurred the use of historical data has benefits particularly for local and state governments who often want to determine how much flood damage has occurred above and beyond what is covered by flood insurance of other related federal emergency relief programs. Flood reduction benefits based on avoided flood insurance premiums primarily accounts for benefits captured by individual property owners (who may no longer be required to purchase flood insurance as the result of a specific flood mitigation project). Similarly, marginal property value impacts associated with flood reduction are also usually captured by, and of most interest to, private property owners. However, these price impacts usually generate lower flood reduction benefits due to the fact that many homebuyers either do not understand the present value of a future stream of insurance premium costs, or, they are not aware of floodplain risks. The final and lowest expected relative benefit associated with flood reduction is avoided flood insurance for properties placed into the floodplain after purchasing their homes (i.e. when floodplain maps are updated by FEMA). Although these are captured by private property owners, these benefits and costs

are often of societal concern under the premise that such property owners did not voluntarily purchase floodplain properties.

Historical damage data does not exist in sufficient frequency or detail in the Douglas-Papio Creek floodplains and the estimation of potentially avoided flood damage using the USACE approach requires information and data associated with flood mitigation projects and specifically impacted properties. However this information can be very difficult and time consuming to accurately estimate. As well, most of these USACE flood reduction benefits should be accounted for by the avoided insurance approach. Therefore, this study concentrates on the remaining three approaches: property price impacts (hedonic-based estimates), flood insurance for homes in the original 100-year floodplain, and alternatively, in the new (2008-09) floodplain.

Methods and Procedures

Hedonic Price Impacts of Floodplains

The hedonic price analysis quantifies the impact of the 100-year floodplain on residential housing sale prices within 2 miles of Douglas-Papio Creeks over the 1996 to 2007 time period. The study area includes the Big, Little, and West reaches of the Papio Creek within Douglas County (Figure 1.2). There are approximately 7,200 acres of existing (pre 2008) floodplains within this study area. The corresponding floodplain area in the Sarpy county portions of the Papio Creeks is approximately 6,200 acres.

Figure 1.2 Douglas-Papio Creek Study Locations

The real estate transaction dataset used for the study was generated by combining a Douglas county parcel database with real estate transaction data from the Great Plains Realtors Multiple Listing Service (MLS) over the January 1996 – June 2007 time-period. The MLS data was deemed necessary to account for detailed structural housing characteristics and transaction information (particularly the existence of any seller concession). The resulting database includes 22,350 arms-length sales.

Since the database was in a GIS format, it was possible to determine whether homes were within FEMA 100-year floodplain zones (zones A, AE, AJ and AO) based on spatial overlays of residential parcels and both original and 2008-09 FEMA floodplain maps (which were provided to us in a GIS format by the PMNRD). The identification of the floodplain status of sold residential properties first involved a spatial overlay of floodplain and parcel boundaries and then manual (visual-on-screen) inspections of house locations and floodplain boundaries using NAIP air-photos. This manual approach was

necessary since while a lot may be in the floodplain, flood insurance is only required if the actual house boundary is located in the floodplain and because the GIS database of properties does not explicitly contain the boundaries of housing structures. The resulting map contained in Figure 1.3 shows the locations (in red) of all the floodplain homes sold between 1996 and 2007 within the study area. Examples of the manual (property-by-property) analyses of whether homes were in or out of the floodplain (both the old floodplain and the revised 2008-09 floodplain) are show in Figure 1.4.

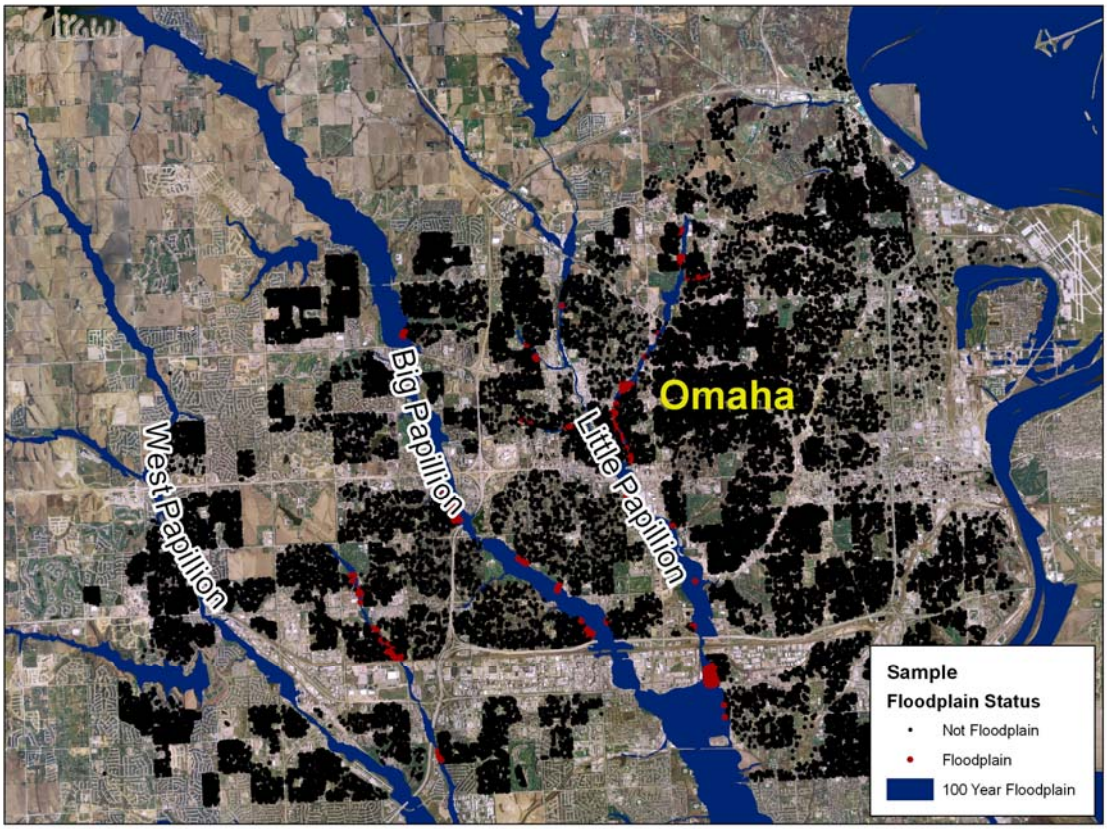


Figure 1.3 Sold Homes and Papio Creek 100-year Floodplain (1996-2007)

A. A Modern Subdivision Partially in the Original 100-Year Floodplain

B. Homes Previously Not in the Floodplain but now in the Year 2008 Floodplain (red areas)

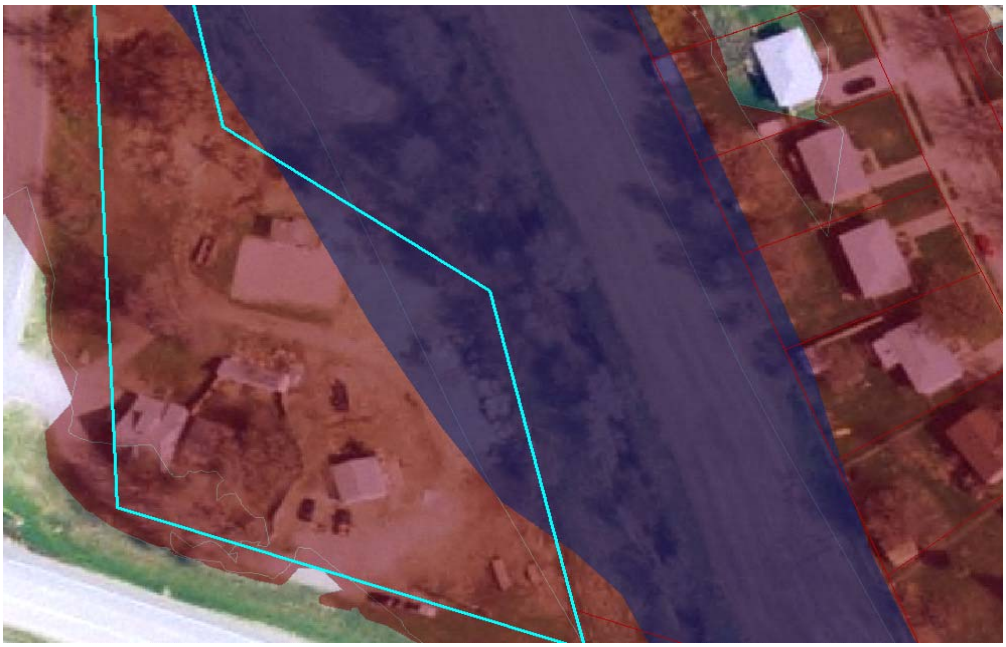


Figure 1.4 Examples of Sold Douglas County Floodplain Homes

GIS techniques were also used to quantify how far floodplain homes were from major roadways and/or, industrial areas, and water features (streams and/or impounded water bodies). The full range of explanatory variables used in the hedonic price model is summarized in Table 1.1. The functional form used to represent the relationship between

particular explanatory variables and housing prices varies based on the literature (previous studies) and our own experiences with hedonic price modeling in Omaha. Log terms are used with lot size, house size, distance to water, and distance to industrial locations in that the marginal effects of these characteristics are less as the magnitude of the variable gets larger, i.e. diminishing marginal returns.

With respect to the floodplain explanatory variable (whether or not a property is located within the floodplain) log-linear functional form is used. Therefore the resulting coefficient can be interpreted directly as percentage change in sale price resulting from whether or not a home is located in the 100-year floodplain. It has been pointed out previously by Kennedy (1981) that the interpretation of log-linear coefficients must be adjusted for by using the following equation: $\hat{g} = e(\hat{c} - (½)V(\hat{c})) - 1$ where $\hat{g}$ is the percentage effect of the dummy variable as adjusted by the variance of the coefficient $V(\hat{c})$.

The Market Value of Floodplain Homes

The market value of residential properties in the 100-year floodplain portions of the Douglas-Papio Creeks was estimated by cross listing Douglas County tax assessment records and our GIS based analyses of housing structures within the most recent FEMA floodplain maps. After quantifying sale assessment ratios of Papio Creek floodplain homes in Douglas County (i.e. comparing assessed values to actual sale prices while accounting for any potential seller concession), the reciprocal of these ratios are multiplied by the aggregate (total) assessed values of all residential properties in the Douglas-Papio Creek floodplains to generate an estimate of the market value of all residential properties both within the original and the revised (2008-09) floodplains.

Table 1.1. Variables in the Douglas County Hedonic Price Model

Variable Name	Definition	Functional Form Used	Expected Sign (impact)
1) Dependent Variable (Y)			
Adjusted Price	Sale Price minus any seller concessions ($)	(log Price)	
2) Explanatory Variables			
D Floodplain	In the 100-year floodplain? (yes/no)	linear	-
Industry	Distance to Industrial Land Uses (ft)	log	+
Road	Distance to Major Road (ft)	Linear	+
Water	Distance to Water Body	Log	-
House Size	Finished House Size (sft)	Log	+
LotSize	Lot Size	Log	
Age	The home age (years)	Linear	-
Fireplaces	Number of fireplaces	Linear	+
Garage Spaces	Number of garage stalls	--	+
Bathrooms	Number of bathrooms	Linear	
DAvg	Home is average condition	Linear	+
DAboveAvg	Home is above avg. condition	Linear	+
Year	Year of Sale 1999-2007	Linear	Varies

Potential Flood Mitigation Benefits

The potential economic benefits associated with hypothetical flood mitigation projects that result in the elimination (removal) of the floodplain designation for residential properties in Douglas-Papio Creek floodplains involves using all the previously generated information on floodplain price impacts, floodplain properties and the market value of floodplain properties.

The marginal benefits of homes potentially removed from the floodplain based on estimated hedonic price estimates (i.e. homebuyer preferences) account for increases in property values (i.e. likely selling prices) resulting from the floodplain status of homes being eliminated. In particular, marginal price impacts of floodplains are multiplied by estimates of the total property value of all Douglas-Papio Creek floodplain homes.

Estimates of the present value of floodplain insurance premiums they are assumed to no longer be required for Douglas-Papio Creek floodplain homes in the original 100-year floodplain first requires multiplying the assessed values of homes (buildings only) by an estimated average cost of a floodplain policy that covers the building and personal contents valued at 30% of building value. These flood insurance costs were obtained from the National Flood Insurance Program website of FEMA (NFIP, 2008) and should be considered only approximate estimates for floodplain insurance costs for properties located in floodplain zones A, AE, AJ and AO. In reality, premiums are based on site specific home and site data. To determine the present value of insurance premiums over time, annual premiums are discounted over a 30-year period using a 7% discount rate.

Flood insurance premium costs for homes designated to be in the new (2008-09) 100-year floodplain are assumed to be 25% of the cost of flood insurance associated with the original 100-year floodplain. This is due to the widely known loophole that allows homeowners in the new floodplain designation to obtain a flood insurance policy based on the previous (non-floodplain) status prior to the official approval of revised and expanded floodplain maps.

Results

Properties in the Douglas-Papio Creek Floodplains

A total of 1,643 residential homes were found to potentially be in the Douglas-Papio Creek 100-year floodplain (based on original and new 2008 floodplain maps). Visual (GIS-based) inspections of individual homes found that only 1,123 (or 68%) of these homes were actually in the floodplain (i.e. parts of the property lot may have been in the floodplain but the house structure itself was not).

Over the 1996 to 2007 time-period, 243 Douglas-Papio Creek floodplain homes with lots (in the original, pre-2008 floodplain) were sold through the MLS and manual inspections of house locations determined that only 200 (82%) of these homes were actually located in the floodplain. The characteristics of floodplain versus non-floodplain homes sold over this period are summarized in Table 1.2 Floodplain homes are on average priced 16% lower than sold non-floodplain homes, but these homes were also smaller and had fewer fireplaces, garage spaces, and bathrooms. However, floodplain homes on average have larger lot sizes and were farther from major roads or industrial areas, and were closer to water bodies. The advantage of using a hedonic price equation to quantify the marginal effect of floodplain location on sale prices is that it controls for different characteristics of properties.

Hedonic Price Estimates of Floodplains

The multiple regression model summarizing the hedonic floodplain results is summarized in Table 1.3. All of the explanatory variables in the model are statistically significant at the 90% confidence level or higher and have the expected directional impact on property values. The R^2 of the model is 0.79 meaning that 79% of the variation in price is explained by the model and the F-statistic was significant at the 1% level indicating that all variables considered jointly have a statistically significant impact on sale prices.

Coefficients for non-linear variables (with logs) need to be numerically manipulated before directly interpreting their marginal effects on sale price but the linear coefficients can be interpreted directly. For example, each additional year of age decreases a home's

sale price by 0.3% while each additional bathroom contributes 4.2% and an ‘above average condition home would be worth around 15% more than an otherwise similar home. The dummy variable coefficient for floodplain location was negative and statistically significant and indicates that floodplains reduce property values by 3.9% (based on both the original coefficient and the Kennedy coefficient transformation).

This floodplain price discount of 3.9% observed in Douglas County is substantially lower than floodplain impacts noted in other locations of the country and appears to be considerably less than the present value cost of flood insurance premiums that are required for mortgage loans. There are three possible explanations for this. First, these homes may have natural resource amenities that are not being fully accounted for in our model. That is, homebuyers may be overlooking floodplain risk because these homes are on large lots with streams and/or nearby other open space amenities (views, wildlife etc). A second possible explanation is homebuyers may not be fully aware of the full extent of floodplain risks in light of the fact that no major flood events have occurred in the region in recent years. Third, homeowners may not fully understand the present value costs of flood insurance premiums required over time.

Table 1.2 Floodplain/Non-Floodplain Housing Sale Characteristics (Douglas-Papio Floodplain, 1996-2007)

Variable	Non-Floodplain Sales(n=22,150)				Floodplain Sales (n= 200)			
	Mean	Median	Min	Max	Mean	Median	Min	Max
Adjusted Price	$138,413	$123,000	$14,000	$899,000	$100,803	$95,000	$26,759	$212,500
Industry	4,450	3,448	38	16,462	2,437	2,120	139	6,291
Road	804	720	30	2,616	838	823	85	2,460
Water	2,185	1,904	27	7,606	517	372	53	4,764
LotSize (sqft)	10,045	8,712	0	460,429	9,322	7,841	2,178	62,726
HouseSize (sqft)	1,900	1,724	400	6,511	1,453	1,415	750	3,698
Age [Years]	34.3	33.0	0.0	136.0	38.1	41.5	0.0	96.0
Fireplaces	0.73	1.00	0.00	4.00	0.34	0.00	0.00	2.00
Garage Spaces	1.73	2.00	0.00	4.00	1.35	1.00	0.00	4.00
Bathrooms	2.42	2.00	0.00	4.00	1.81	2.00	1.00	4.00
D Avg.*	0.32	0.00	0.00	1.00	0.44	0.00	0.00	1.00
D Above Avg.*	0.34	0.00	0.00	1.00	0.20	0.00	0.00	1.00
D 1997 to D 2007 (% Sold in)	0.07	0.00	0.00	1.00	0.06	0.00	0.00	1.00
D 1998	0.08	0.00	0.00	1.00	0.09	0.00	0.00	1.00
D 1999	0.08	0.00	0.00	1.00	0.06	0.00	0.00	1.00
D 2000	0.08	0.00	0.00	1.00	0.07	0.00	0.00	1.00
D 2001	0.09	0.00	0.00	1.00	0.07	0.00	0.00	1.00
D 2002	0.10	0.00	0.00	1.00	0.11	0.00	0.00	1.00
D 2003	0.11	0.00	0.00	1.00	0.09	0.00	0.00	1.00
D 2004	0.11	0.00	0.00	1.00	0.14	0.00	0.00	1.00
D 2005	0.12	0.00	0.00	1.00	0.14	0.00	0.00	1.00
D 2006	0.10	0.00	0.00	1.00	0.11	0.00	0.00	1.00
D 2007	0.05	0.00	0.00	1.00	0.05	0.00	0.00	1.00

Table 1.3 Regression Results: Douglas County-Papio Creek Hedonic Model

Variable	Coef.	Std. Err.	P>t
D Flood	-0.039	0.013	0.003
Ln Industry	0.016	0.002	0.000
Ln Road	0.006	0.001	0.000
Ln Water	-0.006	0.002	0.001
Ln LotSize (sqft)	0.079	0.003	0.000
Ln HouseSize (Sqft)	0.618	0.006	0.000
Age [Years]	-0.001	0.000	0.000
Fireplaces	0.067	0.002	0.000
Garage Spaces	0.081	0.002	0.000
Bathrooms	0.020	0.002	0.000
D Avg.	0.003	0.005	0.537
D Above Avg.	0.051	0.005	0.000
D 1997	-0.022	0.006	0.000
D 1998	0.021	0.006	0.000
D 1999	0.076	0.006	0.000
D 2000	0.103	0.007	0.000
D 2001	0.115	0.007	0.000
D 2002	0.146	0.007	0.000
D 2003	0.177	0.006	0.000
D 2004	0.219	0.006	0.000
D 2005	0.263	0.006	0.000
D 2006	0.257	0.005	0.000
D 2007	0.227	0.006	0.000
Constant	5.907	0.048	0.000
Obs.		22350	
F(26, 35704)		3656.22	
Prob > F		0.0000	
R^2		0.7902	
Adj R^2		0.7900	
Root MSE		0.1831	
Interpretation*		-3.9%	

** Calculated using Kennedy's (1981) equation*

Flood Insurance Costs

Based on NFIP flood insurance calculators and our sample of floodplain homes, annual flood insurance premiums among Papio-Creek properties are assumed to be 1% of the building (improved value) of properties. This also assumes that contents up to 30% of building value are also insured. Based on the average $100,000 property value of these

homes in the sample this indicates that the average value of buildings/improvements would be $86,000 and that the typical cost of a flood insurance policy for such a home (covering the structure and contents) is therefore $860 per year. The present value of these insurance premiums over 30 years (and using a 7% discount rate) is $10,672 which corresponds to 11% of the total property value or 12% of the improved (home value). Alternatively, flood insurance costs over a hypothetical 30-year ownership period represent 11% of the value of Douglas-Papio Creek floodplain homes located in the original 100-year floodplain

Corresponding present values of floodplain insurance costs for homes designated to be in the new (2008-09) floodplain (based on an insurance premium calculated for non-floodplain homes) is therefore 2.8% of the value of homes (25% the cost of a regular insurance policy).

Market Values of Douglas-Papio Creek Homes

The total value of all 971 residential properties in the original Douglas-Papio Creek floodplains is $111,166,877 or $96,517,196 for improvements (buildings). The corresponding values for the 152 residential properties in the new (2009-09) Douglas-Papio Creek floodplains are $13.9 million, or $11.8 million for improvements.
The ratio of assessed values to market sales among 200 Douglas County-Papio Creek floodplain homes sold between 2002 and 2007 ranges from 80% to 91% (in 2007 based on 26 sale ratio comparisons). These observed year 2007 assessment ratios are used to convert year 2007 assessed improved values to market value improved values (i.e. assessed improved values are multiplied by 1.1).

Therefore the estimated market value for properties in all Douglas-Papio Creek floodplains (both the original and the revised 2008-09 floodplains) is $136.3 million or $118 million for improvements (buildings). Corresponding values specific to the original floodplain (971 properties) are $121.2 million and $105.2 million (improved). Corresponding values for the new 2008-09 floodplain (152 homes) are $15.1 million and $12.9 million (improvements).

Potential Flood Mitigation Benefits

1) Observed Homebuyer Preferences (Hedonic Price Estimates)

Multiplying the total assessed value of all 1,234 Douglas-Papio Creek residential floodplain properties (both the original and new floodplains) by the observed price impact of floodplain status (-3.9%) results in a total property value reduction due to the existence of the Douglas-Papio Creek floodplain of $5.3 million.

This means that if the 100-year floodplain status for all Douglas-Papio Creek floodplain homes was changed (i.e. removed) through a hypothetical upstream flood mitigation project then it is likely that these property values would increase by 3.9% (i.e. $5.3 million). This marginal price effect for an assumed 100% effective flood mitigation project (a highly optimistic scenario) can be adjusted downwards to reflect the actual impacts of flood mitigation projects. For example, if such a flood mitigation project was expected to reduce the floodplain status of only 50% of the homes in the floodplain than projected benefits would be cut in half to 1.95% (or $2.7 million). It should be noted that such benefits are captured directly by private property owners and some people in society may object to using public funds to create economic gain for private individuals, particularly when property owners either paid discounted prices for floodplain properties and/or receive other offsetting amenity benefits associated with floodplains areas (open space, wildlife, viewing, etc).

Besides being useful for cost-benefit analyses, the approach used here to estimate benefit measures from the perspective of marginal increases to property values, are useful in that they identify who specifically receives the flood mitigation benefits (in this case it is private property owners), and by how much (here, it is 3.9% of the market value of properties.) This monetary estimate could therefore be used to assign special tax assessments to individual property owners based on the relative value of flood mitigation project benefits they receive. For example, if it is assumed that floodplain property owners would be willing to paying $5.3 million in flood mitigation project costs in order for their property values to increase by the same amount (3.9%), then the proponents of flood mitigation projects should attempt to capture contributions from these private

property owners. Hopefully this would reduce the tax cost burden of other residents who will receive little or no specific private benefits from flood mitigation projects.

2) Avoided Flood Insurance Costs

Multiplying the total estimated market value of improvements in the original 100-year floodplain ($105.2 million) by the observed present value cost of flood insurance (11% of structural values), generates a present value flood insurance policy cost (specific to the original pre-2008 floodplain) of $11.6 million.

This means that if the 100-year floodplain status for these 1,123 Douglas-Papio Creek properties was changed (removed) through some upstream flood mitigation project, then it is likely $11.6 million of combined flood insurance costs would be avoided. Again, these benefits accrue directly to private property owners.

It should be noted that these flood insurance premiums are only estimates and likely to be lower since many floodplain owners are likely to have obtained lower cost flood insurance policies (issues prior to official floodplain status notification from the Federal Government) and the fact that some property owners are likely to own their homes outright and hence are not legally required to have flood insurance policies. Nevertheless, this insurance cost estimate does provide a possible measure of the marginal benefits of a flood mitigation project that is 100% successful.

Since many floodplain property owners do not appear fully aware of the full costs of their flood insurance policies (in that these insurance costs are not fully capitalized into the price discounts they pay for floodplain properties), it is not very likely that these property owners would be willing to pay $11.6 million for a flood mitigation project that would reduce the present value of flood insurance costs. For this reason, the earlier hedonic based economic flood mitigation project benefits are considered more reliable for use in cost benefit analyses. Further support of the use of these potential project benefits could easily be measured through surveys of floodplain property owners in order to gauge their willingness to contribute specific monetary amounts for expected floodplain risk benefits.

Corresponding flood insurance costs for the 152 homes recently designated to be in the new (2008-2009) floodplain is only $360,000. Therefore if it was assumed that for whatever reasons Douglas County was responsible for the floodplain status of these properties, it would cost the County only $360,000 to compensate these property owners by paying their insurance premiums. Alternatively this $360,000 cost could be compared to the potential costs of proposed flood mitigation projects to determine whether it is feasible for the County to contribute to such projects.

Finally, it should be noted that there are other approaches used by policy makers to quantify flood mitigation benefits that were not evaluated by this present research. These include quantifying actual flood damage after specific flood events (i.e. historical flood data), and/or the determination of the value of first-floor housing structures (and home contents) that would be potentially damaged during 100-year flood events. This issue is discussed further in the Policy and Implications section.

Summary and Policy Implications

This research has demonstrated a methodology to accurately measure flood mitigation benefits using empirical real estate transaction data. The observed price differences between floodplain and non-floodplain homes in Douglas County (3.9%) could potentially be used by the PMNRD and/or County governments or others in negotiating fair market prices to pay for floodplain homes as part of their floodway purchase program. These statistics may also be taken into consideration by county tax assessors when valuing floodplain residential properties.

Alternatively this floodplain impact measure can be used as a reliable measure of avoided flood damage (i.e. an economic benefit of particular flood mitigation projects). In this case it was shown that if a future flood mitigation project was able to remove the 100-year floodplain status for all of the Douglas-Papio Creek floodplain properties (which is a highly optimistic and perhaps impossible and/or expensive outcome), then it is likely that these property values would increase by 3.9% (i.e. $5.3 million). Similar benefits

associated with mitigation projects that reduce the floodplain status for fewer homes can also be estimated using the data and analyses contained in this report. This information is expected to be useful for Douglas County when evaluating the economic feasibility of participating in future flood mitigation projects associated with the Papio Creeks.

If flood insurance costs were considered a more relevant measure of potential flood mitigation benefits, then flood mitigation project costs should be compared to $11.9 million for all floodplain properties or $360,000 for only properties in the new floodplains.

A summary of potential estimated benefits of future (hypothetical) Douglas-Papio Creek flood mitigation projects requires multiplying property value impacts and/or insurance costs by the estimated value of properties expected to be removed from the floodplain (which would hopefully be quantified by the 'feasibility studies' of particular flood mitigation projects). A full range of these potential benefits associated with hypothetical flood mitigation projects that remove between 10% and 100% of homes from the Douglas-Papio Creek floodplain are summarized in Table 1.4. Depending on the likely effectiveness of flood mitigation projects and the types of benefits considered, the value of future (hypothetical) Douglas-Papio Creek flood mitigation projects ranges from $36,000 (only 10% of homes removed from the floodplains and considering only new insurance costs to homes placed in the floodplain in 2008-09) to $11.9 Million (100% of homes removed from the floodplains and considering all avoided insurance costs).

Table 1.4. Potential Estimated Benefits of Douglas-Papio Flood Mitigation Projects

	Homes Potentially Removed From the 100-Year Floodplain (from a hypothetical flood mitigation project)			
	10%	***25%***	***50%***	***100%***
A) Property Value Increases (hedonic estimates, all floodplain homes)		$ 1.3 million	$ 2.7 million	$ 5.3 million
B) Avoided Insurance Costs (All Floodplains homes)		$ 2.9 million	$ 6.0 million	$11.9 million
C) Avoided Insurance Costs (2008-09 Floodplain home additions only)	$36,000	$90,000	$180,000	$360,000

** Note these potential benefits should not be combined as this would be a form of double (or even triple) counting of the same benefits.*

A possible limitation in using this floodplain impact and benefit valuation research is that two other key property types have not been considered. These include commercial property which ***may*** be as much or more valuable than residential property within Douglas County floodplains, and undeveloped property, which if removed from the floodplain could have a significantly higher and best use.

It is therefore proposed that these two missing classes of floodplain properties be included on a list of recommended future research. But it should also be noted that if commercial property values are two, three or even four times the value of residential property values in the Douglas-Papio Creek floodplains, this does not necessarily mean that the marginal benefits of removing commercial floodplains from the properties will automatically generate flood mitigation benefits that are this magnitude or larger than observed with residential properties. This is due to various differences between structural characteristics of commercial and residential properties. For example, many commercial properties are multi-storied meaning that flood risk is only associated with ground floor portions of the structures. It is therefore highly recommended that future research be conducted on the impact of floodplains on commercial properties in the Douglas-Papio Creek areas. If and when this does occur it will be very important to identify the level of potential flood mitigation efforts captured by specific commercial property owners.

This research has generated transparent and replicable research that should in the future be useful to Douglas County or other local government entities for the task of evaluating the benefits and economic feasibility of flood mitigation projects. In particular the data provided here can be used to evaluate different types of economic benefits associated with flood mitigation projects that directly impact Douglas County. This information can also be used to determine how much individual property owners should contribute to flood mitigation projects, and to taxpayers in deciding whether or not they support particular flood mitigation projects.

Proposed Follow-up Studies

1) Comparable sales-based appraisal analyses.
It would be prudent to re-estimate these impacts using an alternative approach, namely the use of traditional appraisal-based comparable sales analyses where floodplain homes are compared directly to two or three nearby comparable sales not in the floodplain.

2) Improving flood insurance cost estimates.
More accurate estimates are needed based on home specific characteristics. This would likely require site inspections of individual homes and/or surveys of homeowners.

3) Surveys of floodplain property owners.
It would be interesting to determine the percentage of homebuyers who knew about the floodplain status of their homes when they were purchased, their understanding of the financial implications (required flood insurance costs), and their perception concerning flood risk and the pros and cons of living in the floodplain.

4**) Estimating the impact of floodplain status of undeveloped land.**
It may likely be that that floodplain status has a larger impact on undeveloped residential and/or commercial lots than what was observed for developed properties. It is expected that the hedonic methodologies used in this present study can be adapted to a lot-level analyses with recently collected lot sales data in Douglas County. This analysis is planned by the UNO research team in the coming months (a supplemental project for

which no additional funding is needed or sought). This is considered critical to estimating the total potential benefits of proposed floodplain mitigation benefits.

5) Estimating the impact of floodplain status on commercial properties.
It may be that commercial property values in the Douglas-Papio floodplain may be substantially (up to four times) higher than residential values. In addition to evaluating the accuracy of assessed tax values for estimating commercial market values in these floodplains, it will be necessary to quantify how floodplain designations impact commercial property values, and it is also necessary to estimate the present value of flood insurance premiums for commercial properties.

6) Replication of the entire research effort in Sarpy and Washington Counties.
It would be advisable to replicate these completed and proposed research items studies in Sarpy and Washington County. The acreage of Douglas-Papio Creek floodplains is around 7,200 acres versus around 6,200 acres for the Sarpy-Papio Creek floodplains.

Lake Views, Access, and Residential Property Values

Background and Objectives

In the last decade, several man-made lakes have been constructed in the Omaha area for the purposes of flood control, recreation, and to create amenities for adjacent and/or nearby residential housing. Additional lake construction is now actively being planned and promoted for these same purposes, as well as for stormwater management, primarily by the Papio Missouri Natural Resource District (PMNRD).

The intent of this present study component is to evaluate how different types of man-made lakes in the Omaha area impact residential property values. The goal is to quantify premiums that homebuyers are willing to pay for both lake views and access, and to determine how much of these premiums are captured by the private sector (i.e. residential housing developers) through the sale of residential lots that have views and/or good access to man-made lakes. Hopefully this information will be used in the future to ensure that private developers make adequate (fair market) contributions to future lake construction efforts which they will benefit from. It is assumed that such private sector contributions are only appropriate in cases where developers sell, trade, or contribute land or financial assistance to lake construction that is adjacent to land which they own.

This study relies on four interrelated approaches. First, hedonic price modeling is used to quantify the determinants of residential housing sales at four different lakes over the 2000 to 2007 time period. The lakes include: Zorinsky, Standing Bear, Candlewood, and Walnut Creek. The validity of the use of this hedonic valuation approach for valuing lake views has already been established as preliminary research results that focused on only two of these lakes (Zorinsky and Standing Bear) have recently been accepted for publication in the summer, 2008 issue of the peer reviewed The Appraisal Journal.

Second, comparisons are made between the sale prices of vacant lots with and without views in order to determine if original landowners and/or developers capture lake amenity premiums at the time lakes are constructed or alternatively, whether lake view

premiums develop gradually over time and hence are captured by subsequent homeowners. Third, comparisons are made between the prices of non-view lots with close access to lakes (within 2000 feet), and the prices of non-view lots that are further away (more than 2000 feet away but within ½ mile) to quantify access values.

Fourth, detailed comparisons of lot prices both within the Elk Ridge subdivision on the western shore of the Dam Site 13 Lake which is the most recent lake constructed in the Omaha area, and the first 'Public-Private Partnership' between the PMNRD and a residential housing developer. Since not enough homes within this sub-division have yet sold, it was not possible to estimate a conventional hedonic valuation model at this lake. Instead, several alternative comparisons are made between sold lot prices within and nearby the subdivision in order to estimate both view and access premiums that are likely to be captured over time by the developer. View premiums are based on observed differences between view and non-view lot prices within the subdivision.

In contrast, access premiums are based on observed differences between non-view lots in Elk Ridge and in several nearby subdivisions that do not have as good access to the Dam Site 13 Lake. View and access premiums are then used along with existing lot maps for the subdivision, to estimate total premium values be captured by the developer.

All of these analyses combined, are expected to be useful for demonstrating the economic value that Omaha area residents place on lake amenities, and to estimate the economic benefits generated by the construction of different types of new lakes in the Omaha area in the coming years. As well, the results of this study might be a useful tool for negotiating 'fair-market' financial contributions which real estate developers (who build single-family residences adjacent to and/or nearby future lakes) should make to the future lake construction efforts.

Background Information on the Five Study Lakes

The location of all five of the lakes evaluated by this study are shown in Figure 2.1. Standing Bear Lake was constructed by the USACE in 1977 and encompasses 135 acres.

It contains an extensive 396 acres of public parkland and buffers between the lake and nearby residences. Lake Zorinsky, completed in 1993 by the U.S. Army Corps of Engineers (USACE), covers 255 acres and is surrounded by private residential housing along with some public use areas and public buffers.

Candlewood Lake was constructed in 1978 entirely by a private developer after the USACE determined that it was not economically feasible for the purposes of flood control. It is only 34 acres in size and is completely surrounded by private residences (98 homes) and contains no public access of buffers. Water quality in the lake is marginal. In stark contrast is Walnut Creek Lake, which is 105 acres and was constructed in 1999 with funds from the PMNRD, the Nebraska Natural Resource Commission, and the Nebraska Game and Parks Commission. It contains very extensive (450 acres) public recreation areas and land buffers around the lake and so far appears to have good water quality.

The Dam Site 13 Lake was constructed in 2005 and 2006 by the PMNRD and with financial contributions from a private developer. The developer purchased the entire land parcel where the lake, parks and residential developments are for $53,000 per acre and then sold to the PMNRD all the land needed for the dam and lake as well as adjacent land on the western and southern shore for the same price (on a per acre basis). The developer retained control of the western shore of the lake as well as a small land tract on the eastern shore, and contributed $1 million in cash and $600,000 in future payments to help offset the cost of the dam and lake construction (Deed of Trust, PMNRD, 2006). The remaining project costs of around $6.4 million were met by PMNRD and the majority of these expenses were associated within land procurement and dam construction costs. The present value of dam maintenance costs over time (which will be the responsibility of the PMNRD) have not been explicitly stated.

Much of the adjacent land on the southern shore of the Dam Site 13 Lake has been turned over to the City of Omaha for a public park (‘Memorial Park of the West’), and this park area is connected to the western fringe of the lake via a public walking trail (See figure 2.3). Although none of the residential lots on the western shore that are being developed

have 100% exclusive access to the lake, their boundaries are very close to the lake and there are no visibly planned public parking or access points located on the western or northern shores of the lake (i.e. within the Elk Ridge housing development). Therefore, lake access for the majority of the public will have to be through the southern part of the lake. Alternatively, almost half of the lake appears to have been captured for private use. The developer also owns a small commercially-zoned area on the western shore of the lake that is next to a privately-owned industrial land use.

Finally, the PMNRD states that the lake will reduce runoff from the 2-square mile watershed by 90% in a 500-year flood event but will not reduce any of the main-stem Papio 100-year floodplain (Personal Communication March 4, 2008, Paul Woodward, PMNRD).

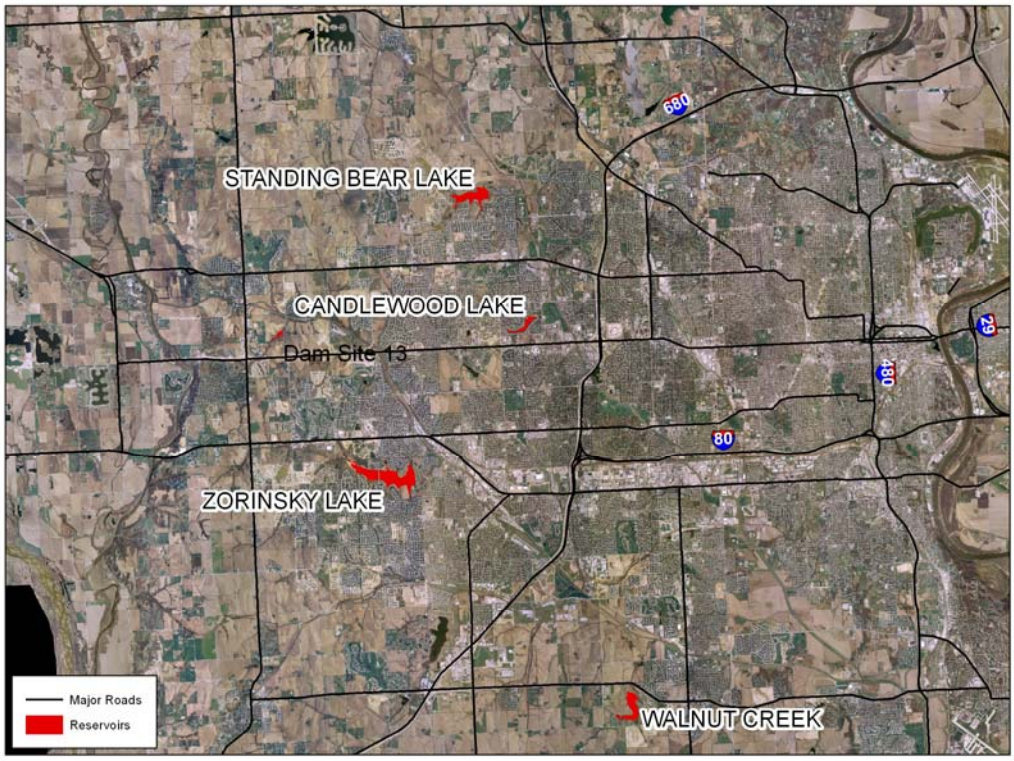


Figure 2.1. Location of the Five Lakes Evaluated

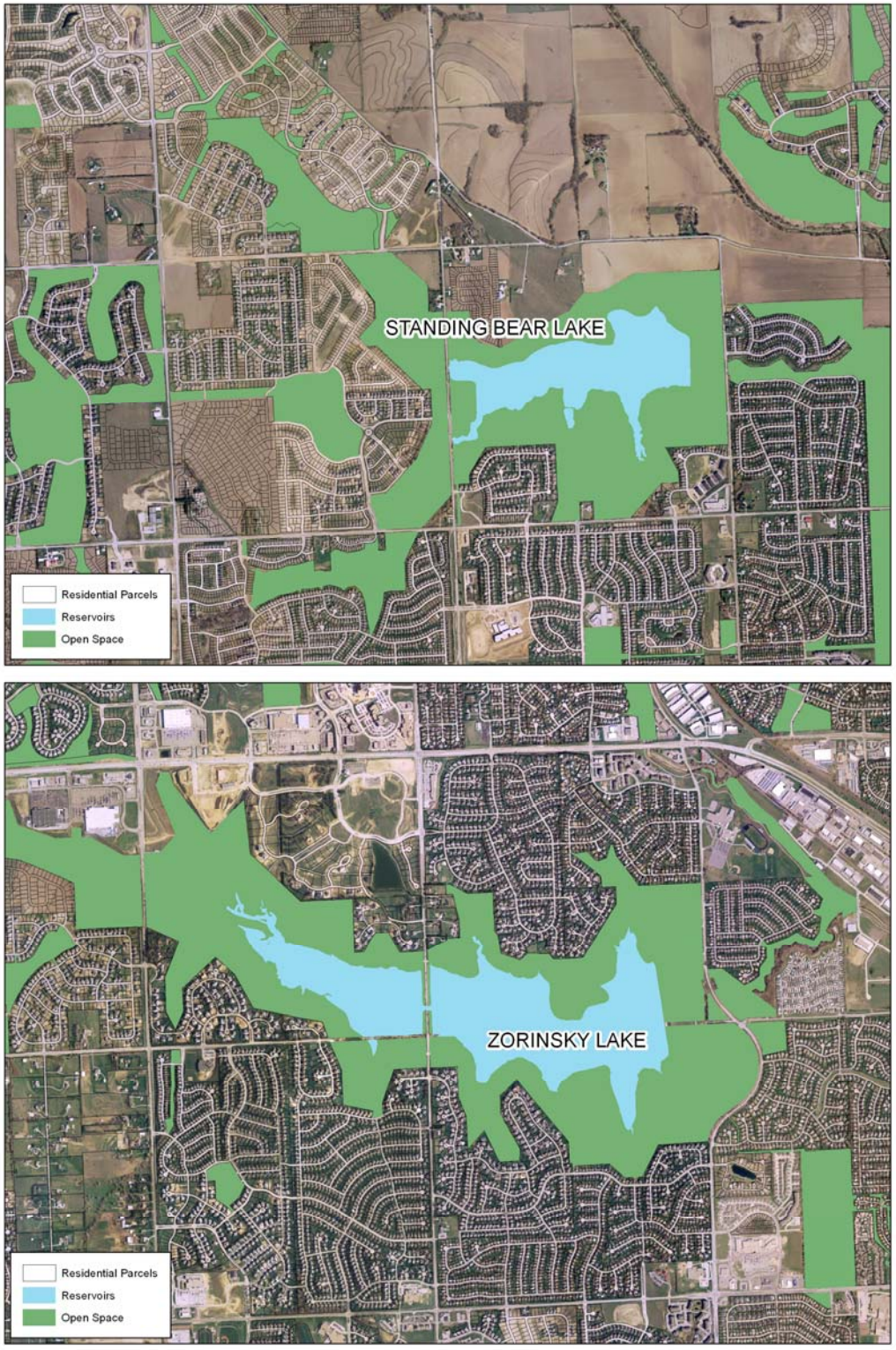


Figure 2.2 Land Uses Surrounding Standing Bear and Zorinsky

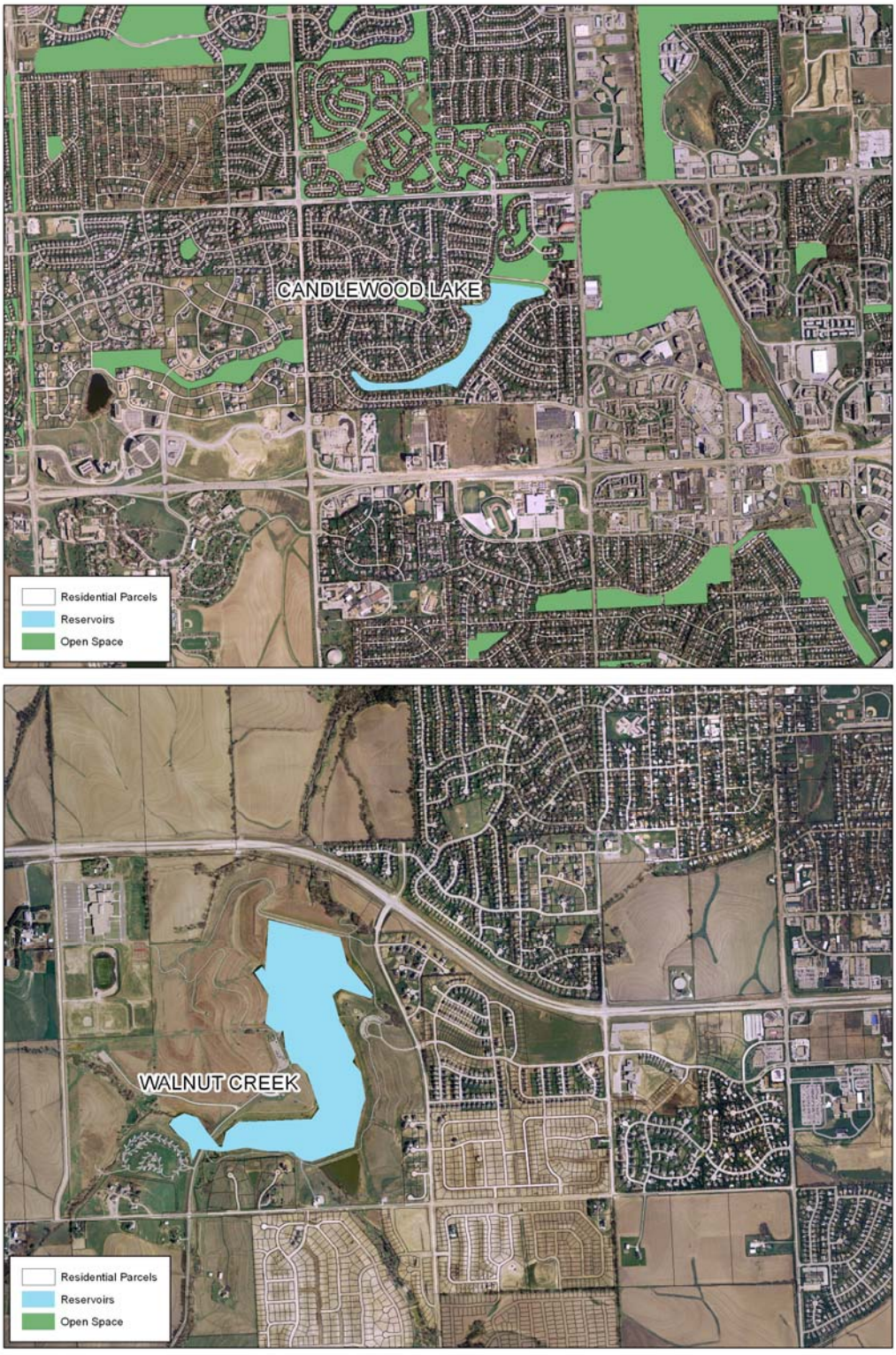


Figure 2.3. Land Uses Surrounding Candlewood and Walnut Creek

Figure 2.4. Land Uses Surrounding Dam Site 13
Source: http://www.elkridgelake.com/Elk%20Ridge/Images/newERdevplan.pdf

Methods and Procedures

Hedonic Price Models for Four Lakes

Four separate hedonic valuation models are estimated to quantify the factors influencing single-family housing sale prices over the 2000 to 2007 time period at Zorinsky, Standing Bear, Candlewood, and Walnut Creek. The specifications of these hedonic models are very similar to the floodplain hedonic model described in the previous section of this report. Sale prices (represented as natural logs), are regressed against structural, neighborhood characteristics, and the lake view status of individual homes.

The sale price and structural characteristics of homes were obtained from both the multiple listing service (MLS) and Douglas County property records, and referenced to a parcel-level GIS database. The resulting 2,188 sale transactions represent all sold homes within one half mile miles of the Zorinsky, Standing Bear and Candlewood lakes and within 1 mile of the Walnut Creek Lake. The additional half mile study area was needed at Walnut Creek due to the large public buffer areas around the lake and the infrequency of residential sales that have occurred around the lake.

Structural variables in the hedonic models include house and lot size, house age, presence of a walkout basement, number of fireplaces and garage stalls, and house style. Dummy variables representing the year a home was sold are also included to account for housing price appreciation over the study period. Condition is accounted for simply as a dummy variable equal to 1 if the home was classified as in average condition by the Douglas county assessors office (this variable was not available for Walnut Creek Lake in Sarpy County). The classification of whether a home has a lake view is based on GIS viewshed analyses in conjunction with drive-by inspections. Due to the use of the log-linear specification with the lake view variable, the marginal implicit price of views can be interpreted directly from the model coefficient and measures the percentage change in housing price due to the existence of a view. However, a more precise interpretation of this variable was calculated by using the Kennedy (1981) equation.

Comparative Analyses of Lot Sales (Zorinsky and Standing Bear)

Differences between the sale prices of undeveloped lots with and without views were evaluated at both Zorinsky and Standing Bear lakes in order to identify the extent of view premiums that were captured by developers (or homebuilders/buyers) at the time the lakes were first constructed. Such comparisons are made on a per square foot basis in order to control for varying lot sizes. Again, these comparisons were not possible at Candlewood Lake due to the infrequency of locatable lot sales with view of the lake (it appears that many lots were built by the developers themselves and not sold on the open market. Similarly, lot comparisons were not made at Walnut Creek Lake because not enough lot sales could be located (it appears that many multiple-lot sales were made directly to builders). Lot sales data for the remaining two lakes (Standing Bear and Zorinsky) was collected by performing backward deed searches for all of the residential housing lots within one-half mile of the lakes. Again, the GIS viewshed analyses were used to classify whether or not particular lots had lake views.

Similar comparative lot sale price analyses at Standing Bear and Zorinsky were made in order to capture potential **access** premiums. This involved comparing sold lot prices of lots (again on a square foot basis) of non-view lots within 2000 feet of lakes versus non-view lots that were between 2000 feet and one-half mile away from each lake.

Dam Site 13 (Elk Ridge) Analyses

The first methodological approach for the analysis of the Dam Site 13 Lake development was to create a GIS database of the lake site and all of the plotted residential parcels around the lake. This included those parcels immediately adjacent to the lake (within the Elk Ridge subdivision which is the focus of the analysis) and parcels in three nearby subdivisions (Elk Valley, Five Fountains, and Silverleaf). A detailed deed search was then conducted to identify the sale prices of all lots within each of these four subdivisions up to February 1, 2008. The asking prices and view status of all Elk Ridge subdivision lots were also obtained directly from an employee of the Elk Ridge Development. Finally, the view status of all lots was determined using both GIS viewshed analyses and manual drive-by inspections of all lots.

Lot view premiums were estimated by calculating the differences between view and non-view lot sale prices *within* the subdivision again, on a dollar per square foot basis in order to control for varying lot sizes. These view premiums were then multiplied by the total area (square feet) of actual and potential view lots within the development. Potential view lots involve the substitution of five residential lots (of average size) in the place of the existing assisted living building on the northwest side of the lake, and four more potential residential lots (again of average size), substituted in the place of the planned condos and office units on the east side of the lake. Since the assisted living and condo/office lots are likely to have relatively higher values than conventional residential lots, the resulting premium values associated with these substitutions are considered to generate conservative (lower bound) premium estimates.

Lake access premiums for non-view lots were estimated by calculating the difference between non-view lot prices *within* the Elk Ridge subdivision with non-view lot sale prices *outside* the subdivision (again on a dollar per square foot basis in order to control for varying lot sizes). The three nearby subdivisions used for the comparisons were Elk Valley, Five Fountains, and Silverleaf and all were within one-half to one-quarter mile from Elk Ridge (see Figure 2.10). Lot sales at these subdivisions have been recent except for Elk Valley, which was developed 2 years prior to Elk Ridge. Only non-view lots were used for these comparisons so as to not 'double count' view and access values.

It is hypothesized that access premiums exist at Elk Ridge since it's residents will be able to walk to the lake in contrast to the residents of the other subdivisions will need to cross busy streets to gain lake/park access and/or will only be able to park in the extreme southern part of the Omaha City Park (Memorial Park West) since there does not appear to be any public parking on the northern or western parts of the Lake.

Resulting access premiums are then multiplied by the total (aggregate) square footage of all non-view lots within Elk Ridge to generate an estimate of the total premium value associated with non-view access.

Finally, lake access premiums for view lots were calculated by subtracting the average price premium calculated for view lots from the average prices of view lots, and then multiplying this value by the percentage-based access premium associated with non-view lots. Access premiums for view lots are then multiplied by the total square footage of actual and potential view lots.

The combined (view and access) premiums expected to be captured by the Elk Ridge developers were then discounted over a five-year period under the assumption that no lot sales (and premiums) occurred in year one and that the remaining lot sales and premium captures are spread out evenly over the remaining four years. This five-year project cycle is based on the observations of lot developments at other Omaha lake sites.

Results

Hedonic Price Estimates

Table 2.1 contains a summary of the available housing sale transaction data for view and non-view properties within a half-mile of Standing Bear, Zorinsky and Candlewood Lakes and within one mile of Walnut Creek Lake, over the 2000 to mid 2007 time period. Actual sales by view status at each of the four lakes are shown in Figures 2.5 and 2.6.

Table 2.1. Sale Data for View and Non-View Properties (Houses and lots) by Lake

	Sales		Time Frame	Median Prices		Mean Size Finished (ft^2)	
	View	Non-View		View	Non-View	View	Non-View
Standing Bear	35	446	2000 – 2006	203,500	167,225	2,219	2,011
Zorinsky	62	755	2000 – 2006	331,250	184,900	3,874	2,442
Candlewood	15	295	2000 – 2007	330000	198000	4042	2905
Walnut Creek	26	233	2000 - 2007	307253	163500	2826	2137

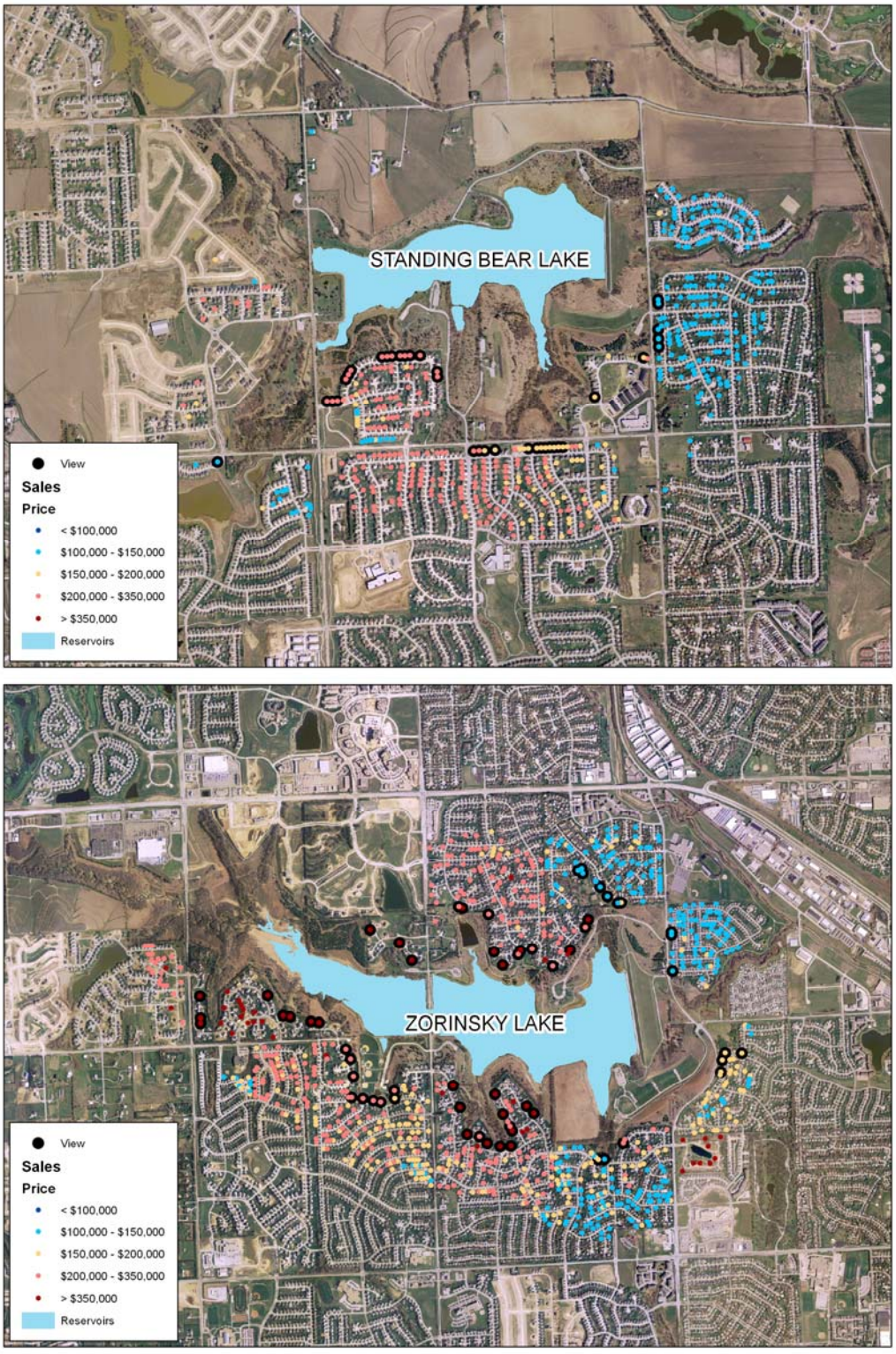


Figure 2.5. Sold Homes with Direct Views of Standing Bear Lake and Zorinsky

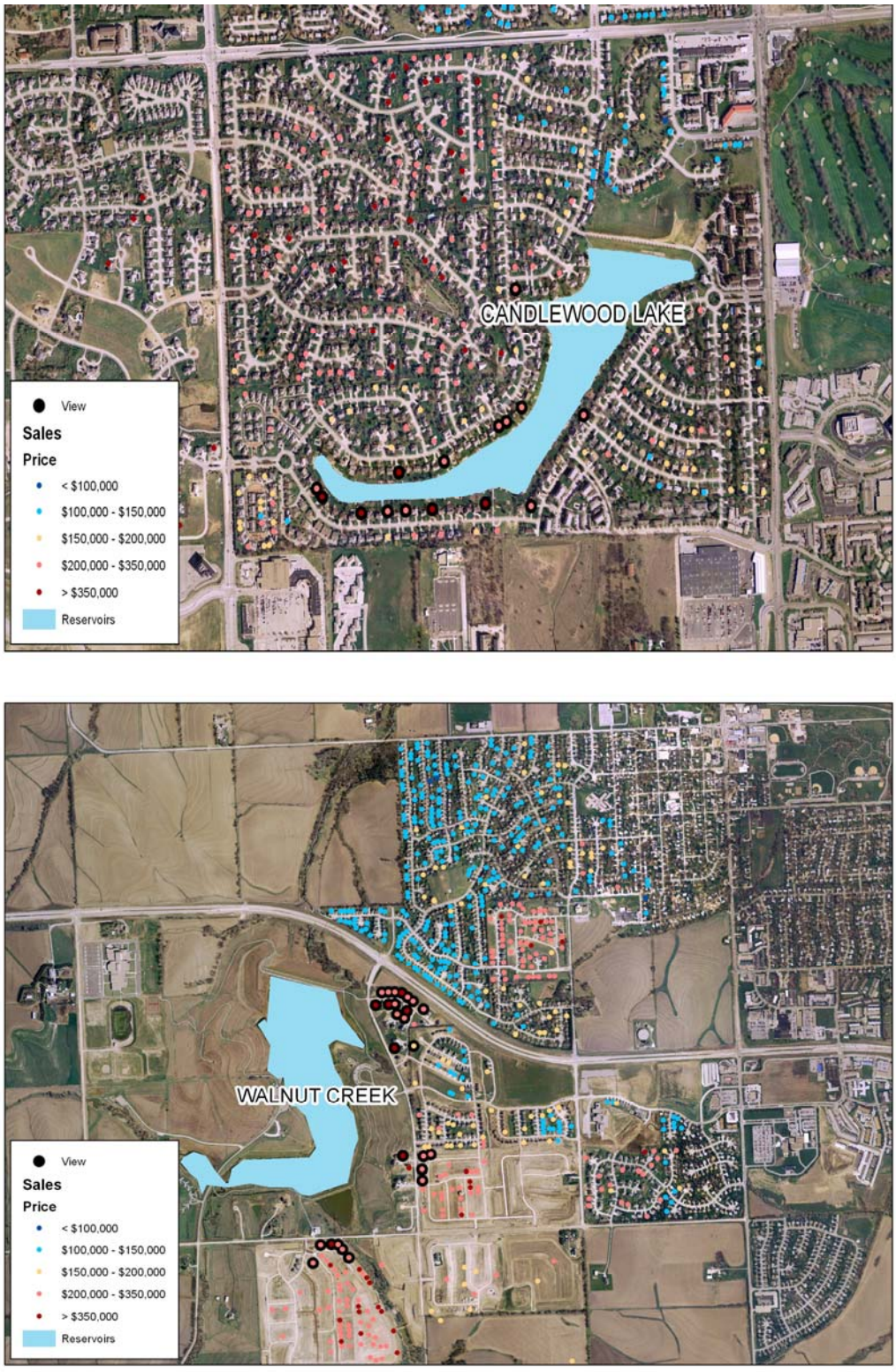


Figure 2.6. Sold Homes with Direct Views of Candlewood and Walnut Creak Lake

The hedonic valuation regression results measuring the marginal impacts of lake views and other housing characteristics (considered jointly) on housing prices at each of the four lakes are summarized in Table 2.2 (and described in greater detail in Tables 2.3 and 2.4). All four models have relatively high adjusted R^2 values of .92, meaning that 92% of the variation in housing prices is explained by the models. As well, the direction and magnitude of all of the model coefficients are as expected with most being statistically significant at the 1% level.

Of particular interest is the 'D View' variable measuring whether or not a home has a direct view of the lake. The coefficient can be interpreted as the marginal impact of a view on the sale price of a home holding all other factors constant.[1] This translates to 8.3% at Standing Bear, 7.5% at Zorinsky, 17.9% at Candlewood and 6.5% at Walnut Creek (Table 2.2). In dollar terms, this corresponds to an impact of $19,851 for an average-priced home at Standing Bear versus $44,589 at Zorinsky, $61,258 at Candlewood, and $20,420 at Walnut Creek.

Extrapolating these values to all the existing and potential homes with views of these lakes generates $15.4 million in premium value at Zorinsky versus $3.2 million at Standing Bear, $6 Million at Candlewood and $2.1 Million at Walnut Creek. This corresponds to an additional $26.7 million in increased property values.

Table 2.2. A Summary of the Hedonic Price Models and View Premiums by Lake

	R^2	Hedonic View Impact (Price Premium)		
		%	$/House(Avg.)	Total Value
Standing Bear	.92	8.3%	$19,851	$3.2 Million
Zorinsky	.91	7.5%	$44,589	$15.4 Million
Candlewood	.92	17.9%	$61,258	$6 Million
Walnut Creek	.92	6.5	$20,429	$2.1 Million

[1].When estimating a semi-log model a direct interpretation of the dummy variable coefficient as a percentage of sale price is not valid. Therefore, the equation presented by Kennedy is used to adjust the coefficients for interpretation: $\hat{g} = e(\hat{c} - (½)V(\hat{c})) - 1$ where c is the regression coefficient and V(c) is the variance of the coefficient or the standard error squared Kennedy (1981)

Table 2.3. Hedonic Regression Results: Standing Bear & Zorinsky

	Standing Bear			Zorinsky		
Variable	Coef.	Std. E.	P>t	Coef.	Std. E.	P>t
Constant	7.621	0.210	0.000	5.218	0.190	0.000
Structural Variables						
Ln Lot Size	0.147	0.020	0.000	0.246	0.019	0.000
Ln Sq. Ft.	0.364	0.023	0.000	0.563	0.021	0.000
Age	-0.008	0.001	0.000	-0.011	0.001	0.000
D Walk Base.	0.037	0.010	0.000	0.034	0.010	0.001
Fireplaces	0.028	0.010	0.005	0.059	0.009	0.000
Garage Stalls	0.071	0.009	0.000	0.098	0.011	0.000
D Avg_Cond	-0.007	0.012	0.531	-0.026	0.012	0.028
D 1.5 Story	0.429	0.046	0.000	0.104	0.026	0.000
D 2 Story	0.202	0.019	0.000	0.020	0.014	0.154
D Split	-0.021	0.012	0.085	-0.009	0.014	0.505
D Ranch	0.168	0.016	0.000	0.060	0.016	0.000
Time Trend Variables						
D 2001	0.022	0.014	0.129	0.054	0.016	0.001
D 2002	0.041	0.015	0.007	0.079	0.016	0.000
D 2003	0.048	0.015	0.002	0.114	0.015	0.000
D 2004	0.098	0.015	0.000	0.160	0.016	0.000
D 2005	0.119	0.015	0.000	0.190	0.016	0.000
D 2006	0.109	0.020	0.000	0.199	0.024	0.000
D View*	0.080	0.016	0.000	0.073	0.018	0.000
Obs.	481 (View = 35)			817 (View = 62)		
F	322.48			433.85		
p>F	0.000			0.000		
R2	0.9263			0.9073		
Adj. R2	0.9234			0.9052		
Root MSE	0.08421			0.11754		

** Note: These dummy variable coefficients cannot be interpreted directly as percentages (unlike continuous variables) using Kennedy's (1981) equation the marginal implicit values are 8.3% and 7.6% respectively.*

Table 2.4. Detailed Hedonic Regression Results: Candlewood & Walnut Creek

	Candlewood			Walnut Creek		
Variable	Coef.	Std. E.	P>t	Coef.	Std. E.	P>t
Constant	6.177	0.237	0.000	5.392	0.247	0.000
Structural Variables						
Ln Lot Size	0.099	0.020	0.000	0.169	0.022	0.000
Ln Sq. Ft.	0.637	0.036	0.000	0.639	0.025	0.000
Age	-0.013	0.001	0.000	-0.008	0.001	0.000
D Walk Base.	0.009	0.021	0.681	0.047	0.013	0.000
Fireplaces	0.051	0.016	0.001	-0.011	0.015	0.462
Garage Stalls	0.091	0.021	0.000	0.114	0.012	0.000
D Avg_Cond	-0.018	0.028	0.519	-	-	-
D 1.5 Story	0.068	0.030	0.022	0.104	0.034	0.002
D 2 Story	0.031	0.025	0.218	0.039	0.018	0.027
D Split	-0.068	0.029	0.021	-0.052	0.015	0.000
D Ranch	0.010	0.027	0.717	0.039	0.019	0.037
Time Trend Variables						
D 2001	-0.011	0.030	0.720	-0.023	0.025	0.360
D 2002	0.068	0.029	0.019	0.003	0.023	0.908
D 2003	0.079	0.030	0.010	0.036	0.020	0.081
D 2004	0.144	0.030	0.000	0.085	0.020	0.000
D 2005	0.194	0.031	0.000	0.151	0.020	0.000
D 2006	0.188	0.030	0.000	0.139	0.019	0.000
D 2007	0.176	0.033	0.000	0.105	0.023	0.000
D View/ Frontage*	0.166	0.042	0.000	0.063	0.026	0.017
Obs.	310 (View =15)			259(View =26)		
F	166.72			161.79		
p>F	0.000			0.000		
R2	0.9161			0.9239		
Adj. R2	0.9106			0.9182		
Root MSE	0.13502			0.11834		

** Note: These dummy variable coefficients cannot be interpreted directly as percentages (unlike continuous variables) using Kennedy's (1981) equation the marginal implicit values are 17.9% and 6.45% respectively.*

Lot Sale Comparisons to Quantify View and Access Values

At Standing Bear, view lots sold for 18.8% ($13,598) more than non-view lots. This value is more than twice as large as view premiums estimated by the hedonic approach which illustrates an interesting and somewhat surprising situation: It would appear that view premiums at Standing Bear appear to have declined over time. Alternatively, when Standing Bear Lake was developed, developers were able to capture a premium for lake view lots that is higher (in percentage terms) than subsequently observed lake view premiums determined though hedonic valuation models (and housing sale transactions).

At Zorinsky, developers captured a 5.7% premium ($3,507) when the lots were initially sold and over time this premium increased slightly to 7.5%.

The access premiums observed for lot sales at Standing Bear Lake is 11% and a similar 12% at Zorinsky. But there are several potential problems with the approaches used here to value access premiums at each of these lakes. In particular, simple distance measurements (lots less than 2000 feet from the lake but not being frontage or view lots versus lots that are more than 2000 feet from the lake) are not likely to perfectly measure the quality of lake access. Therefore, it is proposed that a future study measure the distances from individual lot sales to trail access points, and/or conduct comparisons of lots within particular subdivisions that are deemed to classified to have excellent versus poor access to lake recreation areas.

Lake View and Access Premiums at Dam Site 13

The platted parcels for the Elk Ridge subdivision classified by property types ('villas' without views, 'estates' with views, and frontage lots with views) are shown in Figure 2.7 and summarized in Table 2.4. The location of the five potential lake frontage lots in the northwestern part of the lake (where an assisted living facility is now located) and four potential frontage lots on the western shore of the lake (where a series of condos and commercial structures are located) can be seen in the earlier Figure 2.4.

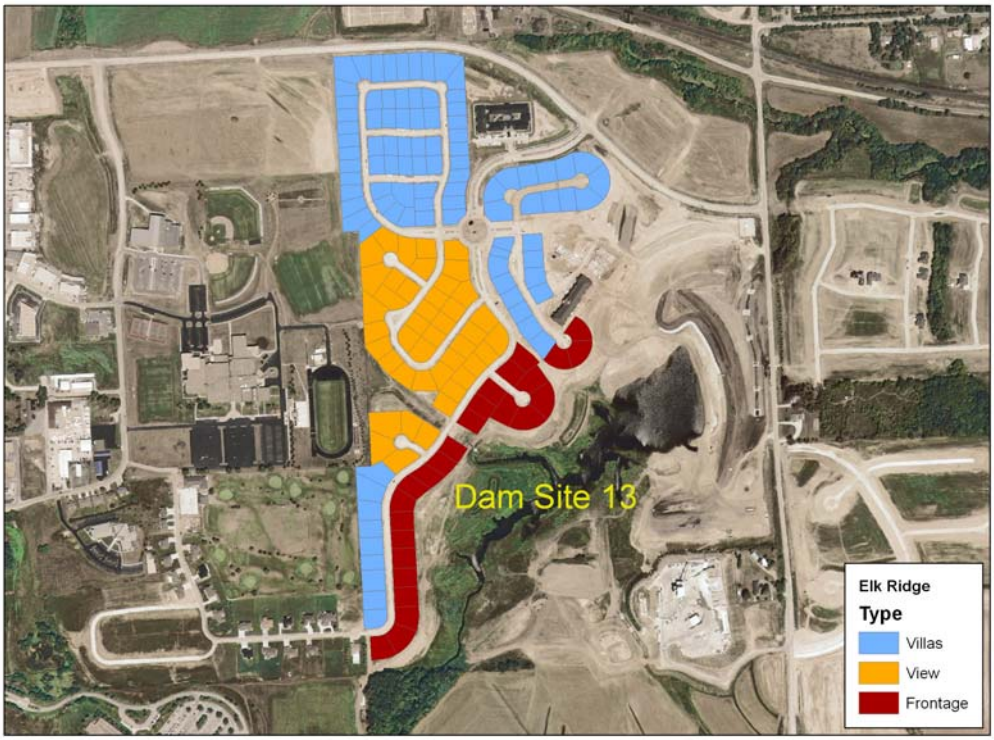


Figure 2.7. Residential Lots in the Elk Ridge Subdivision

Table 2.5. Summary Statistics of All Elk Ridge (Dam Site 13) Lots

Lot Type	N	Size			
		Mean	***Min***	***Max***	***Total***
'Villas' (non-view)	92	14,033	9,583	28,314	1,291,119
View ('Estates')	43	17,079	13,068	30,056	734,423
Frontage	25	19,096	16,988	24,829	572,898*
View/Frontage Lots (combined)	68	17,821	13,068	30,056	1,307,325*

** Nine average frontage size lots added to square foot total to account for potential lots in the areas of he assisted living care (northwest shore) and the condos (western shore)*

Figure 2.8 shows the location of the Elk Ridge parcels that have sold as of February 1, 2008. This includes 14 'Villa' (non-view) lots and four 'Estate' (view) lots. While none of the frontage view lots have sold as of February 1, it should be noted that the asking prices (on a square foot basis) are 36% higher than non-frontage view lots. And, according to a representative of the developer, they are planning to have frontage view lots be made part of a '2009 Street of Dreams' promotion.

The asking prices of all lots in the Elk Ridge subdivision are shown in Figure 2.9 and direct comparisons of the asking and sold lot prices from 2005 to February 1, 2008 are summarized in Table 2.6. Somewhat surprisingly, all of the lots have been selling for their asking prices and some have actually sold for amounts slightly above their asking prices. This demonstrates that the developer of Dam Site 13 was able to accurately estimate buyer premiums for views and access.

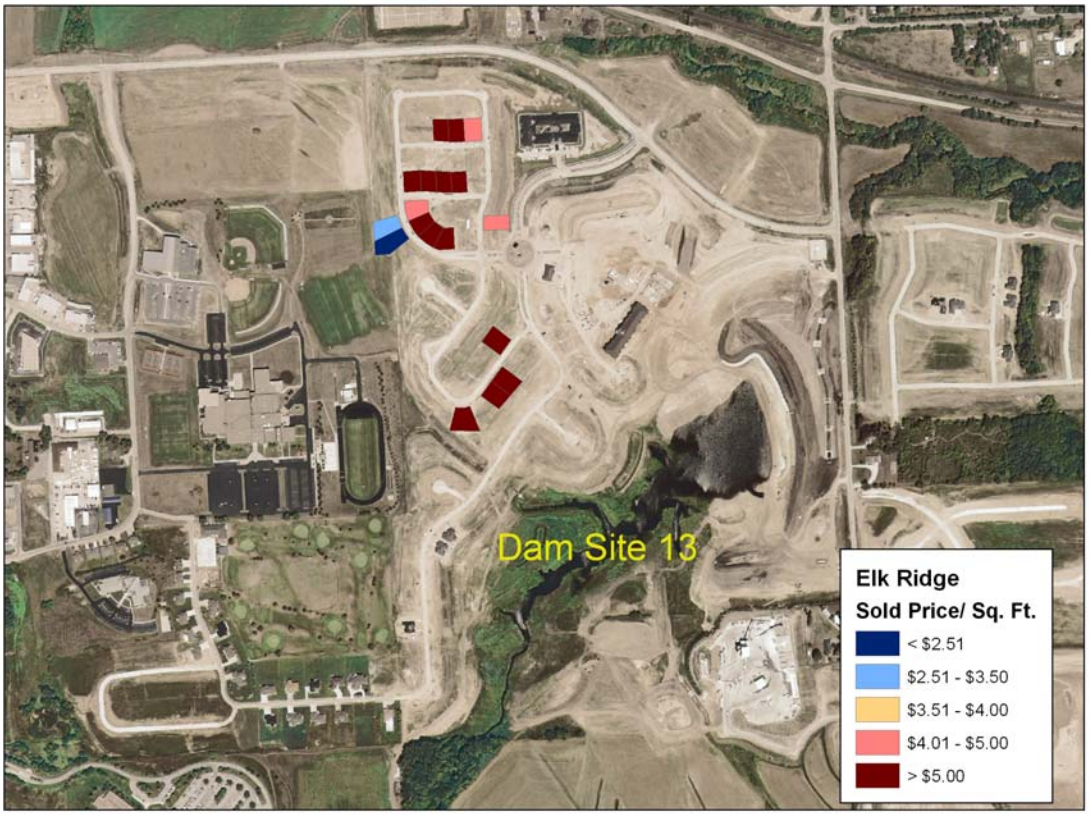


Figure 2.8. The Location of Sold Residential Lots in the Elk Ridge Subdivision

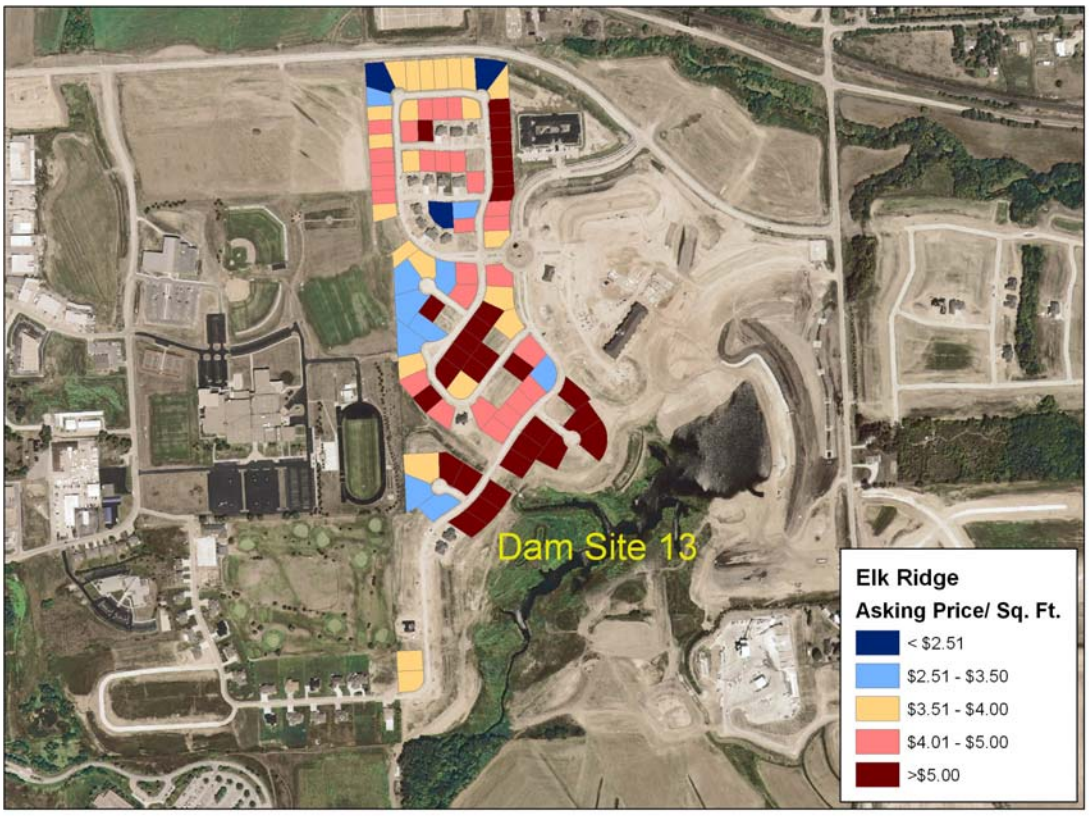


Figure 2.9. Asking Prices of Elk Ridge Lots

Table 2.6. Asking and Selling Prices of Elk Ridge Lots (2005 to February, 2008)

	Villas (Non-Views)	Views	Frontage	All
Asking Price Lot	$50,217 (46)	$74,486 (37)	$128,500 (10)	$68,290 (93)
Sold Price Lot	$54,954 (14)	$90,000 (4)	(0)	$62,742 (18)
Sold Price House	$458,414 (6)	(0)	(0)	$458,414 (6)
Asking Price/ Sqft	$4.14 (46)	$4.45 (37)	$6.73 (10)	$4.55 (93)
Sold Price Lot/ Sqft	$4.71 (14)	$5.96 (4)	(0)	$4.99 (18)

View premiums at Elk Ridge based on comparisons of the sold lot prices (on a square foot basis) of view versus non-view lots are 27% ($1.26/sft). This assumes assumption that frontage view lots will sell at the same price as regular view lots when in reality, it is likely that the frontage view lots will sell for much higher amounts (possibly 26% more

based on asking price differentials between view and frontage lots). Therefore a lower bound estimate for the view premium for all view lots in the subdivision (including nine substitute residential lots) is $1.7 million (Table 2.7).

Access premiums based on comparisons of the sale price of the smaller sized non-view lots at Elk Ridge (i.e. Villas) with similar sized and non-view lots at three other nearby subdivisions (shown in Figure 2.10), are as follows: Non-view access premiums are 58% or ($1.72/sft.) which totals $2.2 million. Alternatively, access premiums for view lots were calculated by subtracting view premiums of $1.26/sft from the average value of all view lots ($5.26/sft.) and then multiplying this value by the estimated access premium of 58%. The resulting access value for view lots therefore separates view and access values and is $2.73/sft. which is 46% of the value of view lots and generates access values for view lots of $3.6 million. Combined view and access premiums are $7.7 million.

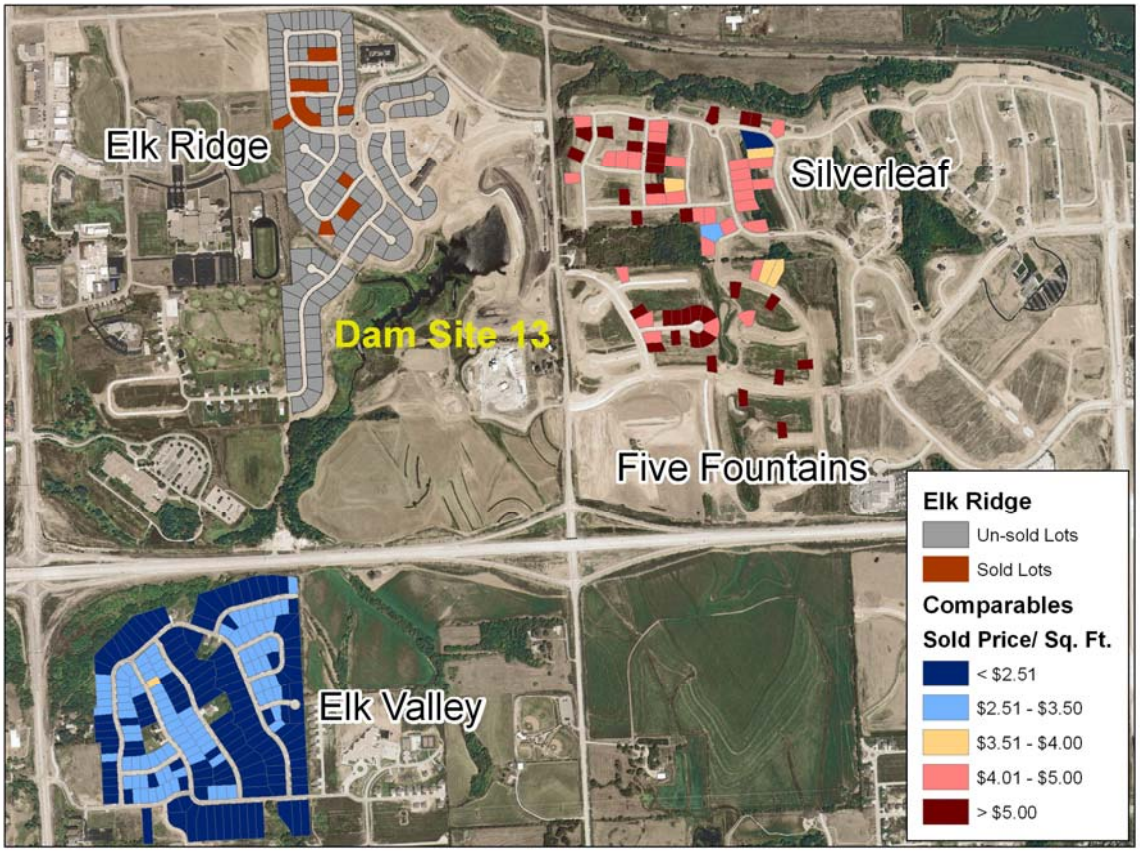


Figure 2.10. Sold Comparisons Across Four Subdivisions

Both the view and access premiums captured by the Elk Ridge Developers as a result of the creation of Dam Site 13 are considerably higher than those observed at other area lakes. This is assumed to be a direct result of level of exclusivity and privacy (i.e. lack of public access) associated with the Elk Ridge development. While technically it is true that Elk Ridge lot owners do not have exclusive (100%) private access to the lake, they for the most part, they have captured accessibility and frontage characteristics of the lake since no public parking or access points are located on the western or northern shores of the lake, meaning that lake access for the majority of the public will have to be through the southern shore (Memorial Park) area. As well, the frontage lots at Elk Ridge come very close to the shoreline which enhances the value of frontage lots but could potential threaten the long-term water quality of the lake due to potential fertilizer run-off from adjacent lawns.

There are three possible scenarios that could lead to Elk Ridge lake view and access premiums being lower than the values estimated by this study. First, if the already built senior care/living building and the planned condo/office developments are actually less valuable than residential lots, then actual premiums will be lower than estimated. Second, it may be that the Elk Ridge development is of higher quality than the other nearby subdivisions for which lot price comparisons were made in order to determine access values. In particular, we have noted that the promotional website for the Elk Ridge development is of higher quality, and the multi-housing style aspects of the development as well as the road planning and lot preparation of this development appear to be superior to those observed in the other subdivisions. While these impacts may exist they are difficult to quantify and it is unlikely that they themselves would explain the large price premiums discovered at Elk Ridge. Third, it is possible that access values to the lake may be influenced by the close proximity to the nearby high school, the golf course and/or the city park that is adjacent to the lake (Memorial Park West). The park amenity value is particularly interesting since it may be creating a prestige factor since in the last century many of the most valuable homes in Omaha were built around Memorial Park East. Therefore, we are proposing some follow-up studies that would further evaluate these issues (these are described in the next section).

In summary, the developer of the Elk Ridge subdivision made a $1.6 million contribution to the project (a $1,000,000 cash contribution in year 1, interest payments of 7.5% interest on $180,000, and final balance of balance of $480,000 to be paid in 2010. Comparing these discounted project costs to the present value of expected lot sale premiums (spread out from years 2 through 5 of the project which results in a value of $6 million) generates an estimated rate of return of 437% or an annual return of 87% per year over 5-years (table 2.7).

Table 2.7. A Summary of Captured Premiums and Returns at Dam Site 13

	View Premiums	Access Premiums		Total Premiums
		Non-View Lots	View Lots [b]	
Level of Analysis	*Within Elk Ridge*	*Elk Ridge Vs. 3 Subdivisions*	*Based on non-view Access Premium* [d]	
Comments				
Sample Size (sold comparisons)	18	370	225	613
Premium %	27% [a]	58% [b]	46% [c]	
Premium $	$1.26	$1.72	$2.73	
Total Square Feet	1,378,609 [b]	1,291,119	1,378,609[b]	
Total Premium Value	$1,737,047	$2,220,725	$3,625,742	**$7,715,860**
Present Value of Premiums (5 years, 7.5%)				**$6,009,984**
Discounted Marginal Return				**437%**
Discounted Annual Return				**87%** [d]

Explanatory Notes:

a. This is a lower-bound estimate as frontage/view lots are combined with non-frontage view lots (they are assumed to have the same value because no frontage/view lots have yet sold). Since frontage/view asking prices are 36% higher than non-frontage view lots, actual view premiums are likely higher

b . Includes five view/frontage lots where the Assisted Living Building is on the northwest shore of the lake and 4 view/frontage lots where the condos are located on the western shore (based on average view lot sizes of 17,821 sqft)

c. Estimated by multiplying the difference between average view lot values ($5.96) and view premiums ($1.26) by the estimated access premium of non-view lots (58%).

d. If a 10% discount rate is used the discounted average annual return is 84%.

Summary and Policy Implications

This analysis of the relationships between residential housing and lot sales surrounding five different Omaha area man-made lakes indicates that reasonably large but varied price premiums are associated with view and access amenities associated with the lakes. It appears that landowners and/or developers capture the majority of those premiums at the time the lakes are constructed. It is also evident and that the level of exclusivity or privacy of the lake and residential housing designs has a large impact on the magnitude of the premiums that are captured by developers (i.e. captured amenity values increase with exclusivity and decline with public facilities, land buffers and/or access).

This Dam Site 13 analysis is of particular interest since it is the first 'public-private lake construction partnership'. In this case, the developer appears to have been very well compensated for their participation. However, before a final conclusion is drawn regarding the extent to which the PMNRD potentially under-charged their private partner, additional analyses and follow-up studies are warranted. In particular, continued analyses of lot sales are planned and it is proposed that a hedonic valuation model of lot sales be conducted at Elk Ridge and nearby subdivisions in order to determine whether or not some of the access value premiums at Elk Ridge have been influenced by other (non lake related) factors. Nevertheless, based on these preliminary study results, if and when the PMNRD or others plan additional public-private partnerships for the purposes of lake construction, it is recommended that:

1) Higher contributions be sought from private developers (increased cash payments or reduced land sale prices). This could be facilitated by relying on empirical research (such as this report) which quantifies view and access premiums that can be expected from different types of lake designs.

2) Scenarios be considered where the PMNRD purchase entire land parcels (quarter to full sections of land), and then after planning and/or constructing a lake, conduct a public auction off available adjacent residential development areas (either all together or in individual sections). This would help ensure that a fair

('market') price is paid for land adjacent to publicly funded lakes. Again, empirical research which quantifies ranges of possible view and access premiums could help developers determine optimal bid prices for land adjacent to lakes.

3) In cases where it is not possible to negotiate a mutually acceptable fair market price for land adjacent to man-made lakes, the PMNRD should consider having larger public buffer areas surrounding lakes which would ensure more public access, improved recreational opportunities, and better water quality in the lakes. At a minimum, such policies would ensure that the public captures all (or at least most) of the economic amenity values that are created with public funds.

Suggested Future Research

1) Conduct a hedonic price analysis of sold lots at Standing Bear, Zorinsky, and Dam Site 13 that account for lot-specific characteristics (size, shape, location, nearby land uses, etc) in order to better quantify the access values of lakes.

2) Continue to collect and monitor both lot and housing sales at Dam Site 13 and in the nearby subdivisions to confirm view and access premium estimates over time and to conduct a more detailed hedonic price analysis of these access based amenity values.

3) Conduct surveys of homebuyers at Dam Site 13 and nearby subdivisions to identify factors that may have influenced their purchase decisions and in particular to assess the importance of lake views, access, and other factors.

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LID, Open Space and Single Family Housing Values

Background and Study Objectives

In the Omaha Metropolitan Area, typical Midwestern urbanization trends are the cause of increasing flooding and water quality problems. One proposed solution is the promotion (or requirement) of Low Impact Developments (LIDs) which can generally be defined as the use of Best Management Practices (BMPS) ranging from more impervious surface materials to local retention basins, and other measure that jointly reduce surface runoff from precipitation events. Alternatively LIDs in the context of subdivision designs, provide for a 'de-centralized' management of stormwater. That is, LIDs attempt to mimic naturally hydrology by using techniques that capture storm water where it falls.

One of the critical questions regarding the feasibility (in addition to their cost and their effectiveness in reducing runoff) is how LIDs will be perceived and accepted by homebuyers and, in particular, if they will pay a premium or discount for homes within LID subdivisions. Therefore, the focus and goal of this present research is to determine homebuyer preferences for different types of subdivision open space design that is intended to proxy for alternative LID designs. For example, do homebuyers prefer clustered or more open landscape design? Do they prefer managed or native/natural plant systems? What are their preferences for trails, public recreation access, and trees? And finally, do they prefer these open spaces to be publicly or privately managed?

The classic example of an LID subdivision involves *clusters* of homes, often with small lots, surrounded by publicly-owned open-space (Figure 3.1). The open-space is usually planted in natural vegetation and may or may not have trails and other recreational features. Another example of LID is the use of *greenways* where **not** all homes abut (face) the open space, yet all residents have access to a relatively large undeveloped open space area (Figure 3.1). Open space areas can be publicly or privately owned or managed (by city or county governments, Natural Resource Districts, utilities, homeowner associations, or even SIDs).

Figure 3.1 An Example of Clustered Low Impact Development

Figure 3.2 An Example of Greenway Low Impact Development

No actual LID subdivisions (designed exclusively for storm water management and with a history of housing sales) currently exist in the Omaha area. However, a wide variety of different subdivision designs with respect to quantities and types of open space do exist. It is hypothesized that homebuyers will be most concerned with the open space components of different LID designs when they are deciding whether or not to purchase a home and/or how much to pay for that home. In other words, open space designs are assumed to proxy for different LID designs. It is important to note however that open space requirements for new subdivisions are currently regulated by non-LID goals in Douglas County.

These research results are expected to be useful to both the public and private sector. In particular it is expected that real estate developers and builders will have a greater self-interest in developing LID subdivisions if they can be shown the relative profit levels they can obtain from different open space/LID subdivision designs. From the public sector perspective, it is also necessary for planners and/or regulators to understand the homebuyers' preferences for open space designs, and hence potential profit margins for developers who build LID subdivisions. For example, if it turns out that a particular open space design leads to property price premiums then the value of these premiums could potentially offset some (if not all) of the potential LID development costs borne by developers. Alternatively, if it was discovered that a particular LID/open space design was discounted by homebuyers, the public (through local governments) might justify subsidizing developers who voluntarily adopt such LID designs.

Methods and Procedures

The study area is based in Douglas County and encompasses all of the area North of Harrison Street, South of Lake Cunningham Road, East of 204th Street, and West of I680/I80. The study area was chosen because it contained a large percentage of undeveloped land and the drive time to major employment centers (downtown Omaha) was similar for the entire area (Figure 3.3). Furthermore, most homes in the area are of newer construction (post-1950) therefore eliminating much of the modeling difficulties associated with older historical neighborhoods. In addition, newer development often

exhibits high degrees of housing homogeneity (many similar home styles and sizes). For example, see the price consistency (and clustering) of homes across 321 different subdivisions across the study area (Figure 3.3).

The real estate transaction database used for this study was the same one used for the floodplain impact study described earlier except it focused on different areas and included sales up to May 30, 2007. Again this database includes sales transaction and housing characteristics data from the Multiple Listing Service with county parcel and housing data, all within a GIS framework. Only sales that are contained in a platted subdivision are used in the analysis. Other homes that may have sold in the study area but were either original farmsteads or were platted independently on an individual basis were removed from the sample. The resulting sales are shown in Figure 3.3.

This research effort required the estimation of 14 different hedonic price models. Alternative models were needed to evaluate different types of open space amenities at different levels of spatial scale (for example, subdivisions versus buffers of different sizes). The focus was to evaluate open space impacts on housing prices from the perspectives of public versus private ownership and management of the open space, the type of open space measured by it's groundcover type, and location aspects (distances abutments, etc). A reporting of all the model results is beyond the scope of this present study report but readers interested in the full study results should refer to the Masters Thesis of Nick Schmitz after April 1, 2008.

All of the estimated hedonic price models share a set of explanatory variables intended to account for structural housing, lot and neighborhood factors. These variables are listed in Table 3.1

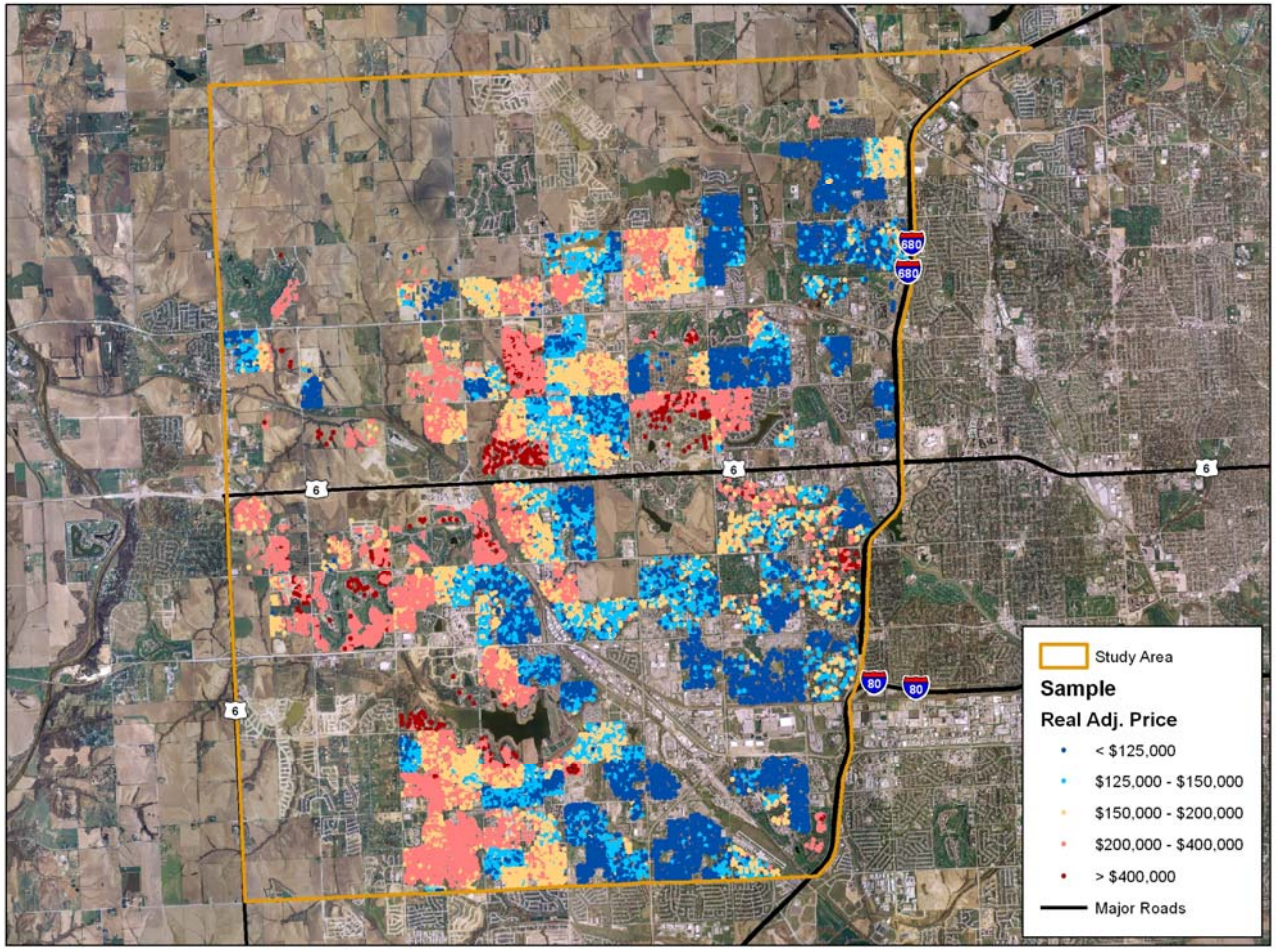

Figure 3.3 Study Area with Sales and Prices shown as Classes of Points

Table 3.1 Explanatory Variable Descriptions and Expected Signs

Variable	Description	Source	Expected Sign
LN Lot Size	Size of Lot in Square Feet	County	+
LN House Size	Finished Square Feet of the House	MLS[a]	+
Age	Age in Years	MLS	-
D New	Dummy = 1 if House is New	MLS	+
D Walk Out	Dummy =1 if Walk Out Basement	MLS	+
Fireplaces	Number of Fireplaces	MLS	+
Garage Stalls	Number of Garage Stalls	MLS	+
D 1.5 Story	Dummy = 1 if 1.5 Story House	County	+
D 2 Story	Dummy = 1 If 2 Story House	County	+
D Split Foyer	Dummy = 1 if Split Foyer	County	-
D Ranch	Dummy = 1 if Ranch	County	+
D 1997	Dummy = 1 If Sold Year is 1997	MLS	+
D 1998	Dummy = 1 If Sold Year is 1998	MLS	+
D 1999	Dummy = 1 If Sold Year is 1999	MLS	+
D 2000	Dummy = 1 If Sold Year is 2000	MLS	+
D 2001	Dummy = 1 If Sold Year is 2001	MLS	+
D 2002	Dummy = 1 If Sold Year is 2002	MLS	+
D 2003	Dummy = 1 If Sold Year is 2003	MLS	+
D 2004	Dummy = 1 If Sold Year is 2004	MLS	+
D 2005	Dummy = 1 If Sold Year is 2005	MLS	+
D 2006	Dummy = 1 If Sold Year is 2006	MLS	+
D 2007	Dummy = 1 If Sold Year is 2007	MLS	+
D Double Frontage	Dummy = 1 if Lot is Double Frontage Lot i.e. Abuts Two Streets	Aerial Photos[b]	-
D Floodplain	Dummy = 1 if Home is in the Floodplain	FEMA [cf]	-
Housing Density	Housing Units per Square Mile	US Census[f]	-
LN Dist. Com	Distance to Commercial Property in Feet	County[f]	+
LN Dist. Ind	Distance to Industrial Property in Feet	County[f]	+
LN Dist. Arterial Road	Distance to Arterial Road in Feet.	MAPA[df]	?
LN Dist. Dodge St.	Distance to Dodge Street in Feet	ESRI[ef]	?
LN Dist. I80/I680	Distance to I80/I680 in Feet	ESRI[ef]	?
LN Dist. High School	Distance to Nearest High School in Feet	Douglas County[f]	?
LN Dist Other School	Distance to Nearest Middle/Elementary School in Feet	Douglas County[f]	?
D Omaha	Dummy = 1 if Omaha Public School District	MLS	-
D Millard[g]	Dummy = 1 if in Millard Public School District	MLS	-

[a] Great Plains Multiple Listing Service (MLS)
[b] Manual Classifications
[c] Federal Emergency Management Agency (FEMA) Digital Flood Insurance Rate Map (DFIRM)
[d] Metro Area Planning Association (MAPA)
[e] Environmental Systems Research Institute
[f] Spatially Integrated With Sale Points using GIS
[g] Omitted Classification is Elkhorn School district which is generally considered to be the preferred district in the study area

Classifying Open Space Conditions

A wide variety of open space models intended to proxy for alternative LID subdivision designs were evaluated. These are summarized in Table 3.2 and shown in a map in Figure 3.4. Recall however, that not all these variables are contained in a single hedonic model. Images showing examples of these open space variables at different levels of geographic scales (for example, within subdivisions, buffers, and for abutting properties) are shown in Figures 3.5 to 3.10.

The procedures used to quantify these open space characteristics involved complex GIS operations which are described in detail in Schmitz (2008) and summarized here. Each open space parcel is grouped into one of five ownership classes: homeowners association, sanitary improvement district (SID), public, private, and golf course. Homeowner association parcels are owned jointly by all residents of the subdivisions who pay dues to the homeowners association who in turn manages the open space along with other aspects of the neighborhood. SID-owned parcels are in new subdivisions which have not been formally annexed into the city. Public parcels can be owned by local governments such as the City of Omaha or the PMNRD, or other public entities. In most instances these parcels are managed as public parks with varying levels of accessibility. Private parcels are owned by individuals, in many instances they are tilled and placed in row crops or pasture.

Besides ownership type, explicitly defined characteristics for each parcel were made using manual classifications. These open space classifications were made qualitatively based on GIS land use coverages, street and subdivision designs, and NAIP aerial imagery. Specifically the presence of trails, parking lots, pool, baseball diamonds, or soccer fields was noted for each parcel. Groundcover variables are defined as percent trees, mowed, prairie, wooded and tilled. It should be recognized that ground cover is inherently complex and can be represented by different plant species grouped into different distributions. Percentage values of these land uses are calculated in an effort to simplify the description of each parcel.

The study characterizes *mowed* areas as any manicured grass not covered or shaded by a tree canopy with *trees* being shade trees in a maintained setting, i.e. the grass underneath them is mowed such as one would find in a city park. *Grass* (not mowed) and *prairie* are grouped into a single category, while there are a number of prairie restoration projects in the study area it is impossible to distinguish these from parcels simply planted in grass. Wooded areas are considered different from trees in that the ground underneath the canopy is not maintained in any way. Finally, tilled parcels were almost all located on the fringe of the city and in almost all instances only affect the new homes in the sample.

After defining the characteristics for each parcel the objective is to summarize these proximate open areas with respect to the sold homes in the sale sample. The literature and conventional wisdom describe three distinct ways to reference a parcel with respect to open space, abutments where a lot borders an open area, neighborhoods where a home references a defined area around itself, and proximity which in this study is the Euclidean (straight line) distance in feet to an open area. Finally, a home is defined as abutting open space when its lot boundary is shared with an open area. Lots located directly across the street from common areas are not considered as abutting open space. For abutment parcels each groundcover type is measured as a percentage within neighborhoods for each parcel and expected signs being positive except for woods which may be negatively signed due to perceived externalities such as animal populations or lack of maintenance.

Neighborhood classifications (in which a parcel was located) were made using two defined areas through which the percentage of open space can be estimated and taken into consideration by home buyers. Neighborhoods can be defined as 400 meter buffers and platted subdivisions. This study does not attempt to determine the long-term existence of open space that currently exists.

Ownership type is measured both on a neighborhood percentage basis and by distance calculations (distance to the nearest of each type). The effects of ownership type are unknown. No known studies have shown a significant *negative* relationship between ownership types of open space and home values although some discussion of negative

externalities has been noted (Dehring and Dunse 2006) and other researchers have noted that ownership types will realize different magnitudes in effects (Irwin 2002).

Due to the conjunctive use of groundcover and ownership variables in this study it is expected that certain open space amenities may appear to negatively impact property values not because of the open space amenity per se, but rather because of who owns or manages the open space. For that reason the study makes the distinction between public and privately-owned open space throughout the analyses.

The hedonic models are also estimated separately for homes that are near open space and homes that actually abut open space. This is considered particularly important when analyzing public facilities such as trails, parking lots, pools, baseball diamonds, and soccer fields. Pools and trails are expected to positively impact housing prices as they are a positive use amenity. Parking will likely have negative effects on parcels since parking lots allow people outside the neighborhood or immediate area to use the park. Both baseball and soccer fields will likely have negative signs due to the noise and congestion associated with sporting events.

Table 3.2 Open Space Variables and Expected Signs

	Variable	Description	Expected Sign
Percentages	*Within Neighborhoods*		
	% Trees	% Trees within the parcel (i.e. trees where grass underneath is mowed; shade trees)	+
	% Mowed	% of the parcel that is mowed and not covered by trees i.e. open mowed fields	+
	% Grass/Prairie	% of the parcel that is planted in un-mowed grass or natural prairie	+
	% Wooded	% of the parcel that is wooded i.e. non manicured trees or forests	-
	% Tilled/ Farmed	% tilled or farmed this can be row crops or hay land	+
Distance to and Percentages	*In Proximity and Within Neighborhoods*		
	Homeowners Association	If parcel is owned by a homeowners association	?
	SID	If parcel is owned by an SID	?
	Public	If a parcel is owned by a public entity i.e. County, City, etc.	?
	Private	If the parcel is owned by a private individual or company	?
	Golf Course	If the parcels land use is a gold course or is owned by a particular golf course	?
Dummies	*Individual Open Space Parcels*[a]		
	Trails	If there are visible trails on the parcel	+
	Parking	If there is a parking lot on the parcel	-
	Pool	If there is a pool on the parcel	+
	Tennis	If there are tennis courts on the parcel	+
	Baseball	If there is baseball/softball diamond on the parcel	-
	Soccer	If there is a soccer field on the parcel	-

[a]Analyzed only with respect to abutment homes in this report (mainly due to the fact that within neighborhoods it would be impossible to tell the relative location of these amenities/disamenities to other parcels)

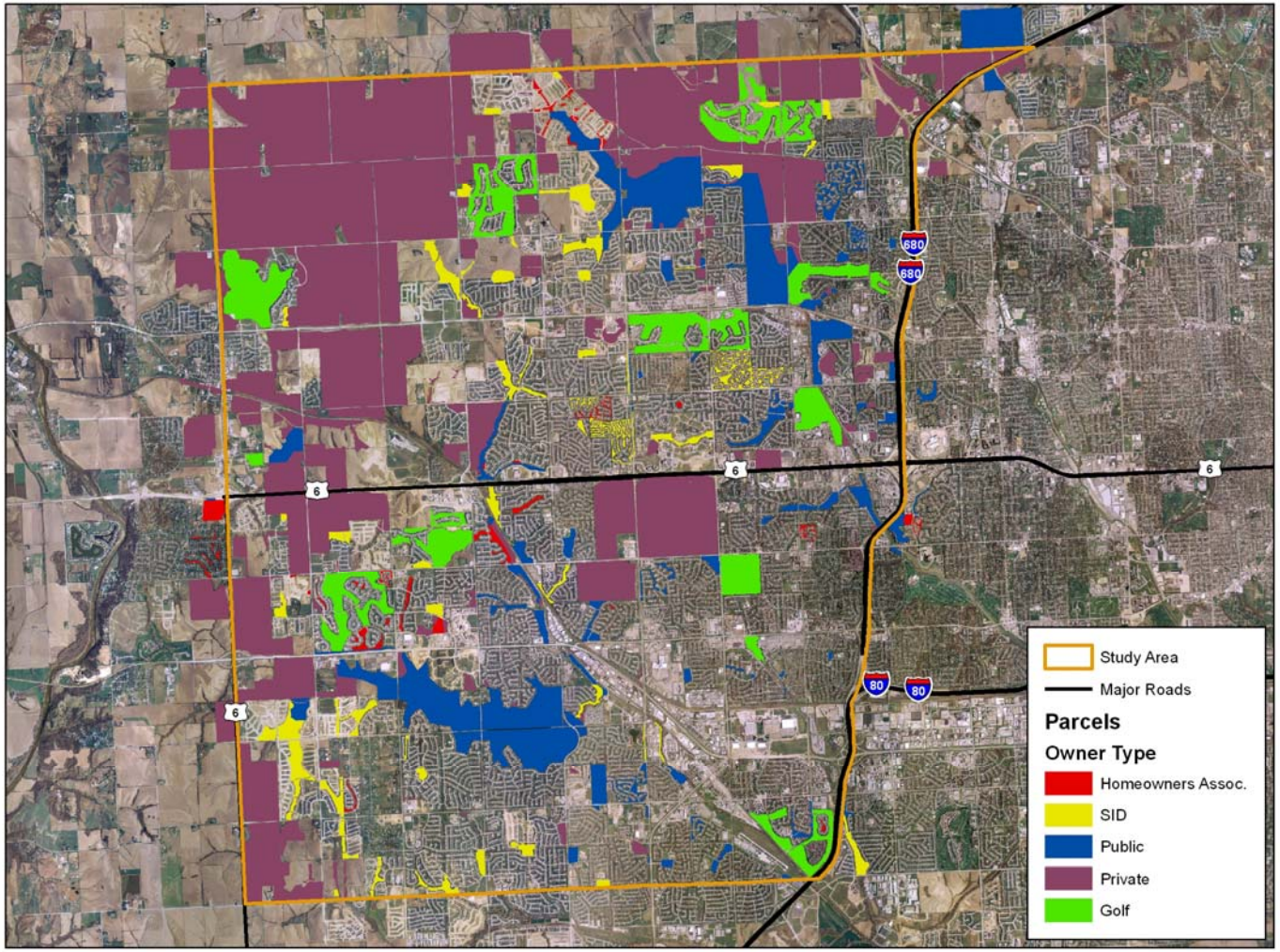

Figure 3.4 Distribution of Open Space in the Study Area

Figure 3.5 Open Space With Baseball Diamonds, Trails, and Parking

Figure 3.6 Open Space with 50% Trees and 50% Mowed

Figure 3.7 Open Space 80% Grass/Prairie and 20% Wooded

Figure 3.8 100% Tilled Open Space

Figure 3.9 Parcels Abutting Open Space (Shown in Red)

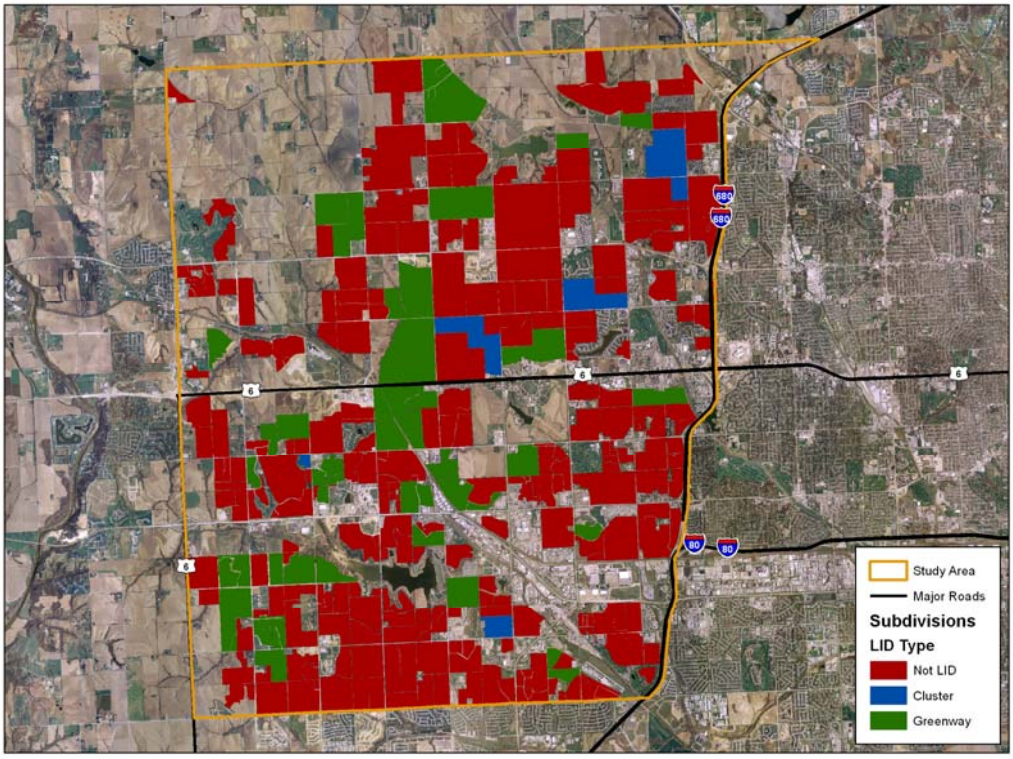

Figure 3.10 Emphasis Subdivisions by LID Type

Results

Table 3.3 summarizes the mean sale prices of homes by open space percentages across subdivisions across the study area. In general, as open space increases within a neighborhood, home values tend to increase and the highest open space premiums appear to be in neighborhoods with at least 20% open space

Table 3.3 Prices by Open Space Percentages Across Subdivisions

Percent of Open Space	Mean	Median	Min	Max	n
<5%	$161,583	$145,391	$64,294	$981,395	10,117
5% - 10%	$183,419	$181,750	$63,103	$624,205	3,706
10% - 20%	$190,317	$135,927	$67,673	$789,123	2,543
20% - 40%	$176,687	$156,451	$71,324	$539,522	1,781
> 40%	$248,621	$247,087	$80,479	$629,203	245

Table 3.4 adds an additional dimension to the analysis of housing prices and open space by including the size of sold parcels. This required omitting parcels that directly abutted open spaces since these parcels tended to skew the results. It can be seen that prices tend to increase as open space increases with smaller lot sizes. With larger lot sizes these results are not consistent. In particular, prices in bold in the table indicated incidences where prices tend to have fallen with more open space. The two conclusions from this are: 1) Public open space is likely less important to large parcels that often have their own open space, and in fact this open space is publicly managed may have a negative impact on its relative value; 2) More complex (multivariate) analyses of the factors influencing sale prices are needed .

Table 3.4 Mean Housing Prices by Open Space and Lot Classes (in subdivisions)

	Acres			
% Total Open Space	<0.2 Acres	0.2 – 0.25	0.25 – 0.3	>0.3
<5%	$129,449	$162,172	$180,423	$218,936
5% - 10%	$126,239	$188,885	$217,909	$243,988
10% - 20%	$125,953	$155,367	$215,897	$345,687
20% - 40%	$130,035	$183,065	$198,523	$239,224
> 40%	$111,754	$166,834	$292,887	$373,117

Finally, Table 3.5 shows how sale prices change mean prices by distance away from different types of open space that are categorized across ownership types. From this it can be seen that in general home values are positively related to private open space versus a negative impact associated with publicly-owned open space.

Table 3.5 Housing Prices by Distance Classes across Ownership Type

Distance Classes (ft)	Homeowner Assoc.	SID	Public	Private	Golf
<500	$253,281	$187,172	$153,523	$187,973	$231,490
500-1000	$221,835	$214,835	$156,425	$175,766	$184,720
1000 – 2000	$190,566	$232,192	$162,605	$174,344	$160,633
2000 – 4000	$172,619	$179,011	$188,488	$176,079	$162,096
>4000	$156,033	$144739	$211,389	$131,086	$174,224

Hedonic Price Estimates

The hedonic price regression results for the model that measures the impact of open space within different ownership classes is presented in Table 3.6. In this case the relationship between sold homes and open space ownership classes is measured by distances between them (i.e. proximity). Most variables are statistically significant with their expected signs (i.e. their impacts on sale prices are as expected). The adjusted coefficient of determination is 0.88 indicating that the model explains 88% of the variation in home prices. The f-statistic of 3429.92 signifies that all variables considered jointly have a statistically significant impact on price at the 1% level.

In this model, the distance to open space coefficient is negative and significant indicating that as homes are closer to open space they increase in value. Ownership classification are statistically insignificant in this model and this is expected to be a result of the distance measure not accounting for abutments and/or the actual open space amenities associated with particular neighborhoods or subdivisions. Ownership issues are further evaluated in subsequent models.

Table 3.6. Hedonic Results Related to Open Space Ownership Impacts

Variables	Ownership Dummies				Ownership Distances		
	Coef.	*Sd. Err.*	*p>|t|*		*Coef.*	*Sd. Err.*	*p>|t|*
LN Lot Size	0.197	0.004	0.000		0.195	0.004	0.000
LN House Size	0.534	0.005	0.000		0.525	0.005	0.000
Age	-7.6E-03	1.5E-04	0.000		-8.2E-03	1.6E-04	0.000
D New House	0.074	0.004	0.000		0.075	0.004	0.000
D Walk Out	0.026	0.002	0.000		0.029	0.002	0.000
Fireplaces	0.039	0.002	0.000		0.039	0.002	0.000
Garage Stalls	0.081	0.002	0.000		0.081	0.002	0.000
D 1.5 Story	0.139	0.007	0.000		0.136	0.007	0.000
D 2 Story	0.037	0.003	0.000		0.032	0.003	0.000
D Split Foyer	-3.2E-02	0.003	0.000		-3.0E-02	0.003	0.000
D Ranch	0.060	0.003	0.000		0.053	0.003	0.000
D 1997	-3.6E-02	0.005	0.000		-3.7E-02	0.005	0.000
D 1998	-7.1E-03	0.005	0.146		-7.6E-03	0.005	0.118
D 1999	0.029	0.005	0.000		0.029	0.005	0.000
D 2000	0.037	0.005	0.000		0.038	0.005	0.000
D 2001	0.037	0.005	0.000		0.039	0.005	0.000
D 2002	0.053	0.005	0.000		0.055	0.005	0.000
D 2003	0.065	0.004	0.000		0.067	0.004	0.000
D 2004	0.079	0.004	0.000		0.083	0.004	0.000
D 2005	0.074	0.004	0.000		0.079	0.004	0.000
D 2006	0.057	0.004	0.000		0.062	0.004	0.000
D 2007	0.043	0.005	0.000		0.049	0.005	0.000
D Double Front.	-5.0E-02	0.004	0.000		-5.0E-02	0.004	0.000
D Floodplain	-4.4E-02	0.011	0.000		-2.6E-02	0.011	0.018
Housing Density	-2.5E-05	1.8E-06	0.000		-2.8E-05	1.8E-06	0.000
LN Dist. Com.	-1.7E-03	0.001	0.220		9.1E-04	0.001	0.505
LN Dist. Industrial	0.021	0.002	0.000		0.016	0.002	0.000
LN Dist. Art. Road	-1.6E-03	0.001	0.232		0.001	0.001	0.355
LN Dist. Dodge St.	-1.9E-02	0.002	0.000		-1.1E-02	0.002	0.000
LN Dist. I80/I680	-1.7E-02	0.002	0.000		-1.5E-02	0.002	0.000
LN Dist. H. Sch.	-6.3E-03	0.002	0.000		-8.1E-03	0.002	0.000
LN Dist O. Sch.	0.006	0.001	0.000		0.007	0.001	0.000
D Omaha	-4.1E-02	0.004	0.000		-9.1E-03	0.005	0.048
D Millard	-1.9E-02	0.004	0.000		0.003	0.005	0.529
LN Dist Open	-1.3E-02	0.001	0.000		-	-	-
D Homeowners'	8.8E-04	0.006	0.873	**LN Dist**	-2.5E-02	0.001	0.000
D SID	-4.3E-02	0.005	0.000	**LN Dist**	0.007	0.001	0.000
D Public	-3.9E-02	0.004	0.000	**LN Dist**	0.001	0.001	0.232
D Private	-5.4E-02	0.004	0.000	**LN Dist**	0.004	0.001	0.001
D Golf[a]	-	-	-	**LN Dist**	-1.6E-02	0.002	0.000
Constant	6.248	0.057	0.000		6.372	0.059	0.000
Observations	18392				18392		
F-Value	3429.92				3565.81		
Prob > F	0.000				0.000		
R-squared	0.8820				0.8834		
Adj. R-squared	0.8818				0.8832		
Root MSE	0.13145				0.13067		

Note: Ownership Delineated by Dummy Indicators and Through Separate Distance Variables

[a] Dropped to prevent a dummy variable trap, represented by the constant or intercept.

Ownership and Groundcover Impacts by Area Analyses

The full hedonic regression results that evaluate open space from an ownership perspective and by different groundcover classifications are summarized in Table 3.7. The thesis document of Schmitz (2008) contains the reporting of these full regression model results.

Table 3.7. Price Impacts: Ownership & Groundcover

	% Homeowners	% SID	% Public	% Private	% Golf
% Trees	30%	14%	14%	24%	27%
% Mowed	15%	-1%	-1%	9%	12%
% Prairie/Grass[a]	7%	-8%	-9%	1%	4%
% Wooded	18%	2%	2%	12%	15%
% Tilled/Farmed	-14%	-30%	-30%	-20%	-17%

Note: For a $172,356 Home With 30% Open Space.
[a] Coefficient was not significant at the 10% level in the subdivision model.

Table 3.7 demonstrates the relative impacts that both ownership status and open space groundcover have on residential housing prices. For example, homes with nearby tree dominated open space which is homeowner association owned has 24% of their value impacted by this open space scenario. Alternatively, 24% of the value of such homes is influenced by this nearby privately owned tree open space. From this it can be that all types of open space increase property values (except for the case of farmland next to subdivisions). SID-managed open space in most cases has a negative impact on property values (unless it is in trees or woodlands). Finally, golf course-based open space is positive under all ownership classes while native prairie or mowed open space is positive only when these spaces are privately owned and managed.

Open Space Impacts for Abutment Homes

Table 3.8 summarizes the hedonic regression models that specifically focused on sold homes that abutted open spaces (i.e. frontage homes)**.** From this it can be seen that the presence of trails increases values by around 17.2%, i.e. if a home abuts a parcel with trails its value will increase considerably. Parking lots, as expected, cause a negative stigma. The presence of a pool is insignificant possibly because this can be both a

positive or negative amenity depending on tastes and preferences. Baseball and soccer fields are both negatively signed indicating that homeowners prefer not to abut parcels with these amenities which is expected due to the noise and congestion associated with baseball, soccer, and football games.

Table 3.8 Impacts of Recreation Amenities on Housing Prices

Variable	Percentage Effect
D Trails	17.20%
D Parking Lot	-16.52%
D Pool	3.80% (insig.)
D Tennis	29.80%
D Baseball	-12.26%
D Soccer	-9.25%

Hedonic Results Specific to LID Subdivision Designs

Table 3.9 evaluates the impact of two particular types of LID subdivision design on property values: clustered open space versus greenway open space. The greenway subdivisions generate a premium of between 1.1% to 2.74% depending on whether greenway areas were observed or calculated using a GIS approach. In contrast, the impacts of clustered subdivisions range from 0.7% to 1.1%. These are considered to be lower-bound estimates since homebuyers will likely be willing to pay for non-open space related benefits of LID designs (i.e. ‘green’ or ‘environmentally friendly’ developments).

Table 3.9. A Summary of LID/Subdivision Price Impacts

Variable	Greenway Observed			Greenway Calculated[a]		
	Coef.	*Sd. Err.*	*p>|t|*	*Coef.*	*Sd. Err.*	*p>|t|*
D Double Front.	-4.6E-02	0.004	0.000	-4.5E-02	0.004	0.000
D Floodplain	-4.4E-03	0.010	0.673	-6.1E-03	0.010	0.558
Housing Density	-2.8E-05	1.8E-06	0.000	-2.6E-05	1.8E-06	0.000
LN Dist. Com.	-2.8E-03	0.001	0.034	-2.3E-03	0.001	0.091
LN Dist. Industrial	0.019	0.002	0.000	0.020	0.002	0.000
LN Dist. Art. Road	-1.6E-03	0.001	0.222	-5.6E-04	0.001	0.671
LN Dist. Dodge St.	-1.9E-02	0.002	0.000	-2.0E-02	0.001	0.000
LN Dist. I80/I680	-1.3E-02	0.002	0.000	-1.5E-02	0.002	0.000
LN Dist. H. Sch.	-4.1E-03	0.002	0.007	-5.4E-03	0.002	0.000
LN Dist O. Sch.	0.006	0.001	0.000	0.004	0.001	0.000
D Omaha	-4.2E-02	0.004	0.000	-4.6E-02	0.004	0.000
D Millard	-2.4E-02	0.004	0.000	-2.6E-02	0.004	0.000
D Cluster	0.007	0.006	0.225	0.011	0.006	0.065
D Greenway	0.014	0.003	0.000	0.027	0.002	0.000
D Abut Open	-8.6E-03	0.006	0.134	-8.5E-03	0.006	0.138
Constant	6.062	0.055	0.000	6.092	0.055	0.000
Observations	19,589			19,589		
F-Value	3917.51			3940.94		
Prob > F	0.0000			0.0000		
R-squared	0.8811			0.8818		
Adj. R-squared	0.8809			0.8815		
Root MSE	0.1327			0.1323		

[a] Subdivision is Considered Greenway if it has > 10% Open Space

Summary and Policy Implications

This research has direct implications for policy makers and developers planning residential housing developments in the Omaha market that include open space amenities and/or LID practices (also known as 'conservation design'). Clustered open space tends to negatively impact sale prices or in some cases have neutral effect. In contrast, the more wide open greenway-based open spaces have larger positive impacts on home prices. It is also clear that home buyers prefer open space to be owned and maintained by a homeowners association or a private entity and that they prefer open areas to be mowed and/or planted in trees. In conclusion, while many types of open space generate positive values there are some combinations of open space, ownership and ground cover characteristics that negatively impact property values.

Planners and residential housing developers are suggested to evaluate the specific neighborhood and open space conditions associated with existing and planned subdivisions in conjunction with these research results (particularly the full thesis results of Schmitz, 2008). Combined with information on the relative costs to plan, design and build specific open space amenities, this information is expected to maximize homeowner preferences and hence development profits. In the case of planning LID/open space designs, it is recommended that developers rely more on open greenway designs rather than clustered open space designs and that the maintenance of these open spaces be privatized (i.e. under the control of homeowner associations or SID's).

Proposed Follow-Up Research

1) Replicate these hedonic price models focusing on open space using only undeveloped lot sales. This would potentially be more helpful for residential housing developers to identify different profit levels associated with different open space designs

2) Surveys of homebuyers to elicit their perceptions of and preferences for different open space amenities. This could potentially confirm many of the conclusions reached in this study based on observed housing sale prices.

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Fate of microcontaminants in streams augmented by wastewater treatment plant effluent use

Basic Information

Title:	Fate of microcontaminants in streams augmented by wastewater treatment plant effluent use
Project Number:	2008NE168B
Start Date:	3/1/2008
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Focus Category:	Toxic Substances, Surface Water, Water Quality
Descriptors:	
Principal Investigators:	Shannon Bartelt-Hunt, Daniel Davidson Snow

Publications

1. Brown, D. Bartelt-Hunt, S.L., Snow, D.D. Quantitative Evaluation of Aqueous Concentrations of Organic Compounds Using POCIS Samplers, in preparation as of a 5/24/10.
2. Brown, D., Bartelt-Hunt, S.L., Snow, D.D. Persistence of Pharmaceuticals in Receiving Waters Influenced by Wastewater Treatment Plant Effluent, in preparation as of 5/24/10.
3. Use of Passive Samplers to Evaluate Pharmaceutical Fate in Surface Waters Author: DelShawn L. Brown Publication: Civil Engineering Theses, Dissertations, and Student Research 2010

Final Report: Fate of Microcontaminants in Streams Augmented by Wastewater Treatment Plant Effluent

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Project Objectives

This project was conducted over a 15 month period from March 1, 2008 to May 31, 2009. The objective of this project was to evaluate the fate and transport characteristics of selected WWTP microcontaminants and to determine if a passive sampling technology can be used in quantitatively assessment of contaminant fate in receiving waters. To achieve this objective, the following experiments were performed:

1) Laboratory Calibration Study: In March 2009, we conducted a laboratory calibration study of the POCIS samplers. Briefly, the POCIS samplers were exposed to DI water spiked with selected contaminants of interest for a 21 day exposure period. POCIS were placed in glass beakers containing 2L of DI water and spiked with the microcontaminants of interest. A positive control (spiked water with no POCIS) and a negative control (unspiked water with no POCIS) were also carried throughout the exposure period. Aqueous samples were obtained from each beaker at 0, 3, 7, 14 and 21 days and analyzed for the compounds of interest using LC/MS/MS. We are currently in the process of calculating contaminant uptake rates for each compound. These uptake rates can be used to quantify contaminants recovered from POCIS after field deployment.
2) Field Deployment: in May 2009, we deployed POCIS samplers in the field at two locations: at the WWTP at Hastings, Nebraska and at the Theresa St. WWTP in Lincoln, NE. Samplers were deployed in triplicate at four locations at each site: in the effluent prior to discharge, within the mixing zone just after discharge, approximately 500 ft downstream, and approximately 1500 feet downstream. The POCIS will be deployed in the field for a 21 day exposure period. At the conclusion of the exposure period, the POCIS will be collected and returned to the laboratory where they will be extracted and analyzed. Using this data, we intend to evaluate the persistence of selected pharmaceuticals originating from WWTP effluent. We will simulate contaminant fate in the receiving water body using a simple 1D model

Student Training

DelShawn Brown, a graduate student working on this project, will graduate with a M.S. in Environmental Engineering in August 2009.

Dissemination of Results

A manuscript will be prepared for publication in a peer-reviewed journal based on the results of this study. This manuscript will be submitted no later than October 2009.

Geographic Trends in Contamination of Nebraska's Surface Waters as indexed by sex Steroids of Common Carp

Basic Information

Title:	Geographic Trends in Contamination of Nebraska's Surface Waters as indexed by sex Steroids of Common Carp
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Descriptors:	
Principal Investigators:	Kevin Lee Pope, Alan S Kolok, Daniel Davidson Snow

Publications

There are no publications.

Geographic trends in contamination of Nebraska's surface waters as indexed by sex steroids of common carp

FINAL REPORT
Submitted to University of Nebraska—Lincoln Water Center

9 April 2009

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ABSTRACT

Endocrine disrupting compounds (EDCs) have been identified in the streams and rivers of Nebraska during the past few years. We initiated a multi-disciplinary assessment of geographic trends in the occurrence of EDCs in water bodies (all but one were lentic systems) throughout Nebraska. We used common carp sex steroids and carp gene expression profiles as indirect indicators of exposure to EDCs, and water samples from each reservoir were used to provide a "snapshot" of EDCs concentration. The specific objectives of this project were to document occurrence and concentrations of steroidogenic contaminants in water from water bodies throughout Nebraska and examine geographic variation in effects of sex steroids on adult common carp. We hypothesized that sex steroid profiles would vary considerably across the state, and would be associated with bioavailability of steroidogenic compounds within each reservoir. A primary goal of this project was to obtain preliminary data (geographical variation in concentrations of sex steroids in adult common carp) needed to assemble a grant proposal for a large, multiyear assessment on the occurrence and biological effects of steroidogenic compounds in lakes and reservoirs throughout the Midwest. Contrary to our *a priori*

expectations, we did not find a geographic trend in the occurrence of steriodogenic compounds. Further, endpoints from the two measures we used to assess biological effects of EDCs in water bodies across Nebraska (plasma sex steroid concentrations and hepatic vtg mRNA expression) did not agree. Thus, compelling evidence necessary to obtain a large, multiyear grant for assessment of geographic variation in sex steroids in aquatic systems is still lacking.

INTRODUCTION

Endocrine disrupting compounds (EDCs) have been identified in the streams and rivers of Nebraska during the past few years, most notably downstream from beef cattle feedlots (Soto et al. 2004; Kolok et al 2007) and local wastewater treatment plants (Kolok et al. 2007). Furthermore, feral and caged populations of fathead minnows living in these watersheds exhibited reproductive abnormalities and alterations in the expression of reproductively important genes (Soto et al. 2004; Kolok et al. 2007). The two studies published to date were restricted in their geographical scope, limiting our understanding of the geographic variation in occurrence and effect of EDCs in Nebraska. Indeed, a preliminary analysis of minnows caged in four different watersheds throughout Nebraska has documented pronounced defeminization of female minnows, indicating probable exposure to EDCs.

Although wastewater treatment plants and beef feedlots are often located adjacent to streams, evaluating the extent to which EDCs occur throughout the lakes and reservoirs of Nebraska is also important. A vast majority of anglers in Nebraska concentrate their fishing efforts on lakes and reservoirs, producing a large marginal economic value from recreation for these water bodies. Recruitment of fishes in Nebraska lakes and reservoirs is extremely variable, and in some reservoirs natural recruitment has been so limited that annual stockings of sportfish became necessary. It is possible, and has been suggested, that EDCs may be responsible for the limited recruitment of sportfish (Blazer 2002). The first step in determining whether fishes of Nebraska are being exposed to EDCs is implementation of a study to determine if geographical variation in EDCs occurrence and effect exist throughout the lakes and reservoirs of Nebraska.

There are many reasons to believe that geographical analysis of endocrine disruption of fish that reside in small, lacustrine environments may be particularly informative. First, lakes

and reservoirs serve as catchments for storm-water runoff, and EDCs that are in the runoff will likely enter these water bodies. Second, geographical variations in land use (e.g., urban housing, row-crop agriculture, pastureland, etc.) will profoundly influence the chemical composition of the runoff that enters a water body. Third, EDCs that enter these systems through time will accumulate in the sediments where they can ultimately be released by benthic-feeding fishes.

Common carp *Cyprinus carpio* is as an excellent environmental sentinel organism, especially in Nebraska because they are established in virtually every major lake and reservoir throughout the state. Further, common carp are benthic feeders that routinely roil the bottom sediments, exposing themselves to EDCs trapped within the sediments. Common carp have been used as the model organism in other studies. For example, studies of common carp in Lake Mead, Arizona-Nevada, documented differences in gonad size (gonadosomatic index) and rates of histopathological gonad abnormalities for males collected from different sections of the reservoir. These differences in reproductive physiology provide strong circumstantial evidence that male reproductive performance is hinder by the discharge of treated industrial and municipal effluents into this large reservoir (Bevans et al. 1996; Patiño et al. 2003).

We initiated a multi-disciplinary assessment of geographic trends in the occurrence of EDCs in lentic systems throughout Nebraska. We used common carp sex steroids and carp gene expression profiles as indirect indicators of exposure to EDCs, and water samples from each reservoir were used to provide a "snapshot" of EDCs concentration. The specific objectives of this project were to document occurrence and concentrations of steroidogenic contaminants in water from water bodies throughout Nebraska and examine geographic variation in effects of sex steroids on adult common carp. We hypothesized that sex steroid profiles would vary

considerably across the state, and would be associated with bioavailability of steroidogenic compounds within each reservoir.

METHODS

This study focused on the evaluation of techniques for assessing possible fish-contaminant interactions in 20 lakes and reservoirs in Nebraska. Water bodies were randomly selected within a stratified design based on type of water body (lake or reservoir) and geographic location within the state (Figure 1). Water samples and fish tissue were collected from each study site during July-August 2007 for assessment of steroidogenic compounds. We expected that temporal variation in concentration of sex steroids would be minimal during this period because of the reduced potential for run-off, thereby allowing for geographic assessment without the need to correct for expected seasonal differences in concentration of sex steroids.

Field procedures: Standard water-quality parameters (e.g., temperature, conductivity, turbidity, etc.) were measured at each water body. In addition, depth-integrated grab samples of water were collected using a Teflon bailer from three locations within each water body. Grab samples within each water body were homogenized and placed in pre-cleaned amber bottle and stored on ice. Samples were frozen as quickly as possible to minimize changes in steroid concentration after collection, and then samples were delivered to the UNL Water Sciences Laboratory, where they were analyzed for steroidogenic compounds.

Twenty common carp from each water body were captured using daytime electrofishing (pulsed DC) during July-August 2007. Adult common carp were anesthetized with MS-222 (0.1 g/L water) and blood was collected from the caudal vein of these fish using a heparinized syringe. Blood from each fish was transferred into pre-labeled 10-cc vacutainers and stored on

ice. After blood was collected, fish were euthanized, measured and weighed, and their sex verified by visual inspection of gonads. Gonads and liver were removed via dissection and weighed individually. A portion of the liver was excised and stored in liquid nitrogen. This process was repeated on randomly selected fish until we reached our target sample size of six male and six female fish, after which the remaining fish were released unharmed; in several cases, we processed all 20 fish without obtaining our target sample size. Liver and blood samples were transported to the Aquatic Toxicology Laboratory at UNO, where they were analyzed for plasma sex steroids and the hepatic mRNA expression of vitellogenin 1 (vtg), an estrogen-responsive gene.

Laboratory procedures: Steroidogenic compounds monitored in reservoir water included synthetic steroid growth promoters (trenbolone, melengestrol acetate, zeralonol) and natural steroid hormones (17β-estradiol, estrone, estriol, testosterone, androstenedione). Frozen grab samples were thawed immediately prior to analysis. . Samples were analyzed for natural and synthetic steroid hormones using on-line solid phase extraction (SPE) liquid chromatography-tandem mass spectrometry (LC/MS/MS). This highly sensitive method makes use of a commercial automated extraction system coupled to an LC/MS/MS and is similar to that described by Rodriguez-Mozaz et al.(2004) for analysis of ng/L concentrations of natural estrogens in water. Method development and validation is described elsewhere (Damon et al, in preparation).

Pure standards steroids were purchased from Sigma-Aldrich (St. Louis, MO) or Acros Chemicals, and Hayashi Pure Chemical Industries (Osaka, Japan). Deuterium-labeled steroid hormone analogues were obtained from Sigma Aldrich (St. Louis, MO) and used as internal standards. Calibration standards and samples were fortified with standard compounds

immediately prior to extraction and analysis using a Symbiosis Environ on-line solid phase extraction system (Spark Holland, Emmen, The Netherlands). The system was configured with an automatic cartridge exchanger, integrated stream switching valve, high pressure dispenser, gradient pump with control using SparkLink software. Twenty mL aqueous samples were extracted using Prospekt 2/Symbiosis 1.0 x 10mm Oasis HLB solid phase extraction cartridges. Each cartridge was eluted directly to a Waters 2695 HPLC and then to a Micromass Quattro Micro triple-quadrupole mass spectrometer in atmospheric pressure photoionization (APPI) mode. Detection and quantification of steroids utilized multiple reaction monitoring (MRM) with argon collision gas. A Thermo HyPurity C18 column (250 x 2 mm, 5 um, 50°C) was used for gradient separation at a flow rate of 0.35 ml/min. The gradient consisted of solvent A (0.1% formic acid water) and solvent B (0.1% formic acid methanol), with 0-3 min 50%B, 3-14 min 65% B, 14-20 min 95%B, with a return to initial solvent conditions for the last 10 minutes of the gradient (30 minutes total). Identification of target compounds was accomplished by comparing the retention times for the respective MRM transition in a sample to that of a standard analyzed under the same conditions. Retention times were considered to match if they were within ±5% of the standards. Recovery, measured through analysis of 10 portions of 25mL reagent water fortified at 5 ng/L, averaged between 62% for estrone and 121% for progesterone.

Plasma sex steroid concentrations and hepatic vtg mRNA expression was evaluated for five males from each field site. Fish were chosen for analysis based on their body mass, GSI and HSI, and outliers were removed from consideration. Analysis was conducted on individuals chosen randomly from the remaining pool of fish from each field site.

Plasma estradiol and testosterone concentrations were measured by radioimmunoassay (RIA) according. Plasma estradiol/testosterone ratios were determined by dividing plasma estradiol concentrations by plasma testosterone concentrations

Hepatic vtg mRNA expression analysis was conducted using previously published protocols (Kolok et al. 2007). Hepatic mRNA expression was determined using a Bio-Rad MyiQ Real-Time Polymerase Chain Reaction Detection System managed by Optical System Software version 1.0. Data were quantified by the standard curve method using series diluted cDNA samples as a standard. The expression of each gene was normalized by the expression of L8 mRNA, a "housekeeping" gene, and expressed in relative terms.

Statistical analysis: A single factor analysis of variance (ANOVA, Statview 5.0) was used to test for differences in body mass, organ indices, plasma estradiol/testosterone ratios and hepatic mRNA expression among water bodies. Newman-Kuels multiple comparison tests were used to separate water bodies when a significant difference existed. Statistical significance was set at $\alpha = 0.05$.

RESULTS

Steroid hormones in water

Except for a trace of androsterone in one sample at 0.006 μg/L, no steroid hormones were detected in water samples above the 0.005 μg/L detection limit (Table 1). Thus, no geographic trend could be determined with respect to steroid hormone concentrations across the environmental conditions sampled.

Plasma sex steroids

Significant differences ($P < 0.0001$) in plasma estradiol/testosterone ratios were detected (Figure 2). Specifically, male common carp collected from Lake Zorinski had significantly higher estradiol/testosterone ratios than male carp collected from any other site. In addition, male common carp collected from Lake Ericson had significantly higher estradiol/testosterone ratios than male carp collected from Bluestem, Calamus, Enders, Johnson, Medicine Creek, Pawnee, Red Willow, Stagecoach and Standing Bear.

Hepatic vtg mRNA expression

There were no significant differences in the hepatic mRNA expression of male carp collected from any of the field sites. Furthermore, the vast majority of males collected had vtg mRNA expression below detectable levels.

DISCUSSION

Except for a trace of androsterone in one sample, we detected no steroid hormones in water samples collected from the 18 water bodies across Nebraska. The lack of detectable levels of steroid hormones in water samples is consistent with other studies of surface water systems, as they typically occur in extremely low concentrations (<0.001 μg/L), if at all. Nonetheless, we did detect differences in plasma sex steroid concentrations in male common carp from these water bodies. The plasma sex steroid concentrations in male common carp suggests that biological exposure to EDCs differs among water bodies throughout Nebraska. Contrary to the plasma sex steroid endpoint, however, we detected no systematic differences in hepatic vtg mRNA expression and male common carp from these water bodies. Expression of hepatic vtg

mRNA in male common carp provides evidence that biological exposure to EDCs by common carp, if any, has not caused feminization of the individuals assessed. Thus, we were unable to assess geographic trends because the reproductive toxicity indicators were not in agreement. The lack of detectable levels of steroid hormones in water samples collected for this study implies either that other types of contaminants (pesticides, metals, etc.) are responsible for any endocrine disrupting effects to indigenous populations of fish in Nebraska or that these contaminants do not occur in the dissolved phase. Further, the dynamics of wild fish populations adds additional complexity for our understanding of these results. For example, a difference in age of common carp within and among water bodies is likely positively correlated with period of exposure to EDCs, which is an important factor for biological responses to EDCs.

A primary goal of this project was to obtain preliminary data (geographical variation in concentrations of sex steroids in adult common carp) needed to assemble a grant proposal for a large, multiyear assessment on the occurrence and biological effects of steroidogenic compounds in lakes and reservoirs throughout the Midwest. Contrary to our *a priori* expectations, we did not find a geographic trend in the occurrence of steriodogenic compounds. Further, endpoints from the two measures we used to assess biological effects of EDCs in water bodies across Nebraska (plasma sex steroid concentrations and hepatic vtg mRNA expression) did not agree. Thus, compelling evidence necessary to obtain a large, multiyear grant for assessment of geographic variation in sex steroids in aquatic systems is still lacking.

ACKNOWLEDGEMENTS

We thank Marlo Sellin, Teyona Damon, Nathan Gosch, Carla Knight, Christopher Lewis, Alexis Maple, Dustin Martin, Mark Pegg, Derek Tomes and Jason Weigel for assistance in the

field and laboratory. Funding for this project was provided by the U.S. Geological Survey through their 104b project; these funds were awarded and administered by University of Nebraska—Lincoln Water Center.

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Table 1. Results of the LC/MS/MS analysis for steroid hormones in the water samples collected during summer 2008. Concentrations are in μg/L.

Water Body	4-Androstenedione	Androsterone	17a-Trenbolone	17b-Trenbolone	a-Zearalenol	b-Zearalenol	a-Zearalanol	Estriol	Estrone	Ethynyl Estradiol	Melengestrol Acetate	Progesterone	17b-estradiol	Testosterone
Zorinski	<0.005	0.006	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Ericson	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Willow Creek	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Spalding	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Merritt	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Elkhorn River	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Conestoga	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Eagle Scout	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Red Fox	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Blue Stem	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Calamus	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Enders	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Johnson	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Medicine Creek	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Pawnee	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Red Willow	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Stage Coach	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Standing Bear	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005

Figure 1. Geographic location (latitude and longitude) of the 18 Nebraska water bodies assessed for steroidogenic compounds and their influences on sex steroids of common carp.

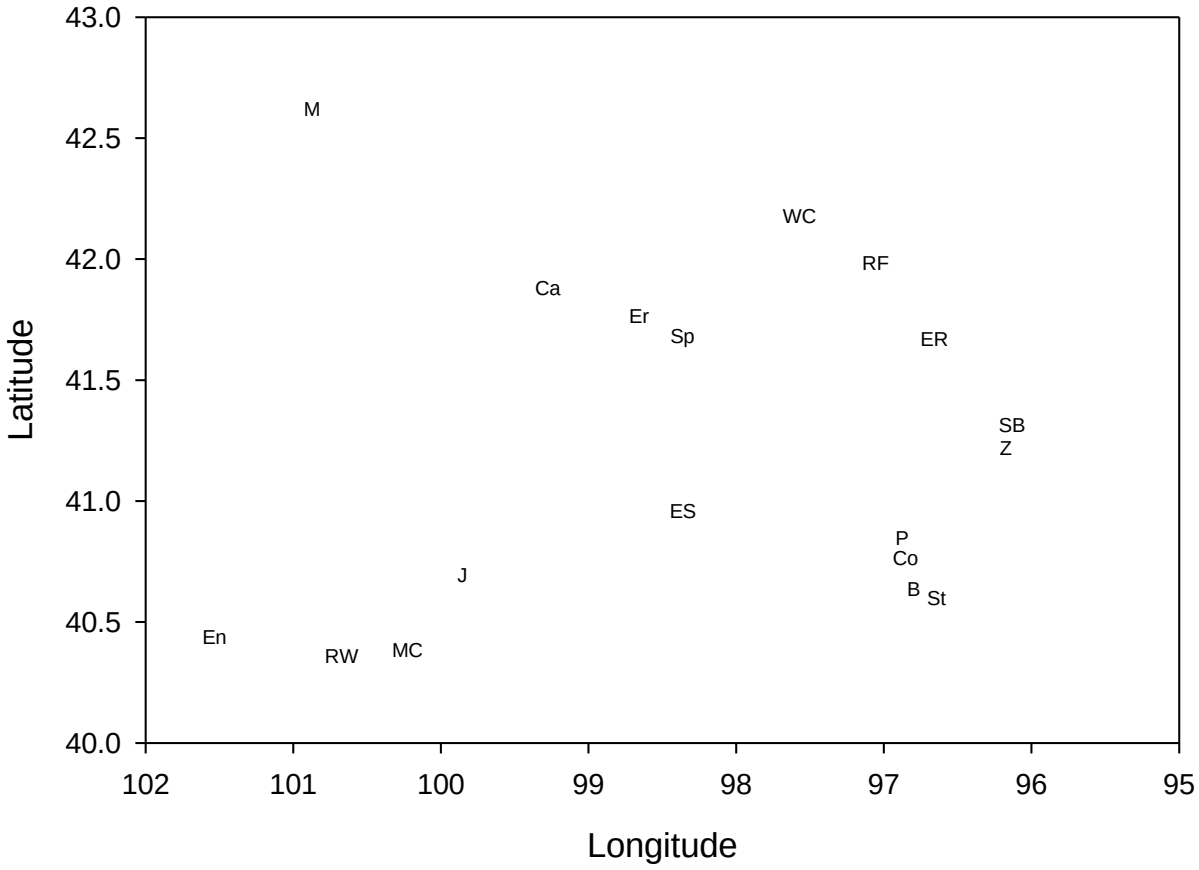
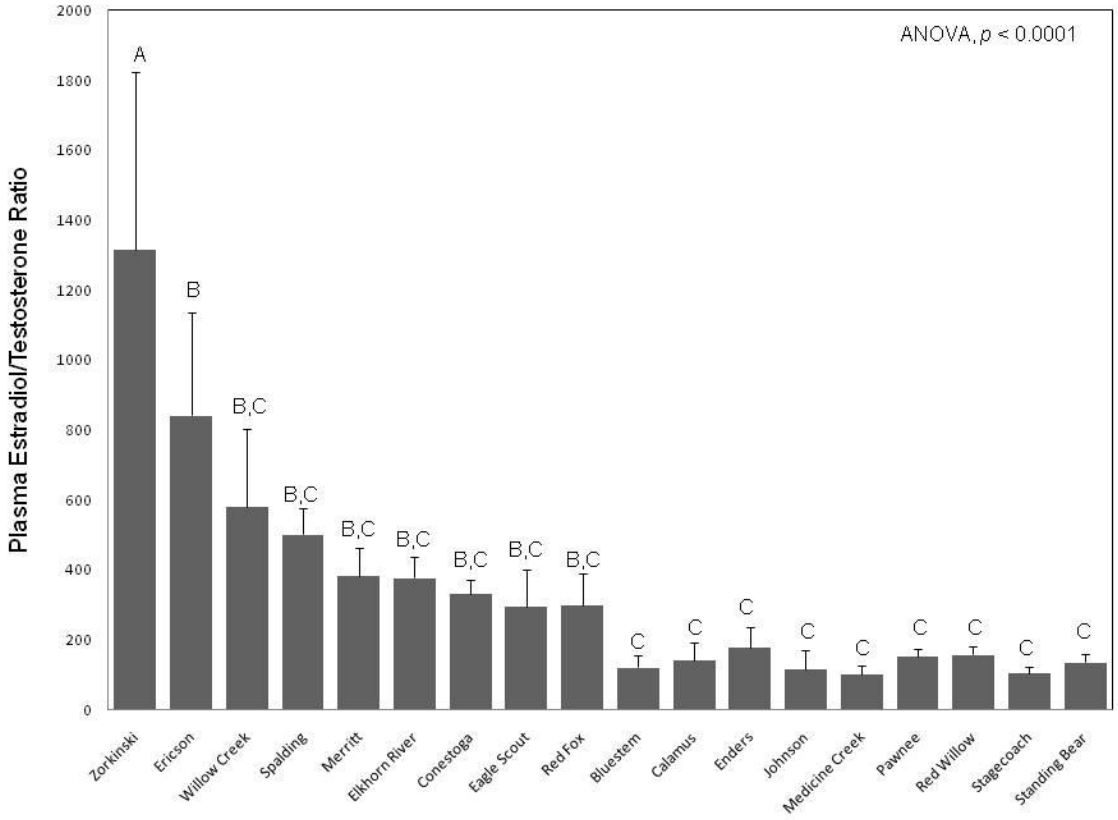


Figure 2. Plasma estradiol/testosterone ratios among males collected from 18 field sites throughout the state of Nebraska. Capital letters indicate significant differences between groups.



Award No. G09AP00031 Standards of Practice for Adaptive Management

Basic Information

Title:	Award No. G09AP00031 Standards of Practice for Adaptive Management
Project Number:	2008NE198S
Start Date:	1/15/2009
End Date:	9/30/2009
Funding Source:	Supplemental
Congressional District:	2
Research Category:	Biological Sciences
Focus Category:	Hydrology, Models, Methods
Descriptors:	Adaptive Management
Principal Investigators:	Kyle D. Hoagland, Steven Light

Publications

There are no publications.

Standards of Practice for Adaptive Management

PI: Steven Light
January 15 - September 30, 2009

As of May 27, 2010, Kyle Hoagland and Tricia Liedle have been unable to communicate with Steven Light (he has moved from Omaha but left no forwarding information), therefore, a final report is unavailable at this time. We will continue to attempt to make contact and to obtain a final report for future submission. The funds received for 2008NE198S from the U.S. Army Corps of Engineers in Omaha, NE required that the project funding be passed through the USGS and ultimately through the UNL Water Center, for which we obtained all necessary permission; however, this was our only direct involvement in the project. An annual report by Dr. Light was provided in 2009.

A Solute Transport System for Systematically Evaluating Remedial Technologies for Chlorinated Solvent-Contaminated Groundwater

Basic Information

Title:	A Solute Transport System for Systematically Evaluating Remedial Technologies for Chlorinated Solvent-Contaminated Groundwater
Project Number:	2009NE177B
Start Date:	3/1/2009
End Date:	2/28/2010
Funding Source:	104B
Congressional District:	1
Research Category:	Ground-water Flow and Transport
Focus Category:	Solute Transport, Treatment, Toxic Substances
Descriptors:	
Principal Investigators:	Steve Douglas Comfort, Yusong Li

Publications

There are no publications.

A Solute Transport System for Systematically Evaluating Remedial Technologies for Chlorinated Solvent-Contaminated Groundwater

ANNUAL REPORT

Submitted to the University of Nebraska-Lincoln

19, May 2010

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Research Goal and Objectives

Contamination of soil and water by chlorinated solvents is widespread problem nationally and world-wide. The overall goal of this research was to address one of the most pressing needs regarding the cleanup of sites contaminated with chlorinated solvents. Namely, to develop remedial treatments that can remove chlorinated solvents from low-permeable zones in contaminated aquifers.

To accomplish this goal, we constructed a two-dimensional (2-D) tank transport system that mimics the movement and behavior of chlorinated solvents in heterogeneous media containing transmissive and low-permeability zones. This transport system allowed us to methodically produce the phenomena known as “rebound,” which is the release of chlorinated solvents from low permeability zones following the removal of solvents from transmissive zones. This 2-D system is now allowing us to systematically evaluate, develop and fine-tune remedial treatments to remove chlorinated solvents from low permeable zones in contaminated aquifers.

Objectives

(1) Construct a column and 2-D tank transport system capable of repeatedly producing “rebound” of chlorinated solvents from low-permeable zones.

(2) Validate and calibrate our proposed model for the transport of chlorinated solvents in aquifer media containing transmissive and low-permeable zones.

(3) Systematically evaluate and develop in situ chemical and biological treatments to remove chlorinated solvents from low-permeable zones.

Background and Related Research

Chlorinated solvents clearly represent the most prevalent groundwater contaminants. Dichloromethane (CH_2Cl_2), trichloroethene (C_2HCl_3), teterachloroethene (C_2Cl_4), and 1,1,1-trichloroethane ($C_2H_3Cl_3$) are undoubtedly among the top 10 organic groundwater pollutants worldwide (Schwarzenbach et al., 1993).

Sites contaminated with chlorinated solvents are so prevalent that there are an estimated 15,000 to 25,000 chlorinated solvent sites in the U.S. alone with groundwater plumes ranging from 500 to 5000 ft. Most plumes discovered today were likely caused by releases that occurred in the 1960 through the 1980s (Sale et. al., 2007). Spills of chlorinated solvents in aquifers are exceptionally difficult to clean up. At some sites, plumes have tainted water supply wells at concentrations above the maximum contaminant levels (MCLs) for drinking water. At each site where DNAPLs have contaminated the local groundwater, there are two major problems: a subsurface source zone and a groundwater plume. Usually, most of the contaminant mass is in the source zone, but the tainted plume usually occupies a much larger volume of the aquifer. Thus, unless most of the source is removed (i.e., > 99.9%), permanent aquifer restoration to drinking water standards will not be readily achievable. Pump and treat methodologies are generally not effective and too slow. Moreover, excavation is not practical because of the depths to which the DNAPL has moved (Pankow and Cherry, 1996).

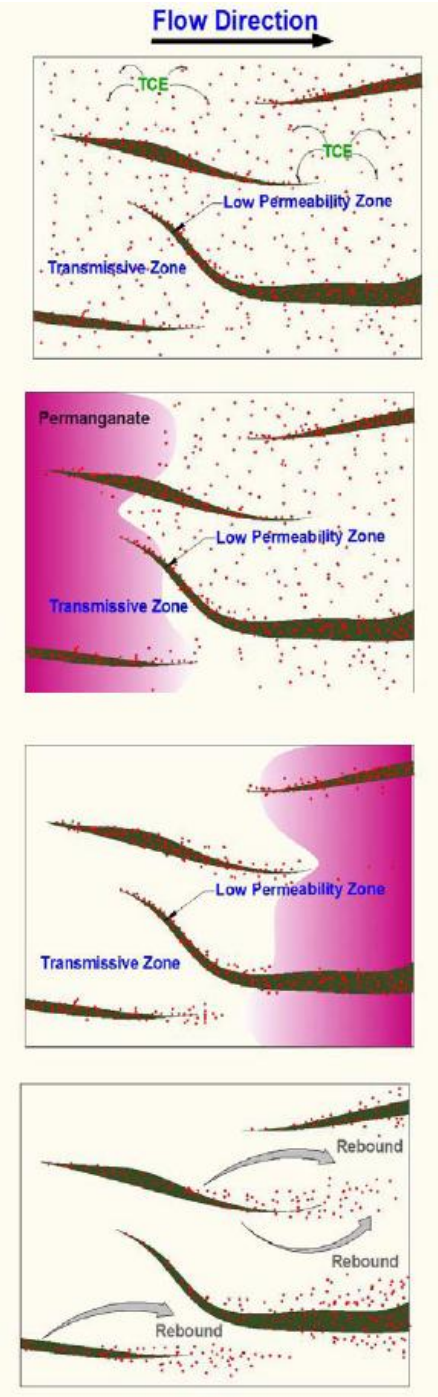


Figure 1. TCE "rebound" following treatment with permanganate.

As the chlorinated solvents migrate from source zones, dissolved solvents tend to migrate into low permeability clay layers via diffusion and or slow advection. Solvents stored in these low permeable layers can be present as sorbed, dissolved or DNAPL phases. Both natural processes and remediation technologies will deplete chlorinated solvents in the transmissive zones (i.e., where water is moving). When this occurs, contaminants are released from the low permeability zones (i.e., where water is stagnant) back into the transmissive zone via back diffusion and slow advection (Sale et al.,

2007). The replenishment of the moving water in the aquifer from the low-permeable zones following a remedial treatment has been termed "rebound." Figure 1 illustrates this effect following treatment with the chemical oxidant, permanganate. Because low-permeability zones serve as contaminant reservoirs, remedial treatments that primarily address transmissive zones may miss substantial contaminant mass zones and prevent remedial treatments from achieving groundwater cleanup goals.

New technologies being developed for source-zone remediation are of two-types, those that bring the contaminant mass to the surface for treatment or disposal (pump and treat) and those that treat the source zone *in situ*. In situ treatments can be categorized into physical, chemical and biological approaches. Several types of chemical treatments have been developed and applied to the subsurface. Commonly used chemical treatments include: direct chemical oxidation, direct chemical reduction, secondary reduction or oxidation, and metal-enhanced dechlorination. Direct chemical oxidation involves injecting chemical oxidants such as hydrogen peroxide (with ferrous iron), permanganate (sodium or potassium), perchlorate, persulfate, and ozone. Direct chemical reduction uses reducing agents like sodium dithionite. Secondary reduction or oxidation occurs when injected chemicals influence the oxidation-reduction potential of the aquifer, which subsequently induces transformation of the contaminant. Metal-enhance dechlorination typically involves the use of zerovalent iron in either granular or colloidal form.

All of these aforementioned remedial treatments have had various degrees of success in removing chlorinated solvents from aquifers. ***What has not been widely researched and the main focal point of this proposal was to systematic evaluate in situ treatments abilities to reduce the rebound phenomenon that has plagued many field sites and prevented groundwater cleanup criteria from being met.*** Once we have identified the treatments showing the most promise, we can then develop and fine-tune these treatments for optimum performance.

Experimental Results

Transport System Construction

A two-dimensional (2-D) transport tank was custom made for this grant. This tank was made from aluminum by a computer-controlled cutting instrument and then finished with a Class 3 anodizing. The tank consists of three parts: (1) inlet mixing chamber, (2) outlet mixing chamber, and (3) packing area (Fig. X). The packing area size is 8.5" x 5" x 2" (L x W x D) yielding a volume of 85 in^3 or 1,393 cm^3. Two sides of the tank were assembled with layers of lexan plastic and glass for real-time observation. A rectangular-shaped fiber glass wool and a titanium mesh are placed at the inlet and outlet of the packing area to keep the aquifer material in place. Once the tank is packed and flushed, the pore volume is ~475 to 485 cm^3 depending of particle size of aquifer material. We used Ottawa sand (20/30) to represent permeable zone while the combination of Ottawa sand (40/50) and silt

represents the low-permeable zone (LPZ). Each time packing material weight is monitored for keeping bulk density as consistent as possible (i.e., approximately 1.7 kg/l). After packing, the tank was flushed with CO_2 gas for at least 30 minutes to facilitate the saturating process and prevent air bubbles forming in the chamber. We used a 3-L collapsible tedlar bag as a reservoir for TCE. When collecting samples, we used a flow rate of 3 ml/min.

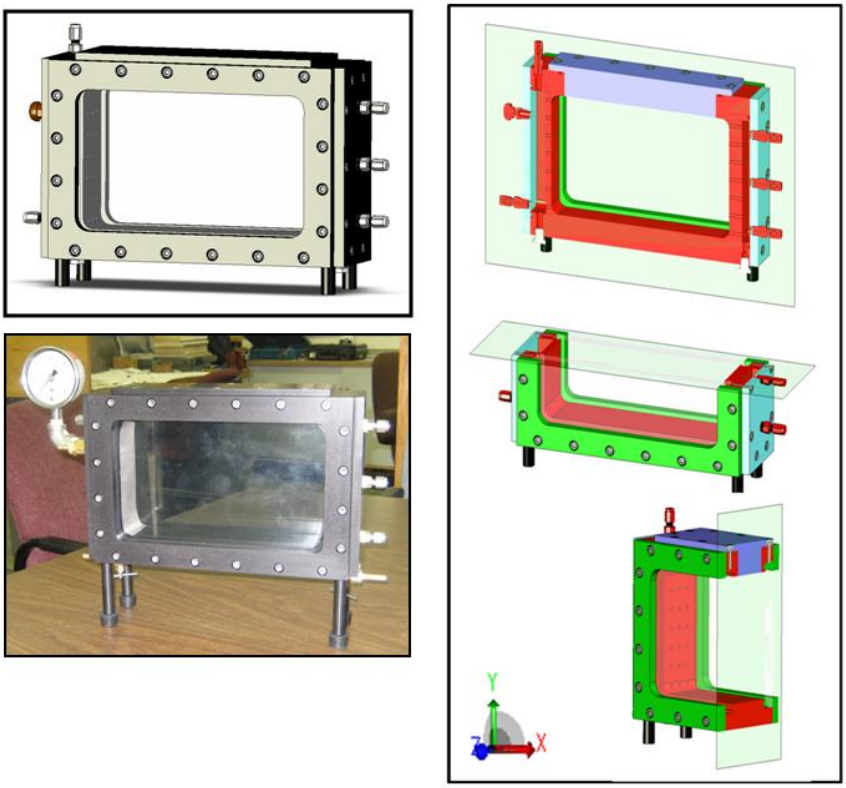


Figure 2. Photograph and schematic drawings of 2-D Tank with cross-sections.

Solute Transport System

The 2-D tank was connected to a HPLC where solute was transported through the system. A collapsible Teflon bag was used to store the TCE prior to pumping into the 2-D tank. Samples are collected by hooking a syringe to one of the sampling ports and opening a sampling value. Once opened, the syring is filled with solute without headspace. This sampling procedure prevented volatilization.

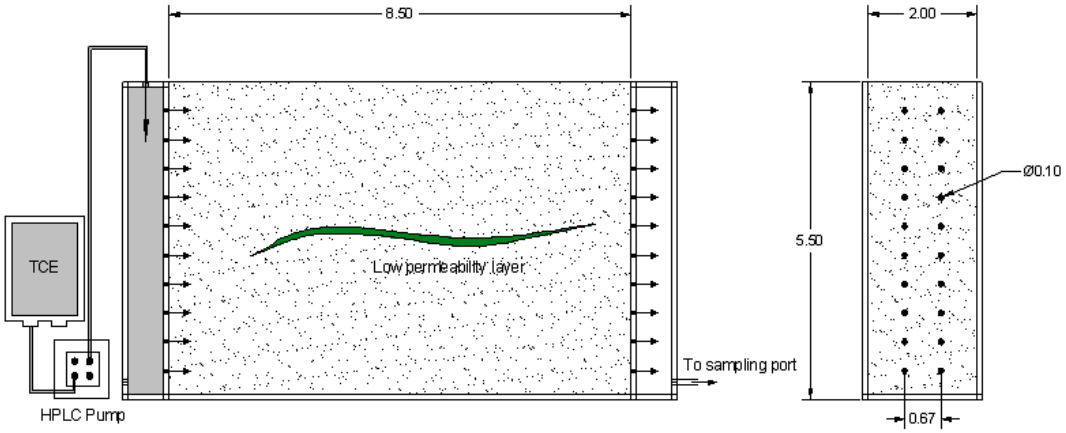


Figure 3. Schematic of 2-D transport system.

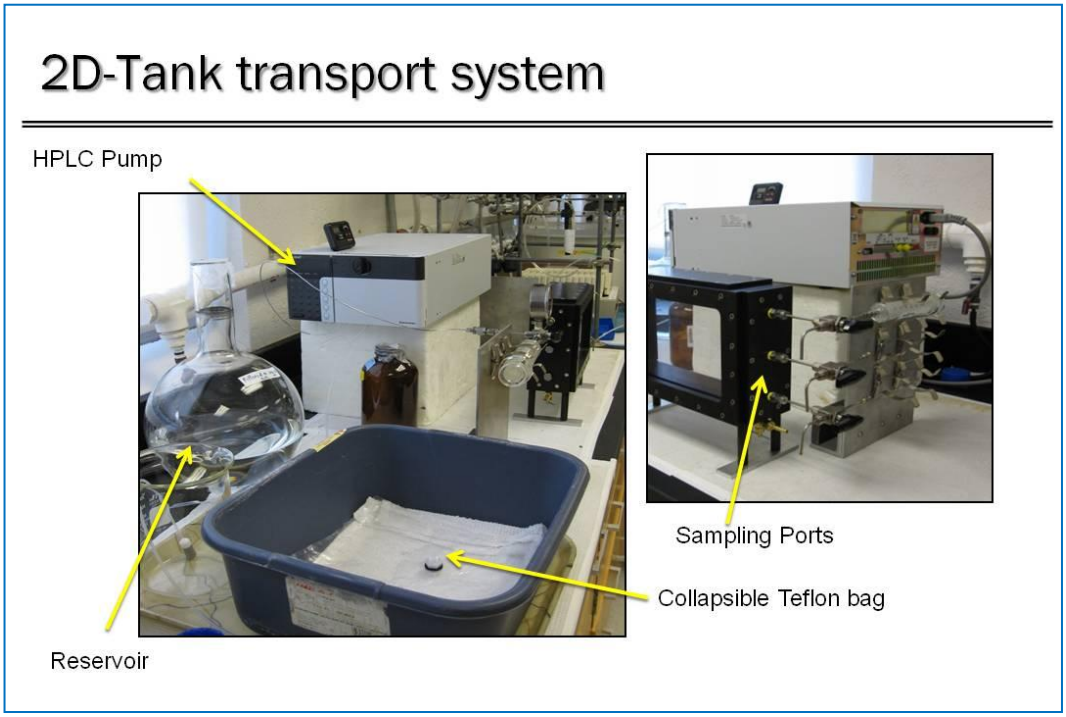


Figure 4. Photographs of transport system illustrating the HPLC pump, reservoir and collapsible Teflon Bag (for chlorinated solvent) and 2-D Tank.

Solute Transport Experiments

The 2-D tank was packed with a transmissive sand and a low permeable zone. The tank was then saturated with ^{14}C-labled TCE and flushed with $^{3}H_2O$ (with and without xanthan gum). Various dyes were used to visualize solutes moving into the LPZ (Fig. 5).

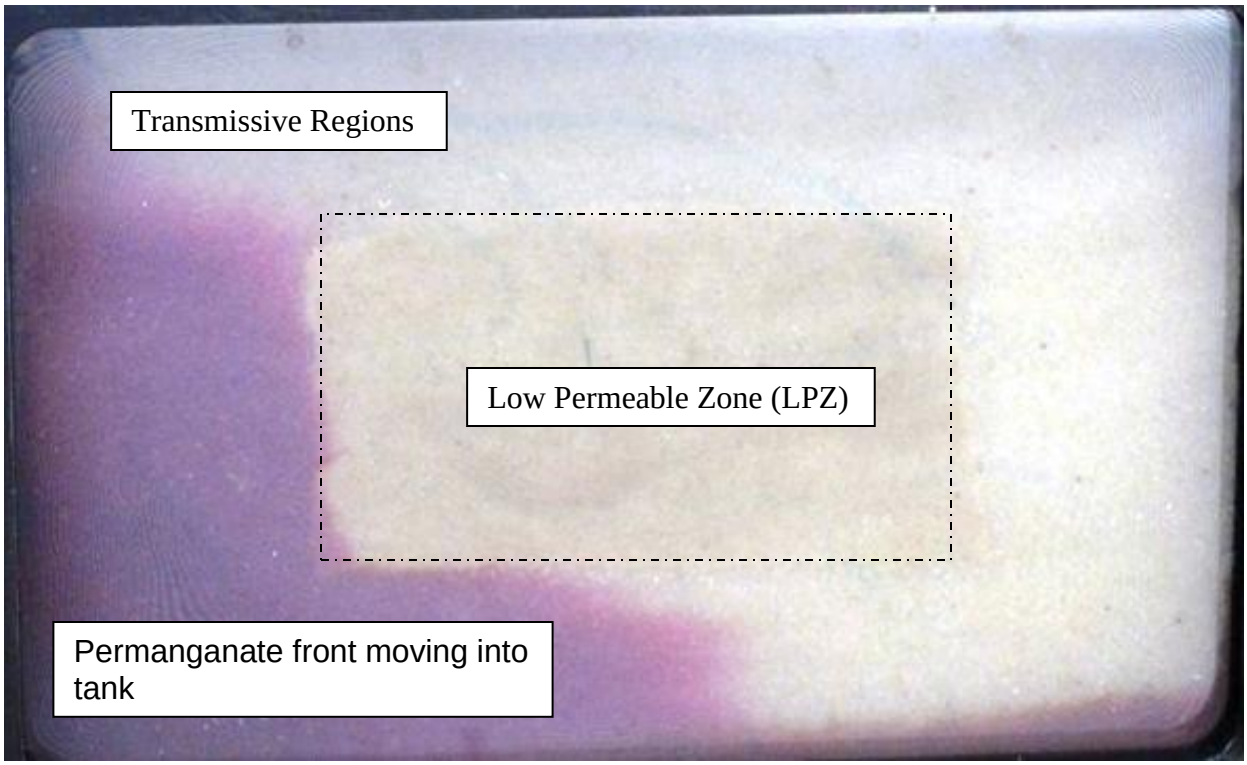


Figure 5. Up close photograph of 2-D Tank being flushed with permanganate.

One treatment that we have been used to facilitate the movement of solutes into the low permeable zone (LPZ) is xanthan gum. Results showed that the use of xanthum gum improved the movement of dyes and permanganate into the LPZ (compare Experiments 18.1 vs. 18.2 and 18.4 vs 18.6; Fig. 6). Likewise, monitoring effluent coming out of the 2-D Tank, the breakthrough curves with xanthum gum are sharper and more indicative of piston-type flow (Figs. 7 and 8).

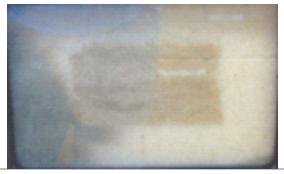
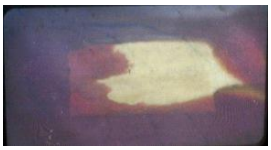
	Saturate with TCE and ^{14}C-TCE then flush			
Experiment Code	**18.1**	**18.2**	**18.4**	**18.6**
Packing	20/30 + LPZ			
Low Permeable Zone	yes (Silt & 40/50; 1:16)			
Flush Type	Black Dye + $^{3}H_2O$	Red Dye + $^{3}H_2O$ + *XanthanGum*	MnO_4^- + $^{3}H_2O$	MnO_4^- + $^{3}H_2O$ + *XanthanGum*
0.27 PV				
0.54 PV				
0.81 PV				
1.08 PV				
1.53 PV				
1.98 PV				

Figure 6. Visualization of solute movement into LPZ under various treatments as a function of pore volumes added.

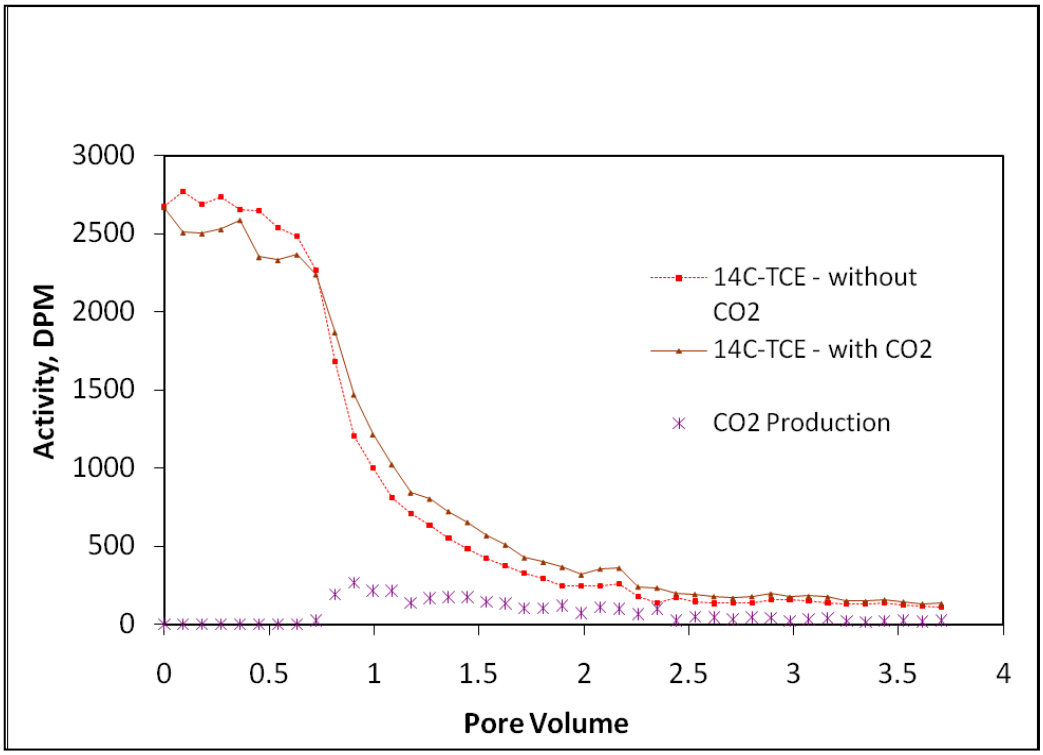


Figure 7. Breakthrough curve of ^{14}C-TCE being flushed from 2-D Tank with aqueous solution.

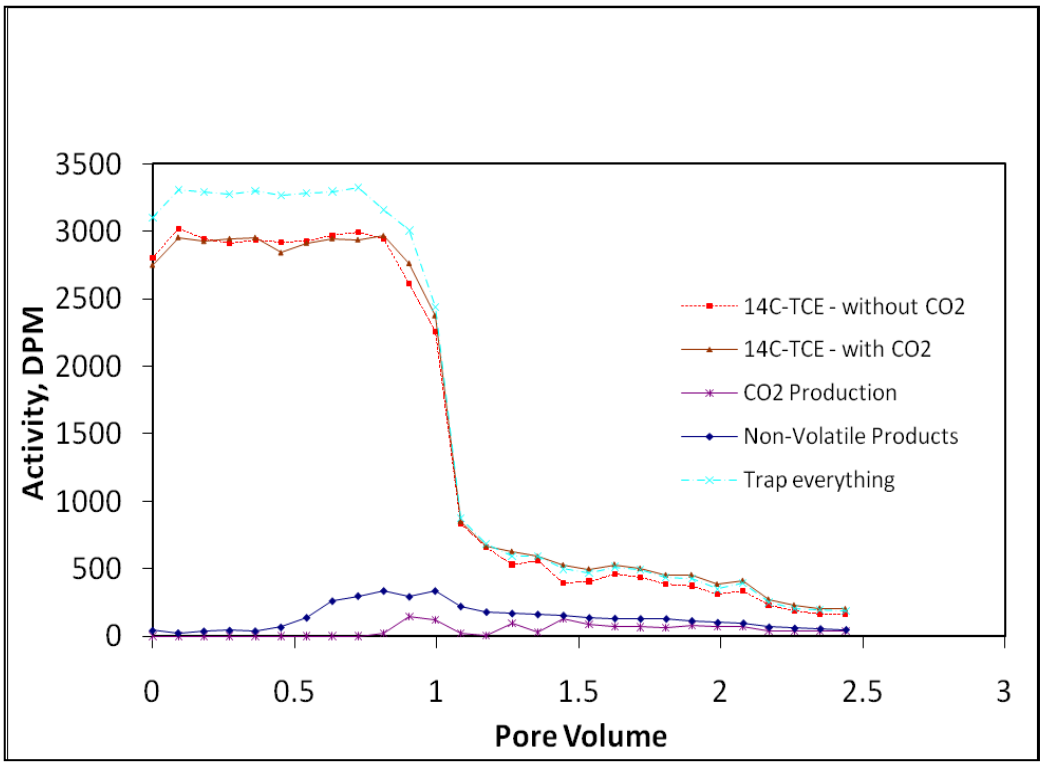


Figure 8. Breakthrough curve of 14C-TCE being flushed from 2-D Tank with xanthum gum.

Conclusion

The goal of this research was to construct a solute transport system for systematically evaluating remedial technologies for chlorinated solvent-contaminated groundwater. To that end, this goal has been accomplished during the past year. We anticipate using this system for the next several years to develop remedial treatments. As more data is gathered, future work will also include validating and calibrating our proposed model for the transport of chlorinated solvents in aquifer media containing transmissive and low-permeable zones.

Literature Cited

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Understanding Microbial Communities in Hyper Alkaline-Saline Sandhills Lakes as an Indicator of Global Warming

Basic Information

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Principal Investigators:	Julie J Shaffer, Bradley A Plantz

Publications

There are no publications.

Understanding Microbial Communities in Hyper Alkaline-Saline Sandhills Lakes as an Indicator of Global Warming

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Abstract

The Nebraska Sandhills consist of the largest vegetated desert in North America. This area has a wide range of shallow lakes that range from freshwater to hyper alkaline-saline. This area and these lakes in particular will be especially sensitive to global warming and changes in precipitation and being extreme environments have reduced species diversity, making it a good place to monitor changes. We propose to monitor the microbial populations by first identifying microbial community structure using DNA pyrosequencing of 16S rRNA genes from six hyper alkaline-saline lakes. Secondly, these lakes tend to be some of the most productive aquatic systems in the world, so we intend to profile the oxic microbial community using lignocellulosic enzyme assays to understand the flow of carbon through this system. Finally, trace metal availability is many times a limiting nutrient factor in these highly alkaline-saline lakes, so we propose to profile oxic and anoxic lake microbial communities for siderophores. These studies will help us to understand the movement of metals under these extreme conditions. With these techniques we will have preliminary data to help us to create models of the movement of carbon and iron through this system with the overall goal of understanding the function of these communities and how global warming is affecting them.

Objectives

The **long-term goal** of this research is to predict carbon flux and sense changes in community species structure as temperature, precipitation and solar radiation levels change long-term.

Short-term Objectives: We have identified clusters of lakes in the Crescent Lake National Wildlife Refuge (CLNWR); East of Alliance, Nebraska and West of Ellsworth Nebraska. Within each location are several lakes representing water chemistries of hyper alkaline-saline. Approximately 6 lakes will be sampled from which we will complete the following short-term objectives:

1. Profile oxic water column microbial communities using ribosomal gene amplification and pyrosequencing.
2. Profile oxic microbial communities using known lignocellulosic enzyme assays. These communities will help us to follow the movement of carbon through the lake.
3. Profile oxic and anoxic lake microbial communities using standard siderophore assays. These communities will help us to identify the availability of iron in the lakes.

4. Measure solar radiation and quantify pH, alkalinity, salinity, turbidity, macro- and micro-elemental composition from the lake water. These data will be used as the environmental inputs for multivariate analysis and modeling.

Methods, Procedures, and Facilities

Sampling protocols: The study sites were lakes located on the Crescent Lake National Wildlife refuge and the Louden and Herian properties (both kindly provided access) located East of Alliance, NE. Multiple samples from each lake were evaluated to capture total diversity. Samples were pooled and DNA extracted. Water samples were prefiltered through a sieve (>500 microns) to remove macroscopic particulates. Heterotrophic plate counts and siderophore assay samples were obtained from the sieved water. The microbes were captured onto a 45 mm diameter 0.2 µm filter and frozen on dry ice. A portion of the filtered water was sent to the University of Nebraska Water Sciences laboratory for in-depth chemical analysis of macro and trace elements, such as carbon, nitrogen, phosphorous, iron, magnesium, and molybdenum.

Objective 1. Profile oxic water column microbial communities using ribosomal gene amplification and pyrosequencing.

DNA Pyrosequencing and sequence analysis: This objective was funded as a match from a grant from the Office of Technology and Advancement at the University of Nebraska-Lincoln. We sent samples to UNL's Core for Applied Genomics and Ecology. They use the Roche-GS FLX 454 pyrosequencer (please see www.cage.unl.edu for complete description). The methods for using the Roche 454 system in conjunction with PCR amplification of the hypervariable V6 region of the 16S rRNA gene have been described elsewhere (Sogin et al.,2006; Huber et al., 2007) and have been adapted by the UNL Gut Function Initiative. In brief, unique 6-base barcodes are attached to the 16S rRNA gene PCR primers A-8FM, 5'- AGAGTTTGATCMTGGCTCAG-3', and B357, 5'-CTGCTGCCTYCCGTA-3'. DNA from each unique environment was assigned a unique barcode, the amplicons were pooled, sequenced, and then binned by the software. Primers were created for Eubacteria, Archaea, and Eukaryotes.

Principal Findings and Significance

We sampled 6 lakes. Two of the lakes were categorized as weakly alkaline, two as moderately alkaline, and two as highly alkaline. When comparing the pyrosequencing data for the three alkalinity groups, we were unable to identify differences in diversity. One problem with the data was the lack of Archaea identified. New primers need to be created to get a more accurate representation of the entire microbial community. There was a difference in diversity if we compared the locations of the lakes. The lakes in Garden county are different than the lakes in Sheridan county. We did not have replication, so no significance could be estimated. This experiment must be repeated. Additional funds have been obtained for supplemental pyrosequencing.

A collaboration was established with Dr. Dawn Simon at the University of Nebraska at Kearney to further analyze the data. Dr. Simon has expertise in bioinformatics. She is currently breaking down the data into clusters and comparing the communities further. These data should help to identify differences in the composition

of the microbial communities in each lake. This information will provide us with the first known use of pyrosequencing to identify the microbial community of an alkaline lake.

Objective 2. Profile oxic microbial communities using known lignocellulosic enzyme assays.

Lignocellulosic enzyme assay: We screened for microorganisms that produce cellulases, xylanases, and esterases. All three of these enzymes can be identified easily and activity quantified quickly at various pH's. Substrates were added to chemically defined media of varying pH's. Cellulases were identified using cm-cellulose as the carbon source and flooding the plate with 0.03% congo red. There is a clear zone surrounding cellulase producing colonies (Strauss et al., 2001). Xylans make the media opaque, so when colonies are able to produce xylanases, there is a zone of clearing around the colony. Ethyl ferulate makes the media yellow, so if esterases are produced by the colony, the media becomes colorless (Donaghy et al., 1998). These assays were performed at multiple pH's and enzyme activity compared by creating a ratio of the zone of clearing and colony diameter (Chand et al., 2005). Positive isolates were purified to axenic cultures and identified by 16S rRNA gene sequencing.

Principal Findings and Significance

Cellulases: Bacterial isolates from four lakes from CLNWR were screened for cellulases. Fourteen isolates were purified to axenic cultures and then activity was measured for ph's 6 through 9 (Table 1). According to the calculations, there was no signficant difference in celluase activity between pHs for B1, B4A, B4B, B5B, RH1, M1, M3, KJ2A, KJ2B, and TC. According to the calculations and the graph, B1 showed the best activity at pH 6. M2 and RH2 showed the best activity at pH 8.

Cellulase producing isolates were grown to stationary phase and DNA isolated for 16S rDNA amplification and sequencing. There appears to be three separate genera represented: *Halomonas, Rhodobacter*, and *Cellulomonas*. Literature searches indicated that *Halomonas venusta* was isolated on cellulose-containing alkaline medium from bacterial communities associated with decomposing rhizomes of the common reed, *Phragmites australis*. In the study, the optimal pH of *H. venusta* was pH 9 with 12 % NaCl, and *H. venusta* was able to grow between pH 7 and 11 (Borsodi et al., 2005). There were no previous studies on cellulase production of *Rhodobacter,* making this a new observation. *Cellulomonas* sp has been shown to produce cellulase. However, previous studies showed an optimal activity at pH 7 (Rajoka and Malik, 1984), while our study indicates activity at higher pHs.

Table 1: Comparison of cellulase activity as varying pHs. Values show the mean ratio of the ratio, calculated by dividing the diameter of the clear zone by the diameter of the colony, and standard deviation of two trials done in triplicate of each pH. The ng signifies no growth. Bacterial isolates are labeled with lake abbreviations (B=Border; RH=Red Head; M=Mixed sample; KJ=Kokjohn; TC=Tree

Claim) and colony number.

Bacterial Isolate	pH 6	pH 7	pH8	pH9
B1	1.25 ± 0.07	1.05 ± 0.07	1 ± 0	1 ± 0
B2	1 ± 0	0.48 ± 0.68	0.47 ± 0.66	1.05 ± 0.07
B4A	1 ± 0	1.06 ± 0.08	1 ± 0	0.92 ± 0.12
B4B	0.5 ± 0.73	0.79 ± 0.16	0.9 ± 0.14	0.75 ± 0.35
B5B	0.95 ± 0.21	0.94 ± 0.007	1 ± 0	0.88 ± 0.06
RH1	0.97 ± 0.05	0.95 ± 0.007	1 ± 0	0.92 ± 0.12
RH2	0.88 ± 0.18	0.5 ± 0.71	0.52 ± 0.74	0.92 ± 0.05
M1	1.03 ± 0.24	0.9 ± 0.14	0.92 ± 0.12	0.92 ± 0.12
M2	1 ± 0	0.93 ± 0.1	1.13 ± 1.18	0.89 ± 0.007
M3	1 ± 0	1 ± 0	1 ± 0	1 ± 0
KJ1	ng	0.4 ± 0.57	0.5 ± 0.71	ng
KJ2A	0.9 ± 0	0.85 ± 0.06	0.95 ± 0.08	0.92 ± 0.12
KJ2B	0.75 ± 0	0.87 ± 0.014	0.9 ± 0.14	0.83 ± 0.04
TC	1 ± 0	1.04 ± 0.05	1 ± 0	1.05 ± 0.07

Xylanases: Bacterial isolates from four lakes from CLNWR were screened for xylanases, using birch wood xylan. Eight bacterial isolates were identified and purified to axenic cultures. Six of the isolates showed the greatest activity at ph 6, and two isolates showed the same activity at all four pHs. When identified by 16S rDNA sequencing, four bacterial genera were represented: *Nesterenkonia, Bacillus, Cellulomonas*, and *Paenibacillus*. The *Bacillus* sp. exhibited the xylanase activity that remained active at all four pHs. Reports have already revealed production of alkaline active xylanase by an alkaliphilic *Bacillus* species (Subramaniyana and Premaa, 2006) and *Cellulomonas* at neutral pH (Horcasitas et al., 1998). There are no reports in the literature for xylanase production for *Nesterenkonia* or *Paenibacillus*. These two species have potential to provide new xylanases.

Esterases: Bacterial isolates from two highly alkaline lakes from CLNWR were screened for esterases, using ethyl ferulate. Nine isolates appeared to produce esterases and were screened for activity from pH 6-9 (Table 2). Table 2 contains averages from three experiments with standard deviation reported. Zone of clearing were normalized to colony size which accounts for differences in culture growth rates. Ng indicates no growth. Analysis of variance was performed for each pH and significant differences were found in pH 7 and pH 9. The Tukey means separation test indicated that Mix1 was statistically different (*) than all other isolates within that pH.

After identification with 16S rDNA sequencing, all of the KJ and Bor isolates appear to be *Halomonas*. The Mix1 isolate has been very difficult to amplify. We have tried universal bacterial and archaea primers, but still have not found primers that amplify the 16S rDNA in this isolate. Both of these isolates are of particular interest because very few ferulic acid esterases have been identified.

Table 2. Esterase activity at varying pH's. Values show the mean ratio of the ratio, calculated by dividing the diameter of the clear zone by the diameter of the colony, and standard deviation of two trials done in triplicate of each pH. The ng signifies no growth. Bacterial isolates are labeled with lake abbreviations (Bor=Border; M=Mixed sample; KJ=Kokjohn) and colony number.

Normalized clear zone (mm)				
	pH 6	pH 7	pH 8	pH 9
KJ1	ng	2.067 ± 0.503	2.569 ± 0.664	2.232 ± 0.489
KJ2	ng	2.106 ± 0.329	2.200 ± 0.346	2.162 ± 0.147
KJ3	ng	2.550 ± 0.853	2.341 ± 0.413	2.299 ± 0.524
KJ4	ng	2.267 ± 0.356	2.097 ± 0.417	2.081 ± 0.330
KJ5	ng	1.790 ± 0.355	1.815 ± 0.182	2.226 ± 0.340
KJ6	ng	2.218 ± 0.386	2.000 ± 0.661	1.964 ± 0.258
Bor1	ng	2.392 ± 0.400	1.733 ± 0.391	2.029 ± 0.271
Bor6	ng	2.319 ± 1.031	2.384 ± 0.593	2.211 ± 0.271
Mix1	ng	4.917 ± 2.003*	4.484 ± 2.702	4.532 ± 0.921*

Dr. Bradley Plantz attended a U.S. Department of Energy Joint Genome Institute workshop to learn IMG sequence alignment and annotation tools. He has since annotated the genomes for two alkaline lake isolates, PXY22 (*Bacillus sp.* nov), and PC1 (*Jonesia sp* nov). These two genomes each have multiple xylanases and cellulases. The gene sequences have been used to create primers for cloning into *E. coli*. Once completed, the expressed enzymes will be purified and functional assays completed. This travel was funded by the UNK match money for this grant.

Objective 3. Profile oxic and anoxic lake microbial communities using standard siderophore assays.

Siderophore assay: To identify bacterial isolates that are capable of producing siderophores, we used an assay from Schwyn and Neilands (1986). The dye chrome azurol S hexadecyltrimethylammonium bromide (azurol S) is blue when complexed with iron(III), as well as gallium and aluminum (Gascoyne et al., 1991). Siderophores strongly chelate iron(III) and competitively strip the iron away from azurol S resulting in a color change from blue to orange. We used this plate assay to quantify the ratio of siderophore producing isolates within each lake by comparing counts of orange hallowed colonies to the background colonies. Isolates with distinctively unique colony morphologies were purified to axenic culture from which phylotype were determined using standard 16S rRNA gene sequencing methods.

Siderophores from bacterial supernatants can be captured onto Amberlight XAD-4 resin and eluted into non-polar solvents (Sayyed and Chincholkar, 2004). The standard chromogenic assays of Arnow (1937) and Atkin et al. (1970) will be used to differentiate between catecholate-type and hydroxamate-type siderphores respectively eluted from the Amberlight.

Principal Findings and Significance

Bacterial isolates producing siderophores were isolated from ten lakes in Sheridan county. These lakes varied from weakly to highly alkaline. Fifty eight siderophore producing isolates were purified to axenic cultures. Using colony morphology this number was reduced to twenty-two that exhibited unique colony morphology for the lake in which it was isolated. DNA was isolated from the twenty-two

bacteria, amplified for 16S rRNA, and sent for sequencing. Siderophore producing isolate sequence was compared to known bacterial sequence using BLAST and then cluster analysis allowed us to make comparisons to known siderophore producers (Fig. 1)

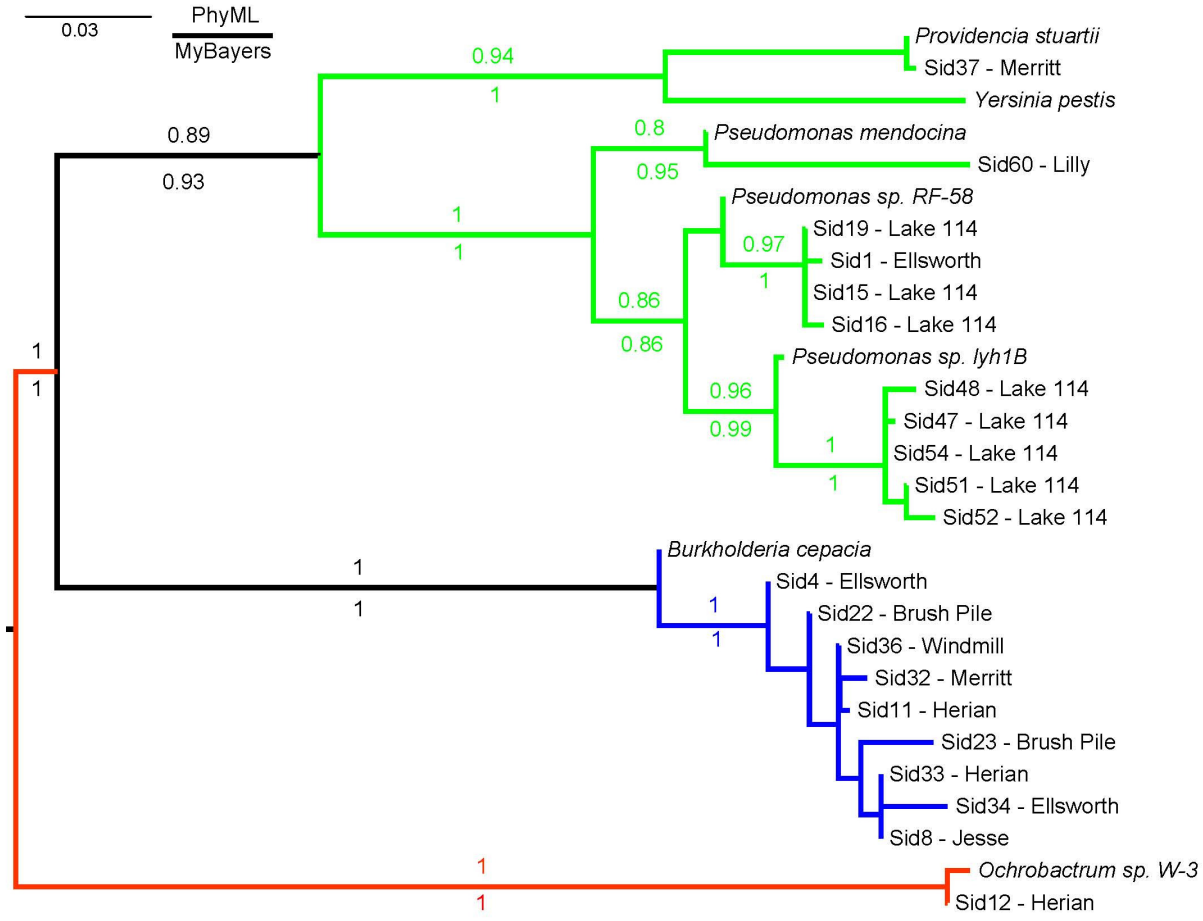

Figure 1. Cluster analysis of the siderophore producing isolates.

From the cluster analysis, we were able to observe that isolates from lower alkalinity lakes, such as Lake 114, clustered together and with *Pseudomonas* sp. Higher alkalinity lakes, such as Brush Pile and Herian, clustered together and with *Burkholderia* sp. These data suggest that there is a difference between the alkalinity in the lakes and the siderophores that are being produced in those environments. We have selected an isolate from the *Burkholderia* cluster and are now preparing to isolate the siderophore based upon knowledge of siderophores produced by *Burkholderia*.

Objective 4. Measure solar radiation and quantify pH, alkalinity, salinity, turbidity, macro- and micro-elemental composition from the lake water.

Geochemical and Environmental data: Basic geochemical data were determined with the appropriate field method. We quantified temperature, turbidity, alkalinity, pH, conductivity, ammonia, chlorine, nitrate, and phosphate in the field for ten lakes. The University of Nebraska Water Sciences Laboratory has the instrumentation necessary

to quantify specific ion concentration and to measure total organic carbon, soluble carbon, nitrogen, etc., on a fee-for-service basis. They were able to collect concentration of Cl, Li, B, Na, Mg, K, Ca, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Mo, Br, F, and Total Dissolved Solids. The High Plains Regional Climate Center has stations for the continuous monitoring of key climate indicators such as temperature, precipitation and evapotranspiration. These data are publically available.

Principal Findings and Significance

We found differences in water chemistries between the lakes, although all of the lakes except one had pH's above 9. Alkalinities ranged from 14,000-151 and varied from all carbonate to all bicarbonate depending upon the lake. Of particular interest in this study was the concentration of soluble minor nutrients because they can have a profound effect on the growth of the microbial community. These data are reported in Table 3. As suspected, iron concentrations are lower than average freshwater concentrations. This may account for the production of siderophores that has been established in this study. Also of interest is the fairly high concentrations of copper. Copper can be toxic to cyanobacteria in concentrations from 5-10 µg/L. Most of the alkaline lakes have concentrations of copper within this range. Another nutrient of interest is molybdenum. There was a large variation in the concentrations in the alkaline lakes. Althought not at toxic levels, all of the lakes appear to have significant concentrations of molybdenum, but this range varies by almost 100x in some cases. Soluble nutrient concentrations change throughout the year, so additional samples need to be taken, but these data have the potential to help us to understand differences in the microbial communities.

Table 3. Concentration of soluble minor nutrients in the alkaline lakes. Sampled in June of 2009.

Concentration of Soluble Minor Nutrients (mg/L)						
	Fe	Mn	Cu	Zn	Co	Mo
Brushpile	0.0261	0.003398	0.009049	0.02556	0.000328	0.20106
Ed	0.02034	0.001759	0.005704	0.04968	0.002297	0.57186
Lilly	0.0441	0.002979	0.007079	0.04824	0.000741	2.6748
Herian	0.06444	0.002801	0.00497	0.08604	0.000687	0.152352
Merritt	0.09828	0.014819	0.003339	0.0432	0.000652	0.03483
Louden	0.0684	0.012202	0.007884	0.03168	0.000288	0.065862
Ellsworth	0.04482	0.005665	0.003031	0.02826	0.000249	0.093078
Jesse	0.01854	0.000903	0.005868	0.03672	0.000444	0.288
114	0.06264	0.004507	0.004304	0.04518	0.00062	0.037368
Windmill	0.10098	0.023076	0.004716	0.03726	0.000442	0.047196

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Nitrate stimulated oxidative dissolution of U(IV) bearing minerals leading to U mobility in Nebraska groundwater

Basic Information

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Descriptors:	
Principal Investigators:	Karrie Anne Weber, Daniel Davidson Snow

Publications

There are no publications.

2010 Project Report: Nitrate stimulated oxidative dissolution of U(IV) bearing minerals leading to U mobility in Nebraska groundwater

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Project Summary

Soluble uranium (U) is a recognized contaminant in public water supplies in various counties throughout the state of Nebraska. The mechanism driving U mobilization in these environments remains poorly understood. In order to begin to consider mitigation strategies and prevent further contamination of drinking water sources, it is necessary to gain a fundamental understanding of the mechanisms stimulating U mobilization. In the state of Nebraska U originated from the weathering of uranium-rich igneous rocks in the Rocky Mountains and deposited in shallow alluvial or ground water environments as insoluble reduced uranium minerals, such as uraninite and coffinite. These reduced U (U(IV)) minerals are subject to oxidation by available oxidants, such as oxygen and nitrate. The oxidation product exists primarily as a dissolved U(VI) species. It is well recognized that anthropogenic activities such as livestock operations and the application of N onto agricultural fields and urban landscapes have resulted in nitrate contamination of surface and groundwaters in the state of Nebraska. Abiotic and bio-oxidative dissolution of U(IV) coupled to nitrate reduction has been recently recognized as a potential U oxidative mechanism. Oxidative dissolution of U(IV) would result in the subsequent mobilization of U in groundwater. Thus, the influx of nitrate as a primary groundwater contaminant can subsequently influence U mobility resulting in a secondary contaminant in ground water through both biotic and abiotic mechanisms (Figure 1).

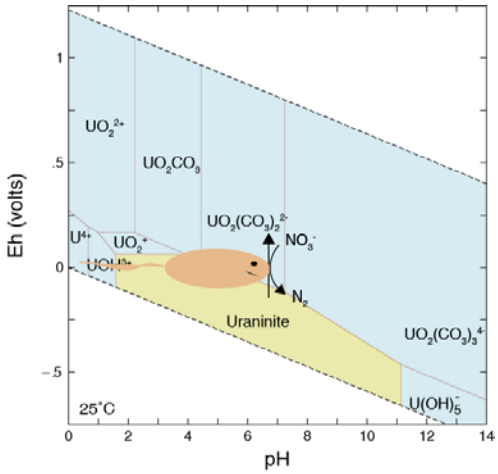

Fig. 1. Model of nitrate stimulated biotic uraninite oxidative dissolution.

The objective of this project was to examine the oxidative dissolution of U(IV) minerals coupled to the reduction of nitrate, according to the following working hypothesis: *Abiotic and biotic catalysis of nitrate-dependent uraninite and coffinite oxidation results in U mobility in Nebraska groundwaters*.

Project Results

A field site near Alda, NE (40°5’22” N, 98°30’34” W, altitude 3413 ft.) was selected for this study based on the prior data demonstrating aqueous U in the groundwater (Snow, 1996). While the prior study evaluated aqueous and total sedimentary U concentrations, it was unknown if U(IV)-bearing minerals were present in these sediments. In order to determine if U(IV) was present at this site, groundwater and sediment cores (20’-64’ below surface) were collected and geochemically characterized. Groundwater pH revealed near neutral pH across 3 depths sampled

(Figure 2A). The reduction potential (Eh) revealed a reducing environment across the three depths sampled (Figure 2B), although nitrate persisted in the groundwater to a depth of 60 ft. (Figure 2C). Nitrate concentrations were observed to decrease slightly from 38 mg/L (40 ft.) to 30 mg/L (50 and 60 ft), this pattern is in contrast to aqueous U concentrations that significantly increased with depth from 30.3 μg/L (40ft) to values of 302 μg/L (60 ft) (Figure 2D), 10 times in excess of the maximum contamination level.

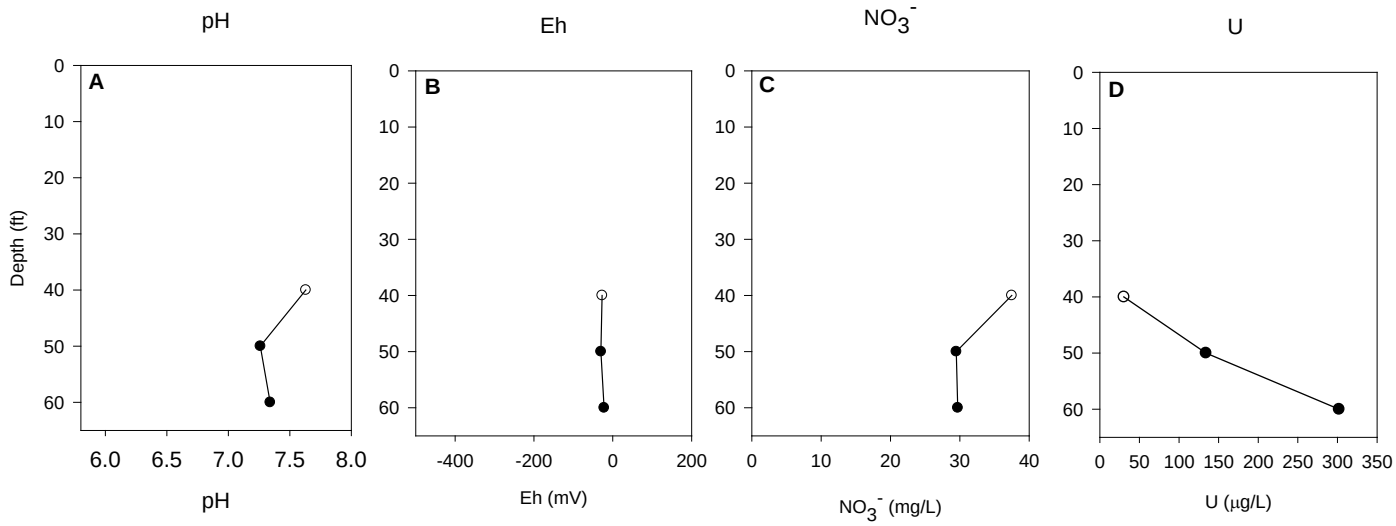

Figure 2. Groundwater geochemical data collected from Alda, NE, October 2009. A) pH, B) Eh, C) nitrate, and D) Total dissolved Uranium. Depth is reported as feet below ground surface.

While the presence of dissolved uranium is consistent with prior studies at this field site (Snow, 1996), these data do not indicate the presence of U(IV). Inductively coupled plasma mass spectroscopy (ICP-MS) analysis of sequentially extracted U(VI) and U(IV) was conducted as described by Elias and colleagues (Elias et al., 2003) in order to determine the valence state of the U. U(IV) concentrations in the sediments immediately above the water table, 22.5 ft., 18.7 ± 1.4 μg kg^{-1}, and at the water table, 23.5 ft., 15.0 ± 4.8 μg kg^{-1}, exceeded bicarbonate extractable U(VI) concentrations (2.4 ± 0.4 μg kg^{-1} and 1.6 ± 0.3 μg kg^{-1}, respectively). Extracted samples from the remaining sediment cores were collected and are awaiting (ICP-MS) analysis in the Water Science Laboratory at the University of Nebraska, Lincoln. Additionally, U(IV) and U(VI) concentrations will be verified with the HPLC-ICP-MS method currently in development as described below. The presence of U(IV) is consistent with the low reduction potential observed in the groundwater (Figure 2B) and sediments (Figure 3B) as well as reduced Fe (Fe(II)) observed in these sediments (Figure 3C). The data currently collected indicates that U(IV) is present in these sediments. Thus the potential for U(IV) oxidative processes are likely operative and could contribute to U immobilization in the groundwater.

Tetravalent U (U(IV)) phases are stable in reduced environments, however the input of an oxidant such as oxygen or nitrate into these systems would result in the oxidation and thus the mobilization of U. The increase in the reduction potential at different depths suggests significant heterogeneity and that portions of the aquifer contain oxygen, however groundwater geochemical data suggests that the aquifer is suboxic. It has been recognized in recent years that nitrate is a suitable U(IV) oxidant via abiotic or biotic mechanisms (Finneran et al., 2002; Senko et al., 2002; Beller, 2005). A recent study conducted by Moon and colleagues further indicated that the

oxidation rate of U(IV) was greater in the presence of nitrate than in the presence of oxygen (Moon et al., 2007). Thus the presence of nitrate in this system suggests that nitrate could be a U(IV) oxidant in this subsurface system. In order to further evaluate the potential of biological activity in the oxidation of U(IV) and thus the biologically-catalyzed mobilization of U several most probable number (MPN) enumeration series were initiated to assess the abundance of the nitrate-dependent U(IV) oxidizing, the heterotrophic nitrate reducing, and the uranium reducing microbial community. Incubations of the MPN series will complete in June. Upon receipt of the remaining U(IV) data we will select sediments in which U(IV) concentrations are the greatest for stimulation of the nitrate-dependent U(IV) oxidizing microbial activity relative to killed controls. Uranium oxidation and nitrate reduction will be monitored over time in order to assess abiotic and biotic factors controlling U oxidation. The active microbial community in these sediments will be determined to be the greatest will be identified using pyrosequencing of reverse transcribed small-subunit 16S rRNA (Liu et al., 2007). Together these data will provide information regarding biotic and abiotic mobilization of U in these subsurface sediments.

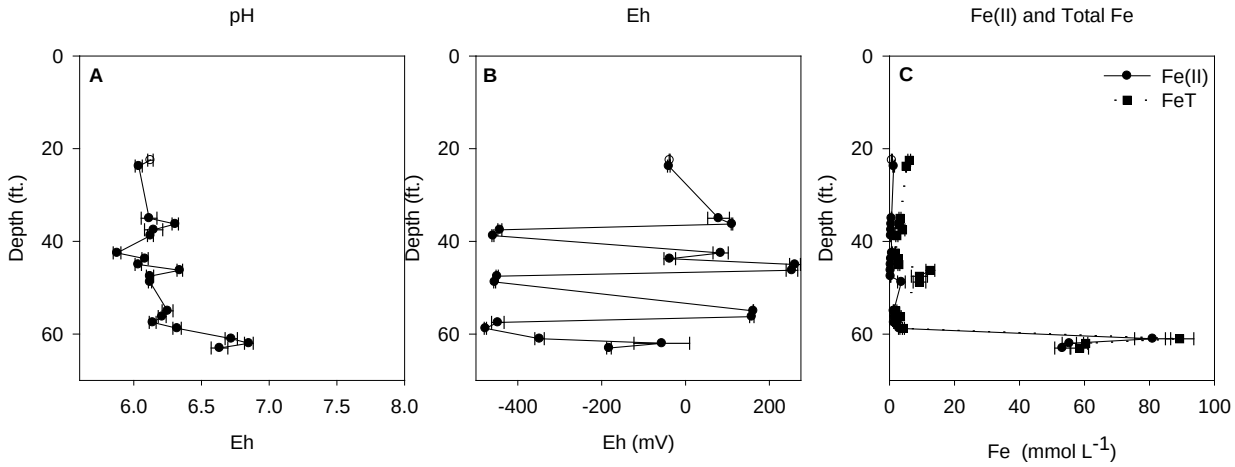

Figure 3. Sediment geochemical data collected from Alda, NE, October 2009. A) pH, B) Eh, and C) acid-extractable Fe(II) and total Fe. Depth is reported as feet below ground surface.

HPLC-ICP-MS Method Development. Uranium speciation experiments using ion exchange chromatography coupled to ICP-MS (Truscott, 2001) are currently underway. Hexavalent uranium U(VI) was reduced in hydrochloric acid solution with titanium trichloride and immediately analyzed by HPLC-ICP-MS (Sill, 1980). Preliminary tests indicate that U(IV) can be separated from U(VI) on an IonPac CG10 cation column using dilute nitric acid mobile phase. The addition of a chelating agent is expected to improve peak shape and chromatography in order to achieve quantative results. As described above, this method will be used to confirm the identification of U(IV) measured by the sequential extraction technique in sediment samples.

Results Summary

To date the data that we have gathered has allowed us to establish a basis as well as identify an appropriate field site for future research to continue to investigate the abiotic and biotic catalysis of U(IV) oxidation and the subsequent significance to U mobility in Nebraska

groundwaters. Additionally this preliminary research has also led to the development of a method to allow the simultaneous measurement of U(IV) and U(VI) in solid samples via HPLC-ICP-MS. We expect the additional modifications to the preliminary method will result in a technique that can be used to easily quantify U(IV) in sedimentary systems. The data we have obtained to date as well as the data we will continue to collect has provided us with valuable information in order to begin to understand the mechanisms driving U mobilization in Nebraska groundwaters.

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Information Transfer Program Introduction

The University of Nebraska-Lincoln (UNL) Water Center maintains and expands its leadership tradition of information transfer programming utilizing USGS and other public and private funding sources. This program complements a full range of research, extension and outreach programming that the UNL Water Center is engaged in. The UNL Water Center is easily in the top five of the more than 50 Water Resources Research Institutes nationwide in terms of comprehensive, diverse and up-to-date information transfer programming. The UNL Water Center combines experienced and dedicated research, extension and teaching faculty and staff, the latest technologies and techniques, and a comprehensive, needs-based programming itinerary to provide a wide-range of science-based information to a broad clientele. Information transfer needs are constantly being reassessed and new methods and programming are tried.

Information transfer supports a variety of research, engagement and education programming sponsored or co-sponsored by the Water Center, the Water Resources Research Initiative, UNL's Office of Research and Economic Development, School of Natural Resources, UNL Extension and the University of Nebraska's Institute of Agriculture and Natural Resources. May of these projects and programs are undertaken in concert with a variety of federal and state agencies, non-governmental organizations and other entities.

Mediums utilized include print, electronic, broadcast and web-based. Delivered events include conferences, symposiums, seminars, colloquiums, tours, trade shows and other public events. Information is published in the form of newsletters, brochures, fact sheets, press releases, proceedings, research briefs, Internet web sites, public and commercial radio and television coverage, videotape/DVD, books and others.

Information Transfer Plan/Water Education

Basic Information

Title:	Information Transfer Plan/Water Education
Project Number:	2008NE173B
Start Date:	3/1/2009
End Date:	2/28/2010
Funding Source:	104B
Congressional District:	1
Research Category:	Not Applicable
Focus Category:	Education, None, None
Descriptors:	
Principal Investigators:	Kyle D. Hoagland, Steven W. Ress

Publications

There are no publications.

Newsletter:

The *Water Current* newsletter is in its 41st year of continuous publication (dating to 1968). Published quarterly in a magazine format, 16 to 20-pages, full-color on semigloff paper. It has a free subscriber-based distribution of approximately 3,100 copies per issue (up about 400 copies per issue over 2008), more than 95 percent of which represent requested subscriptions. It is also available online in pdf format. Historic issues of the *Water Current* are also archived online.

An annual reader survey is published the spring issue. Water-related research, engagement, education and outreach faculty and water-related professional staff are featured in each issue. Guest columns and articles are encouraged from faculty, students and constituents. A director's column is published in each issue. Liberal use is made of color photographs and graphics.

Other Print Resources (all distributed free of charge):

Brochures and pamphlets: All full color. Updated and produced regularly. These include, but are not limited to mission and programming of the UNL Water Center, Water Resources Research Initiative (WRRI), Great Plains Cooperative Ecosystems Studies Unit, UNL Water Sciences Laboratory, Tern and Plover Conservation Partnership, UNL Water and Natural Resources Tour and other units or programs affiliated with the Water Center.

Water Center Pocket Resources Directory: A full-color, accordion-fold pocket brochure listing key NU, federal, state and local water resource agencies and water-related points of contact for the public. Third edition published in early 2009.

Water Center fact sheets: All full-color, generally one sheet, printed front-to-back. Used to inform and to promote both general themes, such as the Water Center itself, or to announce specific programs, seminars, courses, etc. Several separate editions, designed around specific audiences, both internal and external.

UNL Water Faculty Director: Full-color spiral-bound professional directory of all water-related faculty within the University of Nebraska system (four campuses) and their areas of expertise. Used for many public and fund-raising events by the Water Center, UNL Office of Research and Economic Development and affiliated UNL departments and centers.

A range of publications produced outside the UNL Water Center, particularly fact sheets, research project results and other print materials from USGS, Nebraska Department of Environmental Quality, U.S. Environmental Protection Agency, U.S. Army Corps of Engineers, local Natural Resources Districts and University of Nebraska-Lincoln Extension, are available through Water Center and School of Natural Resources web sites. UNL Water Center assists with content, design, editing and production on many of these publications

News Releases:

The Water Center produces about 30 press releases annually focused on research results or progress, extension programs, educational opportunities, public tours, seminars, lectures, symposiums, award of major research grants and other matters of public impact involving the Water Center, Water Resources Research Initiative and other natural resource-focused UNL departments and offices. Conferences, seminars, tours, collections of waste pesticides, pesticide container recycling and other activities are similarly announced.

The releases support a wide variety of UNL water-related research and outreach that cross departmental and academic disciplines. The press releases are naturally focused on public impact of UNL-sponsored research and programming. The UNL Water Center writes these for a number of UNL environmental science-related departments that do not have a dedication communicator on their staffs.

The Water Center coordinates public media requests for information and interviews with appropriate sources on any water-related topic of interest to media and devotes significant attention to cultivating long-term relationships with members of the working media. The Water Center has a well-developed reputation as a willing and reliable "source" among local and state reporters specializing in water and natural resources news. Media calls are frequent and routine and water-related faculty and staff are accustomed to fielding questions from the media, doing radio and television interviews, etc. The Water Center makes wide use of electronic and broadcast journalism sources, as well as the more traditional print (newspaper) sources.

Electronic Resources:

Print materials produced by the UNL Water Center, and other information, are available online at http://watercenter.unl.edu . The Water Center co-sponsors, designs and maintains the following related Internet web sites utilizing a dedicated, fulltime webmaster/IT specialist:

UNL Water:
http://water.unl.edu/home

UNL Water Center:
http://watercenter.unl.edu/

Water Sciences Laboratory (WSL):
http://waterscience.unl.edu

Water Law, Policy and Science Conference:
http://snr.unl.edu/waterconference/

Water Resources Research Initiative (WRRI):
http://wrri.unl.edu/

UNL Food Science (currently under development, to be online by Fall 2010):
http://food.unl.edu/

These sites are vigorously scrutinized, maintained and updated almost daily.

<u>Conferences, Seminars, Tours and Retreats</u>:

Water Law, Policy and Science Conference: Conducted each Spring. Co-sponsored by the Water Center, Water Resources Research Initiative, College of Law, School of Natural Resources and various other UNL entities, depending on featured topic(s). The conference explores pertinent current issues related to emerging state and regional water and environmental law, policy and research. Nationally and internationally known speakers are invited to present. Sixth consecutive year. It attracts 150 to 200 attendees annually. News releases, brochures, a printed program, radio spots and web-based information are produced in support of this event. Media are encouraged to attend and given full access to speakers.

Water and Natural Resources Seminars: A longstanding series of 12 to 14 free weekly public lectures from January to April each year. Co-sponsored by the School of Natural Resources, Institute of Agriculture and Natural Resources and other UNL entities. The series may be taken for graduate or undergraduate student credit, or as free public lectures. Individual lectures attract an audience of 60-100, as well as approximately 15 for-credit registered students. News releases, mailings, brochures, posters and web-based information are produced in support of this long-standing series.

Summer Water and Natural Resources Tour. Co-sponsored by the Kearney Area Chamber of Commerce, Nebraska Public Power District, Central Nebraska Public Power and Irrigation District, Gateway Farm Expo and others. Conducted annually over three to five days in June or July. Used to educate and inform on current water and natural resources issues effecting Nebraska. Typically limited to 50 participants. Attendees include state legislators and congressional staff. News releases, mailings and a brochure are produced in support of this event. This year's tour traveled to Northern California's Sacramento-San Joaquin River Bay-Delta area in June 2009. Planning for the 2010 tour is centered on examining North and South Platte River basin issues in Nebraska, Colorado and Wyoming.

Fall Research Colloquium. Held in conjunction with UNL's School of Natural Resource Sciences. Brings water and natural resource faculty, staff and students together to share in research results/significant progress, discuss possible research collaborations / grant-writing opportunities.

Faculty/Staff Retreats: Another vehicle to present completed and/or significant progress research activity to colleagues, take time for interdisciplinary brainstorming to develop research programming and secure funding and to foster an increased sense of collegiality among professionals dispersed throughout the state.

Educational Displays:

The Water Center makes frequent public displays in association with conferences, symposiums, agricultural trade shows, educational open houses and water and environmental education festivals.

In addition, Water Center staff makes presentations and sit on the steering committees for such annual educational and informational festivals as "Earth Wellness Festival," "Husker Harvest Days" (one of the largest commercial agricultural expos in the country), "Gateway Farm Expo" and others. UNL Water Center staff chaired the first major revamping of UNL Extension presence at Husker Harvest Days in nearly 30 years in September 2008. More than 50,000 tour UNL exhibits during the three-day run of the show, ranking it among the event's top-10 most visited attractions. The Water Center continues to superintend this single-largest UNL Extension event of the year.

Promotional Items:

Custom promotional items are distributed at nearly every Water Center event. These include fishing lures, umbrellas, golf balls, key chains, pencils, lanyards, book bags, etc. They are designed and procured for general distribution and for student recruitment.

Support for the UNL Pesticide Education Office:

The Water Center handles press relations and publicity for federal-restricted use pesticide educational programming conducted by the UNL Pesticide Education Office within UNL's Department of Agronomy and Horticulture. This unit was once part of the UNL Water Center. These efforts include publicity for very successful statewide plastic pesticide container recycling and waste pesticide collection programs that are closely linked to groundwater quality issues.

Primary Information Dissemination Clientele:

U.S. Department of Agriculture
U.S. Environmental Protection Agency
U.S. Geological Survey
U.S. Bureau of Reclamation
U.S. Army Corps of Engineers
U.S. Bureau of Land Management
Nebraska Department of Natural Resources
Nebraska Department of Agriculture

Nebraska Department of Health and Human Services System
Nebraska Department of Environmental Quality
Nebraska Environmental Trust Fund
Nebraska Association of Resources Districts (and 23 individual NRDs)
Nebraska Congressional delegation
Nebraska State Senators
Public and private power and irrigation districts
The Audubon Society
The Nature Conservancy
Nebraska Alliance for Environmental Education
Nebraska Earth Science Education Network
Other state Water Resources Research Institutes
University and College researchers and educators
NU students
Public and parochial science teachers
Farmers
Surface and groundwater irrigators
Private citizens

Cooperating Entities:

In addition to primary support from the USGS, the following agencies and entities have helped fund information dissemination (communications) activities by the UNL Water Center during the past year.

U.S. Environmental Protection Agency
U.S. Department of Agriculture
Nebraska Department of Environmental Quality
Nebraska Research Initiative
Nebraska Game and Parks Commission
National Water Research Institute
Nebraska Water Conference Council
Nebraska Public Power District
Central Nebraska Public Power and Irrigation District
Farm Credit Services of America
Kearney Area Chamber of Commerce
Nebraska Association of Resources Districts
UNL Institute of Agriculture and Natural Resources
UNL Agricultural Research Division
UNL College of Agricultural Sciences and Natural Resources
UNL School of Natural Resources
UNL Water Resources Research Initiative

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	1	0	0	0	1
Masters	1	0	0	0	1
Ph.D.	1	0	0	0	1
Post-Doc.	0	0	0	0	0
Total	3	0	0	0	3

Notable Awards and Achievements

Dr. Julie Shaffer and Dr. Bradley Plantz created a research group to study the hyper alkaline-saline lakes in western Nebraska which applied for a Nebraska Environmental Trust grant for $600,000. The grant was not funded but the collaborative group is going to resubmit the grant this fall.

Dr. Bradley Plantz and Dr. Julie Shaffer are currently writing an NSF grant in their Dimensions in Biodiversity program. This grant is due the first part of June.

Publications from Prior Years