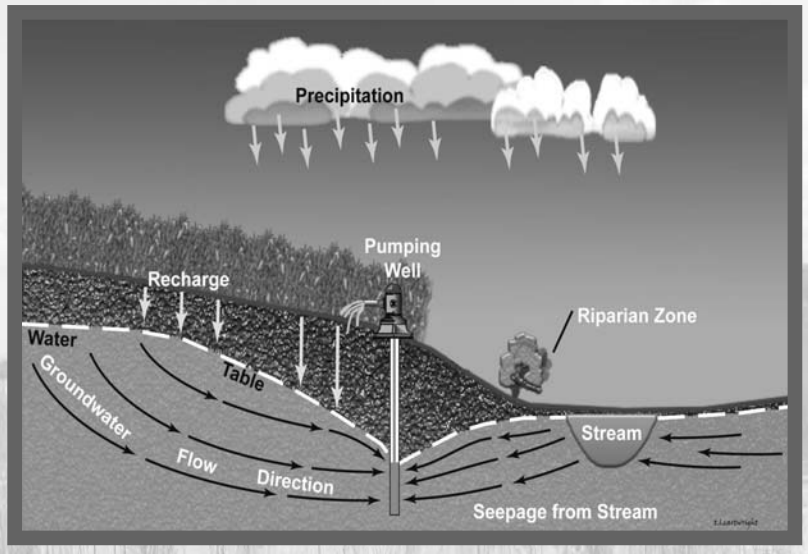
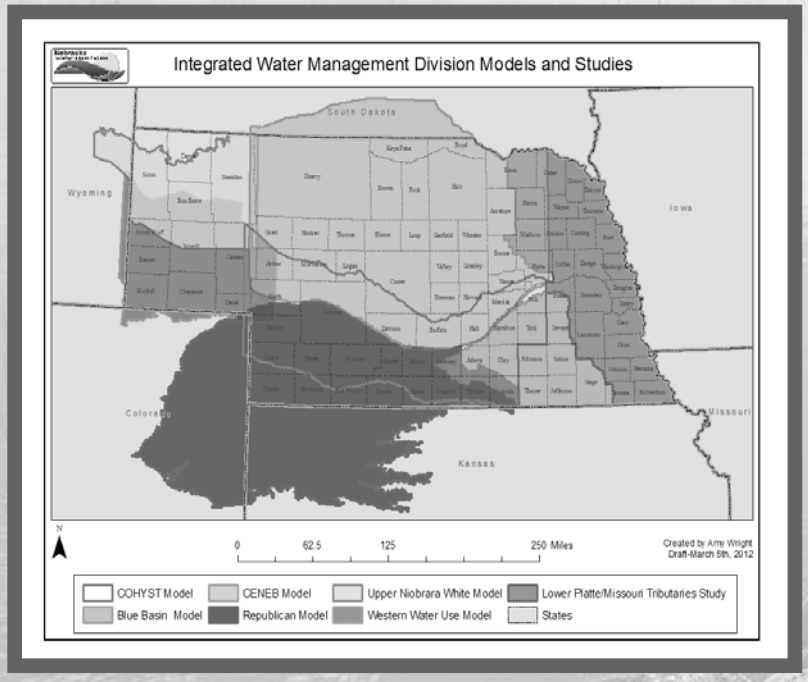
Integrated Water Management Concepts and Applications



Interactions Between Hydrologically Connected Ground and Surface Water Systems



Current Integrated Water Management Models and Studies

Nebraska
Department of Natural Resources

A Modeling Tool for Determining Spatial Boundaries of Fully Appropriated Areas in Nebraska

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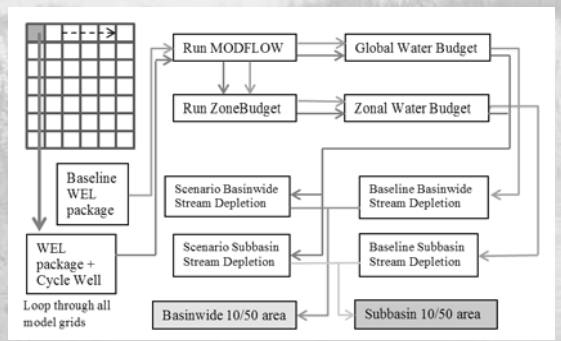
Background

The interaction between groundwater and surface water affects stream discharge, water quality, and ecosystem services. Integrated Water Management (IWM) has been recognized as an effective strategy for managing the conjunctive use of groundwater and surface water. The IWM division of the Nebraska Department of Natural Resources (NDNR) focuses on the management of hydrologically connected groundwater and surface water supplies. The NDNR is commissioned to guarantee "the management, conservation, and beneficial use of hydrologically connected groundwater and surface water" for the "sustained economic prosperity and well-being of the state." Understanding the spatial boundaries of fully appropriated areas (i.e., 10-50 areas) is one of the research priorities in the field of IWM in Nebraska. This delineation helps water managers in different management roles identify the areas where groundwater and surface water are hydrologically connected and then apply focused management strategies to these areas.

The purpose of this research is to present the design and use of a modeling tool to assist in the determination of the fully appropriated areas.

Cycle Well Analysis



The state of Nebraska considers a hydrologically connected area to be the area in which pumping of a well for 50 years will deplete streamflow by at least 10 percent of the amount pumped, in accordance with NDNR rule *457 Neb. Admin. Code* Chapter 24, § 001.02. In Nebraska, the hydrologically connected area is also known as the "10/50 area." Cycle Well Analysis (CWA) is the tool used by the NDNR to determine this area.

The basic design principle of the CWA tool is to place a hypothetical well into each model grid cell, run the groundwater model developed using MODFLOW, and then run the ZoneBudget program in a cyclical manner. Outputs (zonal water budgets) from each cycle are compared with those from the baseline run (i.e., the original model run without the hypothetical well). The stream depletion factor (SDF) was computed as the ratio of stream depletion change in the total pumpage of the hypothetical well. The CWA process to determine SDFs has also been used in previous projects such as COHYST and INSIGHT.

Reference

COHYST. (2004). The 40-Year, 28-Percent Stream Depletion Lines for the COHYST Area West of Elm Creek, Nebraska. Retrieved from http://cohyst.dnr.ne.gov/adobe/dc012_28-40_lines_092104.pdf.

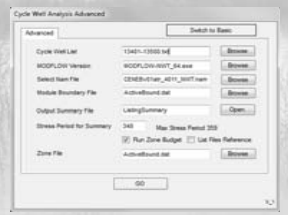
The CWA process involves the following major steps:

1) Run the original groundwater model and compute the baseline water budget terms;
2) Place a hypothetical well with a predefined pumping rate into the model's well package, run the scenario model and compute the budget terms;
3) Calculate the SDF as the ratio of differential net stream depletion and differential well pumping from the baseline and scenario models;
4) If the SDF is equal or above 10%, designate the model cell that contains the hypothetical well as within 10/50 area;
5) Loop the above process through all model grid cells.

Software Overview

Graphic User Interfaces (GUIs)

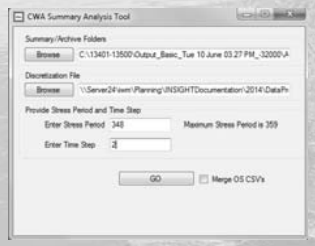
The CWA program features two user-friendly GUIs, Basic and Advanced, both of which can be switched by clicking the top tabs of the program.



Post-Processing

The computation of the long-term SDF and the determination of the 10/50 area depend on the post-processing procedure.

1) Subtracting water budgets from the baseline and cycle well runs;
2) Accumulating the differences in water budgets over 50 years;
3) Computing the fraction of the accumulative volumes of stream leakage in the total accumulative well pumpage;
4) Determining 10/50 areas using 10% as the threshold.

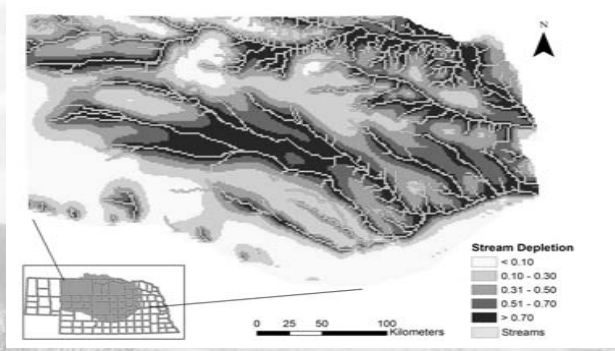


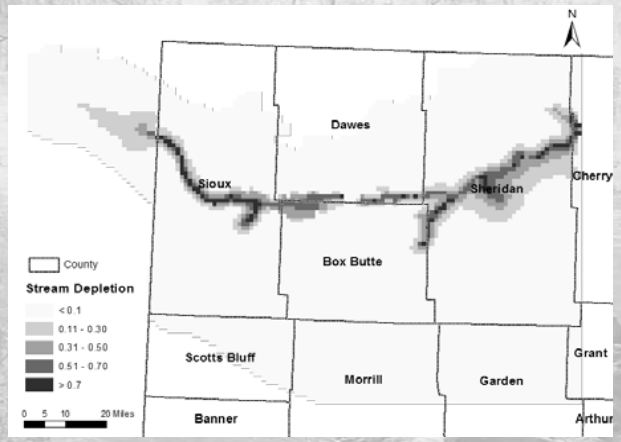
Software Availability

Software name: Cycle Well Analysis (CWA)
Programming Language: Visual Basic .NET
System Requirements: Windows 7, Windows Server 2008, and Windows 8
Availability: Free download at http://dnr.ne.gov/iwm

Examples

As seen in the two figures below, the CWA modeling tool has been applied in order to map areas with different degrees of stream depletion in Nebraska.





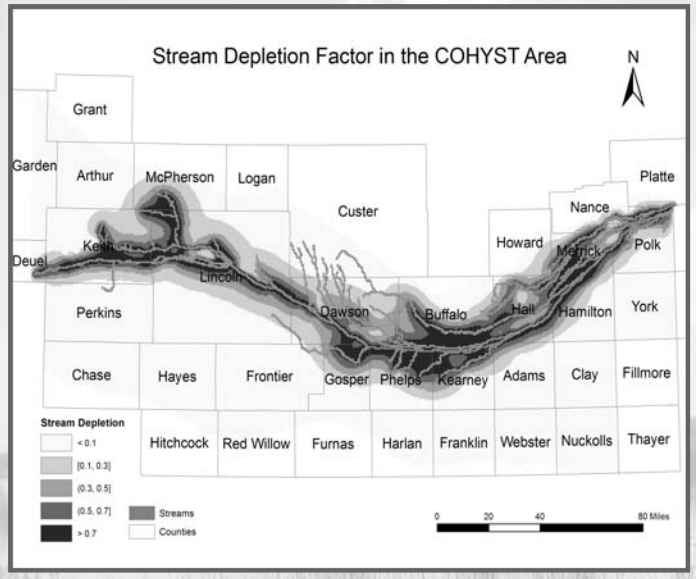
Discussion and Summary

The 50 year planning window is assumed to be a time frame long enough to allow the impacts transferred from the well depression cones to the streams, and 10% is adopted as the critical threshold;

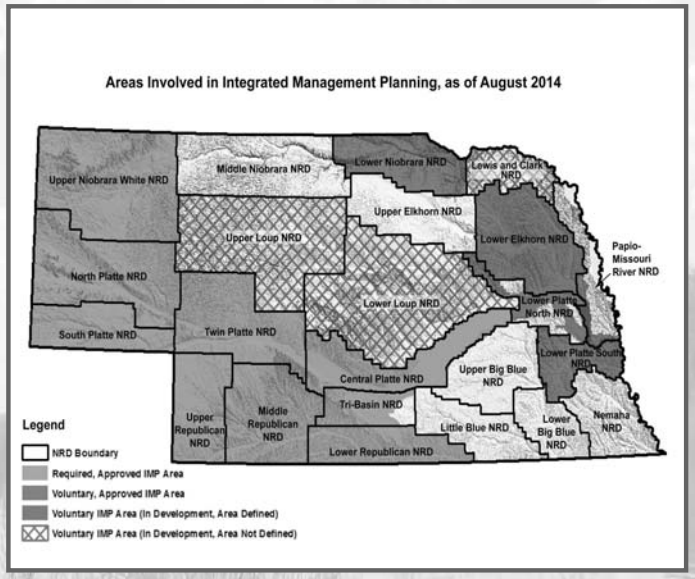
The CWA program, along with an appropriate groundwater model, may assist other regulatory or management agencies in the determination of rates of interactions between hydrologically connected surface and groundwater systems;

NDNR's use of CWA in the modeling process shows that it is preferable to incorporate the 10/50 analysis in the development phase of numerical groundwater models.

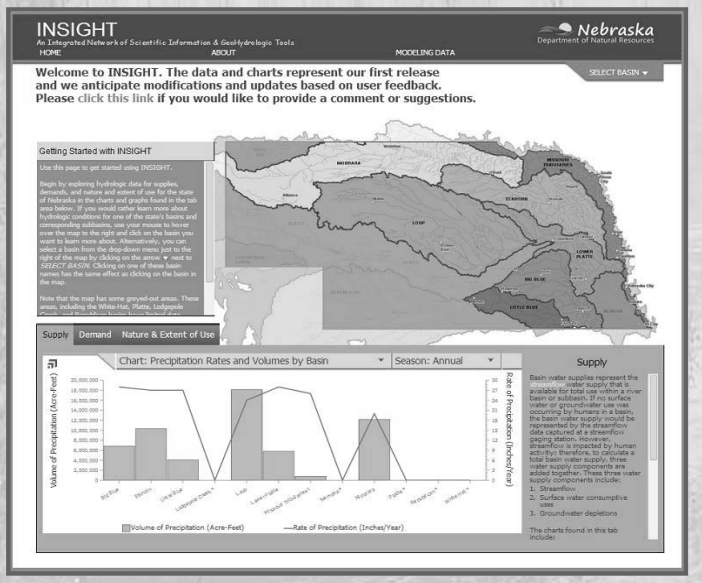
Ongoing Projects Involving Cycle Well Analysis



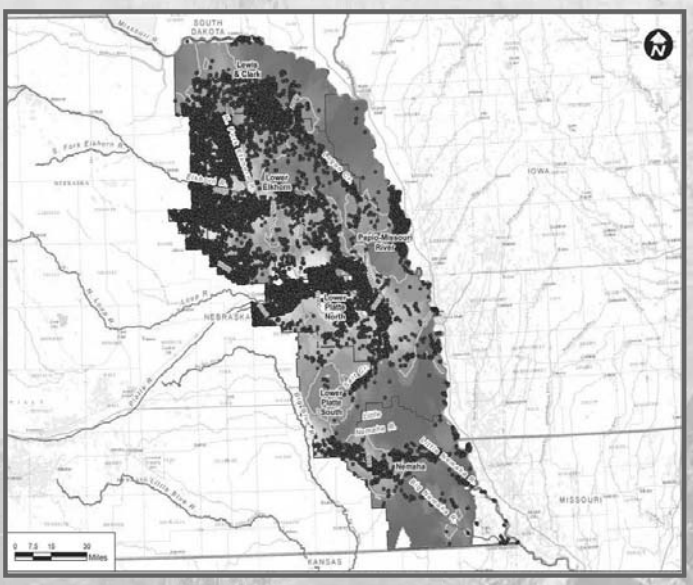
10-50 Area of the Platte Basin



Integrated Water Management Planning



(INSIGHT)
Integrated Network of Scientific Information & GeoHydrologic Tools



Lower Platte Missouri Tributary Modeling Project

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