EVALUATION OF EXISTING HYDROLOGIC MODELS DEVELOPED FOR THE CENTRAL PLATTE RIVER VALLEY, NEBRASKA

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In conjunction with the

EVALUATION AND DEVELOPMENT OF A CONJUNCTIVE WATER RESOURCE MANAGEMENT PLAN FOR THE GOTHENBURG TO KEARNEY REACH OF THE CENTRAL PLATTE VALLEY, NEBRASKA

The Nebraska Department of Natural Resources
The Central Platte Natural Resources District
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Date

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1. INTRODUCTION

The purpose of this report is to provide a description of existing models that have been developed for use in the Central Platte valley and to evaluate their utility in analyzing and administering a conjunctive surface and ground water management program. Other models that may be of use for this purpose are also described. This report was written to support the development of a program to conjunctively manage surface and ground water in order to maximize the water supply and optimize its use in the Study Area.

Specifically, the report objectives are as follows:

1. Describe existing analytical tools developed for the Central Platte valley.
2. Evaluate their ability to simulate changes in surface water management and to quantify resulting changes to ground water recharge, return flows, etc.
3. Evaluate their potential use as a management tool for administering a conjunctive use program.

2. PREVIOUSLY DEVELOPED ANALYTICAL TOOLS

The purpose of describing previously developed analytical tools is to give the reader a brief perspective on the studies conducted and tools that have been developed for parts of the Study Area. The ground and surface water hydrology in the Study Area have been studied using various techniques and for various purposes since the early 1970s. The following describes some of these studies. If the reader is interested in obtaining more detail on these studies, references are provided at the end of this report.

2.1 Digital Simulation of Conjunctive Use in Dawson County

In 1975, Keasling completed a Master's Thesis that documented the development of a digital simulation model to evaluate conjunctive surface and ground water use in Dawson County (Keasling, 1975). Specifically, the purpose of the model was to provide a technique to investigate and determine management policies to optimize irrigation practices in Dawson County (Marlette and Lewis, 1973).

The simulation model consisted of a one-layer ground water model that analyzed the interrelationships of seepage from surface water canals, river gains/losses, irrigation well pumpage, subirrigation of alfalfa, etc. The boundaries for the model generally corresponded to those of Dawson County

2.2 Central Platte Natural Resources District Ground Water Management Plan

In the late 1970s, the Central Platte Natural Resources District (CPNRD) contracted with the USGS to develop a tool (a two-layer, two-dimensional ground water model) for evaluating potential water table declines due to well development and for analyzing and prescribing ground water management alternatives (Peckenpaugh and Dugan, 1983). In 1984, the CPNRD retained the consulting firm of HDR Infrastructure, Inc. to update/extend the ground water model and to assist in the development of a ground water management plan.

The model was used to evaluate ground water level declines if no management plan was initiated. It was then used to evaluate the effectiveness of various management alternatives including moratoriums on new drilling, irrigation scheduling, allocations, and reducing irrigated acres. The boundary of the HDR model generally conformed to that of the CPNRD (CPNRD and HDR Infrastructure, 1985).

2.3 1992 Study of Modified Platte River Operation

In 1992, the consulting firm of CH2M Hill conducted a hydrologic and economic analysis of lining irrigation canals and increasing surface water irrigation application efficiency and the resulting impacts on ground water levels and ground water quality. Study objectives included creating ground and surface water models of a portion of the Central Platte valley and using the models to determine hydrologic impacts of operational alternatives. The analysis was conducted on behalf of the Central Platte Natural Resources District, the Tri-Basin Natural Resources District, and the Nebraska Water Users, Inc. in response to Platte River operational alternatives proposed by the U.S. Federal Energy Regulatory Commission during the Kingsley Dam relicensing process.

The ground water model MODFLOW was used for the analysis of impacts to ground water levels and river gains/losses. The ground water model for this study was a two-layer model. It was based on previous models developed by Peckenpaugh and Dugan (1983) and HDR (CPNRD and HDR Infrastructure, 1985) and generally conformed to the same boundaries.

A water balance based flow accounting model (similar to but more detailed than OPSTUDY) was used to model changes in river flows due to changes in canal diversions, return flows, and river gains/losses (calculated by the ground water model).

Economic impacts of changes in ground water levels and their effect on pumping costs and subirrigated cropland were quantified. Costs for implementation of alternatives were also analyzed (CH2M Hill, 1992).

3. EXISTING ANALYTICAL TOOLS DEVELOPED FOR THE CENTRAL PLATTE VALLEY

3.1 COHYST

The following description of the COHYST model is based on draft model documentation written by Carney (2005) and other documentation by the COHYST Technical Committee (2004).

The Cooperative Hydrology Study (COHYST) is a hydrologic study of the Platte River Basin in Nebraska upstream from Columbus, Nebraska. The study will assist Nebraska in meeting its obligations under the Three-State Cooperative Agreement, assist the Natural Resources Districts in the study area with regulation and management of groundwater, provide Nebraska with the basis for groundwater and surface-water policy, and help analyze the hydrologic effects of proposed activities of the Three-State Cooperative Agreement.

The COHYST study area covers 29,300 square miles and extends from the Republican River and Frenchman Creek on the south to the Loup River, South Loup River, and a mapped groundwater divide on the north. The eastern boundary follows county lines. The western boundary and part of the southern boundary are 6 miles inside Colorado and Wyoming. The COHYST study area was divided into three overlapping areas, called Model Units, for the purpose of constructing groundwater flow models (Figure 1).

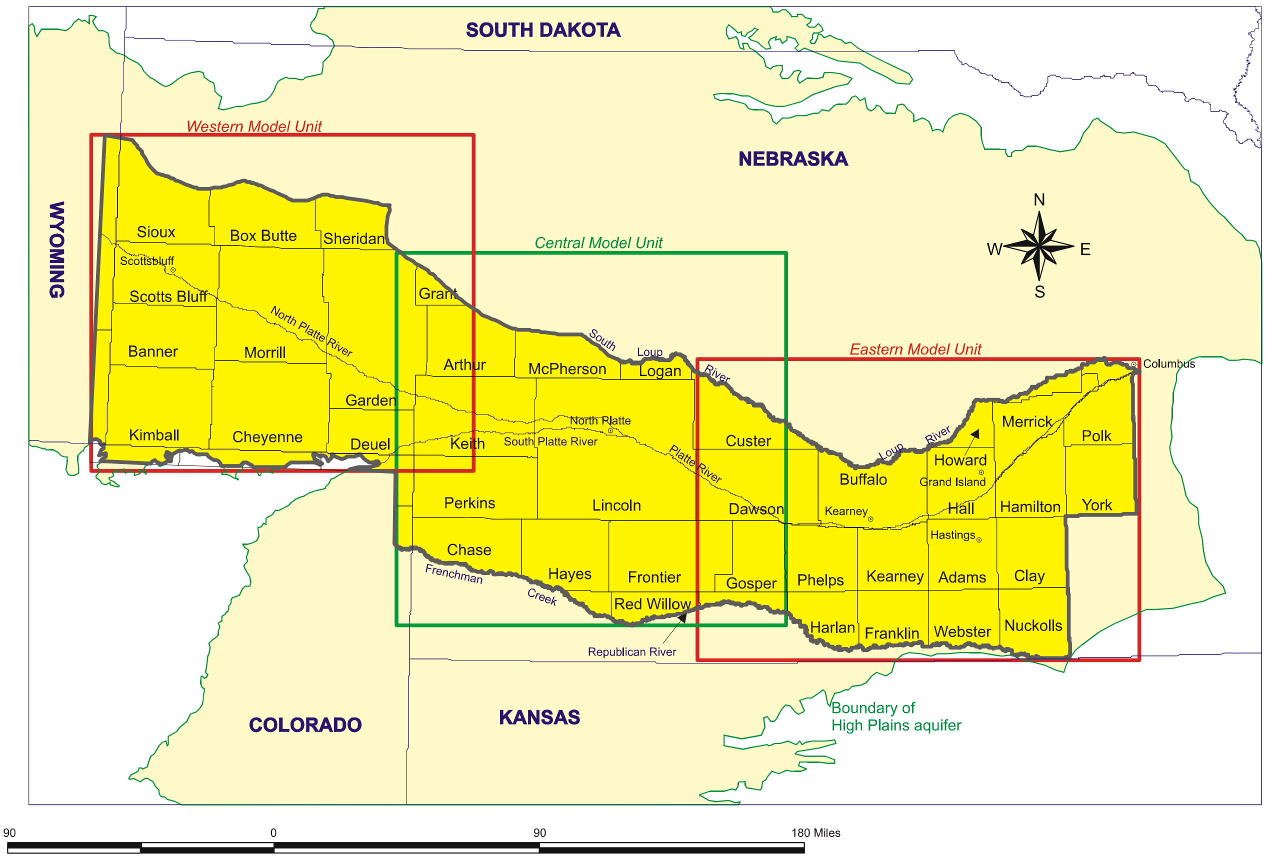

Figure 1. COHYST modeling area

MODFLOW-96 was selected as the groundwater flow modeling code for this study. The Groundwater Modeling System (GMS version 3.1) was selected as the pre- and post-processor for MODFLOW-96 input and output data.

The development of aquifer-related data are described in the report titled "Cooperative Hydrology Study Hydrostratigraphic Units and Aquifer Characterization Report". Based on the spatial distribution and thickness of the geologic materials that make up the aquifer within the COHYST area, hydrostratigraphic units were defined and mapped. The units were to develop model layers that represent major geologic changes in the aquifer system. Ten hydrostratigraphic units were defined for use in the COHYST Study. The geologic interpolation of the units was made from approximately 6500 geologic logs that cover the COHYST area.

The hydraulic properties for the Hydrostratigraphic Units were estimated using test-hole geologic log descriptions of the sand, silt, clay, or gravel material. The properties estimated include hydraulic conductivity and specific yield.

Grid size for the final COHYST model was ¼ mile by ¼ mile.

COHYST developed a formal strategy for construction and calibration of flow models. The overall strategy was to start simple and add detail to the models as required. Over the course of the COHYST project, three separate models were constructed. The initial model simulated aquifer conditions prior to any anthropogenic influence on the hydrologic system of the High Plains. The second stage of the model used the water levels from the initial model as the starting water levels and incorporated canal seepage estimates as additional recharge to the aquifer as the area became further settled and developed between 1895 and 1950. The third and final stage of model development simulated the period of 1950 to 1998, a time period of major groundwater development.

This model was designed to be a regional representation of the groundwater flow system. As such, it is useful for investigating the effects of water-management plans over large areas such as townships or counties. Depending on the modeling needs of the conjunctive management plan, the resolution of the existing COHYST model may be adequate. However, it is possible to increase the model resolution if needed.

3.2 OPSTUDY

OPSTUDY was developed by the USBR. It is a FORTRAN-based software package that has been used extensively to evaluate different scenarios for the operation of Lake McConaughy and its impact on the central Platte River. OPSTUDY has been modified several times by various agencies to evaluate various operational alternatives with respect to their interests.

The upstream boundary of the model is Lewellen, Nebraska on the North Platte River and Julesburg, Colorado on the South Platte River. The downstream boundary is on the Platte River at Duncan, Nebraska.

Computational procedures used by OPSTUDY are described in general terms below:

1. Establish storage content and determine operational release from Lake McConaughy
2. Determine downstream demands.
3. Estimate total available flow based on instream and canal flows, bypass requirements, and instream flow requirements.
4. Determine total demand on Lake McConaughy.
5. Determine evaporation, bank storage, release, spill, etc. for Lake McConaughy.
6. Route the flow downstream.

OPSTUDY is a surface water model. However, gains from groundwater and surface water return flows are accounted for in the model by using estimates of historical gains. Within OPSTUDY, there is no way to evaluate how changes in surface water operations would impact these gains.

The majority of OPSTUDY applications have used a monthly time step to evaluate various operational scenarios. However, a daily version of OPSTUDY has been developed. It has had little success in ……..

3.3 PWAP

PWAP (the Platte Water Accounting Program) is a PC-based computer program used by the NDNR to determine the amount of natural, storage, and environmental account flows in the North Platte and Platte Rivers from Sinclair, Wyoming to Grand Island, Nebraska. The program is run each day. Inputs to the program include daily gage data from the rivers, tributary inflows, and canal diversions.

The program divides the rivers into a series of reaches. Reach lengths were derived based on a 24-hour travel time from the upstream end of the reach to the downstream end. Figure 2 shows a representation of a typical river reach and the inflows and outflows associated with the reach.

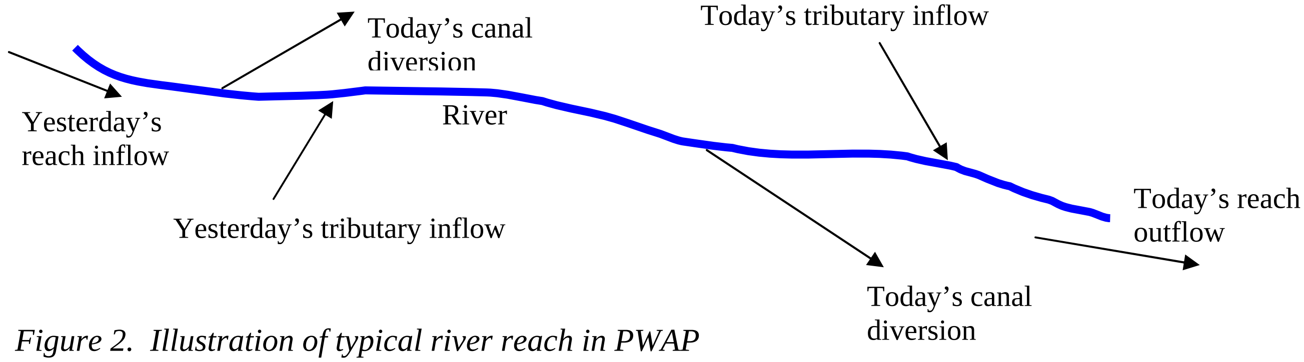

Figure 2. Illustration of typical river reach in PWAP

Each day the program is run, a water balance is performed on each reach of the river. The water balance includes the previous day's river inflows to the reach and any gaged tributary inflows. Either the current or previous day's gage records are used for tributary inflows based on their location within the reach (see Figure 2). For example, the current day's records would be used for tributaries whose mouth is near the downstream end of the reach. The current day's canal diversions, reach outflows, and conveyance losses make up the remaining inputs to the water balance. The current day's records are used for all canal diversions regardless of their location within the reach.

For the vast majority of daily PWAP runs, an imbalance or residual is calculated for the water balance in each reach. The residual exists for a number of reasons, some of which are described in the following bullets:

- Error associated with flow measurement. Even the best flow measurements might include 5% error.
- Timing of large storage water releases or tributary inflows.
- Contribution of direct precipitation is not included in the water balance.
- Small tributaries are not gaged.
- Inability to measure the contribution of return flows.
- Inability to measure decrease in stream flow due to seepage and bank storage.
- Evaporation losses are included in PWAP, but they are based on monthly averages. Accounting for daily variations in evaporation losses is not included in the program.

Prior to the calculation of the water balance, evaporation or conveyance losses are deducted from natural, storage, and environmental account flows based on their relative proportion of the total flow in the reach. Once conveyance losses are deducted, the water balance is calculated. If outflow (river discharge at downstream end of reach + canal diversions) from a reach is greater than the inflow (river discharge at upstream end of reach + tributary contributions – evaporation losses), the water balance results in a residual gain. Residual gains are added to the natural flow in the reach. If inflow to a reach is greater than the outflow, a residual loss is calculated. The loss is deducted from natural, storage, and environmental account flows based on their relative proportion to the total flow at the upstream end of the reach.

After the distribution of losses or gains, natural and storage flows are allocated to canal diversions. Allocations are made based on water right priority dates and permitted natural flow diversion rates (water rights and rates of diversion are included as inputs to PWAP). On any given day, if the amount of diversion within a reach is greater than the available natural flow or the permitted natural flow diversion, the remainder is deducted from the amount of storage flow available within the reach. If there was insufficient storage and natural flow water in the river to meet diversions, the difference is considered a natural flow diversion in excess of permits. If this occurs, NDNR takes action and issues notices to reduce diversions.

PWAP is primarily a tool for surface water administration and a method of accounting for allocations of storage and natural flow that occurred the day before the model is run. Currently it has no ability to predict how changes in surface water allocations may impact the amount of surface water available to other users. It is anticipated that PWAP may be useful in conjunctive management as a reference in creating other administrative or analytic tools.

4. Other Models That Could Be Adapted to the Central Platte Valley

4.1 MODSIM-DSS

4.2 Riverware

5. Evaluation of Models

Currently, none of the existing models that cover the central Platte River have the capability on their own to fulfill the modeling requirements for the conjunctive management plan. For example, the COHYST model is a ground water model that does not have a surface water routing component that may be necessary to administer a conjunctive management plan. OPSTUDY is strictly a surface water model that includes historical estimates of return flows and has no mechanism to predict changes in return flows based on changes in surface water deliveries. PWAP currently has no predictive capability.

In 1992, a combination of a ground water model and surface water routing model (similar to OPSTUDY) were used to evaluate the ground water impacts of changes in surface water irrigation. With updates and changes to OPSTUDY and a customization of the COHYST model to the Study Area, this approach could be used to evaluate various conjunctive management scenarios. If more detail and a daily timestep were successfully added to OPSTUDY, it may be useful in administering a conjunctive management plan.

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