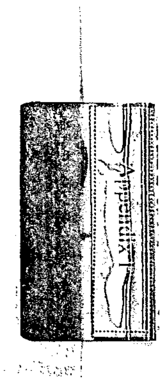

APPENDIX F

DETAILED PROGRESS REPORT
OF
KANSAS STATE UNIVERSITY

POTYLDR is a unit area water balance model that also simulates the water balance for small reservoirs. Results from up to 18 separate areas that have unique land-use, soil type, and conservation practices can be aggregated to estimate the streamflow and recharge from a small watershed. This model, like all of those reviewed, runs on a daily time-step but it is not a daily hydrograph model. Results should be used in monthly or yearly time steps and for purposes of predicting long-term effects of changes resulting from land-use conversion, conservation practices, and small reservoirs.

CROPSIM (CROP SIMulator) developed by the University of Nebraska, Lincoln (Martin, 2000) was developed to estimate crop yield and water use primarily for irrigated crops in the Great Plains. CROPSIM was developed by Derrel Martin. Continuously improved versions of this model have been widely used to determine irrigation requirements and evaluate alternative irrigation management practices.

CROPSIM is a daily, unit area, water balance model that tracks evapotranspiration (ET), runoff, deep percolation and soil moisture. Crop ET is estimated as a function of stored plant available moisture, growth stage, max-min temperature, solar radiation and wind run. Runoff is estimated as a function of soil characteristics, rainfall events and irrigation practice. The sprinkler irrigation practices used in this analysis were assumed to result in no runoff. Deep percolation occurs when the amount of rainfall and irrigation water that infiltrates exceeds the capacity of the soil to store it in the root zone. Soil moisture is what remains after accounting for rainfall, crop ET, runoff and percolation below the root zone.

CROPSIM also simulates the effect of water management on crop yields. Fully watered yields are a data input that is usually based on yield trials in the area of interest. CROPSIM computes annual yields as a function of the fully watered yield less yield reductions due to the amount of temperature and moisture stress that occurs during the season.

Comparison of algorithms for various aspects of the water balance between POTYLDR and CROPSIM are underway. We anticipate using some of the algorithms in our unit-area version of the model.

SWAT, The **S**oil **W**ater **A**ssessment **T**ool (Arnold et al., 1994) was developed by the USDA-ARS to simulate the impact of land use and management on larger watersheds. The model includes many processes to predict crop and plant development, plant water use, runoff, deep percolation and recharge and the water balance of reservoirs. The model integrates readily available soil characteristics and builds on georeferenced databases for land and stream elevations. A geographic information system is used to simplify data management and to better present results. The method has been widely used across the United States, at varying resolutions, to assess water management issues. The method provides estimates of the inflow of water and sediment into reservoirs which may enhance long-term simulation of the effects of ponds and terraces. The model was recently modified to include estimates of irrigation demand.

SWAT does not represent individual terraced fields effectively. Terraces can only be included by changes in the RCN to represent them similar to POTYLDR.

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Also, individual reservoirs are not easily managed in SWAT. Because the SWAT model is maintained by the USDA, it is not feasible to modify the coding of the model. For this reason, use of the SWAT model will not be considered further for this project.

SWAT does have some features that we have evaluated. One, in particular, the effect of land slope on RCN will be incorporated into our water budget model.

The POTYLDR model will serve as the basic framework for the water budget simulation model.

The Overall Modeling Approach for this Project

The KSU and UNL teams met four times to work on details of this project. Also, we have shared information and data as needed via e-mail and ftp procedures. The development of the computer simulation model has been a continuing topic that has received considerable attention.

The total model will consist of four parts"

1) A GIS pre-processor framework to define geographical areas, extract characteristics of the areas from GIS coverages such as soils, land use, extent of terracing, applicable meteorological stations, and other information that can be put in GIS format. This pre-processor will generate input data for the water budget simulation model hydrologic response units (HRUs).

2) A unit area water budget simulation model capable of receiving input data for individual land-use, soil, conservation practices, and location combinations throughout the basin that will operate on a daily basis for at least 25 years to produce output of daily, monthly and annual water budgets for each applicable HRU. The operation of a terraced field will be done as an HRU as described later in detail.

3) A water budget simulation model of a small reservoir using daily outputs from the applicable HRUs for that represent its watershed conditions and reservoir stage-storage-area-discharge relationships as well as estimated seepage loss rate under the surface area of the reservoir

4) A GIS post-processor to combine results from the HRU and reservoir simulation models on an areal basis to produce monthly and annual recharge and runoff amounts from the sub-basin. Finally, a simple percent-per-mile transmission loss factor based upon the flowpath-length within the sub-basin will be used to redistribute runoff into infiltration losses to add to recharge and reduce surface runoff from the sub-basin.

Because this project requires us to simulate the conditions in about 25 sub-basins of the Republican Basin, the process must be one that can be automated and efficient. Previous work with POTYLDR and SWAT by Koelliker and co-workers showed that developing inputs for each sub-basin without employing GIS techniques to gather data is well beyond the time and resources available for this project. This approach minimizes the need to "hard-wire" values

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into the HRU simulation model. It does require running many HRU combinations within the overall basin, but allows a much easier process to consider different scenarios simply by changing weighting for HRUs with the GIS post-processor to obtain different results for comparison analyses. Without such an approach we will not have nearly enough time and resources to simulate the entire basin.

The GIS pre-processor and post-processor aspects of the project are being led by the Nebraska cooperators of this project. Interactions and interfacing for data handling are in process.

Revisions to the POTYLDR Model for this Project

The overall POTYLDR model will serve as the basic operational framework for the water budget simulation model to operations the HRUs. It will run a daily water budget of the inputs of precipitation and outputs of evaporation, transpiration, surface runoff and recharge and the resulting daily change in water amounts in the interception account, soil water volume, and snow storage accounts for each combination of conditions at the various locations within the basin. Some changes in various components in the model are still under consideration as we try to incorporate more tested and accepted practices no used in simulation models.

Small Reservoir Operations Simulations

In the case of small reservoirs in a sub-basin, a separate simulation sub-model will be developed to simulate the operations of the reservoir. It will use the characteristics needed, reservoir stage-storage-area-discharge relationships, to simulate the operation of the reservoir. The simulation model will use the output of runoff from the simulated HRU results of the runoff from unit area water budget model runs for the land uses in the reservoir watershed from the sub-basin as inputs to the reservoir. It will also use the precipitation and evapotranspiration in the area as the final inputs to the reservoir operations simulation. Estimates of seepage will be made. Finally, a variable amount of a pasture/range land use will be used to account for the effects of change in the size of the surface area for the reservoir. Overflow and seepage from the reservoir will be provided as input to the GIS processing routine for the sub-basin where the amount of the sub-basin in the watershed for the reservoir will be subtracted from the overall area of the sub-basin to account for the reservoir. Where information is available for particular reservoirs, it will be used directly. For those reservoirs without sufficient information to simulate them directly, they will be represented by a "typical reservoir and results scaled to account for the reservoirs in the sub-basin.

Simulating Operations of Terraces

A more precise method to simulate terraces is now under development. The POTYLDR original model used the RCN Method for the entire field. This approach works acceptably if only surface water yield is required. Runoff results are acceptable even for level, closed-end terraces by reducing the RCN sufficiently. This method also produces additional recharge because it increases infiltration over the entire terraced field. It does not, however, provide for the increased infiltration that occurs only in the channel of the terraces in the field.

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This results in a lower estimate of overall recharge and an increase in total evapotranspiration from the terraced field, particularly from storage-type terraces. It also affects the infiltration, potential for crop damage from extended inundation which POTYLDR does not now consider. Previously, Koelliker (1985) had a version of POTYLD that simulated the operation of the upslope and terrace bottom for level, closed-end terraces and it was used to estimate the recharge from terraces in Northwest Kansas.

The original modeling simulation work by Koelliker (1985) for closed-end terraces in Northwest Kansas predicted that from 60 to 90 percent of the additional water (runoff plus blown snow) that ends up in the terrace channel would become potential groundwater recharge in a wheat-fallow rotation. That simulation did not consider the sloping areas immediately adjacent to the channel. That work did estimate that an additional eight percent of recharge from these areas might be expected from flat channel terraces and as much as 43 percent more would was estimated for conventional terraces.

In this work, a three-area system is being examined for the modeling the operation of a level-closed end terrace – the upslope area, a flat-bottom section, and a second flat section that is higher in elevation than the terrace bottom to represent the sloping side areas. There is a need to have these three defined areas to allow for a more complete water balance calculation for the terraced area and a separate water balance will be operated for each area. The terrace bottom section is obvious and so is the upslope of the field where no runoff will pond. The transition area between these two is important because it can have important effects in years with more runoff. Representing the area outside the bottom of the terrace by a flat section that is 0.5 ft higher (or half the maximum depth of possible water accumulation in the terrace channel whichever is less) in elevation and of a width equal to the width of the terrace channel at an elevation 1.0 ft higher (at the top of the maximum depth of terrace if it is less than 1.0 foot) than the bottom minus the flat-bottom width provides a reasonable representation of this second area in the terrace channel. This will be called the transition area. This overall representation for the terrace can be visualized similar to river channel with a first terrace on its floodplain. Finally, the upslope portion of the field is the total width between terraces or to the top of the field minus the width of the two sections in the terrace channel.

Runoff will be generated from the upslope portion and the transition area by the conditions used for the HRU. This runoff will be added to the channel bottom section as additional "precipitation" to create ponding. If the depth of ponding does not exceed 0.5 feet, none will be added to the transition zone. If there is additional water accumulated, the depth on the channel will increase and the depth on the transition area will increase until the entire amount of runoff is redistributed evenly over both areas. A daily rate of infiltration based upon soil characteristics and total infiltration since ponding began will used to represent a decreasing rate with time for extended periods that may result in crop drowning.

If the total depth exceeds the storage capacity of the two storage sections minus infiltration, the terrace channel will overflow and contribute to surface runoff from the terraced land use.

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In the case of level terraces with open ends, only the bottom section will be considered. Water will be allowed to accumulate to an average depth of 0.5 feet on the channel bottom. Beyond that all water will be lost that day as surface runoff. A daily rate of infiltration based upon soil characteristics and total infiltration since ponding began will used to represent a decreasing rate with time for extended periods that may result in crop drowning. This will decrease the rate of infiltration during a wet period when they occur.

The water budget simulation model for HRUs will operate the water budget for each of the three areas for closed-end and level terraces. It will then weight the results for each aspect of the water budget to produce a result that will be same as those for other HRUs without terraces.

Gradient terraces will be modeled using the regular method with a RCN to represent the entire field. There will be some differences in infiltration within the field but this difference is considered to be of similar magnitude of what is likely with fields without gradient terraces.

Transmission Losses for Runoff

The other aspect of the model development that is under study is transmission losses of streamflow during events. For our previous work in the Wet Walnut watershed in Kansas (Ramireddygari et al., 2000), we developed a physical relationship based upon actual recharge studies that were done in that watershed. I have not been able to find any such data for streams in the Republican Basin. There is a method that has been developed by the Natural Resources Conservation Service (1983) in the National Engineering Handbook, Part 630 Hydrology, Chapter 19, Transmission Losses. This method appears to be of use in this work although we may not have as much information about soil characteristics as we would like. Jordan (1977) looked at flood flows extensively in Kansas and several of the streams are in the Republican Basin. He concluded that the transmission loss in one mile for medium- to large-sized streams in western Kansas averages 2% of the flow volume at the beginning of the mile. It concludes that value can be used for each succeeding mile. For purposes of this study, using the general relationship from Jordon may be as good as we can expect to achieve. The effects have important implications on loss of streamflow and recharge distribution within the basin. So, accounting for them will have effects on where and how terracing and small reservoirs affect both recharge and streamflow within the basin.

b. Lead the effort to modify and apply a version of the selected water balance model to the land terraces and non-Federal reservoirs in the basin.

Most of the progress on this task is described above.

c. Select and administer postdoctoral research assistant(s), graduate assistant(s), and/or undergraduate student assistant(s) to complete Research Project effort.

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Personnel working on this project at this time are Koelliker, 30% time, and Ravikumar, a 50% time doctoral graduate student. Dr. Phil Barnes, a research-extension engineer in our department, is working with us on the field work aspects of this project. He has worked closely with our Nebraska colleagues in securing and setting up and instrumenting our terraced fields. His total time commitment is about 5%.

Dr. David Chandler, assistant professor at Utah State University, has just signed a contract in the civil engineering department at Kansas State University to begin if August 2006. Dr. Chandler has considerable experience and reputation watershed modeling of natural systems. He will be working 30% time on this project.

d. Collaborate with UNL on modeling efforts and field work involved with monitoring a small sample of land terraces and non-Federal reservoirs.

Two terrace sites in Kansas have been selected and information on them is contained in Appendix A. One site is a flat-channel storage-type terrace on the Kansas State University Experiment Field at Colby Kansas. It is representative of the broad, flat-bottom types used in Northwest Kansas. This site was one of three that was a part of the earlier study (Koelliker, 1985) to evaluate recharge capabilities of level terraces. The other site is just west of Norton on the north side of Sebelius Lake. It is a more conventional storage-type terrace. Installation of instrumentation has been completed and data is beginning to be collected. Reporting on the data from the Kansas sites along with the sites in Nebraska will be a part of the Nebraska portion of the total report.

Cursory examination of data from soil cores at the Kansas and Nebraska sites indicate that the terraces that are being monitored are similar in nature to the sites in Thomas County Kansas that Koelliker (1985) studied from 1980-85 to develop estimates of potential recharge for the Northwest Kansas Groundwater Management District #4, Colby, Kansas. Soil water contents in the upslope and in the terrace channel are similar in distribution and amounts.

e. Provide an update on the Research Project activities to Reclamation and the Conservation Committee by May 1st and December 1st of each year. The update due by May 1 will allow the Conservation Committee time to review the update and brief the RRCA at their annual meeting normally scheduled in June of each year.

This report is my May 2006 update on our work.

f. Lead in the preparation of a final report on or before June 1, 2009 that summarizes the results of the Research Project and addresses items a, b, c, and d included under B.6. Deliverable Products.

Report will be delivered when the project is nearing completion.

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Assessment of Progress on This Agreement:

Work on the project is proceeding. Koelliker has been spending more time on the work than originally expected. My appointment and the nature of the work make this a better way to proceed. I have one doctoral student to lead and direct to get HRU modeling work done. The details of model evaluation have been the major focus for the most of the past year. We are beginning to get some datasets developed of weather and climate data. The addition of Dr. David Chandler will add to our knowledge of water budget simulation modeling and increase or capabilities to work on effective interfacing the HRU and small reservoir modeling processes most effectively with the GIS aspects of this overall project.

We expect to get the HRU model operational and under evaluation this fall 2006. We will begin applying it to conditions in the test sub-basins, Prairie Dog Creek above Sebelius Lake and Medicine Creek above Harry Strunk Lake, by the end of this year.

Resources for completing this major watershed simulation effort are limited. We will try to make the most of them, but if this work should become a basis for decisions affecting the Republican Rive Compact agreements, then the level of detail at which we are forced to work because of limited financial resources are likely not sufficient.

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Appendix A is contained in the electronic file, Kansas Terrace Sites.xls (Excel workbook) These files were transmitted with the December Progress Report.

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