DRAFT

McDonald Morrissey Associates, Inc

Memo

To: Ann Bleed and Mike McDonald

From: Chuck Spalding

CC: Dan Morrissey, Paul Koester, Mike Thompson, Mark Groff, Derrel Martin

Date: ~~October 6, 2003~~ Sept. 8, 2003

Re: Scenarios for Republican River Basin Model Identified September 4, 2003

This memorandum summarizes specifications for the predictive runs of scenarios identified on September 4, 2003 for Republican River Basin Model. All simulations will represent the period January 2001 to December 2040. These scenarios include the following:

- limits to the allowed rate of pumping in inches,
- percentage reductions to pumping in wells within one mile of stream cells,
- reductions in pumping of wells completed after specified dates,
- a 25% reduction in irrigated acres, and
- a reduction in seepage from the CNPPID system canals.

The general assumptions and processes for each of these scenarios are described in detail below. Details of files and procedures are provided as an appendix.

Scenario 1: Limits to the Allowed Rate of Pumping

Ground water irrigation is often allocated based on a specified rate in inches that can be applied by the ground water user in a given year. Under certain conditions, the rate of water withdrawn and applied can be limited to a specified rate under administrative rule. The impact of specifying rate limits on ground water irrigation pumping on stream baseflow will be tested. At the September 4, 2003 meeting, the Upper, Middle, and Lower NRD managers asked that the impact of limiting ground water irrigation pumping rate to 14 ½ inches be evaluated.

Currently, ground water irrigation withdrawals in the Republican River Basin Model are specified based on an average rate per county per year. Because averages have been used, rates higher and lower than these estimates can be expected to occur. To assess what the effect of a limit would be, a statistical relationship between average ground water irrigation withdrawals and the range of estimated ground water withdrawals will be developed. This task has been assigned to Derrel Martin with assistance from Mark Groff, Flatwater Group. Once this relationship has been developed, estimates of average future pumping rates by county by year can be specified. Pumping by cell is then specified based on irrigated acres per cell and the registered well database.

In addition to the 14 ½ inch limit other limits may be tested. At a minimum a limit of 12 inches will be simulated. Limits will be applied to the Nebraska portion of the model and to each NRD (Upper, Middle, and Lower) to evaluate the impacts on a NRD basis.

Scenario 2: Percentage Reductions in Pumping Within One Mile of Stream Cells

An additional option for NRD administrators is to limit ground water irrigation within a certain distance of perennial streams and the Republican River. At the September 4, 2003 meeting, the results for excluding pumping within various distances from model stream cells were presented. Based on those results, the NRD managers requested that a 25% and a 50% reduction of pumping of stream cells within one mile of model stream cells be prepared. For each of these scenarios, the impact on baseflow in dry years will be evaluated. Simulations will be completed such that impacts can be evaluated for Nebraska and each of the NRDs (Upper, Middle, and Lower).

Scenario 3: Reductions in Pumping of Wells Completed After Specified Dates

Ground water usage may be limited by reducing pumping from wells that have been registered more recently than older wells. The NRD managers requested that two reductions 25% and 50% be specified for more recent wells. The Lower NRD specified that pumping in wells registered after January 1, 2001 be reduced. The Middle NRD requested that pumping from wells installed after January 8, 1998 be reduced. The Upper NRD was not interested in these simulations.

Scenario 4: Reduction in Irrigated Acres

Ground water usage may be limited by reducing the number of irrigated acres. The Middle NRD requested that a simulation in which irrigated acres are reduced by 25% with ground water irrigation withdrawals unchanged be completed.

Scenario 5: Reduction in Seepage from the CNPPID System Canals

Seepage from the Central Nebraska Public Power and Irrigation District (CNPPID) canals contribute a significant portion of ground water recharge to area studied in the Republican River Model, particularly in Gosper, Phelps and Kearney Counties. This seepage has reduced the impact of pumping on the baseflow in the Republican River and its tributaries. Over time, CNPPID has initiated canal lining programs to limit canal seepage and improve system efficiency. At the September 4, 2003 meeting NRD managers requested that simulations be run to evaluate the impact of continued CNPPID lining programs. As a limiting case, a simulation maybe completed where starting in 2003 all seepage from the CNPPID system be eliminated. Other simulations where lining is phased in will be considered.

Combined Scenarios:

Combinations of five scenarios above??????

Appendix A

Scenario File Specifications

[To be Modified]

Kansas & CO were simply repeated for 1981-2000. So acres(2001) = acres ~~2002~~(1981) vol2001 = vol1981

Precipitation Recharge

Precipitation recharge for the period 2001 to 2040 will be based on precipitation from the period 1981 to 2000. All weather stations used in the development of the Republican River Basin Model will be used to develop the predictive input data sets. Two cycles of precipitation from 1981 to 2000 will be used to specify conditions for 2001 to 2040.

Data sources

MODFLOW input data sets for the predictive period will be developed by modifying the file ppt.dat which specifies annual precipitation at 34 weather stations in and near the Republican River Basin. This data was reportedly compiled by Mary Kay Brengosz of Spronk Engineers. Annual precipitation for 1981 to 2000 will be copied 2001 to 2020 and then to 2021 to 2040. Ppt.dat is read by the Republican River Basin Model preprocessor RRPP which creates MODFLOW data sets.

Ground Water Irrigation Pumping and Ground Water Irrigated Acreage

Ground water irrigated areas in the Republican River Basin Model have been segregated into areas that are exclusively irrigated by ground water and areas that are irrigated by both surface water and ground water (commingled sources). For the predictive simulations, pumping in ground water irrigated exclusive areas for the period 2001 to 2020 will be based on 1981 to 2000 estimated pumping rates specified for the Republican River Basin Model adjusted for the number of wells identified in 2000. This pumping cycle will be repeated for the period 2021 to 2040. As an example, for a given model cell,

$$\text{Volume Pumped in 2001} = \frac{\text{Volume Pumped in 1981} \times \text{Number of Wells in 2000}}{\text{Number of Wells in 1981}} \quad (1)$$

For ground water exclusive areas, irrigated acres from 2000 will be specified as constant for the period 2001 to 2040.

Pumping and irrigated acres in ground water irrigated areas with a commingled source will be based on estimates of 1981 to 2000 conditions. For 2001 to 2020 commingled acreages and pumping from 1981 to 2000 will be used. This will be repeated for 2021 to 2020.

Depending on which scenario is applied, the future pumping specifications will be further adjusted. Future pumping for the rate limiting scenarios will be limited base on statistical rate limits as previously described. Percent reduction scenarios will reduce pumping in specified areas by specified amounts.

Data sources

The ground water exclusive pumping data file, GWOnlyWellsExport.txt, will be modified by Mark Groff of the Flatwater Group to reflect the 2001 to 2040 predictive period. This file contains the annual cell-by-cell acreage and pumpage estimates for acres irrigated only with groundwater. The original file covered the time period 1940 to 2000. Pumpage volumes for the years 2001 through 2040 will be specified based on formula (1) above. Ground water exclusive area irrigated acres from 2000 will be specified as constant for the period 2001 to 2040

The ground water commingled pumping data file, CoWell_Export.txt, will be modified by Mark Groff of the Flatwater Group to reflect the 2001 to 2040 predictive period. This file contains the annual cell-

by-cell acreage and pumpage estimates for acres irrigated with a commingled water supply. The original file covered the time period 1940 to 2000. Ground water irrigated acres and pumping estimates for commingled areas will be based on commingled acreages from 1981 to 2000. These acreages and pumping estimates will be cycled twice for the period 2001 to 2040.

The files, GWOnlyWellsExport.txt and CoWell_Export.txt will be used by the PERL program mknedat. Mknedat creates files in a specified format read by the Republican River Basin Model preprocessor RRPP which creates MODFLOW data sets.

Ground Water Irrigation Return Flows

Ground water irrigation return flows for Nebraska have been specified as a percentage of water applied by ground water irrigation. In the Republican River Basin Model, ground water return flows based on a ground water irrigation efficiency of 70% from 1940 to 1960 and a linear increase from 70% in 1960 to 80% in 2000, i.e., return flow is 30% of pumping from 1940 to 1960, linearly decreasing to 20% of pumping in 2000. For the predictive simulations, ground-water return flow is specified as 20% of pumping for the period 2001 to 2040.

Data sources

Data sets for the predictive period will be specified by modifying the PERL program mknedat. Output from mknedat is read by the Republican River Basin Model preprocessor RRPP which creates MODFLOW data sets.

Ground Water Irrigation Pumping and Return Flows for Kansas and Colorado

Kansas and Colorado pumping and return flows for the predictive period will be based on the pumping and return flows from 1981 to 2000. These stresses will be mapped directly by copying files from 1981 to 2000 to equivalent files for two successive periods from 2001 to 2040.

Data sources

Kansas and Colorado pumping and return flows are contained in files are read by the Republican River Basin Model preprocessor RRPP which creates MODFLOW data sets. The original data files for the period 1918 to 2000 will be distributed with the Republican River Basin Model DVD.

Municipal Well Pumping

Municipal well pumping is specified on an annual basis for each state. In all three states, municipal well pumping will be specified as constant for the period 2001 to 2040 based on the rate specified in 2000.

Data sources

Municipal well pumping is specified in a separate file for each year for each state. The municipal well data files from 2000 for each state will be copied to annual files for 2001 to 2040. These files are read by the Republican River Basin Model preprocessor RRPP which creates MODFLOW data sets. The original data files for the period 1918 to 2000 were distributed with the Republican River Basin Model DVD.

Surface Water Irrigation and Surface Water Irrigated Acreage

Surface water irrigated areas in the Republican River Basin Model have been segregated into areas that are exclusively irrigated by surface water and areas that are irrigated by both surface water and ground water (commingled sources). For the predictive simulations, surface water in both surface water irrigated exclusive areas and areas that are commingled for the period 2001 to 2020 will be based on 1981 to 2000 estimated surface water application rates specified for the Republican River Basin Model, i.e., for any given model cell, surface water application rate for 1981 is equivalent to 2001. This cycle will be repeated for the period 2021 to 2040. Surface water irrigated acres for commingled areas and areas irrigated exclusively by surface water will be based on commingled acreages from 1981 to 2000. These acreages will be cycled twice for the period 2001 to 2040.

Data sources

The surface water exclusive application data file, SWIrrOnlyLandsWDelivery_Export.txt, will be modified by Mark Groff of the Flatwater Group to reflect the 2001 to 2040 predictive period. This file contains the annual cell-by-cell acreage and application estimates for acres irrigated only with surface water. The original file covered the time period 1940 to 2000. Surface-water application (delivery) estimates and surface water irrigation acreages for areas serviced exclusively by surface water for the years 2001 through 2040 will be specified by cycling through the current 1981 through 2000 estimates, e.g. surface water application and irrigated acres specified for a cell in 2001 is equivalent to surface water application and irrigated acres specified in 1981. This cycle will be repeated for 2021 to 2040.

The surface water commingled application data file, SWCoLandsWDelivery_Export.txt, will be modified by Mark Groff of the Flatwater Group to reflect the 2001 to 2040 predictive period. This file will contain the annual cell-by-cell acreage and surface water application estimates for acres irrigated with a commingled water supply. The original file covered the time period 1940 to 2000. Surface water application rates will be based on conditions from 1981 to 2000. Surface water irrigated acres and application rates for commingled areas will be based on commingled acreages from 1981 to 2000. These acreages and application rates will be cycled twice for the period 2001 to 2040.

Surface Water Irrigation Return Flows

Surface water irrigation return flows for Nebraska have been specified as a percentage of water applied by surface water irrigation. In the Republican River Basin Model, surface water return flows for surface water systems in the Central Nebraska Public Power and Irrigation District will be based on a ground water irrigation efficiency of 60% from 1940 to 1960 and a linear increase from 60% in 1960 to 70% in 2000, i.e., return flow is 40% of applied surface water from 1940 to 1960, linearly decreasing to 30% of pumping in 2000. For the predictive simulations, ground-water return flow is specified as 30% of pumping for the period 2001 to 2040. In other surface water irrigation systems, return flows will be assigned as a percentage of surface water irrigation as specified in Section IV.A.2.c in the RRCA Accounting Procedures and agreed upon by the Ground Water Technical Modeling Committee. These other return flows ranged from 18.86% to 40% and will be held constant through the period 2001 to 2040.

Data sources

Data sets for the predictive period will be specified by modifying the PERL program mknedat. Output from mknedat is read by the Republican River Basin Model preprocessor RRPP which creates MODFLOW data sets.

Canal Seepage

Canal seepage for all Nebraska canal systems has been specified as a cycle of data from 1981 to 2000 specified from 2001 to 2020 and to 2021 to 2040. In the canal seepage off scenario, as a first run, seepage from any cell identified as contributing seepage in the CNPPID canal system will cease to recharge the aquifer starting in 2003. Other seepage reduction scenarios will be considered.

Data sources

Canal seepage is specified in files that represent canal and lateral seepage for a given month and year (e.g., 1940.01.rcc represents canal seepage in January, 1940). The units of these files are in acre-ft/month. To project into the future, canal seepage files from the period January 1981 to December 2000 will be copied to files representing January 2001 to December 2020. This will be repeated for the period January 2021 to December 2040. This approach was taken to maintain consistency with applied surface water and the resulting surface water recharge. These files will be read by the Republican River Basin Model preprocessor RRPP which creates MODFLOW data sets.

In the canal seepage off run, canal seepage files will be modified such that seepage is eliminated in the appropriate cells identified for CNPPID. This includes all cells that have been specified as seeping in the CNPPID system except for Elwood Reservoir and Johnson Lake.

Initial Water Levels

Initial water levels specified for the predictive simulations will be assigned as the final calculated water levels for the end of December 2000 from Run 12p, the final Republican River Basin Model. For impact runs initial water levels will be specified as the final calculated water levels from the end of December 2000 from the appropriate impact run.

Data sources

Water level elevations for 2000 are an output of the original MODFLOW data sets as provided on the Republican River Basin Model DVD. Water level elevations for impact runs are output from appropriate impact simulations for the period 1918 to 2000.

Evapotranspiration

Phreatophyte evapotranspiration for the 2001 to 2040 predictive simulations will be based on the potential area of phreatophyte evapotranspiration for 2000 and a cycle of monthly maximum evapotranspiration rates for the period 1981 to 2000.

Data sources

Evapotranspiration is created using the PERL program mket. Two input files to mket will be modified to create conditions for the period 2001 to 2040, basinfactors12p.dbf and monet.dbf. Monet.dbf provides monthly maximum ET rates for three stations, Akron, McCook and Red Cloud. These rates were calculated by Spronk Engineers for the period 1918 to 2000 and are distributed to cells by mket. To project into the future, monet.dbf will be modified such that monthly maximum ET rates from January 1981 to December 2000 will be copied to the period January 2001 to December 2020. This will be repeated for the period January 2021 to December 2040. The area covered by phreatophytes is

specified in a file etarea.dat. The way phreatophyte area changes over time is specified using multipliers contained in basinfactors12p.dbf. For the period 2001 to 2040, all basinfactors assigned to 2000 will be specified through 2040. This assumes that phreatophyte acreage will not vary in the future and will be consistent with that defined for 2000. Extinction depth and the evapotranspiration surface will be the same as specified for the Republican River Basin Model.

Drains and Constant Heads

Springs in the model have been assigned an elevation and conductance term. The specifications for 2000 will be specified through 2040. Constant heads have been assigned to the Platte and Little Blue Rivers, the eastern Kearney and Nuckolls County boundaries and to the outlet of the Republican River from the model. The specifications as assigned for the period 1918 to 2000 will continue through 2040.

Data sources

For drains, the MODFLOW drain package 11.drn was provided in the Republican River Basin Model DVD. This file will be modified to reflect the period 2001 to 2040. Constant heads are specified in the MODFLOW basic package 12.bas also provided on the Republican River Basin DVD.

Streams and Rivers

Streams are assigned in the model using the MODFLOW stream package. Stream cells are specified to a row and column, stream connectivity, stream bed conductivity, Manning coefficient, stream bed top and bottom elevations. The only aspect of the stream package that has changed over time is the elevation of stream cells in reservoirs. Reservoirs in stream cells have been assigned varying elevations based on monthly data from Mark Phillips. These elevations in general have not varied greatly over time. Since reservoir elevation is somewhat dependent on precipitation, however, reservoir elevations for the period 1981 to 2000 will be mapped twice to the period 2001 to 2040.

Data sources

The MODFLOW stream package 12s.str was provided via the download directory on the website http://www.prinmath.com/pm/restricted/republican/v12s/index.html. This file will be modified to reflect the period 2001 to 2040.

Impact Accounting

Impact accounting will be prepared in a form consistent with the impact summaries produced on Willem Schrueder's DVD and website. The output will be modified such that annual accounting will be produced for every year for the period 2001 to 2040. Comparisons will be made for Nebraska, the Upper Republican, Middle Republican, and Lower Republican. NRD assignment to model cells was developed by an intersection of the GIS coverage described in http://www.nrc.state.ne.us/databank/metadata/nrdb_doc.html#1 (downloaded August 2003) with the model grid by Mark Groff of the Flatwater Group, Inc.