Appendix J

STATUS OF AGREEMENT ON RRCA GROUND WATER MODEL

As of November 15, 2002

DOCUMENT CONTEXT

The purpose of this document is to summarize the status of the RRCA Ground Water Model. Agreement has been reached among the State of Colorado, State of Kansas, and State of Nebraska in consultation with the United States in the selection of model calibration targets and methods to estimate groundwater pumping and recharge. The RRCA Ground Water Model will be applied in a consistent manner with the RRCA Accounting and Reporting Procedures to ensure consumptive uses from surface water and ground water are properly accounted for. General agreement has also been reached on the process to calibrate the RRCA Ground Water Model. The States and United States agree that coordinated efforts will continue to refine data inputs and model calibration until completion, on or before July 1, 2003.

MODEL DESCRIPTION

The primary purpose of the RRCA Ground Water Model is to quantify within the Republican River Basin the amount, location, and timing of depletions to stream flow from ground water pumping and accretions to stream flows due to imported water supply from outside the basin. The major structural components of the model are:

? The model uses MODFLOW 2000 with the following modules: BAS1, RCH, WEL, STR, EVT, DRN, CHD, and LPF.

? The model domain extends beyond the Republican River watershed from the Platte River in the north and to the Ogallala aquifer outcrops on the southern, eastern, and western boundaries. The model domain coincides with that described in USGS Open File Report 02-175 except in the eastern portion of the Basin where it was extended eastward to the eastern edge of Kearney County, Nebraska and into Adams County, Nebraska to reflect increased water table elevations caused by imported water supplies from the Platte River. The model domain encompasses approximately 30,000 square miles.

? Constant head boundary conditions for the model were assigned along the Platte River, the eastern boundary of Kearney, Clay, Nuckolls, and Adams Counties, Nebraska; and in Cheyenne County, Colorado where the Republican River exits the domain. All other boundaries are no-flow boundaries. See attachment RRCA Ground Water Model Domain.

? The model represents the long term steady-state conditions up to 1940 and transient conditions from 1940 to 2000. Transient conditions are discretized into monthly stress periods. The model will be updated annually by the RRCA to reflect data from 1940 to the current accounting year.

? The model is discretized into one-square mile grid cells.

? The model is a single layer bounded on the bottom by the impermeable Pierre Shale.

- As an interim measure, Saturated Thickness is based upon an average saturated thickness for the period 1940-2000; values were obtained by kriging across the model domain between known data points. The minimum saturated thickness in a model cell is 10 feet.
- Stream Network was taken from USGS File Report 02-175.
- The interim aquifer base was taken from USGS File Report 02-175, and is subject to adjustment to reflect elevation variances near streams.
- Land surface elevations were obtained the National Elevation Dataset (NED) one arc second Digital Elevation Model (DEM).
- The aquifer is represented as confined in the present model structure, but will be changed to unconfined aquifer conditions prior to final model calibration.
- Initial hydraulic conductivity and specific yield estimates were taken from USGS File Report 02-175 and are subject to adjustment in model calibration.

CALIBRATION TARGETS

WATER LEVEL

Ground water levels have been measured throughout the Basin since the early 1900's, but the number of sites increased dramatically post-World War II. The source of ground water level information used in the RRCA Ground Water Model is the Ground Water Site Inventory (GWSI) maintained by the United States Geological Survey (USGS) in cooperation with all three States. The tenure of static ground water level data ranges from a single-year measurement at a discrete location to a continuum of annual measurements that began in the early 1950's and continues to date at the same well. Ground water levels are typically measured once each year, usually in the non-irrigation season when effects from irrigation pumping are minimized. The RRCA Ground Water Model is calibrated to a ground water level data set that contains a total of 350,233 water level records at 10,835 different sites. The GWSI dataset was converted from latitude/longitude to a X-Y coordinate system. The entire dataset, including one-measurement water levels, is available for model calibration except for wells that were determined by the representative State to be clearly erroneous. Water level data from continuous recorders are not presently being applied. A procedure to weight water level targets during the calibration process may be utilized. Additional water level targets may be included upon agreement by all States.

BASEFLOW

Hydrograph separation is a technique that partitions the amount of surface water and ground water that is measured as total streamflow at a river gaging station. Determining the component of total streamflow that is contributed by ground water (also called baseflow) requires professional expertise and judgment. The hydrograph separation analysis used in this application is referred to as the Pilot Point method. This procedure was adopted for application in this ground water model since it combines the increased accuracy of graphical baseflow analysis with the computational efficiency afforded by electronic spreadsheets. Daily streamflow information for one, or multiple years, is easily tabulated in a Microsoft Excel© electronic spreadsheet. Daily hydrographs are subsequently plotted using the graphics package. The analyst performing the baseflow separation uses the tools available in the electronic graphics package to select pilot or turning points that signify the baseflow component in the total amount of streamflow measured at a river gaging station. A significant contribution of the graphics and computational package afforded by Microsoft Excel© is the flexibility to easily change the assignment of each pilot or turning point upon comparative review with other nearby streamflow hydrographs or in collaboration with another analyst. The analyst may change one or multiple pilot points using the click-and-drag tool to another turning point and instantly recalculate the amount of baseflow for a defined period of time – from a month up to decades. Use of the electronic graphical/computational Pilot Point method also dampens the objectivity criticism of the traditional hand-graphics technique performed by an individual analyst.

For the RRCA Ground Water Model, fifty-seven (57) independent baseflow analyses were performed and adopted as calibration targets. A summary of the estimated monthly baseflows of each analysis is attached. Existing baseflow targets may be revised if found to be flawed, and additional baseflow targets may be adopted upon unanimous agreement by the RRCA Ground Water Modeling Committee. Adjustments for surface water diversions may also be considered and adopted by the RRCA Ground Water Modeling Committee, upon unanimous agreement.

As a supplement to the baseflow separation information developed for selected gaging stations and stream segments, Nebraska compiled miscellaneous streamflow measurements and synoptic baseflow survey data available from the USGS and State of Nebraska into a Microsoft Access© electronic database. The data were collected periodically since 1975, except for the data provided in the USGS Water Supply Paper 779, which were collected in the late 1920's and early 1930's. The synoptic baseflow data has not been included in model calibration to date, but is available for review and consideration in the final model calibration.

PUMPING

The pumping for municipal and industrial purposes was obtained from the USGS. Each State developed its own estimate of gross irrigation pumping. The following general methodologies for estimating ground water pumping have been agreed to by the States. The States commit to mutual verification of pumping datasets, primarily by comparison to meter records (where available) and to a lesser extent by power records, and independent CIR calculations. The RRCA Ground Water Modeling Committee will continue to refine pumping estimates on commingled irrigated lands in Nebraska.

<u>Colorado</u>

The State of Colorado employed a seven-step procedure to estimate ground water pumping:

1. Total acres irrigated by surface and ground water is estimated for each county based upon data from the respective County Assessor's Office for the area contained in the RRCA Ground Water Model boundaries.
2. The acreage irrigated by surface water is identified from the County Assessor's Records
3. The acreage irrigated by ground water is calculated as the difference between the total acreage and the acreage irrigated by surface water.
4. The maximum farm efficiency for center-pivot sprinkler irrigation and flood irrigation is estimated for each year.
5. The percent of acreage irrigated by center-pivot sprinkler is estimated for each county for each year.
6. The crop water requirement is estimated for each county using the Hargreaves empirical formula calibrated to the Penman-Montieth method for reference crop evapotranspiration. The crop mix for each county is determined from County Assessor records. The effective precipitation is estimated using the procedure outlined in Irrigation Water Requirements, Technical Release No. 21, United States Department of Agriculture, April 1967 (Revised September 1970). The crop irrigation requirement is calculated as the total or potential crop water requirement minus the effective precipitation.
7. Pumping for each county is estimated as Irrigated Ground water Acreage multiplied by Crop Irrigation Requirement multiplied by Fraction of Crop Irrigation Requirement satisfied. This total is then divided by the maximum farm efficiency. The maximum farm efficiency is a weighted average based on the amount of sprinkler and flood irrigation.

<u>Kansas</u>

The State of Kansas uses the following procedure to estimate irrigation pumping for the period of 1940 – 1988:

1. Determine the potential evapotranspiration (PET) for the irrigated area and crops determined for the study area.
   a. Compute reference ET with the Penman-Montieth method for years when detailed climate data are available.
   b. Develop calibration coefficients for the Hargreaves method to use prior to availability of detailed weather data.
   c. Compute crop PET for study period.
   d. Compute effective precipitation.
   e. Determine crop distribution from county level crop statistics.
   f. Compute crop demand for irrigation water (CIR) on a unit basis (inches per acre).

2. Compile a history of well development, including location, date and source. The main data source is the Kansas water right information system, including its water use database.
3. Compile irrigated area estimates, based on county crop statistics, previous studies and water use reports.
4. Compute the volume of crop demand for irrigation (CIR) on a countywide basis, and use this as an initial estimate of the net irrigation pumping.
5. Compare the estimated net irrigation pumping to the water use reports for 1989 - 1999. This comparison was used to calculate factors by county, averaged over the period.
6. Use the comparison of estimated to reported pumping to develop a factor to multiply by the crop demand to estimate the actual net pumping for 1940-1988.

The State of Kansas uses the following procedure to estimate irrigation pumping for the period of 1989-2000:

> Kansas has received water use reports from water right holders since 1957. In 1989, the Kansas Division of Water Resources (KDWR) was given additional enforcement authority and resources to require, obtain, and review water user reports of all water right holders. As a result, for the period 1989-2000, Kansas relied on the water use reports as its basis for estimating irrigation pumping. The water use report includes the total metered quantity or hours of operation, pumping rate, irrigated acreage, and crop type. Water users with meters are expected to report metered quantity; while those without meters report hours of pumping and diversion rate. Each water use report received by KDWR is reviewed for accuracy and completeness. All wells in the alluvium of the Republican River and its tributaries have been metered since 1998.
>
> Net pumping was determined by multiplying the total pumping by an estimated irrigation efficiency (which includes evaporative spray loss and runoff loss). Recognizing that the type of irrigation has changed over time, Kansas assumed that all irrigation was flood until 1959, with an efficiency of 65%. Center pivots (85% efficiency) and other sprinklers (75% efficiency) were in use starting in 1960, and Low-Energy Precision Application systems (LEPA, 90% efficiency) use began in 1990. For 1960 to 1993, the proportion of center pivot and other sprinklers was interpolated from zero in 1959 to the value reported in the Kansas Water Rights Information System in 1993. The same procedure was applied to LEPA for the period 1990-1993. Flood irrigation was assumed to comprise the remainder each year to bring the sum to 100%.

Nebraska

> Nebraska estimates pumping by a method that uses power records to estimate the hours of pumping for irrigation wells in a given area by year. The reported pumping rate

for each registered irrigation well is adjusted in accordance with an empirically derived relationship between registered rates and actual rates, as determined through field-testing. The estimated pumping rates are multiplied by scalars that are based primarily on comparisons to metered data. The scalars are required because some wells in Nebraska are supplemental to surface water, because of possible inconsistencies in the registration database, and/or where pumping capacity exceeds potential beneficial use. The hours and rates are combined with the well database to determine pumping amounts, assuming the same hours per well. Scalars are determined based on comparison of countywide pumping totals in the Upper Republican Natural Resources District. An additional scalar is proposed to account for commingled lands in the alluvium. Nebraska will continue its verification of its pumping estimates after 15 November, but does not propose to change its method.

IRRIGATED ACREAGE ESTIMATES

The States agree to the following methodologies for estimating irrigated acreage. The States commit to mutual verification and improving the accuracy of irrigated acreage datasets.

COLORADO

Estimates of the irrigated acreage for 1940 through 2000 in Colorado for the area covered by the RRCA Ground Water Model include lands in Kit Carson, Yuma, and Phillips Counties and parts of Sedgwick, Logan, Washington, Lincoln, and Cheyenne Counties. A small area of Elbert County is located in the RRCA Ground Water Model area, but since there are no irrigation wells or ditches in that area, it was excluded.

The estimates are based on the County Assessors' records of irrigated acreage and well permit information contained in the Colorado Ground Water Commission's Northern High Plains Well Database with adjustments for irrigated fields set aside under federal farm programs. The results were compared to irrigated crop statistics compiled and published by the Colorado Department of Agriculture and the National Agricultural Statistics Service (NASS) and irrigated acreage records for farms participating in federally subsidized programs that were provided by local Farm Service Agency offices through the U.S. Department of Agriculture. Descriptions of these sources and procedures follow.

County Assessor Records

The county assessor is an elected official in county government and their duties are prescribed by Colorado Revised Statutes. Succinctly, the county assessor must discover, list, classify, and value all taxable real and personal property within their respective county. Procedures for classifying and valuing property are set forth in the "Personal Property Valuation Manual", the "Land Valuation Manual", and other references prepared by the Colorado Division of

Taxation. The assessor's appraised property values form the basis for taxing districts to set mill levies and taxes. The county treasurer is responsible for collecting all property taxes.

For agricultural land, the assessor must determine the value of the land based on its production capability by considering soils, irrigation sources and methods, crop yields, crop values and farm sales. The assessor relies on aerial photographs, county clerk records, the county soil survey, agricultural statistics from NASS, climatological records, interviews with local farmers, and other locally available information. Since 1989, all property is appraised every other year based on sales of equivalent property during the preceding two years. Provisions are allowed to conduct interim appraisals if necessary to reflect a change in property values assessment such as conversion from irrigated cropland to dry land pasture.

The county assessors must publish an "Abstract of Assessment" by August 25 of each year that summarizes the amount and value of various categories of property as of the previous January 1. The abstracts also document the valuation, mill levy, and revenue for each taxing district in the county. Categories of property include irrigated farmland, meadow hay land, dry farm land, grazing land, and other agricultural land. Since 1993, the abstracts tabulate acreage by sprinkler and flood irrigation. The Colorado Department of Local Affairs summarizes the abstracts and submits an annual report to the Colorado General Assembly.

Irrigated land that is taken out of production due to farm programs, such as the Payment in Kind (PIK) and Conservation Reserve Program (CRP), remain classified as irrigated by the county assessor pursuant to requirements in federal authorizing legislation for these programs. They remain classified as irrigated to assure payment to the farm owner by the federal government is commensurate with irrigated land production capability and to maintain the assignment of tax burden. The Farm Service Agency (FSA) of the US Department of Agriculture (USDA) administers the federal crop programs. Each year, program participants must report crop acreage to the local FSA office that compiles records of irrigated and non-irrigated croplands. Federal farm program acreage records for 1990 through 2000 were available and summarized for each county as CRP fields and fallow fields. Those annual values were deducted from the assessors' irrigated acreage. The PIK Program reduced irrigated acreage significantly in the 1980s. Since the USDA does not retain records for more than 10 years, Colorado estimated the PIK acreage using NASS records as described later in this document.

Colorado Ground Water Commission's Northern High Plains Well Database

The Northern High Plains Well Database covers the entirety of the RRCA Ground Water Model area in Colorado. The information contained in the well database for the model area includes 3,967 ground water well records. Each record includes the well location, use of the water, place of use, pumping rate, irrigated acreage, owner, and priority date. The records for each county were sorted by use, priority date, and location. For each county and priority year, the number of irrigation wells is counted and the acreage shown on the well permits is quantified.

The irrigated acreage identified in the well permits exceeds the actual irrigated acreage identified through County Assessor data. Review of well permit acreage information indicates most cite a square quarter-section of land, or 160 acres. Center-pivot sprinkler systems are the prevalent water application method in the model area and a typical circular quarter-section system irrigates only 130 acres. Comparison of permitted irrigated acreage with NASS data also indicates the well permit information exceeds the irrigated crop acreage reported by NASS.

Estimate of Surface Water Irrigated Acreage

Surface water irrigation in the Basin in Colorado occurs only in Yuma and Kit Carson Counties. The surface water acreage was obtained from the respective County Assessor's records that documented a total of 2,902 (Yuma) and 1,861 (Kit Carson) acres in 1940. These quantities were carried forth to date and do not reflect the small decrease in surface water irrigation that has occurred since 1940.

Estimate of Irrigated Acreage by County Over Time

The assessors' records of irrigated acreage for Kit Carson and Yuma Counties include land irrigated from surface water sources that precede 1940. Irrigation of additional acreage after 1940 can be attributed exclusively to ground water development. Review of historic county assessor records confirms there has been little change in irrigated acreage since 1979 and the Assessors' records for recent years provide the most accurate quantification of irrigated acreage in each county.

To estimate the irrigated acreage over time, the ratio of the assessors reported acreage in 2000 to the cumulative acreage under all well permits for irrigation is calculated. For Phillips, Sedgwick, Logan, Washington, Lincoln, and Cheyenne Counties, that ratio is multiplied by the annual cumulative well permit acreage to determine the acreage in a specific year. For Kit Carson and Yuma Counties, the ratio was multiplied by the yearly permitted acreage and the resultant was added to the previous year's acreage to account for surface-water irrigated land developed before 1940. For 1990 through 2000, the fallow irrigated fields and fields idled due to farm programs (USDA records) were deducted from the calculated acreage to determine the net irrigated acreage for those years. From 1982 through 1988, significant acreage was taken out of production through the USDA's Payment in Kind (PIK) program. The USDA represents that it does not have records of the county acreage idled by this program during the 1980's because it retains records on individual farms for only 10 years. The NASS records show significant reductions in irrigated acreage, up to 110,000 acres in 1983, in Kit Carson, Yuma, and Phillips Counties. To reflect this program, Colorado combined the NASS acreage for the three counties[1] and calculated the annual reduction percentage from the acreage in 1981.

[1] The NASS records for the other five counties were not used for these calculations because the irrigated acreage in these counties overlaps into other river basins.

Year	Total Irrigated Acres	Reduction as Percent of 1981
1981	507,774	0.0
1982	480,443	5.4
1983	392,562	22.7
1984	426,248	16.1
1985	431,243	15.1
1986	416,416	18.0
1987	465,633	8.3
1988	468,627	7.7

The annual reduction percentages were multiplied by the irrigated acreage in each county and the resultant was subtracted to determine net irrigated acreage.

Colorado Irrigated Acres Summary

The total irrigated acreage in the Basin in Colorado in 2000 was 572,483 acres. Surface water irrigated lands are located only in Kit Carson and Yuma Counties and account for 4,763 acres. The total for lands irrigated by ground water is the difference, or 567,720 acres in 2000. No lands were identified that were irrigated by a combination of surface water and ground water pumping.

KANSAS

For the period 1989-1999, irrigated acres from the Water Use Reports were used. Data for 1999 was used for 2000, as the 2000 data have not been compiled yet. The National Agricultural Statistics Service (NASS) Agricultural Statistics provide countywide data that is most complete in Kansas after 1972; however, some irrigated crops are not tracked individually. The Census of Agriculture data from 1987, 1992 and 1997 were used to distribute some acreage to irrigated crops from the total acreage given in the Agricultural Statistics for the years 1972 to 1988. The revised acreages were then multiplied by an estimate of the percentage of each county's irrigated acreage in the model area, determined from the Water Use Report data, and used as the irrigated acres for 1972-1988. For the pre-1972 acreage, the annual well count was multiplied by a ratio of acres per well determined from either the Water Use Reports or the adjusted Agricultural Statistics for 1972, whichever gave a better fit to the subsequent year's estimates. Irrigated acreage for each section was calculated by multiplying the annual well count by the irrigated acres per well, with a maximum of 520 irrigated acres per section. All remaining acreage above the 520 limit was assigned pro rata to other sections with less than 416 irrigated acres (80% of 520 acres).

Kansas Irrigated Acres Summary

The total irrigated acreage for Kansas's counties in 2000 is 449,891 acres.

NEBRASKA

National Agricultural Statistics Service (NASS) is an agency of the US Department of Agriculture (USDA). In cooperation with the Nebraska Department of Agriculture (NDA), NASS prepares an estimate of crop acreage by county. Annually they produce "Nebraska Agricultural Statistics" which is a compilation of information about farms, crops, and livestock. Every five years, NASS produces the Census of Agriculture, which is a detailed counting of farms, crops, and livestock. For the intervening four years, the estimates are prepared using a much smaller sample than the census. Periodically, NASS presents revisions to the annual estimates based on the results of the most recent census.

Reports are prepared annually for Nebraska and the data are collected and summarized statewide and by county. Farmers are surveyed each fall following harvest. Those surveys are supplemented with surveys of grain elevators and mills for volumes of grain received, meat packing plants, and other agribusiness. Crops are added and deleted from the annual report as cropping patterns change. For example, broom corn was deleted from the surveys in the 1960s and sunflowers were added in 1990. Generally, the USDA is most interested in farm program crops such as corn and wheat and the NDA is interested in other crops such as alfalfa, grass hay, fruits, and table vegetables.

The annual reports break out irrigated and non-irrigated acreage for some crops. For other crops, such as alfalfa and corn for silage, NASS reports total acreage harvested every year but reports irrigated acreage periodically. In these cases, estimates of the irrigated acreage for the crop is based on the ratio of reported irrigated acreage and total harvested acreage in other years.

Nebraska Irrigated Acres Summary

The total irrigated acreage for Nebraska counties in the ground water model domain in 2000 is 1,692,521 acres.

CROP IRRIGATION REQUIREMENTS (CIR)

Colorado

The potential irrigation requirements for each crop for each county and year was estimated using the Hargreaves equation calibrated to the Penman-Monteith equation. The crop mix was obtained by County Assessor data. Effective rainfall was estimated using the procedure outlined in Technical Report 21. The gain in soil moisture from winter and spring precipitation was an average of 2.0 inches (source: Republican River Basin Water Management Study, Steven J. Vandas, United States Bureau of Reclamation, March 1983). The net crop irrigation requirement is calculated as the potential consumptive use minus effective precipitation minus the gain in soil moisture from winter and spring precipitation.

Kansas

Using the Penman-Monteith calculations, the composite crop-weighted unit CIR was obtained for each year. Requisite data to calculate the CIR for 1945-1949 was not available, so the average for 1950-1959 was substituted for these years. The unit CIR for 1945-2000, was multiplied by the irrigated acreage described above to obtain volume of irrigation demand for each county. To account for winter soil moisture, a preliminary soil moisture factor was applied to each county in April and, if necessary, May, and was used to offset the CIR at the beginning of the irrigation season. The remaining CIR was then used as an initial estimate of net pumping.

RECHARGE

Estimated recharge is the result of two sources of water: recharge from precipitation and recharge from human activities such as irrigation. Recharge from irrigation is further segmented into two principal components based upon the source of water, surface or groundwater.

PRECIPITATION RECHARGE

Precipitation recharge is a significant variable in the overall water budget because its effect encompasses the entire model domain of over 19 million acres. Average precipitation between 1940 and 2000 varies from approximately 16 inches per year in the western part of the study area to approximately 27 inches per year in the eastern part of the Basin. Recharge from precipitation generally increases from west to east across the domain. Recharge from precipitation is also influenced by soil type. More recharge is generated on sandy soils than clay soils for the same amount of precipitation. Therefore, STATSGO soil maps were used to locate sandy soils in the domain. These areas are commonly referred to as the *sand hills* of Colorado and western Nebraska. Different precipitation to recharge mathematical relationships are assigned to sandy and non-sandy soils.

More complex relationships may be considered, i.e. to account for additional variations in soil types, for non-linear precipitation effects, and for topography. A change in precipitation recharge over time, due to construction of farm terraces and ponds, may be considered.

GROUNDWATER IRRIGATION RECHARGE

The following methodologies are generally agreed upon. The RRCA Ground Water Modeling Committee will develop a common set of procedures and recharge values by system type.

Colorado – Recharge from ground water pumping in Colorado is calculated for each year and for each county. Groundwater recharge from sprinkler irrigation is calculated by multiplying the product of the gross pumping for sprinkler irrigation by the percentage that returns as deep percolation. In a similar manner, the amount of groundwater recharge from flood irrigation is calculated by multiplying the product of the gross pumping for flood irrigation by the percentage that returns to the aquifer as deep percolation. The total amount of recharge from groundwater per county and year is the sum of the returns to deep percolation from sprinkler and flood irrigation.

Kansas - Return flow from ground water irrigation was calculated by subtracting the net pumping from the gross pumping. Once the county monthly pumping and return flow values were calculated, they were distributed to the sections within the county using the annual well count and irrigated acreage. A section's percentage of the county's total irrigated acreage was calculated and multiplied by the county pumping and return flows to obtain values for the section

Nebraska - Based on professional judgment, Nebraska has assumed recharge rates that are generally inverse to assumed farm efficiency. From 1940-1970, recharge is assumed to be 30% of pumping, a value representative of gravity irrigation. Thereafter efficiency is assumed to increase, and recharge to decrease, with implementation of sprinkler irrigation and improvements to gravity irrigation systems. The recharge rate is assumed to be 20% in 2000, and the annual values 1970-2000 are determined by interpolation.

SURFACE WATER IRRIGATION RECHARGE

Estimates of surface water recharge that were used in the RRCA Ground Water Model are calculated as follows:

1. Forty (40) percent of diversions for small non-federal ditches and canals.
2. Twenty-five (25) percent for small surface water pumping plants.
3. As provided by the United States Bureau of Reclamation for federal irrigation projects (reference Section IV.A.2.c in the RRCA Accounting Procedures).

PHREATOPHYTES

The potential evapotranspiration rate for the various classifications of phreatophyte vegetation (forest, woody, and marsh) was collapsed into a single ET rate obtained from CROPSIM (Martin, 1984) results for the Akron, McCook, and Red Cloud climate stations on a monthly time step. The maximum phreatophyte ET rate elevation is set at two (2) feet below ground surface and the extinction depth is at twelve (12) feet below the ground surface. For the initial ground water model runs, the change or encroachment of phreatophytes over time was adjusted in accordance with the curvilinear time-relationship developed from aerial photographic data provided by Michaela Johnson in a published Master's Thesis (Johnson, 2001). The method to quantify the aerial coverage of phreatophytes and the distribution over time is subject to review and adoption by the RRCA Ground Water Modeling Committee, upon unanimous agreement.

Colorado – The Colorado Gap Analysis Project (CO-GAP) was initiated in 1991 as a cooperative effort among federal, state, and private natural resource groups in Colorado. The major objectives of the project are to: map actual land cover as closely as possible and make all GAP Project information available to users in a readily accessible format to institutions, agencies, and private land owners. Landsat imagery was acquired or interpreted to establish a baseline map of vegetation and land cover. Attributes were assigned to each polygon describing primary, secondary, and other land cover, crown closure for forested primary types, and the types of wetlands and/or disturbance found in the polygon, if any. Polygon attributes were assigned using image interpretation, existing maps, field reconnaissance, digital reference layers from Federal land management agencies, and literature sources.

Kansas – Landsat TM7 imagery from 2000 was obtained covering most of the RRCA Ground Water area, except for the far south-central and far-eastern portions. Tributaries with visible phreatophyte cover were mapped as a subset of the hydrographic drainage network available as a digital line graph from the USGS. Tributaries were then divided according to the relative width of the riparian cover. Within each of these discrete reaches, cross sections from the outside boundaries of the riparian vegetation were then mapped and the average cross section within the reach was calculated. One-half of this average cross section was used as the distance from the hydrographic channel mapped by the USGS to map a polygon to enclose the riparian phreatophyte corridor along the reach. These polygons were merged with the Nebraska polygons denoting woody phreatophytes because some areas mapped as woody phreatophytes lay well outside of the riparian corridor. For evaluation of the change in phreatophyte ET over time, Kansas is using two techniques: (1) the Normalized Difference Vegetation Index (NDVI) satellite index to evaluate the change in relative water use between 1974 and 2000 on selected major tributaries, and (2) a time series of air photos for 16 main stem and tributary locations spread throughout the basin on which the vegetation will be evaluated using intercept methods

Nebraska – the Nebraska Department of Natural Resources (NDNR), in association with the Nebraska Conservation and Survey Division maintain a collection of digitally rectified aerial photography for landscape analysis. This data has a resolution of 20-ft. and was projected in UTM, Nad83. The NDNR digitized the 1993 Digital Orthophoto Quarter Quadrangle to identify phreatophyte forests from visual examination of the black and white aerial photography at a scale of 1:15,000. Polygons were fit over the photographs in ESRI's Arc View GIS then re-projected into the RRCA Groundwater Model projection (UTM, Nad27). Approximately 100 sites were visually inspected during field reconnaissance to verify the distribution of woody phreatophytes obtained from the aerial photography. The polygon output provided by Kansas was combined with the aerial photography analysis by Nebraska to include wetland areas in the minor tributaries, with corrections to exclude polygons of irrigated croplands. To accommodate the synoptic biases due to scale, polygon correction was performed at a scale of 1:50,000. Polygons to represent the phreatophyte areas downstream of Red Cloud, Nebraska and the extended groundwater mound area in Kearney and Adams County, Nebraska were derived from aerial photography at a scale of 1:50,000.

CALIBRATION PARAMETERS

Calibration parameters are physical, climatic, and/or aquifer properties that can be adjusted to so that the mathematical representation of a ground water model better represents actual conditions. Selection of final values for calibration parameters requires consideration of the match between model outputs and calibration targets, and whether such values are reasonable considering geologic, climatic, and other conditions in the Basin. Calibration parameters may vary in a spatial context to reflect different physical and/or geographic conditions. The two principal calibration parameters used in application to the RRCA Groundwater Model are hydraulic conductivity and precipitation recharge.

<u>Hydraulic Conductivity:</u> hydraulic conductivity may be defined as the measure of the ease in which water can be transmitted through a porous material, i.e. flow through an aquifer. The hydraulic conductivity values applied in the model are based upon professional expertise and vary across the model domain. The values were distributed spatially using a parameter estimation (PEST) algorithm. Hydraulic conductivity will continue to be refined and statistically distributed throughout the model domain during the calibration process.

<u>Precipitation Recharge:</u> the amount of precipitation that percolates into the ground water aquifer is expressed as a percentage of effective precipitation and is segmented into monthly distributions. Two general soil classifications were identified with the following preliminary precipitation recharge rates: 4 % of annual precipitation for sandy soils, and 1% for non-sandy soils, distributed throughout the year. The precipitation recharge rates may change upon final model calibration. An empirical relationship to reflect the non-linear precipitation/recharge rate was developed to satisfy the physical reality that the recharge rate increases in a curvilinear function with increasing precipitation. In general, the relationship adopted for the calibrated model will be expected to corroborate the basin water budget and the space and time distribution of both runoff and recharge.

Lesser calibration parameters that are used to further refine the ground water model include:

? Canal seepage: will be calculated using a water budget approach of the basic form: *Seepage is equal to Diversions minus Net Evaporation minus Other Net Outflows minus Change in Storage*, when adequate data is available. If only diversions are known, canal seepage will be estimated using the unit loss rates calculated by nearby canals that have sufficient data to employ the water budget approach.

? Phreatophyte potential evapotranspiration rate is indexed to the Red Cloud, Nebraska and Akron, Colorado climate stations with annual rates of 18-36 inches and 30-48 inches respectively. The annual potential evapotranspiration rates were kriged across the model domain.

- Specific yield estimates will continue to be refined during model calibration.
- Residuals: it is recognized that the calibrated model may not perfectly match all the calibration targets, and that residuals (differences between model predictions and target values) may be positive in some sub-basins and negative in others. If necessary, the RRCA Ground Water Modeling Committee will codify a procedure that fairly distributes the residuals among contributory sub-basins and among the three States.