A.1.4 Memorandums on Municipal, Industrial, and Domestic Use for COHSYT2010

Appendix 4-R

Processing Municipal, Industrial, and Domestic Withdrawals and Discharge

Appendix 4-R.
COHYST M & I
Municipal, Industrial, and Domestic Withdrawals and Discharge
Data Acquisition, Estimation, and Incorporation into the COHYST Grid.

To:	COHYST Group
From:	The Flatwater Group
Subject:	M & I write up
Date:	9/19/2011

This memo describes the production of municipal, domestic, and industrial datasets by The Flatwater Group, Inc., for use in the COHYST 2010 numerical ground water model from 1985 to 2010. Using available sources of withdrawals, returns, and population, "baseline" conditions were developed monthly for each entity in the region. Domestic consumptive use was determined from pumping withdrawals and returns converted to a per capita volume, and trended according to annual population estimates. The Industrial consumptive use baseline was developed using data acquired from the surveys mailed to industrial water users. When calculating consumptive use, large industrial uses were separated from municipal uses.

The databases were combined and applied to the COHYST grid in GIS with a descriptive rate of acre-feet per month. Data sources and method used to estimate municipal, industrial, and domestic withdrawals and returns within the eastern and central portions of the COHYST model region are described below.

DATA Sources

Data used in estimating the industrial and municipal withdrawals for the eastern and central portions of the COHYST area were acquired from several locations. The Department of Natural Resources (DNR), local natural resource districts (NRD) (Central Platte NRD, Tri-Basin NRD, Twin Platte NRD), and the United States Geological Survey (USGS) provided pumping measurements and estimates. DNR, NRDs, and the Nebraska Department of Environmental Quality (DEQ) provided discharge measurements and estimates. Information on population and demographics was acquired from the DNR and combined with data from the United States Census Bureau and USGS. The spatial location of the wells was attained from DNR.

DNR circulated two types of water use surveys to industries throughout the COHYST area. In addition, DNR provided population estimates for the COHYST counties and municipalities during several inter-census years. Finally, the DNR provided spatial information on the location of municipal, domestic and industrial wells across the area in the form of the registered groundwater wells database.

The first survey type was titled “Historical Surveys”. Many of the industries surveyed receive their water source from municipal water supplies. This was reported in the upper right-hand section of the first page of the survey. Requested information included industry type, method of discharge, location of discharge if into a stream, DEQ NPDES permits, and the technique used to acquire the annual or monthly data (metered or estimated).

A second DNR water use survey was sent to owners of registered industrial wells. The survey included a list of wells used at an industrial location and requested information on any other wells that were used to supply water to the industry. The survey requested information on the industry type, well, DEQ NPDES permits, and the location where waste water was discharged into the stream, along with monthly or annual pumping and discharge values or estimates and the technique used to arrive at these estimates.

The USGS prepares withdrawal estimates in the form of a USGS water use circular titled “Estimated use of Water in the United States”. These Water use estimates are published every 5 years. Electronic data on a county-level were available from 1985 to the most current publication in 2005. USGS’s water use circular includes withdrawal estimates from publicly supplied water sources, self-supplied domestic water use, self-supplied industrial water use, irrigation, livestock production, mining, thermoelectric power production, and withdrawal totals on a statewide basis, with background data available on a county-level. The water use circulars also include estimates of total population, self-supplied population and publicly supplied population.

For the USGS circulars, the source of all self-supplied domestic withdrawals in Nebraska is assumed to be groundwater. A county’s self-supplied population was calculated as the difference between the total county population and the estimated publicly-supplied population. Withdrawals were estimated based upon the self-supplied population and the average zonal[1] residential delivery per-capita rate based on the results from the public water system survey. Data sources for the self-supplied domestic withdrawals in the 2005 water use circular include the following: a public water supply

[1] As defined by the USGS estimation methods for the self-supplied domestic population withdrawals.

database maintained by the Nebraska Department of Health and Human Services System; a DNR 2005 Public Water System Survey; USGS Water Use in Nebraska, 2000 (USGS); DNR 1995 Water Use Report, and a U.S. Bureau of Census, 2006, 2000-2005 County Population Estimates report.

Besides information on withdrawals, estimates of returns were also obtained. Municipal and Industrial water users who discharge waste water into the streams are required to submit discharge monitoring reports (DMR) to the DEQ. These discharge reports were obtained, when available, to confirm the amount of wastewater discharged by the industry or municipality.

United States Census Bureau records were also used to acquire population estimates for the municipalities and counties that were in the eastern and central portions of the COHYST area. Population estimates from the census were available on a ten-year basis.

Industrial Data and Estimates

The data supplied by the industry contacts came in several different formats. Industries typically provided monthly or annual data based upon metered pumping data, while a few provided summaries of utilities statements. However, many of the industries did not have meters on either their water source or discharge point, and several cited this as the reason they were unable to report their water use. Other industries attempted to make good-faith estimates of either monthly or annual values based on their instantaneous pumping rates, consumption rates, or other methods.

Industries that possessed a DEQ NPDES permit often did not include discharge data, and instead referred to the DMRs submitted to the DEQ. Discharge data were acquired for sites with NPDES permits to match the time period for which the industry supplied withdrawal records.

The metered and estimated data, as well as the DEQ DMR discharge values, were compiled into a database for each surveyed location. While the scope of the project was to investigate municipal and industrial water use from 1985-2010, none of the industrial records were complete for the entire time period. To account for these limitations, estimation techniques were developed to fill in the gaps.

Partially completed set of monthly data points for a year

This first technique was used for those situations where there were unknown monthly water withdrawal values in partially reported years. Water use was not consistent throughout the year for many industries; there were periods where withdrawals were relatively higher or relatively lower. This may be due to a variety of reasons, but when estimating unknown values, it was important that an attempt be made to account for these temporal patterns.

Using years where a complete set of monthly data was available, the monthly distribution for each year was developed by calculating the average proportion of the annual withdrawals that occurred during each month. Using this average monthly distribution, the total amount of withdrawals were estimated by averaging the quantity of the known monthly value divided by the average monthly withdrawal proportion for those months where withdrawal data were available.

$$\widetilde{W_a} = \frac{\sum_{i=1}^{n} \frac{W_i}{\overline{P_i}}}{n}$$

$\widetilde{W_a}$	Estimated annual withdrawals
W_i	Known monthly withdrawal for month i
$\overline{P_i}$	Average monthly proportion of the annual distribution of withdrawals $\left(\sum_{i=1}^{12} \overline{P_i} = 1.0\right)$
n	Number of months with available monthly withdrawal data

The unknown monthly values were estimated by multiplying the estimated annual withdrawals by the corresponding average monthly proportion of the annual distribution of withdrawals. This same technique was applied to the discharge values to estimate missing monthly data points in an incomplete year.

Missing annual and monthly data

For some industrial withdrawal records, entire years' worth of records were missing. For these situations, annual withdrawal data were estimated, using an established procedure. The industries were investigated to ensure that they were operational during the investigation period, and that if they had private wells, that those wells were present during a given year. If the industry had multiple wells, and one or more of those wells was completed during the investigation time period, the estimated withdrawals by the industry were prorated according to the pumping capacity of active wells compared to total pumping capacity for the years prior to the completion date of the well or wells in question. If the industry used a consistent amount of water each year, it was assumed that the pattern for the known period persisted during periods with missing records, and this annual amount was then applied to all the missing years.

Withdrawals for industries that saw fluctuating annual amounts were estimated by considering the average portion of non-irrigation pumping within a respective county that could be attributed to the particular industry. Using the supporting data from the USGS circulars for the years 1985-2005, estimates for the total irrigation withdrawals and the total county withdrawals were obtained. Irrigation encompasses the majority of the total withdrawals for most of the counties of interest. By removing the irrigation estimate from the total estimate, an estimate of the non-irrigation withdrawals was developed. The non-irrigation annual withdrawals for the year 2010 were estimated as either the average of 1985-2005 withdrawals if the volume of water being withdrawn was fluctuating up and down over time, or using a linear regression trend if there was a persistent growth or decline over the time period. Linear interpolation was used to determine the intermediate values.

$$W_t = W_a + (W_z - W_a)\left(\frac{Y_t - Y_a}{Y_z - Y_a}\right)$$

W_t	Estimated non-irrigated withdrawals for a year between Y_z and Y_a
W_a	Estimated non-irrigated withdrawals for a known year prior to the year of interest
W_z	Estimated non-irrigated withdrawals for a known year following the year of interest
Y_t	Year of interest
Y_a	Year of available data prior to the year of interest
Y_z	Year of available data following the year of interest

Initially, the USGS industrial withdrawals estimate was considered as the benchmark for comparisons. However, the USGS water use circulars do not always have a consistent format from publication to publication, and some categories have been eliminated and/or combined to form other categories. This appears to have been the case for industries that use a municipal source. Occasionally, withdrawal estimates obtained for a single industry within the DNR survey data exceeded the annual self-supplied industrial water use estimates in the USGS circular. Because of these circumstances, non-irrigation withdrawal values were developed instead.

These estimates were derived by removing the major source of withdrawals (irrigation) from total USGS county withdrawal estimates. Having estimated the county's non-irrigation withdrawal, the proportion of non-irrigation withdrawals associated with a given industry was determined for each year in which industry withdrawal data were available. These annual proportions were then averaged across all years of available records. This average proportion was then used to estimate annual pumping volumes for each unknown year in the period of interest by multiplying that fraction by the USGS non-irrigation withdrawal value for each year with missing data. The final step was to distribute the annual value to monthly values, which was done by using the average monthly distribution.

The self-supplied industrial withdrawals were geospatially referenced by assigning those values to the COHYST cells where their wells were located. If an industry acquired its water from a municipal supply, the industrial withdrawals were applied to the cell representing the centroid of the municipality. Several municipalities contained multiple industrial sites, in which case the withdrawal values were simply summed and applied to that location.

Estimating Discharge

When discharge values were present in conjunction with the withdrawal values, the annual ratio of discharge to withdrawals was computed. The average relationship was then applied to the years when no annual estimates or values were present, by multiplying the annual withdrawals by this average ratio. This process was undertaken to approximate the annual discharge in unknown years, including years where the withdrawals were estimated. Once the annual amounts had been estimated they were partitioned using the average monthly discharge proportion of total discharge.

Some industry sites included only annual values or estimates. If there were industries that served the same purposes (i.e. two alfalfa pelleting plants) and only one of them had monthly values, the monthly distributions for that industry were applied to the industry that included only annual values. Otherwise the withdrawals or discharges were spread uniformly across the year.

The discharge values were assigned to the COHYST cell that contained the location of discharge, but only if the industry had a known discharge location into a stream. If no discharge locations were identified, it was assumed that the industry had a zero-discharge facility.

Municipal Data and Estimates

Municipal withdrawals and discharges were acquired for 36 communities and estimated for an additional 12 communities in the COHYST model area. Monthly withdrawal and/or discharge data were provided by the Twin Platte NRD, Central Platte NRD, and the Tri-Basin NRD. Supplemental discharge data were acquired from the DEQ DMRs.

Municipal pumping estimates were heavily dependent on the size of the municipal population. Population estimates supplied by the DNR for the years 1994-1999 and 2005 were combined with data from the U.S. Census Bureau from 1980, 1990, 2000, and 2010 to estimate the population for each year during the investigation period. Linear interpolation between two known annual population values was used between the known data points.

Once the population was estimated, the per capita withdrawals or discharges were calculated on a monthly basis for the years with available data. For years with missing data, a moving average of the previously calculated per capita withdrawals or discharges was used to calculate the monthly withdrawal or discharge by multiplying the moving average with the estimated population.

$$\widetilde{W}_{m,y} = \frac{P_y \sum_k C_{m,k}}{n}$$

$\widetilde{W}_{m,y}$	Estimated withdrawal or discharge for the municipality for a given month and year.
$C_{m,k}$	Per Capita withdrawals for a given month (m) and year (k).
P_y	Estimated Population of the municipality during a given year y
n	Number of years in the moving average. An 8 year moving average was used except for those cases with less than 8 years of available data.
m	The month being estimated
k	The years being used in the moving average (n years total).

The next step was to remove the municipally supplied industrial withdrawals from the municipal withdrawals, which was done on a city-by-city basis. Lexington, NE, municipal withdrawals were approximately half of the withdrawals used by Tyson Fresh Meats, the largest industrial user. While the Tyson Fresh Meats water use survey from DNR states that Tyson's water source was from the municipal supply, it was assumed that the industrial withdrawals have already been removed from the municipal withdrawals in Lexington. The municipal withdrawals were then assigned to the COHYST cell containing the centroid of the municipality.

Estimating discharge when no data were present

If no discharge data were available, the annual discharge was estimated as a proportion of withdrawals. The proportion used was calculated in different ways, depending upon the population of the municipality. For municipalities smaller than 1,500, between 1,500 and 10,000, and greater than 10,000, ratios of .341, 0.438, and 0.630 were used to estimate discharge, respectively.

The annual discharge was then distributed by using distributions calculated for other nearby municipalities or municipalities with similar populations. For each town that lacked discharge data, the average monthly discharge distribution for the four closest towns was compared to the average monthly discharge distribution of the four towns with similar population size regardless of location (with the caveat that the towns used to calculate the averages needed to have discharge data available). The difference between these two discharge distribution estimates was rarely greater than 1%, and often below 0.5%. With this in consideration, estimates were made using the distribution of similar sized towns.

Blank values for partial years were estimated using the same procedure explained for the industries. If only the annual amount was reported, it was distributed according to the average distribution based upon municipalities of similar size.

Discharge values were assigned to the COHYST cell at the location where the municipality discharged into a stream. For municipal discharges with no known discharge locations, it was assumed that they employed zero-discharge wastewater facilities.

Domestic Self-Supplied Withdrawal Estimates

Self-supplied domestic withdrawals were calculated based upon the USGS water use circulars published in 1985, 1990, 1995, 2000, and 2005. A value for 2010 was estimated using either 1) the average over the period 1985-2005 if there were sigmoidal fluctuations (Figure 1) every five years or 2) a linear regression model if there was a persistent rise (Figure 2) or decline in the withdrawal rate. Withdrawal rates for years between USGS circulars were estimated using linear interpolation. The monthly distribution developed for a municipality with a population less than 1,500 residents was used to partition the annual withdrawals into monthly values.

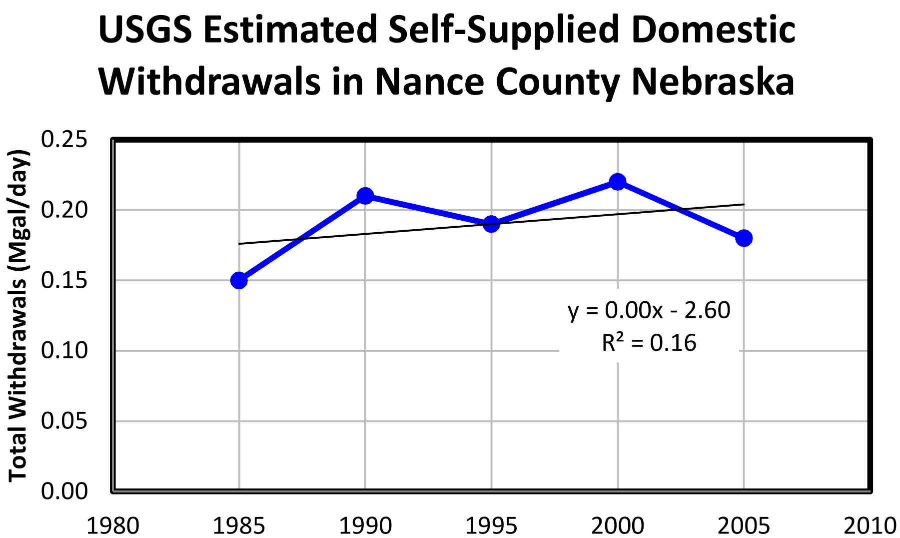


Figure 1. Fluctuating self-supplied domestic withdrawals in Nance County, Nebraska.

A list of all domestic wells with their geographic location was acquired from the DNR registered groundwater well database. The monthly self-supplied domestic withdrawal values were then assigned to the COHYST cells based upon the number of wells present in each cell. A uniform quantity of water withdrawals was assigned to each well and the cumulative amount was assigned to the cell. This process was done for 32 counties wholly or partially contained in the middle and eastern sections of the COHYST model area.

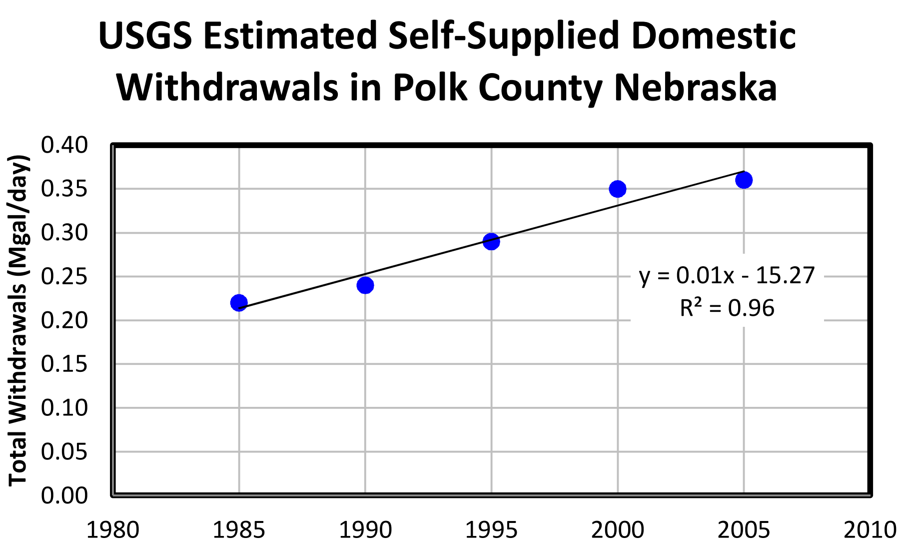


Figure 2. Upward trending self-supplied domestic withdrawals in Polk County, Nebraska.

The maximum level of withdrawals in any given cell was 275,000 gallon pumped in a single month. This occurred during January, 2005, in cell 85066, which was located in Hall County, Nebraska, and contains 49 domestic wells. If the pumps were run 24 hours a day for the entire month, the combined capacity of the 49 wells would need to be less than 6.4 gpm, or 0.13 gpm per well. Assuming the wells were active a quarter of the time, the combined capacities of the well would need to be 25.5 gpm, or 0.52 gpm per well. These values appear to be within the pumping capabilities for a typical domestic well.

Municipal and Industrial Pumping

Prepared By:
The Flatwater Group, Inc

1. Introduction

1.1. Authorization

The Flatwater Group, Inc. (TFG) has prepared this as authorized in the contract between the Nebraska Department of Natural Resources (DNR) and TFG originally dated 9 August 2010.

1.2. Purpose and Scope

Municipal and industrial (M&I) pumping is a small but significant element crucial to the acumen of a robust conjunctive management model. While not encompassing as much spatial area as other parts of the Regionalized Soil Water Balance model (RSWB); the impact of M&I pumping can be substantial in localized area. The M&I development process is shown in figure 1.

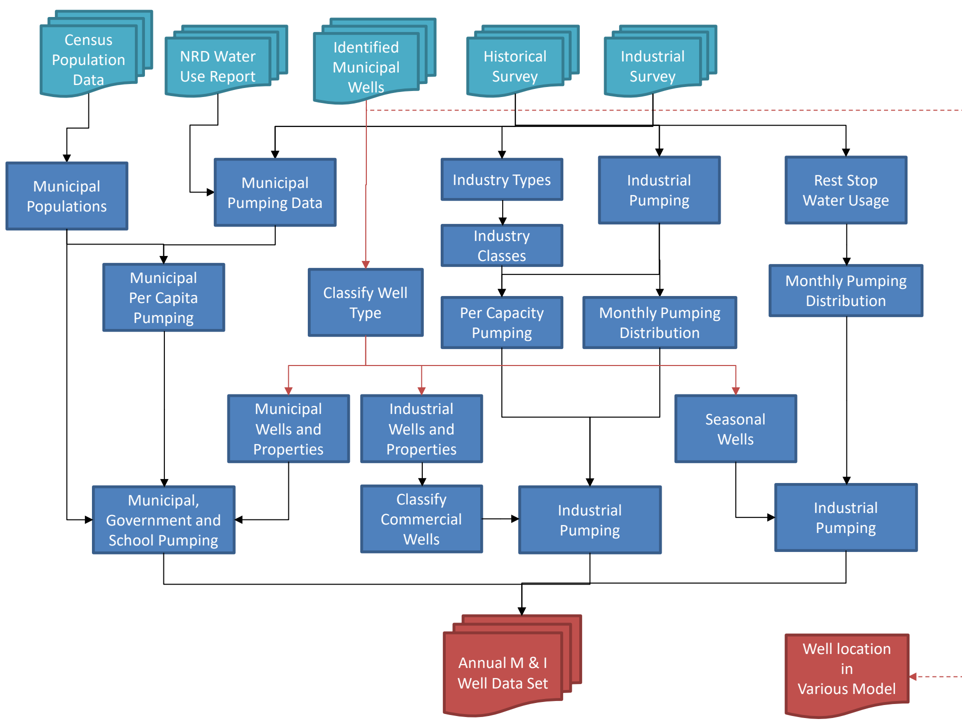


Figure 1. The development process for the M&I state-wide data set.

TFG received a statewide shapefile of registered groundwater wells designated as either Commercial (C) or Public (P or U) from the Nebraska Department of Natural Resources (NDNR). The process to develop the industrial and municipal withdrawals included drawing on data from multiple sources. The Department of Natural Resources (DNR) and the natural resource districts (NRDs) in the COHYST model area (Central Platte NRD, Tri-Basin NRD, Twin Platte NRD) provided pumping measurements and estimates; and additionally the spatial location of the wells. United States Census Bureau data was downloaded from the Nebraska Department of Economic Development website.

DNR circulated two types of water use surveys to industries throughout the COHYST model area. The first type was title “Historical Surveys”. Information contained in the surveys includes the industry type, monthly and or annual pumping, and the technique used to acquire the data (metered or estimated). Many of the industries surveyed received their water source from municipal water supplies; however, this information provided valuable insight into the volume of water that was withdrawn by the industry.

A second type of water use survey was sent to owners of registered industrial wells; "Industrial Surveys". The survey included a list of wells used at an industrial location; with the request for information on all pumping from any other wells supplying water to the industry. Additionally, the survey requested information on the type of industry, well properties, and the technique used to arrive at the reported pumping totals.

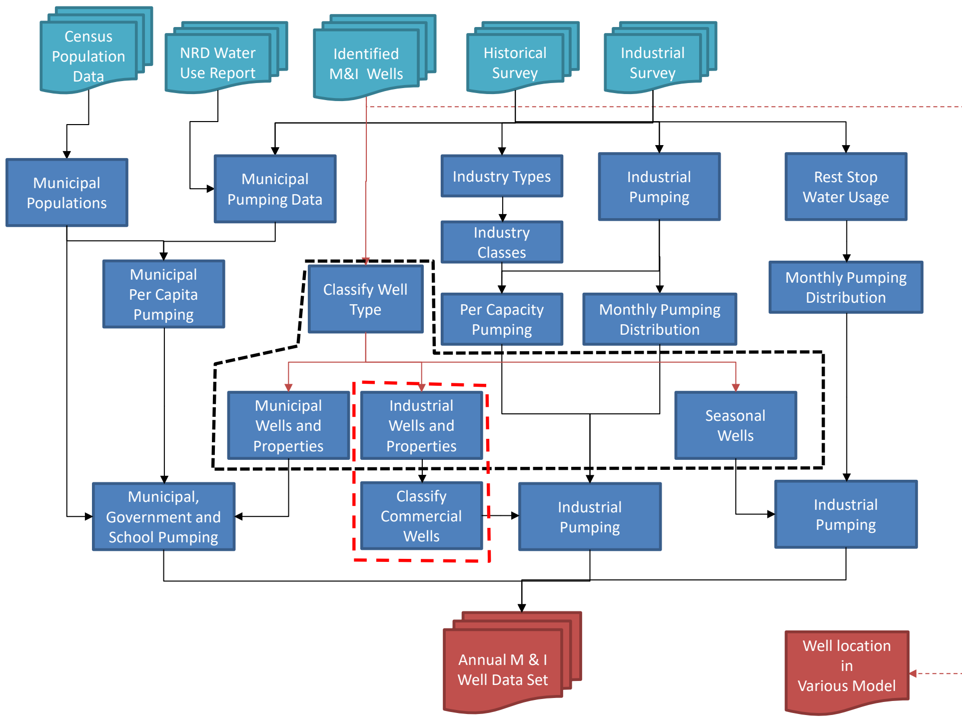
The inclusion of municipal pumping information in either the industrial or historical surveys was sparse. To supplement this limited information, data used in the development of the 2010 NRD water use reports from the TPNRD, CPNRD, and TBNRD was incorporated into the development of the M&I pumping data set.

The populations of the municipalities were acquired from the US Census Bureau for the years 1930-2010.

The statewide well coverage was overlaid with the 6 water basin model grids individually as well as the statewide model grid to determine the grid cells each well resided within. This tabular data was imported into a database where it is combined with the population data based on municipality. The total well capacity of a municipality is calculated to be used in the distribution process. A separate municipal well capacity is also calculate based on the model grid which the wells are located in. For instance, if a municipality has several wells located in one model grid and others located within another model grid, a separate capacity is calculated for each group of wells and associated with the appropriated model grid id.

This data was used in various forms to develop three different datasets depicting pumping estimates from municipalities and industries based upon the characteristics of the well and the type of industry using the well.

2. Well Classification



The first step was to classify all of the identified wells. Six different types of wells were readily identifiable based upon the owner of the well; public, commercial, seasonal, governmental, public interest, and educational.

- Public wells were defined as those wells that fed the municipalities.
- Commercial wells were owned by individual or companies whose was deemed as neither agricultural nor domestic in use. Examples included private business, power production facilities, golf courses, etc…
- The seasonal classification consisted of wells that provided water for items such as campgrounds or the Nebraska Game and Parks Commission.
- The governmental class includes wells for governmental services associated with public safety. These items include prisons, military installations, and law enforcement centers.
- Public Interest well mainly consisted of wells to meet the needs of the travellers and transportation. These wells included those owned by the Nebraska Department of Roads and the wells used to operate rest stops.
- Educational wells were wells that were owned by school districts or institutions of high learning.

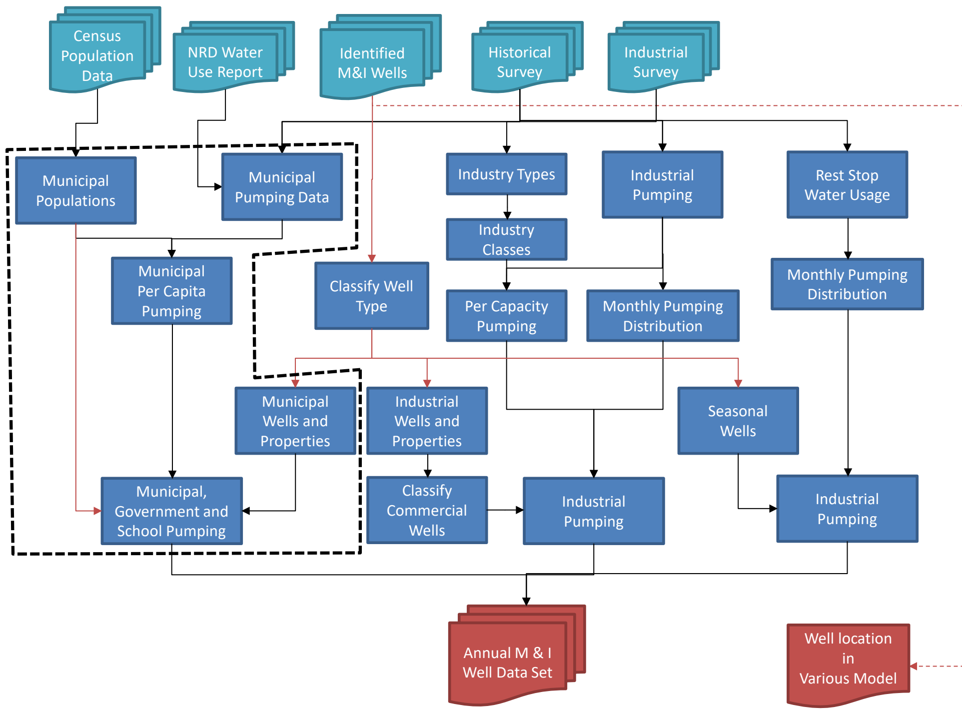
Unfortunately, this level of classification was not sufficient to match the well information with the available information from the data sources. To account for this these classes were further combined into three groups.

The educational and the governmental wells were combined with the public wells to form the municipal well group. Data limitations failed to provided enough information to independently develop estimates for the water usage by the entities described in the governmental or educational well classes. However, the presences of similar entities potentially exist within the constructs of the users of the public wells used to develop municipal pumping estimates.

Seasonal and public interest wells were combined as they were both deemed dependent upon the number of users with small amounts of net consumptive use.

The commercial wells are the only group included in the industrial well data set.

3. The Estimation of Municipal Pumping



The estimated pumping for municipal, governmental, and educational wells was developed using a per capita pumping values for the municipality to which the well belongs. By interpolating between the decadal populations retrieved from the 10 year census, an annual population was developed. The population in 2011-2012 was the product of extrapolating each town's population trend between 2000 and 2010.

$$pop_i = pop_1 + (pop_2 - pop_1)\left(\frac{year_i - year_1}{year_2 - year_1}\right)$$

pop	population
year	year
i	pertaining to the estimated year
1	first interpolating/extrapolating point
1	second interpolating/extrapolating point

Next, the municipal pumping data was organized by municipality. Using the annual population estimates, the per capita pumping was determined by dividing each monthly pumping value by the annual population. An average per capita pumping for each month was taken over the period of available pumping data. This process was repeated for each municipality. The list of municipalities is shown located in Appendix A.

An average monthly per capacity pumping distribution was developed for three groups based upon population. These however, did not differ significantly from a simple average over the entire set of municipalities. Therefore, the single average monthly per capita pumping distribution was utilized. The distribution is shown in Table 1.

Table 1. Monthly Per Capita Pumping

Month	Per Capita Pumping (Mgal/person)
Jan	0.0053
Feb	0.0048
Mar	0.0057
Apr	0.0066
May	0.0095
Jun	0.0119
Jul	0.0161
Aug	0.0134
Sep	0.0110
Oct	0.0079
Nov	0.0057
Dec	0.0054

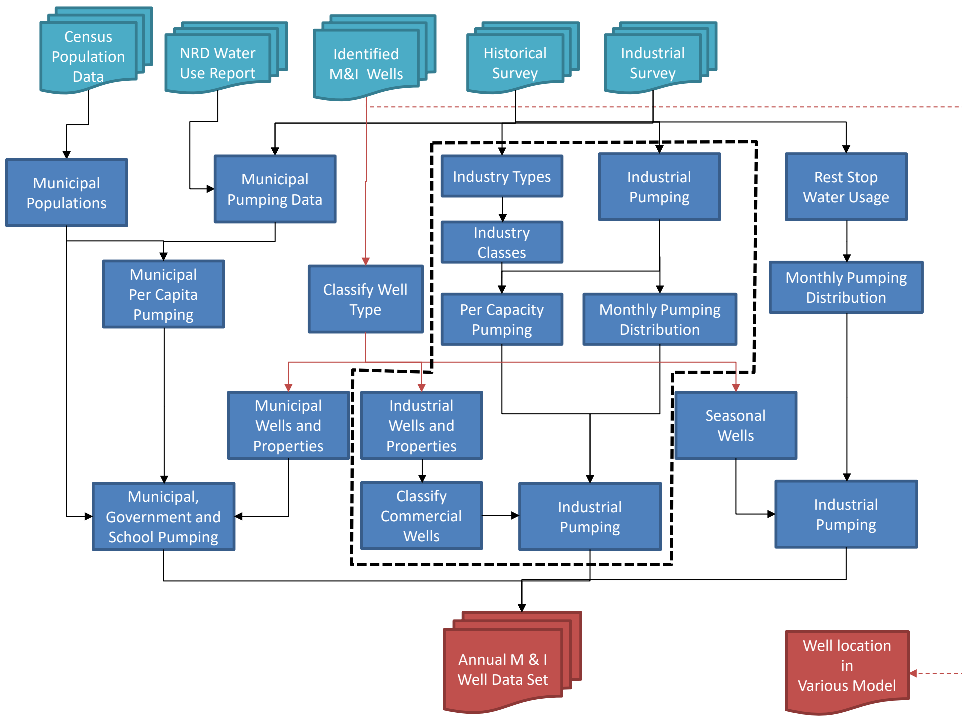
Having developed the monthly per capita pumping distribution and annual population estimates, the total volume of water pumped by the municipality can be estimated. This amount is then split between all active wells feeding the municipality, weighted by the relative capacity of the well.

$$P_{well,i} = Pop_j * P_{pc,i} * \frac{Cap_{well}}{Cap_{muni,j}}$$

$P_{well,i}$	Pumping for the well in month i
Pop_j	Population for the municipality in Year j
$P_{pc,i}$	Pumping per capita in month i
Cap_{well}	Capacity of the well
$Cap_{muni,j}$	Total capacity of the municipality in year j

The towns of Yankton, SD; Julesburg, CO; and Bern, KS all had water sources within the state of Nebraska. However, total pumping capabilities for these municipalities was unknown. Therefore, the populations were adjusted to 10%, 25%, and 25% respectively.

4. The Estimation of Industrial Pumping



Using the data collected by DNR in the Historical and Industrial Surveys, the following technique was developed to estimate industrial pumping volumes for the state-wide M&I dataset. The survey results provided water use information for 50 different industrial sites. The average annual volume of water usage and the average monthly pumping distribution were compiled for each industrial site. Also, when available the pumping capacity of the individual industry was obtained. This information was augmented with data relating to the industry from the Nebraska Well Registry.

The next step was to create and assigned different industrial categories to group similar types of water users. Twelve different classes were developed. Additionally two large water users, Western Sugar Cooperative and the Sutherland coal power plant, remained as unique groups. The different industrial classes are:

1. Western Sugar Cooperative
2. Ethanol Production
3. Golf Courses
4. Meat Packing and Animal Byproduct Manufacturing
5. Sand and Gravel
6. Confined Animal Feeding Operations (CAFO)
7. Construction
8. Power Plants

9. Small Manufacturing
10. Medium Manufacturing
11. Large Manufacturing
12. Small Business
13. Raceways
14. The Sutherland Coal Power Plant

As with any water user, even within an industry, the amount of water that is consumed varies for several reasons including: size, product, etc... Therefore, a technique was developed to estimate the per capacity annual pumping for each defined industrial class. This was accomplished first by determining the average annual volume of water used for each industrial class. Next the average total capacity per industrial class was computed. The industrial class per capacity pumping was the result of dividing the average industrial pumping by the average industrial capacity.

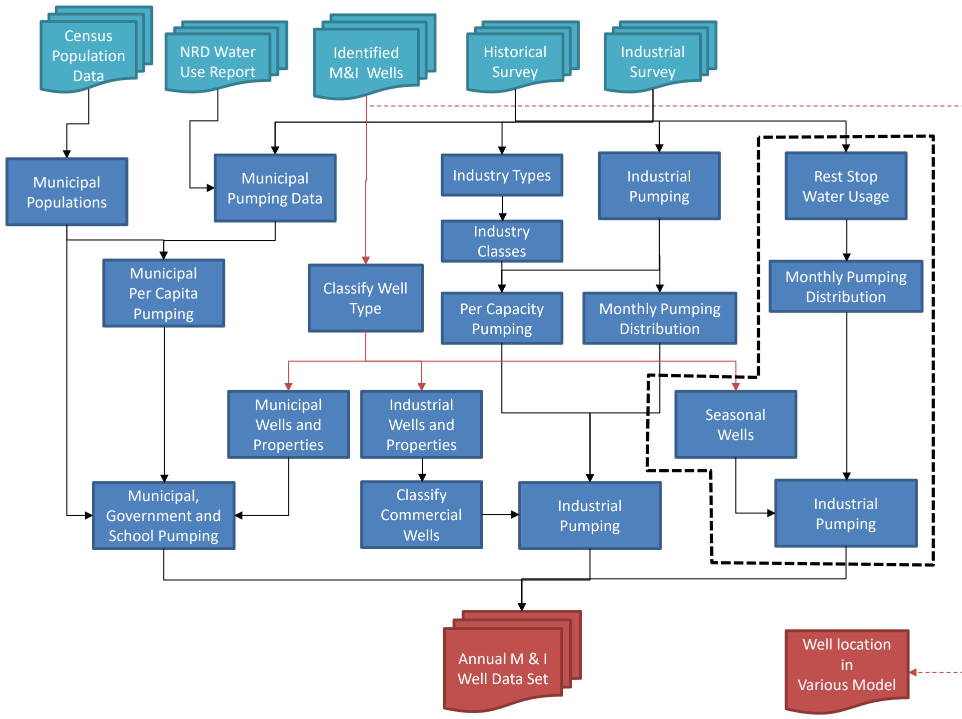
Finally the monthly distribution for each industry class was determined by averaging the distribution for each industry. Two exceptions existed, CAFO and power plant. All CAFOs reported that they were using the same volume of water throughout the year. Therefore, the CAFO water use was evenly distributed between the months. The power plant monthly distribution was developed using the monthly power production distribution from US Energy Information Administration for 2011-2012.

The next step was to assign the various industries within the well file to the corresponding industrial class. A short internet search was performed on each individual company. The results were used to classify the company to the correct group. Unfortunately, the sample of industries in the historical and industrial surveys was not sufficient to cover all types of industries within the state. Therefore, some rules were developed to classify the remaining businesses.

- Mining and Fossil Fuel extraction was classified as large industrial
- Agriculture production types were classified as golf course (nurseries, vegetable, etc…)
- Well drilling was classified with sand and gravel
- Game and Parks wells were classified as golf courses
- Unknown Business types were classified by total well capacity (gpm):
    - 0 – 350 small business
    - 350 – 600 small manufacturing
    - 600 – 1250 medium manufacturing
    - 1250 + large manufacturing

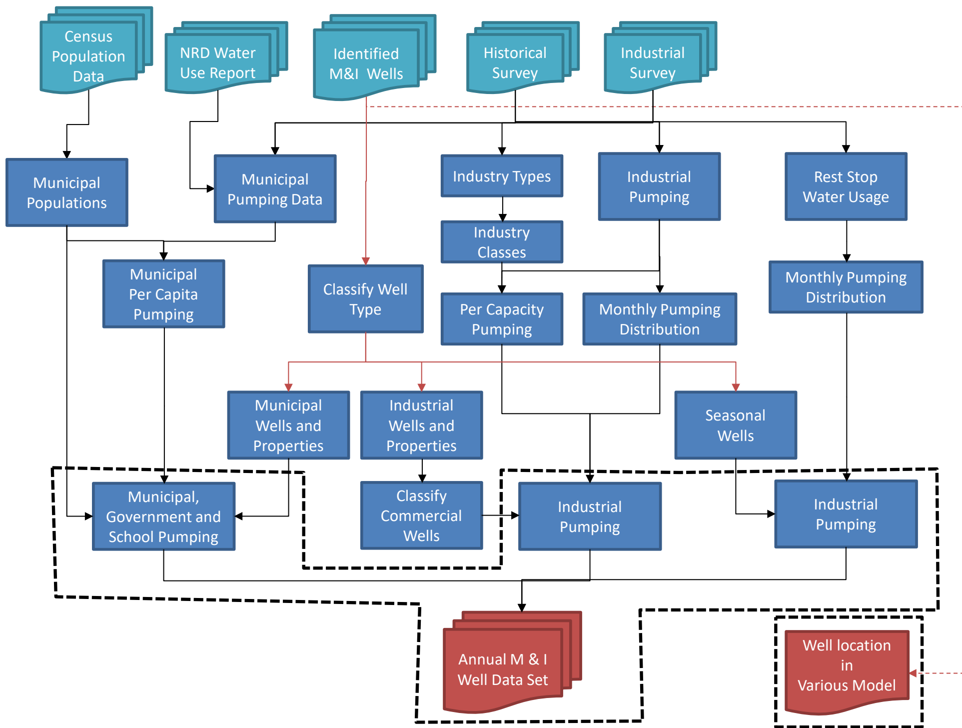
The appropriate per capacity pumping and monthly distribution was applied to each well to develop the industrial pumping data set from industrial wells.

5. The Estimation of Seasonal Industrial Pumping



The seasonal industrial pumping data set was developed based upon the results of the Rest Stop Water Usage from the Industrial Survey. The rest stop water data was developed based upon the per visitor water usage, with each visitor using 2.5 gal. The total monthly water usage was estimated for each rest area in the sample population. The monthly average over all sample rest areas was used to define the monthly pumping distribution for the seasonal industrial wells. The distribution was then applied to all seasonal wells to create the Seasonal Industrial Pumping data set.

6. Process Results



The results from the municipal pumping, industrial pumping, and seasonal industrial pumping are compiled to create the Annual M&I state wide data base. This file contains the well, the years and the volume of pumping that occurs from the well each month.

The Annual M&I state wide data base is to be used in combination with the well location file. The well location file contains the model cell ID for each RSWB model and the state-wide grid; Western Water Use Model (WWUM), Upper Niobrara White Model (UNW), the Central Nebraska Model (CNEB), the Blue Basin Model (BBM), COHYST, and the Missouri Tribs; in which the well is located.

Appendix A

The municipalities used to create the per capita pumping distribution are listed in Table A.1. Each month contains the average per capita pumping for each town over the time period when pumping records were available. The average population is also depicted over this same time period.

Table A.1. Municipality average per capita pumping values used to create the municipal per capita pumping distribution.

#	city	Ave Pop	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Brady	396	0.005	0.006	0.005	0.007	0.014	0.017	0.028	0.022	0.016	0.009	0.005	0.005
2	Brule	367	0.005	0.004	0.004	0.006	0.010	0.013	0.016	0.014	0.010	0.006	0.004	0.005
3	Maxwell	311	0.004	0.004	0.005	0.005	0.006	0.009	0.010	0.008	0.005	0.005	0.003	0.004
4	Ogallala	4771	0.004	0.003	0.004	0.005	0.009	0.010	0.013	0.012	0.009	0.005	0.004	0.003
5	Paxton	554	0.004	0.004	0.005	0.006	0.009	0.010	0.014	0.014	0.010	0.007	0.005	0.004
6	Sutherland	1223	0.005	0.005	0.006	0.006	0.007	0.010	0.012	0.012	0.011	0.007	0.005	0.005
7	North Platte	24097	0.005	0.005	0.005	0.007	0.009	0.012	0.014	0.014	0.012	0.009	0.005	0.005
8	Axtell	711	0.005	0.004	0.005	0.006	0.009	0.012	0.019	0.015	0.011	0.008	0.005	0.005
9	Bertrand	778	0.005	0.005	0.005	0.007	0.012	0.014	0.024	0.017	0.015	0.009	0.006	0.005
10	Elwood	720	0.006	0.005	0.006	0.008	0.011	0.013	0.017	0.015	0.012	0.009	0.007	0.006
11	Funk	194	0.011	0.007	0.010	0.008	0.005	0.011	0.014	0.013	0.014	0.013	0.006	0.011
12	Loomis	382	0.004	0.005	0.005	0.008	0.014	0.020	0.029	0.021	0.016	0.008	0.005	0.004
13	Smithfield	62	0.004	0.004	0.005	0.005	0.007	0.008	0.012	0.012	0.010	0.012	0.005	0.005
14	Alda	631	0.004	0.004	0.004	0.004	0.007	0.010	0.012	0.010	0.008	0.005	0.004	0.004
15	Amherst	257	0.010	0.009	0.011	0.013	0.015	0.020	0.027	0.020	0.021	0.020	0.012	0.012
16	Cairo	786	0.004	0.004	0.004	0.005	0.008	0.010	0.015	0.012	0.009	0.006	0.004	0.004
17	Central City	2929	0.005	0.006	0.006	0.007	0.010	0.010	0.010	0.014	0.011	0.010	0.009	0.009
18	Cozad	4185	0.006	0.006	0.017	0.009	0.014	0.018	0.023	0.018	0.015	0.009	0.006	0.006
19	Doniphan	773	0.006	0.006	0.006	0.007	0.009	0.013	0.018	0.014	0.012	0.008	0.006	0.006
20	Duncan	346	0.006	0.003	0.003	0.009	0.012	0.010	0.011	0.009	0.007	0.005	0.003	0.003
21	Elm Creek	873	0.006	0.005	0.006	0.007	0.011	0.014	0.020	0.015	0.013	0.008	0.006	0.006
22	Eustis	427	0.006	0.005	0.005	0.008	0.014	0.018	0.025	0.019	0.017	0.010	0.006	0.005

#	city	Ave Pop	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
23	Farnam	213	0.004	0.004	0.004	0.005	0.007	0.009	0.013	0.013	0.011	0.007	0.006	0.006
24	Gibbon	1785	0.006	0.005	0.006	0.006	0.005	0.009	0.011	0.009	0.008	0.008	0.007	0.004
25	Grand Island	44164	0.008	0.007	0.008	0.008	0.011	0.013	0.017	0.015	0.012	0.010	0.008	0.008
26	Gothenburg	3606	0.005	0.005	0.006	0.008	0.012	0.014	0.019	0.016	0.013	0.009	0.006	0.005
27	Kearney	28722	0.004	0.004	0.004	0.005	0.007	0.009	0.012	0.010	0.009	0.006	0.005	0.004
28	Lexington	9840	0.005	0.004	0.006	0.006	0.010	0.010	0.013	0.010	0.008	0.006	0.005	0.005
29	Overton	650	0.002	0.003	0.003	0.004	0.005	0.005	0.007	0.005	0.003	0.003	0.002	0.002
30	Riverdale	206	0.004	0.004	0.004	0.005	0.007	0.009	0.011	0.008	0.006	0.005	0.013	0.004
31	Shelton	1085	0.005	0.004	0.004	0.005	0.007	0.008	0.013	0.011	0.008	0.006	0.004	0.004
32	Wood River	1217	0.005	0.005	0.006	0.007	0.009	0.012	0.015	0.013	0.011	0.007	0.005	0.005

Appendix B

The list of industries from the historical or industrial surveys used to create the industrial classes and their distributions are shown in Table B.1.

Table B.1. Industrial sites used to create the industrial pumping data.

#	Name	Industrial Class
1	Gothenburg Feed Products Co	10
2	Chief Fabrication	10
3	Chief Buildings	10
4	Chief Agri Industrial	10
5	Chief Custom Products	10
6	Chief Automotive Systems Inc	12
7	Tyson Fresh Meats, Inc.	4
8	Diamond Plastics Corp	10
9	Pennington Seed, Inc	9
10	Consolidated Concrete, Co	5
11	Masonite Internatinoal Corp	9
12	Eilers Machine and Welding	9
13	L & S Industries, Inc	9
14	G Tech, Inc	9
15	Archer Daniels Midland Co.	9
16	Dy-NA Tool & Mold, Inc	10
17	Sutherland Industries	12
18	Monroe Auto Equipment Co	10
19	Consolidated Blenders Inc.	5
20	Island Dehy Co Inc.	10
21	Hornady Manufacturing Company	11
22	Orthman Manufacturing, Inc	9
23	West Company Inc.	11
24	Veetronix, Inc.	12
25	Electronic Display Systems	9
26	Baldwin Filters, Inc	10
27	Baldwin Filters	11
28	Big Flag Farm Supply Inc.	12
29	Western Sugar Cooperative	1
30	Werner	5
31	Wood Drive Dairy	6
32	Werner Construction	7
33	US 30 Speedway, LLC	13
34	KCC Feeding Inc.	6

#	Name	Industrial Class
35	Brown Sheep Company Inc	10
36	Alma Golf Course	3
37	Procter & Gamble	11
38	Nebraska Public Power District	8
39	Philips - Golf Course	3
40	Halimage Farms LLC	6
41	Nebraska Energy LLC	2
42	Agriculture Services Inc	10
43	Simon Contractors	5
44	Petersons Supermarket	12
45	Nitro Construction	7
46	Abengoa Bioenergy	2
47	Gibbon Packing Inc	4
48	Island Land Handlers	5
49	Nutra-Flo Company	10
50	Miscellaneous Ethanol Plant*	2

*By request of the ownership and to protect trade secrets, this name is being withheld from publication.

Appendix C

The list of industrial classes is shown in Table C.1. The table includes the average class annual pumping, the average class per capacity pumping, and the average portion of the annual pumping that occurs during each month.

#	Industrial Class	Annual Pumping (Mgal)	Per Capacity Pumping (gal/gpm)	Average Distribution of Annual Pumping											
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Western Sugar Cooperative	1,463.786	221,786	0.107	0.084	0.096	0.055	0.038	0.037	0.050	0.063	0.081	0.142	0.120	0.126
2	Ethanol	311.029	112,150	0.083	0.073	0.080	0.082	0.083	0.084	0.091	0.087	0.085	0.090	0.081	0.081
3	Golf Course	17.390	53,922	-	-	0.038	0.066	0.085	0.094	0.131	0.192	0.178	0.160	0.056	-
4	Meat Packing and Animal ByProducts	614.104	372,185	0.081	0.079	0.084	0.074	0.081	0.088	0.085	0.093	0.087	0.084	0.083	0.080
5	Sand and Gravel	29.450	26,652	0.051	0.051	0.058	0.074	0.092	0.099	0.095	0.102	0.147	0.098	0.076	0.058
6	CAFO	39.541	36,111	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083
7	Construction	0.110	109	-	-	0.044	0.108	0.108	0.216	0.201	0.137	0.137	0.049	-	-
8	Power Plant	6.760	193,143	0.084	0.084	0.080	0.089	0.098	0.112	0.108	0.090	0.083	0.082	0.090	-
9	Small Manufacturing	0.426	2,131	0.087	0.087	0.077	0.068	0.074	0.082	0.079	0.086	0.091	0.083	0.079	0.107
10	Medium Manufacturing	3.057	1,703	0.053	0.054	0.076	0.058	0.069	0.123	0.121	0.103	0.124	0.077	0.064	0.078
11	Large Manufacturing	78.822	43,912	0.093	0.090	0.095	0.077	0.076	0.077	0.079	0.082	0.080	0.083	0.080	0.088
12	Small Business	0.233	4,673	0.023	0.021	0.021	0.027	0.050	0.093	0.117	0.172	0.149	0.144	0.119	0.065
13	Raceway	0.120	400	-	-	0.038	0.066	0.085	0.094	0.131	0.192	0.178	0.160	0.056	-
14	Sutherland Power Plant	4,353.780	72,989	0.084	0.084	0.080	0.089	0.098	0.112	0.108	0.090	0.083	0.082	0.090	-

Appendix D

The seasonal industrial pumping is dependent upon the rest stop water use. The rest stops listed in Table D.1. were included in the development of the rest stop pumping distribution.

Table D.1. Rest stops included in the creation of the seasonal pumping distribution.

Station	County	City
Melia Hill	Sarpy	Gretna
Platte River	Cass	Greenwood
Lincoln Solar	Lancaster	Lincoln
York WB	York	York
York EB	York	York
Grand Island WB	Hall	Grand Island
Grand Island EB	Hall	Grand Island
Sutherland WB	Lincoln	Sutherland
Sutherland EB	Lincoln	Sutherland
Brady WB	Lincoln	Brady
Brady EB	Lincoln	Brady
Chappell WB	Duel	Chappell
Chappell EB	Duel	Chappell
Sidney WB	Cheyenne	Sidney
Sidney EB	Cheyenne	Sidney
Kimball EB	Kimball	Kimball
Kimball WB	Kimball	Kimball
Ogallala EB	Keith	Ogallala
Ogallala WB	Keith	Ogallala
Cozad EB	Dawson	Cozad
Cozad WB	Dawson	Cozad
Kearney EB	Buffalo	Kearney
Kearney WB	Buffalo	Kearney
Goehner WB	Seward	Goehner
Blue River EB	Seward	Milford

Table D.2. Monthly distribution of seasonal industrial pumping.

Mon	Pumping (gal)
Jan	30,799
Feb	29,426
Mar	43,174
Apr	48,037
May	61,025
Jun	69,021
Jul	84,227
Aug	65,488
Sep	57,772
Oct	54,188
Nov	44,495
Dec	37,589

Memorandum

To:	Ann Dimmitt – TPNRD; Kari Burgert – NDNR
From:	The Flatwater Group, Inc.
CC:	Michael Krondak - NPPD
Date:	10/22/2018
Subject:	COHYST Area Robust Review: Gerald Gentleman Station M&I Pumping

Project Background and Workflow

The Flatwater Group, Inc. (TFG) was contracted by the Platte Basin Water Coalition through the Nebraska Department of Natural Resources (NDNR) to provide technical assistance for the Robust Review project. The purpose of the Robust Review project is to assess streamflow impacts resulting from management actions taken as part of the Basin-Wide Plan and/or Natural Resource District (NRD) Integrated Management Plans (IMPs). The focus of this memorandum is to document changes to the Municipal and Industrial (M&I) Pumping at the Gerald Gentleman Station (GGS) within the Twin Plate NRD (TPNRD).

TFG's primary task was to modify the GGS M&I pumping by replacing the estimated GGS pumping developed as part of the Statewide M&I efforts[1] with the values from the Nebraska Public Power District (NPPD) annual reports to NDNR. The new M&I data sets are to be used in the Robust Review Scenarios.

Data Collection

TPNRD and TFG reached out to NPPD, who provided TFG with the monthly pumping volumes from 2005 forward. NPPD provided three files:

1. GGS Industrial Well Report for 2013.pdf
2. GGS Industrial Well Report for 2012.pdf
3. Historical GGS Well Field Monthly pumping from Isaac Mortensen modeling.xlsx

The GGS pumping is divided between two well fields. One well field (Well Field 1) is used to meet the plant operation needs. Well field 1 is comprised of 5 wells, but unmetered. The pumping for the Well Field 1 was estimated by NPPD based upon their typical annual usage. This amounted to 873 AF/year. The pumping was split evenly throughout the year based upon NPPD's description of typical usage.

The second well field (Well Field 2) is part of the cooling water system. Well Field 2 has 38 wells, of which 27 are currently being utilized. Monthly pumping volumes for Well Field 2 were provided from commencement of operations in 2005 through 2013 (Table 1). To project the M&I pumping into the future, an average of the last 6 years of reported data was used[2].

To estimate the net effect operation of the Well Field 1 & 2 have on the aquifer, it was assumed that 50% of the total pumping was consumed with the other 50% returning eventually to the aquifer. This

[1] Details on the Statewide M&I efforts are documented in: ftp://dnrftp.dnr.ne.gov/Pub/INSIGHTDocumentation/2015/DataAndDocumentation/AdditionalBackUpData/MunicipalAndIndustrialPumping/MunicipalAndIndustrialPumping_TFG2014.pdf

[2] The initial GGS pumping estimates were based upon the M&I Survey performed by NDNR. NPPD provided pumping volumes for the years 2005-2007 for that survey. The 6-year average was used to reflect more current operating procedures.

assumption is consistent with the approach taken in developing the Statewide M&I dataset. This assumption was incorporated by applying a multiplier of 0.5 to the estimates of total pumping discussed above. This yielded 436.5 AF/year from Well Field 1, while the net pumping estimates from Well Field 2 are shown in Table 2.

Table 1. GGS Well Field 2 reported pumping volumes.

Year	Annual Pumping	January	February	March	April	May	June	July	August	September	October	November	December
2005	4,210.9	-	-	-	-	-	-	1,551.3	2,165.2	490.7	3.7	-	-
2006	3,442.4	-	-	-	-	1.2	43.4	957.3	2,440.5	-	-	-	-
2007	8,194.0	-	-	-	-	4.0	870.9	1,705.3	5,406.2	207.6	-	-	-
2008	426.1	-	-	-	-	5.2	167.7	94.5	158.7	-	-	-	-
2009	3,241.1	-	-	-	1.0	11.4	1,243.5	1,391.0	587.7	-	6.5	-	-
2010	1,127.0	-	-	-	-	7.1	589.2	530.7	-	-	-	-	-
2011	13.3	-	-	-	-	5.0	1.0	1.0	0.4	5.5	0.4	-	-
2012	47.0	-	-	-	-	5.0	-	13.0	-	-	21.0	8.0	-
2013	116.0	-	-	-	-	-	9.0	-	1.0	100.0	5.0	1.0	-
Projected	828.4	-	-	-	0.2	5.6	335.1	338.4	124.6	17.6	5.5	1.5	-

Table 2. GGS Well Field 2 net M&I pumping volumes.

Year	Annual Pumping	January	February	March	April	May	June	July	August	September	October	November	December
2005	2,105.5	-	-	-	-	-	-	775.7	1,082.6	245.4	1.9	-	-
2006	1,721.2	-	-	-	-	0.6	21.7	478.7	1,220.3	-	-	-	-
2007	4,097.0	-	-	-	-	2.0	435.5	852.7	2,703.1	103.8	-	-	-
2008	213.1	-	-	-	-	2.6	83.9	47.3	79.4	-	-	-	-
2009	1,620.6	-	-	-	0.5	5.7	621.8	695.5	293.9	-	3.3	-	-
2010	563.5	-	-	-	-	3.6	294.6	265.4	-	-	-	-	-
2011	6.7	-	-	-	-	2.5	0.5	0.5	0.2	2.8	0.2	-	-
2012	23.5	-	-	-	-	2.5	-	6.5	-	-	10.5	4.0	-
2013	58.0	-	-	-	-	-	4.5	-	0.5	50.0	2.5	0.5	-
Projected	414.2	-	-	-	0.1	2.8	167.5	169.2	62.3	8.8	2.7	0.8	-

Creation of the new Watershed Model M&I Pumping input files

The new input data sets were developed by beginning with the original COHYST M&I dataset: *MI001*. Returning to the statewide M&I dataset list of industrial well locations, the COHYST model cells containing GGS wells were identified. The M&I pumping within these cells was removed to create the M&I data set: *MIrr_001*[3].

The GGS pumping was used to create a separate M&I dataset: *GGSrr_002*. The GGS well field volumes were split between the individual wells based upon the relative well capacity compared to the total capacity of all actively utilized wells in the respective well field. The pumping was spatially placed in the COHYST model grid using the location of the wells.

Results

By switching from the initial GGS estimates to the reported values, the net pumping for GGS was reduced by ~6,500 AF/year after well field 2 was completed. Total GGS pumping from both well fields in the projected period reduced by just under 7,000 AF/year.

Table 3 provides an overview of the annual M&I pumping used in the first (Baseline 001[4]; Column A) and second (Baseline 002; Columns B-D) iterations of the robust review baseline. The information used for the second iteration of the baseline contains a summary of the GSS pumping (D) and the balance of the COHYST M&I pumping (C). These volumes are combined to arrive at the total M&I pumping (B). Finally, Table 3 continues with a summation of the resultant change in M&I as a result of the changes to the GGS pumping.

Table 3. M&I Pumping in the Robust Review

	Baseline 001	Baseline 002			
Year	(A) M&I Pumping (MI001)	(B) = C + D Total M&I Pumping	(C) M&I Pumping (MIrr_001)	(D) Gerald Gentlemen Station (GGSrr_002)	(E) = B - A Change in M&I Pumping
1950	14,790	14,790	14,790	-	-
1951	14,898	14,898	14,898	-	-
1952	15,183	15,183	15,183	-	-
1953	16,165	16,165	16,165	-	-
1954	17,594	17,594	17,594	-	-
1955	17,824	17,824	17,824	-	-
1956	19,085	19,085	19,085	-	-
1957	19,548	19,548	19,548	-	-
1958	19,736	19,736	19,736	-	-
1959	19,840	19,840	19,840	-	-
1960	20,024	20,024	20,024	-	-
1961	20,756	20,756	20,756	-	-
1962	21,288	21,288	21,288	-	-

[3] TFG checked for additional M&I wells not belonging to GGS in these cells and found none.
[4] The same M&I pumping used in Baseline 001 was also used in the documented COHYST 2010 Run028.

Table 3. M&I Pumping in the Robust Review

Year	Baseline 001 (A) M&I Pumping (MI001)	Baseline 002 (B) = C + D Total M&I Pumping	(C) M&I Pumping (MIrr_001)	(D) Gerald Gentlemen Station (GGSrr_002)	(E) = B - A Change in M&I Pumping
1963	22,498	22,498	22,498	-	-
1964	23,612	23,612	23,612	-	-
1965	24,352	24,352	24,352	-	-
1966	25,042	25,042	25,042	-	-
1967	25,623	25,623	25,623	-	-
1968	26,225	26,225	26,225	-	-
1969	26,693	26,693	26,693	-	-
1970	27,551	27,551	27,551	-	-
1971	27,847	27,847	27,847	-	-
1972	28,873	28,873	28,873	-	-
1973	29,171	29,171	29,171	-	-
1974	29,887	29,947	29,510	437	60
1975	30,812	30,576	30,139	436	(236)
1976	31,955	31,719	31,283	436	(236)
1977	33,029	32,792	32,356	436	(236)
1978	33,345	33,108	32,672	436	(236)
1979	33,635	33,398	32,962	436	(236)
1980	34,061	33,736	33,299	436	(325)
1981	34,437	34,112	33,675	436	(325)
1982	34,720	34,394	33,958	436	(325)
1983	35,120	34,795	34,358	436	(325)
1984	35,265	34,940	34,503	436	(325)
1985	35,339	35,014	34,577	436	(325)
1986	35,400	35,075	34,638	436	(325)
1987	35,903	35,577	35,141	436	(325)
1988	36,433	35,752	35,316	436	(681)
1989	37,291	36,610	36,173	436	(681)
1990	38,155	37,474	37,038	436	(681)
1991	38,528	37,847	37,411	436	(681)
1992	38,867	38,186	37,749	436	(681)
1993	39,253	38,572	38,135	436	(681)
1994	39,880	39,199	38,762	436	(681)
1995	40,850	40,169	39,733	436	(681)
1996	41,239	40,558	40,121	436	(681)
1997	42,001	41,320	40,884	436	(681)
1998	43,068	42,387	41,951	436	(681)

Table 3. M&I Pumping in the Robust Review

	Baseline 001	Baseline 002			
Year	(A) M&I Pumping (MI001)	(B) = C + D Total M&I Pumping	(C) M&I Pumping (MIrr_001)	(D) Gerald Gentlemen Station (GGSrr_002)	(E) = B - A Change in M&I Pumping
1999	43,547	42,866	42,430	436	(681)
2000	44,177	43,451	43,015	436	(725)
2001	44,606	43,881	43,444	436	(725)
2002	44,786	44,061	43,625	436	(725)
2003	45,564	44,839	44,402	436	(725)
2004	52,490	45,084	44,648	436	(7,406)
2005	53,217	47,916	45,374	2,542	(5,301)
2006	54,051	48,366	46,208	2,158	(5,685)
2007	55,404	52,095	47,561	4,534	(3,309)
2008	55,738	48,544	47,895	649	(7,193)
2009	56,104	50,319	48,262	2,057	(5,786)
2010	56,312	49,469	48,469	1,000	(6,843)
2011	56,494	49,095	48,651	443	(7,399)
2012	56,658	49,276	48,816	460	(7,383)
2013	56,658	49,310	48,816	494	(7,348)
Projected	56,658	49,666	48,816	851	(6,992)

Summary

New M&I pumping data for NPPD's GGS power station was implemented into the Robust Review in the COHYST area. The GGS pumping estimates from the Statewide M&I efforts were replaced with the records from NPPD reports to NDNR. This resulted in a reduction of the average GGS M&I net pumping estimates in the Robust Review of just under 7,000 AF/year for the period after Well Field 2 began operations in 2005.