

# Memo

## Adaptive Resources, Inc.

To: Western Water Use Management Modeling Joint Board  
From: Thad Kuntz, P.G., Joe Reedy, and Jason Yuill  
Date: 10/23/2015  
Re: Technical Documentation: Development of Water Level Calibration Targets

### INTRODUCTION

To complete the Western Water Use Management (WWUM) Modeling ground water (GW) model calibration, a comparison of the computed heads to the recorded GW level observations was completed. The GW model calibration was completed using several models that varied specific parameters within each model and is described in the Partially Integrated Calibration and Data Integration Plan, dated January 17, 2013. The GW level calibration targets were created for use in both the pre-GW development period (steady state) and the GW development period (transient) GW models. For more details on the GW model and the use of the GW level target data see the reports: *Ground Water Flow Model for the Southern Half of the Nebraska Panhandle* by Richard R. Luckey (High Plains Hydrology, LLC) dated June 2013 and *Western Water Use Management Modeling Ground Water Model Update through April 2014* by Thad Kuntz and Joe Reedy (Adaptive Resources, Inc.) dated May 20, 2016. Data was utilized for the entire model area, including parts of Nebraska, Wyoming, and Colorado.

### PRE-GROUND WATER DEVELOPMENT PERIOD TARGETS

The pre-GW development period GW level calibration targets consist of a single GW level measurement taken at available wells on May 1, 1953, or as close to that date as possible. Very few water level observation targets were recorded during and prior to 1953, so a query of the United States Geological Survey (USGS) recorded measurements was completed through 1965. There was limited GW development throughout the GW model area through 1965, measurements recorded during this time period should be similar to pre-1953 values. The USGS GW level database was utilized to compile the data. Table 1 provides the criteria for selecting wells for the pre-GW development period from each State's USGS water level database.

Table 1	
Pre-Ground Water Development Period Ground Water Level Calibration Targets	
Criteria	Selected Criteria
<b>NEBRASKA</b>	
County	Arthur, Banner, Box Butte, Cheyenne, Deuel, Garden, Grant, Keith, Kimball, Morrill, Perkins, Scotts Bluff, Sheridan, and Sioux
Number of Observations	≥ 1
First Observation Date	Left Blank for Earliest Date in Database
Last Observation Date	05/01/1965
<b>WYOMING</b>	
County	Goshen and Laramie
Number of Observations	≥ 1
First Observation Date	Left Blank for Earliest Date in Database
Last Observation Date	05/01/1965
<b>COLORADO</b>	
County	Weld, Logan, and Sedgwick
Number of Observations	≥ 1
First Observation Date	Left Blank for Earliest Date in Database
Last Observation Date	05/01/1965



# Memo

The above queries produced 1,509 wells within the model area. To create a representative dataset close to May 1, 1953, the data from each well was manually evaluated using the following criteria:

- If a well had only one observation, that measurement was chosen.
- If a well had multiple measurements after May 1 of any year, the measurement with the date closest to May 1, 1953, was selected.
- If the well had multiple measurements, the spring measurement prior to May 1 of any year up to 1965 was selected.

To provide flexibility in using a large number of head observation targets, a weighting scheme was created to provide GW level observations that were minimally influenced by surface water bodies such as lakes and streams. The weights were established using a range of distances from the measured well to the nearest lake (lk\_dist) and stream (strm\_dist). As the distance from those features increased, a larger weight was applied. Larger weights indicate targets farther away from surface features. Table 2 provides the weighting used for each range of distances for the pre-GW development period targets.

<b>Range of Distances to Closest Lake</b>	<b>Weight</b>	<b>Range of Distances to Closest Stream</b>	<b>Weight</b>
0 ≤ 6,500	0.3	0 ≤ 50,000	0.3
6,500 ≤ 11,400	0.4	50,000 ≤ 83,300	0.4
11,400 ≤ 16,800	0.5	83,300 ≤ 157,000	0.5
16,800 ≤ 25,800	0.6	157,000 ≤ 246,000	0.6
25,800 ≤ 36,000	0.7	246,000 ≤ 304,000	0.7
36,000 ≤ 50,000	0.8	304,000 ≤ 352,000	0.8
50,000 ≤ 64,500	0.9	352,000 ≤ 406,000	0.9
> 64,500	1.0	> 406,000	1.0

After the weights had been applied to each category, the weights were multiplied to obtain an overall weight for that well.

The USGS recorded GW observation data as depth-to-water below ground surface in feet. The GW model was created using elevation information, so the GW level data used for model water level targets was converted to elevation in feet using the following equation:

$$\text{Elevation of the Ground Surface (feet)} - \text{Depth to Water (feet)} = \text{Water Elevation (feet)}$$

Each recorded GW observation from the USGS has supplemental well information where a ground altitude or elevation value in feet was provided. This was then compared to the 10 meter USGS Digital Elevation Model (DEM) value at each point. In some instances, there were significant discrepancies between the supplemental well information and the DEM value. To create a consistent dataset, the DEM value was used as ground surface elevation to compute the elevation of the GW level target.

After the development of the dataset, an evaluation of the data was completed to determine if unrealistic data outliers existed where water levels were above the ground surface or below the base of the aquifer. This was accomplished by mapping the water elevations over the model area. During that process, 19 measurements in Nebraska and 9 measurements in Wyoming were removed from the dataset. The outliers include errors in the locations reported by the USGS dataset or error in the topographic contours which propagate into the DEM values.



# Memo

The pre-GW development GW level calibration targets are described in a shapefile for each state.

NE\_PRE\_GW\_DEV\_FINAL\_03\_31\_2011.shp  
WY\_PRE\_GW\_DEV\_FINAL\_04\_01\_2011.shp  
CO\_PRE\_GW\_DEV\_FINAL\_04\_01\_2011.shp

The attributes within these files contain all supplemental data from the USGS database and the GW level target per site. The GW elevation target data is in feet.

NE\_PRE\_GW\_DEV\_WLS\_FINAL\_MODEL\_03\_31\_2011.SHP  
WY\_PRE\_GW\_DEV\_WLS\_FINAL\_MODEL\_04\_01\_2011.SHP  
CO\_PRE\_GW\_DEV\_WLS\_FINAL\_MODEL\_04\_01\_2011.SHP

These files contain only the fields FID, SHAPE, AGENCY\_CD, SITE\_NO, STATION\_NM, WEIGHT, POINT\_X, POINT\_Y, LEV\_DT, and WL\_ELEV. The GW elevation target data is in feet.

## **GROUND WATER DEVELOPMENT PERIOD TARGETS: 1953 through 2011**

The GW development period GW level calibration targets consist of multiple water level observations in chronological order taken from each well from May 1, 1953, to April 30, 2011. Table 3 describes the criteria for selecting wells from the Nebraska USGS water level database.

<b>Table 3</b>	
<b>Ground Water Development Period Ground Water Level Calibration Targets</b>	
<b>Criteria</b>	<b>Selected Criteria</b>
County	Arthur, Banner, Box Butte, Cheyenne, Deuel, Garden, Grant, Keith, Kimball, Morrill, Perkins, Scotts Bluff, Sheridan, and Sioux
Number of Observations	≥ 5
First Observation Date	05/01/1953
Last Observation Date	05/01/2011

The above criteria produced 1,010 wells within the model area. Also within this USGS supplemental well dataset, an altitude or elevation value was recorded. This was compared to the USGS DEM values at each point, as well as elevations of the ground surface taken through GPS mapping completed by the North Platte Natural Resources District (NPNRD), South Platte Natural Resources District (SPNRD), and the Nebraska Department of Natural Resources (NDNR). If the NRD or NDNR values existed for a particular monitor well USGS ID, that information was used as the most accurate elevation data and replaced the USGS data. If the elevation reported in the USGS dataset was 10 feet above or below the DEM values, then DEM value was used as the source of the ground surface elevation of that monitor well.

To provide flexibility in using a large number of GW level observation targets, a weight was applied to the observations using the following data characteristics: range of the number of observations (gw\_count\_n), range of total years observed (final date of observation – initial date of observation = total years of observation; yr\_count), distance from monitor well to nearest lake range (lk\_dist), and distance from monitor well to nearest stream range (strm\_dist). Table 4 demonstrates the weighting used for the GW development period targets.



# Memo

Table 4							
Ground Water Development Period Ground Water Level Calibration Target Weights							
Range of Number of Observations	Weight	Range of Total Years Observed	Weight	Range of Distances to a Lake	Weight	Range of Distances to a Stream	Weight
0 ≤ 14	0.65	0 ≤ 6	0.65	0 ≤ 5058	0.65	0 ≤ 465	0.65
14 ≤ 16	0.70	6 ≤ 9	0.70	5058 ≤ 7521	0.70	465 ≤ 1468	0.70
16 ≤ 24	0.75	9 ≤ 12	0.75	7521 ≤ 8721	0.75	1468 ≤ 3637	0.75
24 ≤ 48	0.80	12 ≤ 17	0.80	8721 ≤ 11184	0.80	3637 ≤ 8325	0.80
48 ≤ 122	0.85	17 ≤ 26	0.85	11184 ≤ 16241	0.85	8325 ≤ 18460	0.85
122 ≤ 343	0.90	26 ≤ 43	0.90	16241 ≤ 26628	0.90	18460 ≤ 40370	0.90
343 ≤ 1010	0.95	43 ≤ 74	0.95	26628 ≤ 47956	0.95	40370 ≤ 87735	0.95
> 1010	1.00	> 74	1.00	> 47956	1.00	> 87735	1.00

After the weights had been applied to each category, the targets were multiplied to obtain an overall weight for that well.

The GW development period GW level calibration targets were calculated and organized in both shapefile and excel workbook formats.

GW\_Development\_Period\_WL\_Calibration\_Targets\_12\_28\_2010\_version\_2.shp

This file contains all supplemental data from the USGS database and weighting of each well.

GW\_Development\_Period\_WL\_Calib\_Tagets\_Seq\_Order\_T\_Kuntz\_01\_05\_2011.xlsx

This file contains sequential GW development period targets.

The relevant files were provided to Richard Luckey of High Plains Hydrology for final review and modification prior to being incorporated into the GW model calibration. The original 1,010 GW development period calibration targets were thinned to 131 using criteria described in *Ground Water Flow Model for the Southern Half of the Nebraska Panhandle* by Richard R. Luckey, which were then utilized for model calibration.

## GROUND WATER DEVELOPMENT PERIOD TARGETS: 2014 MODEL UPDATE

The existing GW level calibration targets were extended from May 1, 2011, to April 30, 2014, to ensure GW model calibration moving forward.

The 131 head calibration targets were exported as a target text file from the 2011 GW model (file name: model\_1953-2011\_130621) using the Groundwater Vistas software. GW levels were then retrieved from the USGS National Water Information System ([nwis.waterdata.usgs.gov/nwis/gwlevels](http://nwis.waterdata.usgs.gov/nwis/gwlevels)) using the exported target names [unique value filter] and the multiple site numbers identifier for the period from May 1, 2011, to April 30, 2014. Data was delivered as a text file, with 85 target sites having records during that time frame. The updated records contain only site number, depth to water measurement, and date information. To determine ground surface elevation for each target site, USGS information was obtained for the first relevant measurement for each of the 131 targets; the elevation was then calculated by



# Memo

adding the depth to water value to the exported model target value. The ground surface elevations were transcribed to calculate the new target values for the 2011 - 2014 GW level calibration targets following the same procedure as outlined in the pre-GW development section. Additionally, time values were calculated to provide the GW model with a date of observation. This was done by converting the date values into serial date values, which represent the number of days since January 1, 1900. In serial date format, May 1, 1953, has a value of 19,480. This value was then subtracted from the observation serial date to adjust the value for the May 1, 1953, model start time. Model coordinate information, target weight, target group, model elevation, and site coordinate information were all carried through from the 2011 GW model.

The process to update the GW level calibration targets was conducted utilizing an excel workbook.

gw\_development\_period\_wl\_calibration\_targets\_2014\_141111.xlsx

A shapefile was generated from the target\_file worksheet in the above excel workbook for use in importing the updated GW level calibration targets into the extended model.

gw\_development\_period\_wl\_calibration\_targets\_2014\_141111.shp

The updated GW level calibration target information included the historic and most recent dataset and supersedes the previous efforts. This dataset should be consulted for any future GW development period GW level calibration information needs.

## REFERENCES

Luckey, R.R., High Plains Hydrology, June 2013, Ground Water Flow Model for the Southern Half of the Nebraska Panhandle: Nebraska Department of Natural Resources/North Platte Natural Resources District/South Platte Natural Resources District Report

Kuntz, T.A., and Reedy, J.R., 5/20/2016, Western Water Use Management Ground Water Model Update through April 2014, Report to Western Water Use Management Modeling Joint Board

