Review of RRCA Model

For the Period 2001 to 2004

prepared for

Nebraska
Department of Natural Resources

by

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Reston, Virginia
and
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1.0 Introduction and Study Objectives

The Republican River Compact Administration (RRCA) ground-water model was developed jointly by the States of Nebraska, Kansas, and Colorado to estimate streamflow depletions and accretions caused by pumping and recharge from imported water. The model was calibrated by assuring that water levels calculated by the model were consistent with observed water levels and base flow calculated by the model was consistent with base flow calculated from observed streamflow. Observed water levels and observed streamflow used for checking the model calibration were collected prior to the end of December 2000.

McDonald Morrissey Associates, Inc., with assistance from HDR, Inc.. was commissioned by the Nebraska Department of Natural Resources to determine if the RRCA model calculated water levels and model calculated base flow for the period January 1, 2001 – December 31, 2004 are consistent with observed water levels and stream discharge for the same period.

Calibration of the RRCA model was established independently by teams from each of the three states. Each team established water level targets for the entire basin. The water-level targets used by the team from Nebraska consisted of water levels observed at a set of 44 wells throughout the basin --- the Nebraska set; the water-level targets used by the team from Kansas consisted of water levels observed at a set of 196 wells throughout the basin --- the Kansas set. A number of the wells were coincident between the two states target lists. The combined total of the two sets with consideration of overlap was 217 wells.

Water level targets for this study consisted of water levels observed throughout the period January 1, 2001 – December 31, 2004 in all of those wells that are either in the Nebraska set or in the Kansas set and are located in Nebraska. There are 81 such wells.

Colorado, Kansas, and Nebraska used the same base-flow targets to check the calibration of the RRCA model. Base-flow targets for this study were estimated for every gaging station in the model area that is in Nebraska and that had records for the interval January 1, 2001 – December 31, 2004.

Ground-water flow model input data sets were obtained from the official RRCA websites. Minor modifications of these files were completed to facilitate this analysis as described in Section 2.0 and Appendix A. A complete set of all files used in this analysis is provided in a DVD which supplements this report.

2.0 Methods of Analysis

2.1 Creation of Model Data Sets

The RRCA model as completed July 1, 2003 simulates monthly ground-water flow for the period 1918 to 2000. For each year subsequent to 2000, Kansas, Colorado, and Nebraska provide data sets of pumping, canal losses, and irrigation return to the RRCA on an annual basis. These data are combined with information on precipitation and evapotranspiration parameters and an annual simulation update is completed. Initial ground-water levels specified for each annual simulation were based on the previous year's final simulated ground-water levels.

For this investigation, ground-water flow simulation results, model-calculated water levels and stream baseflows, for the period 1918 to 2000 were combined with results of a simulation of January 1, 2001 to December 31, 2004. Model calculated water levels and baseflows were then compared with observed stream baseflows and water levels. A detailed description of the steps involved in creating model input data sets is provided in Appendix A.

Computer simulations were completed using MODFLOW-2000 version 1.15.01 as downloaded from the United States Geological Survey. MODFLOW-2000 is a publicly available computer code that simulates ground-water flow. Source code for MODFLOW 2000 was downloaded from the following USGS website, http://water.usgs.gov/nrp/gwsoftware/modflow2000/modflow2000.html, on June 10, 2005. The source code was then compiled with Lahey-Fujitsu Fortran Professional Compiler v5.7 in double precision. The executable version of this code was named mf2k_1_15_01_Lahey_dbl.exe. The make file used to create this version is provided in Appendix B.

Following completion of MODFLOW-2000 simulations, model output was post-processed to allow analyses of trends in simulated ground-water levels and stream baseflows. Simulated surface-water baseflows and ground-water levels were stored during the simulation using the HYDMOD package of MODFLOW-2000. The HYDMOD package allows the storage of water level data and simulated stream-flows at specified locations in an unformatted file for later processing.

2.2 Ground-Water Level Target Processing

Recent observed water levels for the combined 217 target well data set of Nebraska and Kansas targets were obtained from the USGS Ground-Water Site Inventory Database (GWSI) by Jennifer Schellpeper, Nebraska DNR in January 2006. These data were joined by the Nebraska Department of Natural Resources (DNR) with well construction data from the USGS in an Access Database, GWLevels.mdb. This file was transmitted to McDonald Morrissey Associates, Inc. on January 17, 2006 by Jennifer Schellpeper, Nebraska DNR.

Ground-water levels were calculated within the GWLevels.mdb database based on USGS recorded land surfaces and depth to water as contained in the GWSI data files. For this analysis, no water levels measurements were screened out from this data set.

Simulated ground-water levels for the 217 selected GWSI long-term monitoring wells were extracted from the unformatted HYDMOD output files, 1918_2000_Baseflow_Waterlevel.sfi and 2001_2004_Baseflow_Waterlevel.sfi., using the USGS FORTRAN program HYDFMT, available with MODFLOW-2000 Version 1.15.01. HYDFMT was compiled using the with Lahey-Fujitsu Fortran Professional Compiler v5.7 in double precision. HYDFMT provides an ASCII file with a record for every model time step and a column of simulated water level for each of the 217 target well locations. At six locations, where wells were too close to model boundaries, simulated ground-levels at cell center were used instead of interpolated values.

After running HYDFMT for the 1918 to 2000 and 2001 to 2004 HYDMOD output files, HYDFMT output was placed in the EXCEL spreadsheet "RRCA_Head_Comparison_06_03_17.xls" in the tab [HYDFMT output]. This EXCEL spreadsheet contains observed water levels as obtained from the GWSI database for the 217 selected long-term monitoring wells. Additional details are provided within that spreadsheet.

Hydrographs of ground-water level versus time were made for each of the 217 well locations. For the purposes of this investigation, hydrographs for 81 targets, those which were in Nebraska and had water level data since December 31, 2000, were reviewed.

2.3 Stream Baseflow Target Processing

Stream baseflows for streams and rivers within Nebraska were developed on behalf of the Nebraska DNR by Larry Land, HDR, Inc. Stream baseflow spreadsheets originally developed by RRCA ground-water model committee member, Jim Slattery, Helton and Willamsen, P.C. for the July 1, 2003 RRCA model were appended with recent stream total flows and diversions. Stream baseflows were then estimated for the 24 locations with recent data in a manner consistent with the methodology used by Jim Slattery. Estimates of average monthly stream baseflows in cubic feet per second (cfs) were provided to McDonald Morrissey Associates by Larry Land in two spreadsheets; BaseflowbyMonth_thru2004(Revised021406).xls on February 14, 2006 and BaseflowbyMonth_thru2004(Pal-CulbRevised_031306).xls on March 13, 2006.

Simulated baseflows and calculated gains/losses along reaches were extracted from the unformatted HYDMOD output file using the FORTRAN file HYDTABLE created by MMA. HYDTABLE extracts unformatted data from the HYDMOD output file and organizes the data into a comma-separated text file. Data for every model time step is extracted. HYDTABLE was compiled using the with Lahey-Fujitsu Fortran Professional Compiler v5.7 in double precision. HYDTABLE requires an input parameter file, RRCA_target_hyd.def that identifies stream cells to be processed by segment and reach and identifies those stream reaches in which a gain/loss is to be calculated.

Results from the HYDTABLE output were combined with estimated stream baseflows and reach gains/losses in the spreadsheet Baseflow_Comparison_06_03_17.xls. Additional details are provided within that spreadsheet.

3.0 Results

The results of the analysis described above consist of water level hydrographs for all target wells in Nebraska and base-flow hydrographs for all target gaging stations in Nebraska. The water-level hydrographs are contained in Appendix C. The base-flow hydrographs are contained in Appendix D.

The hydrographs were studied to evaluate whether the model was as consistent with observations since 2001 as it was consistent with observations prior to 2001. Table 1 summarizes the results. Column 1 contains a project well identifier. That identifier is plotted on Figure 1 to show the location of the well. There are a total of 118 target wells in Nebraska. Of these 118 wells, 81 had water level observations since 2001. Three wells were eliminated from consideration because they only had one measurement after December 31, 2000.

Among the remaining 78 wells there were 57 for which observed water level trends matched model trends prior to 2001. Among those 57 wells there were 53 wells for which observed water level trends matched model water level trends since 2001. The distribution of these targets is provided in Figure 2.

Some of the hydrographs in Appendix C show what appears to be big differences between reported and calculated water levels. For some hydrographs the difference is exaggerated because the y-axis has a small range. For others there is a large difference between reported and calculated water levels. The large differences may be caused by lack of precision in the reported water level or lack of precision of the model.

The lack of precision in reported water level measurement is generally caused by relying on estimates of the elevation of the measuring point rather than measuring the elevation of the measuring point. For this project many reported water levels are likely to be in error by 10 feet and may be in error by 20 feet. Although individual target water levels may be in error, the error is expected to be regular. Therefore trends should be consistent.

The model is imprecise because it does not represent all features of the flow system but only those which are deemed to be significant and because input specifications are estimates. In one area of the RRCA model, the “mound” area or an area in portions of Kearney, Phelps, Harlan, and Franklin counties, model-calculated water levels appear to be consistently too high. A further study of the mound area and the stream depletions/accretions relating to this area is being initiated. This study will attempt to establish the reason for lack of precision in the mound area and evaluate the impact of these high water levels on stream depletions/accretion calculations.

There are 24 base flow target locations that were used in the development of the RRCA model for which stream flow data were collected since 2001. Figure 3 shows the location of these 24 base flow targets. The stream flow data was used to estimate base flow at each of the stations for each month. Output from the RRCA model was used to calculate base flow at the same stations for each month. Base flows from the two sources are plotted on hydrographs shown in Appendix D.

For most of the base flow target locations base flow trends for the period prior to January 1, 2001 from the model are consistent with base flow trends calculated from observed stream flow. The only exceptions are Turkey Creek at Edison and Driftwood at McCook. For the period after January 1, 2001 base flow trends continue to be consistent.

4.0 Summary and Conclusions

The RRCA model was calibrated to water levels and base flow that prevailed in the period prior to January 1, 2001. During the period since January 1, 2001 precipitation in the basin has been unusually low. Water levels and stream flow have also been unusually low. The model was tested to see if it was able to duplicate conditions that prevailed since January 1, 2001 as well as it duplicated conditions prior to that time.

Hydrographs showing model calculated water levels and observed water levels indicate that the model continues to match conditions since January 1, 2001. Hydrographs showing base flow calculated by the model and base flow calculated from observed stream flow support that conclusion.

Tables

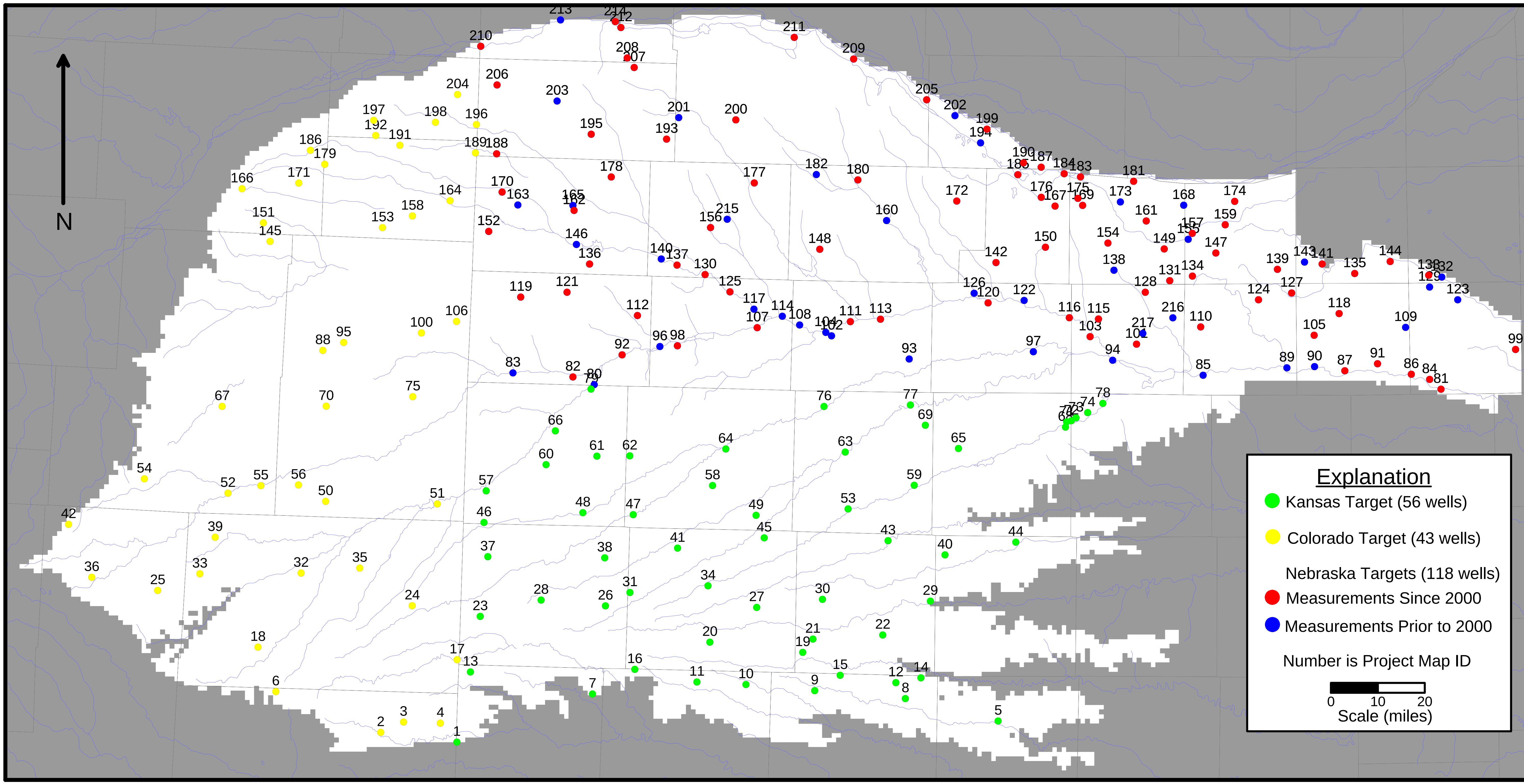
Table 1.Results of review of ground-water level hydrographs for wells with measurements since December 31, 2000.

Map ID	USGS GWSI Site Number	UTM-X	UTM-Y	Does the Trend of Observations Prior to 2001 Match the Trend of Model Calculated Values Prior to 2001?	Does the Trend of Observations After 2001 Continue to Match the Trend of Model Calculated Values Prior to 2001?
81	400050098083001	1,880,753	14,532,259	No	No
82	400130101374401	904,398	14,546,011	Yes	Yes
84	400240098111301	1,867,973	14,543,267	Yes	Yes
86	400339098153801	1,847,321	14,549,055	Yes	Yes
87	400423098314001	1,772,526	14,552,997	No	Yes
91	400539098234501	1,809,386	14,560,908	No	Yes
92	400551101260301	959,643	14,570,865	Yes	Yes
98	400748101124501	1,021,938	14,581,081	No	Yes
99	400802097502401	1,964,653	14,576,914	No	Yes
103	401041099330901	1,486,087	14,591,362	No	Yes
105	401059098390101	1,738,097	14,592,895	Yes	Yes
217	401120099202501	1,545,382	14,595,008	Yes	Yes
107	401130100533601	1,111,642	14,601,477	No	Yes
110	401233099062701	1,610,402	14,602,229	No	Yes
111	401257100310701	1,216,451	14,608,266	Yes	No
112	401307101222101	976,923	14,615,145	Yes	Yes
113	401329100241701	1,250,237	14,610,949	No	Yes
115	401357099311001	1,495,436	14,611,132	Yes	Yes
216	401414099131101	1,579,095	14,612,503	Yes	Yes
118	401459098325801	1,766,138	14,617,298	No	Yes
119	401559101505601	845,616	14,635,825	Yes	Yes
120	401647099575301	1,371,342	14,629,368	Yes	Yes
121	401703101394801	897,758	14,641,292	Yes	Yes
125	401801101002301	1,080,961	14,641,726	Yes	Yes
127	401850098442601	1,712,743	14,640,451	No	No
130	402107101063001	1,052,981	14,661,203	Yes	Yes
131	402110099140001	1,575,624	14,654,304	Yes	Yes
133	402158098111301	1,866,900	14,660,403	Yes	Yes
134	402202099082201	1,601,160	14,659,387	Yes	Yes
135	402224098290901	1,783,626	14,662,408	No	Yes
136	402236101343101	923,110	14,673,046	Yes	Yes
137	402244101132101	1,021,415	14,671,795	Yes	Yes
139	402313098475201	1,696,730	14,667,013	No	Yes
141	402411098370101	1,747,061	14,673,047	No	No
142	402416099560500	1,380,189	14,674,697	No	No
144	402434098203101	1,823,606	14,675,824	Yes	Yes
147	402612099025401	1,627,497	14,685,369	Yes	Yes
148	402614100373001	1,181,968	14,689,635	Yes	Yes
149	402703099150901	1,569,445	14,689,939	Yes	Yes
150	402711099440801	1,435,785	14,691,876	Yes	Yes
152	402757101591201	809,627	14,709,737	Yes	Yes
154	402802099285801	1,506,136	14,696,550	Yes	Yes
156	402950101052601	1,059,187	14,713,996	Yes	Yes
157	402952099083901	1,600,974	14,707,467	Yes	Yes
159	403125099003701	1,638,012	14,717,097	Yes	Yes
215	403127101012701	1,077,872	14,723,378	Yes	Yes

Table 1.Results of review of ground-water level hydrographs for wells with measurements since December 31, 2000.

Map ID	USGS GWSI Site Number	UTM-X	UTM-Y	Does the Trend of Observations Prior to 2001 Match the Trend of Model Calculated Values Prior to 2001?	Does the Trend of Observations After 2001 Continue to Match the Trend of Model Calculated Values Prior to 2001?
161	403210099194201	1,549,187	14,721,440	Yes	Yes
162	403220101384001	905,631	14,733,307	Yes	Yes
167	403449099415201	1,446,662	14,738,121	Yes	Yes
169	403506099350101	1,477,642	14,739,004	Yes	Yes
170	403518101561601	824,716	14,753,900	Yes	Yes
172	403534100054601	1,336,110	14,743,800	No	Yes
174	403546098580301	1,648,729	14,743,506	Yes	Yes
175	403625099361001	1,472,363	14,746,897	Yes	Yes
176	403626099451401	1,431,165	14,748,062	Yes	Yes
177	403817100550401	1,108,344	14,764,196	Yes	Yes
178	403843101295201	947,488	14,770,867	Yes	Yes
180	403913100295401	1,224,817	14,767,601	No	No
181	403922099223301	1,535,023	14,766,007	No	Yes
183	404020099355301	1,475,224	14,770,980	Yes	Yes
184	404046099393601	1,456,897	14,774,577	Yes	Yes
185	404046099504501	1,404,792	14,773,458	Yes	No
187	404209099450201	1,431,021	14,781,888	No	No
188	404221101575501	818,524	14,796,955	No	No
190	404250099493701	1,411,174	14,786,823	Yes	No
193	404601101164001	1,009,675	14,813,523	Yes	Yes
195	404624101352001	924,917	14,819,012	Yes	Yes
199	404850099583001	1,370,025	14,824,644	Yes	Yes
200	404953100595401	1,087,596	14,835,108	Yes	Yes
205	405413100131601	1,302,215	14,857,710	Yes	Yes
206	405506101582301	818,995	14,874,433	Yes	Yes
207	405907101250201	973,255	14,894,082	Yes	Yes
208	410058101264501	965,422	14,904,831	Yes	Yes
209	410138100312401	1,220,133	14,903,573	Yes	Yes
210	410209102024101	800,685	14,917,917	No	No
211	410523100455501	1,153,303	14,927,952	Yes	No
212	410627101283301	958,341	14,939,054	Yes	Yes
214	410745101294801	952,013	14,945,594	Yes	Yes

Figures



Data Source: Well Location Data from J. Schellpeper 1/16/06
Access Database GWLevels.mdb (Table tblGWsiteData)

Figure 1. Location of combined Nebraska and Kansas RRCA model GWSI target wells in the Republican River Basin.

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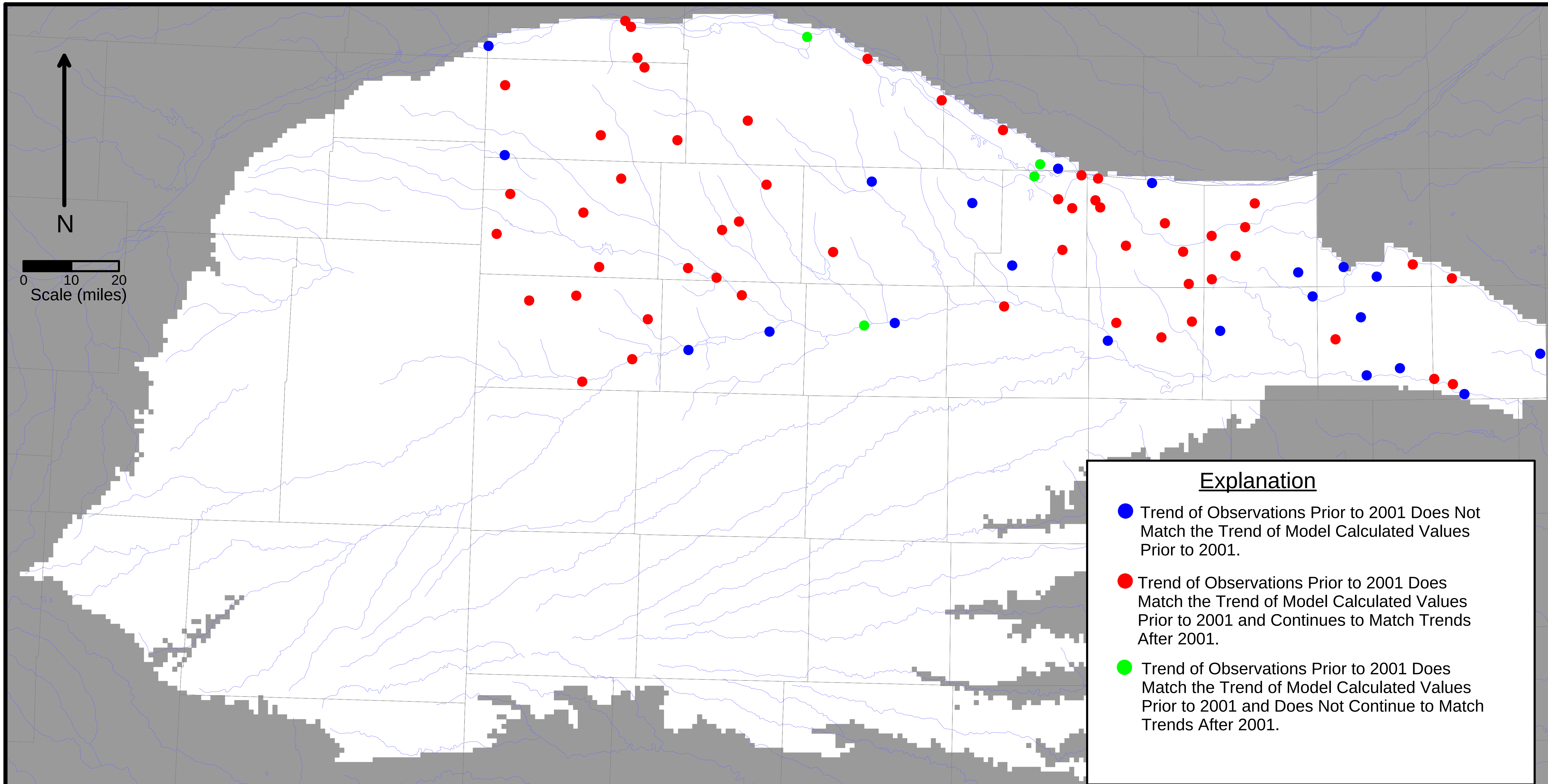

Data Source: Well Location Data from J. Schellpeper 1/16/06
Access Database GWLevels.mdb (Table tblGWsiteData)

Figure 2. Map showing results of evaluation of match of water-level targets.

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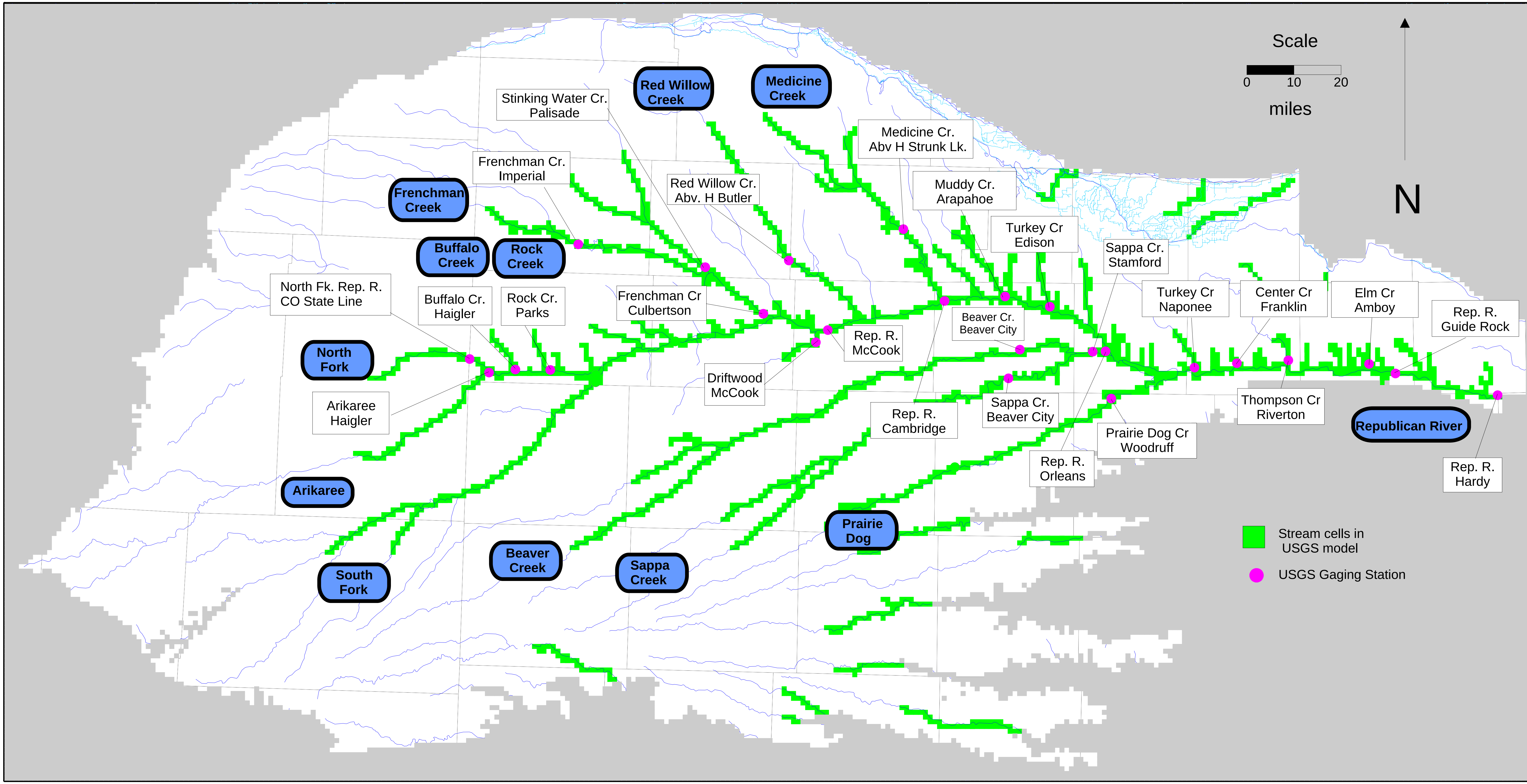

Figure 3. Map showing location of RRCA model baseflow targets with estimates available for the period January 1, 2001 to December 31, 2004.

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Appendix A

Development of MODFLOW Data Sets

MODFLOW data sets source

For the period 1918 to 2000, original MODFLOW data sets were obtained from the DVD labeled Appendix A-Republican River Compact Administration Groundwater Model, Technical Groundwater Model Committee, Version 12p7, 30 June 2003. For the period 2001 to 2003, original MODFLOW data sets were obtained from the RRCA archive website below during the first week of January 2006. This website is currently restricted to users approved by the RRCA.

(http://www.republicanrivercompact.org/2003/html/zip/)

For 2004, original MODFLOW data sets were also obtained during the first week of January 2006 from the RRCA website below.

(http://www.republicanrivercompact.org/2004/index.html)

Modifications to original MODFLOW data sets

To facilitate post-processing of computed head and stream baseflows and provide more detailed analyses a number of modifications to the original MODFLOW data sets were made.

1918 to 2000 MODFLOW Files

Changes to name file, 12p.nam:

1) Output file names were changed to provide clarity.

2) A single cell-by-cell budget file was specified to contain information on all simulated cell-to-cell flows and stresses.

3) A revised hydmod file, 1918_2000_Baseflow_Waterlevel.hyd was used to calculate simulated baseflow and water levels at selected sites. This hydmod file contained all baseflow targets contained in 12.hyd as well as locations for water-level targets to track simulated water levels for 217 long-term monitoring wells found in the USGS GWSI database. These monitoring wells include wells in Nebraska, Colorado, and Kansas. HYDMOD will automatically interpolate heads at wells based on well locations specified as offsets from the lower-left corner of the model. For this file where wells are too near model boundaries to be interpolated the value at the center of the model cell was used. Upon model execution HYDMOD will store values at each of the locations for every time step. Stream baseflows locations were specified by stream reach and segment for locations of interest.

Changes to stress packages:

All stress packages were specified to provide cell-by-cell output to a single file.

1) 12.str-->Changed cell-by-cell output unit from 41 to 40

2) 11.drn-->Changed cell-by-cell output unit from 43 to 40, Removed NOPRINT command

3) 12p.evt-->Changed cell-by-cell output unit from 42 to 40

4) 12p.rch-->Changed cell-by-cell output unit from 0 to 40

5) 12p.wel-->Changed cell-by-cell output unit from 0 to 40, Removed NOPRINT command

2001 to 2004 MODFLOW Files

Changes to name file, 2001.nam:

1) Output file names were changed to provide clarity, changed name to 2001_2004.nam

2) Added a revised hydmod file, 2001_2004_Baseflow_Waterlevel.hyd. This file was used to calculate simulated baseflow and water levels at the same site described in 1918_2000_Baseflow_Waterlevel.hyd. The only difference between this file and 1918_2000_Baseflow_Waterlevel.hyd is that 2001_2004_Baseflow_Waterlevel.hyd uses all baseflow targets contained in 12s.hyd as well as the 217 GWSI well target locations. The file 12s.hyd was set up to address an error found in the stream package in the original compact model.

3) Renamed the following input files that were modified

   a. 2001.bas → 2001_2004.bas

   b. 2001.dis → 2001_2004.dis

   c. 2001.evt → 2001_2004.evt

   d. 2001.rch → 2001_2004.rch

   e. 2001.wel → 2001_2004.wel

4) Assigned all cell-by-cell flow terms to a single binary file to contain information on all simulated cell-to-cell flows and stresses.

Changes to individual packages:

1) Modified the 2001_2004.bas package

   a. Changed the directory call for 02.ibound for the BASIC package, 2001_2004.bas

   b. Initial heads for the 2001 simulation were specified to be read from the binary file 2001.shead. These heads represent the final heads from the 1918 to 2000 simulation. The FORTRAN program Initial_Heads_Lahey.exe was used to strip out the last heads from the binary file 12p_Head_Save_1918_2000.head. This program was developed in-house and compiled in double precision using Lahey-Fujitsu Fortran Professional Compiler v5.7. The source code for this file is presented in Appendix B.

2) Changed the directory call for 12p.k and 12.ss for the lpf package, annual.lpf.

3) Modified 2001_2004.dis package with the following changes:

   a. Changed the directory call for 12.bot and 12.top

   b. Increased the number of stress periods to 48 from 12 to reflect monthly stress periods for the period 2001 to 2004.

   c. Added the appropriate stress period length for all stress periods from 2001 to 2004.

4) Modified 2001_2004.str:

   a. Assigned cell-by-cell flow terms to unit 40.

   b. Concatenated stream packages 2001.str, 2002.str, 2003.str, and 2004.str eliminating the head line in 2002.str, 2003.str, and 2004.str prior to concatenation.

5) Modified 2001_2004.evt

   a. Changed the directory call for 11.etsurf

   b. Concatenated evt packages 2001.evt, 2002.evt, 2003.evt, and 2004.evt.

6) Modified 2001_2004.rch

   a. Assigned cell-by-cell flow terms to unit 40.

   b. Concatenated rch packages 2001.rch, 2002.rch, 2003.rch, and 2004.rch

7) Modified 2001_2004.wel

   a. Changed cell-by-cell output unit from 0 to 40, Removed NOPRINT command

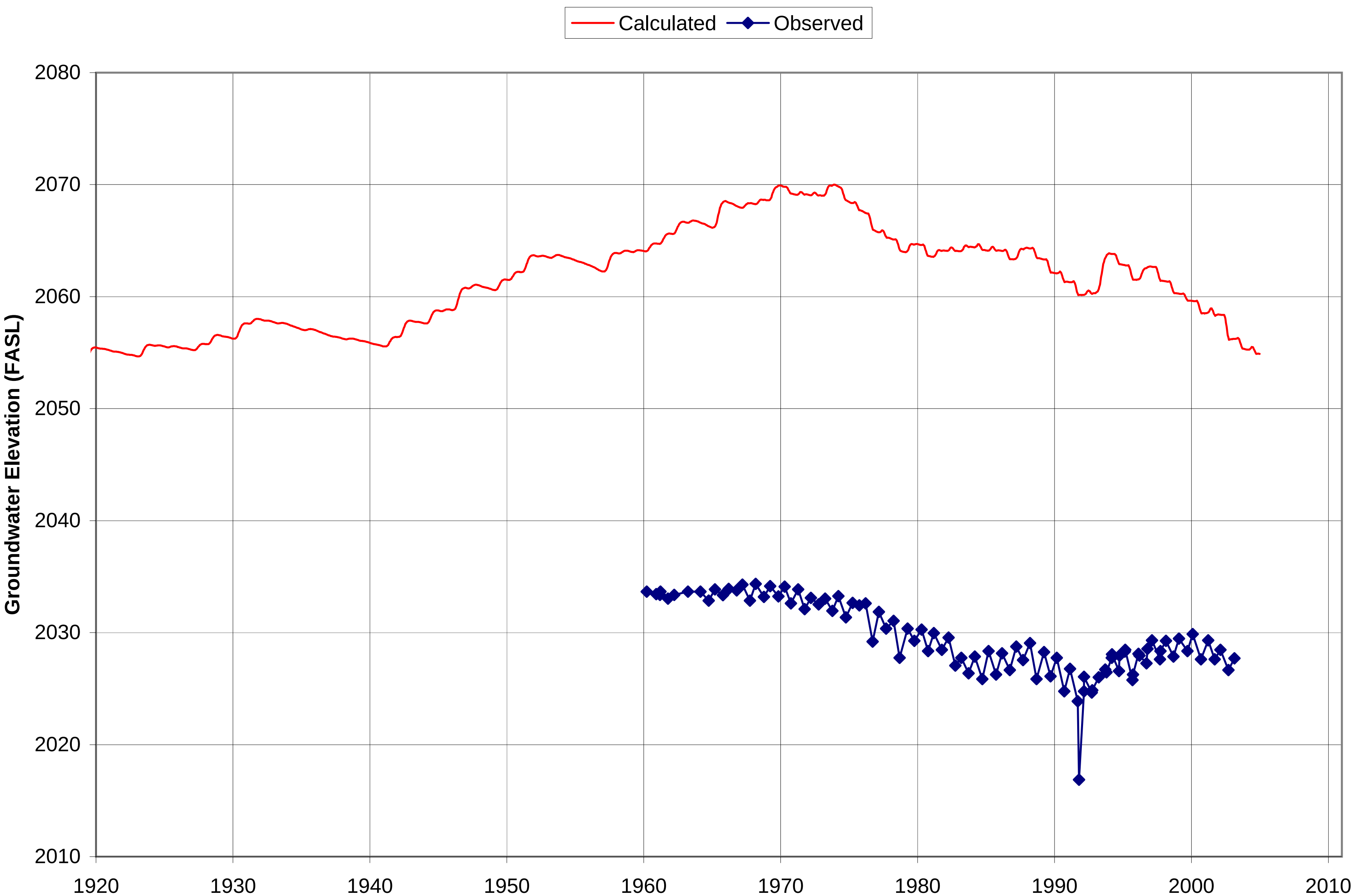
   b. Concatenated wel packages 2001.wel, 2002.wel, 2003.wel, and 2004.wel

Appendix B MODFLOW-2000
Make File Used to Create mf2k_1_15_01_Lahey_dbl.exe

```
        QUITONERROR
        FILES=mf2k.f
        COMPILE=@lf95 -dbl  -o0 -I %id -c -trace -trap dio  -nchkglobal -nco -nlst -
nxref -nobanner -f95 -nsav -stchk -nw %fi -o %od%sf%oe -winconsole
        INCLUDE=.OBJDIR=.\objLF95

        AND

        FILES=*.f
        COMPILE=@lf95 -dbl  -o1 -I %id -c -trace -trap dio  -nchkglobal -nco -nlst -
nxref -nobanner -f95 -nsav -stchk -nw %fi -o %od%sf%oe -winconsole
        INCLUDE=.
        OBJDIR=.\objLF95

        AND

        FILES=.\serial\para-non.f
        COMPILE=@lf95 -dbl  -o1 -I %id -c -trace -trap dio  -nchkglobal -nco -nlst -
nxref -nobanner -f95 -nsav -stchk -nw %fi -o %od%sf%oe -winconsole
        INCLUDE=.
        OBJDIR=.\objLF95

        AND

        FILES=*.c
        COMPILE=@fcc /c /D _UF /I C:\LF9557\Include /o .\objLF95\%sf%oe %fi
        OBJDIR=.\objLF95

        LINK=@lf95 @%rf   -nobanner -warn -nco -exe %ex -Stack 350000 -
winconsole
        TARGET=mf2k_1_15_01_Lahey_dbl.exe
```

Appendix C Ground-Water Level Hydrographs

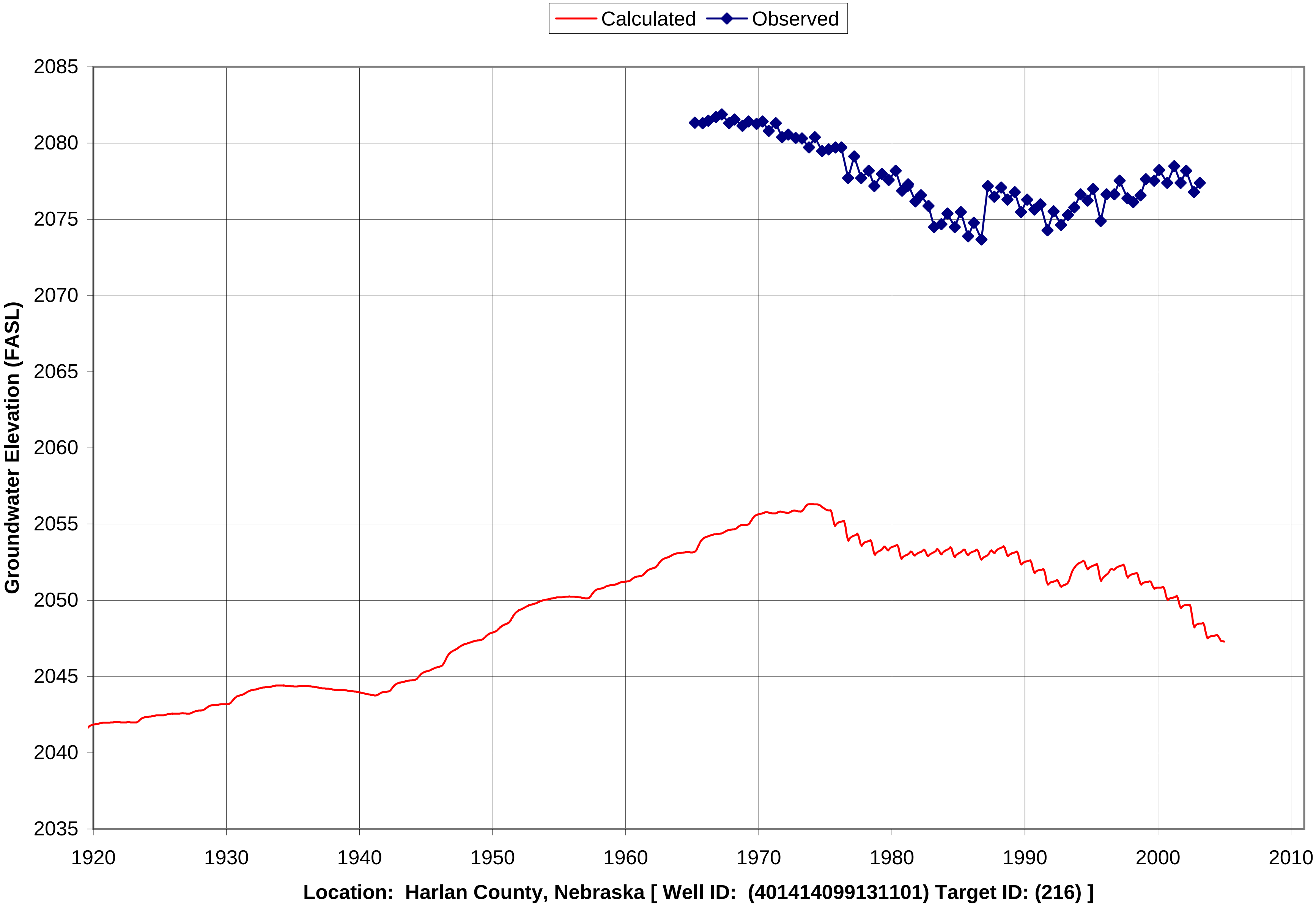
Well ID: (401120099202501)



Location: Harlan County, Nebraska [Well ID: (401120099202501) Target ID: (217)]

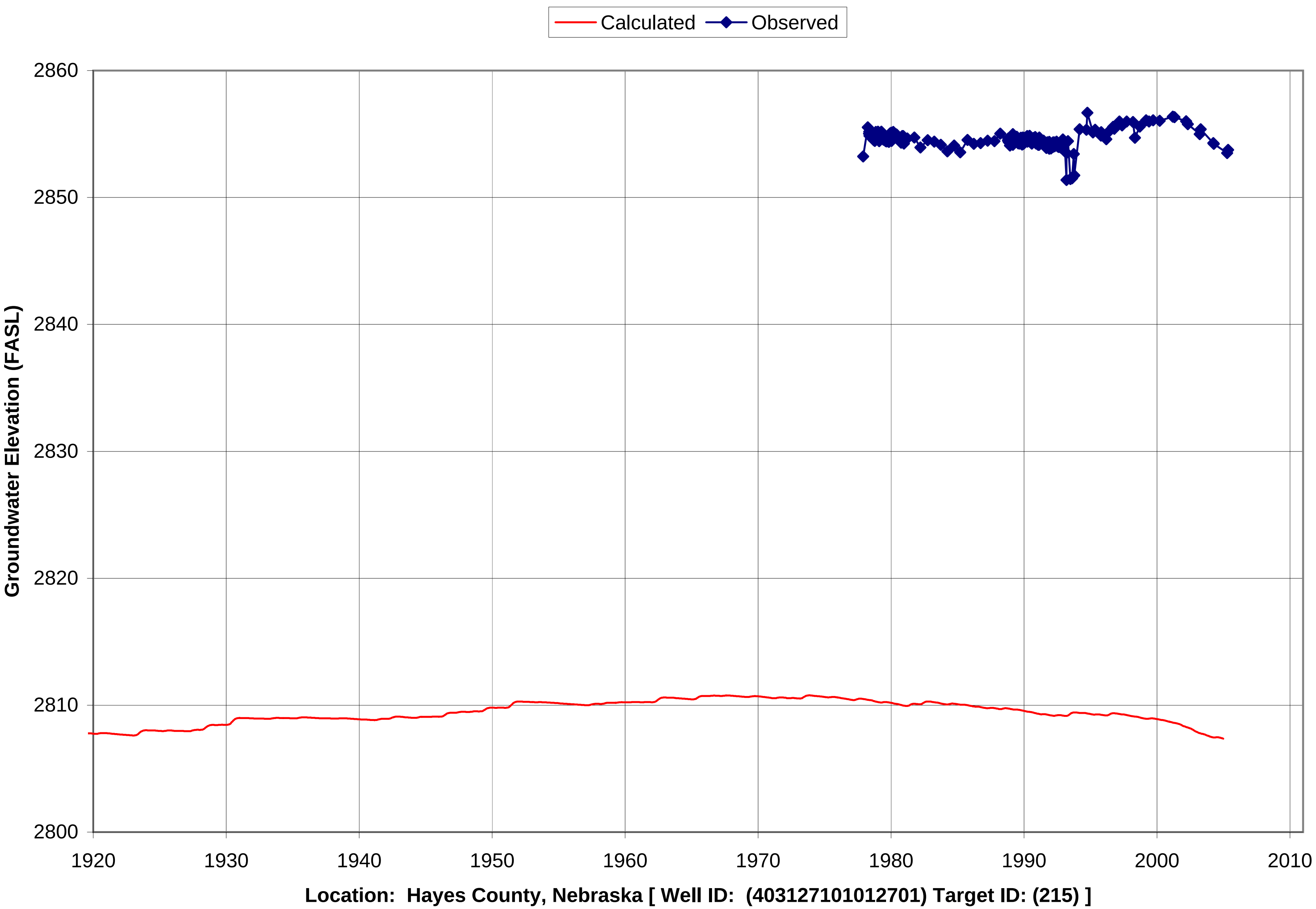
Target ID: (217)

Well ID: (401414099131101)



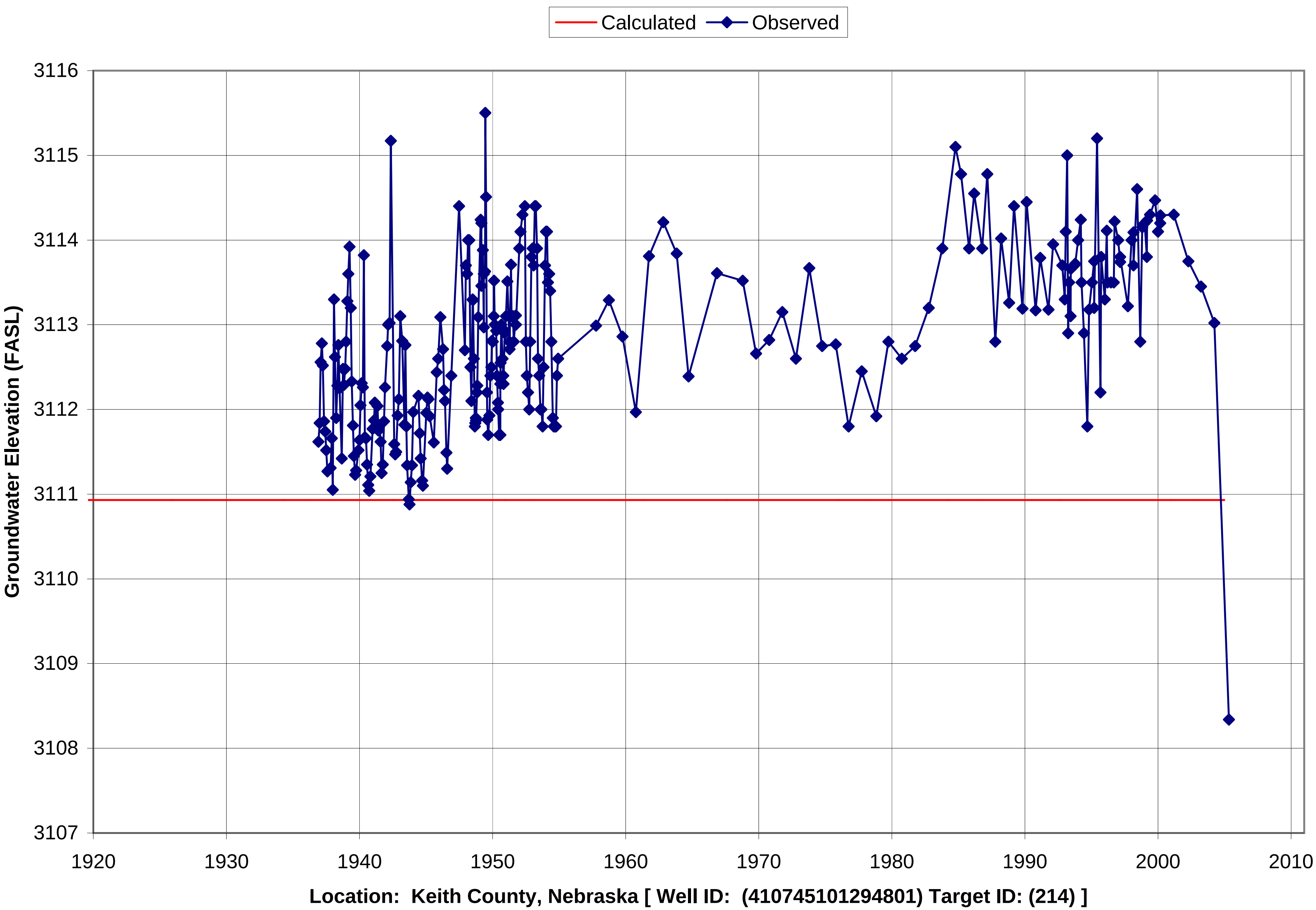
Target ID: (216)

Well ID: (403127101012701)



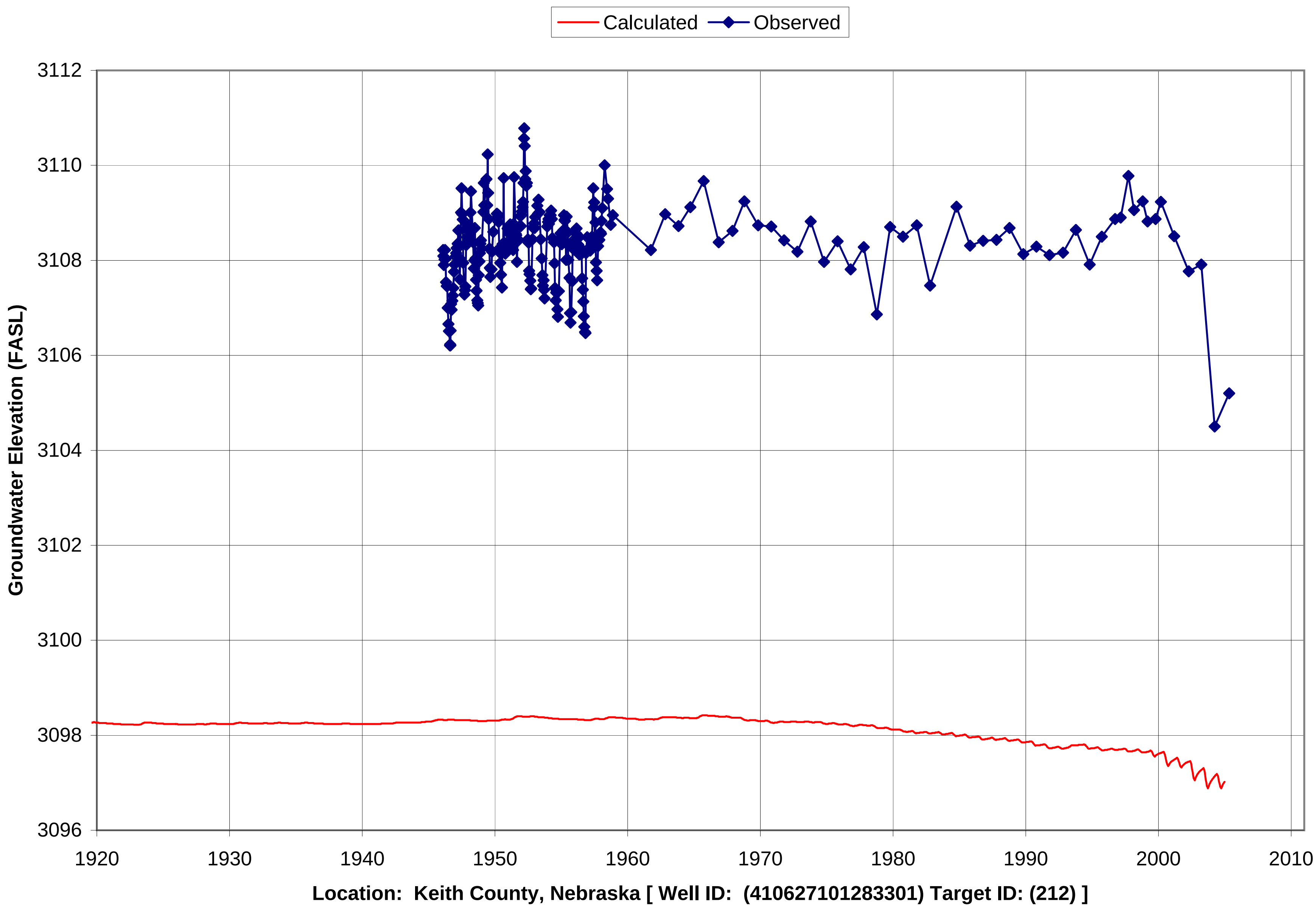
Target ID: (215)

Well ID: (410745101294801)



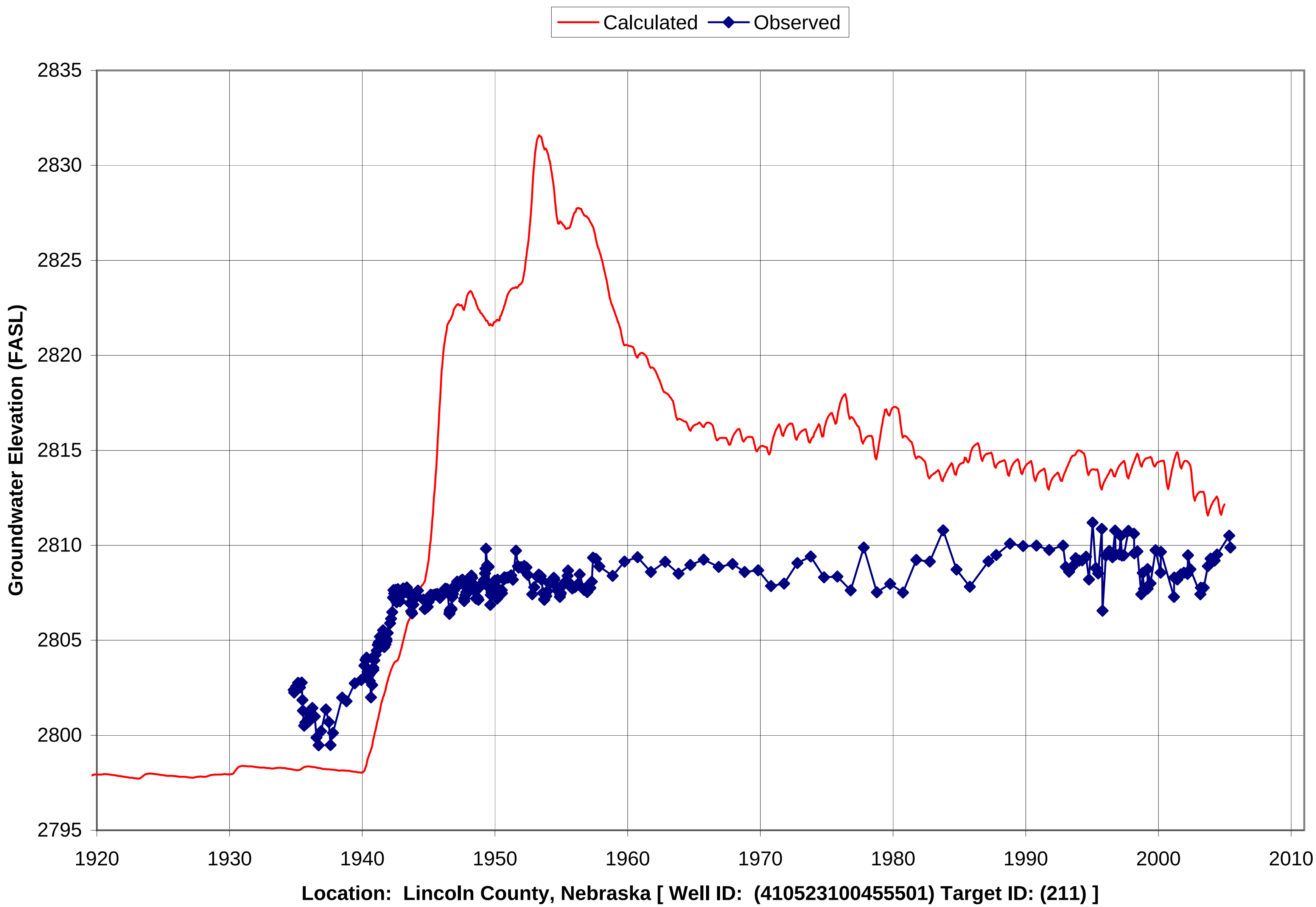
Target ID: (214)

Well ID: (410627101283301)



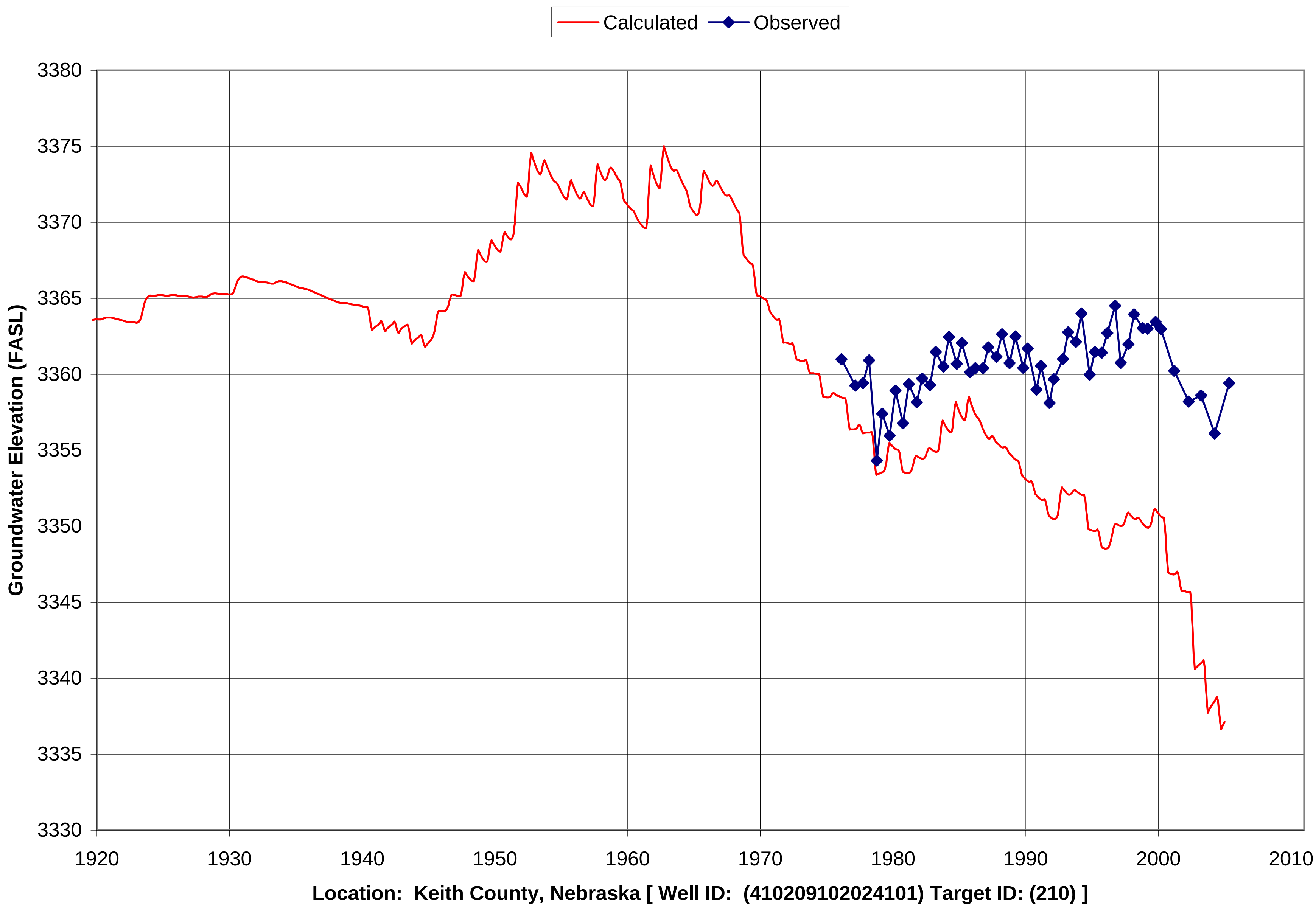
Target ID: (212)

Well ID: (410523100455501)



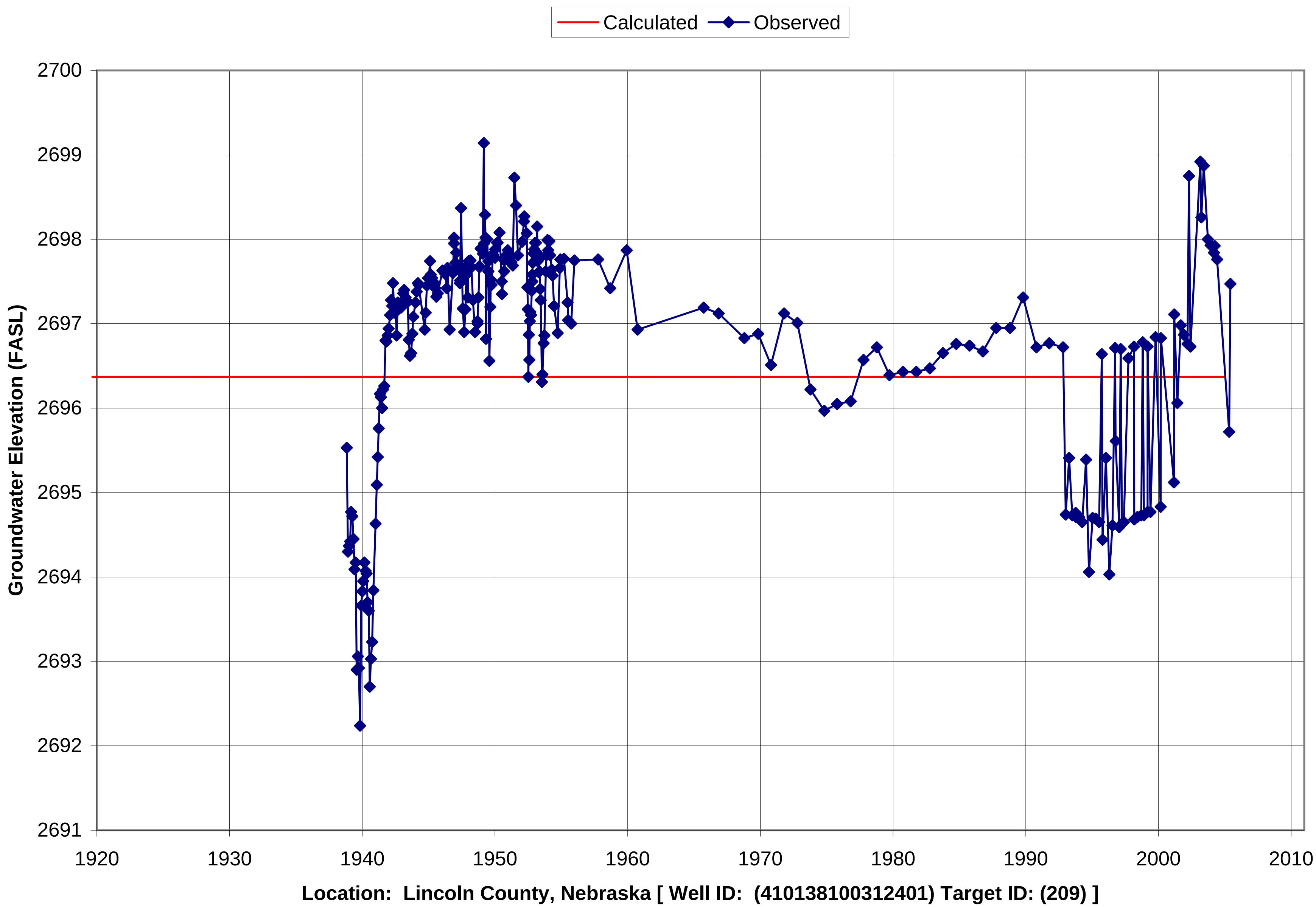
Target ID: (211)

Well ID: (410209102024101)

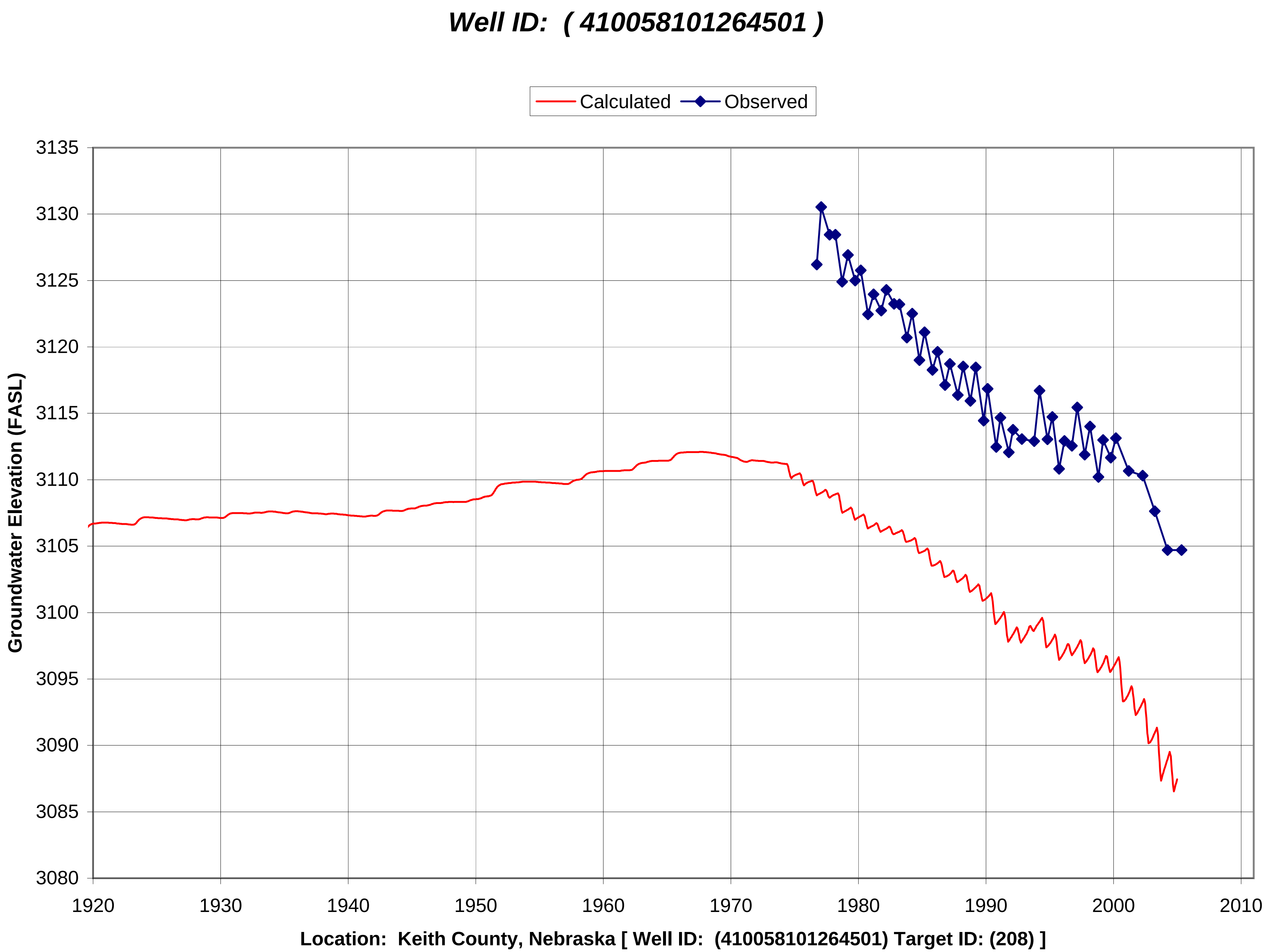


Target ID: (210)

Well ID: (410138100312401)

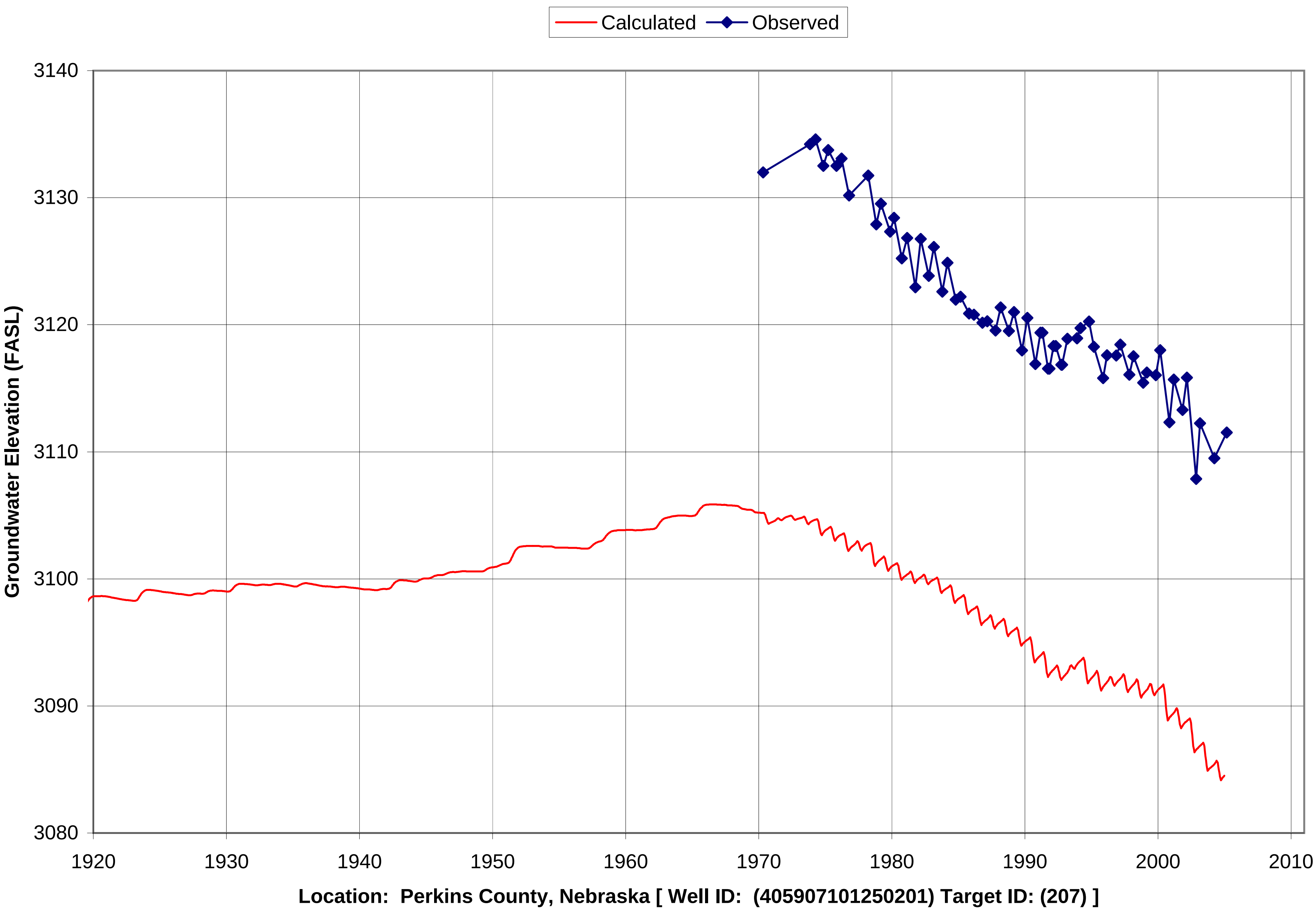


Target ID: (209)

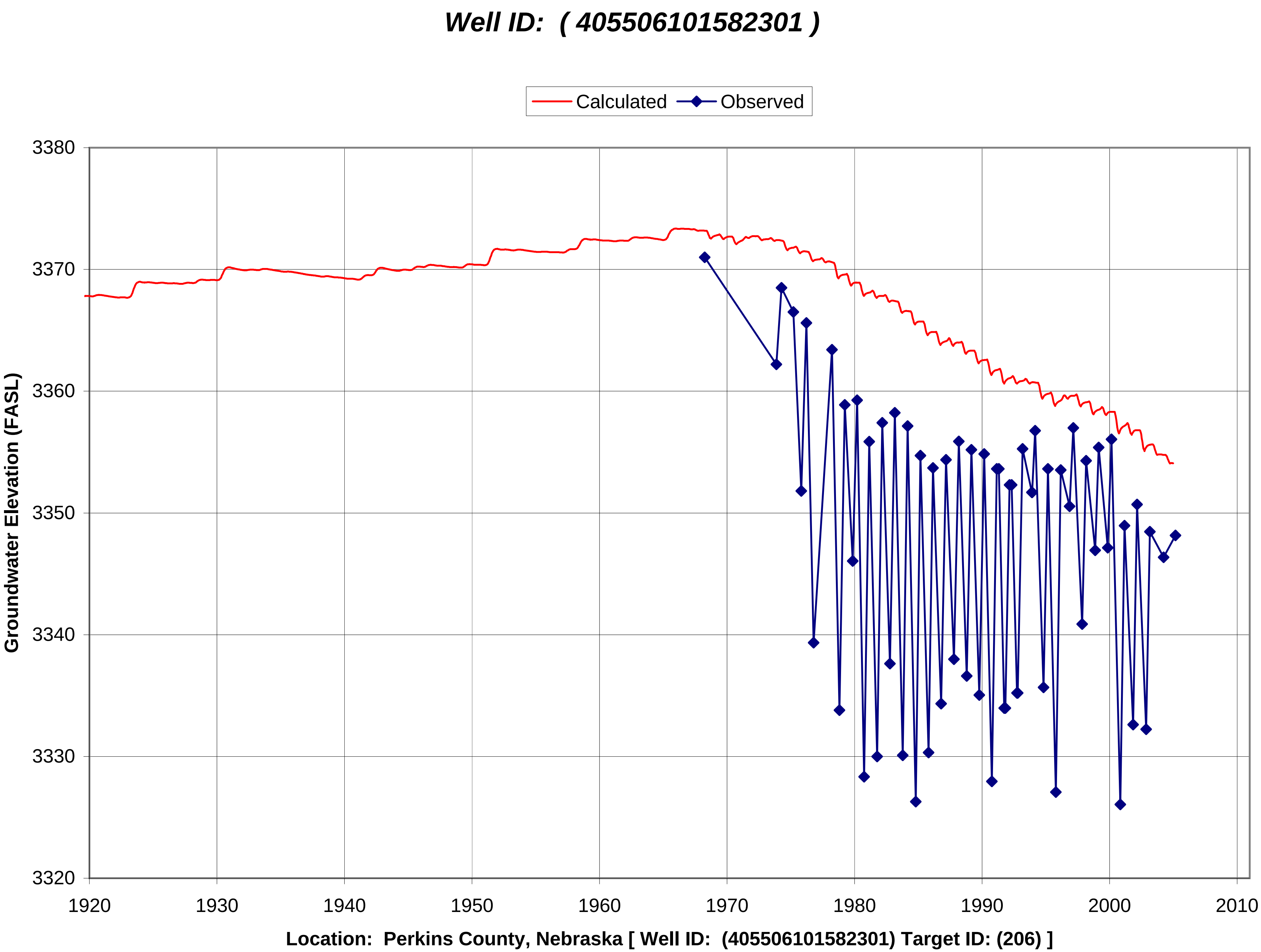


Target ID: (208)

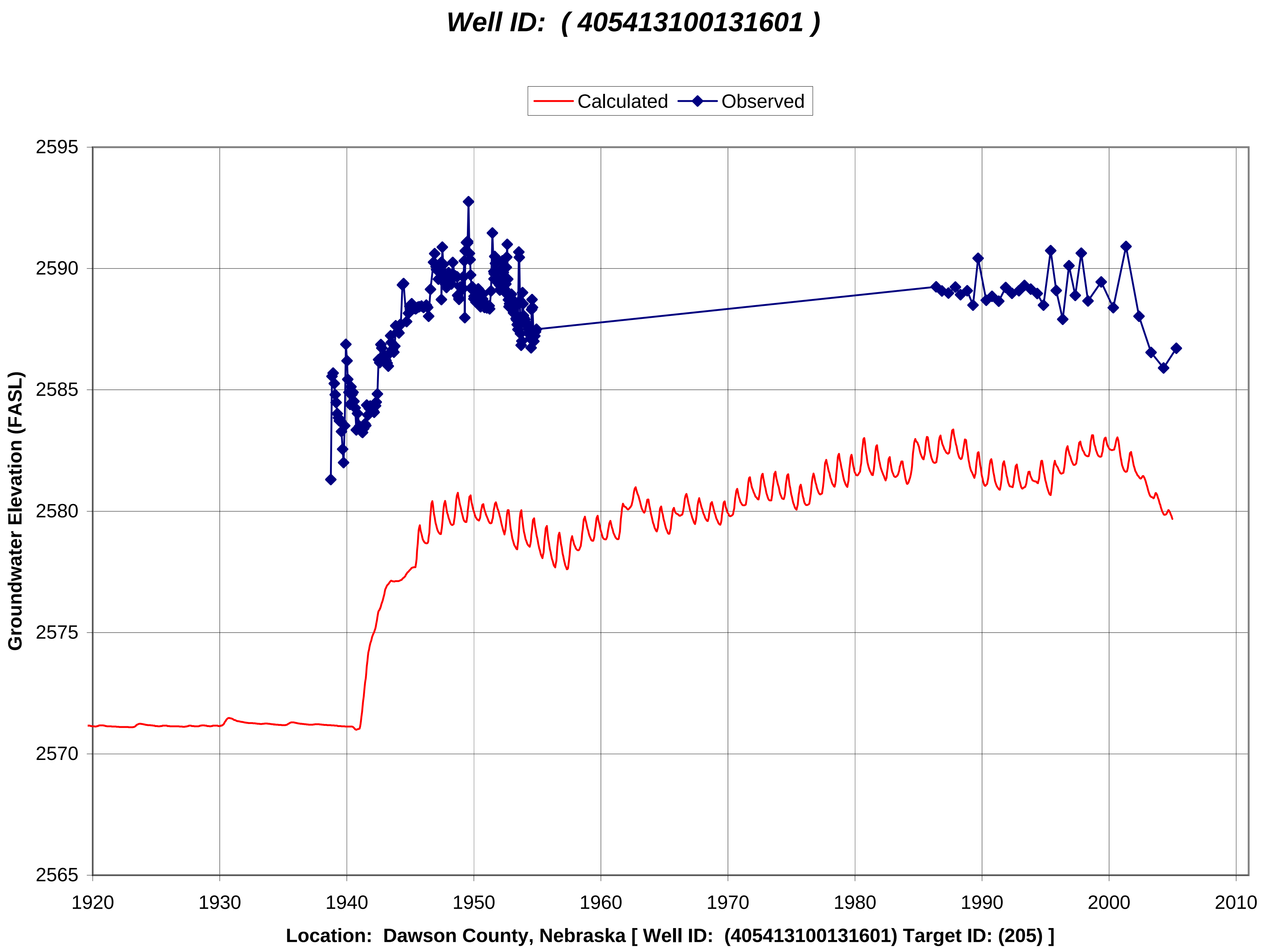
Well ID: (405907101250201)



Target ID: (207)

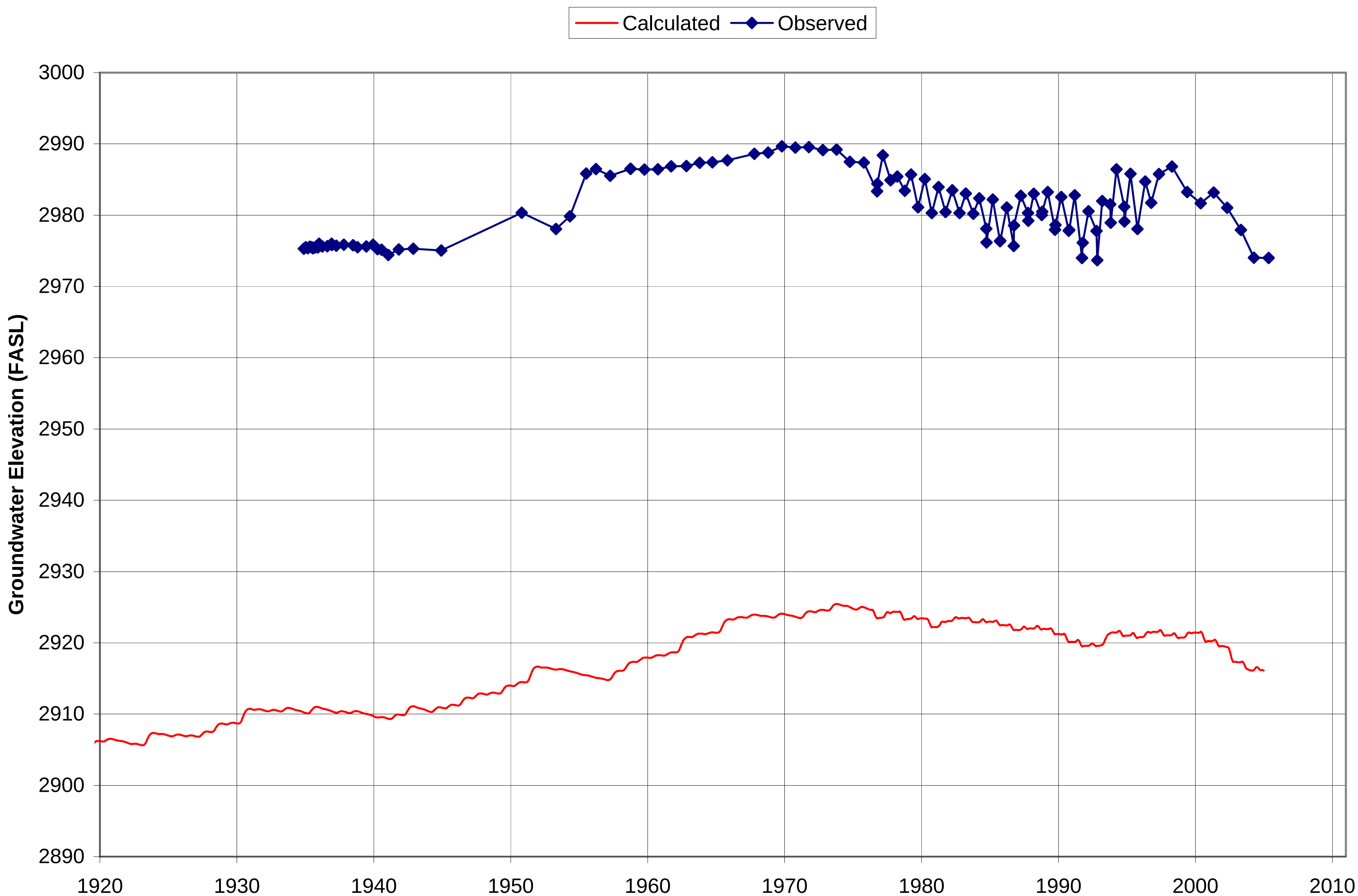


Target ID: (206)



Target ID: (205)

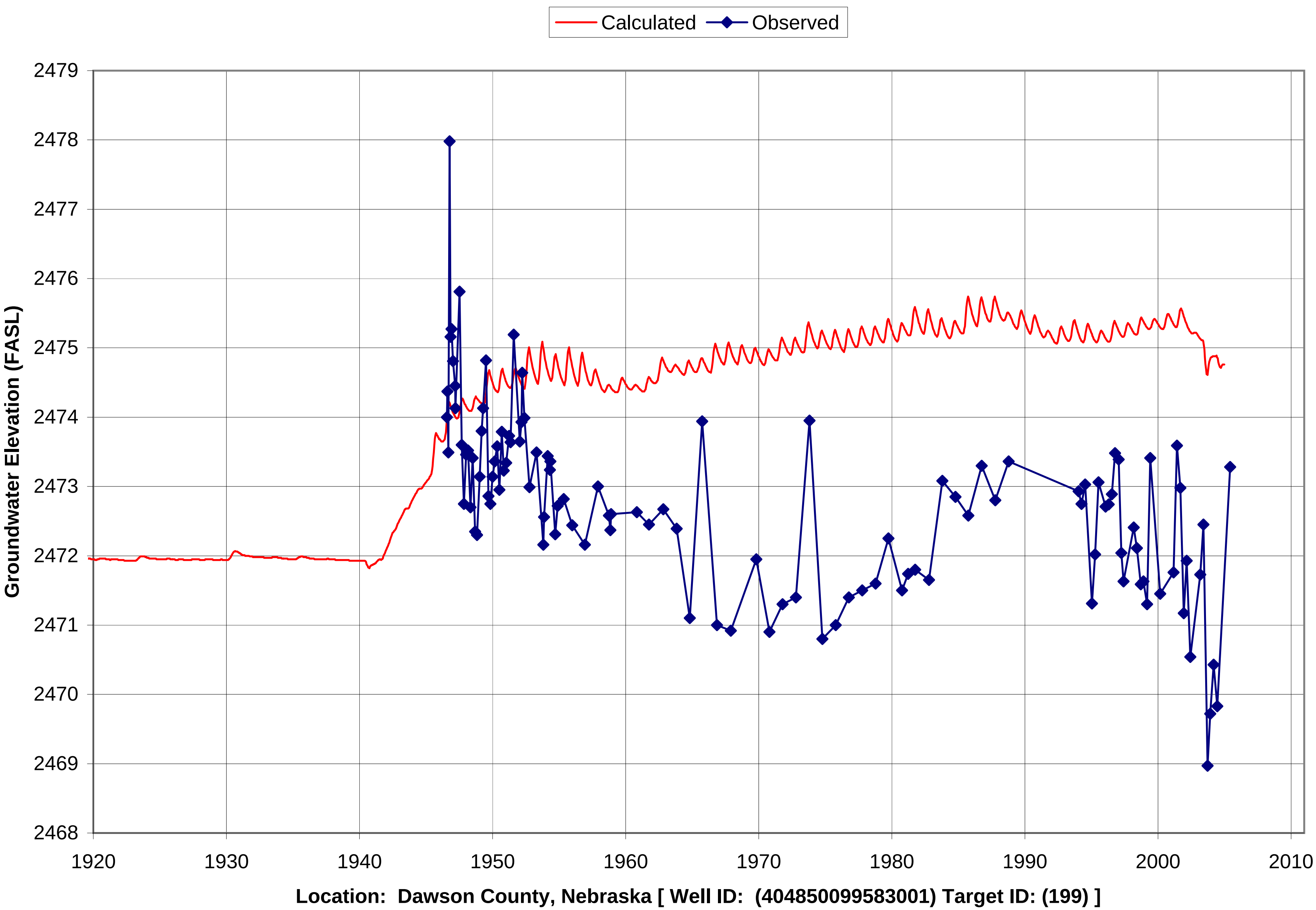
Well ID: (404953100595401)



Location: Lincoln County, Nebraska [Well ID: (404953100595401) Target ID: (200)]

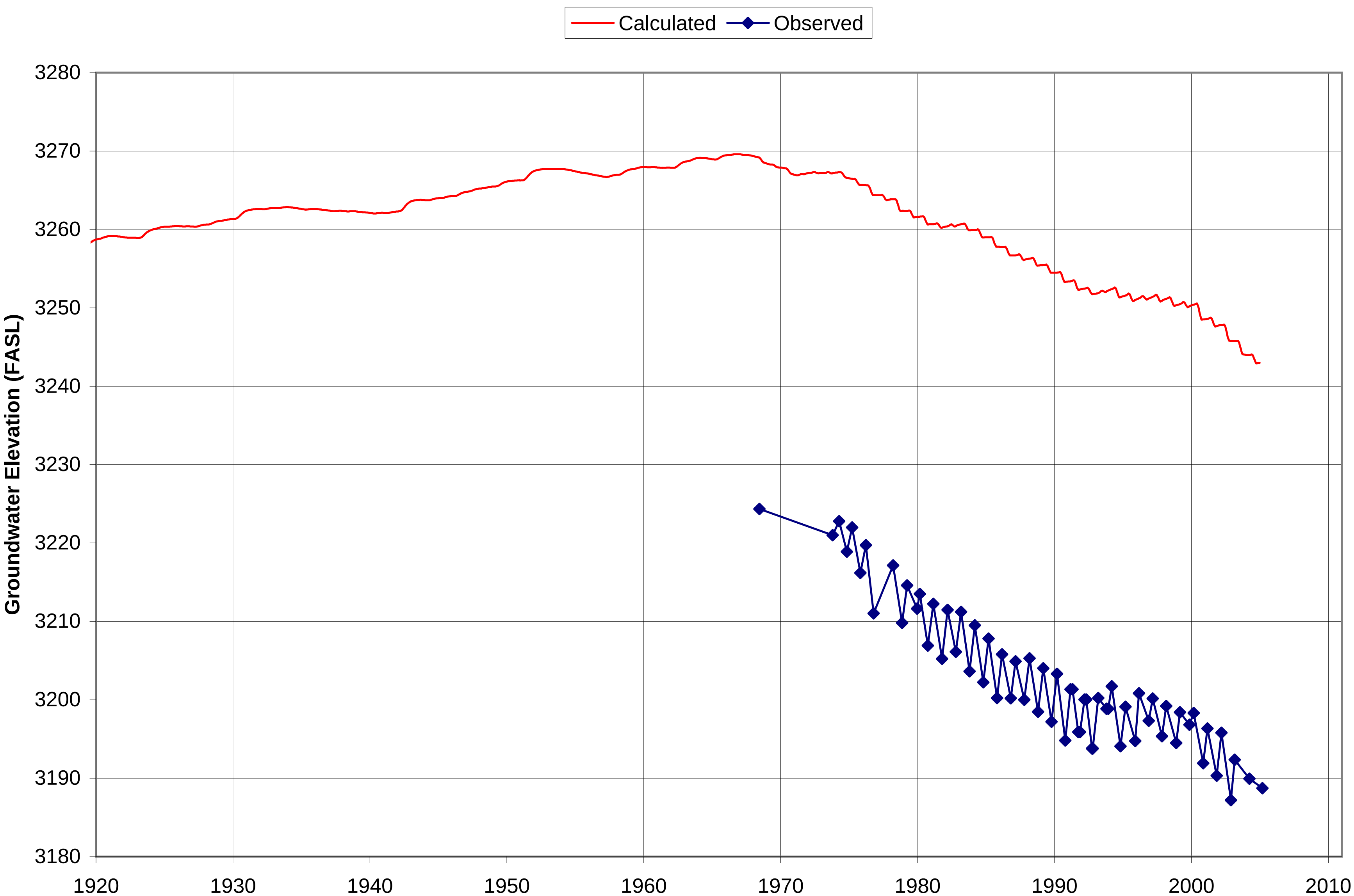
Target ID: (200)

Well ID: (404850099583001)



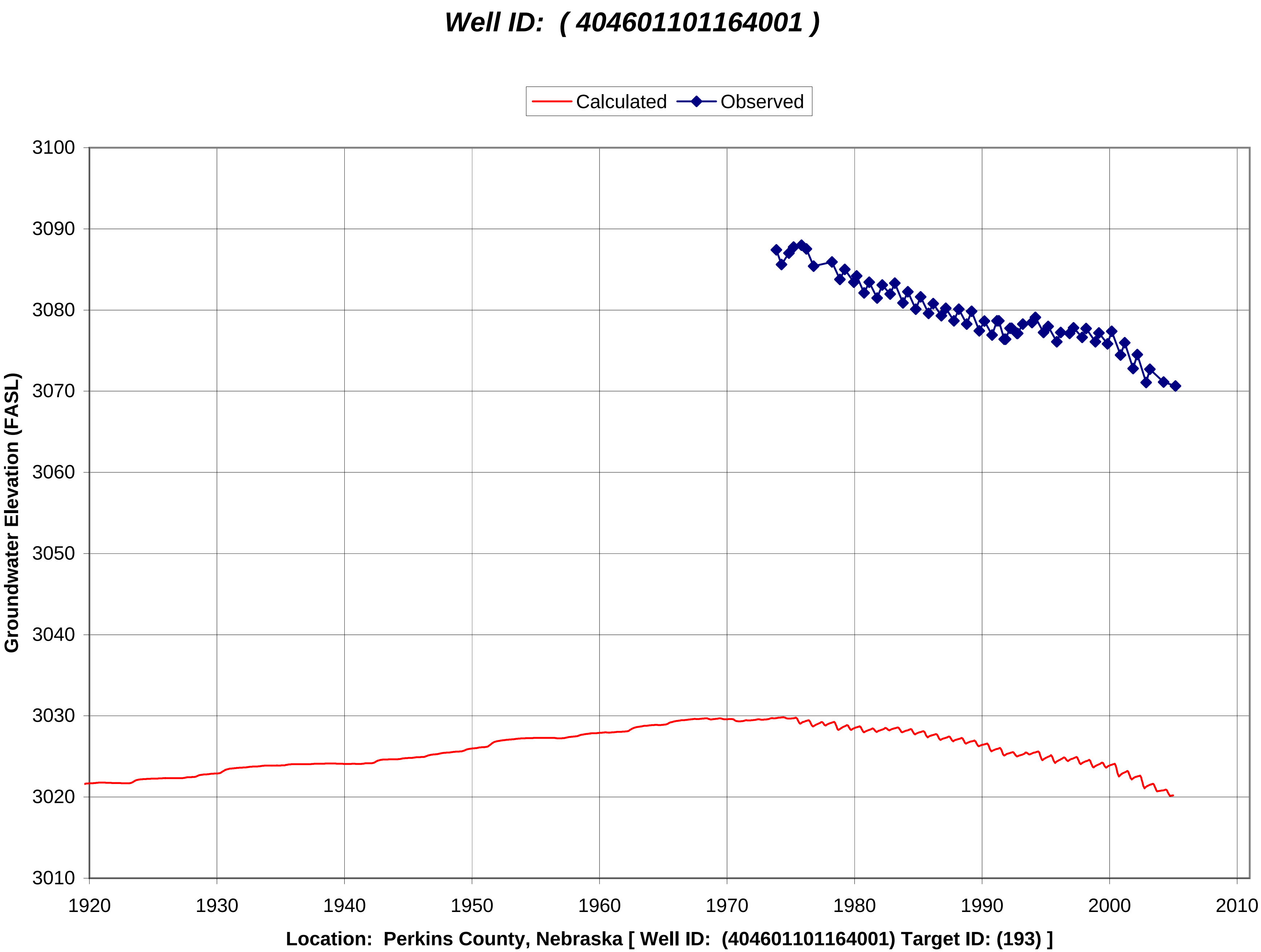
Target ID: (199)

Well ID: (404624101352001)



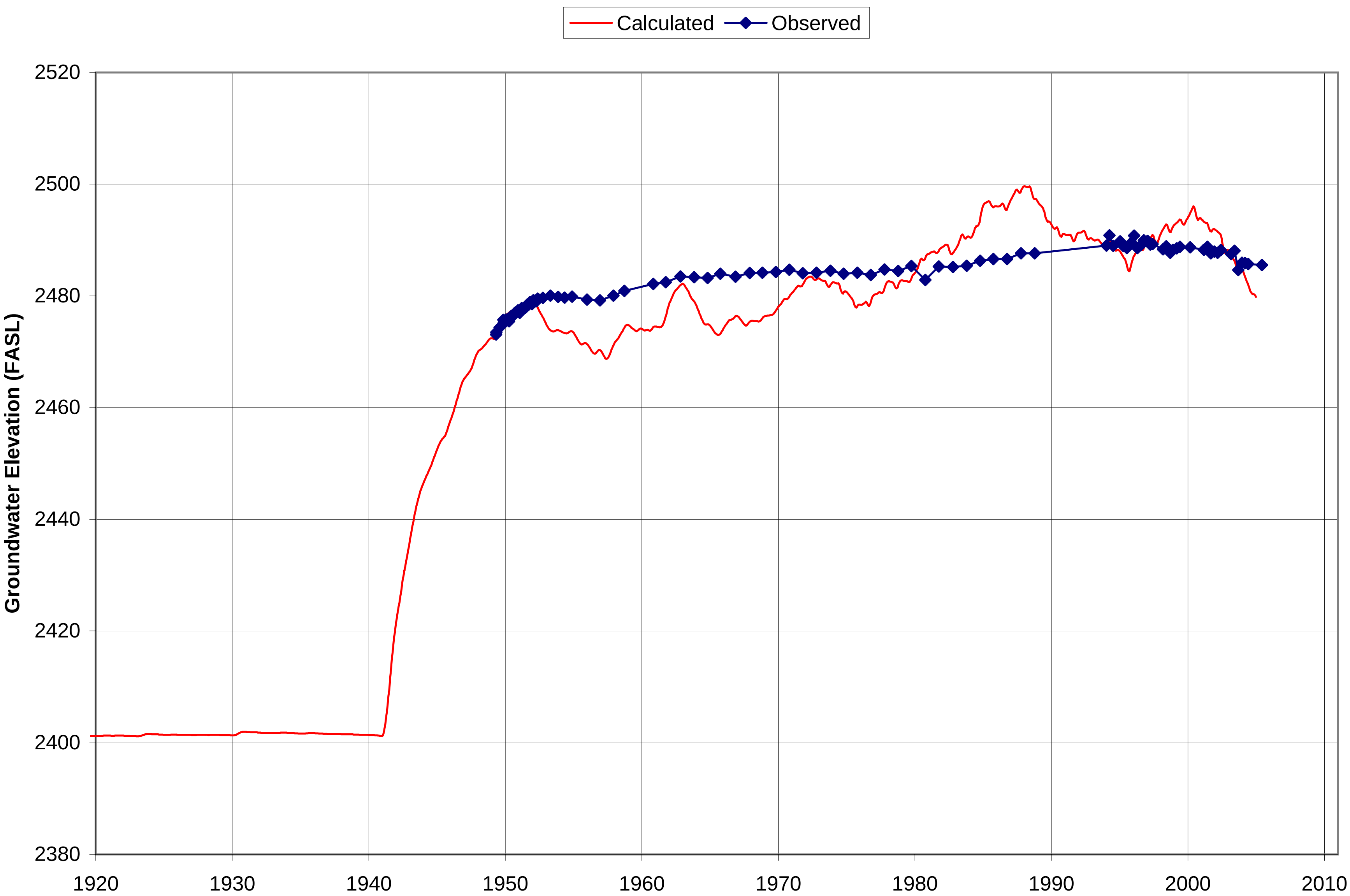
Location: Perkins County, Nebraska [Well ID: (404624101352001) Target ID: (195)]

Target ID: (195)



Target ID: (193)

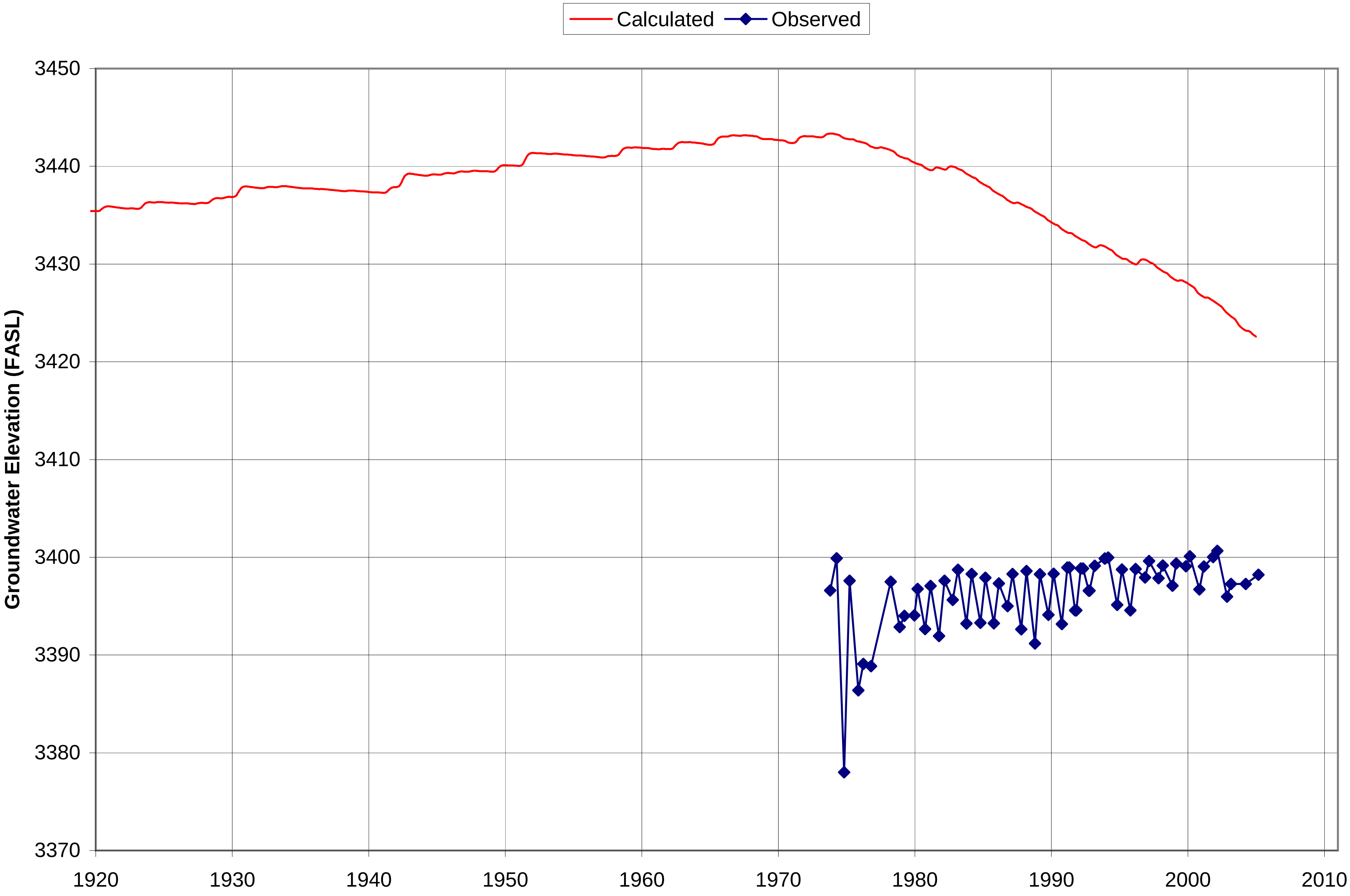
Well ID: (404250099493701)



Location: Dawson County, Nebraska [Well ID: (404250099493701) Target ID: (190)]

Target ID: (190)

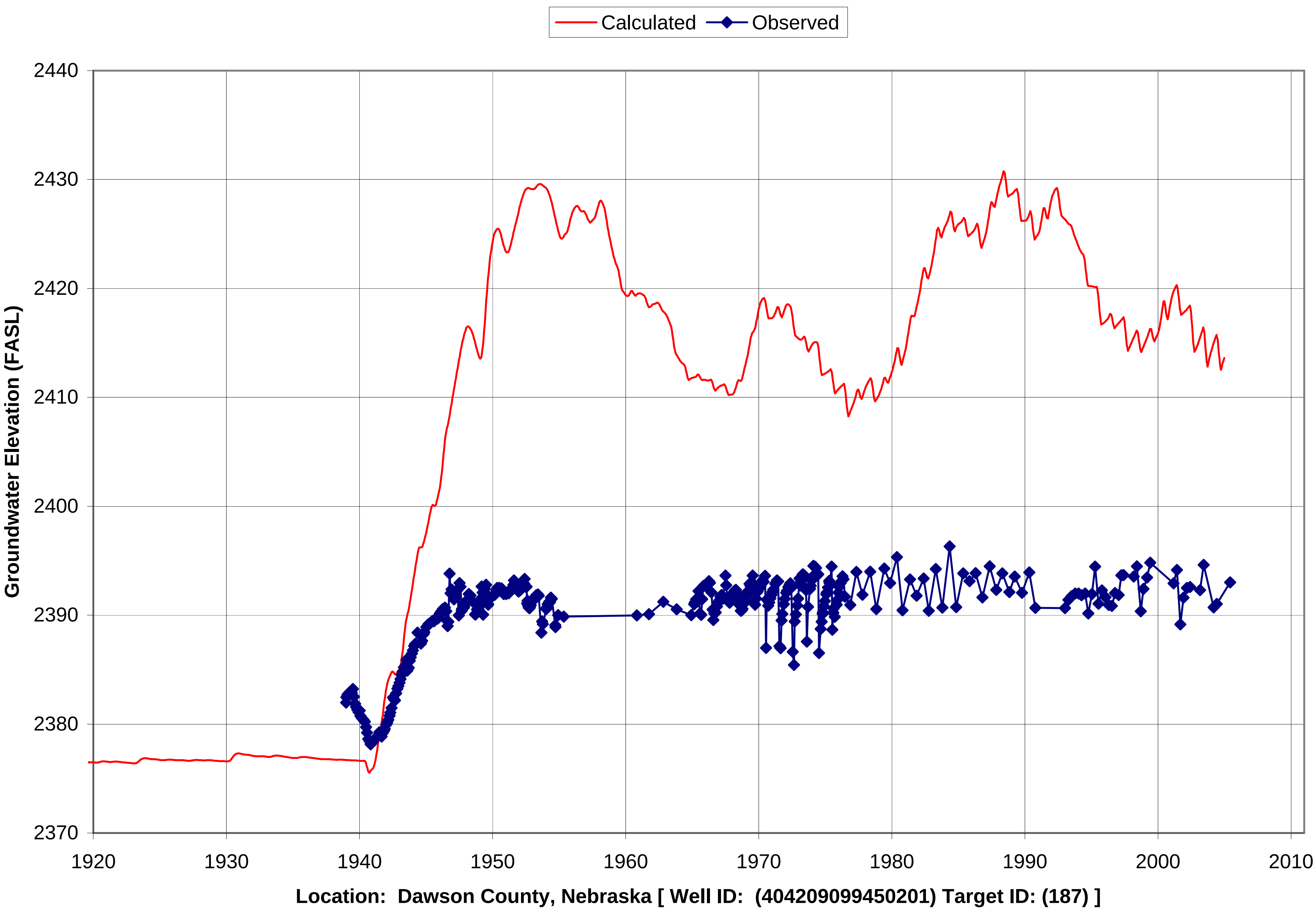
Well ID: (404221101575501)



Location: Perkins County, Nebraska [Well ID: (404221101575501) Target ID: (188)]

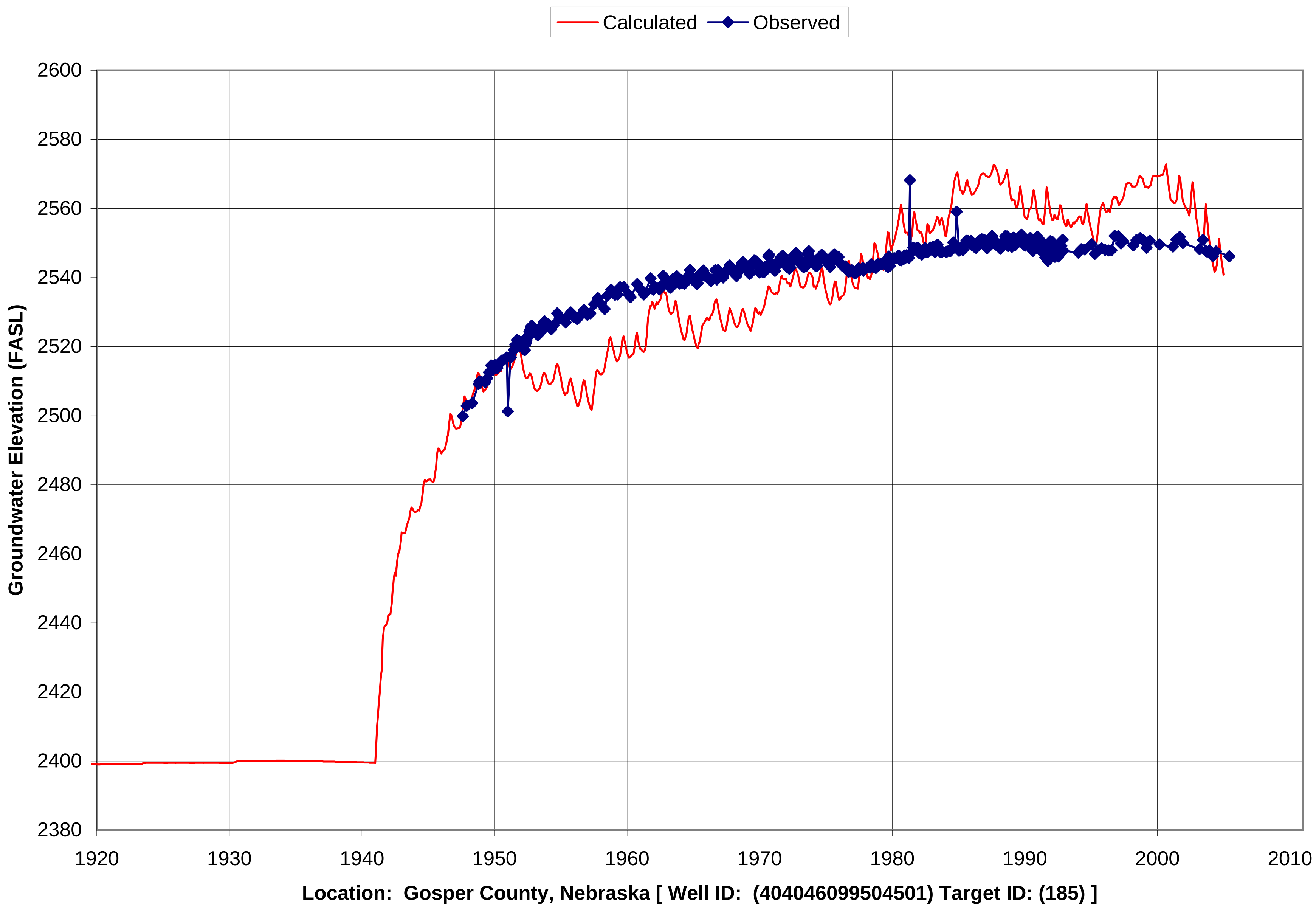
Target ID: (188)

Well ID: (404209099450201)



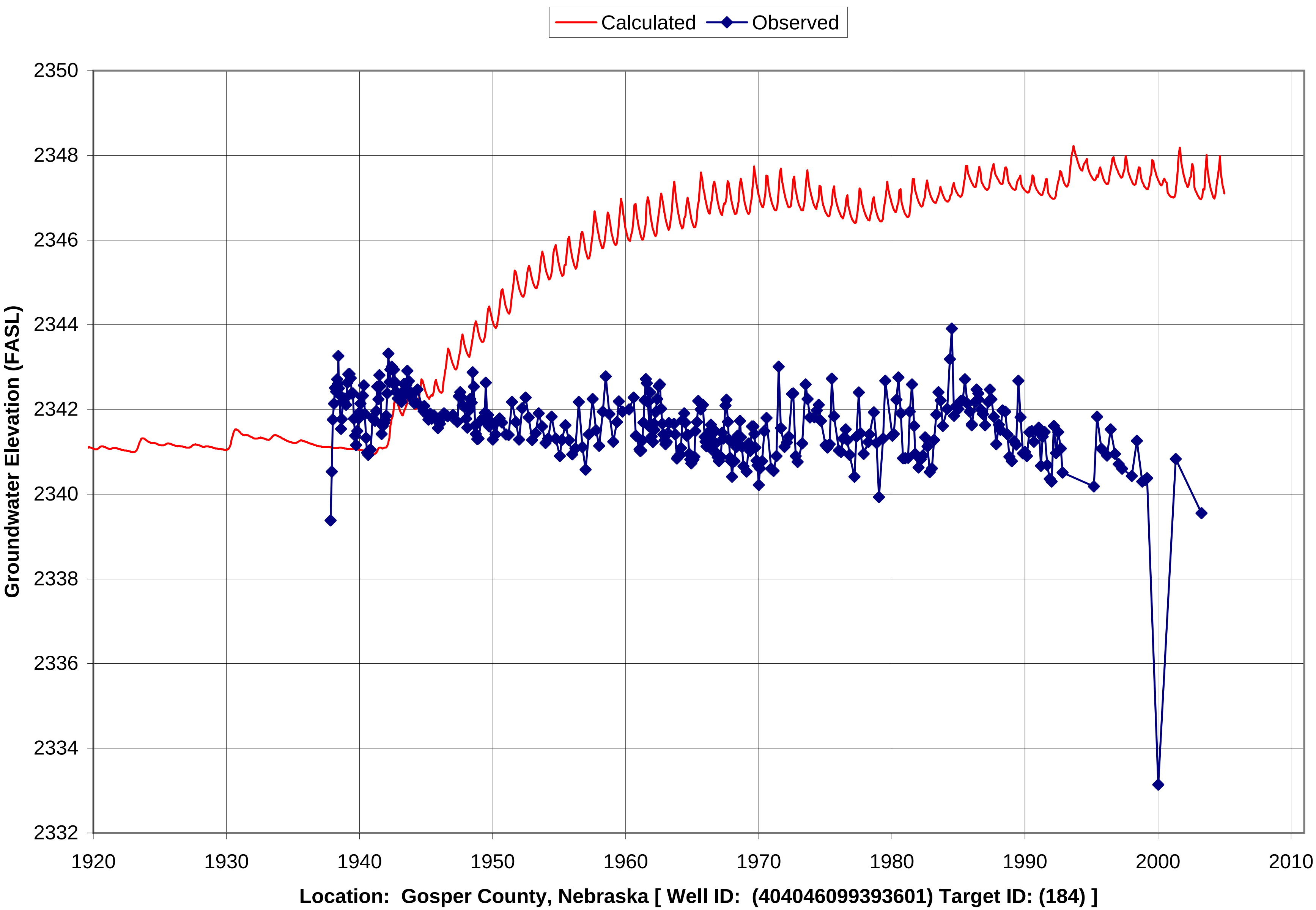
Target ID: (187)

Well ID: (404046099504501)



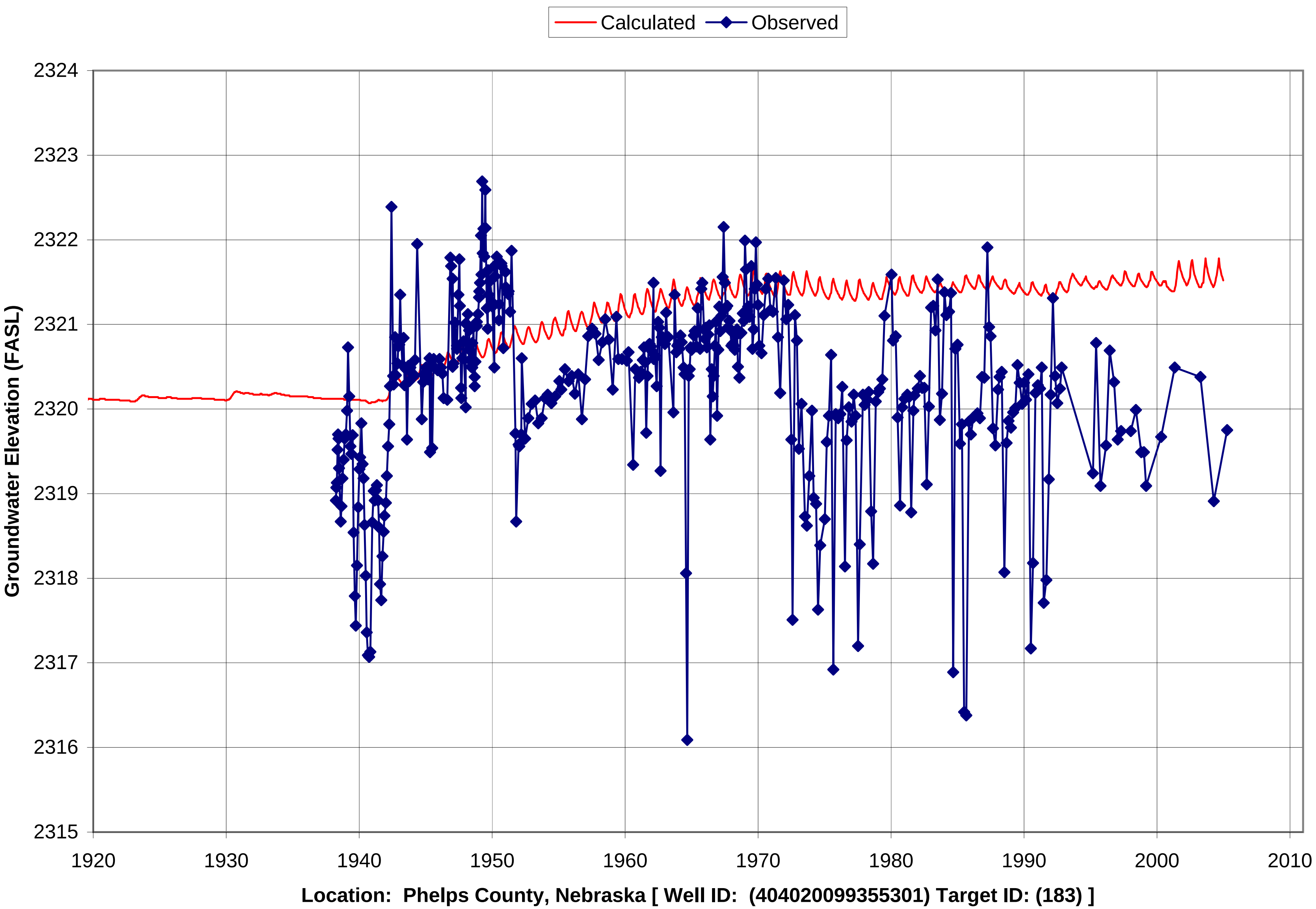
Target ID: (185)

Well ID: (404046099393601)



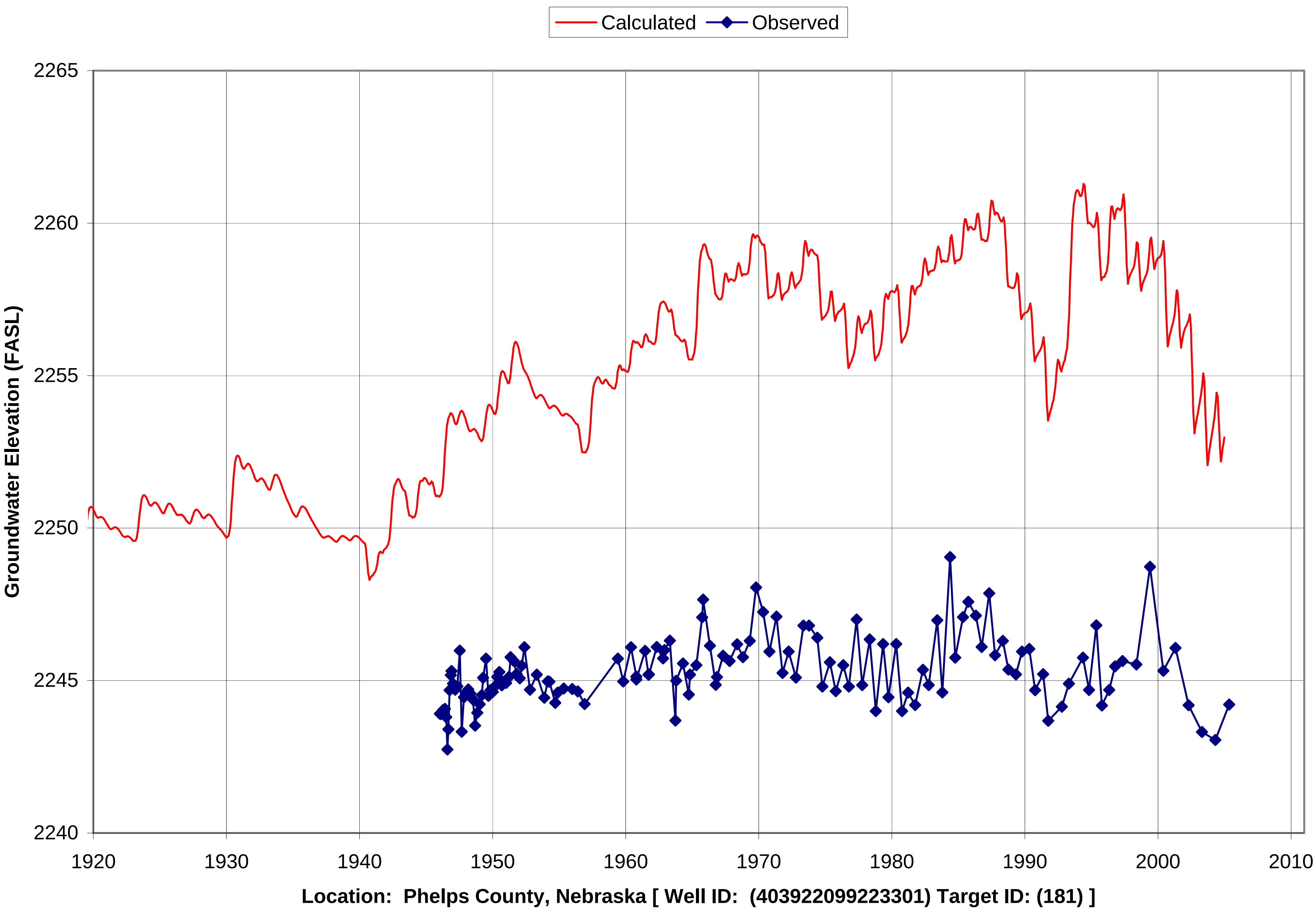
Target ID: (184)

Well ID: (404020099355301)



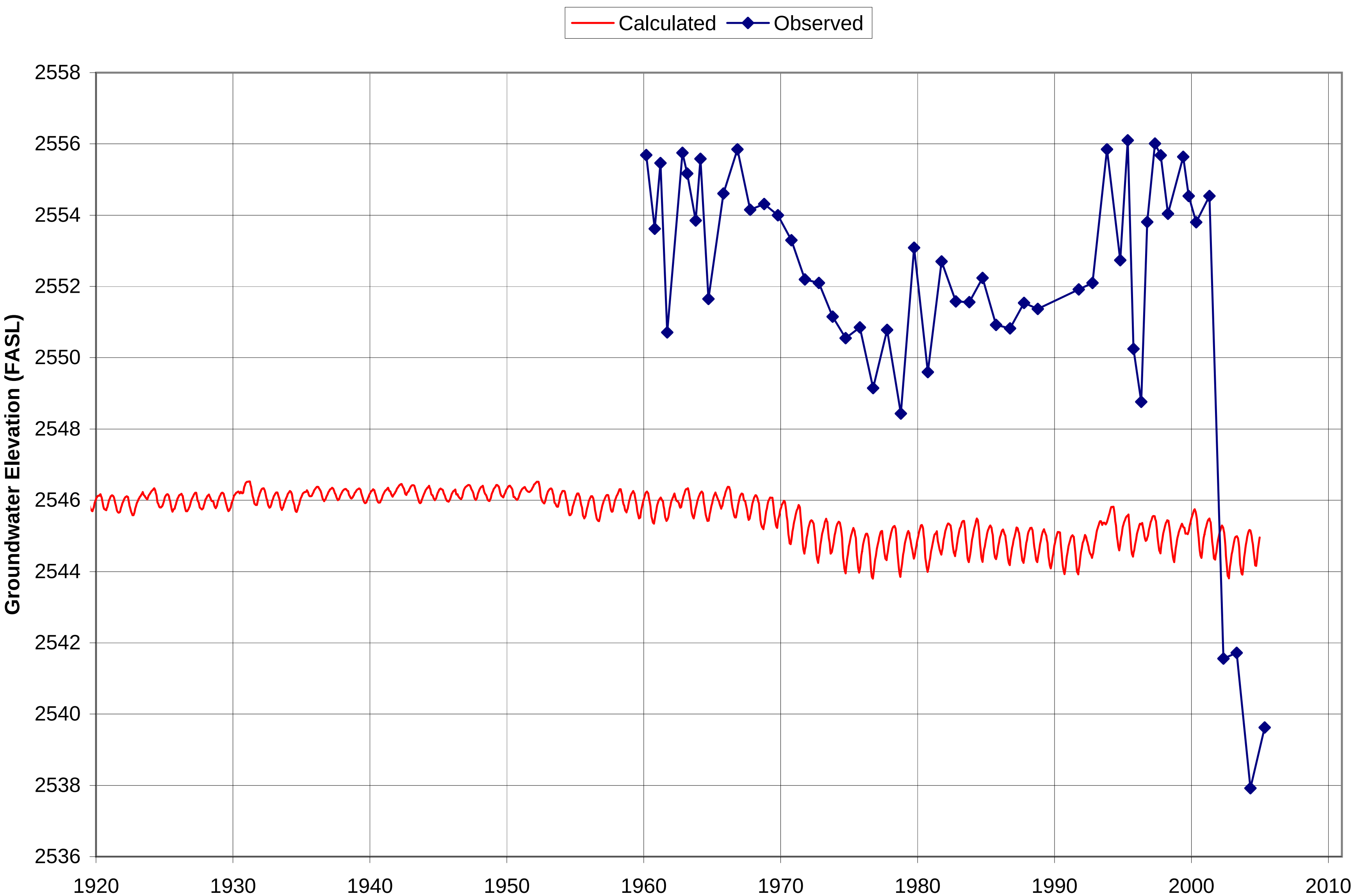
Target ID: (183)

Well ID: (403922099223301)



Target ID: (181)

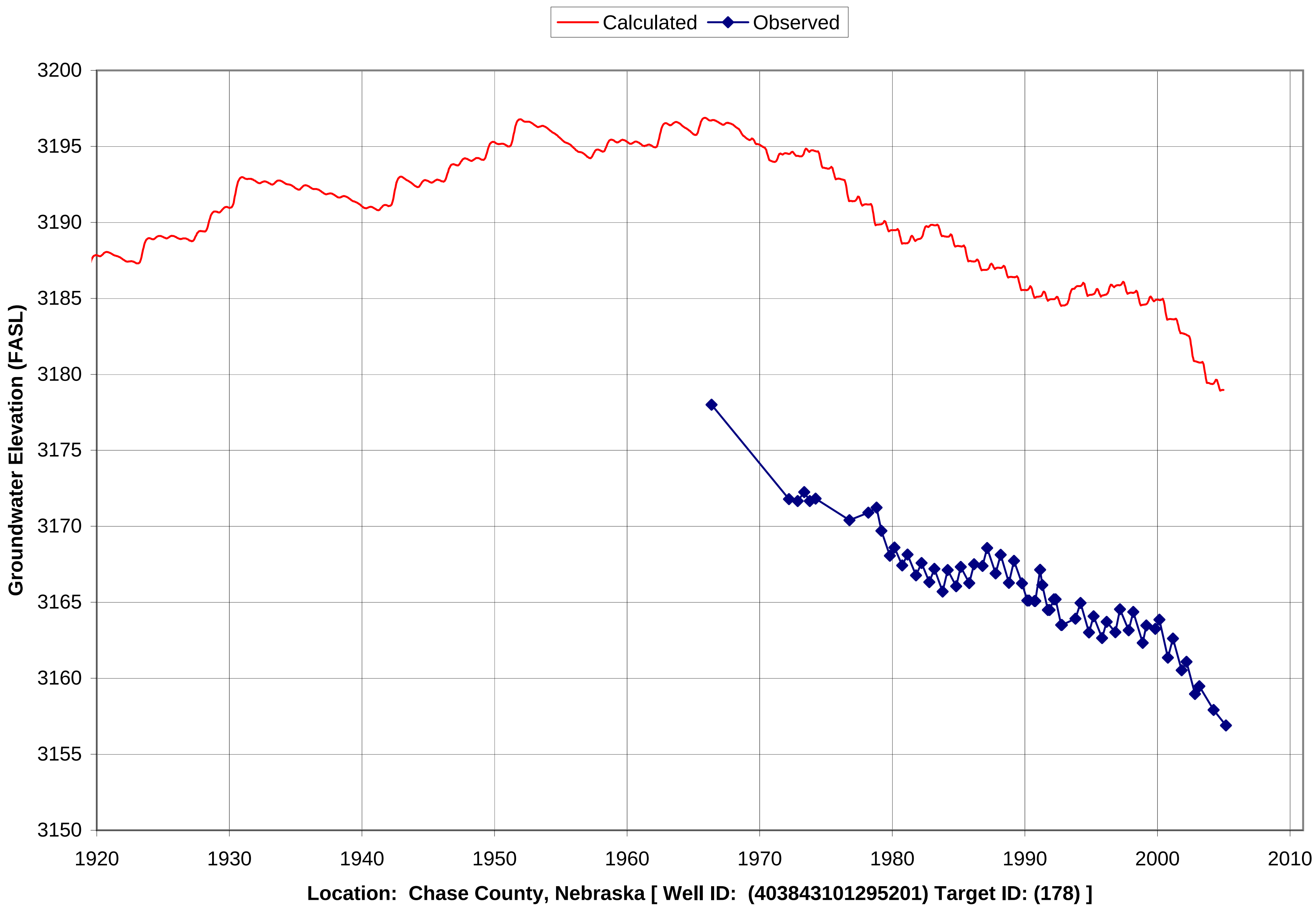
Well ID: (403913100295401)



Location: Frontier County, Nebraska [Well ID: (403913100295401) Target ID: (180)]

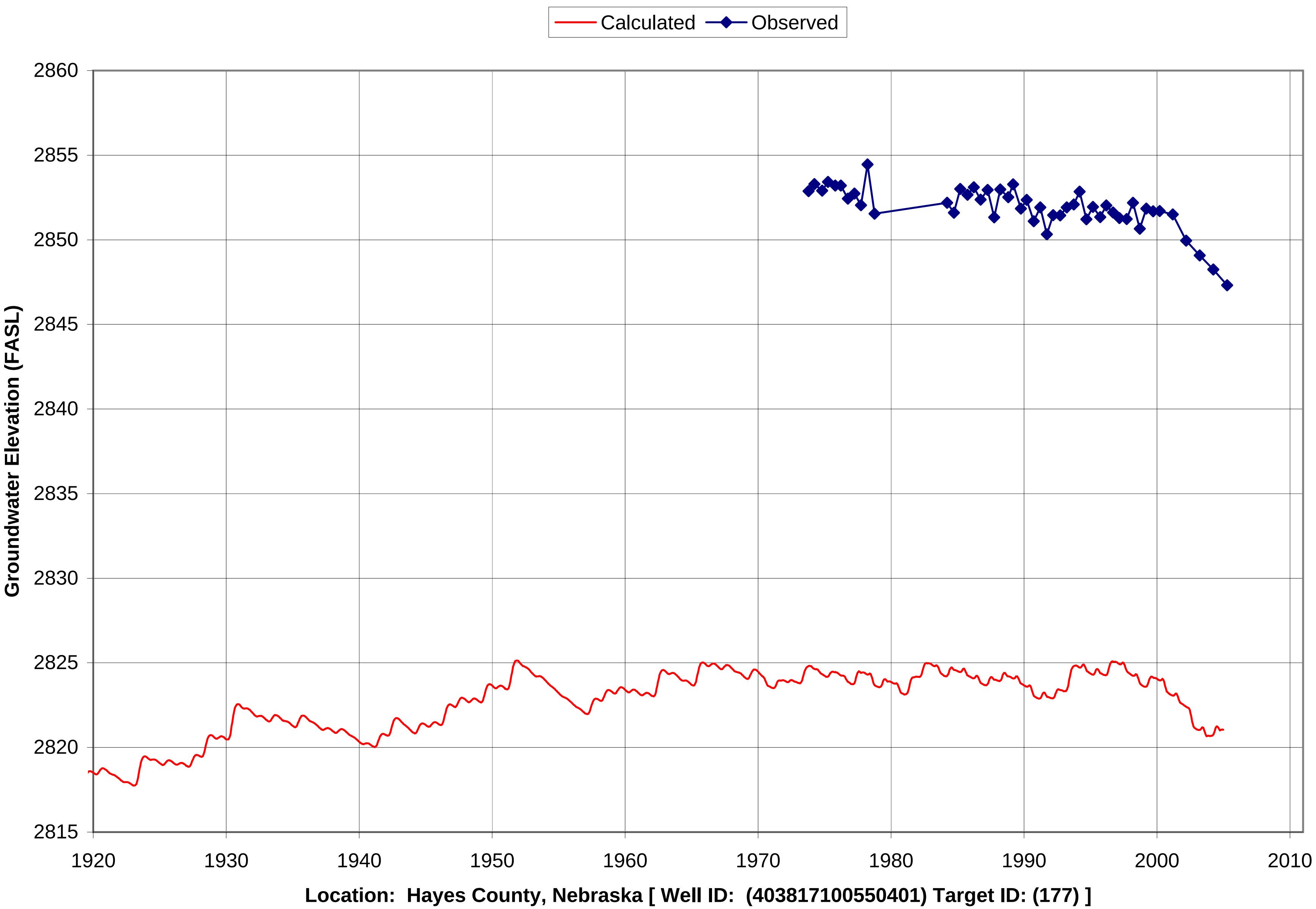
Target ID: (180)

Well ID: (403843101295201)



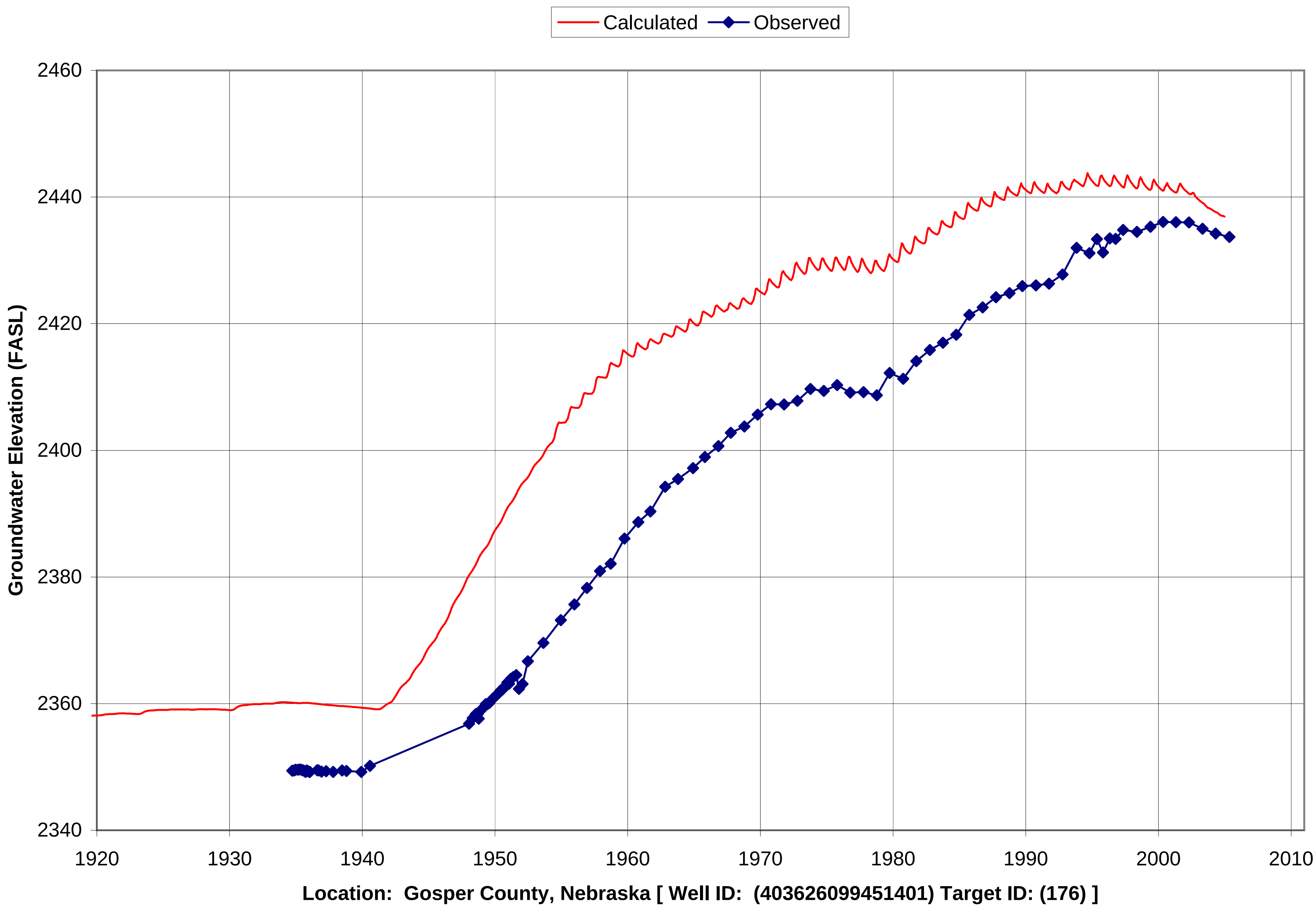
Target ID: (178)

Well ID: (403817100550401)



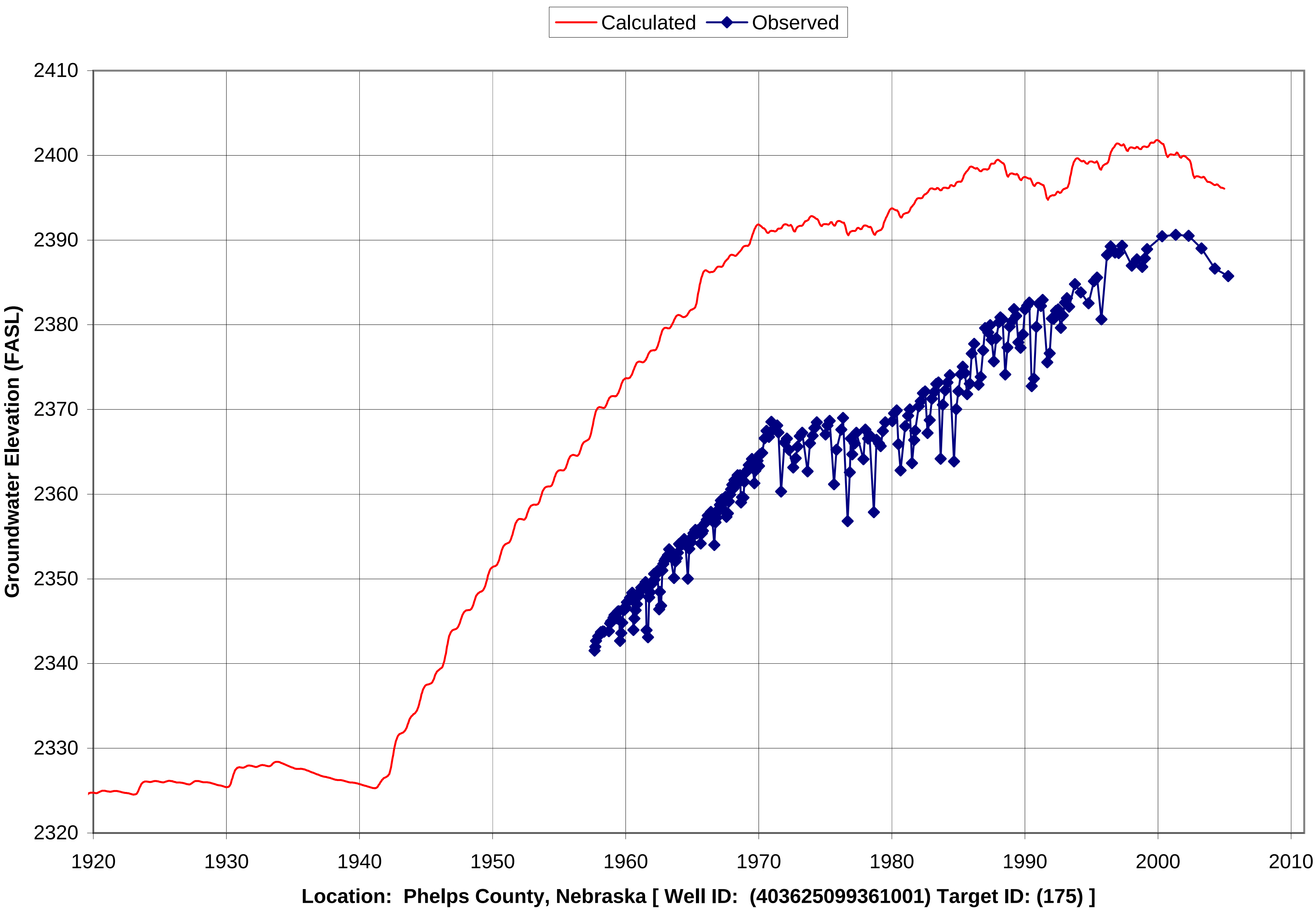
Target ID: (177)

Well ID: (403626099451401)



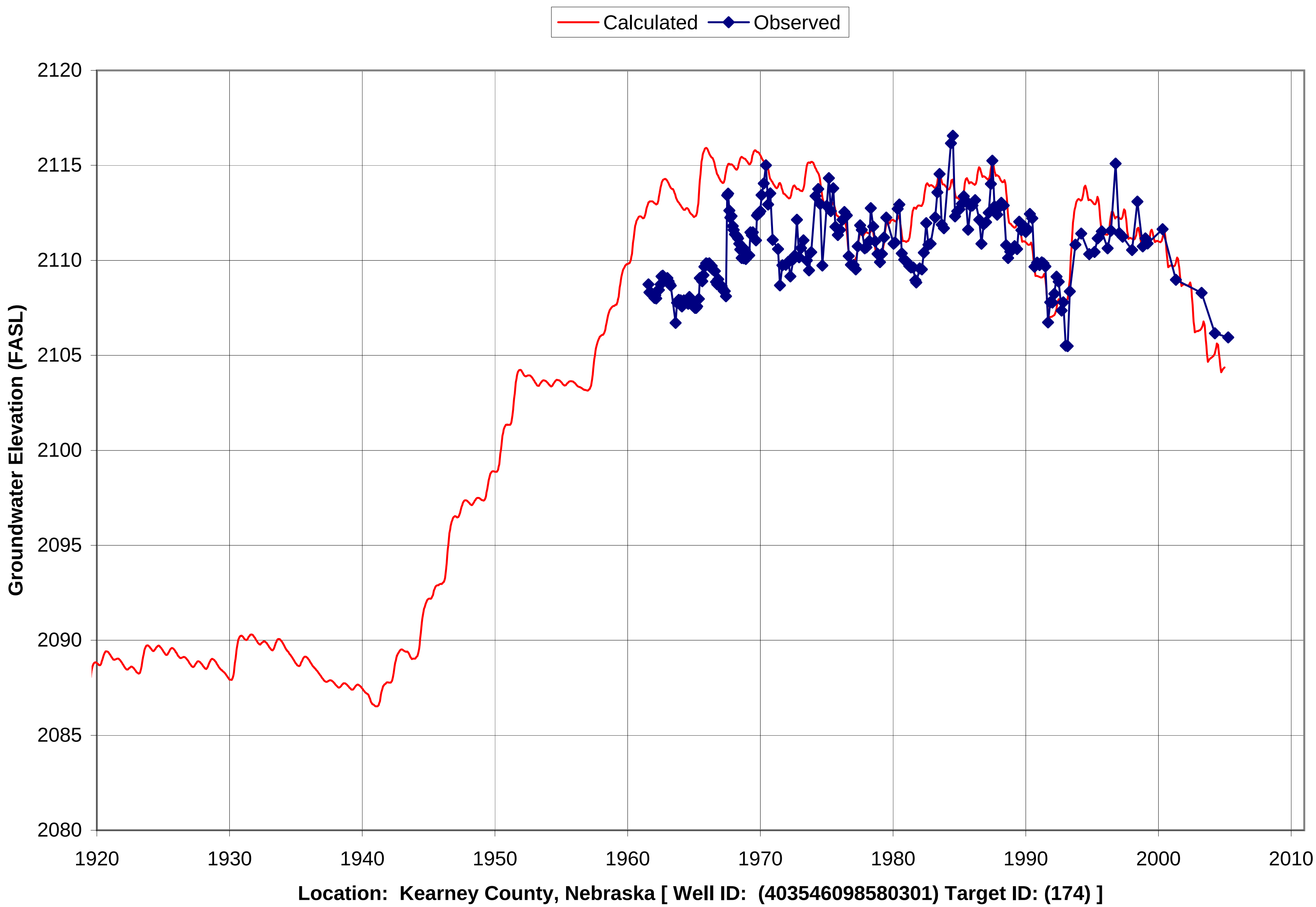
Target ID: (176)

Well ID: (403625099361001)



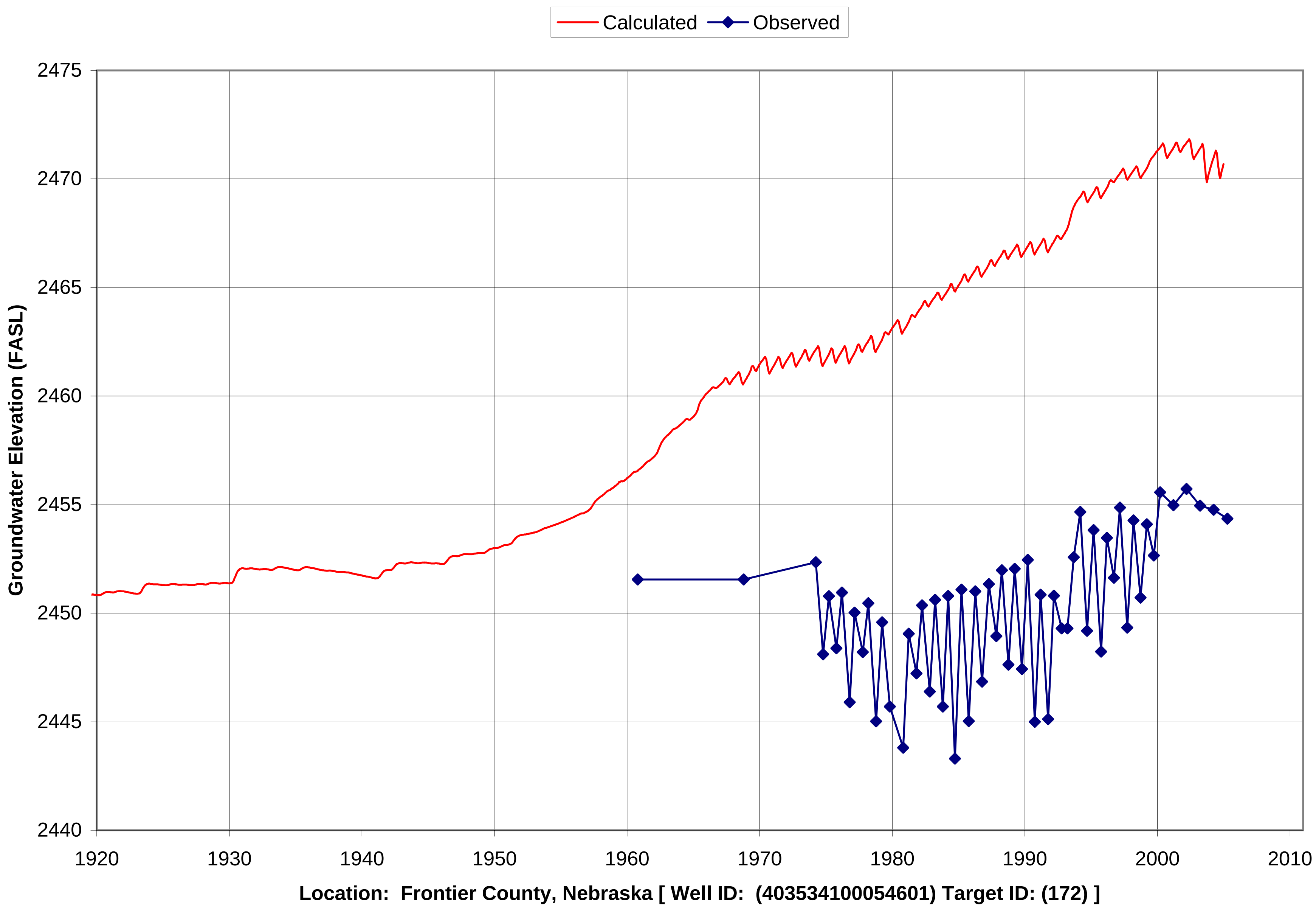
Target ID: (175)

Well ID: (403546098580301)



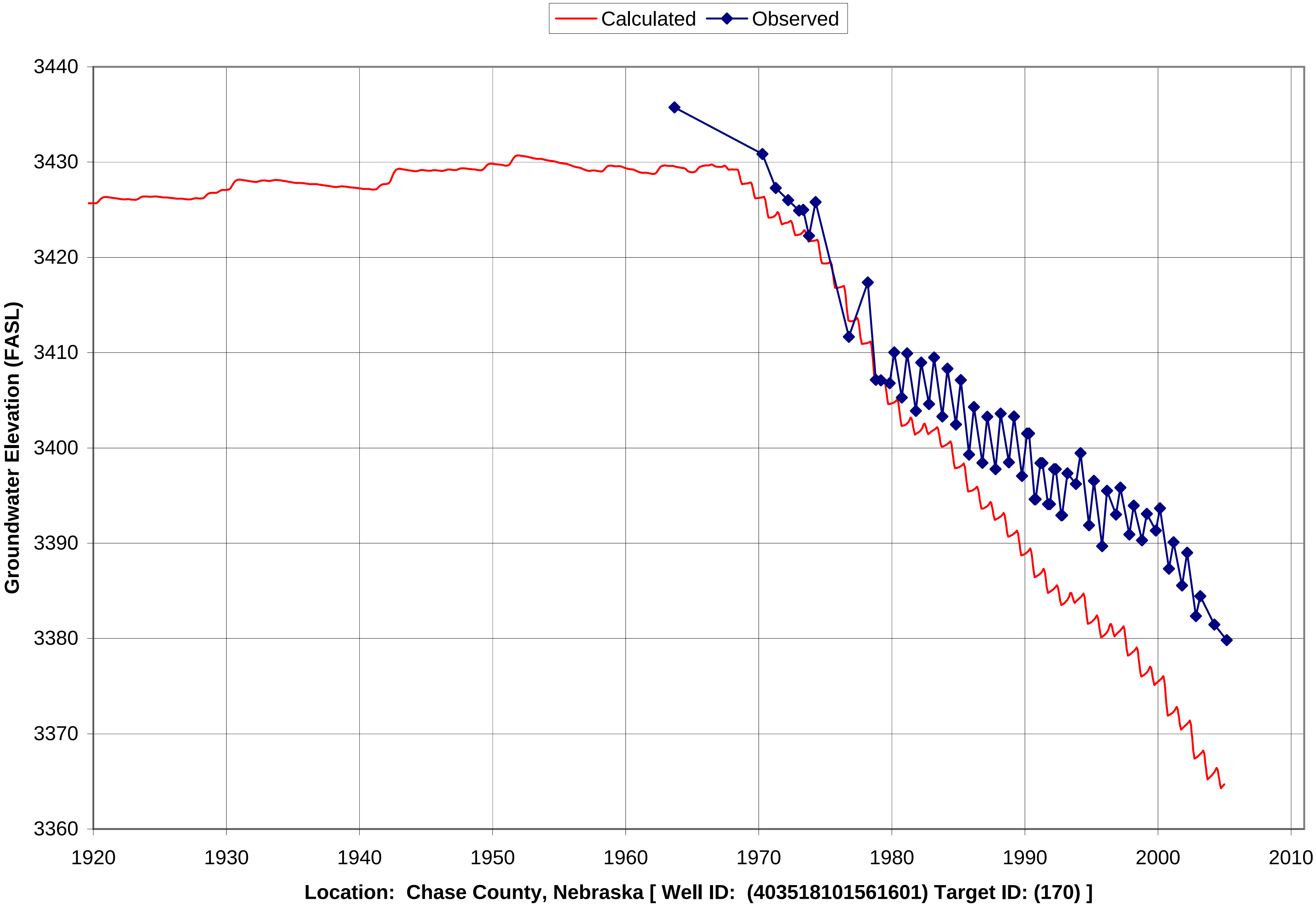
Target ID: (174)

Well ID: (403534100054601)



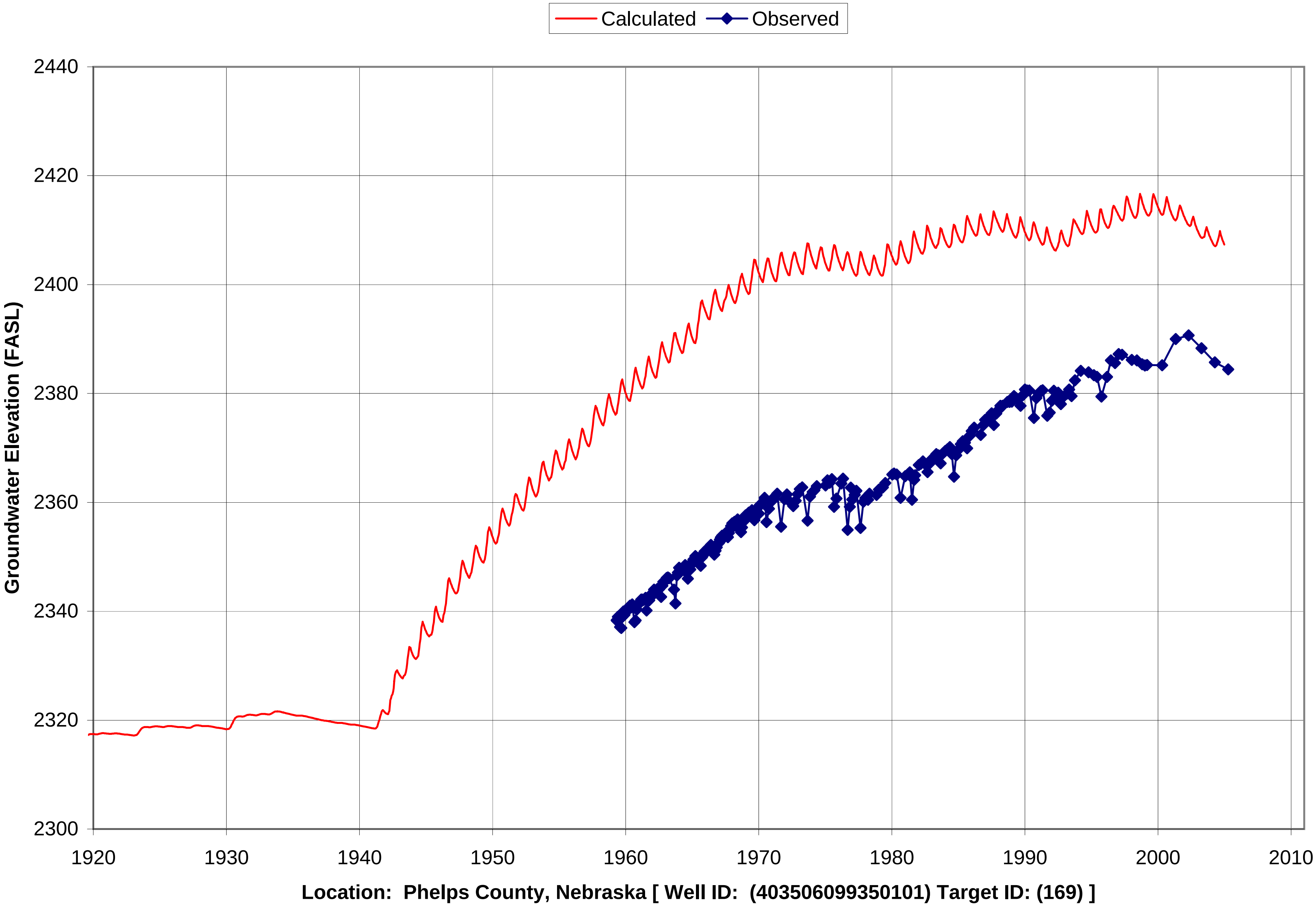
Target ID: (172)

Well ID: (403518101561601)



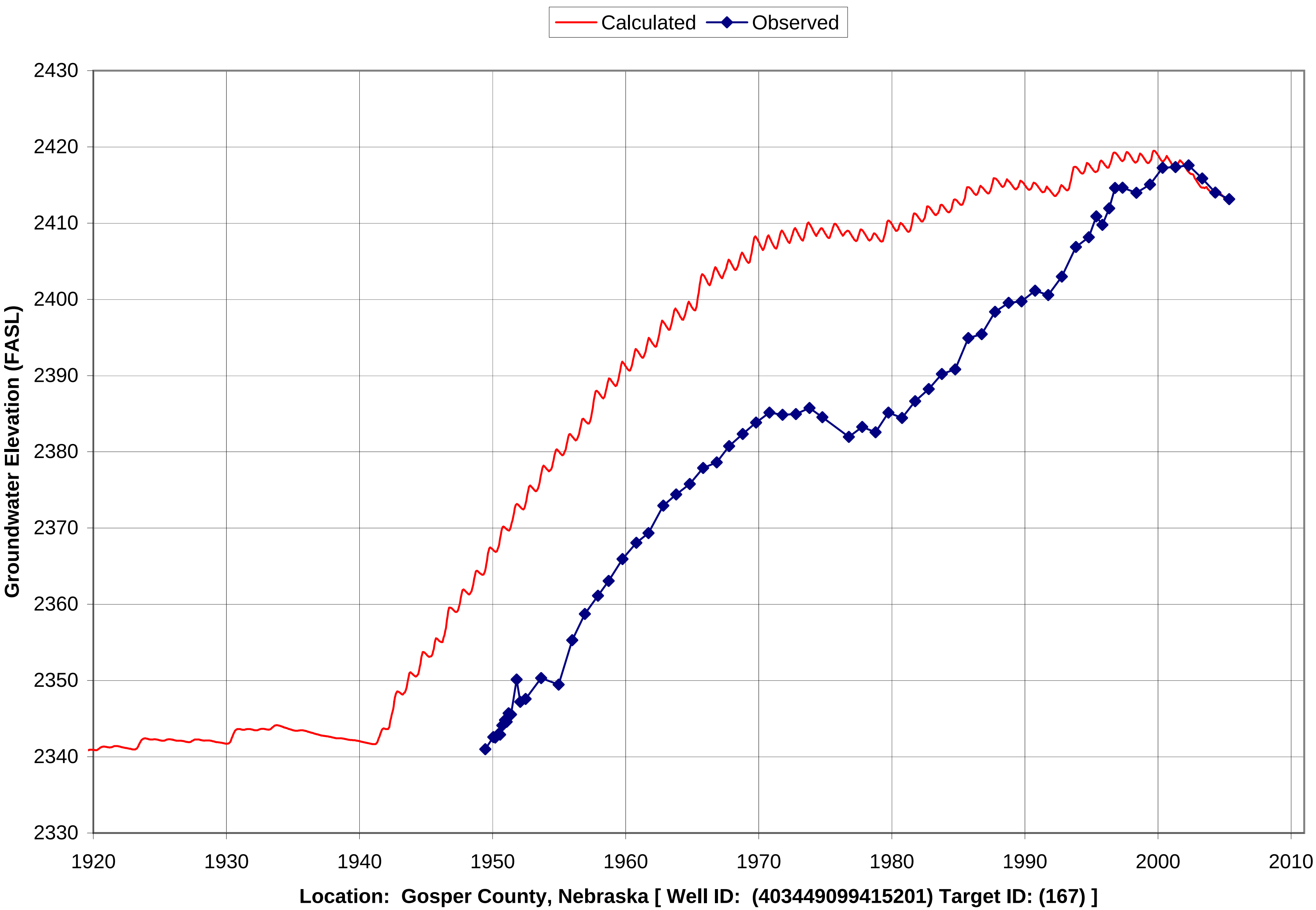
Target ID: (170)

Well ID: (403506099350101)



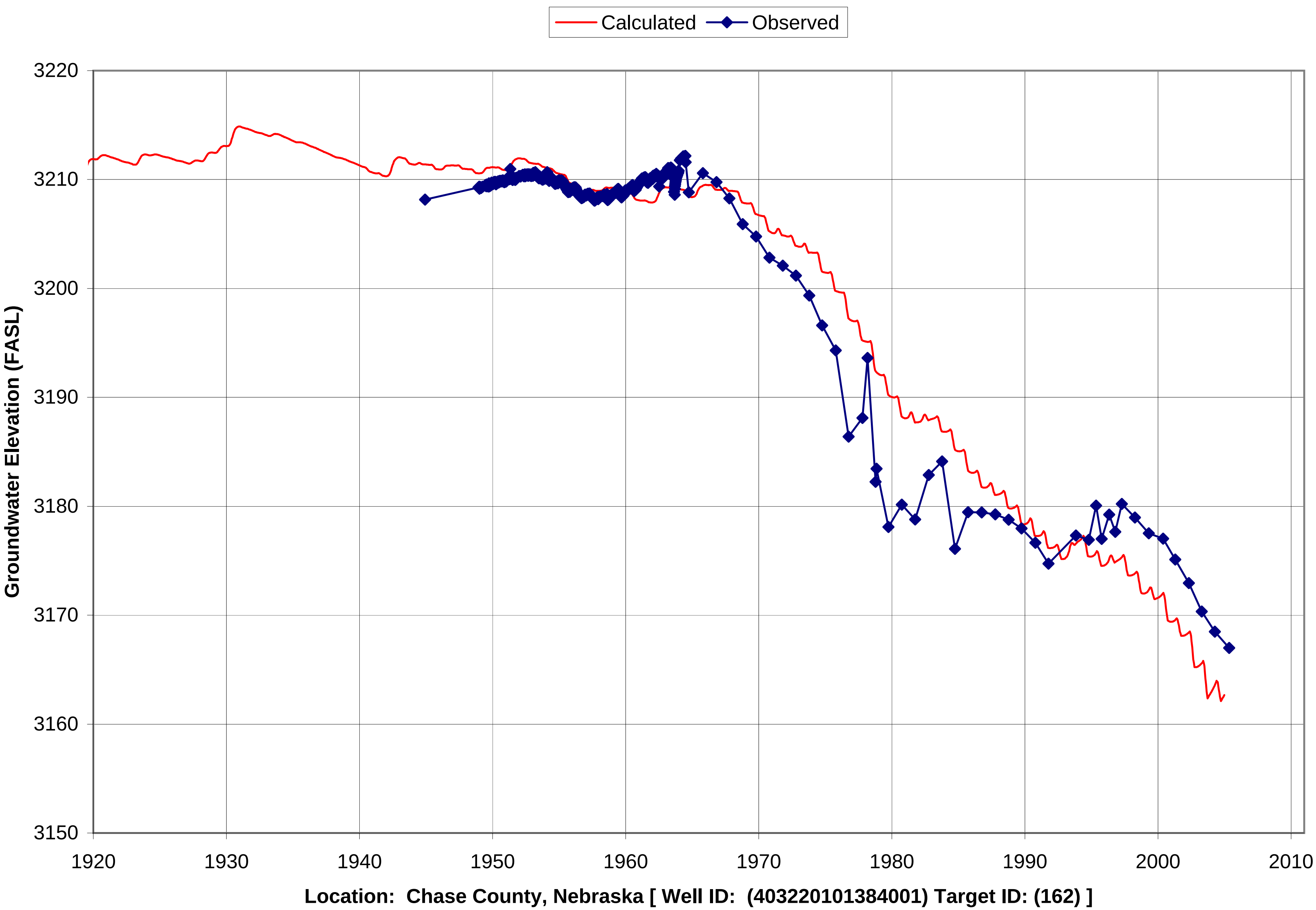
Target ID: (169)

Well ID: (403449099415201)



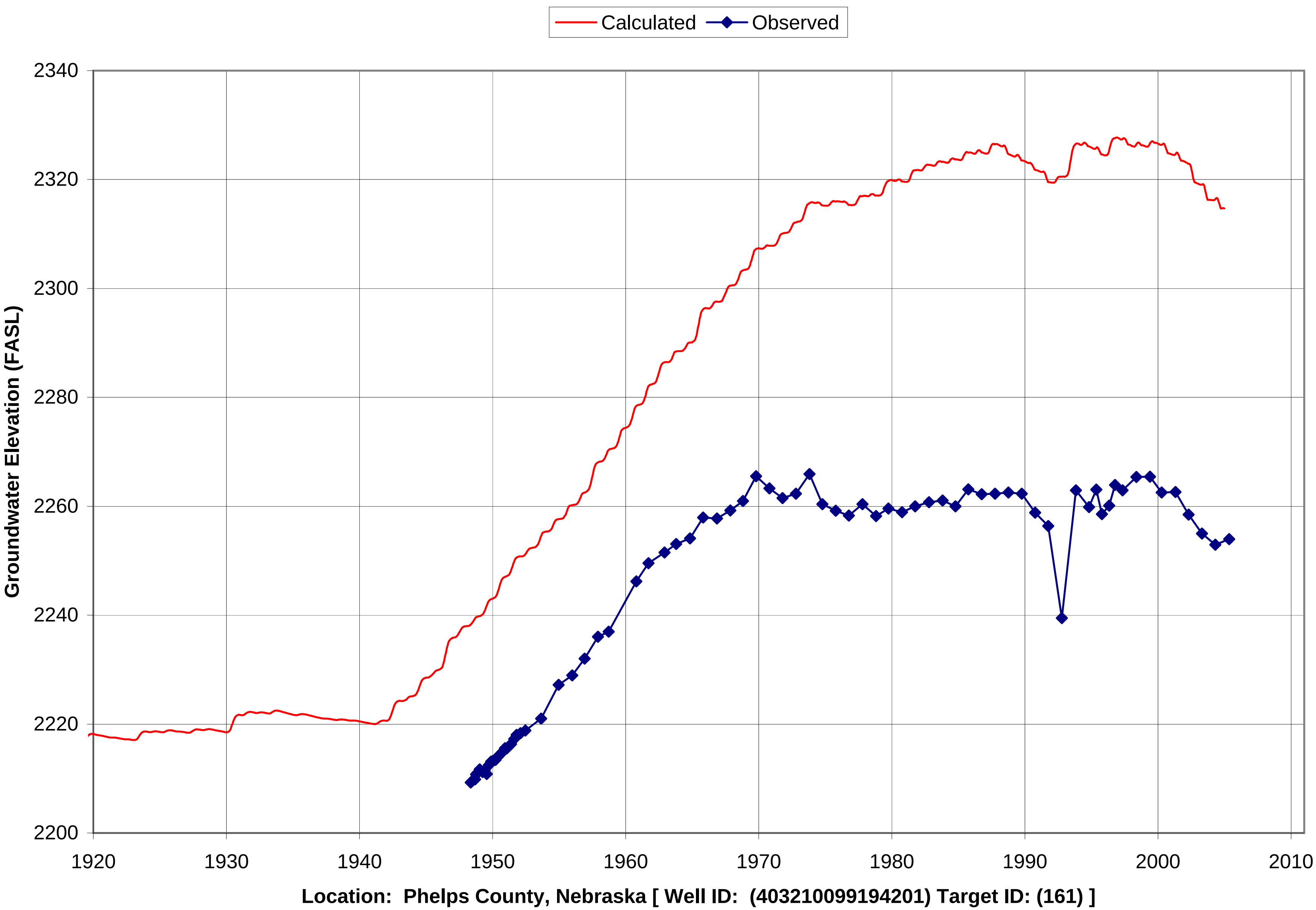
Target ID: (167)

Well ID: (403220101384001)



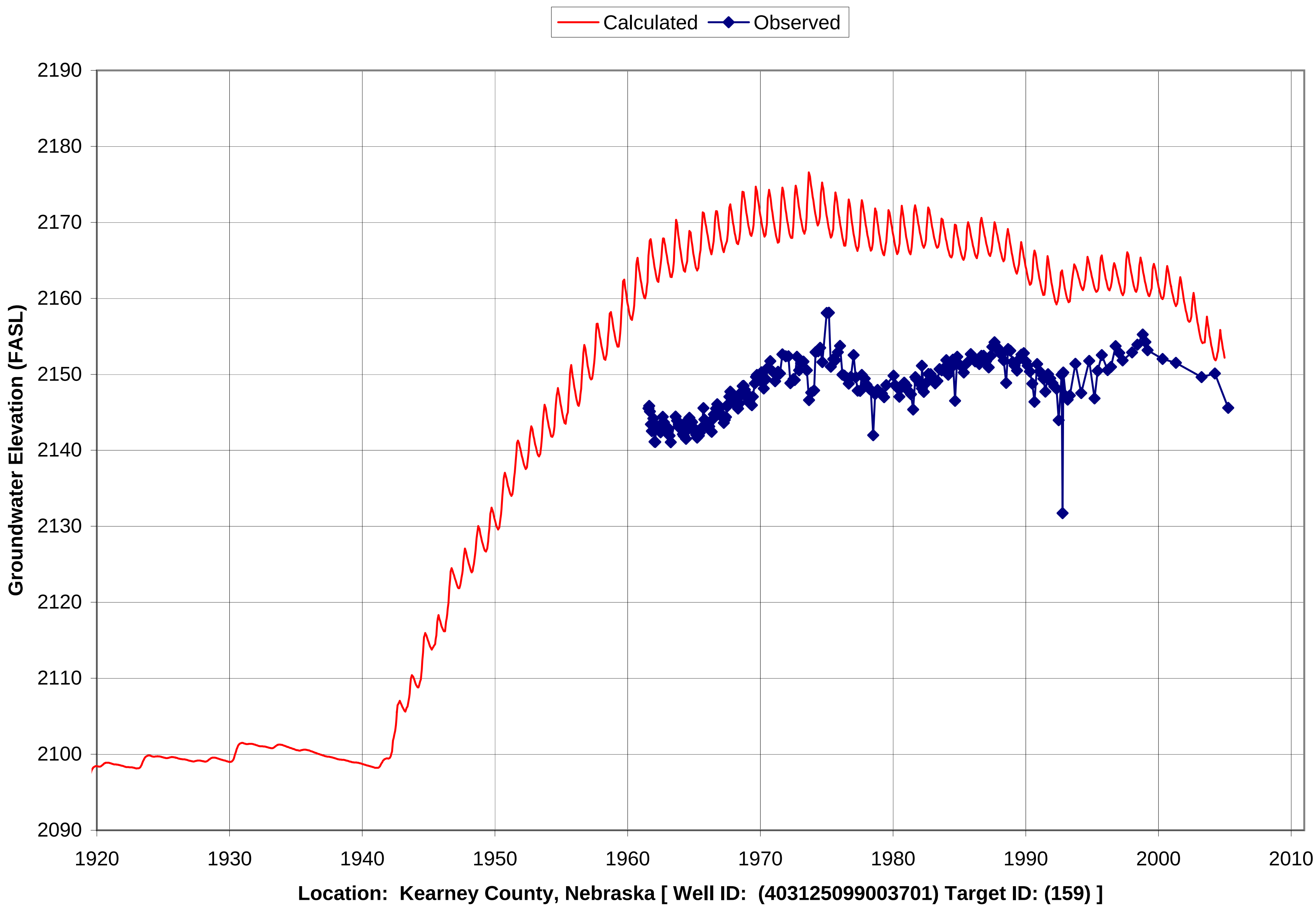
Target ID: (162)

Well ID: (403210099194201)



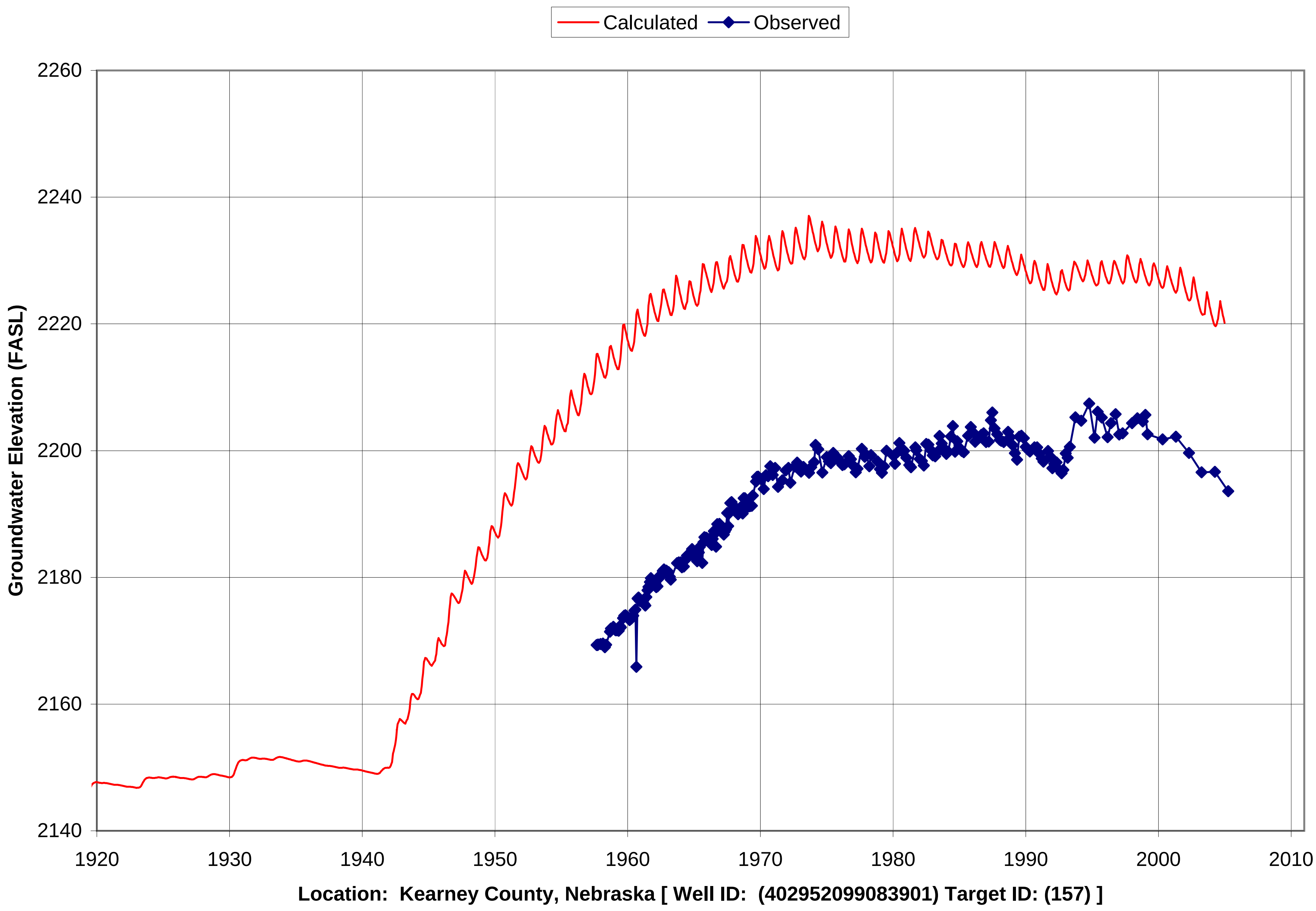
Target ID: (161)

Well ID: (403125099003701)



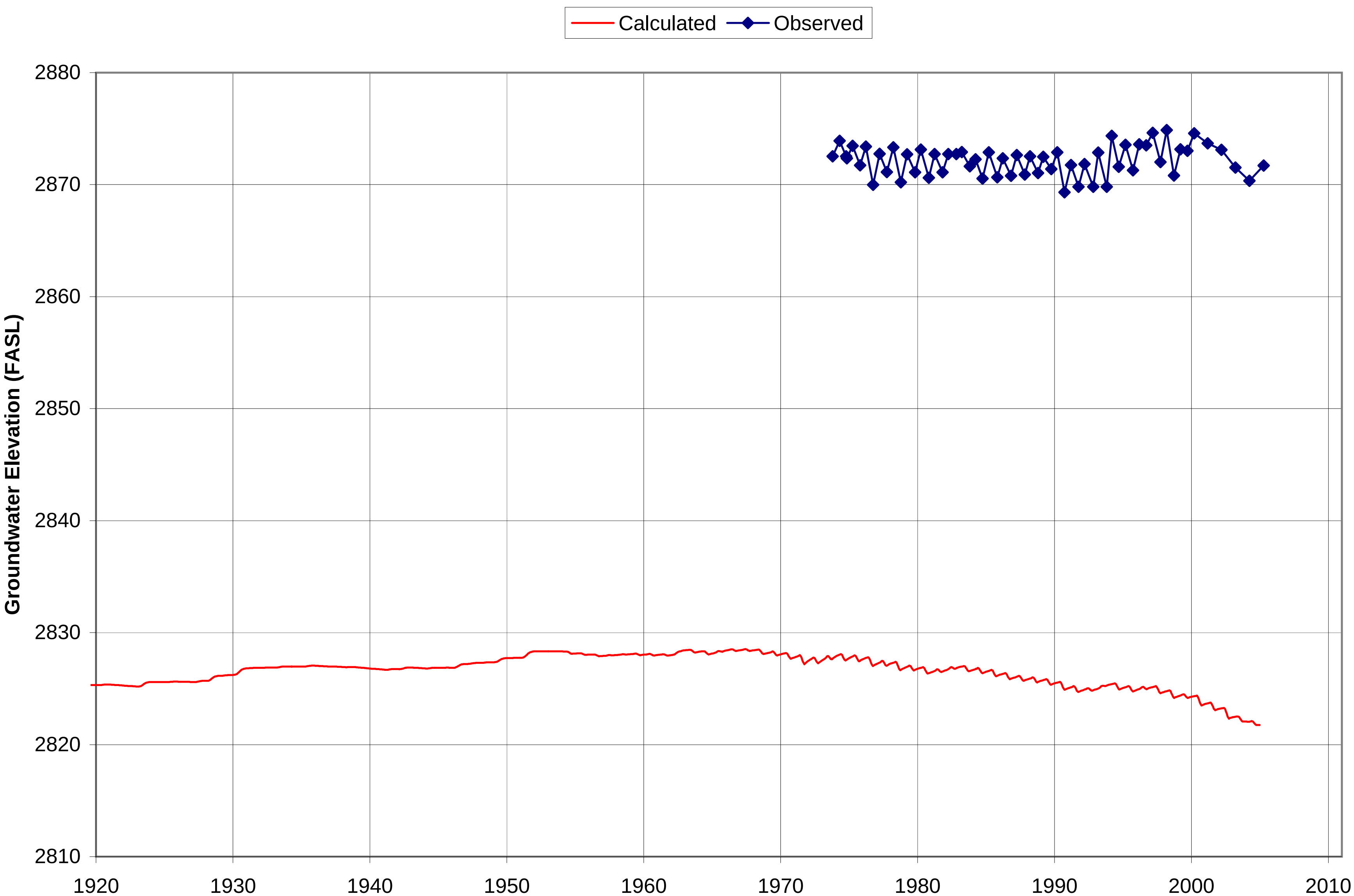
Target ID: (159)

Well ID: (402952099083901)



Target ID: (157)

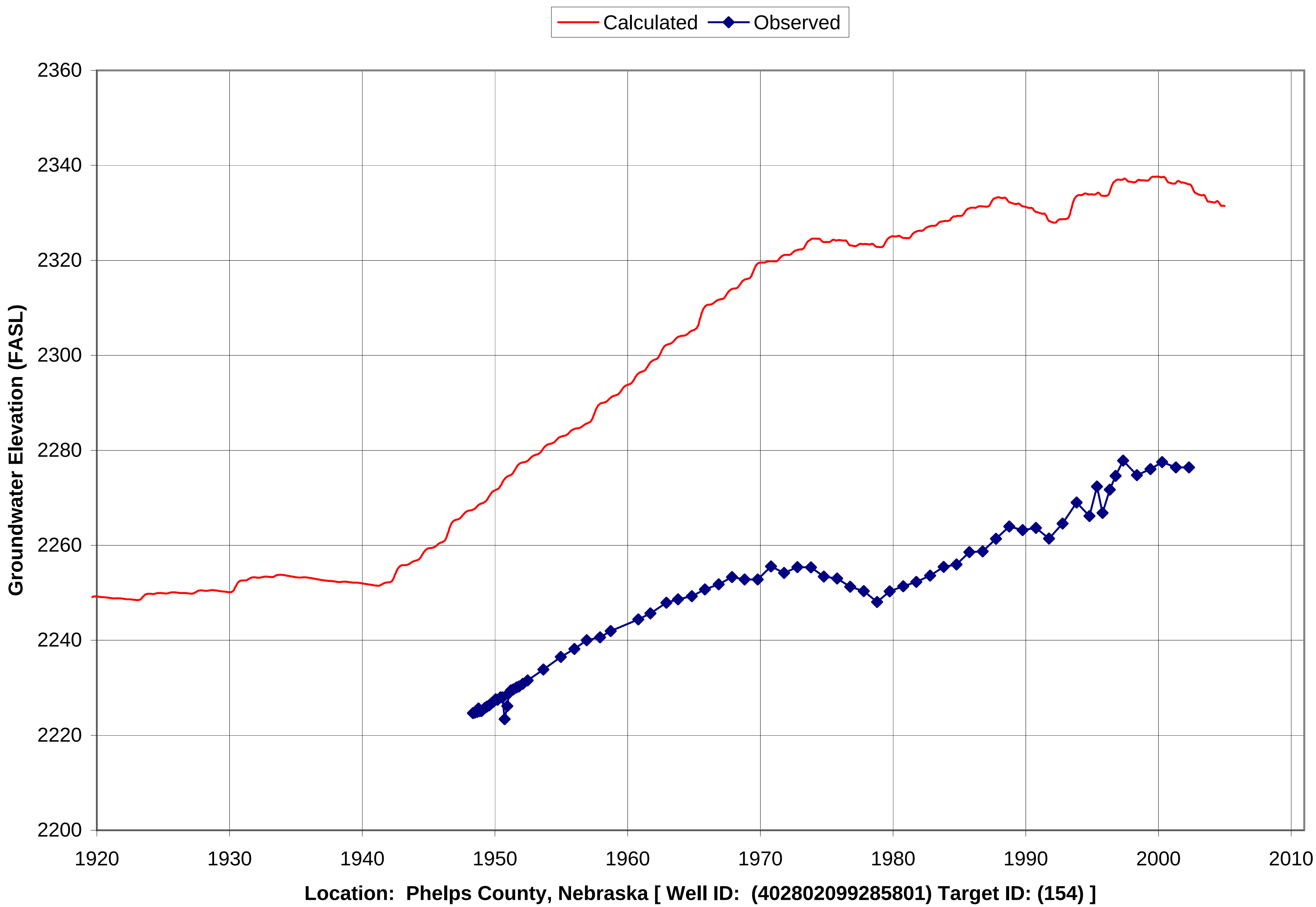
Well ID: (402950101052601)



Location: Hayes County, Nebraska [Well ID: (402950101052601) Target ID: (156)]

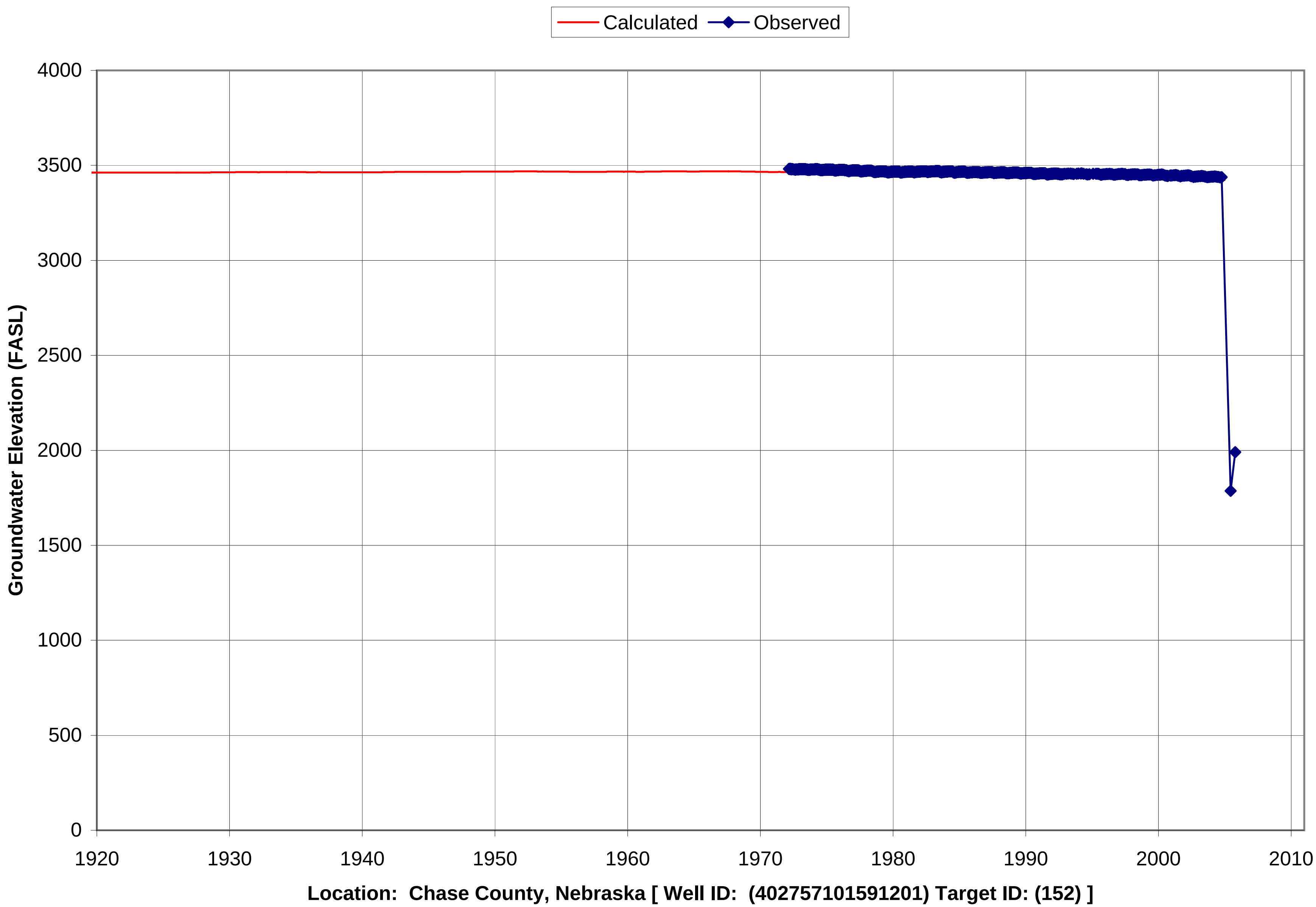
Target ID: (156)

Well ID: (402802099285801)



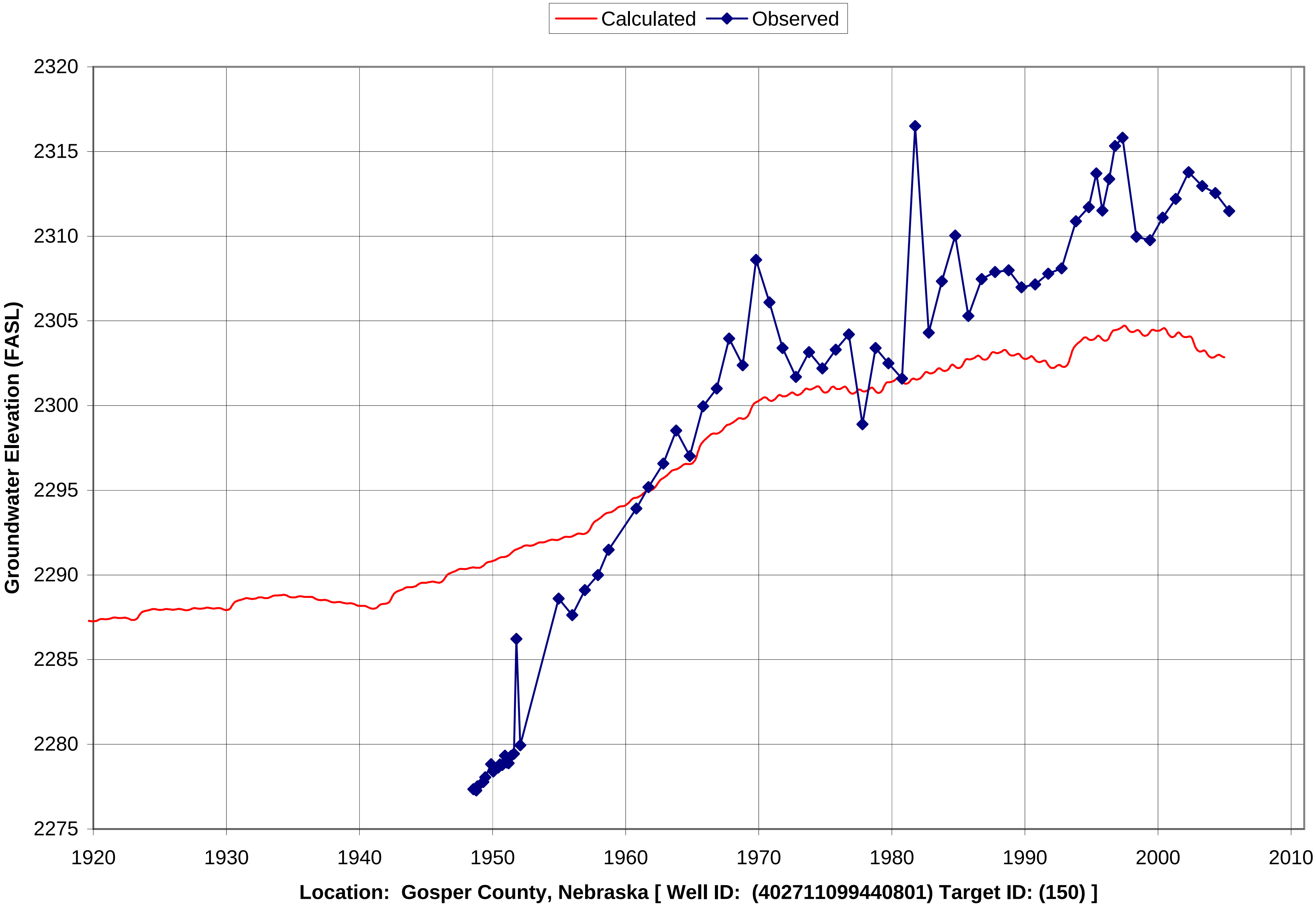
Target ID: (154)

Well ID: (402757101591201)



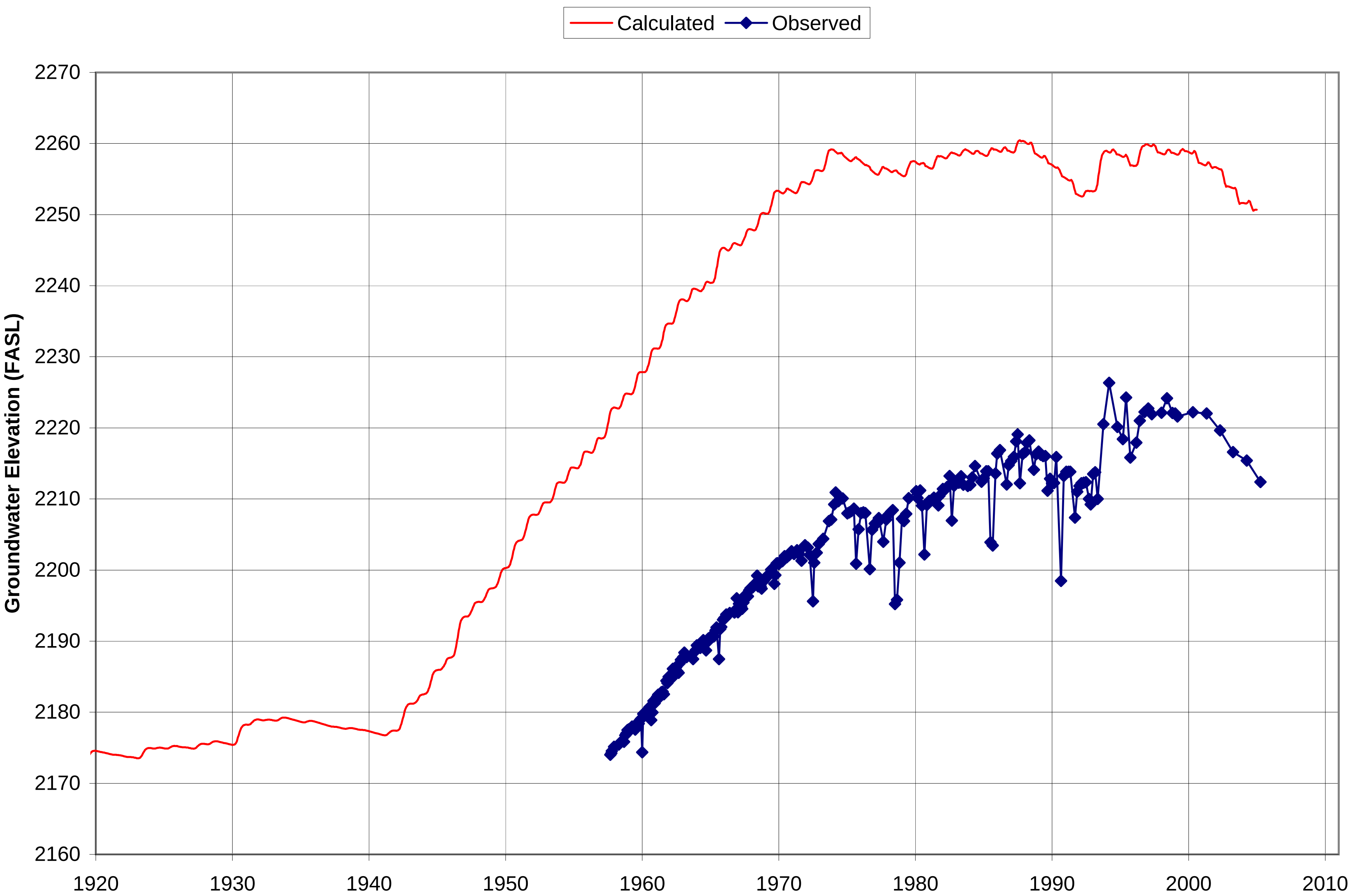
Target ID: (152)

Well ID: (402711099440801)



Target ID: (150)

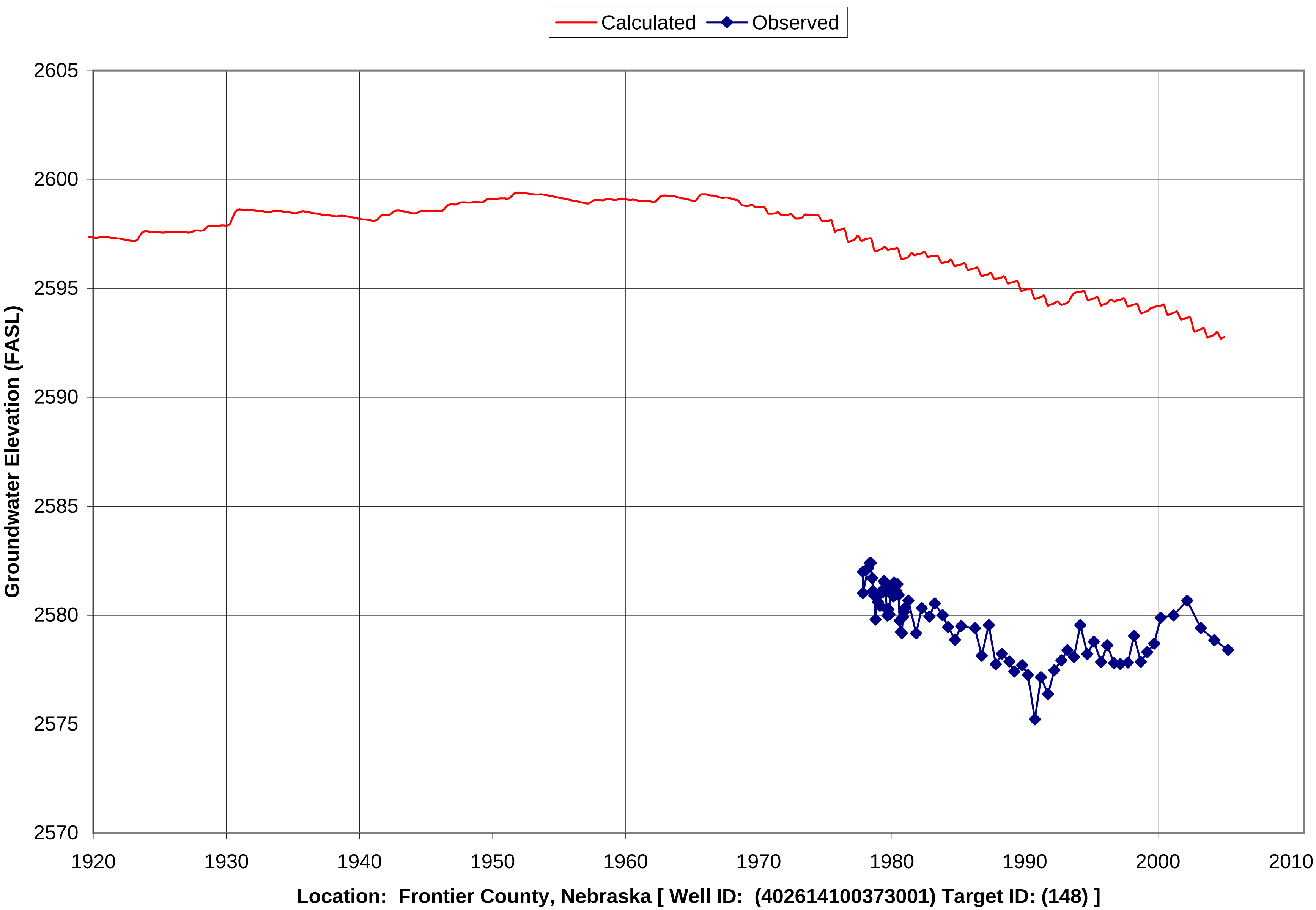
Well ID: (402703099150901)



Location: Phelps County, Nebraska [Well ID: (402703099150901) Target ID: (149)]

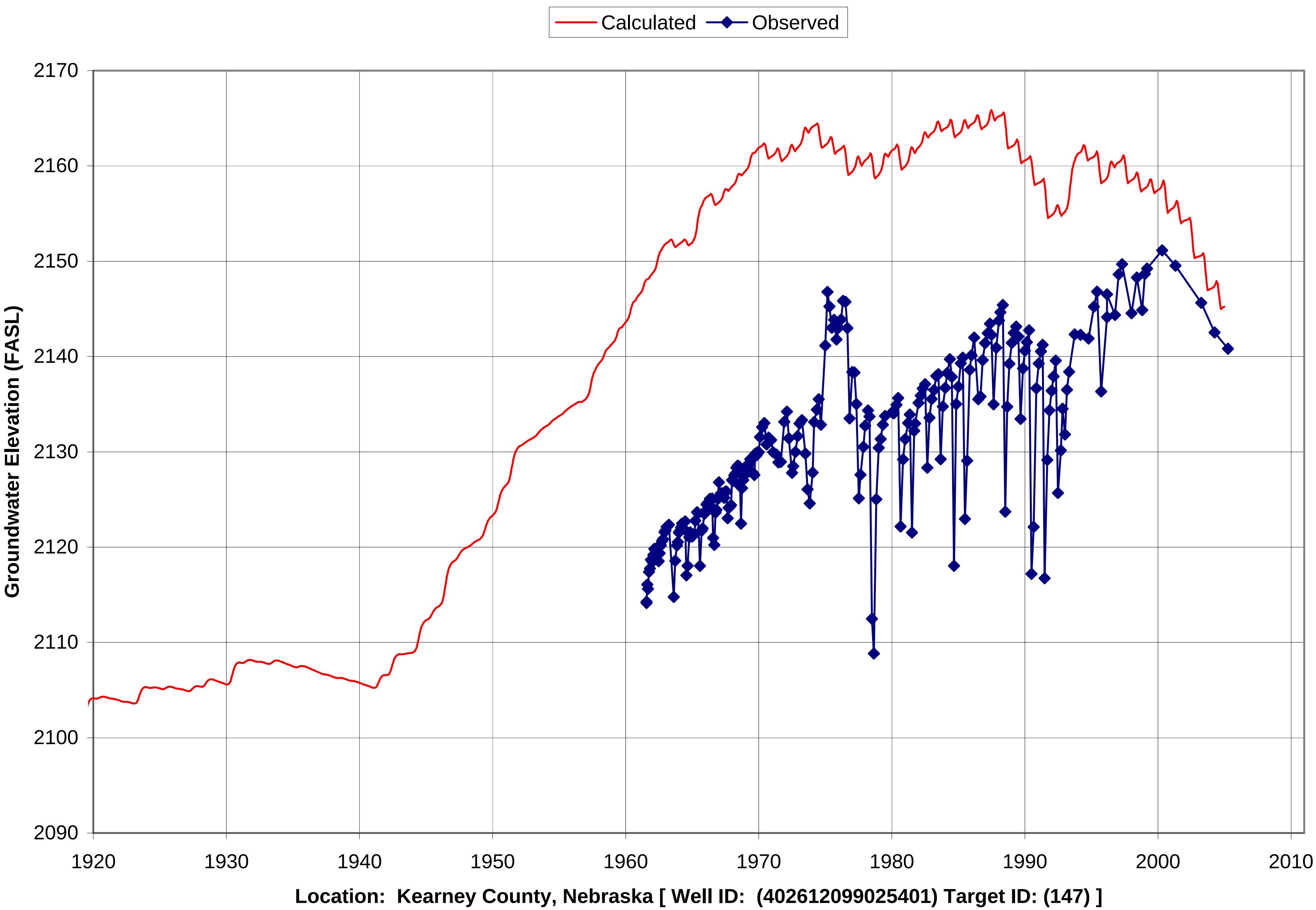
Target ID: (149)

Well ID: (402614100373001)



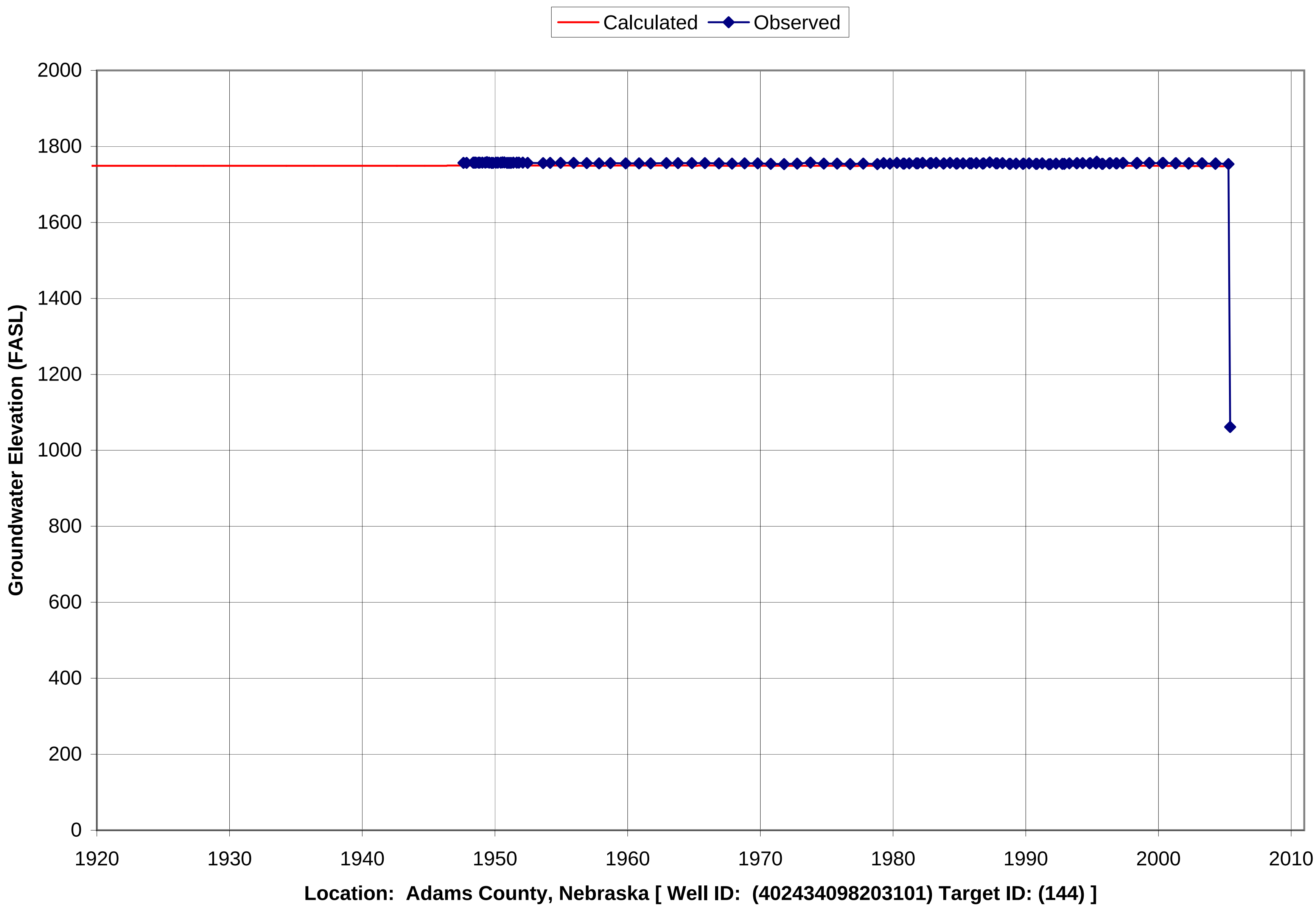
Target ID: (148)

Well ID: (402612099025401)



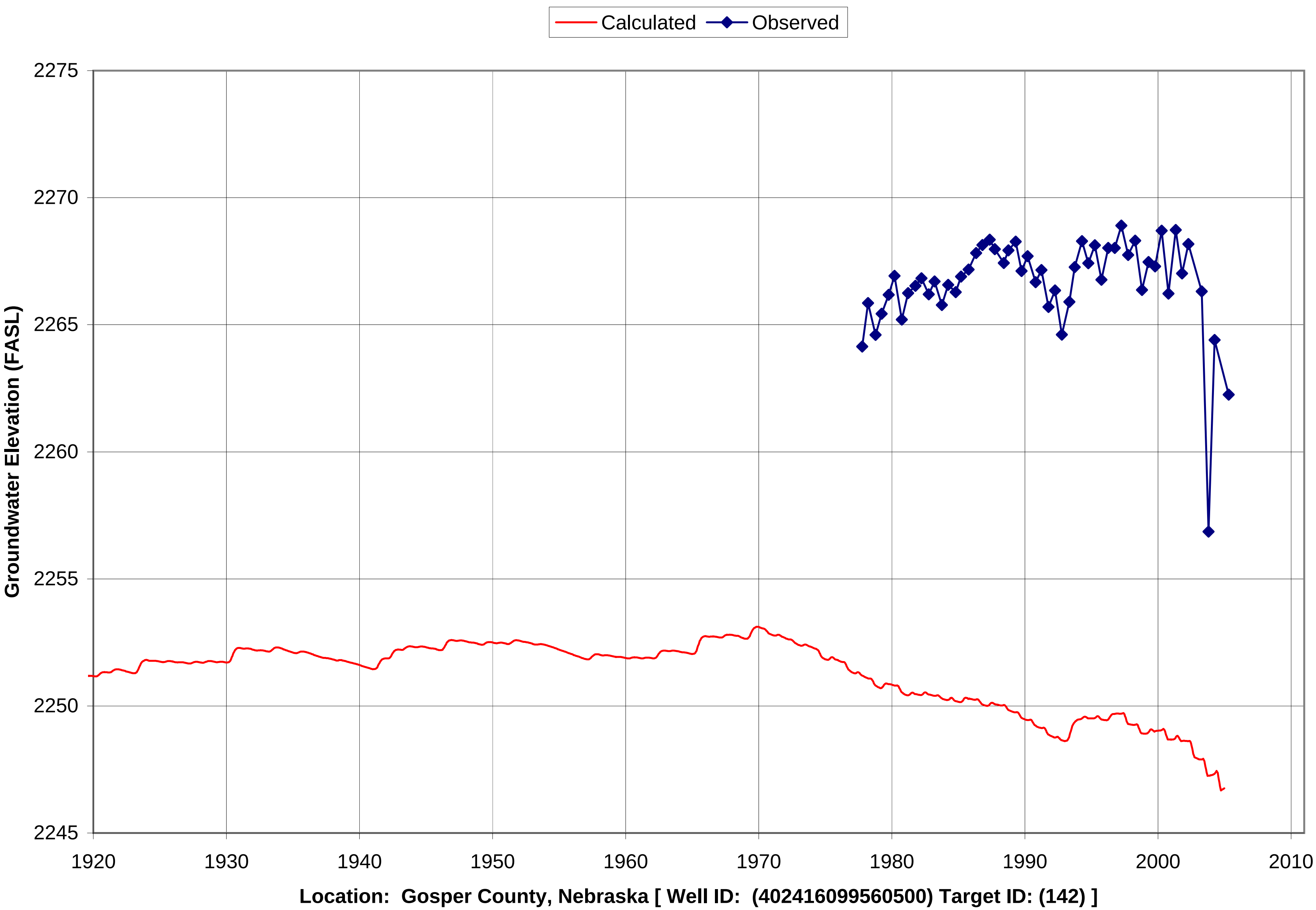
Target ID: (147)

Well ID: (402434098203101)



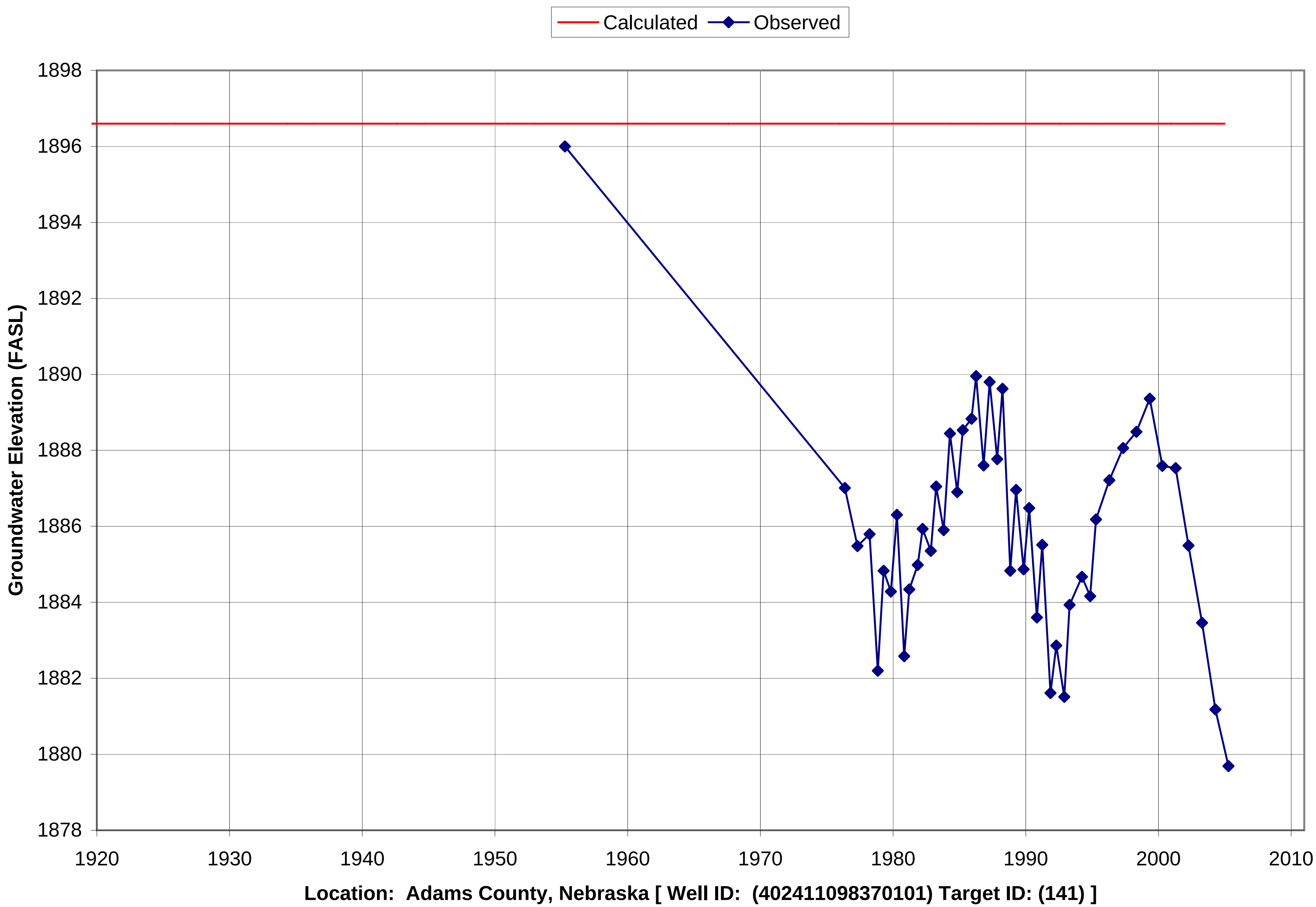
Target ID: (144)

Well ID: (402416099560500)



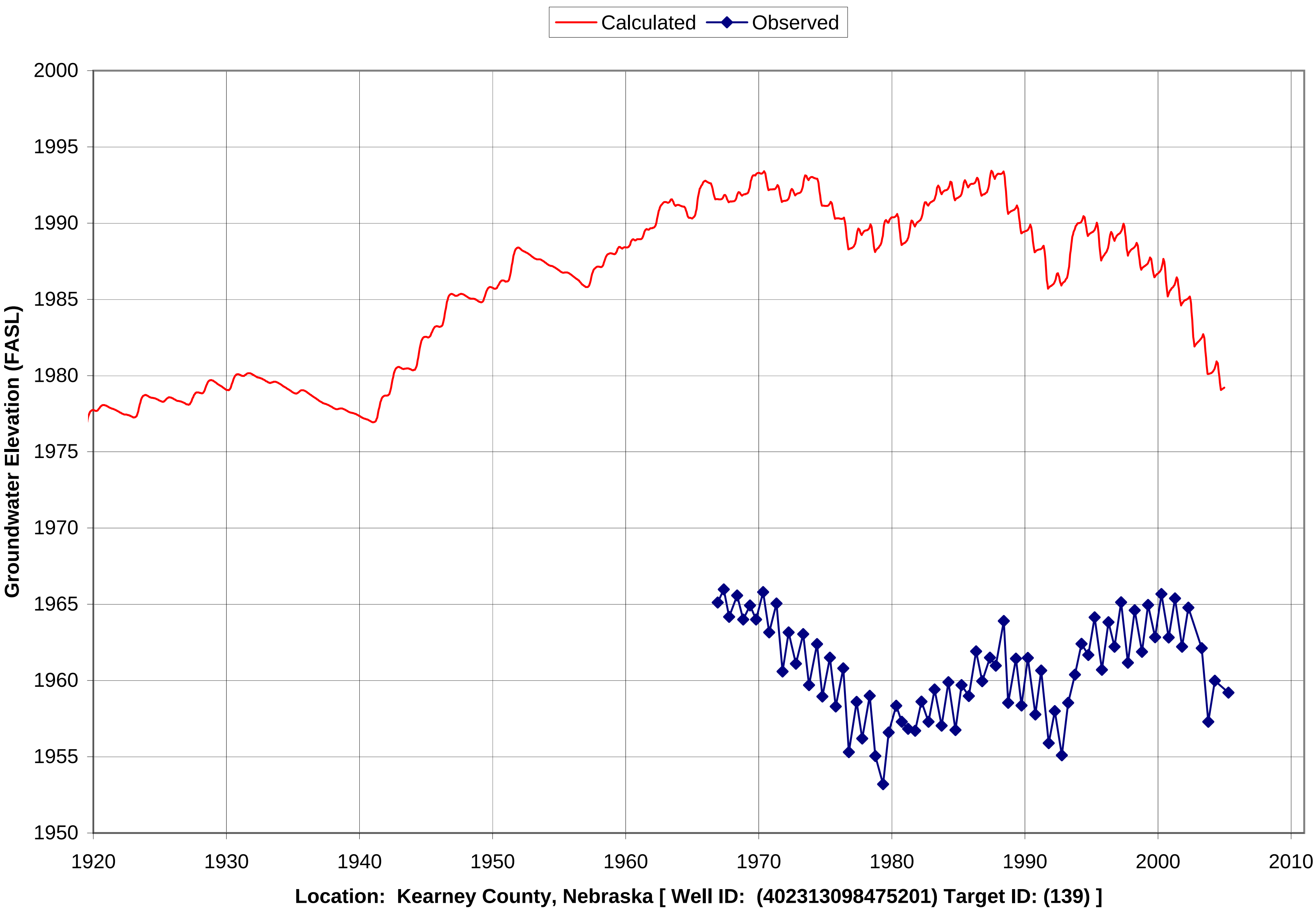
Target ID: (142)

Well ID: (402411098370101)

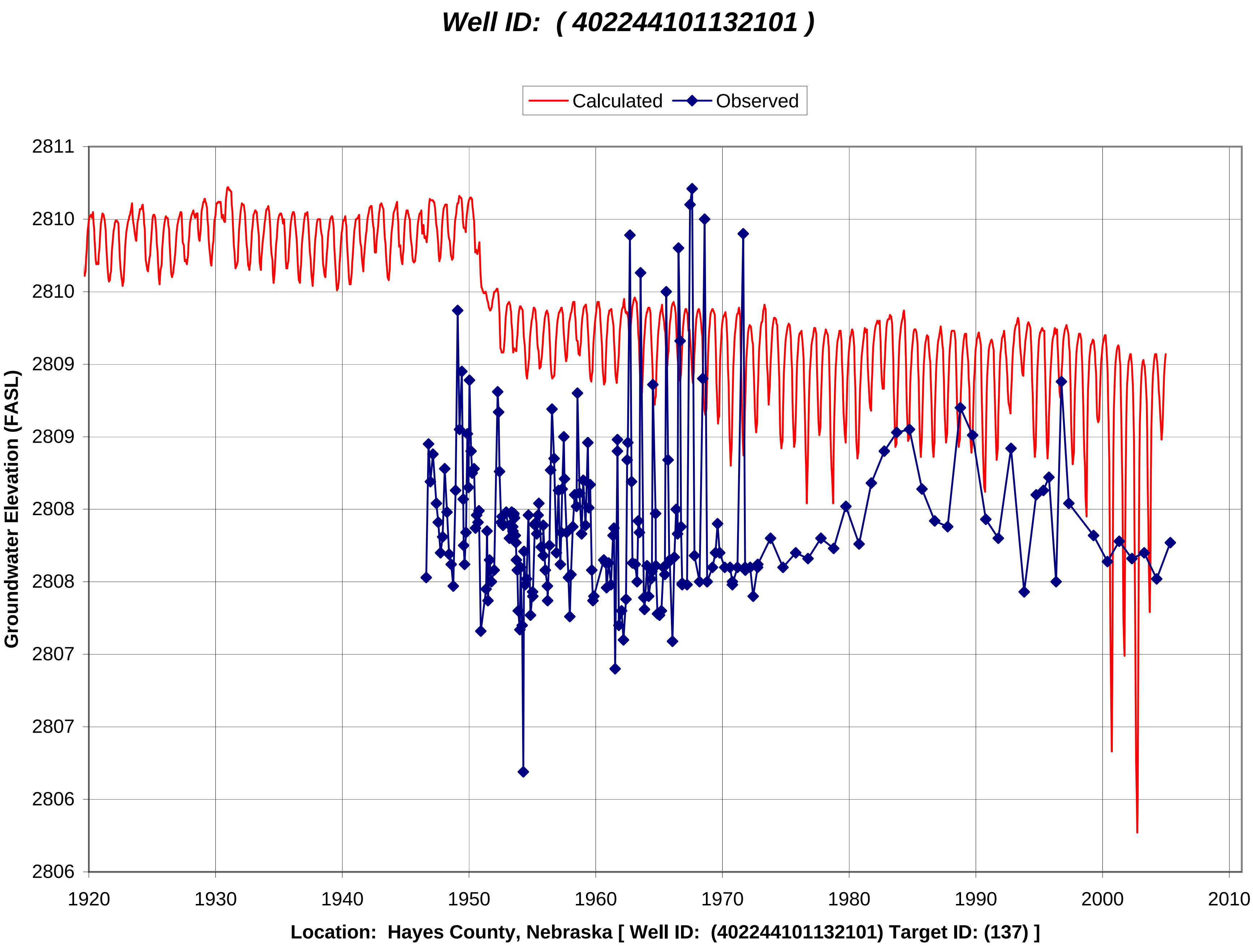


Target ID: (141)

Well ID: (402313098475201)

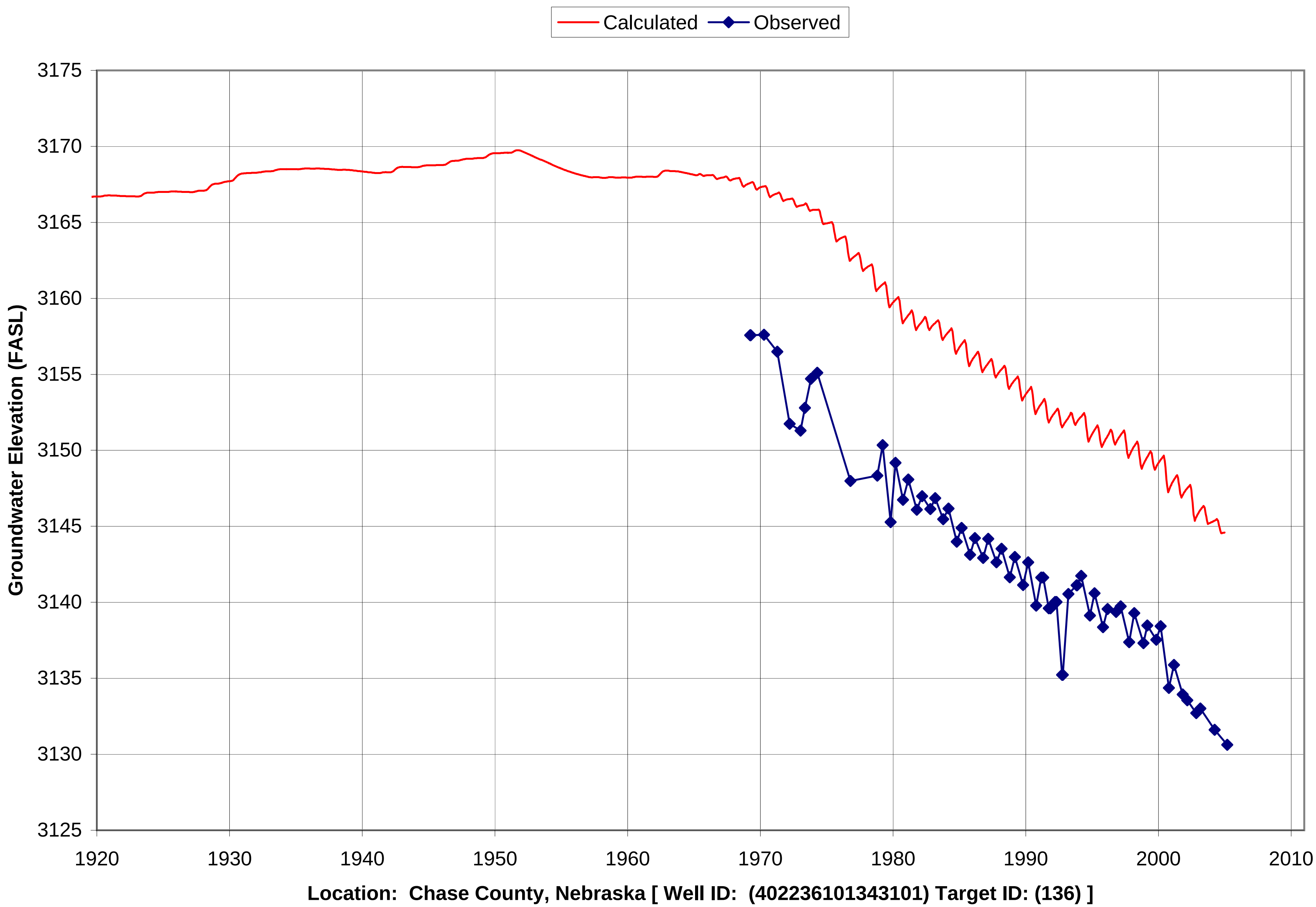


Target ID: (139)



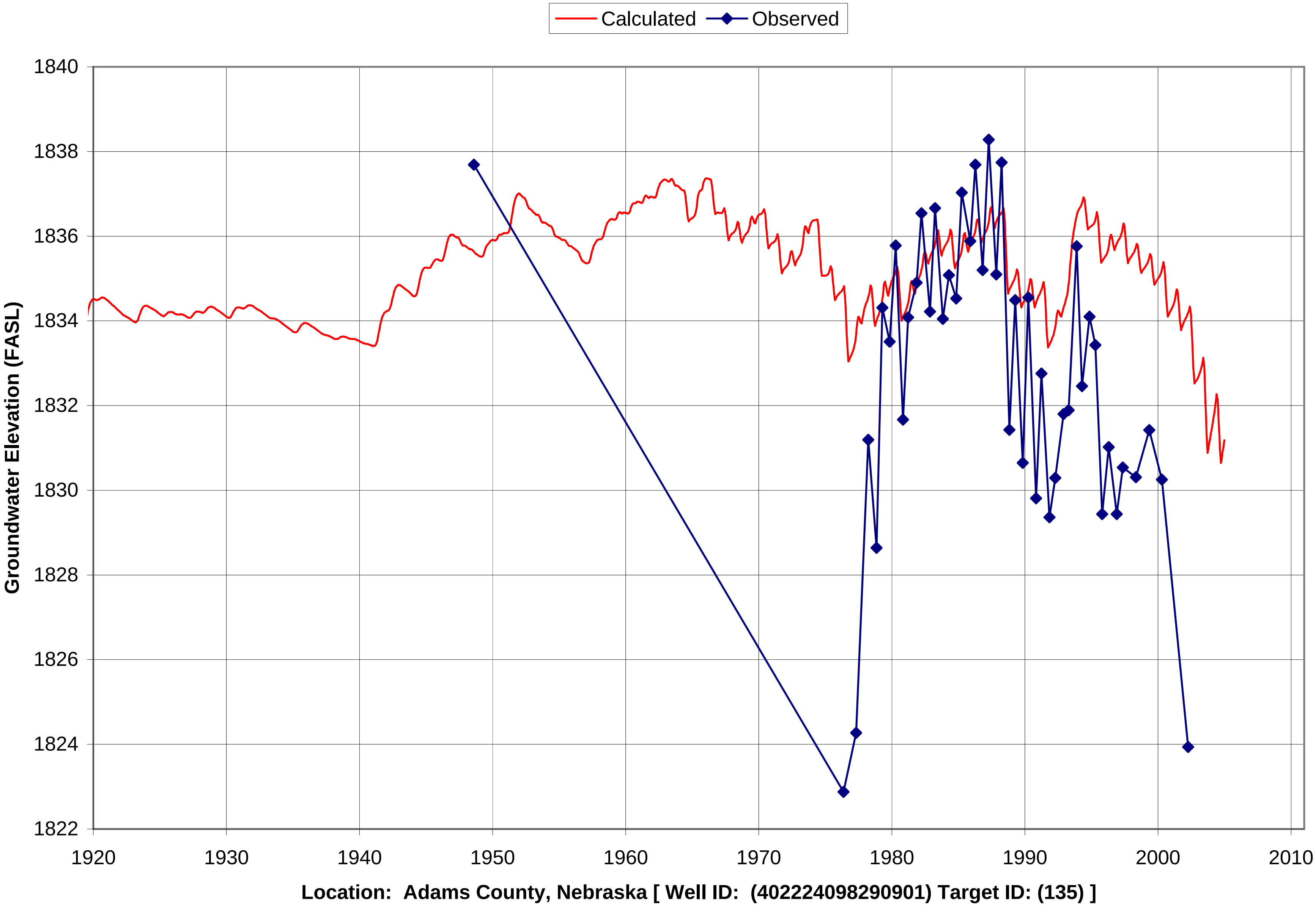
Target ID: (137)

Well ID: (402236101343101)



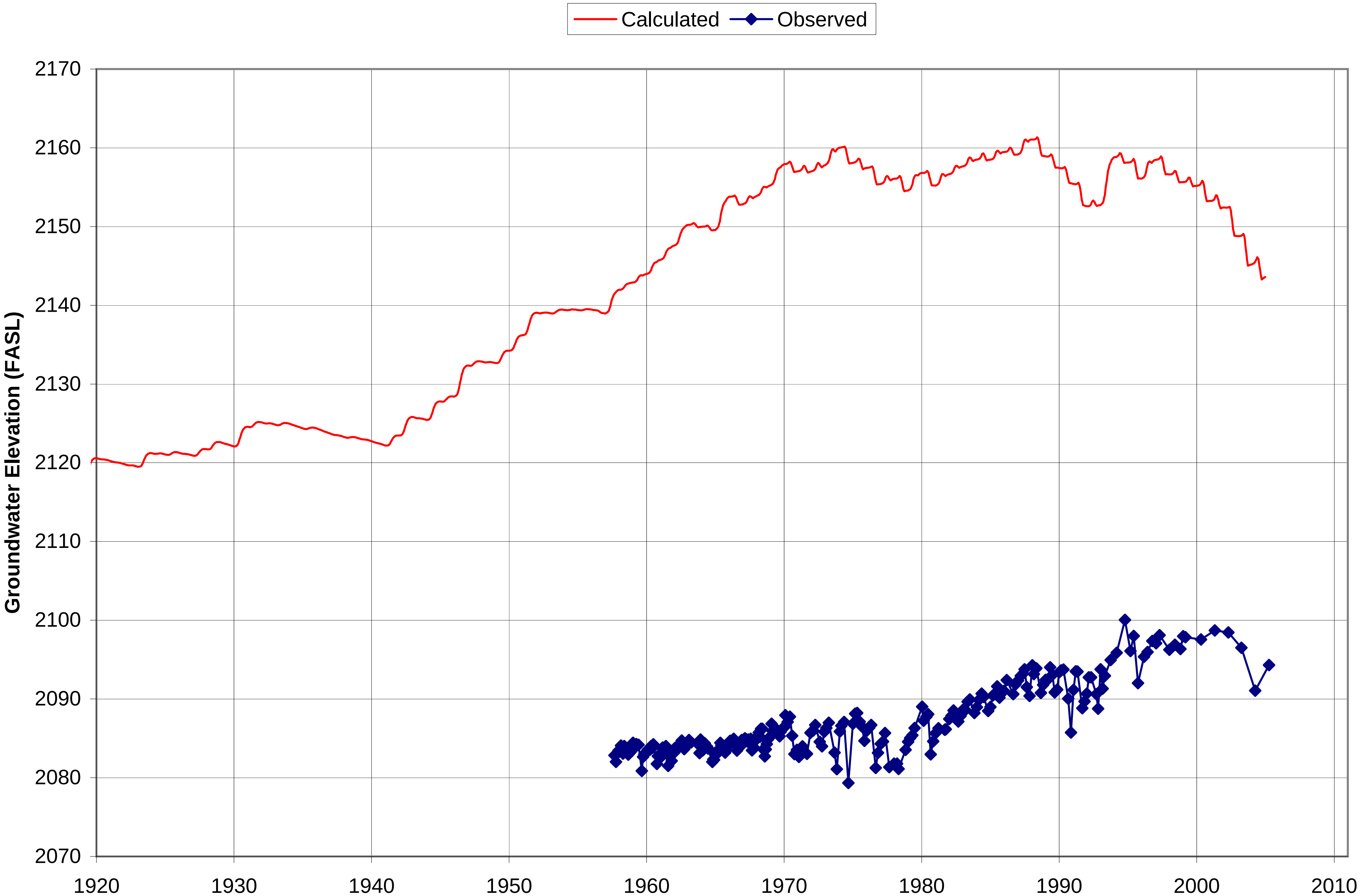
Target ID: (136)

Well ID: (402224098290901)



Target ID: (135)

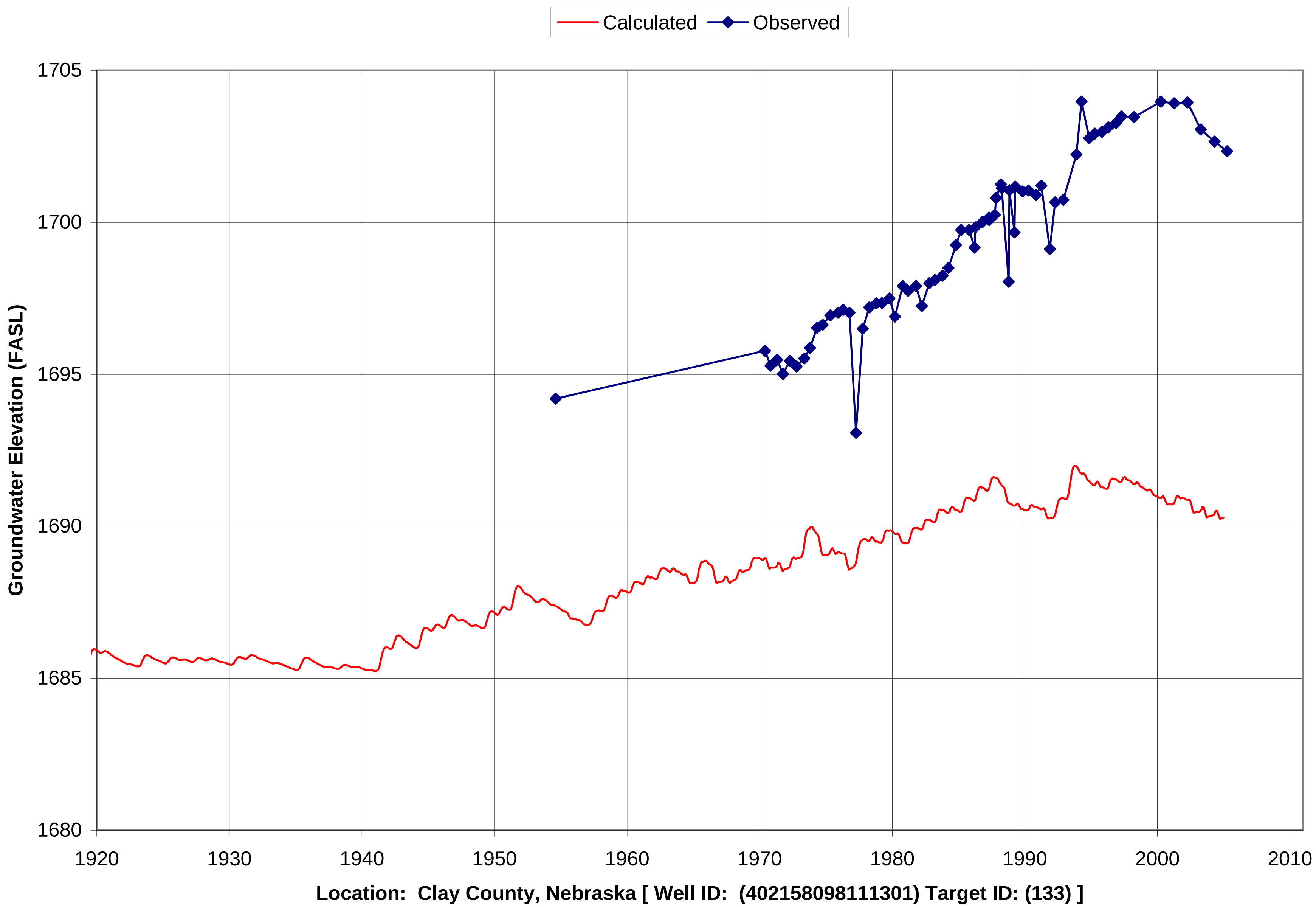
Well ID: (402202099082201)



Location: Kearney County, Nebraska [Well ID: (402202099082201) Target ID: (134)]

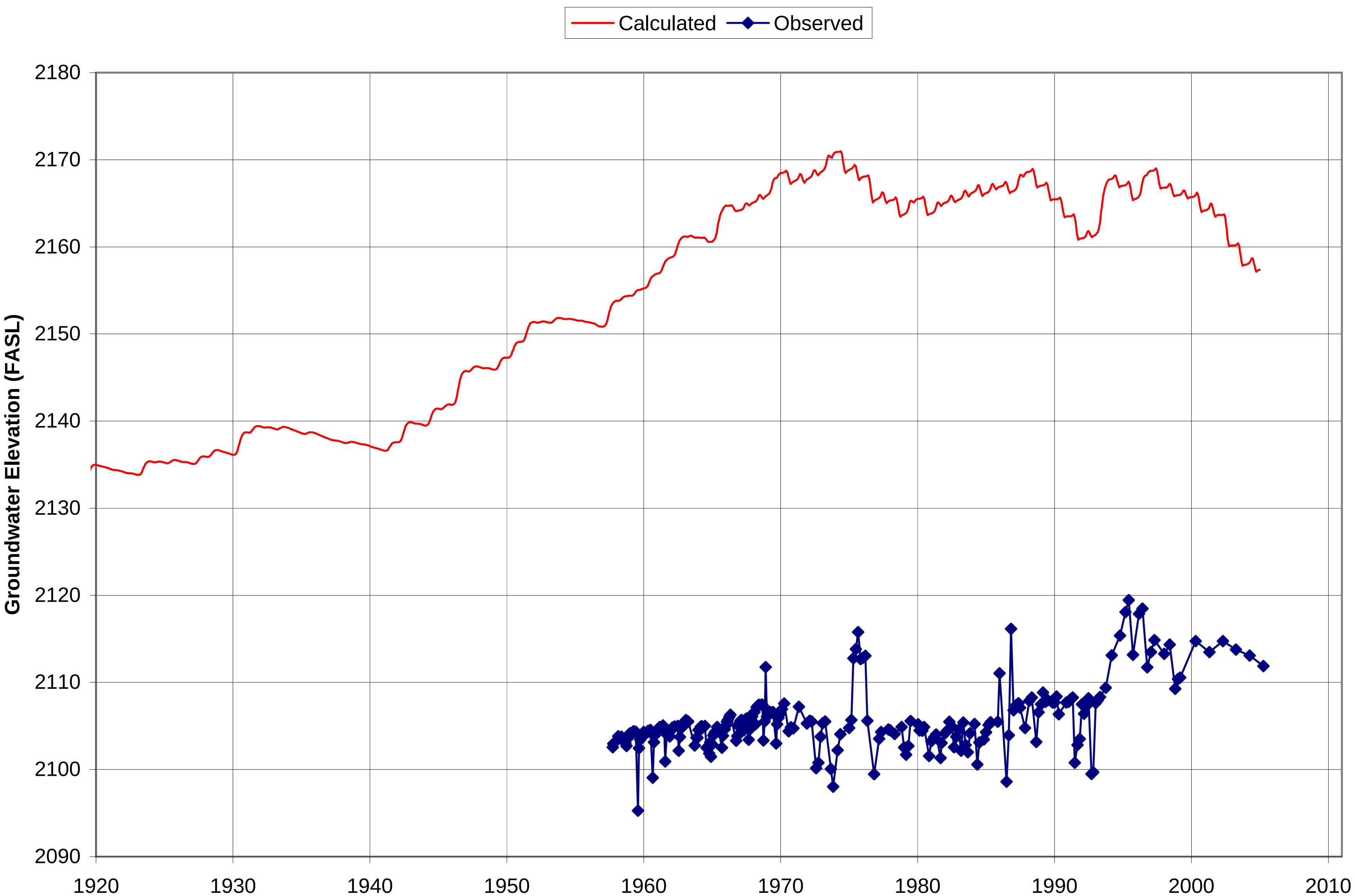
Target ID: (134)

Well ID: (402158098111301)



Target ID: (133)

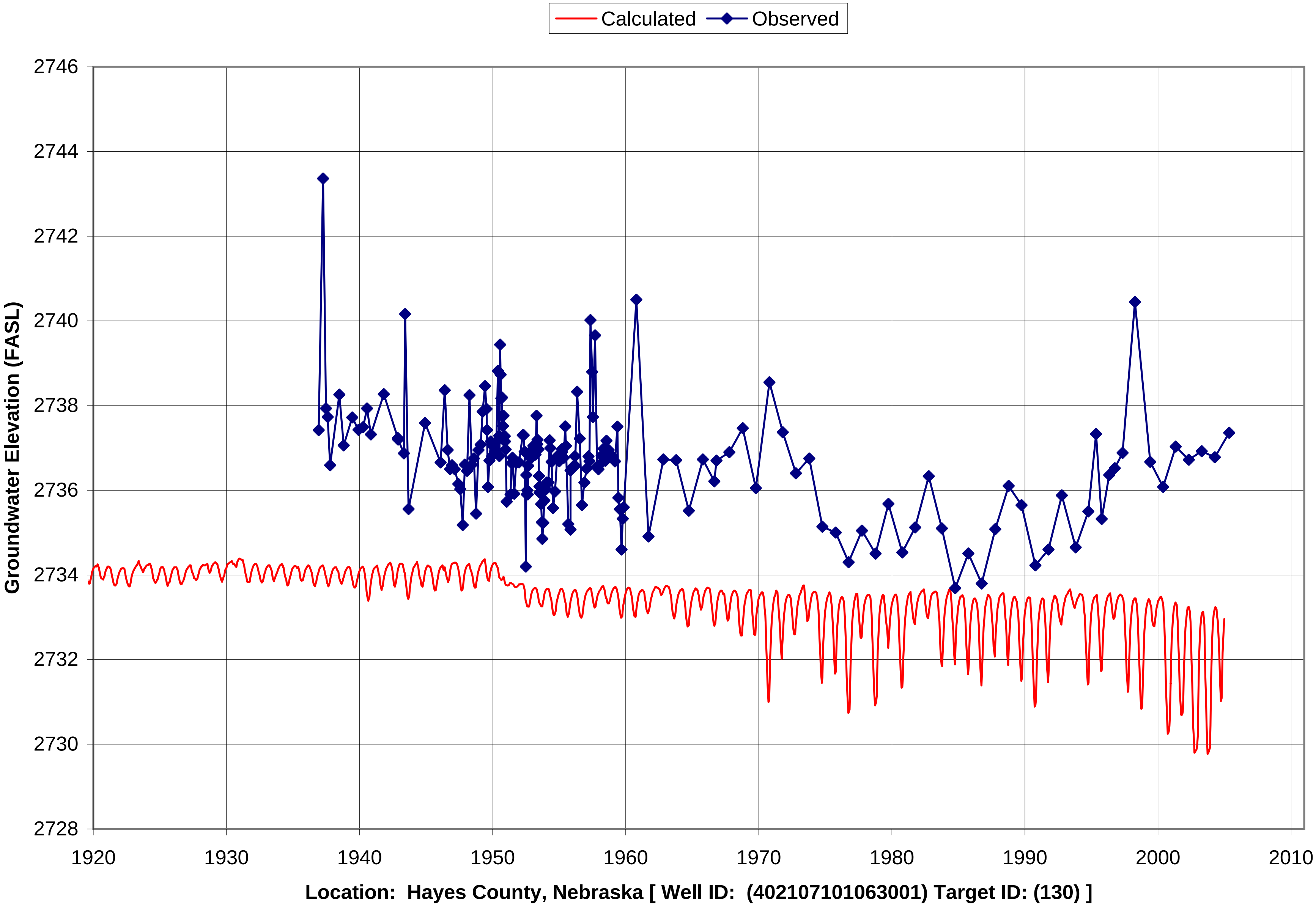
Well ID: (402110099140001)



Location: Phelps County, Nebraska [Well ID: (402110099140001) Target ID: (131)]

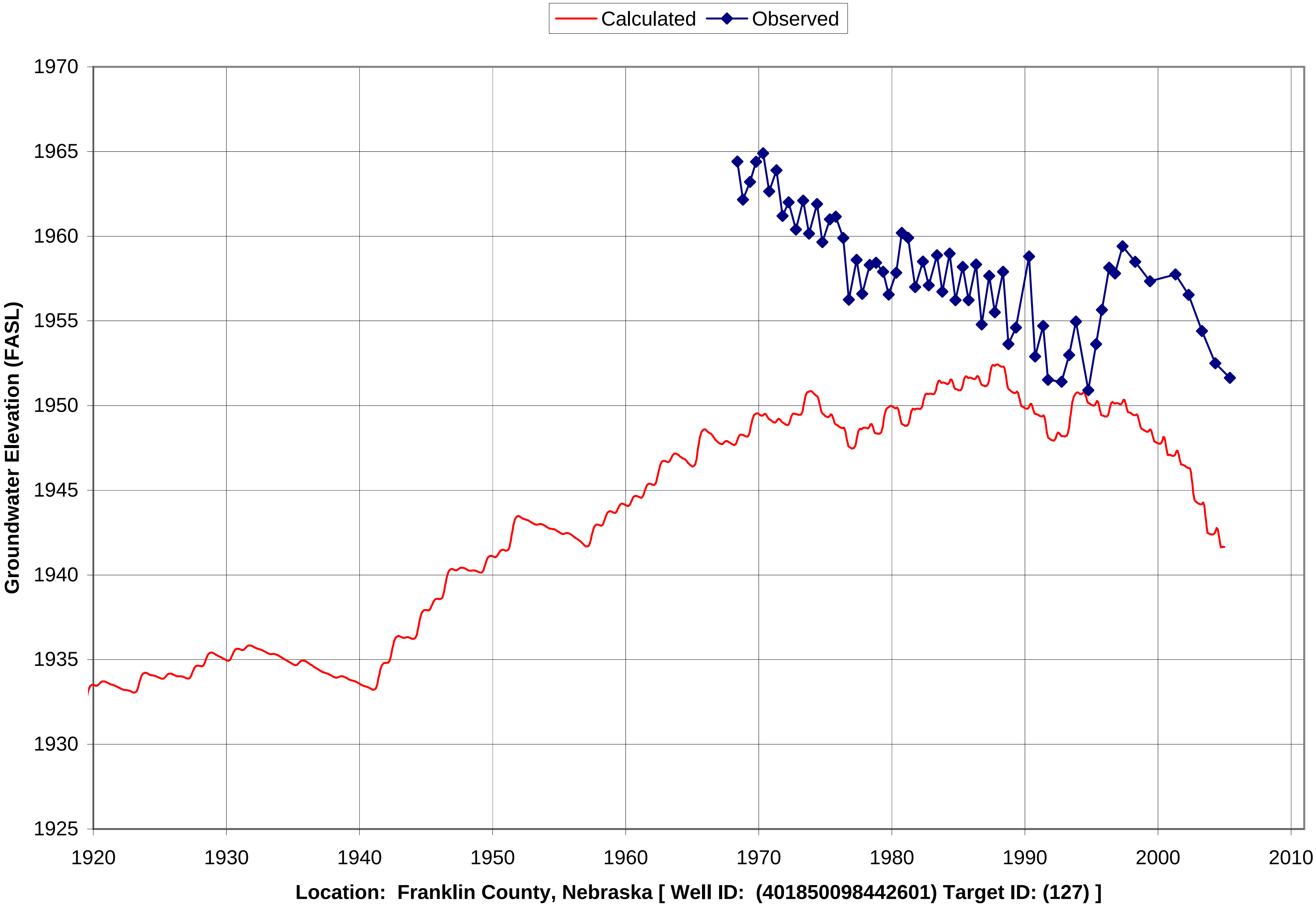
Target ID: (131)

Well ID: (402107101063001)



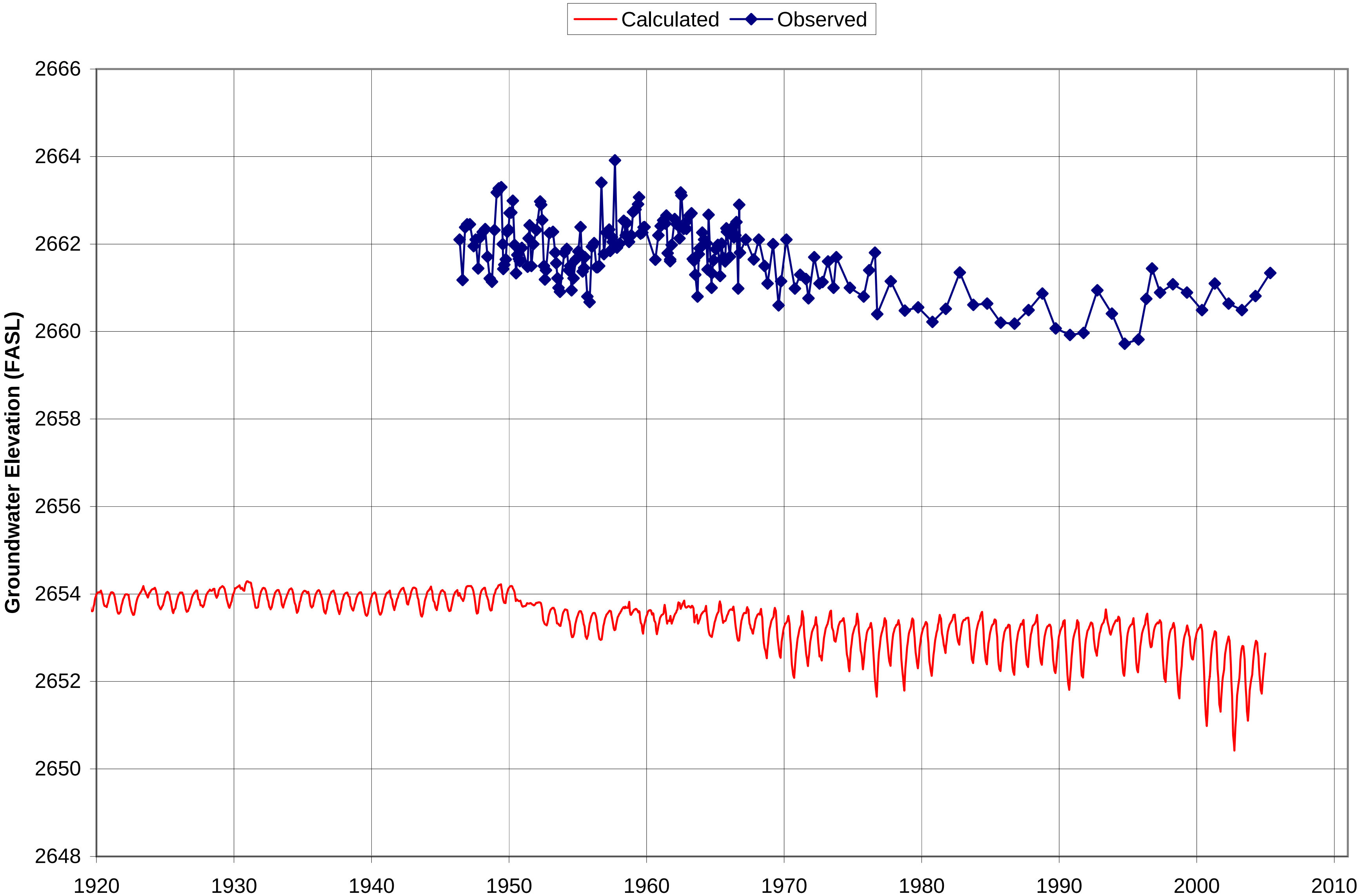
Target ID: (130)

Well ID: (401850098442601)



Target ID: (127)

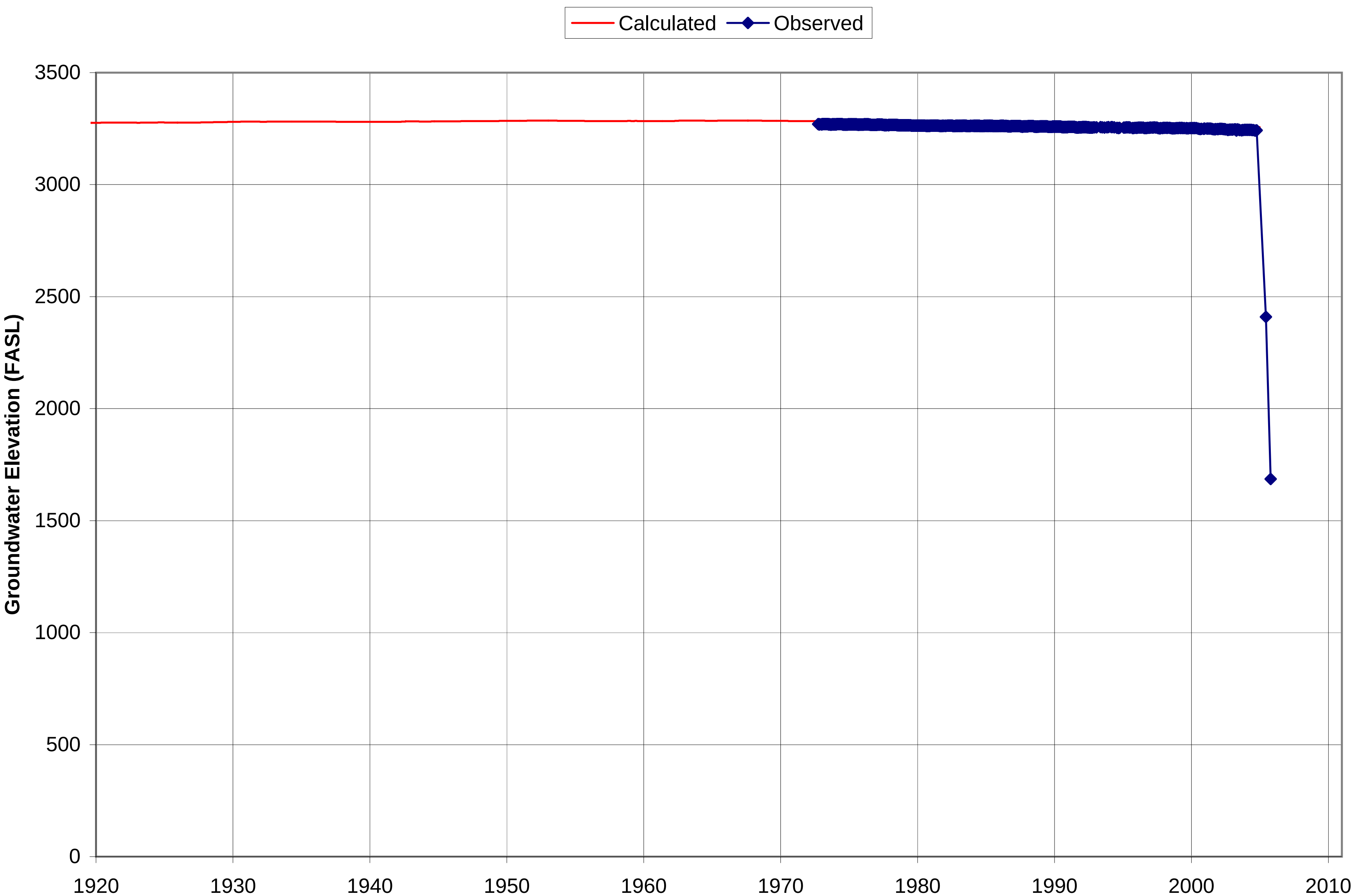
Well ID: (401801101002301)



Location: Hitchcock County, Nebraska [Well ID: (401801101002301) Target ID: (125)]

Target ID: (125)

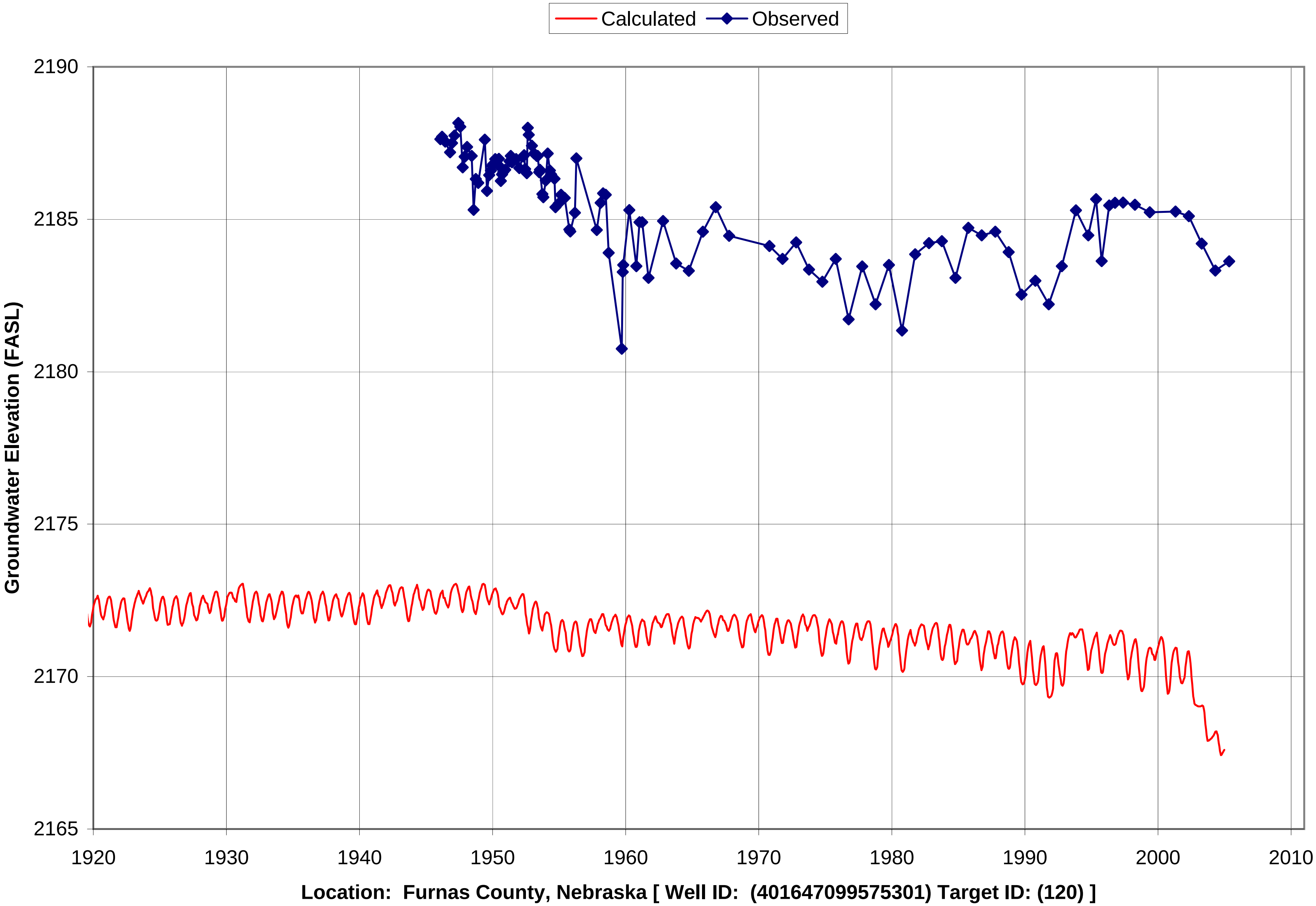
Well ID: (401703101394801)



Location: Dundy County, Nebraska [Well ID: (401703101394801) Target ID: (121)]

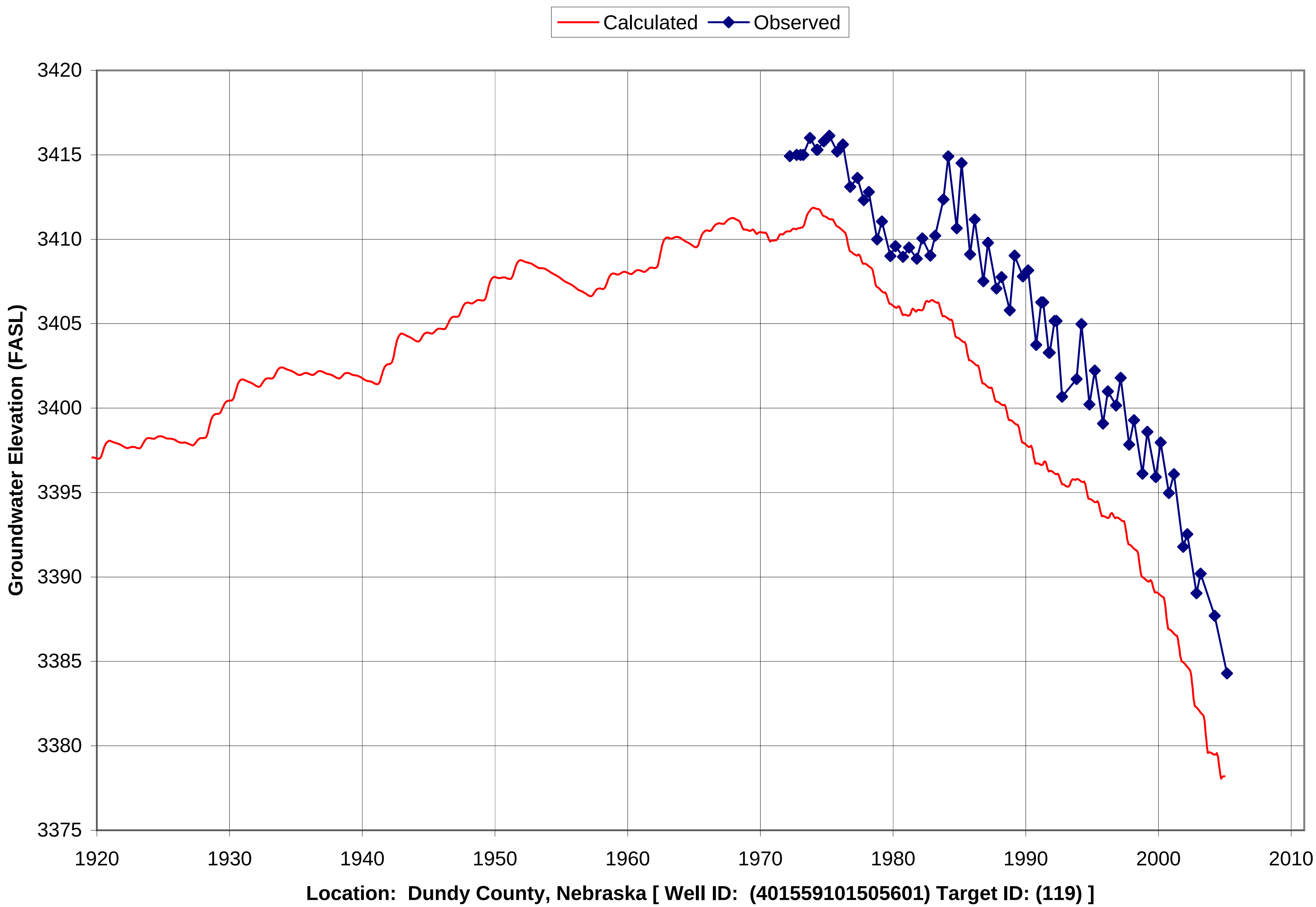
Target ID: (121)

Well ID: (401647099575301)



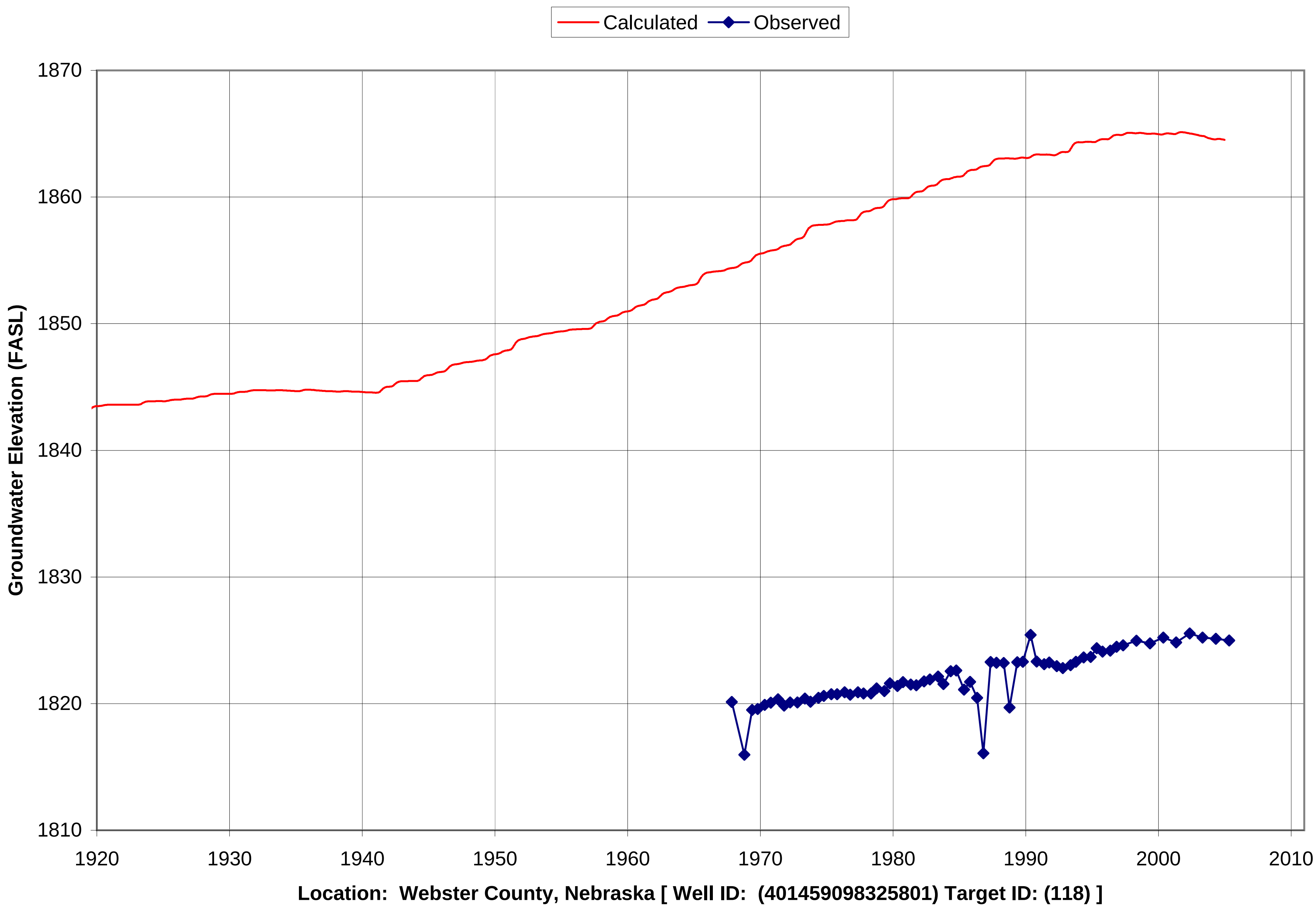
Target ID: (120)

Well ID: (401559101505601)



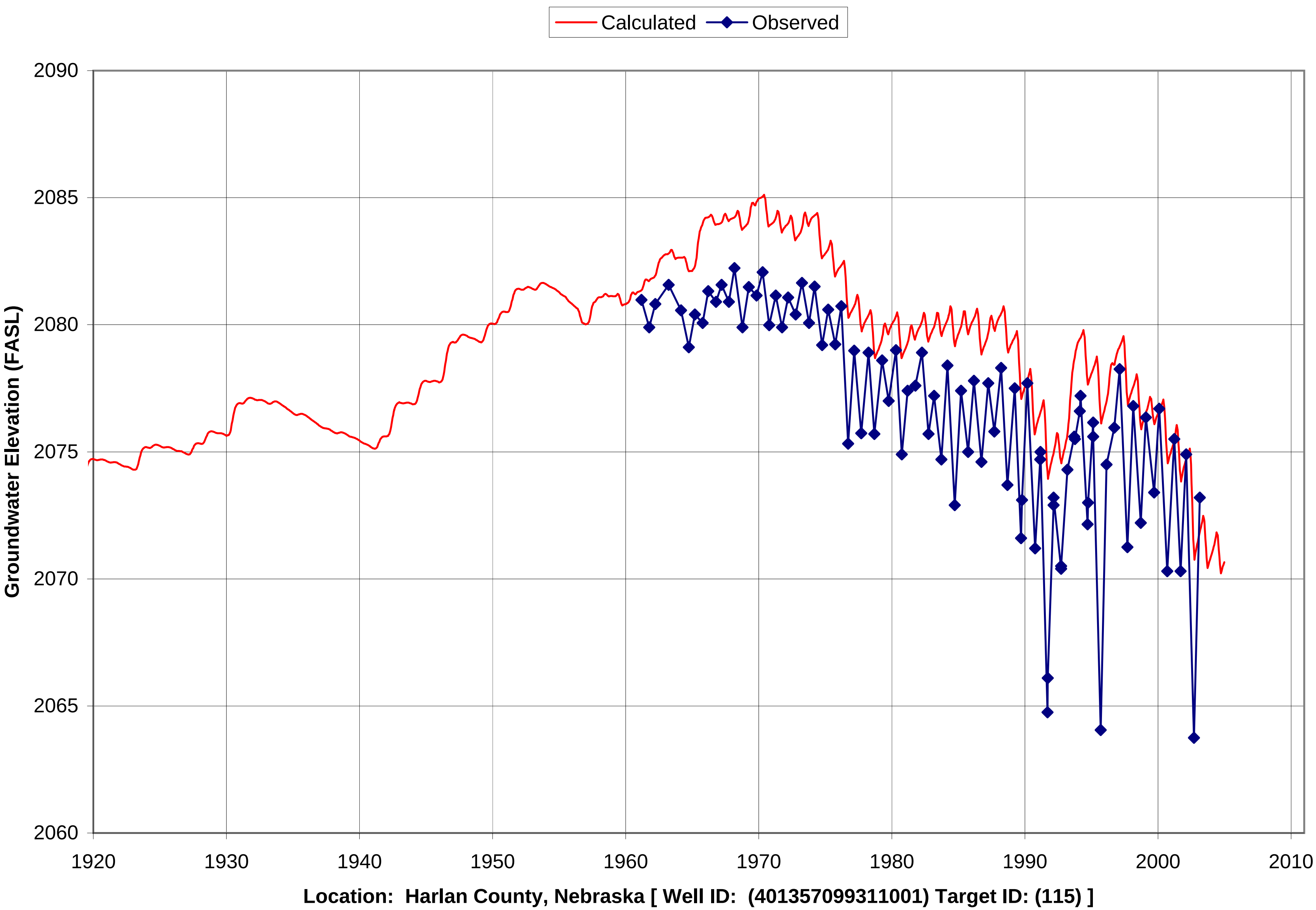
Target ID: (119)

Well ID: (401459098325801)



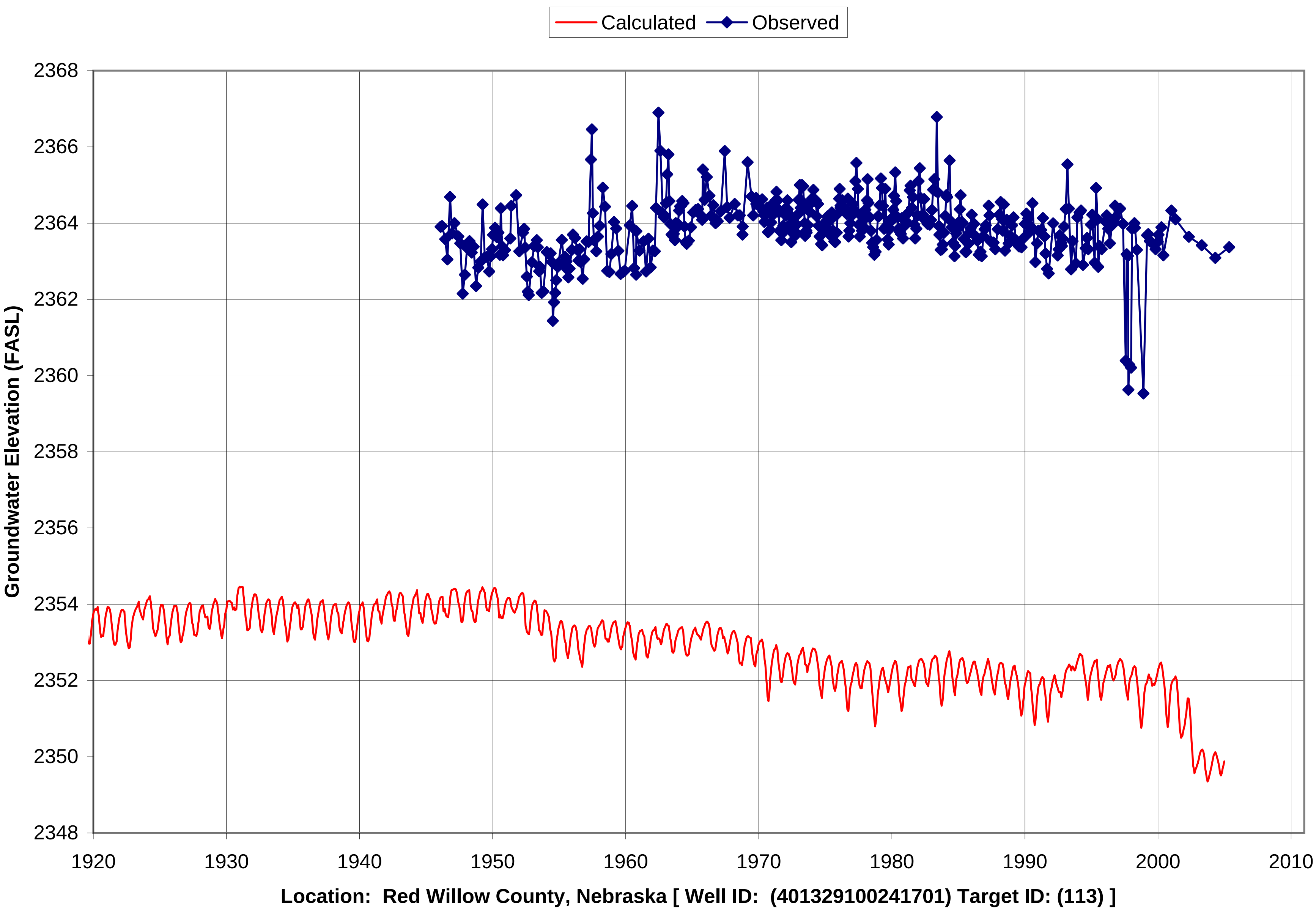
Target ID: (118)

Well ID: (401357099311001)



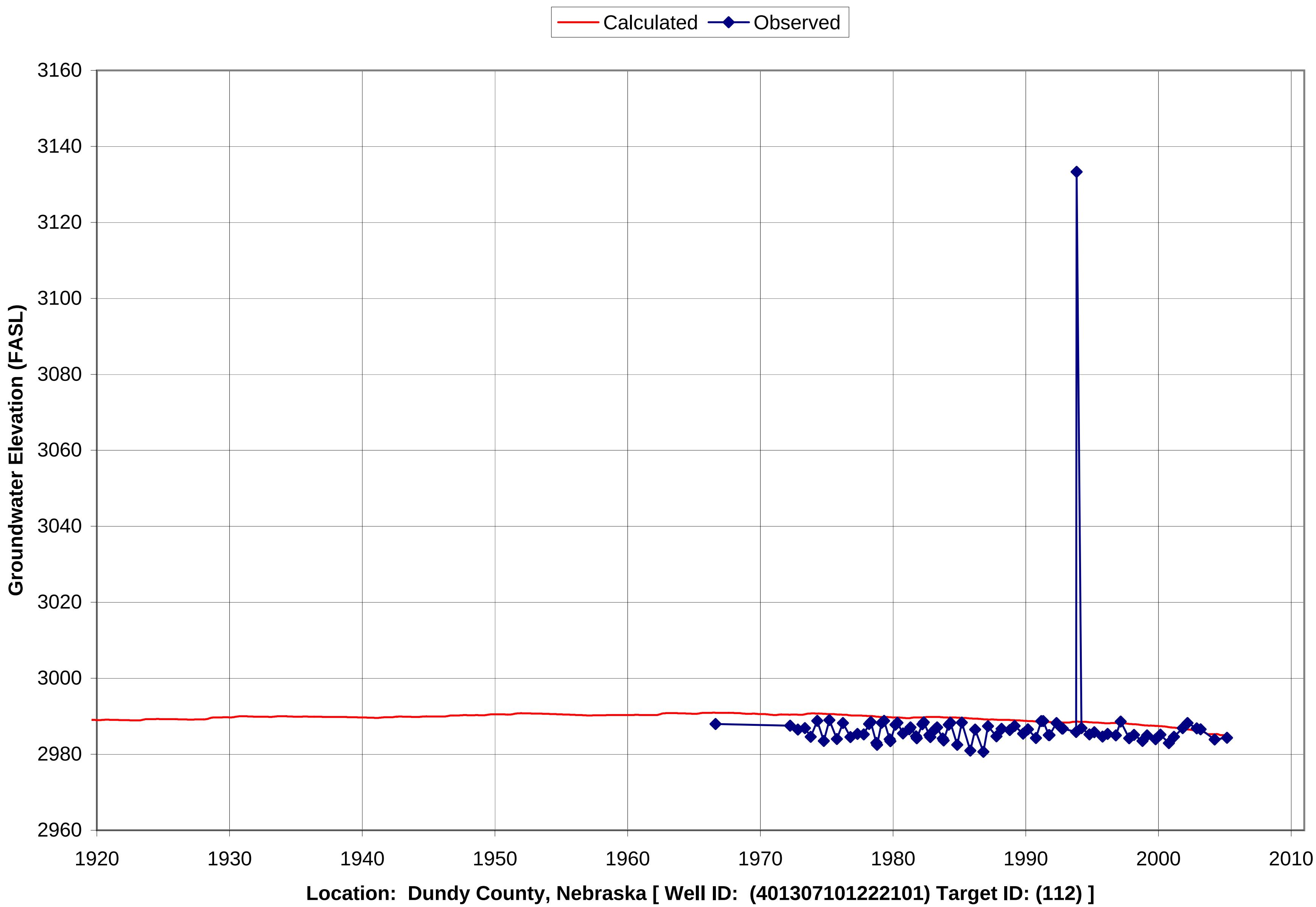
Target ID: (115)

Well ID: (401329100241701)



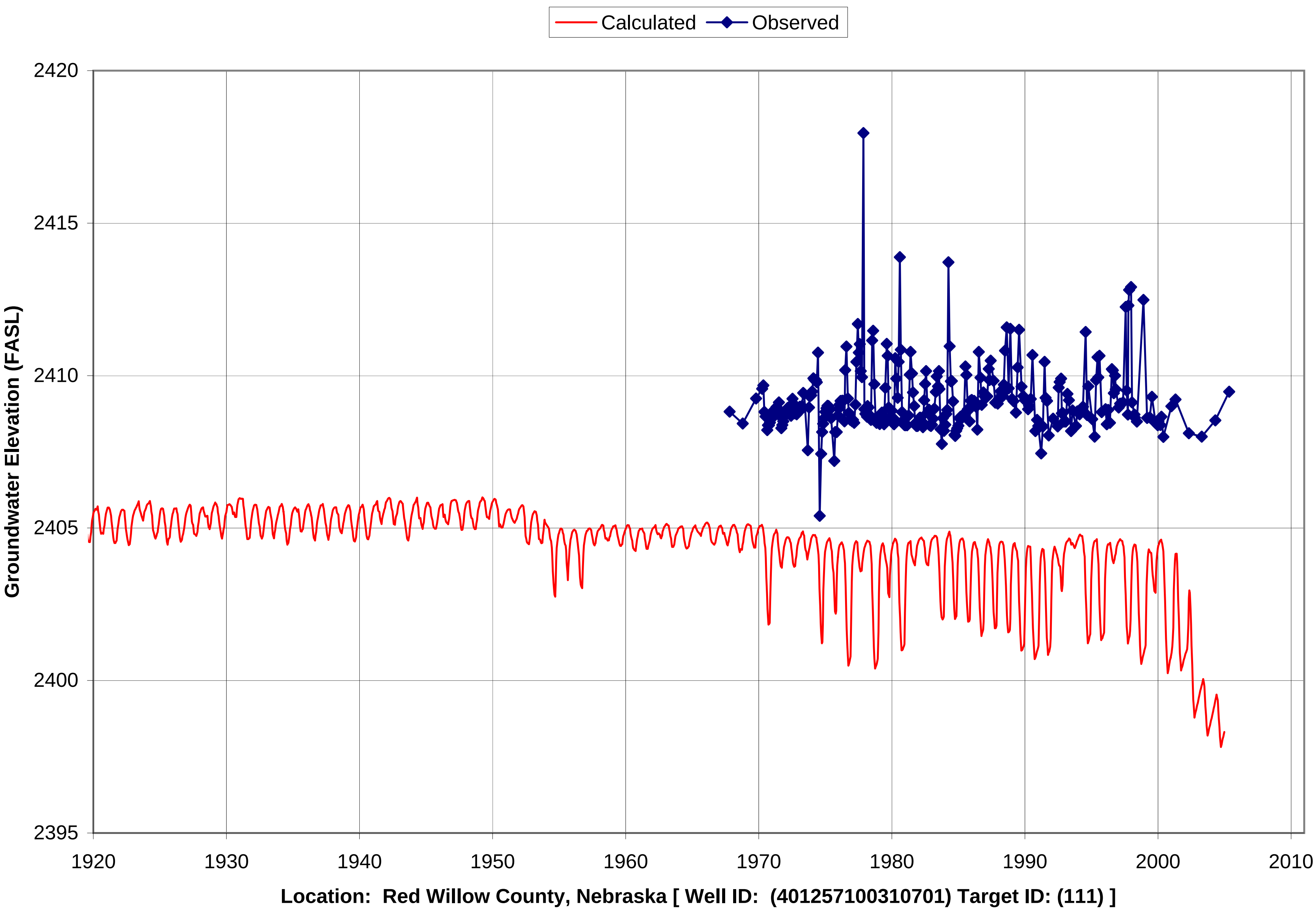
Target ID: (113)

Well ID: (401307101222101)



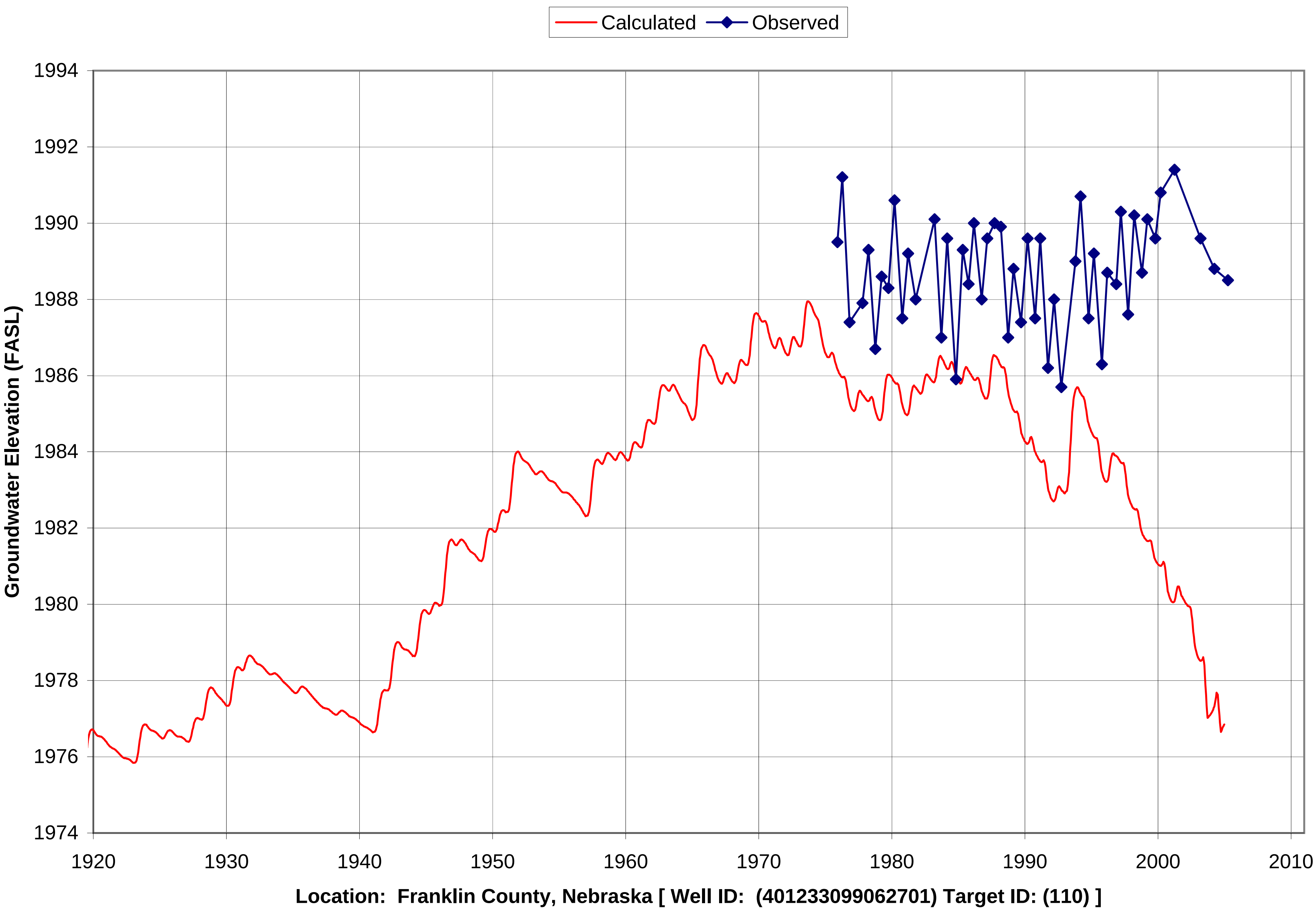
Target ID: (112)

Well ID: (401257100310701)



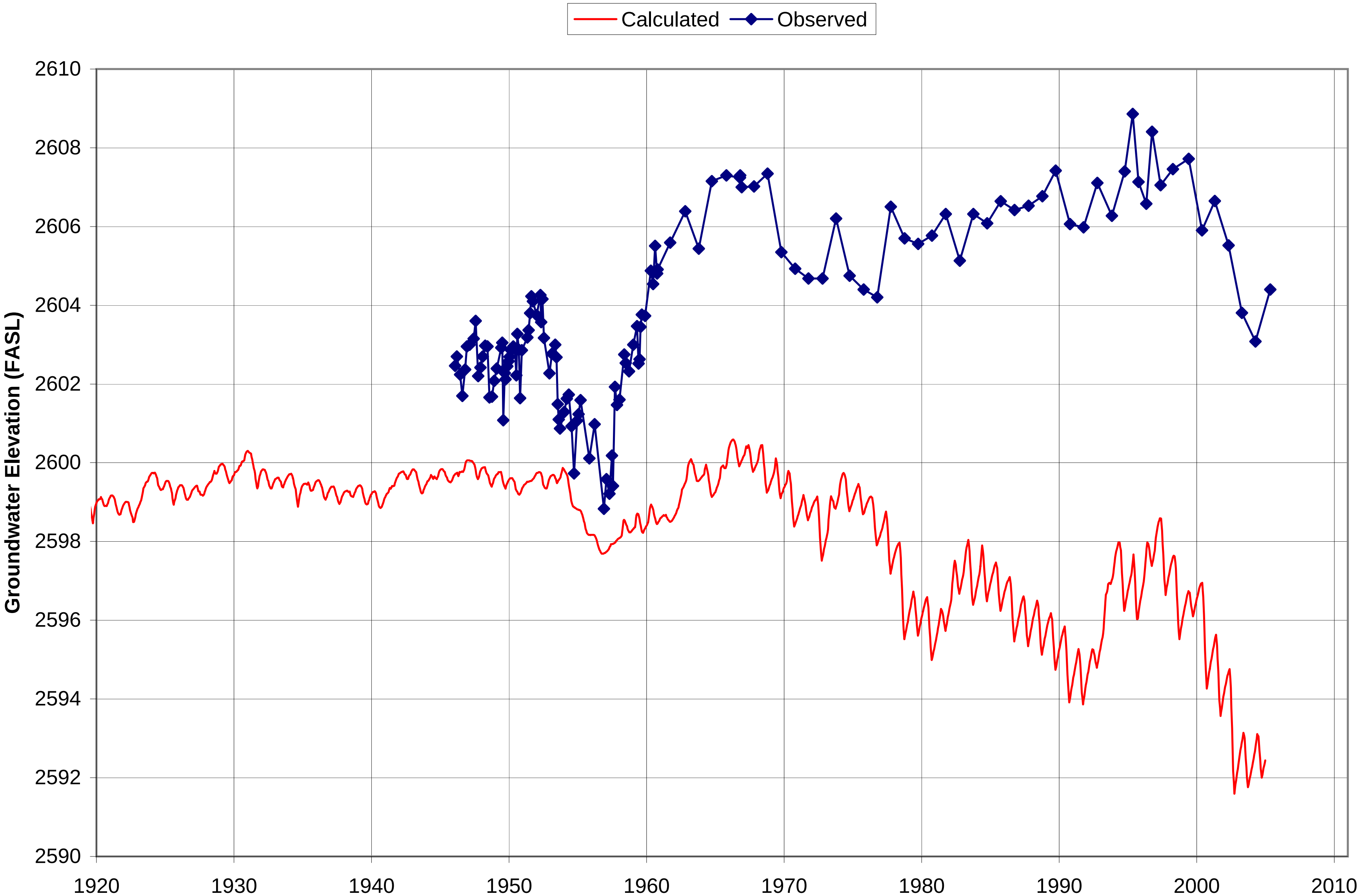
Target ID: (111)

Well ID: (401233099062701)



Target ID: (110)

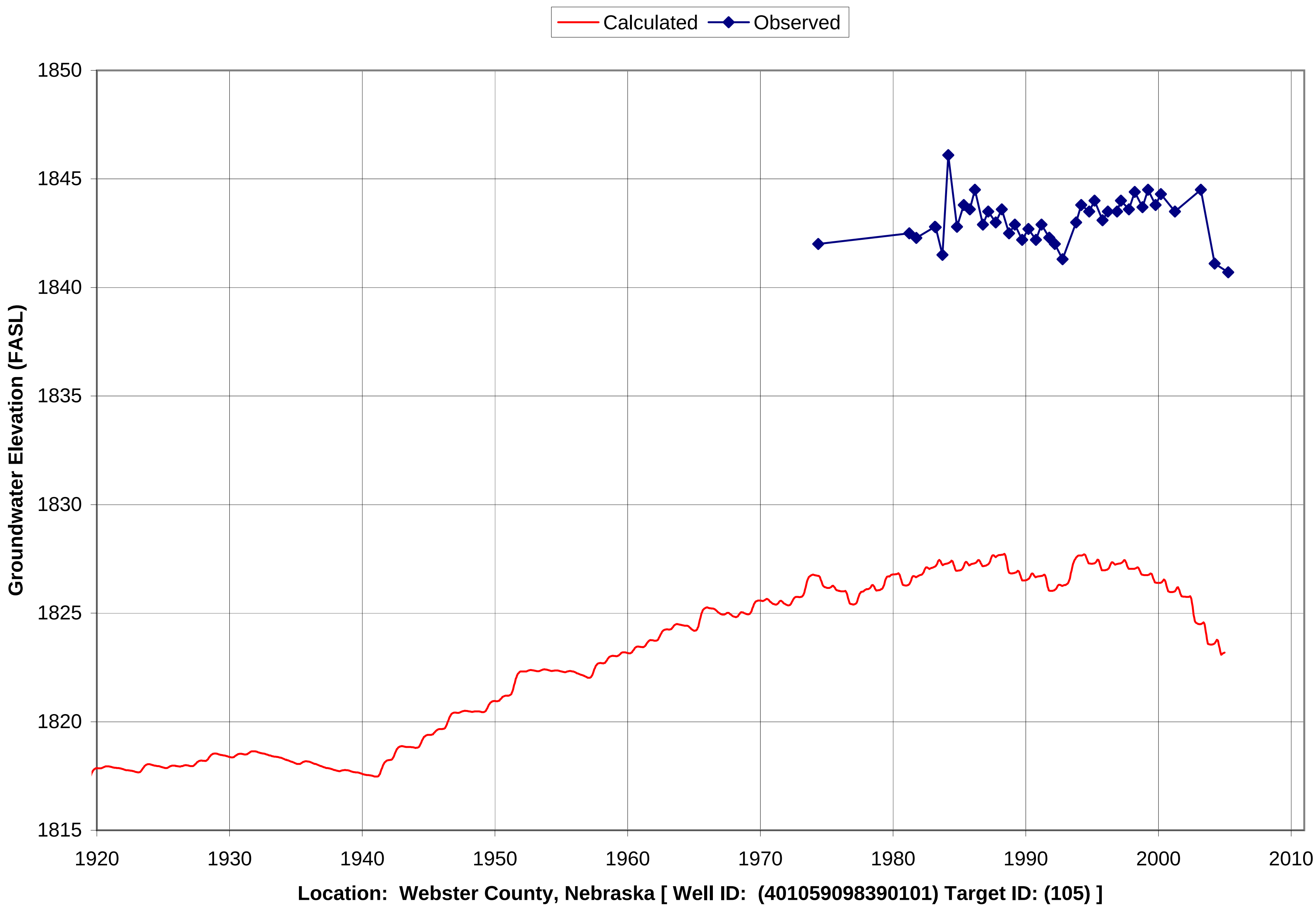
Well ID: (401130100533601)



Location: Hitchcock County, Nebraska [Well ID: (401130100533601) Target ID: (107)]

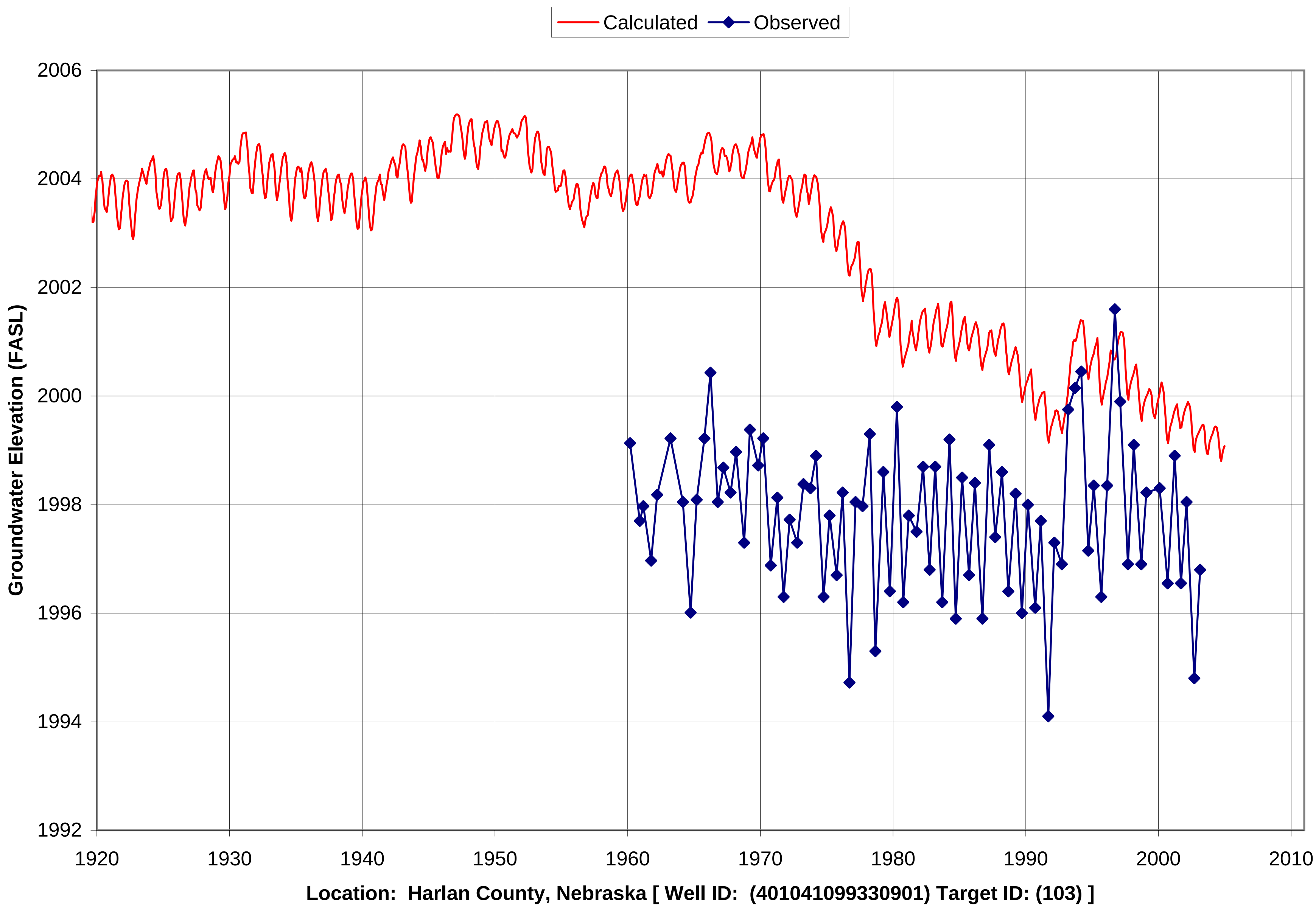
Target ID: (107)

Well ID: (401059098390101)



Target ID: (105)

Well ID: (401041099330901)



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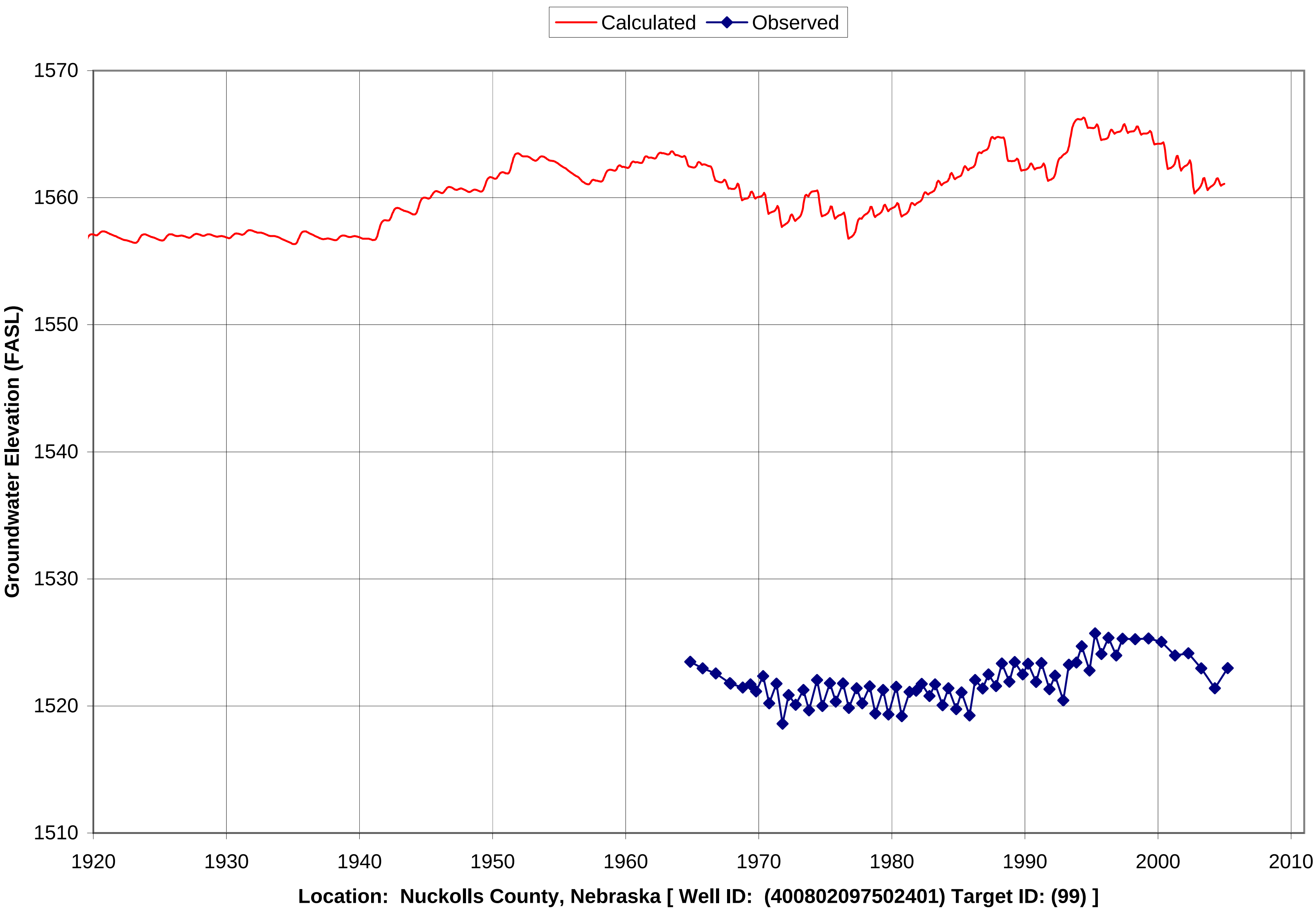

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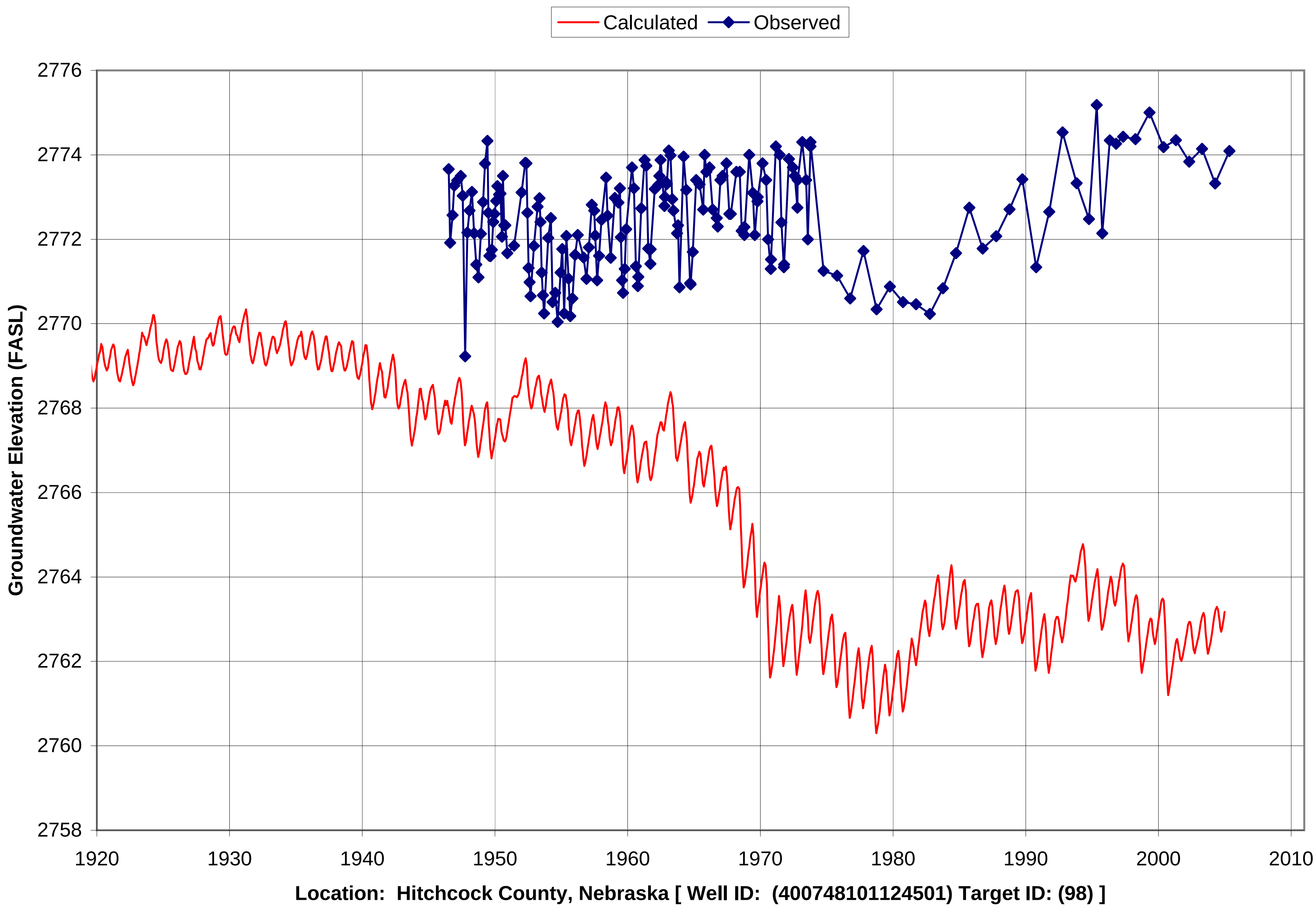

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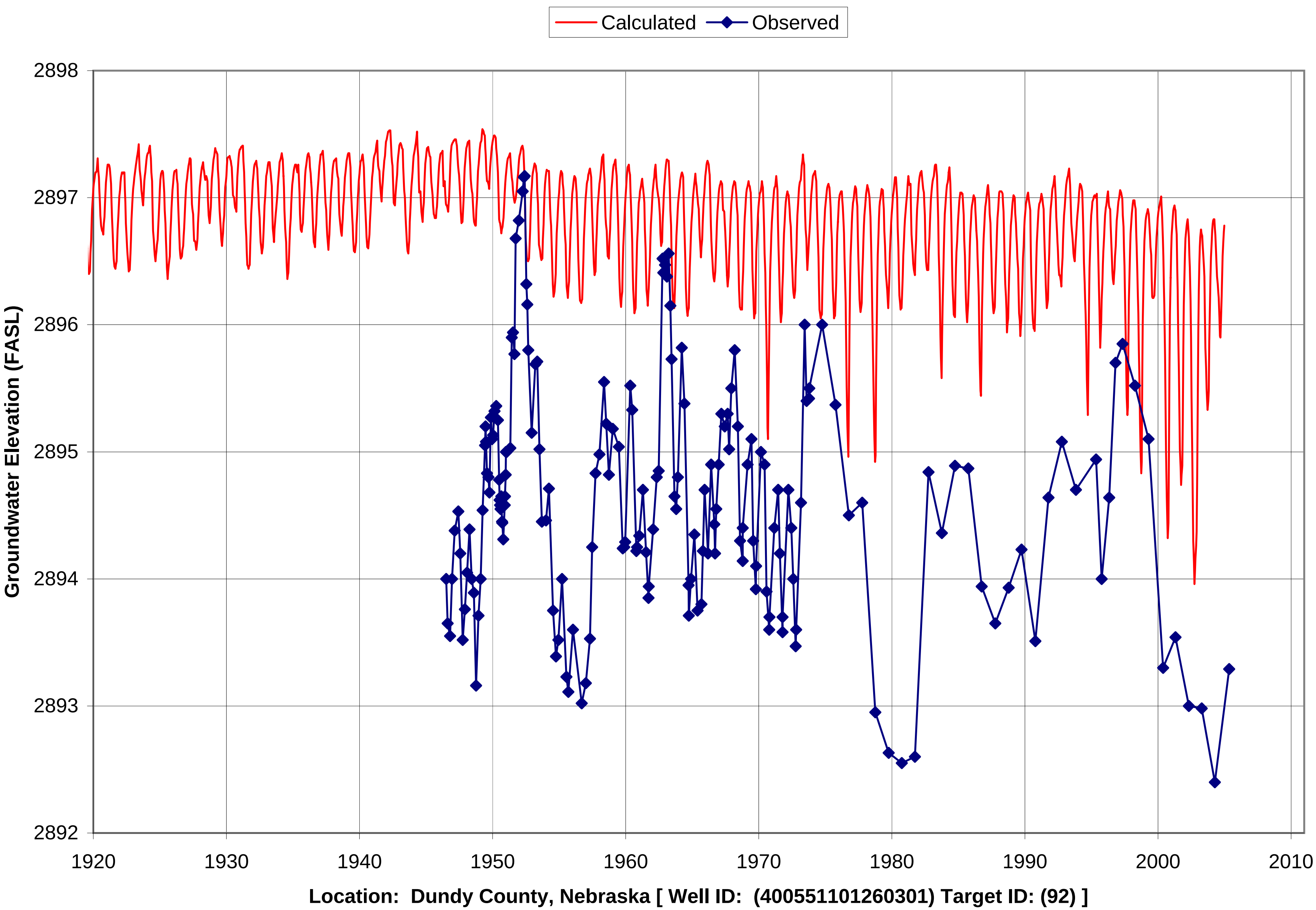

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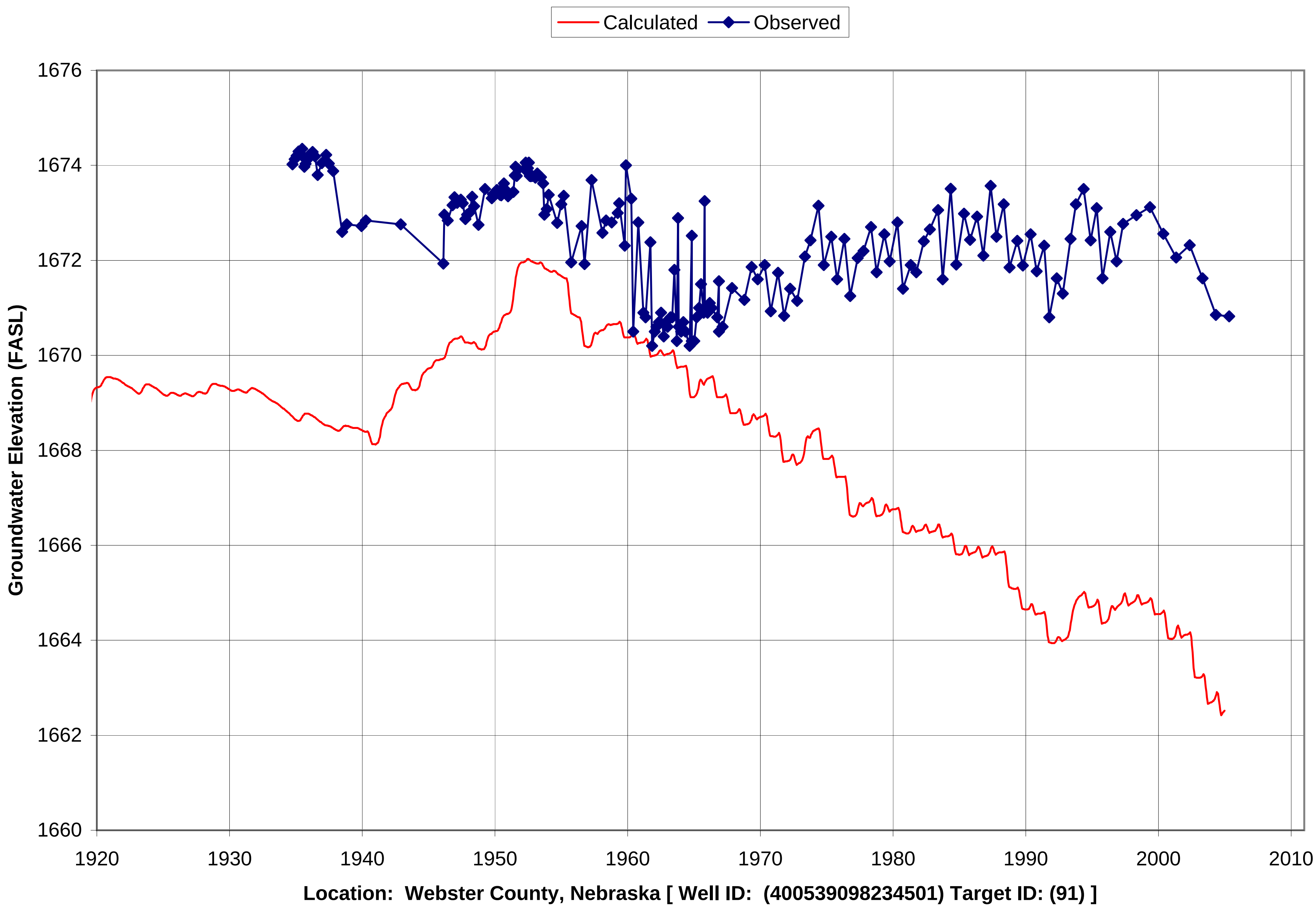

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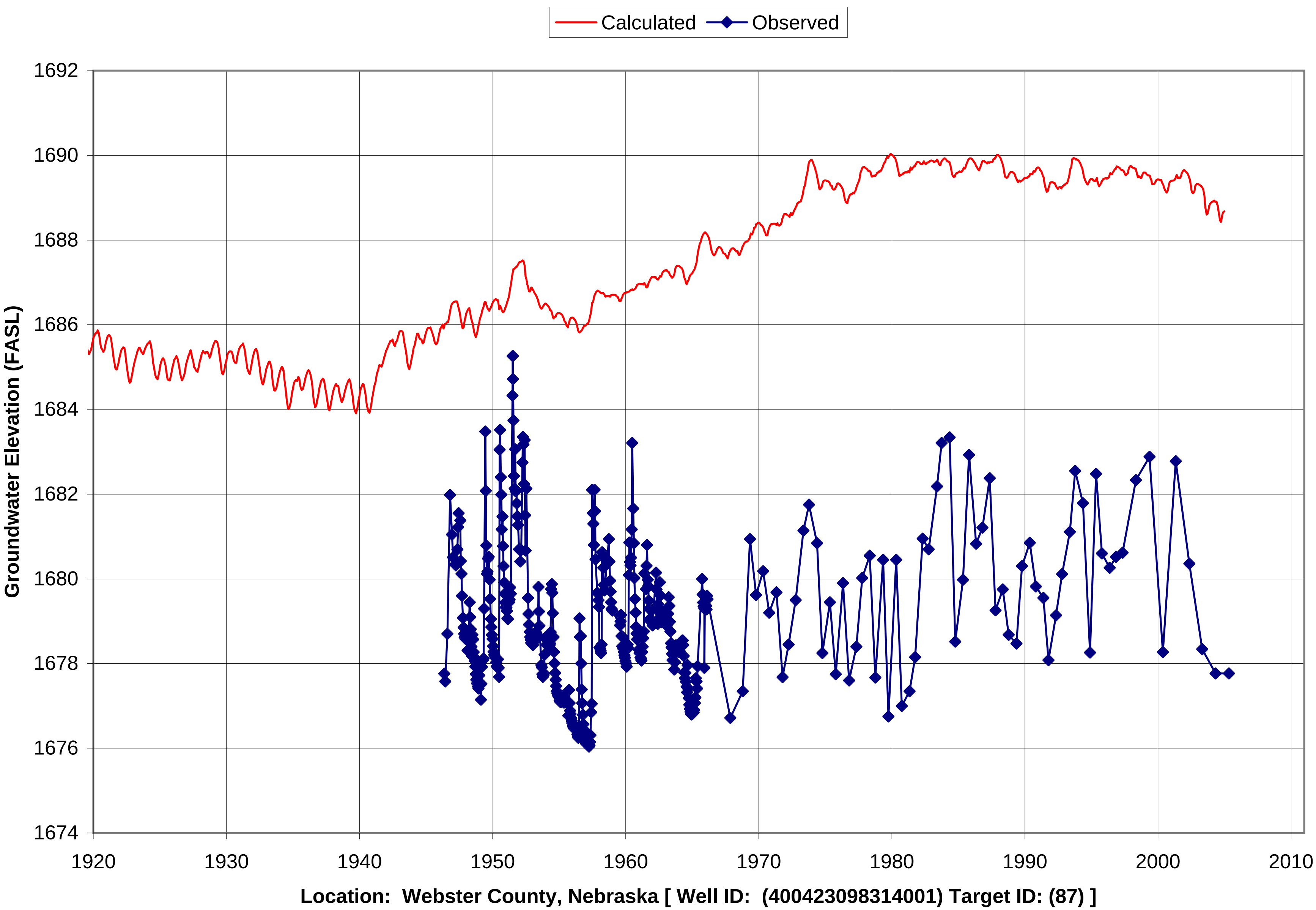

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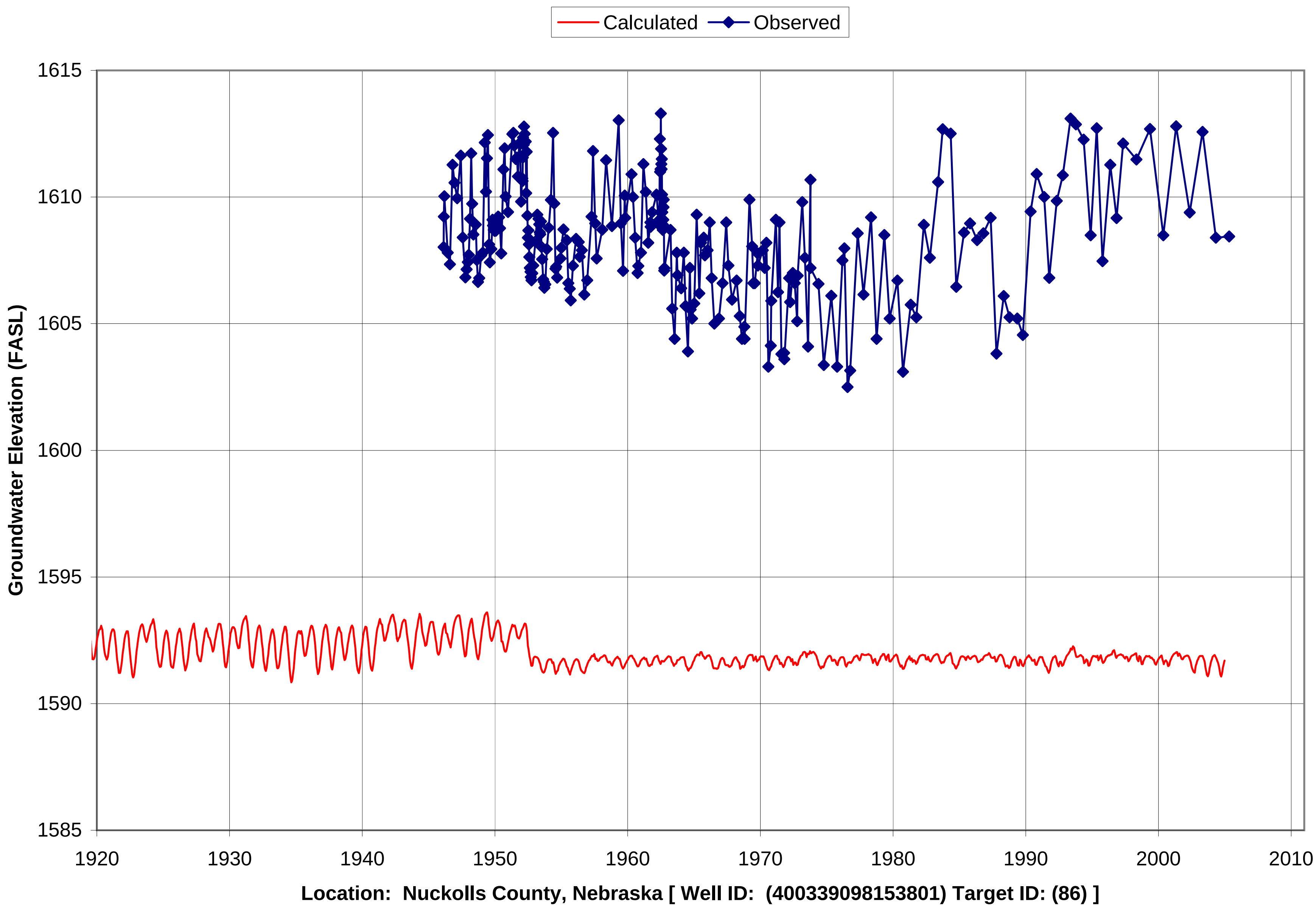

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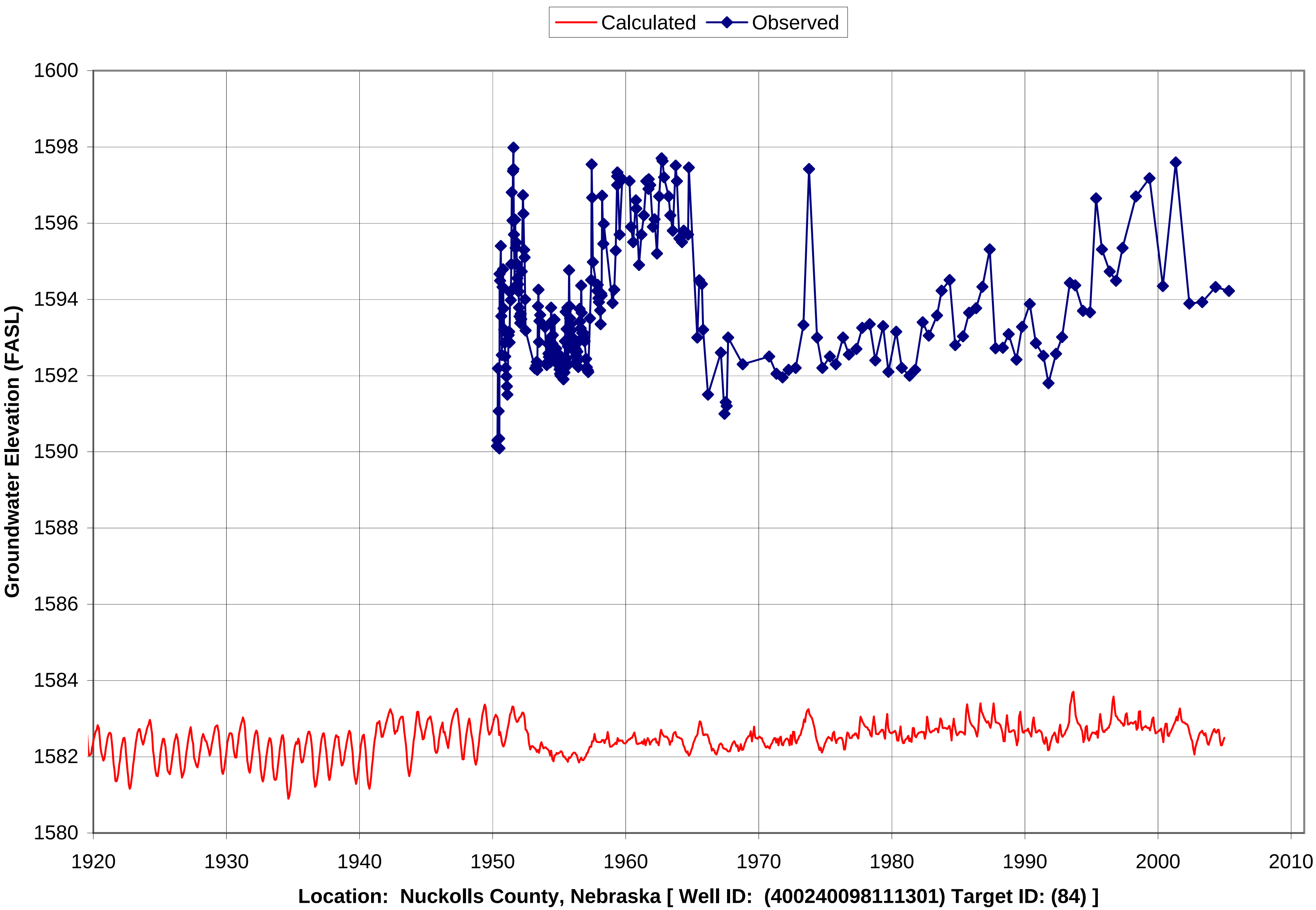

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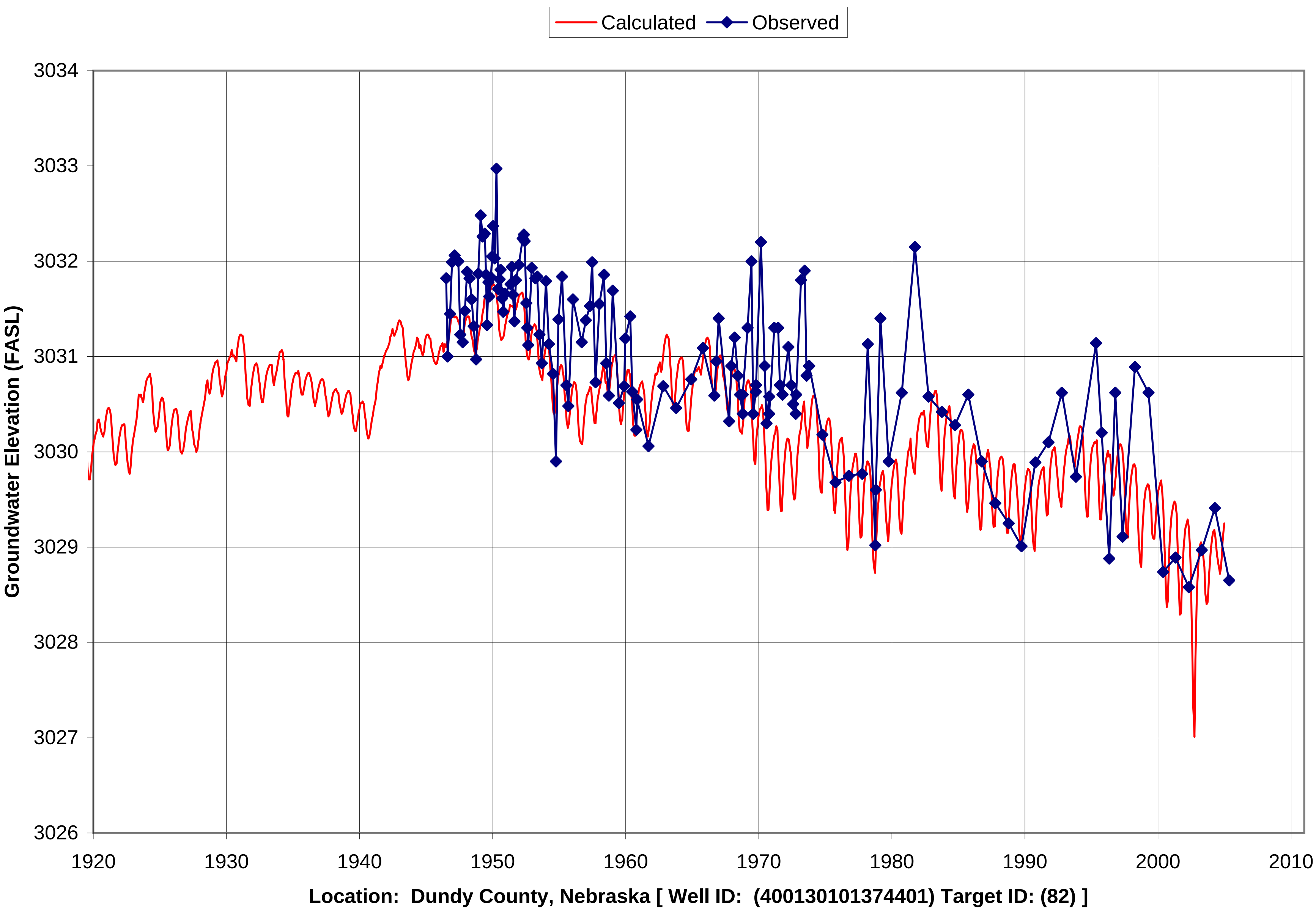

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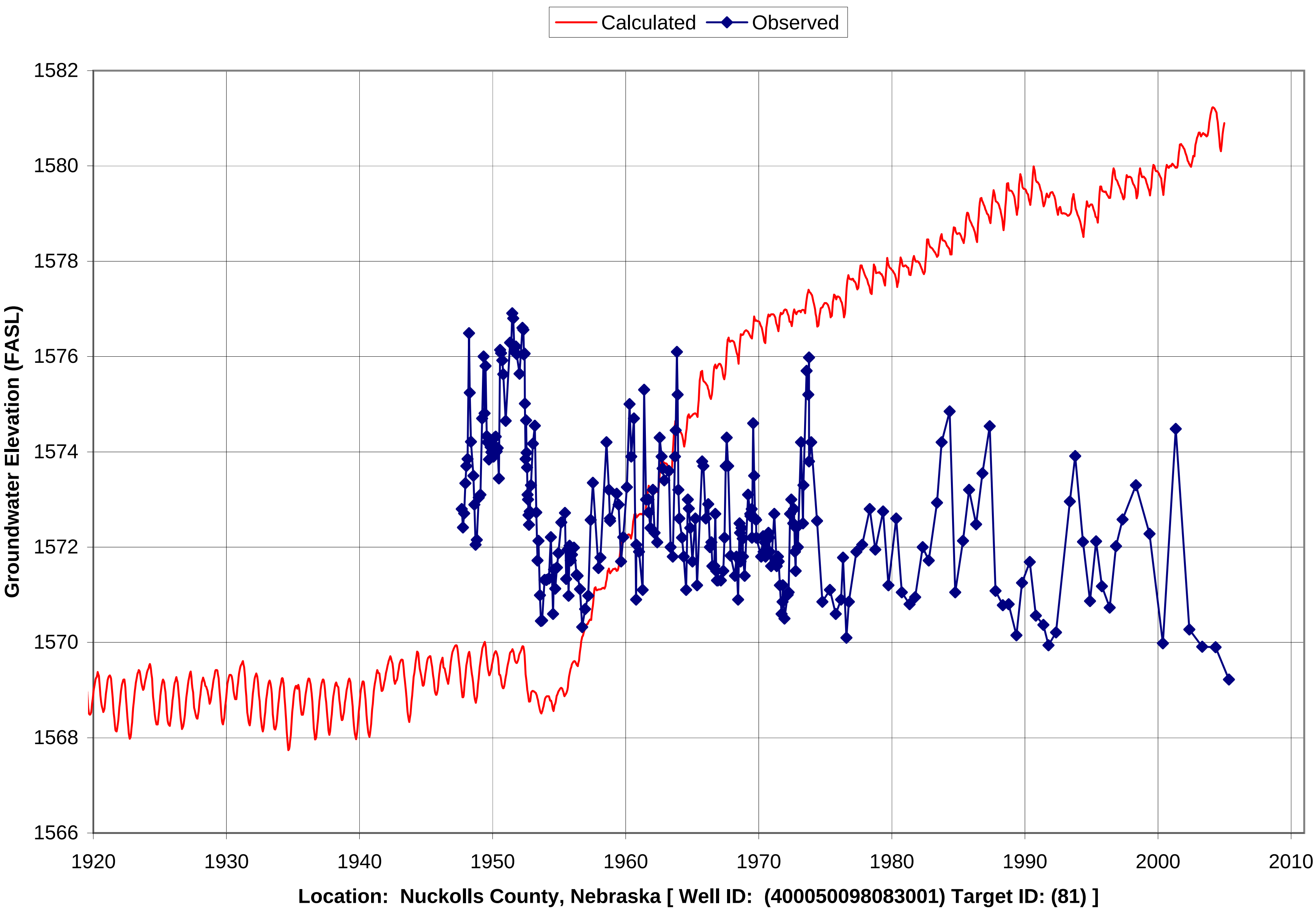

Target ID: (81)

Appendix D Stream Baseflow Hydrographs

Comparison of Calculated and Observed Stream Baseflow In Republican River Basin Nebraska