Geospatial Database of Ground-Water Altitude and Depth-to-Ground-Water Data for Utah, 1971-2000

Prepared in cooperation with the
UTAH DEPARTMENT OF ENVIRONMENTAL QUALITY

Data Series 302

U.S. Department of the Interior
U.S. Geological Survey

Cover photo: Photograph of the Wasatch Range near Provo, Utah, looking east from near Tupliff Hill, Tooele County, Utah. Photo taken April 16, 2006, by Susan G. Buto, U.S. Geological Survey.

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Conversion Factors and Datums

SI to Inch/Pound to SI

Multiply	By	To obtain
	Length	
meter (m)	3.281	foot (ft)

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NVGD 29).

National Elevation Dataset is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Altitude, as used in this report, refers to distance above the vertical datum.

Geospatial database of ground-water altitude and depth-to-ground-water data for Utah, 1971-2000

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Abstract

A geospatial database of ground-water-level altitude and depth-to-ground-water data for Utah was developed. Water-level contours from selected published reports were converted to digital Geographic Information System format and attributes describing the contours were added. Water-level altitude values were input to an inverse distance weighted interpolator to create a raster of interpolated water-level altitude for each report. The water-level altitude raster was subtracted from digital land-surface altitude data to obtain depth-to-water rasters for each study. Comparison of the interpolated rasters to actual water-level measurements shows that the interpolated water-level altitudes are well correlated with measured water-level altitudes from the same time period. The data can be downloaded and displayed in any Geographic Information System or can be explored by downloading a data package and map from the U.S. Geological Survey.

Introduction

The U.S. Geological Survey (USGS), in cooperation with the Utah Department of Environmental Quality, developed a geospatial database of ground-water-level altitude and depth-to-ground-water data for Utah. Water-level contours derived from selected reports published by the USGS, the State of Utah Department of Natural Resources (UDNR), and the State of Utah Division of Water Rights (UDWR) were converted to digital Geographic Information System (GIS) format, and attributes describing the water-level contours were added to the data. Water-level altitude values from the contours were input to an inverse distance weighted (IDW) interpolator to create a separate continuous surface or raster of interpolated water-level altitude for each report. The interpolated water-level altitude raster was subtracted from digital land-surface altitude data to obtain depth-to-water rasters for each study. Comparison of the interpolated rasters to water-level measurements from the USGS National Water Information System (NWIS) database shows that interpolated water-level altitudes are well correlated with measured water-level altitudes from the same time period.

The data in this database represent estimates of water level or the potentiometric surface of the measured aquifer in each study area. The potentiometric or pieziometric surface is defined as an imaginary surface that everywhere coincides with the level of water in the aquifer (Domenico and Schwartz, 1990). If the aquifer is unconfined, the water-level contours represent the water table. If the aquifer is confined, the water-level contours represent the static level of water in tightly cased wells. The water-level contour values and the interpolated water-level-altitude raster values are the altitude of the potentiometric surface. The interpolated depth-to-water raster value is the depth to the potentiometric surface. The depth to the potentiometric surface is positive if the potentiometric surface is below land surface and negative if the potentiometric surface is above land surface.

This report presents the geospatial database of ground-water-level altitude and depth-to-ground-water data for Utah. The water-level altitude database is not intended to be an exact predictor of ground-water level at any location. The data are intended to be used as a general guide to aid the management and protection of ground-water resources in Utah. Errors in the interpolated water-level values can result from errors in the source data, vertical datum differences between the interpolated water levels and digital elevation model, and error in the interpolation algorithm used to develop the rasters. The location of the studies used to construct the database are shown in figure 1.

Data Collection

A literature search for Utah reports published after 1980 and containing potentiometric contours was conducted. Sixteen reports were selected based on the area covered and the date of the water-level contours. If two candidate reports covered the same study area, both reports were selected only if at least 5 years separated the water-level contour dates. Nine of the 16 identified reports had source maps available as Adobe Illustrator files in USGS Utah Water Science Center project archives. The digital files were converted to GIS format using the Map Publisher plug-in for Adobe Illustrator. For the remaining seven reports, a scanned image of the source map was downloaded and georeferenced by matching known

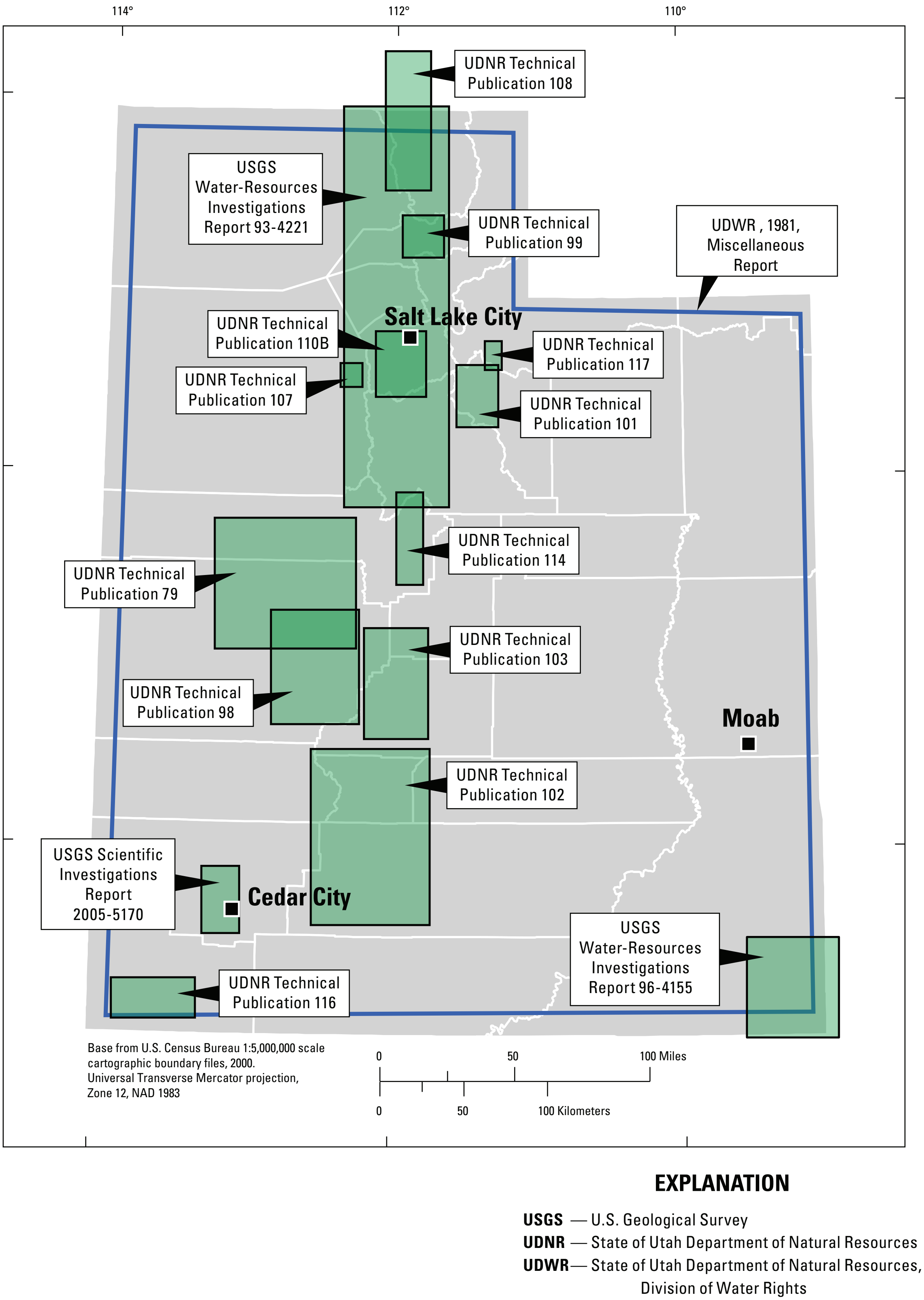

Figure 1. Location and extent of studies used to construct the geospatial ground-water database for Utah.

latitudes and longitudes on the source map with corresponding latitudes and longitudes on a digital topographic map. The water-level contours were digitized into the GIS and manually checked for positional and attribute accuracy against the source figure. The data were not altered in cases where water-level contours from a single source did not match across map boundaries. A summary of the reports used to compile the database is shown in table 1.

Raster Development

A water-level altitude raster for each study area was created from the digitized water-level contours using the ESRI ArcGIS 9.2 Spatial Analyst IDW tool (Environmental Systems Research Institute, 2007). Several interpolation methods including regularized spline, tension spline, and natural neighbor were investigated before selecting the IDW method. Interpolation methods were considered only if they were exact. Exact interpolators create an interpolated raster that matches the value of control points used to create the raster. Selected water-level contour datasets were passed through each interpolator and the results were visually compared. IDW and tension spline techniques maintained grid cell values that most closely honored the published water-level contour values. IDW was selected because it required the least manipulation of interpolation parameters to produce consistent rasters.

The rasters were interpolated to 300-meter resolution. The raster resolution was selected to account for horizontal positional inaccuracy on the source maps and unknown errors introduced to the digital data during the conversion and georeferencing process. The majority of source maps were drawn at 1:250,000-scale or smaller. The horizontal positional accuracy of data mapped at 1:250,000-scale is about 145 meters (Federal Geographic Data Committee, 1998). The positional accuracy of the interpolated raster data was conservatively estimated to one half the raster cell size or 150 meters at a cell resolution of 300 meters to match the estimated positional accuracy of the majority of source maps.

The extent of each raster was constrained to a boundary developed independently for each set of water-level contours. The raster extent was constrained by a boundary obtained from the source map where a boundary was present. Unconsolidated units from 1:500,000-scale digital geologic data (Ludington and others, 2005) were used to estimate the maximum extent of ground water in the study area where the measured aquifer was in the unconsolidated valley fill but no boundary was available from the source map. Boundaries were digitized around sets of water-level contours that could be logically connected when the raster extent needed to be further constrained or where the measured aquifer was in consolidated rock. The water-level altitude contours and the interpolated water-level altitude raster from UDNR Technical Publication No. 108 in Cache Valley, Utah and Idaho, is shown in figure 2.

Table 1. Summary of reports used to construct the geospatial database of ground-water altitude and depth-to-ground-water data for Utah.

[USGS, U.S. Geological Survey; UDNR, Utah Department of Natural Resources; UDWR, State of Utah Department of Natural Resources, Division of Water Rights]

Report	Report code	Report year	Area(s) covered	Source map	Contour year
USGS Scientific Investigations Report 2005-5170	SIR05-5170	2005	Cedar Valley	Figure 5	2000
UDNR Technical Publication 79	UDNR-TP079	1984	Sevier Desert	Plate 1	1981
UDNR Technical Publication 98	UDNR-TP098	1990	Pahvant Valley	Plate 2	1986
UDNR Technical Publication 99	UDNR-TP099	1994	Ogden Valley	Figure 11	1985
UDNR Technical Publication 101	UDNR-TP101	1991	Heber and Round Valleys	Plate 1	1989
UDNR Technical Publication 102	UDNR-TP102	1993	Upper Sevier River basin	Plate 1	1989
UDNR Technical Publication 103	UDNR-TP103	1995	Central Sevier Valley	Plate 1	1988
UDNR Technical Publication 107	UDNR-TP107	1994	Tooele Valley	Plate 2	1989
UDNR Technical Publication 108	UDNR-TP108	1994	Cache Valley	Plate 2	1991
UDNR Technical Publication 110B	UDNR-TP110B	1995	Salt Lake Valley	Figure 25	1991
UDNR Technical Publication 114	UDNR-TP114	1996	Juab Valley	Figure 8	1993
UDNR Technical Publication 116	UDNR-TP116	2000	Central Virgin River basin	Plate 2	1996-1997
UDNR Technical Publication 117	UDNR-TP117	2003	Kamas Valley	Plate 1	1999
UDWR Miscellaneous Report 1981	UDWR-MR1981	1981	State	Plates 1-1 to 1-14	[1]1970-1980
USGS Water-Resources Investigations Report 93-4221	WRIR93-4221	1993	Cache Valley	Figure 5	1971
			Lower Bear River area	Figure 6	1971
			Wasatch Front	Figures 7, 12, and 14	1983-1985
USGS Water-Resources Investigations Report 96-4155	WRIR96-4155	1996	Southeast San Juan County	Figure 8	1994

[1]No year provided in report; dates are assumed.

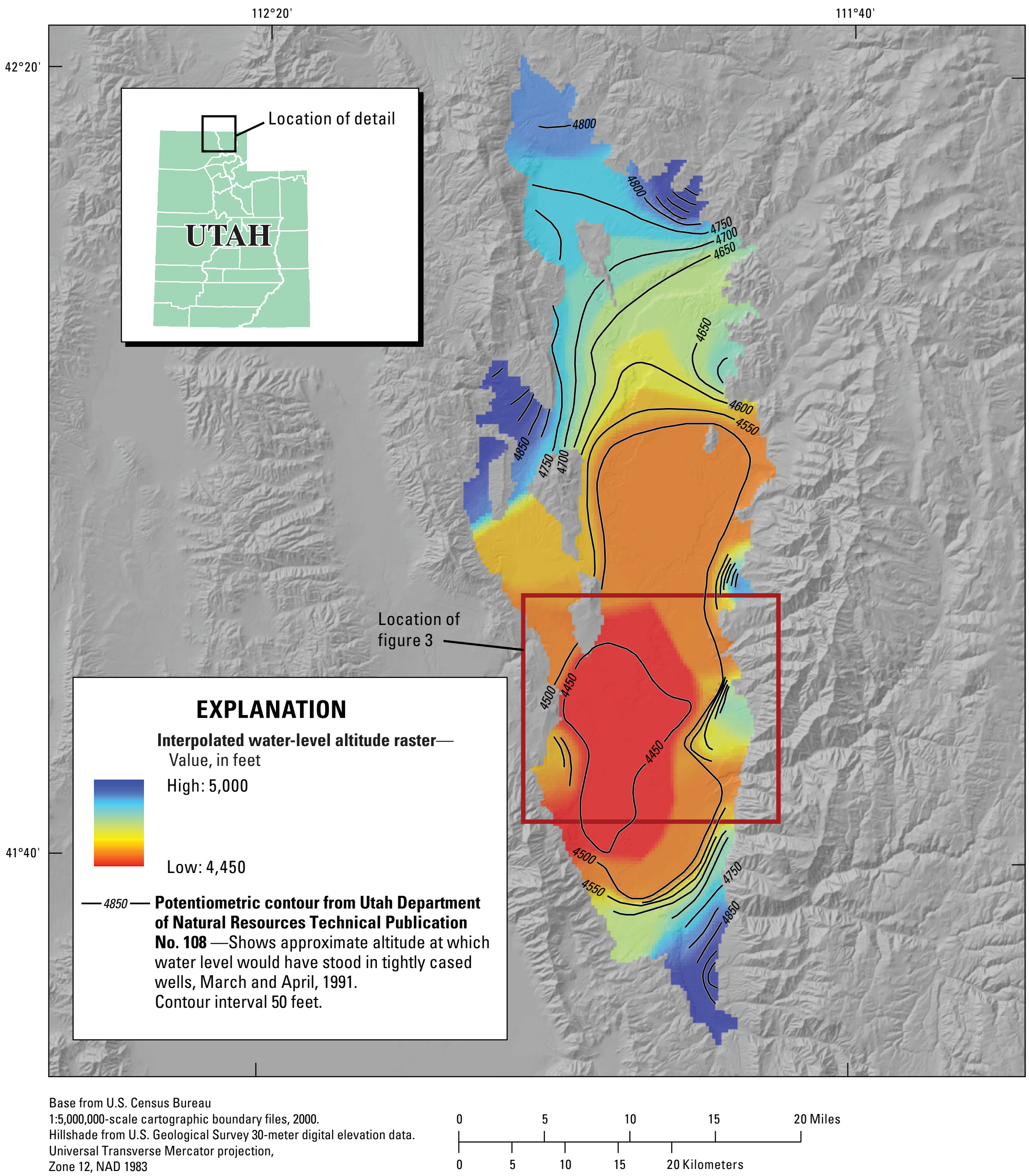

Figure 2. Water-level altitude contours and interpolated water-level altitude raster from Utah Department of Natural Resources Technical Publication No. 108.

USGS 30-meter National Elevation Data (NED) (U.S. Geological Survey, 1999) were resampled to 300 meters. The water-level altitude rasters were subtracted from the resampled NED to obtain depth-to-water rasters for each study area. The NED was registered to the North American Vertical Datum of 1988 (NAVD 88). The source maps were registered to the National Geodetic Vertical Datum of 1929 (NVGD 29). The difference between NAVD 88 and NVGD 29 can range from less than 1 meter in southern Utah to 1.4 meters in northeastern Utah (National Geodetic Survey, 2007). Vertical datum differences were assumed to be within the relative error of the source data sets and were disregarded in the final depth-to-water rasters.

The depth-to-water rasters are estimates of the depth to the potentiometric surface of the measured aquifer for each study. Positive values represent depths below land surface and negative values represent a potentiometric surface above land surface. These values are not exact predictions for any site and do not take into account differences in vertical datum between the source data and the NED, interpolation error, and errors in the horizontal positional accuracy of the data.

Database Design

The vector water-level contour data are collected in an ESRI geodatabase feature dataset with water-level contours from each study area stored as a separate feature class. Feature class attributes include the elevation of the water-level contour in feet, the published confidence level of the source water-level contour, the year the water levels were measured, a report code matching the code in tables 1 and 2, the source figure number, a field hyperlinked to the internet address of the report, and cross-references to the interpolated water-level altitude and depth-to-ground-water rasters derived from the water-level contour data. The water-level altitude and depth-to-ground-water rasters are stored in the geodatabase.

Data Display

The GIS data can be downloaded from the USGS at http://water.usgs.gov/GIS/metadata/usgswrd/XML/DS302.xml. The data also can be explored by downloading the data package and map from http://pubs.usgs.gov/ds/302/DS302_ArcReaderMap.zip. This option requires ArcReader, a free map and data viewer that can be downloaded from ESRI at http://www.esri.com/software/arcgis/arcreader/index.html.

The map can be accessed by downloading and uncompressing the map package, starting ArcReader and navigating to the directory \USGSDS302\pmf from the file-open menu. The map is named USGSDS302.pmf. A short tutorial describing how to navigate and access specific features and information in the map is available in the directory \USGSDS302\tutorial. The tutorial can also be accessed from inside the map.

Error Analysis

Site locations and water-level measurements from the USGS NWIS database were retrieved for dates corresponding to the water-level contour dates for each report. The site locations were converted to a point feature class and the measured water-level altitude was compared to the interpolated water-level altitude value at each site. Water-level values retrieved from NWIS were limited to measurements from the aquifer measured for the study when possible. A detailed view of the location of measured ground-water levels showing the difference between measured and interpolated values for the sites, and the altitude accuracy value reported in NWIS for each measurement from UDNR Technical Publication No. 108 is shown in figure 3.

Results of the comparison for each study were plotted and a linear trend line with the coefficient of determination (R^2) between the measured and interpolated values was added to the plot. The coefficient of determination is a measure of the strength of the correlation between two variables. R^2 can range from 0 to 1. An R^2 value of 1 indicates that the trend line fits the data perfectly; 0 indicates no correlation between the variables. An example of the comparison for UDNR Technical Publication No. 108 is shown in figure 4. R^2 values for all of the studies ranged from 0.826 to 0.995 as shown in table 2.

The difference between the interpolated and measured values were plotted to show the distribution of values around zero as shown in figure 5. Error bars show the accuracy of the altitude value of the site as reported in the NWIS database. The accuracy of the water-level measurement reported in NWIS is typically substantially smaller than the reported altitude accuracy and was disregarded in this analysis. Graphs showing R^2 and the difference between interpolated and measured water levels for all 16 study areas can be viewed in the ArcReader project described above.

Summary

The USGS, in cooperation with the Utah Department of Environmental Quality, developed a geospatial database of ground-water-level altitude and depth-to-ground-water data for Utah. Water-level contours derived from selected reports were converted to digital GIS format, and attributes describing the water-level contours were added to the data. Water-level altitude values from the contours were input to an inverse distance weighted interpolator to create a separate continuous surface of interpolated water-level altitude for each report. The interpolated water-level altitude raster was subtracted from digital land-surface altitude data to obtain depth-to-water

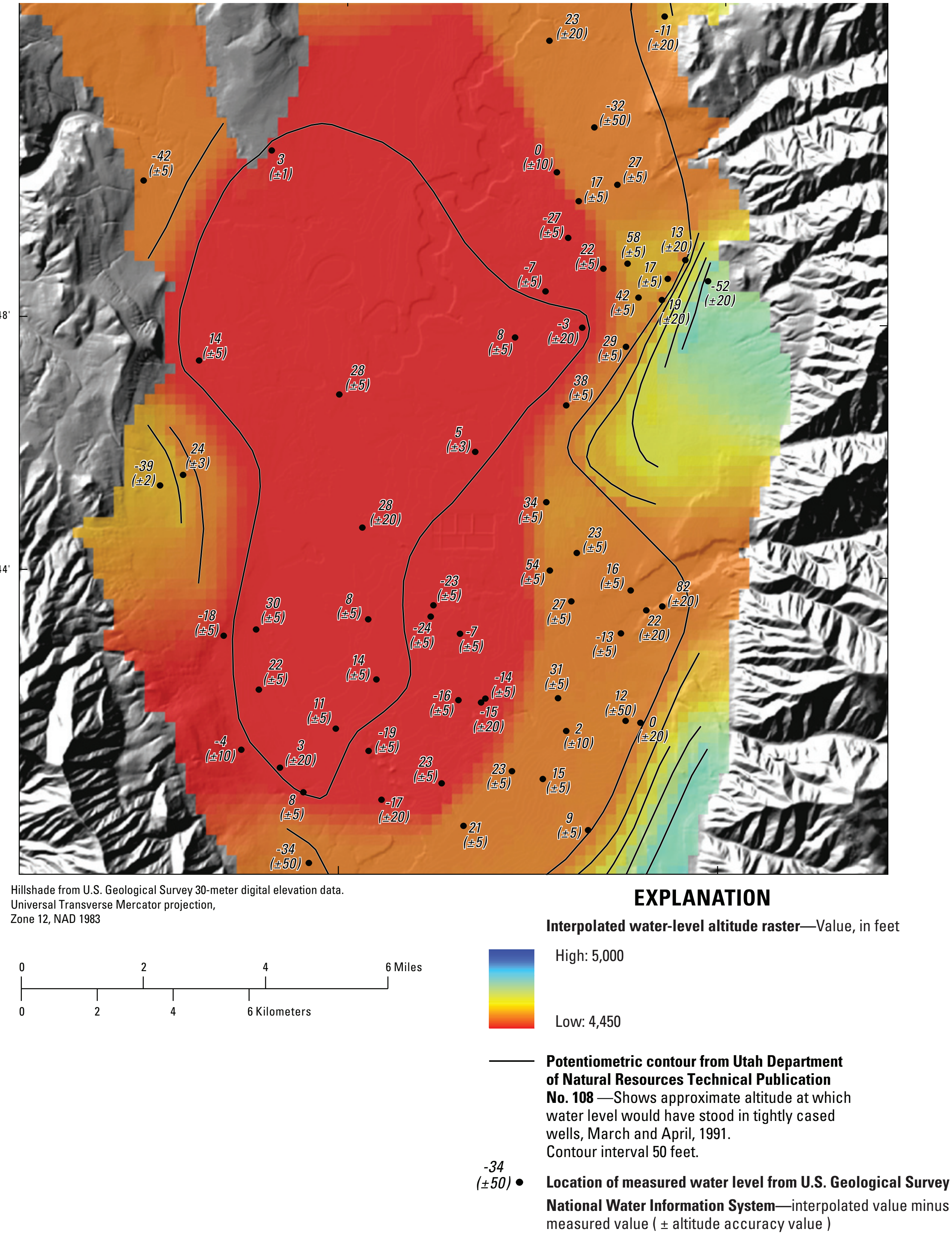

Figure 3. Detail of interpolated water-level altitude raster, measured water levels, and altitude accuracy values from the U.S. Geological Survey National Water Information System database for sites in Utah Department of Natural Resources Technical Publication No. 108.

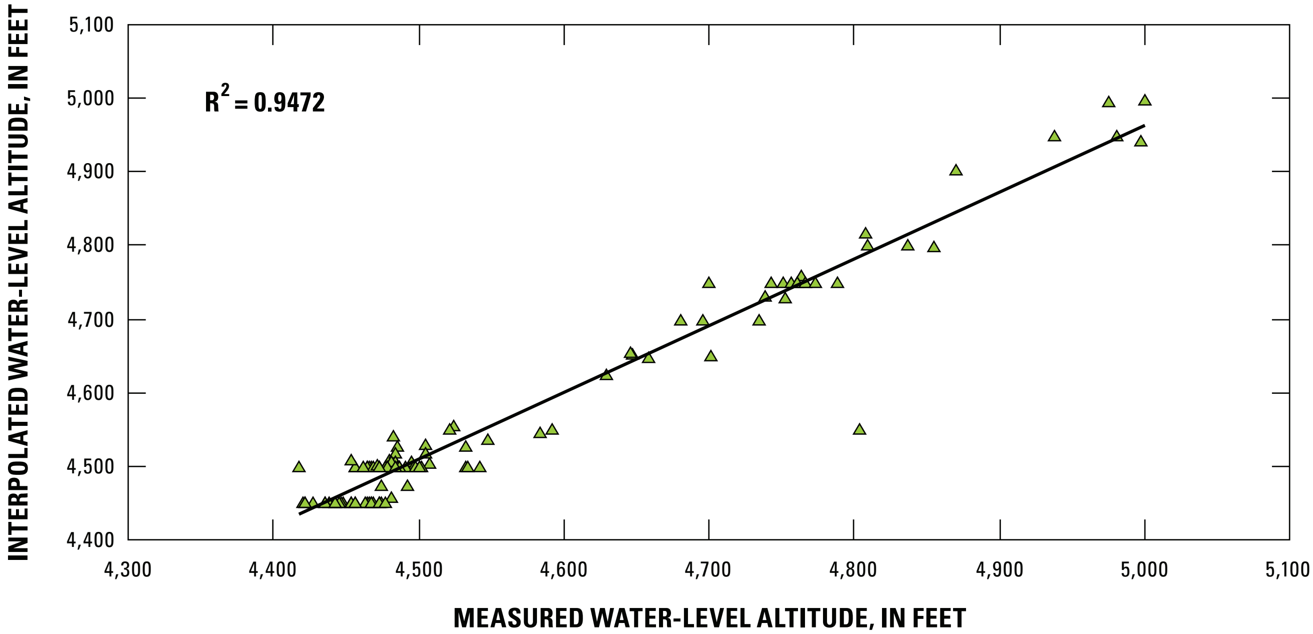

Figure 4. Relation of interpolated and measured water-level altitude for sites in Utah Department of Natural Resources Technical Publication No. 108.

Table 2. Summary of R-squared values for all of the Utah studies.

[See table 1 for report title and report code]

Report code	Source map	Contour year	R^2
SIR05-5170	Figure 5	2000	0.882
UDNR-TP079	Plate 1	1981	.986
UDNR-TP098	Plate 2	1986	.930
UDNR-TP099	Figure 11	1985	.980
UDNR-TP101	Plate 1	1989	.960
UDNR-TP102	Plate 1	1989	.993
UDNR-TP103	Plate 1	1988	.870
UDNR-TP107	Plate 2	1989	.906
UDNR-TP108	Plate 2	1991	.947
UDNR-TP110B	Figure 25	1991	.826
UDNR-TP114	Figure 8	1993	.950
UDNR-TP116	Plate 2	1996-97	.995
UDNR-TP117	Plate 1	1999	.950
UDWR-MR1981	Plates 1-1 to 1-14	[1]1981	.993 for three spot-checked areas (Uinta, Milford, and Rush Valleys)
WRIR93-4221	Figure 5	1971	.982
	Figure 6	1971	
	Figures 7, 12, and 14	1983-85	
WRIR96-4155	Figure 8	1994	.947

[1]No year provided in report; dates are assumed.

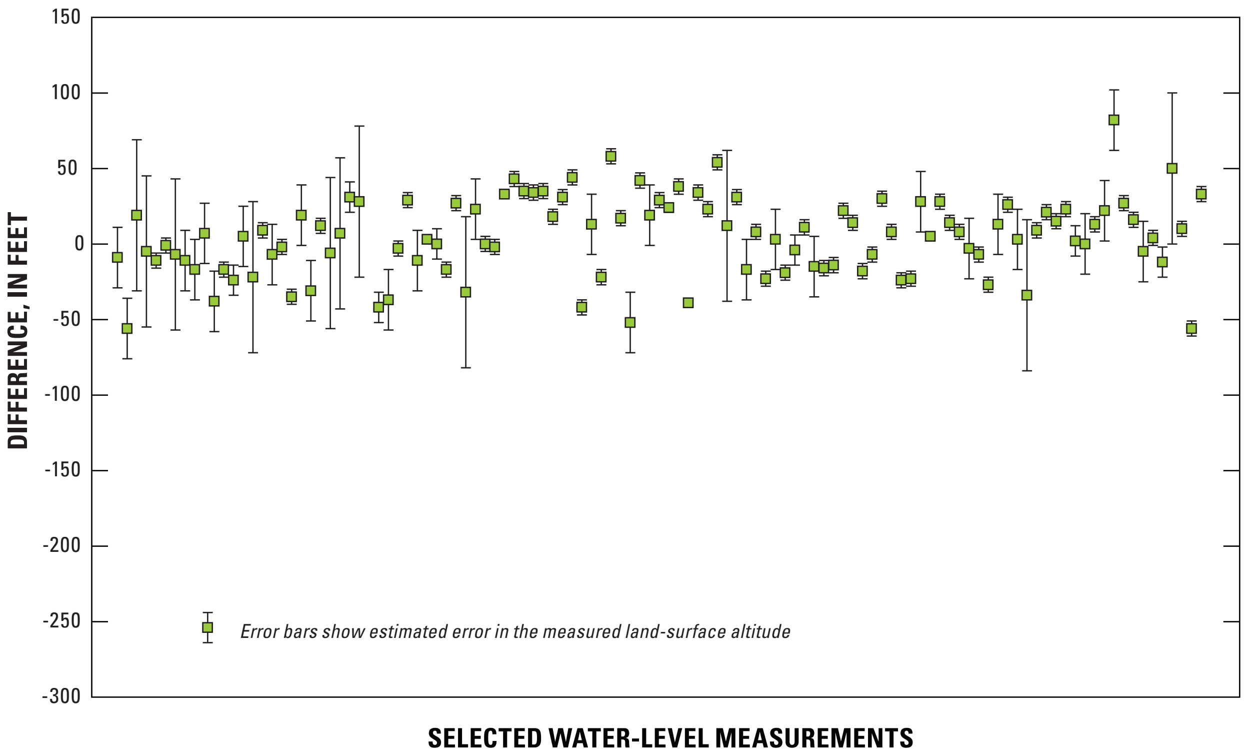

Figure 5. Difference between the interpolated and measured water-level altitude for sites in Utah Department of Natural Resources Technical Publication No. 108.

rasters for each study. The data in this database represent estimates of water level or the potentiometric surface of the measured aquifer in each study area. The interpolated depth-to-water raster value is the depth to the potentiometric surface. The depth to the potentiometric surface is positive if the potentiometric surface is below land surface and negative if the potentiometric surface is above land surface. The water-level altitude database is not intended to be an exact predictor of ground-water level at any location. The data are intended to be used as a general guide to aid the management and protection of ground-water resources in Utah. Errors in the interpolated water-level values can result from errors in the source data, vertical datum differences between the interpolated water levels and digital land surface data, and error in the interpolation algorithm used to develop the rasters.

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