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Geospatial Database of Estimates of Groundwater Discharge to Streams in the Upper Colorado River Basin

Data Series 851

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

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Conversion Factors and Datums

Inch/Pound to SI

Multiply	By	To obtain
	Area	
acre	0.004047	square kilometer (km^2)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
acre-foot (acre-ft)	43,560	cubic feet (ft^3)
	Flow rate	
acre-foot per year (acre-ft/yr)	1,233	cubic meter per year (m^3/yr)
cubic foot per day (ft^3/d)	0.02831	cubic meter per day (m^3/d)
acre-foot per year (acre-ft/yr)	0.00138	cubic foot per second (ft^3/s)
cubic foot per second (ft^3/s)	724.463	acre-foot per year (acre-ft/yr)

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

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

Geospatial Database of Estimates of Groundwater Discharge to Streams in the Upper Colorado River Basin

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Abstract

The U.S. Geological Survey, as part of the Department of the Interior's WaterSMART (Sustain and Manage America's Resources for Tomorrow) initiative, compiled published estimates of groundwater discharge to streams in the Upper Colorado River Basin as a geospatial database. For the purpose of this report, groundwater discharge to streams is the baseflow portion of streamflow that includes contributions of groundwater from various flow paths. Reported estimates of groundwater discharge were assigned as attributes to stream reaches derived from the high-resolution National Hydrography Dataset. A total of 235 estimates of groundwater discharge to streams were compiled and included in the dataset. Feature class attributes of the geospatial database include groundwater discharge (acre-feet per year), method of estimation, citation abbreviation, defined reach, and 8-digit hydrologic unit code(s). Baseflow index (BFI) estimates of groundwater discharge were calculated using an existing streamflow characteristics dataset and were included as an attribute in the geospatial database. A comparison of the BFI estimates to the compiled estimates of groundwater discharge found that the BFI estimates were greater than the reported groundwater discharge estimates.

Introduction

Groundwater is an important component of water availability in the Upper Colorado River Basin (UCRB) (fig. 1). The Colorado River provides water for about 25 million people and is used to irrigate 2.5 million acres of farmland (Belnap and Campbell, 2011). Demand for water is expected to increase as the population continues to increase in the region. It is projected that the population will increase to 38 million by 2020 (Belnap and Campbell, 2011). In addition to the human population, water in springs, streams, and rivers supports a range of aquatic and riparian ecosystems that encompass many endangered species. Recent climate change models predict future warmer temperatures, reduced precipitation, and a decrease in streamflow from 5 to 45 percent by 2050 (Belnap and Campbell, 2011).

Precipitation infiltrates and recharges aquifers that in turn discharge water to springs and streams. The groundwater component of streamflow, termed baseflow, is an important part of surface-water supplies and also sustaining ecosystems in the UCRB. The spatial distribution of groundwater recharge, discharge, and use are critical for understanding long-term water availability in the basin.

The U.S. Geological Survey (USGS), as part of the Department of the Interior's WaterSMART (Sustain and Manage America's Resources for Tomorrow) initiative, compiled published estimates of groundwater discharge to streams in the UCRB. For the purpose of this report, groundwater discharge to streams is the baseflow portion of streamflow that includes contributions of groundwater from various flow paths. Compiled estimates were assigned to stream reaches or segments based on version 931v210 of the high-resolution National Hydrography Dataset (NHD) (U.S. Geological Survey, 2009, accessed on August 1, 2012). In addition, groundwater discharge to streams was estimated using a national streamflow characteristics dataset (Wolock, 2003), which includes the average baseflow index (BFI), the ratio of baseflow to total flow volume for a given year, and the mean daily streamflow. These BFI calculated groundwater discharge estimates were included in the database as separate attributes and were compared to reported estimates of groundwater discharge. Estimates of groundwater discharge were summarized by 8-digit hydrologic unit codes (HUCs) by utilizing the Watershed Boundary Dataset (United States Department of Agriculture, accessed on July 31, 2012). In some cases, discharge estimates for reaches span more than one 8-digit HUC. For estimates of groundwater discharge that spanned more than one 8-digit HUC, multiple 8-digit HUCs are listed in the attribute table.

Database Design

Estimates of groundwater discharge to streams were compiled from USGS Professional Papers, USGS Water-Resource Investigations Reports, U.S. Department of Energy Open-File Reports, and Technical Publications from the Utah Department of Natural Resources (UDNR). Estimates were compiled

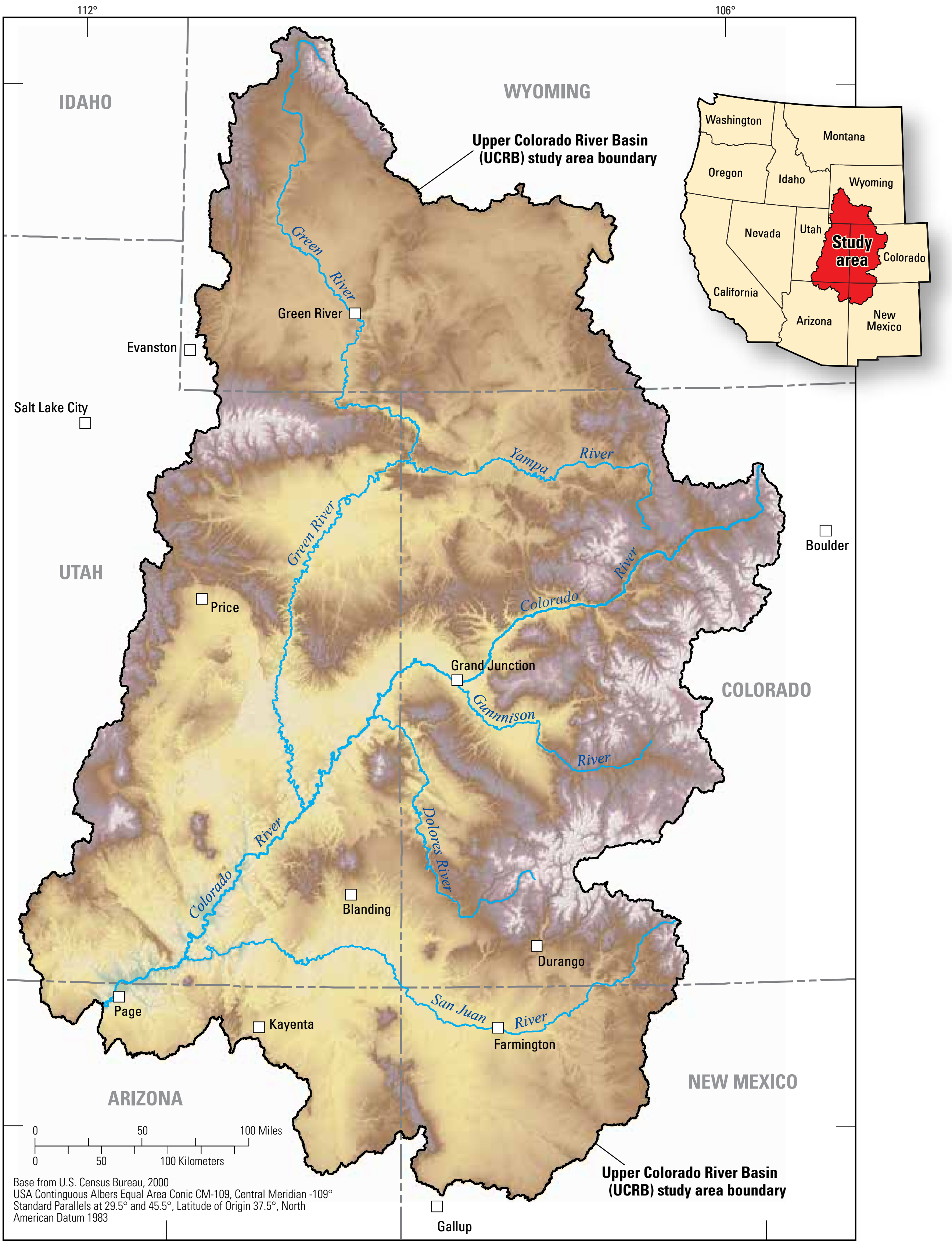

Figure 1. Location map of the Upper Colorado River Basin study area.

for 8-digit HUCs in the UCRB. Groundwater discharge estimates of small streams, with less than 35 acre-feet per year (acre-ft/yr) of annual discharge, were not included in the dataset due to the difficulty of representing partial or relatively short reaches in the dataset. Although an extensive literature search was conducted, the geospatial database is likely not a complete representation of all published data available for groundwater discharge in the UCRB. Table 1 in the geodatabase presents a summary of all compiled estimates.

Estimates of groundwater discharge were assigned over an entire stream reach if the reported estimate was from the mouth of a stream. If a reported estimate was for an entire watershed, it was assigned to all the stream reaches in the watershed. Estimates of groundwater discharge from the compiled reports were made using a variety of methods. The most common method was the use of streamflow measurements along a reach and the calculation of gains or losses in streamflow. Table 2 in the geodatabase is a summary and description of each method used. Groundwater discharge was calculated based on the difference between streamgages. Where groundwater discharge was reported for the entire watershed, the groundwater discharge of smaller tributaries was subtracted from the overall watershed groundwater discharge to find the groundwater discharge for a selected reach. For example, the streamgage in the Green River near Greendale, Utah, records the baseflow discharge of the entire watershed above it. The groundwater discharge for the Green River was found by taking the baseflow discharge estimate at the Greendale streamgage and subtracting all the reported baseflow discharge estimates for the tributaries to the Green River. Studies that were conducted during fall and winter months generally assumed that streamflow was comprised of baseflow, or primarily groundwater discharge. When the same reach had more than one published estimate of groundwater discharge, all estimates were included in the dataset as separate features. For example, there are two polyline features in the database for the Big Sandy River in Wyoming. One polyline feature represents the estimate of groundwater discharge from the water budget method of estimation in Martin (1996) and one represents the estimate from streamflow measurements in Warner and others (1985). Warner and others (1985) measured streamflow during December 1977 and January 1978, and assumed that the streamflow consisted primarily of groundwater discharge. In some cases, compiled estimates of groundwater discharge overlapped. For example, groundwater discharge estimates for the Colorado River between Cisco and Hite, Utah (Freethey and Cordy, 1991) and between the mouth of the Green River and Hite, Utah (Rush and others, 1982) overlap. In these cases, both estimates were included in the dataset with their associated reach. The reports examined in this study were published from 1965 to 2005. Not all published groundwater discharge estimates were included in the geospatial database. Several groundwater discharge estimates did not have locations or stream reaches defined. These estimates could not be associated with a defined reach and were omitted from the compilation. For the complete list of groundwater discharge estimates, stream reach or stream locations, methods, and cited abbreviations of estimates that were included in the geospatial database, refer to table 3 in the geodatabase.

An alternative method for estimating the baseflow portion of streamflow uses the BFI. The BFI value is the ratio of baseflow to total flow volume for a given year (Wahl and Wahl, 1995). The average annual BFI value and the average daily streamflow value from Wolock's (2003) national streamflow characteristics dataset were used to calculate groundwater discharge to streams in the UCRB. These estimates were calculated using a method proposed by the Natural Environment Research Council (Institute of Hydrology, 1980) and compared to other previously reported estimates. For the purpose of this analysis, the estimated baseflow is assumed to represent the total groundwater discharge to the stream. The procedure uses a stepwise approach to divide the water year into 5-day increments, determine the minimum discharge value for each increment, and connect the turning point values. Minimums that are 90 percent less than adjacent minimums are considered inflection points. Straight lines are then drawn between inflection points on semi-logarithmic paper, defining the baseflow hydrograph, and the area beneath the line is an estimate of the volume of baseflow for the period (Wahl and Wahl, 1995). The advantage of the BFI algorithm is that it uses a deterministic and repeatable method to calculate BFI, which can be used to objectively evaluate a long period of record.

The BFI ratio reported by Wolock (2003) was used to calculate groundwater discharge to streams using streamflow data from Wolock's dataset. The mean daily streamflow for the period of record for the streamgage was multiplied by the BFI value provided by Wolock (2003) to estimate the total groundwater discharge throughout the stream reach and watershed above the gage. If there were two streamgages on a stream, groundwater discharge was estimated between the streamgages by multiplying the mean daily streamflow by the BFI value at each gage, then taking the difference of the two values. This value represents the total groundwater discharge between the two streamgages. The resulting mean daily baseflow estimates in ft^3/s were converted to acre-ft/yr.

The vector stream reach data are stored in an ESRI geodatabase as a separate feature class, and were selected from the high-resolution NHD (U.S. Geological Survey, 2009). Feature class attributes associated with each stream reach include groundwater discharge (in acre-ft/yr), method of measurement, citation abbreviation, defined reach, BFI estimate (in acre-ft/yr), and 8-digit HUC(s). The citation abbreviation attribute is an abbreviated form of the report reference; for the complete citation refer to table 3 in the geodatabase. The defined reach attribute simply states whether or not the exact location of the groundwater discharge estimate was known. Several reports listed station locations, towns, dams, etc. to identify where the estimate was measured and for what extent of the reach that estimate applied to. Other reports only mentioned a general area. For example, Eisinger and Lowe (1999) published a groundwater discharge estimate for the Green River through Grand County without defining actual end points of the reach.

Data Display

The GIS data can be downloaded from the USGS at *http://water.usgs.gov/lookup/getspatial?ds851*_UCRBBaseflow. The data can also be accessed by downloading the data package and tables from *http://pubs.usgs.gov/ds/851*.

Comparison of Baseflow Index Calculated and Reported Groundwater Discharge Estimates to Streams

Wolock (2003) created a BFI grid for the conterminous United States to estimate the baseflow values for ungaged streams. A comparison between groundwater discharge estimates calculated using BFI values and previously reported groundwater discharge values, however, shows that the BFI dataset overestimates groundwater discharge in the UCRB. A subset of the previously reported groundwater estimates along reaches with USGS streamgages were compared to the calculated groundwater discharge values using the BFI and are listed in table 4 in the geodatabase. Most of the reported estimates in other reports were calculated using the flow duration curve method or streamflow measurements. Stream reaches with reported estimates that did not have any corresponding streamgages were omitted from the comparison because no groundwater discharge could be calculated using the BFI. The percent difference values varied from -82 percent at Bitter Creek, Rock Springs Uplift, Wyoming to +1,496 percent at Blacks Fork near Little America, Wyoming. Negative percent difference values indicate that the calculated BFI estimate is less than the estimate from compiled reports. Only 7 percent of the previously reported groundwater estimates were greater than the BFI calculated estimate. There are not a sufficient number of previously reported groundwater estimates that were calculated using other methods, such as seepage investigations or Darcy's Law calculations, which limit the ability to make a comparison between BFI calculated estimates and groundwater discharge estimates using other methods. Overall, the trend indicates that the BFI overestimates groundwater discharge.

Wolock (2003) notes that users should be cautious when using BFI ratios to estimate baseflow for regulated streams or streams that experience significant snowmelt runoff. These are factors that most likely account for the differences and general overestimation of baseflow by the BFI when compared to other estimates in the UCRB. According to Wahl and Wahl (1988), the BFI program was developed to produce estimates of the annual baseflow volume on unregulated rivers. BFI values could be overestimated if the drainage upstream from a gaging station is regulated by a dam, has extensive diversions of streamflow for irrigation, or is dominated by snowmelt (Rosenberry, 2008). Wolock's (2003) streamflow characteristics dataset cannot be used to estimate groundwater discharge to the UCRB in areas that lack groundwater discharge information, and does not help with understanding the rate and spatial distribution of groundwater recharge and discharge.

Summary

The U.S. Geological Survey, as part of the Department of the Interior's WaterSMART initiative, compiled published estimates and developed a geospatial database of groundwater discharge estimates to streams in the Upper Colorado River Basin. A total of 235 estimates of groundwater discharge to streams were compiled and included in the dataset. The previously reported groundwater discharge estimates were also compared to groundwater estimates calculated using a baseflow index ratio, which was principally developed to estimate groundwater discharge in areas that lacked previously reported data. Stream reaches for which groundwater discharge estimates existed were included in a geospatial database and referenced to the National Hydrography Dataset. Attributes and tables describing the groundwater discharge estimates to these reaches were added to the dataset. Although an extensive literature search was conducted, additional studies and resources may have been overlooked. In addition, groundwater discharge estimates for very small streams or watershed areas were not included in the dataset, as these estimates were typically correlated to relatively short reaches and largely generalized areas, and there were insufficient data available to represent these values. This study focused on the scale of the 8-digit hydrologic unit code, composed of major watersheds and tributaries to the Green and Colorado Rivers.

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