Groundwater Resources of the Harney Basin, Southeastern Oregon

Introduction

In response to increasing groundwater demand and declining groundwater levels in the Harney Basin of southeastern Oregon, the U.S. Geological Survey and the Oregon Water Resources Department conducted a cooperative groundwater-availability study during 2016–22. This Fact Sheet summarizes the results of this study. Full details of the study are provided in Gingerich and others (2022a, 2022b), Garcia and others (2022), and the other supporting documents listed on the last page of this Fact Sheet.

Important Study Findings

- The lowland groundwater budget is out of balance by about 110,000 acre-feet per year, which has led to substantial groundwater-level declines.
- Surface water flowing from upland to lowland areas in streams is the primary source of recharge to groundwater beneath lowland areas. Recharge from precipitation falling on lowland areas is minimal.
- Most groundwater pumped from lowland wells is ancient and not being replenished at meaningful human timescales.

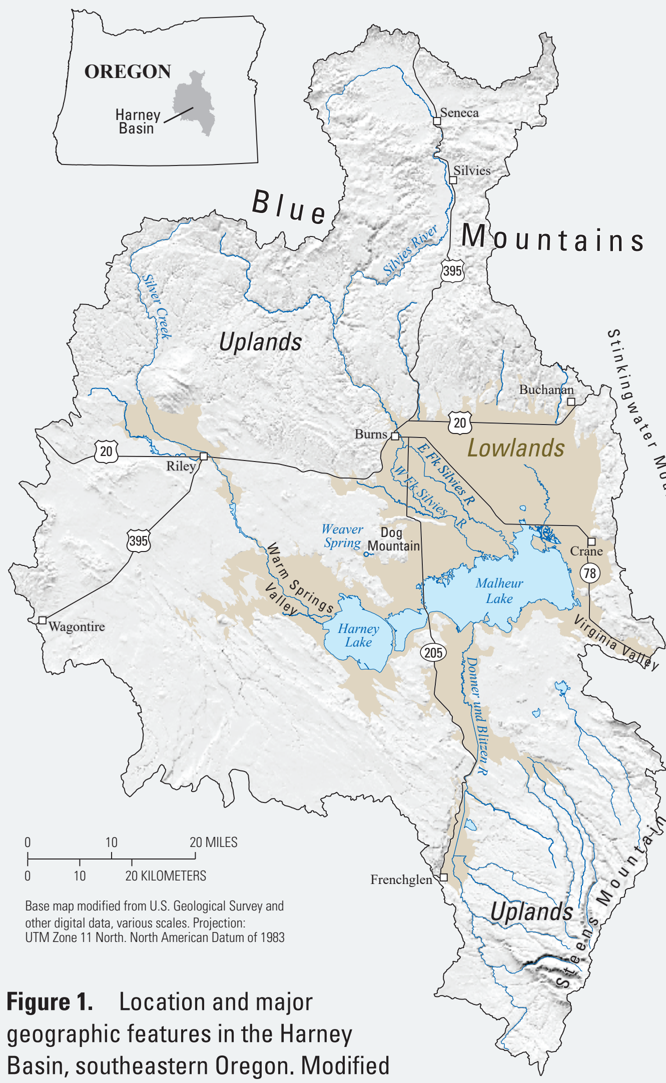


Figure 1. Location and major geographic features in the Harney Basin, southeastern Oregon. Modified from Gingerich and others, 2022.

Groundwater in the Harney Basin

Groundwater in the 5,240 square mile Harney Basin (fig. 1) occurs within an aquifer system that, when pumped, can produce substantial amounts of water in some areas but little water in other areas. More- and less-productive areas are distinguished by the underlying rocks and sediments, and the rate and magnitude of groundwater recharge and discharge. Like a stream, groundwater flows from higher to lower elevations—from recharge areas (where water enters the groundwater system) toward discharge areas (where water leaves the groundwater system) (fig. 2).

Hydrologists use the term *recharge* to describe the various processes through which water can enter a groundwater system. The term *discharge* likewise describes the processes through which water leaves a groundwater system. In Harney Basin, the principal groundwater recharge processes are infiltration of precipitation in higher-elevation parts of the basin (*uplands*—for example, Steens Mountain; figs. 1 and 2) and infiltration of surface water in lower-elevation, low-relief parts of the basin (*lowlands*—for example, the area between Burns and Malheur Lake; figs.1 and 2). There is no evidence of any substantial movement of groundwater into Harney Basin from surrounding basins.

Upland groundwater recharge and discharge

Groundwater recharge is largest in Harney Basin uplands—however, the rocks that underlie most upland areas limit groundwater flow. The term *permeability* describes the ability of groundwater to flow through rocks or sediments. Groundwater can more easily flow through high-permeability rocks and sediments than those with low permeability. Most upland rocks have low permeability. Because of this low permeability, groundwater-flow paths in upland areas generally are short and shallow. More than 80 percent of water that recharges the upland groundwater system discharges to nearby streams and springs rather than flowing deep underground (figs. 2 and 3).

A lesser amount of upland groundwater is discharged through direct evapotranspiration (ET) by wetland vegetation. This upland groundwater discharge is crucial to maintaining flow in streams, springs, wetlands, and meadows during the dry summer months. A portion of the groundwater discharged to upland streams eventually flows as surface water to the lowlands where it sustains wetlands (such as the Malheur National Wildlife Refuge), is diverted for irrigation, or seeps into the ground and recharges the lowland groundwater system (fig. 2).

Lowland groundwater recharge and discharge

The lowland groundwater system in Harney Basin is mostly recharged by the infiltration of surface water through lowland stream channels and flooded areas (irrigated and natural) (figs. 2 and 3). Most lowland recharge from surface water occurs during the spring freshet, although seepage in lesser amounts occurs year-round from perennial stream channels and flooded wetlands. Infiltration of surface water provides about two-thirds of the recharge to the lowland groundwater system (fig. 3). Deep groundwater inflow from the uplands provides the other one-third (fig. 3). The amount of precipitation falling in the lowlands is not enough to be an appreciable source of groundwater recharge.

Natural discharge of groundwater in the Harney Basin lowlands occurs primarily through ET by (1) deep-rooted dryland plants such as greasewood and salt grass, (2) wetland vegetation, and (3) springs and seeps (figs. 2 and 3). A substantially smaller amount of groundwater is discharged from the lowlands as groundwater flow to the Malheur River Basin to the east (through Virginia Valley; figs 1–3).

Discharge of groundwater occurs through pumping in upland and lowland parts of Harney Basin. In the uplands, the volume of groundwater removed through pumping (*pumpage*), represents an exceedingly small portion of the total groundwater discharge. In the lowlands, however, pumpage (primarily for irrigated agriculture) is the largest source of groundwater discharge. In the lowlands, pumpage is about 1.2 times greater than natural discharge (fig. 3).

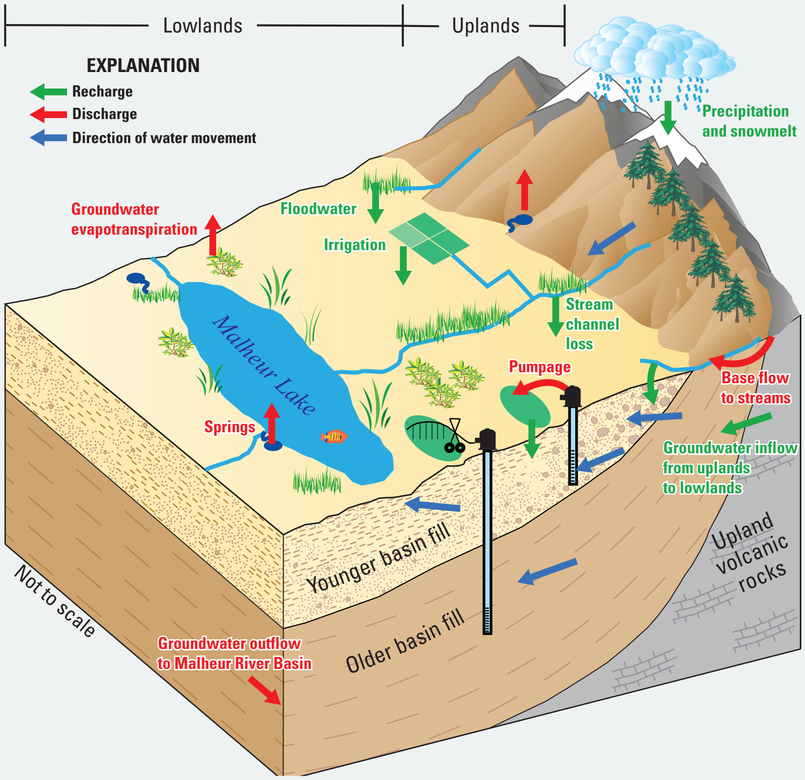
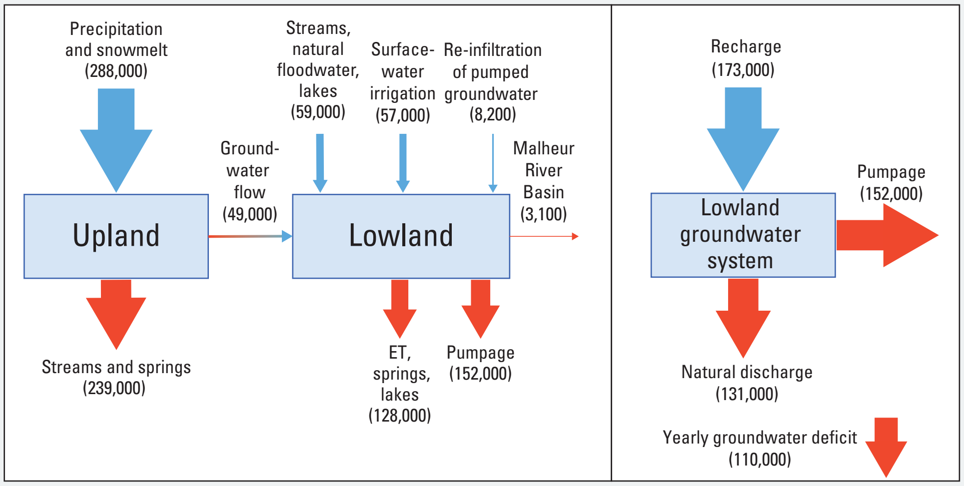


Figure 2. Groundwater recharge and discharge and direction of water movement, Harney Basin, southeastern Oregon. Modified from Garcia and others, 2022.

Groundwater Budget

The water budget of a groundwater system, or *groundwater budget*, provides an accounting of groundwater recharge and discharge. Prior to groundwater development in the Harney Basin, the groundwater budget was in balance, meaning the amount of groundwater discharging to streams, springs, and native vegetation was roughly equal to the amount of water entering the groundwater system through precipitation and surface-water infiltration. When a groundwater system is in balance, water levels in wells generally fluctuate around a long-term average value and fluctuations reflect natural cycles of wetter and drier conditions. The upland groundwater budget is minimally affected by groundwater development and generally represents the budget of the natural system. The lowland groundwater budget for Harney Basin represents a combination of natural conditions and human activity.

Figure 3. Mean annual upland and lowland groundwater budgets, Harney Basin, southeastern Oregon, 1982–2018. Modified from Garcia and others, 2022. [ET, evapotranspiration.]



EXPLANATION

[Width of arrows indicates relative volume]

Recharge, in acre-feet (inflow)

Discharge, in acre-feet (outflow)

Imbalance in the lowland groundwater budget

The Harney Basin groundwater budget in the lowlands is substantially out of balance. Total discharge of groundwater in the lowlands (283,000 acre-feet per year [acre-ft/yr]) exceeds recharge to the lowlands (173,000 acre-ft/yr) by 110,000 acre-ft/yr (fig. 3). The imbalance is largely a result of pumping for irrigated agriculture, which accounts for 95 percent of all groundwater use in Harney Basin. Groundwater pumped for irrigation tripled during 1991–2018, increasing from 51,000 acre-ft/yr to about 150,000 acre-ft/yr (fig. 4). The imbalance in the groundwater budget is why groundwater levels have declined in many areas of the Harney Basin lowlands.

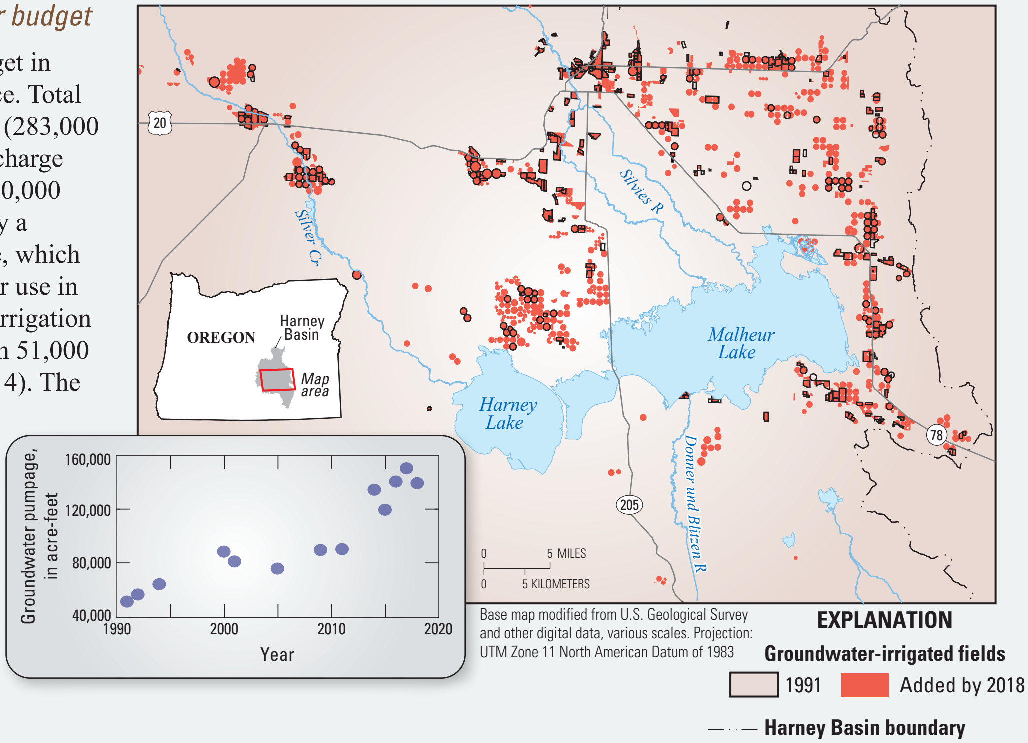


Figure 4. Irrigated fields during 1991 and 2018 and graph of groundwater pumped for irrigation, 1991–2018. Modified from Garcia and others, 2022.

Groundwater-level declines in Harney Basin

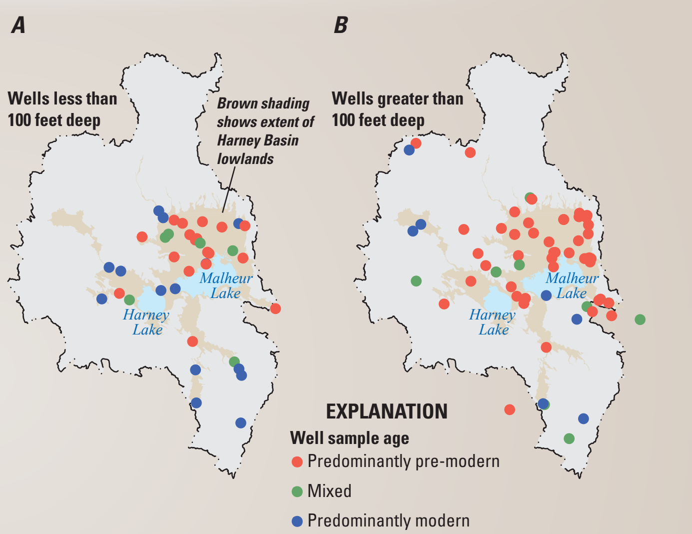
Groundwater levels in the Harney Basin fluctuate seasonally and over multi-year periods. Across the basin, these fluctuations reflect natural variations in groundwater recharge and discharge due to seasonal or multi-year cycles of wetter and drier conditions and warmer and cooler temperatures. In some areas of Harney Basin, particularly in the lowlands, groundwater-level fluctuations are largely the result of groundwater pumping.

Groundwater levels typically reach their highest in the late winter or early spring because of (1) the weight of ponded freshet water on the surface and re-wetting of soils in the lowlands, (2) recharge from winter precipitation and runoff, and (3) recovery from irrigation pumping as groundwater moves in from adjacent areas of the groundwater system. Groundwater levels decline during summer as groundwater is removed from the system through ET and by pumping. When groundwater pumpage consistently exceeds groundwater recharge, year-to-year groundwater-level declines develop as water is removed from storage in the groundwater system.

In the Harney Basin, the nature of groundwater-level declines depends principally on (1) the number of wells and intensity of pumping, (2) the proximity to recharge areas and their respective recharge volumes, and (3) the permeability of the rocks and sediments being pumped and the permeability of the rocks and sediments surrounding the pumped area.

Ancient Groundwater—A Finite Resource

Most of the groundwater beneath the Harney Basin lowlands was recharged thousands of years ago (pre-modern). Analyses of stable isotopes of water, tritium, and carbon-14 in water samples from wells, springs, and streams indicate that most of the lowland groundwater was recharged about 30,000–5,000 years ago. Most lowland groundwater in Harney Basin was recharged when the climate was cooler and wetter than it is today. Groundwater recharged after 1953 (modern) generally is limited to a thin, shallow zone beneath lowland recharge areas (figs. 2 and 3). These recharge areas include stream channels, floodplains, flood-irrigated fields, and flooded wetlands. Little modern recharge circulates through the lowland groundwater system and most lowland wells are extracting ancient, pre-modern water. Lowland areas with the largest groundwater-level declines receive little or no modern recharge, which contributes to the continued growth and extent of their declines.

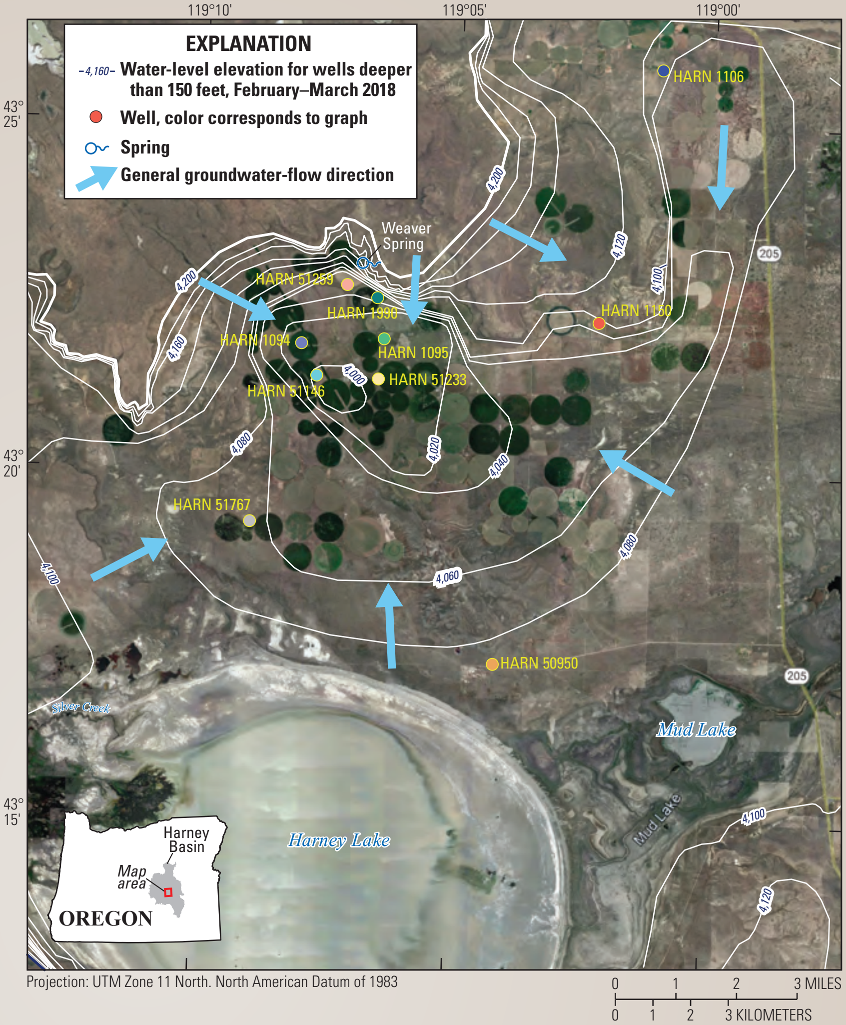


Relative groundwater age in (A) shallow wells (less than 100 feet deep) and (B) deep wells (greater than 100 feet deep) within and adjacent to the Harney Basin, southeastern Oregon. Relative age is based on the analysis of stable isotopes of hydrogen in water and its relation to tritium and carbon-14 age dates. Modified from Gingerich and others, 2022.

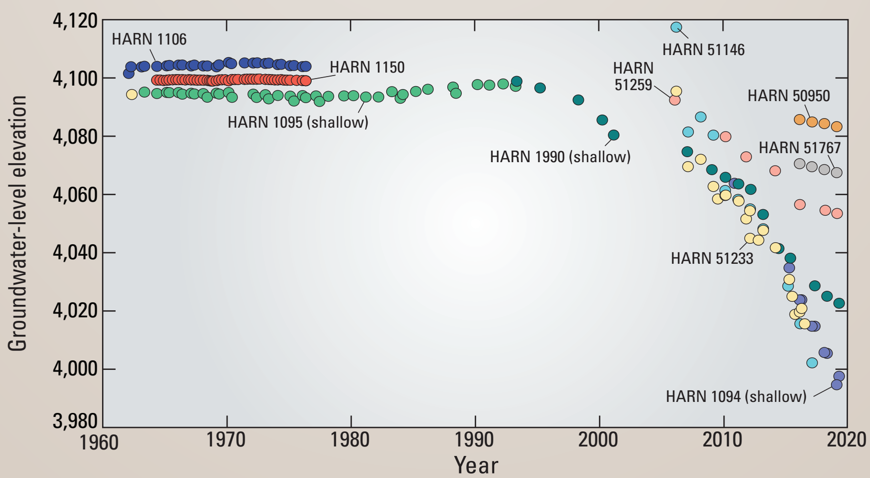
Weaver Spring/Dog Mountain—Focused, Rapid Groundwater-Level Decline

In the Weaver Spring/Dog Mountain area, pumping has lowered the water table more than 140 feet (ft) relative to pre-development levels and groundwater levels have declined as much as 8 feet per year (ft/yr) since 2016. In this area, much of the groundwater pumped for irrigation water is removed from highly permeable volcanic rocks and sediments. The volcanic rocks and sediments in this area are among the most productive in the Harney Basin lowlands. However, minimal recharge from precipitation or surface-water infiltration supplies this area. Furthermore, the highly permeable rocks and sediments being pumped have a limited spatial extent and are surrounded by much less permeable rocks and sediments. These low-permeability units cannot supply groundwater at a rate sufficient to balance the groundwater currently being extracted by irrigation wells tapping the more permeable units. The groundwater being pumped from this area was recharged thousands of years ago and the water removed from storage is only partially replenished by the inflow of equally ancient groundwater from the surrounding low-permeability rocks and sediments; as a result, groundwater levels decline.

Prior to groundwater development in the west-central lowlands, groundwater flowed toward Harney Lake, where groundwater-level elevations were lowest. Groundwater levels in the Weaver Spring/Dog Mountain area are now nearly 90 ft lower than the bed of Harney Lake, which has caused local groundwater-flow paths to shift away from Harney Lake and toward the Weaver Spring/Dog Mountain pumping center.



Locations of selected groundwater-level sites and groundwater-level contours (in feet above North American Vertical Datum of 1988) in the Weaver Spring/Dog Mountain area, Harney Basin, southeastern Oregon. Contours from Gingerich and others, 2021. Background aerial image source: GoogleEarth™ 2019.

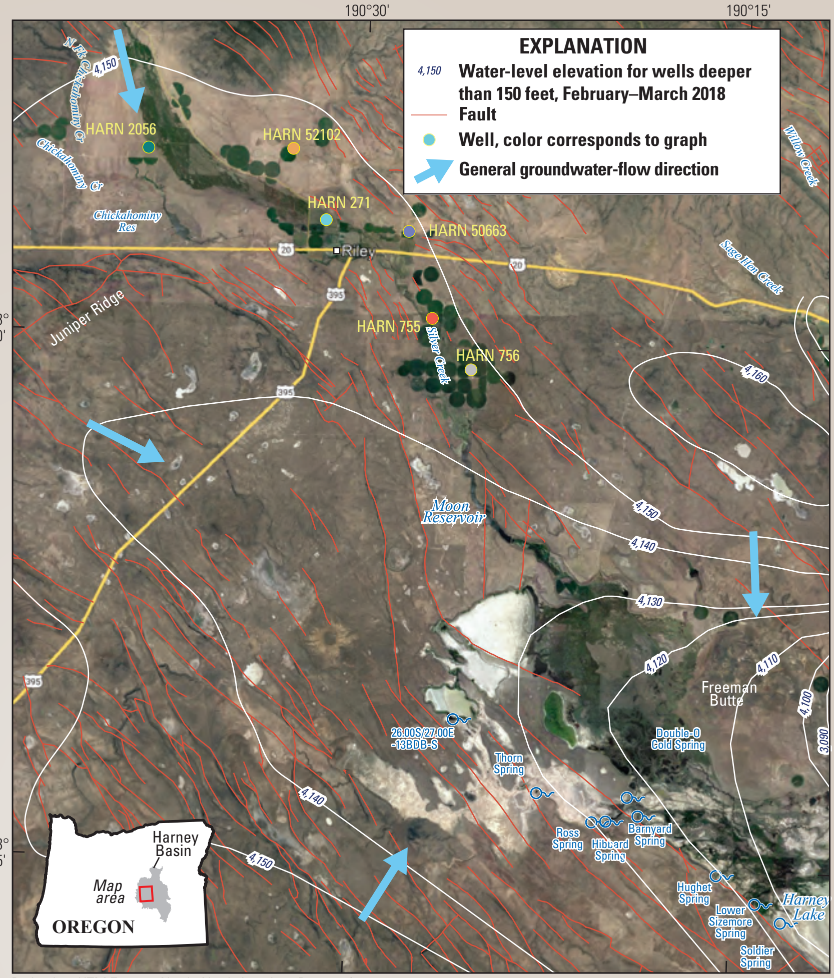


Groundwater levels (in feet above North American Vertical Datum of 1988) during 1960–2020. From Gingerich and others, 2022.

Silver Creek Upper Floodplain—Broad, Slow Groundwater-Level Decline

In the upper floodplain of Silver Creek, groundwater pumping has lowered the water table about 10 ft across a broad area since 1980. Groundwater-level declines in wells 200–400 ft deep averaged about 0.5 ft/yr during 2015–19. In this area, groundwater is pumped from a widespread area of highly permeable rocks overlain by less-permeable sediments. Groundwater recharge in this area occurs through infiltration of surface water beneath stream channels and from seasonal flooding, groundwater inflow from the uplands, and infiltration of irrigation water. Infiltration of Silver Creek water is substantial and mostly occurs upstream from U.S. Route 20. Water chemistry data including tritium and stable isotopes of water indicate that some of the irrigation water recharging groundwater in the area was previously stored in Chickahominy Reservoir.

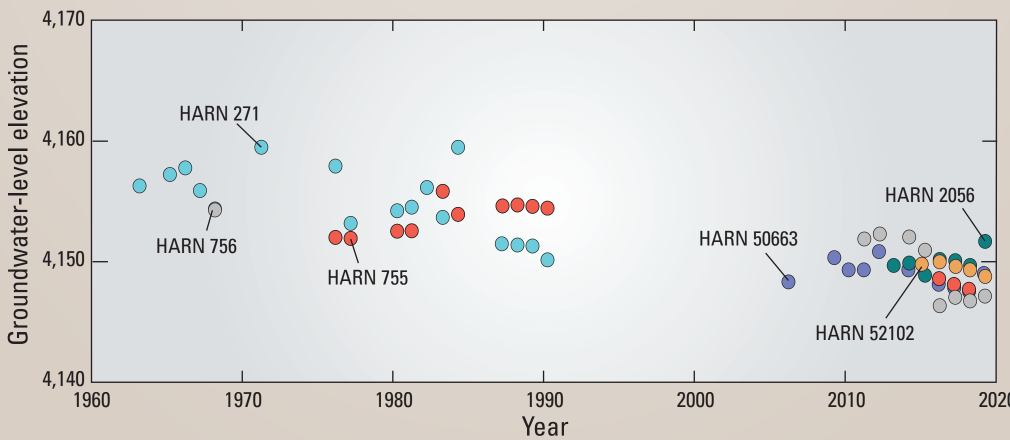
Although this area receives recharge, groundwater levels are declining because pumping and natural discharge rates exceed average annual recharge rates. Compared to the Weaver Spring/Dog Mountain area, rates of decline are minimized by the widespread area of permeable rocks underlying pumping centers, which supplies more groundwater to balance pumping rates than the low-permeability rocks and sediments surrounding the Weaver Springs/Dog Mountain pumping area. More groundwater inflow from surrounding areas, in turn, creates a broader, shallower area of decline than is present at the Weaver Spring/Dog Mountain area. The loss of groundwater from storage in the upper floodplain of Silver Creek also is substantial but is distributed over a much larger area than that of Weaver Spring/Dog Mountain. Continued groundwater pumping in the upper and lower floodplains of Silver Creek will ultimately reduce groundwater discharge in the downgradient areas, including the Warm Springs Valley, which constitutes part of the Malheur National Wildlife Refuge.



Projection: UTM Zone 11 North. North American Datum of 1983

0 2 4 6 MILES
0 2 4 6 KILOMETERS

Locations of selected groundwater-level sites and groundwater-level contours (in feet above North American Vertical Datum of 1988) in the Silver Creek floodplain area, Harney Basin, southeastern Oregon. Contours from Gingerich and others, 2021. Background aerial image source: GoogleEarth™ 2019.



Groundwater levels (in feet above North American Vertical Datum of 1988) during 1960–2020. From Gingerich and others, 2022.

The most substantial groundwater-level declines in the Harney Basin lowlands are occurring in areas with intensive groundwater pumping, with minimal recharge, and surrounded by low-permeability rocks and sediments that limit replenishment of water removed from storage in the groundwater system. However, smaller areas of groundwater-level decline are found across the lowlands. Areas of notable groundwater-level declines include the Weaver Spring/Dog Mountain area, the Crane area east of Malheur Lake, the U.S. Route 20 corridor between Harney and Buchanan, the Silvies River/Poison Creek floodplains, Virginia Valley, and the upper Silver Creek floodplain.

Declines can manifest as small year-over-year changes over large areas akin to the draining of a bathtub, or as large year-over-year changes that create cone-shaped depressions (drawdown cones) in the water table or reduce the water levels in deeper parts of the groundwater system. The Weaver Spring/Dog Mountain area, the Crane area east of Malheur Lake, and the U.S. Route 20 corridor between the unincorporated communities of Harney and Buchanan are areas that have such depressions. The drawdown in these three areas is deeper but less widespread than in other pumping centers in the lowlands. In these areas, groundwater levels within drawdown cones are declining at rates of as much as 8 feet ft/yr and some cones extend more than 140 ft deep. In contrast, groundwater-level declines around Virginia Valley and beneath the Silver Creek floodplain are occurring over substantially larger areas, but with considerably smaller rates of decline—averaging about 0.5–1 ft/yr during 2010–18.

Related Reports and Data Releases

Beamer, J.P., and Hoskinson, M.D., 2021, Historical irrigation water use and groundwater pumpage estimates in the Harney Basin, Oregon, 1991–2018: Oregon Water Resources Department Open File Report 2021–02, 53 p. [Also available at https://www.oregon.gov/owrd/wrdreports/OWRD_OFR_2021-02_Harney_Basin_METRIC_Irrigation_Use_Report.pdf.]

Boschmann, D.E., 2021, Generalized geologic compilation map of the Harney Basin: Oregon Water Resources Department Open File Report 2021–01, 57 p. [Also available at https://www.oregon.gov/owrd/wrdreports/OFR_2021-01_report.pdf.]

Corson-Dosch, N.T., and Garcia, C.G., 2022, Soil-water-balance (SWB) model archive used to simulate mean annual upland recharge from infiltration of precipitation and snowmelt in Harney Basin, Oregon, 1982–2016: U.S. Geological Survey data release. [Also available at https://doi.org/10.5066/P94NH4D8.]

Garcia, C.A., Corson-Dosch, N.T., Beamer, J.P., Gingerich, S.B., Grondin, G.H., Overstreet, B.T., Haynes, J.V., and Hoskinson, M.D., 2022, Hydrologic budget of the Harney Basin groundwater system, Oregon: U.S. Geological Survey Scientific Investigations Report 2021–5128, 140 p. [Also available at https://doi.org/10.3133/sir20215128.]

Garcia, C.A., Haynes, J.V., Overstreet, B., and Corson-Dosch, N., 2021, Supplemental data—Hydrologic budget of the Harney Basin groundwater system, Oregon: U.S. Geological Survey data release. [Also available at https://doi.org/10.5066/P9QABFML.]

Gingerich, S.B., Johnson, H.M., Boschmann, D.E., Grondin, G.H., and Garcia, C.A., 2021, Contour data-set of the potentiometric surfaces of shallow and deep groundwater-level altitudes in Harney Basin, Oregon, February–March 2018: U.S. Geological Survey data release. [Also available at https://doi.org/10.5066/P9ZJTZUV.]

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Gingerich, S.B., Johnson, H.M., Boschmann, D.E., Grondin, G.H., Garcia, C.A., and Schibel, H.J., 2022b, Location information, discharge, and water-quality data for selected wells, springs, and streams in the Harney Basin, Oregon: U.S. Geological Survey data release. [Also available at https://doi.org/10.5066/P9J0FE5M.]

Grondin, G.H., 2021, Methods and results for estimating groundwater pumped, returned, and consumed for non-irrigation uses in the Harney Basin, Oregon: Oregon Water Resources Department Open File Report 2021–03, 28 p. [Also available at https://www.oregon.gov/owrd/wrdreports/OWRD_OFR_2021-003_Harney_Basin_non_irrigation_GW_use_report_stamped.pdf.]

Grondin, G.H., Boschmann, D.E., Barnett, H.J., and Scandella, B.P., 2021, Methods and results for estimating the hydraulic characteristics of the subsurface materials in the Harney Basin, Oregon: Oregon Water Resources Department Open File Report 2021–04, 63 p. [Also available at https://www.oregon.gov/owrd/wrdreports/OFR_2021-04_Harney_Basin_subsurface_hydraulic_properties.pdf.]

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Background photograph: View looking north toward Sodhouse Spring and the lowlands surrounding Malheur Lake, Harney Basin, southeastern Oregon. Sodhouse Spring discharges modern groundwater from highly permeable volcanic rocks likely recharged farther to the south from the Donner und Blitzen River. Photograph by Henry M. Johnson, U.S. Geological Survey, July 19, 2018.

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