2.3.1 **Quantity**

Groundwater in the Upper Deschutes Basin is a unique regional aquifer system that transitions from high elevation precipitation in the Cascade Mountains in the west and Newberry Volcano in the south, to the flat, arid center of the basin. Recharge to the groundwater system primarily occurs in the uplands where heavy winter rain and snow from the Cascades infiltrate into the permeable volcanic soils and bedrock. This elevation and recharge gradient drives large groundwater flux towards the basin center (K. E. Lite and Gannett 2002). A considerable amount of that groundwater discharges to the surface at the edges of the Cascades at large volume spring vents to feed prominent perennial streams like the Fall, Deschutes, and Metolius Rivers. As these streams transition into the central basin and major population centers, the groundwater system drops to several hundred feet below land surface as it flows through the volcanic and alluvial deposits of the Deschutes Formation. Groundwater levels become coincident with surface level elevations near the confluence of the Crooked and Deschutes rivers, where large amounts of groundwater discharge back to the surface, either as springs or direct discharge to the riverbed. The groundwater that was recharged in the Cascades flows through the aquifer for dozens of miles until it discharges back to the surface at large spring complexes at the confluence of the Crooked and Deschutes rivers at Lake Billy Chinook.

Gannett et al. (2017) estimated average recharge rate of 4,436 cfs for the Upper Deschutes Basin based on data from 1980 through 2013 (M.W. Gannett et al. 2017). However, a 2013 study also found that there was a high interannual variability of recharge and a declining trend of decadal average recharge from 1980 to 2008 (Marshall W Gannett and Lite 2013). Of the 4,436 cfs average recharge rate, 3,031 cfs is estimated to come from direct in-basin precipitation, 994 cfs from precipitation via interbasin flow (mostly into the Metolius subbasin), and 411 cfs from canal leakage (M.W. Gannett et al. 2017). However, rates of recharge and discharge vary spatially throughout the basin. Up to approximately 1,500 cfs of total recharge is discharged back to surface water above Bend. Over 1,000 cfs is typically diverted into irrigation conveyance systems – 350 to 500 cfs of which then leaks back into groundwater from unlined canals. At the bottom of the basin, nearly 2,000 cfs of groundwater discharges to the Deschutes, Crooked, and Whychus near Lake Billy Chinook.

Since 1995, about 382 cfs of groundwater use has been permitted to water right holders for municipal and agricultural use in the Deschutes Basin. This includes about 190 cfs of 7j permits issued following the establishment of State Scenic Waterways flows in 1995 and about 192 cfs (155 cfs permitted and 37 cfs pending) of permits issued since the start of the Groundwater Mitigation Program in 2021. There are other groundwater rights which were issued prior to 1995. However, for all irrigation permits and many municipal permits, there are seasonal limitations and volume limitations such that the full permitted rate cannot be pumped continuously over the whole year. This means that the amount of permitted groundwater use cannot be used as an indication of annual pumping rates. In 2024, OWRD updated its estimates of annual groundwater pumping in the Upper Deschutes Basin. It was found that average annual groundwater pumping from [year] to [year] was [XXX cfs (YYY acre-feet per year)]. Of this total, [AAA cfs (BBB AF/yr)] of pumping is attributed to public water systems, [CCC cfs (DDD AF/yr)] is for irrigation use, and [EEE cfs (FFF AF/yr)] comes from private domestic (exempt) wells in unincorporated communities of the basin (information from OWRD forthcoming).

Commented [AE1]: Does OWRD have these numbers?

Commented [AE2]: Include a couple of sentences here from Gannett (2017) and Gannet (2001) only if private domestic wells are not included in OWRD's numbers

Pumping and total recharge can vary spatially and temporally based on how groundwater flows through the overall system. The local impact of pumping and/or reductions in recharge from canal piping in a certain area may have a greater impact on the resource relative to other parts of the basin. For example, in the center of the basin, groundwater levels have shown persistent, year-on-year declines since the mid-1990s despite the wetter-than-normal periods of the late 1990s and early 2010s. Long-term groundwater level records have shown that some areas, particularly the area extending from the vicinity of Bend, north toward Lake Billy Chinook, and northeast toward Redmond and Powell Butte, are experiencing persistent groundwater level declines (Figure 7) (Thoma et al. 2021). Analysis by OWRD in Thoma et al. (2021) normalized long-term groundwater records to spring 1995 levels to show the spatial variability of trends in water level changes since spring 1995. Wells east of the Sisters Fault Zone (SFZ) have observed long-term trends of groundwater level decline relative to other wells in other sub-areas (within SFZ and west of SFZ) (Figure 8) (Thoma et al. 2021). The wells which have experienced persistent groundwater level declines are those located within the Upper Deschutes Phase I Planning Area. This indicates that there is an imbalance between the recharge and discharge of the water budget at a more local scale (OWRD, personal communication 2023).

Figure 7. Map showing select wells with long-term groundwater level records, color-coded by the observed rate of decline; inset map shows Deschutes Groundwater Study Area boundary and extent of larger map (Thoma et al. 2021),

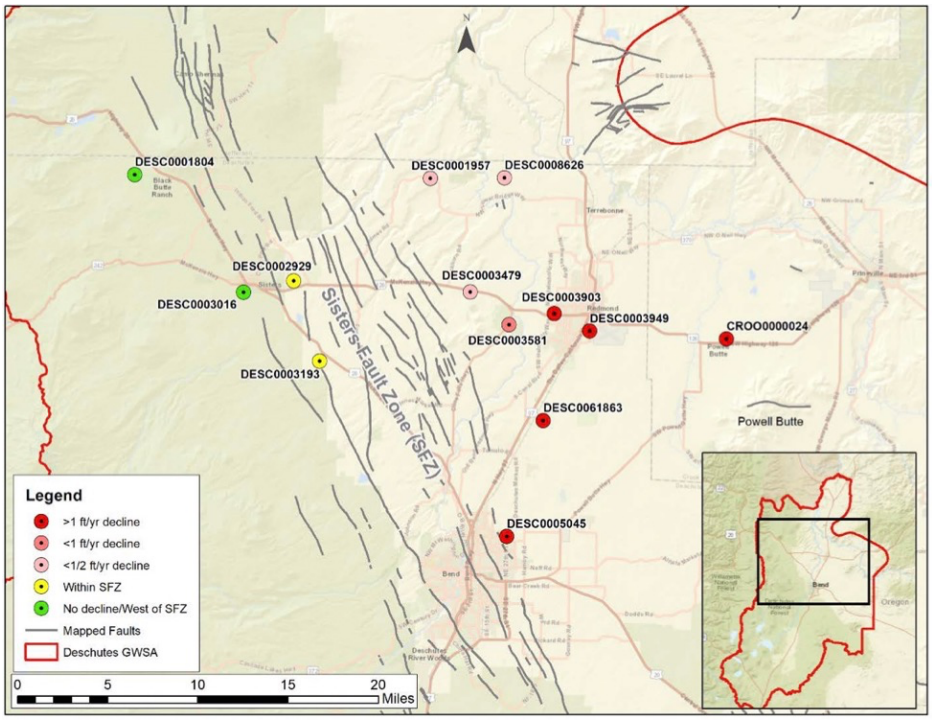
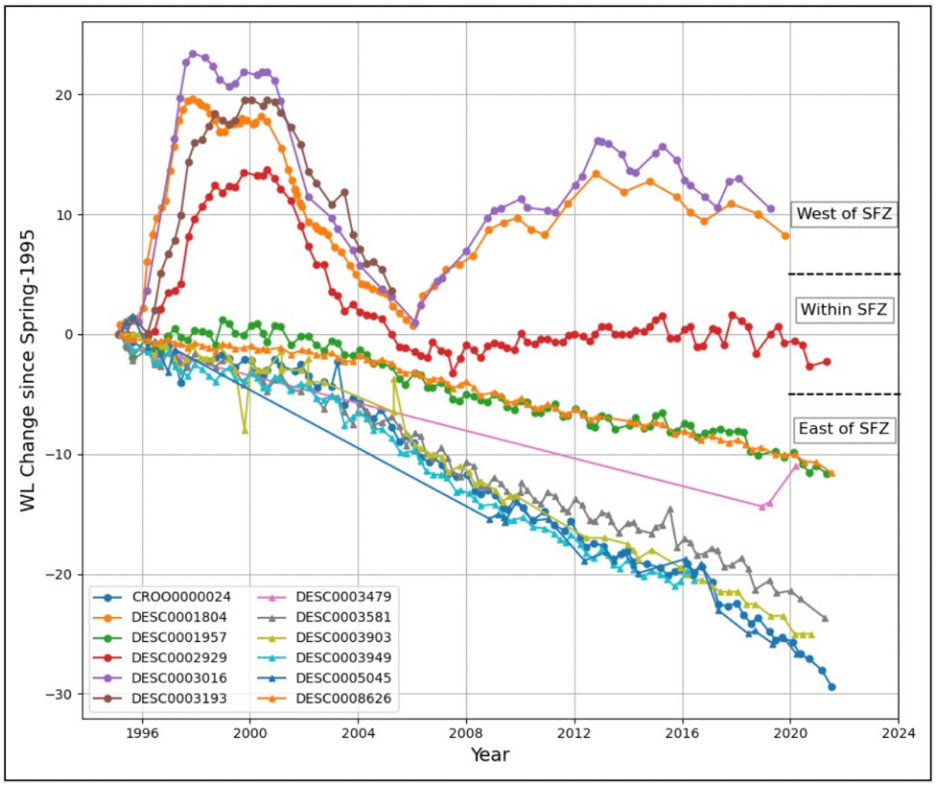


Figure 8. Groundwater level changes since Spring 1995 for wells shown in Figure 5 (excludes DESC0061863 which has an intermittent period of record) (Thoma et al. 2021).



Hydrologic trends show a shift towards drier conditions since the later 1990s that has accompanied a warming trend in the basin (Frankson et al, 2017; Mote et al, 2018). Those decadal scale changes to precipitation have been shown to impact groundwater levels in the region (Gannett and Lite 2013). Projections of climate models on precipitation in the Oregon cascades varies, but models generally coalesce around a slight increase in precipitation (Rogers and Mauger 2021; Mass et al. 2022). Waibel et al. (2013) found that changes in the precipitation regime would not cause a significant impact to major groundwater discharge areas at the terminal end of the groundwater flow system (Waibel et al. 2013). However, uncertainty about future climate regimes and their effect on the hydrologic cycle have the potential to exacerbate existing groundwater level declines. Further groundwater development will contribute to groundwater level declines (and any new permits issued will have mitigation requirements which offset potential impacts to surface water flows in the Middle Deschutes). Finally, irrigation canals have been a significant source of artificial groundwater recharge to this region for several decades,

and continued lining and piping of canals (which helps to conserve surface water) will also contribute to groundwater level declines (Thoma et al. 2021).

Gannett and Lite (2013) identified the location and extent of groundwater declines from 1997-2008 and then estimated the relative influence of those declines between climate-driven reduction in recharge, groundwater pumping, and reduced leakage from canal lining. Using the calibrated basin-scale MODFLOW model, the authors systematically changed those three variables in several locations across the basin to observe the resulting change in groundwater levels the model predicted. The results showed some spatial variability, but showed that declines in the center of the basin were 60-70 percent due to climate, 20-25 percent due to pumping, and 5-10 percent due to decreases in canal leakage from lining/piping projects (Table 12) (Gannett and Lite 2013). It should be noted that the relative impacts of the pumping and piping stressors may have changed since time period of this study. Since 2008, groundwater pumping has increased by XX percent (pending number from OWRD), and a number of canal piping projects have been completed which have reduced recharge from canal leakage.

Table 12. Summary of Observed Groundwater Level Declines by Sub-Area (Thoma et al. 2021).

Sub-Area as Described in USGS Report[2]	Observed Water Level Change (this memo)		Simulated Decline and Drivers from USGS Report[2] for period of record 1997-2008			
	Avg. Decline Since 1995 (feet)	Decline Rate* 2006 - 2020 (ft/yr)	Decline (feet)	Climate Influences (%)	Pumping (%)	Canal Lining (%)
Redmond to Powell Butte: CROO0000024 DESC0003903 DESC0003949 DESC0005045	25.1	1.04	13-14	60-65	25-30	10
Cline Buttes to Redmond: DESC0003581	23.7	0.83	12-14	60-70	20-25	5-10
Lower Bridge: DESC0001957 DESC0003479 DESC0008626	11.1	0.45	5-6	60-70	20-30	10
Sisters: DESC0001804 DESC0002929 DESC0003016 DESC0003193	-	-	22	80	13	7
* Decline rate is the average of the decline rate for all wells in a sub-area						