Memorandum

To: OWRD Groundwater Allocation Rulemaking Team

From: Ben Scandella, Groundwater Data Chief

Date: February 22, 2024

Regarding: Susceptibility of Oregon wells to being dried by water level declines

Summary

The Department is in the process of updating its rules for issuing new groundwater permits, and the proposed new rules include a new definition for Reasonably Stable Groundwater Levels. This proposed definition attempts to balance multiple policy objectives, including limiting the impacts of water level declines. One such impact is causing wells to go dry by lowering the water level below the bottom of the well. This memo evaluates the susceptibility of wells statewide to cumulative water level declines from a reference level.

Results show that the number of wells susceptible to being dried by additional declines increases linearly between total declines of 5 to 100 feet, with a rate of approximately 1,600 additional wells dried statewide with each additional foot of decline. If 25 feet of decline occurred statewide, approximately 6% of wells (15,000 wells, including 12,000 domestic wells) would be susceptible to going dry. With 50 feet of decline, the impacts increase to 21% and 55,000 wells (including 47,000 domestic wells). Distributions of susceptibility to declines varied significantly between counties. These estimates should be considered reconnaissance-level estimates rather than firm predictions due to the assumptions used in the analysis. However, the order of magnitude, combined with the tens to hundreds of thousands of dollars required to deepen or replace wells, suggest a considerable cost associated with increasing the allowable total decline in the proposed definition of Reasonably Stable Groundwater Levels.

Contents

Introduction

During the 2023 update to administrative rules for allocation of new groundwater rights, the Department has proposed a definition for the term Reasonably Stable Groundwater Levels. The department is charged in statute with determining and maintaining these levels (ORS 537.525 (7)), and the proposed rule update requires the Department to find that groundwater levels are Reasonably Stable for water to be available for further allocation. A significant focus of the groundwater allocation update process is to sustainably manage the GW reservoirs and to protect existing water right holders. At the same time, the proposed definition of Reasonably Stable was developed to balance several policy objectives and follow a variety of analyses of available data. For example, there is tension between the objective to limit harm from declining water levels and the objective to maintain consistency of findings of reasonably stable in wells whose fluctuations are consistent with behavior exhibited in wells that are stable over the long run. Impacts may be limited by reducing the limit on total declines in Reasonably Stable, while maintaining consistency motivates increasing the limit. This memo informs part of that tension by estimating the susceptibility of wells to going dry in response to water-level declines of various magnitudes. In addition to drying wells, significant cumulative groundwater level declines dry springs, reduce the capacity of aquifers to store and transmit water, drive subsidence, require more energy to pump, expose poor-quality groundwater, and impact surface water quality and quantity.

The methods presented in this memo are described in detail below and summarized here. A well is considered to go dry following a given magnitude of decline if the annual high water level would drop below the bottom of the well. That is, this analysis neglects wells that become dry due only to pumping within a season. Declines are imposed from the highest known water level in order to align these estimates with the definition of Reasonably Stable Groundwater Levels. The reference level may be different from the water level when a well was drilled. Pre-drilled water level changes are removed from the amount of additional decline imposed on the well when assessing whether it would go dry following a given amount of total decline from the reference level. In areas where water levels have declined from pre-development levels, considering these pre-drilled declines reduces the estimated number of wells that would be dried by a given amount of decline. This analysis also accounts for well deepenings and abandonments to the extent that they can be considered with available data.

The analysis presented above should not be interpreted as a direct estimate of the number of wells expected to go dry by a particular maximum allowable total decline in the proposed definition of Reasonably Stable Groundwater Levels. The total decline evaluated may be significantly greater than the limit on total declines in the definition of Reasonably Stable Water Levels, because declines will typically continue for years after the cessation of issuance of new groundwater permits. Such declines persist because the time to full capture of hydraulically connected surface water, or the time to establish a new equilibrium water level, is typically years to decades for wells in Oregon (Conlon *et al.*, 2005; Gannett *et al.*, 2007, 2012; Gannett and Lite Jr., 2004; Herrera *et al.*, 2014). This effect means that the number of wells dried by a given limit on total declines (which would trigger a stop to issuance of new groundwater permits) may be *more* than the number estimated based on a decline evaluated in this analysis. On the other hand, the number of wells allowed to go dry by a given limit on total declines in some areas will be *fewer* than the number indicated by this analysis because this analysis assumes a total water-level declines occur uniformly over all wells, while in practice other constraints on groundwater pumping will limit groundwater level declines before the maximum allowable decline is reached. Those constraints may include land use restrictions, suitable topography or climate for agriculture, and the rate test also included in the proposed definition of Reasonably Stable Groundwater Levels. These considerations, as well as numerous sources of potential bias discussed below, make the reconnaissance-level estimates presented below appropriate for understanding the approximate magnitude of impacts of groundwater level declines.

Methods

Counting Well Logs

A well's vulnerability to drying due to a given long-term decline may be estimated by comparing its total depth against the water level measured after drilling. If the well's depth below water is less than the magnitude of water level decline being evaluated, then the well would go dry following such a decline. This evaluation can be performed over all well logs to count those that were likely too shallow compared with the water level to endure a given amount of decline. Not all well logs have sufficient and reliable information in the Department's Well Log Information System; the following analysis excludes well logs without a total depth or post-drilling static water level measurement, or where the post-drilling static water level measurement is less than 10 feet above the bottom of the well (which was taken as an indication that the water level had not yet recovered after drawdown associated with drilling). The total number of wells that would go dry following a given amount of decline was estimated by multiplying the total number of new well logs by the percent of wells deep enough among wells with sufficient data.

The analysis presented in this memo offers some improvements over the basic counting exercise described above, to consider both well deepenings and declines that occurred before a well was drilled.

Estimating Pre-Drilled Declines from Highest Known

The proposed definition of Reasonably Stable Groundwater Levels includes a test of long-term, cumulative decline from a reference level in an aquifer (which will be referred to simply as the "reference level" hereafter). In order to best inform the Department's proposal for a maximum allowed total decline consistent with Reasonably Stable, this memo also considers the impact of declines from that reference level, rather than from the level measured when each well was drilled. Within an aquifer, water levels may decline over the period of years to decades, and many wells may have been drilled after significant water level declines have already occurred. Therefore, in order to estimate the percent and number of wells that would go dry following a given amount of decline from the reference level, this analysis estimates the amount of additional decline that a particular well would experience associated with a given amount of total decline from the reference level in the aquifer. The amount of additional decline ($y_{additional}$) that a well would experience having been drilled at time *t* is the decline from the reference level (y_{total}) minus the amount of decline that occurred before the well was drilled ($y_{pre\text{-}drilled}$):

$$y_{additional} = y_{total} - y_{pre-drilled} \tag{1}$$

A well is expected to go dry following total decline y_{total} from the reference level if the additional decline after drilling $y_{additional}$ is greater than the tolerable decline in the well, $y_{tolerable}$, which is the difference between a well's total depth and its water level when drilled (Figure 1).

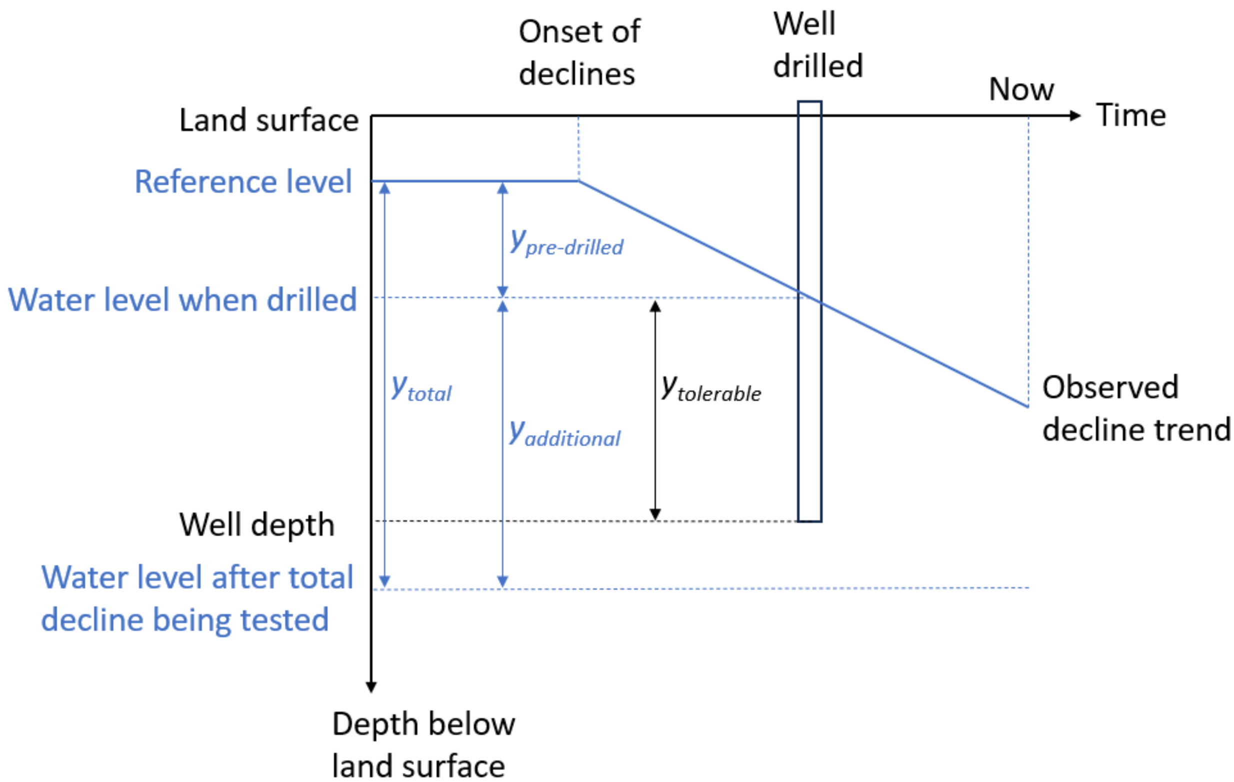

Figure 1: Conceptual model for evaluating a well's susceptibility to going dry in response to long-term water level declines in an aquifer. A well is expected to go dry following total decline y_{total} from the reference level if the additional decline after drilling $y_{additional}$ is greater than the tolerable decline in the well, $y_{tolerable}$, which is the difference between a well's total depth and its water level when drilled.

For the purposes of this analysis, water level changes before drilling are only considered if they are declines. If water levels rose in an aquifer before drilling, then the pre-drilled decline is defined to be zero. Such a well could, in fact, experience additional decline larger than y_{total} from the reference level; those cases are expected to be rare in Oregon and are neglected in this analysis. Thus, the additional decline a well is subject to is always less than the total decline from the reference level. Because of this, the consideration of pre-drilled declines can only reduce the number of wells found to be vulnerable to a given total decline, compared with neglecting pre-drilled declines. In other words, this component of the analysis makes the overall estimates conservative in the sense of reducing the expected impact of groundwater level declines.

For the purposes of this reconnaissance-level analysis, the history of long-term declines is estimated for each Public Land Survey System township, which are squares 6 miles on a side. Townships are large enough that, in Oregon, they typically contain multiple wells such that long-term decline trends may be estimated with some robustness. This approximation neglects spatial variability in decline trends within a township, including due to stacked aquifer systems. While pre-drilled decline is specific to an aquifer, the vast majority of well logs in Oregon have not been analyzed to associate with an aquifer, so performing such aquifer-specific analyses would not be useful for this analysis of well logs. Other researchers have addressed this issue by restricting their analysis to alluvial aquifers by considering only wells with total depth limited to 100 meters (Perrone and Jasechko, 2017). That research effort interpolated water levels in order to determine which alluvial wells were likely dry across the Western United States in a particular period (2013 to 2015), but that approach would not enable estimating the impact of total declines from reference levels that vary across the state. That analysis also neglects wells accessing confined aquifers and in steeper terrain, which constitute a substantial portion of wells in Oregon.

Using the Groundwater Information System

The most reliable source for evaluating long-term trends in groundwater levels in Oregon is the Department's Groundwater Information System (GWIS). This database focuses on permitted wells but also includes exempt wells included in scientific studies or evaluated for impacts of additional proposed pumping. It is also regularly synchronized with the U.S. Geological Survey's National Water Information System (NWIS). For this analysis, the water level trend was modeled as a piecewise linear function as shown in Figure 1, including a pre-development constant level and a linear rate of change from pre-development levels. The magnitude of total decline in each well was estimated using the difference between the most recent and highest annual high water level among wells with records spanning at least 20 years. The representative decline in each Public Land Survey System township was the median among all wells with sufficient data to be evaluated in that township. Other forms of the characteristic decline were considered, including the 75th and 90th percentiles, but the median was considered appropriate because irrigation wells are over-represented in GWIS, and these irrigation wells tend to experience larger-magnitude declines than typical wells due to the localized influence of pumping on groundwater levels. The onset time for declines was taken as the 90th percentile years with the highest water level measured, which was expected to be less influenced by the overrepresentation of permitted wells. The decline was assumed to occur linearly between the onset time and the present. Using this approach, 400 (18% of 2221) townships had water level trends estimated from GWIS.

Using the Well Log Information System

For townships without any wells in GWIS with sufficient data to establish a long-term water-level trend, the trend was estimated instead using the Department's Well Log Information System (WLIS). The pre-development water level was taken as the median depth to water on the first 20 well logs drilled in the township, or as many well logs as had been drilled by 1950 if 20 had been drilled before that time. The onset time for declines was the median year among that same group of well logs. The present water level was estimated as the median water level among the most recently-drilled 20 well logs, or all the well logs drilled within the past 5 years if they were more than 20. Similar to Perrone and Jasechko (2017), well logs included in this analysis were restricted to those drilled shallower than 300 feet, in order to limit the conflation of water levels measured in separate, stacked aquifers. In some parts of the state that rely on deeper groundwater, this restriction may have artificially reduced the inferred pre-drilled declines. The long-term decline was assumed to occur linearly between the onset time and the present. Using this approach, 538 (24% of 2221) townships had water level trends estimated from WLIS.

Using data from both GWIS and WLIS, water level trends were estimated in 938 (42% of 2221) townships. In the other 58% of townships, insufficient data were available to estimate water level trends using either source, so the rate of long-term decline before drilling was assumed to be zero. However, townships with insufficient data typically had few wells, such that pre-drilled declines were unable to be estimated in only 7% of the wells analyzed. The distribution of total declines per township is shown in the left side of Figure 2. These decline trends were then applied to individual wells in order to estimate the amount of water level decline or rise that occurred before their date of completion (right side of Figure 2).

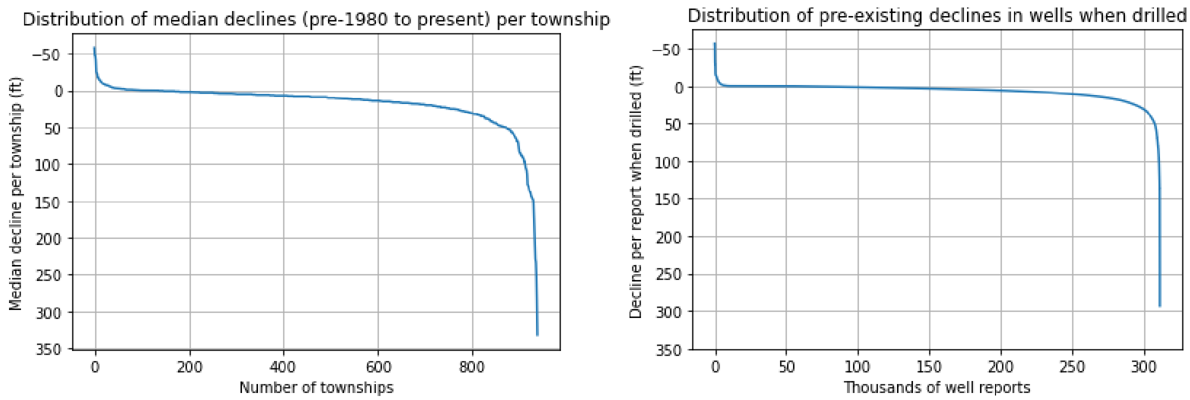

Figure 2: Distributions of water level declines per township (left) and per well log (report) before drilling (right). Positive values indicate declines, and negative values indicate water level increases.

Effects of Deepenings and Abandonments

Subject to the assumptions and limitations, the number of wells dried by a given water level decline (*y*) of a given magnitude can be estimated as N_{dry} from counts of well reports ("well logs") using the following equation:

$$N_{dry}(y) = N_{new\ and\ too\ shallow}(y) - N_{deepened\ from\ too\ shallow}(y) - N_{abandoned\ from\ too\ shallow}(y) \tag{2}$$

Where N refers to a number of wells with the appropriate subscript. $N_{new\ and\ too\ shallow}(y)$ is the number of new well logs that were originally drilled with a total depth less than y feet below the water level measured after drilling. Wells with fewer than 10 feet reported depth below water were omitted from the analysis, assuming that the water level was measured before fully recovering after drilling (which typically lowers the water level in the well). The other terms remove wells that were deepened or abandoned after having originally been drilled too shallow. These deepenings or abandonments may have been triggered by precisely the declines of interest here, but this work attempts to estimate the number of additional wells that would go dry, not just those that could have gone dry due to declining water levels. Ideally, these wells would be excluded from $N_{new\ and\ too\ shallow}$ in the first place, but the relationship between original, deepening, and abandonment well logs is only available for 15% of deepening logs and 1% of abandonment logs in the Department's Well Log Information System (WLIS).

Instead, one can estimate the number of deepenings and abandonments that began too shallow for a given amount of decline *y* by defining the fraction of well logs that began too shallow for that amount of decline, $f_{started\ too\ shallow}(y)$, and the total counts of abandonments and deepenings that were drilled deep enough for y, all of which can be evaluated without tracking relationships between original and deepening logs.

$$N_{deepened\ from\ too\ shallow}(y) = f_{started\ too\ shallow}(y) * N_{deepened\ enough}(y)$$

(3)

$$N_{abandoned\ from\ too\ shallow}(y) = f_{started\ too\ shallow}(y) * N_{abandoned}$$

(4)

This analysis assumed that this fraction is the same for deepenings or abandonments and that it is approximately equal to the fraction of new wells drilled too shallow:

$$f_{started\ too\ shallow}(y) = \frac{N_{new\ and\ too\ shallow}(y)}{N_{new}}$$

(5)

This is likely an underestimate in most cases, because deepenings and abandonments are likely to be caused by wells being originally drilled too shallow. On the other hand, multiple deepenings of the same well may cause it to overestimate the number deepened or abandoned from a too-shallow original log. This approximation is useful, because it enforces that the number of wells deepened or abandoned from being originally too shallow is reduced to zero as *y* is reduced to zero; any model without this feature causes the estimates of dry wells to become negative (Equation (2).

An important feature of Equation (3 is that it accounts for declines that may have occurred between the original drilling and deepening of a well. While deepening logs are not explicitly linked to their original logs in this analysis, the estimation of long-term decline trends allows rough accounting for pre-drilled declines in both new and deepening logs. Deepening logs are considered to have been deepened enough if their tolerable decline (total depth minus water level depth) is larger than the additional decline expected beyond the year of the deepening, not larger than the total decline from the reference level.

Using this approach, the impact accounting for deepenings and abandonments is small, as seen in Figure 3 below. Well logs were only included in the analysis if they have sufficient and plausible data. Those logs are either abandonment logs or new or deepening logs where the reported depth drilled (or completed, if drilled is not reported) is deeper than the post-static water level.

Seasonal Variability

In Oregon, groundwater levels typically fall during summer and autumn due to groundwater pumping and rise again during winter and early spring due to increased precipitation. The magnitude of the seasonal drawdown may vary widely depending on the hydrogeologic setting and intensity of pumping. Groundwater levels measured in the early months of a calendar year tend to be less influenced by seasonal swings and are a more robust indicator of interannual changes in storage in an aquifer. It is for this reason that the proposed definition of Reasonably Stable Groundwater Levels focuses on Annual High Water Levels, which are typically measured in January through April. This analysis seeks to identify wells that would be dried by long-term declines rather than seasonal drawdown. For wells drilled during a time of year such that the water level reported on the log is roughly equal to the Annual High Water Level, the neglect of seasonal drawdown limits the number of wells that would be considered dry. On the other hand, wells drilled during periods of seasonal drawdown (during later months) could have water levels artificially low compared with the annual high water level, reducing the well's apparent tolerance for additional declines without going dry. Compensating for this seasonal drawdown would be an interesting exercise but would require analysis beyond the scope of this memo. Instead, this is noted as a potential source of bias that would inflate estimates of numbers of wells dried by a given total decline from an Annual High reference level.

Restrictions by Use

Wells were counted according to their use as indicated on the well log. Groups of wells considered include all wells and domestic wells.

Results

Statewide Results

All Wells

The above analysis allows estimating the percent and number of wells that would go dry following an arbitrary decline from the reference level in an aquifer (Figure 3). Results suggest that a decline of 25 feet would cause approximately 6% (15,000 wells) to go dry. Declines of 50 feet would cause 21% (55,000 wells) of wells to go dry, and declines of 75 feet would cause 36% (95,000 wells) to go dry. For each additional foot of decline between 25 and 100 feet, an additional 0.6% or 1,600 wells would go dry.

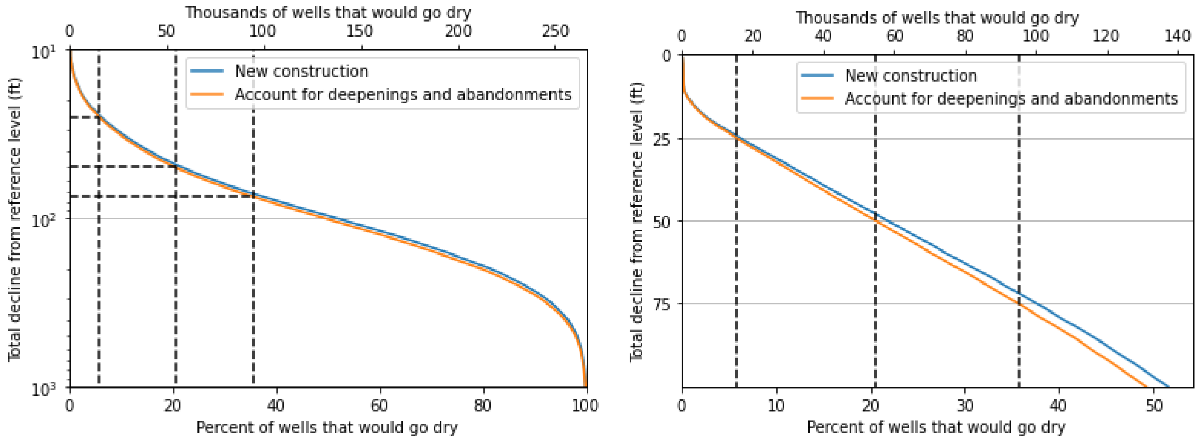

Figure 3: Sensitivity of the percent of all water wells that would be dried by declines to the magnitude of declines (y axes, increasing downward) and whether to account for deepenings and abandonments (line colors). The left subfigure shows the y axis in logarithmic scale up to 1000 feet, while the right subfigure shows the y axis in linear scale up to 100 feet. Vertical dashed lines in the right subfigure indicate the number and percent of wells that would be dried by declines of 25, 50, and 75 feet. The total number of wells is estimated by multiplying the total number of water wells (approximately 266,000 wells) by the percentage of wells drilled shallower, which was estimated from a subsample with sufficient data (248,421 wells).

Domestic Wells

The same analysis can be focused specifically on domestic wells (Figure 4). Results suggest that a decline of 25 feet would cause approximately 5% (12,000 wells) to go dry. Declines of 50 feet would cause 20% (47,000 wells) of wells to go dry and declines of 75 feet would cause 35% (85,000 wells) to go dry. For each additional foot of decline between 25 and 100 feet, an additional 0.6% or 1,400 domestic wells would go dry.

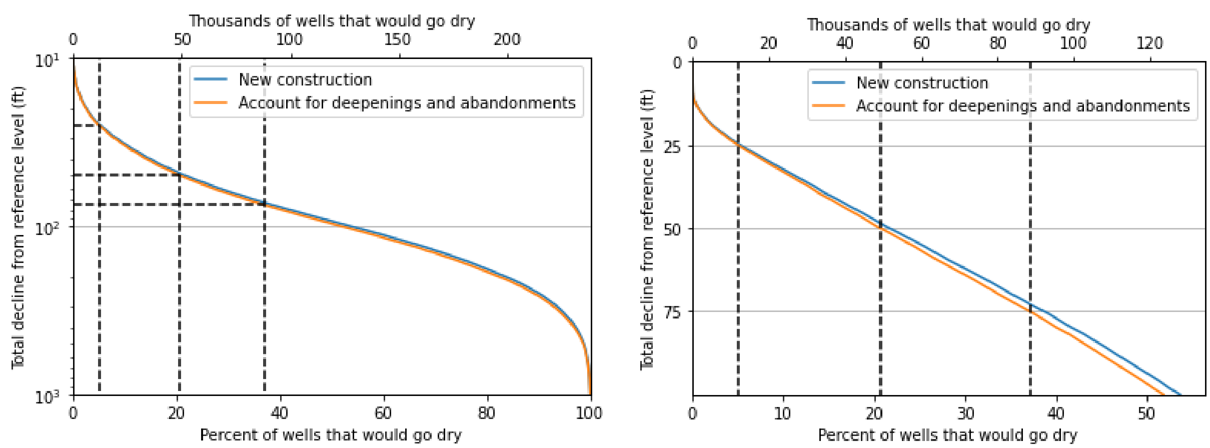

Figure 4: Sensitivity of the percent of domestic wells that would be dried by declines to the magnitude of declines (y axes, increasing downward) and whether to account for deepenings and abandonments (line colors). The left subfigure shows the y axis in logarithmic scale up to 1000 feet, while the right subfigure shows the y axis in linear scale up to 100 feet. Vertical dashed lines in the right subfigure indicate the number and percent of wells that would be dried by declines of 25, 50, and 75 feet. The total number of wells is estimated by multiplying the total number of domestic wells (approximately 240,000 wells) by the percentage of wells drilled shallower, which was estimated from a subsample with sufficient data (225,779 wells).

County-Specific Results

The impact of accounting for deepenings and abandonments is relatively minor statewide (Figure 3 and Figure 4), these subsequent drilling activities have a larger impact in some portions of the state. Figure 5 shows how deepenings and abandonments reduce the number of wells dried by 50 and 75 feet of decline in Deschutes County more than in Klamath, Harney, and Wallowa Counties.

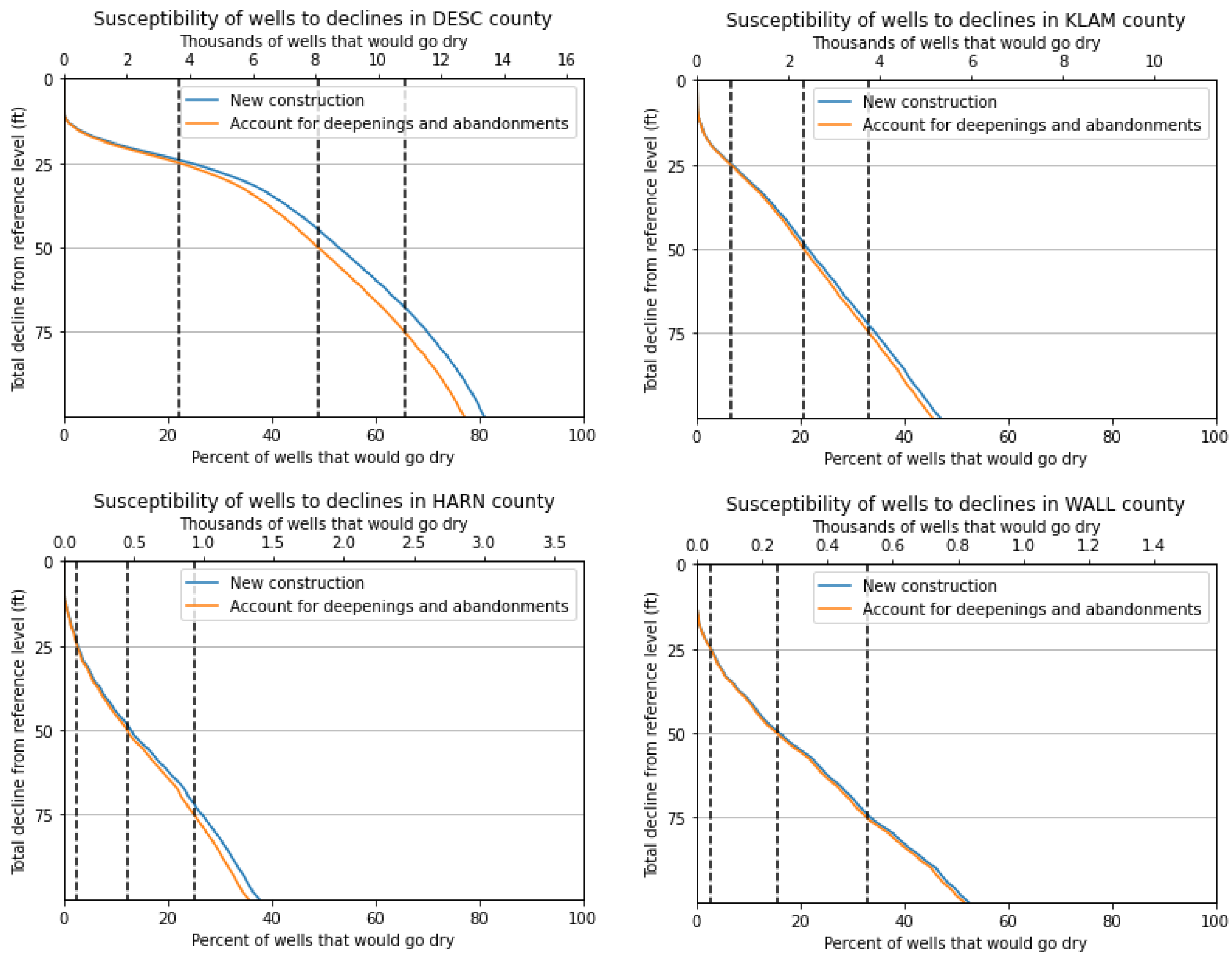

Figure 5: Susceptibility of wells to declines of different magnitudes for select counties in Oregon. Deepenings and abandonments play a larger role in Deschutes County than in most others.

The susceptibility of wells to going dry due to declines varies somewhat across the state, as can be seen in Figure 6 and Figure 7, as well as in Table 1. The counties, ordered by median tolerance for water level decline, show a spectrum of tolerances. Boxplots by county show that counties at one end of the spectrum (Deschutes, Multnomah, Curry, Clatsop) have significantly lower tolerances for declines than counties at the other end (Harney, Sherman, Jackson, Gilliam). All of the counties have cumulative distributions of total declines causing them to go dry that are statistically different from the statewide distribution according to the Komolgorov-Smirnov test (α=0.05), in large part due to the large number of wells.

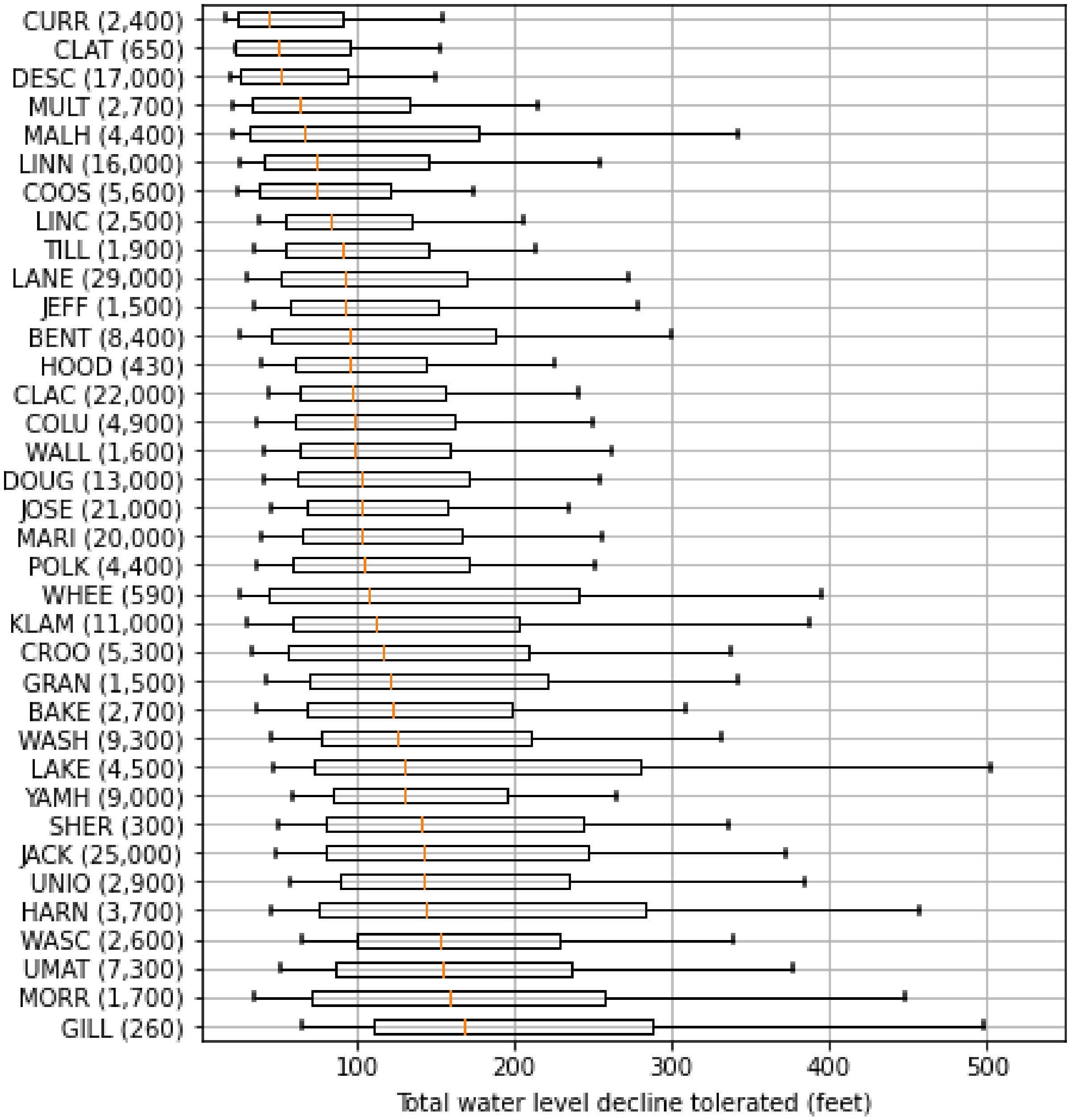

Figure 6: Box plot of depths of declines that would cause all wells to go dry in different counties of Oregon, indicated by 4-letter codes. The whiskers represent the 10th and 90th percentiles, and flier points are not shown due to the limitations of the method of accounting for well deepenings without tracking well construction history on individual wells. Counties are ordered by increasing median decline magnitude (depth of decline that would cause 50 percent of wells to go dry). The total number of wells statewide is about 270,000 wells, and the number in each county (rounded to 2 significant figures) is shown in parentheses next to the county code.

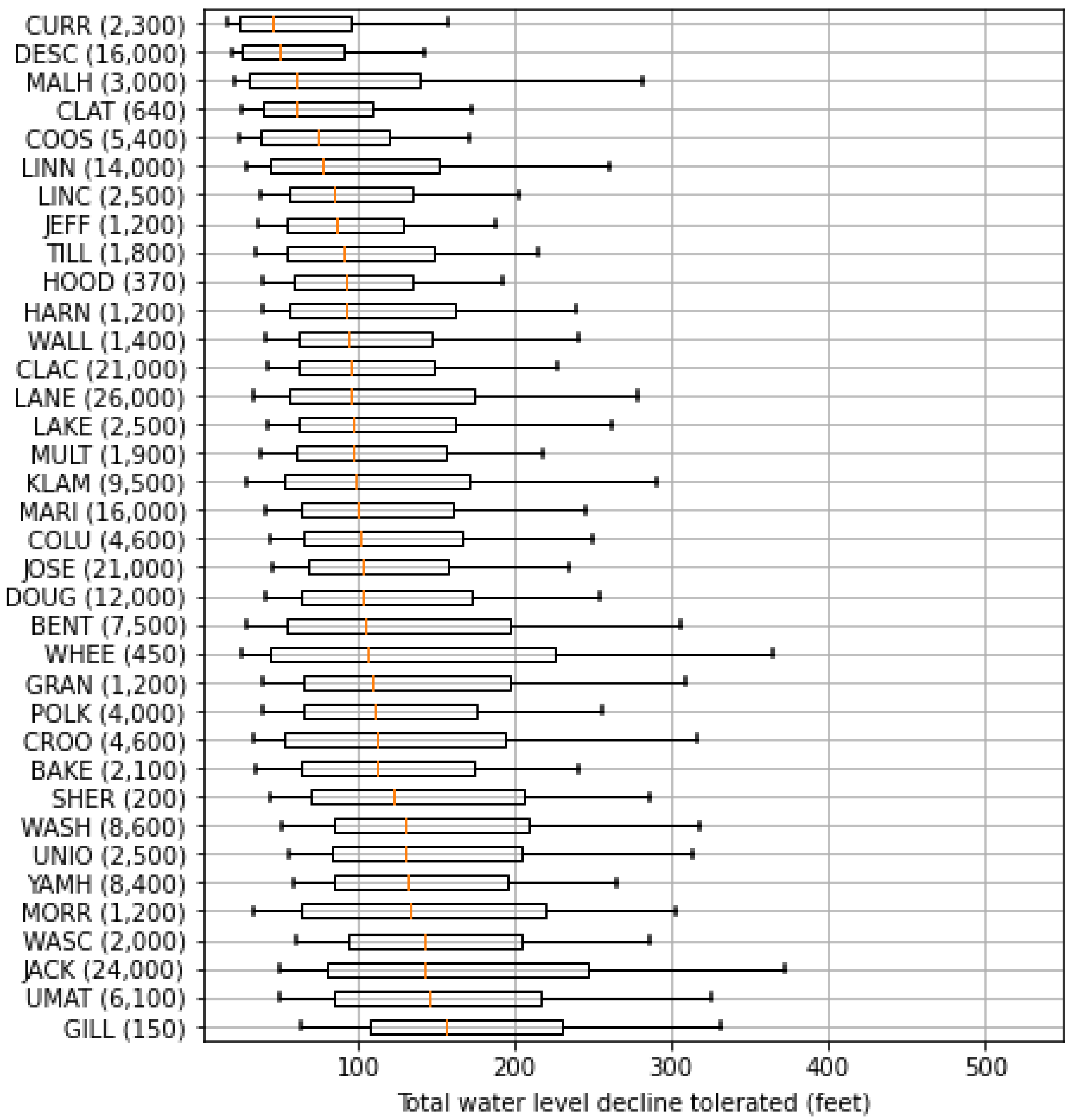

Figure 7: Box plot of depths of declines that would cause domestic wells to go dry in different counties of Oregon, indicated by 4-letter codes. The whiskers represent the 10th and 90th percentiles, and flier points are not shown due to the limitations of the method of accounting for well deepenings without tracking well construction history on individual wells. Counties are ordered by increasing median decline magnitude (depth of decline that would cause 50 percent of wells to go dry). The total number of domestic wells statewide is about 240,000 wells, and the number in each county (rounded to 2 significant figures) is shown in parentheses next to the county code.

Table 1: Counts of number of wells in existence (# Total) and that would become dry following declines of 25, 50, and 75 feet from the level reported upon completion of construction. Results are summarized statewide (top, orange row labeled "All") and by county (following rows). Results are presented as including only Domestic wells (first 4 data columns) and including all water wells (final 4 data columns). Well counts are estimated by scaling the total number of wells in each county (# Total) by the percent of wells that would be dried by a given magnitude of decline in that county (from the same distribution used to generate Figure 7). Statewide sums are rounded to 2 significant figures, respecting the precision of the method.

	Domestic Wells Only				All Water Wells			
County	# Total	# Dry by 25' Decline	# Dry by 50' Decline	# Dry by 75' Decline	# Total	# Dry by 25' Decline	# Dry by 50' Decline	# Dry by 75' Decline
All	240000	12000	47000	85000	270000	15000	55000	95000
Baker	2100	89	390	650	2700	100	440	740
Benton	7500	550	1700	2700	8400	830	2300	3400
Clackamas	21000	280	3200	7400	22000	280	3200	7600
Clatsop	650	61	240	390	650	180	320	430
Columbia	4600	74	680	1500	4900	270	870	1700
Coos	5400	590	1900	2700	5600	600	2000	2800
Crook	4600	180	1100	1600	5300	210	1200	1800
Curry	2300	630	1300	1600	2400	660	1400	1700
Deschutes	16000	3700	8000	11000	17000	3700	8100	11000
Douglas	12000	340	1900	4100	13000	370	2000	4200
Gilliam	150	2	9	19	260	6	17	32
Grant	1200	43	180	370	1500	46	200	410
Harney	1200	39	230	490	3700	93	450	930
Hood River	370	15	60	140	430	15	69	160
Jackson	24000	430	2500	5400	25000	560	2700	5700
Jefferson	1200	52	250	500	1500	70	290	560
Josephine	21000	370	2600	6200	21000	360	2600	6200
Klamath	9500	700	2200	3600	11000	740	2300	3800
Lake	2500	56	380	840	4500	120	550	1200
Lane	26000	1300	5500	10000	29000	1900	6800	12000
Lincoln	2500	78	490	1100	2500	86	510	1100
Linn	14000	930	4400	7000	16000	1500	5400	8200
Malheur	3000	530	1400	1700	4400	670	1900	2300
Marion	16000	440	2500	5300	20000	740	3100	6200
Morrow	1200	44	260	360	1700	64	300	450
Multnomah	1900	53	340	720	2700	350	1100	1500
Polk	4000	120	640	1300	4400	170	860	1500
Sherman	200	3	24	56	300	4	31	66
Tillamook	1800	77	370	690	1900	83	400	770
Umatilla	6100	92	610	1200	7300	110	700	1400
Union	2500	29	180	510	2900	30	190	530

Wallowa	1400	34	220	470	1600	43	250	530
Wasco	2000	33	140	300	2600	38	160	340
Washington	8600	80	790	1700	9300	100	1200	2200
Wheeler	450	44	130	180	590	55	170	230
Yamhill	8400	51	470	1600	9000	86	560	1700

Discussion

The analysis presented above shows that a substantial number of wells are susceptible to being dried by groundwater level declines of 25, 50, and 75 feet. Declines of 25 feet are expected to dry 6% (15,000) of wells, and declines of 50 feet are expected to dry 21% (55,000) of wells. For each additional foot of decline between 25 and 100 feet total, approximately an additional 0.6% or 1,600 wells would go dry. Considering that deepening or replacement of a dry well may cost tens to hundreds of thousands of dollars (average $26,500 per well from the Department's Well Abandonment Repair and Replacement Fund), this analysis helps to illuminate the cost of increasing the allowable total decline in the proposed definition of Reasonably Stable Groundwater Levels.

Susceptibility to declines varied significantly by county. Counties including Curry, Clatsop, and Deschutes had distributions of tolerance for total declines that were at the shallow end of the statewide spectrum. This may reflect typical well construction that is relatively shallow compared with water levels. Meanwhile, counties with a substantial portion of wells accessing basalt aquifers like Wasco, Umatilla, Morrow, and Gilliam anchor the other end of the spectrum. These wells may be typically drilled much deeper within the saturated aquifer.

The analysis presented above is subject to a number of sources of potential bias, some of which influence the results in each direction (more or fewer wells dried). Biases that cause underestimation of the number of wells dried include accounting for pre-drilled declines, using GWIS to establish decline trends in many townships, and neglecting long-term rising trends in water levels. Accounting for pre-drilled declines reduces the additional decline that a well must endure to avoid going dry, compared with evaluating declines relative to the water level when drilled. Using GWIS to establish decline trends in a township tends to decrease estimates of additional declines by increasing estimates of pre-drilled declines, because GWIS wells preferentially include irrigation wells and wells experiencing significant declines. Long-term rising trends in groundwater levels would mean that declines from a lower reference level would imply greater additional declines after drilling in order to achieve a given decline from the reference level.

On the other hand, biases that cause overestimation of the number of wells dried include incomplete water level recovery after drilling, not compensating for seasonal drawdown in wells completed during summer and fall months, and estimating the impact of deepenings and abandonments using the fraction that started too shallow among new wells. Incomplete water level recovery after drilling causes water levels to be reported as artificially deep in well logs reducing a well's apparent tolerance for declining water levels. Seasonal drawdown can reduce groundwater levels reported on well logs below the annual high, which also reduces a well's apparent tolerance for declines beyond what it would be if measured using an annual high water level. Finally, estimating the impact of deepenings and abandonments using the fraction that started too shallow among new wells was necessary to evaluate susceptibility to small declines but likely undercounts the ability for deepenings and abandonments to mitigate a new well's susceptibility to going dry.

On top of the caveats described above, the analysis presented above should not be interpreted as a direct estimate of the number of wells which will go dry under any proposed definition of Reasonably Stable Groundwater Levels. In many areas, total declines are expected to be less than the maximum allowed in the proposed definition, because groundwater pumping is not expected to cause water level declines to reach that maximum allowed everywhere. There are numerous constraints on groundwater pumping other than Water Availability. In addition, the proposed definition includes a rate test that can cause water levels to cease being Reasonably Stable before the total decline test is triggered. On the other hand, cumulative groundwater level declines may exceed the maximum allowed under Reasonably Stable if declines continue after levels cease to be Reasonably Stable and issuance of groundwater permits stops. This may occur if the hydraulic connection with surface water is absent or insufficient to offset additional pumping authorized when declines are just under the maximum allowed. Even in hydraulically connected systems, the time to full capture of surface water may extend for decades such that significant declines continue long after pumping rates stabilize. Total groundwater pumping may also still increase (up to a limit) even if no new groundwater permits are issued, as existing permits which currently use only a portion of their authorized allocation may be further developed.

Text of Proposed Definitions

The following two definitions are proposed to be added to OAR 690-008:

(1) "**Annual High Water Level**" in a groundwater reservoir or part thereof means the highest elevation (shallowest depth) static groundwater level that exists in a year.

(9) "**Reasonably Stable Groundwater Levels**" means:

(a) The Annual High Water Levels as measured at one or more representative wells in a groundwater reservoir or part thereof:

(A) indicate no decline or an average rate of decline of less than 0.6 feet per year over any immediately preceding averaging period with duration between 5 and 20 years. Four Annual High Water Levels are required to calculate the rate of change; one must have been measured in the year to which the evaluation of reasonably stable applies, and at least one must have been measured between 5 and 20 years prior; and

(B) have not declined by more than 25 feet from a reference level to the level in the year to which the evaluation of reasonably stable applies. The reference level shall be the highest known water level unless Annual High Water Levels have been increased measurably by human activity, in which case the Department may set a different reference level using best available information.

(b) If water level data are insufficient to perform either test in (a) for a given year, then the Department will presume that groundwater levels are not reasonably stable unless:

(A) the most recent evaluation of reasonably stable applies to a year within 5 years of the given year, in which case the Department may presume that the recent evaluation still applies; or

(B) groundwater has not yet been extracted or authorized for extraction from the groundwater reservoir, in which case the Department may presume that groundwater levels are reasonably stable.

(c) The Department may evaluate Reasonably Stable Groundwater Levels for the year of the priority date of a groundwater right application or for a later year if more recent data are available.

(d) The limits in part (a) of this definition may be superseded by limits defined in a basin program rule adopted pursuant to the Commission's authority in ORS 536.300 and 536.310. Any proposed superseding basin program definition must consider, at a minimum, the anticipated impacts of the new definition on:

(A) the number of wells that may go dry; and

(B) the character and function of springs and groundwater dependent ecosystems; and

(C) the long term, efficient, and sustainable use of groundwater for multiple beneficial purposes.

(e) This definition does not apply to Critical Groundwater Areas designated under OAR 690-010.

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Gannett, M.W., K.E. Lite Jr., J.L. La Marche, B.J. Fisher, and D.J. Polette, 2007. Ground-Water Hydrology of the Upper Klamath Basin, Oregon and California. USGS Numbered Series, U. S. Geological Survey, Reston, VA.

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Data Files

1. well_logs_depth_drilled_below_water.xlsx: This spreadsheet contains the raw well log data analyzed in the analysis described above. Each row contains one well log, and columns contain relevant data about the year and depth drilled, as well as the water level measured after drilling. The column "tr_key" indicates the PLSS township.
2. gwis_declines_by_well.xlsx: This spreadsheet contains the data that were used to evaluate water-level decline trends for the purposes of estimating pre-drilled declines, as described in the section "Using the Groundwater Information System."