

2021 OREGON GROUNDWATER RESOURCE CONCERNS ASSESSMENT



OREGON



WATER RESOURCES
DEPARTMENT

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STATE OF OREGON

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Summary

Groundwater is a critical resource for Oregon, but increased groundwater pumping can have impacts on existing users and hydraulically connected surface water sources. The Department continues to develop new tools to understand and communicate these impacts in order to balance needs for both water supply and instream flow. This report details a statewide, data-driven assessment of concerns associated with the development of groundwater resources, including:

1. Statutory or administrative rule restrictions to obtaining a groundwater right for the purpose of irrigation. Groundwater use for irrigation purposes currently accounts for approximately 90% of permitted groundwater allocation in the state, and therefore was selected as the focus of this assessment.
2. Data indicating sustainability problems like excessive groundwater level declines or diminished groundwater contributions to state scenic waterways.
3. The physical ability of an aquifer to supply water to a well at a rate sufficient to support relatively large uses, such as irrigation uses typical in a given area.

This report and associated map are intended to facilitate understanding, awareness, and discussion about these groundwater concerns. It is not a decision-making tool for water availability or allocation, which will continue to occur according to existing Department practices implementing rule and statute. The map does not identify all potential concerns, nor does it indicate that concerns identified would result in new water right applications being denied or existing rights being curtailed within an area.

The map incorporates many types of information used to assess groundwater resource concerns in each Public Land Survey Township in Oregon (Figure 1). The report also presents a series of component maps representing the various inputs to the primary map. Generally, the concern categories represent:

- Significant Concern (dark red): groundwater pumping for new irrigation is prohibited by an area-specific rule, has been proposed for a use beyond the capacity of the resource, or has caused significant declines in groundwater levels.
- Concern (red): groundwater pumping for new irrigation is restricted by an area-specific rule, is likely to impact hydraulically-connected surface water with no August availability, or has caused moderate declines in groundwater levels.
- Yield-limited Wells (orange): groundwater pumping appears limited by aquifer characteristics that limit productivity, where typical well yield is insufficient to meet typical irrigation demand.
- No Concerning Data Available (gray): not enough reliable data have been collected within the Township to objectively assess a concern rating using this state-wide analysis, or available data indicates no concern related to the categories above (about 5% of all Townships in this category).

Groundwater Resource Concerns

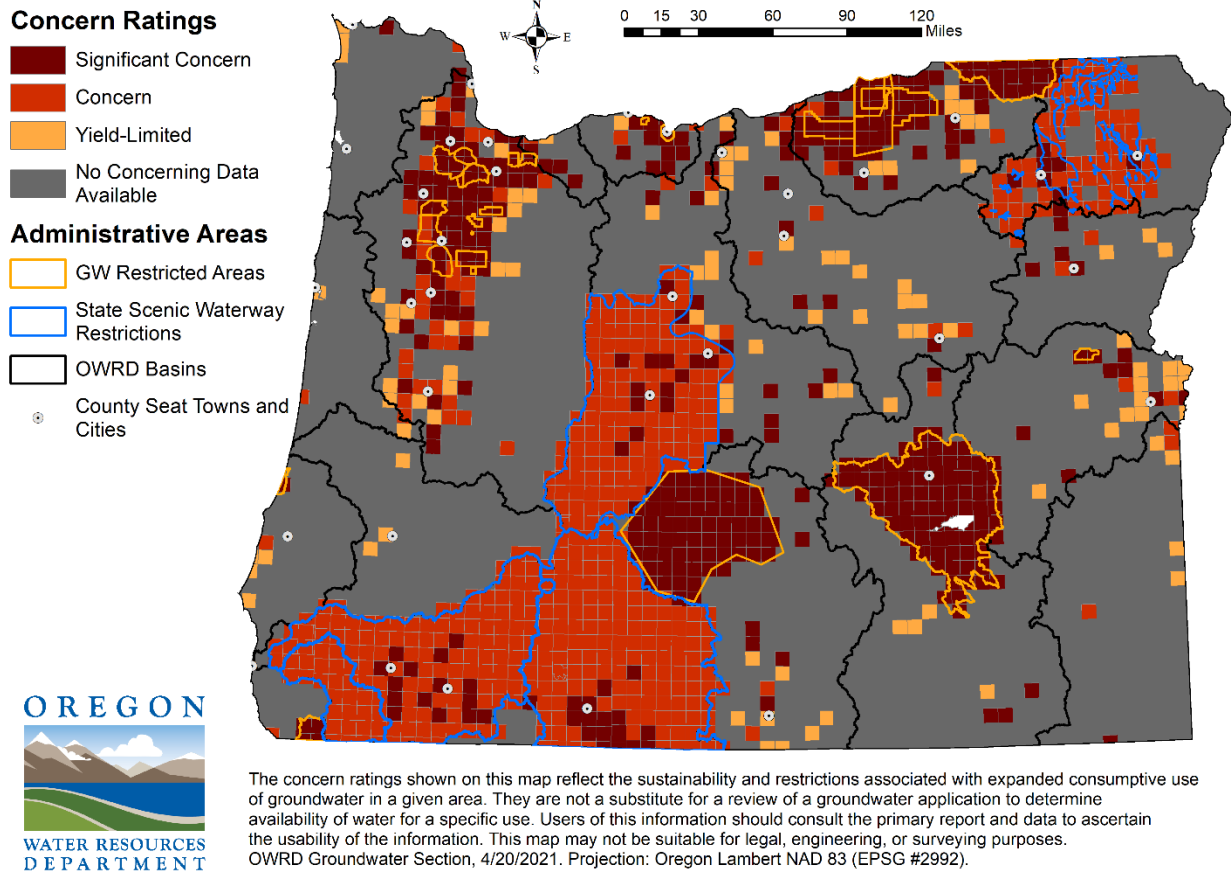


Figure 1: 2021 groundwater resource concerns, by Township (typically 36 square miles in area).

Key observations from the map include:

- Of the 410 Townships with significant concerns, a third fall entirely outside of existing Groundwater Restricted Areas or areas above State Scenic Waterways where flows have been measurably reduced per ORS 390.835 (9) and (12). These Townships may warrant further study and potential inclusion in expanded or new Groundwater Restricted Areas.
- Over 80% of applications for groundwater permits and limited licenses since 2010 are in areas of concern or significant concern, and 80% of these applications were approved or proposed for approval (79% in areas of significant concern and 83% in areas of concern, versus 81% statewide). Further groundwater development in these areas has the potential to exacerbate negative impacts and conflicts between users. Investments are needed in data, studies, planning and management to resolve complex issues.
- Over half of Oregon lacks readily-available data to evaluate groundwater resource concerns. As permitted groundwater use expands across the state, annual water level measurements are reported as a common condition of new groundwater permits. However, additional

investments are needed in monitoring and studies to manage groundwater resources proactively. Funding is needed to enable the Department to expand groundwater monitoring and develop basin-scale water budgets and information inventories. Such efforts are important initial components of groundwater basin studies, which are the best way to understand groundwater availability in Oregon's complex aquifers.

Results of this analysis should be considered in the context of some significant limitations of this approach. On one hand, evaluating concerns at the scale of Townships that have a typical area of 36 square miles tends to spread point data over space and over areas that may contain multiple aquifers. This aggregation is convenient for visualization and is generally reasonable for capturing long-term trends, but it also means that any concerns that are concentrated in a small area or single aquifer nonetheless impact the concern rating for the whole Township. The extrapolation of concern is balanced somewhat by underestimation of concern due to neglect of impacts that could not be readily incorporated into this analysis. For example, the concern ratings do not consider potential interference with senior groundwater rights. In addition, they consider the potential for depletion of surface water only when relevant analyses were available, which was true across only 36% of the state (see discussion in report section "Availability of Hydraulically-Connected Surface Water Sources"). Therefore, this map does not consistently reflect the facts that groundwater pumping depletes hydraulically connected surface water, and that nearly all surface water in Oregon is fully appropriated in August. It is impossible to characterize any overall bias because concerns are subjective, but the accuracy and utility of the estimates will continue to improve as more data and more types of data become available for state-wide analysis. This map and report will be updated periodically to incorporate those improvements, such that they should be considered evolving tools for building shared understanding.

Background

The mission of the Water Resources Department (Department) is to practice and promote responsible water management through directly addressing Oregon's water supply needs in a manner that protects the long-term sustainability of Oregon's ecosystems, economy, and quality of life. The Water Resources Commission adopted Oregon's first Integrated Water Resources Strategy (IWRS) in 2012 to understand and meet Oregon's water needs, and updated the IWRS in 2017 (Mucken and Bateman, 2017).

The IWRS identifies groundwater as one of four cross-cutting issues of vital importance to Oregon's water future. Groundwater occurs almost everywhere beneath the land surface. Because of its connection to surface water, it is a major contributing source of water for many surface water features in Oregon. More than half of the state's population is directly dependent on groundwater for drinking, industrial, or irrigation water. The remainder relies on groundwater as a backup supply to surface water sources or as an important source of summer streamflow. As a result, the state's entire population is affected by activities of the Department with respect to groundwater.

The IWRS also acknowledges that significant work remains to characterize Oregon's groundwater resources and calls for additional groundwater investigations and improved water resources data collection in Recommended Actions 1A and 1B. This groundwater resource concern report assesses the

data collected in response to these recommended actions, as well as historic data, to address one component of the identified critical issue of further understanding limited supplies and systems (Mucken and Bateman, 2017, Chapter 1).

Previous State-Wide Assessments of Groundwater Vulnerability

In 2015, the Water Resources Department generated a state-wide map of groundwater level changes and vulnerability (Figure 2), and the present project seeks to build upon that work. This first map included point data for wells, colored to indicate the magnitude of declines or recovery over the period of record measured for each well. In addition, surface water sub-basins were colored according to an index of groundwater vulnerability that was determined by Department staff and explained in a narrative report, based on individual professional experience with groundwater across the state.

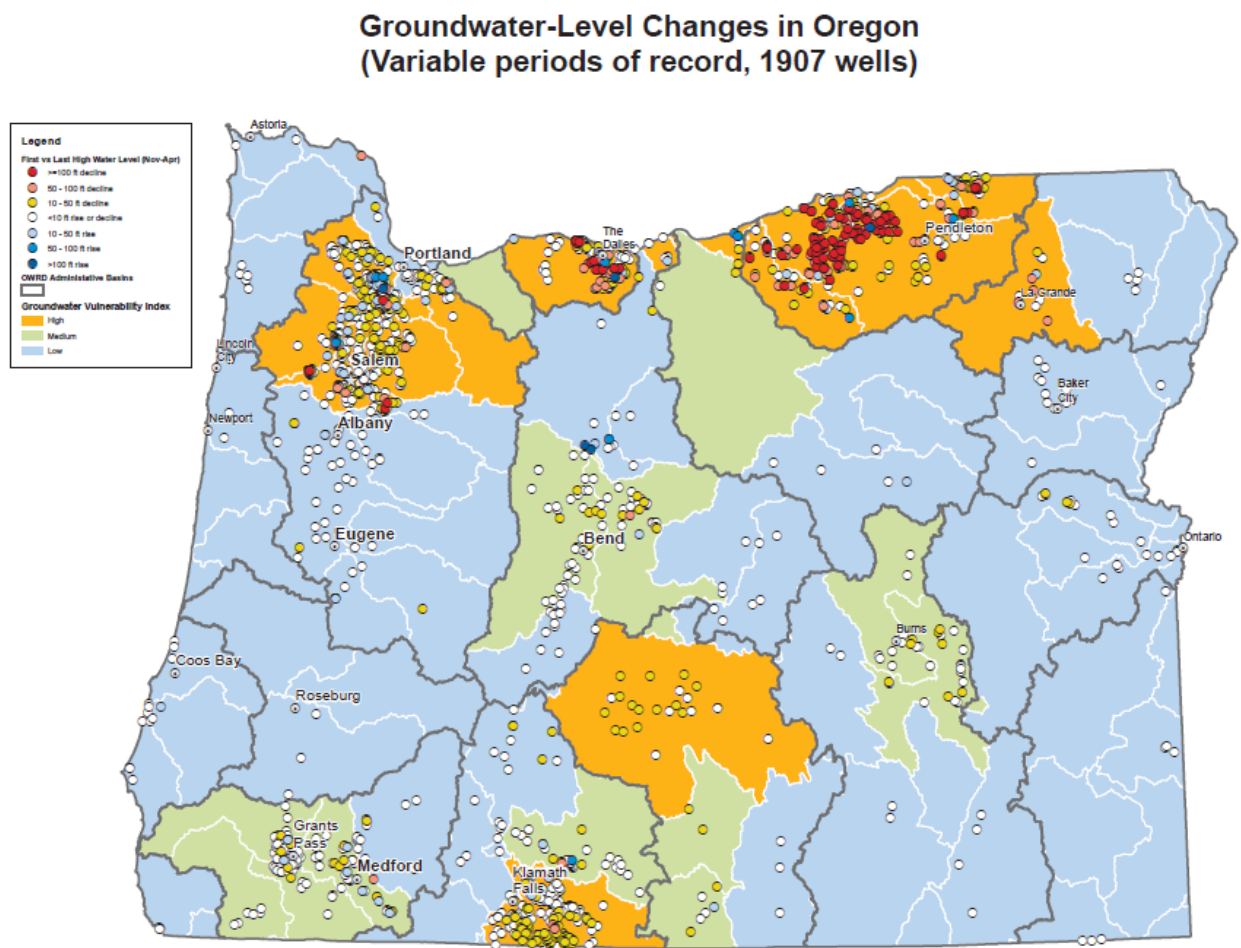


Figure 2: Groundwater level change and vulnerability map from 2015.

Feedback suggested that this map was highly informative but difficult to digest in a short period of time as part of a presentation, especially because it represented water level changes in individual wells. It also lacked some relevant features, and the fact that it was based on the professional judgement of an expert meant that it could not easily be updated or compared to prior versions. Finally, it did not clearly distinguish areas with insufficient data to evaluate groundwater vulnerability. These limitations

motivated a central principle of the new version, that it should be based primarily on available data and generated with the greatest degree possible of automation in a manner that could be easily replicated for future updates.

Comparing the 2015 map (Figure 2) against the updated estimate (Figure 1: 2021) shows a great degree of correspondence between concerns in 2021 and vulnerability in 2015. Some notable differences between the 2015 and 2021 maps include:

- The updated map summarizes concerns within individual Townships instead of vulnerability within sub-basins. See discussion in the section “Spatial Resolution” below.
- The updated map outlines the Groundwater Restricted Areas (GWRAs) and areas above State Scenic Waterways (SSWs) where mitigation for groundwater impacts on the scenic waterway flows is required.
- The Southern Willamette Valley is indicated as having concerns and significant concerns, compared with low vulnerability in 2015. This difference reflects the fact that the 2021 map accounts for availability of hydraulically connected surface water sources, where sufficient analyses are available (over about 36% of the state). The concerns in this region arise from predominant hydraulic connection with surface water sources lacking availability in August. Surface water availability was evaluated in August for simplicity and to allow comparison against the map of August SW availability across Oregon.
- The Greater Harney Valley Groundwater Area of Concern (GHVGAC) was established in 2016. This area is indicated as having Significant Concerns in 2021, compared with the finding of Medium groundwater vulnerability in 2015.

Evaluating Groundwater Resources Concerns

The approach described here utilized reliable data that are available statewide to evaluate groundwater resource concerns of varying degrees. Areas subject to restricted groundwater use by rule were assumed to imply different levels of concern depending on the type of restriction. Findings of over-appropriation and use beyond the capacity of the resource in groundwater application reviews, as well as excessive groundwater declines and exceedance of decline permit conditions, were considered evidence of an unsustainable imbalance between groundwater recharge and withdrawal. Hydraulic connection to over-appropriated surface water sources was evaluated in aggregate where sufficient data were available. Yields measured in irrigation wells were used to identify areas limited by aquifer productivity.

Groundwater Information System and Water Rights Information System

Over the past 4 years, the Groundwater (GW) section of the Department has been migrating its database into a coherent Groundwater Information System (GWIS). The GWIS data are stored in SQL (Structured Query Language) and can be accessed via custom webapps for data entry, querying, mapping, and download. For the purposes of the present project, this availability enables analysis and mapping of trends in groundwater levels via scripts that can re-generate the results at will using the latest available data. An eventual goal is that all of the underlying data will be automatically re-

evaluated regularly and made available for staff and the public to view the current state of groundwater resource concerns.

The incorporation of GWIS into SQL also allows for tighter connections between GWIS and the Department's Water Rights Information System (WRIS). These improved connections facilitate the Department's ability to track the relationships between physical wells and their manifestations on groundwater rights, called Points of Appropriation (POAs). These relationships are important for associating findings on technical reviews of groundwater right applications with the correct aquifer system, as well as for evaluating whether decline conditions on groundwater permits have been met according to measured data.

Resource Concern Categories

Significant Concern

The highest degree of concern about groundwater resources is represented by the "Significant Concern" category. A Township was rated as having significant concern if any of the following were true in any of the aquifer systems present:

- Groundwater Restricted Areas: At least 25% of the Township overlapped an area that is critical, classified to prohibit irrigation, or withdrawn, and the restriction applies to an aquifer system present in that Township.
- A technical review of a groundwater permit application, drought application, or permit extension with POAs found that groundwater for the proposed use is either over-appropriated or not likely available within the capacity of the resource.
- Any well is either Excessively Declined or Declining Excessively (see discussion below).
- Any POA has exceeded any of its decline permit conditions.

Concern

A rating of "Concern" indicates moderate restrictions or indications of limited resources. A Township was rated as having concern if it lacked any significant concerns but did have at least one of the following associated pieces of data:

1. Groundwater Restricted Areas (GWRAs): The Township significantly overlapped an area subject to groundwater restrictions.
 - a. If more than 25% of the Township overlapped an area within, above, or hydraulically connected to a State Scenic Waterway (SSW) where new groundwater permits require ad hoc mitigation, or an area subject to a SSW Mitigation Program.
 - b. If more than 25% of the area was within a groundwater limited area, as long as the use within that limited area is still classified to include irrigation.
2. Any well in that Township has declined moderately or is moderately declining. The "moderately" qualifier is defined for the purposes of this assessment as half way to the quantitative rule definitions for excessively declining or declined as per OAR 690-008. Additional information is provided in the Data Sources discussion.

3. Unavailable hydraulically connected surface water sources: The majority of all (at least 3) POAs in the Township that were evaluated for hydraulic connection to surface water sources were found to be hydraulically connected to at least 1 surface water source. This majority-connected finding was used to approximate that future Points of Appropriation in that aquifer system will likely also be hydraulically connected. In addition, the majority of the area of the Township was covered by Watershed Availability Basins (WABs) with no water available in August.

Yield-Limited

Groundwater was considered to be Yield-Limited if the only problematic information in the Township was a median yield on well tests that is below a threshold considered necessary for irrigation from a well. Development of those township-specific threshold values is discussed below in sub-section “Low-Yielding Wells.”

No Concerning Data Available

Any Township lacking data that indicate concern using the automated methods outlined in this report was indicated as having “No Concerning Data Available.” In this report and map, the “No Concerning Data Available” rating could mean that either no data are available, or all available data indicate no concern. In most cases of this category, no data were available for this state-wide analysis, meaning there was nothing to indicate either concern or lack of concern. In about 5% of cases, data were available that did not indicate concern, such as water level records that showed minimal or no long-term declines. Rigorously indicating “no concern” would require characterizing the distinct aquifer systems that may exist in each Township and associating available data with a specific aquifer system. This assessment is planned for future reports.

The caveat “...Data Available” was also added to emphasize the data-driven nature of this assessment and the fact that not all existing data were available in an electronic format amenable to being incorporated into this automated analysis. In other words, other information may exist that could indicate groundwater concern or not, but any such information is located outside of electronic data systems available for the analyses described in this report. The potential for other data to exist means that the all concern ratings in this report should be considered preliminary and require further review before being used for decision-making.

Data Sources

The concern categories were assigned by assessing multiple sources of data in a logical and consistent manner across the state. Each of those sources is described below:

Groundwater Declines

Declining water levels measured in wells over the course of many years indicate that groundwater discharge exceeds groundwater recharge over this time period, resulting in the depletion of groundwater storage. For this map, excessive declines were considered to be significant concerns, while moderate declines were considered concerning, as they may lead to a finding of further appropriation being beyond the capacity of the resource.

1. For the purpose of this assessment, a well may experience excessive declines ([OAR 690-008-0001](#)) in either of 2 ways:
 - a. Declined excessively: annual high water level elevations display a total decline of over 50 feet from the highest value to the most recent value.
 - b. Excessively declining: annual high water level elevations over the past 10 years display an average downward trend (interpreted as the slope of the least-squares best fit line) of 3 or more feet per year. At least 3 water levels are required for evaluation of the best-fit trend, and “for at least 10 years” is interpreted to mean a period of duration 10 years. Future work could consider all the possible trends calculated over periods of at least 10 years into the past and check for the greatest rate of decline, potentially detecting more excessively declining wells.

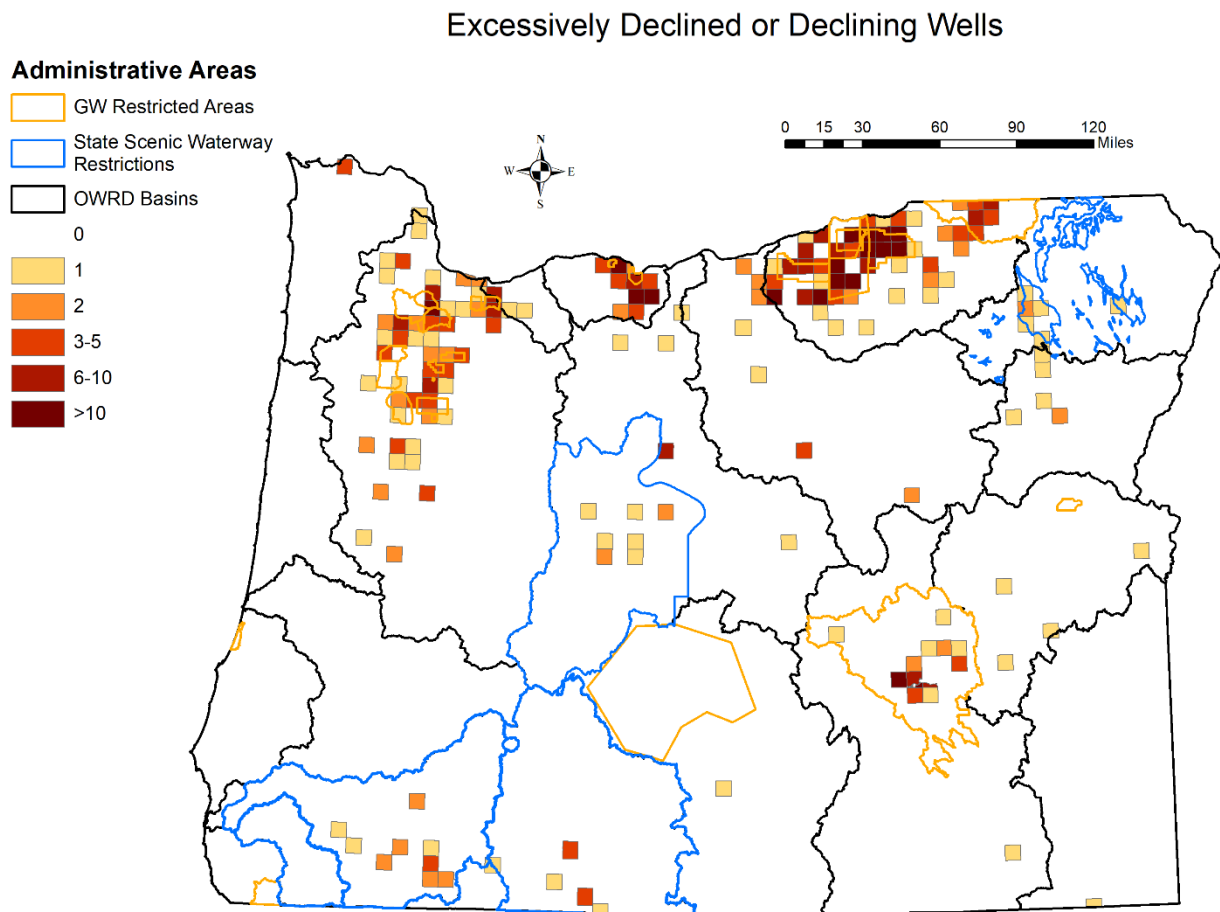


Figure 3: Number of wells Excessively Declined or Declining per Township.

2. Moderate declines are defined as a total decline of over 25 feet (half-way to declined excessively). Future versions of the map could consider incorporating moderate rates of decline and thresholds for moderate declines that are specific to the primary aquifer system.

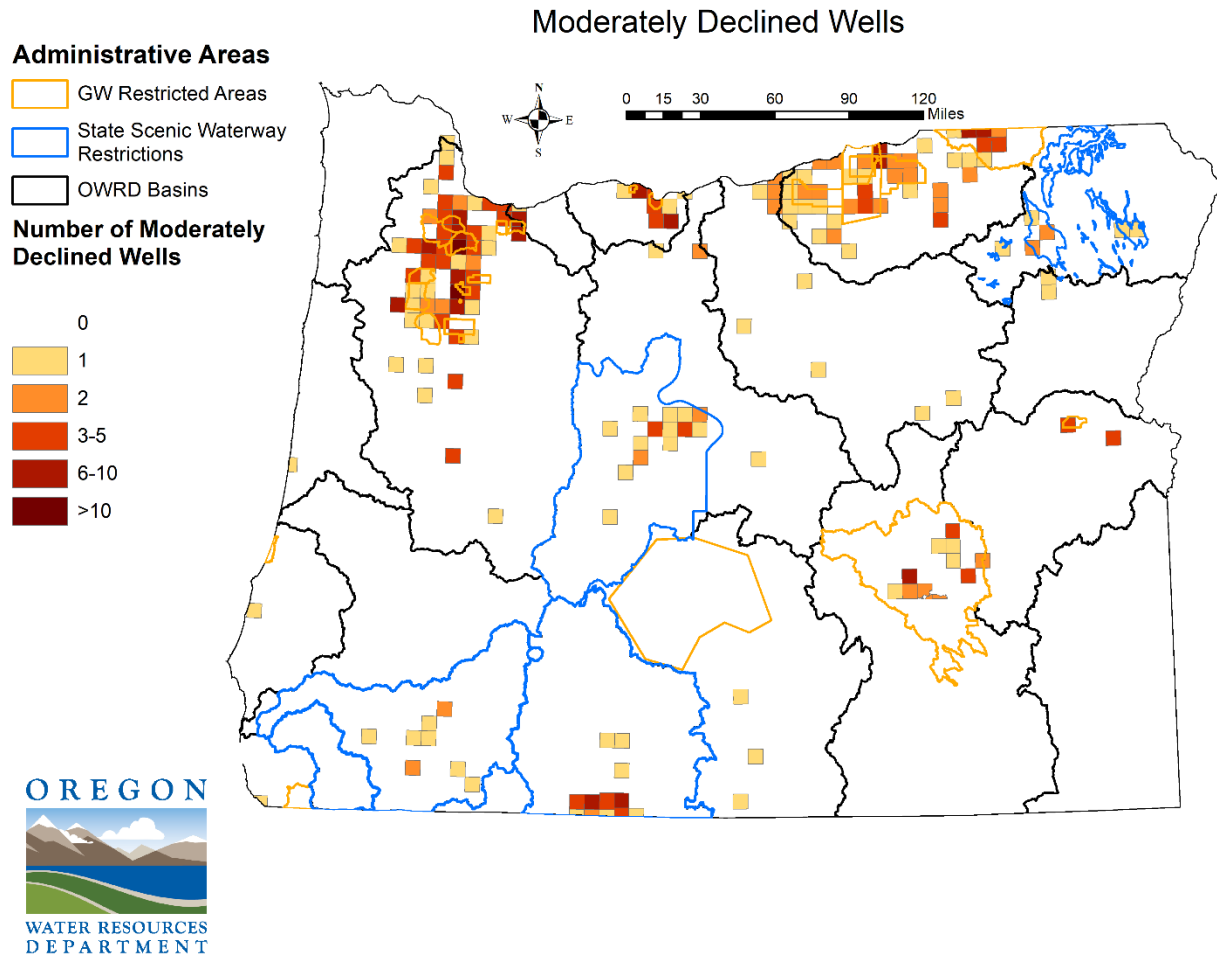


Figure 4: Number of wells with moderate declines per Township.

Exceeded Decline Permit Conditions

Most groundwater permits in Oregon are subject to conditions limiting the allowable decline in water level, and a well with any exceeded decline condition was considered a significant concern. As with other groundwater declines, the following were evaluated on spring high static measurements. In the following, X, Y, and Z are thresholds specific to each permit.

- A. An average water level decline of X or more feet per year for five consecutive years. This was evaluated by taking the difference between the most recent water level and the level 5 years before it, then dividing by 5 to get an annual rate. If no water level was measured 5 years before, then that level was linearly interpolated using the next most recent water level before 5 years previous. The recent annual high water level must have been measured within the past 10 years, to ensure that permit conditions exceeded on this criterion do not persist forever.

- B. A water level decline of Y or more feet in fewer than five consecutive years. This is evaluated as the maximum difference between the most recent annual high water level and any previous water level measured less than 5 years before then. The recent annual high water level must have been measured within the past 10 years, to ensure that permit conditions exceeded on this criterion do not persist forever.
- C. A total water level decline of Z or more feet below the reference level. This was evaluated by comparing the most recent spring high water level against the reference level in WRIS, if one is available. Over 85% of more than 5,800 decline permit conditions have not had their reference levels set in WRIS as of 2021, which typically means that they have not been evaluated. These reference levels are set primarily when Claims of Beneficial Use are evaluated by Certificates staff, but they may also be evaluated by Groundwater staff in a manner consistent with the permit and when appropriate data are available.

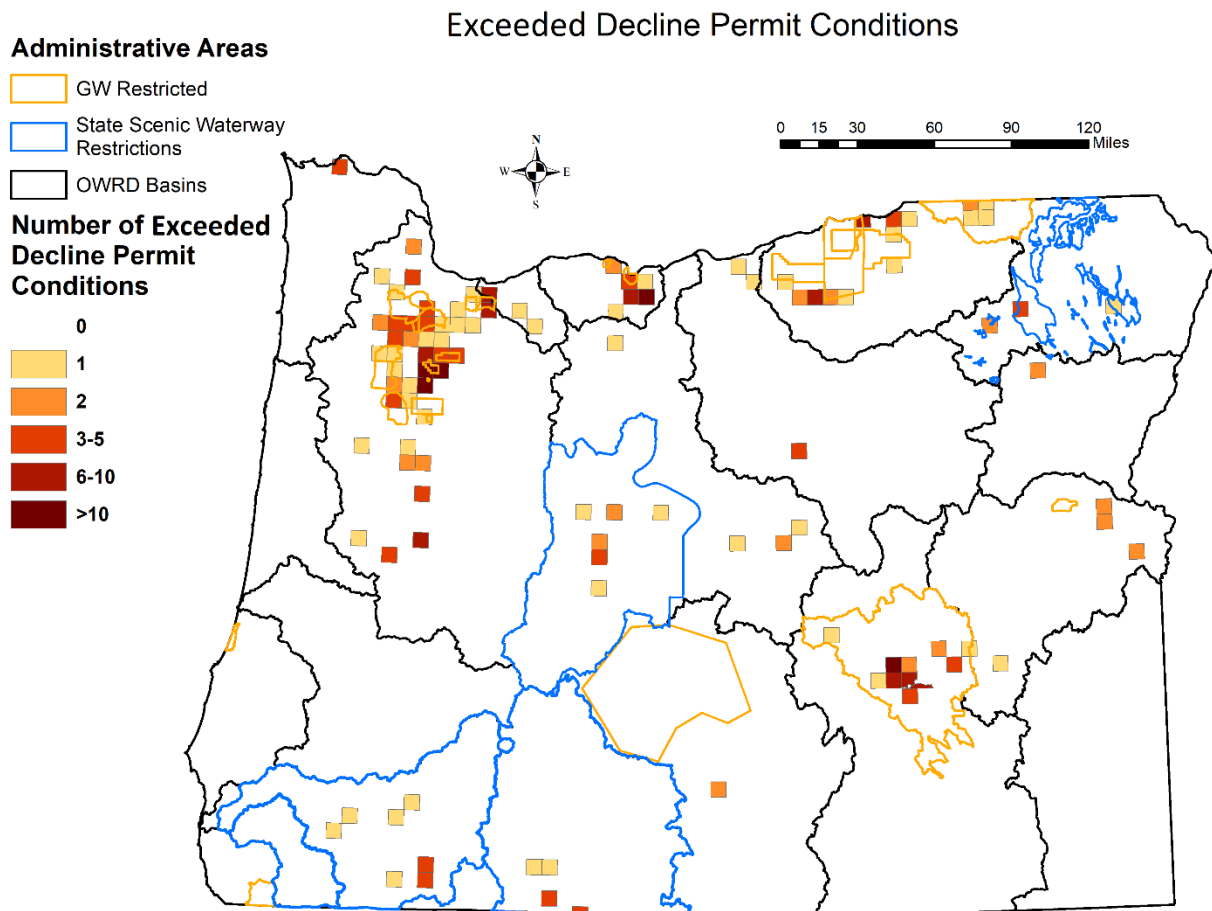


Figure 5: Number of exceeded water level decline permit conditions per Township.

Groundwater Restricted Areas

All GW Restricted Areas (GWRAs) were mapped as outlined polygons on the final map. In addition, GWRAs impacted the concern rating in a manner that depended on the status and classified uses in each Restricted Area. An aquifer system in a Township inherited the rules of the strictest GWRA that intersected with it over at least 25% of the area of the Township.

State Scenic Waterways

Under Oregon's State Scenic Waterways (SSW) program, the Department is charged with tracking and limiting the issuance of water rights that "measurably reduce the surface water flows necessary to maintain the free-flowing character of a scenic waterway in quantities necessary for recreation, fish and wildlife." ([ORS 390.835](#)) The cumulative consumptive use of groundwater rights hydraulically connected to surface water and within the area contributing to the flow of a SSW reach is tracked starting on the date of a SSW designation. Once the cumulative consumptive use exceeds the lesser of 1% of the average daily flow by month or 1 cfs (past the point of no water availability), the SSW and its contributing area are considered to have been "triggered." Any further allocation of groundwater hydraulically connected to surface water and within the contributing area of these triggered SSW reaches requires that the consumptive use be mitigated. Therefore, these areas are considered to have groundwater resource concerns if they have been triggered in August, and a Township inherits the restriction if it lies more than 25% within one of these areas. In 2021, there are 6 SSWs with no August availability:

- Per the Water Availability Reporting System (WARS):
 - o The Wallowa-Grande Ronde Scenic Waterway, currently limited to the alluvial basin of the Grande Ronde Valley. Thus, the outline of this SSW was restricted to mapped alluvium in that basin.
 - o The Minam Scenic Waterway
 - o The Illinois Scenic Waterway
 - o The Rogue Scenic Waterway
- Evaluated for availability using numerical models developed during basin studies:
 - o The Deschutes and Metolius Scenic Waterways, which are governed by the [Deschutes State Scenic Waterway Mitigation Program](#)
 - o [The Klamath Scenic Waterway](#)

Approximately 14% of Townships in Oregon lie at least 25% within or above one of these triggered SSW reaches.

GW Review Findings

Technical reviews of applications for GW rights include determinations about the groundwater resource, and two of these findings were considered significant concerns:

- Groundwater is not available within the capacity of the resource.
- Groundwater is over-appropriated during any period of the proposed use, as defined in [OAR 690-400-0010](#) (11).

Groundwater Permit Applications found Beyond the Capacity of the Groundwater Resource

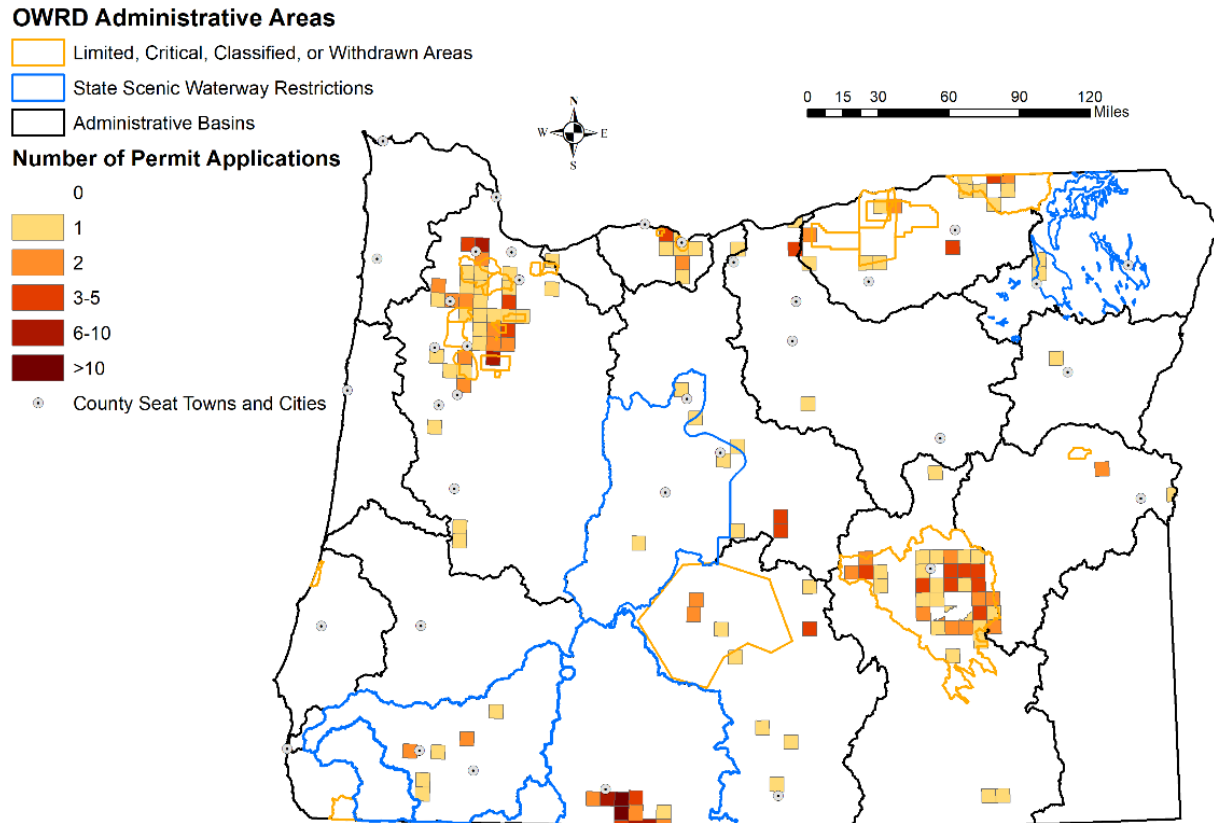


Figure 6: Number of groundwater applications where technical review found the proposed use to be beyond the capacity of the groundwater resource, including findings of over-appropriation.

Availability of Hydraulically-Connected Surface Water Sources

Groundwater and surface water are managed conjunctively in Oregon ([OAR 690-410-0010](#) (2)(a)). Therefore, groundwater is only available for appropriation when it does not have the Potential for Substantial Interference (PSI) ([OAR 690-009](#)) with fully-allocated surface-water sources. Over the scale of decades or more, even groundwater that does not have PSI but is hydraulically connected to surface water sources will eventually capture water from those sources. Determining the exact relationship between all wells and surface water sources is beyond the scope of this mapping project, and representing concerns on a single map is challenging because surface water availability varies by month. For the purposes of this map, concern was indicated in Townships where wells were typically found to be hydraulically connected, and where at least 25% of the Township's area was within Water Availability Basins (WABs) that did not have water available in August.

Percentage of Area of Hydraulically Connected Townships in WABs with No August Availability

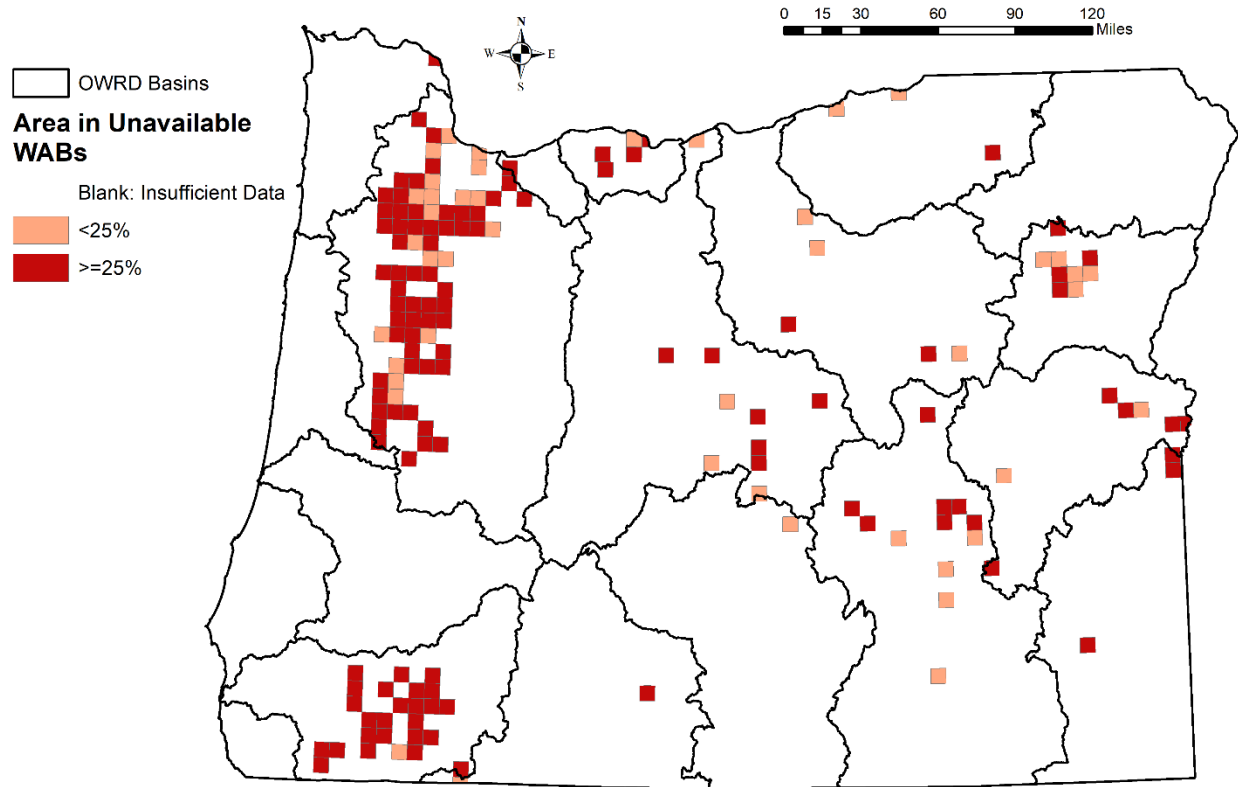


Figure 7: Percentage of area in each hydraulically-connected Township within WABs lacking August availability. A percentage greater than 25% was considered concerning.

Findings of hydraulic connection are not currently recorded in any of the Department’s databases. For the purposes of this first iteration of the map, the findings were read directly from a relatively recent subset of review files. The readable files were those in the .docx format, and the Python code that extracted the findings assumed:

1. Well numbers as indicated on the GW review correspond to POD numbers in WRIS
2. If a well is hydraulically connected to any surface water source in the review, then it is considered hydraulically connected to every WAB within the Township. For small WABs, this assumption may indicate spurious connections, but for large WABs (such as the Owyhee WAB), this assumption was much more conservative than evaluating hydraulic connection across an entire WAB.

A Township was only evaluated for hydraulic connection if it contained at least 3 POAs that were evaluated for hydraulic connection. A Township was considered hydraulically connected only if at least half of the POAs evaluated within it were found to be hydraulically connected. Using this test, only 161 Townships were evaluated for hydraulic connection (less than 6% of the state), of which 130 were found

to be connected. For Townships found to be generally hydraulically connected, concern was indicated if at least 25% of the Township's area was in WABs with no water available in August. This was the case in 117 Townships¹.

The relatively small number of Townships eligible for evaluation (161 out of nearly 3,000 Townships in the state) in part reflects the restriction that only GW reviews conducted after about 2014 could be queried. The earlier reviews were saved as .doc files instead of .docx, so extracting data from the tables contained within them is much more difficult. Expanding the code to extract findings from the reviews from .doc review files (from about 2004 to 2014) could roughly double the number of reviews eligible for evaluation, from about 1,000 to over 2,000. An additional limitation is that groundwater technical reviews in the Deschutes Mitigation Program area were not evaluated for hydraulic connection during the evaluation period.

Low-Yielding Wells

In some parts of Oregon, even the most productive aquifers are made of such low-permeability material that wells fail to yield sufficient water for typical irrigation use. Well yield is typically tested shortly after drilling and is reported on well reports, which are available through the Department's online [Well Report Query](#) tool. These well reports are not correlated to any aquifer system, are often not precisely located, and report well yield based on a variety of testing methods. However, it is a relatively large dataset consisting of approximately 260,000 well reports, and the sheer number of logs was used to compensate for the variable quality of the data as reported and entered in the Department's well log database.

¹ The Chehalem and Champoeg WABs are not in the WARS so were not considered for this purpose. However, a finding of unavailable, hydraulically-connected surface water would not increase the degree of concern in either WAB:

- The Chehalem WAB is primarily within the Chehalem Mountain GWLA, which indicates concern.
- The Champoeg WAB is primarily within township 4S2W, which already has a review finding of Insufficient Capacity (G-18849 with well MARI 51725) and an Excessively Declined well (MARI 1068). Both of these trigger a finding of significant concern, which supersedes concerning findings of unavailable hydraulically-connected surface water.

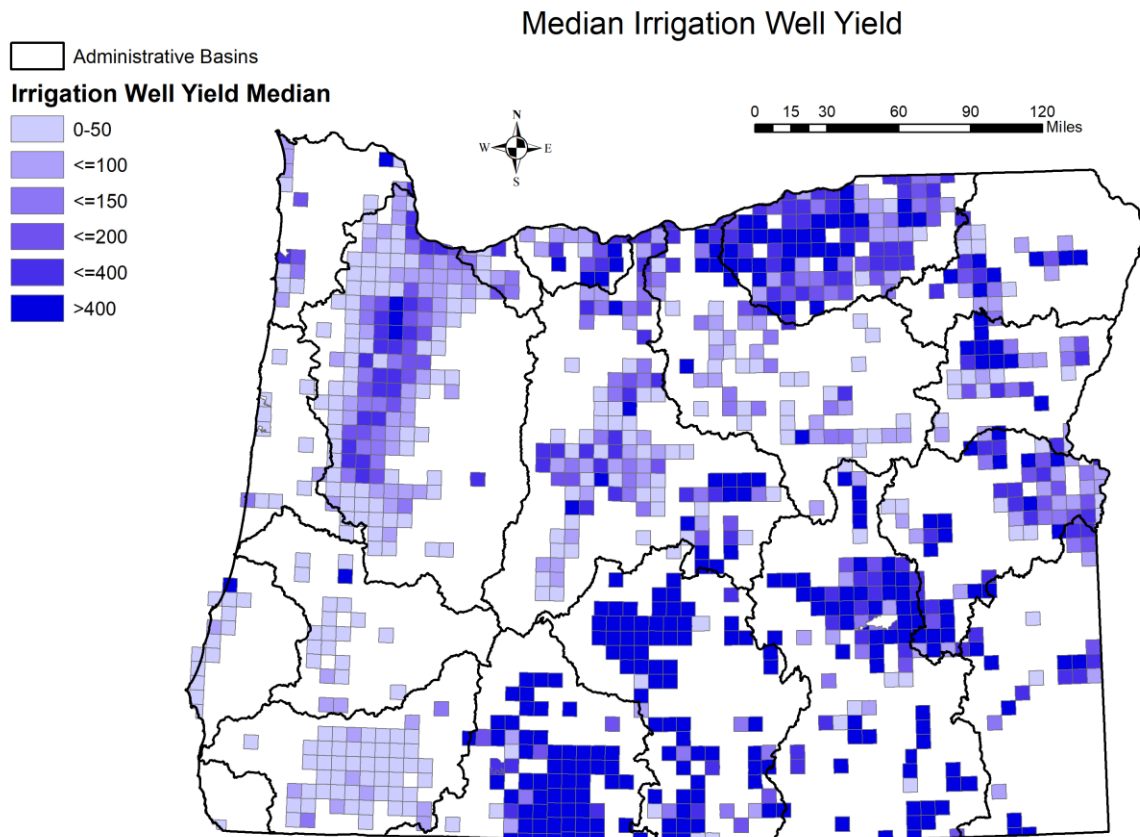


Figure 8: Median yield (gpm) of irrigation wells in each Township.

In order to detect areas likely limited by well yield, the median reported well yield among irrigation wells was calculated in each Township (Figure 8) and compared with a Township-specific threshold that represents a typical yield necessary for irrigation (Figure 9). The median well yield was queried only from irrigation wells, which tend to have a larger diameter than others to supply water faster than domestic wells. The appropriate yield threshold was calculated to represent the rate necessary to supply mean irrigation duty (depth of water for irrigation over the season, AF per acre per year) by pumping for 24 hours per day throughout the irrigation season. Conceptually, this threshold is the same as supplying half the duty while pumping 12 hours per day. The number of acres that a well should be able to irrigate in this way was estimated by calculating the mean number of acres per POA requested on GW right applications in the basin.

Estimated Minimum Thresholds for Well Yield for Irrigation

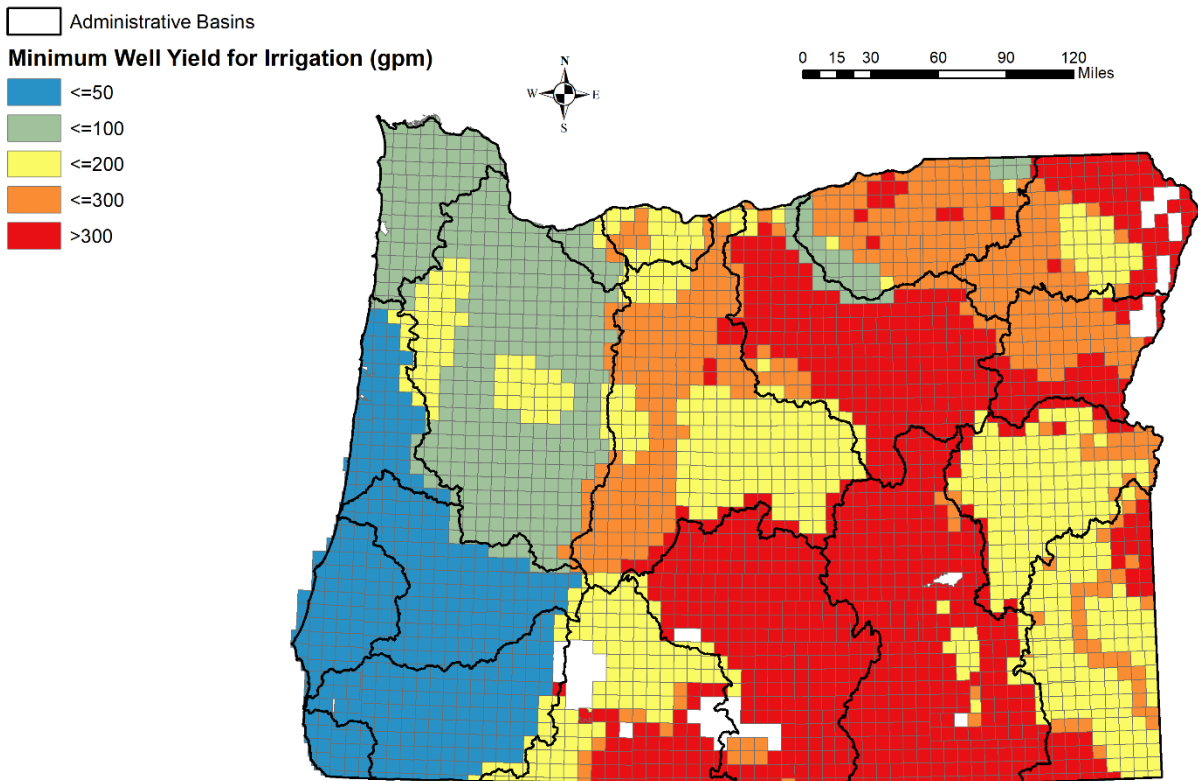


Figure 9: Estimated minimum well yield required for irrigation.

To compensate for the variable quality of reported well yields, a minimum of 3 tests per Township was required to evaluate the yield limitation. Using this minimum, the Townships below were found to be Yield-Limited (Figure 10). Many Townships had fewer than 3 well tests (Figure 11), and these were considered ineligible for designation as yield-limited.

In the calculation of concern ratings, yield limitation was considered the least reliable and least severe concern. Therefore, it was often overridden by other concerns, such that in Figure 1: 2021 the total number of Townships limited only by yield was 109.

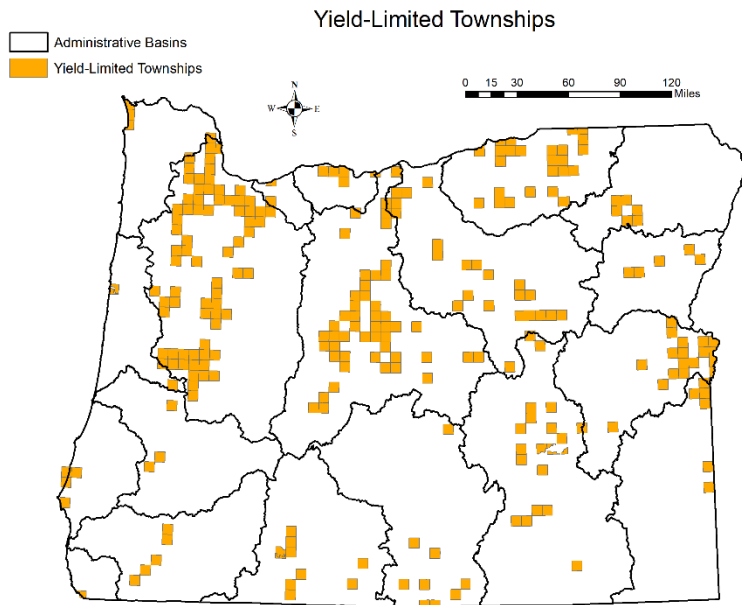


Figure 10: Townships found to be yield-limited, when at least 3 irrigation well tests are required per Township to calculate the median.

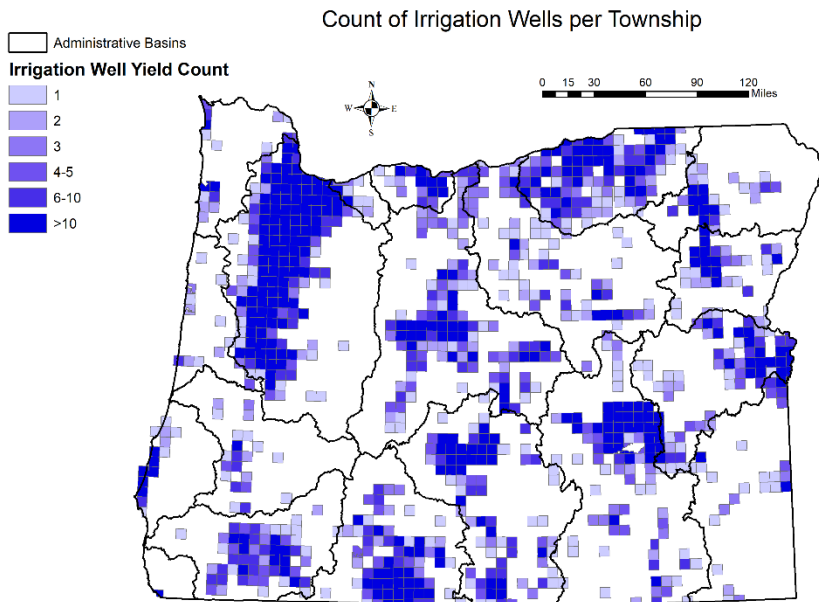


Figure 11: Count of irrigation wells per Township.

Display Choices

Spatial Resolution

Presenting GW resource concerns across Oregon requires reconciling a tension between fine-scale information and the ability to digest the map quickly. The previous version of this project, a map of GW vulnerability, included water level changes in individual wells, which was informative but difficult to process or even see on a presentation slide. For this map, both point-based information from wells and polygon areas subject to GW restrictions were summarized into concern ratings within Public Land Survey System Townships, which are typically squares 6 miles on a side. This choice of resolution had multiple advantages:

- Resolves spatial variability in GW resource concerns within basins.
- Distinguishable from a view of the entire state.
- Generally consistent size, allowing for consistent comparison of statistics between Townships.
- Shape is independent of surface hydrologic features, such as Water Availability Basins, such that the Township grid avoids unintentionally implying that aquifers are isolated along boundaries of surface water features.
- Much data within Departmental databases is located by Township but without further detail. For example, many well logs and application-stage POAs have a Township but no GPS coordinates.

Some drawbacks of using Townships include:

- Townships do not conform to polygons of existing GW Restricted Areas. This was resolved by assuming that a Township inherits the rules of a GWRA it intersects if the overlapping area is at least 25% of the Township's area. Using such a low threshold causes some spatial diffusion of these rules, but using a stricter threshold of 50% prevents some GWRAs from being captured by any Townships (such as between the Fort Rock GWRA and both the Deschutes and Klamath basins, and with the Cooper Mountain – Bull Mountain Critical Groundwater Area).
- Fine-scale spatial features like faults and boundaries of aquifer systems within a Township are neglected. Therefore, problems isolated to one aquifer may be indicated as impacting the entire aquifer system over the entire Township containing the observation well.

Aquifer Systems

A significant challenge to evaluating groundwater resources in Oregon is posed by the complex hydrogeology across the state. The Department has identified over 130 aquifers and 7 aquifer systems in Oregon. However, the depths, lateral extents, recharge zones, and degrees of hydraulic connection between them have not yet been systematically characterized across the state. Multiple aquifer systems may be present within a single Township (Figure 12), but without consistent evaluation of their hydraulic connection, it is difficult to determine whether problems observed in one system should be considered to impact other systems. The best way to identify distinct hydrogeologic units is through cooperative groundwater basin studies with the U.S. Geological Survey, but to date these basin studies

have only been conducted in 4 basins covering 28% of the state. So, for the purposes of this map, groundwater resource concerns are presented without distinction between aquifers or aquifer systems.

Legend

- Quaternary-Late Tertiary Sedimentary Aquifers
- Quaternary-Late Tertiary Volcanic and Volcaniclastic Rock Aquifers
- Late Tertiary Basaltic Aquifers
- Middle-Early Tertiary Volcanic and Volcaniclastic Rock Aquifers
- Tertiary Marine Volcanic and Sedimentary Rock Aquifers
- Mesozoic Granitic Rock Aquifers
- Mesozoic-Paleozoic Rock Aquifers

Aquifer Systems (All Sources)

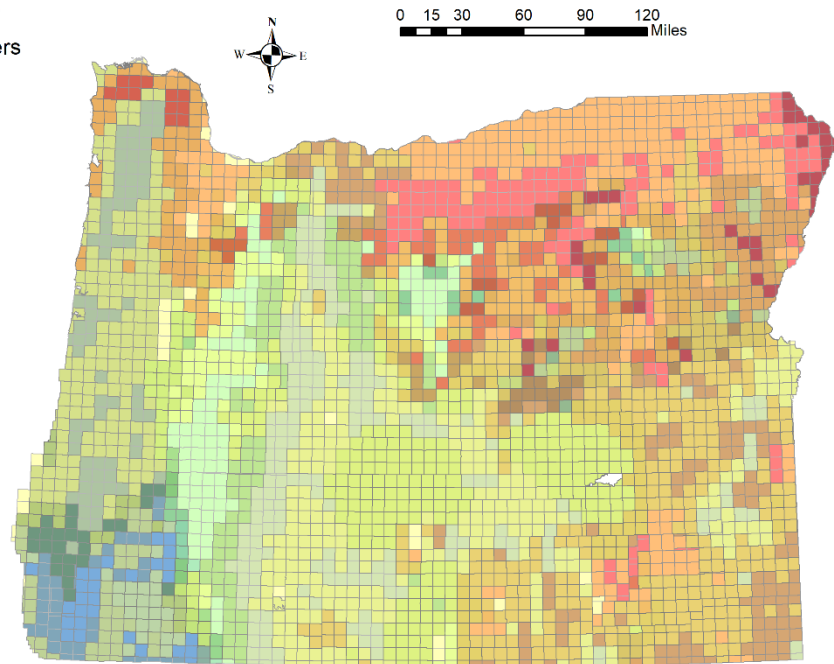


Figure 12: Known presence of aquifer systems from surficial exposure, reference in GW Restricted Areas, and/or presence of GWIS wells tied to the aquifer system. In Townships with multiple aquifer systems present, the translucent colors overlap, such that orange is the combination of yellow (QLTS) and red (LTBA).

Color Scale and Outlines

The color scale for resource concerns was chosen such that more significant concern was indicated both by deeper red color and darker colors, such that the image would still express substantially the same information to a colorblind person. Only Townships with concern ratings based on data were outlined. This allows a viewer to distinguish the generally connected areas with no concerning data available, even though the gray color used to represent them is within the range of darkness values used for the concern scale. Using a lighter color was considered as an option, but the fact that the vast majority of Townships lacking concerning data also lacked *any* data suggested that it was more appropriate to avoid implying that a lack of data implied a lack of concern. In addition, the potential for aquifers within a

Township to be disconnected means that stable water levels in one aquifer may not indicate a lack of concern in all aquifers in that area.

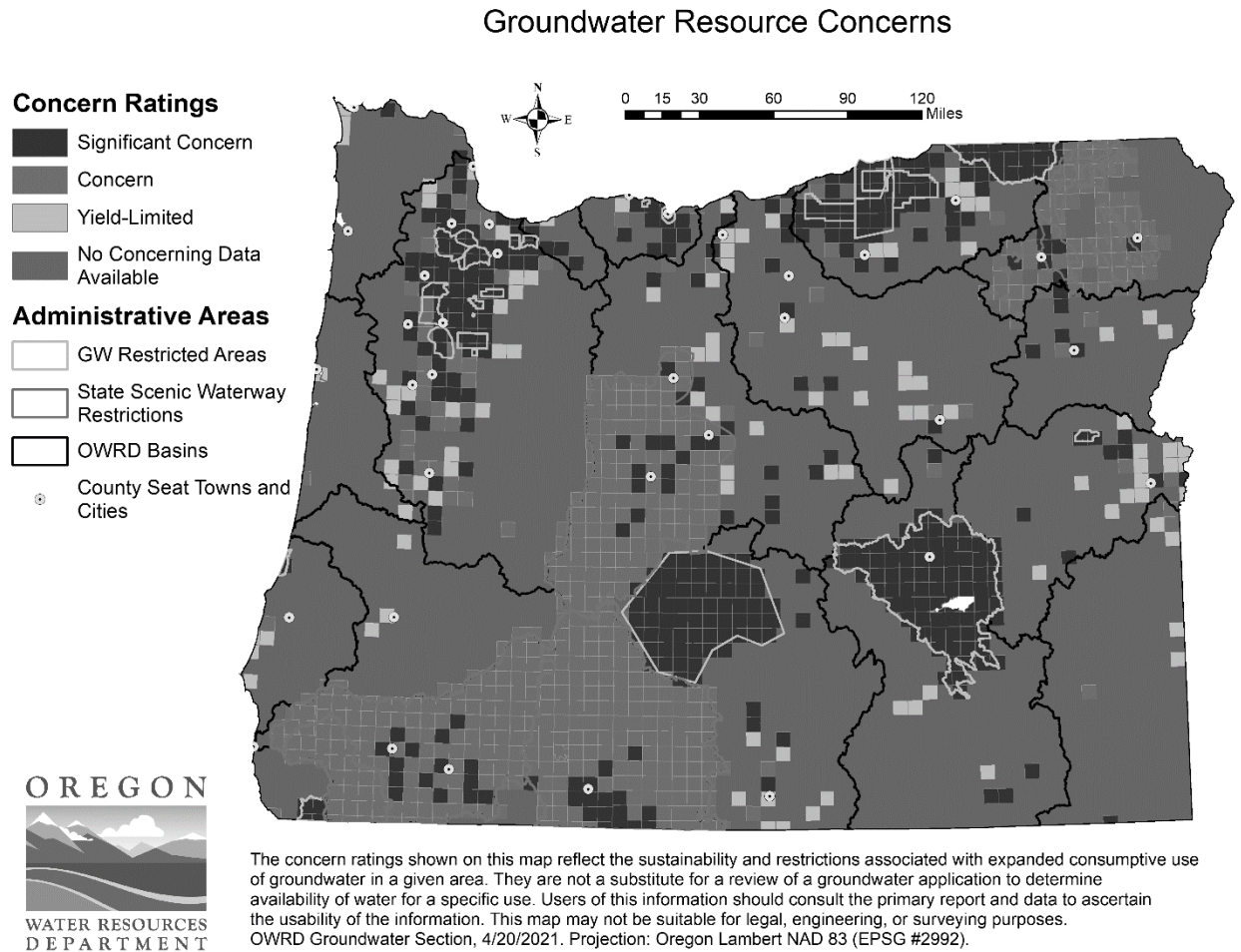


Figure 13: Grayscale version of the groundwater resource concerns map.

Discussion

Evaluation of Areas by Concern

The percentages of Oregon’s area estimated to have each concern rating are summarized in Table 1, along with relevant statistics about availability of surface water and recent applications for groundwater rights. These show that 62% of Oregon lacks sufficient data to evaluate concern using the approach described in this report, or have data not indicating concern given the analyses described above. Within the area with no concerning data, 76% of the area is in WABs with no August availability. Therefore, increased groundwater pumping in areas indicated as having no concerning data may nonetheless further deplete fully-allocated or over-allocated surface water bodies where groundwater and surface water are hydraulically connected.

Table 1: Summary of areas and recent water right applications for each concern rating. The columns “% of area with SW available in August” and “% of area with SW unavailable in August” refer to the percentage of area with each concern rating, not percentage of area across Oregon. These two columns do not sum to 100% within a given row (concern rating) because portions of the state have not been evaluated for SW availability, such that SW is neither available nor unavailable.

Concern Rating	% of Oregon area	% of area with SW available in August	% of area with SW unavailable in August	% of GW apps received since 2010	# of GW apps processed	# of GW apps approved	% of GW apps approved
Significant Concerns	15%	9%	69%	60%	1168	919	79%
Concerns	19%	2%	91%	23%	410	342	83%
Yield-Limited	4%	5%	86%	4%	67	59	88%
No Concerning Data Available	62%	6%	76%	14%	251	211	84%
Total	100%	N/A	N/A	100%	1896	1531	81%

Together, 34% of the state had concerns or significant concerns (Table 1). This combined area hosted 1719 (83%) of 2071 applications for groundwater permits and limited licenses since 2010, which suggests continued interest in expanding irrigation in these areas. The complexity of evaluating the impact of proposed changes in areas with significant groundwater restrictions makes these reviews more resource-intensive than they were in previous decades. Of the processed applications in Townships with concern or significant concern, 80% were approved (79% in areas with significant concern and 83% in areas with concern). Applications for drought permits were excluded from the approval analysis above, because they are subject to different criteria. The high rate of approval of recent applications in areas with concern or significant concern demonstrates that the associated restrictions and problems incorporated in the concern ratings do not necessarily preclude obtaining a groundwater right. This finding also reflects the extrapolation from point data to Townships with a typical area of 36 square miles and that may contain multiple layered or adjoining aquifers.

About 15% of the state indicated significant groundwater resource concerns. These estimates reflect a combination of Excessive Declines (Figure 3), exceeded permit conditions (Figure 5), findings of use beyond the capacity of the groundwater resource (Figure 6), and Groundwater Restricted Area designations (GWRAs). Most of this area with significant concern is within GWRAs. However, areas with significant concern have expanded outside of GWRAs in the Willamette, Hood, and Umatilla Basins. In addition, clusters of significant concern appear within most of the regions subject to State Scenic Waterway restrictions: Deschutes, Klamath, Rogue, and Wallowa-Grande Ronde.

Groundwater resource concerns were found in 19% of the state. The vast majority of this area is subject to State Scenic Waterway restrictions, though scattered Townships primarily within the Willamette and Umatilla basins reflect a combination of unavailable, hydraulically connected surface water sources (Figure 7) and moderately declined water levels.

Yield-Limited areas are distributed around the state but show up in greater concentrations along the Oregon coast, along the margins of the Willamette Valley, and in the John Day and Malheur basins (Figure 1: 2021, Figure 10). Relaxing the requirement for 3 irrigation well tests to calculate the median increases the number of yield-limited Townships, especially along the coast, but the limitation was maintained to support the reliability of the concern ratings.

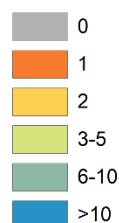
Robustness of Concern Ratings

In each Township, the number of data points supporting the concern rating was counted and presented in Figure 14. The following assumptions were employed when making the data counts:

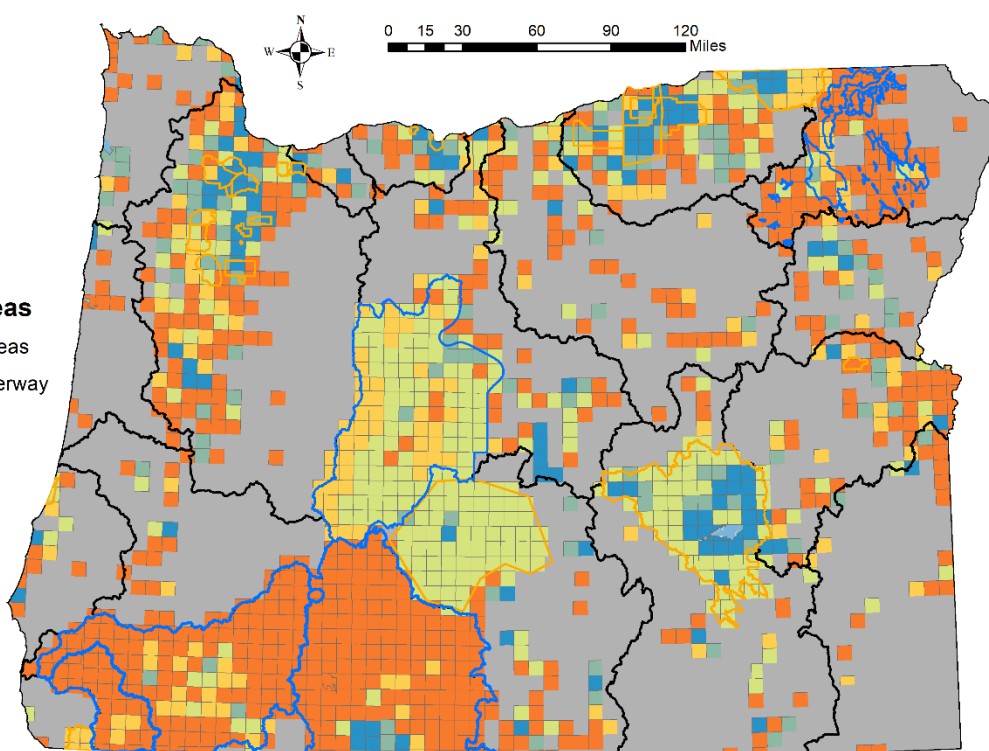
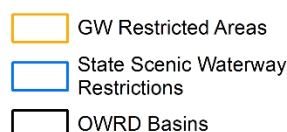
- The median well yield in each Township was considered 1 data point, even though a minimum of 3 well tests per Township were required, and most Townships utilized many more to calculate the median yield.
- Significant overlap with various areas subject to restriction each count only as 1 data point:
 - o Groundwater Restricted Areas.
 - o State Scenic Waterways lacking August availability.
 - o Hydraulically connected WABs lacking August availability, even though the finding of hydraulic connection must rest on evaluation of at least 3 POAs and typically reflects more.
- Each well with a set of water level records sufficient to evaluate a test of significant declines or exceeded permit conditions was considered a separate data point. This means that a well could have been counted both for evaluation of excessive declines and for each of the permit conditions for which it is a POA.

Number of Data Points Supporting Concern Ratings

Number of Supporting Data Points



Administrative Areas



The concern ratings shown on this map reflect the sustainability and restrictions associated with expanded consumptive use of groundwater in a given area. They are not a substitute for a review of a groundwater application to determine availability of water for a specific use. Users of this information should consult the primary report and data to ascertain the usability of the information. This map may not be suitable for legal, engineering, or surveying purposes. OWRD Groundwater Section, 4/20/2021. Projection: Oregon Lambert NAD 83 (EPSG #2992).

Figure 14: Number of data points supporting the concern rating in each Township.

Given the broad range of data sources and variability in data availability, it was important to evaluate the robustness of the concern ratings. A summary of the number of data points and Townships with each concern rating shows that Townships with significant concern tend to be the most robust of the ratings, with a median number of 3 data points per Township, a mean of over 6, and with only 13% of the 410 Townships based on only a single data point (Table 2). The majority of Townships rated as having no concerning data available had no data at all, as indicated by the median of 0 data points per Township.

Table 2: Summary of robustness of concern ratings for each concern category.

Concern Rating	# of Townships	# of data points	Median # of data per Township	Mean # of data per Township	% Townships with only 1 data point
Significant Concern	410	2708	3	6.6	13%
Concern	538	827	1	1.5	70%
Yield-Limited	109	109	1	1.0	100%
No Concerning Data Available	1837	1606	0	0.9	5%

Of the 2895 Townships in Oregon, 1545 (53%) have no data available to evaluate groundwater resource concerns using the methods outlined in this report. When the Department receives an application for groundwater use in areas with sparse data, any resulting Permits and Limited Licenses typically include conditions requiring regular reporting of water level measurements. The resulting water level data allow the Department to better evaluate groundwater availability in subsequent applications and in this report.

Future Analyses

More Comprehensive Treatment of SW/GW Connection

The current version of map only considers hydraulically connected surface water in a limited set of circumstances, such that the concern ratings often underestimate the likely long-term impacts on surface water from increased groundwater development. Hydraulic connection was evaluated in Townships where multiple wells were evaluated for hydraulic connection in GW technical reviews conducted beginning around 2014. The 160 Townships where this test was able to be applied represent only 5% of the area of Oregon (Figure 7). A Township includes concern if at least 25% of its area lies within the contributing area to a State Scenic Waterway (SSW) that has been triggered by GW appropriation, and approximately 20% of Townships were either evaluated for hydraulic connectivity or at least 25% within a triggered SSW. Future analyses will automatically incorporate findings from subsequent technical reviews of groundwater right applications. However, the Department should also seek to incorporate joint availability in a more comprehensive manner that accounts for the fact that groundwater and surface water are typically connected in Oregon and that most surface water is fully appropriated in August.

Distinct Aquifer Systems with Mixed Concern Ratings

For the purposes of this map, concerns were displayed without regard to the aquifer or aquifer system associated with a given concern. This assumption has the impact of indicating the maximum degree of concern in Townships with mixed concern ratings among poorly connected aquifer systems.

Future work can incorporate and indicate different levels of concern among distinct aquifer systems. This elaboration would be necessary in order to indicate “no concern” with any rigor, because a lack of concern should reflect unconcerning data in all distinct aquifer systems in an area. Challenges of

implementing this approach include identifying where aquifer systems are connected or not and deciding how to indicate or categorize mixed concern between disconnected systems within a Township. Given that many of the wells in the Department's groundwater database have not been correlated to a primary aquifer system, this elaboration would require deciding how problems associated with an unknown aquifer system should impact the overall concern.

Distinguishing levels of concern among different aquifer systems would also be useful for evaluation and update of Groundwater Restricted Areas, which are typically focused on a particular aquifer system.

Age of data

Concern here is estimated using all available data² in the Department's databases, without respect to the date when it was collected. More recent data are more relevant, given the potential for groundwater development to cause declining water levels. Future analyses should account for the age of the various data points that contribute to each Township's concern rating.

Works Cited

Mucken, A. and B. Bateman, 2017. Oregon's 2017 Integrated Water Resources Strategy. Oregon Water Resources Department, Salem, OR.
https://www.oregon.gov/owrd/wrdpublications1/2017_IWRS_Final.pdf.

Appendices

Appendices may be downloaded from OWRD's website as the file named "[2021 Groundwater Concerns Appendices](#)" on the "[Publications and Reports](#)" section of the Department's website. The current URL is:

https://www.oregon.gov/owrd/WRDPublications1/gw_concerns_appendices_2021.zip

- A. Spreadsheet of compiled data for each Township
- B. Python code for main analysis
- C. Python code to evaluate hydraulic connection from GW application reviews
- D. SQL code water level statistics
- E. SQL code for State Scenic Waterways areas intersecting each Township
- F. SQL code for median yield threshold

² As noted above in the section "Availability of Hydraulically-Connected Surface Water SourcesGW Review Findings," only reviews conducted after about year 2014 were used for determining hydraulic connection, because only those reviews saved as ".docx" files could be readily searched for this analysis.