A Manual for

Completion of

Hydrogeology Reviews and Studies

in compliance with the

Marion County Sensitive

Groundwater Overlay Zone

Prepared by

Marion County Planning Division

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A Manual for Completion of Hydrogeology Reviews and Studies in Compliance with the Marion County Sensitive Groundwater Overlay Zone

INTRODUCTION

Chapter 181 of the Marion County Rural Zoning Ordinance, the "Sensitive Groundwater Overlay" (SGO) zone, requires applicants for certain developments to submit with the application evidence of the long-term sustainability of groundwater resources in the vicinity of the new land use. Residential land divisions (partitions and subdivisions), and non-residential (commercial or industrial) developments, that use water from wells not subject to permitting requirements through the Oregon Water Resources Department (i.e., exempt-use wells) within the SGO boundary must comply with the requirements of the overlay zone.

Marion County provides this document with the intent of expanding upon the ordinance requirements and provide a format for registered geologists and engineering geologists hired by land-use applicants to complete required analyses and reports. Including all the elements described in this manual in a report should *not* be considered sufficient to satisfy the needs for complete, accurate information in all cases. This is a guide only. Professional judgment is still needed.

This manual may be revised as additional hydrogeologic data become available.

TYPES OF ANALYSIS REQUIRED

Chapter 181 refers to three types of reports. These are, in order of depth of analysis: Water Use Inventory, Hydrogeology Review, and Hydrogeology Study. The ordinance does not require completion of Water Use Inventories by a registered professional, so they are not discussed in detail here. A Water Use Inventory is the first study required for most small land divisions (two- or three-parcel partitions), but the results of the inventory may trigger the need for a Hydrogeology Review.

A Hydrogeology Review is more in-depth than a Water Use Inventory, and includes professional analysis and conclusions

regarding groundwater supply (see section 181.130, Exhibit A). A Hydrogeology Review does not, however, include gathering new data. The Review depends on careful collection and expert interpretation of existing information such as driller's well reports, previous studies, and geologic maps. If inadequate information exists to make sound conclusions, or if the Review indicates the proposed development may result in unsustainable use of the groundwater resource, a Hydrogeology Study is required. Therefore, *it is advisable for the professional performing the analysis to determine early on whether a Hydrogeology Study is likely to be needed*, so that data accumulation, if necessary, can begin as soon as possible.

Please note:

PEER REVIEW

A Hydrogeology Study includes all the elements of a Review plus the generation and interpretation of new data. Because the circumstances at each proposed development site vary, the ordinance relies upon the professional completing the Study to design the methods of investigation using generally accepted methods. Some guidance is provided, but the ordinance provides flexibility to contend with unique situations.

Please note:

HYDROGEOLOGY REVIEWS

Section 181.150 (Exhibit A) requires that Hydrogeology Reviews and Studies be reviewed by a registered geologist or engineering geologist *of the county's choice*. This peer review must be accomplished *before submittal of the land-use application*. The county strongly recommends that applicants apply for peer review **before** the Hydrogeology Review or Study gets underway so the consulting geologist and the peer reviewer can confer on the needs for the particular analysis. *If consensus cannot be reached regarding data needs or analysis methodology, the recommendations of the peer reviewer shall be followed by the consulting geologist in order for the county to approve the review.*

The peer review report shall state whether the Hydrogeology Review or Hydrogeology Study adequately

1) Addresses all required elements identified in Chapter 181 and described in this document

2) Uses generally accepted study procedures and assumptions

3) Supports all conclusions with appropriate data and analysis and all conclusions are reasonable.

The peer review report shall also include the final water balance results and other conclusions accepted by the peer reviewer, including any mitigation or water conservation practices on which the conclusions or water balance depend.

Section 181.100 in Exhibit A lists types of information that need to be included in a Hydrogeology Review. The information ultimately leads to a water budget. The ordinance requirements are designed to ensure that adequate data and information are provided to make an informed estimate of long-term water availability. The following sections explain the minimum information needed in order for the county to approve a Review.

Study Area

The ordinance requires that the study area (or "area of concern") extend "at least one-quarter mile" from the *boundary* of the subject property. Include the entirety of lots bisected by the one-quarter mile radius line. The study area should be enlarged to include:

- large-volume wells located within one-half mile *of the property boundary* (or farther if professional judgment indicates it is warranted);

- wells anecdotally implicated as causing interference or regional water-level decline;
- homogeneous development (i.e., include all of a subdivision, rather than letting the study area boundary bisect a development);

- hydrogeologic boundaries (if known) that could significantly influence groundwater movement (e.g., faults).

The acreage in the study area is used in calculating recharge (see the "Water Budget" subsection, below). This acreage must include *all* the area included in the study, including the full acreage

of lots wholly or partially within the one-quarter mile radius line, not just the area within the circle.

Maps

The report should include at least the following maps. All maps should include a scale (preferably a bar style) and a north arrow.

Examples of maps are provided in Exhibit B

- county assessor's map(s) or equivalent, showing all property ownership boundaries within the study area;
- USGS 7½ -minute quad showing the study area;
- surface geology; and
- the Water Use Inventory map, if one exists.

The applicant's property and study area (not just a one-quarter mile radius perimeter) should be clearly outlined on each map. If the study area does not follow the boundary of the lots within the one-quarter mile study area, explain why it differs.

All located wells within the study area, labeled with a unique identification number (preferably the OWRD well log number), must be shown on the quad. At a minimum, the wells used for the cross-sections (discussed below) and those discussed in the report need to be shown on the quad. A map, on a quad or some other base, must show *all* located wells. The text of the report needs to explain the method used for fixing well locations.

Cross-Sections

Although the county recognizes that adequate information to identify precise well locations is not always available, a reasonable attempt to locate wells should be made. All wells with a state permit must be shown on the map, and the report should identify the source of the information (e.g., field ID, other reports). Wells used for cross-sections need to be accurately located and identified on the map.

A sample cross-section is provided in Exhibit B

Include one or more cross-sections based on well locations to show subsurface structure and water-bearing zones. Include horizontal and vertical bar scales. In addition, cross-sections should show:

- surface elevation;
- stratigraphy

Tabular Well Data

- the screened or open interval in the well casings;
- water level data and date(s) measured;
- well deepening information; and
- the GRID well-identification number.

Include a table of located wells with the following information:

- Oregon Water Resources Dept. (OWRD) well log identification number;
- identification number used on topographic map (if different than OWRD's);
- township, range, section, and quarter section (or quarter-quarter section if available), and tax map and lot number;
- owner's name;
- address of well location (not necessarily the same as the address on the well report);
- approximate elevation of the well-head of the wells discussed in the report (the text of the report needs to explain how elevations were determined);
- dates of original drilling and any deepening(s);
- depth originally drilled and any deepening(s);
- depth to water and date measured;
- primary aquifer (e.g., Columbia River Basalt); and

Existing Information

- yield.

All data regarding depth to water and yield (including any more recent than that contained on the well report) and the date measured should be included.

Previous studies and mapping

If the consulting geologist has access to the OWRD GRID system, a printout of wells from that source should be included.

It would be beneficial if the consultant can provide the well data table in digital form, preferably in ASCII comma-delimited or other generic format, on a 3.5-inch floppy disc.

Deepenings & replacements

The consulting geologist must review existing*, publicly available* information and report the findings and conclusions from earlier work in the vicinity of the subject site (or in other areas with similar geologic characteristics). This may include geologic mapping, pumping tests, well monitoring data, theses, or other hydrogeologic investigations. The text of the Hydrogeology Review can include a general summary of this research, but it should explain how the existing information relates to the circumstances of the subject site.

Target Aquifer

The report needs to include an evaluation of identified well deepenings and replacements within the study area with a discussion of the consultant's conclusions regarding likely reasons. The detail of this evaluation may depend on how many have occurred. The report should address the relationship between deepenings and (1) long-term water-level (head) trends, (2) groundwater use, and (3) climate.

Water Budget

The report must state which aquifer is intended for development by the proposed new land-use. That is, the geologic formation from which water will be taken (e.g., basalt, alluvium, or marine sediments) needs to be identified. Identification of the exact water-bearing zone, if the formation includes more than one, is not required.

The report must include calculations to indicate an estimated partial water budget for the target aquifer in the study area. The

consultant should calculate the portion of the water budget that is pertinent to the amount of recharge that can be captured (i.e., that available without causing aquifer depletion).

The partial water budget must employ a generally accepted method that is:

- applicable to, and incorporates the effects of, the hydrogeologic conditions in the study area; and
- fully employs existing water-level (head) data.

The report must clearly document the sources of data, assumptions, and limitations of the methods used.

Conversion rates

Regarding the discharge side of the equation, the calculations need to include:

- Non-exempt use in the study area. For irrigation wells, annual use of 1.5 feet per acre may be assumed for primary irrigation and one foot per acre for supplemental irrigation. The consultant should explain the calculated consumption for other permitted uses;

Recognition of water conservation

- All existing lots and parcels in the study area at a rate of 525 gallons of water per day; and

- All lots proposed for the subject property at a rate of 525 gallons per day.

The Water Resources Department provides the following conversion rates in "Water Rights in Oregon" (1997):

Recharge rates for basalt aquifers are in Exhibit C

1 cubic foot/second =	7.48 gallons/second
	448.8 gallons/minute
	646,272 gallons/day
	1.98 acre-feet/day
1 acre-foot =	43,560 cubic feet
	325,851 gallons

To ensure comparability of findings, these rates should be used.

The rate of water use by the proposed development may be altered if the applicant demonstrates that water conservation practices or programs will reduce consumption (see section 181.100(C) in Exhibit A). This must still be based upon an assumption that a "typical" residence uses 525 gallons per day, and that the conservation measures will reduce consumption from that level. *If water conservation practices or programs are used to reduce the rate of water use, they shall be clearly described in the Review, including specific practices followed, who is implementing the practices or program and reasonable expectations for continuation of the practices or program. The peer reviewer shall document any such practices and programs in the peer-review report. Practices to be implemented on the subject property may be included as a condition of approval for subsequent land use applications.*

Conclusions

See sections 181.100(C) and (D) in Exhibit A for ordinance requirements regarding study results

Regarding recharge, the ordinance requires the use of "recharge data and assumptions contained in "Geologic and Hydrogeologic Study of the Residential Acreage-Zoned Areas of Marion County Underlain by the Columbia River Basalt and Older Rocks" (NGS, 1997) or explain why another source is used." The section of the NGS report and a table of average regional recharge rates for Columbia River Basalt aquifers are provided in Exhibit C. The figures in the table are based on six percent of precipitation being available after natural discharge. This level of available recharge may be inappropriate for the circumstances at any given location, as explained in the text of Exhibit C, so some attempt to verify the six percent or some other level of available recharge is needed. This may be via historic nearby monitoring.

Use an average annual recharge rate of two percent (2%) of precipitation for marine sediment aquifers, or provide adequate analyses to support a different recharge rate.

NGS also calculated a water budget on a section basis for the SGO, expressed in percent of recharge used (Exhibit D). The Hydrogeology Review should compare the NGS results with the water budget calculated for the more limited area. Particular attention should be paid to this issue if the table in Exhibit D

shows more than 90 percent of the recharge in the section will be consumed by full development and the Hydrogeology Review indicates a lower level of consumption for the study area.

Results

Do not convert the tabular data, which is section-based, to the study area. Be careful to use the actual size of the study area, not simply a quarter-section or quarter-mile radius circle.

The primary issue to address is whether the proposed use will result in withdrawal of more than 90 percent of the recharge to the study area before or after development of the proposed land use. In arriving at this conclusion, the assumptions and analysis discussed above need to be incorporated. These include:

HYDROGEOLOGY STUDIES

- The geologic conditions that affect recharge and discharge in the study area;
- Analysis of why wells in the study area have been deepened or replaced;
- Long-term water level (head) trends in the area, if available;

Please note:

- Predicted water use in the study area using development of all existing lots and future development of the proposed lots on the subject property (the water budget); and
- Whether adequate information exist to make reasonable conclusions on these factors.

In addition to the "90 percent of recharge" standard, the county must also make findings that the proposed use:

- Will not adversely affect the long-term water supply of existing uses or potential new uses on existing vacant parcels in the study area; and

New Information

- Will not "deplete" the groundwater resource over the long or short term.

Aquifer tests

Monitoring

These considerations are more subjective than the results of the water budget, but the county is interested in the professional conclusions of the consultant regarding these factors.

Results

If Hydrogeology Review shows the standards discussed in the previous section are satisfied, the peer-reviewed report must be submitted with the land-use application. If the calculations and conclusions of the Review demonstrate that the standards are not satisfied, a Hydrogeology Study is required. Keep in mind conservation measures or other alterations to the proposal may change the water budget sufficiently that it satisfies ordinance standards.

SPECIAL CIRCUMSTANCES

The purpose of a Hydrogeology Study is to give the applicant the opportunity to show that conditions are more favorable than indicated in the Hydrogeology Review. The requirements for a Hydrogeology Study start with the elements of a Hydrogeology Review, but include the requirement for generation of new data. The ordinance provides flexibility in the design of the project to satisfy the needs of the particular circumstances, so *the specifics of the work program should be determined in consultation with the peer reviewer assigned to the project*.

In addition to the requirements for a Hydrogeology Review, a Hydrogeology Study must:

- Identify aquifers;
- Characterize aquifer properties; and
- Estimate use from each aquifer.

The study area guidelines provided for a Hydrogeology Review are also valid for a Study.

SUMMARY

If existing information is inadequate to identify aquifers or characterize their use, aquifer testing data may be required. It is strongly advised that the subject property contain at least one of the wells

used for aquifer testing. Aquifer test procedures should be coordinated with the peer reviewer prior to performing the test.

Monthly water-level measurements from a well or wells on or around the subject property for at least one year will provide important information for completing the water budget. If the property owner has adequate time, these measurements are suggested, and are, in fact, preferable to aquifer tests.

ACKNOWLEDGMENTS

The county relies on the consultant preparing a Hydrogeology Study to make professional conclusions regarding the long-term sustainability of groundwater supply. The standard that the water budget shows the development will not result in more than 90 percent of recharge being used applies to Hydrogeology Studies.

The Sensitive Groundwater Overlay zone was designed to help insure the long-term sustainability of aquifers in the Columbia River Basalt or Marine Sediment formations. Not every property in the overlay zone will depend on water from these aquifers, however, as local conditions may result in adequate water availability from overlying strata. If this is the case, and the results of a Water Use Inventory showed a need for a Hydrogeology Review, a property owner can avoid the need to submit the Review under the following circumstances.

A report, prepared by a professional that is qualified to perform a Hydrogeology Review, explaining that the circumstances within the study area (as defined in the Hydrogeology Review section of this manual) can substitute for the Review. The report must show that *all* wells (that have well reports) in the study area are shallower than the targeted aquifers (Columbia River Basalt and Marine Sediments). Marion County requires this analysis by a professional because the well reports require interpretation.

The Sensitive Groundwater Overlay zone requires demonstration that new developments will not result in unsustainable use of groundwater. Specific requirements regarding submittal of data on groundwater supply result in additional study if initial investigations indicate long-term decline of the resource may occur as the result of existing or new development.

Reports prepared by professional geologists or engineering geologists must be reviewed by a peer representing the county. The design and performance of required studies should be coordinated with the peer-reviewer.

The design and/or functioning of a proposed development has an influence on water use. The overlay zone requirements allow consideration of these factors in concluding whether a particular use satisfies the standards in the ordinance.

This manual was prepared by Marion County Planning Division staff with assistance and input of staff from three firms contracted by the county to perform peer reviews (David Newton Associates, Inc., EMCON, and Pacific Hydro-Geology, Inc.) and from the firm contracted by the county to complete a hydrogeologic investigation for parts of the county (Northwest Geological Services, Inc.).

EXHIBIT A

From Chapter 181 of the Marion County Rural Zoning Ordinance, the "Sensitive Groundwater Overlay" zone.

181.090 WATER USE INVENTORIES. The purpose of a Water Use Inventory is to use existing information to gain specific information to make conclusions regarding ground-water availability for an individual lot or a partition. Findings, maps, and conclusions shall be presented in a clear and understandable report.

(A) A Water Use Inventory shall include, at a minimum, the following information in addition to the application requirements in section 181.040:

(1) A map showing all lots and parcels within at least one-quarter mile of the proposed development;

(2) The location of permitted wells with valid water rights within at least one-quarter mile of the proposed development, and the quantity of water permitted to be used;

(3) The estimated use of groundwater within at least one-quarter mile of the proposed development, including 525 gallons/day use for each lot and parcel and water use from permitted wells (as required in subsection (2) of this section);

(4) The quantity of water the proposed land use will utilize. If the proposal is for residential use, water use shall be calculated as 525 gallons/day. If the proposal is for a land division for residential purposes, all proposed lots or parcels shall be included in the calculation.

(B) A Water Use Inventory shall demonstrate the following:

(1) Whether the density of lots and parcels within one-quarter mile of the proposed development is greater or less than, or the same as, the threshold parcel size for the subject parcel. In the case of applications for a land division, the density calculation shall assume full development (i.e., the maximum number of lots or parcels that could be created, considering the minimum lot size in the zone) of the subject lot or parcel.

(2) The percent of of available recharge that will be utilized by all users (exempt and permitted), including the proposed new use, for the area within one-quarter mile of the subject lot or parcel based on use information generated for the Inventory and recharge data contained in "Geologic and Hydrogeologic Study of the Residential Acreage-Zoned

Areas of Marion County Underlain by the Columbia River Basalt and Older Rocks" (assuming one dwelling results in use of 525 gallons/day).

(C) Water Use Inventory Results.

(1) A Hydrogeology Review pursuant to section 181.100 shall be required if the Water Use Inventory establishes that any of the following circumstances exist:

(a) The average size of lots and parcels within one-quarter mile of the proposed development, including all existing lots and parcels and all proposed parcels in the subject application (if any), is smaller than the "threshold" size indicated on the applicable zone label on the official zoning map (for example, if the applicable zone is "SGO-5" and the average size of lots and parcels in the area is four acres); or

(b) The new use will result in consumption of more than 90 percent of the available recharge within one-quarter mile, based on use information generated for the Inventory and recharge data contained in "Geologic and Hydrogeologic Study of the Residential Acreage-Zoned Areas of Marion County Underlain by the Columbia River Basalt and Older Rocks" (NGS, 1997), and assuming one dwelling results in use of 525 gallons/day.

(2) If the Water Use Inventory demonstrates that the new use will result in consumption of 70 percent or more, but less than 90 percent, of the available recharge within one-quarter mile, based on use information generated as part of the Inventory and recharge data contained in "Geologic and Hydrogeologic Study of the Residential Acreage-Zoned Areas of Marion County Underlain by the Columbia River Basalt and Older Rocks" (NGS, 1997), and assuming one dwelling results in use of 525 gallons/day, the county may apply conditions pursuant to section 181.140 to approval of the proposed use.

(3) If the results of the Water Use Inventory establish that none of the circumstances described in subsections (1) or (2) of this section exist, no further evidence of water availability is required.

181.100 HYDROGEOLOGY REVIEWS. The purposes of a Hydrogeology Review are to provide information regarding the geology and hydrogeology of the area in the immediate vicinity of the proposed development and to furnish professional analysis of the information. A Hydrogeology Review generally requires compilation and analysis of existing information but not development of new data. Study findings, maps, and conclusions shall be presented in a clear and understandable report.

(A) A Hydrogeology Review report shall include, at a minimum, the following information:

(1) The information required for a Water Use Inventory in section 181.090(A);

(2) The location of all wells within at least one-quarter mile of the proposed development;

(3) Identification of aquifers in the area of the subject property;

(4) Compilation and review of available geologic and hydrogeologic studies of the area;

(5) Compilation and evaluation of well deepening and replacement well information;

(6) Compilation and analysis of existing geologic information, including representative well logs, physical location of representative wells, and an evaluation of the local stratigraphy and geologic structure;

(7) Compilation and analysis of existing water level and pump test information including evaluation of long-term stability of groundwater levels (heads); and

(8) Interpretation of the information gathered for subsections (1) through (7) of this section, including preparation of geologic and hydrogeologic maps and cross sections necessary to support and/or illustrate the interpretation.

(B) A Hydrogeology Review shall demonstrate the following:

(1) The available geologic and hydrogeologic information is sufficient to make a reasonably accurate estimate of the groundwater budget;

(2) The geologic conditions that affect the recharge and discharge of ground water;

(3) The locations and causes of well deepenings and/or replacements in the area of concern;

(4) Long-term water level (head) trends in the area of concern if available; and

(5) The groundwater budget for the area of concern indicates that additional recharge is available for the proposed new use. The groundwater budget will:

(a) assume that all lots and parcels in the area of concern are developed; and

(b) use the recharge data and assumptions contained in "Geologic and Hydrogeologic Study of the Residential Acreage-Zoned Areas of Marion County Underlain by the Columbia River Basalt and Older Rocks" (NGS, 1997) or explain why another source is used; and

(c) assume that one dwelling results in use of at least 525 gallons/day.

(C) Hydrogeology Review Results. A Hydrogeology Study pursuant to section 181.110 shall be required if the Hydrogeology Review establishes that any of the following circumstances exist. If none of the following circumstances exist, no further evidence of water availability is required. As used in this section, "proposed development" includes any water conservation practices or standards proposed in the application that will influence the quantity of water needed for the use.

(1) More than 90 percent of the recharge in the area of concern will be used after the proposed development is completed;

(2) The proposed use will adversely affect the long-term water supply of existing uses or potential new uses on existing vacant parcels in the area of concern;

(3) The additional proposed use will deplete the ground water resource over the long or short term; and

(4) Existing information is inadequate to determine whether any of the circumstances described in subsection (1) through (3) of this section exist.

181.110 HYDROGEOLOGY STUDIES. The purpose of a Hydrogeology Study is to provide professional conclusions and recommendations regarding long-term aquifer capacity in areas where there is already considerable evidence that the groundwater resource is inadequate to support additional development. A Hydrogeology Study will include development of new data to help determine the availability of groundwater in the immediate vicinity of a proposed development. Study findings, maps, and conclusions shall be presented in a clear and understandable report.

(A) A Hydrogeology Study report shall include, at a minimum, the following information:

(1) The information required for a Hydrogeology Review in section 181.100(A);

(2) Identification of aquifers in the area, characterization of aquifer properties, and estimation of the amount of use from each aquifer;

(3) Estimation of a detailed groundwater budget for the proposed development and surrounding area;

(4) Factual support for interpretations and study conclusions, which may include, but is not limited to: water level monitoring, pump tests to define aquifer properties, and surveys of well owners in the area; and

(5) Identification and discussion of all assumptions and methods employed in the study together with a discussion of the uncertainties of the analysis and the probable size of errors inherent in the assumptions and methods employed.

(B) The report shall include the following findings and recommendations in a form usable by the county in making a land-use decision:

(1) Identification of the level or density of development the aquifer(s) supplying the proposed development can sustain without exceeding 90 percent use of recharge;

(2) Identification of specific measures that can be employed to mitigate impact of the proposed development on existing users of groundwater and the groundwater resource.

* * *

181.130 QUALIFICATIONS FOR PERFORMANCE OF HYDROGEOLOGY REVIEWS AND STUDIES.

In order for the county to accept a Hydrogeology Review or Hydrogeology Study pursuant to Sections 181.100 and 181.110, the report shall bear the stamp of a geologist, engineering geologist, or professional engineer that qualifies under ORS 672, registered with the state of Oregon.

* * *

181.150 REVIEW OF HYDROGEOLOGY STUDIES. All studies and reviews required by this chapter shall be reviewed by a qualified professional, pursuant to Section 181.130, of the county's choice prior to acceptance of the land-use application. Such review shall include examination to ensure required elements have been completed, study procedures and assumptions are generally accepted, and all conclusions and recommendations are supported and reasonable.

From:"Geologic and Hydrogeologic Study of the Residential Acreage-Zoned Areas of Marion County Underlain by the Columbia River Basalt and Older Rocks" (NGS, 1997)

EXHIBIT C

4.3 Best Estimates Of Recharge

The estimates of average annual recharge (Section 4.1 and 4.2) range from less than 0.02 acre-feet/acre to nearly 0.7 acre-feet/acre, or from about 0.5 percent to 16 percent of the annual precipitation. Which of these estimates are most believable, and which should be used to estimate the amount of recharge available for new domestic (or other) wells?

These are important questions because, at the section-by-section resolution of this study, the available recharge is the difference between the estimated recharge and the estimated total use for a section. If the estimated recharge is higher (or lower) than the actual recharge, then less (more) water is actually available than estimated. Likewise, if the use estimate is lower (or higher) than the actual use, then the estimate of available recharge will be correspondingly higher (or lower) than the amount actually available in the section.

In our judgment, an estimate of average annual recharge of approximately 6 percent of the precipitation is the most defensible estimate for the Columbia River Basalt and Little Butte Series. This estimate is based on data for the Salem Heights and Sublimity-Stayton areas (Table 3). In both these areas:

- ? observation well data allow reasonable assessment of the annual fluctuations in water levels and good estimates of the short and long term rate of decline;
- ? a major part of the annual use was municipal (Table 4), which is probably more accurately estimated than irrigation, so the use estimates are probably more accurate than in other areas; and
- ? the extent of the declining areas are reasonably defined by observation wells and other wells with multiple water level measurements (Table 1).

The estimate of 6 percent of precipitation must be used with caution. It is the "most defensible" because it is based on the best data. However, the best known areas are problem areas.[1] When applying the 6 percent of precipitation estimate, we need to remember that the annual fluctuations in water levels indicate that recharge to the basalt in areas with stable water

[1] The "best" data are from areas where the water table (head) is or was declining. Many of the State Observation Wells were established, and numerous measurements made in them, because people complained to OWRD about affects of declining water levels (e.g. people had to deepen their wells or drill new wells, wells produced less than before the decline, or the pump in a well had to be lowered). As the agency responsible for protecting water resources, OWRD has to respond to such complaints, determine if there is a problem, and if there is, the cause. Consequently there are a lot of data in problem areas and few data in areas with stable or slowly declining water levels.

levels ranges from 0.7 to 4.4 percent of precipitation and averages only 2.3 percent (Section 4.2.1, Table 3).[2]

More recharge can be induced by drawing the aquifers down by pumping from wells. This is the primary reason why the recharge estimates for Stayton-Sublimity and Salem Heights are higher than those for the stable areas. The usual consequence of inducing an increase in recharge is a general decline of water levels. Generally, water levels will eventually stabilize at some new, lower elevation where the increase in use is balanced by the induced increase in recharge. However, the new level may be deep enough to be below the pumps in some wells or the bottoms of other wells (Section 3.5).

There are also geologic explanations for variations in recharge in the study area (As discussed in Section 3.2). Evaluation of the Macleay-Shaw and Pratum decline areas suggests that higher than average recharge in these areas results from a combination of geologic factor, and induced recharge. For example, the high estimated recharge in the Pratum area (~16 percent of precipitation) is partially explained by the presence of a perennial aquifer in the alluvium that overlies the basalt. The saturated alluvium:

- ? provides recharge to the basalt all year by leakage, (whereas basalts in upland areas generally get recharge only during the wet season) and protects the basalt from evapotranspiration losses in the dry season; and .
- ? the head in the saturated alluvium drives recharge into the basalt at a higher rate than it percolates from the thin, seasonal soil aquifers in slope and upland areas.

Additionally, where the basalt is buried beneath the alluvium the natural discharges to streams and springs are eliminated or greatly reduced. Thus a greater proportion of the recharge is available to wells than in other areas.

A perennial saturated zone in the Troutdale and/or Sardine Formation overlying the basalt would have a similar affect to the saturated alluvium. Such an overlying aquifer appears to be present in the Sardine Formation in part of the Shaw-Macleay decline area (Plate 2) and explains in part the high estimate of recharge there (8.5 percent of precipitation). However, the Highway 22 structure also appears to direct some extra recharge into the area (Section 2.5, Table 2).

There are few data available to estimate recharge to the marine sedimentary rocks that underlie the CRB. However, the three State Observation Wells that do tap aquifers in these strata (SOB 620, 678 and 694, Appendix C) provide 20 to 36 years of observations. (Table 3). These 3 wells indicate that annual recharge to the marine sedimentary rocks ranges from around 0.03 acre-feet/acre to 0.09 acre-feet/acre. This amount of recharge represents approximately 0.7 percent to 2.2 percent of the average local precipitation.

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[2] Recharge of as much as 5 percent of precipitation has been reported in some stable areas where several interflow zones are present in the Columbia River Basalt. However, the most detailed of these studies (for Chinook Estates, Ltd. in 8S/3W-32; NGS, 1994) assumed lower precipitation in upland areas than used for this study. Consequently, the amount of recharge (~0.2 acre-feet/acre) was estimated correctly, but the recharge as a percentage of precipitation (5%) was overestimated. The more extensive precipitation estimates presented herein (Section 3.1 and Figure 4) indicate that recharge of 0.2 acre-feet/acre is approximately 3.7 percent of the average local precipitation.

In summary, the "most defensible" estimate of recharge to the basalt aquifers is on the order of 6 percent of precipitation, but this estimate is based on the Salem Heights and Stayton-Sublimity areas, where more than average recharge was induced by pumping. The consequence of the additional recharge was that these areas experienced a general decline in water levels (heads).[3] Recharge in areas with apparently stable water levels averages about 3 percent of the average local precipitation (2.6 percent with a standard deviation of 1.2 percent; Section 4.2.1). Local geologic features may also enhance recharge. However, as discussed in Sections 5.2 and 6, these features must be evaluated in more detail than presented herein to refine the estimate beyond 6 percent.

[3] The decline ceased or slowed greatly in the Salem Heights area after city water was extended to the area in August, 1961 (Foxworthy, 1970). The decline appears to be continuing in the Stayton Sublimity area (Appendix C).

Recharge Estimates

From Table 4 of "Geologic and Hydrogeologic Study of the Residential Acreage-Zoned Areas of Marion County Underlain by the Columbia River Basalt and Older Rocks" (NGS, 1997)

Location	Estimated Recharge at 6% of precip (acre-ft/year)	Location	Estimated Recharge at 6% of precip. (acre-ft/year)	Location	Estimated Recharge at 6% of precip. (acre-ft/year)
6S/1E-19	167	8S/2W-2	169	8S/3W-36	199
6S/1E-20	180	8S/2W-3	166	8S/4W-11	134
6S/1E-21	195	8S/2W-4	164	8S/4W-12	185
6S/1E-27	209	8S/2W-9	180	8S/4W-13	213
6S/1E-28	204	8S/2W-10	180	8S/4W-14	158
6S/1E-29	197	8S/2W-11	172	8S/4W-23	185
6S/1E-30	174	8S/2W-12	174	8S/4W-24	229
6S/1E-31	193	8S/2W-13	169	8S/4W-25	226
6S/1E-33	231	8S/2W-14	175	8S/4W-26	182
6S/1E-34	202	8S/2W-15	177	8S/4W-36	220
6S/1W-25	157	8S/2W-16	177	9S/2W-6	165
6S/1W-36	167	8S/2W-17	165	9S/2W-7	185
7S/1E-5	223	8S/2W-19	184	9S/2W-17	191
7S/1E-6	212	8S/2W-20	167	9S/2W-18	221
7S/1E-7	225	8S/2W-21	174	9S/2W-19	220
7S/1E-8	238	8S/2W-22	174	9S/2W-20	191
7S/1E-17	244	8S/2W-23	168	9S/2W-21	162
7S/1E-18	229	8S/2W-24	171	9S/2W-28	162
7S/1W-1	191	8S/2W-25	149	9S/2W-29	187
7S/1W-2	181	8S/2W-26	154	9S/2W-30	189
7S/1W-3	168	8S/2W-27	162	9S/2W-32	187
7S/1W-10	176	8S/2W-30	183	9S/2W-33	166
7S/1W-11	195	8S/2W-31	164	9S/3W-1	199
7S/1W-12	204	8S/2W-32	145	9S/3W-2	181
7S/2W-12	135	8S/2W-35	154	9S/3W-3	185
7S/2W-13	135	8S/3W-5	178	9S/3W-4	200
7S/2W-14	135	8S/3W-6	155	9S/3W-9	170
7S/2W-24	135	8S/3W-7	195	9S/3W-10	192
7S/2W-25	145	8S/3W-8	184	9S/3W-11	187
7S/2W-26	140	8S/3W-17	187	9S/3W-12	212
7S/2W-33	137	8S/3W-18	197	9S/3W-13	226
7S/2W-34	167	8S/3W-19	213	9S/3W-14	187
7S/2W-35	158	8S/3W-20	197	9S/3W-15	158
7S/2W-36	170	8S/3W-21	188	9S/3W-22	171
8S/1W-17	188	8S/3W-22	182	9S/3W-23	171
8S/1W-18	166	8S/3W-24	175	9S/3W-24	225
8S/1W-19	158	8S/3W-25	177	9S/3W-25	144
8S/1W-20	164	8S/3W-26	189	9S/3W-26	143
8S/1W-28	167	8S/3W-27	194	9S/3W-27	133
8S/1W-29	162	8S/3W-28	203	9S/3W-28	133
8S/1W-30	158	8S/3W-29	200	9S/3W-34	143
8S/1W-31	151	8S/3W-30	218	9S/3W-35	144
8S/1W-32	162	8S/3W-31	214	9S/3W-36	143
8S/1W-33	165	8S/3W-32	212	10S/3W-1	150
8S/1W-34	172	8S/3W-33	205	10S/3W-2	135
8S/1W-35	173	8S/3W-34	199		
8S/2W-1	172	8S/3W-35	192		

Percent of Recharge Used

EXHIBIT D

From Table 4 of "Geologic and Hydrogeologic Study of the Residential Acreage-Zoned Areas of Marion County Underlain by the Columbia River Basalt and Older Rocks" (NGS, 1997)

Location	Percent of Recharge Used (Recharge = 6% of Precipitation)	Location	Percent of Recharge Used (Recharge = 6% of Precipitation)	Location	Percent of Recharge Used (Recharge = 6% of Precipitation)
6S/1E-19	162	8S/2W-2	107	8S/3W-36	40
6S/1E-20	84	8S/2W-3	71	8S/4W-11	2
6S/1E-21	2	8S/2W-4	64	8S/4W-12	24
6S/1E-27	5	8S/2W-9	17	8S/4W-13	9
6S/1E-28	14	8S/2W-10	100	8S/4W-14	91
6S/1E-29	12	8S/2W-11	156	8S/4W-23	23
6S/1E-30	109	8S/2W-12	123	8S/4W-24	8
6S/1E-31	239	8S/2W-13	194	8S/4W-25	30
6S/1E-33	4	8S/2W-14	311	8S/4W-26	143
6S/1E-34	9	8S/2W-15	81	8S/4W-36	18
6S/1W-25	147	8S/2W-16	31	9S/2W-6	97
6S/1W-36	117	8S/2W-17	35	9S/2W-7	43
7S/1E-5	1	8S/2W-19	10	9S/2W-17	11
7S/1E-6	12	8S/2W-20	115	9S/2W-18	7
7S/1E-7	7	8S/2W-21	35	9S/2W-19	48
7S/1E-8	7	8S/2W-22	20	9S/2W-20	30
7S/1E-17	0	8S/2W-23	31	9S/2W-21	8
7S/1E-18	1	8S/2W-24	46	9S/2W-28	64
7S/1W-1	68	8S/2W-25	285	9S/2W-29	24
7S/1W-2	30	8S/2W-26	110	9S/2W-30	41
7S/1W-3	58	8S/2W-27	179	9S/2W-32	7
7S/1W-10	102	8S/2W-30	18	9S/2W-33	139
7S/1W-11	5	8S/2W-31	101	9S/3W-1	18
7S/1W-12	5	8S/2W-32	265	9S/3W-2	26
7S/2W-12	695	8S/2W-35	33	9S/3W-3	2
7S/2W-13	427	8S/3W-5	32	9S/3W-4	10
7S/2W-14	358	8S/3W-6	34	9S/3W-9	28
7S/2W-24	401	8S/3W-7	28	9S/3W-10	30
7S/2W-25	261	8S/3W-8	28	9S/3W-11	4
7S/2W-26	287	8S/3W-17	51	9S/3W-12	5
7S/2W-33	192	8S/3W-18	58	9S/3W-13	1
7S/2W-34	93	8S/3W-19	10	9S/3W-14	8
7S/2W-35	67	8S/3W-20	28	9S/3W-15	17
7S/2W-36	14	8S/3W-21	28	9S/3W-22	165
8S/1W-17	33	8S/3W-22	23	9S/3W-23	14
8S/1W-18	115	8S/3W-24	60	9S/3W-24	41
8S/1W-19	39	8S/3W-25	93	9S/3W-25	2
8S/1W-20	94	8S/3W-26	17	9S/3W-26	2
8S/1W-28	53	8S/3W-27	20	9S/3W-27	12
8S/1W-29	40	8S/3W-28	33	9S/3W-28	61
8S/1W-30	30	8S/3W-29	22	9S/3W-34	497
8S/1W-31	126	8S/3W-30	7	9S/3W-35	30
8S/1W-32	35	8S/3W-31	21	9S/3W-36	21
8S/1W-33	165	8S/3W-32	24	10S/3W-1	28
8S/1W-34	248	8S/3W-33	43	10S/3W-2	158
8S/1W-35	322	8S/3W-34	32		
8S/2W-1	129	8S/3W-35	10		

EXHIBIT E

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Hydrogeology reviews* for the following locations have been peer-reviewed and found in conformity with Sensitive Groundwater Overlay zone requirements:

Township 7 South, Range 2 West, SE of the NW Quarter of Section 34
T8S, R1W, Sec. 1, SE/4
T8S, R1W, Sec. 29, SE/4
T8S, R2W, Sec. 2, NE/4, Tax Lot 800
T8S, R2W, Sec. 2, NE/4, Tax Lot 1400
T8S, R2W, Sec. 2, SW/4
T8S, R2W, Sec. 11, SW/4
T8S, R2W, Sec. 14, SW/4
T8S, R2W, Sec. 14, SE/4
T8S, R3W, Sec. 20, NE/4
T8S, R3W, Sec. 26, NW of the SE/4
T8S, R3W, Sec. 27, NE/4
T9S, R2W, Sec. 6