

METHODS AND RESULTS FOR ESTIMATING THE HYDRAULIC CHARACTERISTICS OF THE SUBSURFACE MATERIALS IN THE HARNEY BASIN, OREGON

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Contents

Contents	ii
Figures.....	iii
Tables.....	iv
Appendices.....	v
Acknowledgements.....	vii
Abstract	1
Introduction.....	2
Purpose	2
Geographic Area	3
Harney Basin Stratigraphic Units.....	5
Hydraulic Properties of Subsurface Materials.....	8
Determining Harney Basin Hydraulic Property Values.....	8
General Results	11
Relation to Well Construction.....	17
Relation to Well Performance	21
Property to Property Relation.....	25
Relation to Spatial Distribution	27
Relation to Stratigraphic Units.....	31
Hydrostratigraphic Units	35
Determining Harney Basin Hydrostratigraphic Units	35
Determining Hydraulic Property Values of Harney Basin Hydrostratigraphic Units	35
Marine Sedimentary Rocks (MSR).....	42
Upland Volcanic Rocks (UVR)	42
Silicic Lava Flows and Domes (SFD).....	44
Dry Mountain Lavas (DML)	45
Older Basin Fill (OBF)	46
High Lava Plains Basalt (HLP).....	47
Proximal Vent Deposits (PVD)	48
Voltage Basalt (VB).....	49
Younger Basin Fill (YBF).....	50
Subsequent Hydraulic Property Testing and Analyses Recommended.....	52
Summary	52
References Cited.....	56

Figures

Figure 1.	Locations of Harney County, Malheur Lake Administrative Basin, Harney Basin, and Greater Harney Valley Area	3
Figure 2.	Harney Basin surface water watersheds.....	4
Figure 3.	Greater Harney Valley Area	5
Figure 4.	Generalized geologic map of the Harney Basin	7
Figure 5.	Well location of aquifer test data analyzed for hydraulic properties using graphical methods..	9
Figure 6.	Location of well yield tests analyzed for hydraulic properties using numerical methods	10
Figure 7.	Cumulative distribution of specific capacity ((gallons / minute) / foot) results.....	14
Figure 8.	Cumulative distribution of transmissivity (feet ² / day) results	15
Figure 9.	Cumulative distribution of hydraulic conductivity (feet / day) results	16
Figure 10.	Specific capacity ((gallons / minute) / foot) relation to well construction	18
Figure 11.	Transmissivity (feet ² / day) relation to well construction.....	19
Figure 12.	Hydraulic conductivity (feet / day) relation to well construction	20
Figure 13.	Specific capacity ((gallons / minute) / foot) relation to well performance.....	22
Figure 14.	Transmissivity (feet ² / day) relation to well performance	23
Figure 15.	Hydraulic conductivity (feet / day) relation to well performance	24
Figure 16.	Specific capacity ((gallons / minute) / foot) relation to transmissivity (feet ² / day)	25
Figure 17.	Specific capacity ((gallons/minute) / foot) to relation hydraulic conductivity (feet / day).....	26
Figure 18.	Transmissivity (feet ² / day) relation to hydraulic conductivity (foot / day)	26
Figure 19.	Specific capacity spatial distribution map: all well depths, all value ranges	28
Figure 20.	Transmissivity spatial distribution map: all well depths, all value ranges	29
Figure 21.	Hydraulic conductivity spatial distribution map: all well depths, all value ranges	30
Figure 22.	Specific capacity of Harney Basin stratigraphic units.....	32
Figure 23.	Transmissivity of Harney Basin stratigraphic units.....	33
Figure 24.	Hydraulic conductivity of Harney Basin stratigraphic units.....	34
Figure 25.	Surficial map of Harney Basin hydrostratigraphic units.....	37
Figure 26.	Specific capacity of Harney Basin hydrostratigraphic units.....	38
Figure 27.	Transmissivity of Harney Basin hydrostratigraphic units.....	39
Figure 28.	Hydraulic conductivity of Harney Basin hydrostratigraphic units.....	40

Tables

Table 1.	Harney Basin surface water watersheds.....	4
Table 2.	List of Harney Basin stratigraphic units.....	6
Table 3.	Summary of specific capacity results.....	12
Table 4.	Summary of transmissivity results.....	13
Table 5.	Summary of hydraulic conductivity results.....	13
Table 6.	List of Harney Basin hydrostratigraphic units.....	36
Table 7.	Marine Sedimentary Rocks hydrostratigraphic unit hydraulic property statistics.....	42
Table 8.	Upland Volcanic Rocks hydrostratigraphic unit hydraulic property statistics.....	43
Table 9.	Silicic Lava Flows and Domes hydrostratigraphic unit hydraulic property statistics.....	44
Table 10.	Dry Mountain Lavas hydrostratigraphic unit hydraulic property statistics.....	45
Table 11.	Older Basin Fill hydrostratigraphic unit hydraulic property statistics.....	47
Table 12.	High Lava Plains Basalt hydrostratigraphic unit hydraulic property statistics.....	48
Table 13.	Proximal Vent Deposits hydrostratigraphic unit hydraulic property statistics.....	49
Table 14.	Voltage Basalt hydrostratigraphic unit hydraulic property statistics.....	50
Table 15.	Younger Basin Fill hydrostratigraphic unit hydraulic property statistics.....	51

Appendices

Appendix A Description of Compiled Harney Basin Stratigraphic Units

Mesozoic rocks – (Mzu)
Older volcanic rocks – (Tov)
Steens Basalt – (Tsb)
Devine Canyon Ash-flow Tuff – (Tdv)
Andesite – (Ta)
Basalt and andesite of Dry Mountain – (Tdm)
Basalt of Harney Lake – (Tbh)
Drinkwater Basalt – (Tdw)
Rattlesnake Ash-flow tuff – (Trt)
Olivine basalt and andesite of Gum Boot Canyon – (Tobg)
Olivine basalt – (Tob)
Silicic lava flows and domes – (Trd)
Tuffaceous sedimentary rocks and tuff – (Tts)
Basalt – (QTb)
Voltage basalt – (Qvb)
Mafic vent complexes – (QTV)
Diamond Crater basalt and tephra – (Qdc)
Quaternary Sedimentary deposits – (Qs)

Appendix B Hydrogeologic Terminology and Description of Hydraulic Properties of Subsurface Materials

Hydrogeologic Terminology
Description of Hydraulic Properties of Subsurface Materials

Appendix C Aquifer Tests

Ideal Aquifer Tests
Log-log Graphical Method for Analyzing Ideal Aquifer Test Data
Semi-log Time versus Drawdown Graphical Method for Analyzing Ideal Aquifer Test Data
Semi-log Time versus Recovery Graphical Method for Analyzing Ideal Aquifer Test Data
Earth Tide and Barometric Pressure Change Influence on Aquifer Test Data
No-Flow and Recharge Boundary Influence on Aquifer Test Data
Groundwater Leakage Influence on Aquifer Test Data
Unconfined Groundwater Delayed Yield Influence on Aquifer Test Data
Noordbergum Effect Influence on Aquifer Test Data
Non-Test Well Influence on Aquifer Test Data
Well Loss Influence on Aquifer Test Data from the Pumping Well

Appendix D Specific Capacity

Specific Capacity
Estimating Transmissivity from Specific Capacity
Vorhis Numerical Method for Estimating Transmissivity from Specific Capacity

Appendix E	Aquifer-Interference Test Conducted and Analyzed
	Barometric Pressure During Test Pumping Well Discharge Rate During Test Water Levels Measured During Test Graphical Analysis Conducted
Appendix F	Analysis of Recorder Data
	Analysis of Recorder Data from Northeast Harney Valley Analysis of Recorder Data from Northwest of Harney Lake
Appendix G	Analysis of Pump Test Data
	Oregon Pump Test Program Pump Test Program Requirements Hydraulic Property Analysis of Pump Test Data
Appendix H	Table of Selected Harney Basin Aquifer Tests
Appendix I	Specific Capacity and Transmissivity from Well Yield Tests
	Water Well Reports Water Well Reports: Types-Sources Water Well Reports: Best Available Well Location Geographic Area to Identify Water Well Reports to Query and Select Selection of Water Well Report Subset for Harney Well Test Master Data Table Calculating Specific Capacity then Transmissivity from Well Yield Test Data Transmissivity Calculated by Vorhis Numerical Method versus Semi-log Graphical Method
Appendix J	Table Listing Wells with Well Yield Test Data and Related Harney Basin Study Hydraulic Property Calculation Results
Appendix K	Hydraulic Property Spatial Distribution Maps
Appendix L	Well Lithology Conversion to Stratigraphic Units
	Well Lithology and Water Bearing Zones Well Lithology Conversion to Stratigraphic Units

Appendix M Well Open Interval Definitions, Calculations, and Use

Well Construction Data

Well Construction Features Identified as Open Interval

Definition and Calculation for Total Open Interval

Definition and Calculation for Saturated Open Interval

Definition and Calculation for Water-Bearing Open Interval within a Total Open Interval

Definition and Calculation for Water-Bearing Open Interval within a Saturated Open Interval

Well Open Interval Option Selected for Harney Basin Groundwater Investigation

Well Open Interval Use: Calculate Hydraulic Conductivity from Transmissivity

Well Open Interval Use: Calculate Stratigraphic Unit Percentage of Well Open Interval

Well Open Interval Use: Calculate Hydrostratigraphic Unit Percentage of Well Open Interval

Well Open Interval Use: Assign Hydraulic Property to Stratigraphic and Hydrostratigraphic Units

Appendix N Summary Statistics of Hydraulic Property Values for Each Harney Basin Stratigraphic Unit

Appendix O Summary Statistics of Hydraulic Property Values for Each Harney Basin Hydrostratigraphic Unit

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Abstract

A joint U.S. Geological Survey and Oregon Water Resources Department Harney Basin groundwater investigation was conducted to better define the 5,243 mi² Harney Basin groundwater system, its water budget, and its response to groundwater development. Observed groundwater level declines and questions about groundwater resource sustainability prompted the investigation. This report presents the hydraulic properties of the basin's subsurface materials. The investigation used existing data from one aquifer-interference test, two automated groundwater level recorders at wells influenced by nearby pumping wells, 41 single well pump tests, and more than 1,000 well yield tests to characterize the hydraulic properties of 18 stratigraphic units grouped into nine hydrostratigraphic units. The data from these tests can be divided into two data categories (aquifer test data and specific capacity data) that required using different data analysis methods (graphical method and numerical method respectively). All the tests yielded data useful to characterize well response to pumping (specific capacity) and subsurface control on groundwater flow (transmissivity by all tests and hydraulic conductivity by most tests). Only the two automated groundwater level recorders yielded data sufficient to calculate groundwater storage coefficients. Only the one aquifer-interference test yielded sufficient data to indicate possible deformability, plasticity, and/or elasticity of one or more Harney Basin subsurface materials. Analyses indicate specific capacity, transmissivity, and hydraulic conductivity values are generally spatially ubiquitous for smaller values and increasingly spatially segregated for the largest values. The largest value range is most concentrated along the Harney Valley perimeter and the Riley vicinity. The largest median hydraulic property values relate to younger volcanic deposits, intermediate median values relate to Silicic and High Lava Plains volcanic deposits and basin-fill sediments, and the smallest median values generally relate to upland deposits. The two storage coefficient values available indicate unconfined to intermediate (between confined and unconfined) groundwater storage. Conducting additional tests (single pumping well with observation wells) to more completely characterize the shallow and deep, upland and lowland hydraulic property, particularly storage coefficient, of each hydrostratigraphic unit is recommended. The test results would refine well to well interaction calculations and aid future groundwater modeling efforts to characterize Harney Basin groundwater flow and storage under various conditions or scenarios.

Introduction

This report presents the hydraulic properties of subsurface materials in the Harney Basin. The report is part of a multi-year joint U.S. Geological Survey and Oregon Water Resources Department investigation to better define the basin's groundwater system, its water budget, and its response to groundwater development. Observed groundwater level declines and questions about groundwater resource sustainability prompted the investigation.

Geologic units possess hydraulic characteristics that control groundwater recharge, flow, discharge, storage, and the groundwater system's response to natural and anthropogenic stress such as floods, drought, change in native plant evapotranspiration, and groundwater pumping. The basic parameters used to characterize subsurface hydraulic properties, the estimates or ranges of those parameter values for the various Harney Basin subsurface materials (stratigraphic units and hydrostratigraphic units), and the methods used to obtain those values are presented in this report. Knowing the hydraulic properties of the basin's subsurface materials is important for understanding and describing the basin's groundwater flow system, the observed groundwater level declines, the sustainability of the groundwater resource, and the development of numerical groundwater models that represent the groundwater system.

Purpose

The purpose of this report is to present a summary of the stratigraphic units in the Harney Basin, the various methods used to determine hydraulic property values of these units, the hydraulic property values determined, and how stratigraphic units with similar hydraulic and physical properties were grouped into hydrostratigraphic units. The joint U.S. Geological Survey and Oregon Water Resources Department investigation needed the hydraulic property values to characterize the basin's hydrogeology, the natural groundwater flow system, and the groundwater flow system response to stress and change (natural and anthropogenic), including actual or potential interference. The hydraulic property values are also necessary for developing a numerical groundwater flow model representing the basin.

Geographic Area

The 5,243 square-mile (mi²) Harney Basin is mostly located in northern Harney County where it overlaps the north portion of the Malheur Lake Administrative Basin (figure 1). It is a closed surface water basin that drains to Malheur and Harney Lakes via three major surface water watersheds identified by the Oregon Water Resources Board (1967) as Silver Creek, Silvies River, and Donner und Blitzen River (table 1, figure 2). Most development in the basin has occurred within a 2,440 mi² sub-area informally and unofficially named in this report as the “Greater Harney Valley Area” shown in figure 3. That area includes Harney Valley, the adjoining Silver Creek, Donner und Blitzen River, and Virginia valleys, and the lower elevation flanks of uplands facing those valleys. The area was delineated by selecting hydrologic units (HU12s) from the USGS Watershed Boundary Dataset (WBD) located within those valleys and along the lower elevation portion of the upland flanks facing those valleys. Documentation of the Watershed Boundary Dataset hydrologic units can be found in a techniques and methods report by the U.S. Geological Survey and others (2013).

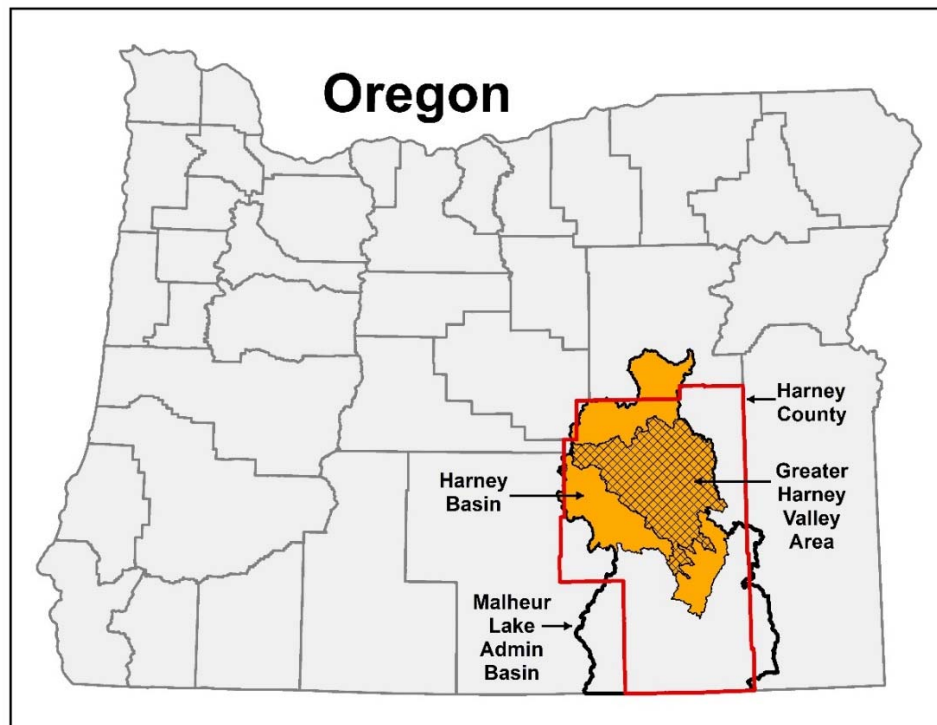


Figure 1. Locations of Harney County, Malheur Lake Administrative Basin, Harney Basin, and Greater Harney Valley Area

Table 1. Harney Basin surface water watersheds

Watershed ¹	Area ²	
	(acres)	(square-miles)
Silvies River	1,381,270	2,158
Silver Creek	1,345,900	2,103
Donner und Blitzen River	628,515	982
Harney Basin Total	3,355,685	5,243
"Greater Harney Valley Area"³	1,561,313	2,440

¹Each watershed was derived and adapted from Oregon Water Resources Board (1967)

²Each area value was obtained using GIS geometry calculation

³Harney Basin adjoining lowland valleys (Harney, Silver, Blitzen, Virginia) and bounding uplands

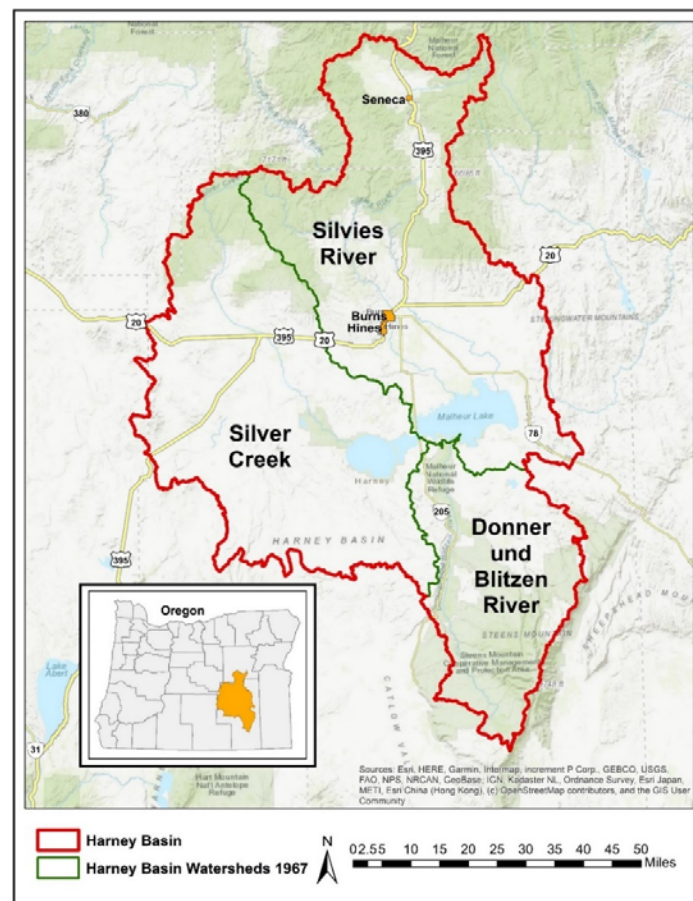


Figure 2. Harney Basin surface water watersheds

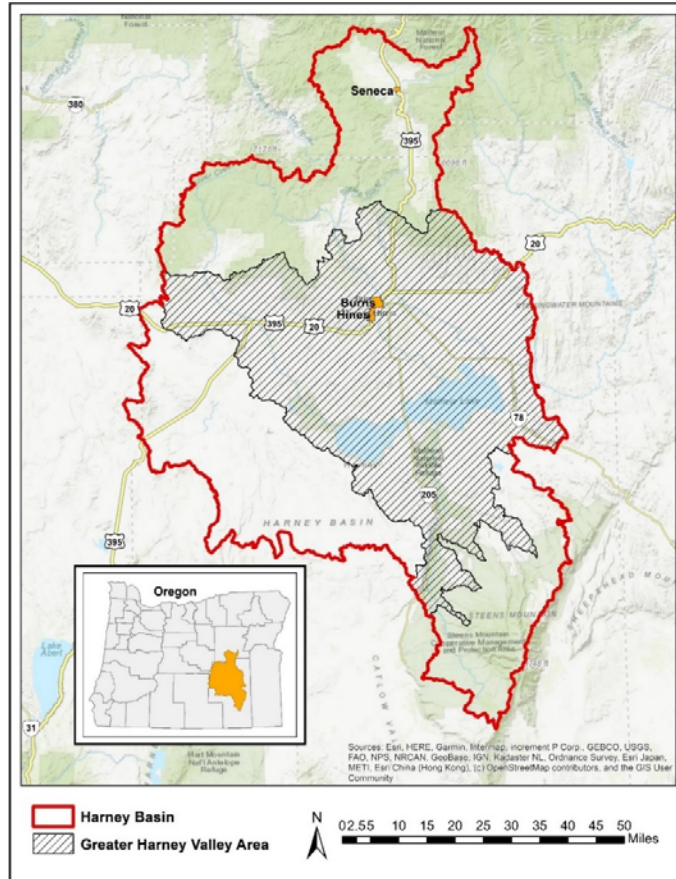


Figure 3. Greater Harney Valley Area

Harney Basin Stratigraphic Units

Every stratigraphic unit has hydraulic properties that control groundwater recharge, movement (flow), discharge, and storage within the subsurface. Boschmann (2021) identified 18 stratigraphic units in the Harney Basin (table 2) compiled from previous studies. Figure 4 shows the surface exposure of those units, and appendix A presents a brief description of each unit. Methods and results for determining the hydraulic properties for each stratigraphic unit listed in table 2 are presented in following sections of this report and accompanying appendices. Those hydraulic properties were used jointly with the geologic descriptions summarized in appendix A to group the stratigraphic units into hydrostratigraphic units that are listed and described later in this report. Additional discussion of the basin's general geology, geologic history, and available geologic references is beyond the scope of this report but can be found in companion reports (Gingerich and others, 2021; Boschmann, 2021).

Table 2. List of Harney Basin stratigraphic units

Stratigraphic Units (Oldest to Youngest)	
Unit Name	Unit Abbreviation
Mesozoic rocks	Mzu
Older volcanic rocks	Tov
Steens Basalt	Tsb
Devine Canyon Ash-flow Tuff	Tdv
Andesite	Ta
Basalt and andesite of Dry Mountain	Tdm
Basalt of Harney Lake	Tbh
Drinkwater basalt	Tdw
Rattlesnake Ash-flow tuff	Trt
Olivine basalt and andesite of Gum Boot Canyon	Tobg
Olivine basalt	Tob
Silicic lava flows and domes	Trd
Tuffaceous sedimentary rocks and tuff	Tts
Pleistocene-Pliocene basalt	QTb
Voltage basalt	Qvb
Mafic vent complexes	QTV
Diamond Craters basalt and tephra	Qdc
Quaternary sedimentary deposits	Qs

Notes:

The stratigraphic units are listed from oldest on top to youngest on bottom

The stratigraphic units are as compiled by Boschmann (2021) from previous studies

Appendix A presents a brief description for each stratigraphic unit

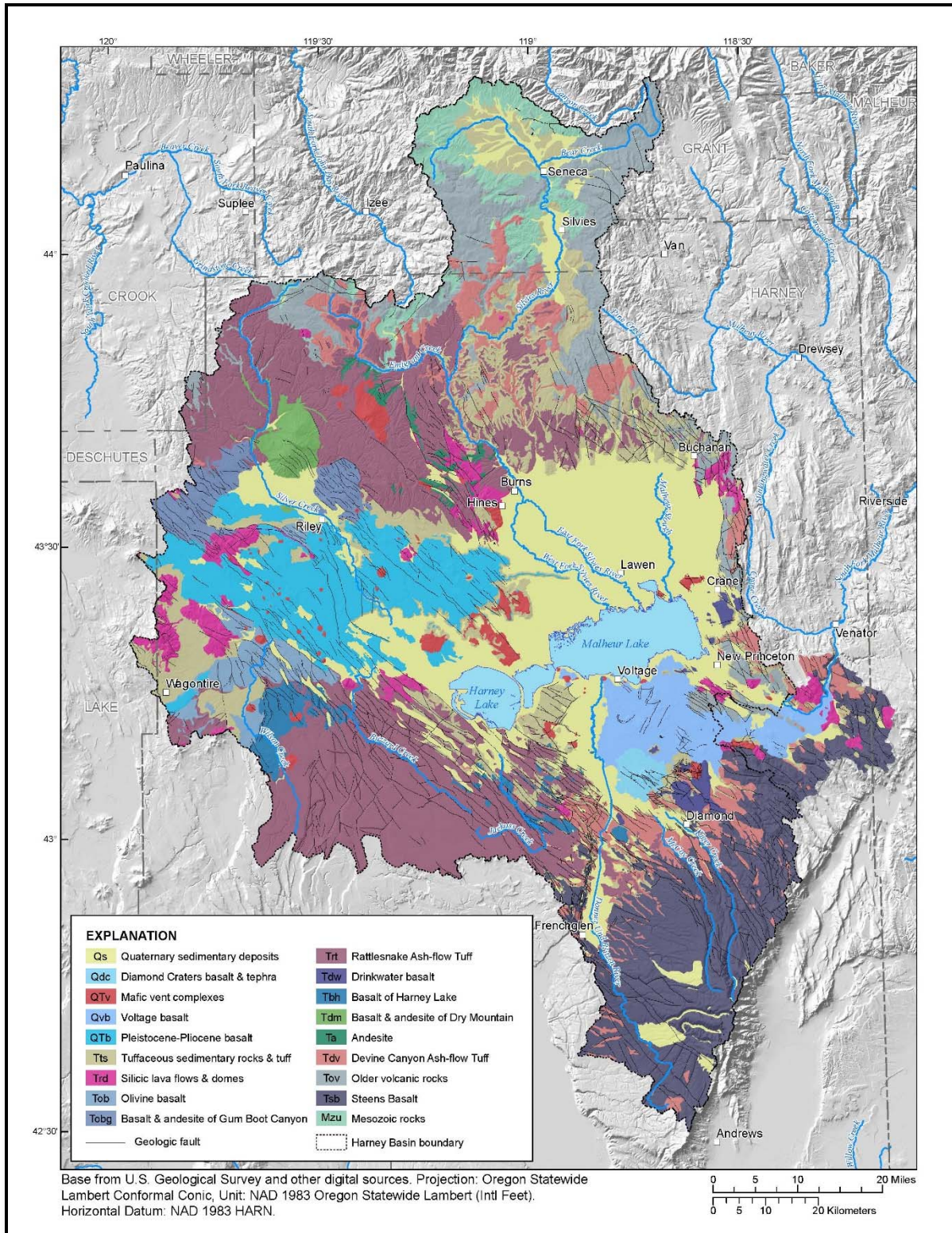


Figure 4. Generalized geologic map of the Harney Basin
[From Boschmann, 2021]

Hydraulic Properties of Subsurface Materials

Each stratigraphic unit has hydraulic properties that control groundwater recharge, movement (flow), discharge, and storage within the subsurface as previously noted. Appendix B presents the basic parameters used to characterize subsurface hydraulic properties as well as basic hydrogeologic terminology. Hydraulic property parameters most commonly used (including in this investigation) are transmissivity (T), hydraulic conductivity (K), and storage coefficient (S) as defined in appendix B. Thorough discussions of hydraulic property parameters and methods for determining them can be found in Bear (1979), Cooper and Jacob (1946), Davis and DeWeist (1966), Fetter (2001), Freeze and Cherry (1979), Heath (1983), Lohman (1972a), Theis (1935), and Vorhis (1979).

Determining Harney Basin Hydraulic Property Values

The hydraulic properties of Harney Basin subsurface materials were determined from two data categories (aquifer test data and specific capacity data) that required using different data analysis methods (graphical method and numerical method respectively). Appendix C describes aquifer tests in general, the common graphical methods used to determine hydraulic properties from aquifer test data, and possible influences affecting aquifer test data and analyses. Appendix D describes specific capacity and methods to estimate transmissivity from specific capacity data including the Vorhis (1979) numerical method. Appendices E, F, and G respectively describe one aquifer-interference test, two recorder well data sets, and 41 pump tests and the graphical analyses used to estimate transmissivity values from the 44 tests and storage coefficient values from two of the 44 tests. Figure 5 shows the test locations (all within the Harney Basin), and appendix H lists the hydraulic property results from the 44 tests. Appendix I describes how specific capacity values were derived from 1,451 well yield tests and how the Vorhis (1979) numerical method was used to estimate transmissivity values from the specific capacity values. Figure 6 shows the test locations (1,161 within the Harney Basin and 290 surrounding the basin), and appendix J lists the hydraulic property results from the 1,451 tests. Appendix I additionally compares transmissivity results derived by the Vorhis (1979) numerical method applied to specific capacity data versus transmissivity results derived by a graphical method applied to aquifer test data related to the same Harney Basin well (40 to 53 test pairs). Results from specific capacity data were generally larger.

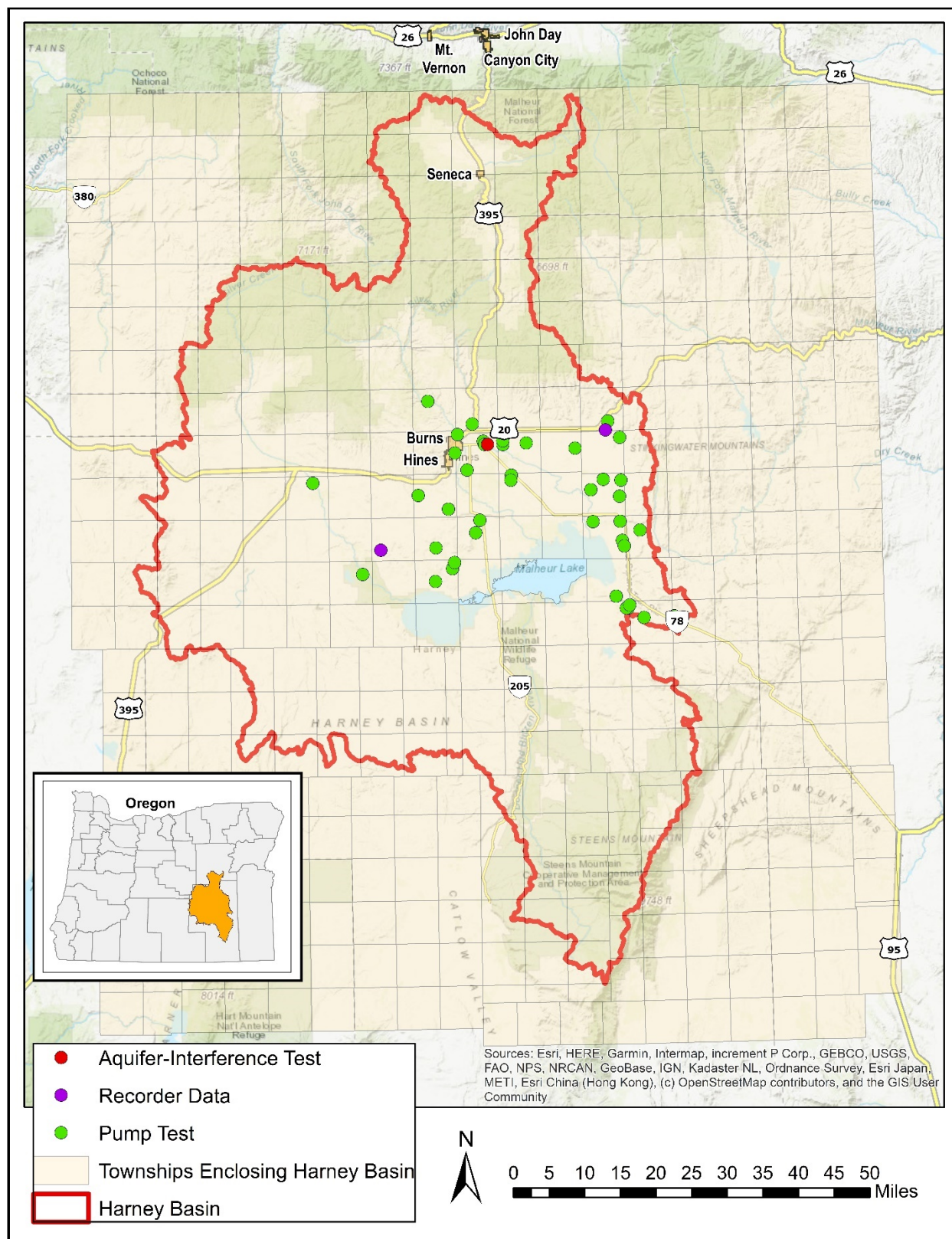


Figure 5. Well location of aquifer test data analyzed for hydraulic properties using graphical methods [44 tests, all within the Harney Basin]

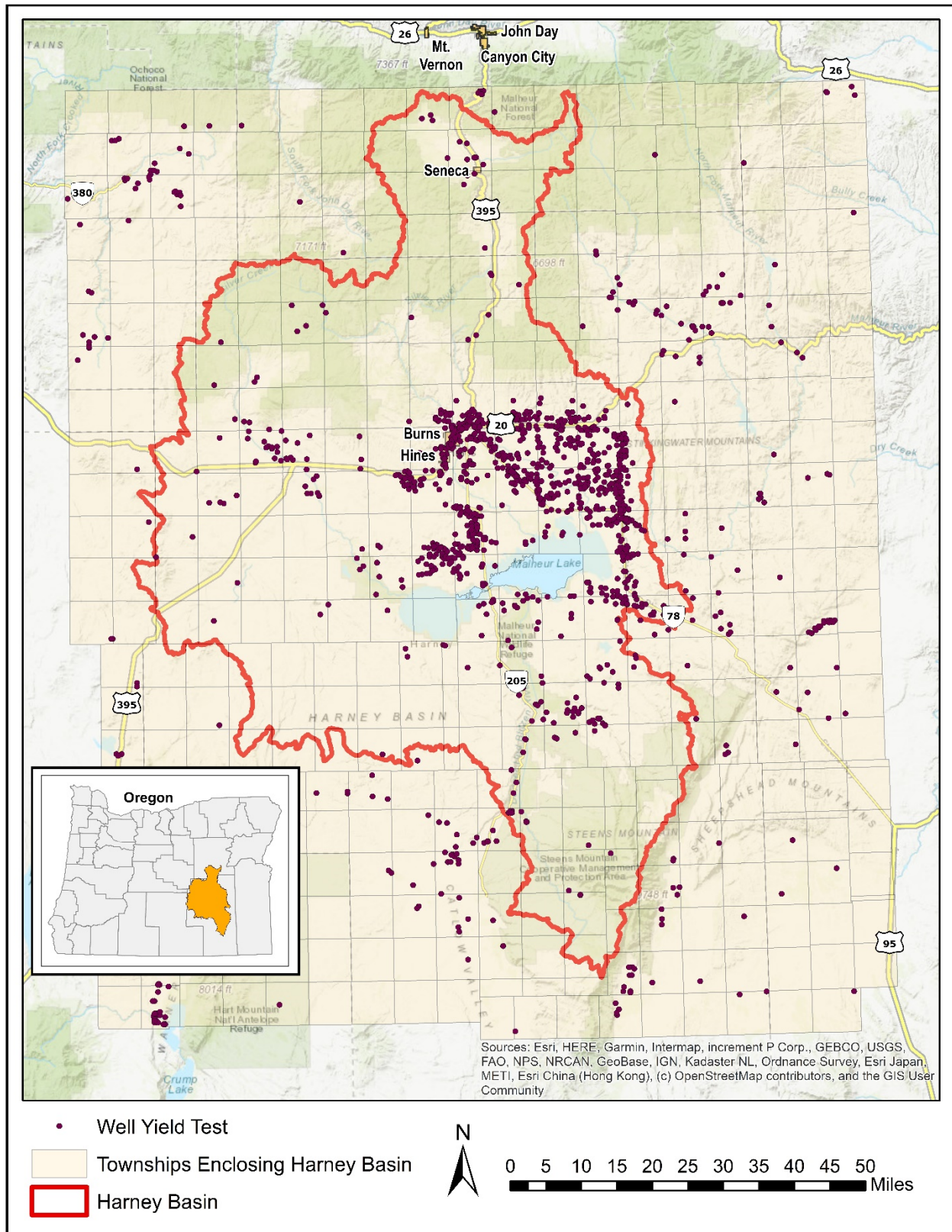


Figure 6. Location of well yield tests analyzed for hydraulic properties using numerical methods [1,451 tests, 1,161 within the Harney Basin, 290 surrounding the basin]

General Results

The calculated specific capacity, transmissivity, and hydraulic conductivity values listed in appendix H (aquifer test data, 44 tests) and appendix J (well yield test data, 1,451 tests) are summarized in tables 3 to 5 and shown in figures 7 to 9. The tables and figures show 90 percent of the calculated values are less than 85 gallons per minute per foot drawdown (gpm/ft) for specific capacity, 13,000 feet² per day (ft²/d) for transmissivity, and 230 feet per day (ft/d) for hydraulic conductivity. The interquartile values range from 0.5 to 50 gpm/ft for specific capacity, 105 to 6,300 (ft²/d) for transmissivity, and 0.8 to 73 (ft/d) for hydraulic conductivity. The median value varies from two to 16 gpm/ft for specific capacity, 415 to 1,310 ft²/d for transmissivity, and four to 19 (ft/d) for hydraulic conductivity depending on the test grouping considered. The values for tests from the area surrounding the Harney Basin are generally smaller than the corresponding values for tests from within the basin. Additionally, values related to the aquifer test data category are generally more narrowly distributed, have larger median values for specific capacity and transmissivity, and have a smaller median value for hydraulic conductivity than the values related to the well yield test data category. The larger specific capacity and transmissivity median values are likely due to the aquifer test data being related to irrigation wells which are selectively biased toward higher yield, production. The lower hydraulic conductivity (K) values are likely due to irrigation wells having longer total open intervals which were used as the thickness (b) to divide transmissivity (T) to calculate hydraulic conductivity ($K = T / b$).

Storage coefficient determination was limited to graphical analyses of the two automated groundwater level recorder data records from northeast Harney Valley and northwest of Harney Lake respectively (figure 5) that yielded a range of values depending on the graphical analysis used (appendix F). For northeast Harney Valley, the storage coefficient value that best reproduced the May through September 2017 recorder data using the Theis equation was 0.050, indicating unconfined groundwater conditions at the 157-foot total depth recorder well (HARN 52494). That well is cased to 157 feet, sealed to 48 feet, and perforated from 124 to 142 feet below land surface. For northwest of Harney Lake, the storage coefficient value that best reproduced the May through October 2018 data using the Theis equation was 0.005, indicating intermediate groundwater conditions (between unconfined and confined) at the 432-foot total depth recorder well (HARN 52534). That well is cased and sealed 250 and 50 feet below land surface respectively.

The hydraulic property value results determined from the various tests within and surrounding the Harney Basin are considered representative and reliable given the following: 1) the results derived by the varying methods are consistent overall, 2) the range of result values are reasonable and consistent for the stratigraphic units described in appendix A, and 3) the results proved useful to successfully reproduce time-series groundwater level recorder data (appendix F, figures F-6, F-11, and F-12).

The 2008 aquifer-interference test near Burns airport (figure 5, appendix E) also showed an apparent Noorbergum Effect (an initial reverse water level response to the onset and shutoff of pumping) observed at two observation wells shallower than the pumping well (appendix E, figures E-5 and E-6) and a possible surface water influence. The Effect arises from a three-dimensional deformation of geologic materials hosting groundwater (Yin and others, 2009, appendix C). If present, this indicates elasticity, plasticity, and/or deformability within some Harney Basin subsurface materials. Changes in Silvies River flow during and after the test may have additionally dominated the water level changes at the observation wells (appendix E, figures E-7 and E-8).

Table 3. Summary of specific capacity results

Variable	Type of Test			
	Aquifer Test ¹	Reported Well Yield Test ²		
	Aquifer-Interference Recorder Data Pump Tests	Outside Basin	Inside Basin	Inside & Outside
Number of Tests	44	290	1,161	1,451
Specific Capacity (gpm/ft)				
Median	1.58 E+01	2.06 E+00	5.00 E+00	4.46 E+00
Minimum	1.07 E+00	7.30 E-03	1.18 E-02	7.30 E-03
10 percentile	2.56 E+00	1.64 E-01	5.94 E-01	4.67 E-01
25 percentile	5.56 E+00	5.62 E-01	1.72 E+00	1.45 E+00
50 percentile	1.58 E+01	2.06 E+00	5.00 E+00	4.46 E+00
75 percentile	4.95 E+01	1.07 E+01	1.73 E+01	1.60 E+01
90 percentile	8.14 E+01	3.88 E+01	5.00 E+01	5.00 E+01
Maximum	3.84 E+02	3.00 E+03	4.00 E+03	4.00 E+03

Notes:

¹Summary of results listed in appendix H

²Summary of results listed in appendix J

Specific capacity is discussed in appendix D

Table 4. Summary of transmissivity results

Variable	Type of Test			
	Aquifer Test ¹	Reported Well Yield Test ²		
	Aquifer-Interference Recorder Data Pump Tests	Outside Basin	Inside Basin	Inside & Outside
Number of Tests	44	290	1,161	1,451
Transmissivity (feet²/day)				
Median	1.31 E+03	4.20 E+02	1.17 E+03	1.00 E+03
Minimum	3.50 E+01	1.04 E+00	1.87 E+00	1.04 E+00
10 percentile	2.09 E+02	2.75 E+01	1.18 E+02	8.44 E+01
25 percentile	5.73 E+02	1.10 E+02	3.71 E+02	2.99 E+02
50 percentile	1.31 E+03	4.20 E+02	1.17 E+03	1.00 E+03
75 percentile	6.23 E+03	2.58 E+03	4.17 E+03	3.82 E+03
90 percentile	1.17 E+04	8.56 E+03	1.28 E+04	1.23 E+04
Maximum	1.78 E+04	9.16 E+05	1.27 E+06	1.27 E+06

Notes:

¹Summary of results listed in appendix H. Transmissivity derived by graphical methods. Tests and methods are presented in appendix C, E, F, and G.

²Summary of results listed in appendix J. Transmissivity derived from specific capacity using Vorhis (1979) numerical method. Specific capacity and determining transmissivity are presented in appendix D and I.

Table 5. Summary of hydraulic conductivity results

Variable	Type of Test			
	Aquifer Test ¹	Reported Well Yield Test ²		
	Aquifer-Interference Recorder Data Pump Tests	Outside Basin	Inside Basin	Inside & Outside
Number of Tests	44	290	1,161	1,451
Hydraulic Conductivity (feet/day)				
Median	8.34 E+00	3.93 E+00	1.86 E+01	1.45 E+01
Minimum	1.65 E-01	2.20 E-03	5.80 E-03	2.20 E-03
10 percentile	1.26 E+00	2.28 E-01	1.10 E+00	7.10 E-01
25 percentile	2.50 E+00	8.47 E-01	4.94 E+00	3.19 E+00
50 percentile	8.34 E+00	3.93 E+00	1.86 E+01	1.45 E+01
75 percentile	5.33 E+01	2.41 E+01	7.26 E+01	6.20 E+01
90 percentile	1.09 E+02	1.27 E+02	2.26 E+02	2.08 E+02
Maximum	4.00 E+02	2.45 E+04	4.62 E+04	4.62 E+04

Notes:

¹Summary of results listed in appendix H

²Summary of results listed in appendix J

Hydraulic conductivity was derived for all tests by dividing transmissivity by the well total open interval (total OPI) at each well

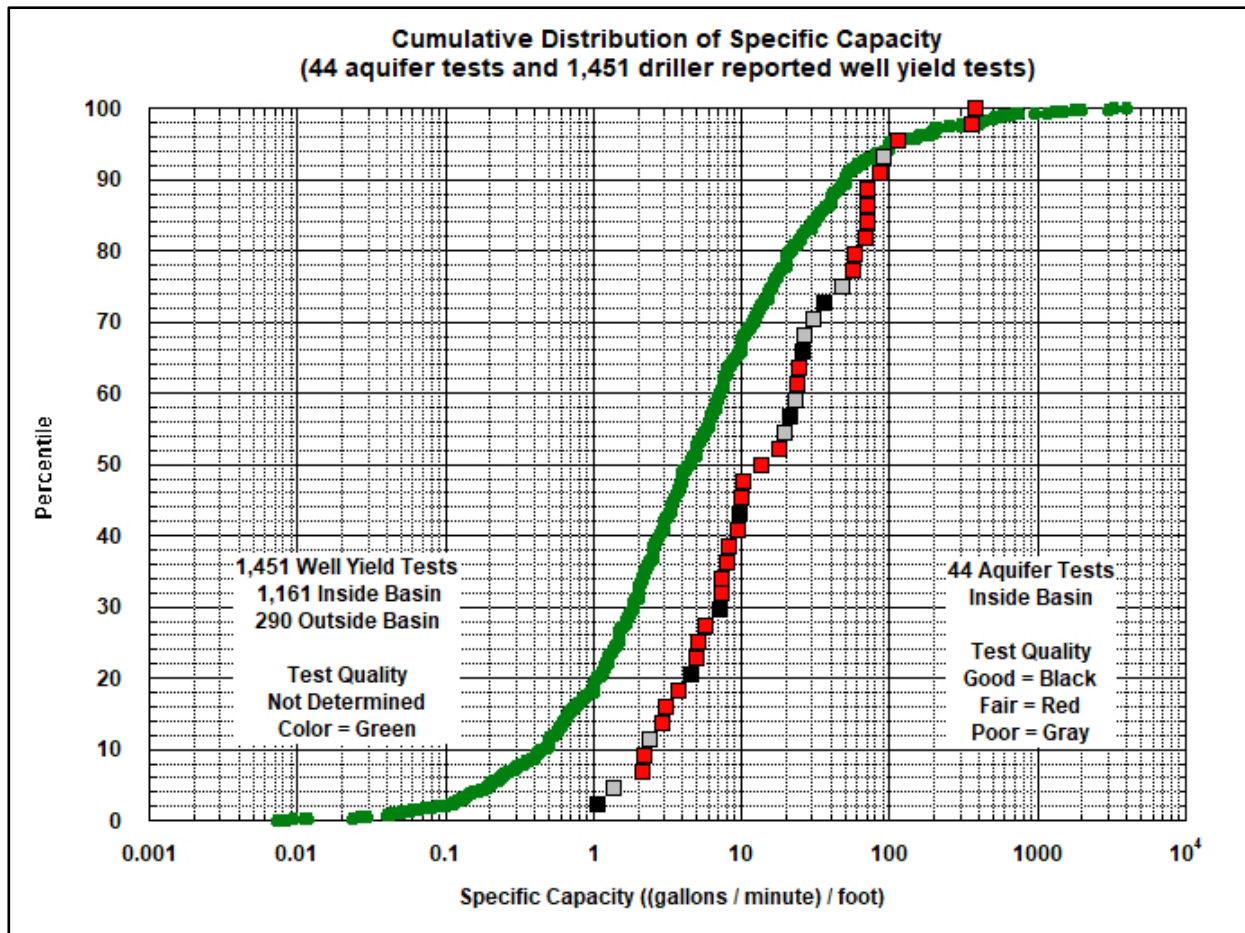


Figure 7. Cumulative distribution of specific capacity ((gallons / minute) / foot) results
[Aquifer test data (44 tests: pump tests, aquifer test, and recorder data), Water well report well
yield test data (1,451 tests)]

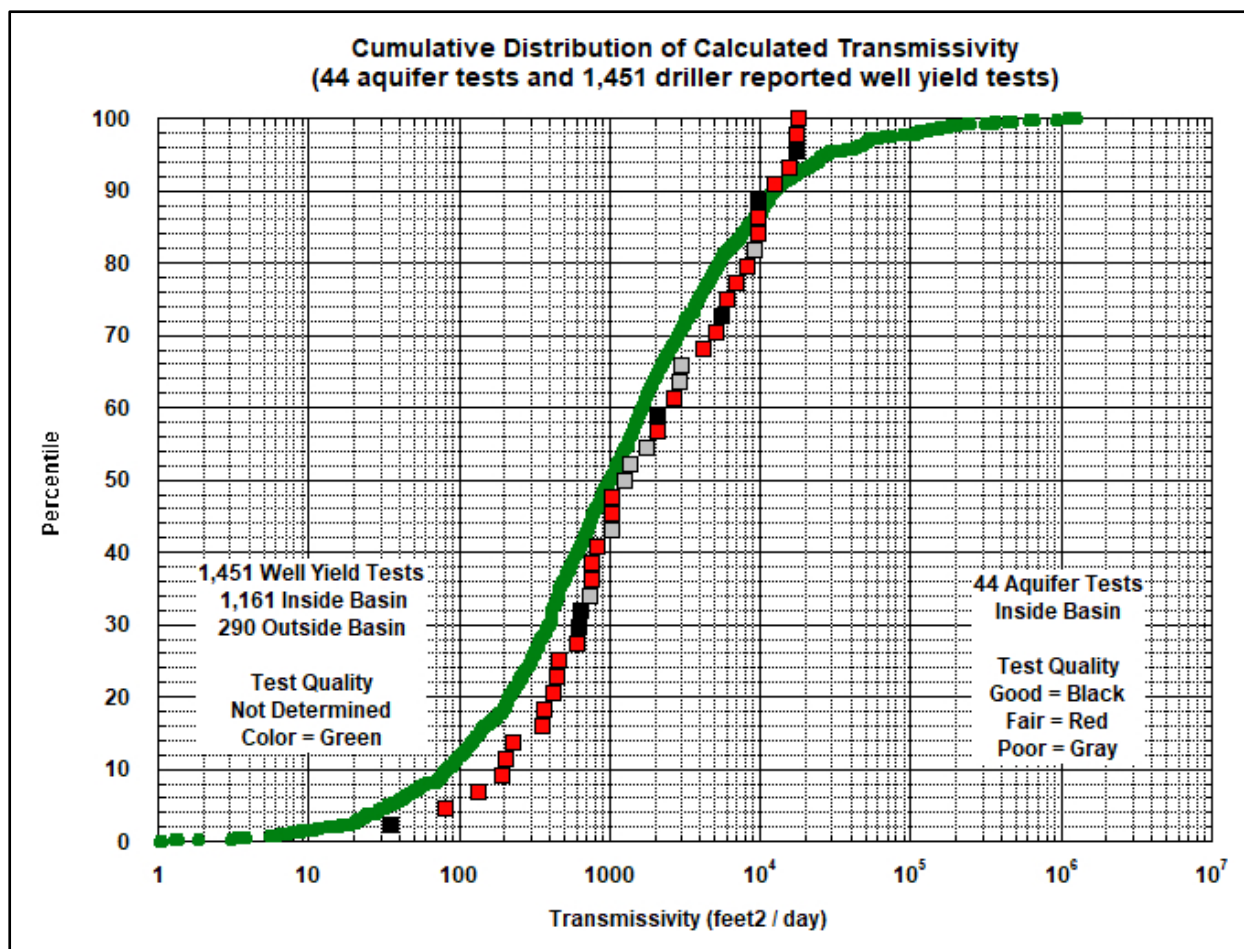


Figure 8. Cumulative distribution of transmissivity (feet² / day) results
[Aquifer test data (44 tests: pump tests, aquifer test, and recorder data), Water well report well yield test data (1,451 tests)]

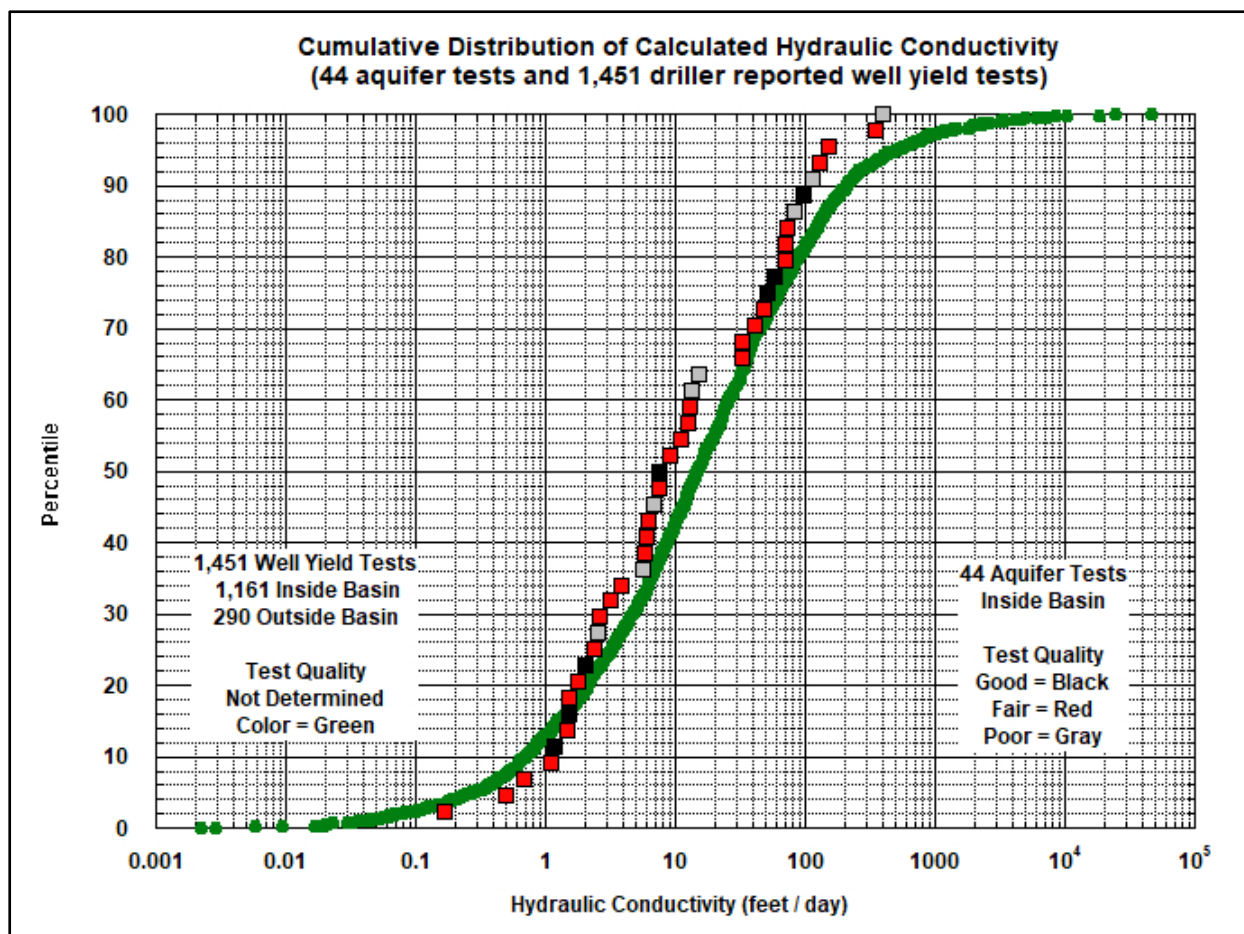


Figure 9. Cumulative distribution of hydraulic conductivity (feet / day) results
[Aquifer test data (44 tests: pump tests, aquifer test, and recorder data), Water well report well
yield test data (1,451 tests)]

Relation to Well Construction

The potential for well construction influence upon hydraulic property values calculated from data related to 1,451 well yield tests was evaluated using 12 scatter-plot graphs. Figures 10 to 12 group the graphs into three sets, one set each for specific capacity, transmissivity, and hydraulic conductivity respectively. The four graphs within each set shows a point for a hydraulic property value calculated and a corresponding well construction parameter value (total well depth, total well open interval length, depth to the top of the total open interval, and the total open interval diameter) for each well yield test.

The figure 10 and 11 graph set for specific capacity and for transmissivity calculated from specific capacity (appendix D and I) indicate a relation to well construction from none to weak. Graphs A, B, and C in both figures show clustered points with a curve fit R^2 value less than 0.02 for total well depth, total open interval length, and depth to total open interval top indicating no relation. Graph D in both figures shows points spread across the range of hydraulic property values with a curve fit R^2 value more than 0.10 for total open interval diameter indicating a weak relation. The graph D curve fit shows specific capacity and transmissivity values increasing with larger well diameter. Rorabaugh (1953) noted larger specific capacity values corresponding to larger well radii (diameters).

The figure 12 graph set for hydraulic conductivity calculated from transmissivity (appendix M) indicates a possible relation to two well construction parameters. Graphs A and B show clustered points with a possible inverse trend for total well depth and total open interval length respectively. The curve fit R^2 value is more than 0.15 indicating a weak relation. If real, the inverse trend indicates a decreasing hydraulic conductivity with increasing total well depth and with increasing total open interval length. A decreasing value with increasing total depth may relate to increasing age, alteration, and compaction of stratigraphic units with depth. A decreasing value with increasing open interval length may relate to how hydraulic conductivity was calculated (dividing transmissivity by total open interval length). It may also relate to longer open intervals being associated with deeper wells and/or resulting from a larger proportion of lower yield layers occurring within longer total open intervals. Graphs C and D show points spread as a horizontal band across the range of hydraulic conductivity values, similar to specific capacity and transmissivity. The curve fit R^2 value is less than 0.01 indicating no relation.

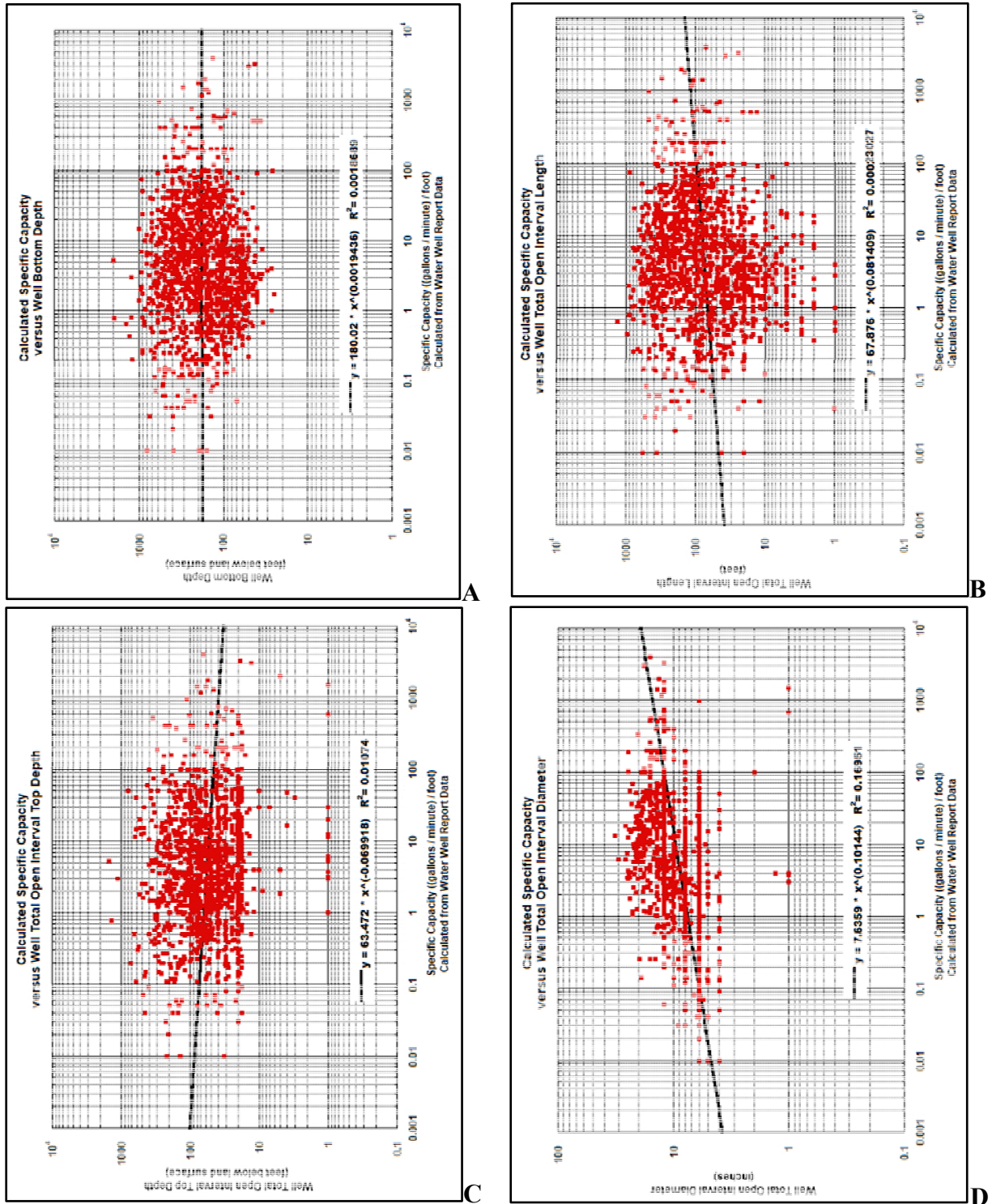


Figure 10. Specific capacity ((gallons / minute) / foot) relation to well construction [Graph A: well total depth, Graph B: total open interval length, Graph C: depth to total open interval top, Graph D: total open interval diameter, hydraulic property derived from water well report well yield test data (1,451 tests)]

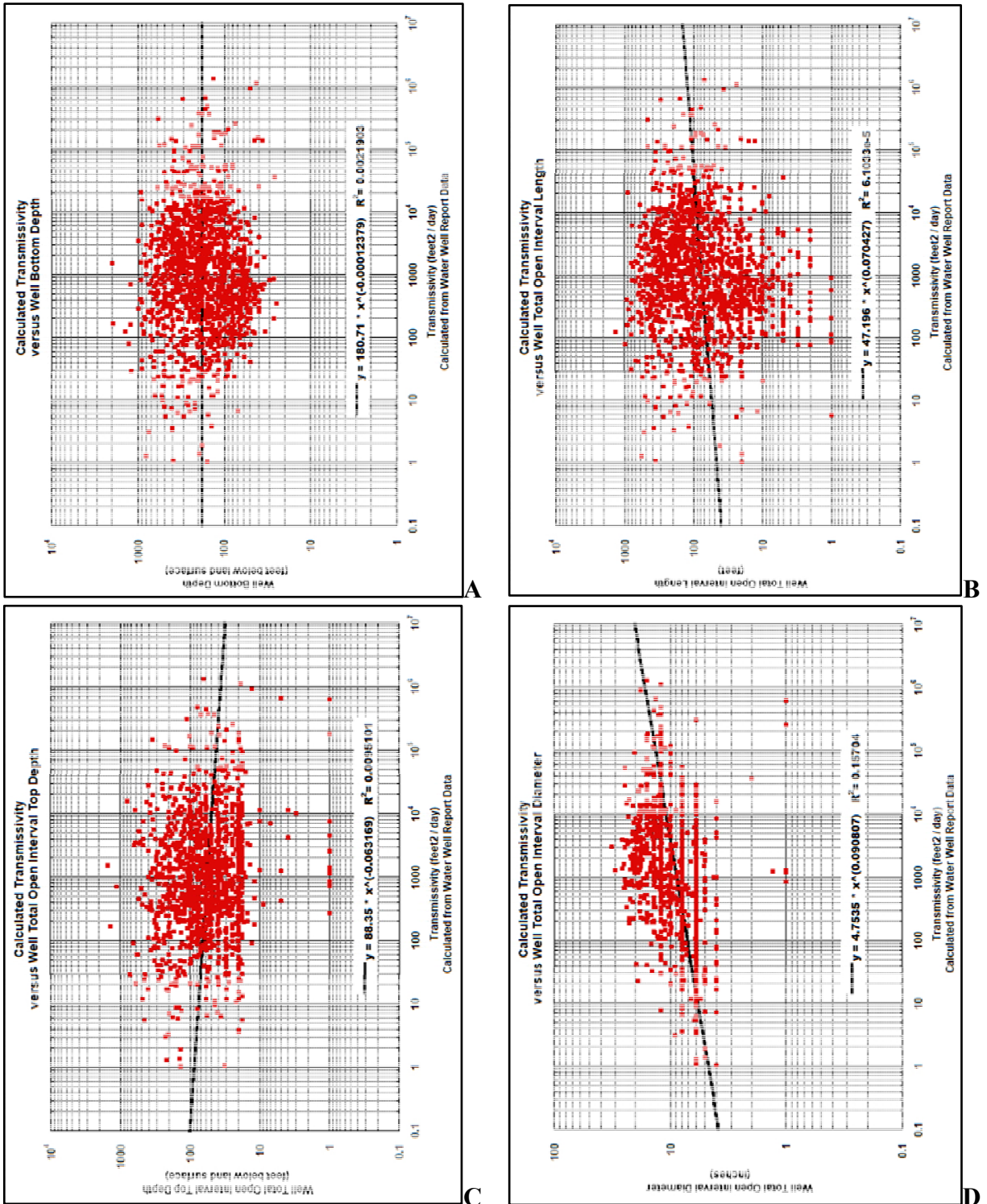


Figure 11. Transmissivity (feet² / day) relation to well construction
 [Graph A: well total depth, Graph B: total open interval length, Graph C: depth to total open interval top, Graph D: total open interval diameter, hydraulic property derived from water well report well yield test data (1,451 tests)]

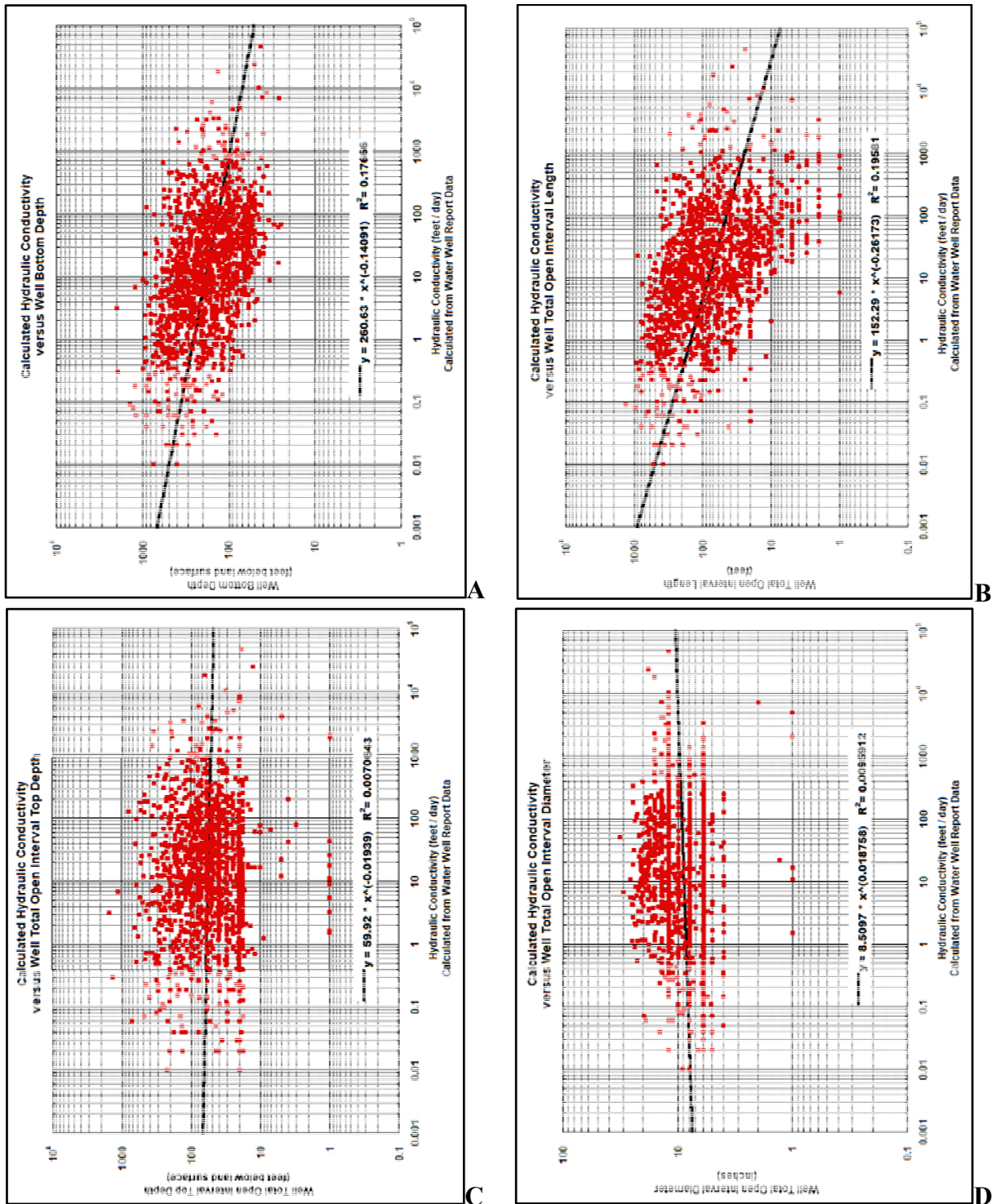


Figure 12. Hydraulic conductivity (feet / day) relation to well construction [Graph A: well total depth, Graph B: total open interval length, Graph C: depth to total open interval top, Graph D: total open interval diameter, hydraulic property derived from water well report well yield test data (1,451 tests)]

Relation to Well Performance

The relation between well performance and hydraulic property values calculated from data related to 1,451 well yield tests was evaluated using six scatter-plot graphs. Figures 13 to 15 group the graphs into three pairs, one pair for specific capacity, transmissivity, and hydraulic conductivity respectively. The paired graphs show a point for a hydraulic property value calculated and a corresponding well performance value (well discharge rate or total drawdown) for each well yield test.

A relation between well performance parameters (well discharge rate and total drawdown) and the hydraulic properties (specific capacity, transmissivity, and hydraulic conductivity) should be expected given the discussion and equations in appendix C and D. The hydraulic properties should be directly proportional to the well discharge rate, an increasing hydraulic property value with increasing discharge rate. Conversely, the hydraulic properties should be inversely proportional to the total drawdown, a decreasing hydraulic property value with increasing total drawdown.

All six graphs show a relation between well performance and hydraulic property values as expected. The relation appears best for specific capacity and transmissivity, which is understandable given specific capacity equals well discharge rate divided by total drawdown and the transmissivity graphed included specific capacity in the calculations (appendix D and I). The well performance and hydraulic property value relation for hydraulic conductivity is visibly present in the graphs but not as obvious. This less obvious relation may be a result of using the total open interval length to calculate hydraulic conductivity from transmissivity (see previous section).

The relation between well performance and hydraulic property values shown in all six graphs occurs in a value range band that spans at least two orders magnitude for each hydraulic property. The broad value range band may relate to the diversity and/or complexity of the subsurface materials being represented.

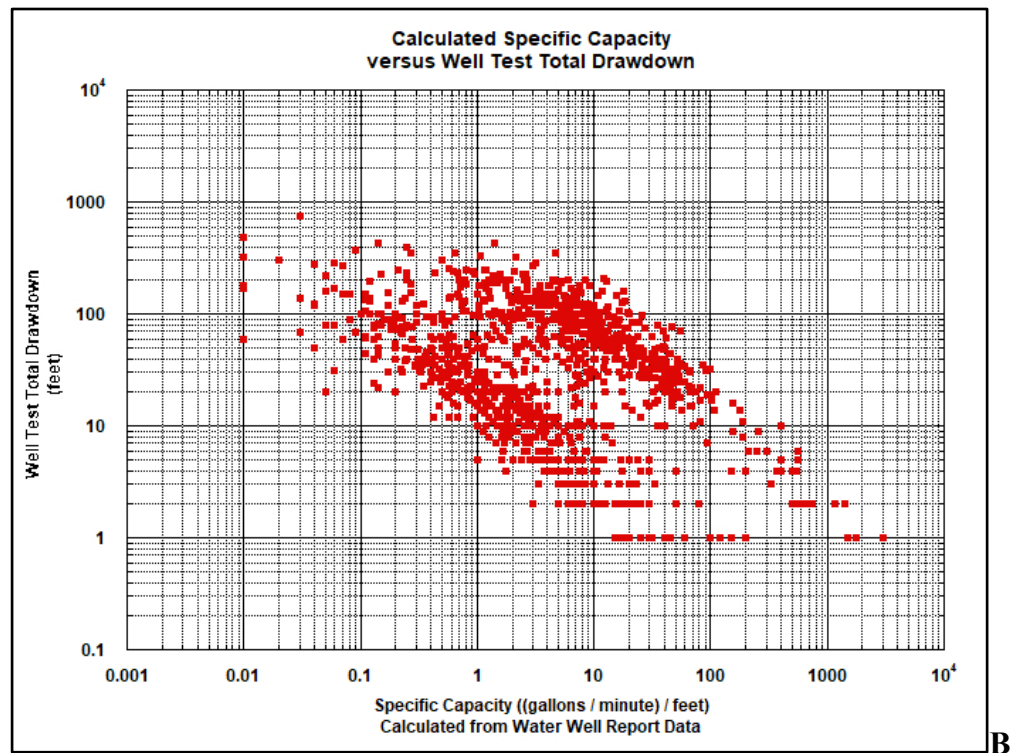
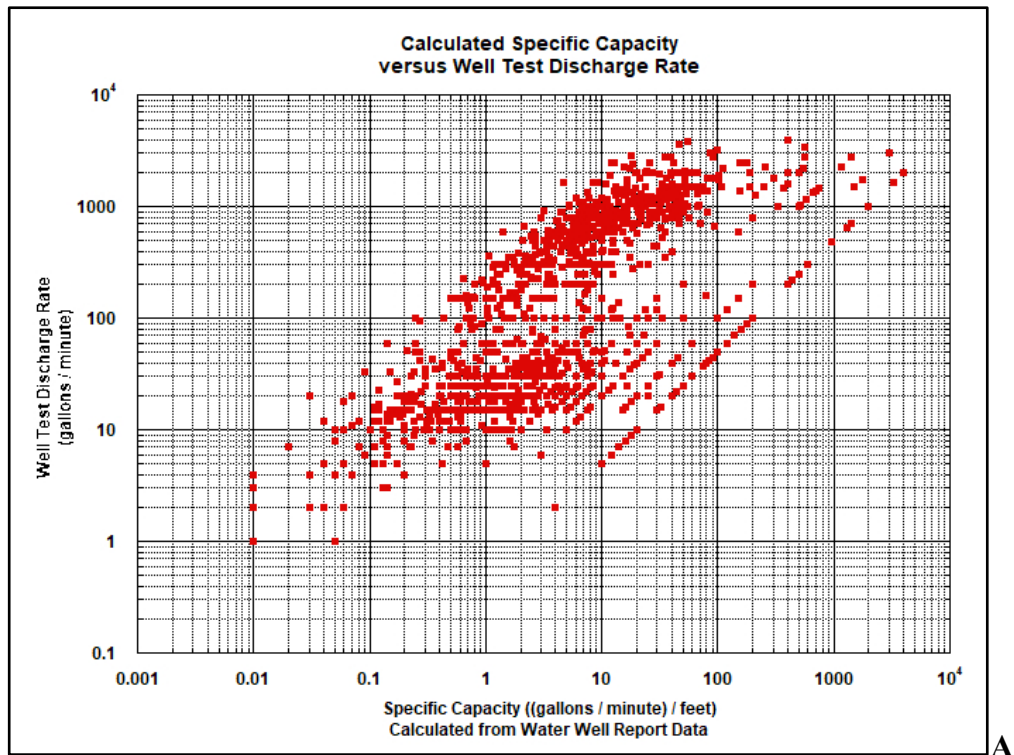


Figure 13. Specific capacity ((gallons / minute) / foot) relation to well performance
[Graph A: well discharge rate, Graph B: well total drawdown, hydraulic property derived from
water well report well yield test data (1,451 tests)]

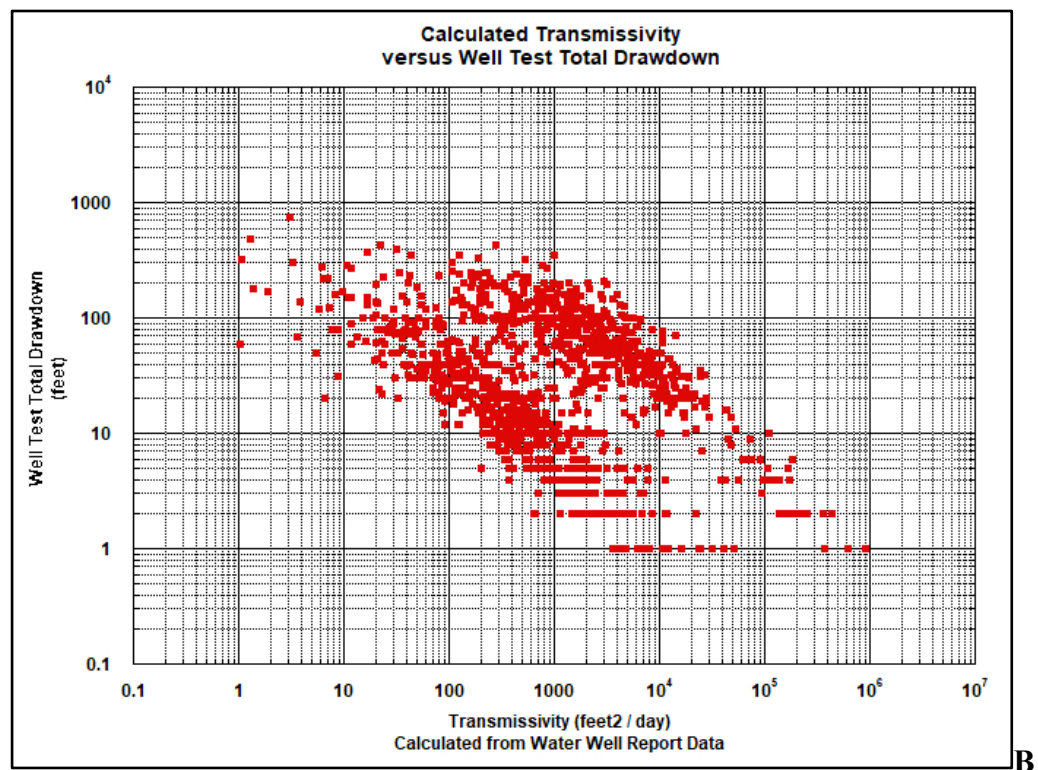
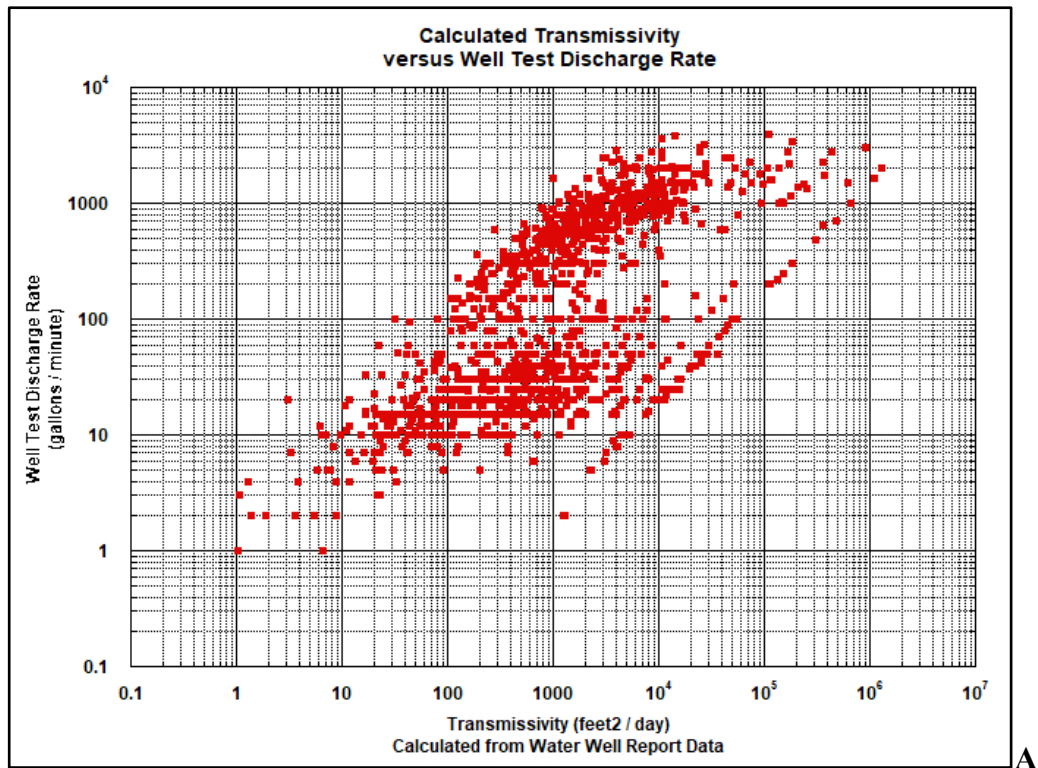


Figure 14. Transmissivity (feet² / day) relation to well performance
[Graph A: well discharge rate, Graph B: well total drawdown, hydraulic property derived from water well report well yield test data (1,451 tests)]

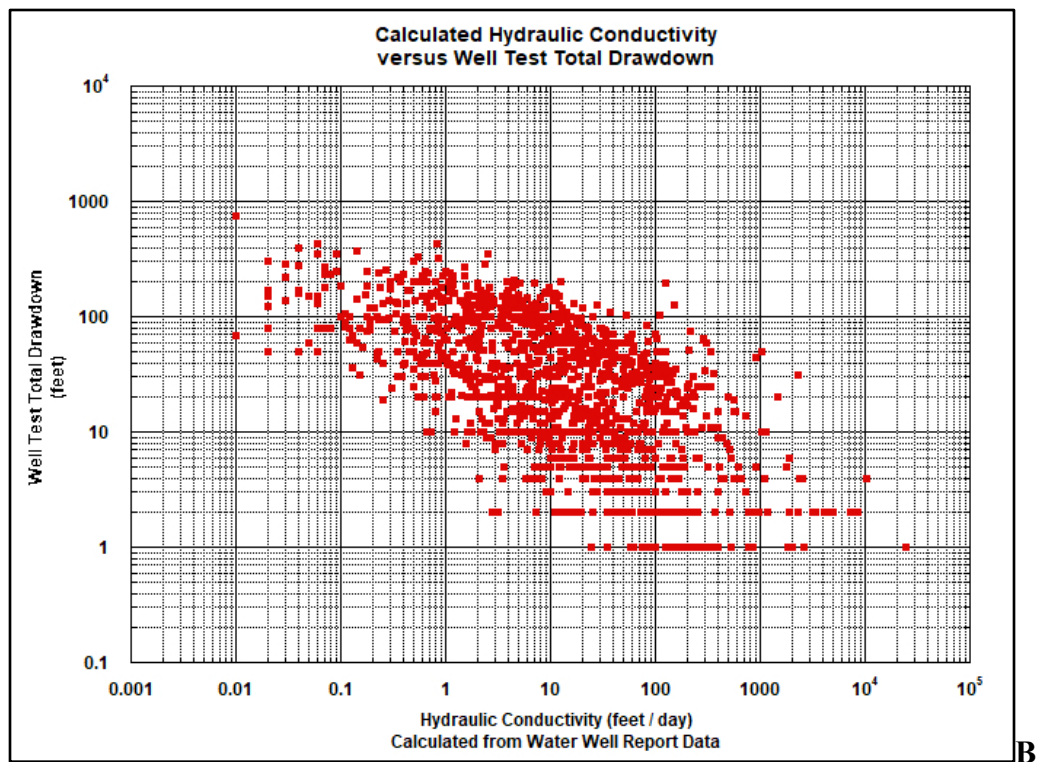
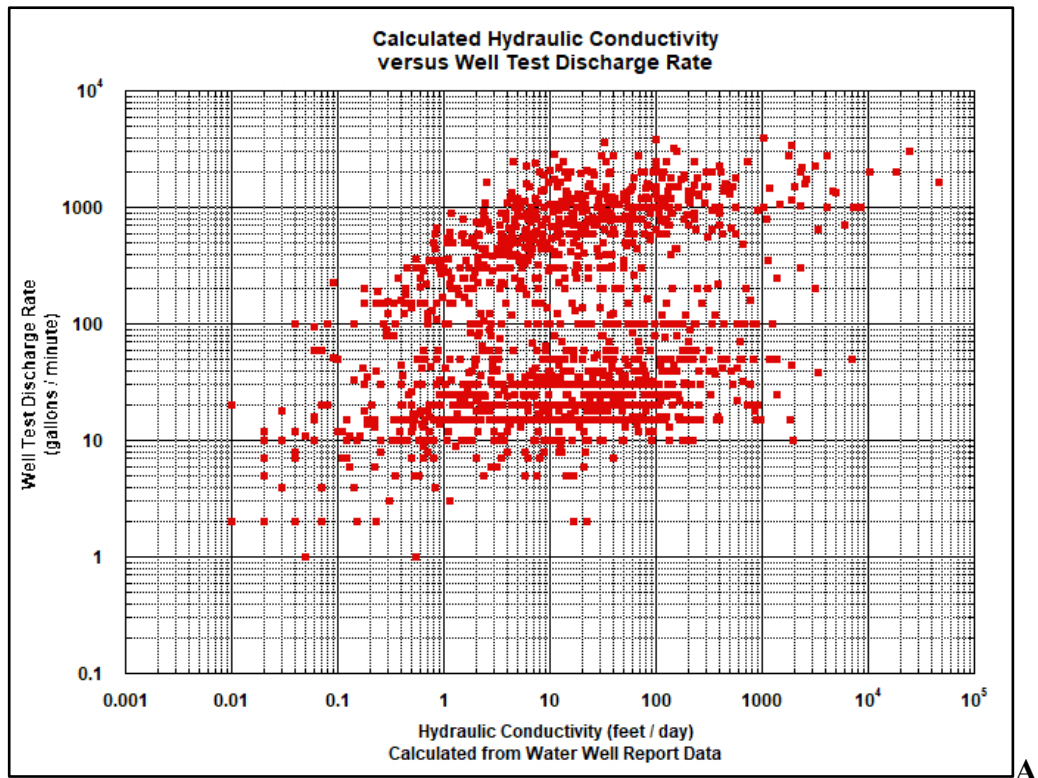


Figure 15. Hydraulic conductivity (feet / day) relation to well performance
[Graph A: well discharge rate, Graph B: well total drawdown, hydraulic property derived from
water well report well yield test data (1,451 tests)]

Property to Property Relation

The relation between hydraulic property values (specific capacity, transmissivity, and hydraulic conductivity) calculated from data related to 1,451 well yield tests was evaluated using three scatter-plot graphs (figures 16 to 18). The graphs show a point for a hydraulic property value calculated and a corresponding hydraulic property value for each well yield test. There should be a relation between the hydraulic property values given the discussion and equations in appendix C and D. The hydraulic properties should be directly proportional to each other. All three graphs show that relation. The relation is best (nearly a line) between specific capacity and transmissivity (figure 16), which is understandable given the transmissivity graphed included specific capacity in the calculations (appendix D and I). The relation between hydraulic conductivity and the other properties (figures 17 and 18) occurs in a value range band generally within two orders magnitude. This may be a result of using the total open interval length to calculate hydraulic conductivity from transmissivity (see previous section) and/or may relate to the diversity and/or complexity of the subsurface materials being represented.

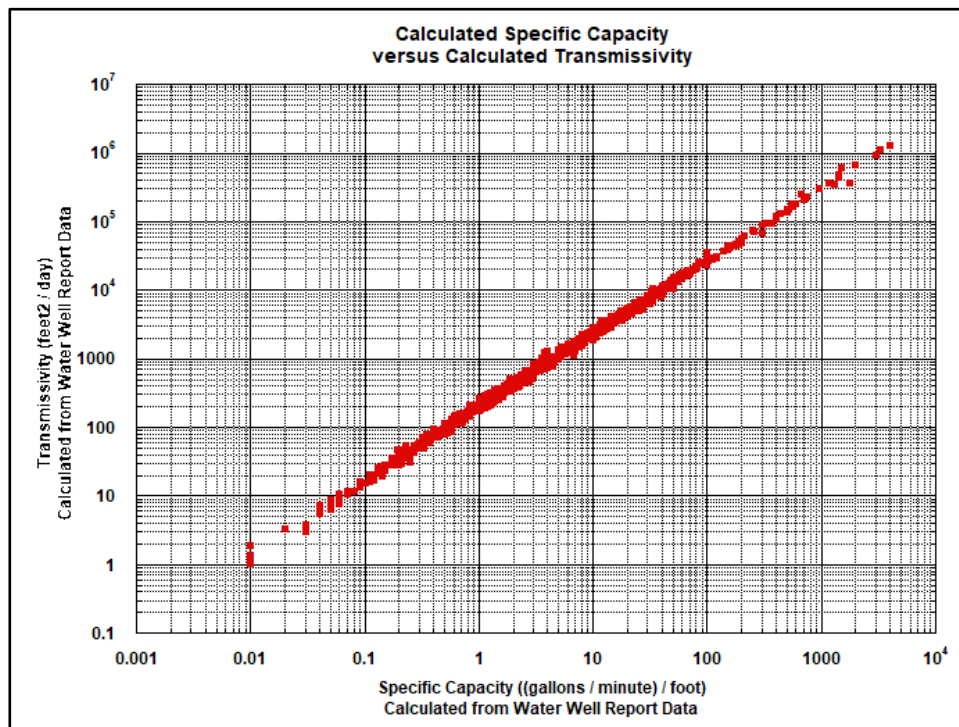


Figure 16. Specific capacity ((gallons / minute) / foot) relation to transmissivity (feet² / day)

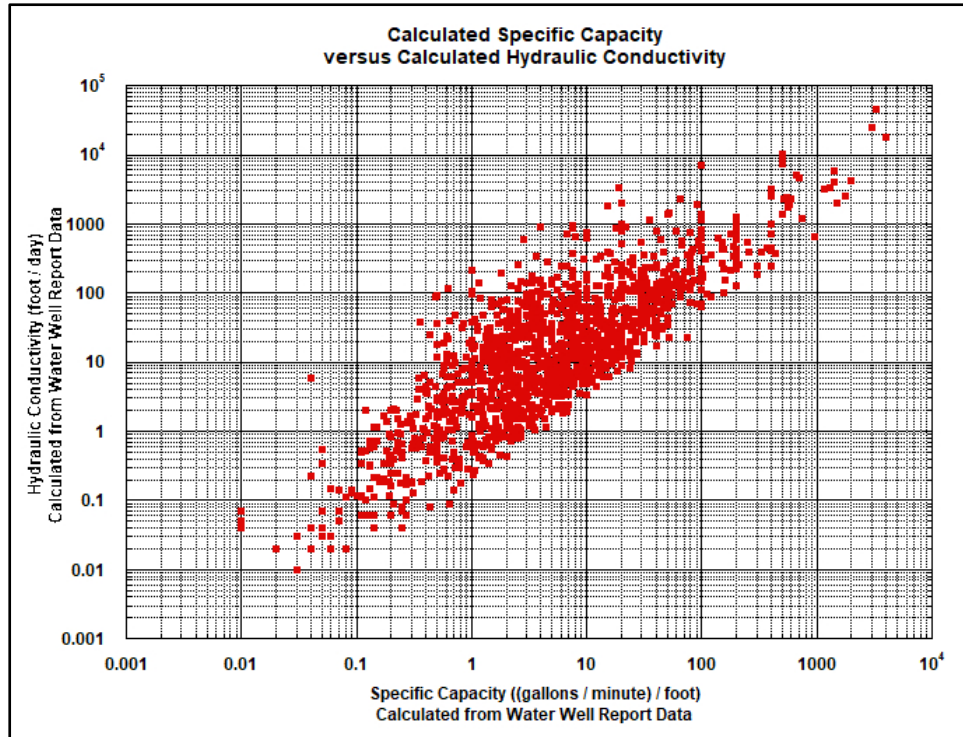


Figure 17. Specific capacity ((gallons/minute) / foot) to relation hydraulic conductivity (feet / day)

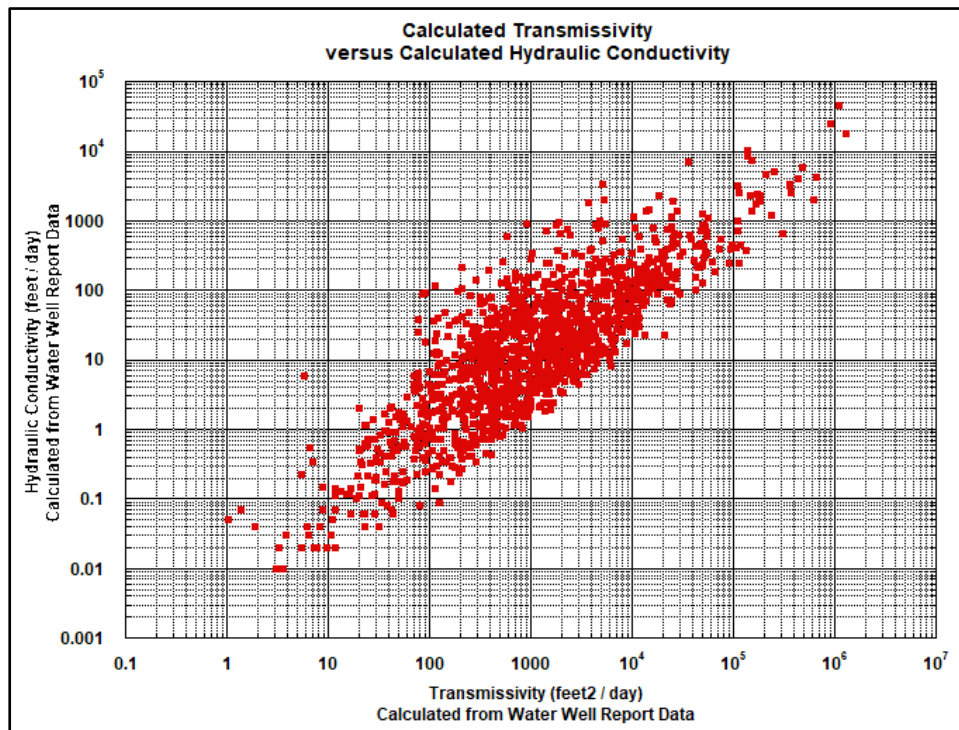


Figure 18. Transmissivity (feet² / day) relation to hydraulic conductivity (foot / day)

Relation to Spatial Distribution

OWRD identified 1,161 water well reports within the Harney Basin with sufficient well yield test data for calculating specific capacity (appendix I) from which a transmissivity estimate was calculated using the Vorhis (1979) numerical method (appendix D). Additionally, a hydraulic conductivity estimate was calculated by dividing the transmissivity by the well total open interval. The reports from which calculations were made and the calculated specific capacity, transmissivity, and hydraulic conductivity values are listed in appendix J.

Figures 19 to 21 are maps showing the spatial distribution of the calculated specific capacity, transmissivity, and hydraulic conductivity values for all 1,161 tests and for all well depths. Appendix K shows the same information grouped into three map sets: figures K-1 to K-15 for specific capacity, figures K-16 to K-30 for transmissivity, and figures K-31 to K-45 for hydraulic conductivity. Each set is divided into three subsets: all 1,161 results, 498 results for wells with a total depth less than 150 feet, and 663 results for wells with a total depth 150 feet or greater. Within each subset are 5 maps. The first map shows four value ranges together ordered from smallest (bottom) to greatest (top) when results overlap. The remaining four maps show the four value ranges individually to better view the distribution of each range.

Generally, spatial distribution segregation is greatest with the largest hydraulic property value range and increasingly less segregated, more ubiquitous with successively lower value ranges. The largest value range is most concentrated along the Harney Valley perimeter and the Riley vicinity. For wells less than 150 feet total depth, the largest value range distribution is concentrated along the southwest, south, and east perimeter of Harney Valley. For wells 150 feet total depth and greater, the largest value range is concentrated along the southwest, west, north, and east perimeter of Harney Valley and the Riley vicinity. The second largest value range is most concentrated along the southwest, west, north, and east perimeter of Harney Valley for all well depths and the Riley vicinity for wells 150 feet total depth and greater. These larger value distributions appear to coincide with eruptive centers, younger volcanic flows, coarser grained sedimentary deposits, and possibly geologic structure. The two lowest value ranges are the least spatially segregated, the most ubiquitous. They are found intermixed with the two largest value ranges indicating the complexity, heterogeneity of the Harney Basin subsurface materials.

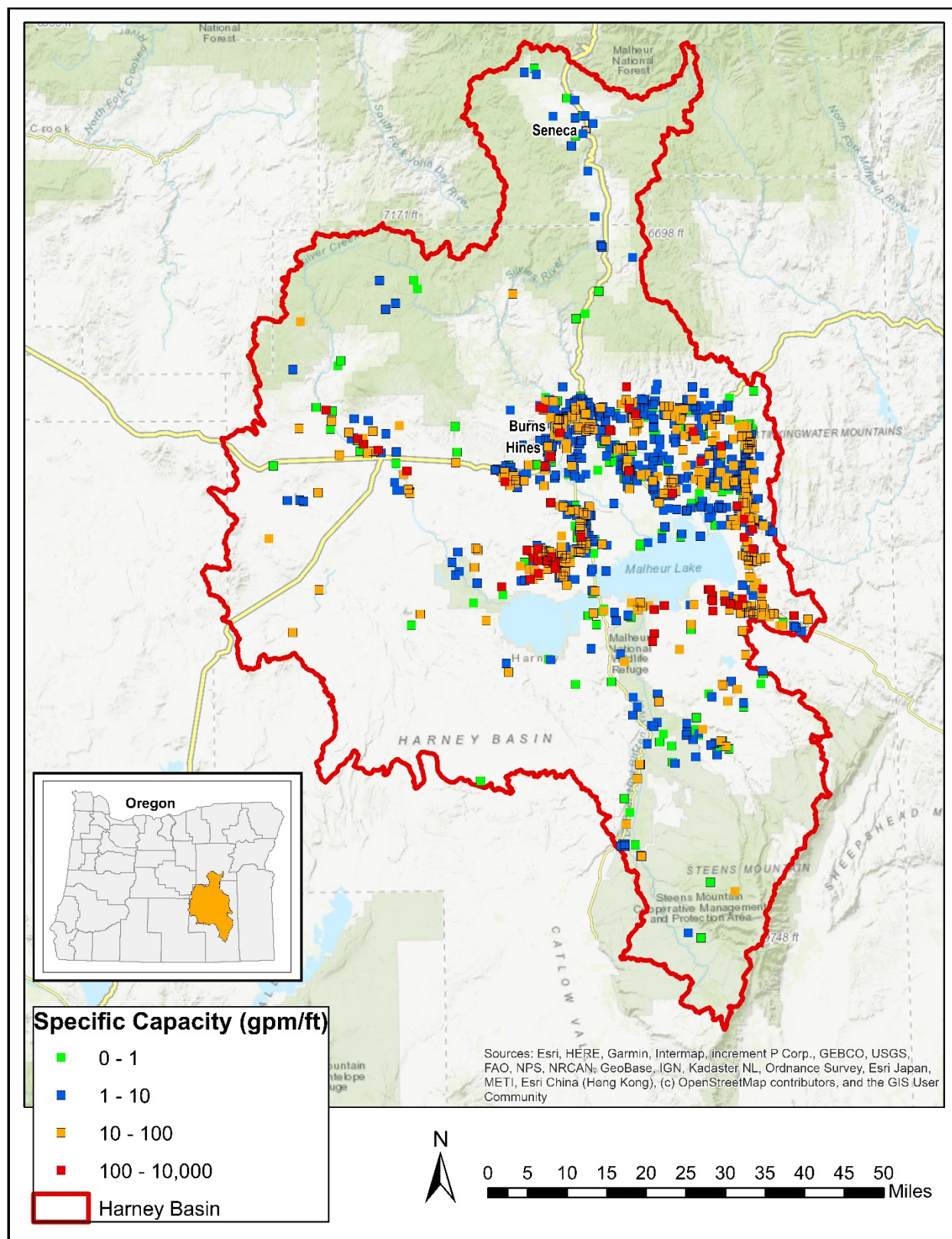


Figure 19. Specific capacity spatial distribution map: all well depths, all value ranges [from 1,161 well yield tests inside Harney Basin]

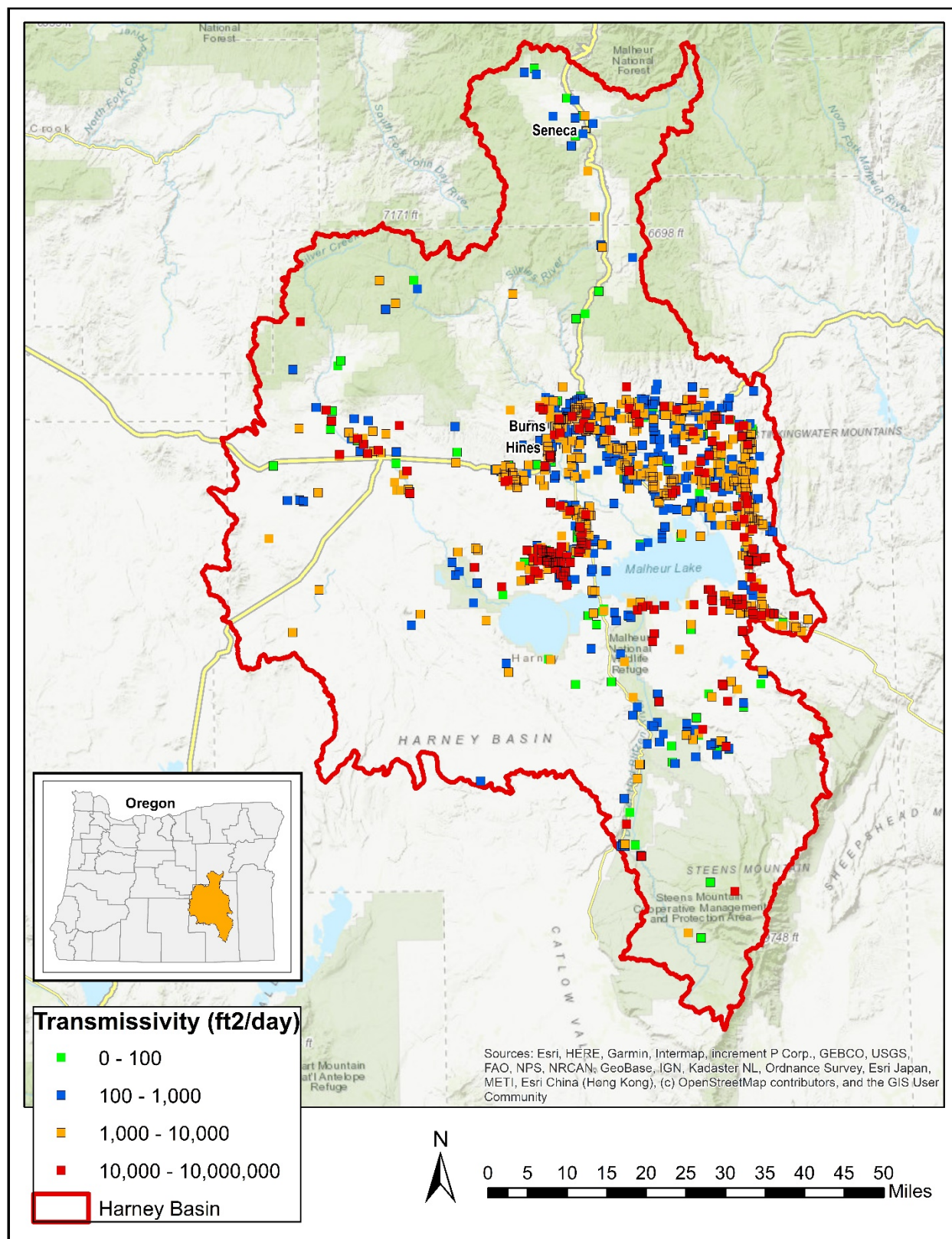


Figure 20. Transmissivity spatial distribution map: all well depths, all value ranges [from 1,161 well yield tests inside Harney Basin]

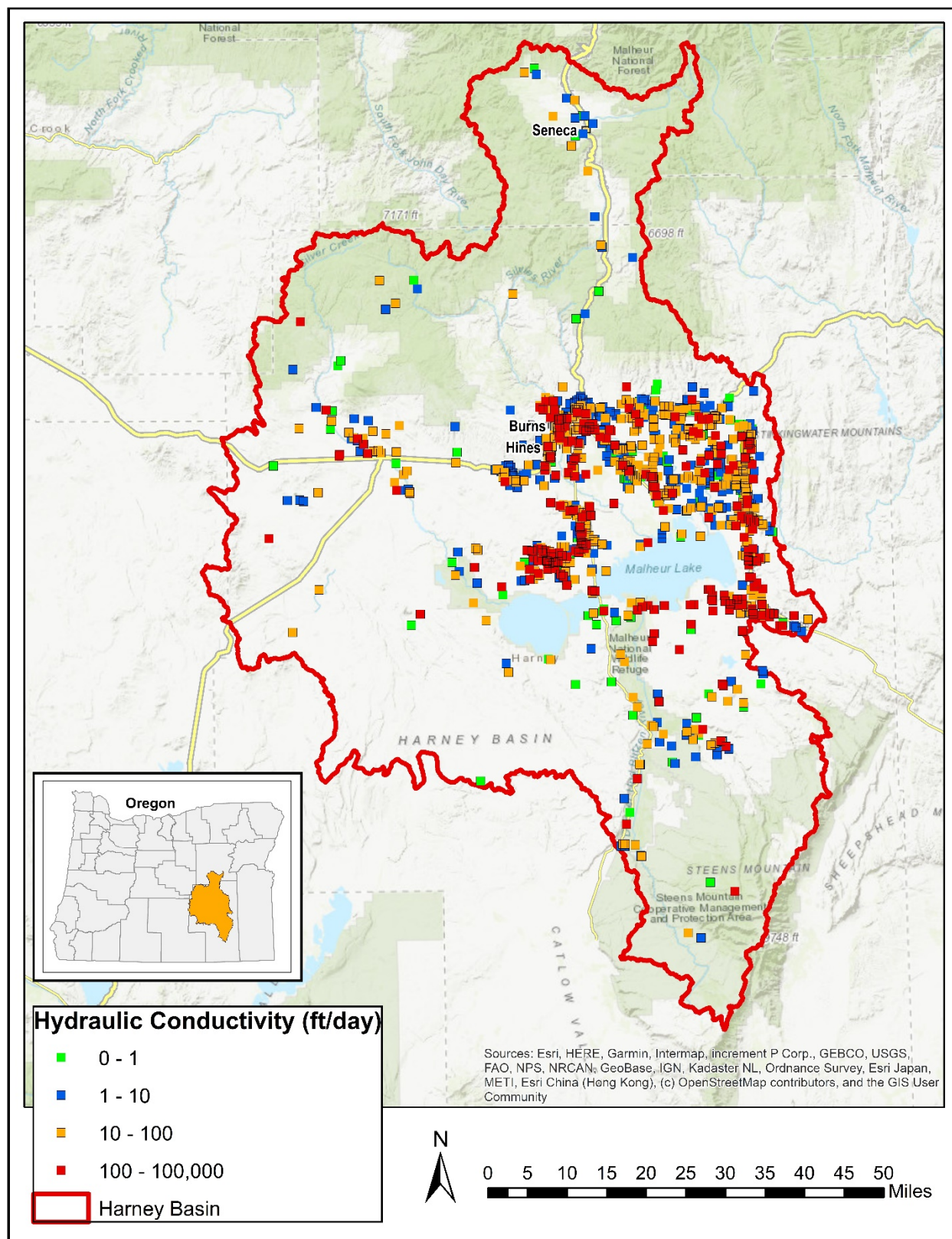


Figure 21. Hydraulic conductivity spatial distribution map: all well depths, all value ranges [from 1,161 well yield tests inside Harney Basin]

Relation to Stratigraphic Units

Assigning the hydraulic property value from each hydraulic property test to the appropriate subsurface stratigraphic unit(s) required a multi-step process detailed in appendix L and M and summarized here. Driller reported descriptions of subsurface materials (lithologic units) related to 2,242 wells were entered into the OWRD Groundwater Information System (GWIS) database (Oregon Water Resources Department, 2019a). The process is named “lith-coding.” Of the 2,242 wells, 1,810 were identified as having hydraulic property tests or other study use which made them candidates for correlating the coded lithologic units to the Harney Basin stratigraphic units summarized in appendix A. That correlation process is named “strat-coding.” Of the 1,810 wells, 1,495 wells were strat-coded using the reported lithologic unit descriptions and available geologic data. The 1,495 wells are listed in appendix L (table L-1) and the associated lith-coding and strat-coding can be found via the OWRD GWIS database (Oregon Water Resources Department, 2019a). Next, the open interval allowing groundwater inflow for each well was identified. This investigation had four open interval definition options available as described in appendix M. This investigation used the total open interval (total OPI) option defined as the continuous well section that includes every open interval and any non-open interval occasionally present between open intervals. The stratigraphic units exposed at the open interval was identified and the percentage of the open interval occupied by each exposed stratigraphic unit was calculated as described in appendix M. The results are listed by well in appendix H and J. Calculated hydraulic property values related to a well was assigned to a single stratigraphic unit exposed at the well only when the stratigraphic unit occupied 90 to 100 percent of the total OPI. This percentage range was used to maximize the likelihood the hydraulic property assigned to the stratigraphic unit represents that unit at that well. The total number of hydraulic values assigned to each stratigraphic unit ranged from none to 744. Lastly, summary statistics of all the hydraulic property values assigned to each stratigraphic unit were determined. The specific capacity, transmissivity, and hydraulic conductivity statistics for each stratigraphic unit are graphically shown as box and whiskers plots in figures 22 to 24 and are listed in appendix N tables.

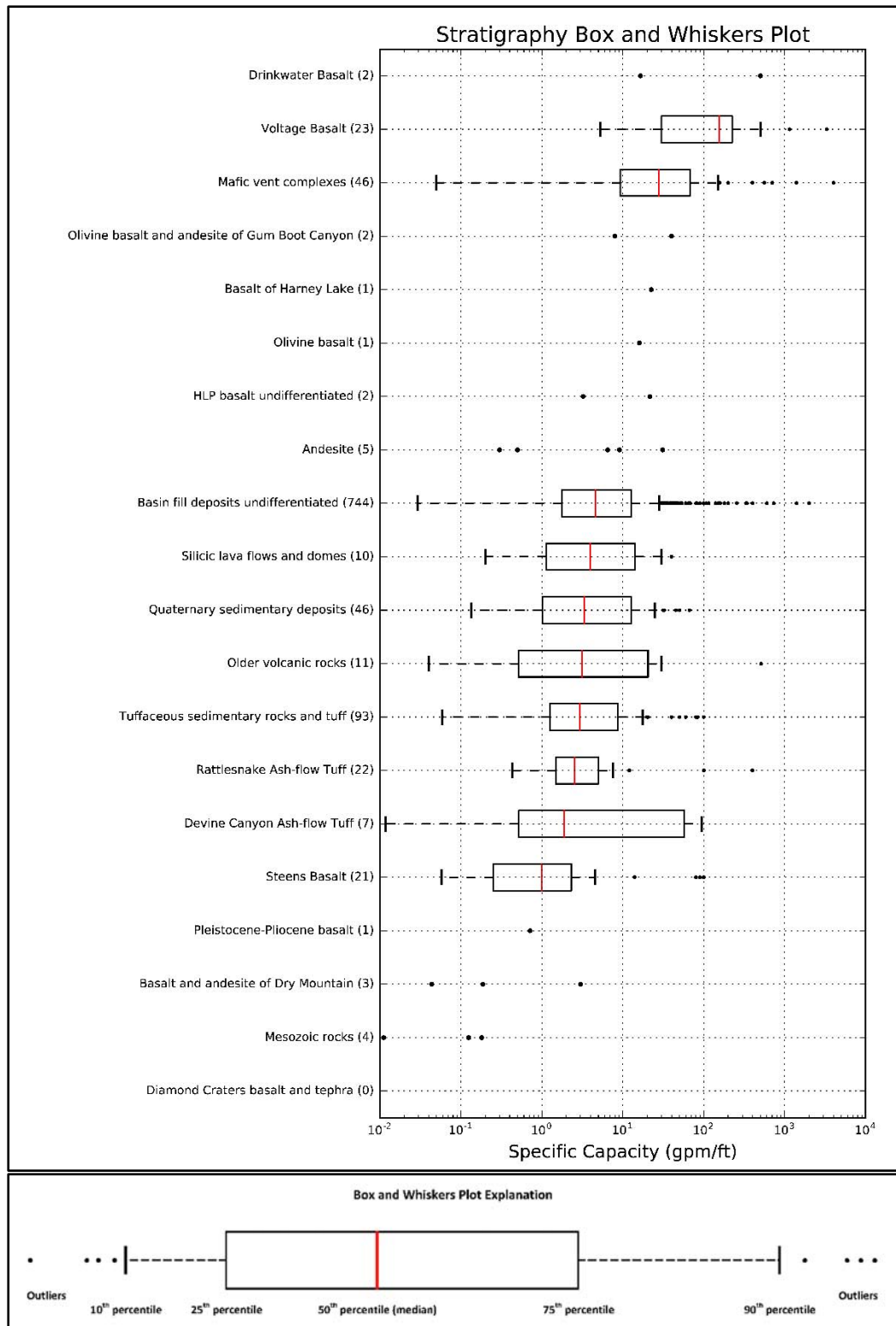


Figure 22. Specific capacity of Harney Basin stratigraphic units
 [from 1,044 tests at 1,011 wells inside Harney Basin, ordered from largest to smallest median value, two undifferentiated units were added to represent values related to wells with subsurface descriptions insufficient to distinguish a particular stratigraphic unit]

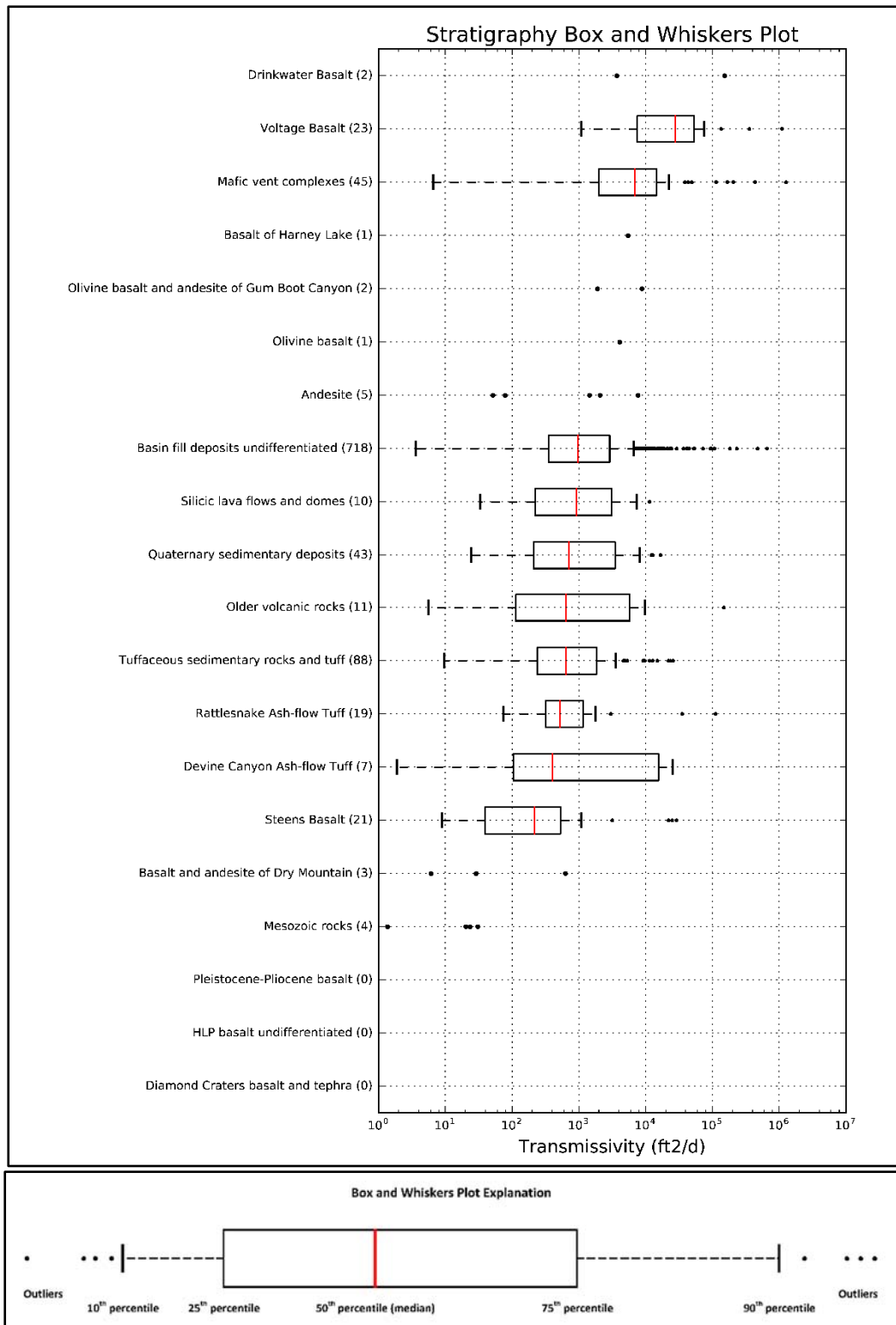


Figure 23. Transmissivity of Harney Basin stratigraphic units
 [from 1,003 tests at 976 wells inside Harney Basin, ordered from largest to smallest median value, two undifferentiated units were added to represent values related to wells with subsurface descriptions insufficient to distinguish a particular stratigraphic unit]

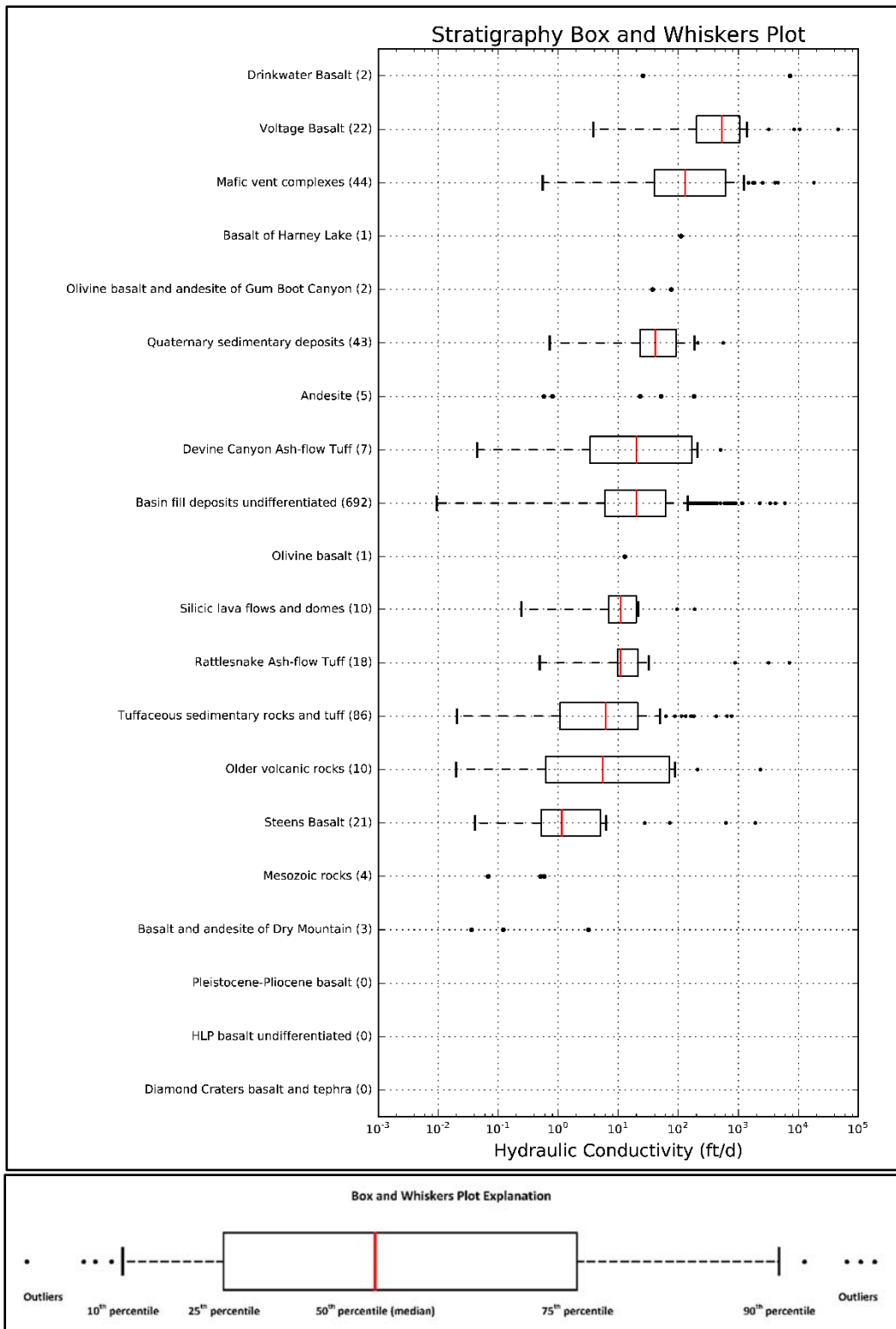


Figure 24. Hydraulic conductivity of Harney Basin stratigraphic units
 [from 971 tests at 971 wells inside Harney Basin, ordered from largest to smallest median value, two undifferentiated units were added to represent values related to wells with subsurface descriptions insufficient to distinguish a particular stratigraphic unit]

The box and whiskers plot for each stratigraphic unit in figures 22 to 24 are ordered from largest to smallest median value. The exact unit order from figure to figure shifts due to increasing data required for each successive property calculated affecting the total number and range of specific capacity, transmissivity, and hydraulic conductivity value results available for each unit statistics. Nevertheless, there is an overall pattern. The largest median values relate to basalts and mafic vent deposits. Intermediate median values appear relate to andesite, various tuffaceous deposits, silicic flows and domes, and basin-fill sediments. The smallest median values relate to older volcanic deposits and the complex of Mesozoic rocks. The median values for all stratigraphic units collectively range three to four orders of magnitude depending on the hydraulic property. The maximum range for all values for all stratigraphic units collectively is approximately five to six orders of magnitude depending on the hydraulic property.

Hydrostratigraphic Units

Determining Harney Basin Hydrostratigraphic Units

The Harney Basin stratigraphic units listed in table 2, shown in figure 4 (surficial exposure map), and described in appendix A were grouped into nine hydrostratigraphic units based upon similar hydraulic property value ranges (figures 22 to 24, appendix N), geologic characteristics (appendix A), and stratigraphic position. Table 6 lists the Harney Basin hydrostratigraphic units and their underlying stratigraphic units. Their surficial exposure is shown in the figure 25 map.

Determining Hydraulic Property Values of Harney Basin Hydrostratigraphic Units

Hydraulic property values were determined and assigned to each hydrostratigraphic unit as described in appendix M. The process repeated the stratigraphic unit process. Hydrostratigraphic units exposed at the total open interval (total OPI) of each well was identified and the percentage of the total OPI occupied by each exposed unit was calculated. The percentage results are listed by well in appendix H and J. The hydraulic property related to a well was assigned to a single hydrostratigraphic unit at the well when the unit occupied 90 to 100 percent of the total OPI. Summary statistics for each hydrostratigraphic unit specific capacity, transmissivity, and hydraulic conductivity are shown as box and whiskers plots in figures 26 to 28, in appendix O tables, and in tables 7 to 15 that accompany the unit descriptions that follow.

Table 6. List of Harney Basin hydrostratigraphic units

Hydrostratigraphic Unit		Stratigraphic Unit	
Younger basin fill	YBF	Quaternary sedimentary deposits	Qs
Voltage Basalt	VB	Voltage Basalt	Qvb
Proximal vent deposits	PVD	Diamond Craters basalt and tephra	Qdc
		Mafic vent complexes	QTV
Older basin fill	OBF	Basin fill deposits undifferentiated	Qtsu
		Tuffaceous sedimentary rocks and tuff	Tts
		Rattlesnake Ash-flow Tuff	Trt
		Devine Canyon Ash-flow Tuff	Tdv
High Lava Plains basalt	HLP	HLP basalt undifferentiated	HLPu
		Pleistocene-Pliocene basalt	QTb
		Olivine basalt	Tob
		Olivine basalt and andesite of Gum Boot Canyon	Tobg
		Drinkwater Basalt	Tdw
		Basalt of Harney Lake	Tbh
Dry Mountain lavas	DML	Basalt and andesite of Dry Mountain	Tdm
Silicic lava flows and domes	SFD	Silicic lava flows and domes	Trd
		Andesite	Ta
Upland volcanic rocks	UVR	Older volcanic rocks	Tov
		Steens Basalt	Tsb
Marine sedimentary rocks	MSR	Mesozoic rocks	Mzu

Notes:

Units are generally sorted from youngest to oldest

Stratigraphic unit geologic descriptions are found in appendix A

Stratigraphic unit hydraulic property statistics are found in figures 22 to 24, and appendix N

Basin fill deposits undifferentiated (Qtsu) was created to account for hydraulic property values associated with reported subsurface material descriptions that were not sufficient to assign to Quaternary sedimentary deposits (Qs), Tuffaceous sedimentary rocks and tuff (Tts), or another unit

HLP basalt undifferentiated (HLPu) was created to account for hydraulic property values associated with reported subsurface material descriptions that were not sufficient to assign to a particular basalt unit

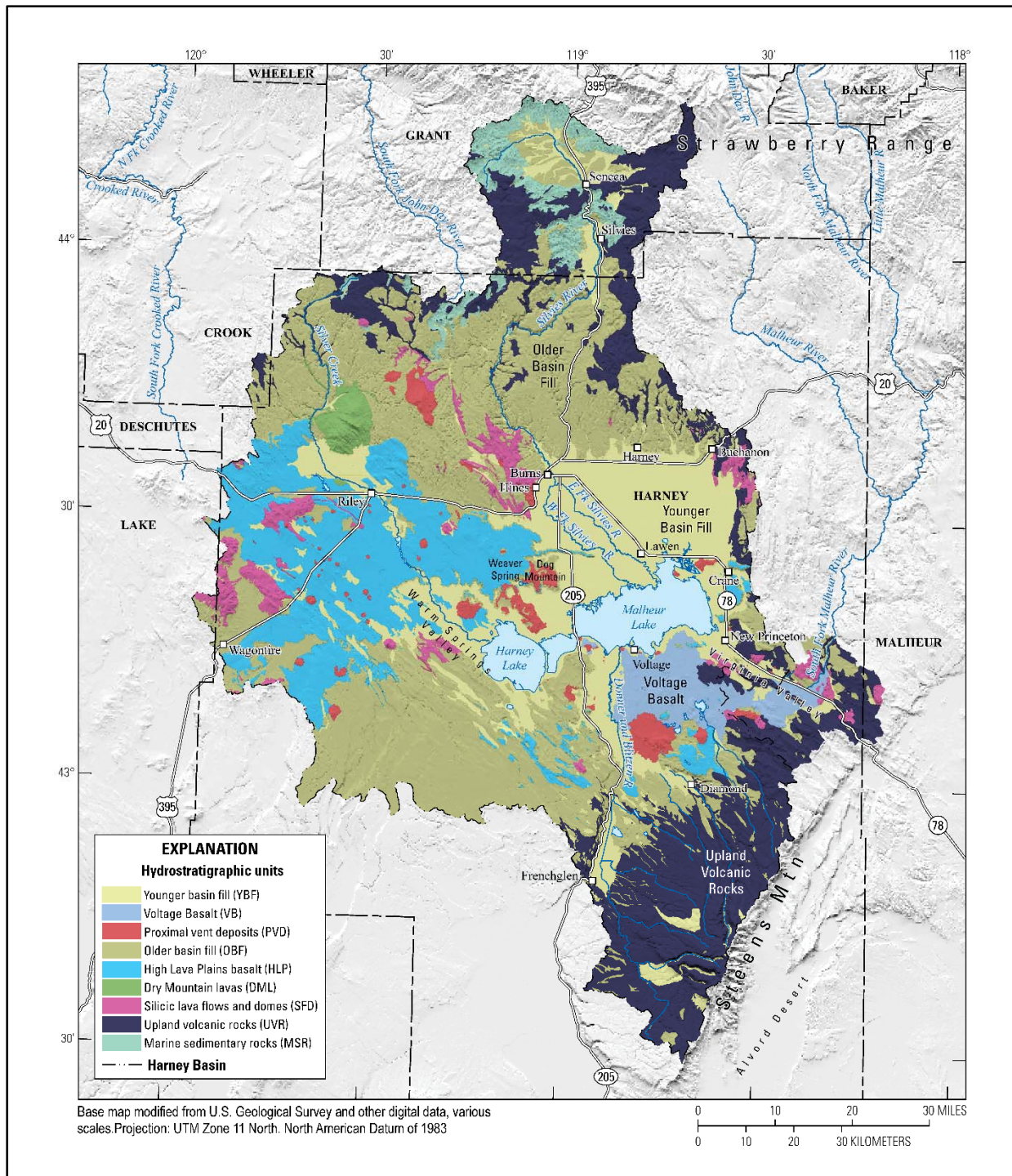


Figure 25. Surficial map of Harney Basin hydrostratigraphic units

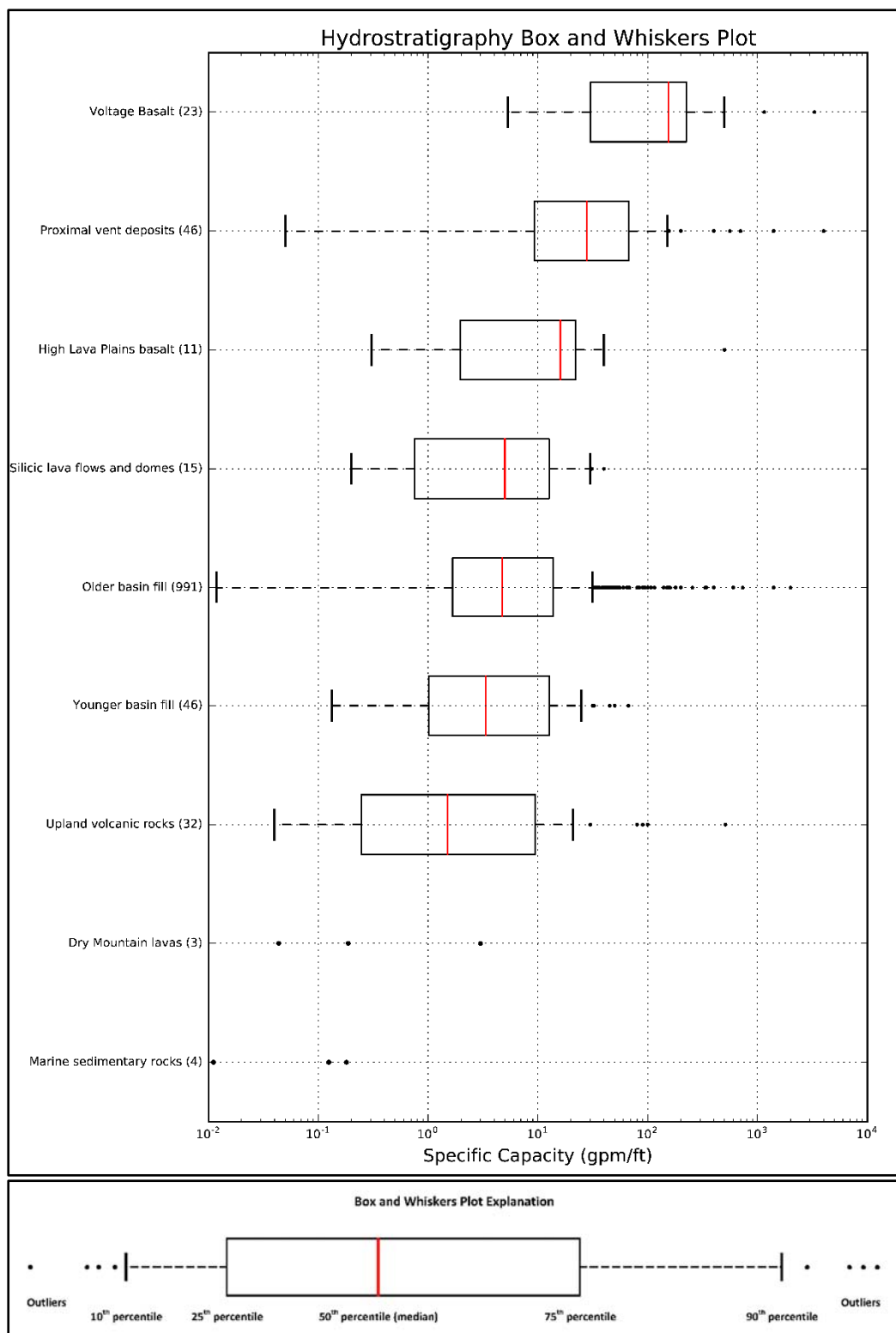


Figure 26. Specific capacity of Harney Basin hydrostratigraphic units
[from 1,171 tests at 1,060 wells inside Harney Basin, largest to smallest median value order]

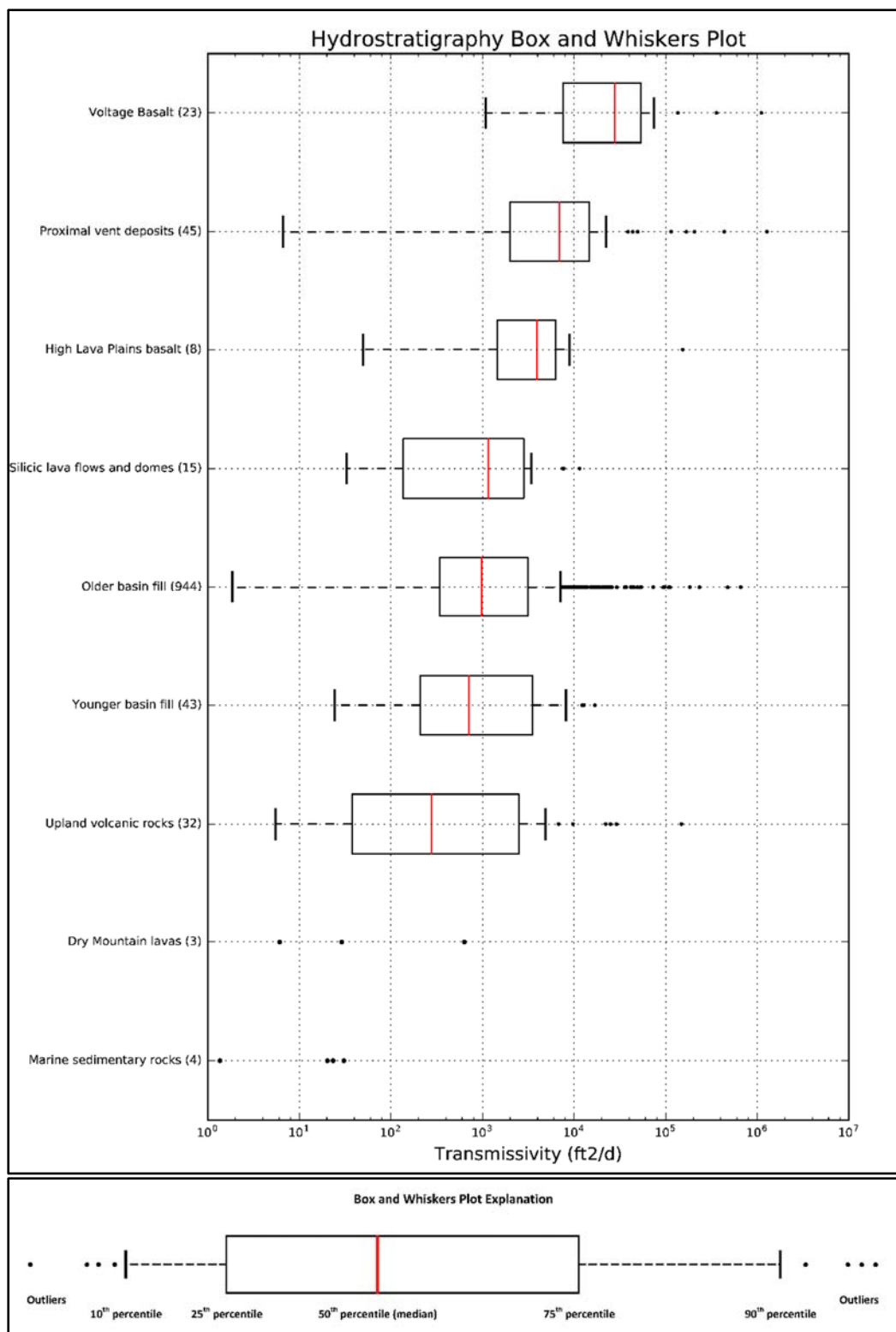


Figure 27. Transmissivity of Harney Basin hydrostratigraphic units
 [from 1,117 tests at 1,020 wells inside Harney Basin, largest to smallest median value order]

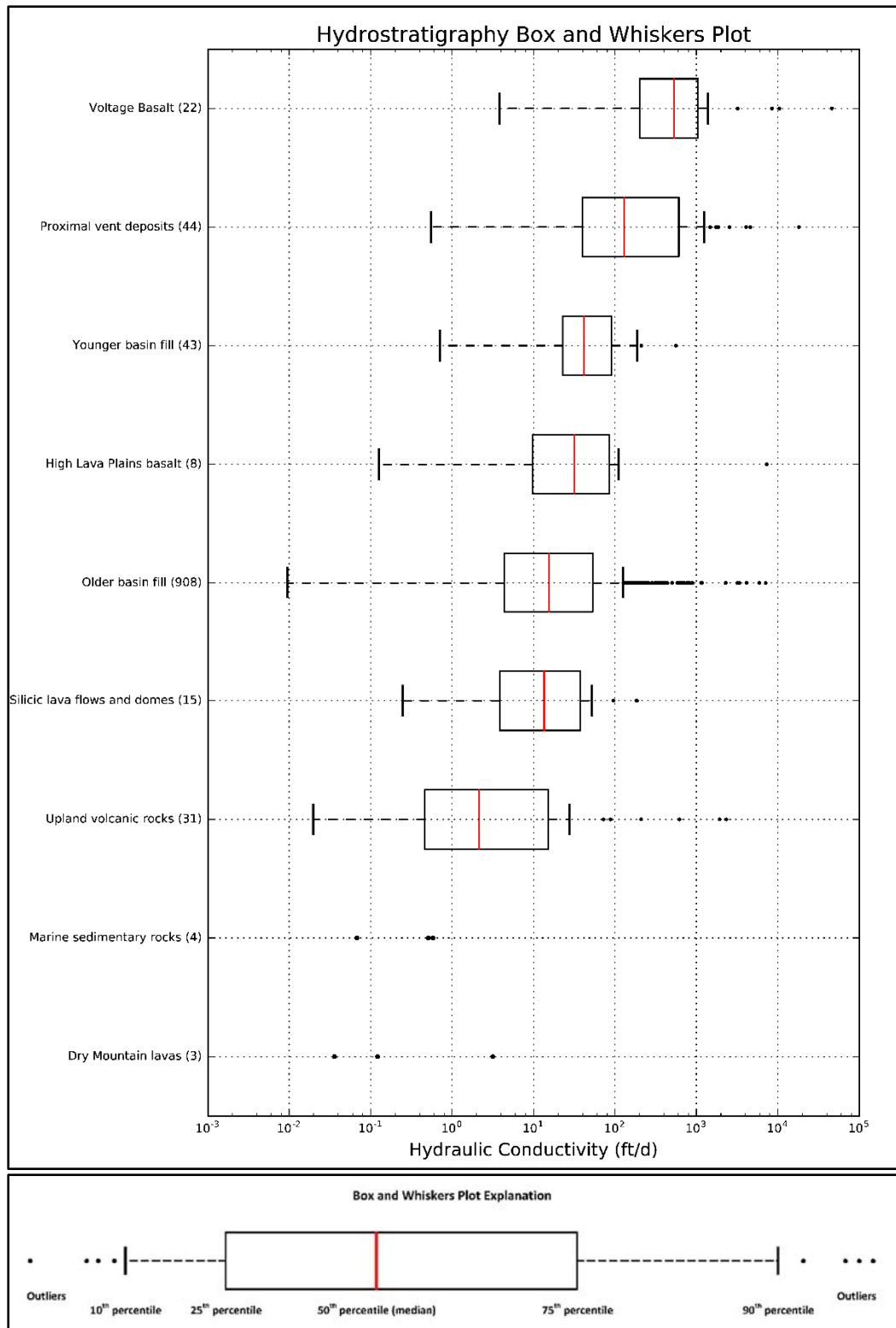


Figure 28. Hydraulic conductivity of Harney Basin hydrostratigraphic units
[from 1,078 tests at 1,013 wells inside Harney Basin, largest to smallest median value order]

The hydrostratigraphic unit hydraulic property statistics shown in figures 26 to 28 and listed in tables 7 to 15 are based on hydraulic property calculation results related to pump tests (appendix G and H) and well yield tests recorded on water well reports (appendix I and J). The pump test quality rating included good, fair, and poor (appendix H). The well yield tests included tests with a 0.00 feet total drawdown reported (appendix J). The 0.00 feet total drawdown tests were assigned 0.5 feet total drawdown for hydraulic property calculations. Some wells have multiple tests, such as a pump test and a well yield test (each test is a separate record), resulting in tables 7 to 15 occasionally noting more tests total than wells total.

Pump tests rated poor quality relate to two of the nine hydrostratigraphic units: High Lava Plains basalt (specific capacity only) and Older basin fill (specific capacity and transmissivity) (appendix O). For the High Lava Plains basalt, the median did not change. For the Older basin fill, the specific capacity and transmissivity medians decreased from 4.8 to 4.5 gpm/ft and 977.9 to 965.9 ft²/d when tests rated poor were excluded. See appendix O for other comparisons.

Each successive hydraulic property calculated (specific capacity, transmissivity, hydraulic conductivity) required additional data. Not every test included the additional data resulting in a decreasing total number of tests and wells for each successive hydraulic property for some hydrostratigraphic units. A decreasing total number can occasionally cause a changing range of specific capacity, transmissivity, and hydraulic conductivity values available for each hydrostratigraphic unit statistics.

The hydrostratigraphic units shown in figures 26 to 28 are ordered from largest to smallest median hydraulic property value. The hydrostratigraphic unit order is the same for specific capacity and transmissivity but shifts for hydraulic conductivity. The shift can be due to the total open interval lengths used to calculate hydraulic conductivity from transmissivity varying well to well and/or a decreasing total number of tests and wells noted for each successive hydraulic property for some hydrostratigraphic units as noted above. Regardless, the largest median hydraulic property values relate to younger volcanic deposits, intermediate median values relate to Silicic and High Lava Plains volcanic deposits and basin-fill sediments, and the smallest median values generally relate to upland deposits. The median values for all units collectively range three orders of magnitude. The maximum range for all values for all units collectively is five to six orders of magnitude depending on the hydraulic property.

Marine Sedimentary Rocks (MSR)

Exposures of the Marine sedimentary rocks (MSR) hydrostratigraphic unit are limited to the northern uplands (figure 25), but they are thought to form the basement underlying much of the Harney Basin (Streck, 2002; McClaughry and others, 2019). The MSR unit contains the Mesozoic rocks stratigraphic unit (table 6), which contains mostly marine sedimentary rocks but includes minor amounts of intrusive and metamorphic rocks. The MSR unit is composed of fine-grained lithologies having low permeability. Even where coarse-grained lithologies exist, compaction, cementation, and metamorphism has eliminated much of the permeability. Secondary minerals are common in fracture zones and faults, indicating that much of the permeability created through structural deformation has also been subsequently lost (Brown and Thayer, 1963). In the Mount Vernon quadrangle report, Brown and Thayer (1966b) recognized that the marine sedimentary rocks in the Aldrich Mountains have low permeability and are unfavorable reservoir rocks for groundwater. The hydraulic property estimates for this unit are limited and have the lowest values (table 7, figures 26 to 28, appendix O).

Table 7. Marine Sedimentary Rocks hydrostratigraphic unit hydraulic property statistics

Variable	Marine Sedimentary Rocks		
	Specific Capacity (gallons/minute)/foot	Transmissivity (feet ² /day)	Hydraulic Conductivity (feet/day)
Number of Tests	4	4	4
Number of Wells	4	4	4
Mean	1.10 E-01	1.89 E+01	4.18 E-01
Median	1.25 E-01	2.19 E+01	5.10 E-01
Minimum	1.11 E-02	1.36 E+00	6.80 E-02
Maximum	1.81 E-01	3.07 E+01	5.85 E-01

Upland Volcanic Rocks (UVR)

The Upland volcanic rocks (UVR) hydrostratigraphic unit forms the base of the Cenozoic section and is extensively exposed in the northern and southern uplands and along the eastern margin of the basin (figure 25). The UVR unit combines the Steens Basalt and Older volcanic rocks stratigraphic units (table 6). The thickness is variable, but it reaches a maximum of almost

10,000 feet in the south (Minor and others, 1987) and may be more than 6,500 feet thick in the northern uplands (Thayer, 1957). On the flanks of Steens Mountain, the unit is dominated by thin basalt lava flows with brecciated, vesicular, or clinkery upper and lower crusts and massive, vesicle-poor cores (Bondre and Hart, 2008). Camp and others (2013) observed that sedimentary and tuffaceous interbeds are notably absent in the Steens Basalt.

The contacts between flow units within the UVR unit are locally welded to varying degrees, and some flows are composed of thinner units whose margins have been annealed (Bondre and Hart, 2008). These flow characteristics may account in part for the relatively low transmissivities observed for wells developed in these rocks. Furthermore, Fuller (1931) describes north-south-trending basaltic dikes exposed in valley walls of Steens Mountain. Dikes cut across the gently dipping lava flows that form most of Steens Mountain and generally impede groundwater flow. UVR unit hydraulic property values are listed in table 8 and appendix O and shown in figures 26 to 28.

Table 8. Upland Volcanic Rocks hydrostratigraphic unit hydraulic property statistics

Variable	Upland Volcanic Rocks		
	Specific Capacity (gallons/minute)/foot)	Transmissivity (feet ² /day)	Hydraulic Conductivity (feet/day)
Number of Tests	32	32	31
Number of Wells	32	32	31
Mean	2.80 E+01	8.02 E+03	1.72 E+02
Median	1.50 E+00	2.77 E+02	2.16 E+00
Minimum	4.00 E-02	5.53 E+00	1.96 E-02
Maximum	5.10 E+02	1.49 E+05	2.33 E+03
Percentile			
2nd	5.12 E-02	7.63 E+00	3.22 E-02
9th	8.33 E-02	1.55 E+01	1.15 E-01
10th	9.01 E-02	1.70 E+01	1.38 E-01
25th	2.46 E-01	3.77 E+01	4.64 E-01
75th	9.50 E+00	2.50 E+03	1.52 E+01
90th	7.50 E+01	2.08 E+04	2.10 E+02
91st	8.21 E+01	2.27 E+04	3.33 E+02
98th	2.56 E+02	7.46 E+04	2.08 E+03

Silicic Lava Flows and Domes (SFD)

The Silicic lava flows and domes (SFD) hydrostratigraphic unit occurs as widely scattered eruptive centers forming structural and constructional volcanic highs along the margins of the central lowlands (figure 25). The SFD unit combines the andesite and silicic lava flows, and domes stratigraphic units (table 6), which are typically extruded as thick, highly viscous lava flows and domal masses of generally low permeability. Alteration to clay minerals and secondary silicification further reduces the potential for permeability in these rocks. Primary permeability may occur locally in brecciated bottoms of lava flows and along flow margins. Fragmental deposits associated with explosive eruptions and elastic deposits including talus breccias and block and ash-flow deposits may also provide local permeability. Secondary permeability occurs where these rocks are extensively fractured and faulted. The total thickness of these rocks is unknown but is likely substantially greater than 1,000 feet near central dome and vent areas, progressively thinning toward flow margins. SFD unit hydraulic property values are listed in table 9 and appendix O and shown in figures 26 to 28.

Table 9. Silicic Lava Flows and Domes hydrostratigraphic unit hydraulic property statistics

Variable	Silicic Lava Flows and Domes		
	Specific Capacity (gallons/minute)/foot)	Transmissivity (feet ² /day)	Hydraulic Conductivity (feet/day)
Number of Tests	15	15	15
Number of Wells	15	15	15
Mean	1.02 E+01	2.56 E+03	4.10 E+01
Median	5.00 E+00	1.15 E+03	1.35 E+01
Minimum	2.00 E-01	3.31 E+01	2.45 E-01
Maximum	4.00 E+01	1.15 E+04	1.86 E+02
Percentile			
2nd	2.00 E-01	3.42 E+01	2.74 E-01
9th	2.26 E-01	4.07 E+01	4.07 E-01
10th	2.40 E-01	4.28 E+01	4.39 E-01
25th	7.50 E-01	1.37 E+02	3.84 E+00
75th	1.27 E+01	2.83 E+03	3.76 E+01
90th	3.06 E+01	7.62 E+03	1.49 E+02
91st	3.07 E+01	7.65 E+03	1.61 E+02
98th	3.75 E+01	1.04 E+04	1.86 E+02

Dry Mountain Lavas (DML)

The Dry Mountain lavas (DML) hydrostratigraphic unit is found 6 miles northwest of Riley. Dry Mountain is a shield volcano rising more than 2,000 feet above Silver Creek and is composed of numerous basaltic and andesitic lava flows with an exposed thickness of more than 700 feet. The total thickness is unknown but likely greatly exceeds 700 feet given the mountain's size. A series of northwest-trending faults cuts through Dry Mountain, creating a stepped graben structure across which substantial extension has occurred. Some faults may have been active as recently as middle to late Quaternary (Weldon and others, 2003). Scarce springs, minimal surface-water runoff, and anecdotal reports of livestock-watering ponds unable to retain water all indicate that the DML unit should be highly permeable. However, limited data related to few wells completed in this unit have substantially lower than anticipated hydraulic property values (table 10, appendix O, figures 26 to 28). These few wells are along lower, unfaulted mountain flanks. DML unit exposures in the canyon of Silver Creek downstream of McCanlies Road exhibit blocky, poorly connected fractures and jointing and little primary permeability. Secondary permeability likely exists at upper elevations where the DML unit is faulted.

Table 10. Dry Mountain Lavas hydrostratigraphic unit hydraulic property statistics

Variable	Dry Mountain Lavas		
	Specific Capacity (gallons/minute)/foot)	Transmissivity (feet ² /day)	Hydraulic Conductivity (feet/day)
Number of Tests	3	3	3
Number of Wells	3	3	3
Mean	1.08 E+00	2.23 E+02	1.11 E+00
Median	1.88 E-01	2.90 E+01	1.21 E-01
Minimum	4.36 E-02	6.10 E+00	3.59 E-02
Maximum	3.00 E+00	6.32 E+02	3.16 E+00

Older Basin Fill (OBF)

The Older basin fill (OBF) hydrostratigraphic unit extends from upland exposures to the lowlands where it is buried beneath the Younger basin fill (YBF) hydrostratigraphic unit (figure 25). The stratigraphic units composing the OBF unit include tuffaceous sedimentary rocks and tuff, the Devine Canyon and Rattlesnake ash-flow tuffs, and undifferentiated basin fill deposits (table 6). Undifferentiated units were assigned to the OBF unit because in many places the overlying Quaternary sedimentary deposits of the Younger basin fill unit are relatively thin.

The sedimentary strata within the Older basin fill unit formed in a variety of depositional environments and include fluvial, lacustrine, colluvial, aeolian, and evaporite deposits. The deposits are diverse in physical character, highly lenticular, greatly varied in thickness locally, and grade into sediments of different lithology over short distances. Consequently, OBF unit sediments have a broad range of permeability depending on the depositional environment, grain size, sorting, depth and duration of burial, compaction, and cementation. In some areas, fine grained lithologies such as siltstone and claystone can provide sufficient groundwater to irrigation wells through secondary fracturing. The individual ash-flow tuffs also exhibit a wide range of permeability depending on facies variations and alteration. In some locations, secondary minerals fill pore spaces within the various basin-fill lithologies and reduce primary permeability. The combined effect of these depositional and diagenetic processes results in a complex basin-fill unit with highly heterogenous permeability.

The OBF unit varies greatly in thickness. Along the flanks of Steens Mountain and in the northern uplands, the unit thins considerably and pinches out where it laps onto the underlying rocks. The unit thickens substantially toward the central Harney Basin lowlands where it is penetrated by numerous wells to depths greater than 1,000 feet. Drilling records from oil and gas wells within the basin indicate that the deposits may be nearly 4,000 feet thick in some places, although stratigraphic interpretations from the records are ambiguous. OBF unit hydraulic property values are listed in table 11 and appendix O and shown in figures 26 to 28.

Table 11. Older Basin Fill hydrostratigraphic unit hydraulic property statistics

Variable	Older Basin Fill		
	Specific Capacity (gallons/minute)/foot)	Transmissivity (feet ² /day)	Hydraulic Conductivity (feet/day)
Number of Tests	991	944	908
Number of Wells	883	850	844
Mean	2.07 E+01	5.58 E+03	8.96 E+01
Median	4.76 E+00	9.78 E+02	1.56 E+01
Minimum	1.18 E-02	1.87 E+00	9.50 E-03
Maximum	2.00 E+03	6.61 E+05	7.10 E+03
Percentile			
2nd	1.89 E-01	2.97 E+01	1.86 E-01
9th	6.00 E-01	1.12 E+02	9.22 E-01
10th	6.43 E-01	1.24 E+02	1.09 E+00
25th	1.67 E+00	3.42 E+02	4.40 E+00
75th	1.38 E+01	3.12 E+03	5.33 E+01
90th	4.09 E+01	1.02 E+04	1.56 E+02
91st	4.55 E+01	1.08 E+04	1.67 E+02
98th	1.51 E+02	4.21 E+04	6.87 E+02

High Lava Plains Basalt (HLP)

The High Lava Plains basalt (HLP) hydrostratigraphic unit is widely exposed at the surface in the western part of the basin, interbedded with the OBF unit, and underlies the Younger basin fill hydrostratigraphic unit beneath much of Silver Creek (figure 25). A few exposures also occur along the southeastern margin of the Harney Basin lowlands and in the faulted uplands south of Harney Lake. The HLP unit contains the stratigraphic units identified as basalt (Pleistocene and Pliocene), olivine basalt, olivine basalt and andesite of Gum Boot Canyon, Drinkwater Basalt, and the basalt of Harney Lake (table 6). These rocks commonly occur as thin compound lava flows with vesicular, brecciated or clinkery zones at flow tops, and vesicular, brecciated basal zones. Columnar and platy jointing are common and thin interbeds of tuffaceous sedimentary rocks occur locally. The jointing, vesicles, breccia zones, and thin, overlapping nature of these flows provide abundant interconnected pore space, and much of the primary permeability remains intact due to the relatively youthful age of the unit. Wells along Silver Creek Valley produce groundwater from the HLP unit with reported yields greater than 1,000 gpm. The thickness of the HLP unit varies widely across the basin, but based on well reports and mapped exposures, the total composite

thickness may approach 1,000 feet. HLP unit hydraulic property values are listed in table 12 and appendix O and shown in figures 26 to 28.

Table 12. High Lava Plains Basalt hydrostratigraphic unit hydraulic property statistics

Variable	High Lava Plains Basalt		
	Specific Capacity (gallons/minute)/foot)	Transmissivity (feet ² /day)	Hydraulic Conductivity (feet/day)
Number of Tests	11	8	8
Number of Wells	10	7	7
Mean	5.72 E+01	2.22 E+04	9.47 E+02
Median	1.60 E+01	3.91 E+03	3.15 E+01
Minimum	3.06 E-01	4.98 E+01	1.25 E-01
Maximum	5.00 E+02	1.54 E+05	7.31 E+03
Percentile			
2nd	3.06 E-01	4.98 E+01	1.25 E-01
9th	3.06 E-01	4.98 E+01	1.25 E-01
10th	3.06 E-01	4.98 E+01	1.25 E-01
25th	1.98 E+00	1.44 E+03	9.67 E+00
75th	2.21 E+01	6.33 E+03	8.49 E+01
90th	4.00 E+01	5.22 E+04	2.27 E+03
91st	8.60 E+01	6.24 E+04	2.77 E+03
98th	4.08 E+02	1.33 E+05	6.30 E+03

Proximal Vent Deposits (PVD)

The Proximal vent deposits (PVD) hydrostratigraphic unit created by fragmentation of magma during explosive eruptions of lava are scattered widely across the High Lava Plains province of the basin (figure 25). The PVD unit combines mafic vent complexes and Diamond Craters basalt and tephra (table 6). These highly fragmented piles of volcanic material and thin lava flows have abundant interconnected open pore space and commonly have very high permeability. Variations in clast size, sorting, and degree of welding and induration can result in variable permeability. Localized clay-rich altered tuff formed by phreatomagmatic eruptions associated with these deposits results in low-permeability in some areas. Generally, however, PVD unit deposits are among the most permeable rocks in the basin, and many wells completed in these deposits have high yields. The thickness of the PVD unit depends on the overall size of the eruptive center that produced the deposits and proximity to the central part of the eruptive center.

Generally, the deposits are thickest at the central part of the eruptive center, thinning toward the margins where they feather out into the surrounding deposits. At the Weaver Spring/Dog Mountain area (figure 25), the PVD unit deposits are complexly interbedded with the OBF unit sediments. Here, individual layers of the PVD unit deposits are commonly 20–100 feet thick but can range up to nearly 500 feet thick. PVD unit hydraulic property values are listed in table 13 and appendix O and shown in figures 26 to 28.

Table 13. Proximal Vent Deposits hydrostratigraphic unit hydraulic property statistics

Variable	Proximal Vent Deposits		
	Specific Capacity (gallons/minute)/foot)	Transmissivity (feet ² /day)	Hydraulic Conductivity (feet/day)
Number of Tests	46	45	44
Number of Wells	45	44	44
Mean	2.16 E+02	5.71 E+04	9.63 E+02
Median	2.79 E+01	6.91 E+03	1.29 E+02
Minimum	5.00 E-02	6.61 E+00	5.51 E-01
Maximum	4.00 E+03	1.27 E+06	1.82 E+04
Percentile			
2nd	3.86 E-01	6.72 E+01	1.48 E+00
9th	3.33 E+00	6.68 E+02	6.78 E+00
10th	3.33 E+00	6.89 E+02	8.66 E+00
25th	9.34 E+00	2.01 E+03	3.96 E+01
75th	6.75 E+01	1.47 E+04	6.09 E+02
90th	4.80 E+02	8.84 E+04	1.83 E+03
91st	5.52 E+02	1.17 E+05	1.95 E+03
98th	1.66 E+03	5.38 E+05	6.50 E+03

Voltage Basalt (VB)

The Voltage Basalt (VB) hydrostratigraphic unit covers more than 150 mi² south and southeast of Malheur Lake (figure 25). Thin, overlapping lava flows composing the VB unit are commonly rubbly and scoriaceous with abundant blocky, fragmental zones and surface crusts uplifted and fractured by formation of tumuli. Thin, ropy pahoehoe flows fed by large- and small-scale distributary tube systems are also common. The resulting volcanic pile has abundant interior void space and very high permeability. Many wells developing groundwater from the VB unit can pump greater than 1,000 gpm with minimal drawdown. A total VB unit thickness up to 320 feet

has been penetrated by wells in the central part of the volcanic deposit, but most wells that penetrate through the entire VB unit encounter the underlying OBF unit after less than 200 feet. Greater thicknesses may exist where these lavas filled in low areas in the paleotopographic surface. VB unit hydraulic property values are listed in table 14 and appendix O and shown in figures 26 to 28.

Table 14. Voltage Basalt hydrostratigraphic unit hydraulic property statistics

Variable	Voltage Basalt		
	Specific Capacity (gallons/minute)/foot)	Transmissivity (feet ² /day)	Hydraulic Conductivity (feet/day)
Number of Tests	23	23	22
Number of Wells	22	22	22
Mean	3.30 E+02	9.70 E+04	3.48 E+03
Median	1.56 E+02	2.77 E+04	5.32 E+02
Minimum	5.29 E+00	1.08 E+03	3.80 E+00
Maximum	3.30 E+03	1.11 E+06	4.62 E+04
Percentile			
2nd	5.44 E+00	1.13 E+03	3.91 E+00
9th	7.46 E+00	1.77 E+03	4.85 E+00
10th	7.53 E+00	1.81 E+03	1.10 E+01
25th	3.00 E+01	7.56 E+03	2.02 E+02
75th	2.25 E+02	5.38 E+04	1.05 E+03
90th	5.00 E+02	1.36 E+05	7.97 E+03
91st	5.13 E+02	1.40 E+05	8.71 E+03
98th	2.35 E+03	7.79 E+05	3.12 E+04

Younger Basin Fill (YBF)

The Younger basin fill (YBF) hydrostratigraphic unit consists of Quaternary sediments deposited after the damming of Virginia Valley by the Voltage Basalt about 1.5 Ma. The YBF unit occupies modern stream channels and floodplains and makes up the uppermost part of the basin fill in the Harney Basin lowlands (figure 25). The YBF unit sedimentary strata formed in a variety of depositional environments that include fluvial, lacustrine, colluvial, aeolian, and evaporite deposits, as well as glacial till and morainal deposits on Steens Mountain. YBF unit sediments are commonly unconsolidated but locally semi-consolidated at depth. Waring (1909), Piper and others (1939), and Leonard (1970) observed the Younger basin fill HU is generally finer

toward the center of the valley where low energy fluvial and lacustrine processes dominate, and coarser toward the margins where higher energy streams enter the valley floor from the upper elevation parts of their catchments.

The YBF unit sediments are sourced from the same upland lithologies as the OBF unit and therefore can have similar petrologic character and degree of consolidation. This makes the two units difficult to distinguish in the subsurface, especially when making interpretations based solely on drillers' subsurface material (lithologic) descriptions listed in water well reports. Previous investigators recognized the difficulty of estimating the thickness of the YBF unit and made their estimates based largely on water well report lithologic descriptions that indicated consolidation and/or cementation at depth. Waring (1909) estimated that the Quaternary fill is less than 300 feet thick at most places; Piper and others (1939) estimated that the Quaternary fill is about 100 feet thick within 5 miles of Burns and along the northeastern margin of the valley, thickening to 200–275 feet north of Malheur Lake; and Leonard (1970) indicated that the unconsolidated valley fill has a maximum thickness of about 250 feet. YBF unit hydraulic property values are listed in table 15 and appendix O and shown in figures 26 to 28.

Table 15. Younger Basin Fill hydrostratigraphic unit hydraulic property statistics

Variable	Younger Basin Fill		
	Specific Capacity (gallons/minute)/foot)	Transmissivity (feet ² /day)	Hydraulic Conductivity (feet/day)
Number of Tests	46	43	43
Number of Wells	46	43	43
Mean	1.00 E+01	2.65 E+03	7.40 E+01
Median	3.33 E+00	7.08 E+02	4.16 E+01
Minimum	1.33 E-01	2.43 E+01	7.14 E-01
Maximum	6.67 E+01	1.68 E+04	5.60 E+02
Percentile			
2nd	2.06 E-01	6.89 E+01	2.13 E+00
9th	5.73 E-01	1.17 E+02	7.98 E+00
10th	5.86 E-01	1.18 E+02	9.41 E+00
25th	1.02 E+00	2.09 E+02	2.29 E+01
75th	1.27 E+01	3.49 E+03	9.14 E+01
90th	3.16 E+01	8.05 E+03	1.44 E+02
91st	3.16 E+01	8.08 E+03	1.51 E+02
98th	5.17 E+01	1.35 E+04	2.67 E+02

Subsequent Hydraulic Property Testing and Analyses Recommended

This investigation collected, compiled and analyzed numerous existing tests for Harney Basin subsurface materials hydraulic properties: one aquifer-interference test, two groundwater level recorder data influenced by nearby irrigation wells, 41 pump tests, and more than 1,000 well yield tests. All the tests yielded data useful to characterize well response to pumping (specific capacity) and subsurface control on groundwater flow (transmissivity by all tests and hydraulic conductivity by most tests). Only the two groundwater level recorder data influenced by nearby irrigation wells yielded data useful to characterize groundwater storage. Only the one aquifer-interference test yielded sufficient data to indicate possible deformability, plasticity, and/or elasticity of one or more Harney Basin subsurface materials.

Limited investigation time and resources precluded conducting additional tests to more completely characterize groundwater storage or assess subsurface material flexibility. Future work should conduct such tests both shallow and deep for each hydrostratigraphic unit in the Harney Basin uplands and lowlands. The test results would refine well to well interaction calculations and aid future groundwater modeling efforts to characterize Harney Basin groundwater flow and storage under various conditions and scenarios.

Summary

This report is part of a multi-year joint U.S. Geological Survey and Oregon Water Resources Department investigation to better define the 5,243 mi² Harney Basin groundwater system, its water budget, and its response to groundwater development. Observed groundwater level declines and questions about groundwater resource sustainability prompted the investigation. This report presented the hydraulic properties of the basin's subsurface materials.

Subsurface materials (stratigraphic units and hydrostratigraphic units) possess hydraulic characteristics that control groundwater recharge, flow, discharge, storage, and the groundwater system's response to natural and anthropogenic stress such as floods, drought, change in native plant evapotranspiration, and groundwater development. The parameters used to characterize the subsurface hydraulic properties (specific capacity, transmissivity, hydraulic conductivity, and storage coefficient), the methods used to obtain those values, and the estimates or ranges of those

parameter values for the various stratigraphic units and hydrostratigraphic units in the basin were presented in this report text and appendices. Quantifying hydrostratigraphic unit hydraulic properties is important for understanding and describing the basin's groundwater flow system, the observed groundwater level declines, the sustainability of the groundwater resource, and the development of numerical groundwater models that represent the groundwater system.

This investigation collected, compiled and analyzed numerous existing tests for Harney Basin subsurface materials hydraulic properties: one aquifer-interference test, two data records from two automatic groundwater level recorder groundwater level recorder wells influenced by nearby irrigation wells, 41 single-well pump tests, and more than 1,000 well yield tests. The data from these tests can be divided into two data categories (aquifer test data and specific capacity data) that required using different data analysis methods (graphical method and numerical method respectively). All the tests yielded data useful to characterize well response to pumping (specific capacity) and subsurface control on groundwater flow (transmissivity by all tests and hydraulic conductivity by most tests). Only the two data records from the two automatic groundwater level recorder groundwater level recorder wells influenced by nearby irrigation wells yielded data useful to characterize groundwater storage. Only the one aquifer-interference test yielded sufficient data to indicate possible deformability, plasticity, and/or elasticity of one or more Harney Basin subsurface materials.

The calculated specific capacity, transmissivity, and hydraulic conductivity results collectively show 90 percent of the results are less than 85 gallons per minute per foot drawdown (gpm/ft) for specific capacity, 13,000 feet² per day (ft²/d) for transmissivity, and 230 feet per day (ft/d) for hydraulic conductivity. The interquartile values range from 0.5 to 50 gpm/ft for specific capacity, 105 to 6,300 (ft²/d) for transmissivity, and 0.8 to 73 (ft/d) for hydraulic conductivity. The median value varies from 2 to 16 gpm/ft for specific capacity, 415 to 1,310 (ft²/d) for transmissivity, and 4 to 19 (ft/d) for hydraulic conductivity depending on test grouping considered.

Storage coefficient value results were limited to analyses of two automated groundwater level recorder data from northeast Harney Valley and northwest of Harney Lake. For northeast Harney Valley, the storage coefficient value that best reproduced May through September 2017 data was 0.050 indicating unconfined groundwater conditions at the 157-foot total depth recorder well (HARN 52494) which is cased to 157 feet, sealed to 48 feet, and perforated from 124 to 142

feet below land surface respectively. For northwest of Harney Lake, the storage coefficient value that best reproduced May through October 2018 data was 0.005 indicating intermediate groundwater conditions (intermediated between unconfined and confined) at the 432-foot total depth recorder well (HARN 52534) which is cased 250 below land surface and sealed to 50 feet below land surface.

The sole aquifer-interference test yielded sufficient data to show an apparent Noorbergum Effect (an initial reverse water level response to the onset and shut-off of pumping) observed at two observation wells shallower than the pumping well. The effect arises from a three-dimensional deformation of geologic materials hosting groundwater. This indicates possible deformability, plasticity, and/or elasticity of one or more Harney Basin subsurface materials.

The hydraulic property results generally showed no relation to well construction with two possible exceptions. The specific capacity and transmissivity results show a possibly weak relation to the well diameter. The hydraulic conductivity results show a possibly weak inverse relation with total well depth (decreasing hydraulic conductivity with increasing well depth). If real, a decreasing value with increasing total depth may relate to increasing age, alteration, and compaction with depth and/or may relate to longer open intervals at deeper wells biasing hydraulic conductivity calculations.

Specific capacity, transmissivity, and hydraulic conductivity results are generally spatially ubiquitous for smaller values and increasingly spatially segregated for the largest values. The largest value range is most concentrated along the Harney Valley perimeter and the Riley vicinity. For wells less than 150 feet total depth, the largest value range distribution is concentrated along the southwest, south, and east perimeter of Harney Valley. For wells 150 feet total depth and greater, the largest value range is concentrated along the southwest, west, north, and east perimeter of Harney Valley and the Riley vicinity. The second largest value range is most concentrated along the southwest, west, north, and east perimeter of Harney Valley for all well depths and the Riley vicinity for wells 150 feet total depth and greater. These larger value distributions appear to coincide with eruptive centers, younger volcanic flows, coarser grained sedimentary deposits, and possibly geologic structure. The two lowest value ranges are generally ubiquitous and are found intermixed with the two largest value ranges indicating the complexity, heterogeneity of the Harney Basin subsurface materials.

Assigning the hydraulic property value from each hydraulic property test to one or more of 18 identified Harney Basin subsurface stratigraphic unit(s) or two “unidentified units” (created for descriptions insufficient to discern a particular stratigraphic unit but sufficient enough to assign to a hydrostratigraphic unit) at a related well required a multi-step process summarized in the report text and detailed in the report appendices. The stratigraphic units exposed at the total open interval (total OPI) of 1,495 wells was identified and the percentage of the open interval occupied by each exposed stratigraphic unit was calculated. The hydraulic property related to a well was assigned to a single stratigraphic unit exposed at the well when the stratigraphic unit occupied 90 to 100 percent of the total OPI. The total number of hydraulic values assigned to each stratigraphic unit ranged from none to 744. Summary statistics of all the hydraulic property values assigned to each stratigraphic unit were determined.

The specific capacity, transmissivity, and hydraulic conductivity statistics for each stratigraphic unit were listed in tables and comparatively presented as box and whiskers plot graphs. There is an overall pattern. The largest median values relate to basalts and mafic vent deposits. Intermediate median values appear related to andesite, various tuffaceous deposits, silicic flows and domes, and basin-fill sediments. The smallest median values relate to older volcanic deposits and the complex of Mesozoic rocks. The median values for all stratigraphic units collectively range three to four orders of magnitude depending on the hydraulic property. The maximum range for all values for all stratigraphic units collectively is approximately five to six orders of magnitude depending on the hydraulic property.

The Harney Basin stratigraphic units were grouped into nine hydrostratigraphic units based upon similar hydraulic property value ranges, geologic characteristics, and stratigraphic position. Hydraulic property values were determined and assigned to each hydrostratigraphic unit repeating the process used for the stratigraphic units. The hydraulic property related to a well was assigned to a single hydrostratigraphic unit at the well when the unit occupied 90 to 100 percent of the well total OPI. Summary statistics of all the hydraulic property values assigned to each hydrostratigraphic unit were determined, were listed in tables, and comparatively presented as box and whiskers plot graphs. Consistent with the stratigraphic units, the hydrostratigraphic unit largest median hydraulic property values relate to younger volcanic deposits, intermediate median values relate to Silicic and High Lava Plains volcanic deposits and basin-fill sediments, and the smallest median values generally relate to upland deposits. Median values for all units collectively

range three orders of magnitude. The maximum range for all values for all units collectively is five to six orders of magnitude depending on the hydraulic property.

Limited investigation time and resources precluded conducting additional tests to more completely characterize groundwater storage or assess subsurface material flexibility. Future work should conduct such tests both shallow and deep for each hydrostratigraphic unit in the Harney Basin uplands and lowlands. The test results would refine well to well interaction calculations and aid future groundwater modeling efforts to characterize Harney Basin groundwater flow and storage under various conditions and scenarios.

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Appendix A: Description of Compiled Harney Basin Stratigraphic Units

This appendix briefly describes each of the 18 Harney Basin stratigraphic units as compiled in Boschmann (2021). They are presented from oldest to youngest.

Mesozoic rocks – (Mzu): late Jurassic to late Triassic

The oldest rocks exposed in the basin are variably deformed and metamorphosed, Upper Jurassic to Upper Triassic marine deposits of the accreted Izee terrane, including interbedded volcanic and tuffaceous mudstone, siltstone, shale, graywacke, calcareous sandstone, conglomerate, limestone, tuff, and minor andesite lavas (Brooks and Vallier, 1978; Brown and Thayer, 1977; Dickinson, 1979; Dickinson and Thayer, 1978; Silberling and Jones, 1984). Minor areas of Miocene intrusive rocks, as well as Permian to pre-Permian(?) metamorphic rocks of limited extent associated with the Canyon Mountain Complex (Brown and Thayer, 1977; Wallace and Calkins, 1956) are also included with this unit. Exposures of Mesozoic rocks in the basin are limited to the northern uplands, however they are presumed to form the basement underlying much of the basin (McClaghry and others, 2019; Streck, 2002). The aggregate thickness of Upper Triassic to Upper Jurassic rocks in the region is estimated at nearly 50,000 feet (Brooks, 1979; Dickinson, 1979).

Older volcanic rocks – (Tov): Miocene and late Oligocene

A thick section of late Oligocene and Miocene volcanic rocks underlies the Devine Canyon Ash-flow Tuff in the northern and eastern uplands. Primarily basalt and andesite lava flows, but also includes rhyolite lava flows and tuffs, rhyodacite and dacite lavas, and interbedded tuffaceous sedimentary deposits. In the northern uplands, this unit includes undifferentiated Columbia River Basalt Group lavas, Strawberry Volcanics, and Dinner Creek Tuff (Brown and Thayer, 1966a; Greene and others, 1972; Houston and others, 2018; Niewendorp and others, 2018). The unit may also include undifferentiated Steens Basalt in some areas (Camp and others, 2013). Age assignment based on stratigraphic position and $^{40}\text{Ar}/^{39}\text{Ar}$ ages, including an andesite age of 24.75 ± 0.15 Ma (Houston and others, 2018).

Steens Basalt – (Tsb): early Miocene

Dark- to medium-gray, vesicular to massive, aphanitic to coarsely plagioclase –phyric, intergranular to diktytaxitic olivine basalt. The continental flood basalt lavas of the Steens Basalt were erupted from a low, elongate shield volcano centered near the Steens Mountain escarpment where numerous north- and northeast-striking dikes are exposed. The Steens Basalt includes more than 100 individual flows with an average composite thickness of about 2,000 feet and maximum reported thickness of 4,300 feet. The sequence was largely erupted as compound flows ranging in thickness from 30–150 feet, although individual flow lobes rarely exceed 6 feet (Camp and others, 2013; Johnson and others, 1998; Minor and others, 1987). The initial eruption of Steens Basalt occurred by 16.97 ± 0.06 Ma as the earliest pulse of Columbia River Flood Basalt volcanism (Camp and others, 2013; Moore and others, 2018).

Devine Canyon Ash-flow Tuff – (Tdv): late Miocene

Light-gray to greenish-gray, nonwelded to densely welded, crystal-rich (up to 30%) rhyolite tuff that forms a single cooling unit and represents an important stratigraphic marker bed throughout much of the basin. The tuff sheet ranges from a few feet to over 200 feet thick, with an estimated original extent of over 7,000 mi² (Greene, 1973; McClaughry and others, 2019; Walker, 1979). Greene (1973) proposed a source caldera in the central Harney Basin near Burns based on unit thickness and crystal content distribution. An $^{40}\text{Ar}/^{39}\text{Ar}$ age of 9.74 ± 0.04 Ma is reported by Jordan and others (2004).

Andesite – (Ta): late Miocene

Fine grained, dense and commonly flow-banded andesite and basaltic-andesite lava flows occur as multiple thin flows with a total thickness of a few tens to locally over 200 feet. These flows erupted from several vent complexes in the uplands northwest of Burns (Brown and others, 1980a; Brown, 1982; Greene and others, 1972; McClaughry and others, 2019). The age of these lava flows is bracketed by the 8.41 Ma Prater Creek Ash-flow Tuff and 7.1 Ma Rattlesnake Ash-flow Tuff (Jordan and others, 2004; McClaughry and others, 2019).

Basalt and andesite of Dry Mountain – (Tdm): late Miocene

Numerous flows of dark-gray, aphanitic to fine-grained andesite with rare olivine, and high-alumina olivine basalt erupted from a large shield volcano at Dry Mountain at about 7.9 Ma (Greene and others, 1972; Streck and Grunder, 2012). A thickness of 535 feet is penetrated by a well (HARN 50475/50729) on the flanks of Dry Mountain, and a 700+ foot section is exposed at the summit scarp; the total thickness is unknown.

Basalt of Harney Lake – (Tbh): late Miocene

Black to dark-gray olivine-bearing basaltic rocks with common yellowish devitrified glass and pillow structures. Consists of several flows, each 10–20 feet thick with a total thickness of about 150 feet (Brown and others, 1980b; Greene and others, 1972). The unit is located south and west of Harney Lake where it underlies Rattlesnake Ash-flow Tuff and overlies Devine Canyon Ash-flow Tuff. May intertongue locally with sedimentary rocks of unit Tts. Included in this unit are Basalt of Hog Wallow (Johnson, 1994) and Basalt of Black Rim (Sherrod and Johnson, 1994) on the basis of stratigraphic position. A late Miocene age is based on stratigraphic position and $^{40}\text{Ar}/^{39}\text{Ar}$ ages of 7.68 ± 0.16 Ma and 7.54 ± 0.26 Ma (Jordan and others, 2004).

Drinkwater Basalt – (Tdw): late Miocene

Medium- to dark gray diktytaxitic basaltic rocks with locally abundant phenocrysts and glomerocrysts of plagioclase and olivine. Forms ridge-capping basalt flows along the eastern margin of the basin near Crane and south and east of Diamond Craters. Commonly one flow, but locally several flows with a total thickness ranging from 20–200 feet (Greene and others, 1972). An $^{40}\text{Ar}/^{39}\text{Ar}$ age of 7.25 ± 0.09 Ma is reported for exposures of this unit east of the basin near the South Fork Malheur River (Meigs and others, 2009).

Rattlesnake Ash-flow tuff – (Trt): late Miocene

Light-brown to red-brown to gray, nonwelded to densely welded, pumice-rich rhyolite tuff that forms a single cooling unit and represents an important stratigraphic marker bed throughout much of the basin. The tuff sheet typically ranges from 30–100 feet thick with a maximum reported thickness of about 240 feet and an estimated original extent of 13,500 mi² (Brown and others, 1980b; Streck and Grunder, 1995). Streck and Grunder (1995) proposed a source caldera in the

western Harney Basin on the basis of outcrop, pumice size, and facies distribution as well as flow-direction indicators. An $^{40}\text{Ar}/^{39}\text{Ar}$ age of 7.09 ± 0.03 Ma is reported by Jordan and others (2004).

Olivine basalt and andesite of Gum Boot Canyon – (Tobg): late Miocene

Medium- to dark-gray, fine- to medium-grained, aphyric and diktytaxitic basalt with groundmass olivine, and medium-gray aphanitic and nonporous andesite with less than 1 percent plagioclase and olivine phenocrysts. Several flows, each a few feet to a few tens of feet thick with a maximum thickness of about 300 feet are exposed along fault scarps southeast of Dry Mountain (Greene and others, 1972). As mapped by Greene and others (1972), the unit overlies the Rattlesnake Ash-flow Tuff, but an $^{40}\text{Ar}/^{39}\text{Ar}$ age of 7.60 ± 0.22 Ma from a basalt flow southeast of Dry Mountain (Jordan and others, 2004) indicates part of the unit may be older.

Olivine basalt – (Tob): late Miocene

Dark-gray to black, fine-grained olivine basalt with some andesite. Locally includes thin interbeds of tuffaceous sedimentary rock (Greene and others, 1972) that overlies Rattlesnake Ash-flow Tuff in the southwest part of the basin. A late Miocene age assignment is based on stratigraphic position and a K-Ar age of 6.2 ± 0.8 Ma (Feibelkorn and others, 1982; Parker and Armstrong, 1972).

Silicic lava flows and domes – (Trd): Pliocene and Miocene

Medium- to light-gray, pale-red, and reddish-brown, commonly streaked and flow-banded rhyolite, rhyodacite and dacite with associated vitrophyre and obsidian. The unit occurs as exogenous domes and related flows and plugs (Brown and others, 1980b; Brown and others, 1980a; Greene and others, 1972).

Tuffaceous sedimentary rocks and tuff – (Tts): Pliocene to Miocene

White to buff and pale-brown to yellowish-gray, semi- to well-consolidated lacustrine and fluvatile tuffaceous mudstone, siltstone, sandstone and conglomerate with numerous air-fall ash beds and tuffs, and occasional thin carbonate and chert beds. Commonly consists of a poorly sorted mixture of pumice, scoria, other rock fragments, plagioclase grains, and glass shards in a clay matrix (Brown and others, 1980b; Brown and others, 1980a; Greene and others, 1972). Locally,

the tuffaceous sedimentary rocks and tuffs are diagenetically altered to clay minerals, zeolites, and potassium feldspar (Sheppard, 1994; Walker and Nolf, 1981; Walker and Swanson, 1968). This unit includes all tuffaceous sediments and tuff interbedded with the Rattlesnake Ash-flow Tuff and Devine Canyon Ash-flow Tuff, and includes the 8.41 ± 0.32 Ma Prater Creek Ash-flow Tuff (Jordan and others, 2004; Walker, 1979). The upper section of the unit is partially equivalent to the Harney Formation of Walker (1979).

Basalt – (QTb): early Pleistocene and late Pliocene

Medium-gray, fine-grained, diktytaxitic, olivine-bearing vesicular basalt occurring as a series of thin flows locally separated by thin layers of sedimentary rock (Brown and others, 1980b; Brown and others, 1980a; Greene and others, 1972); includes the Wrights Point member of the Harney Formation (Walker, 1979). The Pleistocene–Pliocene age assignment is based on $^{40}\text{Ar}/^{39}\text{Ar}$ ages of 2.83 ± 0.89 Ma, 2.54 ± 0.07 Ma, and 2.2 ± 0.08 Ma (Jordan and others, 2004; Streck and Grunder, 2012).

Voltage basalt – (Qvb): Pleistocene

Medium-gray, vesicular olivine basalt erupted as thin lava flows from numerous vents south and east of Malheur Lake (Brown and others, 1980b; Brown and others, 1980a; Greene and others, 1972). The lava field contains abundant well-preserved tumuli and pressure ridges. The unit is over 300 feet thick in the central part of the Voltage lava field, however elsewhere the thickness is generally less than 200 feet. $^{40}\text{Ar}/^{39}\text{Ar}$ ages of 1.23 ± 0.10 Ma and 1.47 ± 0.16 Ma are reported by Jordan and others (2004).

Mafic vent complexes – (QTV): Pleistocene to late Miocene

Basaltic to andesitic scoria, cinders, agglomerate, thin flows, and intrusive masses forming lava cones, domes, and small shield volcanoes associated with eruptive centers of mafic and intermediate volcanic units in the basin. Locally this unit includes partly consolidated subaqueous deposits of palagonitized basaltic ejecta occurring as tuff and breccia cones and rings, and reworked volcanic sediments (Brown and others, 1980b; Brown and others, 1980a; Greene and others, 1972).

Diamond Crater basalt and tephra – (Qdc): Holocene

Fine- to medium-grained olivine and plagioclase phyric basalt lava flows and juvenile tephra including agglomerate, cinders and ash. The basalt is medium to dark gray and mostly vesicular, forming thin flows with ropy pahoehoe surfaces (Brown and others, 1980b; Greene and others, 1972; Russell and Nicholls, 1987). Many small craters are rimmed with lava spatter, cinders and bombs. The lava field was emplaced sometime between about 7,320 to 7,790 years ago on the basis of radiocarbon ages and paleomagnetic constraints (Sherrod and others, 2012).

Quaternary Sedimentary deposits – (Qs): Holocene and Pleistocene

Unconsolidated to poorly consolidated clay, silt, sand, and gravel of Quaternary age. The deposits originated as alluvium, alluvial fan deposits, colluvium, floodplain deposits, lacustrine deposits, talus, landslide, and other recent sedimentary deposits. This unit includes glacial deposits on Steens Mountain.

Appendix B: Hydrogeologic Terminology and Description of Hydraulic Properties of Subsurface Materials

Geologic units have hydraulic properties that control groundwater movement and storage. This appendix presents and defines basic hydrogeologic terminology and the parameters used to characterize subsurface hydraulic properties. A thorough discussion of hydrogeologic terminology and the parameters used to scientifically characterize subsurface hydraulic properties can be found in Bear (1979), Cooper and Jacob (1946), Davis and DeWeist (1966), Freeze and Cherry (1979), Fetter (2001), Heath (1983), and Lohman (1972a).

Hydrogeologic Terminology

Hydrogeology or *groundwater hydrology* is an interdisciplinary science subdivision that deals with the occurrence, movement, and quality of water beneath the earth's surface (Heath, 1983). It can be one of the most complex sciences given it deals with water in an almost infinitely complex subsurface environment that is often hidden from view. Nevertheless, its basic concepts, principles, and methods can be understood readily by non-hydrologists and used by them to solve groundwater problems (Heath, 1983).

All water below the land surface is referred to as *subsurface water* or *underground water*, which occurs in two different zones, the *unsaturated zone* where air and water share the subsurface material open spaces from land surface to the water table and the *saturated zone* where only water occupies the open spaces from the water table to depths below (Davis and DeWeist, 1966, Bear, 1979, Lohman, 1972a, Heath, 1983). The term *groundwater* correctly applied refers solely to all water within the saturated zone (Davis and DeWeist, 1966, Bear, 1979, Freeze and Cherry, 1979, and Heath, 1983).

The term *aquifer* within scientific usage applies to the geologic unit, group of geologic units, or a portion of a geologic unit within the saturated zone that yields a “usable” or an “economic” quantity of water to a well or a spring (Davis and DeWeist, 1966, Lohman, 1972a, Bear, 1979, Freeze and Cherry, 1979, Heath, 1983). What qualifies as “usable” or “economic” is ambiguous, can vary greatly, and can possibly be contentious given the intended use can range from 5 gallons per minute for a house well, to 1,000 gallons per minute for an irrigation well to much higher yields for municipal or industrial use. A more encompassing and useful term is

groundwater system (Alley and others, 2002), which refers to the groundwater occurrence, flow, and storage within the entire saturated zone from the smallest yield portions to the highest yield portions. It recognizes that the low yield portions of the saturated zone (*aquitard*) also stores and transmits sufficient water to be significant to the basin and sub-basin-scale flow of groundwater (Davis and DeWeist, 1966, Bear, 1979).

Description of Hydraulic Properties of Subsurface Materials

The primary geologic factors that influence groundwater flow and storage are the porosity and permeability of the rock or sediment through which it moves. *Pore space* (*void space* or *interstitial space*) is the portion of the subsurface materials (geologic units) not occupied by solid matter (Bear, 1979). *Porosity* (n) is the ratio of the total pore space volume (V_p) to the total volume (open and solid) (V_t) of the subsurface material containing the pore spaces (equation B-1) (Freeze and Cherry, 1979, Lohman, 1972a). *Primary (original) pore spaces* and *primary (original) porosity* refer and relate to pore spaces that were formed by geologic processes concurrent with the deposition of the subsurface materials (geologic units) (Freeze and Cherry, 1979, Bear, 1979, Lohman, 1972a, and Heath, 1983). *Secondary pore spaces* and *secondary porosity* refer and relate to pore spaces that were formed by geologic processes after the deposition of the subsurface materials such as the development of fissures, joints, and solution-dissolution passages (Freeze and Cherry, 1979, Bear, 1979, Lohman, 1972a, and Heath, 1983). Pore space sizes can range from microscopic to caverns, and only the connected pore spaces act as conduits within the subsurface (Bear, 1979). *Effective porosity* (n_e) is the ratio of only the interconnected pore space volume (V_e) to the total volume (open and solid) (V_t) of the subsurface material containing the pore spaces (equation B-2) (Lohman, 1972b).

Permeability (*intrinsic permeability* or *specific permeability*) (k) is related to porosity. It is a measure of the ease with which a fluid can move through a particular rock type, sediment, geologic deposit, or soil; it is an intrinsic property of the solid material only, completely independent of the fluid properties (Davis and DeWeist, 1966, Lohman 1972a, 1972b, Freeze and Cherry, 1979, Bear, 1979). Permeability is widely used in the petroleum industry where the presence of gas, oil, and water in multiphase flow makes the use of a fluid independent parameter attractive (Freeze and Cherry, 1979). It is proportional to the mean diameter of grains in the solid (d) by a constant (C) that accounts for porosity and the shape and sizes of the pore spaces which

are influenced by grain size distribution, roundness, and packing (equation B-3) (Davis and DeWeist, 1966, Lohman 1972a, 1972b, Freeze and Cherry, 1979). The permeability of subsurface materials can change with time due to pore space changes resulting from changes in the subsurface materials including compaction, consolidation, dissolving the solid, swelling or shrinking of clays in the pore spaces, biological activity in the pore spaces, and deposition of sediments in the pore spaces (Bear, 1979). Additional changes can include mineral formation in the pore spaces, or conversely the development of fissures and joints. Given the relationship to porosity and the factors that control porosity, it can be inferred that the *primary permeability* of subsurface materials were formed by geologic processes concurrent with the deposition of the subsurface materials and *secondary permeability* of subsurface materials were formed by geologic processes after the deposition of the subsurface materials.

$$n = V_p / V_t \quad [\text{dimensionless}] \quad (\text{equation B-1})$$

where:

n = porosity, as a dimensionless decimal fraction

V_p = total volume of pore spaces (voids, interstices)

V_t = total volume (open and solid) of the subsurface material containing the pore spaces

$$n_e = V_e / V_t \quad [\text{dimensionless}] \quad (\text{equation B-2})$$

where:

n_e = effective porosity, as a dimensionless decimal fraction

V_e = total volume of the interconnected pore space (interconnected voids, interstices)

V_t = total volume (open and solid) of the subsurface material containing the pore spaces

$$k = Cd^2 \quad [L^2] \quad (\text{equation B-3})$$

where:

k = intrinsic permeability

C = a dimensionless constant that accounts for porosity and the shape and sizes of the pore spaces which are influenced by grain size distribution, roundness, and packing

d = mean diameter of grains in the solid

Hydraulic conductivity (K) is related to permeability (k), and it is more commonly used than permeability in quantitative groundwater discussions given it includes the properties of the solid material and the fluid properties (equation B-4) (Davis and DeWeist, 1966, Freeze and Cherry, 1979). Additionally, hydraulic conductivity (K) is the constant of proportionality in the groundwater flow equation known as Darcy's law (equation B-5) (Davis and DeWeist, 1966, Freeze and Cherry, 1979, Heath, 1983). It has the units of length per unit time (LT^{-1}), such as feet per day (ft/d). If a porous medium is isotropic and the fluid within is homogeneous, the hydraulic conductivity (K) of the medium is the volume of water (V_w) at the existing kinematic viscosity that will move in unit time (t) under a unit hydraulic gradient ($\Delta h / \Delta l$) through a unit area (A) measured at right angles to the direction of flow (equation B-6) (Lohman 1972a, 1972b). Hydraulic conductivity values for different materials commonly span several orders of magnitude from less than 0.1 ft/d for fine sand and silt to over 1,000 ft/d for well-sorted sand and gravel (Heath, 1983).

$$K = k\rho g / \mu = Cd^2\rho g / \mu \quad [LT^{-1}] \quad \text{(equation B-4)}$$

where:

K = hydraulic conductivity

k = Cd^2 = intrinsic permeability of the solid material (see equation B-3)

ρ = density of the fluid

g = gravity (strength of the gravitational field)

μ = kinematic viscosity of the fluid

$$Q = V_w / t = KA (\Delta h / \Delta l) \quad [L^3T^{-1}] \quad \text{(equation B-5, Darcy's law)}$$

$$K = Q / A (\Delta h / \Delta l) \quad [LT^{-1}] \quad \text{(equation B-6, reorder Darcy's law)}$$

where:

Q = volumetric flow rate = volume (V_w) of fluid (water) per unit time (t)

K = hydraulic conductivity (see equation B-4)

A = cross-sectional area at right angles to the fluid flow direction

$(\Delta h / \Delta l) = [(h_2 - h_1) / (l_2 - l_1)]$ = hydraulic gradient (change in total head per unit distance)

The *hydraulic gradient* ($\Delta h / \Delta l$) in Darcy's law is the energy potential that drives groundwater flow. It is defined as the change in total head (h) per unit distance in a given direction with the direction understood to be the direction where the maximum change of total head occurs (Heath, 1983). Different total heads at different locations yields the hydraulic gradient, and groundwater moves in the direction of decreasing total head. *Total head* (h) is the total height or altitude of the top of a column of fluid (often water in a well) above a standard datum (often sea level) composed of three components: *elevation head* (h_e) which is the height or altitude above the datum of the entry point where the fluid enters the column, *pressure head* (h_p) which is the height of the fluid above the entry point being supported by static pressure at the entry point, and *velocity head* (h_v) which is the height added to the column of fluid by the kinetic energy of the fluid capable of lifting the fluid (equation B-7) (Lohman, 1972b, Heath, 1983). The velocity head is ignored when the groundwater velocity (v) is small enough to make the velocity head negligible.

$$h = h_e + h_p + h_v \quad [L] \quad (\text{equation B-7})$$

where:

h = total head

h_e = elevation head

h_p = pressure head

$h_v = v^2 / 2g$ = velocity head (v = groundwater velocity, g = gravity)

Transmissivity (T) is a parameter related to hydraulic conductivity (K) and is often used instead of hydraulic conductivity. It is hydraulic conductivity multiplied by a thickness (b) of a groundwater flow system (equation B-8) (Davis and DeWeist, 1966, Freeze and Cherry, 1979, Heath, 1983). Transmissivity is defined as the rate (volume per unit time) that water of the prevailing kinematic viscosity will flow through a unit width of a groundwater flow system perpendicular to the flow direction under a unit hydraulic head gradient (equation B-9 and B-10) (Lohman, 1972b). It has units of length squared per unit time, such as feet squared per day (ft^2/d). Transmissivity integrates the hydraulic conductivity (smallest to largest) of one or more layers (lowest yield to highest yield) with each layer having a distinct thickness and hydraulic conductivity (Lohman, 1972b, Bear, 1979). Transmissivity descriptions often imply an entire

groundwater flow system thickness, but the thickness can be partial given what may be tested or considered is a portion of the entire thickness with the associated transmissivity representing that portion only (Heath, 1983).

$$T = Kb = KA / w = Kwb / w \quad [L^2T^{-1}] \quad \text{(equation B-8)}$$

where:

T = transmissivity

K = hydraulic conductivity (see equations B-4 and B-6)

$A = wb$ = cross-sectional area at right angles to the flow direction

w = a width of a groundwater flow system at right angles to the flow direction

b = a thickness of a groundwater flow system

$$Q = V_w / t = Tw (\Delta h / \Delta l) \quad [L^3T^{-1}] \quad \text{(equation B-9, Darcy's law)}$$

$$T = Q / w (\Delta h / \Delta l) \quad [L^2T^{-1}] \quad \text{(equation B-10, reorder Darcy's law)}$$

where:

Q = volumetric flow rate = volume (V_w) of fluid (water) per unit time (t)

T = transmissivity (see equation B-8)

$(\Delta h / \Delta l) = [(h_2 - h_1) / (l_2 - l_1)]$ = hydraulic gradient (change in total head per unit distance)

The storage characteristics of a groundwater system are represented by a parameter known as the *storage coefficient* (S), which is defined as the volume of water (V_w) released or taken into storage per unit surface area (A_s) of a groundwater system per unit change in head (Δh) (equation B-11) (Lohman, 1972a, 1972b, Freeze and Cherry, 1979, Heath, 1983). The water volume has units of length cubed (such as cubic feet), the surface area has units of length squared (such as square feet), and the head change has units of length (such as feet). Consequently, the storage coefficient is dimensionless. Storage coefficients range several orders of magnitude from 10^{-5} for *confined* groundwater to 0.1 for *unconfined* groundwater (Lohman, 1972a, Heath 1983). Storage coefficients commonly fall between these two end members because groundwater systems often have varying degrees of confinement and the division between confined and unconfined groundwater is often gradational rather than abrupt (Davis and DeWeist, 1966).

$$S = V_w / (A_s)(\Delta h) \quad [\text{dimensionless}] \quad (\text{equation B-11})$$

where:

V_w = volume of water [L^3]

A_s = surface area of the groundwater system [L^2]

$\Delta h = h_2 - h_1$ = change in head [L]

Characterizing groundwater as “confined” does not imply that it is not hydraulically connected to other groundwater or to surface water. Instead, the terms “confined” and “unconfined” describe the physics of how water is stored in the groundwater system at a particular location and depth and consequently how the groundwater will respond to pumping at that location and depth (Davis and DeWeist, 1966, Lohman, 1972a, 1972b, Freeze and Cherry, 1979, Heath 1983). For unconfined conditions, water is stored and released primarily by filling and gravity draining of pore spaces. For confined conditions, water is stored and released by pressure changes that compact or expand water by increasing or decreasing the water pressure (such as water pressure change caused by injection wells versus pumping wells) and/or by compacting or expanding the aquifer materials. Under confined conditions, pore spaces remain filled when storing and releasing water.

Determining the hydraulic property parameter values for various subsurface materials can be accomplished by analyzing aquifer test data, observation well recorder data, and well yield test data. Such data were analyzed by this investigation to primarily determine transmissivity (T) and when possible, storage coefficient (S).

Appendix C: Aquifer Tests

Aquifer tests (pump tests) are controlled field experiments intended to determine basic hydraulic properties of the water-bearing subsurface materials in the vicinity of a pumping well (Bear, 1979). The tests typically consist of pumping groundwater from a single well at a constant discharge rate for a time period ranging from hours to days and recording measured water level changes with time during the pumping drawdown phase and post-pumping shut-off recovery phase at the pumping well and/or “observation” wells (Bear, 1979; Heath, 1983). *Drawdown* is the difference between the water level at any time during the test versus the level it would have been if groundwater withdrawals had not occurred. The drawdown rate is initially very rapid but slows with time as a hydraulic gradient cone of depression around the pumping well expands with time which expands a cylinder of radial groundwater flow at a constant volumetric rate to the pumping well (Heath, 1983). *Recovery* under ideal conditions is the mirror image of the drawdown. The water level change during the recovery phase is the same as if the constant rate discharge at the pumping well had continued and at the actual moment of pump discharge shut-off an imaginary recharge well had begun returning water at the same point and at the same rate (Heath, 1983).

Ideal Aquifer Tests

Figures C-1, C-2, and C-3 show drawdown and figure C-1 additionally includes recovery under the following ideal test conditions as compiled from Lohman (1972a), Freeze and Cherry (1979), Bear (1979), and Heath (1983). There is only one pumping well which penetrates the entire thickness of the water-bearing body being tested. Additionally, the pumping well has an infinitesimally small well diameter (the well diameter and the related initial volume of water in the well has negligible significance when the pumping period is longer than a few minutes), and it pumps at a constant rate with time. The water-bearing body being tested is horizontal, has a constant thickness, is homogeneous and isotropic with respect to transmissivity and storage coefficient parameters, and has infinite areal extent (any boundary is beyond the effects of the pumping well within the time considered). Groundwater flow to the pumping well is horizontal, radially converges toward the well, and obeys Darcy’s Law (equation C-1). Total hydraulic head is uniform throughout the water-bearing body prior to pumping, and after pumping begins, water is removed instantaneously from storage when and where total hydraulic head declines.

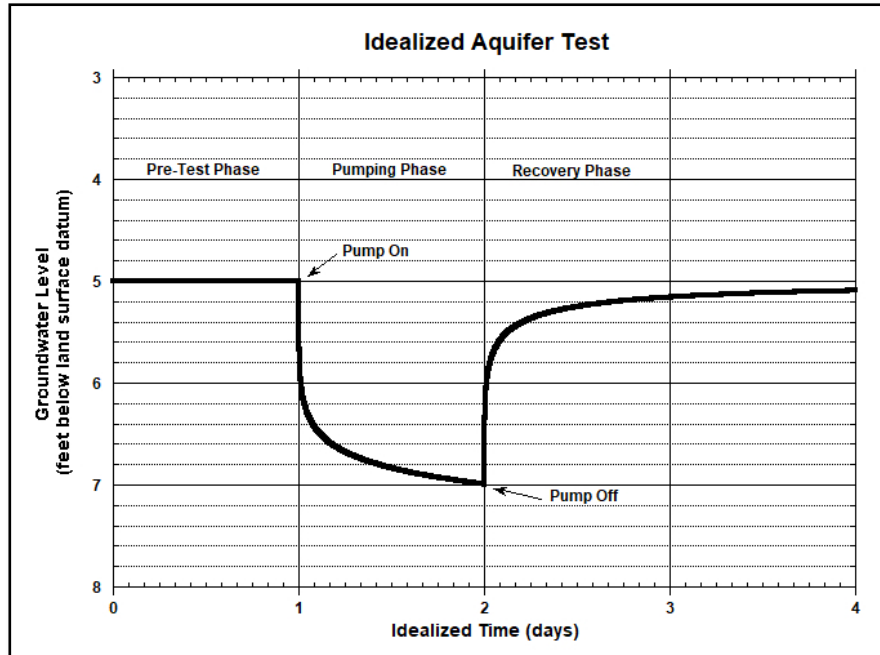


Figure C-1. Linear graph of idealized groundwater level drawdown and recovery at an observation well responding to pumping and shut off at a neighboring well
[Increasing depth is from graph top to bottom]

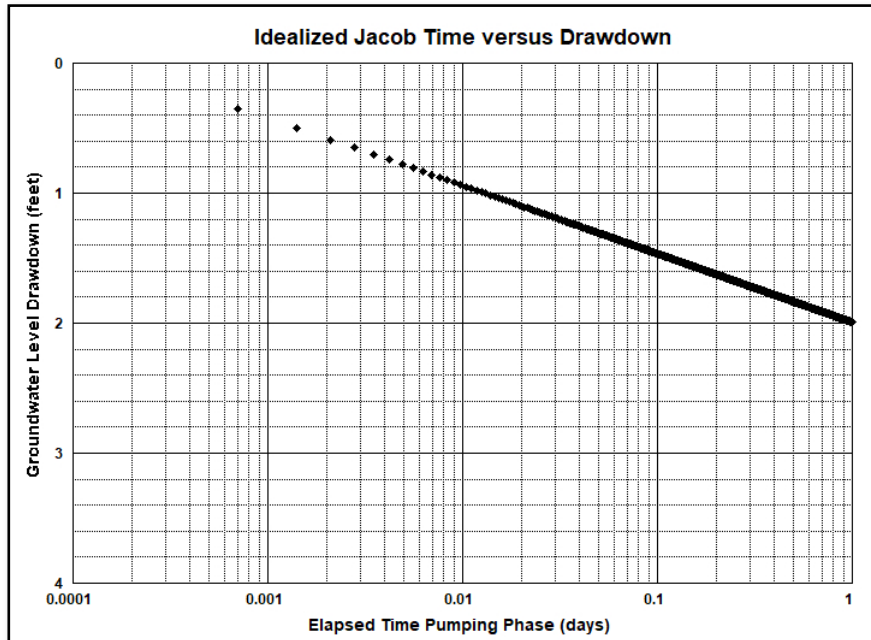


Figure C-2. Semi-log graph of idealized groundwater level drawdown at an observation well responding to pumping at a neighboring well
[Graph uses same data as figure C-1, increasing depth is from graph top to bottom]

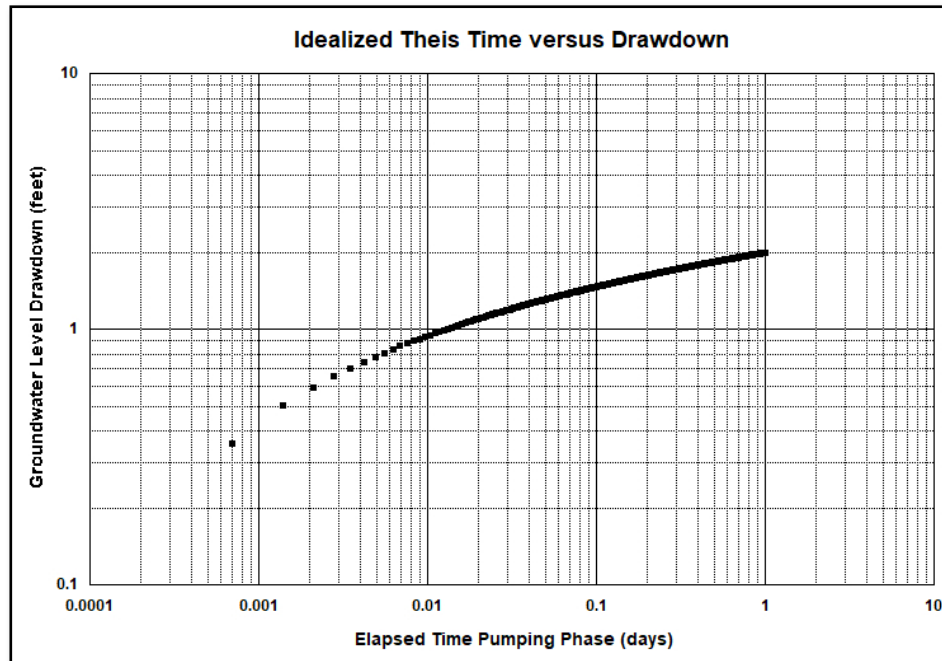


Figure C-3. Log-log graph of idealized groundwater level drawdown at an observation well responding to pumping at a neighboring well

[Graph uses same data as figure C-1. Increasing depth is from graph bottom to top.]

$$Q = V_w / t = KA (\Delta h / \Delta l) \quad [L^3T^{-1}] \quad (\text{equation C-1, Darcy's law})$$

where:

Q = volumetric flow rate = volume (V_w) of fluid (water) per unit time (t)

K = hydraulic conductivity (see equation C-4)

A = cross-sectional area at right angles to the fluid flow direction

$(\Delta h / \Delta l) = [(h_2 - h_1) / (l_2 - l_1)]$ = hydraulic gradient (change in total head per unit distance)

Ideal test conditions are rarely met. However, useful approximations of transmissivity (T), hydraulic conductivity (K), and storage coefficient (S) can be obtained despite non-ideal test conditions. The influence of several non-ideal test conditions and methods to determine hydraulic property parameters from those tests are summarized later in this appendix. The next section presents graphical methods to determine hydraulic property parameters from ideal aquifer test data.

Log-log Graphical Method for Analyzing Ideal Aquifer Test Data

Theis (1935) adapted heat flow theory by C.I. Lubin to groundwater flow theory to develop with Lubin's assistance an equation (Theis equation) useful for analyzing drawdown at any time and distance from a pumping well (Davis and DeWeist, 1966; Lohman, 1972a; Freeze and Cherry, 1979). The Theis equation can be rewritten to determine transmissivity (equation C-2) and storage coefficient (equation C-3) values as presented in Lohman (1972a), Freeze and Cherry (1979), and Heath (1983).

$$T = [Q/(4\pi s)]W(u) \quad [L^2T^{-1}] \quad (\text{equation C-2})$$

$$S = (4Tt)/r^2 \quad [\text{dimensionless}] \quad (\text{equation C-3})$$

where:

T = transmissivity

Q = volumetric flow rate

$\pi = \pi = 3.141592654$

s = drawdown

$W(u) = (-\ln u) - (0.5772157) + (u/1*1!) - (u^2/2*2!) + (u^3/3*3!) - (u^4/4*4!) + \dots$

S = storage coefficient

t = elapsed time since pumping began

r = radial distance from pumping well

$u = r^2S/4Tt$

Transmissivity and storage coefficient values cannot be determined directly from the equations given $W(u)$ (well function) and u depend on knowing the transmissivity and storage coefficient values. Theis overcame the problem by developing a graphical method of superpositioning and matching a $W(u)$ versus $1/u$ type curve (log-log) to the time versus drawdown curve (log-log) (figure C-4) (Heath, 1983). The type curve can be plotted using a $W(u)$ versus u table found in Wenzel and Fishel (1942), repeated in Lohman (1972a).

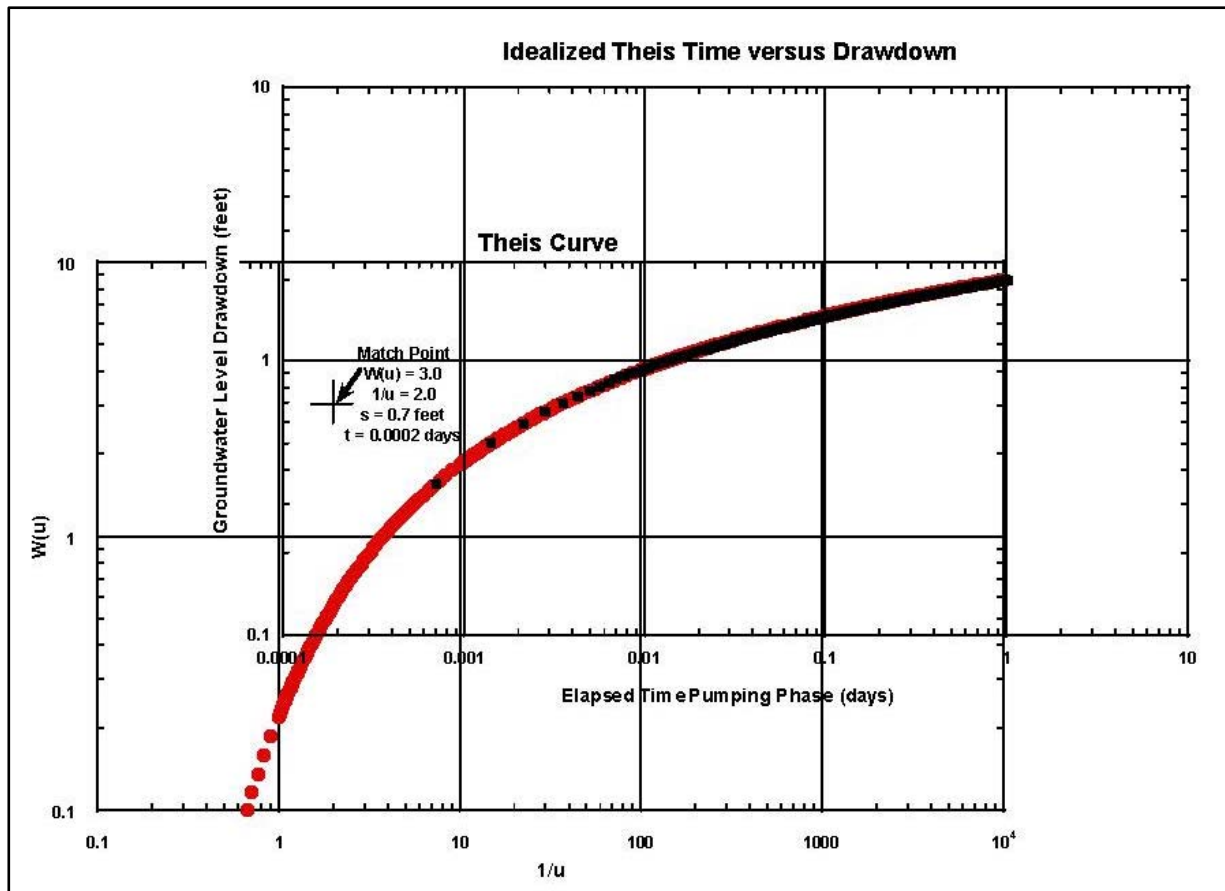


Figure C-4. Theis curve (in red) super positioned and matched to log-log graph of idealized groundwater level drawdown (in black) at an observation well responding to pumping at a neighboring well [Time versus drawdown graph is same as figure C-3 using same data as figure C-1]

The accuracy of the calculated transmissivity and storage coefficient depends upon the accuracy of the data used and the curve matching alignment accuracy. Random values used to create an idealized groundwater level drawdown in figure C-4 were 334,201 feet²/day for transmissivity and 0.00050 for storage coefficient. Using the match point values in figure C-4 in equations C-2 and C-3 yields a transmissivity value of 300,902 feet²/day and a storage coefficient value of 0.00048, 11 percent and 4 percent difference respectively. This illustrates the Theis graphical method often yields good estimates, approximations of the transmissivity and storage coefficient values rather than completely accurate results. The values obtained are useful for comparisons, making general observations, and can be used in numerical models and other calculations with some flexibility (a reasonable range of values) rather than no flexibility.

Semi-log Time versus Drawdown Graphical Method for Analyzing Ideal Aquifer Test Data

Cooper and Jacob (1946) found equations C-2 and C-3 can be simplified and rewritten as equations C-4, C-5, and C-6 when the u value in equations C-2 and C-3 is small ($u \leq 0.01$ in Lohman, 1972a; $u \leq 0.05$ in Heath, 1983) and found drawdown ($h_o - h$) versus $\log_{10}$ time ($\log t$) should plot as a straight line (previous figure C-2) (Lohman, 1972a; Freeze and Cherry, 1979). This u -value condition is met when the hydraulic gradient cone of depression around the pumping well assumes a relatively steady shape which first occurs near the pumping well (radial distance, r , from pumping well is small) and with increasing time (larger time, t) the relatively steady shape gradually spreads to greater radial distances until steady state is achieved (Heath, 1983).

If Δs is the drawdown for one log cycle of time and if t_o is the time where the drawdown line intercepts the zero-drawdown line on the drawdown versus $\log_{10}$ time plot, manipulating equation C-4 yields equations C-5 and C-6 (Lohman, 1972a; Freeze and Cherry, 1979; Heath, 1983):

$$T = [2.303Q/(4\pi s)] [\log_{10}(2.25Tt/r^2S)] \quad [L^2T^{-1}] \quad (\text{equation C-4})$$

$$T = (2.303Q)/(4\pi\Delta s) \quad [L^2T^{-1}] \quad (\text{equation C-5})$$

$$S = (2.25Tt_o)/r^2 \quad [\text{dimensionless}] \quad (\text{equation C-6})$$

where:

T = transmissivity

Q = volumetric flow rate

π = $\pi = 3.141592654$

s = drawdown

Δs = drawdown for one log cycle of time

S = storage coefficient

t = elapsed time since pumping began

t_o = time intercept, time where the drawdown line intercepts the zero-drawdown line

r = radial distance from pumping well

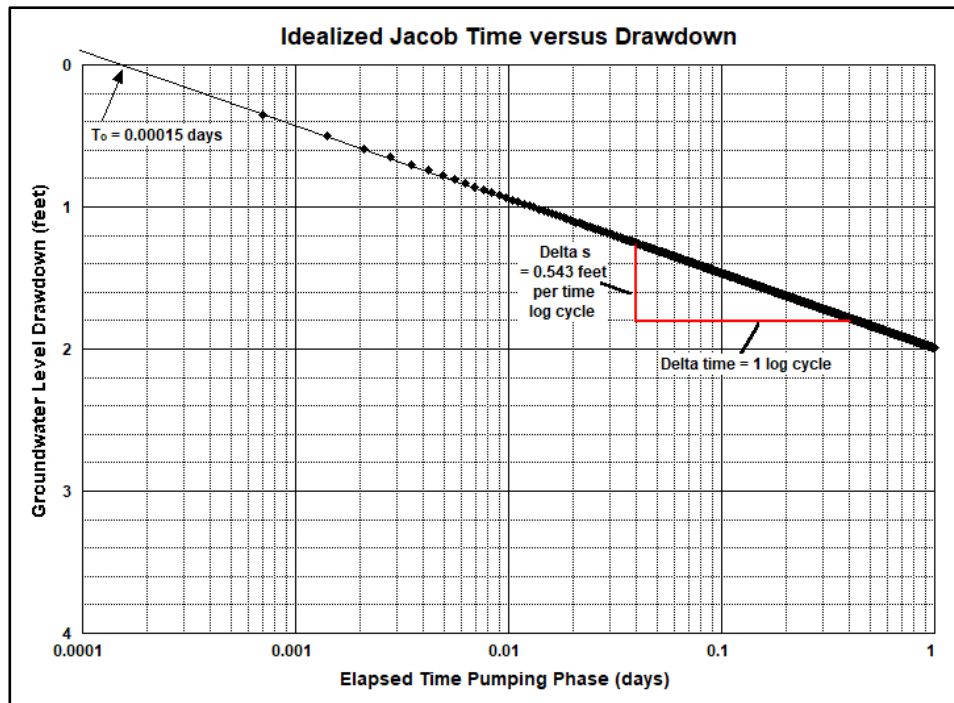


Figure C-5. Analysis of semi-log graph of idealized groundwater level drawdown at an observation well responding to pumping at a neighboring well using Cooper-Jacob (1946) method
[Graph is same as figure C-2 using same data as figure C-1. Increasing depth is from graph top to bottom]

The accuracy of the calculated transmissivity and storage coefficient depends upon the accuracy of the data used and the accuracy of determining Δs (drawdown per log cycle of time) and t_0 (time intercept) on the graph. Using the values in figure C-5 in equations C-5 and C-6 yields a transmissivity value of 324,428 feet²/day and a storage coefficient value of 0.00044. The random values used to create the idealized groundwater level drawdown in the figure were 334,201 feet²/day for transmissivity and 0.00050 for storage coefficient, 3 percent and 14 percent different respectively. This illustrates the Jacob graphical method can yield good estimates, approximations of the transmissivity and storage coefficient values. The values obtained are useful for comparisons, making general observations, and can be used in numerical models and other calculations with some flexibility (a reasonable range of values), not as inflexible absolute values.

Semi-log Time versus Recovery Graphical Method for Analyzing Ideal Aquifer Test Data

Theis (1935) noted a corollary to the Theis equation (equation C-2 written to solve for drawdown (s)) could be derived from an analysis of pump shutoff recovery data (Theis, 1935; Wenzel and Fishel, 1942; Ferris and others, 1962; Davis and DeWiest, 1966). Theis named the recovery “residual drawdown” (s’) noting the residual drawdown at any instant is mathematically the same as if pumping at the discharge well had continued but a recharge well with the same rate had been introduced at the discharge well location at the instant actual pumping stopped. The “instant” within the Theis recovery equation is represented by the elapsed time since pumping started (t_i) and the elapsed time since recovery started (t_r). Graphs of s’ versus $\log_{10}(t_i/t_r)$ plot as a straight line. When $(r^2S)/(4Tt_i)$ is sufficiently small, the Theis recovery equation can be simplified and rewritten to equation C-7 and C-8 which is equation 7.40 in Davis and DeWiest (1966, p. 223) rewritten to solve for transmissivity (T). If $\Delta s'$ is the recovery (residual drawdown) over one log cycle of (t_i/t_r), equation C-8 becomes equation C-9 (similar to equation C-5). Davis and DeWiest (1966) further note the storage coefficient (S) can be calculated using the drawdown value (s) at the time of pump shutoff (see equation C-10 derived from equation C-7)

$$T = [(2.303Q)/(4\pi s')] [(\log_{10}(2.25Tt_i/r^2S)) - (\log_{10}(2.25Tt_r/r^2S))] \quad (\text{equation C-7})$$

$$= [(2.303Q)/(4\pi s')] [\log_{10}(t_i/t_r)] \quad [L^2T^{-1}] \quad (\text{equation C-8})$$

$$T = (2.303Q)/(4\pi \Delta s') \quad [L^2T^{-1}] \quad (\text{equation C-9})$$

$$S = [(2.25Tt_i)/r^2] [1/\text{antilog}_{10}((4\pi Ts)/(2.303Q))] \quad [\text{dimensionless}] \quad (\text{equation C-10})$$

where:

T, Q, π , r = same as for equations C-4 and C-5

s = drawdown at the time of pump shutoff

s' = residual drawdown (recovery)

$\Delta s'$ = residual drawdown (recovery) for one log cycle of t_i/t_r

S = storage coefficient

t_i = elapsed time since pumping began

t = t_i at pump shutoff

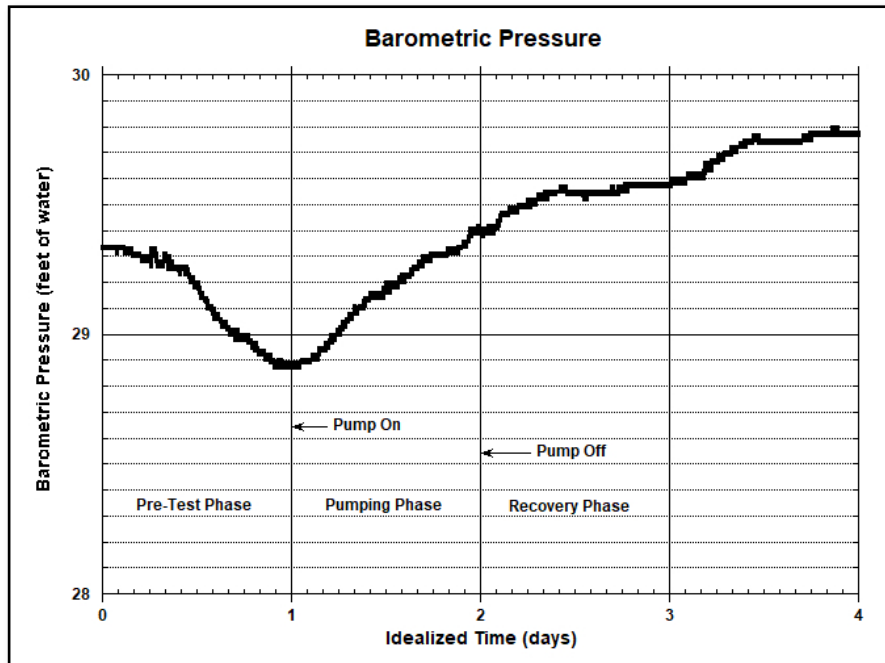
t_r = elapsed time since pumping stopped, recovery began (elapsed time since t)

Earth Tide and Barometric Pressure Change Influence on Aquifer Test Data

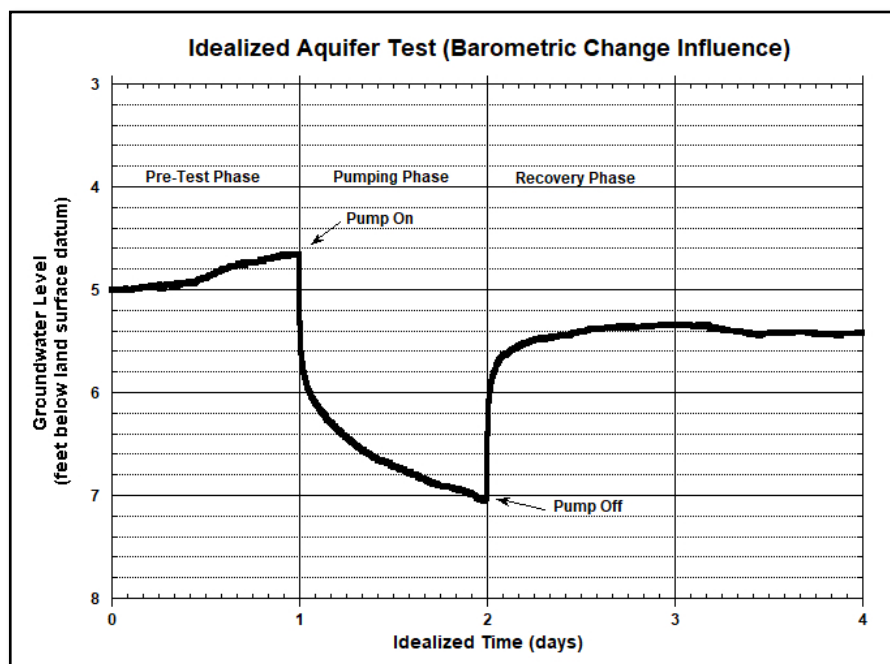
Earth tides and barometric pressure changes can occur during an aquifer test. Their occurrence can be a potentially significant influence on the drawdown and recovery water levels measured at some wells during an aquifer test, especially when the total drawdown and recovery is less than several feet. Their degree of influence and the possible need to remove that influence from the aquifer test data should be considered during aquifer test data analyses.

The earth tide influence is generally less than 0.1-foot amplitude. It shows two minima per day corresponding to the moon's upper and lower culminations of maximum tidal attraction. That attraction slightly dilates the solid material hosting groundwater which can increase pore space volume and/or reduces pressure on the groundwater causing water in the well to drop (Davis and DeWiest, 1966).

Atmospheric pressure changes can produce large water level fluctuations (possibly 0.5-feet) at wells open to groundwater under pressure greater than atmospheric (confined groundwater) and can cause smaller water level fluctuations (possibly 0.2-feet) at wells open to groundwater at or near the water table under little to no pressure greater than atmospheric (unconfined groundwater) (Davis and DeWiest, 1966; Freeze and Cherry, 1979). The measured water level in the well responds inversely to the atmospheric pressure change. The water level lowers when atmospheric pressure increases and rises when atmospheric pressure decreases (figures C-6, C-7, and C-8). The ratio of the water level change in response to atmospheric pressure change is called *barometric efficiency*, which can range from 0.2 to 0.8 (20 to 80 percent). For confined groundwater, atmospheric pressure change is transmitted directly to groundwater via water in the well where water is forced from the well into surrounding groundwater (Davis and DeWiest, 1966). Theoretically, no response should occur for unconfined groundwater at or near the groundwater table given the atmospheric pressure change should occur simultaneously and equally in the well and at the surrounding groundwater table. However, Weeks (1979) noted a response can occur for unconfined groundwater when the materials composing the unsaturated zone can store air with a change in atmospheric pressure and resist air movement slowing the direct transfer of atmospheric pressure change through the unsaturated zone to the groundwater table while the atmospheric pressure change and response in the well is instantaneous.



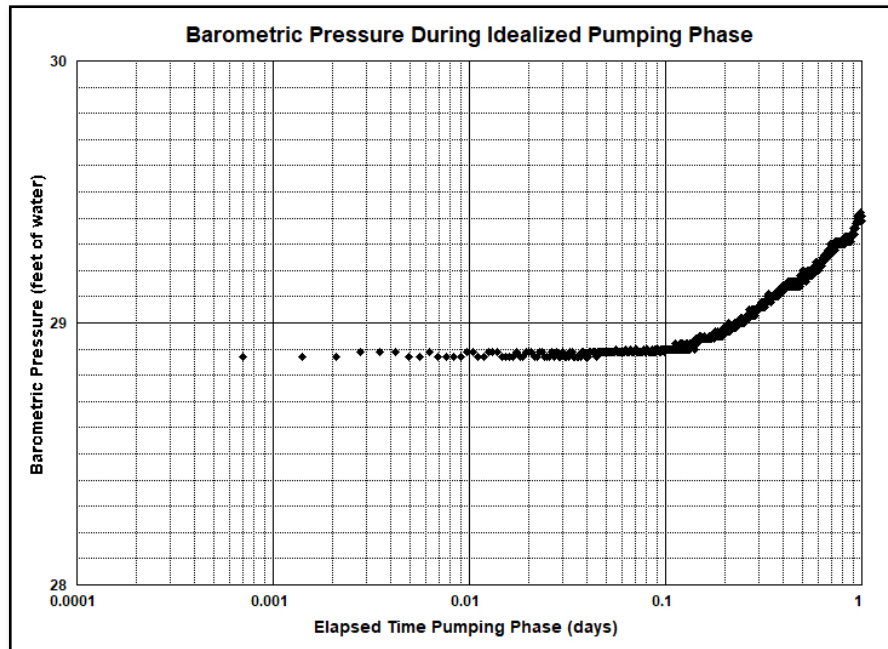
A



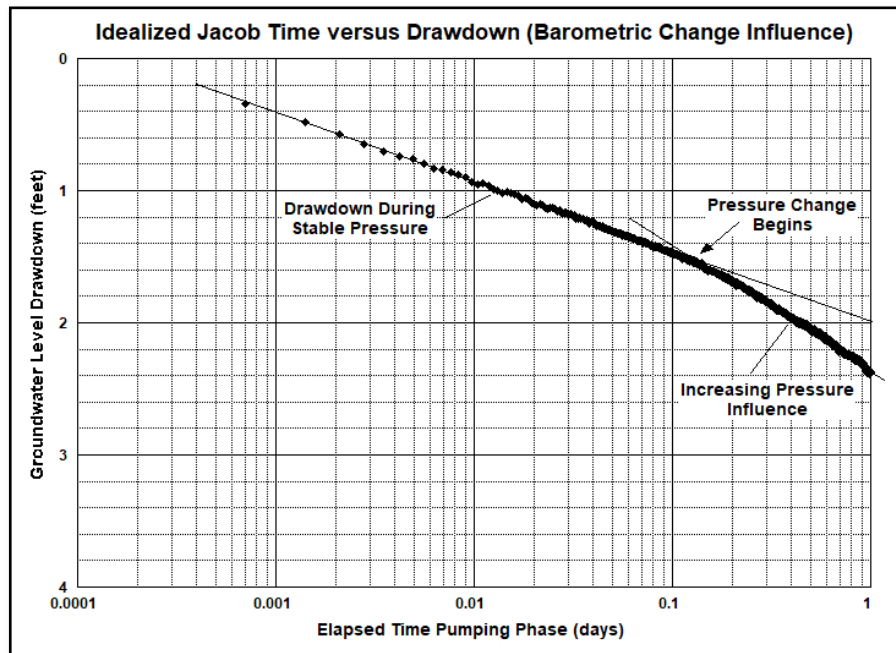
B

Figure C-6. Linear graph of idealized groundwater level at an observation well responding to pumping and shut off at a neighboring well and barometric pressure change influence

[Graph A is barometric pressure (converted to feet of water) recorded near Burns Airport from 3 to 7 November 2008. Increasing pressure is from graph bottom to top. Graph B is figure C-1 after barometric pressure changes in Graph A are applied. A barometric efficiency of 75% was used to exaggerate and highlight the influence. Increasing depth is from graph top to bottom]



A



B

Figure C-7. Semi-log graph of idealized groundwater level drawdown at an observation well responding to pumping at a neighboring well and barometric pressure change influence

[Graph A is barometric pressure (converted to feet of water) recorded near Burns Airport from 3 to 7 November 2008, the same pressure data as in figure C-6, but only the pumping period data is shown. Increasing pressure is from graph bottom to top. Graph B is figure C-2 after barometric pressure changes in Graph A are applied. A barometric efficiency of 75% was used to exaggerate and highlight the influence. Increasing depth is from graph top to bottom]

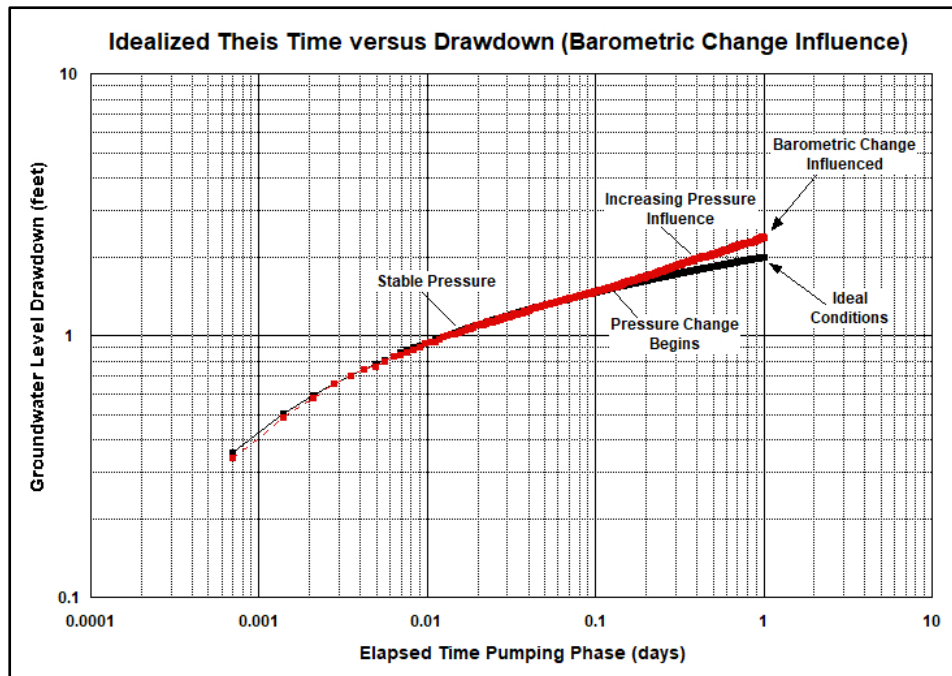


Figure C-8. Log-log graph of idealized groundwater level at an observation well responding to pumping and shut off at a neighboring well and barometric pressure change influence

[Barometric pressure (converted to feet of water) was recorded near Burns Airport from 3 to 7 November 2008, the same pressure data as in figures C-6 and C-7 (only the pumping period data is shown). The black line is from figure C-3. The red line is figure C-3 after barometric pressure changes are applied. A barometric efficiency of 75% was used to exaggerate and highlight the influence. Increasing depth from graph bottom to top.]

Good practice assesses the need to account for earth tide and/or barometric pressure change influence during aquifer test data analyses. Obvious earth tide influence appears as 12-hour maximum-minimum fluctuations nearly coincident with the nearest ocean tides superimposed on an otherwise smooth line or curve on an aquifer test data analysis graph. An earth tide influence may not be obvious at first because another influence has dwarfed it such as barometric pressure change influence. Consequently, the barometric pressure change influence should be assessed before the earth tide influence. Obvious barometric pressure change influence appears as irregular changes to an otherwise smooth line or curve on an aquifer test data analysis graph that coincides with barometric pressure change recorded at the aquifer test site on the same schedule as the water level measurements before and during an aquifer test (figures C-6 to C-8).

Assessing the need to account for earth tide and/or barometric pressure change influence occurs by comparing the maximum earth tide 12-hour fluctuation (maximum amplitude minus

minimum amplitude) and the maximum barometric pressure change during the test (maximum pressure minus minimum pressure converted to feet of water) to the total measured water level drawdown and total measured water level recovery. The maximum earth tide 12-hour fluctuation and/or the maximum barometric pressure change during the test should be accounted if they exceed 1 to 2 percent of the total measured water level drawdown and total measured water level recovery. The earth tide influence is accounted by directly subtracting the cyclic fluctuation from the raw water level measurement data. The barometric pressure change influence is accounted by: determining the barometric efficiency at each water level measurement well; calculating the cumulative barometric pressure change (cumulative pressure increase and decrease converted to feet of water) from a start time during the pre-test period to the end of the test recovery period; multiplying the cumulative barometric pressure change by the barometric efficiency; and adding the barometric efficiency adjusted cumulative barometric pressure change at a given measurement time to the corresponding raw water level measurement. Once adjusted, corrected for earth tide and/or barometric pressure change influence, the data is ready for analyses to better determine transmissivity and storage coefficient values as well as identify other influences such as no-flow and recharge boundaries and delayed yield presented in the following sections.

No-Flow and Recharge Boundary Influence on Aquifer Test Data

The discussion so far has assumed the groundwater-bearing body being tested has infinite areal extent (any boundary is beyond the effects of the pumping well within the time considered). No groundwater system is infinite in reality. All have boundaries in the vertical and horizontal directions, but many are extensive enough that the assumption is satisfied for some well locations and within some pumping periods (Lohman, 1972a; Heath, 1983). For other well locations and/or longer pumping periods, the hydraulic head cone of depression expanding from the pumping well encounters one or more boundaries that influence the test's measured, observed drawdown and recovery. A particular boundary is often one of two types. An impermeable (no-flow) boundary exists where groundwater flow is impeded, does not cross due to a geologic structure, a geologic formation change or a permeability change increasing the measured, observed drawdown rate (figure C-9), and a recharge boundary exists where groundwater flow can originate such as at a stream or lake decreasing the measured, observed drawdown rate (figure C-10) (Heath, 1983).

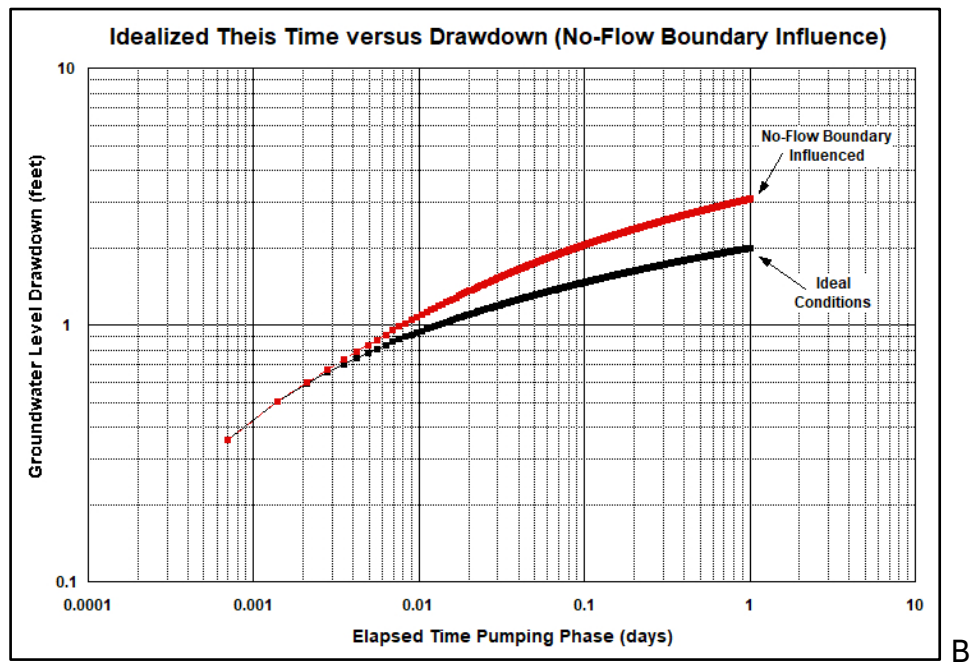
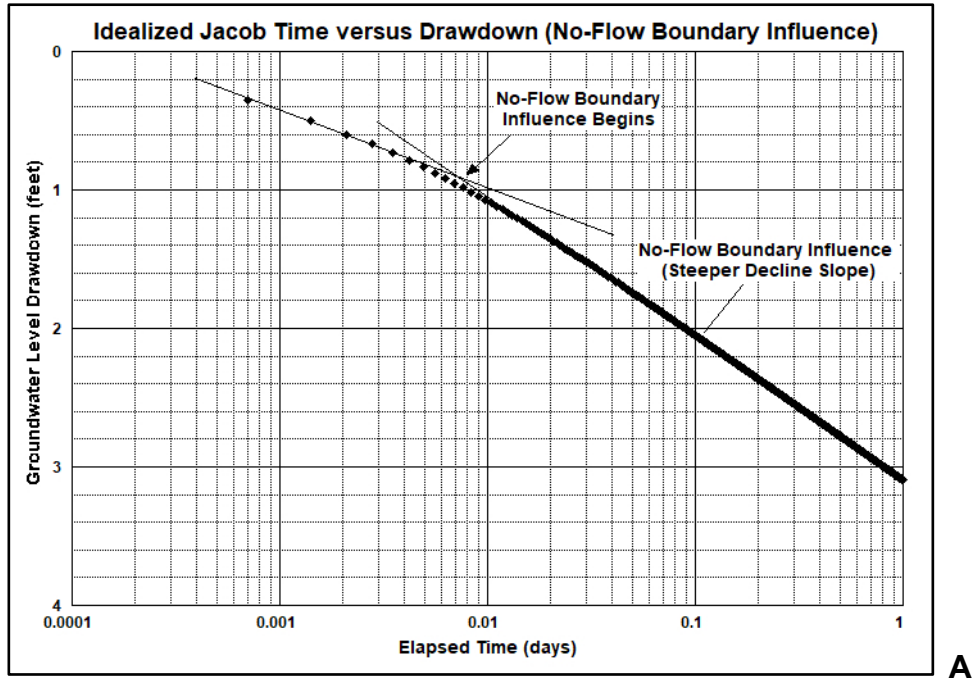
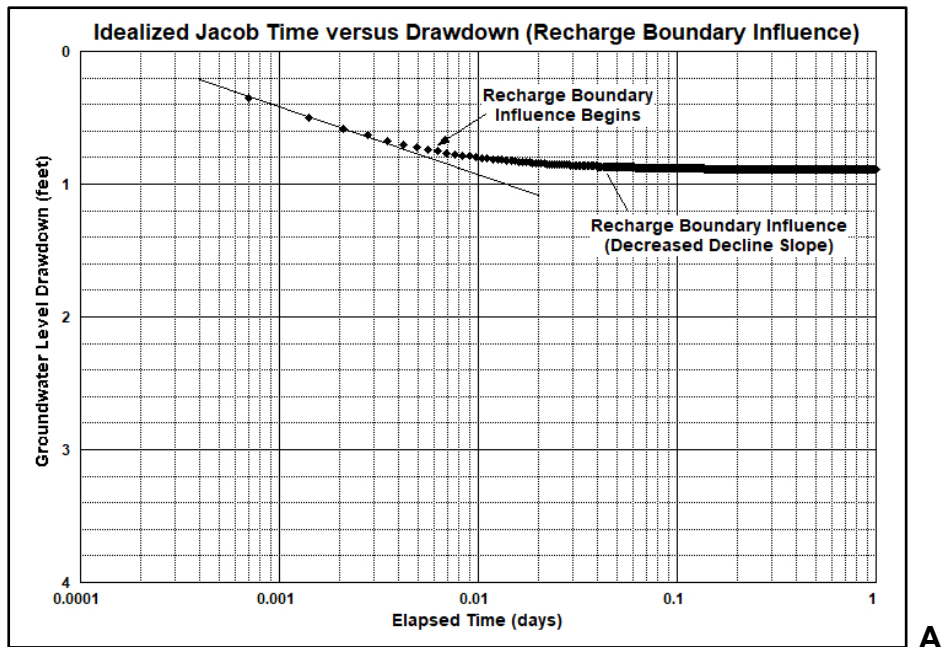
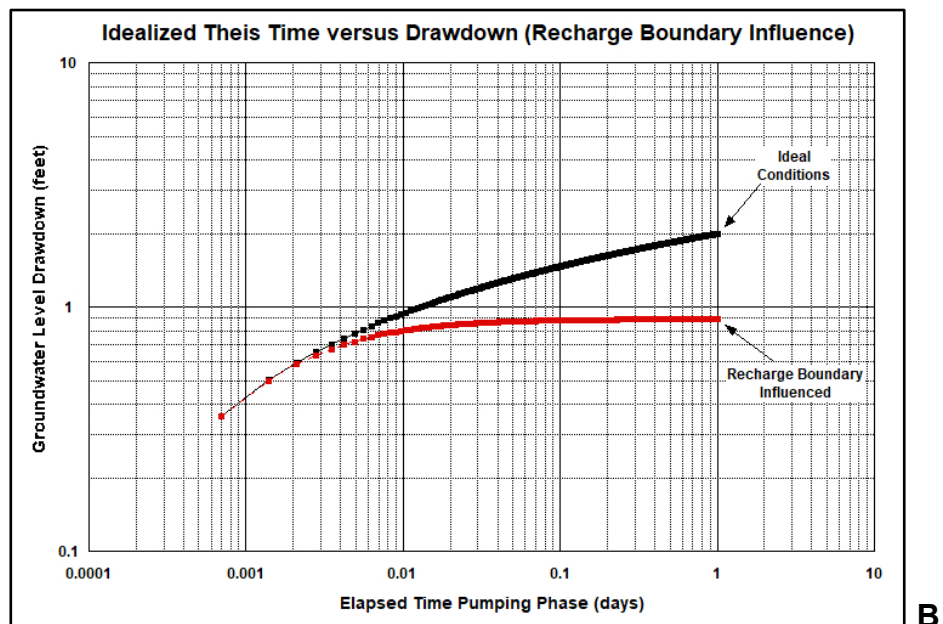


Figure C-9. Semi-log and log-log graph of idealized groundwater level drawdown at an observation well responding to pumping at a neighboring well and a no-flow boundary influence

[Graph A and graph B are figures C-2 and C-3 respectively after a no-flow boundary influence is applied. Increasing depth is from graph top to bottom in graph A and from graph bottom to top in graph B.]



A



B

Figure C-10. Semi-log and log-log graph of idealized groundwater level drawdown at an observation well responding to pumping at a neighboring well and a recharge boundary influence

[Graph A and graph B are figures C-2 and C-3 respectively after a recharge boundary influence is applied. Increasing depth is from graph top to bottom in graph A and from graph bottom to top in graph B.]

Ferris and others (1962) presented a hypothetical “image system” as a substitute for the boundaries encountered in a real system for the purpose of analysis and prediction whereby the image system hydraulically duplicates the boundaries of certain type of aerially restricted groundwater-bearing bodies, a method adapted from heat flow theory. Under the image system, an aerially limited groundwater-bearing body is treated as infinite to meet the ideal aquifer test condition, imaginary (fictitious) discharging (pumping) and/or recharging wells are introduced to represent impermeable and/or recharge boundaries respectively (figures C-11 and C-12), and the Theis equation can be used for analysis and prediction.

Ferris and others (1962) note an imaginary discharging well representing an impermeable boundary is placed the same distance as the real well from the boundary but on the opposite side with both wells on a common line perpendicular to the boundary. The real well and the image well discharge at the same time and rate. The hydraulic head cone of depression for the real well and the image well are symmetrical and intersect. The drawdown at a given location is the sum of the hydraulic head cone of depression drawdown for the real well and the image well for that location. At the boundary, the drawdown caused by the real well and the image well are equal all along the boundary line producing an imaginary divide prohibiting groundwater flow across. The resultant hydraulic head cone of depression is flatter between the real well and the impermeable boundary and steeper on the side away from the boundary than would occur if no boundary were present (figure C-11).

Similarly, Ferris and others (1962) note an imaginary recharging well representing a recharge boundary is placed the same distance as the real well from the boundary but on the opposite side with both wells on a common line perpendicular to the boundary. The real well discharges water and the image well returns water at the same time and rate. The hydraulic head cone of depression for the real well and the hydraulic head cone of impression for the image well are symmetrical and intersect. The drawdown at a given location is the sum of the hydraulic head cone of depression drawdown for the real well and cone of impression for the image well for that location. At the boundary, the drawdown by the real well and the mounding by the image well are equal resulting in zero drawdown all along the boundary line. The resultant hydraulic head cone of depression is steeper between the real well and the recharge boundary and flatter on the side away from the boundary than would occur if no boundary were present (figure C-12).

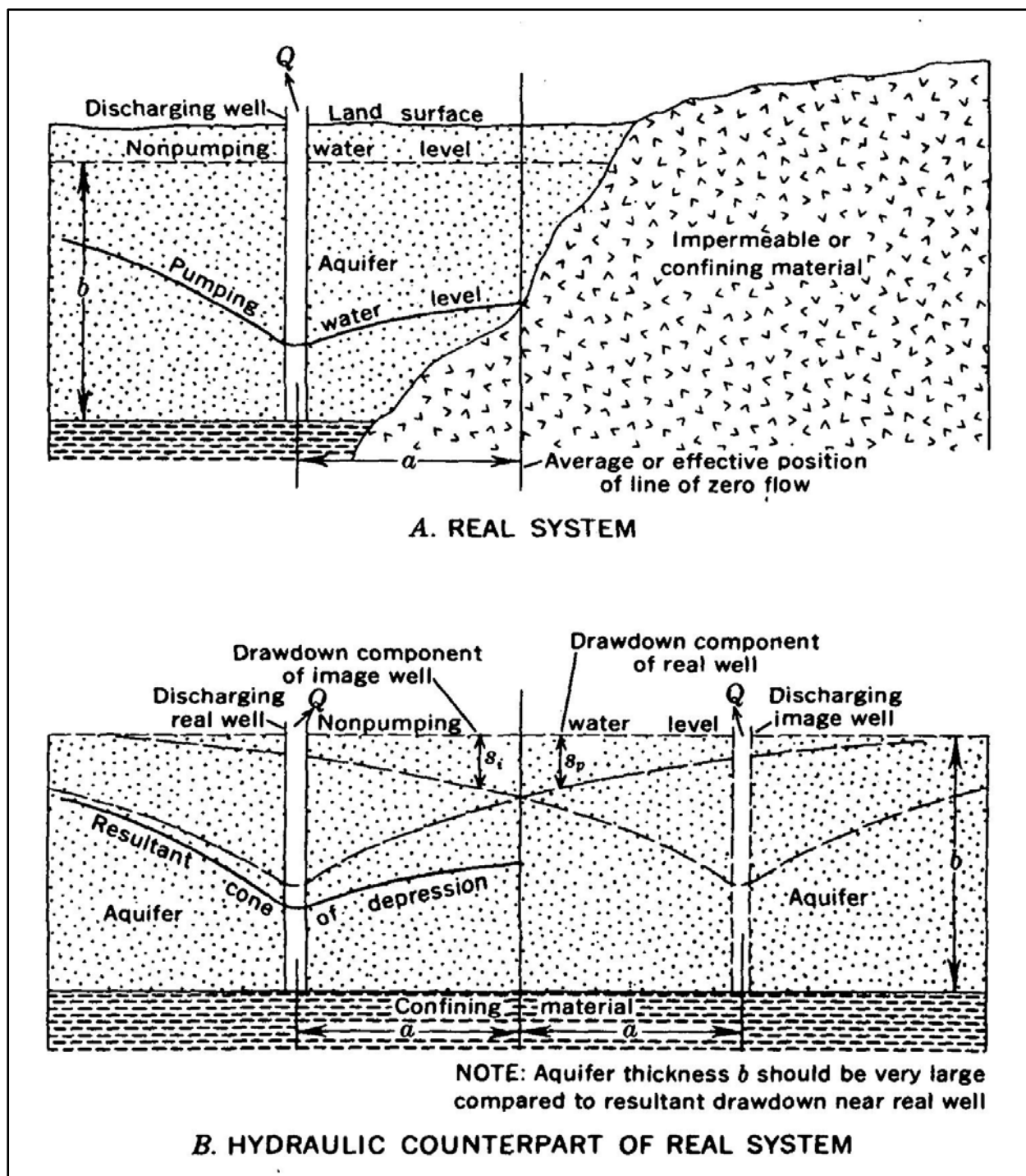


Figure C-11. Idealized cross-sectional views of a pumping well in a groundwater-bearing body bounded by an "impermeable" barrier and an equivalent hydraulic system with a discharging image well in an infinite groundwater-bearing body

[Figure is from Lohman, 1972a, figure 37 adapted from Ferris and others, 1962, figure 37]

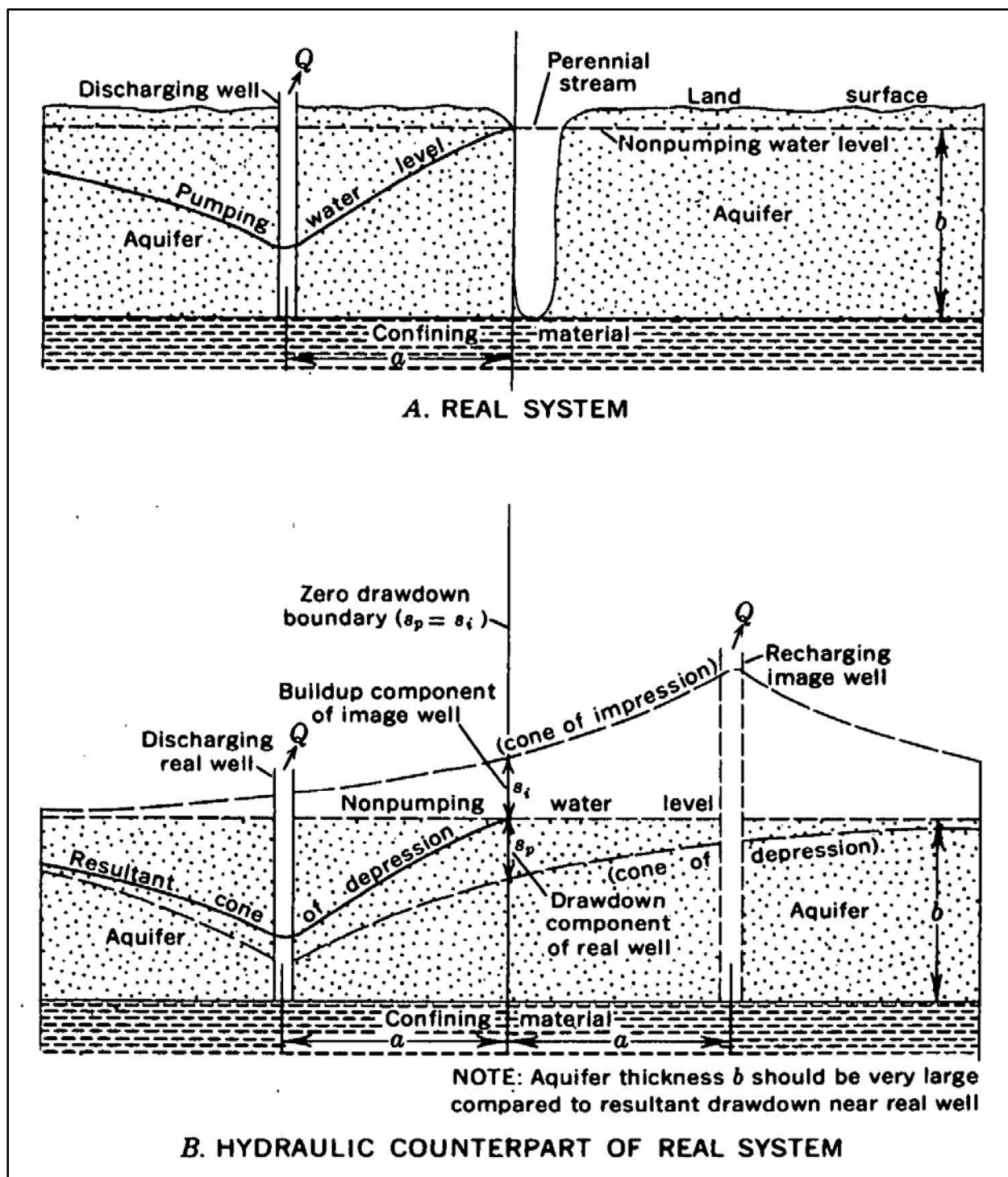


Figure C-12. Idealized cross-sectional views of a pumping well in a groundwater-bearing body bounded by a perennial stream (recharge boundary) and an equivalent hydraulic system with a recharging image well in an infinite groundwater-bearing body

[Figure is from Lohman, 1972a, figure 40 adapted from Ferris and others, 1962, figure 35]

The Theis graphical method and Jacob graphical method can be used to determine the transmissivity (T) and storage coefficient (S) hydraulic properties using the early time data only, the data not yet influenced by a boundary (Ferris and others, 1962; Lohman, 1972a; Heath, 1983). Otherwise, the transmissivity and storage coefficient obtained will likely be erroneous when boundary influenced data is included in the analysis. Limiting analysis to early time data only requires conducting an aquifer test where water level measurements occur very frequently (every 30 to 60 seconds) during the first hours of the aquifer test's pumping period and recovery period to provide sufficient early time data for graphical analyses. Limiting analysis to early time data only can be problematic for the Jacob graphical method where u must be small ($u \leq 0.01$ Lohman, 1972a; $u \leq 0.05$ Heath, 1983) to yield reliable estimates of transmissivity and storage coefficient. Given $u = r^2S/4Tt$ (see equations C-2 and C-3), a small u can be achieved during early time if the radial distance (r) between the pumping well and the measured well is sufficiently small.

Ferris and others (1962) and Stallman (1963) modified the Theis graphical method to determine the transmissivity and storage coefficient hydraulic properties and additionally the radial distance from a measured well (observation well) to the image well representing the boundary. The boundary location can be determined using the radial distances from 3 or more observation wells to the image well (Stallman, 1963; Heath, 1983). Harney Basin groundwater investigation data limitations precluded using the Ferris and others (1962) and Stallman (1963) modified Theis graphical methodologies. Consequently, providing more detail about these methodologies to determine the transmissivity, storage coefficient, and boundary location is beyond the scope of this report. However, more detail can be compiled by reviewing Ferris and others (1962), Stallman (1963), Lohman (1972a), and Heath (1983).

Groundwater Leakage Influence on Aquifer Test Data

Ideal aquifer tests and the Theis equation (equations C-2 and C-3) assume strictly horizontal flow to the pumping well in the groundwater body being tested with no vertical inflow from or through lower permeability geologic units above and/or below the groundwater body being tested (Lohman, 1972a; Freeze and Cherry, 1979). In reality, significant vertical flow from and through lower permeability geologic units can and does occur providing an additional source of water to the groundwater body being tested resulting in drawdown versus time graphs looking similar to graphs representing a recharge boundary influence (figure C-10). The Theis equation

may predict the drawdown adequately for a test's earliest times, but the equation over-predicts the drawdown for later times. This observation prompted significant research resulting in a modification of the Theis equation replacing the well function $W(u)$ with a leaky well function $W(u, r/B)$. The research and equation modifications are summarized in Freeze and Cherry (1979).

Unconfined Groundwater Delayed Yield Influence on Aquifer Test Data

Ideal aquifer tests and the Theis equation (equations C-2 and C-3) assume only horizontal groundwater flow occurs (no vertical flow) and confined groundwater conditions exist implying the geologic material hosting groundwater remains saturated (no dewatering) and two physical mechanisms causes groundwater to flow to a pumping well: water expansion due to reduced fluid pressure and compaction of the geologic material hosting the groundwater (Freeze and Cherry, 1979). When groundwater conditions are unconfined, vertical groundwater flow does occur and the hydraulic cone of depression expanding from the pumping well extends to the water table causing it to lower and drain the geologic material hosting the groundwater in addition to the previously noted horizontal groundwater flow, water expansion, and compaction of the geologic material hosting the groundwater. The resulting drawdown versus time graph is similar to figure C-13. This observation prompted significant research resulting in Neuman (1972, 1973, 1974, 1975) modifying the Theis equation (equations C-2 and C-3) to represent unconfined conditions by replacing the well function $W(u)$ with an unconfined well function $W(u_A, u_B, \eta)$ as summarized in Freeze and Cherry (1979) and Modica (1998) and as shown in equations C-11 to C-14.

$$T = [Q/(4\pi S)] W(u_A, u_B, \eta) \quad [L^2T^{-1}] \quad (\text{equation C-11})$$

$$u_A = r^2 S / 4 T t \quad [\text{dimensionless}] \quad (\text{equation C-12})$$

$$u_B = r^2 S_y / 4 T t \quad [\text{dimensionless}] \quad (\text{equation C-13})$$

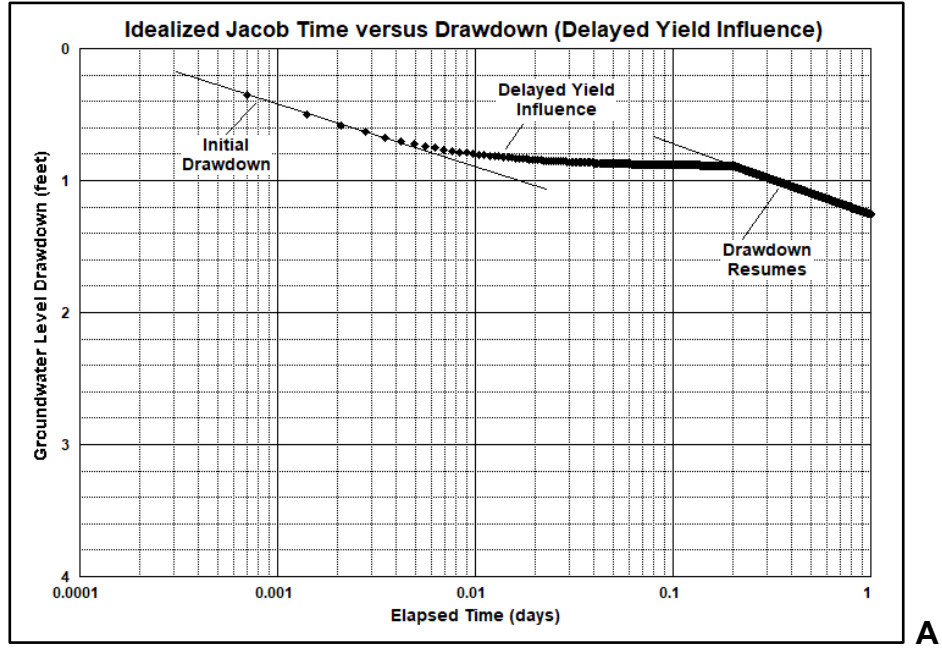
$$\eta = r^2 K_v / r^2 K_h \quad [\text{dimensionless}] \quad (\text{equation C-14})$$

where:

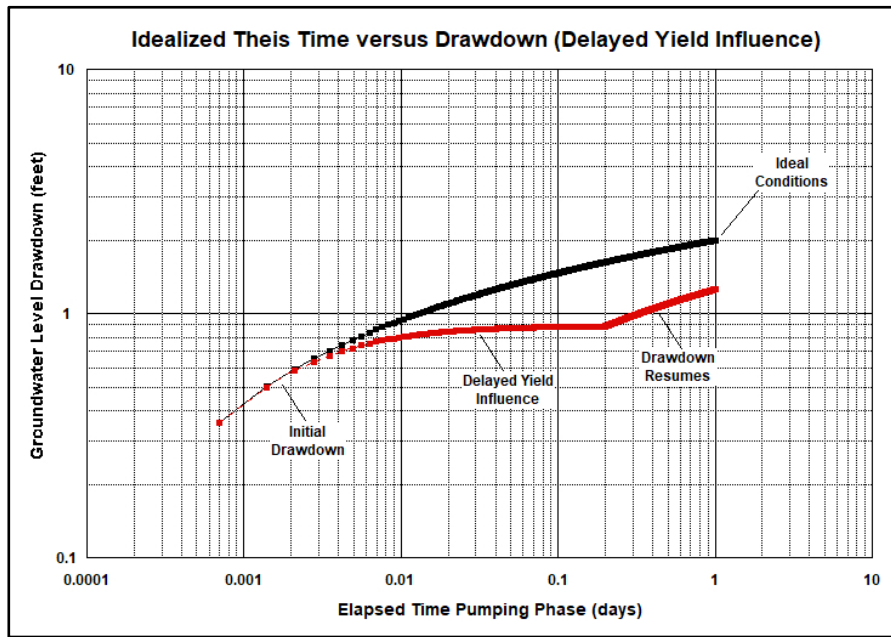
T, Q, π, s, t, r = same as for equations C-2 and C-3

S and S_y = storage coefficient for confined and unconfined groundwater conditions

K_v and K_h = vertical and horizontal hydraulic conductivity



A



B

Figure C-13. Semi-log and log-log graph of idealized groundwater level drawdown at an observation well responding to pumping at a neighboring well and unconfined delayed yield influence
 [Increasing depth is from graph top to bottom in graph A and from graph bottom to top in graph B]

Neuman (1972) notes drawdown of unconfined groundwater due to pumping occurs in three stages-phases as shown in figure C-14 from Modica (1998). During the first-early time phase, drawdown is consistent with the Theis equation for confined groundwater indicating initial horizontal flow and groundwater being released by water expansion due to reduced fluid pressure and compaction of the geologic material hosting the groundwater. During the second phase, significant vertical gravity drainage occurs (resembles leakage, recharge), both vertical and horizontal groundwater flow occurs, and the greatest decline in the water table occurs. In the final phase, groundwater flow is predominantly horizontal, and drawdown is consistent with the Theis equation again but with a larger storage coefficient equal to specific yield (S_y) for unconfined groundwater (water released from storage by gravity drainage). Neuman (1972) notes unconfined groundwater drawdown versus time response to pumping within a groundwater body is not uniform but varies with depth below the water table and distance from the pumping well.

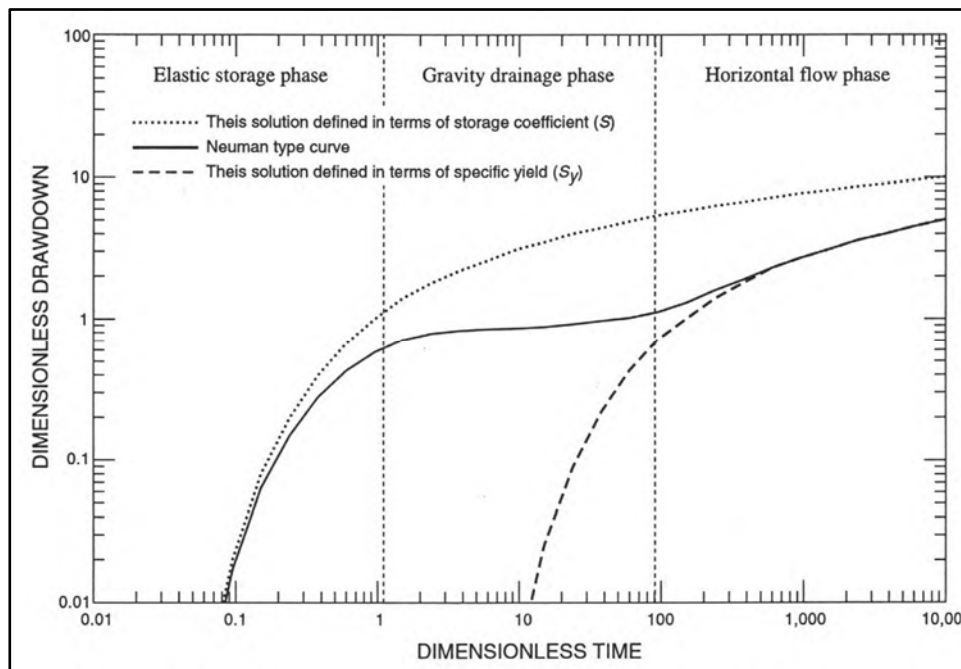


Figure C-14. Log-log graph of Theis equation and Neuman equation results for dimensionless drawdown versus time for unconfined groundwater with a fully penetrating pumping well

[Figure is from Modica, 1998, figure 2. Increasing depth is from graph bottom to top.]

Noordbergum Effect Influence on Aquifer Test Data

Pumping groundwater from a well typically causes groundwater levels at nearby wells to go down during the pumping drawdown phase and rise during post-pumping recovery phase. However, a reverse water level response occasionally occurs during early times of pumping and recovery and has been termed the *Noordbergum effect* after the Netherlands location where it was first observed (Hoffman, 1984). Yin and others (2009) note the effect arises from a three-dimensional deformation of the geologic materials hosting groundwater resulting in an uneven load transfer. They note analyzing the effect requires fully coupled fluid flow and deformation modeling, including the effect of overburden transfer. They report overburden thickness and stiffness and groundwater body depth and width influences the Noordbergum effect magnitude; the effect increases with depth to some maximum, then decreases with additional depth. An apparent Noordbergum effect was observed by one test in the Harney Basin.

Non-Test Well Influence on Aquifer Test Data

The assumptions for ideal aquifer tests imply and require that no non-test pumping, injection, or shut-off recovery associated with non-test wells occurs before the aquifer test pumping begins, during the test pumping phase, or over the duration of the test shut-off recovery phase. Consequently, aquifer tests should be conducted between primary groundwater use seasons at a time when the groundwater level is static (any change within a week is imperceptible). When this ideal is not met, the groundwater response to the non-test activity will be superposed upon the groundwater response to the aquifer test pumping and shut-off. That superposition will be in a manner similar to the image wells previously discussed in the no-flow and recharge boundary influence section except the non-test wells are real rather than images, are at varying distances from the aquifer test well(s), likely have pumping rates different from the aquifer test, and likely have pumping commencement and shut-off times different from the aquifer test. Assessing non-test well influence upon aquifer test data requires knowing the distance from the aquifer test wells measured, the pumping rates, and the pumping schedule. Otherwise, the non-test well activity can result in a larger or smaller measured drawdown and recovery at the aquifer test wells (depending on whether the non-test wells are pumping or shut-off recovering) resulting in an underestimated or an overestimated transmissivity.

Well Loss Influence on Aquifer Test Data from the Pumping Well

The previous sections assume pumping well induced groundwater level drawdown at every affected location (including the pumping well and all observation wells) is due solely to hydraulic head “losses” in the subsurface materials (“formation losses”). Formation losses are directly (linearly) proportional to the pumping well discharge rate (Q) (Jacob, 1947; Bear, 1979) (equations C-15 and C-16 which are equations C-2 and C-4 rewritten), and the resultant groundwater flow through the subsurface toward the pumping well is assumed laminar (non-turbulent) (Jacob, 1950).

$$s = [Q/(4\pi T)]W(u) \quad [L] \quad (\text{equation C-15})$$

or when u is small ($u \leq 0.01$ in Lohman, 1972a; $u \leq 0.05$ in Heath, 1983)

$$s = [2.303Q/(4\pi T)] [\log_{10} (2.25Tt/r^2S)] \quad [L] \quad (\text{equation C-16})$$

where:

T = transmissivity

Q = volumetric flow rate

$\pi = \text{pi} = 3.141592654$

s = drawdown

$W(u) = (-\ln u) - (0.5772157) + (u/1*1!) - (u^2/2*2!) + (u^3/3*3!) - (u^4/4*4!) + \dots$

$u = r^2S/4Tt$

S = storage coefficient

t = elapsed time since pumping began

r = radial distance from pumping well

In actuality, drawdown within a pumping well can be greater than expected from formation losses alone. Additional head losses can occur at the pumping well due to linear and non-linear “well losses” (Kruseman and de Ridder, 1994). Linear well losses relate to well construction such as head losses across zones of compaction, drilling mud infiltration and gravel packs. Non-linear well losses relate to higher velocity, turbulent flow at the pumping well through well screens, casing perforations, and within the well casing and/or borehole to the pump intake (a “zone of turbulence”) (Jacob, 1947; Rorabaugh, 1953; Bear, 1979; Kruseman and de Ridder, 1994).

Distinguishing the linear and non-linear well losses is seldom possible (Kruseman and de Ridder, 1994). Consequently, they are treated empirically as a combined loss (see Jacob, 1947, 1950; Rorabaugh, 1953; Bear, 1979). The well loss is proportional to a higher power of the pumping well discharge rate (Q^n) (figure C-15). Jacob (1947, 1950) indicated using Q^2 yielded an adequate approximation (equation C-17). Rorabaugh (1953) noted using Q^2 is a reasonable assumption but found cases where Q^n ($n \neq 2$) (equation C-18) is more appropriate possibly due to the laminar-turbulent flow boundary shifting outward from the well as the discharge rate increases. Nevertheless, using Q^2 remains widely accepted (Kruseman and de Ridder, 1994).

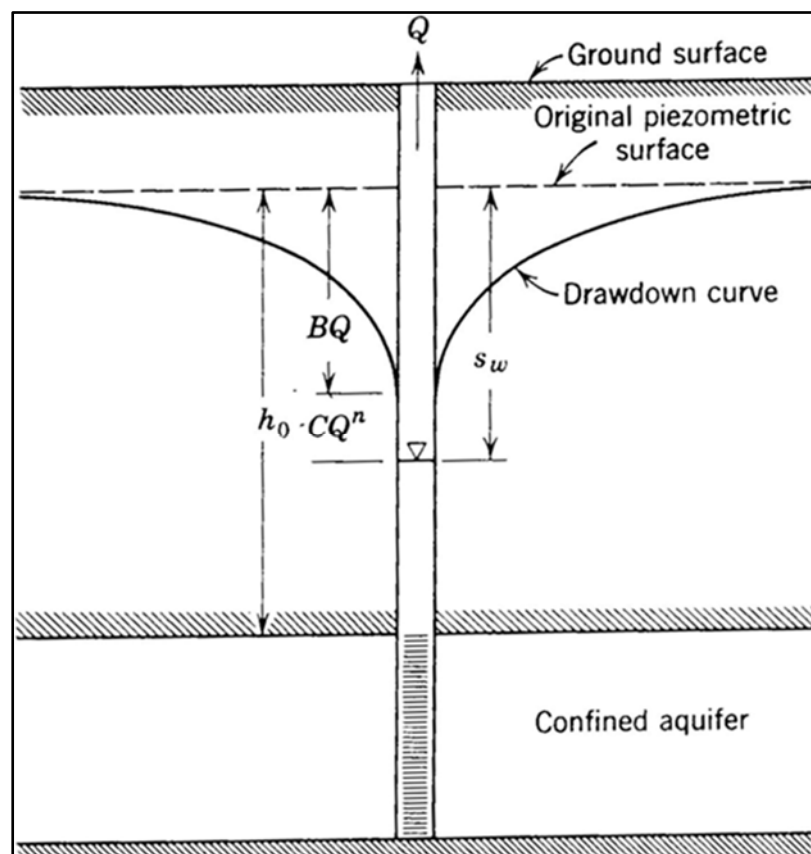


Figure C-15. Diagram of the total drawdown (s_w) measured at a pumping well which equals the sum of two components, formation loss (BQ) and well loss (CQ^n)

[Figure is from Japan International Cooperation Agency (JICA), 2006, figure 3.3-1, p. A1-55]

$$s_w = BQ + CQ^2 \quad [L] \quad (\text{Jacob 1947, 1950}) \quad (\text{equation C-17})$$

$$s_w = BQ + CQ^n \quad [L] \quad (\text{Rorabaugh 1953}) \quad (\text{equation C-18})$$

where:

s_w = drawdown in pumping well

Q = volumetric flow (discharge) rate at the pumping well

B = coefficient for linear formation losses at the pumping well

For transient (time dependent) conditions:

$$B = [1/(4\pi T)]W(u) \quad (\text{from equation C-15), or}$$

$$B = [2.303/(4\pi T)] [\log_{10} (2.25Tt/r^2S)] \quad (\text{from equation C-16})$$

For steady state conditions:

$$B = \text{constant}$$

BQ = drawdown within the formation adjacent to the pumping well

For transient conditions:

$$BQ = [Q/(4\pi T)]W(u) \quad (\text{equation C-15), or}$$

$$BQ = [2.303Q/(4\pi T)] [\log_{10} (2.25Tt/r^2S)] \quad (\text{equation C-16})$$

For steady state conditions:

$$BQ = \text{constant}$$

C = coefficient for non-linear well losses at the pumping well = constant

CQ^n = additional drawdown at the pumping well due to well losses = constant

Distinguishing formation losses and well losses have uses. Determining drawdown due to formation losses (BQ) by subtracting well loss drawdown (CQ^n , a constant) from each drawdown measurement (s_w) at a pumping well is needed for hydraulic property analyses that require using the actual drawdown related to the surrounding subsurface materials rather than a rate of drawdown. Conversely, determining the drawdown at a pumping well due to well loss is useful for determining the pumping well efficiency and effective radius, the primary interest of Jacob (1947, 1950) and Rorabaugh (1953) who presented using step-drawdown tests in their well loss determination methodologies.

Kruseman and de Ridder (1994) describe an ideal step-drawdown test as a single well test where the well is initially pumped at a low constant discharge rate until the drawdown within the

well stabilizes (step 1). Then the pumping rate is increased to a higher constant rate, and the well is pumped until the drawdown stabilizes again (step 2). The process is repeated until three or more steps are completed. The duration for each step should be the same. In practice, many step-drawdown tests change steps before the drawdown stabilizes, and some tests have varying durations for each step.

Methods available to analyze step-drawdown tests vary. Kruseman and de Ridder (1994) present several. The following example is the Hantush-Bierschenk method (Bierschenk, 1963; Hantush, 1964) as presented by Kruseman and de Ridder (1994). The method applies the principle of superposition to equation C-17 (Jacob, 1947), and it yields B and C values. It can be applied to confined, leaky, or unconfined groundwater conditions. The example step-drawdown test data is from a test of a basaltic aquifer in Hawaii conducted and reported by Izuka and Gingerich (1997).

Kruseman and de Ridder (1994) note the Hantush-Bierschenk method assumptions and conditions are:

- The groundwater is confined, leaky, or unconfined;
- The groundwater system has a seemingly infinite aerial extent;
- The groundwater system is homogeneous, isotropic, and of uniform thickness over the area influenced by the test;
- Prior to pumping, the potentiometric surface is horizontal or nearly horizontal over the area influenced by the test;
- The groundwater is pumped at step-wise increased discharge rates;
- The pumping well penetrates the entire thickness of the groundwater saturated zone and consequently receives water via horizontal flow;
- Groundwater flow to the pumping well is in an unsteady state;
- The water removed from storage is discharged instantaneously with decline in head;
- The pumping well diameter is small, meaning storage in the well can be neglected;
- The non-linear well losses are appreciable and vary according to CQ^2

Kruseman and de Ridder (1994) note the procedure for the Hantush-Bierschenk method is:

- Create a semi-log graph (figure C-16) of the measured observed drawdown in the well (s , linear scale axis) versus the elapsed pumping time (t , logarithmic scale axis);
- Extend the plotted data of each step past the end of the next step (figure C-16 red dashed lines);
- Determine the drawdown increments for each step (figure 16, s_{w1} to s_{w4} , table C-1) by taking the difference between the observed drawdown at a fixed time interval (Δt) taken from the beginning of each step and the corresponding drawdown on the extended plotted data (figure C-16 red dashed lines) of the preceding step ($\Delta t = 60$ minutes for this example, see table C-1);
- Determine the cumulative discharge rate (Q_T) (figure C-16, Q_1 to Q_4 , table C-1, Q_T) corresponding to the cumulative s_w (s_{wT}) for each step (figure C-16, s_{w1} to s_{w4} , table C-1, s_{wT});
- Calculate the s_{wT} / Q_T ratio for each step (Table C-1);
- Create a linear graph of the s_{wT} / Q_T values versus the corresponding values of Q_T for each step (figure C-17);
- Draw a straight line through the plotted points (figure C-17);
- Determine the slope of the straight line $[\Delta(s_{wT} / Q_T) / \Delta Q_T]$ (figure C-17) which is the C value;
- Extend the straight line until it intercepts the $Q = 0$ axis. The intercept point on the s_{wT} / Q_T axis gives the B value (figure C-17) for $t = \Delta t$.
- Note: if each step reaches steady state, the drawdown in the well is no longer time dependent, the observed steady state drawdown and corresponding discharge for each step can be used directly in the linear graph of the s_{wT} / Q_T values versus the corresponding values of Q_T and the values determined are steady state constants.

For this example (figures C-16 and C-17, table C-1):

$$s_w = BQ + CQ^2 \quad (\text{for } t = \Delta t = 60 \text{ minutes})$$

where:

$$B = 0.5000 \text{ min/ft}^2 \quad \text{and} \quad C = 0.0080 \text{ min}^2/\text{ft}^5$$

when:

$$Q = 41.10 \text{ ft}^3/\text{min} \text{ (300 gpm)}$$

then:

$$\begin{aligned} s_w &= (0.5000 \text{ min/ft}^2)(41.10 \text{ ft}^3/\text{min}) + (0.0080 \text{ min}^2/\text{ft}^5)(41.10 \text{ ft}^3/\text{min})^2 \\ &= 20.55 \text{ ft (formation loss)} + 13.51 \text{ ft (well loss)} = 34.06 \text{ ft (total drawdown)} \end{aligned}$$

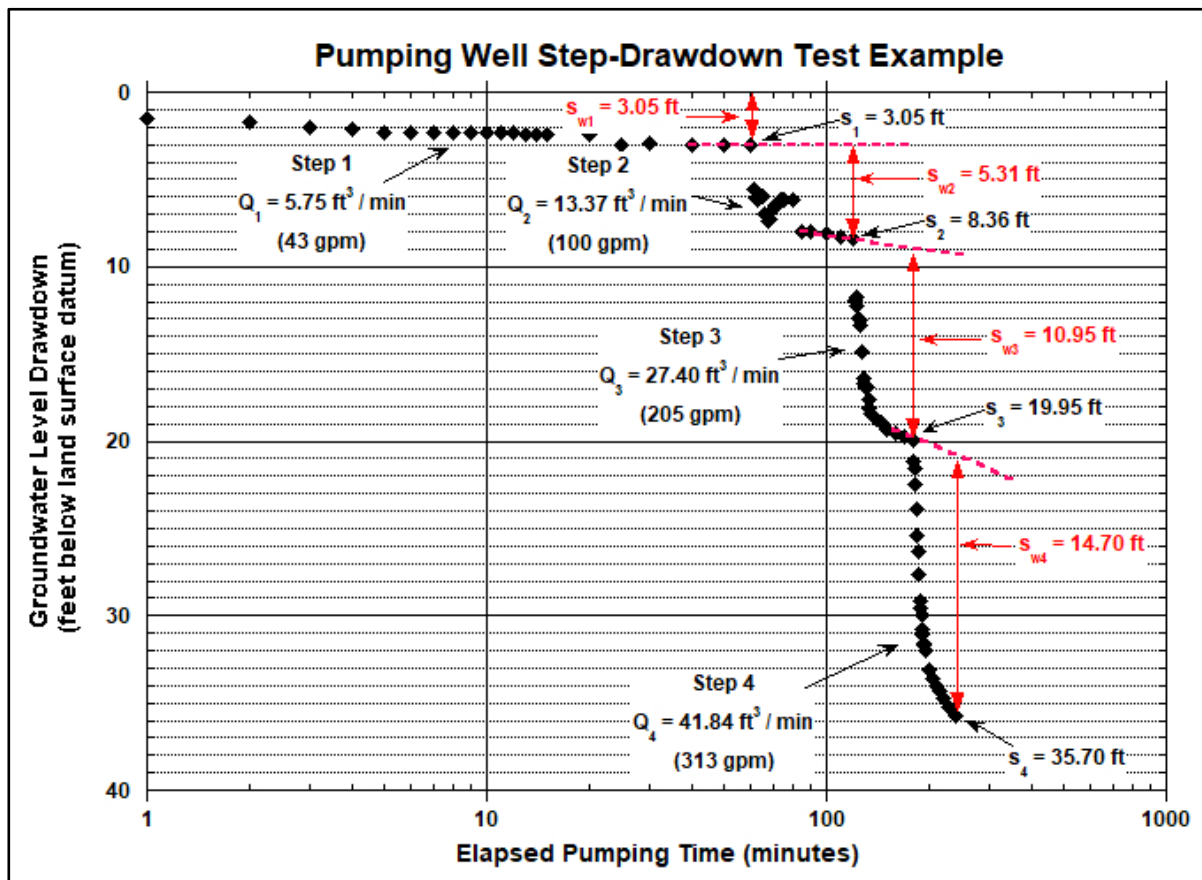


Figure C-16. Time versus drawdown semi-log graph for an example step-drawdown test at a pumping well
[Data for graph is from Izuka and Gingerich (1997)]

Table C-1. Step-drawdown test table derived from figure C-16 for Hantush-Bierschenk analysis method to calculate specific drawdown (s_{wT} / Q_T) for figure 17

[See notes at end of table]

Parameter	Units	Step-Drawdown			
		Step 1	Step 2	Step 3	Step 4
Step start time (t_s)	minutes	0.000	60.000	120.000	180.000
Step end time (t_e)	minutes	60.000	120.000	180.000	240.000
Time increment (Δt)	minutes	60.000	60.000	60.000	60.000
Time total (t_T)	minutes	60.000	120.000	180.000	240.000
Time at Δt	minutes	60.000	120.000	180.000	240.000
Drawdown increment start (s_{ws}) at Δt	feet	0.000	3.050	9.000	21.000
Drawdown increment end (s_{we}) at Δt	feet	3.050	8.360	19.950	35.700
Drawdown increment (Δs_w) at Δt	feet	3.050	5.310	10.950	14.700
Drawdown total (s_{wT})	feet	3.050	8.360	19.310	34.010
Discharge rate previous step (Q_p)	feet ³ /min	0.000	5.748	13.368	27.405
Discharge rate current step (Q_c)	feet ³ /min	5.748	13.368	27.405	41.842
Discharge rate change (ΔQ)	feet ³ /min	5.748	7.620	14.037	14.437
Discharge rate total (Q_T)	feet ³ /min	5.748	13.368	27.405	41.842
Drawdown total / Discharge rate total (s_{wT} / Q_T)	min / feet ²	0.531	0.625	0.705	0.813

Notes:

Values in the table are copied or calculated from figure C-16 values

Specific drawdown = Drawdown total / Discharge rate total = s_{wT} / Q_T

Drawdown increment (Δs_w) at Δt determined for $\Delta t = 60$ minutes

Step-drawdown data source is Izuka and Gingerich (1997)

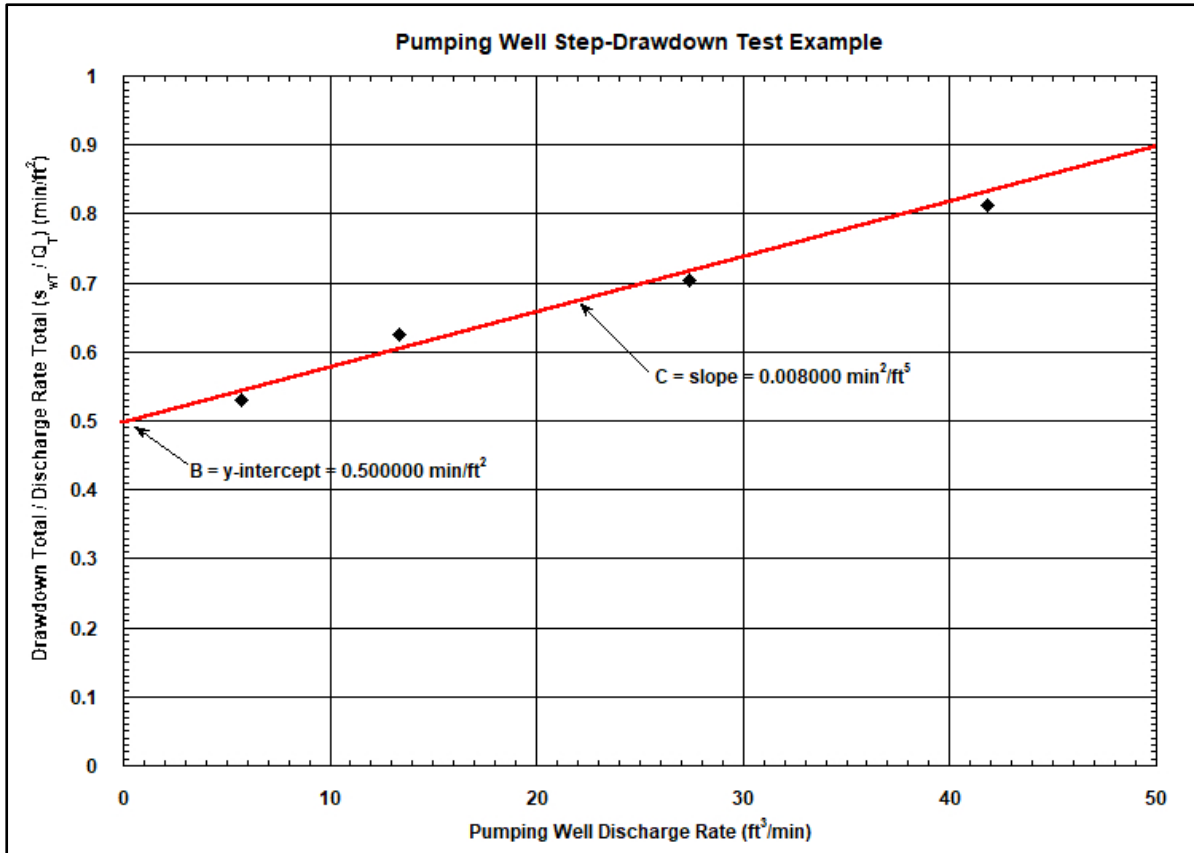


Figure C-17. Specific drawdown (s_{wT} / Q_T) versus pumping well discharge rate for example step drawdown test using Hantush-Bierschenk analysis method to determine well loss coefficient (C, constant) and formation loss coefficient (B, when $t = \Delta t$)

[Step-drawdown data source is Izuka and Gingerich (1997)]

Appendix D: Specific Capacity

Conducting and analyzing aquifer tests presented in appendix C requires significant material and time resources that often limit the number of tests available to characterize the hydraulic parameters (particularly transmissivity and storage coefficient) of various geologic units hosting groundwater at various depths, locations, and hydraulic conditions in a groundwater study area's groundwater system. Theis and others (1963) note useful approximations of transmissivity can be estimated with limitations from specific capacity data related to wells. Specific capacity derived transmissivity values can yield a supplemental quantity and distribution of transmissivity values sufficient to improve groundwater system hydraulic property characterization aerally and vertically and to better numerically model that system (Lohman, 1972a; Heath, 1983).

Specific Capacity

A well's specific capacity is the steady rate of groundwater discharge from the well divided by the total measured drawdown within the well (equation D-1) (Lohman, 1972b; Bear, 1979). The total measured drawdown occurs at either a planned or arbitrary total elapsed time of discharge that should be recorded along with the discharge rate and measured drawdown (Lohman, 1972b).

$$SC = Q/s \quad [L^2T^{-1}] \quad (\text{equation D-1})$$

where:

SC = specific capacity

Q = volumetric flow (discharge) rate

s = drawdown

Factors affecting specific capacity include: the transmissivity (T) of the zone within the groundwater body that supplies groundwater to the pumping well's open interval receiving groundwater inflow (figure D-1); the storage coefficient (S) defined in appendix B; the total elapsed time of discharge (t) when the total drawdown measurement occurs; the well's effective radius (figure D-1); and the rate of steady groundwater discharge from the well (Heath, 1983). Lohman (1972a), Bear (1979), and Risser (2010) note specific capacity values can decrease with greater discharge rate and greater total elapsed time of discharge.

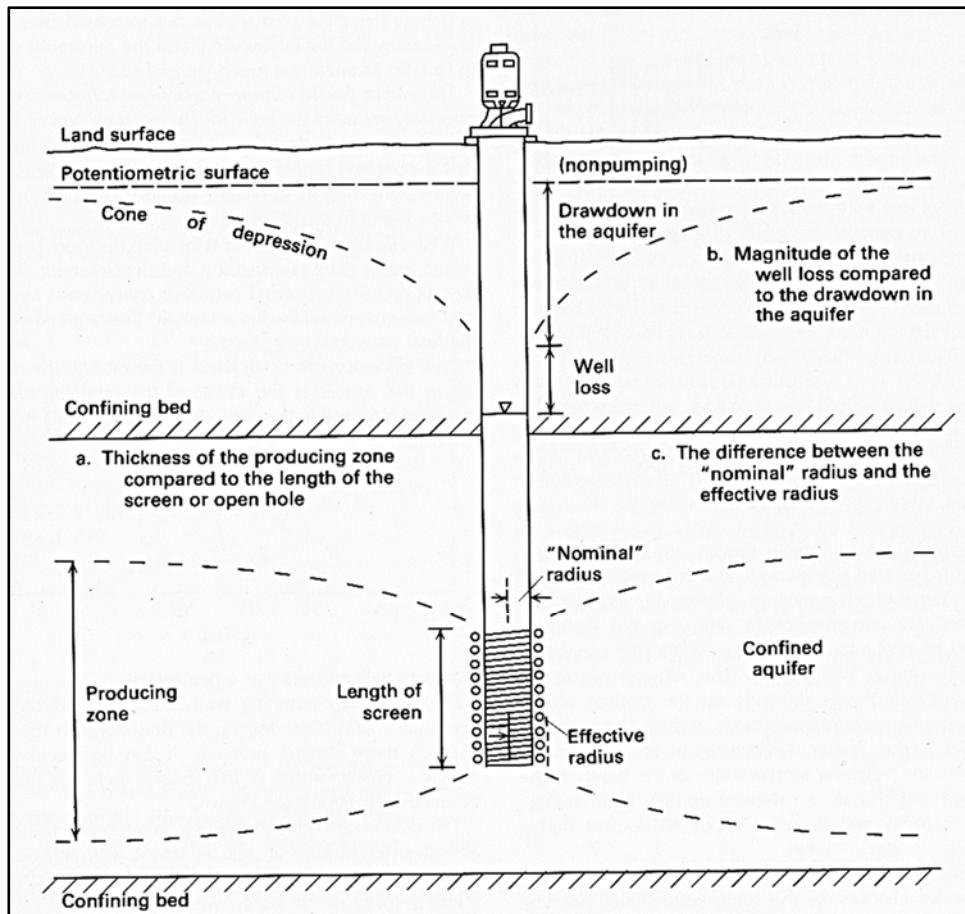


Figure D-1. Factors affecting specific capacity

[Figure is from Heath (1983), p. 60]

Specific capacity values can decrease with greater rates of steady groundwater discharge from a well. The drawdown measured in a pumping well is the sum of two components (Lohman, 1972a, Bear, 1979; Risser, 2010). The first component is drawdown (head loss) within the groundwater body (formation loss, figure D-1 "drawdown in the aquifer") caused by low velocity laminar flow consistent with Darcy's Law (appendix C, equation C-1). The second component is drawdown (head loss) caused by higher velocity turbulent flow adjacent and/or inside the well (figure D-1 "well loss") that violates Darcy's Law. Most groundwater flow stays within the laminar flow range, but flow very close to a pumping well or another outlet can become turbulent (Bear, 1979) given groundwater flow converging radially inward toward a pumping well at a constant volumetric rate increases in flow velocity as the water approaches the well to maintain

the volumetric rate. Drawdown caused by laminar flow is directly proportional to the pumping rate. If all the measured drawdown were caused by laminar flow, the specific capacity derived from multiple tests using different pumping rates would remain the same given the Q/s ratio (equation D-1) is constant for laminar flow (Risser, 2010). The Q to s relationship is linear plotting as a straight line on a graph. Drawdown caused by turbulent flow is not directly proportional to the pumping rate. The Q to s relationship is non-linear plotting as a curve on a graph (see Bear, 1979, figure 8-34). Consequently, multiple tests using different pumping rates that create turbulent flow yield different specific capacity values given the Q/s ratio (equation D-1) varies (is not constant) for the turbulent flow portion. Greater discharge rates at a well can initiate or increase turbulent flow that initiates or increases well loss non-linearly, which increases the measured total drawdown non-linearly resulting in a smaller calculated specific capacity.

Specific capacity values can decrease with greater total elapsed time of discharge. Given appendix C, equation C-4, Lohman (1972a) notes the specific capacity gradually decreases by $1/\log_{10}t$ as time (t) increases. Risser (2010) additionally notes specific capacity values can appear to decrease with greater total elapsed time of discharge given the relationship between specific capacity, total elapsed time of discharge, and well bore storage. The ratio of pre-test well-bore water volume (“well-bore storage”) versus the in-flow water volume in the total well discharge volume shrinks with increasing time. The in-flow rate from the surrounding groundwater body increases up to a constant, steady maximum rate as the pre-test well bore storage is removed. Consequently, well-bore storage within a well effectively lessens the early-time total drawdown (increasing the calculated early time specific capacity). With increasing time, the proportion of well-bore storage volume in the total water volume discharged from the pumping well decreases which decreases its influence-effect on later-time total drawdown. Total drawdown approaches the drawdown that would be observed if no well bore storage had existed effectively increasing the total drawdown relative to the steady discharge rate with time, which shrinks the Q/s ratio (equation D-1) with time (appearing to decrease the calculated specific capacity in later-time).

Estimating Transmissivity from Specific Capacity

Theis and others (1963) note estimating transmissivity from specific capacity should be reasonably reliable using a formula expressing the relationship between a well’s specific capacity and the groundwater body’s transmissivity rather than resorting to elaborate tests for precise

determinations. Both the Theis equation and Jacob equation written to solve for transmissivity are suitable formulas given they include Q/s (see appendix C, equations C-2 and C-4 respectively). The specific capacity (Q/s) of the pumped well can be used for the formula Q/s ; the total elapsed time of discharge (t) when the total drawdown measurement occurred can be used for the time (t) in the formula; the well radius can be used for the radial distance (r); and an arbitrary storage coefficient (S) can be used in the formula given large changes in storage coefficient (S) yield relatively small changes in transmissivity and specific capacity (Theis and others, 1963). The transmissivity value can be determined using graphs similar to figure D-2 by Theis and others (1963) and/or using a numerical method such as developed by Vorhis (1979). The transmissivity value obtained is a useful approximation, not exact, given some of the values used to determine the transmissivity are estimates, not exact (Theis and others, 1963).

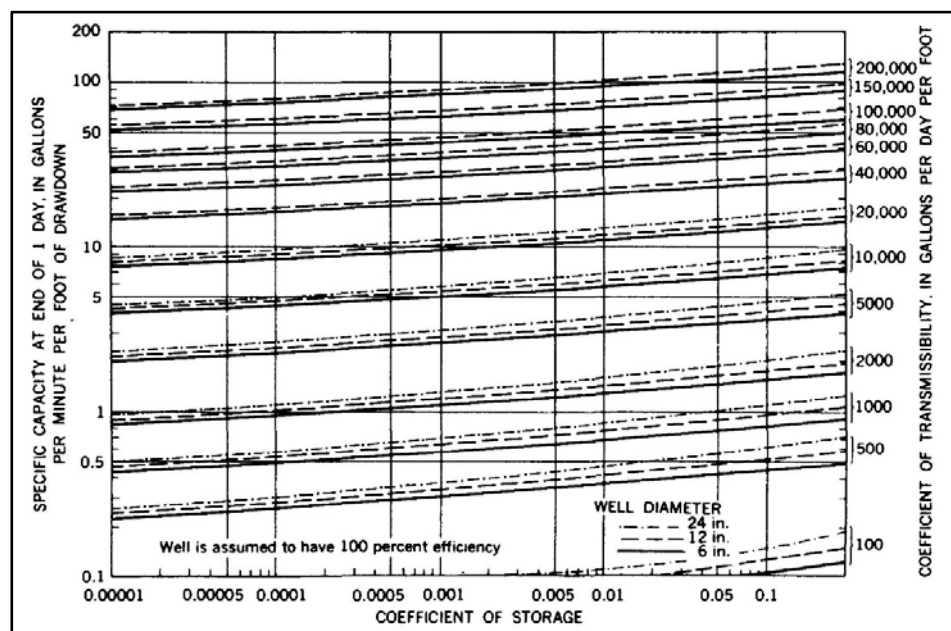


Figure D-2. Graph showing the specific capacity, transmissivity, storage coefficient, and well diameter relationship

[Figure is from Theis and others (1963), figure 100, p. 339]

[Note relatively small transmissivity change in relation to large storage coefficient change]

Vorhis Numerical Method for Estimating Transmissivity from Specific Capacity

With the advent of programmable calculators, Vorhis (1979) developed an iterative numerical method to calculate transmissivity using the Theis equation reordered to solve for transmissivity (T) as presented in appendix C (equations C-2 and C-3) where:

$$T = [Q/(4\pi s)]W(u) \quad (\text{equation C-2 and D-2})$$

$$S = (4Ttu)/r^2 \quad \text{or rewritten as} \quad u = r^2S/4Tt \quad (\text{equation C-3 and D-3})$$

where:

T = transmissivity

Q = volumetric flow rate

$\pi = \text{pi} = 3.141592654$

s = drawdown

$W(u) = (-\ln u) - (0.5772157) + (u/1*1!) - (u^2/2*2!) + (u^3/3*3!) - (u^4/4*4!) + \dots$

S = storage coefficient

t = elapsed time since pumping began

r = radial distance from pumping well

$u = r^2S/4Tt$

The Vorhis method assigns and uses an assumed storage coefficient (S) value to calculate u which is used to calculate W(u) which is used to calculate transmissivity (T). The iterative numerical method can be adapted to available computer spreadsheets and written into computer codes.

Vorhis (1979) notes the transmissivity for a given test is the only unknown given $Q/(4\pi s)$, r, and t are constant, u equals $r^2S/4Tt$ in calculating the well function W(u), and an arbitrary S may be assumed (a safe assumption given figure D-2 shows small transmissivity changes relative to large storage coefficient changes). The numerical iteration process begins the first iteration by using specific capacity ($SC = Q/s$) as the first approximation of the transmissivity T used to calculate u in equation D-3, used to calculate the well function W(u) in equation D-2, and subsequently a new T in equation D-2. The new T is used in the second iteration to calculate a new u in equation D-3, a new well function W(u) in equation D-2, and a newer T in equation D-2.

The newer T is used in the third iteration to calculate a newer u in equation D-3, a newer well function W(u) in equation D-2, and yet a newer T in equation D-2. At the end of each iteration, the difference between the latest T calculated and the previous T calculated is assessed. The iterations continue until the difference between the latest T calculated and the previous T calculated shrinks to less than a user specified amount, indicating the T value has converged to a particular value that can be used. Convergence usually occurs within a few iterations.

This study used the Vorhis iterative numerical method within a Python language script that did the following to calculate transmissivity from specific capacity:

- Used 25 iterations to ensure a calculated transmissivity (T) convergence or stopped earlier if the transmissivity value converged to within 10^{-4} ft²/day
- Used the calculated specific capacity ($SC = Q/s$) to approximate the transmissivity (T) for the first iteration
- Used an assumed storage coefficient (S) value of 0.001 for all records, all iterations
- Used the reported well yield test total drawdown (s) when greater than 0-feet or used 0.5 feet to avoid calculation problems when the reported drawdown was 0-feet
- Used the reported well yield test total elapsed time (t) when reported or used 0.5 hours (0.02 days) total elapsed time when the time was not reported
- Used an average of the reported well open interval diameter(s) divided by 2 for the radial distance (r) (see appendix M regarding well open intervals)

Appendix E: Aquifer-Interference Test Conducted and Analyzed

Oregon Water Resources Department (OWRD) staff conducted and analyzed a 72-hour pumping, 23-hour recovery aquifer-interference test conducted in November 2008 at a site west of Burns Airport (figure E-1), about 3.5 miles east of Burns. The test included three wells, a pumping well (HARN 441) and two observation wells (HARN 440 and HARN 52896) all completed at different depths (table E-1). The test was a combined single well aquifer test involving the pumping well only and a multiple well interference test involving the two observation wells. The single well aquifer test portion provided data useful to estimate transmissivity. The interference test portion attempted to collect sufficient data to assess the hydraulic connection between shallow and deeper groundwater. Data directly related to the test (water level measurements, discharge readings, and barometric pressure readings) and well construction can be found in the OWRD groundwater information system (GWIS) database and the OWRD water well report database respectively (Oregon Water Resources Department, 2019a and 2019b).

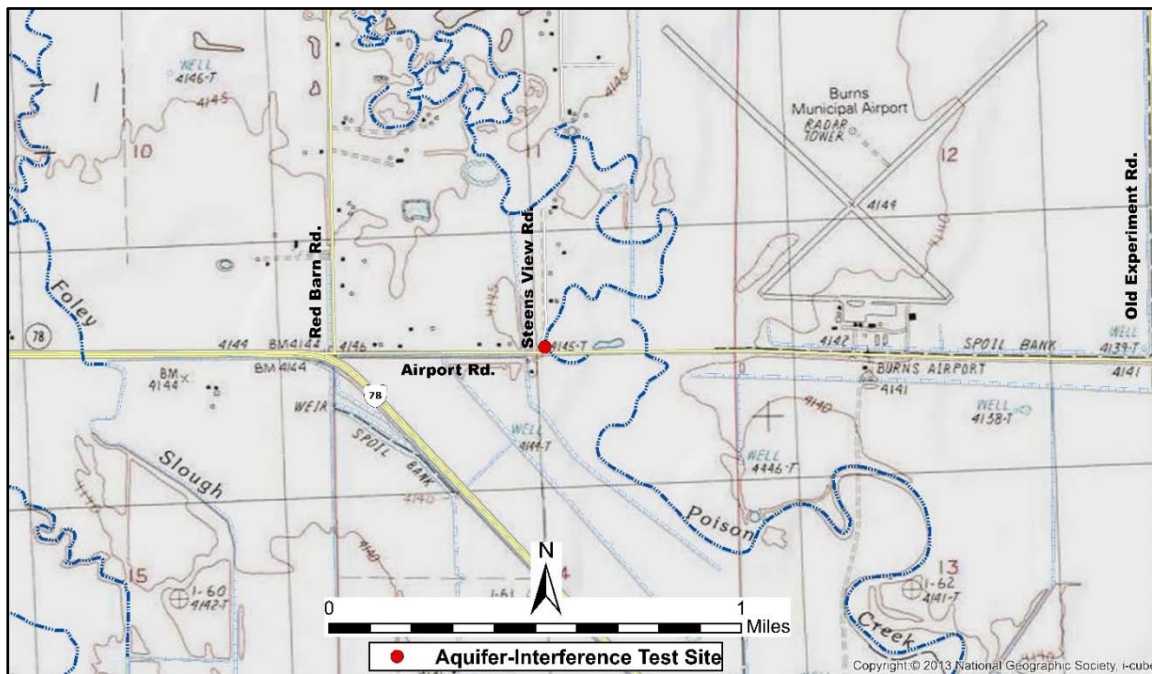


Figure E-1. Location of aquifer-interference test conducted by OWRD staff in November 2008

[Location is west of Burns Airport, about 3.5 miles east of Burns]

Table E-1. Harney Basin aquifer-interference test wells

Well Information	Wells		
OWRD Water Well Report (original)	HARN 441	HARN 440	HARN 52896
OWRD Water Well Report (subsequent)	HARN 51439	HARN 51438	none
Well Use for Test	Pumping	Observation	Observation
Distance from Pumping Well (feet)	0	7	50
Well Total Depth (feet blsd)	561	120	8.3
Well Casing Bottom Depth (feet blsd)	220	120	8.3
Well Seal Bottom Depth (feet blsd)	35	35	none
Well Perforation Interval Depth (feet blsd)	none	15 ¹ to 120	none
Well Open Interval Depth (feet blsd)	220 to 561	50 ² to 120	8.0 to 8.3
Well Total Open Interval Length (feet)	341	85	0.3
Interpreted Open Interval Stratigraphic Unit	Qs & Tts	Qs	Qs

Note: well construction data is from water well reports in Oregon Water Resources Department (2019b)

Note: blsd means below land surface datum, and stratigraphic units are defined in appendix A

¹0 to 50 feet blsd is occupied by a subsequent well seal and solid casing

²Open interval starts at perforation interval set starting at 50 feet blsd

Data Source: Oregon Water Resources Department 2019a, 2019b

Barometric Pressure During Test

Under ideal conditions, barometric pressure remains constant from before the test to after the test. During this test, the barometric pressure fluctuated within a water column pressure equivalent range of about 0.9 feet, initially declining, then rising, and eventually stabilizing (figure E-2). This change was considered when analyzing the test related water level data.

Pumping Well Discharge Rate During Test

Under ideal conditions, the pumping well discharge rate can be adjusted to remain constant throughout the test pumping phase. During this test, the discharge rate could not be adjusted. The rate did change during the test. The cumulative average discharge rate decreased as the pumping period phase progressed from about 170 gallons per minute (gpm) to about 131 gpm (figure E-3). This decreasing discharge rate is likely related to the increasing lift demand on the pump as the water level in the pumping well declined during the test's pumping phase. A decreasing discharge rate can decrease the rate of water level decline measured during the test's pumping phase.

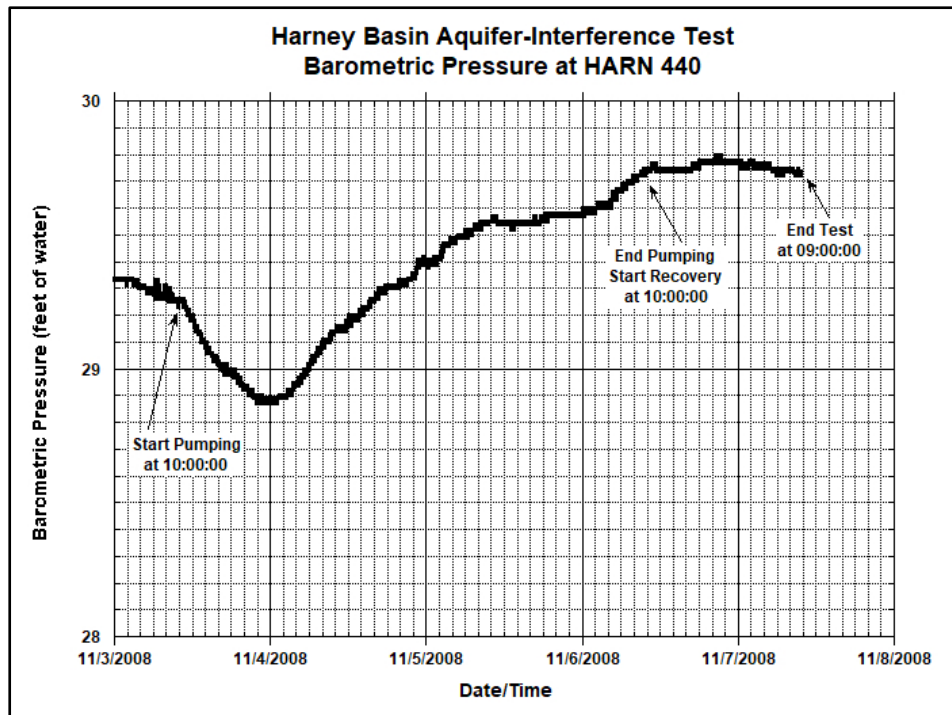


Figure E-2. Barometric pressure changes during the 2008 Harney Basin aquifer-interference test

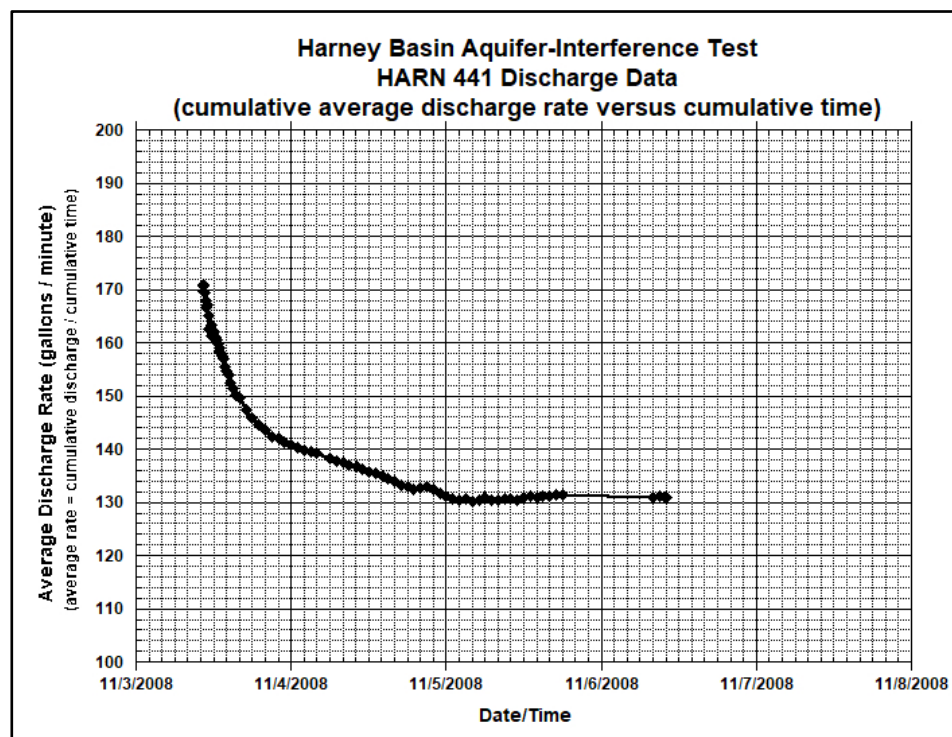


Figure E-3. Cumulative average discharge rate of the 2008 Harney Basin aquifer-interference test

Water Levels Measured During Test

Water levels were measured at the pumping well (HARN 441) and the two observation wells (HARN 440 and HARN 52896). Manual measurements using an electric water level meter were conducted at increasing time intervals at the pumping well (figure E-4). Automated shaft encoder float-counter weight measurements were conducted at one-minute intervals at the observation wells (figures E-5 and E-6) supplemented by manual measurements using an electric water level meter (not shown). The barometric pressure change during the test was less than two percent of the water level change at the pumping well and greater than the water level change at the observation wells. Consistent with the appendix C barometric pressure change influence discussion, the pumping well water level data was not adjusted to account for barometric pressure change, but the water level data for the observation wells were adjusted using a barometric efficiency of 25 percent (figures E-5 and E-6 show the unadjusted and adjusted water levels). That barometric efficiency was derived from an average of 76 water level change to barometric level change ratios within a ten-hour period immediately before the test's pumping phase began.

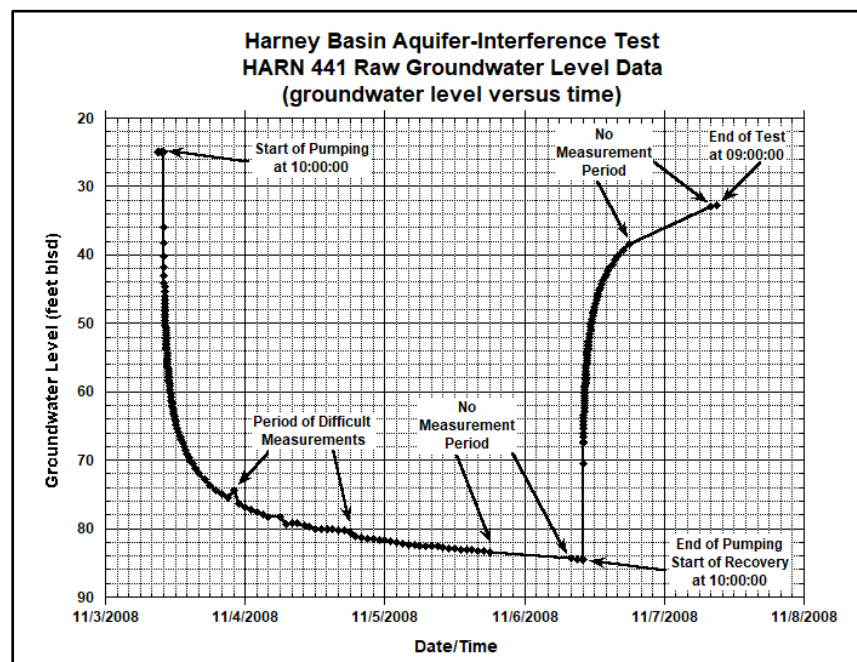


Figure E-4. Linear graph of manual groundwater level measurements at pumping well HARN 441 during 2008 Harney Basin aquifer-interference test

[Difficult measurement means extra effort was required to obtain a reliable measurement. The source of difficulty was not determined.]

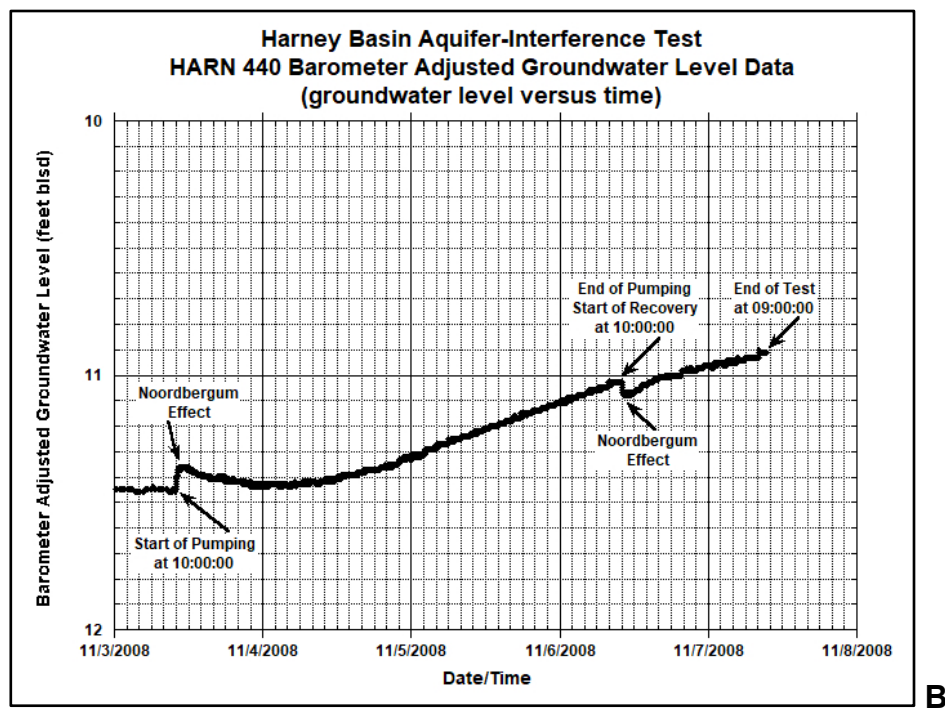
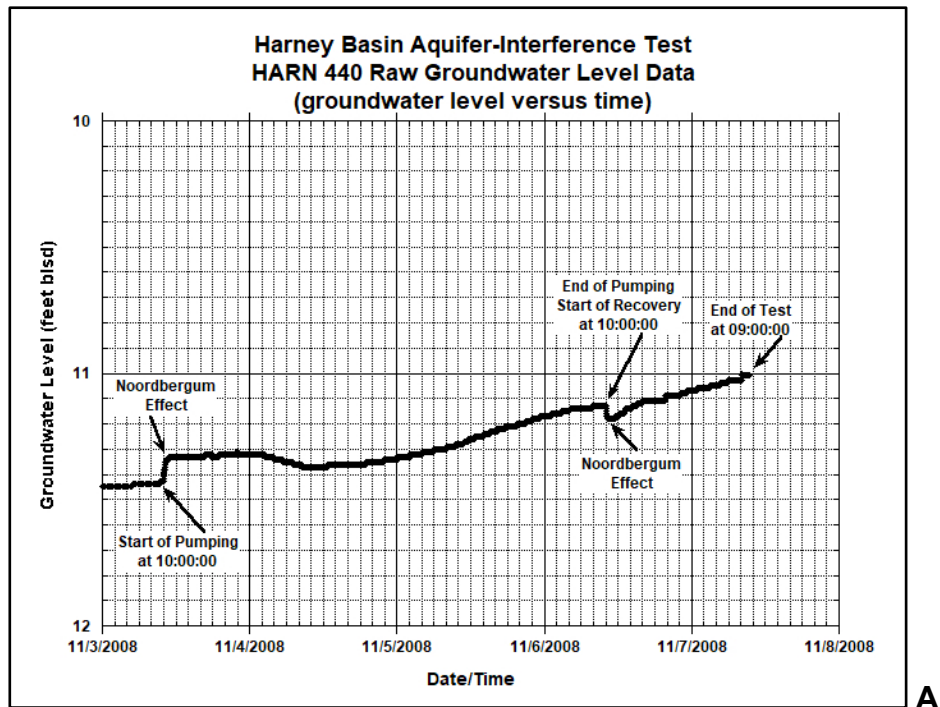


Figure E-5. Linear graph of groundwater level recorded at observation well HARN 440 during 2008 Harney Basin aquifer-interference test

[Graph A is unadjusted. Graph B is Graph A adjusted by barometric pressure change using a barometric efficiency of 25%]

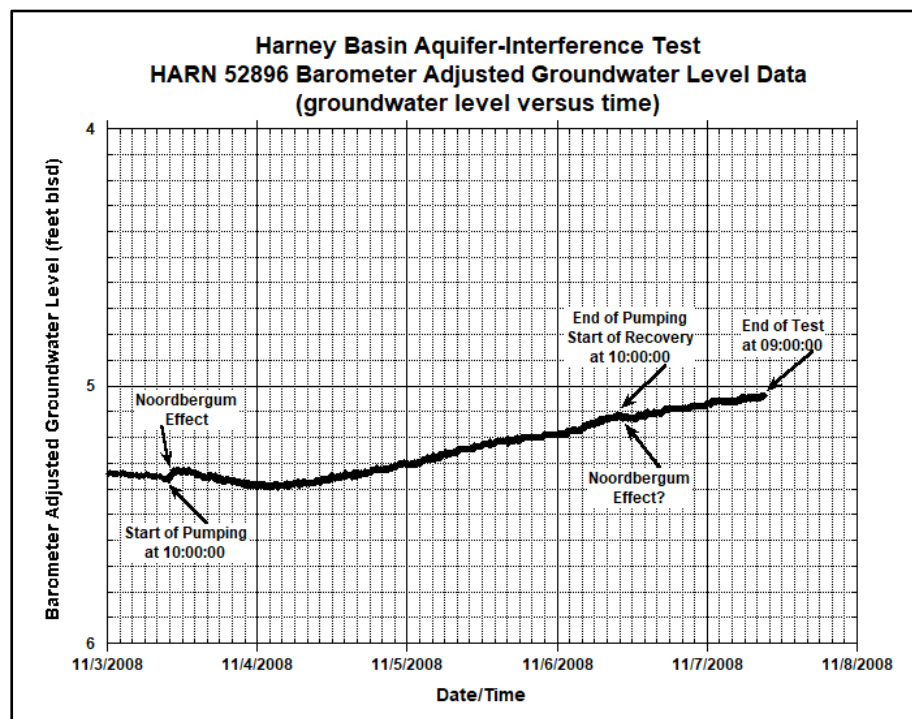
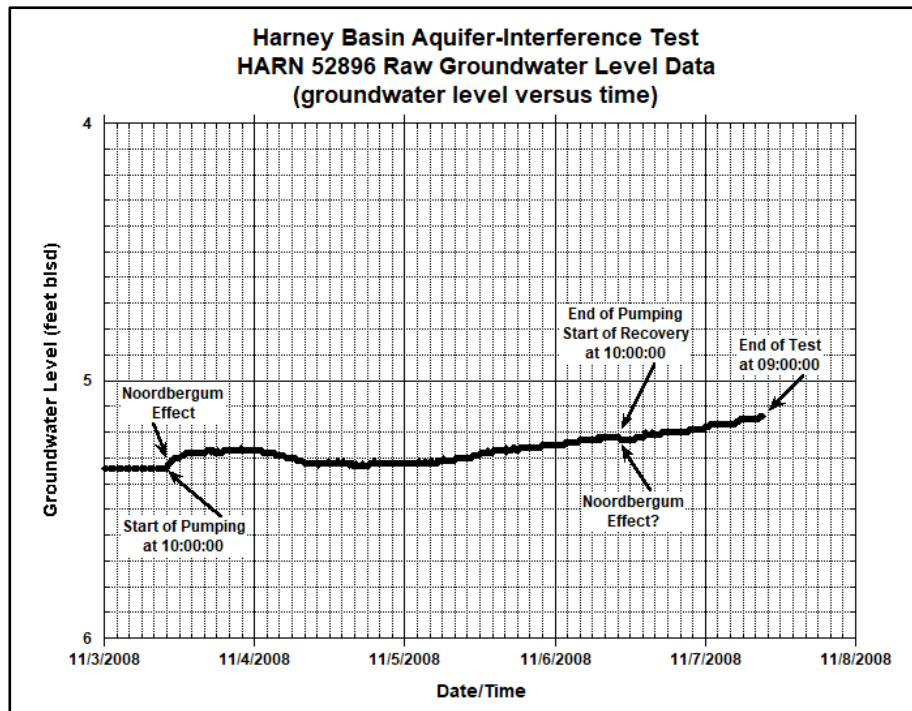


Figure E-6. Linear graph of groundwater level recorded at observation well HARN 52896 during 2008 Harney Basin aquifer-interference test

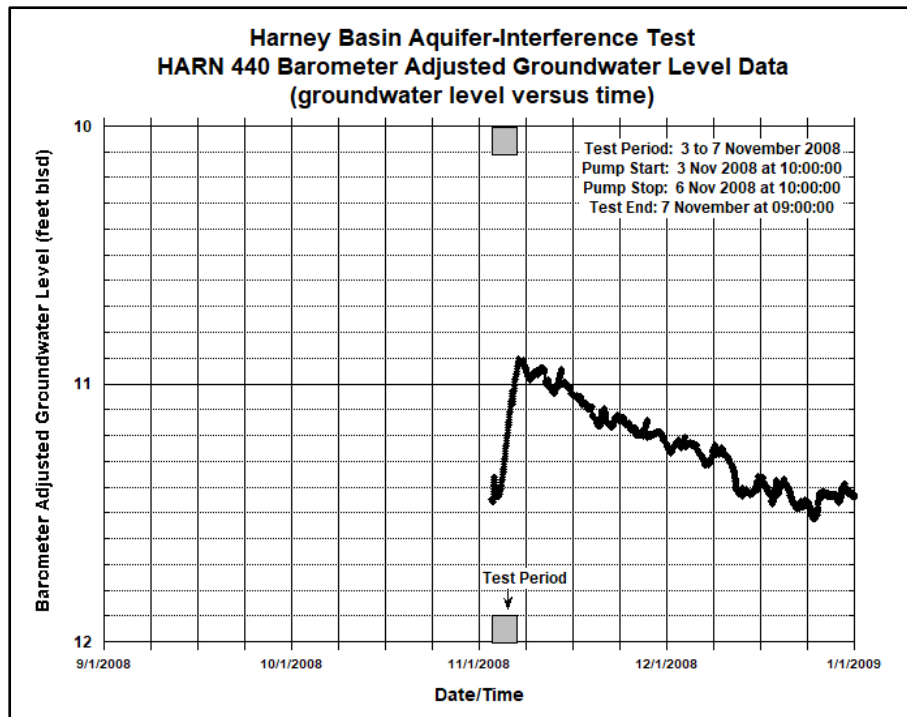
[Graph A is unadjusted. Graph B is Graph A adjusted by barometric pressure change using a barometric efficiency of 25%]

A water level change at the pumping well and the two observation wells did occur during the test. At the pumping well, the influence of the pump operating and shutting off dominated the water level change resulting in a drawdown and recovery that exceeded 59 feet and 51 feet respectively (figure E-4). Any other influence is masked by the influence of the pump operating and shutting off. At the observation wells, the water level change was less than one foot allowing the detection of multiple influences that include barometric pressure changes, the nearby pump operating and shutting off, and possibly changes that were occurring in vicinity surface water.

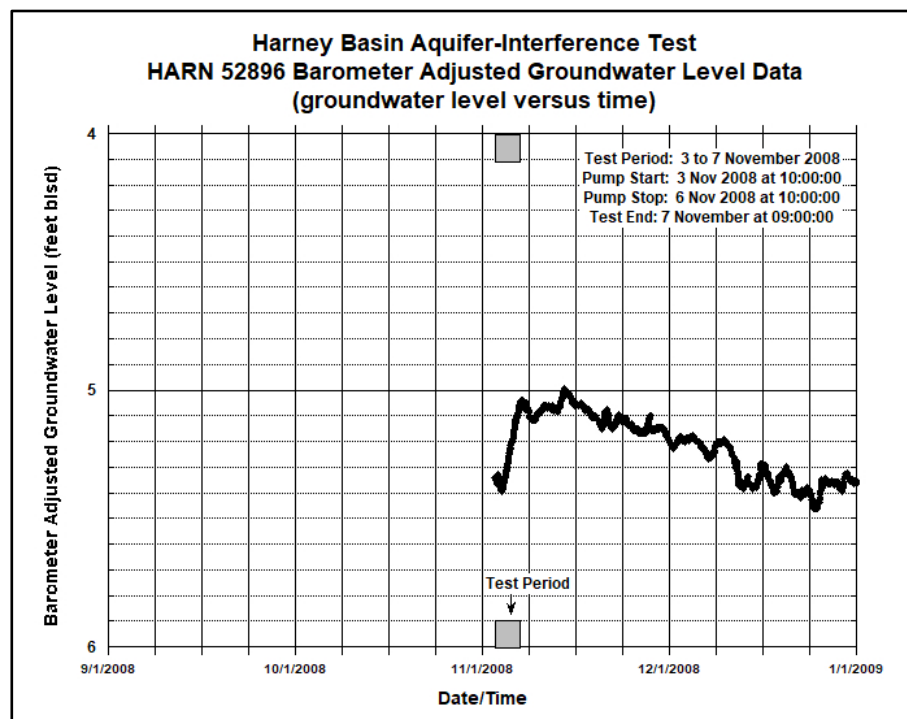
Barometric pressure changed during the test. It fluctuated within a water column pressure equivalent range of about 0.9 feet (figure E-2), which is greater than the water level change at the observation wells. Accounting for the barometric pressure influence on the water level data for each observation well required removing (subtracting) the barometric pressure influence by using a barometric efficiency of 25 percent derived from water level change to barometric level change ratios before the test's pumping phase began as previously noted (figures E-5 and E6).

The nearby pumping well operating and shutting off caused two responses on water level data for each observation well. First was an immediate Noordbergum effect response (reverse water level response) as shown in figures E-5 and E6 and explained in appendix C. Second was a short-lived drawdown response that becomes apparent after the first Noordbergum effect response that accompanied the start of pumping.

The most dominant influence caused the water level at each well observation well to rise through most of the test, during both pumping and recovery phases (figures E-5, E-6, and E-7). This influence is not definitively identified, but it may relate to changes in vicinity surface water as evidenced by increasing flow in the Silvies River before, during, and after the test (figure E-8, Oregon Water Resources Department, 2021). If surface water is the influence, the relationship to the water level at the observation wells needs further investigation to explain: (a) what surface water body (bodies) caused the influence given surface water channels closest to the pumping and observation wells had little to no water before, during, and after the test (at most, unchanging small, shallow, isolated ponds with no flow); (b) why the water level in the deeper observation well appears to show a greater water level response (figure E-5 versus E-6); and (c) why the rise in observation well water levels ends before the period of increasing surface water flow ends (figure E-7 versus E-8).



A



B

Figure E-7. Linear graph of groundwater level recorded at observation wells HARN 440 and HARN 52896 during 2008 Harney Basin aquifer-interference test

[Graph A is HARN 440. Graph B is HARN 52896. Both graphs were adjusted to account for barometric pressure change using a barometric efficiency of 25%]

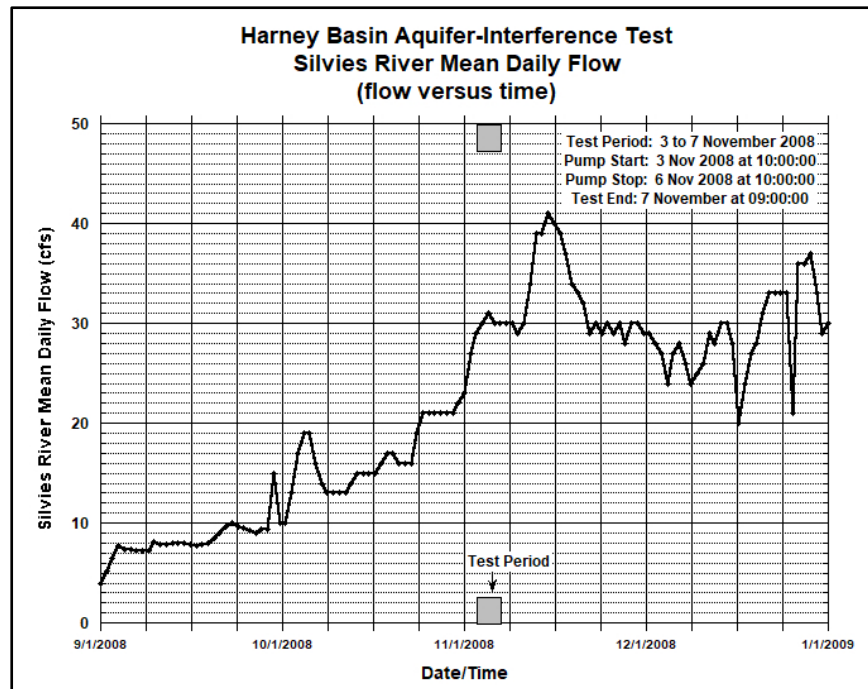
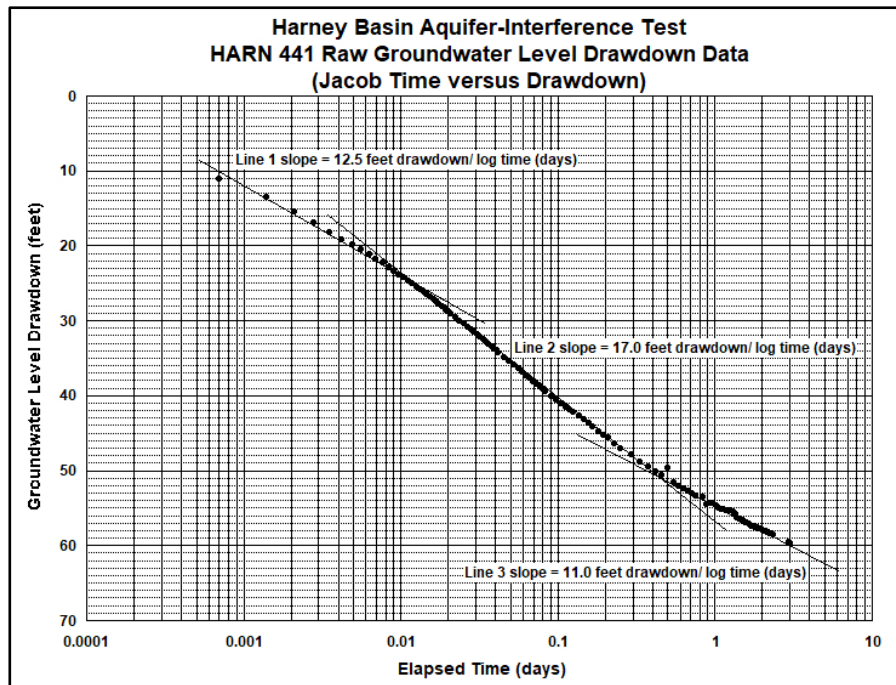


Figure E-8. Silvies River mean daily flows before, during, and after the 2008 Harney Basin aquifer-interference test

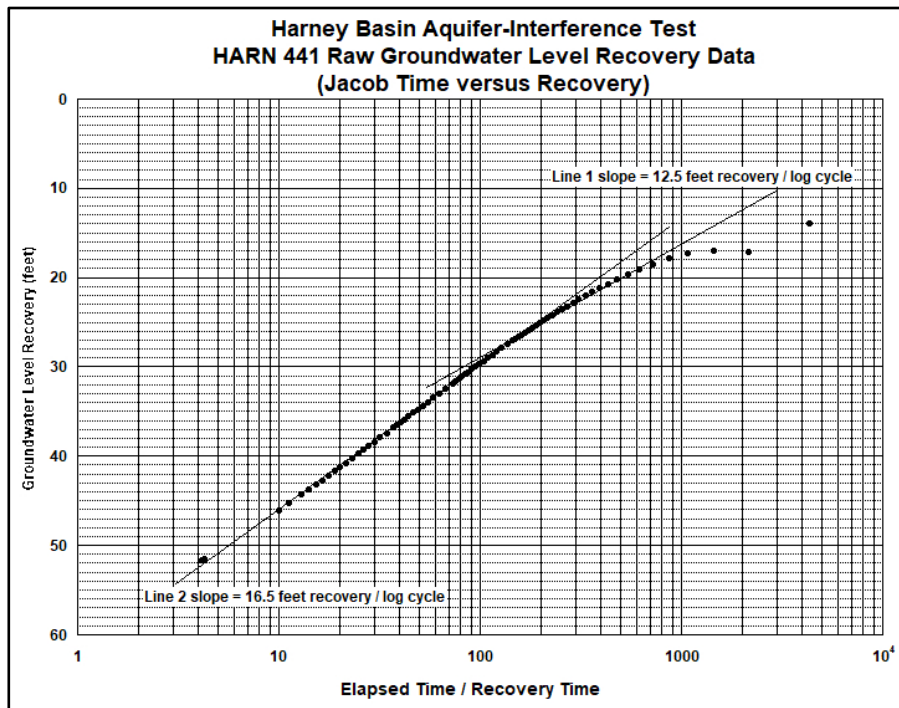
[The river station name is Silvies River near Burns, OR. The station ID is 10393500]

Graphical Analysis Conducted

The pumping well (HARN 441) water level data was analyzed to determine transmissivity using the Jacob graphical method described in appendix C. The pumping well water level data was plotted on two semi-log graphs showing 72 hours of drawdown and 23 hours of recovery respectively (figure E-9). The drawdown data appears to show three successive decline trends where a steeper decline trend (slope 2) separates two similar shallower decline trends (slopes 1 and 3). The recovery data appears to show two successive rising trends, a shallow rise (slope 1) followed by a steeper rise (slope 2). The recovery slopes 1 and 2 rising trends are very similar to the drawdown slopes 1 and 2 decline trends indicating the drawdown and recovery phases experienced the same hydraulic influences. The steeper slope 2 trend being limited to about 35 percent greater than the slope 1 trend for both drawdown and recovery indicates an encounter with a lower yield zone rather than a no-flow boundary. A slope 3 does not appear in the recovery data likely due to terminating the recovery water level measurements before the slope 3 influence occurred.



A



B

Figure E-9. Semi-log graph of the pumping well (HARN 441) water level data during the 2008 Harney Basin aquifer-interference test

[Graph A is the drawdown phase data. Graph B is the recovery phase data.]

Water level data related to the observation wells (HARN 440 and HARN 52896) were not analyzed for transmissivity or other hydraulic properties for two reasons. First, the fully coupled fluid flow and deformation modeling Yin and others (2009) noted as being required to account for the observed Noordbergum effect exceeded the scope of this study and the 2008 Harney Basin aquifer-interference test analyses. Second and primarily, the uncertainties related to the previously noted unidentified but most dominant influence (possibly surface water) on the observation well water level data that caused a water level rise during both the pumping and recovery phases made analyzing the observation well data impractical.

Transmissivity values were calculated from the pumping well (HARN 441) drawdown and recovery water level data using the semi-log graphs (figure E-9) and equations E-1 and E-2 below (same as equations C-4 and C-9 in appendix C) derived, simplified from the Theis drawdown and recovery equations (Theis, 1935; Wenzel and Fishel, 1942, Cooper and Jacob, 1946; Davis and DeWiest, 1966; Lohman, 1972a; Freeze and Cherry, 1979; Heath, 1983).

$$T = (2.303Q)/(4\pi\Delta s) \quad [L^2T^{-1}] \quad (\text{equation E-1})$$

$$T = (2.303Q)/(4\pi\Delta s') \quad [L^2T^{-1}] \quad (\text{equation E-2})$$

where:

T = transmissivity

Q = volumetric flow rate

$\pi = \pi = 3.141592654$

s = drawdown

Δs = drawdown for one log cycle of elapsed time since pumping began ($\log_{10} \Delta t = 1$)

$\Delta s'$ = recovery for one log cycle of elapsed time divided by recovery time ($\log_{10} \Delta t/t_r = 1$)

t_t = elapsed time since pumping began

t_r = recovery time since pumping stopped

Table E-2 shows the calculation results for the pumping well data, not the observation well data for reasons previously noted. Only transmissivity was calculated. Storage coefficient is best calculated using observation well data. The calculations used an average pumping rate of 130.91 gallons per minute (about 25,200 ft³/day). The calculated transmissivity of 369.47 ft²/d from the earliest time data (slope 1, graph line 1) for both graphs is considered closest to representing the subsurface hydraulic properties at the test location (data least biased by influences) and is used to represent the test results. The later time data is considered to include one or more influence biases and was not used to represent the test results.

Table E-2. Harney Basin aquifer-interference test hydraulic property analysis results

Well	GW Data Analyzed ¹	Analysis Method ²	Graph Line ³	Line Slope ⁴	Transmissivity Calculated ⁵	Storage Coefficient ⁶	Comment
HARN 441	Raw	Jacob DD	1	12.50	369.47	not calculated	Early time data
HARN 441	Raw	Jacob DD	2	17.00	271.67	not calculated	Mid time data
HARN 441	Raw	Jacob DD	3	11.00	419.85	not calculated	Late time data
HARN 441	Raw	Theis R	1	12.50	369.47	not calculated	Early time data
HARN 441	Raw	Theis R	2	16.50	279.90	not calculated	Later time data
HARN 440							No Analysis ⁷
HARN 52896							No Analysis ⁷

¹Groundwater level data analyzed was "raw" (as measured-recorded) and/or "adjusted" (barometric pressure influence removed)

²Analysis methods considered-used were Theis log-log curve match (Theis DD), Jacob semi-log drawdown (Jacob DD) or Theis semilog recovery (Theis R) versus time. The methods are discussed in appendix C.

³Straight line plotted through data segment on Jacob semi-log drawdown (DD) or recovery (R) versus time graph

⁴Line slope on Jacob semi-log graph = groundwater level change in feet per log-cycle on graph

⁵Calculated transmissivity units are feet² / day

⁶Calculated storage coefficient has no dimensional units, not calculated for pumping well

⁷Analysis attempted, but yielded spurious-unreliable-unusable results-values

Appendix F: Analysis of Recorder Data

Pumping at irrigation well HARN 52029 in northeast Harney Valley about 20 miles east of Burns and at irrigation well HARN 1084 northwest of Harney Lake about 15 miles southwest of Hines influences the water level at nearby recorder observation wells HARN 52494 and HARN 52534 respectively (figure F-1, table F-1). Oregon Water Resources Department (OWRD) staff conducted aquifer test analyses of the water level data recorded every two hours at the recorder observation wells to determine hydraulic property values (transmissivity and storage coefficient) for those locations. The analyses and results are reported in this appendix.

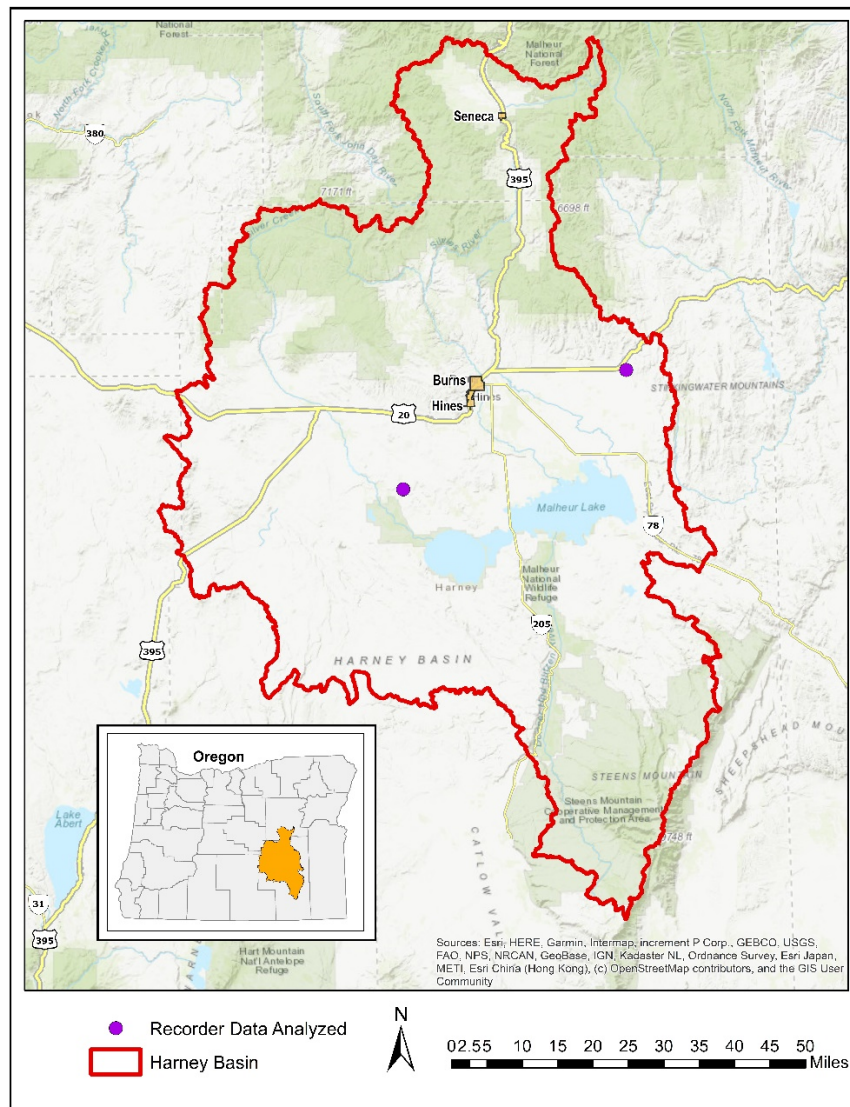


Figure F-1. Irrigation well locations influencing nearby recorder well data used for aquifer test analyses

Table F-1. Harney Basin irrigation and recorder well pairs used for aquifer test analyses

Well Information	Wells			
	Northeast Harney Valley		Northwest of Harney Lake	
OWRD Water Well Report (original)	HARN 52029	HARN 52494	HARN 1084	HARN 52534
OWRD Water Well Report (subsequent)	HARN 52644	none	none	none
Well Use for Test	Pumping	Observation	Pumping	Observation
Distance from Pumping Well (feet)	0	86	0	1795
Well Total Depth (feet blsd)	165	157	457	432
Well Casing Bottom Depth (feet blsd)	119	157	200	250
Well Seal Bottom Depth (feet blsd)	48	48	25	50
Well Perforation Interval Depth (feet blsd)	none	124 to 142	60 to 80 100 to 120	none
Well Open Hole Depth (feet blsd)	119 to 165	none	200 to 457	250 to 432
Sum of Open Well Section Lengths (feet)	46	18	297	182
Interpreted Open Section Stratigraphic Unit	Qtsu	Qtsu	Qtsu, Tts, HLPu	Qtsu, HLPu

Note: well construction data is from water well reports in Oregon Water Resources Department (2019b)

Note: blsd means below land surface datum

Note: QTsu means basin fill deposits undifferentiated

Note: Tts means Tuffaceous sedimentary rocks and tuff

Note: HLPu means High Lava Plains basalt undifferentiated

Data Source: Oregon Water Resources Department 2019a, 2019b

Analysis of Recorder Data from Northeast Harney Valley

OWRD staff analyzed the May through September 2017 recorder data from the recorder observation well HARN 52494 in northeast Harney Valley. The data shows four primary pumping and shutoff events with occasional brief shutoff interruptions during the primary pumping periods (figure F-2). Each primary pumping-shutoff event was analyzed as an independent aquifer test to determine transmissivity and storage coefficient using the log-log curve matching, the semi-log drawdown, and semi-log recovery graphical methods as described and illustrated in appendix C and E. The log-log graphical method was used to analyze the pumping phase drawdown data only. The semi-log graphical method was used to analyze both the pumping phase drawdown data and the shutoff phase recovery data. The log-log time versus drawdown graphs and the semi-log time versus drawdown and recovery graphs used for the analyses are shown in figures F-3 to F-5 respectively. Calculated average pumping rates and transmissivity and storage coefficient calculations related to each graph are shown in tables F-2 to F-5.

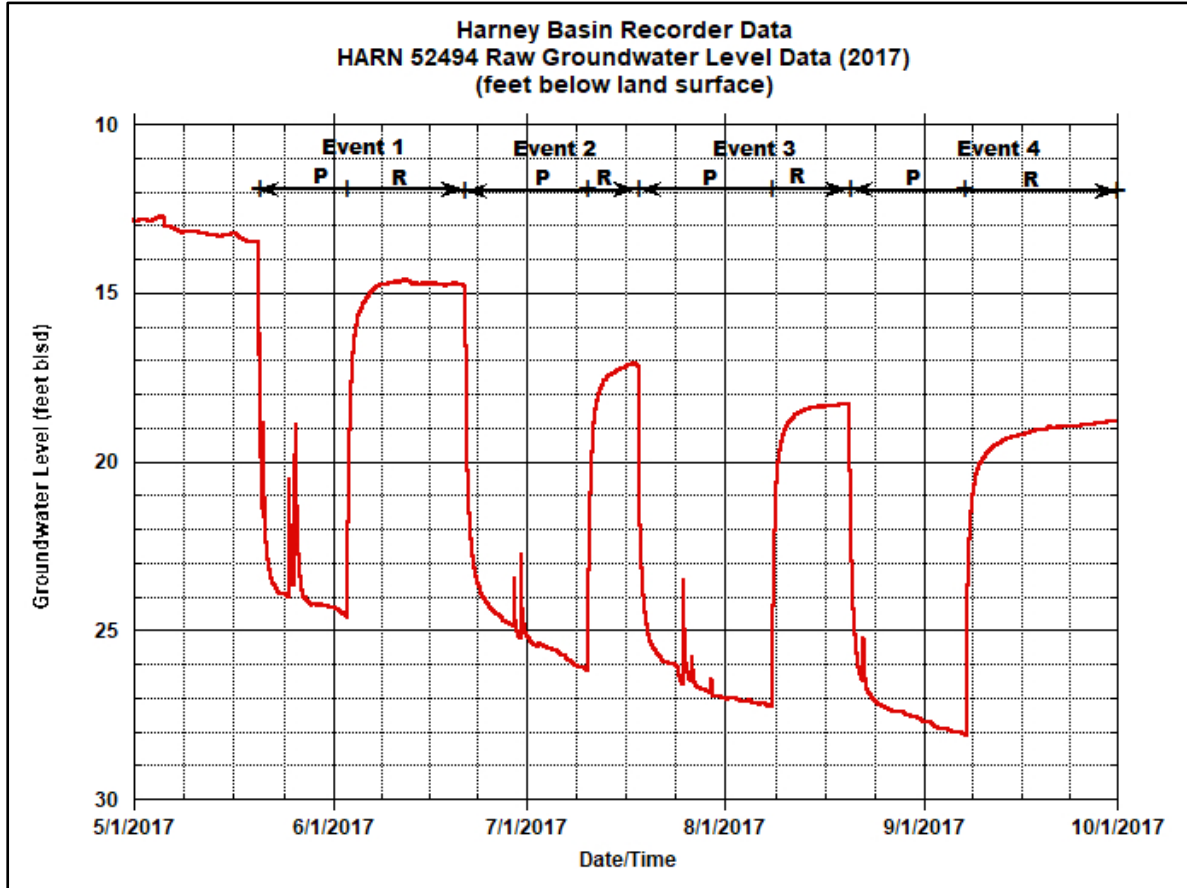
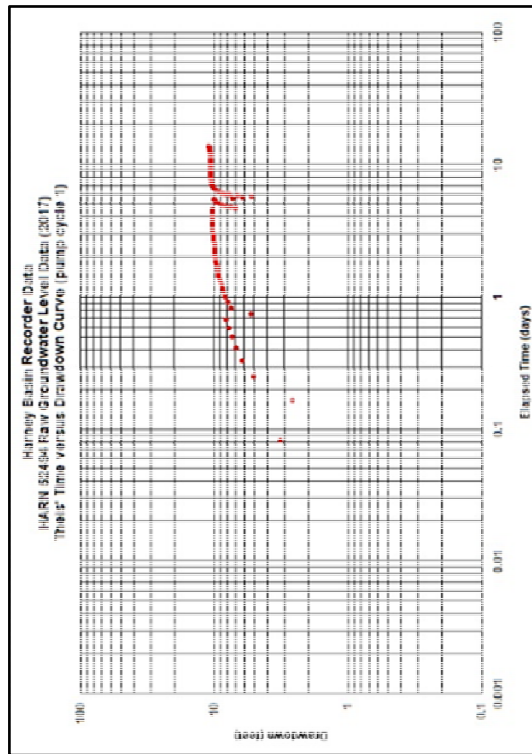


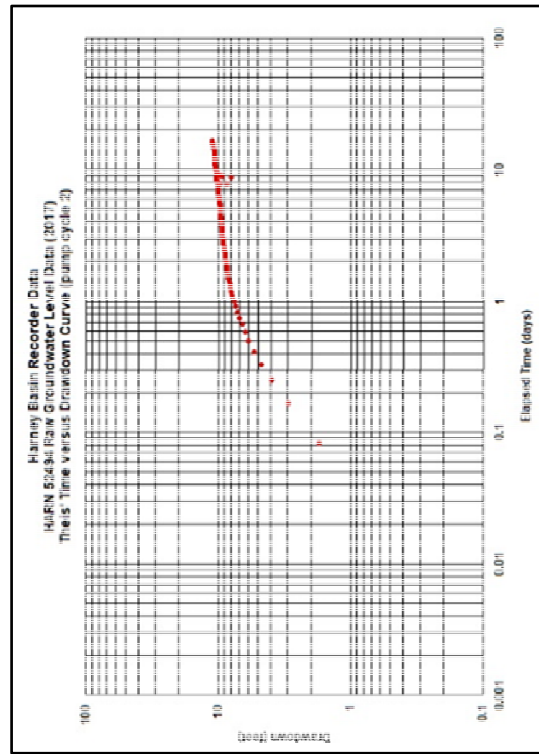
Figure F-2. Recorder data from the Northeast Harney Valley recorder observation well HARN 52494 showing water level response to pumping and shutoff at irrigation well HARN 52029

[This graph shows four primary events that include a pumping (P) drawdown phase and a shutoff recovery (R) phase as follows:

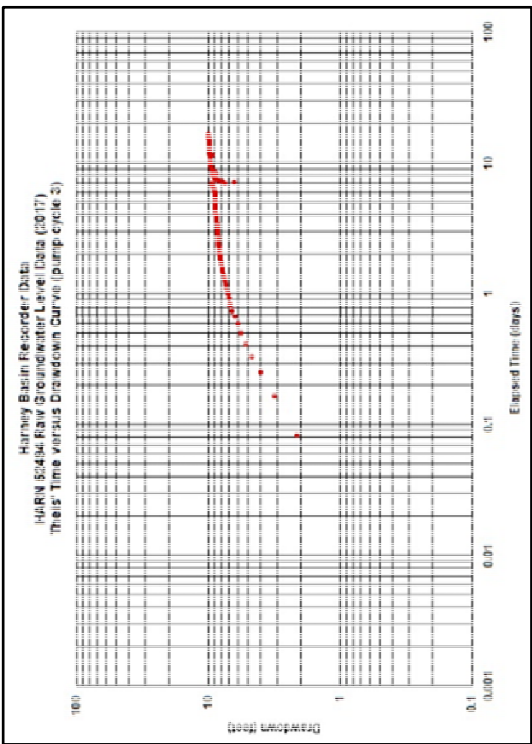
<u>Event</u>	<u>Phase</u>	<u>Start</u>	<u>End</u>
1	Pumping	05/20/2017 at 10:00	06/03/2017 at 06:00
1	Recovery	06/03/2017 at 06:00	06/21/2017 at 12:00
2	Pumping	06/21/2017 at 12:00	07/10/2017 at 14:00
2	Recovery	07/10/2017 at 14:00	07/18/2017 at 10:00
3	Pumping	07/18/2017 at 10:00	08/08/2017 at 06:00
3	Recovery	08/08/2017 at 06:00	08/20/2017 at 08:00
4	Pumping	08/20/2017 at 08:00	09/07/2017 at 10:00
4	Recovery	09/07/2017 at 10:00	10/01/2017 at 00:00]



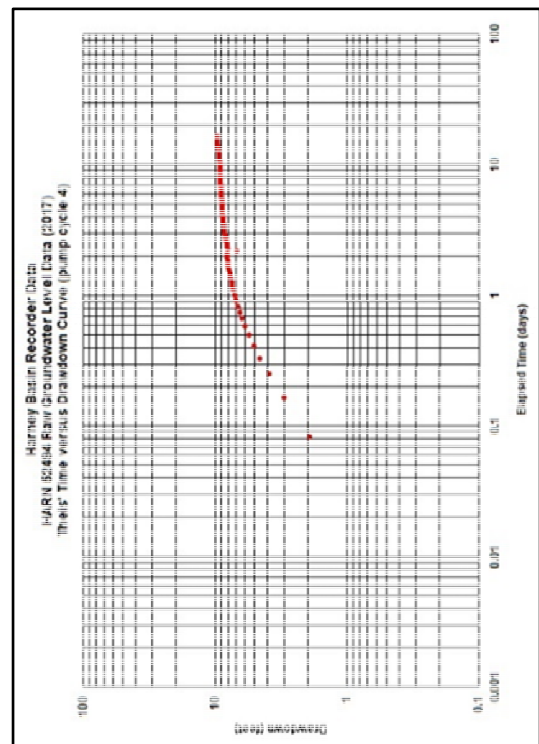
A



B



C



D

Figure F-3. Log-log elapsed time versus drawdown graphs for HARN 52494 recorder data

[Separate graph for each primary pumping and shutoff event at irrigation well HARN 52029. Graph A to D correspond to event 1 to 4 respectively.]

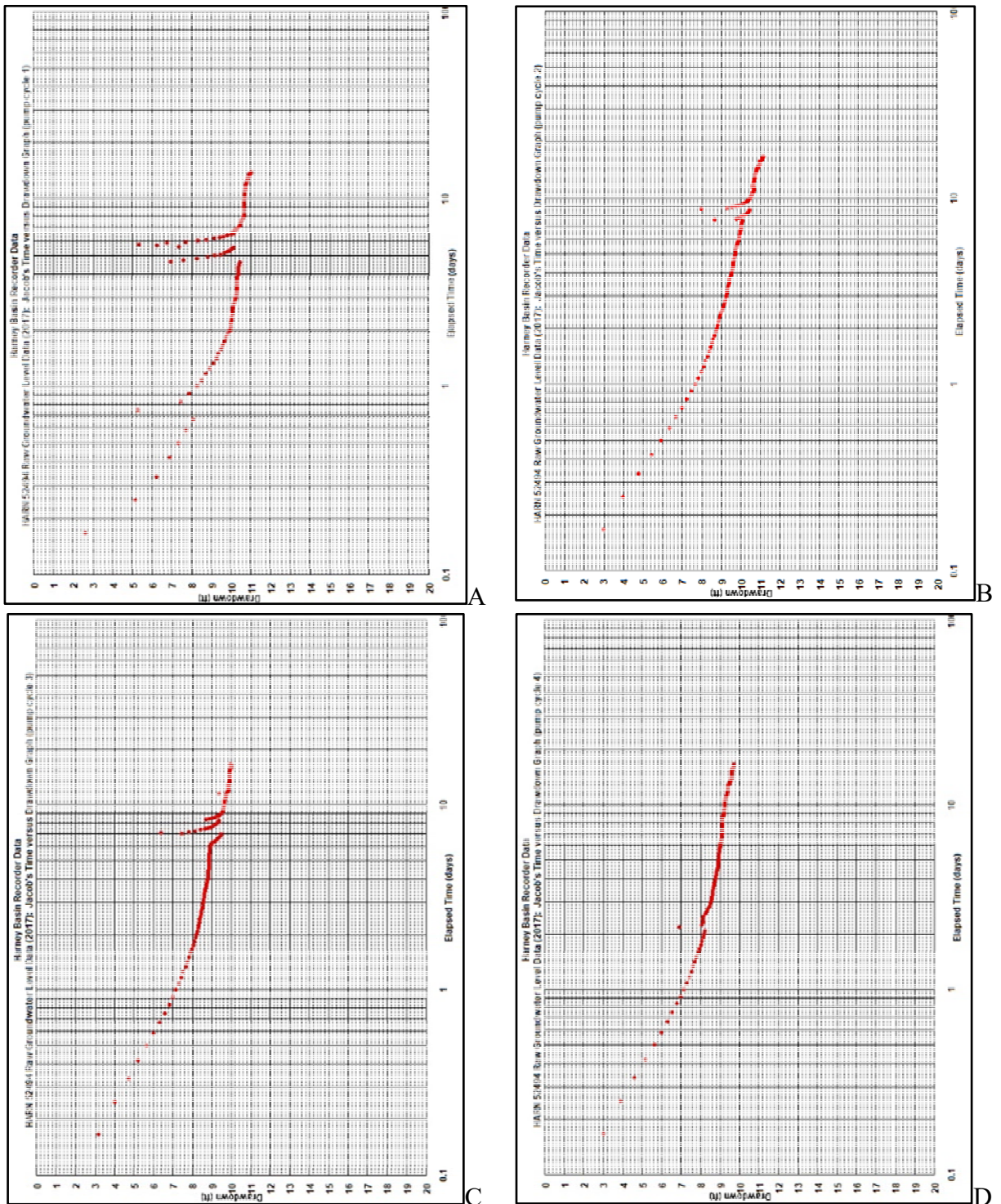


Figure F-4. Semi-log elapsed time versus drawdown graphs for HARN 52494 recorder data

[Separate graph for each primary pumping and shutoff event at irrigation well HARN 52029. Graph A to D correspond to event 1 to 4 respectively.]

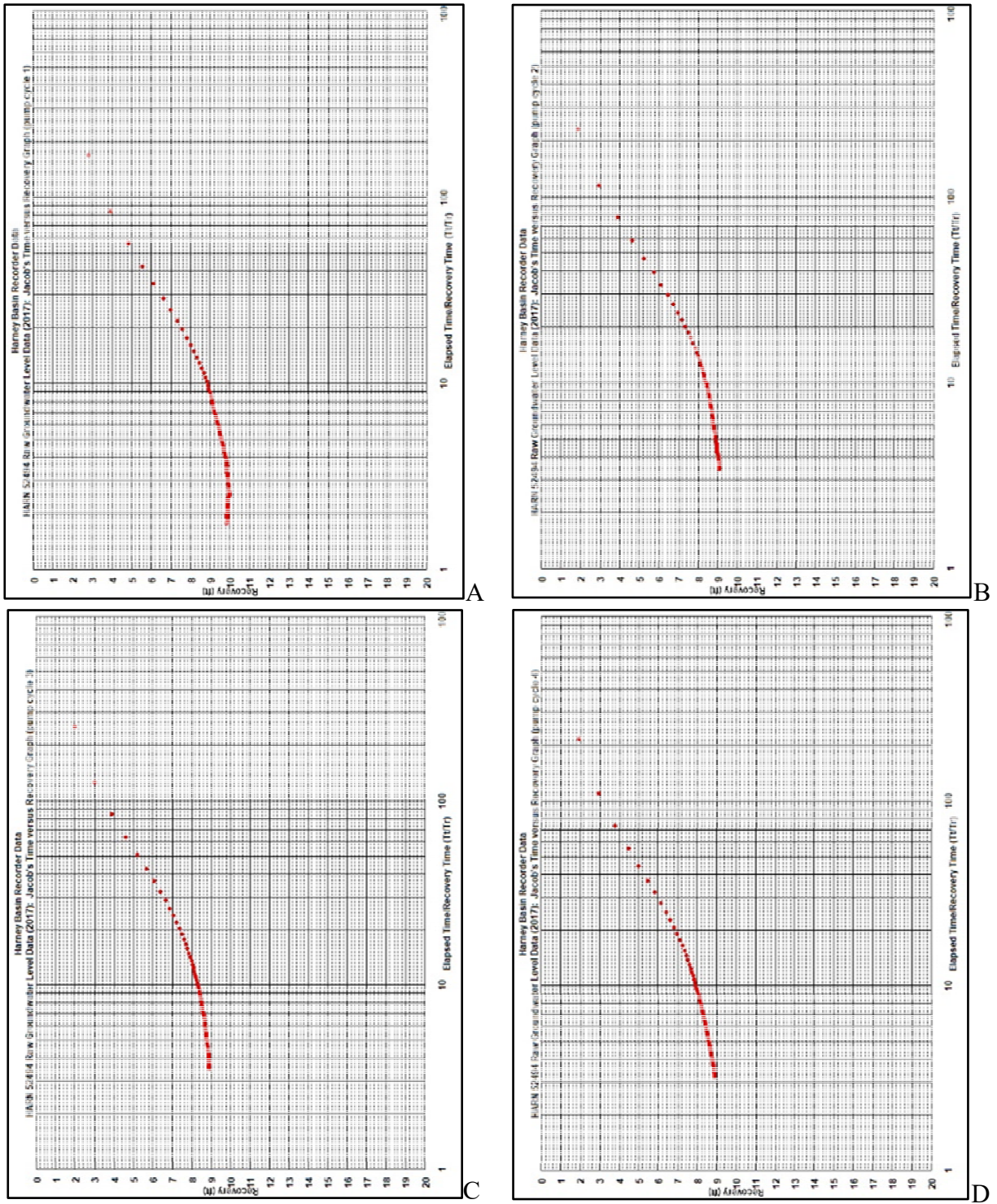


Figure F-5. Semi-log elapsed time versus recovery graphs for HARN 52494 recorder data

[Separate graph for each primary pumping and shutoff event at irrigation well HARN 52029. Graph A to D correspond to event 1 to 4 respectively.]

Table F-2. Estimated pumping rate at irrigation well HARN 52029 for HARN 52494 recorder data aquifer test analyses

Item	Unit	Month in 2017				
		May	June	July	August	September
Total days for month	day	31	30	31	31	30
Total hours for month	hour	744	720	744	744	720
Total time pump off ¹	day	19.92	18.42	11.08	12.17	23.58
Total time pump off ¹	hour	478	442	266	292	566
Total time pump on ¹	day	11.08	11.58	19.92	18.83	6.42
Total time pump on ¹	hour	266	278	478	452	154
Water volume use reported	acre-feet	51	53	49	46	9
Calculated Pumping Rate ²	acre-feet / day	4.60	4.58	2.46	2.44	1.40
	ft ³ / second	2.32	2.31	1.24	1.23	0.71
	gallons / minute	1,041	1,035	557	553	317
Item	Unit	Season in 2017 May to September				
Total days for season	day	153				
Total hours for season	hour	3,672				
Total time pump off ¹	day	85				
Total time pump off ¹	hour	2,044				
Total time pump on ¹	day	68				
Total time pump on ¹	hour	1,628				
Total volume use reported	acre-feet	208				
Season Average Pumping Rate ³	acre-feet / day	3.07				
	ft ³ / second	1.55				
	gallons / minute	694				

¹Total time pump on and off based on interpreted drawdown and recovery periods in HARN 52494 recorder water level data from May through September 2017, the same data used for figure F-2

²Calculated pumping rate = (total reported month water volume) / (total time pump on during month)

³Average pumping rate = (total reported season water volume) / (total time pump on during season)

Data Source: Oregon Water Resources Department 2019a, 2019c

The exact start times and consequently the exact elapsed times for the pumping and recovery phases for each primary pumping-shutoff event graphed are not known. The OWRD analysis assumed the start time for the pumping and recovery phases for each primary pumping-shutoff event graphed was the recorded time of the final two-hour measurement before the first drawdown or recovery measurement observed in the recorded data.

The OWRD analysis conducted two transmissivity and storage coefficient calculation sets using different pumping rates for each calculation set (tables F-3 to F-5). The first calculation set used an average pumping rate calculated for the specific months of May (1,041 gpm), June (1,035 gpm), July (557 gpm), and August (553 gpm) which were used respectively for the first, second, third, and fourth primary pumping-shutoff event. The average pumping rate for each month was determined using the total monthly volume discharged reported by the owner to OWRD divided by the total time of actual pumping per month interpreted from the recorder data and figure F-2. The second calculation set used a constant average pumping rate of 700 gpm based upon the average pumping rate for the entire May to September 2017 season (table F-2) and repeated instantaneous meter readings by OWRD staff during periodic field visits indicating a nearly unchanging instantaneous pumping rate of 700 gpm.

Table F-3. Log-log time versus drawdown graphical method calculations for transmissivity and storage coefficient using Northeast Harney Valley recorder data from 2017

Item	Symbol	Unit	Primary 2017 Pumping and Shutoff Events			
			1	2	3	4
Theis curve match points						
Well function of u	W(u)	dimensionless	0.30	0.07	8.00	0.04
Inverse of u	1/u	dimensionless	8,000.00	0.10	0.10	0.30
Drawdown	s	feet	0.70	0.20	20.00	0.10
Time	t	days	100.0000	0.0040	0.0030	0.0100
Pumping Well						
Distance to pumping well ¹	r	feet	86	86	86	86
Pumping average (owner) ²	Q ₁	gallons / minute	1,041	1,035	557	553
	Q ₁	feet ³ / day	200,393	199,238	107,223	106,453
Pumping average (OWRD) ³	Q ₂	gallons / minute	700	700	700	700
	Q ₂	feet ³ / day	134,750	134,750	134,750	134,750
Calculations						
Transmissivity (using Q ₁)	T ₁	feet ² / day	6,834.31	5,549.19	3,413.00	3,388.49
Transmissivity (using Q ₂)	T ₂	feet ² / day	4,595.60	3,753.07	4,289.23	4,289.23
Storage Coefficient (using T ₁)	S ₁	dimensionless	0.046203	0.120047	0.055376	0.061087
Storage Coefficient (using T ₂)	S ₂	dimensionless	0.031068	0.081191	0.069593	0.077325

Note: $T = [Q * W(u)] / [4 * \pi * s]$ (appendix C, equation C-2)

Note: $S = [4 * t * T * u] / [r^2]$ (appendix C, equation C-3)

Note: Theis curve match points are not shown in corresponding figure F-3

¹Pumping well is HARN 52029 and observation well is HARN 52494

²Pumping average based upon owner reported volume discharged May, June, July, August 2017 (table F-2)

³Pumping average based upon OWRD reading of consistent 700 gpm instantaneous discharge at flow meter

Data Source: Oregon Water Resources Department 2019a, 2019c

Table F-4. Semi-log time versus drawdown graphical method calculations for transmissivity and storage coefficient using Northeast Harney Valley recorder data from 2017

Early Time Data

Item	Symbol	Unit	Primary 2017 Pumping and Shutoff Events			
			1	2	3	4
Semi-log Graph Values						
Line through early time data ¹						
Start of a log ₁₀ segment	t'	days	0.10	0.10	0.10	0.10
End of a log ₁₀ segment	t''	days	1.00	1.00	1.00	1.00
Zero drawdown intercept	t'''	days	0.020000	0.055000	0.041000	0.050000
Drawdown over log ₁₀ segment	s	feet	5.20	6.20	5.20	5.50
Pumping Well						
Distance to pumping well ²	r	feet	86	86	86	86
Pumping average (owner) ³	Q ₁	gallons / minute	1,041	1,035	557	553
	Q ₁	feet ³ / day	200,393	199,238	107,223	106,453
Pumping average (OWRD) ⁴	Q ₂	gallons / minute	700	700	700	700
	Q ₂	feet ³ / day	134,750	134,750	134,750	134,750
Calculations						
Transmissivity (using Q ₁)	T ₁	feet ² / day	7,062.56	5,889.30	3,778.91	3,547.13
Transmissivity (using Q ₂)	T ₂	feet ² / day	4,749.08	3,983.10	4,749.08	4,490.04
Storage Coefficient (using T ₁)	S ₁	dimensionless	0.042971	0.098540	0.047134	0.053955
Storage Coefficient (using T ₂)	S ₂	dimensionless	0.028895	0.066645	0.059235	0.068298
u at t = t'	u'	dimensionless	0.112500	0.309375	0.230625	0.281250
u at t = t''	u''	dimensionless	0.011250	0.030938	0.023063	0.028125

Note: For equations below, see discussion in appendix C for equations C-2 to C-6

Note: $T = [(2.303 * Q) / (4 * \pi * s)] * [\log_{10} (t''/t')]$

Note: $S = [2.25 * T * t'''] / [r^2]$

Note: $u = [r^2 * S] / [4 * T * t]$

Note: u should be ≤ 0.01 for valid Jacob time versus drawdown semi-log graphical method use (Lohman, 1972a)

Note: using T₁ with S₁ and T₂ with S₂ yields the same u value

¹Lines through early, middle, and late time data are not shown in corresponding figure F-4

²Pumping well is HARN 52029 and observation well is HARN 52494

³Pumping average based upon owner reported volume discharged May, June, July, August 2017 (table F-2)

⁴Pumping average based upon OWRD reading of consistent 700 gpm instantaneous discharge at flow meter

Data Source: Oregon Water Resources Department 2019a, 2019c

Table F-4. (continued)

Middle Time Data

Item	Symbol	Unit	Primary 2017 Pumping and Shutoff Events			
			1	2	3	4
Semi-log Graph Values						
Line through middle time data ¹						
Start of a log ₁₀ segment	t'	days	1.00	1.00	1.00	1.00
End of a log ₁₀ segment	t''	days	10.00	10.00	10.00	10.00
Zero drawdown intercept	t'''	days	0.000030	0.003400	0.005500	0.004600
Drawdown over log ₁₀ segment	s	feet	2.05	3.20	3.20	3.10
Pumping Well						
Distance to pumping well ²	r	feet	86	86	86	86
Pumping average (owner) ³	Q ₁	gallons / minute	1,041	1,035	557	553
	Q ₁	feet ³ / day	200,393	199,238	107,223	106,453
Pumping average (OWRD) ⁴	Q ₂	gallons / minute	700	700	700	700
	Q ₂	feet ³ / day	134,750	134,750	134,750	134,750
Calculations						
Transmissivity (using Q ₁)	T ₁	feet ² / day	17,914.79	11,410.52	6,140.73	6,293.30
Transmissivity (using Q ₂)	T ₂	feet ² / day	12,046.45	7,717.26	7,717.26	7,966.20
Storage Coefficient (using T ₁)	S ₁	dimensionless	0.000164	0.011802	0.010275	0.008807
Storage Coefficient (using T ₂)	S ₂	dimensionless	0.000110	0.007982	0.012913	0.011148
u at t = t'	u'	dimensionless	0.000017	0.001913	0.003094	0.002588
u at t = t''	u''	dimensionless	0.000002	0.000191	0.000309	0.000259

Note: For equations below, see discussion in appendix C for equations C-2 to C-6

Note: $T = [(2.303 * Q) / (4 * \pi * s)] * [\log_{10} (t''/t')]$

Note: $S = [2.25 * T * t'''] / [r^2]$

Note: $u = [r^2 * S] / [4 * T * t]$

Note: u should be ≤ 0.01 for valid Jacob time versus drawdown semi-log graphical method use (Lohman, 1972a)

Note: using T₁ with S₁ and T₂ with S₂ yields the same u value

¹Lines through early, middle, and late time data are not shown in corresponding figure F-4

²Pumping well is HARN 52029 and observation well is HARN 52494

³Pumping average based upon owner reported volume discharged May, June, July, August 2017 (table F-2)

⁴Pumping average based upon OWRD reading of consistent 700 gpm instantaneous discharge at flow meter

Data Source: Oregon Water Resources Department 2019a, 2019c

Table F-4. (continued)

Late Time Data

Item	Symbol	Unit	Primary 2017 Pumping and Shutoff Events			
			1	2	3	4
Semi-log Graph Values						
Line through late time data ¹						
Start of a log ₁₀ segment	t'	days	no line	1.00	1.00	1.00
End of a log ₁₀ segment	t''	days	no line	10.00	10.00	10.00
Zero drawdown intercept	t'''	days	no line	0.000200	0.000100	0.000014
Drawdown over log ₁₀ segment	s	feet	no line	2.20	1.90	1.60
Pumping Well						
Distance to pumping well ²	r	feet	86	86	86	86
Pumping average (owner) ³	Q ₁	gallons / minute	1,041	1,035	557	553
	Q ₁	feet ³ / day	200,393	199,238	107,223	106,453
Pumping average (OWRD) ⁴	Q ₂	gallons / minute	700	700	700	700
	Q ₂	feet ³ / day	134,750	134,750	134,750	134,750
Calculations						
Transmissivity (using Q ₁)	T ₁	feet ² / day	----	16,597.12	10,342.29	12,193.27
Transmissivity (using Q ₂)	T ₂	feet ² / day	----	11,225.10	12,997.49	15,434.52
Storage Coefficient (using T ₁)	S ₁	dimensionless	----	0.001010	0.000315	0.000052
Storage Coefficient (using T ₂)	S ₂	dimensionless	----	0.000683	0.000395	0.000066
u at t = t'	u'	dimensionless	----	0.000113	0.000056	0.000008
u at t = t''	u''	dimensionless	----	0.000011	0.000006	0.000001

Note: For equations below, see discussion in appendix C for equations C-2 to C-6

Note: $T = [(2.303 * Q) / (4 * \pi * s)] * [\log_{10} (t''/t')]$

Note: $S = [2.25 * T * t'''] / [r^2]$

Note: $u = [r^2 * S] / [4 * T * t]$

Note: u should be ≤ 0.01 for valid Jacob time versus drawdown semi-log graphical method use (Lohman, 1972a)

Note: using T₁ with S₁ and T₂ with S₂ yields the same u value

¹Lines through early, middle, and late time data are not shown in corresponding figure F-4

²Pumping well is HARN 52029 and observation well is HARN 52494

³Pumping average based upon owner reported volume discharged May, June, July, August 2017 (table F-2)

⁴Pumping average based upon OWRD reading of consistent 700 gpm instantaneous discharge at flow meter

Data Source: Oregon Water Resources Department 2019a, 2019c

Table F-5. Semi-log time versus recovery graphical method calculations for transmissivity and storage coefficient using Northeast Harney Valley recorder data from 2017

Early Time Data

Item	Symbol	Unit	Primary 2017 Pumping and Shutoff Events			
			1	2	3	4
Semi-log Graph Values						
Line through early time data ¹						
Recovery line segment start	t _i '/t _r '	dimensionless	100.00	10.00	10.00	10.00
Recovery line segment stop	t _i "/t _r "	dimensionless	1,000.00	100.00	100.00	100.00
Line segment recovery	s'	feet	5.80	6.00	5.80	5.70
Pumping Phase Data						
Total pump period time	t	days	13.83	19.08	20.83	18.08
Total pump period drawdown	s	feet	11.03	11.38	10.14	9.80
Pumping Well						
Distance to pumping well ²	r	feet	86	86	86	86
Pumping average (owner) ³	Q ₁	gallons / minute	1,041	1,035	557	553
	Q ₁	feet ³ / day	200,393	199,238	107,223	106,453
Pumping average (OWRD) ⁴	Q ₂	gallons / minute	700	700	700	700
	Q ₂	feet ³ / day	134,750	134,750	134,750	134,750
Calculations						
Transmissivity (using Q ₁)	T ₁	feet ² / day	6,331.95	6,085.61	3,387.99	3,422.67
Transmissivity (using Q ₂)	T ₂	feet ² / day	4,257.80	4,115.87	4,257.80	4,332.50
Storage Coefficient (using T ₁)	S ₁	dimensionless	0.334137	0.448206	0.383363	0.359361
Storage Coefficient (using T ₂)	S ₂	dimensionless	0.224684	0.303134	0.481785	0.454888

Note: For equations below, see discussion in appendix C for equations C-7 to C-10

Note: $T = [(2.303 * Q) / (4 * \pi * s')] * \log_{10}[(t_i''/t_r'') * (1/(t_i'/t_r'))]$

Note: $S = [(2.25 * T * t) / (r^2)] * [1/(\text{antilog}((4 * \pi * T * s) / (2.303 Q)))]$

Note: t_i = total elapsed time since pumping started

Note: t_r = total elapsed recovery time = total elapsed time since pumping stopped

Note: s' = recovery ("residual drawdown") over recovery interval considered

Note: s = drawdown at the end of the pumping period

¹Lines through early, middle, and late time data are not shown in corresponding figure F-5

²Pumping well is HARN 52029 and observation well is HARN 52494

³Pumping average based upon owner reported volume discharged May, June, July, August 2017 (table F-2)

⁴Pumping average based upon OWRD reading of consistent 700 gpm instantaneous discharge at flow meter

Data Source: Oregon Water Resources Department 2019a, 2019c

Table F-5. (continued)

Middle Time Data

Item	Symbol	Unit	Primary 2017 Pumping and Shutoff Events			
			1	2	3	4
Semi-log Graph Values						
Line through middle time data ¹						
Recovery line segment start	t _i '/t _r '	dimensionless	10.00	10.00	10.00	10.00
Recovery line segment stop	t _i "/t _r "	dimensionless	100.00	100.00	100.00	100.00
Line segment recovery	s'	feet	2.45	3.20	3.55	3.80
Pumping Phase Data						
Total pump period time	t	days	13.83	19.08	20.83	18.08
Total pump period drawdown	s	feet	11.03	11.38	10.14	9.80
Pumping Well						
Distance to pumping well ²	r	feet	86	86	86	86
Pumping average (owner) ³	Q ₁	gallons / minute	1,041	1,035	557	553
	Q ₁	feet ³ / day	200,393	199,238	107,223	106,453
Pumping average (OWRD) ⁴	Q ₂	gallons / minute	700	700	700	700
	Q ₂	feet ³ / day	134,750	134,750	134,750	134,750
Calculations						
Transmissivity (using Q ₁)	T ₁	feet ² / day	14,989.93	11,410.52	5,535.31	5,134.01
Transmissivity (using Q ₂)	T ₂	feet ² / day	10,079.68	7,717.26	6,956.40	6,498.74
Storage Coefficient (using T ₁)	S ₁	dimensionless	0.001986	0.018403	0.048837	0.074469
Storage Coefficient (using T ₂)	S ₂	dimensionless	0.001335	0.012447	0.061375	0.094264

Note: For equations below, see discussion in appendix C for equations C-7 to C-10

Note: $T = [(2.303 * Q) / (4 * \pi * s')] * \log_{10}[(t''/t_r) * (1/(t'_i/t'_r))]$

Note: $S = [(2.25 * T * t) / (r^2)] * [1/(\text{antilog}((4 * \pi * T * s) / (2.303 Q)))]$

Note: t_i = total elapsed time since pumping started

Note: t_r = total elapsed recovery time = total elapsed time since pumping stopped

Note: s' = recovery ("residual drawdown") over recovery interval considered

Note: s = drawdown at the end of the pumping period

¹Lines through early, middle, and late time data are not shown in corresponding figure F-5

²Pumping well is HARN 52029 and observation well is HARN 52494

³Pumping average based upon owner reported volume discharged May, June, July, August 2017 (table F-2)

⁴Pumping average based upon OWRD reading of consistent 700 gpm instantaneous discharge at flow meter

Data Source: Oregon Water Resources Department 2019a, 2019c

Table F-5. (continued)

Late Time Data

Item	Symbol	Unit	Primary 2017 Pumping and Shutoff Events			
			1	2	3	4
Semi-log Graph Values						
Line through late time data ¹						
Recovery line segment start	t _i '/t _r '	dimensionless	no line	1.00	1.00	1.00
Recovery line segment stop	t _i ''/t _r ''	dimensionless	no line	10.00	10.00	10.00
Line segment recovery	s'	feet	no line	1.40	1.40	2.00
Pumping Phase Data						
Total pump period time	t	days	13.83	19.08	20.83	18.08
Total pump period drawdown	s	feet	11.03	11.38	10.14	9.80
Pumping Well						
Distance to pumping well ²	r	feet	86	86	86	86
Pumping average (owner) ³	Q ₁	gallons / minute	1,041	1,035	557	553
	Q ₁	feet ³ / day	200,393	199,238	107,223	106,453
Pumping average (OWRD) ⁴	Q ₂	gallons / minute	700	700	700	700
	Q ₂	feet ³ / day	134,750	134,750	134,750	134,750
Calculations						
Transmissivity (using Q ₁)	T ₁	feet ² / day	-----	26,081.18	14,035.96	9,754.61
Transmissivity (using Q ₂)	T ₂	feet ² / day	-----	17,639.45	17,639.45	12,347.61
Storage Coefficient (using T ₁)	S ₁	dimensionless	-----	0.000001	0.000005	0.000676
Storage Coefficient (using T ₂)	S ₂	dimensionless	-----	0.000001	0.000006	0.000855

Note: For equations below, see discussion in appendix C for equations C-7 to C-10

Note: $T = [(2.303 * Q) / (4 * \pi * s')] * \log_{10}[(t_t''/t_r'') * (1/(t_t'/t_r'))]$

Note: $S = [(2.25 * T * t) / (r^2)] * [1/(\text{antilog}((4 * \pi * T * s) / (2.303 Q)))]$

Note: t_t = total elapsed time since pumping started

Note: t_r = total elapsed recovery time = total elapsed time since pumping stopped

Note: s' = recovery ("residual drawdown") over recovery interval considered

Note: s = drawdown at the end of the pumping period

¹Lines through early, middle, and late time data are not shown in corresponding figure F-5

²Pumping well is HARN 52029 and observation well is HARN 52494

³Pumping average based upon owner reported volume discharged May, June, July, August 2017 (table F-2)

⁴Pumping average based upon OWRD reading of consistent 700 gpm instantaneous discharge at flow meter

Data Source: Oregon Water Resources Department 2019a, 2019c

Analysis using the log-log time versus drawdown graphical method curve matched the early time drawdown data only. The transmissivity values determined for the four primary pumping and shutoff events using the individual monthly pumping rates and the seasonal average pumping rate ranged from 3,388 to 6,844 feet²/day (table F-3). The corresponding storage coefficient values ranged from 0.0311 to 0.1200 (table F-3) indicating unconfined groundwater conditions.

Analysis using the semi-log time versus drawdown graphical method determined the graphed drawdown data for each primary pumping and shutoff event (figure F-4) can be subdivided by change in slope (see “drawdown over log₁₀ segment” values in table F-4) into two to three approximate straight-line segments identified as early time data, middle time data, and late time data in table F-4. The transmissivity values determined for the four primary pumping and shutoff events using the individual monthly pumping rates and the seasonal average pumping rate ranged from 3,779 to 7,063 feet²/day for the early time data, from 6,140 to 17,915 feet²/day for the middle time data, and from 10,342 to 16,597 feet²/day for the late time data (table F-4). The corresponding storage coefficient values in table F-4 ranged from 0.0289 to 0.0985 for the early time data indicating unconfined groundwater conditions, from 0.0001 to 0.0129 for the middle time data indicating confined to unconfined groundwater conditions, and from 0.0001 to 0.0010 for the late time data indicating confined to intermediate groundwater conditions. The early time data derived transmissivity and storage coefficient values are assumed to be least affected by unaccounted influences and best represent the local subsurface hydraulic properties. However, values derived from the early time data must be used warily, with caution given the u values exceed 0.01 (table F-4). The values derived from the middle and late time data are likely affected by one or more unidentified influences given the data correspond to a change in drawdown slope.

Analysis using the semi-log time versus recovery graphical method determined the graphed recovery data for each primary pumping and shutoff event can also be subdivided into two to three straight line segments identified as early time data, middle time data, and late time data (table F-5). The transmissivity values determined for the four primary pumping and shutoff events using the individual monthly pumping rates and the seasonal average pumping rate ranged from 3,388 to 6,332 feet²/day for the early time data, from 5,134 to 14,990 feet²/day for the middle time data, and from 9,755 to 26,081 feet²/day for the late time data (table F-5). The corresponding storage coefficient values (table F-5) ranged from 0.2247 to 0.4818 for the early time data indicating

unconfined groundwater conditions, from 0.0013 to 0.0943 for the middle time data indicating intermediate to unconfined groundwater conditions, and from 0.0001 to 0.0009 for the late time data indicating confined to nearly intermediate groundwater conditions. The early time data transmissivity and storage coefficient values from this specific analysis are assumed to be least affected by unaccounted influences and best represent the local subsurface hydraulic properties. The values derived from the middle and late time data are likely affected by one or more unidentified influences given the data correspond to a change in recovery slope.

The analysis lastly tested the transmissivity and storage coefficient values derived by the graphical analyses by using the value range to constrain an effort to recreate the May to September 2017 recorder data via a Theis equation (appendix C, equation C-2 and C-3) based method. The method assigns each successive pumping and recovery phase observed with an imaginary pumping well or recharge well. All the imaginary wells are at the same location represented by its own Theis equation. Each imaginary well successively begins discharging or recharging at the corresponding observed drawdown or recovery start times (figure F-2, table F-6) and continues discharging or recharging to the end of the test period. The calculated water level change at the observation well from the original water level is the difference between the sum of the calculated drawdowns at the observation well caused by each discharging imaginary well and the sum of the calculated recovery at the observation well caused by each recharging imaginary well. All the calculations used the 700 gpm season average pumping rate (700 gpm for discharge and -700 gpm for recharge). Iterative calculations were conducted using varying values of transmissivity and storage coefficient. After each calculation, the results were graphed and compared to figure F-2. The transmissivity and storage coefficient values yielding the closest match were 6,000 feet²/day and 0.0500 respectively (figure F-6).

Figure F-6 shows an increasing difference between the observed and calculated groundwater level from no difference in May to greatest difference in September. The increasing lowering of the observed level below the calculated level with time is likely primarily due to the increasing influence of unaccounted pumping wells causing additional drawdown with time at the observation well. Unaccounted additional drawdown with time occurring during each successive drawdown and recovery event can cause increasing bias (discrepancy from actual values) in the transmissivity and storage coefficient values calculated from each event. The bias is likely least for the first event calculations.

Table F-6. Imaginary wells used for Theis equation calculations to recreate May through September 2017 Northeast Harney Valley recorder hydrograph

Imaginary Well	Imaginary Well Start Date & Time (mm/dd/yyyy hh:mm:ss)	Time After Test Start (days)	Time Before Test Ends (days)	Pumping Rate (gal / min)	Comment
Pumping 1	05/20/2017 10:00:00	0.00	133.58	700	Test period starts
Recovery 1	06/03/2017 06:00:00	13.83	119.75	-700	
Pumping 2	06/21/2017 12:00:00	32.08	101.50	700	
Recovery 2	07/10/2017 14:00:00	51.17	82.42	-700	
Pumping 3	07/18/2017 10:00:00	59.00	74.58	700	
Recovery 3	08/08/2017 06:00:00	79.83	53.75	-700	
Pumping 4	08/20/2017 08:00:00	91.92	41.67	700	
Recovery 4	09/07/2017 10:00:00	110.00	23.58	-700	
	10/01/2017 00:00:00	133.58	0.00		Test period ends

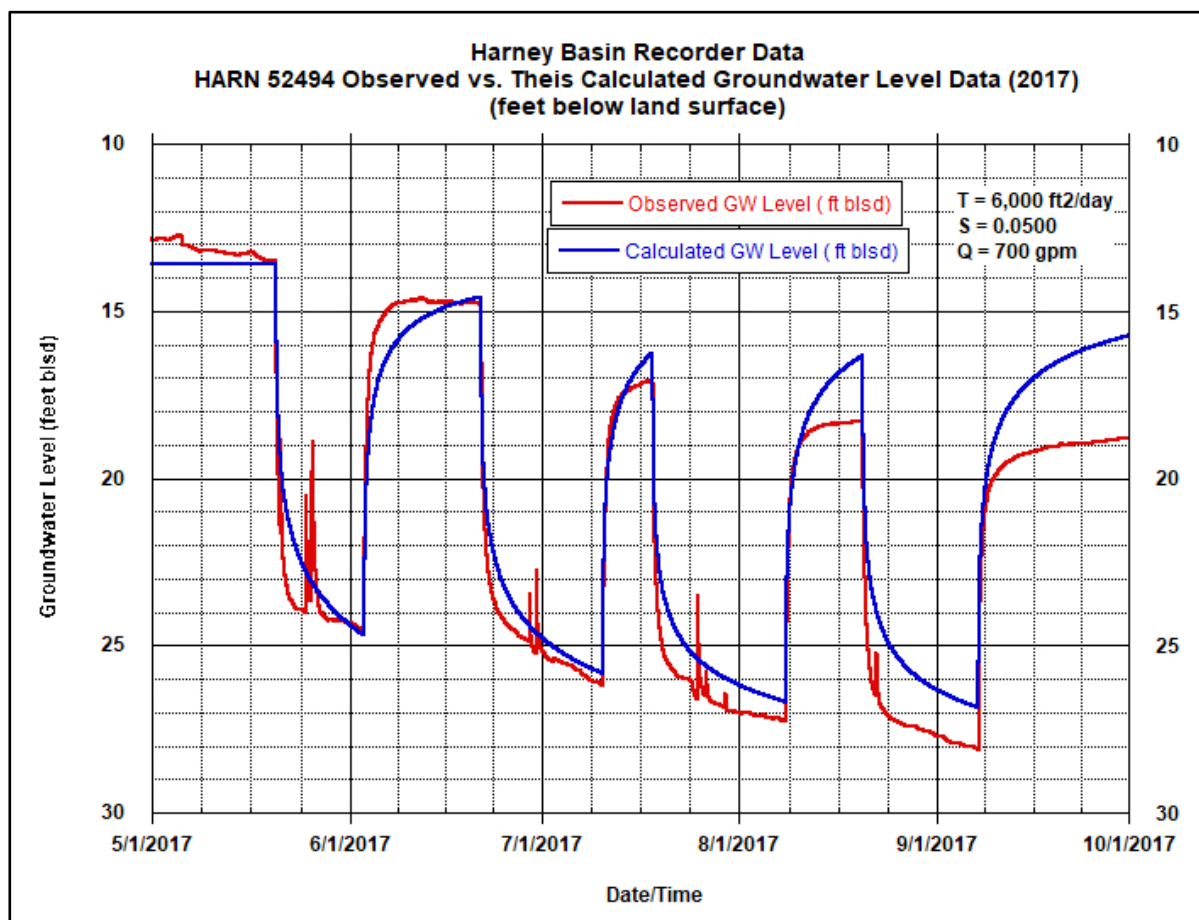


Figure F-6. Calculated and recorded water level response at the Northeast Harney Valley recorder observation well HARN 52494 due to pumping and shutoff at irrigation well HARN 52029

Analysis of Recorder Data from Northwest of Harney Lake

OWRD staff analyzed the May through October 2018 recorder data from the recorder observation well HARN 52534 northwest of Harney Lake. The data shows four primary pumping and shutoff events with occasional brief shutoff interruptions during the primary pumping periods (figure F-7). Each primary pumping-shutoff event was analyzed as an independent aquifer test to determine transmissivity and storage coefficient using the log-log curve matching, the semi-log drawdown, and semi-log recovery graphical methods as described and illustrated in appendix C and E. The log-log graphical method was used to analyze the pumping phase drawdown data only. The semi-log graphical method was used to analyze both the pumping phase drawdown data and the shutoff phase recovery data. The log-log time versus drawdown graphs and the semi-log time versus drawdown and recovery graphs used for the analyses are shown in figures F-8 to F-10 respectively. Calculated average pumping rates and transmissivity and storage coefficient calculations related to each graph are shown in tables F-7 to F-10.

The exact start times and consequently the exact elapsed times for the pumping and recovery phases for each primary pumping-shutoff event graphed are not known. The analysis assumed the start time for the pumping and recovery phases for each primary pumping-shutoff event graphed was the recorded time of the final two-hour measurement before the first drawdown or recovery measurement observed in the recorded data.

The OWRD analysis conducted two transmissivity and storage coefficient calculation sets using different pumping rates for each calculation set (tables F-8 to F-10). The first calculation set used a constant average pumping rate of 827 gpm based upon the owner reported groundwater pumped for the entire May to October 2018 season (table F-7). The second calculation set used a constant average pumping rate of 917 gpm based upon the owner reported groundwater pumped for the June to August 2018 period that yielded somewhat similar calculated pumping rates for each month (table F-7). No OWRD field confirmation of the discharge rate at the pumping well flow meter occurred. The unconfirmed pumping rate in addition to multiple pumping interruptions and other influences apparent in figures F-8 to F-10 increases the uncertainty range of the transmissivity and storage coefficient values determined by the graphical methods used.

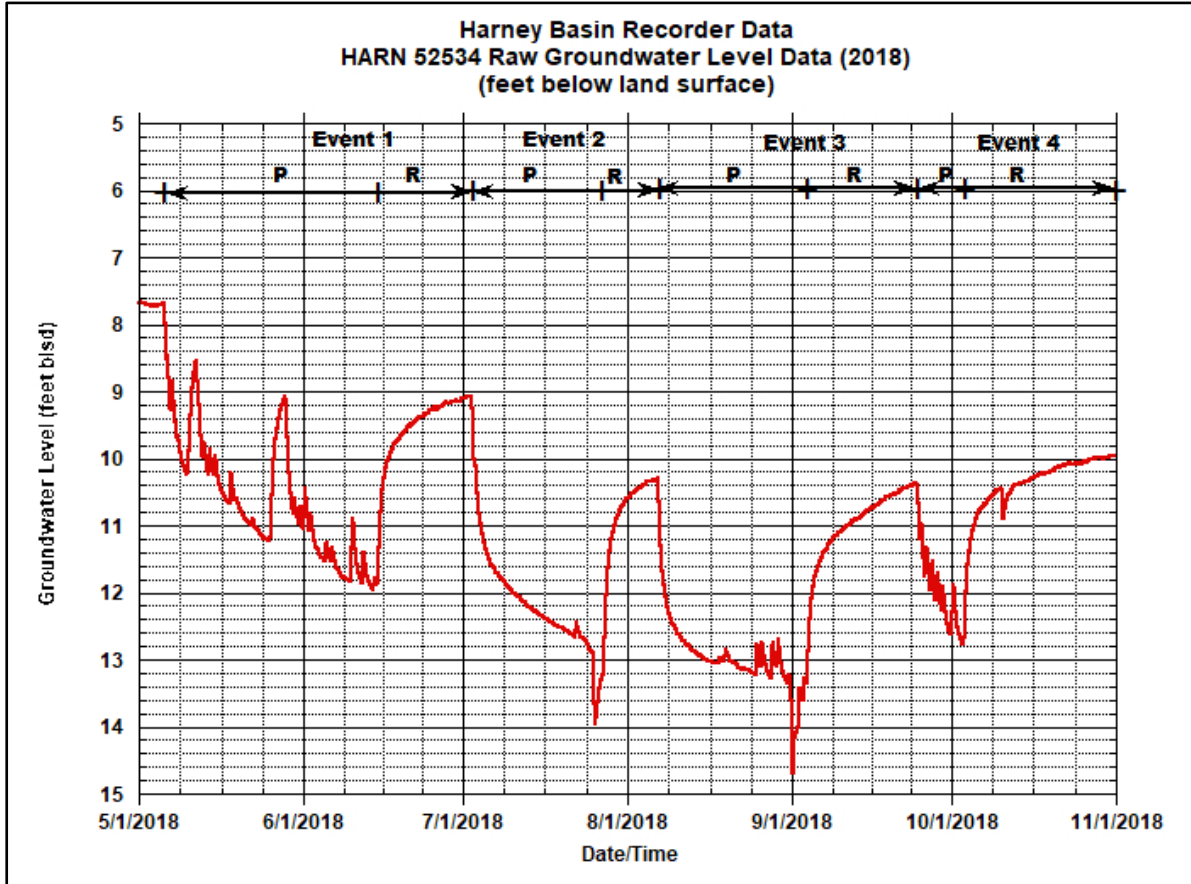
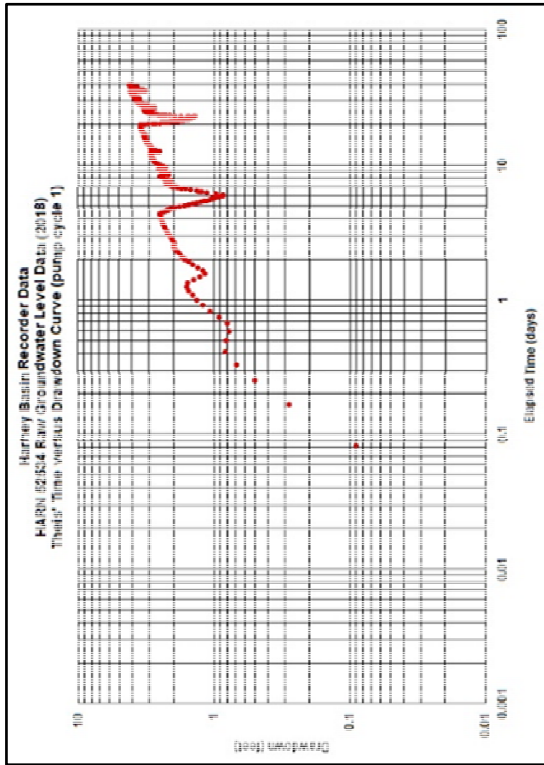


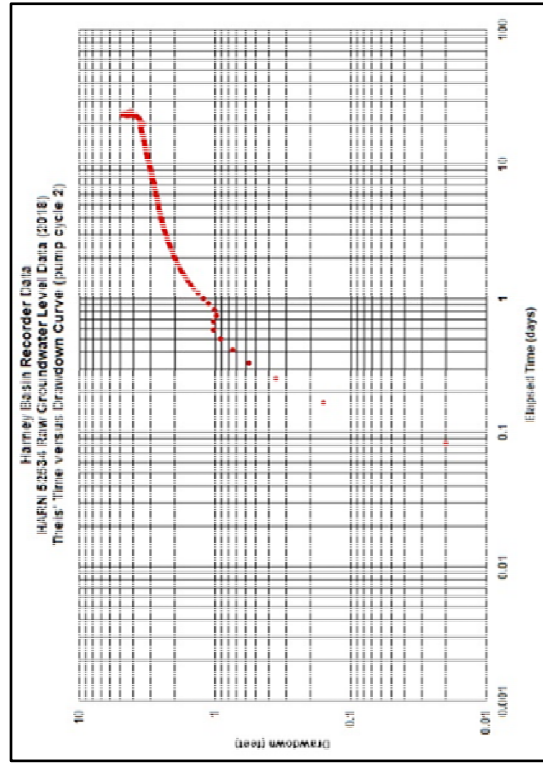
Figure F-7. Recorder data from the recorder observation well HARN 52534 northwest of Harney Lake showing water level response to pumping and shutoff at irrigation well HARN 1084

[This graph shows four primary events that include a pumping (P) drawdown phase and a shutoff recovery (R) phase as follows:

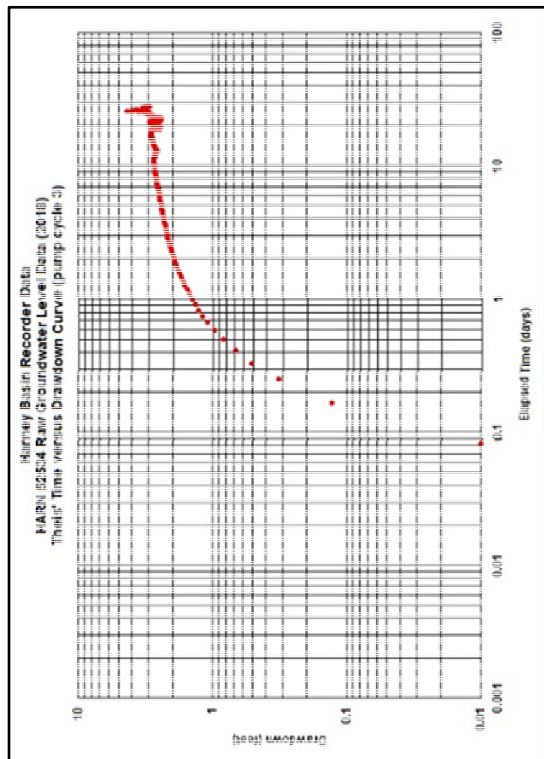
<u>Event</u>	<u>Phase</u>	<u>Start</u>	<u>End</u>
1	Pumping	05/05/2018 at 17:00	06/14/2018 at 19:00
1	Recovery	06/14/2018 at 19:00	07/02/2018 at 13:00
2	Pumping	07/02/2018 at 13:00	07/27/2018 at 07:00
2	Recovery	07/27/2018 at 07:00	08/06/2018 at 17:00
3	Pumping	08/06/2018 at 17:00	09/03/2018 at 15:00
3	Recovery	09/03/2018 at 15:00	09/24/2018 at 13:00
4	Pumping	09/24/2018 at 13:00	10/03/2018 at 07:00
4	Recovery	10/03/2018 at 07:00	11/01/2018 at 00:00]



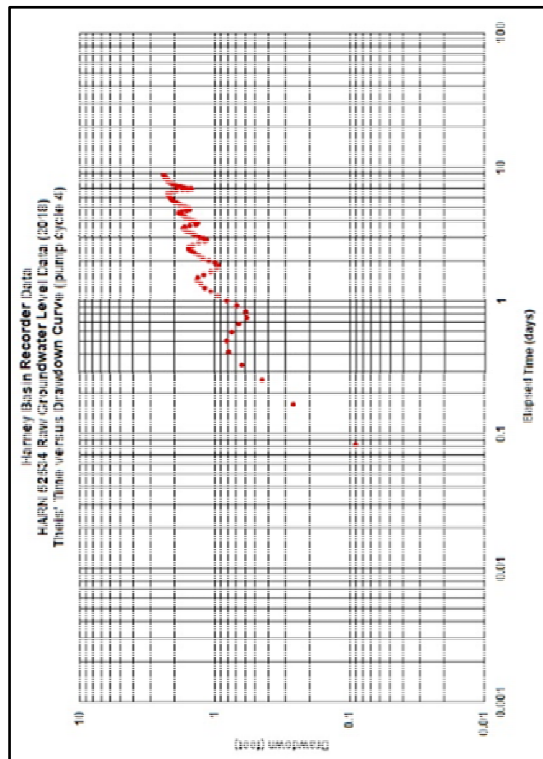
A



B



C



D

Figure F-8. Log-log elapsed time versus drawdown graphs for HARN 52534 recorder data

[Separate graph for each primary pumping and shutoff event at irrigation well HARN 1084. Graph A to D correspond to event 1 to 4 respectively.]

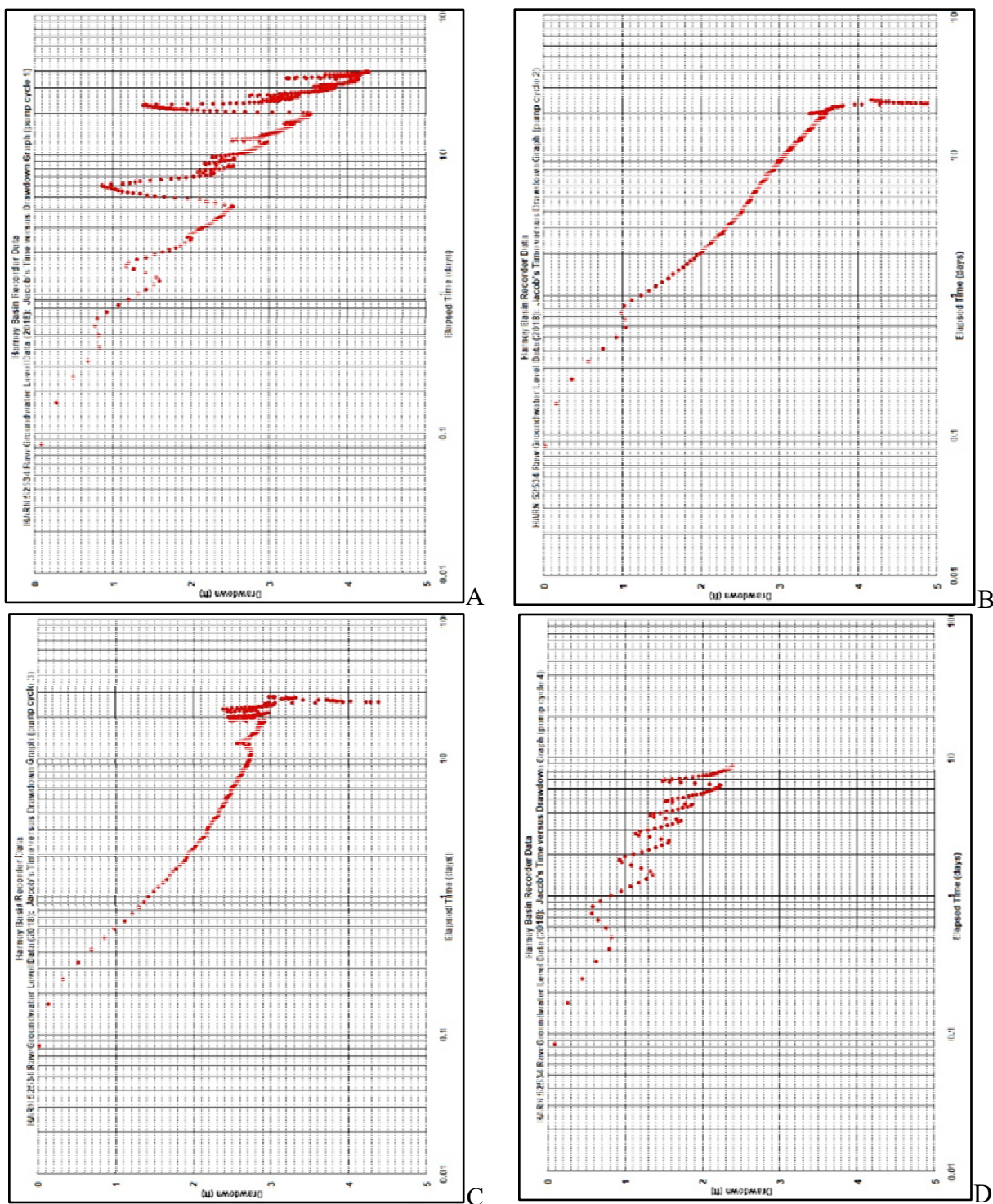


Figure F-9. Semi-log elapsed time versus drawdown graphs for HARN 52534 recorder data

[Separate graph for each primary pumping and shutoff event at irrigation well HARN 1084. Graph A to D correspond to event 1 to 4 respectively.]

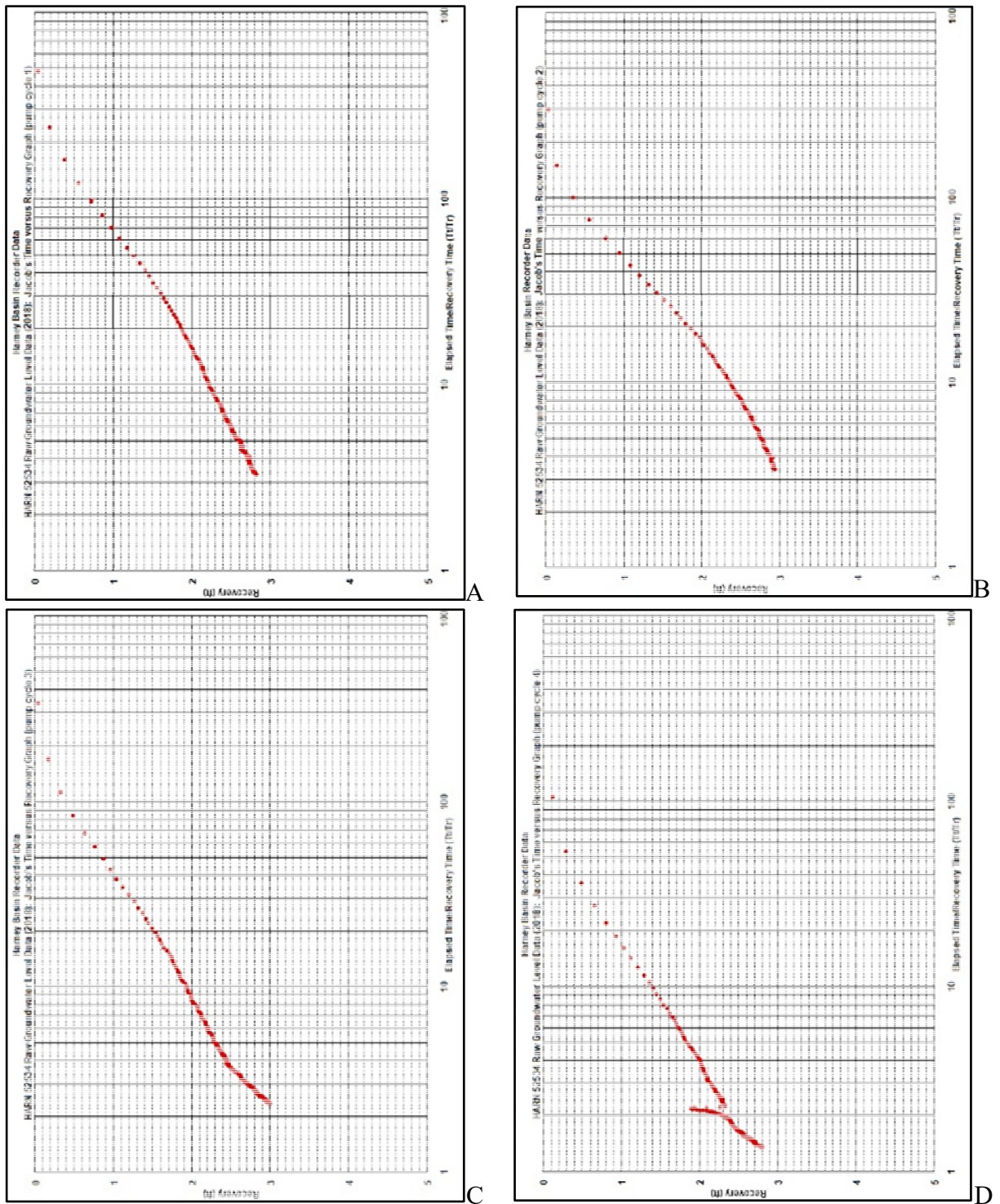


Figure F-10. Semi-log elapsed time versus recovery graphs for HARN 52534 recorder data

[Separate graph for each primary pumping and shutoff event at irrigation well HARN 1084. Graph A to D correspond to event 1 to 4 respectively.]

Table F-7. Estimated pumping rate at irrigation well HARN 1084 for HARN 52534 recorder data aquifer test analyses

Item	Unit	Month in 2018				
		May	June	July	August	September
Total days for month	day	31	30	31	31	30
Total hours for month	hour	744	720	744	744	720
Total time pump off ¹	hour	163	405	148	137	494
Total time pump on ¹	hour	581	315	596	607	226
Water volume use reported	acre-feet	76.37	55.53	100.12	100.79	21.24
Calculated Pumping Rate ²	acre-feet / day	3.15	4.23	4.03	3.99	2.26
	ft ³ / second	1.59	2.13	2.03	2.01	1.14
	gallons / minute	713.81	957.32	912.25	901.71	510.37
Item	Unit	Season in 2018				
		May to September	June to August			
Total days for season	day	153	92			
Total hours for season	hour	3,672	2,208			
Total time pump off ¹	hour	1,347	690			
Total time pump on ¹	hour	2,325	1,518			
Total volume use reported	acre-feet	354	256			
Average Pumping Rate ³	acre-feet / day	3.65	4.05			
	ft ³ / second	1.84	2.04			
	gallons / minute	826.95	917.39			

¹Total time pump on and off based on interpreted drawdown and recovery periods in HARN 52534 recorder water level data from May through October 2018

²Calculated pumping rate = (total reported month water volume) / (total time pump on during month)

³Average pumping rate for months noted = (total reported water volume) / (total time pump on)

Data Source: Oregon Water Resources Department 2019a, 2019d

Table F-8. Log-log time versus drawdown graphical method calculations for transmissivity and storage coefficient using Northwest Harney Lake recorder data from 2018

Item	Symbol	Unit	Primary 2018 Pumping and Shutoff Events			
			1	2	3	4
Theis curve match points						
Well function of u	W(u)	dimensionless	0.01	0.02	0.03	0.06
Inverse of u	1/u	dimensionless	300.00	40.00	300.00	8.00
Drawdown	s	feet	0.01	0.03	0.05	0.05
Time	t	days	40.0000	10.0000	80.0000	1.0000
Pumping Well						
Distance to pumping well ¹	r	feet	1,795	1,795	1,795	1,795
Pumping average (owner) ²	Q ₁	gallons / minute	827	827	827	827
	Q ₁	feet ³ / day	159,188	159,188	159,188	159,188
Pumping average (OWRD) ³	Q ₂	gallons / minute	917	917	917	917
	Q ₂	feet ³ / day	176,597	176,597	176,597	176,597
Calculations						
Transmissivity (using Q ₁)	T ₁	feet ² / day	12,667.79	8,445.19	7,600.68	15,201.35
Transmissivity (using Q ₂)	T ₂	feet ² / day	14,053.14	9,368.76	8,431.88	16,863.76
Storage Coefficient (using T ₁)	S ₁	dimensionless	0.002097	0.002621	0.002516	0.002359
Storage Coefficient (using T ₂)	S ₂	dimensionless	0.002326	0.002908	0.002791	0.002617

Note: $T = [Q * W(u)] / [4 * \pi * s]$ (appendix C, equation C-2)

Note: $S = [4 * t * T * u] / [r^2]$ (appendix C, equation C-3)

Note: Theis curve match points are not shown in corresponding figure F-3

¹Pumping well is HARN 1084 and observation well is HARN 52534

²Pumping average (season) based upon average of June to October 2018 volumes report (table F-7)

³Pumping average (period) based upon average of June to August 2018 volumes report (table F-7)

Data Source: Oregon Water Resources Department 2019a, 2019d

Table F-9. Semi-log time versus drawdown graphical method calculations for transmissivity and storage coefficient using Northwest Harney Lake recorder data from 2018

Early Time Data

Item	Symbol	Unit	Primary 2018 Pumping and Shutoff Events			
			1	2	3	4
Semi-log Graph Values						
Line through early time data ¹						
Start of a log ₁₀ segment	t'	days	0.10	0.10	1.00	0.10
End of a log ₁₀ segment	t''	days	1.00	1.00	10.00	1.00
Zero drawdown intercept	t'''	days	0.125000	0.160000	0.180000	0.100000
Drawdown over log ₁₀ segment	s	feet	1.68	1.80	1.90	1.25
Pumping Well						
Distance to pumping well ²	r	feet	1,795	1,795	1,795	1,795
Pumping average (owner) ³	Q ₁	gallons / minute	827	827	827	827
	Q ₁	feet ³ / day	159,188	159,188	159,188	159,188
Pumping average (OWRD) ⁴	Q ₂	gallons / minute	917	917	917	917
	Q ₂	feet ³ / day	176,597	176,597	176,597	176,597
Calculations						
Transmissivity (using Q ₁)	T ₁	feet ² / day	17,417.27	16,207.74	15,354.70	23,339.14
Transmissivity (using Q ₂)	T ₂	feet ² / day	19,322.01	17,980.21	17,033.88	25,891.50
Storage Coefficient (using T ₁)	S ₁	dimensionless	0.001520	0.001811	0.001930	0.001630
Storage Coefficient (using T ₂)	S ₂	dimensionless	0.001687	0.002009	0.002141	0.001808
u at t = t'	u'	dimensionless	0.703125	0.900000	0.101250	0.562500
u at t = t''	u''	dimensionless	0.070313	0.090000	0.010125	0.056250

Note: For equations below, see discussion in appendix C for equations C-2 to C-6

Note: $T = [(2.303 * Q) / (4 * \pi * s)] * [\log_{10} (t''/t')]$

Note: $S = [2.25 * T * t'''] / [r^2]$

Note: $u = [r^2 * S] / [4 * T * t]$

Note: u should be ≤ 0.01 for valid Jacob time versus drawdown semi-log graphical method use (Lohman, 1972a)

Note: using T₁ with S₁ and T₂ with S₂ yields the same u value

¹Lines through early, middle, and late time data are not shown in corresponding figure F-9

²Pumping well is HARN 1084 and observation well is HARN 52534

³Pumping average (season) based upon average of June to October 2018 volumes report (table F-7)

⁴Pumping average (period) based upon average of June to August 2018 volumes report (table F-7)

Data Source: Oregon Water Resources Department 2019a, 2019d

Table F-9. (continued)

Middle Time Data

Item	Symbol	Unit	Primary 2018 Pumping and Shutoff Events			
			1	2	3	4
Semi-log Graph Values						
Line through early time data ¹						
Start of a log ₁₀ segment	t'	days	no line	1.00	1.00	no line
End of a log ₁₀ segment	t''	days	no line	10.00	10.00	no line
Zero drawdown intercept	t'''	days	no line	0.085000	0.080000	no line
Drawdown over log ₁₀ segment	s	feet	no line	1.50	1.40	no line
Pumping Well						
Distance to pumping well ²	r	feet	1,795	1,795	1,795	1,795
Pumping average (owner) ³	Q ₁	gallons / minute	827	827	827	827
	Q ₁	feet ³ / day	159,188	159,188	159,188	159,188
Pumping average (OWRD) ⁴	Q ₂	gallons / minute	917	917	917	917
	Q ₂	feet ³ / day	176,597	176,597	176,597	176,597
Calculations						
Transmissivity (using Q ₁)	T ₁	feet ² / day	----	19,449.28	20,838.52	----
Transmissivity (using Q ₂)	T ₂	feet ² / day	----	21,576.25	23,117.41	----
Storage Coefficient (using T ₁)	S ₁	dimensionless	----	0.001154	0.001164	----
Storage Coefficient (using T ₂)	S ₂	dimensionless	----	0.001281	0.001291	----
u at t = t'	u'	dimensionless	----	0.047813	0.045000	----
u at t = t''	u''	dimensionless	----	0.004781	0.004500	----

Note: For equations below, see discussion in appendix C for equations C-2 to C-6

Note: $T = [(2.303 * Q) / (4 * \pi * s)] * [\log_{10} (t''/t')]$

Note: $S = [2.25 * T * t'''] / [r^2]$

Note: $u = [r^2 * S] / [4 * T * t]$

Note: u should be ≤ 0.01 for valid Jacob time versus drawdown semi-log graphical method use (Lohman, 1972a)

Note: using T₁ with S₁ and T₂ with S₂ yields the same u value

¹Lines through early, middle, and late time data are not shown in corresponding figure F-9

²Pumping well is HARN 1084 and observation well is HARN 52534

³Pumping average (season) based upon average of June to October 2018 volumes report (table F-7)

⁴Pumping average (period) based upon average of June to August 2018 volumes report (table F-7)

Data Source: Oregon Water Resources Department 2019a, 2019d

Table F-9. (continued)

Late Time Data

Item	Symbol	Unit	Primary 2018 Pumping and Shutoff Events			
			1	2	3	4
Semi-log Graph Values						
Line through early time data ¹						
Start of a log ₁₀ segment	t'	days	no line	no line	1.00	no line
End of a log ₁₀ segment	t''	days	no line	no line	10.00	no line
Zero drawdown intercept	t'''	days	no line	no line	0.025000	no line
Drawdown over log ₁₀ segment	s	feet	no line	no line	1.05	no line
Pumping Well						
Distance to pumping well ²	r	feet	1,795	1,795	1,795	1,795
Pumping average (owner) ³	Q ₁	gallons / minute	827	827	827	827
	Q ₁	feet ³ / day	159,188	159,188	159,188	159,188
Pumping average (OWRD) ⁴	Q ₂	gallons / minute	917	917	917	917
	Q ₂	feet ³ / day	176,597	176,597	176,597	176,597
Calculations						
Transmissivity (using Q ₁)	T ₁	feet ² / day	----	----	27,784.69	----
Transmissivity (using Q ₂)	T ₂	feet ² / day	----	----	30,823.21	----
Storage Coefficient (using T ₁)	S ₁	dimensionless	----	----	0.000485	----
Storage Coefficient (using T ₂)	S ₂	dimensionless	----	----	0.000538	----
u at t = t'	u'	dimensionless	----	----	0.014063	----
u at t = t''	u''	dimensionless	----	----	0.001406	----

Note: For equations below, see discussion in appendix C for equations C-2 to C-6

Note: $T = [(2.303 * Q) / (4 * \pi * s)] * [\log_{10} (t''/t')]$

Note: $S = [2.25 * T * t'''] / [r^2]$

Note: $u = [r^2 * S] / [4 * T * t]$

Note: u should be ≤ 0.01 for valid Jacob time versus drawdown semi-log graphical method use (Lohman, 1972a)

Note: using T₁ with S₁ and T₂ with S₂ yields the same u value

¹Lines through early, middle, and late time data are not shown in corresponding figure F-9

²Pumping well is HARN 1084 and observation well is HARN 52534

³Pumping average (season) based upon average of June to October 2018 volumes report (table F-7)

⁴Pumping average (period) based upon average of June to August 2018 volumes report (table F-7)

Data Source: Oregon Water Resources Department 2019a, 2019d

Table F-10. Semi-log time versus recovery graphical method calculations for transmissivity and storage coefficient using Northwest Harney Lake recorder data from 2018

Early Time Data

Item	Symbol	Unit	Primary 2018 Pumping and Shutoff Events			
			1	2	3	4
Semi-log Graph Values						
Line through early time data ¹						
Recovery line segment start	t _i '/t _r '	dimensionless	1.00	10.00	10.00	1.00
Recovery line segment stop	t _i "/t _r "	dimensionless	10.00	100.00	100.00	10.00
Line segment recovery	s'	feet	1.80	2.20	1.60	1.55
Pumping Phase Data						
Total pump period time	t	days	40.08	24.75	28.00	8.75
Total pump period drawdown	s	feet	4.20	4.17	3.06	2.39
Pumping Well						
Distance to pumping well ²	r	feet	1,795	1,795	1,795	1,795
Pumping average (owner) ³	Q ₁	gallons / minute	827	827	827	827
	Q ₁	feet ³ / day	159,188	159,188	159,188	159,188
Pumping average (OWRD) ⁴	Q ₂	gallons / minute	917	917	917	917
	Q ₂	feet ³ / day	176,597	176,597	176,597	176,597
Calculations						
Transmissivity (using Q ₁)	T ₁	feet ² / day	16,207.74	13,260.87	18,233.70	18,821.89
Transmissivity (using Q ₂)	T ₂	feet ² / day	17,980.21	14,711.08	20,227.73	20,880.24
Storage Coefficient (using T ₁)	S ₁	dimensionless	0.002106	0.002916	0.004361	0.003302
Storage Coefficient (using T ₂)	S ₂	dimensionless	0.002336	0.003235	0.004838	0.003663

Note: For equations below, see discussion in appendix C for equations C-7 to C-10

Note: $T = [(2.303 * Q) / (4 * \pi * s')] * \log_{10}[(t_i''/t_r'') * (1/(t_i'/t_r'))]$

Note: $S = [(2.25 * T * t) / (r^2)] * [1/(\text{antilog}((4 * \pi * T * s) / (2.303 Q)))]$

Note: t_i = total elapsed time since pumping started

Note: t_r = total elapsed recovery time = total elapsed time since pumping stopped

Note: s' = recovery ("residual drawdown") over recovery interval considered

Note: s = drawdown at the end of the pumping period

¹Lines through early, middle, and late time data are not shown in corresponding figure F-10

²Pumping well is HARN 1084 and observation well is HARN 52534

³Pumping average (season) based upon average of June to October 2018 volumes report (table F-7)

⁴Pumping average (period) based upon average of June to August 2018 volumes report (table F-7)

Data Source: Oregon Water Resources Department 2019a, 2019d

Table F-10. (continued)

Middle Time Data

Item	Symbol	Unit	Primary 2018 Pumping and Shutoff Events			
			1	2	3	4
Semi-log Graph Values						
Line through early time data ¹						
Recovery line segment start	t _i '/t _r '	dimensionless	1.00	10.00	1.00	1.00
Recovery line segment stop	t _i ''/t _r ''	dimensionless	10.00	100.00	10.00	10.00
Line segment recovery	s'	feet	1.20	1.60	1.25	3.20
Pumping Phase Data						
Total pump period time	t	days	40.08	24.75	28.00	8.75
Total pump period drawdown	s	feet	4.20	4.17	3.06	2.39
Pumping Well						
Distance to pumping well ²	r	feet	1,795	1,795	1,795	1,795
Pumping average (owner) ³	Q ₁	gallons / minute	827	827	827	827
	Q ₁	feet ³ / day	159,188	159,188	159,188	159,188
Pumping average (OWRD) ⁴	Q ₂	gallons / minute	917	917	917	917
	Q ₂	feet ³ / day	176,597	176,597	176,597	176,597
Calculations						
Transmissivity (using Q ₁)	T ₁	feet ² / day	24,311.60	18,233.70	23,339.14	9,116.85
Transmissivity (using Q ₂)	T ₂	feet ² / day	26,970.31	20,227.73	25,891.50	10,113.87
Storage Coefficient (using T ₁)	S ₁	dimensionless	0.000215	0.000780	0.001627	0.009978
Storage Coefficient (using T ₂)	S ₂	dimensionless	0.000239	0.000866	0.001805	0.011069

Note: For equations below, see discussion in appendix C for equations C-7 to C-10

Note: $T = [(2.303 * Q) / (4 * \pi * s')] * \log_{10}[(t_t''/t_r'') * (1/(t_t'/t_r'))]$

Note: $S = [(2.25 * T * t) / (r^2)] * [1/(\text{antilog}((4 * \pi * T * s) / (2.303 Q)))]$

Note: t_t = total elapsed time since pumping started

Note: t_r = total elapsed recovery time = total elapsed time since pumping stopped

Note: s' = recovery ("residual drawdown") over recovery interval considered

Note: s = drawdown at the end of the pumping period

¹Lines through early, middle, and late time data are not shown in corresponding figure F-10

²Pumping well is HARN 1084 and observation well is HARN 52534

³Pumping average (season) based upon average of June to October 2018 volumes report (table F-7)

⁴Pumping average (period) based upon average of June to August 2018 volumes report (table F-7)

Data Source: Oregon Water Resources Department 2019a, 2019d

Table F-10. (continued)

Late Time Data

Item	Symbol	Unit	Primary 2018 Pumping and Shutoff Events			
			1	2	3	4
Semi-log Graph Values						
Line through early time data ¹						
Recovery line segment start	t _t '/t _r '	dimensionless	no line	1.00	1.00	no line
Recovery line segment stop	t _t "/t _r "	dimensionless	no line	10.00	10.00	no line
Line segment recovery	s'	feet	no line	1.07	2.50	no line
Pumping Phase Data						
Total pump period time	t	days	no line	24.75	28.00	no line
Total pump period drawdown	s	feet	no line	4.17	3.06	no line
Pumping Well						
Distance to pumping well ²	r	feet	1,795	1,795	1,795	1,795
Pumping average (owner) ³	Q ₁	gallons / minute	827	827	827	827
	Q ₁	feet ³ / day	159,188	159,188	159,188	159,188
Pumping average (OWRD) ⁴	Q ₂	gallons / minute	917	917	917	917
	Q ₂	feet ³ / day	176,597	176,597	176,597	176,597
Calculations						
Transmissivity (using Q ₁)	T ₁	feet ² / day	----	27,342.01	11,669.57	----
Transmissivity (using Q ₂)	T ₂	feet ² / day	----	30,332.12	12,945.75	----
Storage Coefficient (using T ₁)	S ₁	dimensionless	----	0.000058	0.013623	----
Storage Coefficient (using T ₂)	S ₂	dimensionless	----	0.000065	0.015113	----

Note: For equations below, see discussion in appendix C for equations C-7 to C-10

Note: $T = [(2.303 * Q) / (4 * \pi * s')] * \log_{10}[(t_t''/t_r'') * (1/(t_t'/t_r'))]$

Note: $S = [(2.25 * T * t) / (r^2)] * [1/(\text{antilog}((4 * \pi * T * s) / (2.303 Q)))]$

Note: t_t = total elapsed time since pumping started

Note: t_r = total elapsed recovery time = total elapsed time since pumping stopped

Note: s' = recovery ("residual drawdown") over recovery interval considered

Note: s = drawdown at the end of the pumping period

¹Lines through early, middle, and late time data are not shown in corresponding figure F-10

²Pumping well is HARN 1084 and observation well is HARN 52534

³Pumping average (season) based upon average of June to October 2018 volumes report (table F-7)

⁴Pumping average (period) based upon average of June to August 2018 volumes report (table F-7)

Data Source: Oregon Water Resources Department 2019a, 2019d

Analysis using the log-log time versus drawdown graphical method curve matched the early time drawdown data only. The transmissivity values determined for the four primary pumping and shutoff events using the June to August and the May to September average pumping rates (table F-7) ranged from 7,600 to 16,864 feet²/day (table F-8). The corresponding storage coefficient values ranged from 0.0021 to 0.0029 (table F-3) indicating intermediate groundwater conditions (groundwater conditions intermediate between unconfined and confined).

Analysis using the semi-log time versus drawdown graphical method determined the graphed drawdown data for each primary pumping and shutoff event can be subdivided by change in slope (see “drawdown over log₁₀ segment” values in table F-9) into one to three approximate straight-line segments identified as early time data, middle time data, and late time data (table F-9). The transmissivity values determined for the four primary pumping and shutoff events using the June to August and the May to September average pumping rates (table F-7) ranged from 15,355 to 25,892 feet²/day for the early time data, from 19,449 to 23,117 feet²/day for the middle time data, and from 27,784 to 30,823 feet²/day for the late time data (table F-9). The corresponding storage coefficient values (table F-9) ranged from 0.0015 to 0.0021 for the early time data, from 0.0012 to 0.0013 for the middle time data, and from 0.0014 to 0.0141 for the late time data). All but one storage coefficient value indicates intermediate groundwater conditions. The early time data transmissivity and storage coefficient values from this specific analysis are assumed to be least affected by unaccounted influences and best represent the local subsurface hydraulic properties. However, values derived from the early time data must be used warily, with caution given the u values exceed 0.01 (table F-9). The transmissivity and storage coefficient values derived from the middle and late time data are likely affected by one or more unidentified influences given the data correspond to a change in drawdown slope.

Analysis using the semi-log time versus recovery graphical method determined the graphed recovery (“residual drawdown”) data for each primary pumping and shutoff event can also be subdivided into two to three straight line segments identified as early time data, middle time data, and late time data (table F-10). The transmissivity values determined for the four primary pumping and shutoff events using the June to August and the May to September average pumping rates (table F-7) ranged from 13,260 to 20,880 feet²/day for the early time data, from 9,117 to 26,970 feet²/day for the middle time data, and from 11,670 to 30,332 feet²/day for the late time data (table F-10). The corresponding storage coefficient values (table F-10) ranged from 0.0021 to 0.0048

for the early time data indicating intermediate groundwater conditions, from 0.0002 to 0.0111 for the middle time data indicating confined to unconfined groundwater conditions, and from 0.0001 to 0.0151 for the late time data indicating confined to unconfined groundwater conditions. The early time data transmissivity and storage coefficient values from this specific analysis are assumed to be least affected by unaccounted influences and best represent the local subsurface hydraulic properties. The transmissivity and storage coefficient values derived from the middle and late time data are likely affected by one or more unidentified influences given the data correspond to a change in recovery slope.

The analysis lastly tested the transmissivity and storage coefficient values derived by the graphical analyses by using the value range to constrain an effort to recreate the May to October 2018 recorder data via a Theis equation (appendix C, equation C-2 and C-3) based method. The method assigns each successive pumping and recovery phase observed with an imaginary pumping well or recharge well. All the imaginary wells are at the same location represented by its own Theis equation. Each imaginary well successively begins discharging or recharging at the corresponding observed drawdown or recovery start times (figure F-7, tables F-11 and F-12) and continues discharging or recharging to the end of the test period. The calculated water level change at the observation well from the original water level is the difference between the sum of the calculated drawdowns at the observation well caused by each discharging imaginary well and the sum of the calculated recovery at the observation well caused by each recharging imaginary well. Separate calculations were conducted using a 827 gpm May to October 2018 average pumping rate (827 gpm for discharge and -827 gpm for recharge) (table F-11) and a 917 gpm June to August 2018 average pumping rate (917 gpm for discharge and -917 gpm for recharge) (table F-12). Iterative calculations were conducted for each pumping rate using varying values of transmissivity and storage coefficient. After each calculation, the results were graphed and compared to figure F-7. Transmissivity and storage coefficient values yielding the closest match for the 827 gpm pumping rate were 11,000 feet²/day and 0.0050 respectively (figure F-11). Transmissivity and storage coefficient values yielding the closest match for the 917 gpm pumping rate were 12,500 feet²/day and 0.0050 respectively (figure F-12).

The resulting comparative graphs (figures F-11 and F-12) are nearly identical. The graphs show increasing differences between the observed and calculated groundwater levels from the least difference in May to greatest difference in September and October. The increasing lowering of

the observed level below the calculated level with time is likely due to temporary shutoffs not included in the calculations and an increasing influence of unaccounted pumping wells causing additional drawdown with time at the observation well. Unaccounted additional drawdown with time occurring during each successive drawdown and recovery event can cause increasing bias (discrepancy from actual values) in the transmissivity and storage coefficient values calculated from each event. The bias is likely least for the first event calculations.

Table F-11. Imaginary wells used for Theis equation calculations to recreate May through October 2018 Northwest Harney Lake recorder hydrograph (827 gpm pumping rate)

Imaginary Well	Imaginary Well Start Date & Time (mm/dd/yyyy hh:mm:ss)	Time After Test Start (days)	Time Before Test Ends (days)	Pumping Rate (gal / min)	Comment
Pumping 1	05/05/2018 17:00:00	0.00	179.29	827	Test period starts
Recovery 1	06/14/2018 19:00:00	40.08	139.21	-827	
Pumping 2	07/02/2018 13:00:00	57.83	121.46	827	
Recovery 2	07/27/2018 07:00:00	82.58	96.71	-827	
Pumping 3	08/06/2018 17:00:00	93.00	86.29	827	
Recovery 3	09/03/2018 15:00:00	120.92	58.38	-827	
Pumping 4	09/24/2018 13:00:00	141.83	37.46	827	
Recovery 4	10/03/2018 07:00:00	150.58	28.71	-827	
	11/01/2018 00:00:00	179.29	0.00		Test period ends

Table F-12. Imaginary wells used for Theis equation calculations to recreate May through October 2018 Northwest Harney Lake recorder hydrograph (917 gpm pumping rate)

Imaginary Well	Imaginary Well Start Date & Time (mm/dd/yyyy hh:mm:ss)	Time After Test Start (days)	Time Before Test Ends (days)	Pumping Rate (gal / min)	Comment
Pumping 1	05/05/2018 17:00:00	0.00	179.29	917	Test period starts
Recovery 1	06/14/2018 19:00:00	40.08	139.21	-917	
Pumping 2	07/02/2018 13:00:00	57.83	121.46	917	
Recovery 2	07/27/2018 07:00:00	82.58	96.71	-917	
Pumping 3	08/06/2018 17:00:00	93.00	86.29	917	
Recovery 3	09/03/2018 15:00:00	120.92	58.38	-917	
Pumping 4	09/24/2018 13:00:00	141.83	37.46	917	
Recovery 4	10/03/2018 07:00:00	150.58	28.71	-917	
	11/01/2018 00:00:00	179.29	0.00		Test period ends

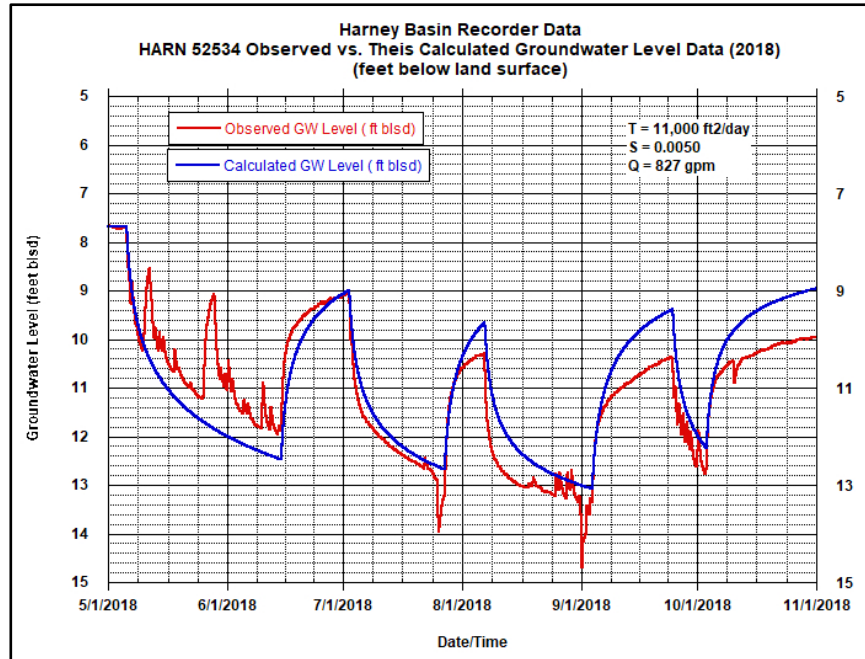


Figure F-11. Calculated and recorded water level response at the Northwest Harney Lake recorder observation well HARN 52534 due to pumping and shutoff at irrigation well HARN 1084 using 827 gpm for calculation

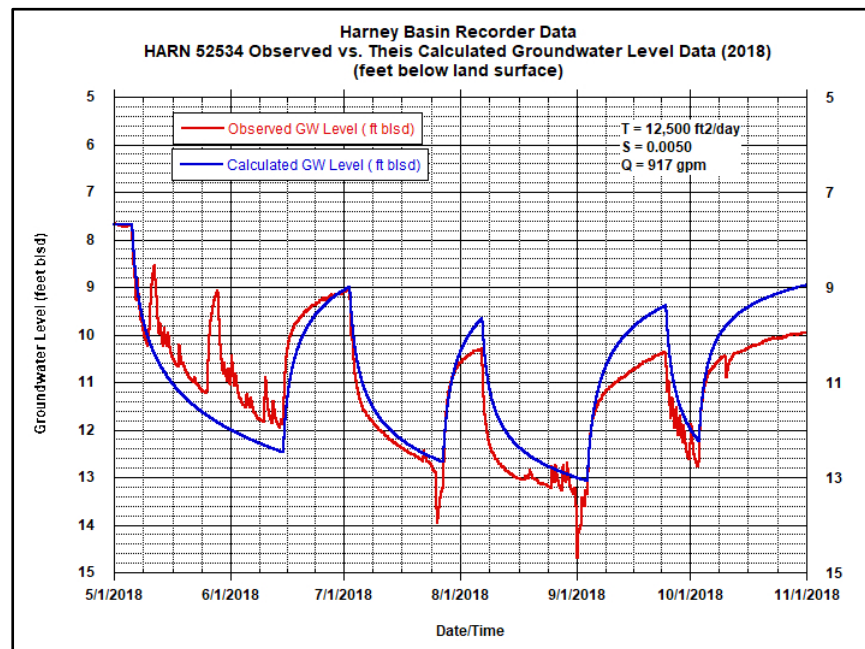


Figure F-12. Calculated and recorded water level response at the Northwest Harney Lake recorder observation well HARN 52534 due to pumping and shutoff at irrigation well HARN 1084 using 917 gpm for calculation

Appendix G: Analysis of Pump Test Data

Oregon Water Resources Department (OWRD) staff analyzed data related to 41 single well pump tests submitted to the Department. Generally, the tests were conducted and submitted to OWRD to meet an Oregon groundwater right condition requiring a pump test under the authority of Oregon Revised Statute (ORS) 537.772 and the related Oregon Administrative Rule (OAR) Chapter 690, Division 217 (OAR 690-217). The wells tested are listed in appendix H, and they are shown in figure G-1.

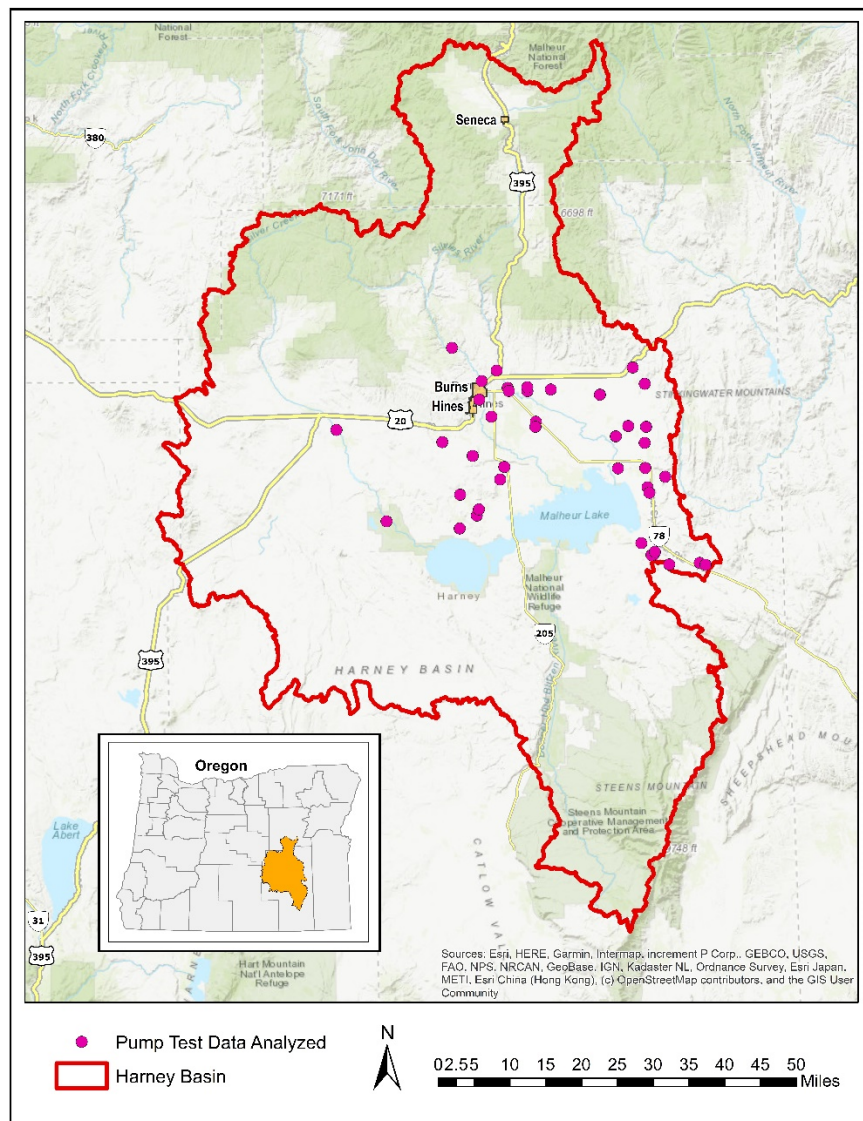


Figure G-1. Location of single well pump tests submitted to OWRD and analyzed by OWRD staff [41 well locations]

Oregon Pump Test Program

Oregon law (ORS 537.772) enacted in 1987 requires many groundwater right well owners to conduct “pump tests” of their wells and submit the results to OWRD. The details for conducting and reporting the pump tests are specified by Oregon rule (OAR 690-217) adopted in 1988. A pump test under Oregon rule is essentially an aquifer test with a required four-hour minimum constant pumping rate at the groundwater right well and scheduled drawdown and recovery measurements required at the pumped well and possibly at observation wells. The test purpose is to provide information for groundwater resource characterization and to help solve well problems (OAR 690-217-0015 (9)). The test can be a single well test (pumping well only) or a multiple well test (one pumping well, one or more non-pumping observation wells). The majority of the pump tests conducted to satisfy the Oregon statute and rule are single well tests. Well owners may request and be granted a pump test exemption for some situations specified by the Oregon rule. No pump test is required for domestic wells, livestock wells, or other exempt wells.

Pump Test Program Requirements

OAR 690-217 notes the pump test must be conducted by the well owner, or their full-time employee familiar with the well(s) and pump(s), or a qualified professional authorized by the well owner. Qualified professionals listed include Oregon licensed water well constructors, pump installers, Oregon registered geologists, Oregon certified engineering geologists, Oregon registered professional engineers, and Oregon certified water rights examiners.

The rule requires the pump test to include three phases. First is a required pre-discharge phase where the well tested and any observation well(s) must be idle for 16 or more hours and measured at least three times at 20-minute intervals during the final hour before discharge at the test well begins. Second is the discharge phase where pumping or artesian flow at a constant rate must occur at the test well for 4 or more hours. Concurrently, water level measurements are made at the test well and any observation well at intervals no more than two minutes apart during the first ten minutes of discharge, no more than five minutes apart during the subsequent 20-minutes of discharge, and no more than 15-minutes for the remainder of the discharge phase. Third and last is the post-discharge recovery phase where no discharge occurs, and water levels measurements are made at the same time intervals as the discharge phase. The third phase duration must be four hours or until 90-percent of the total discharge phase drawdown is recovered,

whichever is first. An approved water level measurement tool must be used, and the measurement precision must be 0.10-feet or better for most tools. Additionally, an approved discharge measurement device must be used, and measurements must occur at the start of discharge and then hourly at minimum.

Lastly, the rule requires the pump test related information and measurements to be submitted to OWRD on approved forms provided by OWRD. OWRD staff review the information and measurements for compliance with OAR 690-217 requirements, analyze the data for hydraulic property values, and rate the quality of the test performance, information, and data for analysis.

Hydraulic Property Analysis of Pump Test Data

Various OWRD staff reviewed the test information and analyzed the data submitted for the 41 single well pump tests. They rated 7 tests as good, 26 as fair, and 8 as poor (appendix H). Additional tests not rated or rated worse than poor were excluded from hydraulic property analysis. Given the varied data quality of the 41 pump tests, staff selectively analyzed the discharge phase drawdown data and/or the shutoff phase recovery data to estimate hydraulic property values. Given the data came from the pumping well only (no observation well data), analysis was limited to estimating transmissivity using the semi-log graphical methods as described and illustrated in appendices C and E. The absence of observation well data precluded estimating storage coefficient values and using the log-log graphical method.

The well tested, associated well information, and the transmissivity calculated for the 41 pump tests is shown in appendix H. That appendix additionally includes for each test a calculated specific capacity (test pumping rate divided by test total drawdown) and a calculated approximate hydraulic conductivity (calculated transmissivity divided by well total open interval determined from driller well report).

Appendix H:

Table of selected Harney Basin aquifer tests
(See remarks and notes at end of table)

OWRD Well ID Pumped Well Groundwater Database	Well Location (best available)				Well Construction				Well OPI Units		Aquifer Test -- Pump Test					Analysis Results		Test Quality Rating by OWRD	Remarks	Calculated			
	Public Land Survey (PLS) Township/Range-Section qtr qtr	Latitude (decimal)	Longitude (decimal)	Error Horizontal (feet)	Well Open Interval (OPI)			Well Bottom (ft. blsd)	Strat Unit(s)	Hydro-Strat Unit(s)	Test Type	Discharge Rate Average		Pumping Duration (hours)	Drawdown Final (feet)	Observation Wells	Transmissivity (ft2/d)			Storage Coefficient	Specific Capacity (gpm / ft)	Transmissivity (feet² / day) (from analysis results)	Hydraulic Conductivity (feet / day)
					OPI Top (ft. blsd)	OPI Bottom (ft. blsd)	OPI height (feet)					(gpm)	(cfs)										
HARN0000441	23.00S/31.00E-11dcc	43.58570810	-118.97012880	0.10	220	561	341	561	Tts (74); Qs (26)	OBF (74); YBF (26)	MWA	131	0.2919	72.00	59.59	2	369	NA	FAIR	1	2.198	369.470	1.083
HARN0052029	22.00S/33.00E-34bc	43.61009200	-118.63976500	25.00	119	165	46	165	QTsu (100)	OBF (100)	MWA	700	1.5597	332.00 - 500.00	9.80 - 11.38	1	6,000	0.0500	FAIR	2	71.429	6,000.000	130.435
HARN0001084	25.00S/29.00E-29cb	43.37447000	-119.27297000	25.00	200	457	257	457	QTsu (87); Tts (10); HLPu (3)	OBF (97); HLP (3)	MWA	917	2.0441	210.00 - 946.00	2.39 - 4.27	1	12,500	0.0050	FAIR	3	383.682	12,500.000	48.638
HARN0000106	22.00S/31.00E-33ba	43.62769601	-119.01189646	250.00	40	425	385	425	Tts (82); QTV (17); Trt (1)	OBF (83); PVD (17)	SWP	700	1.5597	4.00	12.00	0	4,236	NA	FAIR	4	58.333	4,236.000	11.003
HARN0000219	22.00S/33.00E-27da	43.62814225	-118.63255840	0.20	20	833	813	833	Tov (69); Tts (19); QTsu (12)	UVR (69); OBF (31)	SWP	167	0.3721	4.20	57.00	0	134	NA	FAIR	4	2.930	134.000	0.165
HARN0000307	23.00S/30.00E-24aa	43.56944190	-119.06189009	250.00	195	218	23	218	Tts (100)	OBF (100)	SWP	230	0.5125	4.00	95.50	0	9,200	NA	POOR	4	2.408	9,200.000	400.000
HARN0000517	23.00S/31.00E-32db	43.53437505	-119.02864214	9,999.00	18	195	177	195	QTsu (100)	OBF (100)	SWP	1,013	2.2571	5.10	39.00	0	17,370	NA	GOOD	4	25.974	17,370.000	98.136
HARN0000753	24.00S/27.00E-03ddc	43.51231500	-119.46023000	150.00	56	300	244	408	Tts (61); QTb (27); Qs (12)	OBF (61); HLP (27); YBF (12)	SWP	1,630	3.6319	4.00	23.30	0	17,790	NA	FAIR	4	69.957	17,790.000	72.910
HARN0000837	24.00S/30.00E-18dc	43.48443474	-119.16629255	100.00	100	425	325	425	QTsu (100)	OBF (100)	SWP	398	0.8868	4.00	55.50	0	650	NA	GOOD	4	7.171	650.000	2.000
HARN0000844	24.00S/30.00E-26ddc	43.45552516	-119.08255611	50.00	90	501	411	501	QTsu (100)	OBF (100)	SWP	2,189	4.8775	4.40	19.00	0	5,118	NA	FAIR	4	115.211	5,118.000	12.453
HARN0000901	23.00S/32.00E-05ad	43.52237716	-118.90535646	25.00	60	346	286	346	QTsu (100)	OBF (100)	SWP	300	0.6684	4.20	15.25	0	730	NA	POOR	4	19.672	730.000	2.552
HARN0000905	24.00S/32.00E-08ab	43.51208576	-118.90703203	200.00	89	160	71	160	QTsu (100)	OBF (100)	SWP	250	0.5570	4.00	34.08	0	420	NA	FAIR	4	7.336	420.000	5.915
HARN0001014	24.00S/33.00E-17b	43.48950168	-118.68388910	50.00	18	437	419	437	QTsu (100)	OBF (100)	SWP	365	0.8133	4.00	80.20	0	628	NA	GOOD	4	4.551	628.000	1.499
HARN0001028	24.00S/33.00E-24bd	43.47501935	-118.60429987	50.00	106	402	296	402	QTsu (100)	OBF (100)	SWP	611	1.3614	4.20	33.95	0	9,584	NA	FAIR	4	17.997	9,584.000	32.378
HARN0001128	25.00S/31.00E-16ab	43.40676922	-119.00772560	100.00	18	142	124	142	QTsu (100)	OBF (100)	SWP	800	1.7825	4.00	81.00	0	765	NA	FAIR	4	9.877	765.000	6.169
HARN0001213	25.00S/33.00E-01cdb	43.42416361	-118.60406987	100.00	190	205	15	205	QTsu (100)	OBF (100)	SWP	850	1.8939	4.00	28.00	0	1,250	NA	POOR	4	30.357	1,250.000	83.333
HARN0001305	26.00S/28.00E-11dc	43.32595000	-119.32454000	10.00	78	90	12	90	QTsu (100)	OBF (100)	SWP	37	0.0824	4.00	27.41	0	1,365	NA	POOR	4	1.350	1,365.000	113.750
HARN0001333	26.00S/30.00E-12bb	43.33475063	-119.07413461	250.00	45	90	45	110	QTV (100)	PVD (100)	SWP	1,370	3.0526	5.00	16.00	0	6,908	NA	FAIR	4	85.625	6,908.000	153.511
HARN0001979	23.00S/31.00E-06ca	43.60683093	-119.05381720	0.30	170	218	48	218	QTV (79); QTsu (21)	PVD (79); OBF (21)	SWP	550	1.2255	4.30	54.41	0	441	NA	FAIR	4	10.108	441.000	9.188
HARN0050135	27.00S/33.00E-12ab	43.24747000	-118.58756000	25.00	98	300	202	300	QTsu (100)	OBF (100)	SWP	900	2.0053	4.00	10.00	0	3,025	NA	POOR	4	90.000	3,025.000	14.975
HARN0050143	26.00S/30.00E-01ac	43.34707641	-119.06790157	25.00	15	263	248	263	Tts (79); QTV (15); QTsu (6)	OBF (85); PVD (15)	SWP	1,000	2.2282	4.00	14.00	0	17,600	NA	FAIR	4	71.429	17,600.000	70.968
HARN0050150	25.00S/33.00E-24ac	43.38511184	-118.59922146	100.00	20	225	205	225	QTsu (68); Tdw (32)	OBF (68); HLP (32)	SWP	1,700	3.7879	4.00	24.60	0	2,643	NA	FAIR	4	69.106	2,643.000	12.893
HARN0050151	27.00S/33.00E-12ba	43.24750000	-118.59249000	25.00	128	514	386	514	QTsu (100)	OBF (100)	SWP	285	0.6350	4.00	133.20	0	194	NA	FAIR	4	2.140	194.000	0.503
HARN0050238	25.00S/33.00E-25ad	43.37383205	-118.59427344	100.00	50	200	150	200	Tdw (47); QTsu (40); Tts (13)	HLP (47); OBF (53)	SWP	924	2.0588	4.00	35.00	0	1,019	NA	POOR	4	26.400	1,019.000	6.793
HARN0050793	27.00S/35.00E-18ba	43.22941288	-118.45949718	500.00	30	165	135	165	Tts (57); Qvb (43)	OBF (57); VB (43)	SWP	615	1.3703	4.00	11.00	0	9,647	NA	FAIR	4	55.909	9,647.000	71.459
HARN0050898	23.00S/32.00E-11cc	43.58715269	-118.86188923	300.00	60	200	140	200	QTsu (100)	OBF (100)	SWP	915	2.0388	4.00	38.34	0	1,042	NA	FAIR	4	23.865	1,042.000	7.443
HARN0050927	23.00S/32.00E-18ab	43.58478927	-118.92732478	100.00	31	246	215	246	QTsu (81); Trt (12); Tts (4); UNKN (2)	OBF (98); UNKN (2)	SWP	700	1.5597	4.00	30.21	0	2,900	NA	POOR	4	23.171	2,900.000	13.488
HARN0050957	26.00S/33.00E-35bc	43.27222955	-118.61998523	75.00	40	85	45	85	Qvb (100)	VB (100)	SWP	1,800	4.0107	8.00	5.00	0	15,495	NA	FAIR	4	360.000	15,495.000	344.333
HARN0050969	25.00S/31.00E-03cb	43.43217671	-118.99541414	250.00	79	230	151	230	QTsu (100)	OBF (100)	SWP	360	0.8021	4.00	38.25	0	353	NA	FAIR	4	9.412	353.000	2.338
HARN0050973	22.00S/30.00E-09cc	43.67516691	-119.13510841	500.00	145	200	55	200	QTsu (100)	OBF (100)	SWP	128	0.2841	4.30	33.66	0	82	NA	FAIR	4	3.788	82.000	1.491
HARN0051014	23.00S/33.00E-01cd	43.59446784	-118.60029780	25.00	100	380	280	380	Trd (66); QTsu (34)	SFD (66); OBF (34)	SWP	910	2.0276	4.30	95.00	0	2,100	NA	GOOD	4	9.579	2,100.000	7.500
HARN0051259	25.00S/30.00E-28ad	43.37743942	-119.11930497	2.00	60	207	147	207	QTsu (100)	OBF (100)	SWP	339	0.7548	5.30	43.00	0	226	NA	FAIR	4	7.878	226.000	1.537
HARN0051291	27.00S/33.00E-01da	43.25378000	-118.58293000	25.00	99	162	63	162	QTsu (100)	OBF (100)	SWP	700	1.5597	4.50	139.15	0	2,070	NA	FAIR	4	5.031	2,070.000	32.857
HARN0051313	25.00S/34.00E-16bb	43.40546983	-118.54956538	50.00	60	375	315	375	QTsu (100)	OBF (100)	SWP	1,325	2.9523	4.20	28.00	0	1,745	NA	POOR	4	47.321	1,745.000	5.540
HARN0051408	24.00S/33.00E-12ba	43.50745000	-118.59940000	25.00	99	400	301	400	QTsu (100)	OBF (100)	SWP	600	1.3369	4.00	195.00	0	202	NA	FAIR	4	3.077	202.000	0.671
HARN0051441	23.00S/32.00E-07ac	43.59268000	-118.92725000	25.00	50	250	200	270	QTsu (73); Trt (27)	OBF (100)	SWP	585	1.3035	4.30	80.00	0	765	NA	FAIR	4	7.313	765.000	3.825
HARN0051532	23.00S/32.50E-13cb	43.57463092	-118.72577458	100.00	98	300	202																

Remarks:

Appendix I: Specific Capacity and Transmissivity from Well Yield Tests

Oregon Water Resources Department (OWRD) identified 1,451 water well reports (1,161 within the Harney Basin and 290 surrounding the basin) with sufficient well yield test data for calculating specific capacity (appendix D) from which a transmissivity estimate was calculated using the Vorhis (1979) numerical method (appendix D). The reports from which a transmissivity estimate was calculated are listed in appendix J and the well locations are shown in figure I-1. An explanation on how the 1,451 reports were identified and transmissivity was calculated follows.

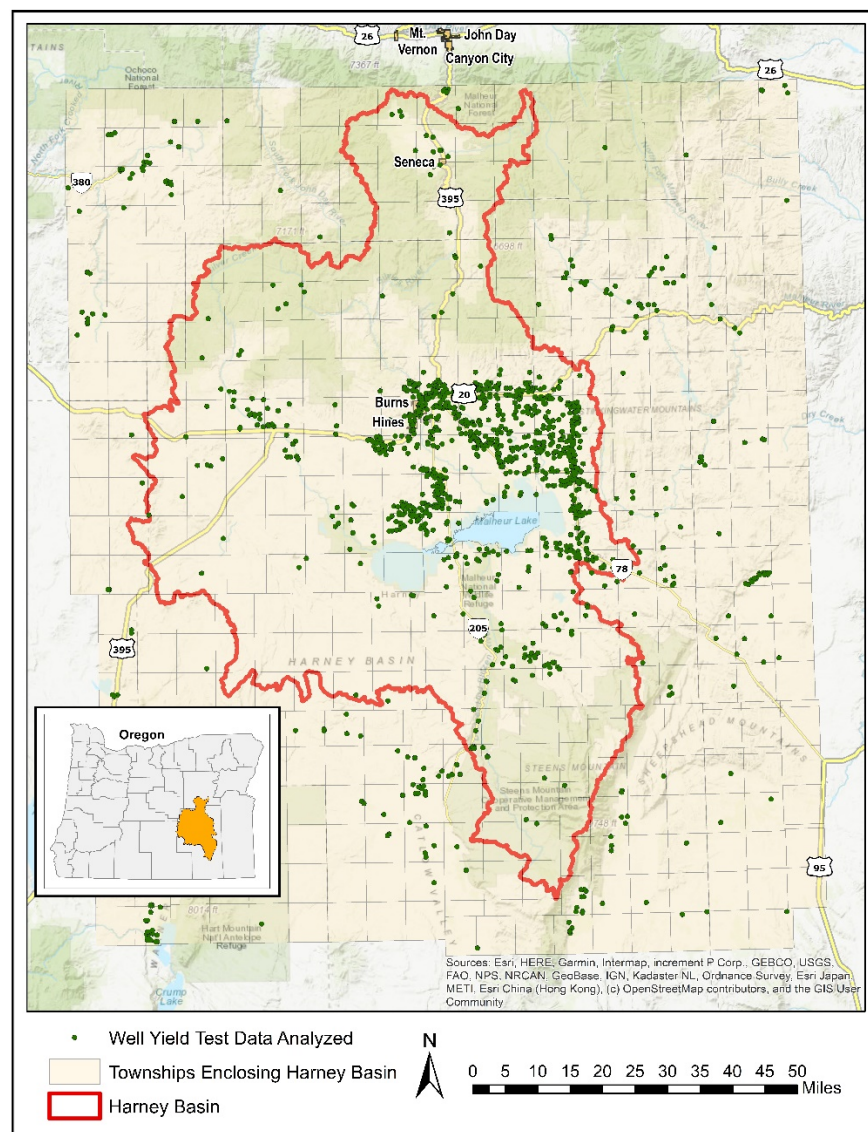


Figure I-1. Location of wells with well yield tests used for transmissivity calculations [1,451 tests, 1,161 for wells inside Harney Basin, 290 for wells surrounding the basin]

Water Well Reports

OWRD is responsible for receiving, storing, and making accessible Oregon water well reports under the authority of Oregon statute (ORS 537.765) and Oregon administrative rule (OAR 690-205-0210 and 690-240-0395). Historically, water well reports were filed and accessed in notebooks sorted by county then by public land survey location (township/range-section). Now, historic and current water well reports are stored and accessed as electronic images and data in the Oregon Water Resources Department (2019b) well report (well log) information system named the Groundwater Report Information Database (GRID). Each report is assigned a unique OWRD well report number consisting of the first four letters of the county where the well was drilled plus a series number; an example is HARN 54321. The corresponding well in the field may have a unique well identification number tag (“well ID” or “well tag” or “well label”) attached to the well that is noted with the well report. A given well should have only one “well tag” but may have one or more well reports for various reasons such as well deepening or alteration.

Water Well Reports: Types-Sources

OWRD stores and makes accessible three types of water well reports derived from three sources. First and primary are “water well reports” and specialty reports for monitoring wells, geotechnical holes, and closed loop ground source heat pump borings prepared and submitted by well constructors or approved personnel. Those reports record well owner, well location, well construction, subsurface material and water bearing zones encountered, static groundwater levels measured, tested well performance, and any abandonment or alteration as field logged and recorded during construction. Second are “well records” created by U.S. Geological Survey (USGS) and/or OWRD staff based on original USGS recorded data from well site visit observations, interviews, and other sources. Lastly are “well information reports” created by OWRD staff to document basic information for pre-existing wells not previously documented by a “water well report,” specialty report, or “well record,,” often based on information reported in groundwater right applications and registrations. This study created “well information reports” for selected wells noted in USGS reports, documented in water rights, and/or “discovered” in the field that could not be correlated to existing well reports. Each report for each report type is assigned a unique OWRD well report number as described in the previous section and can be electronically accessed via OWRD GRID (Oregon Water Resources Department, 2019b).

Water Well Reports: Best Available Well Location

Location data for water wells vary in number, sources, types, and precision. A particular well may have one or more associated location from one or more sources including, but not limited to: well report forms or maps; water right file forms, maps, documents, or reports; surveyor and/or consultant notes, maps, documents, or reports; and USGS and/or OWRD staff field notes, forms, maps, documents, or reports. The recorded or reported location types can be one or more of the following: public land survey (township/range-section), assigned county tax lot, surveyed metes and bounds, and/or latitude-longitude derived from global positioning system (GPS) units, satellite analyses, or interpreted from maps. The location precision (horizontal error) can range from less than one-foot to more than one-mile.

The various well location data is stored and accessed via different OWRD databases. Well report sourced well locations are stored in OWRD GRID (Oregon Water Resources Department, 2019b). Water right sourced well locations are stored in the OWRD Water Right Information System (WRIS) (Oregon Water Resources Department, 2019e). USGS, OWRD, and miscellaneous sourced well locations are stored in the OWRD Groundwater information system (GWIS) (Oregon Water Resources Department, 2019a). A horizontal error generally accompanies well locations stored in GWIS, and generally do not accompany well locations stored in GRID or WRIS.

OWRD staff wrote and executed computer language programs including Python scripting language (“Python” or “script”) and Structured Query Language (“SQL”) to query and report well locations from the OWRD databases. The programs retrieved latitude-longitude locations, retrieved any recorded horizontal error, converted non-latitude-longitude locations to latitude-longitude locations, and assigned a horizontal error value where missing based on whether a location type yields a specific point versus an area (smaller error for points and larger error for areas). The programs converted area locations to points at the area’s center and assigned a horizontal error based upon the area’s size. For each well, the programs identified and assigned the well location with the smallest horizontal error as the best available location for that well. The locations shown for wells listed in appendix H and J are the current best available well locations identified and assigned by the programs.

Geographic Area to Identify Water Well Reports to Query and Select

A rectangular area of approximately 14,875 square mile composed of 433 public land survey (PLS) townships (figure I-1, table I-1 footnotes) that includes and encloses the Harney Basin was used to identify water well reports for subsequent query and selection from three OWRD databases (GWIS, GRID, and WRIS) noted in the previous section. OWRD staff wrote and executed computer language programs to conduct the query. Using the rectangular area helped maximize the number of well yield test derived transmissivity estimates available for analysis to best characterize the aerial and vertical distribution of transmissivity values within and near the basin, determine a range of transmissivity values for each stratigraphic unit noted in appendix A, and assess possible transmissivity value correlations to various factors such as well construction. The query identified 5,696 water well reports (4,376 within the Harney Basin and 1,320 surrounding the basin) available for possible subsequent selection and use. The total number of wells related to the reports is less given some wells relate to one or more reports representing one or more report type (new well, deepening, alteration, conversion, abandonment, or unknown). Table I-1 shows the report type distribution for the 5,696 reports.

Table I-1. Number and Distribution of Water Related Well Report Types for Wells Within Rectangle Enclosing the Harney Basin

Well Report Type	Water Well Reports		
	Within Rectangle ¹	Within Harney Basin	Surrounding Harney Basin
New Well	4,646	3,522	1,124
Well Deepening	212	174	38
Well Alteration	249	199	50
Well Conversion	2	2	0
Well Abandonment	530	436	94
Unknown Type	57	43	14
Report Totals	5,696	4,376	1,320

¹Rectangle composed of 433 public land surface survey (PLS) townships (about 14,875 square miles) enclosing the Harney Basin used to select water related well reports for possible hydraulic property analysis. The 433 PLS townships are: Township 15 through 27 South, Range 22 through 39 East, Township 28 through 36 South, Range 23 through 39 East, and Township 36 South, Range 40 East.

Note: a well may have one or more reports comprising one or more report type

Data Source: Oregon Water Resources Department 2019a, 2019b

Selection of Water Well Report Subset for Harney Well Test Master Data Table

OWRD staff used existing computer programs such as FileMaker and wrote programs to query the three previously noted OWRD databases (GWIS, GRID, and WRIS) to select a subset of well reports from the previously noted 5,696 reports and related additional well information stored in the databases to create a master hydraulic property data table for subsequent queries, analyses, and calculations. Executing the query first occurred in September 2019. Subsequent query executions occurred in December 2019 and February 2021 to update the master data table when the selection criteria was refined and/or more well reports meeting the selection criteria became available. Selecting the subset well reports and related additional data for the master data table was based on the well report and/or additional data meeting the following requirements:

- GWIS database: all the following were selected
 - Well reports and additional data flagged as Project = “Harney Basin Study – All”
 - Well reports and additional data added to GWIS from published reports
- GRID and/or WRIS databases: all the following were required for selection to occur
 - Latitude-longitude location (original or converted best location previously described)
 - Subsurface lithologic information
 - Well construction information (at minimum: well depth, casing depth and diameter)
 - Well yield test data on well report or a submitted pump test or an aquifer test

The query identified, selected, and exported data from the three OWRD databases for well reports and associated additional data that met the above criteria to create a static, stand-alone master data table composed of 2,478 data table records available to query and calculate hydraulic properties. Some of the 2,478 data table records showed the same (duplicate) OWRD well report number. Multiple data table records with the same OWRD well report number occurred when multiple well yield tests recorded on a single well report were exported to the master data table as a separate record for each well yield test. Multiple data table records with the same OWRD well report number also occurred when multiple submitted pump tests related to the same OWRD well report number were exported to the master data table as a separate record for each pump test submitted. Lastly, multiple data table records may relate to the same well due to multiple well

reports (each with a different OWRD well report number) meeting the above selection criteria were exported to the master data table as separate records.

Within the entire master data table 2,478 records are 2,404 records with a well report well yield test (1,443 pump discharge, 323 bailer lift discharge, 610 compressed air discharge, and 28 artesian flow discharge). The remaining 74 records have unspecified or no well report well yield test. They were exported to the master data table because they met one or more of the other selection criteria. Within the 2,404 records with a well report well yield test are 1,766 records with a well yield pump or bailer discharge test. Within those 1,766 records are 1,451 non-duplicate records (1,232 pump discharge, 219 bailer discharge, 1,161 within Harney Basin, and 290 surrounding Harney Basin) that have sufficient data to calculate transmissivity using the Vorhis (1979) numerical method (appendix D). The well yield test data within those 1,451 records represent tests on or after the most recent date of well construction activity and the test with the greatest discharge rate when multiple well yield tests were conducted on the same date. Within the 1,451 non-duplicate records are 81 records associated with submitted pump tests reviewed by OWRD staff (0 rated excellent, 5 rated good, 25 rated fair, 20 rated poor, 27 rated useless, and 4 not rated). Within the 81 records are 40 records that have a calculated transmissivity value (0 rated excellent, 5 rated good, 22 rated fair, 11 rated poor, 2 rated useless, and 0 not rated).

Within the entire master data table 2,478 records are 188 records associated with one or more submitted pump test reviewed by OWRD staff (4 rated excellent, 15 rated good, 55 rated fair, 43 rated poor, 57 rated useless, and 14 not rated). Within the 188 records associated with one or more submitted pump test, there are pump tests related to 88 records that have a calculated transmissivity value (4 rated excellent, 15 rated good, 46 rated fair, 20 rated poor, 2 rated useless, and 1 not rated). Additionally within the 188 records associated with one or more submitted pump test, there are 104 records (pump test: 0 rated excellent, 7 rated good, 33 rated fair, 25 rated poor, 33 rated useless, and 6 not rated) that have sufficient well yield test data to calculate transmissivity using the Vorhis (1979) numerical method (appendix D). However within those 104 records, only 53 records relate to pump tests having a calculated transmissivity value (0 rated excellent, 7 rated good, 30 rated fair, 14 rated poor, 2 rated useless, and 0 not rated). Within those 53 records are 46 non-duplicate records (39 inside Harney Basin, 7 surrounding the basin, and 32 corresponding to the list in appendix H).

Calculating Specific Capacity then Transmissivity from Well Yield Test Data

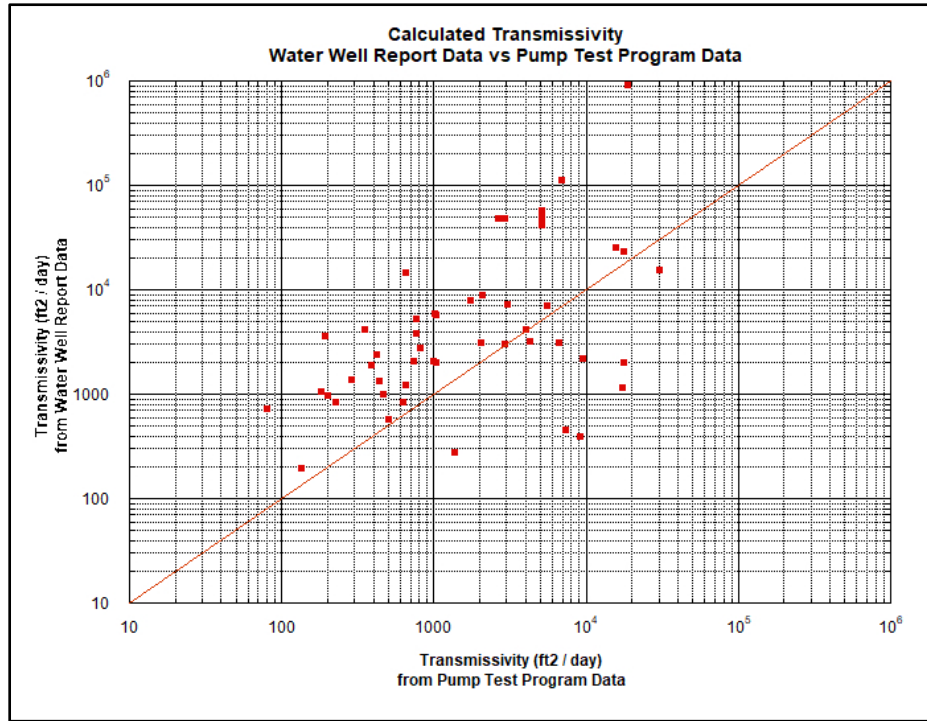
OWRD staff wrote and executed a Python script to (a) query the previously noted 2,478 records in the master hydraulic property data table, (b) select the previously noted 1,451 non-duplicate records, (c) calculate a specific capacity for each record selected using the well yield test data, and then (d) calculate a transmissivity from the calculated specific capacity for each record using the Vorhis (1979) numerical method as described in appendix D. The script selected the 1,451 records because they met all the following criteria:

- The well yield test date must be on or after the most recent construction date recorded
- The well yield test type must be a pump (P) or bailer (B) test (other test types are excluded)
- A well yield test total drawdown must be entered (0-foot entries were assigned 0.5 feet to avoid calculation problems a zero value would create)
- The well yield test discharge rate must be greater than 0 gallons per minute
- The well yield test discharge rate must be the greatest rate whenever multiple well yield tests were conducted on the same date at a well on or after the most recent construction date recorded

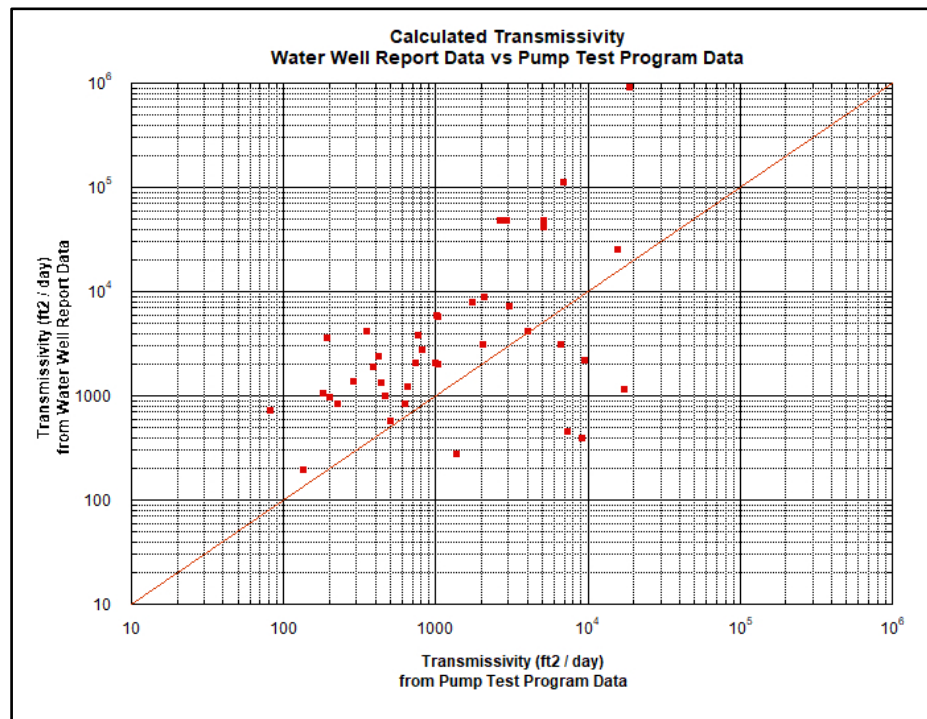
The specific capacity and transmissivity values calculated for each record are listed in appendix J.

Transmissivity Calculated by Vorhis Numerical Method versus Semi-log Graphical Method

Figure I-2 graphically compares transmissivity calculated via the Vorhis (1979) method using well yield test derived data (vertical axis) versus transmissivity calculated via the semi-log graphical method using pump test derived data (horizontal axis) for the few records having transmissivity calculated by both methods. Graph A in figure I-2 compares transmissivity related to both methods for 53 of 2,478 records (about 2.15 percent) that includes duplicates previously described. Graph B in figure I-2 compares transmissivity related to both methods for 40 of 1,451 records (about 2.75 percent) that excludes duplicates. Graphs A and B show a trend that somewhat parallels the one-to-one line (red line). Additionally, figures I-2 and I-3 show most (about 80-percent) of the transmissivity calculated via the Vorhis (1979) method using well yield test derived data is larger than the transmissivity calculated via the semi-log graphical method using pump test derived data (about 60-percent is between 1 to 10 times larger).



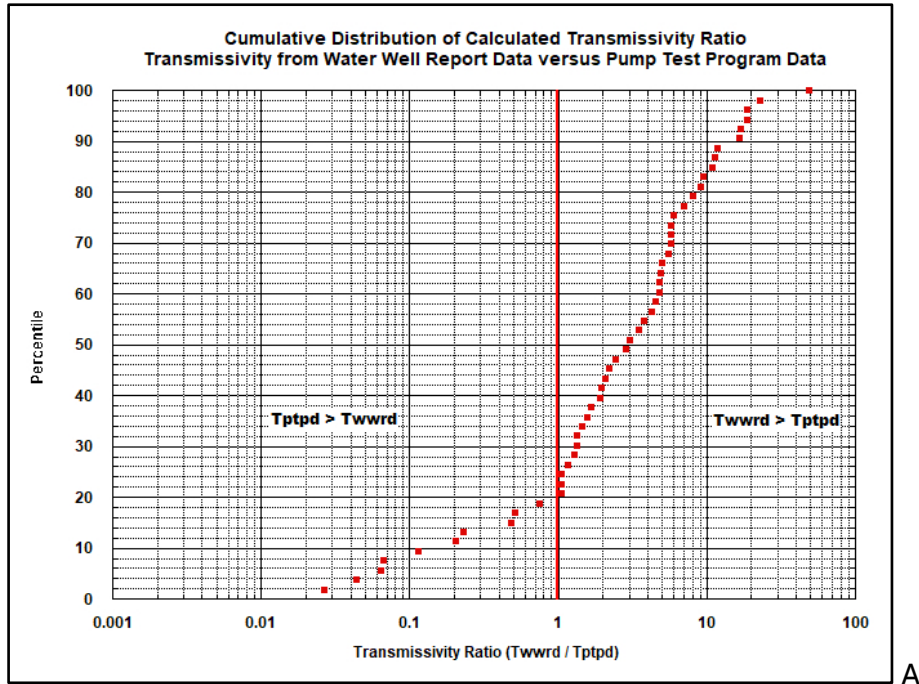
A



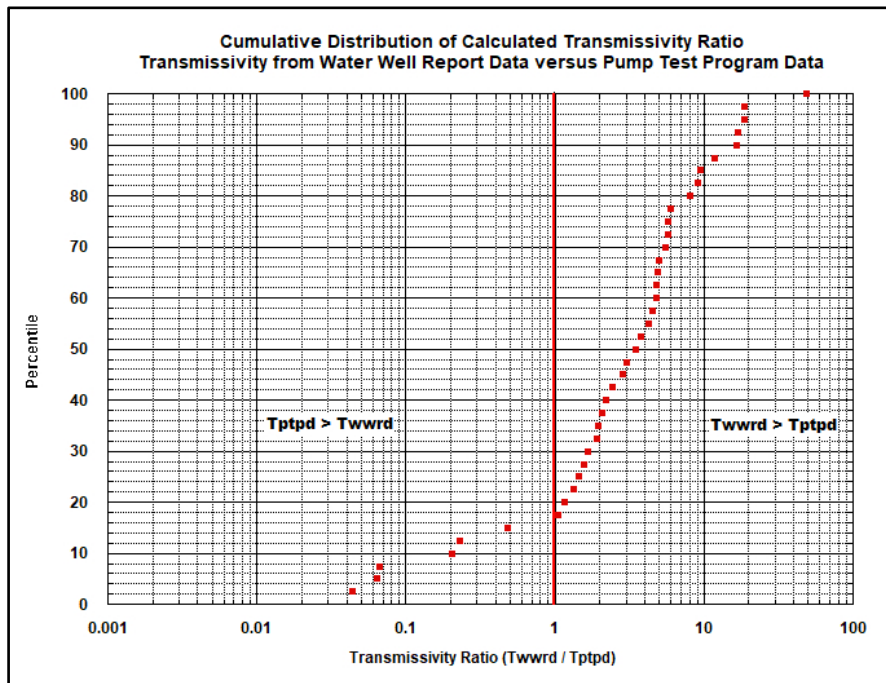
B

Figure I-2. Comparison of transmissivity values calculated by Vorhis method using well yield test data from well reports versus by semi-log graphical method using pump test program data

[Red line in both graphs is 1:1 line, Graph A shows 53 of 2,478 records that includes duplicates, Graph B shows 40 of 1,451 records that excludes duplicates]



A



B

Figure I-3. Cumulative distribution of ratios of transmissivity values calculated by Vorhis method using well yield test data ($T_{w wrd}$) from well reports versus by semi-log graphical method using pump test program data (T_{ptpd})

[Graph A shows 53 of 2,478 records that includes duplicates, Graph B shows 40 of 1,451 records that excludes duplicates, $T_{w wrd}$ means transmissivity from water well report data, T_{ptpd} means transmissivity from pump test program data]

Appendix J:

Table listing wells with well yield test data and related Harney Basin study hydraulic property calculation results
(See notes at end of table)

OWRD Well ID Pumped Well Groundwater Database	Well Location (best available)				Well Construction				Well OPI Units		Well Yield Test				Calculated			
	Public Land Survey (PLS) Township/Range-Section qtr qtr	Latitude (decimal)	Longitude (decimal)	Error Horizontal (feet)	Well Open Interval (OPI)			Well Bottom (ft. blsd)	Strat Unit(s)	Hydro-Strat Unit(s)	Test Type	Duration (hours)	Discharge Rate (gal / min)	Drawdown Final (feet)	Specific Capacity (gpm / ft)	Transmissivity (feet ² / day)	Hydraulic Conductivity (feet / day)	
					OPI Top (ft. blsd)	OPI Bottom (ft. blsd)	OPI height (feet)											OPI Diameter Weighted (inches)
CROO0000155	17.00S/23.00E-1da	44.12455249	-119.90443099	9,999.00	25	362	337	10.00	362	--	--	P	20	1,200	50	24.00	6,649.95	19.73
CROO0000595	16.00S/24.00E-14bc	44.18748502	-119.81828724	9,999.00	36	120	84	6.00	120	--	--	P	4	30	25	1.20	262.26	3.12
CROO0002427	15.00S/24.00E-35ab	44.23284284	-119.80565054	9,999.00	28	98	70	4.00	98	--	--	P	1	3	24	0.13	21.42	0.31
CROO0002432	15.00S/25.00E-33bb	44.23299888	-119.73367215	9,999.00	45	191	146	6.00	191	--	--	P	3	41	20	2.05	456.39	3.13
CROO0002738	16.00S/23.00E-5dc	44.20841967	-119.99067388	9,999.00	18	210	192	22.58	210	--	--	P	10	220	190	1.16	219.12	1.14
CROO0002740	16.00S/23.00E-7ab	44.20470119	-120.01089296	9,999.00	18	210	192	20.63	210	--	--	P	4	200	160	1.25	222.78	1.16
CROO0002741	16.00S/23.00E-8bb	44.20473122	-120.00077062	9,999.00	30	255	225	16.00	255	--	--	P	10	250	190	1.32	266.85	1.19
CROO0002750	16.00S/24.00E-24ba	44.17646437	-119.79278976	9,999.00	40	280	240	10.00	280	--	--	P	24	500	140	3.57	889.49	3.71
CROO0002753	16.00S/24.00E-30	44.15776668	-119.88971760	100.00	184	385	201	18.00	385	--	--	P	4	220	60	3.67	735.89	3.66
CROO0002754	16.00S/24.00E-31da	44.14068587	-119.88338940	25.00	19	400	381	10.56	400	--	--	P	48	500	150	3.33	732.57	1.92
CROO0002757	16.00S/24.00E-31bc	44.14319000	-119.90105000	4.00	25	385	360	10.00	385	--	--	P	6	1,800	6	300.00	89,540.28	248.72
CROO0002758	16.00S/24.00E-31bc	44.14312735	-119.90097713	25.00	25	385	360	10.00	385	--	--	P	6	1,800	6	300.00	67,047.31	186.24
CROO0002759	16.00S/24.00E-31bd	44.14314220	-119.89246019	50.00	25	392	367	10.00	392	--	--	P	10	1,200	50	24.00	6,379.87	17.38
CROO0002760	16.00S/24.00E-31cc	44.13468468	-119.90169085	9,999.00	25	180	155	16.00	180	--	--	P	24	3,000	35	85.71	24,465.36	157.84
CROO0002839	17.00S/22.00E-8	44.11144003	-120.11475056	9,999.00	30	135	105	6.00	135	--	--	P	1	7	90	0.08	11.64	0.11
CROO0002845	17.00S/22.00E-19ad	44.08656216	-120.13642735	20.00	30	403	373	9.69	403	--	--	P	4	600	230	2.61	562.31	1.51
CROO0002846	17.00S/23.00E-1ad	44.12973157	-119.90635008	25.00	25	150	125	10.00	150	--	--	P	10	1,800	35	51.43	14,307.41	114.46
CROO0002856	17.00S/23.00E-4ca	44.12363546	-119.97390137	9,999.00	80	174	94	12.00	180	--	--	B	3	100	0	200.00	54,957.22	584.65
CROO0002857	17.00S/23.00E-4	44.12758000	-119.97540000	9.00	18	95	77	12.00	95	--	--	B	1	20	95	0.21	30.09	0.39
CROO0002859	17.00S/23.00E-4ac	44.12741857	-119.96770128	50.00	144	239	95	8.00	239	--	--	P	8	920	120	7.67	1,923.40	20.25
CROO0002864	17.00S/24.00E-15da	44.09734433	-119.82181621	9,999.00	22	250	228	10.73	250	--	--	B	1	125	10	12.50	2,689.48	11.80
CROO0002865	17.00S/24.00E-15	44.10055740	-119.83130665	9,999.00	40	530	490	8.00	530	--	--	B	2	100	25	4.00	869.95	1.78
CROO0002866	17.00S/24.00E-15db	44.09434223	-119.82748631	9,999.00	19	270	251	10.88	270	--	--	B	2	100	5	20.00	4,676.37	18.63
CROO0002867	17.00S/24.00E-15bc	44.09918512	-119.83481655	9,999.00	35	300	265	12.00	300	--	--	B	2	180	24	7.50	1,608.61	6.07
CROO0002868	17.00S/24.00E-15ad	44.09780310	-119.81963402	9,999.00	60	250	190	10.00	250	--	--	B	2	100	15	6.67	1,457.01	7.67
CROO0002893	18.00S/22.00E-5dd	44.03403755	-120.10208232	9,999.00	333	460	127	6.00	460	--	--	P	6	17	46	0.37	76.06	0.60
CROO0002920	19.00S/22.00E-27cc	43.89817614	-120.07825558	50.00	40	215	175	12.00	215	--	--	P	4	780	30	26.00	6,402.78	36.59
CROO0002929	20.00S/22.00E-25dc	43.80289000	-120.02475000	50.00	13	50	37	18.00	50	Qs (57); HLPu (43)	YBF (57); HLP (43)	P	3	3,000	1	3,000.00	916,407.06	24,502.86
CROO0002936	21.00S/22.00E-3bbc	43.78290000	-120.07802000	5.00	20	220	200	16.00	220	Tts (67); HLPu (23); Qs (10)	OBF (67); HLP (23); YBF (10)	P	4	1,100	79	13.92	3,155.28	15.78
CROO0002975	15.00S/24.00E-35ab	44.23284284	-119.80565054	9,999.00	120	150	30	4.00	150	--	--	P	4	21	92	0.23	46.69	1.56
CROO0003129	20.00S/22.00E-28bc	43.80909322	-120.09557351	9,999.00	60	426	366	7.35	426	--	--	P	1	10	19	0.53	92.15	0.25
CROO0050968	17.00S/24.00E-26bc	44.06994368	-119.81702999	9,999.00	25	90	65	6.00	90	--	--	P	1	40	63	0.63	117.47	1.81
CROO0050969	17.00S/24.00E-14cc	44.09199214	-119.81696594	9,999.00	40	76	36	6.00	76	--	--	P	1	9	63	0.14	22.85	0.63
CROO0051564	21.00S/22.00E-8cd	43.75796133	-120.11035432	9,999.00	65	70	5	6.00	70	--	--	P	1	18	1	18.00	4,324.48	864.90
CROO0051653	20.00S/22.00E-28dd	43.78695700	-120.07837100	10.00	20	200	180	16.00	200	--	--	P	1	380	130	2.92	519.54	2.89
CROO0051694	17.00S/23.00E-10dd	44.10647264	-119.94469416	9,999.00	34	50	16	5.00	50	--	--	P	1	40	5	8.00	1,863.51	116.47
CROO0051699	18.00S/23.00E-4ac	44.04152897	-119.96503499	9,999.00	45	148	103	6.00	148	--	--	P	1	43	29	1.48	295.26	2.87
CROO0051828	20.00S/22.00E-28	43.78592147	-120.07849266	100.00	18	400	382	14.86	400	--	--	B	1	100	0	200.00	49,991.97	130.87
CROO0051962	19.00S/22.00E-27bd	43.89503009	-120.07054966	9,999.00	40	210	170	12.00	210	--	--	B	1	200	1	200.00	51,385.49	302.27
CROO0052449	17.00S/23.00E-11bb	44.11722222	-119.93749999	0.00	303	403	100	12.00	403	--	--	P	1	1,500	8	187.50	47,976.75	479.77
CROO0052642	20.00S/22.00E-34bc	43.79452200	-120.07791500	10.00	20	400	380	16.00	400	--	--	B	1	100	1	100.00	23,620.75	62.16
CROO0054031	20.00S/22.00E-27db	43.80502000	-120.06264000	5.00	42	186	144	16.00	186	--	--	P	8	3,880	71	54.65	14,224.45	98.78
GRAN00000004	16.00S/31.00E-8-8dc																	

Appendix J:

Table listing wells with well yield test data and related Harney Basin study hydraulic property calculation results
(See notes at end of table)

OWRD Well ID Pumped Well Groundwater Database	Well Location (best available)				Well Construction					Well Bottom (ft. blsd)	Well OPI Units		Test Type	Well Yield Test			Calculated		
	Public Land Survey (PLS) Township/Range-Section qtr qtr	Latitude (decimal)	Longitude (decimal)	Error Horizontal (feet)	Well Open Interval (OPI)				Strat Unit(s)		Hydro-Strat Unit(s)	Duration (hours)		Discharge Rate (gal / min)	Drawdown Final (feet)	Specific Capacity (gpm / ft)	Transmissivity (feet ² / day)	Hydraulic Conductivity (feet / day)	
					OPI Top (ft. blsd)	OPI Bottom (ft. blsd)	OPI height (feet)	OPI Diameter Weighted (inches)											
HARN0000011	19.00S/32.50E-3bb	43.95804800	-118.64425200	150.00	42	194	152	12.00	194	--	--	P	8	285	140	2.04	439.39	2.89	
HARN0000014	19.00S/34.00E-18cca	43.91044815	-118.58624962	150.00	207	402	195	6.00	402	--	--	B	2	7	300	0.02	3.29	0.02	
HARN0000018	19.00S/36.00E-31abc	43.87824031	-118.33771860	150.00	30	505	475	9.07	505	--	--	B	1	20	80	0.25	38.85	0.08	
HARN0000019	19.00S/36.00E-30daa	43.88747002	-118.32810085	9,999.00	30	228	198	11.00	228	--	--	P	4	744	126	5.90	1,327.53	6.70	
HARN0000020	19.00S/36.00E-31cb	43.87137411	-118.34512818	9,999.00	20	528	508	6.67	528	--	--	P	1	12	150	0.08	11.72	0.02	
HARN0000021	20.00S/25.00E-34	43.79240748	-119.70703509	9,999.00	21	26	5	2.00	26	Trt (100)	OBF (100)	P	24	50	0	100.00	35,483.33	7,096.67	
HARN0000022	20.00S/27.00E-5	43.86592471	-119.50610993	9,999.00	10	88	78	1.00	88	Qs (81); Tov (19)	YBF (81); UVR (19)	P	24	2	0	4.00	1,301.74	16.69	
HARN0000023	20.00S/27.00E-28bb	43.81309600	-119.49145200	25.00	100	380	280	8.00	400	Tov (100)	UVR (100)	P	5	50	20	2.50	562.08	2.01	
HARN0000024	20.00S/27.00E-22	43.82383015	-119.46650411	9,999.00	5	62	57	1.30	62	Qs (93); Trt (7)	YBF (93); OBF (7)	P	24	2	0	4.00	1,268.15	22.25	
HARN0000026	20.00S/30.00E-18bda	43.83800800	-119.16933500	250.00	19	100	81	8.00	100	QTsu (100)	OBF (100)	B	1	7	0	14.00	3,173.74	39.18	
HARN0000027	20.00S/31.00E-33ca	43.79057326	-119.01075417	9,999.00	260	505	245	5.15	505	Tts (100)	OBF (100)	P	4	12	83	0.14	27.26	0.11	
HARN0000028	20.00S/33.50E-2adb	43.87049625	-118.60989169	9,999.00	20	150	130	6.00	150	--	--	B	1	10	100	0.10	15.39	0.12	
HARN0000029	20.00S/34.00E-4bda	43.86124687	-118.53897588	300.00	32	395	364	6.00	395	--	--	B	1	3	320	0.01	1.06	0.00	
HARN0000031	20.00S/34.00E-4cbd	43.85519238	-118.54363569	300.00	18	47	29	6.00	47	--	--	B	1	15	22	0.68	126.96	4.38	
HARN0000032	20.00S/34.00E-12dbc	43.84171950	-118.47667543	300.00	13	120	107	6.00	120	--	--	B	1	20	40	0.50	90.51	0.85	
HARN0000033	20.00S/34.00E-13ba	43.83509475	-118.47999711	9,999.00	22	350	328	6.00	350	--	--	P	4	18	285	0.06	10.71	0.03	
HARN0000036	20.00S/35.00E-26abb	43.80769354	-118.37598865	300.00	22	116	94	6.00	116	--	--	P	24	10	31	0.32	73.04	0.78	
HARN0000037	20.00S/35.00E-26abc	43.80551799	-118.37734799	300.00	25	90	65	6.00	90	--	--	B	1	24	29	0.83	156.77	2.41	
HARN0000041	20.00S/35.00E-34ddd	43.78035160	-118.38879171	300.00	45	108	63	6.00	108	--	--	B	1	35	5	7.00	1,573.32	24.97	
HARN0000042	20.00S/36.00E-3dd	43.85361853	-118.27038136	9,999.00	100	200	100	10.00	200	--	--	P	1	100	20	5.00	1,011.73	10.12	
HARN0000043	20.00S/36.00E-4dc	43.85360757	-118.29526228	9,999.00	30	125	95	6.00	125	--	--	P	4	20	31	0.65	134.39	1.41	
HARN0000047	20.00S/36.00E-30acc	43.80565622	-118.33262665	300.00	22	105	83	6.00	105	--	--	B	1	30	15	2.00	408.18	4.92	
HARN0000049	20.00S/36.00E-32bba	43.79308868	-118.32488855	100.00	22	285	263	11.19	285	--	--	P	4	250	128	1.95	402.37	1.53	
HARN0000055	22.00S/31.00E-21dcc	43.64329900	-119.00800900	250.00	30	216	186	6.00	216	Tts (62); Trt (38)	OBF (100)	B	2	15	5	3.00	666.68	3.58	
HARN0000057	21.00S/35.00E-13dbc	43.74415054	-118.36065589	500.00	22	250	228	6.00	250	--	--	B	2	45	22	2.05	441.65	1.94	
HARN0000060	21.00S/35.00E-24	43.73247921	-118.36094945	9,999.00	41	407	366	5.00	407	--	--	P	7	5	122	0.04	7.29	0.02	
HARN0000065	22.00S/26.00E-29cd	43.62838098	-119.62918815	9,999.00	180	350	170	6.00	350	Tdm (100)	DML (100)	P	1	12	275	0.04	6.10	0.04	
HARN0000067	22.00S/26.00E-30dbd	43.63014630	-119.64412630	500.00	36	100	64	10.00	100	QTsu (100)	OBF (100)	B	1	100	0	200.00	52,572.63	821.45	
HARN0000068	22.00S/26.00E-35cc	43.61376053	-119.57417817	9,999.00	60	260	200	6.00	260	Tdm (100)	DML (100)	P	1	6	2	3.00	632.39	3.16	
HARN0000071	22.00S/30.00E-23dd	43.64420780	-119.08135703	9,999.00	30	50	20	12.00	56	Qs (100)	YBF (100)	P	3	60	35	1.71	337.31	16.87	
HARN0000078	22.00S/30.00E-25ac	43.63739315	-119.06651363	9,999.00	31	242	211	6.00	242	Trt (53); Tts (47)	OBF (100)	P	2	25	50	0.50	96.29	0.46	
HARN0000079	22.00S/30.00E-25ba	43.64081927	-119.07150170	9,999.00	19	52	33	12.00	53	Qs (100)	YBF (100)	P	9	120	5	24.00	6,196.34	187.77	
HARN0000081	22.00S/30.00E-35bb	43.62562600	-119.09846700	500.00	75	165	90	10.00	165	Ta (100)	SFD (100)	P	3	245	27	9.07	2,089.64	23.22	
HARN0000082	22.00S/30.00E-35bb	43.62562592	-119.09846718	9,999.00	40	122	82	8.00	122	Ta (51); QTsu (45); Tts (4)	SFD (51); OBF (49)	B	1	40	0	80.00	20,416.86	248.99	
HARN0000084	22.00S/30.00E-35bbb	43.62760582	-119.09646638	100.00	20	98	78	12.00	98	QTsu (100)	OBF (100)	B	2	100	0	200.00	53,640.70	692.14	
HARN0000089	22.00S/31.00E-18ac	43.66671983	-119.04702848	9,999.00	300	410	110	6.00	410	Tts (100)	OBF (100)	P	2	15	2	7.50	1,779.48	16.18	
HARN0000090	22.00S/31.00E-21dd	43.64497106	-119.00263665	9,999.00	40	120	80	8.00	120	Trt (100)	OBF (100)	P	4	15	10	1.50	319.11	3.99	
HARN0000093	22.00S/31.00E-21da	43.64858710	-119.00261174	9,999.00	82	120	38	6.00	120	QTsu (100)	OBF (100)	P	3	10	34	0.29	56.03	1.47	
HARN0000099	22.00S/31.00E-27bb	43.64299949	-118.99715168	9,999.00	240	490	250	11.00	490	QTsu (82); UNKN (18)	OBF (82); UNKN (18)	P	3	900	200	4.50	970.27	3.88	
HARN0000100	22.00S/31.00E-27db	43.63518200	-118.98894500	1,000.00	37	300	263	12.00	300	Tts (67); Trt (33)	OBF (100)	P	6	535	67	7.99	1,865.14	7.09	
HARN0000101	22.00S/31.00E-27ad	43.63728042	-118.98356634	9,999.00	19	400	382	9.43	400	Tts (87); Trt (13)	OBF (100)	P	2	120	16	7.50	1,668.14	4.37	
HARN0000103	22.00S/31.00E-28bc	43.63765790	-119.01778689	9,999.00	90	285	195	6.00	285	Tts (65); Trt (35)	OBF								

Appendix J:

Table listing wells with well yield test data and related Harney Basin study hydraulic property calculation results
(See notes at end of table)

OWRD Well ID Pumped Well Groundwater Database	Well Location (best available)				Well Construction				Well Bottom (ft. blsd)	Well OPI Units		Test Type	Well Yield Test			Calculated		
	Public Land Survey (PLS) Township/Range-Section qtr qtr	Latitude (decimal)	Longitude (decimal)	Error Horizontal (feet)	Well Open Interval (OPI)					Strat Unit(s)	Hydro-Strat Unit(s)		Duration (hours)	Discharge Rate (gal / min)	Drawdown Final (feet)	Specific Capacity (gpm / ft)	Transmissivity (feet ² / day)	Hydraulic Conductivity (feet / day)
					OPI Top (ft. blsd)	OPI Bottom (ft. blsd)	OPI height (feet)	OPI Diameter Weighted (inches)										
HARN0000170	22.00S/32.00E-31db	43.61956129	-118.92936752	9,999.00	27	160	133	6.00	160	Tts (69); Trt (31)	OBF (100)	P	1	20	12	1.67	335.12	2.52
HARN0000174	22.00S/32.00E-32cd	43.61555484	-118.91457730	9,999.00	70	110	40	8.00	110	QTsu (100)	OBF (100)	P	2	15	22	0.68	128.30	3.21
HARN0000178	22.00S/32.00E-34bb	43.62538646	-118.88122231	9,999.00	1	305	304	1.00	305	--	--	P	10	1,500	1	1,500.00	609,320.61	2,004.34
HARN0000180	22.00S/32.00E-35dd	43.61530457	-118.84447284	9,999.00	40	60	20	6.00	60	QTsu (100)	OBF (100)	P	1	15	3	5.00	1,096.12	54.81
HARN0000186	22.00S/32.00E-36bbb	43.62778444	-118.84191050	200.00	60	611	551	9.42	611	QTsu (100)	OBF (100)	P	4	110	51	2.16	460.13	0.84
HARN0000187	23.00S/31.00E-12cd	43.58683361	-118.95303510	9,999.00	180	220	40	8.00	220	QTsu (100)	OBF (100)	P	3	15	9	1.67	349.55	8.74
HARN0000190	22.00S/32.50E-13ca	43.66201084	-118.72071096	9,999.00	95	195	100	6.00	195	QTsu (100)	OBF (100)	P	2	30	13	2.31	502.86	5.03
HARN0000191	22.00S/32.50E-18dc	43.65785654	-118.81300648	50.00	18	330	312	12.00	330	QTsu (100)	OBF (100)	P	1	150	100	1.50	264.30	0.85
HARN0000193	22.00S/32.50E-18aad	43.66862204	-118.80917780	500.00	20	445	425	6.00	445	QTsu (100)	OBF (100)	P	4	110	80	1.38	303.59	0.71
HARN0000196	22.00S/32.50E-25ba	43.63870903	-118.72179253	150.00	30	89	59	12.00	89	QTsu (100)	OBF (100)	P	4	1,560	30	52.00	13,393.45	227.01
HARN0000198	22.00S/32.50E-26abd	43.63891859	-118.73474820	0.40	20	260	240	12.00	260	QTsu (100)	OBF (100)	P	7	650	106	6.13	1,421.27	5.92
HARN0000199	22.00S/32.50E-26ad	43.63531053	-118.73205872	150.00	25	350	325	12.00	350	QTsu (100)	OBF (100)	P	4	320	100	3.20	677.97	2.09
HARN0000201	22.00S/32.50E-30ac	43.63683818	-118.81556981	9,999.00	55	67	12	6.00	67	QTsu (100)	OBF (100)	P	48	20	14	1.43	374.38	31.20
HARN0000202	22.00S/32.50E-30cdb	43.63143698	-118.82065733	100.00	30	647	617	12.00	647	QTsu (98); UNKN (2)	OBF (98); UNKN (2)	P	1	450	166	2.71	504.49	0.82
HARN0000205	22.00S/32.50E-36ba	43.62585037	-118.72074265	9,999.00	120	140	20	4.00	145	QTsu (100)	OBF (100)	P	4	15	8	1.88	448.49	22.42
HARN0000206	22.00S/33.00E-30cab	43.62702500	-118.70372100	50.00	71	345	274	12.00	345	QTsu (100)	OBF (100)	P	6	341	51	6.69	1,542.30	5.63
HARN0000207	22.00S/32.50E-36ddb	43.62003317	-118.71360322	50.00	80	840	760	12.00	840	QTsu (100)	OBF (100)	P	5	100	95	1.05	207.52	0.27
HARN0000210	22.00S/32.50E-36aab	43.62735323	-118.71370595	50.00	20	180	160	12.00	186	QTsu (100)	OBF (100)	P	12	540	80	6.75	1,634.69	10.22
HARN0000211	22.00S/32.50E-36aac	43.62362565	-118.71371499	50.00	52	132	80	12.00	132	QTsu (100)	OBF (100)	P	6	560	91	6.15	1,411.10	17.57
HARN0000212	22.00S/32.50E-36ba	43.62581618	-118.72159111	100.00	50	170	120	12.00	170	QTsu (100)	OBF (100)	P	4	347	100	3.47	739.81	6.17
HARN0000213	22.00S/32.50E-36ab	43.62664787	-118.72731129	100.00	58	270	212	12.00	270	QTsu (100)	OBF (100)	P	4	617	90	6.86	1,538.51	7.26
HARN0000214	22.00S/32.50E-36cb	43.61850622	-118.72576213	9,999.00	38	457	419	11.03	457	QTsu (100)	OBF (100)	P	4	100	130	0.77	146.95	0.35
HARN0000218	22.00S/33.00E-19aa	43.65042869	-118.69113205	9,999.00	20	320	300	12.00	320	QTsu (100)	OBF (100)	P	3	300	55	5.45	1,177.73	3.93
HARN0000219	22.00S/33.00E-27da	43.62814225	-118.63255840	0.20	20	833	813	14.50	833	Tov (69); Tts (19); QTsu (12)	UVR (69); OBF (31)	P	4	190	182	1.04	195.20	0.24
HARN0000222	22.00S/33.00E-29da	43.62764080	-118.67665880	0.00	30	275	245	9.31	275	QTsu (100)	OBF (100)	P	4	200	92	2.17	464.95	1.90
HARN0000224	22.00S/33.00E-31aaa	43.62305000	-118.68858000	25.00	145	225	80	6.00	225	QTsu (100)	OBF (100)	B	2	25	20	1.25	259.73	3.25
HARN0000230	22.00S/33.00E-34bbb	43.62220795	-118.64765327	500.00	160	167	7	6.00	167	QTsu (100)	OBF (100)	B	2	20	18	1.11	228.71	32.67
HARN0000232	22.00S/34.00E-20bba	43.65195320	-118.56628033	250.00	20	134	114	8.00	134	QTsu (96); Tov (4)	OBF (96); UVR (4)	B	2	30	30	1.00	194.54	1.71
HARN0000233	22.00S/35.00E-17ddc	43.65509010	-118.43330439	9,999.00	110	115	5	6.00	115	--	--	B	1	25	30	0.83	157.96	31.59
HARN0000238	23.00S/26.00E-5bab	43.61024000	-119.63099200	250.00	32	141	109	8.00	141	QTsu (100)	OBF (100)	B	3	20	0	40.00	10,472.53	96.08
HARN0000242	23.00S/26.00E-8bb	43.59556942	-119.63420567	9,999.00	53	180	127	6.00	180	QTsu (100)	OBF (100)	P	2	20	40	0.50	96.29	0.76
HARN0000243	23.00S/26.00E-10ca	43.58897271	-119.58793220	0.10	258	550	293	18.00	550	QTsu (65); HLPu (35)	OBF (65); HLP (35)	B	1	9	0	18.00	3,673.65	12.56
HARN0000244	23.00S/26.00E-14db	43.57405000	-119.56630000	25.00	95	175	80	5.00	175	QTsu (100)	OBF (100)	P	1	25	50	0.50	93.56	1.17
HARN0000245	23.00S/26.00E-14bb	43.57951706	-119.57656088	100.00	20	135	115	14.63	135	QTsu (100)	OBF (100)	B	3	40	5	8.00	1,725.60	15.01
HARN0000246	23.00S/26.00E-15ac	43.57694000	-119.58255000	25.00	59	206	148	6.00	206	QTsu (100)	OBF (100)	B	2	15	10	1.50	316.20	2.14
HARN0000248	23.00S/26.00E-23cd	43.55459300	-119.55940000	500.00	20	80	60	10.00	80	Qs (100)	YBF (100)	B	1	25	30	0.83	143.71	2.40
HARN0000251	23.00S/26.00E-25ac	43.54992000	-119.54145000	25.00	105	256	151	16.00	256	UNKN (55); HLPu (36); Tts (9)	UNKN (55); HLP (36); OBF (9)	P	4	2,000	31	64.52	16,238.94	107.54
HARN0000253	23.00S/26.00E-28cba	43.54613000	-119.61314000	25.00	192	195	3	6.00	200	Tts (65); HLPu (35)	OBF (65); HLP (35)	P	4	10	0	20.00	5,291.53	1,959.83
HARN0000256	23.00S/27.00E-3dd	43.60049393	-119.46023501	9,999.00	25	295	270	16.00	295	--	--	P	30	2,763	71	38.92	10,750.43	39.82
HARN0000260	23.00S/27.00E-7bd	43.59087189	-119.52741457	50.00	170	407	237	16.00	407	Tobg (92); QTsu (8)	HLP (92); OBF (8)	B	1	20	0	40.00	8,846.52	37.33
HARN0000261	23.00S/27.00E-19cdd	43.55419600	-119.52690000	100.00	20	525												

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OWRD Well ID Pumped Well Groundwater Database	Well Location (best available)				Well Construction				Well Bottom (ft. blsd)	Well OPI Units		Test Type	Well Yield Test			Calculated		
	Public Land Survey (PLS) Township/Range-Section qtr qtr	Latitude (decimal)	Longitude (decimal)	Error Horizontal (feet)	Well Open Interval (OPI)			Strat Unit(s)		Hydro-Strat Unit(s)	Duration (hours)		Discharge Rate (gal / min)	Drawdown Final (feet)	Specific Capacity (gpm / ft)	Transmissivity (feet ² / day)	Hydraulic Conductivity (feet / day)	
					OPI Top (ft. blsd)	OPI Bottom (ft. blsd)	OPI height (feet)											OPI Diameter Weighted (inches)
HARN0000342	23.00S/31.00E-3aa	43.61240722	-118.98254530	9,999.00	88	222	134	12.00	222	QTsu (59); Trt (36); Tts (5)	OBF (100)	P	4	200	60	3.33	708.46	5.29
HARN0000350	23.00S/31.00E-5bc	43.60894027	-119.03759202	9,999.00	189	190	1	6.00	190	--	--	P	1	15	24	0.63	115.47	115.47
HARN0000356	23.00S/31.00E-5aac	43.61270348	-119.02525287	100.00	18	400	382	12.00	400	Tts (61); QTsu (22); Trt (15); QTv (2)	OBF (83); OBF (15); PVD (2)	P	4	1,000	22	45.45	11,607.93	30.39
HARN0000357	23.00S/31.00E-5cb	43.60553578	-119.03670366	200.00	14	205	191	14.00	205	QTsu (100)	OBF (100)	P	41	700	59	11.86	3,160.36	16.55
HARN0000358	23.00S/31.00E-5aad	43.61038175	-119.02098117	100.00	60	438	378	14.00	438	Tts (68); Qs (18); Trt (14)	OBF (82); YBF (18)	P	4	1,000	44	22.73	5,432.27	14.37
HARN0000359	23.00S/31.00E-5cbb	43.60714874	-119.04034851	150.00	15	200	185	12.00	200	QTsu (100)	OBF (100)	P	28	700	55	12.73	3,389.61	18.32
HARN0000366	23.00S/31.00E-6ac	43.60882173	-119.04736810	9,999.00	36	55	19	6.00	55	QTsu (100)	OBF (100)	P	4	25	14	1.79	401.95	21.16
HARN0000367	23.00S/31.00E-6db	43.60503340	-119.04739312	9,999.00	20	260	240	12.00	260	QTsu (100)	OBF (100)	P	5	400	33	12.12	2,877.93	11.99
HARN0000373	23.00S/31.00E-6bc	43.60764215	-119.05497450	150.00	85	150	65	8.00	150	QTsu (100)	OBF (100)	B	1	85	5	17.00	3,908.03	60.12
HARN0000374	23.00S/31.00E-6bcb	43.60881050	-119.05756461	60.00	161	170	9	6.00	170	QTsu (100)	OBF (100)	P	15	350	10	35.00	10,327.37	1,147.49
HARN0000375	23.00S/31.00E-6bd	43.60876264	-119.05220830	9,999.00	126	129	3	6.00	129	QTsu (100)	OBF (100)	P	72	40	11	3.64	1,032.05	344.02
HARN0000376	23.00S/31.00E-6ccd	43.60884781	-119.05176573	9,999.00	110	138	28	8.00	140	QTsu (100)	OBF (100)	P	4	200	55	3.64	826.63	29.52
HARN0000378	23.00S/31.00E-6bcc	43.60709795	-119.05716439	100.00	55	75	20	12.00	120	QTsu (100)	OBF (100)	P	3	200	33	6.06	1,319.11	65.96
HARN0000383	23.00S/31.00E-6add	43.60775398	-119.04061170	50.00	76	185	109	8.00	185	QTsu (100)	OBF (100)	B	1	100	20	5.00	1,048.66	9.62
HARN0000387	23.00S/31.00E-7dd	43.58737564	-119.04288217	9,999.00	26	35	9	6.00	35	Qs (100)	YBF (100)	P	1	20	6	3.33	708.46	78.72
HARN0000394	23.00S/31.00E-7	43.59270128	-119.04986417	9,999.00	83	210	127	6.00	210	Trt (94); QTsu (6)	OBF (100)	P	5	40	8	5.00	1,228.10	9.67
HARN0000396	23.00S/31.00E-7	43.59270128	-119.04986417	9,999.00	15	55	40	6.00	55	Qs (100)	YBF (100)	P	4	50	2	25.00	6,705.09	167.63
HARN0000399	23.00S/31.00E-7	43.59270128	-119.04986417	9,999.00	12	26	14	6.00	27	Qs (100)	YBF (100)	P	1	20	5	4.00	862.19	61.59
HARN0000400	23.00S/31.00E-7bb	43.59772900	-119.05773887	9,999.00	85	100	15	6.00	100	Qs (100)	YBF (100)	P	3	50	6	8.33	2,046.83	136.46
HARN0000407	23.00S/31.00E-9dbb	43.59257560	-119.01015085	50.00	55	364	309	12.00	364	QTsu (100)	OBF (100)	P	22	1,100	65	16.92	4,519.10	14.62
HARN0000415	23.00S/31.00E-10dd	43.58866182	-118.98482317	9,999.00	100	215	115	12.00	215	QTsu (100)	OBF (100)	P	10	800	75	10.67	2,631.19	22.88
HARN0000418	23.00S/31.00E-10bb	43.59818262	-118.99765602	9,999.00	12	40	28	6.00	52	QTsu (100)	OBF (100)	P	2	30	14	2.14	464.32	16.58
HARN0000419	23.00S/31.00E-10da	43.59097347	-118.98278613	9,999.00	195	210	15	6.00	210	QTsu (100)	OBF (100)	P	20	18	31	0.58	135.33	9.02
HARN0000420	23.00S/31.00E-10dd	43.58739822	-118.98278024	9,999.00	195	200	5	6.00	200	QTsu (100)	OBF (100)	P	6	25	10	2.50	593.16	118.63
HARN0000421	23.00S/31.00E-10bb	43.59932834	-118.99648304	9,999.00	195	203	8	12.00	203	QTsu (100)	OBF (100)	P	15	2,000	31	64.52	18,228.06	2,278.51
HARN0000423	23.00S/31.00E-11cd	43.58719303	-118.97285705	9,999.00	80	85	5	6.00	85	QTsu (100)	OBF (100)	P	1	30	15	2.00	408.18	81.64
HARN0000424	23.00S/31.00E-11b	43.59624786	-118.97537972	9,999.00	120	130	10	6.00	130	QTsu (100)	OBF (100)	P	2	15	15	1.00	204.09	20.41
HARN0000425	23.00S/31.00E-11c	43.58908349	-118.97537972	9,999.00	62	65	3	8.00	65	QTsu (100)	OBF (100)	P	18	15	30	0.50	109.71	36.57
HARN0000434	23.00S/31.00E-11cc	43.58719303	-118.97285705	9,999.00	200	280	80	8.00	280	QTsu (100)	OBF (100)	P	4	120	10	12.00	2,962.52	37.03
HARN0000437	23.00S/31.00E-11db	43.58927951	-118.96903078	9,999.00	87	97	10	8.00	97	QTsu (100)	OBF (100)	P	4	100	58	1.72	370.76	37.08
HARN0000438	23.00S/31.00E-11dc	43.58705879	-118.96790030	9,999.00	80	83	3	6.00	83	QTsu (100)	OBF (100)	P	3	32	4	8.00	1,959.62	653.21
HARN0000439	23.00S/31.00E-11bbb	43.59806503	-118.97784681	9,999.00	107	170	63	6.00	170	QTsu (100)	OBF (100)	B	2	150	5	30.00	7,796.89	123.12
HARN0000443	23.00S/31.00E-13cb	43.57397279	-118.95589479	9,999.00	275	280	5	12.00	280	QTsu (100)	OBF (100)	P	5	450	128	3.52	763.23	152.65
HARN0000459	23.00S/31.00E-15abb	43.58492089	-118.99036316	750.00	40	60	20	17.71	60	--	--	P	2	600	50	12.00	2,512.57	125.63
HARN0000469	23.00S/31.00E-18cc	43.57298948	-119.05731577	9,999.00	75	80	5	6.00	80	QTsu (100)	OBF (100)	P	4	15	2	7.50	1,864.48	372.90
HARN0000470	23.00S/31.00E-18bb	43.58386646	-119.05738330	9,999.00	18	140	122	24.38	140	Qs (100)	YBF (100)	P	19	800	50	16.00	3,849.84	31.56
HARN0000474	24.00S/34.00E-29ca	43.45535657	-118.56227665	9,999.00	20	325	305	12.00	325	Tov (78); Tts (22)	UVR (78); OBF (22)	P	5	280	100	2.80	597.36	1.96
HARN0000478	23.00S/31.00E-18bb	43.58265383	-119.05592047	9,999.00	133	290	157	16.00	290	QTsu (69); QTv (31)	OBF (69); PVD (31)	P	5	1,737	17	102.18	26,854.80	171.05
HARN0000482	23.00S/31.00E-18cb	43.57710301	-119.05911158	9,999.00	52	85	33	8.00	85	QTsu (100)	OBF (100)	P	24	70	3	23.33	6,692.18	202.79
HARN0000483	23.00S/31.00E-19da	43.56189452	-119.04247868	9,999.00	0	113	113	15.33	113	QTsu (100)	OBF (100)	P	7	1,450	40	36.25	9,165.06	81.11
HARN0000484	23.00S/31.00E-19daa-																	

Appendix J:

Table listing wells with well yield test data and related Harney Basin study hydraulic property calculation results
(See notes at end of table)

OWRD Well ID Pumped Well Groundwater Database	Well Location (best available)				Well Construction				Well Bottom (ft. blsd)	Well OPI Units		Well Yield Test				Calculated		
	Public Land Survey (PLS) Township/Range-Section qtr qtr	Latitude (decimal)	Longitude (decimal)	Error Horizontal (feet)	Well Open Interval (OPI)					Strat Unit(s)	Hydro-Strat Unit(s)	Test Type	Duration (hours)	Discharge Rate (gal / min)	Drawdown Final (feet)	Specific Capacity (gpm / ft)	Transmissivity (feet ² / day)	Hydraulic Conductivity (feet / day)
					OPI Top (ft. blsd)	OPI Bottom (ft. blsd)	OPI height (feet)	OPI Diameter Weighted (inches)										
HARN0000609	23.00S/32.00E-30ab	43.55199331	-118.92771501	50.00	18	312	294	18.14	312	QTsu (100)	OBF (100)	P	50	1,100	125	8.80	2,255.59	7.67
HARN0000613	23.00S/32.00E-31bbc	43.53920430	-118.94052952	250.00	90	240	150	12.00	240	QTsu (100)	OBF (100)	B	1	50	40	1.25	216.42	1.44
HARN0000614	23.00S/32.00E-32da	43.53194855	-118.90509760	9,999.00	77	110	33	6.00	110	QTsu (100)	OBF (100)	P	2	15	10	1.50	316.20	9.58
HARN0000617	23.00S/32.00E-33dd	43.53026200	-118.88734400	150.00	52	250	198	18.18	250	QTsu (100)	OBF (100)	P	8	1,050	58	18.10	4,310.18	21.77
HARN0000618	23.00S/32.00E-33dc	43.52688300	-118.89238300	100.00	165	180	15	6.00	180	QTsu (100)	OBF (100)	P	4	15	10	1.50	333.34	22.22
HARN0000629	23.00S/32.50E-3bc	43.60782060	-118.76567174	9,999.00	466	483	17	6.00	483	QTsu (100)	OBF (100)	P	6	15	1	15.00	3,997.37	235.14
HARN0000631	23.00S/32.50E-3da	43.60301948	-118.75214230	9,999.00	18	332	314	20.29	332	QTsu (100)	OBF (100)	P	11	447	132	3.39	718.42	2.29
HARN0000633	23.00S/32.50E-4ab	43.61058724	-118.77328185	9,999.00	73	365	292	12.00	365	QTsu (100)	OBF (100)	P	48	600	90	6.67	1,763.84	6.04
HARN0000635	23.00S/32.50E-4ba	43.61154025	-118.78503897	9,999.00	90	210	120	12.00	210	QTsu (100)	OBF (100)	P	8	410	40	10.25	2,484.36	20.70
HARN0000637	23.00S/32.50E-6cb	43.60486091	-118.82013370	0.10	69	205	136	10.00	205	QTsu (100)	OBF (100)	B	1	80	11	7.27	1,516.72	11.12
HARN0000640	23.00S/32.50E-7ca	43.58988259	-118.82004396	9,999.00	50	60	10	8.00	60	QTsu (100)	OBF (100)	P	3	20	5	4.00	896.65	89.67
HARN0000641	23.00S/32.50E-10dc	43.58603877	-118.75571093	9,999.00	80	102	22	6.00	102	QTsu (100)	OBF (100)	P	8	20	32	0.63	137.01	6.23
HARN0000644	23.00S/32.50E-10cdc	43.58468529	-118.76228386	75.00	40	205	165	12.00	205	QTsu (100)	OBF (100)	P	6	1,250	50	25.00	6,305.96	38.22
HARN0000645	23.00S/32.50E-11dd	43.58472000	-118.73306000	25.00	98	118	20	6.00	118	QTsu (100)	OBF (100)	B	1	30	22	1.36	269.65	13.48
HARN0000646	23.00S/32.50E-11dd	43.58610000	-118.72862000	25.00	38	122	84	12.00	122	QTsu (99)	OBF (99)	P	7	475	27	17.59	4,380.91	52.05
HARN0000648	23.00S/32.50E-13ba	43.58051762	-118.72070333	50.00	40	239	199	12.00	239	QTsu (100)	OBF (100)	P	12	1,467	2	733.50	233,381.28	1,172.77
HARN0000649	23.00S/32.50E-13bb	43.58057788	-118.72569854	50.00	38	236	198	12.00	236	QTsu (90); Trt (10)	OBF (100)	P	15	700	45	15.56	4,035.70	20.38
HARN0000651	23.00S/32.50E-14cc	43.57333681	-118.74351793	25.00	250	450	200	12.00	450	Trt (75); QTsu (25)	OBF (100)	P	5	1,323	88	15.03	3,622.52	18.11
HARN0000652	23.00S/32.50E-18ba	43.58263585	-118.82004916	9,999.00	100	135	35	6.00	135	QTsu (100)	OBF (100)	P	6	20	40	0.50	105.40	3.01
HARN0000653	23.00S/32.50E-18	43.57718223	-118.81507159	9,999.00	93	120	27	6.00	120	QTsu (100)	OBF (100)	P	2	15	25	0.60	117.37	4.35
HARN0000654	23.00S/32.50E-20cc	43.55722999	-118.80551746	9,999.00	35	50	15	6.00	50	QTsu (100)	OBF (100)	P	1	15	12	1.25	245.37	16.36
HARN0000655	23.00S/32.50E-20bb	43.56809858	-118.80552282	9,999.00	100	110	10	6.00	110	QTsu (100)	OBF (100)	P	4	14	5	2.80	650.94	65.09
HARN0000657	23.00S/32.50E-24abc	43.56617890	-118.71577840	0.70	18	330	312	21.31	330	QTsu (100)	OBF (100)	P	12	2,000	100	20.00	4,823.02	15.46
HARN0000658	23.00S/32.50E-26cbb	43.54719331	-118.74807676	150.00	161	253	92	6.00	253	QTsu (100)	OBF (100)	B	2	60	1	60.00	16,269.88	176.85
HARN0000659	23.00S/32.50E-31d	43.52874100	-118.81118100	1,200.00	18	332	314	19.98	332	QTsu (100)	OBF (100)	P	20	675	120	5.63	1,298.55	4.14
HARN0000662	23.00S/32.50E-32b	43.53665334	-118.79731528	9,999.00	40	400	360	22.73	400	Tts (54); Qs (46)	OBF (54); YBF (46)	P	6	360	335	1.07	192.61	0.54
HARN0000665	23.00S/32.50E-33cb	43.53036510	-118.78320543	25.00	113	310	197	12.00	310	QTsu (100)	OBF (100)	B	1	125	52	2.40	442.53	2.25
HARN0000669	23.00S/33.00E-5bca	43.60332859	-118.68437575	54.00	20	99	79	14.43	99	QTsu (100)	OBF (100)	B	2	100	5	20.00	4,491.03	57.21
HARN0000671	23.00S/33.00E-4cb	43.60132084	-118.66588177	50.00	33	108	75	14.00	108	QTsu (100)	OBF (100)	B	1	20	5	4.00	749.79	10.00
HARN0000672	23.00S/33.00E-4ba	43.60843824	-118.66170125	9,999.00	20	189	169	17.03	189	QTsu (100)	OBF (100)	P	6	454	100	4.54	966.03	5.72
HARN0000673	23.00S/33.00E-5bd	43.60339122	-118.68135483	9,999.00	70	90	20	6.00	92	QTsu (100)	OBF (100)	P	3	25	1	25.00	6,588.18	329.41
HARN0000674	23.00S/33.00E-6ac	43.60187227	-118.68980444	9,999.00	59	80	21	12.00	80	QTsu (100)	OBF (100)	P	3	1,000	32	31.25	7,642.67	363.94
HARN0000675	23.00S/33.00E-6ad	43.60203200	-118.69852975	9,999.00	79	93	14	10.00	93	QTsu (100)	OBF (100)	B	1	100	10	10.00	2,138.08	152.72
HARN0000677	23.00S/33.00E-8aac	43.59072731	-118.67409393	9,999.00	20	365	345	13.73	365	QTsu (100)	OBF (100)	P	12	1,250	47	26.60	6,918.61	20.05
HARN0000679	23.00S/33.00E-12dc	43.58153245	-118.59673741	9,999.00	89	615	526	8.84	615	QTsu (100)	OBF (100)	P	1	350	150	2.33	452.13	0.86
HARN0000682	23.00S/33.00E-12bb	43.59202943	-118.60538232	9,999.00	94	505	411	12.00	505	Tov (69); QTsu (31)	UVR (69); OBF (31)	P	3	80	105	0.76	139.62	0.34
HARN0000683	23.00S/33.00E-12adb	43.58909977	-118.59351944	200.00	18	160	142	6.00	160	QTsu (93); Tov (7)	OBF (93); UVR (7)	B	2	40	1	40.00	10,583.07	74.53
HARN0000685	23.00S/33.00E-13db	43.56931499	-118.59899046	50.00	20	130	110	16.92	130	QTsu (100)	OBF (100)	P	8	1,300	30	43.33	11,036.62	100.33
HARN0000686	23.00S/33.00E-18bb	43.57671000	-118.70721000	25.00	148	155	7	12.00	155	QTsu (100)	OBF (100)	P	4	568	60	9.47	2,174.67	310.67
HARN0000687	23.00S/33.00E-18	43.57659000	-118.70737000	25.00	90	120	30	6.00	120	QTsu (100)	OBF (100)	P	4	30	21	1.43	316.32	10.54
HARN0000688	23.00S/33.00E-18caa	43.57188443	-1															

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Table listing wells with well yield test data and related Harney Basin study hydraulic property calculation results
(See notes at end of table)

OWRD Well ID Pumped Well Groundwater Database	Well Location (best available)				Well Construction				Well Bottom (ft. blsd)	Well OPI Units		Test Type	Well Yield Test			Calculated		
	Public Land Survey (PLS) Township/Range-Section qtr qtr	Latitude (decimal)	Longitude (decimal)	Error Horizontal (feet)	Well Open Interval (OPI)					Strat Unit(s)	Hydro-Strat Unit(s)		Duration (hours)	Discharge Rate (gal / min)	Drawdown Final (feet)	Specific Capacity (gpm / ft)	Transmissivity (feet ² / day)	Hydraulic Conductivity (feet / day)
					OPI Top (ft. blsd)	OPI Bottom (ft. blsd)	OPI height (feet)	OPI Diameter Weighted (inches)										
HARN0000738	23.00S/34.00E-30bc	43.54721425	-118.58444468	50.00	20	102	82	19.57	102	QTsu (100)	OBF (100)	P	4	920	70	13.14	2,878.70	35.11
HARN0000739	23.00S/34.00E-30ba	43.54724232	-118.57437053	50.00	20	107	87	19.29	107	QTsu (100)	OBF (100)	P	7	650	85	7.65	1,680.86	19.32
HARN0000740	23.00S/34.00E-30cb	43.54178785	-118.58692366	9,999.00	18	100	82	18.31	100	QTsu (100)	OBF (100)	P	11	420	74	5.68	1,271.66	15.51
HARN0000742	23.00S/34.00E-32ac	43.53246000	-118.55580000	25.00	77	328	252	12.00	328	QTsu (59); Tov (41)	OBF (59); UVR (41)	P	24	225	80	2.81	672.73	2.67
HARN0000745	24.00S/25.00E-29ab	43.46563700	-119.74404600	50.00	502	642	140	6.00	662	Tts (100)	OBF (100)	P	24	25	10	2.50	649.74	4.64
HARN0000746	24.00S/25.00E-27ac	43.46384300	-119.70359800	50.00	545	625	80	6.00	625	Tts (100)	OBF (100)	P	24	25	14	1.79	454.31	5.68
HARN0000747	24.00S/25.00E-24ba	43.47977800	-119.66692900	50.00	515	655	140	6.00	675	Tts (100)	OBF (100)	P	24	25	2	12.50	3,575.22	25.54
HARN0000748	24.00S/25.00E-27bb	43.46630753	-119.71356349	9,999.00	40	90	50	6.00	90	--	--	P	1	15	9	1.67	335.12	6.70
HARN0000749	24.00S/27.00E-2db	43.51734000	-119.44240000	25.00	34	320	287	18.00	320	QTsu (74); QTb (23); Tts (3)	OBF (77); HLP (23)	P	4	2,200	20	110.00	28,221.75	98.51
HARN0000755	24.00S/27.00E-11bab	43.51096268	-119.45084250	0.10	32	400	368	26.00	400	Tts (49); QTsu (39); QTb (12)	OBF (88); HLP (12)	P	8	2,850	161	17.70	4,000.36	10.87
HARN0000759	24.00S/27.00E-14dd	43.48354000	-119.44031000	25.00	37	487	450	16.00	487	Tts (73); QTb (22); Qs (5)	OBF (73); HLP (22); YBF (5)	P	12	1,130	104	10.87	2,613.68	5.81
HARN0000760	24.00S/27.00E-15bb	43.49701000	-119.47432000	25.00	19	182	164	6.00	182	HLPu (46); Tts (46); QTb (8)	HLP (54); OBF (46)	B	1	5	0	10.00	2,306.18	14.11
HARN0000762	24.00S/27.00E-22ba	43.48236000	-119.46914000	25.00	77	88	11	6.00	88	Tts (100)	OBF (100)	B	1	13	2	6.50	1,453.02	132.09
HARN0000763	24.00S/27.00E-23bc	43.47648489	-119.43560777	9,999.00	20	400	380	16.00	400	Tts (97); QTb (3)	OBF (97); HLP (3)	B	1	50	0	100.00	23,620.75	62.16
HARN0000768	24.00S/29.00E-1bb	43.52410684	-119.19474308	50.00	65	815	750	10.23	815	--	--	P	4	550	90	6.11	1,392.00	1.86
HARN0000770	24.00S/29.00E-2cab	43.51741487	-119.21144474	50.00	110	150	40	12.00	150	--	--	B	1	100	45	2.22	406.18	10.15
HARN0000771	24.00S/29.00E-2cb	43.51783561	-119.21680393	9,999.00	20	100	80	8.00	100	--	--	P	4	15	3	5.00	1,162.75	14.53
HARN0000772	24.00S/29.00E-11da	43.50320261	-119.20183312	9,999.00	60	150	90	12.00	150	--	--	P	12	350	20	17.50	4,510.14	50.11
HARN0000773	24.00S/29.00E-11da	43.50320261	-119.20183312	9,999.00	21	127	106	8.00	127	--	--	P	3	15	1	15.00	3,687.34	34.79
HARN0000775	24.00S/29.00E-13db	43.48783464	-119.18439832	50.00	35	505	470	14.00	505	QTsu (100)	OBF (100)	P	4	1,500	115	13.04	2,998.94	6.38
HARN0000776	24.00S/29.00E-12bb	43.51219676	-119.19741736	9,999.00	83	245	162	12.00	245	--	--	P	4	750	49	15.31	3,636.66	22.45
HARN0000781	24.00S/29.00E-13ab	43.49760333	-119.18503804	50.00	40	527	487	10.88	527	--	--	P	6	2,500	98	25.51	6,524.63	13.40
HARN0000788	24.00S/29.00E-13bb	43.49524140	-119.19664758	9,999.00	58	210	152	11.00	210	QTsu (100)	OBF (100)	B	1	200	0	400.00	108,411.95	713.24
HARN0000797	24.00S/30.00E-2bc	43.52270124	-119.09528380	100.00	120	190	70	14.00	190	QTv (100)	PVD (100)	P	2	600	4	150.00	38,776.49	553.95
HARN0000805	24.00S/30.00E-3bb	43.52532622	-119.11687472	9,999.00	25	85	60	8.00	85	--	--	P	4	10	20	0.50	97.27	1.62
HARN0000808	24.00S/30.00E-4bb	43.52527923	-119.13654195	9,999.00	40	185	145	8.00	185	Trt (55); Tts (45)	OBF (100)	P	2	15	1	15.00	3,587.89	24.74
HARN0000812	24.00S/30.00E-7bbb	43.51131544	-119.17734330	0.10	53	160	107	10.00	160	Trt (100)	OBF (100)	P	1	300	57	5.26	1,069.45	9.99
HARN0000813	24.00S/30.00E-7cdd	43.49796348	-119.16926700	0.20	18	347	329	19.76	347	QTv (69); QTsu (31)	PVD (69); OBF (31)	P	3	1,800	84	21.43	4,757.59	14.46
HARN0000815	24.00S/30.00E-8bdd	43.50690668	-119.15125182	210.00	110	300	190	12.00	300	Trd (76); QTsu (24)	SFD (76); OBF (24)	P	3	500	88	5.68	1,230.63	6.47
HARN0000816	24.00S/30.00E-8aa	43.50921116	-119.14232844	9,999.00	46	137	91	12.00	137	Trd (52); QTsu (48)	SFD (52); OBF (48)	P	6	320	100	3.20	699.36	7.69
HARN0000818	24.00S/32.00E-9aa	43.51050720	-118.88465205	9,999.00	80	160	80	12.00	160	QTsu (100)	OBF (100)	P	24	700	0	1,400.00	475,576.70	5,944.71
HARN0000824	24.00S/30.00E-12	43.50533585	-119.06931456	9,999.00	80	82	2	6.00	82	QTsu (100)	OBF (100)	P	2	20	11	1.82	389.04	194.52
HARN0000825	24.00S/30.00E-12cd	43.49983505	-119.07173254	9,999.00	440	597	157	8.00	597	QTsu (100)	OBF (100)	B	2	75	30	2.50	524.33	3.34
HARN0000827	24.00S/30.00E-15dd	43.48645017	-119.09907193	50.00	99	700	602	13.00	700	QTsu (100)	OBF (100)	P	5	2,100	85	24.71	6,088.93	10.12
HARN0000829	24.00S/30.00E-15ab	43.49754604	-119.10881139	500.00	68	630	563	12.73	630	QTsu (100)	OBF (100)	P	5	900	105	8.57	1,969.74	3.50
HARN0000830	24.00S/30.00E-17bab	43.49626922	-119.14870959	100.00	120	324	204	12.00	324	QTsu (100)	OBF (100)	P	4	1,050	61	17.21	4,122.84	20.21
HARN0000833	24.00S/30.00E-17bab	43.49611380	-119.15191085	9,999.00	70	300	230	12.00	300	QTv (65); QTsu (35)	PVD (65); OBF (35)	B	0	100	7	14.29	2,888.77	12.56
HARN0000836	24.00S/30.00E-18acb	43.49397605	-119.16899704	50.00	40	240	200	12.00	240	QTsu (52); QTv (48)	OBF (52); PVD (48)	P	3	1,117	46	24.28	5,838.52	29.19
HARN0000837	24.00S/30.00E-18dc	43.48443474	-119.16629255	100.00	100	425	325	12.00	425	QTsu (100)	OBF (100)	P	24	800	160	5.00	1,242.99	3.82
HARN0000844	24.00S/30.00E-26ddc	43.45552516	-119.08255611	50.00	90	501	411	16.00	501	QTsu (100)	OBF (100)	P	4	2,500	16	156.25	41,579.05	101.17
HARN0000848	24.00S/31.00E-5da																	

Appendix J:

Table listing wells with well yield test data and related Harney Basin study hydraulic property calculation results
(See notes at end of table)

OWRD Well ID Pumped Well Groundwater Database	Well Location (best available)				Well Construction				Well Bottom (ft. blsd)	Well OPI Units		Test Type	Well Yield Test			Calculated		
	Public Land Survey (PLS) Township/Range-Section qtr qtr	Latitude (decimal)	Longitude (decimal)	Error Horizontal (feet)	Well Open Interval (OPI)					Strat Unit(s)	Hydro-Strat Unit(s)		Duration (hours)	Discharge Rate (gal / min)	Drawdown Final (feet)	Specific Capacity (gpm / ft)	Transmissivity (feet ² / day)	Hydraulic Conductivity (feet / day)
					OPI Top (ft. blsd)	OPI Bottom (ft. blsd)	OPI height (feet)	OPI Diameter Weighted (inches)										
HARN0000945	24.00S/32.50E-1bc	43.51912260	-118.72836864	500.00	38	484	446	10.70	484	QTsu (100)	OBF (100)	P	2	700	100	7.00	1,519.97	3.41
HARN0000946	24.00S/32.50E-2ca	43.51706890	-118.74081135	9,999.00	30	40	10	6.00	40	QTsu (100)	OBF (100)	P	4	15	1	15.00	3,898.45	389.85
HARN0000949	24.00S/32.50E-11dc	43.49894717	-118.73567187	9,999.00	35	40	5	6.00	110	QTsu (100)	OBF (100)	P	4	15	10	1.50	333.34	66.67
HARN0000950	24.00S/32.50E-12ad	43.50753108	-118.70900576	150.00	20	470	450	12.00	470	QTsu (100)	OBF (100)	P	8	1,600	40	40.00	10,583.07	23.52
HARN0000953	24.00S/32.50E-13cba	43.49351013	-118.71835487	25.00	230	285	55	12.00	285	QTsu (100)	OBF (100)	P	20	1,152	102	11.29	2,924.15	53.17
HARN0000954	24.00S/32.50E-15bb	43.49526148	-118.76523508	9,999.00	18	299	281	18.02	299	QTsu (100)	OBF (100)	P	4	350	51	6.86	1,448.26	5.15
HARN0000955	24.00S/32.50E-16ab	43.49353100	-118.77281300	500.00	20	372	352	20.88	372	QTsu (100)	OBF (100)	P	8	1,300	60	21.67	5,124.26	14.56
HARN0000958	24.00S/32.50E-16ba	43.49391833	-118.78198514	100.00	19	379	360	17.99	379	QTsu (100)	OBF (100)	P	3	632	50	12.64	2,735.53	7.60
HARN0000959	24.00S/32.50E-16bd	43.49014300	-118.77772603	100.00	18	291	273	18.02	291	QTsu (100)	OBF (100)	P	10	534	54	9.89	2,295.44	8.41
HARN0000965	24.00S/32.50E-30add	43.46153037	-118.80831148	150.00	99	185	86	6.00	185	QTsu (100)	OBF (100)	B	2	45	54	0.83	167.56	1.95
HARN0000968	24.00S/32.50E-31aa	43.45203358	-118.80979053	9,999.00	170	180	10	6.00	180	QTsu (100)	OBF (100)	P	2	25	10	2.50	548.06	54.81
HARN0000974	24.00S/33.00E-1ddd	43.50781288	-118.59034298	150.00	171	187	16	6.00	187	QTsu (100)	OBF (100)	B	3	30	9	3.33	768.73	48.05
HARN0000975	24.00S/33.00E-1cda	43.51102775	-118.60209258	100.00	0	357	357	16.36	357	QTsu (100)	OBF (100)	P	10	1,000	100	10.00	2,354.70	6.60
HARN0000976	24.00S/33.00E-2bdc	43.51654018	-118.62176403	9,999.00	229	250	21	6.00	250	QTsu (100)	OBF (100)	P	7	30	2	15.00	4,034.94	189.17
HARN0000977	24.00S/33.00E-4ab	43.51854400	-118.65446900	500.00	20	380	360	20.86	380	QTsu (100)	OBF (100)	P	10	760	100	7.60	1,694.80	4.71
HARN0000980	24.00S/33.00E-7aac	43.50403705	-118.69384001	50.00	226	260	35	12.00	260	QTsu (100)	OBF (100)	P	4	1,325	20	66.25	17,324.98	502.17
HARN0000982	24.00S/33.00E-8cd	43.49513033	-118.68165103	50.00	168	500	332	16.78	500	QTsu (100)	OBF (100)	P	68	909	286	3.18	785.84	2.37
HARN0000983	24.00S/33.00E-8ca	43.49693254	-118.68376645	50.00	18	370	352	23.73	370	QTsu (100)	OBF (100)	P	23	585	168	3.48	764.73	2.17
HARN0000985	24.00S/33.00E-8bac	43.50451158	-118.68327686	50.00	18	620	602	25.12	620	QTsu (70); UNKN (30)	OBF (70); UNKN (30)	P	8	620	180	3.44	689.23	1.14
HARN0000986	24.00S/33.00E-8bac	43.50536079	-118.68177164	50.00	18	380	362	25.20	380	QTsu (100)	OBF (100)	P	8	1,350	180	7.50	1,596.59	4.41
HARN0000987	24.00S/33.00E-9ca	43.49854489	-118.66163456	9,999.00	18	395	377	23.72	395	QTsu (100)	OBF (100)	P	8	320	180	1.78	339.59	0.90
HARN0000992	24.00S/33.00E-9ab	43.50451000	-118.65430000	25.00	18	342	324	16.15	342	QTsu (100)	OBF (100)	P	6	600	55	10.91	2,497.68	7.71
HARN0000993	24.00S/33.00E-10dc	43.49491897	-118.63675614	9,999.00	200	400	200	16.00	400	QTsu (100)	OBF (100)	P	21	1,033	95	10.87	2,715.24	13.58
HARN0000996	24.00S/33.00E-13bb	43.49265863	-118.60549831	25.00	89	140	52	6.00	140	QTsu (100)	OBF (100)	P	24	100	10	10.00	2,824.05	54.84
HARN0000998	24.00S/33.00E-13bb	43.49129571	-118.60687984	9,999.00	170	305	135	6.00	305	QTsu (100)	OBF (100)	P	3	30	44	0.68	139.41	1.03
HARN0001000	24.00S/33.00E-13bb	43.49129571	-118.60687984	9,999.00	160	200	40	6.00	200	QTsu (100)	OBF (100)	P	1	60	40	1.50	298.98	7.47
HARN0001003	24.00S/33.00E-14dc	43.48048097	-118.61687103	9,999.00	160	180	20	6.00	180	QTsu (100)	OBF (100)	P	8	15	10	1.50	350.41	17.52
HARN0001005	24.00S/33.00E-14bd	43.48769573	-118.62183522	9,999.00	21	426	405	23.48	426	QTsu (100)	OBF (100)	P	8	1,400	94	14.89	3,373.33	8.33
HARN0001009	24.00S/33.00E-15cd	43.48227530	-118.64177649	25.00	230	340	110	12.00	340	QTsu (100)	OBF (100)	P	3	800	57	14.04	3,248.56	29.53
HARN0001013	24.00S/33.00E-16dd	43.48048031	-118.65175154	9,999.00	47	62	15	6.00	62	QTsu (100)	OBF (100)	P	2	40	13	3.08	685.05	45.67
HARN0001014	24.00S/33.00E-17b	43.48950168	-118.68388910	50.00	18	437	419	23.49	437	QTsu (100)	OBF (100)	P	8	746	182	4.10	841.13	2.01
HARN0001015	24.00S/33.00E-17dd	43.48047592	-118.67165929	9,999.00	360	460	100	12.00	460	QTsu (100)	OBF (100)	P	4	558	104	5.37	1,182.45	11.82
HARN0001016	24.00S/33.00E-18dba	43.48960811	-118.69410127	50.00	20	333	313	20.47	333	QTsu (100)	OBF (100)	P	8	800	85	9.41	2,103.25	6.72
HARN0001020	24.00S/33.00E-18bdb	43.48936527	-118.70231624	50.00	19	299	280	18.00	299	QTsu (100)	OBF (100)	P	3	1,013	61	16.61	3,668.37	13.10
HARN0001021	24.00S/33.00E-18bb	43.49132990	-118.70615213	9,999.00	220	240	20	5.00	240	QTsu (100)	OBF (100)	P	3	18	9	2.00	456.44	22.82
HARN0001022	24.00S/33.00E-20aaa	43.47782154	-118.67022349	500.00	36	104	68	6.00	104	QTsu (100)	OBF (100)	B	1	40	0	80.00	21,166.13	311.27
HARN0001026	24.00S/33.00E-18cac	43.48244562	-118.70264165	50.00	18	319	301	18.02	319	QTsu (100)	OBF (100)	P	2	909	86	10.57	2,184.94	7.26
HARN0001028	24.00S/33.00E-24bd	43.47501935	-118.60429987	50.00	106	402	296	12.00	402	QTsu (100)	OBF (100)	P	3	820	84	9.76	2,201.29	7.44
HARN0001030	24.00S/33.00E-24ab	43.47520606	-118.59455404	25.00	100	340	240	12.00	340	QTsu (100)	OBF (100)	P	6	500	95	5.26	1,193.35	4.97
HARN0001033	24.00S/33.00E-25ac	43.45982376	-118.59443075	50.00	20	185	165	18.10	185	QTsu (100)	OBF (100)	P	15	2,000	44	45.45	11,978.02	72.59
HARN0001034	24.00S/33.00E-24da	43.46967204	-118.5919618															

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(See notes at end of table)

OWRD Well ID Pumped Well Groundwater Database	Well Location (best available)				Well Construction				Well Bottom (ft. blsd)	Well OPI Units		Test Type	Well Yield Test			Calculated		
	Public Land Survey (PLS) Township/Range-Section qtr qtr	Latitude (decimal)	Longitude (decimal)	Error Horizontal (feet)	Well Open Interval (OPI)					Strat Unit(s)	Hydro-Strat Unit(s)		Duration (hours)	Discharge Rate (gal / min)	Drawdown Final (feet)	Specific Capacity (gpm / ft)	Transmissivity (feet ² / day)	Hydraulic Conductivity (feet / day)
					OPI Top (ft. blsd)	OPI Bottom (ft. blsd)	OPI height (feet)	OPI Diameter Weighted (inches)										
HARN0001098	25.00S/30.00E-35db	43.35626739	-119.09383932	9,999.00	18	175	157	24.08	175	QTv (89); QTSu (11)	PVD (89); OBF (11)	P	24	2,000	36	55.56	14,729.80	93.82
HARN0001101	25.00S/30.00E-36ad	43.36374900	-119.06392600	2.00	70	80	10	12.00	80	QTv (100)	PVD (100)	P	16	1,050	20	52.50	14,685.67	1,468.57
HARN0001106	25.00S/31.00E-4cba	43.43068354	-119.01745266	150.00	90	170	80	12.00	170	QTSu (100)	OBF (100)	B	2	50	8	6.25	1,321.70	16.52
HARN0001109	25.00S/31.00E-6ad	43.43376646	-119.04240711	9,999.00	40	60	20	8.00	60	QTSu (100)	OBF (100)	P	2	15	2	7.50	1,708.72	85.44
HARN0001112	25.00S/31.00E-8dd	43.41203465	-119.02241084	9,999.00	40	140	100	8.00	140	QTSu (100)	OBF (100)	P	4	15	21	0.71	143.19	1.43
HARN0001114	25.00S/31.00E-9db	43.41571795	-119.00752382	9,999.00	23	100	77	16.00	100	QTSu (100)	OBF (100)	P	1	900	41	21.95	4,637.63	60.23
HARN0001115	25.00S/31.00E-9ba	43.41024200	-119.00998500	250.00	20	100	81	23.02	100	QTSu (100)	OBF (100)	P	13	1,150	32	35.94	8,966.92	111.39
HARN0001116	25.00S/31.00E-10cb	43.41410198	-118.99765125	100.00	18	205	187	30.00	205	QTSu (100)	OBF (100)	P	12	550	90	6.11	1,285.94	6.88
HARN0001117	25.00S/31.00E-9ad	43.42129694	-119.00136773	100.00	18	165	147	24.47	165	QTSu (100)	OBF (100)	P	8	550	140	3.93	798.10	5.43
HARN0001118	25.00S/31.00E-9dd	43.41390464	-119.00482681	100.00	18	180	162	24.79	180	QTSu (100)	OBF (100)	P	8	490	145	3.38	676.61	4.18
HARN0001123	25.00S/31.00E-15cb	43.40115807	-118.99732015	9,999.00	40	60	20	8.00	60	QTSu (100)	OBF (100)	P	2	15	5	3.00	638.23	31.91
HARN0001124	25.00S/31.00E-15cc	43.39610145	-118.99607570	500.00	90	110	20	8.00	110	QTSu (100)	OBF (100)	P	2	15	7	2.14	443.96	22.20
HARN0001125	25.00S/31.00E-16ca	43.40272024	-119.00954158	200.00	70	110	40	12.00	110	QTSu (100)	OBF (100)	P	5	800	22	36.36	9,286.35	232.16
HARN0001126	25.00S/31.00E-16cc	43.39768108	-119.01725029	9,999.00	21	115	94	6.00	115	QTSu (100)	OBF (100)	P	3	10	20	0.50	99.66	1.06
HARN0001127	25.00S/31.00E-16dc	43.39957888	-119.00428712	500.00	18	100	82	13.73	100	QTSu (100)	OBF (100)	P	8	1,000	20	50.00	13,191.80	160.88
HARN0001128	25.00S/31.00E-16ab	43.40676922	-119.00772560	100.00	18	142	124	21.19	142	QTSu (100)	OBF (100)	P	8	869	53	16.40	3,794.72	30.60
HARN0001130	25.00S/31.00E-21bc	43.39049119	-119.01723511	9,999.00	20	390	370	6.00	390	QTSu (100)	OBF (100)	P	4	10	80	0.13	22.63	0.06
HARN0001131	25.00S/31.00E-21ab	43.39564642	-119.00816845	9,999.00	70	100	30	12.00	100	QTSu (100)	OBF (100)	P	6	750	50	15.00	3,658.47	121.95
HARN0001133	25.00S/31.00E-21ac	43.39210633	-119.00851372	50.00	30	90	60	8.00	90	QTSu (100)	OBF (100)	B	1	70	0	140.00	37,004.88	616.75
HARN0001135	25.00S/31.00E-22ab	43.39405929	-118.98750219	9,999.00	18	160	142	20.88	160	QTSu (100)	OBF (100)	P	14	1,000	140	7.14	1,624.88	11.44
HARN0001138	25.00S/31.00E-23ca	43.38681426	-118.97274137	9,999.00	200	235	35	6.00	235	QTSu (100)	OBF (100)	P	24	10	10	1.00	244.95	7.00
HARN0001141	25.00S/31.00E-25b	43.37772597	-118.95537396	9,999.00	60	100	40	12.00	100	QTSu (100)	OBF (100)	P	4	600	56	10.71	2,483.04	62.08
HARN0001142	25.00S/31.00E-25ad	43.37595971	-118.94294841	9,999.00	145	440	295	12.00	440	QTSu (100)	OBF (100)	P	3	150	88	1.70	335.23	1.14
HARN0001144	25.00S/31.00E-27bc	43.37730153	-118.99542913	100.00	81	105	24	12.00	105	QTv (100)	PVD (100)	P	3	1,100	52	21.15	5,038.49	209.94
HARN0001145	25.00S/31.00E-27daa	43.38055167	-119.00406579	100.00	75	179	104	8.89	179	QTSu (72); QTv (22); Tts (6)	OBF (78); PVD (22)	P	3	288	63	4.57	1,018.94	9.80
HARN0001146	25.00S/31.00E-28ad	43.37742642	-119.00039801	100.00	67	123	56	15.00	123	QTSu (100)	OBF (100)	P	10	1,320	25	52.80	14,016.42	250.29
HARN0001147	25.00S/31.00E-28ca	43.37048771	-119.00969370	100.00	22	107	85	20.87	107	QTSu (100)	OBF (100)	P	2	534	16	33.38	7,370.70	86.71
HARN0001149	25.00S/31.00E-28da	43.37036681	-119.00484645	100.00	22	116	94	21.10	116	QTSu (100)	OBF (100)	P	2	688	28	24.57	5,293.74	56.32
HARN0001150	25.00S/31.00E-29ccb	43.36976587	-119.03730337	300.00	70	209	139	8.00	209	QTSu (100)	OBF (100)	P	4	100	70	1.43	302.77	2.18
HARN0001151	25.00S/31.00E-30	43.37475079	-119.04926997	9,999.00	104	182	78	12.00	182	QTSu (100)	OBF (100)	P	2	300	45	6.67	1,416.92	18.17
HARN0001154	25.00S/31.00E-30ddb	43.36780099	-119.04368181	600.00	290	660	370	10.00	660	QTSu (89); QTv (11)	OBF (89); PVD (11)	B	2	52	250	0.21	33.43	0.09
HARN0001156	25.00S/31.00E-31cb	43.35849629	-119.05661230	9,999.00	59	61	2	6.00	61	QTv (100)	PVD (100)	P	2	15	1	15.00	3,728.96	1,864.48
HARN0001157	25.00S/31.00E-32aaa	43.36549842	-119.02084716	450.00	65	111	46	8.39	111	QTv (70); Tts (17); QTSu (13)	PVD (70); OBF (30)	P	2	314	40	7.85	1,782.08	38.74
HARN0001161	25.00S/31.00E-34bc	43.36171538	-118.99667953	9,999.00	125	176	51	14.00	176	QTSu (100)	OBF (100)	B	1	40	5	8.00	1,591.84	31.21
HARN0001189	25.00S/32.50E-3bbb	43.43862372	-118.76654136	175.00	40	95	55	6.00	95	QTSu (100)	OBF (100)	B	3	20	10	2.00	444.45	8.08
HARN0001208	25.00S/32.50E-22	43.38848795	-118.75817185	9,999.00	18	652	634	19.63	652	QTSu (55); QTv (37); Tts (7)	OBF (62); PVD (37)	P	10	60	236	0.25	42.84	0.07
HARN0001213	25.00S/33.00E-1cdb	43.42416361	-118.60406987	100.00	190	205	15	12.00	205	QTSu (100)	OBF (100)	P	8	1,100	64	17.19	4,310.95	287.40
HARN0001214	25.00S/33.00E-1ac	43.43187578	-118.59459998	50.00	88	190	102	12.00	190	QTv (80); Tts (20)	PVD (80); OBF (20)	P	5	1,600	48	33.33	8,465.21	82.99
HARN0001220	25.00S/33.00E-9dc	43.40816066	-118.65644816	9,999.00	100	220	120	12.00	220	QTSu (100)	OBF (100)	P	4	420	70	6.00	1,333.35	11.11
HARN0001221	25.00S/33.00E-9dd	43.40816817	-118.65145614	9,999.00	40	544	504	11.37	544	QTSu (78); QTv (22)	OBF (78); PVD (22)	P	4	30				

Appendix J:

Table listing wells with well yield test data and related Harney Basin study hydraulic property calculation results
(See notes at end of table)

OWRD Well ID Pumped Well Groundwater Database	Well Location (best available)				Well Construction				Well Bottom (ft. blsd)	Well OPI Units		Test Type	Well Yield Test			Calculated		
	Public Land Survey (PLS) Township/Range-Section qtr qtr	Latitude (decimal)	Longitude (decimal)	Error Horizontal (feet)	Well Open Interval (OPI)					Strat Unit(s)	Hydro-Strat Unit(s)		Duration (hours)	Discharge Rate (gal / min)	Drawdown Final (feet)	Specific Capacity (gpm / ft)	Transmissivity (feet ² / day)	Hydraulic Conductivity (feet / day)
					OPI Top (ft. blsd)	OPI Bottom (ft. blsd)	OPI height (feet)	OPI Diameter Weighted (inches)										
HARN0001301	26.00S/25.00E-24	43.30213751	-119.66706289	9,999.00	313	499	187	6.00	499	--	--	P	2	8	0	16.00	3,994.41	21.42
HARN0001304	26.00S/28.00E-2bca	43.34916000	-119.33280000	25.00	20	950	930	12.00	950	Tts (95); Tts (3); QTb (2)	OBF (98); HLP (2)	P	4	180	90	2.00	408.18	0.44
HARN0001305	26.00S/28.00E-11dc	43.32595000	-119.32454000	10.00	78	90	12	6.00	90	QTsu (100)	OBF (100)	B	2	20	15	1.33	278.47	23.21
HARN0001306	26.00S/28.00E-12bc	43.33278394	-119.31487782	9,999.00	40	120	80	6.00	120	Tts (100)	OBF (100)	P	1	15	5	3.00	632.39	7.90
HARN0001309	26.00S/29.00E-5cc	43.33955791	-119.27657513	25.00	80	120	40	8.00	120	Tts (100)	OBF (100)	B	1	50	0	100.00	25,884.57	647.11
HARN0001311	26.00S/29.00E-17cd	43.31091568	-119.27077327	9,999.00	20	154	134	22.18	154	QTsu (100)	OBF (100)	P	3	300	120	2.50	456.45	3.41
HARN0001313	26.00S/29.00E-26ac	43.28885985	-119.20626748	9,999.00	735	1,200	465	12.00	1,200	Tts (100)	OBF (100)	P	1	10	50	0.20	28.41	0.06
HARN0001315	26.00S/30.00E-1ac	43.34747048	-119.06631411	9,999.00	40	70	30	12.00	70	QTV (73); Tts (17); QTsu (10)	PVD (73); OBF (17); OBF (10)	P	8	950	25	38.00	10,022.22	334.07
HARN0001316	26.00S/30.00E-1cb	43.34457746	-119.07886856	1.00	25	75	50	1.00	75	--	--	P	3	1,340	2	670.00	250,690.97	5,013.82
HARN0001317	26.00S/30.00E-1bd	43.34565000	-119.07378800	50.00	30	75	45	12.00	90	QTV (100)	PVD (100)	P	3	1,400	2	700.00	206,547.35	4,589.94
HARN0001318	26.00S/30.00E-1cb	43.34457500	-119.07887600	0.00	18	265	247	26.18	265	Tts (88); QTV (8); Qs (4)	OBF (88); PVD (8); YBF (4)	P	24	370	60	6.17	1,396.63	5.65
HARN0001322	26.00S/30.00E-2ab	43.34925657	-119.08397597	9,999.00	18	175	157	24.69	175	QTV (54); Tts (42); Qs (4)	PVD (54); OBF (42); YBF (4)	P	24	470	38	12.37	2,966.18	18.89
HARN0001323	26.00S/30.00E-2bc	43.34904108	-119.09384209	9,999.00	18	170	152	24.62	170	QTV (67); Tts (28); Qs (5)	PVD (67); OBF (28); YBF (5)	P	24	1,934	19	101.79	27,914.85	183.65
HARN0001324	26.00S/30.00E-6dd	43.34092662	-119.16162094	50.00	20	357	337	12.00	357	QTV (76); Tts (24)	PVD (76); OBF (24)	B	1	10	0	20.00	4,384.48	13.01
HARN0001330	26.00S/30.00E-9db	43.32721000	-119.12416000	25.00	20	312	292	8.00	312	Tts (100)	OBF (100)	B	1	5	0	10.00	2,211.63	7.57
HARN0001332	26.00S/30.00E-10cc	43.32689000	-119.11699000	25.00	18	260	242	12.00	260	--	--	P	10	1,255	6	209.17	61,704.88	254.98
HARN0001333	26.00S/30.00E-12bb	43.33475063	-119.07413461	250.00	45	90	45	12.00	110	QTV (100)	PVD (100)	P	3	1,600	4	400.00	114,407.16	2,542.38
HARN0001335	26.00S/30.00E-16ca	43.31625904	-119.12917730	0.30	120	330	210	15.00	330	Tts (68); QTV (32)	OBF (68); PVD (32)	P	4	1,200	40	30.00	7,239.14	34.47
HARN0001336	26.00S/30.00E-16cb	43.31581000	-119.13804000	25.00	18	255	237	20.36	255	QTsu (100)	OBF (100)	P	8	1,000	3	333.33	93,940.39	396.37
HARN0001338	26.00S/31.00E-17bd	43.31419076	-119.15140699	9,999.00	150	350	200	12.00	350	Tts (100)	OBF (100)	P	1	450	120	3.75	718.16	3.59
HARN0001340	26.00S/30.00E-18dad	43.31348600	-119.16021500	1,500.00	200	430	230	12.00	430	QTsu (100)	OBF (100)	P	3	635	104	6.11	1,329.69	5.78
HARN0001342	26.00S/31.00E-10dca	43.32761200	-118.98424900	300.00	348	365	17	6.00	365	QTsu (100)	OBF (100)	P	4	150	39	3.85	914.15	53.77
HARN0001344	26.00S/31.00E-12db	43.32892612	-118.94704072	9,999.00	51	55	4	6.00	55	QTsu (100)	OBF (100)	P	2	18	12	1.50	316.20	79.05
HARN0001348	26.00S/31.00E-18bd	43.32018448	-119.05404244	2.00	45	200	155	12.00	200	Tts (63); QTV (37)	OBF (63); PVD (37)	P	3	1,800	22	81.82	21,294.18	137.38
HARN0001349	26.00S/31.00E-18dbc	43.31320700	-119.04691200	100.00	175	335	160	6.00	335	Tts (96); QTV (4)	OBF (96); PVD (4)	B	2	20	8	2.50	548.06	3.43
HARN0001353	26.00S/31.00E-26bba	43.29250526	-118.97565945	500.00	185	230	45	11.06	230	QTsu (100)	OBF (100)	P	2	440	15	29.33	7,027.09	156.16
HARN0001361	26.00S/31.00E-33ac	43.26992912	-118.88510103	50.00	18	328	310	19.76	328	Qs (75); Qvb (11); Tts (8); QTV (6)	YBF (75); VB (11); OBF (8); PVD (6)	P	3	1,500	90	16.67	3,631.37	11.71
HARN0001362	26.00S/31.00E-34ac	43.27005600	-118.86311700	50.00	210	243	33	12.00	243	Qvb (100)	VB (100)	P	4	1,000	85	11.76	2,744.51	83.17
HARN0001363	26.00S/31.00E-34ddd	43.26208000	-118.85809000	15.00	91	147	56	12.00	147	QTV (100)	PVD (100)	P	6	900	11	81.82	22,216.05	396.72
HARN0001384	26.00S/33.00E-1dc	43.33447080	-118.58902689	50.00	177	244	67	12.00	244	Tdv (94); QTsu (6)	OBF (94); OBF (6)	P	30	1,255	26	48.27	13,952.63	208.25
HARN0001387	26.00S/33.00E-13daa	43.31181000	-118.58266000	15.00	42	101	59	12.00	101	QTV (100)	PVD (100)	P	3	880	19	46.32	11,624.79	197.03
HARN0001389	26.00S/33.00E-13dba	43.31232271	-118.58748834	50.00	91	170	79	12.00	170	QTV (100)	PVD (100)	P	3	775	22	35.23	8,684.32	109.93
HARN0001393	26.00S/33.00E-19ddc	43.29135037	-118.68624860	0.10	1	97	96	12.00	97	--	--	P	11	1,150	2	575.00	179,891.18	1,873.87
HARN0001399	26.00S/33.00E-27cc	43.27843294	-118.63940308	9,999.00	20	105	85	12.00	105	QTsu (100)	OBF (100)	P	6	600	65	9.23	2,178.03	25.62
HARN0001401	26.00S/33.00E-28cbc	43.28006895	-118.65199588	50.00	14	65	51	16.00	65	Qs (61); Qvb (39)	YBF (61); VB (39)	P	9	900	32	28.13	7,070.30	138.63
HARN0001402	26.00S/33.00E-31ad	43.27293968	-118.68400901	25.00	20	365	345	12.00	365	Tts (80); Qvb (20)	OBF (80); VB (20)	P	6	220	0	440.00	131,456.11	381.03
HARN0001403	26.00S/33.00E-32bc	43.27085419	-118.68082017	25.00	20	130	110	12.00	130	Qvb (64); Tts (36)	VB (64); OBF (36)	P	8	250	0	500.00	152,734.51	1,388.50
HARN0001408	26.00S/33.00E-34cca	43.26400000	-118.63708000	15.00	30	81	51	14.00	81	Qvb (100)	VB (100)	P	6	800	4	200.00	56,205.08	1,102.06
HARN0001409	26.00S/33.00E-35d	43.26570133	-118.60730546	9,999.00	148	350	202	12.00	350	QTsu (90); Tov (10)	OBF (90); UVR (10)	P	3	300	80	3.75	786.49	3.89
HARN0001410	26.00S/33.00E-35cd	43.26207978	-118.60741602	9,999.00	43	150	107	12.00</										

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(See notes at end of table)

OWRD Well ID Pumped Well Groundwater Database	Well Location (best available)				Well Construction				Well Bottom (ft. blsd)	Well OPI Units		Test Type	Well Yield Test			Calculated		
	Public Land Survey (PLS) Township/Range-Section qtr qtr	Latitude (decimal)	Longitude (decimal)	Error Horizontal (feet)	Well Open Interval (OPI)			Strat Unit(s)		Hydro-Strat Unit(s)	Duration (hours)		Discharge Rate (gal / min)	Drawdown Final (feet)	Specific Capacity (gpm / ft)	Transmissivity (feet ² / day)	Hydraulic Conductivity (feet / day)	
					OPI Top (ft. blsd)	OPI Bottom (ft. blsd)	OPI height (feet)											OPI Diameter Weighted (inches)
HARN0001477	27.00S/33.00E-2bb	43.26115962	-118.61950640	0.10	35	176	141	16.00	176	Qvb (91); Qs (9)	VB (91); YBF (9)	P	20	1,500	6	250.00	74,946.45	531.54
HARN0001478	27.00S/33.00E-3cb	43.25313223	-118.63950258	9,999.00	30	45	15	6.00	45	Qvb (100)	VB (100)	P	3	30	1	30.00	7,994.74	532.98
HARN0001481	27.00S/33.00E-11ba	43.24643020	-118.61252886	9,999.00	20	198	178	15.76	198	QTsu (74); Trd (26)	OBF (74); SFD (26)	P	3	1,300	35	37.14	8,857.58	49.76
HARN0001484	27.00S/33.00E-23ac	43.21446000	-118.60832500	500.00	420	503	83	8.00	503	Tts (100)	OBF (100)	B	1	30	0	60.00	15,031.18	181.10
HARN0001485	27.00S/33.00E-23aca	43.21359836	-118.60877120	0.10	490	521	31	4.04	521	Tts (100)	OBF (100)	B	3	8	5	1.60	370.50	12.15
HARN0001486	26.00S/33.00E-29cb	43.28033000	-118.68137000	25.00	19	43	24	12.00	43	Qvb (100)	VB (100)	P	8	1,650	0	3,300.00	1,108,231.91	46,176.33
HARN0001488	27.00S/34.00E-9cd	43.24577279	-118.53898320	0.10	60	90	30	14.00	90	Qs (100)	YBF (100)	P	3	1,000	15	66.67	16,793.47	559.78
HARN0001489	27.00S/34.00E-5db	43.25448541	-118.55393776	50.00	100	220	120	14.00	220	Tts (100)	OBF (100)	P	6	800	163	4.91	1,082.30	9.02
HARN0001490	27.00S/34.00E-5	43.25474460	-118.55383597	9,999.00	60	100	40	12.00	100	Qs (100)	YBF (100)	P	8	600	47	12.77	3,139.96	78.50
HARN0001491	27.00S/34.00E-7bb	43.24467207	-118.58036355	50.00	84	176	93	14.00	176	Trd (88); QTsu (12)	SFD (88); OBF (12)	P	72	800	14	57.14	17,197.11	185.91
HARN0001492	27.00S/34.00E-8	43.24019629	-118.55380397	9,999.00	36	52	16	14.00	52	QTsu (88); UNKN (12)	OBF (88); UNKN (12)	P	24	12	2	6.00	1,479.24	92.45
HARN0001493	27.00S/34.00E-8bcd	43.24183280	-118.56010557	50.00	20	215	195	6.00	215	Tts (95); Tdv (5)	OBF (95); OBF (5)	B	2	40	0	80.00	22,066.64	113.16
HARN0001494	27.00S/34.00E-9cb	43.23871000	-118.53963000	25.00	60	125	65	14.00	125	Qs (100)	YBF (100)	P	5	1,200	37	32.43	8,058.81	123.98
HARN0001495	27.00S/34.00E-9aa	43.24392695	-118.52898750	0.10	60	160	100	12.00	160	Qs (100)	YBF (100)	P	4	1,000	20	50.00	12,846.37	128.46
HARN0001497	27.00S/34.00E-13ca	43.22182000	-118.47912000	25.00	38	330	292	14.00	330	Qvb (100)	VB (100)	P	3	450	80	5.63	1,188.77	4.07
HARN0001498	27.00S/34.00E-13dc	43.21837000	-118.47447000	25.00	41	325	284	14.00	325	Qvb (100)	VB (100)	P	2	450	85	5.29	1,078.03	3.80
HARN0001502	27.00S/34.00E-15da	43.22203549	-118.50807793	9,999.00	20	89	69	10.06	89	Qs (100)	YBF (100)	P	5	1,200	38	31.58	8,173.34	118.45
HARN0001503	27.00S/34.00E-15ca	43.22203720	-118.51516998	9,999.00	30	95	65	12.00	125	Qs (100)	YBF (100)	P	5	1,200	38	31.58	7,991.84	122.95
HARN0001513	27.00S/35.00E-3	43.25455677	-118.39656222	9,999.00	18	140	122	21.04	140	--	--	P	6	200	95	2.11	406.39	3.33
HARN0001514	27.00S/35.00E-17bb	43.23253800	-118.44403300	50.00	176	275	99	12.00	275	Tov (73); QTsu (27)	UVR (73); OBF (27)	P	3	650	47	13.83	3,197.69	32.30
HARN0001515	27.00S/35.00E-19ca	43.21060000	-118.46051000	25.00	40	400	360	12.00	400	Qvb (97); Tts (3)	VB (97); OBF (3)	P	6	1,200	157	7.64	1,779.83	4.94
HARN0001516	27.00S/35.00E-22bcd	43.20917061	-118.39893543	9,999.00	20	160	140	6.00	160	--	--	B	1	20	0	40.00	10,131.63	72.37
HARN0001518	27.00S/36.00E-19ab	43.21642737	-118.33500790	9,999.00	7	116	109	12.00	116	Qvb (91); Tts (9)	VB (91); OBF (9)	P	2	450	15	30.00	7,117.94	65.30
HARN0001520	27.00S/36.00E-17ca	43.22376213	-118.32014957	9,999.00	28	103	75	6.00	103	--	--	P	4	15	38	0.39	79.02	1.05
HARN0001521	27.00S/36.00E-28ac	43.19840769	-118.29540087	9,999.00	416	495	79	14.00	495	--	--	P	1	385	200	1.93	337.28	4.27
HARN0001522	27.00S/36.00E-29cd	43.19063668	-118.32054615	200.00	20	116	96	15.60	116	--	--	P	30	3,400	6	566.67	181,511.56	1,890.75
HARN0001523	27.00S/36.00E-33ca	43.17887929	-118.29969619	200.00	100	400	300	12.00	400	--	--	P	3	1,070	60	17.83	4,197.72	13.99
HARN0001525	27.00S/36.00E-33ac	43.18302727	-118.29438647	250.00	17	315	298	16.00	315	--	--	P	2	150	133	1.13	195.55	0.66
HARN0001533	28.00S/29.50E-8ccd	43.14702000	-119.19558000	11.00	70	352	282	6.00	352	Tts (66); Tdv (32); Tts (2)	OBF (100)	B	0	10	0	20.00	4,612.36	16.36
HARN0001534	28.00S/29.75E-3	43.17003500	-119.09526500	500.00	30	180	150	7.33	180	Trt (100)	OBF (100)	P	1	15	35	0.43	73.59	0.49
HARN0001536	28.00S/30.00E-20ca	43.12283995	-119.02847929	9,999.00	18	160	142	8.00	160	Trt (89); Tts (11)	OBF (100)	P	5	20	121	0.17	29.72	0.21
HARN0001537	28.00S/30.00E-24ad	43.12617730	-118.93866020	0.10	45	520	475	6.00	520	Tts (98); Qs (2)	OBF (98); YBF (2)	P	3	10	170	0.06	9.62	0.02
HARN0001541	28.00S/31.00E-36ab	43.10250000	-118.82377000	25.00	20	90	70	7.00	90	UNKN (100)	UNKN (100)	P	24	15	7	2.14	540.77	7.73
HARN0001542	28.00S/31.00E-33ac	43.09728129	-118.88525870	9,999.00	38	65	27	6.00	65	Qs (100)	YBF (100)	P	5	50	9	5.56	1,374.12	50.89
HARN0001544	28.00S/31.00E-36dd	43.08845000	-118.82105000	25.00	38	100	62	6.00	100	Qs (76); Qdc (24)	YBF (76); VB (24)	B	2	30	0	60.00	16,269.88	262.42
HARN0001547	28.00S/33.00E-2adb	43.17035555	-118.60244690	0.10	164	313	149	6.00	313	Tts (87); Qvb (13)	OBF (87); VB (13)	B	4	6	0	12.00	3,075.15	20.71
HARN0001551	28.00S/33.00E-28bb	43.11546484	-118.65947168	9,999.00	4	60	56	16.00	60	Qvb (100)	VB (100)	P	2	1,150	24	47.92	11,284.87	201.52
HARN0001552	28.00S/33.00E-22cb	43.12260007	-118.63968338	9,999.00	140	500	360	15.00	500	Tov (58); Qvb (25); Tdw (17)	UVR (58); VB (25); HLP (17)	P	6	1,100	171	6.43	1,432.57	3.98
HARN0001553	28.00S/33.00E-27ddb	43.10802522	-118.62484995	9,999.00	41	289	249	8.00	289	Tts (100)	OBF (100)	B	1	20	0	40.00	9,755.93	39.26
HARN0001554	28.00S/33.00E-31bb	43.10070792	-118.69655331	9,999.00	20	335	315	8.00	335	Tts (100)	OBF (100)	P	10	42	154	0.27	54.46	0.17
HARN0001558	28.00S/33.00E-21ccc	43.11805																

Appendix J:

Table listing wells with well yield test data and related Harney Basin study hydraulic property calculation results
(See notes at end of table)

OWRD Well ID Pumped Well Groundwater Database	Well Location (best available)				Well Construction				Well Bottom (ft. blsd)	Well OPI Units		Test Type	Well Yield Test			Calculated		
	Public Land Survey (PLS) Township/Range-Section qtr qtr	Latitude (decimal)	Longitude (decimal)	Error Horizontal (feet)	Well Open Interval (OPI)					Strat Unit(s)	Hydro-Strat Unit(s)		Duration (hours)	Discharge Rate (gal / min)	Drawdown Final (feet)	Specific Capacity (gpm / ft)	Transmissivity (feet ² / day)	Hydraulic Conductivity (feet / day)
					OPI Top (ft. blsd)	OPI Bottom (ft. blsd)	OPI height (feet)	OPI Diameter Weighted (inches)										
HARN0001616	30.00S/36.00E-29caa	42.93802776	-118.30962592	9,999.00	28	117	89	6.00	117	--	--	P	4	5	30	0.17	30.97	0.35
HARN0001619	31.00S/28.00E-20	42.87232227	-119.45409685	9,999.00	142	472	330	6.00	472	Tsb (100)	UVR (100)	B	4	10	10	1.00	215.55	0.65
HARN0001620	31.00S/28.00E-24da	42.87050877	-119.36773652	9,999.00	233	272	39	6.00	272	Tsb (100)	UVR (100)	P	12	5	12	0.42	91.34	2.34
HARN0001622	31.00S/29.00E-10ba	42.90694634	-119.29866101	9,999.00	147	275	128	6.00	275	Tsb (87); QTsu (13)	UVR (87); OBF (13)	P	7	4	80	0.05	8.75	0.07
HARN0001623	31.00S/29.00E-25	42.85814672	-119.25675988	9,999.00	19	580	561	7.71	580	--	--	B	2	7	50	0.14	22.79	0.04
HARN0001624	31.00S/29.00E-27bab	42.86340359	-119.29863392	9,999.00	18	605	587	8.00	605	--	--	B	2	22	4	5.50	1,225.02	2.09
HARN0001626	24.00S/31.00E-8bc	43.50647449	-119.03717828	9,999.00	41	56	15	8.00	56	QTsu (100)	OBF (100)	P	2	20	22	0.91	175.42	11.69
HARN0001633	32.00S/30.00E-1cc	42.82363807	-119.14487438	9,999.00	370	380	10	6.00	380	--	--	P	4	25	0	50.00	13,972.54	1,397.25
HARN0001634	32.00S/31.00E-8dd	42.80739500	-119.09351000	200.00	560	580	20	6.00	580	--	--	B	1	12	35	0.34	59.89	2.99
HARN0001639	32.00S/31.00E-25cd	42.76553843	-119.02197559	9,999.00	100	212	112	8.00	212	QTsu (100)	OBF (100)	B	2	30	0	60.00	15,708.79	140.26
HARN0001640	32.00S/31.00E-33bd	42.75818006	-119.07026170	0.50	160	251	91	10.00	251	QTsu (100)	OBF (100)	P	1	6	43	0.14	19.83	0.22
HARN0001642	32.00S/32.00E-2da	42.82574757	-118.91287294	9,999.00	29	200	171	8.00	200	QTsu (100)	OBF (100)	P	24	15	12	1.25	298.99	1.75
HARN0001643	32.00S/32.00E-2da	42.82634000	-118.91521000	25.00	48	78	30	6.00	78	QTsu (100)	OBF (100)	P	0	20	40	0.50	84.69	2.82
HARN0001644	32.00S/32.00E-28db	42.76849838	-118.95719012	9,999.00	60	115	55	6.00	115	Tdv (60); Tts (40)	OBF (100)	P	2	15	18	0.83	167.56	3.05
HARN0001646	32.00S/32.00E-29cac	42.76881333	-118.98179202	9,999.00	30	142	112	6.00	142	QTsu (54); Tsb (46)	OBF (54); UVR (46)	B	2	7	15	0.47	89.34	0.80
HARN0001647	32.00S/32.00E-30dd	42.76532879	-118.99174602	9,999.00	20	160	140	8.00	160	Tsb (100)	UVR (100)	P	2	15	10	1.50	301.91	2.16
HARN0001650	32.00S/32.50E-6cb	42.82733000	-118.88692000	25.00	98	100	2	6.00	100	Qs (100)	YBF (100)	P	12	15	42	0.36	77.39	38.70
HARN0001652	32.00S/32.50E-7dd	42.80652683	-118.87223606	650.00	20	325	305	6.00	325	Tsb (100)	UVR (100)	B	2	40	0	80.00	22,066.64	72.35
HARN0001654	32.00S/32.50E-7dd	42.80761974	-118.87422317	9,999.00	25	120	95	6.00	120	Tsb (100)	UVR (100)	P	3	15	10	1.50	326.23	3.43
HARN0001655	32.00S/32.50E-7dd	42.80609000	-118.87383000	25.00	22	325	303	8.00	325	Tsb (100)	UVR (100)	P	12	36	62	0.58	124.96	0.41
HARN0001661	32.00S/34.00E-36bb	42.72472562	-118.46857854	9,999.00	65	90	25	6.00	90	--	--	P	1	30	11	2.73	570.61	22.82
HARN0001662	32.00S/34.00E-36bc	42.72091941	-118.46987430	25.00	465	490	25	12.00	490	--	--	P	8	2,500	194	12.89	3,171.62	126.86
HARN0001664	32.00S/35.00E-24ab	42.75416199	-118.34152641	9,999.00	245	353	108	6.00	360	--	--	B	2	7	4	1.75	373.35	3.46
HARN0001666	32.50S/33.00E-29aa	42.73895000	-118.64197000	25.00	63	110	47	6.00	110	Tsb (100)	UVR (100)	B	4	50	0	100.00	29,067.21	618.45
HARN0001669	33.00S/29.00E-13db	42.71241017	-119.25692196	9,999.00	17	180	163	12.00	180	--	--	P	5	600	115	5.22	1,166.59	7.16
HARN0001670	33.00S/29.00E-13dd	42.70747010	-119.24983765	9,999.00	15	360	345	12.00	360	--	--	P	5	130	98	1.33	266.61	0.77
HARN0001673	33.00S/30.00E-12dd	42.72419329	-119.13234781	100.00	103	465	362	16.00	465	Tsb (61); QTsu (39)	UVR (61); OBF (39)	B	2	50	0	100.00	24,754.37	68.38
HARN0001678	33.00S/31.00E-4bd	42.74240000	-119.07880000	500.00	100	565	465	14.11	565	Tsb (63); QTsu (37)	UVR (63); OBF (37)	B	4	200	0	400.00	114,171.29	245.53
HARN0001679	33.00S/31.00E-4	42.74210000	-119.08320000	200.00	300	761	461	14.56	761	Tsb (100)	UVR (100)	P	1	300	200	1.50	254.56	0.55
HARN0001683	33.00S/31.00E-31ddcc	42.66289996	-119.11280797	1,000.00	20	610	590	21.30	610	QTsu (100)	OBF (100)	P	10	2,100	40	52.50	13,332.27	22.60
HARN0001688	23.00S/34.00E-18aaa	43.57914206	-118.57165420	550.00	70	130	60	6.00	130	QTsu (100)	OBF (100)	B	1	15	40	0.38	66.07	1.10
HARN0001689	33.00S/34.00E-24aa	42.66660083	-118.45402193	9,999.00	148	800	652	12.55	800	--	--	P	9	2,500	208	12.02	2,950.13	4.52
HARN0001690	33.00S/34.00E-23aad	42.66577253	-118.47131395	50.00	20	310	290	20.73	310	Qs (100)	YBF (100)	P	10	900	140	6.43	1,417.11	4.89
HARN0001691	33.00S/34.00E-25ab	42.65114584	-118.46042371	25.00	0	509	509	12.15	509	--	--	P	6	1,000	90	11.11	2,650.85	5.21
HARN0001698	34.00S/30.00E-10db	42.63835901	-119.17524197	9,999.00	20	115	95	8.00	115	--	--	B	1	20	7	2.86	572.76	6.03
HARN0001699	34.00S/31.00E-3cab	42.65473576	-119.06314946	50.00	375	675	300	16.00	685	QTsu (100)	OBF (100)	P	10	1,500	38	39.47	10,209.08	34.03
HARN0001702	25.00S/35.00E-30ba	43.37590740	-118.46288983	9,999.00	22	80	58	6.00	80	--	--	P	3	15	17	0.88	184.17	3.18
HARN0001704	34.00S/31.00E-23dbb	42.61074791	-119.03968267	100.00	606	1,000	394	13.80	1,000	QTsu (62); Tsb (38)	OBF (62); UVR (38)	P	4	1,413	95	14.87	3,458.94	8.78
HARN0001705	34.00S/31.00E-27cb	42.59469775	-119.06706608	9,999.00	93	125	32	6.00	125	QTsu (100)	OBF (100)	P	2	15	15	1.00	204.09	6.38
HARN0001707	23.00S/33.00E-5ad	43.60336993	-118.67142377	9,999.00	51	54	3	6.00	54	QTsu (100)	OBF (100)	P	3	20	17	1.18	251.15	83.72
HARN0001708	34.00S/31.00E-34b	42.58562500	-119.06472500	25.00	80	325	245	8.73	325	QTsu (100)	OBF (100)	P	3	380	70	5.43	1,228.45	5.01
HARN0001709	34.00S/32.00E-21cbc	42.60740																

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Table listing wells with well yield test data and related Harney Basin study hydraulic property calculation results
(See notes at end of table)

OWRD Well ID Pumped Well Groundwater Database	Well Location (best available)				Well Construction				Well Bottom (ft. blsd)	Well OPI Units		Test Type	Well Yield Test			Calculated		
	Public Land Survey (PLS) Township/Range-Section qtr qtr	Latitude (decimal)	Longitude (decimal)	Error Horizontal (feet)	Well Open Interval (OPI)					Strat Unit(s)	Hydro-Strat Unit(s)		Duration (hours)	Discharge Rate (gal / min)	Drawdown Final (feet)	Specific Capacity (gpm / ft)	Transmissivity (feet ² / day)	Hydraulic Conductivity (feet / day)
					OPI Top (ft. blsd)	OPI Bottom (ft. blsd)	OPI height (feet)	OPI Diameter Weighted (inches)										
HARN0001837	25.00S/31.00E-31ad	43.35650638	-119.04463522	1.00	110	170	60	12.00	170	QTsu (100)	OBF (100)	B	1	50	0	100.00	24,561.99	409.37
HARN0001839	29.00S/33.00E-2dc	43.07526348	-118.60996472	9,999.00	60	250	190	8.00	250	QTsu (100)	OBF (100)	P	2	12	100	0.12	19.08	0.10
HARN0001840	25.00S/34.00E-7bd	43.41551912	-118.58199251	9,999.00	80	103	23	6.00	103	QTsu (100)	OBF (100)	P	24	100	7	14.29	4,116.84	178.99
HARN0001841	28.00S/29.50E-6dda	43.16335429	-119.20078810	0.30	380	450	70	5.00	450	Tdv (57); Tts (43)	OBF (100)	P	1	15	10	1.50	308.05	4.40
HARN0001843	33.00S/31.00E-10ba	42.73110629	-119.06330600	100.00	20	575	555	22.17	575	--	--	P	24	800	140	5.71	1,318.27	2.38
HARN0001844	33.00S/31.00E-10cd	42.72374456	-119.06332140	1,000.00	1	570	569	1.00	570	--	--	P	4	800	270	2.96	864.34	1.52
HARN0001847	24.00S/32.00E-2bc	43.52125040	-118.85998507	9,999.00	160	240	80	6.00	240	QTsu (100)	OBF (100)	P	24	20	2	10.00	2,824.05	35.30
HARN0001848	26.00S/35.00E-4bd	43.34346701	-118.41888654	9,999.00	36	255	219	8.00	255	--	--	P	2	10	220	0.05	6.47	0.03
HARN0001850	24.00S/31.00E-31ba	43.45189031	-119.05194093	9,999.00	72	80	8	6.00	80	QTsu (100)	OBF (100)	P	1	15	7	2.14	439.79	54.97
HARN0001851	23.00S/31.00E-10cc	43.58750114	-118.99754017	9,999.00	219	221	2	8.00	221	QTsu (100)	OBF (100)	P	1	20	3	6.67	1,429.88	714.94
HARN0001852	29.00S/33.00E-31ca	43.00687174	-118.69344390	9,999.00	60	65	5	6.00	65	Qs (100)	YBF (100)	P	1	15	14	1.07	207.57	41.51
HARN0001853	29.00S/33.00E-32cc	43.00322025	-118.67866427	9,999.00	80	150	70	6.00	150	Tts (100)	OBF (100)	P	1	15	32	0.47	84.35	1.21
HARN0001854	29.00S/32.00E-15cd	43.04679816	-118.75284498	9,999.00	25	145	120	8.00	145	Tdv (58); Qdc (42)	OBF (58); VB (42)	P	1	15	9	1.67	319.18	2.66
HARN0001855	23.00S/27.00E-9cc	43.58550852	-119.49486359	9,999.00	38	250	212	6.00	250	Tobg (74); QTsu (26)	HLP (74); OBF (26)	P	1	20	2	10.00	2,306.18	10.88
HARN0001859	23.00S/31.00E-9cc	43.58757214	-119.01766558	9,999.00	29	40	11	6.00	40	QTsu (100)	OBF (100)	P	1	20	15	1.33	263.16	23.92
HARN0001860	23.00S/31.00E-10da	43.59097347	-118.98278613	9,999.00	67	90	23	6.00	90	QTsu (100)	OBF (100)	P	1	70	10	7.00	1,573.32	68.41
HARN0001861	24.00S/32.50E-31aa	43.45567109	-118.80978982	9,999.00	18	238	220	20.92	238	QTsu (100)	OBF (100)	P	17	1,650	180	9.17	2,151.38	9.78
HARN0001863	25.00S/30.00E-34ab	43.36378900	-119.10408700	2.00	60	110	50	12.00	110	QTV (100)	PVD (100)	P	2	2,003	34	58.91	14,627.71	292.55
HARN0001864	29.00S/31.00E-13db	43.05034977	-118.82607190	9,999.00	21	150	129	12.00	150	--	--	P	1	225	92	2.45	450.93	3.50
HARN0001865	21.00S/26.00E-28	43.72027669	-119.60627577	9,999.00	31	270	239	8.00	270	Tdm (100)	DML (100)	P	1	15	80	0.19	29.02	0.12
HARN0001866	24.00S/32.00E-21ad	43.47758873	-118.88426948	9,999.00	38	94	56	6.00	94	QTsu (100)	OBF (100)	P	1	20	1	20.00	4,839.45	86.42
HARN0001867	25.00S/33.00E-36dc	43.35167310	-118.59565593	50.00	135	175	40	12.00	175	QTsu (100)	OBF (100)	P	1	800	70	11.43	2,399.91	60.00
HARN0001870	23.00S/35.50E-22cb	43.56072671	-118.76567892	9,999.00	31	40	9	6.00	40	QTsu (100)	OBF (100)	P	1	15	11	1.36	269.65	29.96
HARN0001878	23.00S/31.00E-5bb	43.61245990	-119.03753486	9,999.00	160	320	161	12.00	320	QTsu (100)	OBF (100)	P	10	300	100	3.00	677.68	4.22
HARN0001879	22.00S/32.50E-33ba	43.62779484	-118.78057591	25.00	101	500	400	14.00	500	QTsu (100)	OBF (100)	P	8	500	240	2.08	439.86	1.10
HARN0001882	24.00S/32.00E-4dc	43.51413754	-118.88946736	9,999.00	18	187	169	13.21	187	QTsu (100)	OBF (100)	P	1	250	40	6.25	1,230.08	7.28
HARN0001883	24.00S/33.00E-3dd	43.50935291	-118.63173666	9,999.00	38	65	27	6.00	65	QTsu (100)	OBF (100)	P	1	15	10	1.50	298.98	11.07
HARN0001885	26.00S/35.00E-33db	43.26914500	-118.41599500	115.00	640	690	50	6.00	690	--	--	P	1	10	20	0.50	90.51	1.81
HARN0001888	24.00S/29.00E-13ab	43.49762114	-119.18859691	50.00	140	418	278	11.28	418	--	--	P	6	2,000	50	40.00	10,476.35	37.68
HARN0001891	23.00S/27.00E-24ab	43.56730000	-119.55124000	100.00	120	303	183	16.00	303	QTsu (98); HLPu (2)	OBF (98); HLP (2)	P	8	2,300	9	255.56	72,917.41	398.46
HARN0001893	27.00S/32.00E-6aa	43.26382656	-118.80236523	9,999.00	20	36	16	12.00	36	Qvb (100)	VB (100)	P	1	1,000	2	500.00	135,913.68	8,494.61
HARN0001894	23.00S/28.00E-25bcb	43.55032000	-119.31627000	16.00	450	490	40	6.00	500	--	--	P	6	12	80	0.15	28.62	0.72
HARN0001896	29.00S/32.00E-23ca	43.03595367	-118.73320177	9,999.00	60	67	7	6.00	67	Qs (100)	YBF (100)	P	30	10	16	0.63	150.57	21.51
HARN0001898	24.00S/33.00E-13da	43.48408291	-118.59194230	9,999.00	18	65	47	9.66	65	QTsu (100)	OBF (100)	P	8	20	8	2.50	565.89	12.04
HARN0001899	23.00S/27.00E-13ad	43.57854000	-119.55214000	0.00	60	190	130	15.23	190	QTsu (100)	OBF (100)	P	8	1,050	45	23.33	5,787.28	44.52
HARN0001906	26.00S/31.00E-10ad	43.33271738	-118.98166047	9,999.00	354	396	42	6.00	396	QTsu (100)	OBF (100)	P	1	15	10	1.50	298.98	7.12
HARN0001907	22.00S/30.00E-36dd	43.61593326	-119.06182505	9,999.00	40	50	10	6.00	50	Qs (100)	YBF (100)	P	1	15	8	1.88	380.67	38.07
HARN0001908	25.00S/32.00E-26cb	43.37215995	-118.86022988	9,999.00	95	115	20	6.00	115	QTsu (100)	OBF (100)	P	3	15	15	1.00	210.80	10.54
HARN0001909	21.00S/25.00E-33	43.70509439	-119.72724744	9,999.00	19	480	462	12.00	480	Tov (43); Tdm (36); Trt (11); Tts (10)	UVR (43); DML (36); OBF (21)	P	20	360	166	2.17	503.02	1.09
HARN0001912	22.00S/32.50E-33ba	43.62756241	-118.78060161	25.00	160	380	220	12.00	380	QTsu (100)	OBF (100)	P	36	2,000	100	20.00	5,554.86	25.25
HARN0001913	25.00S/33.00E-36dd	43.34873532	-118.58944276	500.00	210	270	60	12.00	270	QTsu (100)	OBF (100)	P	10	1,200	50	24.00	6,	

Appendix J:

Table listing wells with well yield test data and related Harney Basin study hydraulic property calculation results
(See notes at end of table)

OWRD Well ID Pumped Well Groundwater Database	Well Location (best available)				Well Construction				Well Bottom (ft. blsd)	Well OPI Units		Well Yield Test				Calculated		
	Public Land Survey (PLS) Township/Range-Section qtr qtr	Latitude (decimal)	Longitude (decimal)	Error Horizontal (feet)	Well Open Interval (OPI)			Strat Unit(s)		Hydro-Strat Unit(s)	Test Type	Duration (hours)	Discharge Rate (gal / min)	Drawdown Final (feet)	Specific Capacity (gpm / ft)	Transmissivity (feet ² / day)	Hydraulic Conductivity (feet / day)	
					OPI Top (ft. blsd)	OPI Bottom (ft. blsd)	OPI height (feet)											OPI Diameter Weighted (inches)
HARN0001981	24.00S/27.00E-24bc	43.47889908	-119.43680890	0.10	60	100	40	6.00	100	QTb (73); Tts (27)	HLP (73); OBF (27)	B	1	15	3	5.00	1,096.12	27.40
HARN0001986	24.00S/31.00E-2dd	43.51333077	-118.96325394	9,999.00	65	70	5	6.00	70	QTsu (100)	OBF (100)	P	3	30	35	0.86	178.50	35.70
HARN0001988	25.00S/31.00E-4ba	43.43778753	-119.01277630	9,999.00	18	102	84	17.01	102	QTsu (100)	OBF (100)	P	7	300	28	10.71	2,458.64	29.27
HARN0001989	25.00S/31.00E-35bc	43.36134232	-118.97277762	9,999.00	240	280	40	6.00	280	QTsu (100)	OBF (100)	P	2	20	36	0.56	107.97	2.70
HARN0001990	25.00S/30.00E-27ddb	43.37435877	-119.10868150	0.30	60	100	40	12.00	100	QTV (100)	PVD (100)	P	5	300	45	6.67	1,517.50	37.94
HARN0001999	23.00S/30.00E-22ab	43.56917184	-119.10712845	9,999.00	108	500	392	8.00	500	Tts (100)	OBF (100)	P	2	23	8	2.88	609.62	1.56
HARN0002000	26.00S/33.00E-30ab	43.29127000	-118.69119000	25.00	20	80	60	12.00	80	Qvb (100)	VB (100)	B	1	100	0	200.00	51,385.49	856.42
HARN0002002	21.00S/35.00E-16bc	43.74734800	-118.42767900	200.00	390	450	60	8.00	460	--	--	P	4	50	0	100.00	28,135.94	468.93
HARN0002004	25.00S/35.00E-21aa	43.39041340	-118.41318406	9,999.00	20	160	140	8.00	160	--	--	P	4	30	16	1.88	405.80	2.90
HARN0002006	24.00S/31.00E-10bd	43.50604186	-118.99313420	9,999.00	45	60	15	6.00	60	QTsu (100)	OBF (100)	P	4	50	5	10.00	2,532.91	168.86
HARN0002017	24.00S/33.00E-33da	43.43932999	-118.65312405	100.00	275	600	325	6.00	600	Tts (100)	OBF (100)	P	2	100	63	1.59	336.08	1.03
HARN0002018	25.00S/32.50E-2ba	43.43735684	-118.74037768	9,999.00	38	45	7	6.00	45	QTsu (100)	OBF (100)	P	1	10	6	1.67	335.12	47.87
HARN0002020	20.00S/28.00E-7ca	43.84985000	-119.41034000	25.00	60	120	60	4.00	120	Tov (100)	UVR (100)	P	4	11	12	0.92	208.51	3.48
HARN0002021	20.00S/27.00E-1da	43.86561460	-119.41921912	9,999.00	60	140	80	5.50	140	Tov (100)	UVR (100)	P	4	4	60	0.07	11.56	0.14
HARN0002022	25.00S/35.00E-21aa	43.39041340	-118.41318406	9,999.00	20	280	260	15.73	280	--	--	P	1	250	109	2.29	399.63	1.54
HARN0002024	22.00S/30.00E-25aa	43.64118861	-119.06155128	9,999.00	30	50	20	6.00	50	QTsu (100)	OBF (100)	P	3	7	32	0.22	40.59	2.03
HARN0002025	22.00S/32.00E-34ab	43.62468600	-118.87136639	9,999.00	58	204	146	12.00	204	QTsu (100)	OBF (100)	P	1	200	51	3.92	753.94	5.16
HARN0002027	23.00S/32.00E-31cd	43.52809573	-118.93416860	9,999.00	65	80	15	6.00	80	QTsu (100)	OBF (100)	P	3	25	35	0.71	146.60	9.77
HARN0002028	22.00S/32.00E-34ab	43.62624594	-118.86957918	9,999.00	80	120	40	6.00	120	QTsu (100)	OBF (100)	P	3	17	60	0.28	53.80	1.35
HARN0002032	23.00S/32.00E-2cc	43.59906309	-118.85669431	250.00	118	180	62	14.00	180	QTsu (100)	OBF (100)	P	41	1,500	25	60.00	17,558.53	283.20
HARN0002033	24.00S/32.50E-30bc	43.46302293	-118.81981016	9,999.00	35	170	135	16.55	170	QTsu (100)	OBF (100)	P	8	150	60	2.50	521.56	3.86
HARN0002034	24.00S/34.00E-29ca	43.45535657	-118.56227665	9,999.00	18	300	282	6.00	300	Tov (100)	UVR (100)	P	1	2	50	0.04	5.53	0.02
HARN0002038	23.00S/31.00E-33ad	43.53626548	-119.00249231	9,999.00	85	95	10	6.00	95	QTsu (100)	OBF (100)	P	1	25	11	2.27	468.65	46.87
HARN0002039	24.00S/32.50E-30bc	43.46302293	-118.81981016	9,999.00	20	350	330	13.91	350	QTsu (100)	OBF (100)	P	7	150	150	1.00	196.98	0.60
HARN0002040	23.00S/31.00E-33bc	43.53649414	-119.01747891	9,999.00	37	50	13	10.00	50	QTsu (100)	OBF (100)	P	2	78	11	7.09	1,556.93	119.76
HARN0002041	24.00S/31.00E-34ac	43.44856385	-118.98803332	9,999.00	25	74	49	6.00	74	QTsu (100)	OBF (100)	P	1	22	6	3.67	785.07	16.02
HARN0002043	22.00S/32.00E-26bd	43.63696326	-118.85462959	9,999.00	40	185	145	6.00	185	QTsu (100)	OBF (100)	P	1	30	60	0.50	90.51	0.62
HARN0002045	20.00S/35.00E-21da	43.81364493	-118.41017196	9,999.00	55	90	35	6.00	90	--	--	P	1	15	8	1.88	380.67	10.88
HARN0002046	20.00S/35.00E-26ab	43.80655466	-118.37519848	9,999.00	57	190	133	6.00	190	--	--	P	1	20	4	5.00	1,096.12	8.24
HARN0002048	32.00S/31.00E-7dc	42.80920052	-119.11532788	9,999.00	20	87	67	6.00	87	--	--	P	2	7	30	0.23	41.97	0.63
HARN0002054	34.00S/32.75E-4bd	42.65520000	-118.72849000	25.00	160	180	20	8.00	180	Tsb (100)	UVR (100)	P	3	3	22	0.14	22.91	1.15
HARN0002057	23.00S/33.00E-6bb	43.60700922	-118.70612341	9,999.00	52	60	8	6.00	60	QTsu (100)	OBF (100)	P	1	16	4	4.00	862.19	107.77
HARN0002058	23.00S/33.00E-7cb	43.58665000	-118.70695000	25.00	55	82	27	6.00	82	QTsu (100)	OBF (100)	P	1	15	7	2.14	439.79	16.29
HARN0002060	23.00S/33.00E-2cb	43.59965446	-118.62659530	9,999.00	40	285	245	6.00	285	QTsu (100)	OBF (100)	P	2	18	74	0.24	43.92	0.18
HARN0002074	24.00S/30.00E-18bd	43.49232580	-119.17190702	9,999.00	80	390	310	14.00	390	QTsu (63); QTV (37)	OBF (63); PVD (37)	P	6	800	65	12.31	2,899.89	9.35
HARN0002075	23.00S/31.00E-13bd	43.57926886	-118.95309062	9,999.00	87	100	13	6.00	100	QTsu (100)	OBF (100)	P	1	15	7	2.14	439.79	33.83
HARN0002076	24.00S/32.00E-4bc	43.52145839	-118.89991930	9,999.00	51	58	7	6.00	58	QTsu (100)	OBF (100)	P	1	50	12	4.17	900.91	128.70
HARN0002081	24.00S/32.50E-15bd	43.49156268	-118.76024348	9,999.00	41	100	59	6.00	100	QTsu (100)	OBF (100)	P	1	40	20	2.00	408.18	6.92
HARN0002082	23.00S/32.50E-3ba	43.61141599	-118.76067779	9,999.00	40	75	35	6.00	75	QTsu (100)	OBF (100)	P	30	18	15	1.20	301.89	8.63
HARN0002085	20.00S/33.50E-1bb	43.87047421	-118.60486733	9,999.00	20	45	25	6.00	45	--	--	P	1	30	10	3.00	632.39	25.30
HARN0002086	19.00S/33.50E-36bd	43.88132918	-118.59987422	9,999.00	20	200	180	10.00	200	--	--	P	4	100	150	0.67	127.94	0.71
HARN0002087	24.00S/29.00E-12ad	43.50866371	-119.18043900	9,999.00	60													

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(See notes at end of table)

OWRD Well ID Pumped Well Groundwater Database	Well Location (best available)				Well Construction				Well Bottom (ft. blsd)	Well OPI Units		Well Yield Test				Calculated		
	Public Land Survey (PLS) Township/Range-Section qtr qtr	Latitude (decimal)	Longitude (decimal)	Error Horizontal (feet)	Well Open Interval (OPI)			Strat Unit(s)		Hydro-Strat Unit(s)	Test Type	Duration (hours)	Discharge Rate (gal / min)	Drawdown Final (feet)	Specific Capacity (gpm / ft)	Transmissivity (feet ² / day)	Hydraulic Conductivity (feet / day)	
					OPI Top (ft. blsd)	OPI Bottom (ft. blsd)	OPI height (feet)											OPI Diameter Weighted (inches)
HARN0050135	27.00S/33.00E-12ab	43.24747000	-118.58756000	25.00	98	300	202	12.00	300	QTsu (100)	OBF (100)	P	1	1,100	34	32.35	7,348.48	36.38
HARN0050141	25.00S/34.00E-7aa	43.41915200	-118.57204687	9,999.00	85	125	40	6.00	125	QTsu (100)	OBF (100)	P	1	25	20	1.25	245.37	6.13
HARN0050150	25.00S/33.00E-24ac	43.38511184	-118.59922146	100.00	20	225	205	17.05	225	QTsu (68); Tdw (32)	OBF (68); HLP (32)	B	1	100	0	200.00	49,094.93	239.49
HARN0050151	27.00S/33.00E-12ba	43.24750000	-118.59249000	25.00	128	514	386	12.00	514	QTsu (100)	OBF (100)	B	1	50	3	16.67	3,603.66	9.34
HARN0050152	24.00S/32.00E-24ad	43.47757044	-118.82491282	9,999.00	199	250	51	6.00	250	QTsu (100)	OBF (100)	P	96	14	72	0.19	46.83	0.92
HARN0050155	24.00S/30.00E-7bc	43.50539081	-119.17511533	9,999.00	83	400	317	12.07	400	--	--	B	1	140	10	14.00	2,984.14	9.41
HARN0050169	24.00S/33.00E-13da	43.48378356	-118.59327604	9,999.00	20	158	138	17.35	158	QTsu (100)	OBF (100)	B	1	140	10	14.00	2,816.08	20.41
HARN0050172	25.00S/31.00E-3da	43.43063280	-118.98271285	9,999.00	42	65	23	6.00	65	QTsu (100)	OBF (100)	P	2	20	2	10.00	2,419.72	105.21
HARN0050173	25.00S/31.00E-28cc	43.37018238	-119.01993239	9,999.00	95	205	110	8.00	205	Tts (100)	OBF (100)	P	2	50	45	1.11	218.11	1.98
HARN0050175	24.00S/32.00E-24aa	43.48119563	-118.82490540	9,999.00	37	100	63	6.00	100	QTsu (100)	OBF (100)	P	2	20	3	6.67	1,568.90	24.90
HARN0050176	23.00S/30.00E-26da	43.54850129	-119.08304849	9,999.00	400	805	405	16.00	805	Tts (100)	OBF (100)	P	6	1,650	350	4.71	1,015.71	2.51
HARN0050177	22.00S/30.00E-27db	43.63353657	-119.10609481	9,999.00	31	59	28	6.00	59	Ta (100)	SFD (100)	P	1	13	2	6.50	1,453.02	51.89
HARN0050178	24.00S/33.00E-31bc	43.44306605	-118.70433490	0.10	20	250	230	6.00	250	QTsu (100)	OBF (100)	B	1	24	4	6.00	1,333.35	5.80
HARN0050179	24.00S/33.00E-31bc	43.44282814	-118.70515750	0.10	260	327	67	6.00	327	QTsu (100)	OBF (100)	P	3	40	6	6.67	1,613.15	24.08
HARN0050181	23.00S/31.00E-21aa	43.56831702	-119.00264950	9,999.00	298	425	127	6.00	425	QTsu (100)	OBF (100)	P	4	80	65	1.23	269.50	2.12
HARN0050182	31.00S/32.00E-2aa	42.91268836	-118.91228185	9,999.00	79	139	60	8.00	139	Tts (100)	OBF (100)	P	12	90	122	0.74	161.67	2.69
HARN0050184	23.00S/26.00E-28bc	43.54917627	-119.61174440	0.00	187	247	60	6.00	247	Tts (100)	OBF (100)	P	12	42	0	84.00	25,670.19	427.84
HARN0050185	23.00S/32.50E-3ad	43.60775505	-118.75071463	9,999.00	48	87	39	6.00	87	QTsu (100)	OBF (100)	P	2	30	15	2.00	431.09	11.05
HARN0050195	23.00S/33.00E-2cb	43.60113875	-118.62881936	9,999.00	20	140	120	14.00	140	QTsu (100)	OBF (100)	B	1	100	2	50.00	11,461.03	95.51
HARN0050196	26.00S/34.00E-30cc	43.27826692	-118.58046860	9,999.00	251	275	24	6.00	275	QTsu (100)	OBF (100)	P	1	30	20	1.50	298.98	12.46
HARN0050197	24.00S/32.50E-30bb	43.46666254	-118.81980822	9,999.00	48	67	19	8.11	67	QTsu (100)	OBF (100)	P	1	20	12	1.67	318.42	16.76
HARN0050204	23.00S/31.00E-17bb	43.58373998	-119.03785269	9,999.00	206	252	46	6.00	252	Trt (100)	OBF (100)	P	1	35	14	2.50	519.46	11.29
HARN0050207	25.00S/34.00E-8dd	43.40831036	-118.55221063	9,999.00	71	108	37	6.00	108	Tts (100)	OBF (100)	P	2	20	4	5.00	1,153.09	31.16
HARN0050208	24.00S/33.00E-33ca	43.44067086	-118.66170019	9,999.00	200	300	100	6.00	300	Tts (100)	OBF (100)	P	2	60	10	6.00	1,401.65	14.02
HARN0050226	25.00S/31.00E-23cb	43.38682544	-118.97768545	9,999.00	24	40	16	6.00	40	QTsu (100)	OBF (100)	P	3	10	6	1.67	365.37	22.84
HARN0050227	24.00S/31.00E-32dc	43.44091000	-119.02565000	25.00	72	112	40	12.00	112	QTsu (100)	OBF (100)	P	1	650	35	18.57	4,048.63	101.22
HARN0050228	26.00S/29.00E-31ad	43.27462737	-119.28063329	9,999.00	50	53	3	6.00	53	Qs (100)	YBF (100)	P	2	18	25	0.72	143.02	47.67
HARN0050233	26.00S/31.00E-27aa	43.29346482	-118.98238820	0.10	36	42	6	6.00	42	QTV (67); Tts (33)	PVD (67); OBF (33)	P	3	60	10	6.00	1,441.49	240.25
HARN0050236	25.00S/33.00E-36ab	43.36103638	-118.59648981	500.00	60	141	81	12.00	141	Tts (98); Tdw (2)	OBF (98); HLP (2)	P	1	42	80	0.53	83.21	1.03
HARN0050237	23.00S/34.00E-7dd	43.58296784	-118.57262300	0.20	30	117	87	6.00	117	QTsu (100)	OBF (100)	P	2	12	50	0.24	43.28	0.50
HARN0050238	25.00S/33.00E-25ad	43.37383205	-118.59427344	100.00	50	200	150	14.00	200	Tdw (47); QTsu (40); Tts (13)	HLP (47); OBF (53)	P	1	1,050	39	26.92	5,897.28	39.32
HARN0050241	22.00S/32.50E-34bd	43.62058400	-118.76164000	25.00	120	450	330	14.00	450	QTsu (100)	OBF (100)	B	1	100	2	50.00	11,461.03	34.73
HARN0050250	23.00S/33.00E-36da	43.52733240	-118.59188026	9,999.00	35	60	25	6.00	60	QTsu (100)	OBF (100)	P	3	20	6	3.33	894.01	35.76
HARN0050251	24.00S/27.00E-22aa	43.48226036	-119.45890280	0.10	97	540	443	14.00	540	Tts (93); QTb (7)	OBF (93); HLP (7)	P	6	1,100	119	9.24	2,134.57	4.82
HARN0050283	24.00S/32.00E-4bb	43.52486295	-118.90009972	9,999.00	61	112	51	8.00	112	QTsu (100)	OBF (100)	P	5	140	22	6.36	1,528.26	29.97
HARN0050284	25.00S/33.00E-8dd	43.40813286	-118.67141195	9,999.00	85	168	83	6.00	168	QTsu (100)	OBF (100)	P	3	20	30	0.67	136.06	1.64
HARN0050285	24.00S/32.50E-21da	43.47339248	-118.76779845	500.00	100	370	270	14.00	370	QTsu (100)	OBF (100)	B	1	100	2	50.00	11,461.03	42.45
HARN0050286	29.00S/32.00E-24ca	43.03589164	-118.71341812	9,999.00	39	68	29	8.00	68	Tts (100)	OBF (100)	P	4	160	2	80.00	22,219.44	766.19
HARN0050287	24.00S/33.00E-13ab	43.49129079	-118.59691520	9,999.00	110	125	15	6.00	125	QTsu (100)	OBF (100)	P	4	45	13	3.46	816.76	54.45
HARN0050290	24.00S/30.00E-2ca	43.51816644	-119.09203235	9,999.00	65	75	10	6.00	75	QTsu (100)	OBF (100)	P	1	60	30	2.00	408.18	40.82
HARN0050291	22.00S/31.00E-35ca	43.61965800	-118.97270392	9,999.00	75	150	75	7.25										

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(See notes at end of table)

OWRD Well ID Pumped Well Groundwater Database	Well Location (best available)				Well Construction				Well Bottom (ft. blsd)	Well OPI Units		Well Yield Test				Calculated		
	Public Land Survey (PLS) Township/Range-Section qtr qtr	Latitude (decimal)	Longitude (decimal)	Error Horizontal (feet)	Well Open Interval (OPI)			Strat Unit(s)		Hydro-Strat Unit(s)	Test Type	Duration (hours)	Discharge Rate (gal / min)	Drawdown Final (feet)	Specific Capacity (gpm / ft)	Transmissivity (feet ² / day)	Hydraulic Conductivity (feet / day)	
					OPI Top (ft. blsd)	OPI Bottom (ft. blsd)	OPI height (feet)											OPI Diameter Weighted (inches)
HARN0050397	22.00S/32.00E-35ba	43.62623593	-118.85455156	9,999.00	20	58	38	6.00	58	QTsu (100)	OBF (100)	P	3	22	3	7.33	1,785.89	47.00
HARN0050398	32.00S/32.00E-2db	42.82708000	-118.91486000	23.00	41	120	79	6.00	120	QTsu (100)	OBF (100)	P	8	10	75	0.13	25.82	0.33
HARN0050399	26.00S/31.00E-19ac	43.30418071	-119.04583900	0.10	89	110	21	6.00	110	QTV (100)	PVD (100)	B	2	30	0	60.00	16,269.88	774.76
HARN0050401	26.00S/30.00E-2bd	43.34735781	-119.09126723	9,999.00	68	102	34	6.00	102	QTV (100)	PVD (100)	P	1	36	85	0.42	75.49	2.22
HARN0050403	22.00S/32.00E-28cb	43.63345444	-118.90007897	9,999.00	80	122	42	8.00	122	QTsu (100)	OBF (100)	P	4	100	8	12.50	3,094.30	73.67
HARN0050422	22.00S/32.50E-34ab	43.62422200	-118.75344500	50.00	80	400	320	12.00	400	QTsu (100)	OBF (100)	P	1	500	185	2.70	502.84	1.57
HARN0050424	23.00S/33.00E-4bb	43.60697068	-118.66645370	9,999.00	40	62	22	6.00	62	QTsu (100)	OBF (100)	P	1	40	14	2.86	599.98	27.27
HARN0050427	25.00S/31.00E-32aa	43.36697439	-119.02326288	9,999.00	75	145	70	12.00	145	QTV (100)	PVD (100)	P	54	900	35	25.71	7,415.48	105.94
HARN0050428	25.00S/31.00E-32aa	43.36528293	-119.02012738	2.00	78	145	67	12.00	145	QTV (100)	PVD (100)	P	42	700	35	20.00	5,604.83	83.65
HARN0050432	23.00S/32.00E-27bb	43.55398792	-118.87978048	9,999.00	138	190	52	6.00	190	QTsu (100)	OBF (100)	P	20	35	19	1.84	464.12	8.93
HARN0050435	24.00S/33.00E-14ab	43.49130055	-118.61684343	9,999.00	120	175	55	6.00	175	QTsu (100)	OBF (100)	P	3	40	4	10.00	2,485.97	45.20
HARN0050437	26.00S/33.00E-33db	43.26906000	-118.65005000	25.00	40	96	56	16.00	96	Qvb (100)	VB (100)	B	1	100	0	200.00	49,508.74	884.08
HARN0050444	33.00S/31.00E-5ba	42.74760095	-119.10029748	9,999.00	20	200	180	6.00	200	QTsu (100)	OBF (100)	P	1	15	13	1.15	224.96	1.25
HARN0050445	25.00S/34.00E-7ac	43.41552563	-118.57701837	9,999.00	70	90	20	6.00	90	QTsu (100)	OBF (100)	P	1	15	5	3.00	632.39	31.62
HARN0050446	23.00S/32.00E-36bd	43.53553431	-118.83478052	9,999.00	40	57	17	6.00	57	QTsu (100)	OBF (100)	P	3	15	8	1.88	414.68	24.39
HARN0050447	23.00S/30.00E-13aa	43.58387091	-119.06218233	9,999.00	20	34	14	6.00	34	Qs (100)	YBF (100)	P	1	8	12	0.67	123.88	8.85
HARN0050448	24.00S/33.00E-21da	43.46964608	-118.65180884	9,999.00	318	345	27	6.00	345	QTsu (100)	OBF (100)	P	48	35	42	0.83	211.08	7.82
HARN0050449	23.00S/32.00E-5ba	43.61188438	-118.91454247	9,999.00	60	100	40	6.00	100	QTsu (100)	OBF (100)	P	2	20	12	1.67	354.23	8.86
HARN0050460	23.00S/32.50E-5ab	43.61270751	-118.79502940	0.60	50	68	18	6.00	68	Qs (100)	YBF (100)	P	3	23	12	1.92	424.59	23.59
HARN0050461	23.00S/32.50E-19ba	43.56814171	-118.82006019	9,999.00	50	84	34	6.00	84	QTsu (100)	OBF (100)	P	3	20	5	4.00	934.43	27.48
HARN0050462	22.00S/30.00E-27dc	43.63016529	-119.10398730	0.20	32	122	90	6.00	122	Ta (100)	SFD (100)	P	1	30	100	0.30	51.74	0.57
HARN0050463	26.00S/30.00E-5bd	43.34715915	-119.15113397	9,999.00	40	290	250	6.00	290	Tts (98); QTV (2)	OBF (98); PVD (2)	P	1	15	30	0.50	90.51	0.36
HARN0050464	24.00S/32.50E-9bb	43.50978925	-118.78540129	9,999.00	45	100	55	6.00	100	QTsu (100)	OBF (100)	P	4	20	15	1.33	293.72	5.34
HARN0050465	23.00S/33.00E-5ba	43.60830995	-118.66138891	9,999.00	1	500	499	10.00	500	--	--	B	1	60	3	20.00	4,504.47	9.03
HARN0050466	23.00S/33.00E-36ad	43.53094572	-118.59187172	9,999.00	45	60	15	6.00	60	QTsu (100)	OBF (100)	P	2	36	7	5.14	1,188.41	79.23
HARN0050467	23.00S/34.00E-30ac	43.54542335	-118.57689926	9,999.00	36	78	42	12.00	78	QTsu (100)	OBF (100)	P	24	700	34	20.59	5,592.49	133.15
HARN0050468	22.00S/32.50E-31ba	43.62604744	-118.82003325	9,999.00	65	105	40	6.00	105	QTsu (100)	OBF (100)	P	2	12	27	0.44	84.72	2.12
HARN0050469	23.00S/32.50E-31bc	43.53460000	-118.82040000	200.00	40	62	22	6.00	62	QTsu (100)	OBF (100)	P	2	30	12	2.50	548.06	24.91
HARN0050472	26.00S/30.00E-10cd	43.32363000	-119.11371000	25.00	39	285	246	13.27	285	Tts (63); QTV (37)	OBF (63); PVD (37)	P	1	1,950	50	39.00	8,849.23	35.97
HARN0050473	24.00S/32.00E-2dc	43.51394783	-118.84997413	9,999.00	50	65	15	6.00	65	QTsu (100)	OBF (100)	P	3	20	8	2.50	564.74	37.65
HARN0050474	29.00S/31.00E-14dd	43.04550000	-118.84118000	25.00	69	80	11	6.00	80	Qs (100)	YBF (100)	P	3	20	10	2.00	444.45	40.40
HARN0050479	23.00S/32.00E-27ca	43.54656487	-118.87483824	9,999.00	20	300	280	14.00	300	--	--	P	10	140	200	0.70	137.73	0.49
HARN0050490	23.00S/32.50E-21aa	43.56798608	-118.77065887	9,999.00	45	58	13	6.00	58	QTsu (100)	OBF (100)	P	2	20	8	2.50	548.06	42.16
HARN0050491	23.00S/32.50E-15cb	43.57521153	-118.76567673	9,999.00	51	90	39	6.00	90	QTsu (100)	OBF (100)	P	4	17	10	1.70	381.28	9.78
HARN0050501	25.00S/31.00E-33ba	43.36386463	-119.01422406	2.00	42	145	103	13.35	145	QTsu (100)	OBF (100)	P	2	1,500	23	65.22	16,074.67	156.06
HARN0050511	25.00S/34.00E-7db	43.41190748	-118.57701373	9,999.00	80	130	50	6.00	130	QTsu (100)	OBF (100)	P	2	20	9	2.22	482.85	9.66
HARN0050512	23.00S/33.00E-35cb	43.52740673	-118.62672170	9,999.00	40	62	22	6.00	62	QTsu (100)	OBF (100)	P	3	20	6	3.33	768.73	34.94
HARN0050514	23.00S/32.50E-14aa	43.58370101	-118.72889100	0.10	198	230	32	6.00	230	QTsu (100)	OBF (100)	P	8	33	4	8.25	2,156.94	67.40
HARN0050515	22.00S/32.00E-26ab	43.64199000	-118.84984000	25.00	27	100	73	6.00	100	QTsu (100)	OBF (100)	P	1	36	16	2.25	463.59	6.35
HARN0050516	26.00S/30.00E-2ca	43.34528796	-119.08892109	1.00	76	97	21	12.00	115	Tts (52); QTV (48)	OBF (52); PVD (48)	B	1	50	0	100.00	24,561.99	1,169.62
HARN0050519	23.00S/33.00E-4bb	43.60706169	-118.66494495	9,999.00	43	205	162	11.94	205	--	--	B	1	100	2	50.00	11,722.44	72.36
HARN0050549	2																	

Appendix J:

Table listing wells with well yield test data and related Harney Basin study hydraulic property calculation results
(See notes at end of table)

OWRD Well ID Pumped Well Groundwater Database	Well Location (best available)				Well Construction				Well Bottom (ft. blsd)	Well OPI Units		Well Yield Test				Calculated		
	Public Land Survey (PLS) Township/Range-Section qtr qtr	Latitude (decimal)	Longitude (decimal)	Error Horizontal (feet)	Well Open Interval (OPI)			Strat Unit(s)		Hydro-Strat Unit(s)	Test Type	Duration (hours)	Discharge Rate (gal / min)	Drawdown Final (feet)	Specific Capacity (gpm / ft)	Transmissivity (feet ² / day)	Hydraulic Conductivity (feet / day)	
					OPI Top (ft. blsd)	OPI Bottom (ft. blsd)	OPI height (feet)											OPI Diameter Weighted (inches)
HARN0050707	26.00S/31.00E-35dc	43.26419000	-118.84334000	25.00	88	108	20	8.00	111	Qvb (95); Tts (5)	VB (95); OBF (5)	P	3	50	0	100.00	27,669.65	1,383.48
HARN0050709	24.00S/33.00E-1ac	43.51576000	-118.59480000	14.50	39	50	11	6.00	50	QTsu (100)	OBF (100)	P	2	33	13	2.54	557.13	50.65
HARN0050714	23.00S/33.00E-35cb	43.52740673	-118.62672170	9,999.00	39	50	11	6.00	50	QTsu (100)	OBF (100)	P	5	15	16	0.94	204.53	18.59
HARN0050715	19.00S/32.00E-27ab	43.90041340	-118.86465586	9,999.00	60	190	130	6.00	190	QTsu (100)	OBF (100)	P	1	20	12	1.67	335.12	2.58
HARN0050717	23.00S/31.00E-32da	43.53283874	-119.02249461	9,999.00	40	45	5	6.00	45	QTsu (100)	OBF (100)	P	1	20	6	3.33	708.46	141.69
HARN0050719	25.00S/32.50E-20bb	43.39546661	-118.80481310	0.10	50	77	27	6.00	77	QTsu (100)	OBF (100)	P	1	14	23	0.61	112.19	4.16
HARN0050722	23.00S/31.00E-33ac	43.53634119	-119.00754299	9,999.00	40	57	17	6.00	57	QTsu (100)	OBF (100)	P	1	20	4	5.00	1,096.12	64.48
HARN0050731	20.00S/34.00E-5ac	43.86002492	-118.55496538	9,999.00	99	163	64	6.00	163	--	--	P	4	18	77	0.23	44.76	0.70
HARN0050733	23.00S/31.00E-3bb	43.61241461	-118.99755828	9,999.00	288	308	20	6.00	308	Tts (100)	OBF (100)	P	1	30	24	1.25	245.37	12.27
HARN0050734	26.00S/31.00E-18dd	43.30940051	-119.04388630	0.10	58	70	12	8.00	70	QTV (100)	PVD (100)	B	1	1	20	0.05	6.61	0.55
HARN0050737	23.00S/31.00E-17bb	43.58373998	-119.03785269	9,999.00	40	45	5	6.00	45	Qs (100)	YBF (100)	P	1	20	10	2.00	408.18	81.64
HARN0050738	19.00S/36.00E-28cb	43.88633080	-118.30524086	9,999.00	30	158	128	6.00	158	--	--	P	1	18	42	0.43	76.47	0.60
HARN0050741	26.00S/30.00E-11ba	43.33418235	-119.09353096	200.00	121	140	19	14.00	140	QTV (100)	PVD (100)	P	2	1,500	63	23.81	5,438.56	286.24
HARN0050744	24.00S/32.00E-11cd	43.49948122	-118.85509180	9,999.00	100	720	620	10.15	720	QTsu (100)	OBF (100)	P	3	90	97	0.93	178.26	0.29
HARN0050747	20.00S/35.00E-25aa	43.80628643	-118.35025890	9,999.00	23	350	327	6.00	350	--	--	P	1	40	95	0.42	75.01	0.23
HARN0050748	25.00S/33.00E-5cc	43.42255668	-118.68642248	9,999.00	99	105	6	6.00	105	QTsu (100)	OBF (100)	P	3	40	10	4.00	934.43	155.74
HARN0050751	24.00S/33.00E-25add	43.45786017	-118.58997080	14.00	119	148	29	6.00	148	QTsu (100)	OBF (100)	P	5	25	8	3.13	743.54	25.64
HARN0050762	34.00S/30.00E-10cd	42.63472304	-119.18017554	9,999.00	36	160	124	6.00	160	--	--	P	1	20	10	2.00	408.18	3.29
HARN0050766	22.00S/32.50E-32aa	43.62742918	-118.79280280	0.10	80	420	340	14.00	420	QTsu (100)	OBF (100)	B	1	100	5	20.00	4,282.84	12.60
HARN0050788	23.00S/32.00E-18cc	43.57171000	-118.93984000	24.00	285	289	4	6.00	289	QTsu (100)	OBF (100)	P	3	50	5	10.00	2,485.97	621.49
HARN0050789	24.00S/32.50E-20da	43.47433139	-118.78769273	500.00	99	420	321	16.00	420	QTsu (100)	OBF (100)	P	5	800	20	40.00	9,901.75	30.85
HARN0050790	25.00S/32.50E-2ba	43.43583000	-118.74239000	9,999.00	199	330	131	14.00	330	QTsu (100)	OBF (100)	P	1	500	80	6.25	1,218.00	9.30
HARN0050795	27.00S/30.00E-2ad	43.25474161	-118.95798040	0.10	75	175	100	6.00	175	Tts (100)	OBF (100)	P	1	10	30	0.33	58.07	0.58
HARN0050801	25.00S/33.00E-11cd	43.40665000	-118.61909000	25.00	293	373	80	12.00	373	QTV (100)	PVD (100)	B	1	100	2	50.00	11,713.88	146.42
HARN0050804	24.00S/33.00E-24bd	43.47228740	-118.60057205	50.00	113	325	212	12.00	325	QTsu (100)	OBF (100)	B	1	100	10	10.00	2,077.85	9.80
HARN0050808	24.00S/29.00E-2dc	43.51418200	-119.20683120	9,999.00	40	125	85	6.00	125	--	--	P	1	50	40	1.25	245.37	2.89
HARN0050887	26.00S/30.00E-2ba	43.34928977	-119.08420490	1.00	40	183	143	19.94	183	QTV (82); Tts (18)	PVD (82); OBF (18)	B	1	50	2	25.00	5,153.43	36.04
HARN0050893	24.00S/32.00E-9aa	43.50970000	-118.88303000	12.00	105	110	5	6.00	110	QTsu (100)	OBF (100)	P	2	20	11	1.82	389.04	77.81
HARN0050895	25.00S/34.00E-7ad	43.41619000	-118.58002000	100.00	155	167	12	6.00	167	QTsu (100)	OBF (100)	P	2	40	12	3.33	746.53	62.21
HARN0050897	23.00S/32.50E-3dc	43.60236000	-118.75334000	12.00	80	115	35	6.00	115	QTsu (100)	OBF (100)	P	1	20	9	2.22	457.41	13.07
HARN0050898	23.00S/32.00E-11cc	43.58715269	-118.86188923	300.00	60	200	140	12.00	200	QTsu (100)	OBF (100)	P	18	1,200	56	21.43	5,734.56	40.96
HARN0050899	24.00S/32.00E-11ad	43.50504000	-118.84692000	14.00	99	145	46	6.00	145	QTsu (100)	OBF (100)	P	8	35	10	3.50	866.15	18.83
HARN0050904	22.00S/30.00E-36ac	43.62464584	-119.06893450	0.30	76	80	4	6.00	80	QTsu (100)	OBF (100)	P	1	10	3	3.33	708.46	177.12
HARN0050909	22.00S/32.00E-34aa	43.62615675	-118.86277641	9,999.00	40	250	210	10.76	250	QTsu (100)	OBF (100)	B	1	60	20	3.00	574.26	2.73
HARN0050912	24.00S/33.00E-13cc	43.48048072	-118.60690194	9,999.00	159	200	41	6.00	200	QTsu (100)	OBF (100)	P	10	30	26	1.15	268.81	6.56
HARN0050920	29.00S/31.00E-24bb	43.04316746	-118.83586970	9,999.00	54	80	26	6.00	80	Tts (88); Qs (12)	OBF (88); YBF (12)	P	2	20	5	4.00	907.82	34.92
HARN0050926	23.00S/30.00E-13cd	43.57371000	-119.07116000	14.00	100	160	60	16.00	160	QTsu (100)	OBF (100)	P	1	500	120	4.17	765.29	12.75
HARN0050927	23.00S/32.00E-18ab	43.58478927	-118.92732478	100.00	31	246	215	17.11	246	QTsu (81); Trt (12); Tts (5)	OBF (100)	B	1	100	0	200.00	49,071.00	228.24
HARN0050929	24.00S/32.50E-30cc	43.45236000	-118.81510000	14.00	20	420	400	12.00	420	QTsu (100)	OBF (100)	P	1	150	80	1.88	337.38	0.84
HARN0050932	25.00S/33.00E-12ca	43.41206000	-118.60395000	100.00	45	65	20	6.00	65	QTsu (85)	OBF (85)	P	1	20	3	6.67	1,493.05	74.65
HARN0050933	23.00S/33.00E-33bb	43.53470509	-118.66653095	9,999.00	20	240	220	14.00	240	QTsu (100)	OBF (100)	B	1	30	4	7.50	1,484.32	6.75
HARN0050944	22.00S/32.00E																	

Appendix J:

Table listing wells with well yield test data and related Harney Basin study hydraulic property calculation results
(See notes at end of table)

OWRD Well ID Pumped Well Groundwater Database	Well Location (best available)				Well Construction				Well Bottom (ft. blsd)	Well OPI Units		Well Yield Test				Calculated		
	Public Land Survey (PLS) Township/Range-Section qtr qtr	Latitude (decimal)	Longitude (decimal)	Error Horizontal (feet)	Well Open Interval (OPI)					Strat Unit(s)	Hydro-Strat Unit(s)	Test Type	Duration (hours)	Discharge Rate (gal / min)	Drawdown Final (feet)	Specific Capacity (gpm / ft)	Transmissivity (feet ² / day)	Hydraulic Conductivity (feet / day)
					OPI Top (ft. blsd)	OPI Bottom (ft. blsd)	OPI height (feet)	OPI Diameter Weighted (inches)										
HARN0051076	25.00S/34.00E-7acc	43.41535728	-118.57774960	0.13	122	123	1	6.00	123	Qs (100)	YBF (100)	P	3	10	10	1.00	210.80	210.80
HARN0051078	25.00S/32.50E-22ab	43.39395972	-118.75537771	9,999.00	50	88	38	6.00	88	QTsu (100)	OBF (100)	P	1	18	3	6.00	1,333.35	35.09
HARN0051080	25.00S/34.00E-7ab	43.42037000	-118.57763000	100.00	128	250	122	6.00	250	QTsu (100)	OBF (100)	P	5	25	26	0.96	210.17	1.72
HARN0051082	25.00S/34.00E-7ad	43.41478000	-118.57383000	100.00	100	126	26	6.00	126	QTsu (100)	OBF (100)	P	1	30	17	1.76	356.50	13.71
HARN0051083	22.00S/33.00E-23cc	43.64005000	-118.62763000	15.00	80	192	112	6.00	192	QTsu (100)	OBF (100)	P	1	25	45	0.56	101.54	0.91
HARN0051126	23.00S/31.00E-12cd	43.58564000	-118.95622000	10.00	100	400	300	7.68	400	QTsu (100)	OBF (100)	P	4	42	47	0.89	183.68	0.61
HARN0051130	23.00S/33.00E-18dc	43.57438000	-118.69624000	18.00	168	230	62	6.00	230	QTsu (100)	OBF (100)	P	6	15	134	0.11	20.82	0.34
HARN0051132	24.00S/33.00E-12aa	43.50744000	-118.59719000	25.00	79	118	39	6.00	118	QTsu (100)	OBF (100)	P	10	15	17	0.88	201.67	5.17
HARN0051134	24.00S/33.00E-18ba	43.49133078	-118.70137508	9,999.00	285	304	19	6.00	304	QTsu (100)	OBF (100)	P	4	14	36	0.39	77.75	4.09
HARN0051138	24.00S/32.00E-13aa	43.49534000	-118.82300000	50.00	59	72	13	6.00	72	QTsu (100)	OBF (100)	P	1	10	5	2.00	408.18	31.40
HARN0051142	26.00S/32.00E-35dc	43.26406399	-118.72805624	9,999.00	20	160	140	22.60	160	QTsu (100)	OBF (100)	P	6	1,020	15	68.00	16,857.99	120.41
HARN0051144	22.00S/31.00E-33bd	43.62304146	-119.01285710	9,999.00	40	80	40	6.00	80	Trt (100)	OBF (100)	P	2	40	22	1.82	389.04	9.73
HARN0051154	25.00S/33.00E-36ac	43.35704361	-118.59765854	500.00	118	153	35	10.00	153	Tts (100)	OBF (100)	B	1	30	20	1.50	273.46	7.81
HARN0051156	24.00S/33.00E-12ac	43.50568000	-118.59707000	25.00	153	209	56	10.00	209	QTsu (100)	OBF (100)	B	2	80	10	8.00	1,772.43	31.65
HARN0051160	23.00S/32.50E-3dbd	43.60243333	-118.75512917	50.00	20	173	153	19.20	173	QTsu (100)	OBF (100)	B	0	100	15	6.67	1,158.86	7.57
HARN0051178	22.00S/31.00E-33ba	43.62652600	-119.01298921	9,999.00	40	105	65	6.00	105	Trt (100)	OBF (100)	P	1	40	10	4.00	862.19	13.26
HARN0051179	22.00S/31.00E-33ba	43.62652600	-119.01298921	9,999.00	40	100	60	6.00	100	Trt (100)	OBF (100)	P	1	40	10	4.00	862.19	14.37
HARN0051187	23.00S/31.00E-1bd	43.60823000	-118.94181000	25.00	80	105	25	6.00	105	QTsu (100)	OBF (100)	P	2	42	10	4.20	956.58	38.26
HARN0051188	28.00S/29.75E-2bdc	43.16866266	-119.08991890	0.09	40	60	20	6.00	60	QTsu (100)	OBF (100)	P	2	25	3	8.33	1,991.58	99.58
HARN0051204	23.00S/32.50E-13cc	43.57064000	-118.72820000	25.00	102	165	63	6.00	165	QTsu (100)	OBF (100)	P	1	25	6	4.17	900.91	14.30
HARN0051208	24.00S/32.00E-12dc	43.49934685	-118.82989127	9,999.00	59	65	6	6.00	65	QTsu (100)	OBF (100)	P	1	20	3	6.67	1,493.05	248.84
HARN0051209	26.00S/33.00E-35ad	43.27279436	-118.60684900	25.00	348	412	64	16.00	412	Tov (100)	UVR (100)	P	6	1,020	2	510.00	148,845.11	2,325.70
HARN0051210	23.00S/25.00E-10bb	43.59735900	-119.71297800	250.00	78	600	522	13.70	600	Tts (54); Tobg (46)	OBF (54); HLP (46)	P	6	1,100	40	27.50	6,860.36	13.14
HARN0051213	23.00S/32.00E-15ab	43.58293324	-118.86963551	9,999.00	80	130	50	6.00	130	QTsu (100)	OBF (100)	P	1	40	3	13.33	3,137.80	62.76
HARN0051225	24.00S/33.00E-4ba	43.52021880	-118.66157430	9,999.00	50	60	10	6.00	60	QTsu (100)	OBF (100)	P	12	15	2	7.50	1,998.69	199.87
HARN0051227	32.00S/32.00E-2ac	42.82943247	-118.91767867	9,999.00	90	100	10	8.00	130	QTsu (100)	OBF (100)	P	1	35	50	0.70	123.91	12.39
HARN0051236	22.00S/31.00E-33ba	43.62652600	-119.01298921	9,999.00	77	78	1	6.00	78	--	--	P	1	10	20	0.50	90.51	90.51
HARN0051253	25.00S/31.00E-28aa	43.38076000	-119.00379000	9,999.00	20	145	125	18.88	180	QTsu (100)	OBF (100)	B	1	50	0	100.00	23,078.39	184.63
HARN0051254	24.00S/32.00E-12bc	43.50726000	-118.84206000	21.00	52	70	18	6.00	70	QTsu (100)	OBF (100)	P	2	20	4	5.00	1,129.47	62.75
HARN0051256	25.00S/31.00E-28aa	43.37763000	-119.00029000	9,999.00	29	136	107	18.58	172	QTsu (100)	OBF (100)	B	1	50	0	100.00	23,131.05	216.18
HARN0051259	25.00S/30.00E-28ad	43.37743942	-119.11930497	2.00	60	207	147	13.75	207	QTsu (100)	OBF (100)	P	6	335	86	3.90	846.46	5.76
HARN0051260	25.00S/31.00E-27bc	43.37759000	-118.99515000	9,999.00	31	133	102	19.04	150	QTsu (100)	OBF (100)	B	1	50	0	100.00	23,050.87	225.99
HARN0051267	26.00S/31.00E-17db	43.31435000	-119.02609000	25.00	78	93	15	6.00	93	QTsu (100)	OBF (100)	P	8	30	29	1.03	235.36	15.69
HARN0051268	25.00S/34.00E-7ad	43.41463000	-118.57232000	100.00	118	160	42	6.00	160	QTsu (100)	OBF (100)	P	8	30	24	1.25	288.27	6.86
HARN0051272	25.00S/30.00E-34cdc	43.35422113	-119.11154325	1.00	77	375	298	13.09	375	QTV (99); Tts (1)	PVD (99); OBF (1)	P	4	550	102	5.39	1,173.30	3.94
HARN0051276	24.00S/32.50E-33cc	43.44099277	-118.78663640	0.10	45	62	17	6.00	62	QTsu (100)	OBF (100)	P	3	20	13	1.54	335.24	19.72
HARN0051278	22.00S/31.00E-33ba	43.62652600	-119.01298921	9,999.00	71	110	39	6.00	110	Trt (87); Tts (13)	OBF (100)	P	1	25	5	5.00	1,096.12	28.11
HARN0051279	22.00S/31.00E-33ba	43.62402000	-119.00953000	12.00	69	103	34	6.00	103	Trt (91); Tts (9)	OBF (100)	P	1	25	5	5.00	1,096.12	32.24
HARN0051281	30.00S/36.00E-29da	42.93451000	-118.31786000	15.00	60	140	80	6.00	140	--	--	P	36	18	21	0.86	213.48	2.67
HARN0051291	27.00S/33.00E-1da	43.25378000	-118.58293000	25.00	99	162	63	14.00	162	QTsu (100)	OBF (100)	P	14	900	27	33.33	8,856.61	140.58
HARN0051313	25.00S/34.00E-16bb	43.40546983	-118.54956538	50.00	60	375	315	12.00	375	QTsu (100)	OBF (100)	P	5	1,400	45	31.11	7,865.87	

Appendix J:

Table listing wells with well yield test data and related Harney Basin study hydraulic property calculation results
(See notes at end of table)

OWRD Well ID Pumped Well Groundwater Database	Well Location (best available)				Well Construction					Well OPI Units		Well Yield Test				Calculated		
	Public Land Survey (PLS) Township/Range-Section qtr qtr	Latitude (decimal)	Longitude (decimal)	Error Horizontal (feet)	Well Open Interval (OPI)				Well Bottom (ft. blsd)	Strat Unit(s)	Hydro-Strat Unit(s)	Test Type	Duration (hours)	Discharge Rate (gal / min)	Drawdown Final (feet)	Specific Capacity (gpm / ft)	Transmissivity (feet ² / day)	Hydraulic Conductivity (feet / day)
					OPI Top (ft. blsd)	OPI Bottom (ft. blsd)	OPI height (feet)	OPI Diameter Weighted (inches)										
HARN0051504	25.00S/31.00E-31dc	43.35321212	-119.04822703	1.00	20	220	200	18.72	220	QTsu (50); QTV (42); Tts (8)	OBF (58); PVD (42)	P	1	688	65	10.58	2,053.18	10.27
HARN0051525	24.00S/32.00E-24aa	43.48119563	-118.82490540	9,999.00	39	42	3	6.00	42	QTsu (100)	OBF (100)	P	1	20	2	10.00	2,306.18	768.73
HARN0051537	23.00S/33.00E-16cb	43.57233000	-118.66535000	25.00	60	145	85	14.20	145	QTsu (94)	OBF (94)	P	10	600	17	35.29	9,201.35	108.25
HARN0051541	27.00S/33.00E-1bb	43.26176626	-118.60138857	100.00	18	120	102	18.25	120	QTsu (100)	OBF (100)	B	1	70	10	7.00	1,315.57	12.90
HARN0051545	24.00S/33.00E-12da	43.49874000	-118.59139000	25.00	96	152	56	10.00	152	QTsu (100)	OBF (100)	P	2	300	25	12.24	2,798.58	49.97
HARN0051555	26.00S/30.00E-1bc	43.34619410	-119.07619103	2.00	230	320	90	12.00	320	--	--	P	3	1,400	20	70.00	18,040.55	200.45
HARN0051557	24.00S/30.00E-7db	43.50256000	-119.16811000	12.70	207	407	200	10.00	407	--	--	P	6	500	120	4.17	953.70	4.77
HARN0051573	25.00S/31.00E-10cd	43.41049564	-118.99497980	0.15	78	250	172	12.28	250	QTsu (100)	OBF (100)	P	8	400	138	2.90	640.30	3.72
HARN0051574	34.00S/32.75E-4bd	42.65577002	-118.72823998	25.00	160	220	60	8.00	220	Tsb (100)	UVR (100)	P	3	2	31	0.06	8.91	0.15
HARN0051575	23.00S/31.00E-1ba	43.61322000	-118.95361000	25.00	20	200	180	14.00	200	QTsu (100)	OBF (100)	P	8	300	140	2.14	453.42	2.52
HARN0051582	24.00S/33.00E-25ba	43.46275000	-118.59982000	12.70	212	600	388	13.07	600	QTsu (100)	OBF (100)	P	2	125	177	0.71	118.27	0.30
HARN0051588	25.00S/31.00E-9ac	43.41742000	-119.01002000	15.20	38	135	97	15.10	135	QTsu (100)	OBF (100)	P	8	850	40	21.25	5,244.27	54.06
HARN0051589	24.00S/33.00E-12aa	43.50490590	-118.59092190	0.09	128	150	22	8.00	150	QTsu (100)	OBF (100)	P	9	165	23	7.17	1,805.79	82.08
HARN0051600	24.00S/33.00E-7bc	43.50308640	-118.70574180	0.10	39	63	24	6.00	63	QTsu (100)	OBF (100)	P	1	25	3	8.33	1,896.88	79.04
HARN0051606	26.00S/30.00E-12dd	43.32433491	-119.06051253	2.00	30	120	90	14.00	120	QTV (100)	PVD (100)	P	4	700	10	70.00	18,017.04	200.19
HARN0051620	23.00S/31.00E-11cb	43.58939489	-118.96937529	50.00	100	120	20	4.00	140	QTsu (100)	OBF (100)	P	5	15	73	0.21	42.43	2.12
HARN0051629	25.00S/33.00E-25aa	43.37721000	-118.59118000	25.00	20	165	145	22.07	165	Tdw (100)	HLP (100)	P	6	825	50	16.50	3,720.58	25.66
HARN0051636	23.00S/32.00E-3bc	43.60761000	-118.87814000	13.20	1	112	111	1.00	112	--	--	P	30	30	8	3.75	1,229.94	11.08
HARN0051638	20.00S/33.00E-32	43.81305556	-118.68755556	0.00	200	220	20	4.00	220	--	--	P	1	10	220	0.05	7.01	0.35
HARN0051641	24.00S/32.50E-19ba	43.48270000	-118.81963000	13.10	39	60	21	6.00	60	QTsu (100)	OBF (100)	P	8	30	7	4.29	1,074.76	51.18
HARN0051650	25.00S/32.50E-20cb	43.38659655	-118.80542659	9,999.00	20	63	43	6.00	63	QTsu (100)	OBF (100)	P	1	20	17	1.18	229.75	5.34
HARN0051653	24.00S/32.50E-22cc	43.47089400	-118.76707600	99.00	39	65	26	6.00	65	QTsu (100)	OBF (100)	P	1	20	10	2.00	408.18	15.70
HARN0051654	25.00S/31.00E-30bc	43.37497000	-119.05740000	11.10	100	260	160	14.00	260	QTV (66); Tts (34)	PVD (66); OBF (34)	P	6	1,000	20	50.00	12,925.50	80.78
HARN0051683	24.00S/33.00E-4ba	43.52186644	-118.65410372	50.00	70	90	20	4.00	90	QTsu (100)	OBF (100)	P	12	8	23	0.35	79.86	3.99
HARN0051684	25.00S/31.00E-30	43.37497261	-119.05747632	250.00	45	175	130	6.00	175	QTsu (77); Tsb (23)	OBF (77); UVR (23)	P	1	15	2	7.50	1,694.21	13.03
HARN0051692	25.00S/34.00E-7da	43.41269000	-118.57219000	20.10	118	130	12	6.00	130	QTsu (100)	OBF (100)	P	3	22	4	5.50	1,313.54	109.46
HARN0051694	26.00S/30.00E-1ab	43.33838000	-119.06885000	19.90	305	700	395	10.00	700	Tts (100)	OBF (100)	P	1	300	222	1.35	244.00	0.62
HARN0051697	25.00S/33.00E-19bb	43.38868041	-118.70832370	0.18	98	124	26	8.15	124	QTV (100)	PVD (100)	P	12	300	41	7.32	1,873.95	72.08
HARN0051707	25.00S/31.00E-10bb	43.42421000	-119.00004000	25.00	59	160	101	13.21	160	QTsu (100)	OBF (100)	P	6	450	100	4.50	994.53	9.85
HARN0051718	20.00S/31.00E-13ba	43.84034000	-118.95216000	13.00	138	180	42	5.00	180	Tdv (100)	OBF (100)	P	8	2	170	0.01	1.87	0.04
HARN0051719	25.00S/31.00E-16dc	43.39574100	-119.00497900	100.00	60	450	390	12.05	450	QTsu (100)	OBF (100)	P	8	300	80	3.75	846.58	2.17
HARN0051720	26.00S/31.00E-7db	43.32869764	-119.04887936	9,999.00	147	450	303	11.06	450	Tts (80); QTV (20)	OBF (80); PVD (20)	B	1	25	0	50.00	11,848.10	39.10
HARN0051721	23.00S/31.00E-10da	43.59214000	-118.98184000	12.20	49	230	181	10.00	230	QTsu (100)	OBF (100)	P	8	300	36	8.33	2,041.27	11.28
HARN0051722	24.00S/33.00E-22ac	43.47249425	-118.63478640	0.38	288	390	102	8.00	390	QTsu (100)	OBF (100)	P	24	30	45	0.67	152.59	1.50
HARN0051738	22.00S/32.50E-35bdc	43.62169246	-118.74293800	0.15	67	200	133	12.00	200	QTsu (100)	OBF (100)	P	1	1,800	50	36.00	8,240.00	61.95
HARN0051740	23.00S/31.00E-1bb	43.61123058	-118.95622734	250.00	120	580	460	11.61	580	QTsu (100)	OBF (100)	P	5	550	226	2.43	516.20	1.12
HARN0051741	25.00S/31.00E-21ab	43.39548000	-119.00822000	14.80	48	150	102	14.53	150	QTsu (100)	OBF (100)	P	1	50	88	0.57	87.13	0.85
HARN0051742	25.00S/31.00E-16ba	43.41024200	-119.00998500	250.00	70	115	45	12.00	115	QTsu (100)	OBF (100)	P	4	900	22	40.91	10,376.89	230.60
HARN0051760	26.00S/30.00E-3bb	43.34987000	-119.11706000	14.00	102	198	96	12.90	198	QTV (100)	PVD (100)	P	6	2,800	5	560.00	168,186.24	1,751.94
HARN0051764	27.00S/33.00E-1bb	43.25857942	-118.59674648	100.00	20	140	120	19.22	140	QTsu (100)	OBF (100)	P	10	950	83	11.45	2,660.04	22.17
HARN0051765	26.00S/30.00E-3bb	43.34983000	-119.11736000	12.60	60	167	107	14.00	167	QTV (100)	PVD (100)	P	6	2,800	2	1,400.00	437,441.61	4,088.24
HARN0051766																		

Appendix J:

Table listing wells with well yield test data and related Harney Basin study hydraulic property calculation results
(See notes at end of table)

OWRD Well ID Pumped Well Groundwater Database	Well Location (best available)				Well Construction				Well Bottom (ft. blsd)	Well OPI Units		Test Type	Well Yield Test			Calculated		
	Public Land Survey (PLS) Township/Range-Section qtr qtr	Latitude (decimal)	Longitude (decimal)	Error Horizontal (feet)	Well Open Interval (OPI)			Strat Unit(s)		Hydro-Strat Unit(s)	Duration (hours)		Discharge Rate (gal / min)	Drawdown Final (feet)	Specific Capacity (gpm / ft)	Transmissivity (feet ² / day)	Hydraulic Conductivity (feet / day)	
					OPI Top (ft. blsd)	OPI Bottom (ft. blsd)	OPI height (feet)											OPI Diameter Weighted (inches)
HARN0051943	23.00S/32.00E-33da	43.53089000	-118.88651000	17.00	47	224	177	18.53	256	QTsu (100)	OBF (100)	P	2	325	148	2.20	394.50	2.23
HARN0051944	24.00S/32.50E-28bd	43.46449000	-118.78226000	13.50	278	920	642	8.06	920	Tts (57); QTsu (23); Trt (20)	OBF (100)	P	2	1,108	158	7.01	1,588.16	2.47
HARN0051959	33.00S/31.00E-9cc	42.72778000	-119.08521000	19.60	122	700	578	19.06	700	--	--	P	5	2,400	130	18.46	4,230.60	7.32
HARN0051965	23.00S/32.00E-32cc	43.52813440	-118.92000590	9,999.00	39	60	21	6.00	60	QTsu (100)	OBF (100)	P	4	10	10	1.00	215.55	10.26
HARN0051972	23.00S/32.00E-36dd	43.52728000	-118.82348000	25.00	236	288	53	14.00	288	QTsu (100)	OBF (100)	P	12	900	110	8.18	1,965.92	37.45
HARN0051977	24.00S/29.00E-12bb	43.50982000	-119.19428000	21.10	97	393	296	12.00	393	--	--	P	4	800	100	8.00	1,815.64	6.13
HARN0051979	24.00S/33.00E-18aa	43.49132745	-118.69150201	9,999.00	310	605	295	8.00	605	QTsu (100)	OBF (100)	P	8	800	145	5.52	1,354.52	4.59
HARN0052002	24.00S/33.00E-18dd	43.48259000	-118.69361000	16.80	323	1,300	977	9.80	1,300	QTsu (100)	OBF (100)	P	4	100	234	0.43	79.14	0.08
HARN0052004	26.00S/30.00E-13ac	43.31797000	-119.06410000	15.80	70	365	295	13.16	365	Tts (73); QTV (27)	OBF (73); PVD (27)	P	4	400	118	3.39	711.05	2.41
HARN0052008	30.00S/29.50E-28ca	42.93513000	-119.17226000	25.00	620	660	40	6.00	660	Tsb (100)	UVR (100)	P	6	5	45	0.11	20.65	0.52
HARN0052011	23.00S/33.00E-22d	43.55460000	-118.63409000	25.00	201	610	409	12.00	610	QTsu (100)	OBF (100)	P	6	450	100	4.50	1,008.73	2.47
HARN0052014	24.00S/33.00E-1bd	43.51652245	-118.60185514	9,999.00	5	40	35	5.00	60	QTsu (100)	OBF (100)	P	3	15	8	1.88	425.92	12.17
HARN0052020	25.00S/34.00E-7bd	43.41729000	-118.57986000	17.70	138	230	92	6.00	230	QTsu (89); Tov (11)	OBF (89); UVR (11)	P	24	15	68	0.22	48.57	0.53
HARN0052022	25.00S/28.00E-26ddd	43.36793000	-119.31767000	10.00	154	720	566	8.00	720	QTsu (100)	OBF (100)	P	24	400	40	10.00	2,730.77	4.82
HARN0052030	25.00S/31.00E-5aa	43.43789000	-119.03937000	25.00	20	400	380	8.00	400	QTsu (100)	OBF (100)	B	1	2	68	0.03	3.61	0.01
HARN0052031	23.00S/33.00E-32ba	43.53621148	-118.68243763	300.00	238	400	162	12.77	400	QTsu (100)	OBF (100)	P	22	2,000	30	66.67	19,150.94	118.22
HARN0052063	25.00S/29.00E-28cb	43.42465000	-118.67971000	11.80	280	425	145	9.10	425	QTsu (48); Tts (28); QTV (24)	OBF (76); PVD (24)	P	3	900	197	4.57	1,014.66	7.00
HARN0052069	23.00S/33.00E-4ac	43.60218000	-118.65900000	13.70	60	285	225	12.00	285	--	--	P	4	1,150	26	44.23	11,275.74	50.11
HARN0052070	23.00S/33.00E-4ad	43.60176000	-118.65268000	12.00	20	100	80	12.00	110	--	--	P	1	125	100	1.25	216.42	2.71
HARN0052081	21.00S/35.00E-7ca	43.75923000	-118.46130000	100.00	98	500	402	8.00	500	--	--	P	24	350	225	1.56	377.64	0.94
HARN0052085	24.00S/33.00E-18cac	43.48275000	-118.70283000	14.90	308	1,225	917	8.00	1,225	QTsu (100)	OBF (100)	P	4	200	250	0.80	161.88	0.18
HARN0052093	23.00S/31.00E-12cc	43.58558000	-118.95561000	13.00	205	267	62	8.15	280	QTsu (100)	OBF (100)	P	20	85	143	0.59	132.79	2.14
HARN0052109	24.00S/33.00E-30ca	43.45402000	-118.70773000	14.10	320	600	280	10.00	600	Tts (63); Trt (27); QTsu (11)	OBF (100)	P	7	220	240	0.92	189.27	0.68
HARN0052116	23.00S/26.00E-14bd	43.57737000	-119.56650000	150.00	234	500	266	10.00	500	QTsu (58); HLPu (42)	OBF (58); HLP (42)	P	4	1,600	4	400.00	118,626.15	445.96
HARN0052121	25.00S/30.00E-29dc	43.36904000	-119.14430000	18.00	192	385	193	14.90	385	QTV (100)	PVD (100)	P	8	2,500	16	156.25	43,697.55	226.41
HARN0052127	24.00S/33.00E-18ad	43.48520000	-118.68972000	14.40	307	860	553	8.00	860	QTsu (100)	OBF (100)	P	4	150	238	0.63	125.04	0.23
HARN0052129	24.00S/33.00E-18da	43.48599000	-118.69089000	17.40	292	590	298	6.16	590	QTsu (100)	OBF (100)	P	8	710	76	9.34	2,453.31	8.23
HARN0052132	24.00S/33.00E-31bb	43.45291000	-118.70185000	14.40	240	440	200	9.17	440	QTsu (100)	OBF (100)	P	4	300	130	2.31	496.98	2.48
HARN0052133	27.00S/31.00E-7ca	43.23774000	-118.92400000	13.00	140	1,000	860	8.74	1,000	Tts (100)	OBF (100)	P	4	150	108	1.39	289.67	0.34
HARN0052136	24.00S/29.00E-3da	43.51677331	-119.22079680	0.27	31	255	224	6.00	255	Tts (100)	OBF (100)	B	3	40	13	3.08	705.55	3.15
HARN0052142	24.00S/32.00E-9cc	43.50075000	-118.88297000	13.80	172	940	768	8.60	940	QTsu (100)	OBF (100)	P	5	500	140	3.57	815.43	1.06
HARN0052155	22.00S/32.00E-25dd	43.63137042	-118.82656826	250.00	57	360	304	12.00	360	QTsu (100)	OBF (100)	P	4	300	120	2.50	519.46	1.71
HARN0052156	32.00S/32.00E-2da	42.82557000	-118.91464000	25.00	180	280	100	4.00	280	QTsu (100)	OBF (100)	P	4	43	123	0.35	74.11	0.74
HARN0052179	23.00S/32.00E-29ba	43.55344557	-118.91367909	200.00	50	254	204	21.26	325	QTsu (100)	OBF (100)	P	7	1,000	123	8.13	1,769.19	8.67
HARN0052188	25.00S/31.00E-10cb	43.41386000	-118.99525000	14.90	150	250	100	12.00	250	QTsu (100)	OBF (100)	P	4	300	50	6.00	1,333.35	13.33
HARN0052215	24.00S/32.50E-29aa	43.46466000	-118.79217000	15.60	300	350	50	10.00	350	QTsu (100)	OBF (100)	B	1	50	10	5.00	1,011.73	20.23
HARN0052217	25.00S/35.00E-4da	43.42685381	-118.41173499	250.00	220	803	583	6.00	803	--	--	P	48	4	480	0.01	1.28	0.00
HARN0052222	24.00S/31.00E-34ad	43.44714639	-118.98530594	50.00	91	111	20	4.00	111	QTsu (100)	OBF (100)	B	1	40	2	20.00	5,104.22	255.21
HARN0052225	25.00S/31.00E-15ba	43.40674500	-118.99485100	250.00	57	120	63	12.19	120	UNKN (100)	UNKN (100)	P	4	600	60	10.00	2,301.01	36.52
HARN0052232	24.00S/33.00E-33ac	43.44610524	-118.65899537	100.00	198	450	252	10.41	450	Tts (92); QTV (8)	OBF (92); PVD (8)	P	8	600	90	6.67	1,599.88	6.35
HARN0052255	23.00S/32.00E-30ab	43.55522393	-118.93143630	0.07	48	345	297	22.36	345	QTsu (100)	OBF (100)	P	7	1,200.				

Appendix J:

Table listing wells with well yield test data and related Harney Basin study hydraulic property calculation results
(See notes at end of table)

OWRD Well ID Pumped Well Groundwater Database	Well Location (best available)				Well Construction				Well Bottom (ft. blsd)	Well OPI Units		Test Type	Well Yield Test			Calculated		
	Public Land Survey (PLS) Township/Range-Section qtr qtr	Latitude (decimal)	Longitude (decimal)	Error Horizontal (feet)	Well Open Interval (OPI)			Strat Unit(s)		Hydro-Strat Unit(s)	Duration (hours)		Discharge Rate (gal / min)	Drawdown Final (feet)	Specific Capacity (gpm / ft)	Transmissivity (feet ² / day)	Hydraulic Conductivity (feet / day)	
					OPI Top (ft. blsd)	OPI Bottom (ft. blsd)	OPI height (feet)											OPI Diameter Weighted (inches)
HARN0052631	25.00S/30.00E-28cd	43.36790927	-119.13226590	0.30	462	486	24	6.22	490	QTV (46); Tts (54)	PVD (46); OBF (54)	P	1	2	50	0.04	5.48	0.23
HARN0052632	24.00S/33.00E-23bb	43.47850000	-118.62890000	0.00	95	210	115	6.14	210	QTsu (100)	OBF (100)	P	1	25	43	0.58	106.26	0.92
HARN0052640	26.00S/29.00E-23bd	43.30352000	-119.20907000	50.00	38	110	72	16.00	110	QTb (83); Tts (17)	HLP (83); OBF (17)	P	20	2,200	4	550.00	171,875.10	2,387.15
HARN0052685	23.00S/31.00E-10da	43.59222000	-118.98178000	50.00	101	175	74	13.55	175	QTsu (100)	OBF (100)	P	5	400	10	40.00	10,118.40	136.74
HARN0052692	25.00S/30.00E-27cc	43.37074339	-119.11668130	250.00	75	115	40	16.00	120	QTV (100)	PVD (100)	B	1	100	0	200.00	49,508.74	1,237.72
HARN0052719	27.00S/34.00E-20ad	43.21173000	-118.54433000	50.00	19	920	901	12.35	920	QTsu (63); Tov (37)	OBF (63); UVR (37)	P	8	1,500	20	75.00	20,538.55	22.80
HOOD0050266	24.00S/32.50E-21cb	43.47355304	-118.78503168	9,999.00	26	50	24	6.00	50	QTsu (100)	OBF (100)	P	1	15	4	3.75	804.31	33.51
LAKE0000024	23.00S/23.00E-34	43.53488961	-119.94541794	9,999.00	615	735	120	9.00	735	Trd (100)	SFD (100)	B	18	20	0	40.00	11,482.50	95.69
LAKE0001216	27.00S/22.00E-36add	43.19024019	-120.01668500	12.00	40	77	37	10.00	77	--	--	B	1	20	0	40.00	9,463.84	255.78
LAKE0001217	27.00S/22.00E-36abd	43.19013000	-120.02055000	9.00	19	292	273	16.00	292	--	--	P	4	2,800	80	35.00	8,460.02	30.99
LAKE0001779	35.00S/24.00E-33cd	42.48709360	-119.89514500	50.00	70	460	390	14.00	460	--	--	P	24	1,750	107	16.36	4,299.52	11.02
LAKE0001781	35.00S/24.00E-33cd	42.48491630	-119.89763409	9,999.00	80	228	148	8.00	228	--	--	P	3	600	40	15.00	3,687.34	24.91
LAKE0001840	36.00S/24.00E-17aa	42.45182565	-119.90725573	9,999.00	20	400	380	13.14	400	--	--	P	24	2,200	126	17.46	4,644.41	12.22
LAKE0001852	36.00S/24.00E-28cc	42.41166705	-119.90254289	9,999.00	22	65	43	8.74	65	--	--	P	2	15	7	2.14	437.70	10.18
LAKE0001853	36.00S/24.00E-28bb	42.42266299	-119.90233877	9,999.00	25	90	65	6.00	95	--	--	P	4	15	25	0.60	124.27	1.91
LAKE0001854	36.00S/24.00E-28cc	42.41166705	-119.90254289	9,999.00	20	60	40	6.00	60	--	--	P	4	15	6	2.50	576.55	14.41
LAKE0001855	36.00S/24.00E-28cc	42.41166705	-119.90254289	9,999.00	20	50	30	7.88	60	--	--	P	5	15	5	3.00	685.04	22.83
LAKE0001856	36.00S/24.00E-28cc	42.41166705	-119.90254289	9,999.00	18	53	35	8.18	60	--	--	P	5	10	18	0.56	110.70	3.16
LAKE0001867	36.00S/24.00E-28cc	42.41166705	-119.90254289	9,999.00	52	72	20	6.00	80	--	--	P	3	20	19	1.05	222.78	11.14
LAKE0001874	36.00S/24.00E-28bb	42.42266299	-119.90233877	9,999.00	79	285	206	6.00	285	--	--	P	50	50	20	2.50	679.57	3.30
LAKE0001876	36.00S/24.00E-29a	42.42085293	-119.90977419	9,999.00	27	100	73	6.00	100	--	--	P	4	15	4	3.75	889.74	12.19
LAKE0001884	36.00S/24.00E-33bb	42.40799441	-119.90259254	9,999.00	40	60	20	6.00	60	--	--	P	4	30	11	2.73	632.85	31.64
LAKE0004233	36.00S/24.00E-34bd	42.40440113	-119.87825563	9,999.00	25	65	40	5.00	65	--	--	P	1	15	1	15.00	3,648.46	91.21
LAKE0004438	28.00S/23.00E-36bc	43.09984294	-119.94967499	9,999.00	20	200	180	10.80	200	--	--	P	3	20	10	2.00	405.63	2.25
LAKE0050080	36.00S/24.00E-17ab	42.45185965	-119.91215362	9,999.00	41	160	119	6.00	160	--	--	P	1	25	34	0.74	137.84	1.16
LAKE0050100	36.00S/24.00E-28cc	42.41166705	-119.90254289	9,999.00	82	95	13	6.00	95	--	--	P	1	36	18	2.00	408.18	31.40
LAKE0050110	36.00S/24.00E-28cc	42.41166705	-119.90254289	9,999.00	70	100	30	6.00	100	--	--	P	1	35	30	1.17	227.67	7.59
LAKE0050111	36.00S/24.00E-28cc	42.41166705	-119.90254289	9,999.00	32	60	28	5.29	60	--	--	P	1	30	3	10.00	2,347.75	83.85
LAKE0050112	36.00S/24.00E-28cc	42.41166705	-119.90254289	9,999.00	82	95	13	6.00	95	--	--	P	1	36	16	2.25	463.59	35.66
LAKE0050548	36.00S/24.00E-28ab	42.42267351	-119.89264485	9,999.00	28	43	15	6.00	70	--	--	P	2	24	3	8.00	1,906.57	127.10
LAKE0050570	36.00S/24.00E-21cc	42.42629124	-119.90227678	9,999.00	63	94	31	6.00	98	--	--	P	1	9	38	0.24	39.90	1.29
LAKE0050958	28.00S/23.00E-36cc	43.09262660	-119.94964327	9,999.00	60	100	40	6.00	100	--	--	P	1	15	4	3.75	804.31	20.11
LAKE0050959	30.00S/23.00E-21bc	42.95536258	-120.00820563	9,999.00	80	100	20	6.00	160	--	--	P	1	20	23	0.87	165.44	8.27
LAKE0050985	30.00S/23.00E-21ad	42.95534661	-119.99338246	9,999.00	25	56	31	6.00	60	--	--	P	1	20	6	3.33	708.46	22.85
LAKE0051132	36.00S/24.00E-20dd	42.42627900	-119.90716744	9,999.00	65	95	30	6.00	100	--	--	P	1	16	2	8.00	1,815.64	60.52
LAKE0051133	36.00S/24.00E-32aa	42.40800706	-119.90746469	9,999.00	95	120	25	6.00	140	--	--	P	1	16	2	8.00	1,815.64	72.63
LAKE0051141	36.00S/24.00E-4cd	42.47021908	-119.89742788	9,999.00	60	70	10	6.00	77	--	--	P	1	16	1	16.00	3,813.14	381.31
LAKE0051148	35.00S/24.00E-33dc	42.48490315	-119.89274112	9,999.00	65	97	32	6.00	100	--	--	P	1	22	5	4.40	955.32	29.85
LAKE0051149	35.00S/24.00E-33cd	42.48491630	-119.89763409	9,999.00	70	93	23	6.00	100	--	--	P	1	16	1	16.00	3,813.14	165.79
LAKE0051151	36.00S/24.00E-21db	42.42993401	-119.89261048	9,999.00	30	60	30	6.71	60	--	--	P	1	16	2	8.00	1,786.06	59.54
LAKE0051220	36.00S/24.00E-28cc	42.41166705	-119.90254289	9,999.00	30	50	20	6.00	55	--	--	P	1	15	1	15.00	3,558.97	177.95
LAKE0051221	36.00S/24.00E-33ba	42.40801145	-119.89772918	9,999.00	30	60	30	6.00	63	--	--	P	1	15	2	7.50	1,694.21	56.47
LAKE0051223	36.00S/24.00E-27bd	42.41905892	-119.87809661	9,														

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OWRD Well ID Pumped Well Groundwater Database	Well Location (best available)				Well Construction					Well OPI Units		Well Yield Test				Calculated		
	Public Land Survey (PLS) Township/Range-Section qtr qtr	Latitude (decimal)	Longitude (decimal)	Error Horizontal (feet)	Well Open Interval (OPI)				Well Bottom (ft. blsd)	Strat Unit(s)	Hydro-Strat Unit(s)	Test Type	Duration (hours)	Discharge Rate (gal / min)	Drawdown Final (feet)	Specific Capacity (gpm / ft)	Transmissivity (feet ² / day)	Hydraulic Conductivity (feet / day)
					OPI Top (ft. blsd)	OPI Bottom (ft. blsd)	OPI height (feet)	OPI Diameter Weighted (inches)										
MALH0002334	27.00S/38.00E-26bb	43.20053587	-118.03330423	9,999.00	20	600	580	10.29	600	--	--	P	8	150	130	1.15	244.08	0.42
MALH0002335	27.00S/38.00E-26bc	43.19670000	-118.03350500	100.00	50	390	340	11.98	390	--	--	P	12	680	100	6.80	1,648.03	4.85
MALH0002336	27.00S/38.00E-26ad	43.19704995	-118.01820985	9,999.00	45	260	215	10.00	260	--	--	P	8	580	98	5.92	1,416.60	6.59
MALH0002338	27.00S/38.00E-33aa	43.18597559	-118.05828639	9,999.00	305	470	165	12.00	470	--	--	P	14	1,670	200	8.35	2,072.22	12.56
MALH0002340	27.00S/38.00E-33cb	43.17836022	-118.07573559	9,999.00	49	211	162	16.00	211	--	--	P	2	180	140	1.29	225.76	1.39
MALH0002341	27.00S/38.00E-33cd	43.17602641	-118.06833704	9,999.00	50	485	435	12.00	485	--	--	P	10	270	145	1.86	406.02	0.93
MALH0002342	27.00S/38.00E-34ba	43.18773500	-118.04630000	50.00	50	345	295	12.00	345	--	--	P	12	375	140	2.68	608.11	2.06
MALH0002355	27.00S/38.00E-27dc	43.18960671	-118.04340868	9,999.00	175	500	325	13.38	500	--	--	P	9	1,200	201	5.97	1,384.34	4.26
MALH0002357	28.00S/37.00E-25cb	43.10733514	-118.13069733	200.00	365	935	570	10.11	935	--	--	P	1	350	160	2.19	411.81	0.72
MALH0002358	28.00S/38.00E-25dc	43.10473610	-118.00119848	9,999.00	20	220	200	12.40	220	--	--	P	200	1,330	40	33.25	10,394.12	51.97
MALH0002374	29.00S/37.00E-16aa	43.05860831	-118.17102893	25.00	175	215	40	4.00	215	--	--	P	3	100	25	4.00	987.51	24.69
MALH0002378	29.00S/38.00E-17ba	43.05581364	-118.08405822	200.00	247	287	40	6.00	287	--	--	B	1	4	20	0.20	33.12	0.83
MALH0002379	29.00S/38.00E-30cb	43.02139277	-118.10928258	9,999.00	205	245	40	4.00	245	--	--	P	3	60	2	30.00	8,389.57	209.74
MALH0002380	29.00S/39.00E-31ac	43.01082177	-117.98075023	9,999.00	0	140	140	13.54	140	--	--	P	30	1,200	45	26.67	7,347.71	52.48
MALH0002395	30.00S/37.00E-24	42.95089307	-118.12121314	9,999.00	113	580	467	6.00	580	--	--	P	3	480	0	960.00	309,604.10	662.96
MALH0002396	29.00S/38.00E-35cc	43.00204065	-118.02809501	200.00	74	580	506	6.00	580	--	--	P	5	16	10	1.60	363.13	0.72
MALH0002446	32.00S/37.00E-15dd	42.75607572	-118.13756964	250.00	346	400	54	6.00	400	--	--	B	1	37	0	74.00	19,484.85	360.83
MALH0002453	33.00S/37.00E-28bc	42.64768470	-118.17216708	1,000.00	339	388	49	6.00	389	--	--	B	1	16	0	32.00	7,988.83	163.04
MALH0002454	33.00S/38.00E-11bb	42.69642943	-118.01814540	50.00	152	199	47	7.42	199	--	--	P	18	30	10	3.00	753.71	16.04
MALH0002467	36.00S/40.00E-1bc	42.44468800	-117.98069300	30.00	400	550	150	8.11	550	--	--	P	18	20	40	0.50	109.50	0.73
MALH0002611	27.00S/38.00E-27cd	43.18961676	-118.04835354	9,999.00	180	600	420	13.38	600	--	--	P	4	350	204	1.72	339.60	0.81
MALH0002752	26.00S/37.00E-23cc	43.29160969	-118.15207486	9,999.00	20	240	220	6.00	240	--	--	P	2	11	55	0.20	35.46	0.16
MALH0002910	24.00S/37.00E-29ba	43.46365500	-118.20280500	250.00	25	225	200	10.00	225	--	--	P	1	60	60	1.00	175.51	0.88
MALH0002914	24.00S/37.00E-29cd	43.45236516	-118.20494566	9,999.00	46	520	474	7.53	520	--	--	P	1	30	20	1.50	287.68	0.61
MALH0003062	24.00S/37.00E-29ab	43.46336833	-118.20000689	9,999.00	55	152	97	7.08	152	--	--	P	7	85	105	0.81	174.70	1.80
MALH0003063	24.00S/37.00E-29ab	43.46336833	-118.20000689	9,999.00	135	165	30	6.00	165	--	--	P	4	60	94	0.64	132.85	4.43
MALH0003064	24.00S/37.00E-29ab	43.45236516	-118.20494566	9,999.00	145	770	625	6.00	770	--	--	P	2	125	100	1.25	259.73	0.42
MALH0050290	24.00S/38.00E-16ba	43.49272722	-118.06597616	9,999.00	30	50	20	6.00	50	--	--	P	2	12	29	0.41	78.39	3.92
MALH0051423	21.00S/37.00E-12bb	43.76997440	-118.13021381	9,999.00	23	62	39	6.00	62	--	--	P	2	18	4	4.50	1,030.00	26.41
MALH0054024	27.00S/38.00E-33ad	43.18172084	-118.05652254	250.00	250	601	351	16.00	601	--	--	P	8	2,800	31	90.32	24,248.31	69.08
MALH0054355	16.00S/37.00E-31ba	44.13756087	-118.22106856	99.00	160	200	40	4.00	200	--	--	B	1	14	100	0.14	24.26	0.61

Notes:

Wells total = 1,451

Wells inside the study area perimeter = 1,161

Wells outside the study area perimeter = 290

The locations listed are the best well location that was available for each well listed: smallest error generally from GPS and surveyed locations; largest error generally related to using center of public land survey (PLS)

Latitude-Longitude: datum is WGS1984

Error: horizontal distance error assigned for the best well location available for the particular well listed, 9999.00 is a flag indicating an estimated error was not determined and possibly very large

Well construction data is from water well reports (well logs)

Well open interval (OPI): portion of the well open to receive groundwater directly-horizontally from the surrounding geologic units via well screens, slots, perforations, or open borehole

OPI height: OPI bottom minus OPI top

OPI diameter: the weighted average of the well diameter(s) corresponding to the well's open interval, the diameters for different depth intervals as reported on the water well reports (well logs)

Well yield test type, duration, discharge, and drawdown is from water well reports (well-logs)

Test type: method used to discharge water from the well, B = bailer, P = pump

Specific capacity: value calculated from the well yield test discharge and drawdown data (discharge rate divided by final drawdown)

Transmissivity: value calculated from specific capacity using the Vorhis (1979) method (see appendix D and E)

Hydraulic conductivity: value calculated by dividing the transmissivity value by the OPI height (OPI bottom minus OPI top)

Sources:

Data Source for OWRD Well ID, Well Location, Well Construction, and Well Yield Test is Oregon Water Resources Department (2019a, 2019b)

Appendix K: Hydraulic Property Spatial Distribution Maps

This appendix presents 45 hydraulic property spatial distribution maps related to 1,161 water well reports the Oregon Water Resources Department (OWRD) identified within the Harney Basin with well yield test data sufficient for calculating specific capacity (appendix D) from which a transmissivity estimate was calculated using the Vorhis (1979) numerical method (appendix D and I), and a hydraulic conductivity estimate was calculated by dividing the transmissivity by the well total open interval. The reports from which calculations were made and the calculated specific capacity, transmissivity, and hydraulic conductivity values are listed in appendix J.

The maps in this appendix are grouped into three sets: figures K-1 to K-15 for specific capacity, figures K-16 to K-30 for transmissivity, and figures K-31 to K-45 for hydraulic conductivity. Each set is divided into three subsets: (a) all 1,161 results; (b) 498 results for wells with a total depth less than 150 feet; and (c) 663 results for wells with a total depth 150 feet or greater. Within each subset are 5 maps. The first map shows four value ranges together ordered from smallest (bottom) to greatest (top) when results overlap. The remaining four maps show the four value ranges individually to better view the distribution of each range.

Generally, spatial distribution segregation is greatest with the largest value range and increasingly ubiquitous with successively lower value ranges. The largest value range is most concentrated along the Harney Valley perimeter and the Riley vicinity. For wells less than 150 feet total depth, the largest value range distribution is concentrated along the southwest, south, and east perimeter of Harney Valley. For wells 150 feet total depth and greater, the largest value range distribution is concentrated along the southwest, west, north, and east perimeter of Harney Valley and the Riley vicinity. The second largest value range is most concentrated along the southwest, west, north, and east perimeter of Harney Valley for all well depths and the Riley vicinity for wells 150 feet total depth and greater. The two lowest value ranges are the least spatially segregated, the most ubiquitous. They are found intermixed with the two largest value ranges demonstrating the heterogeneity of the Harney Basin subsurface materials.

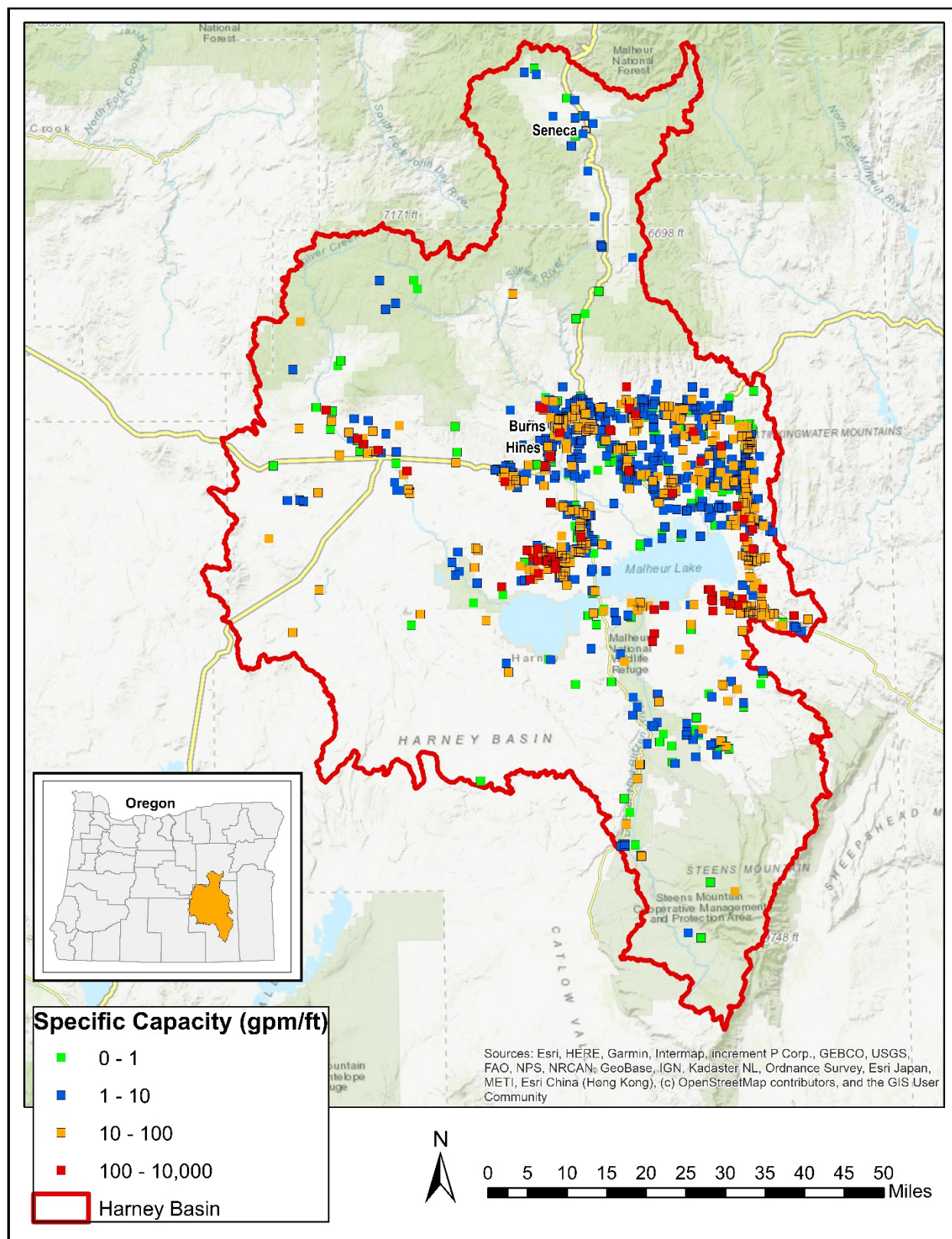


Figure K-1. Specific capacity spatial distribution map: all well depths, all value ranges [from 1,161 well yield tests inside Harney Basin]

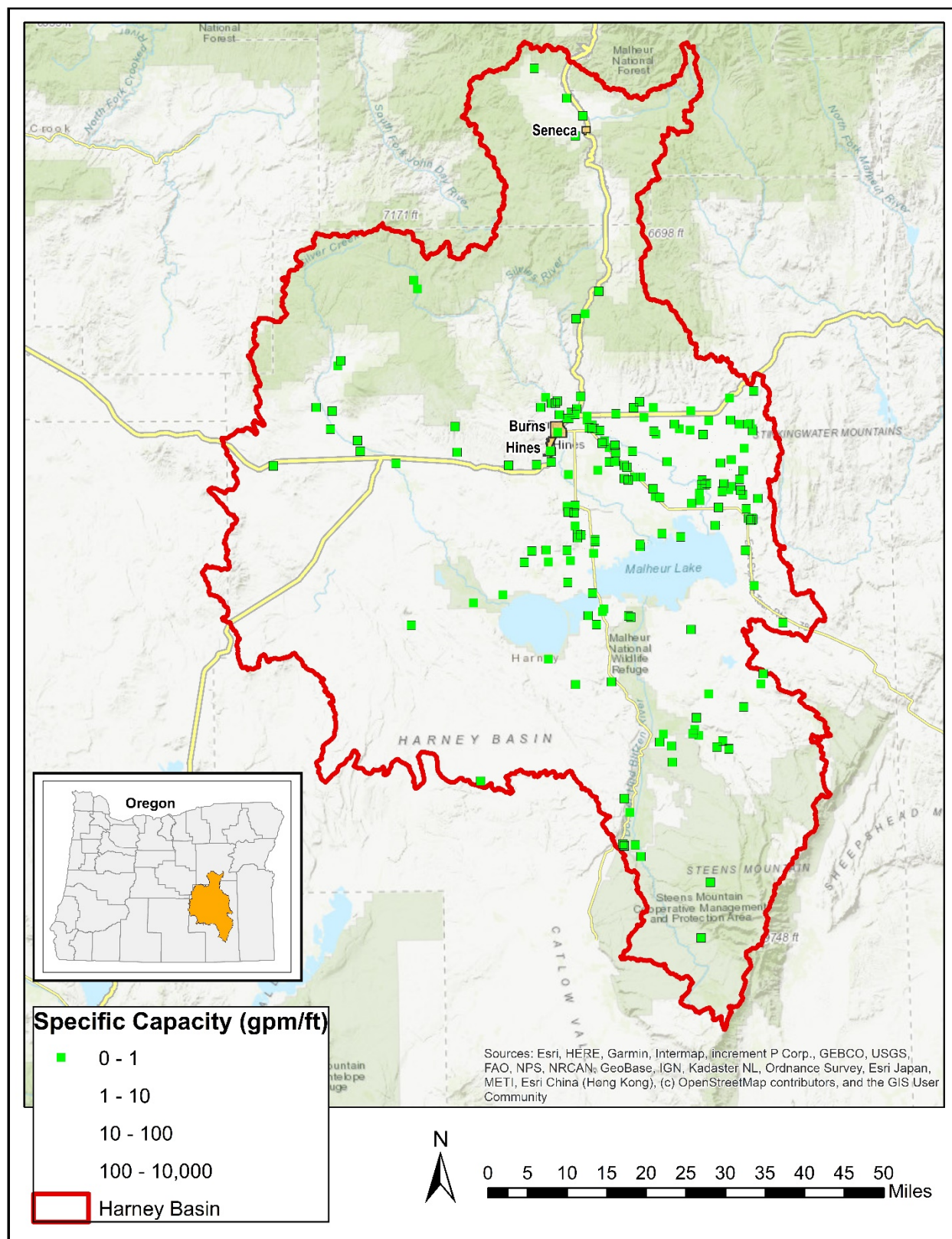


Figure K-2. Specific capacity spatial distribution map: all well depths, lowest value range [from 1,161 well yield tests inside Harney Basin]

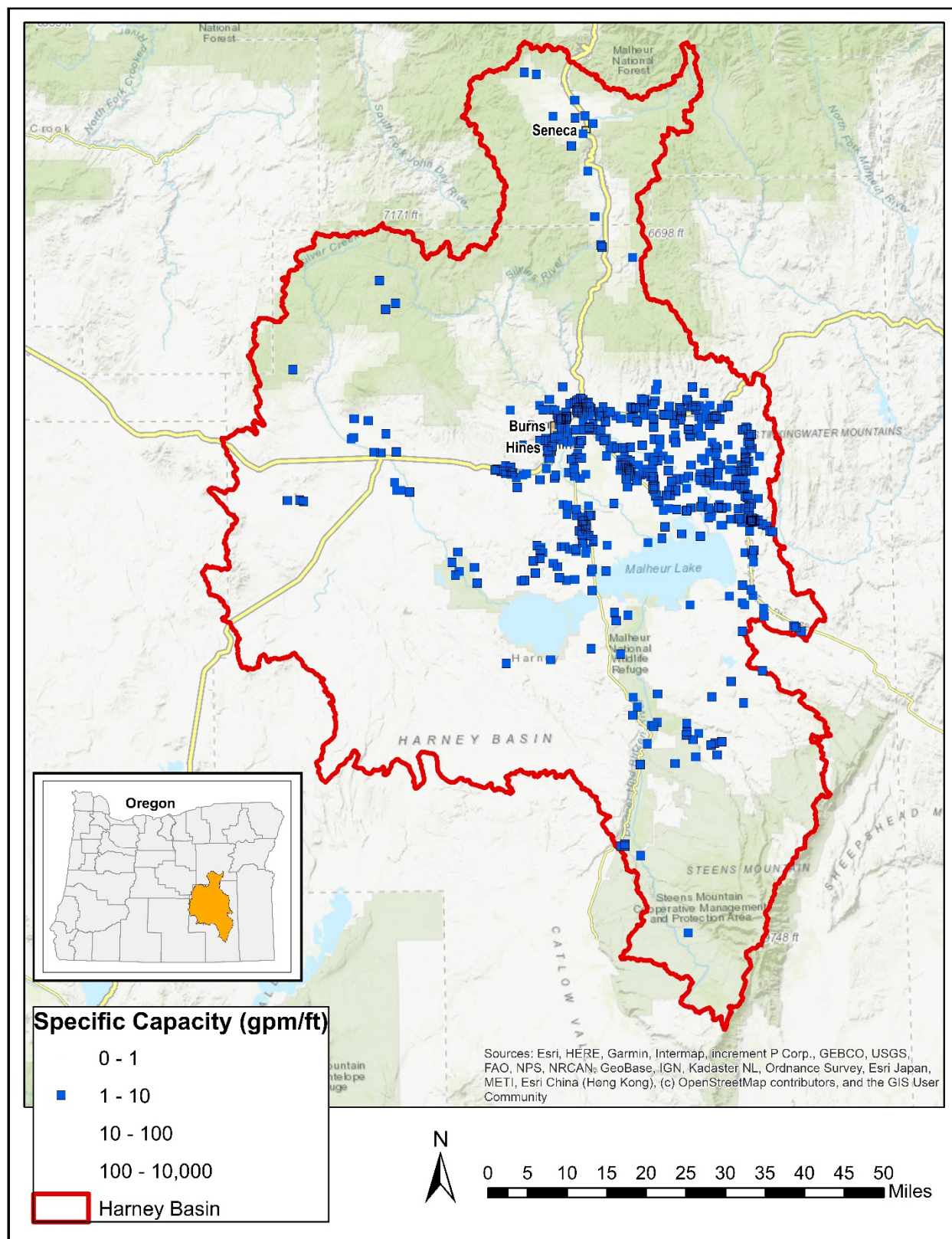


Figure K-3. Specific capacity spatial distribution map: all well depths, mid-low value range [from 1,161 well yield tests inside Harney Basin]

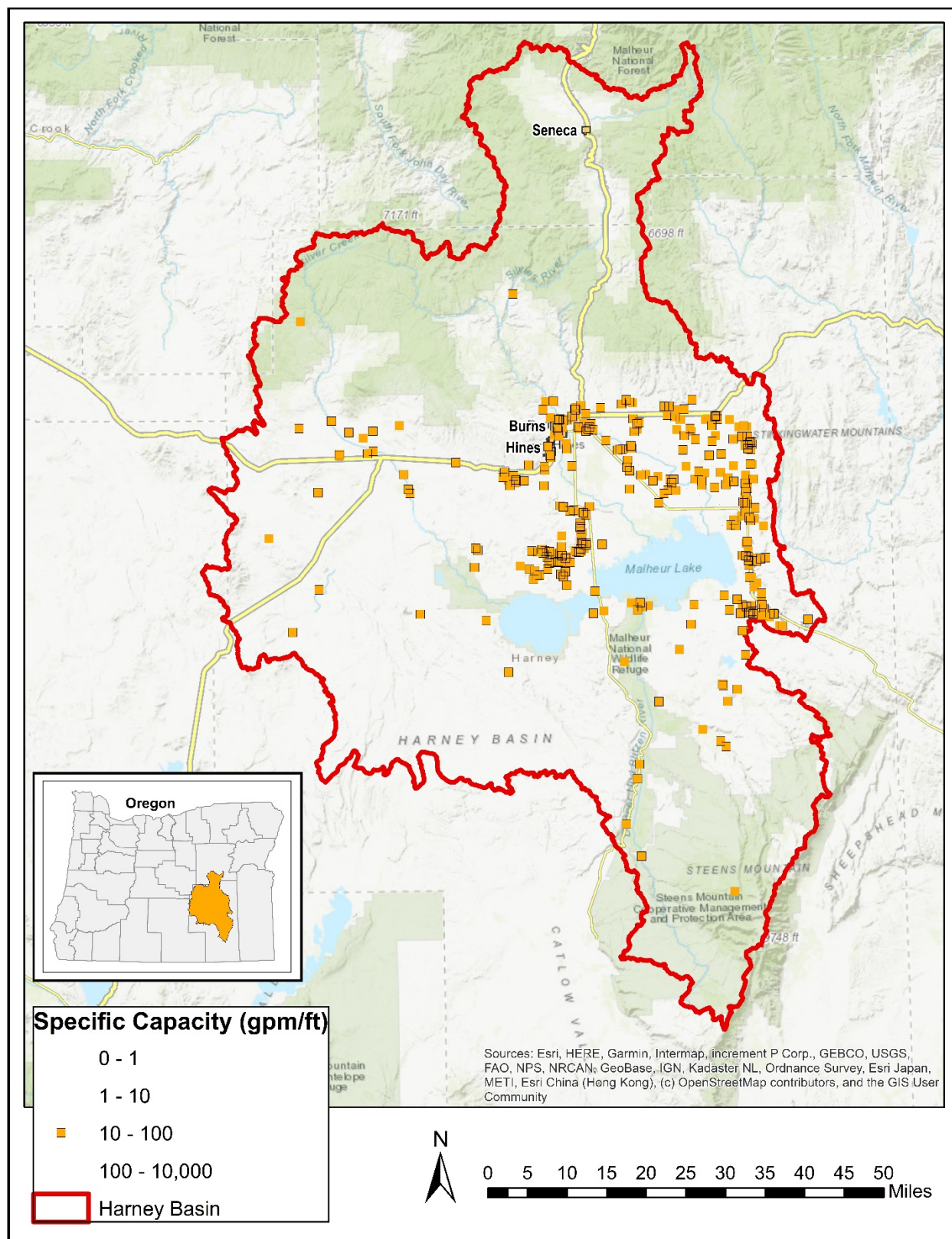


Figure K-4. Specific capacity spatial distribution map: all well depths, mid-high value range [from 1,161 well yield tests inside Harney Basin]

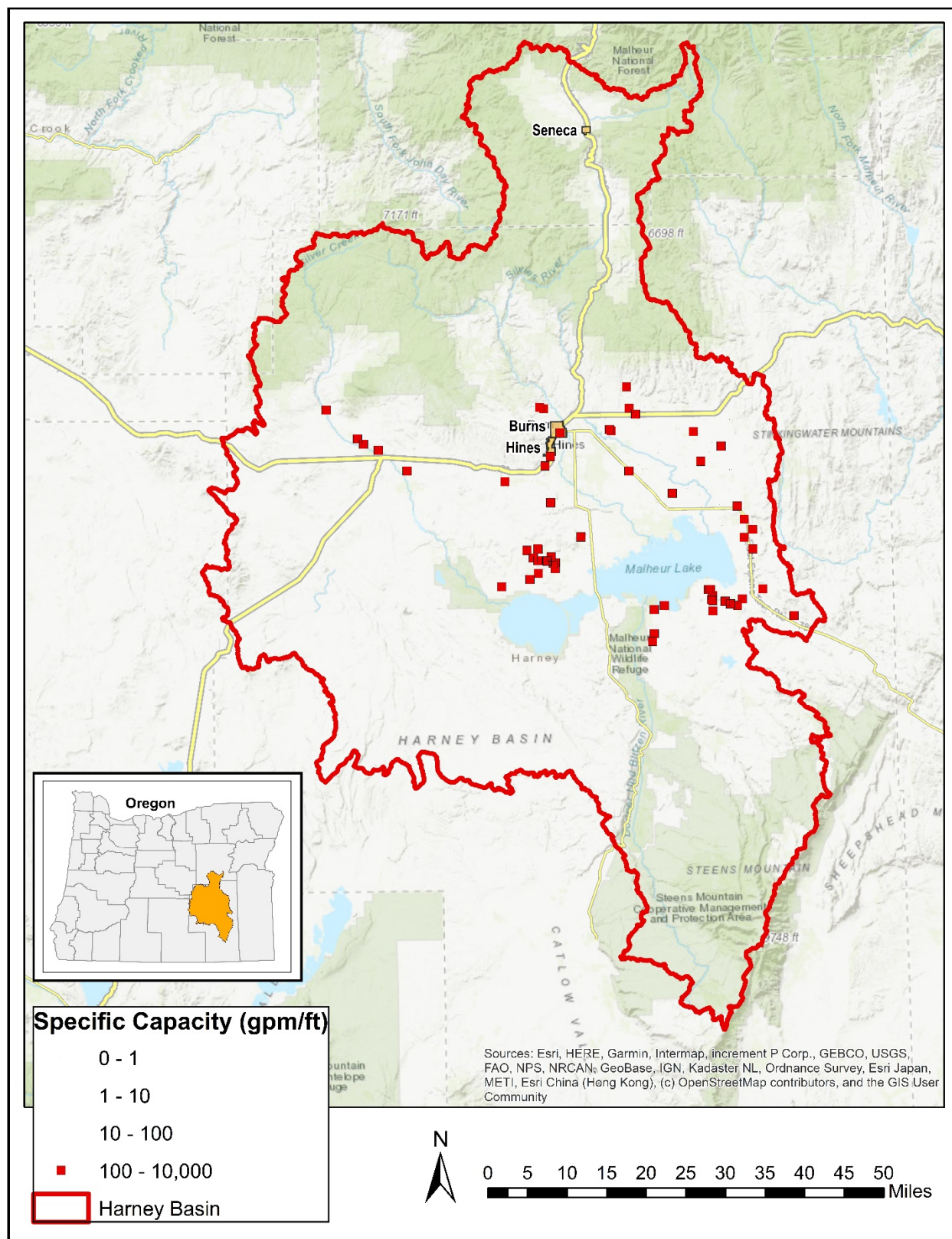


Figure K-5. Specific capacity spatial distribution map: all well depths, highest value range [from 1,161 well yield tests inside Harney Basin]

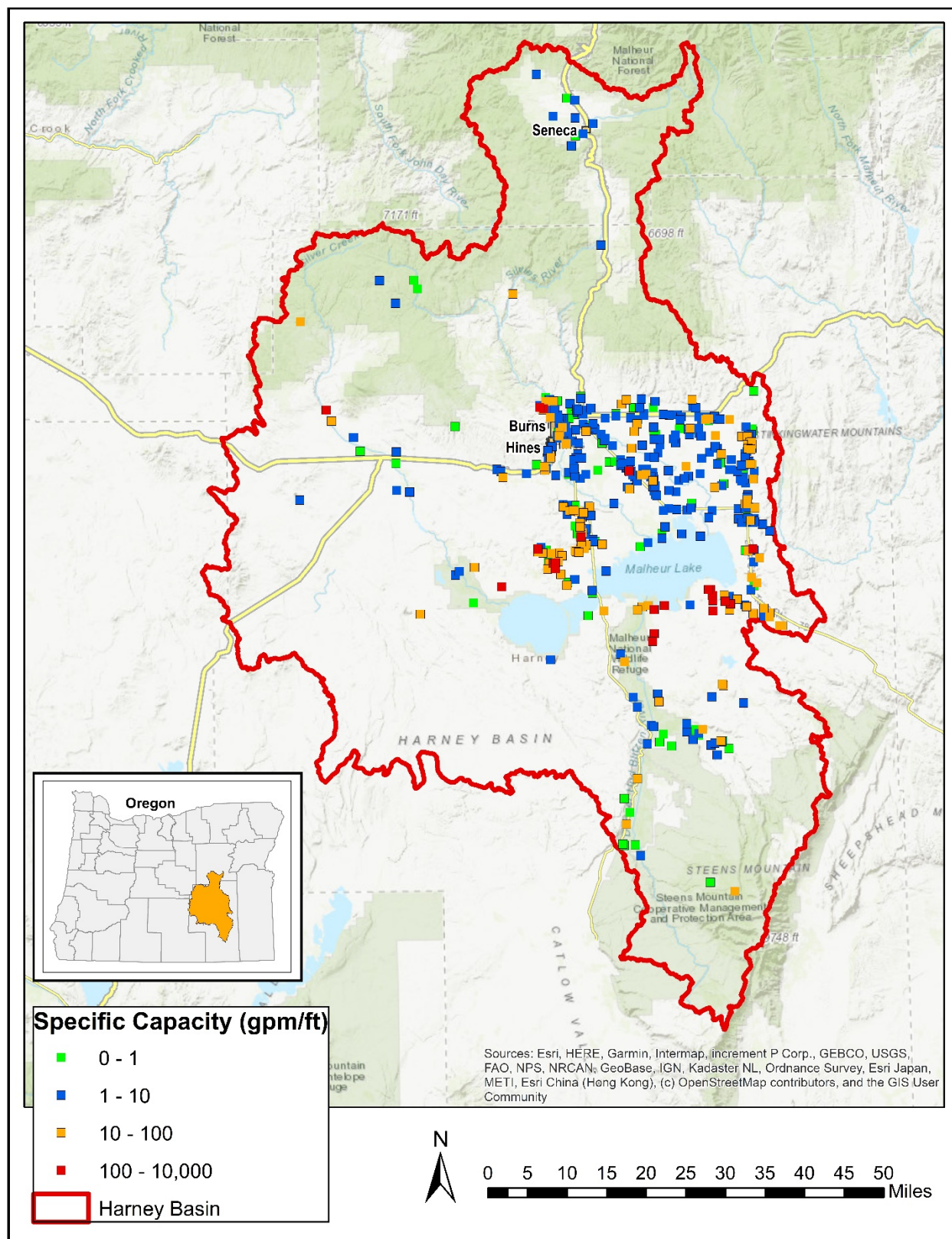


Figure K-6. Specific capacity spatial distribution map: shallower well depths, all value ranges [from 498 of 1,161 well yield tests inside Harney Basin, total well depth less than 150 feet]

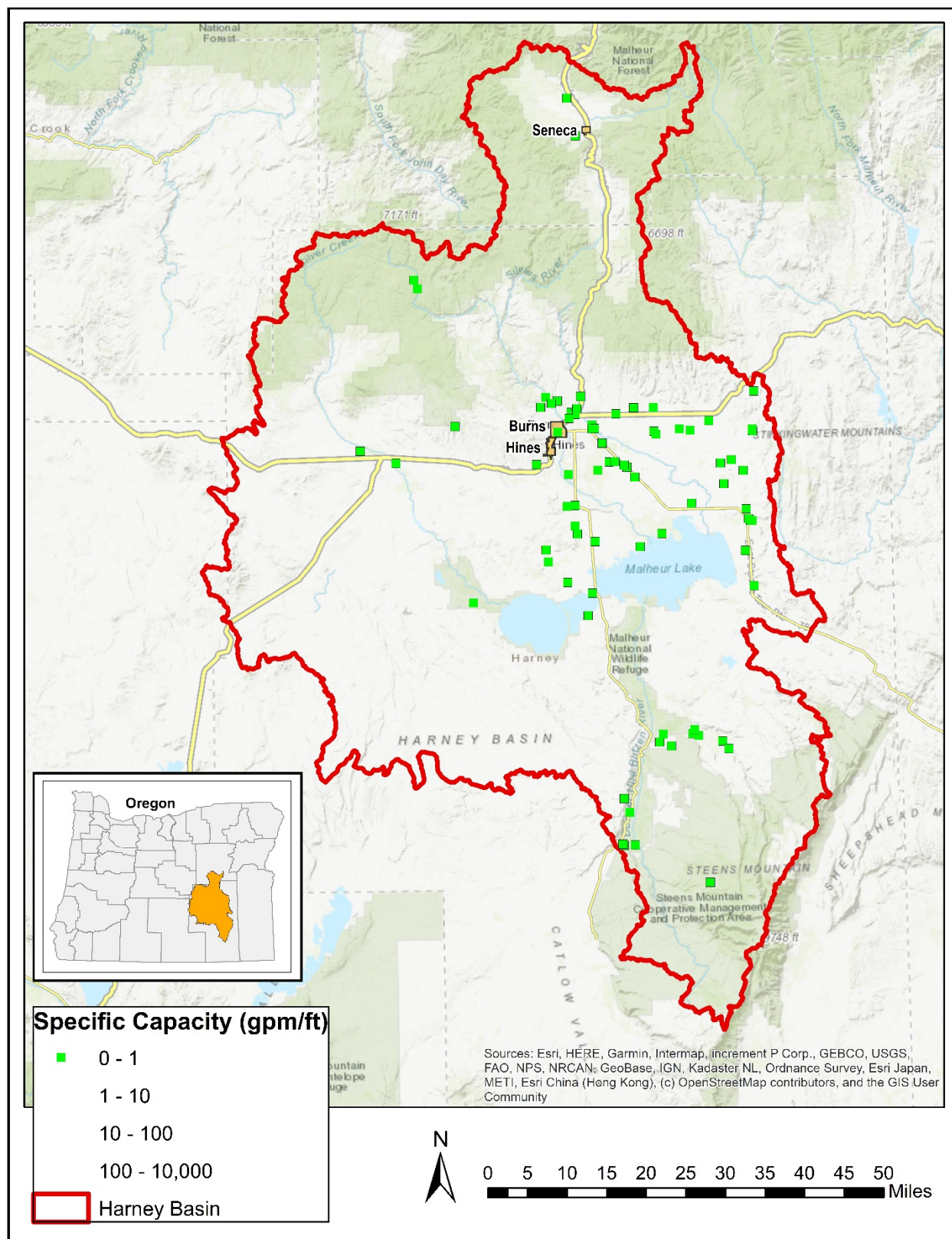


Figure K-7. Specific capacity spatial distribution map: shallower well depths, lowest value range [from 498 of 1,161 well yield tests inside Harney Basin, total well depth less than 150 feet]

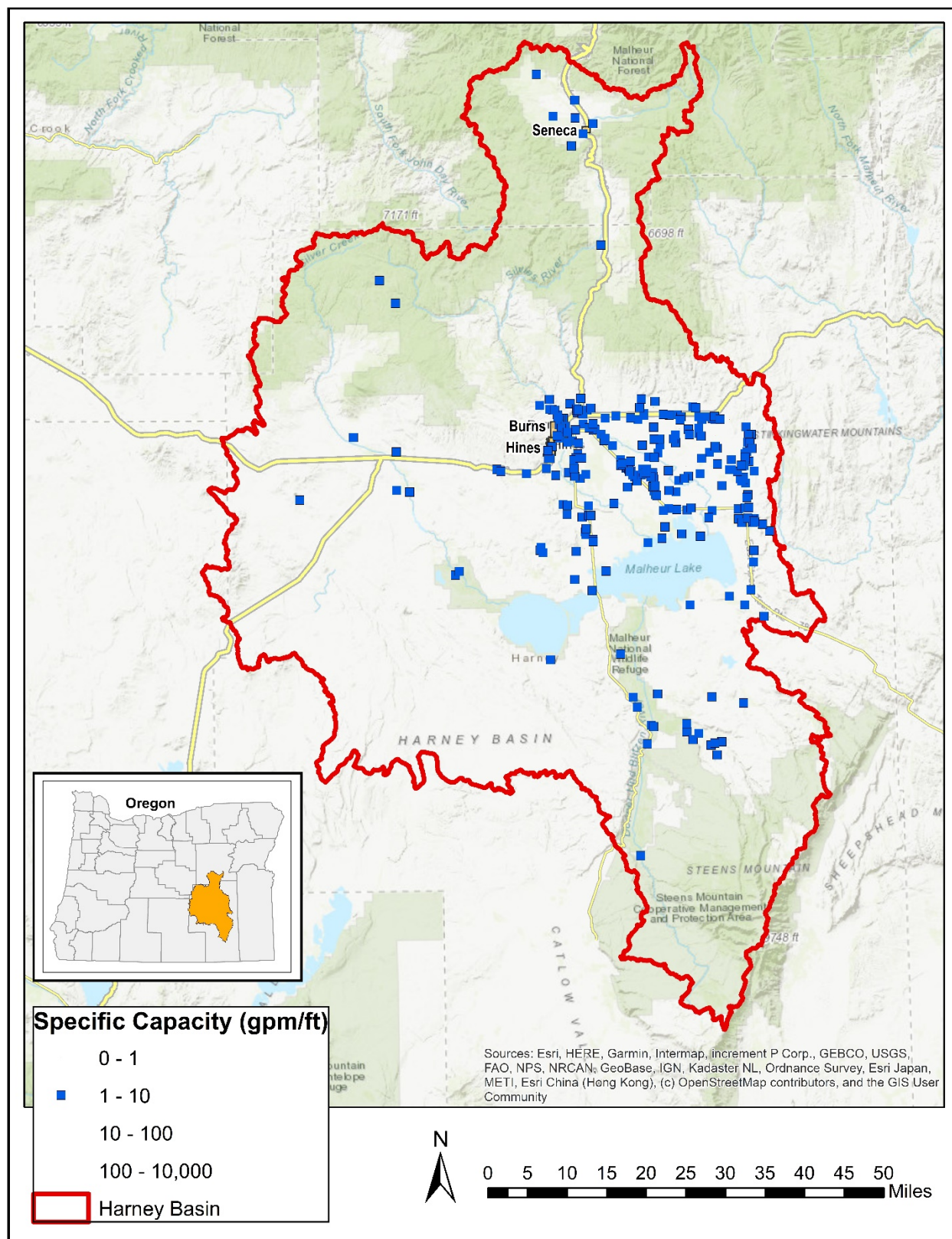


Figure K-8. Specific capacity spatial distribution map: shallower well depths, mid-low value range [from 498 of 1,161 well yield tests inside Harney Basin, total well depth less than 150 feet]

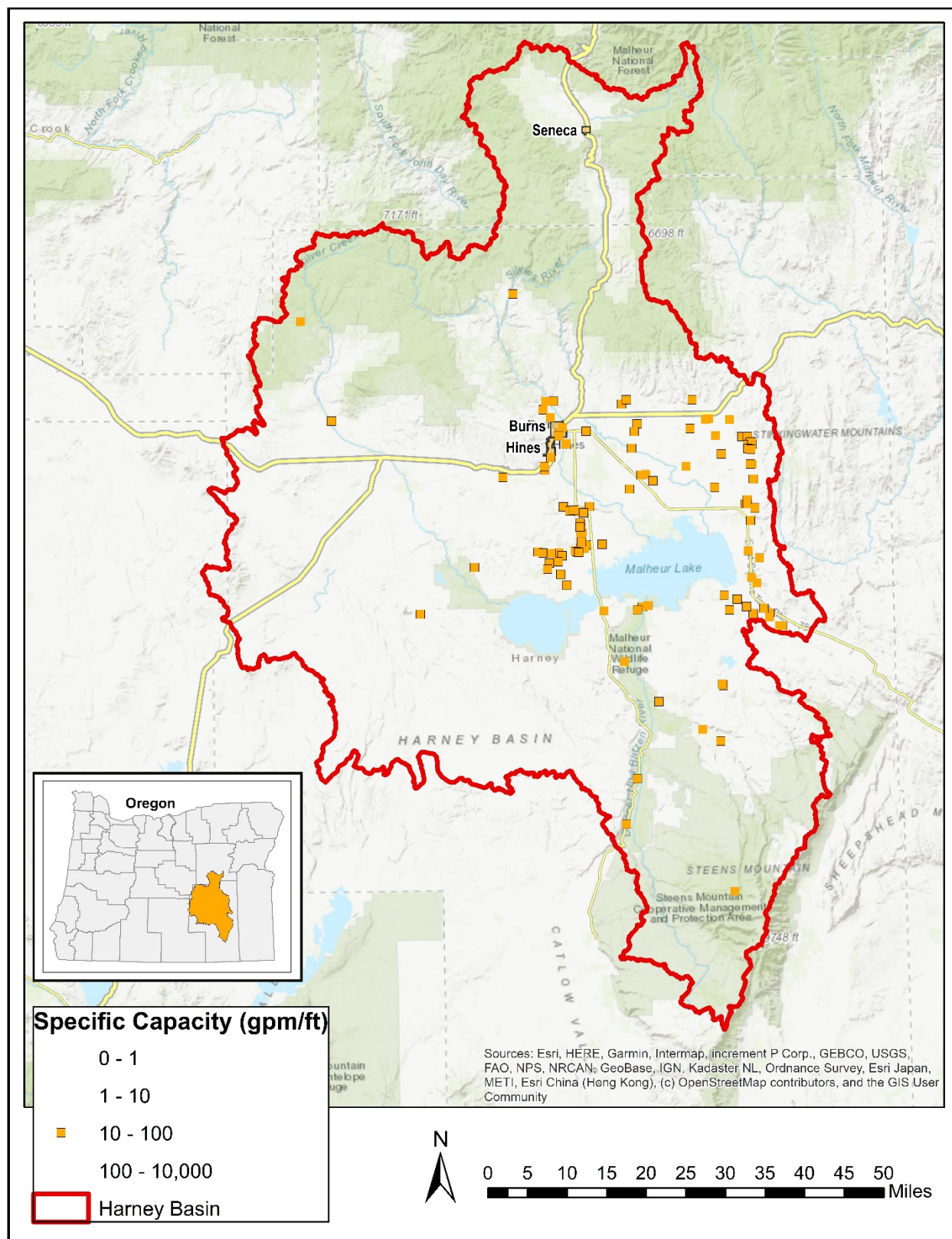


Figure K-9. Specific capacity spatial distribution map: shallower well depths, mid-high value range [from 498 of 1,161 well yield tests inside Harney Basin, total well depth less than 150 feet]

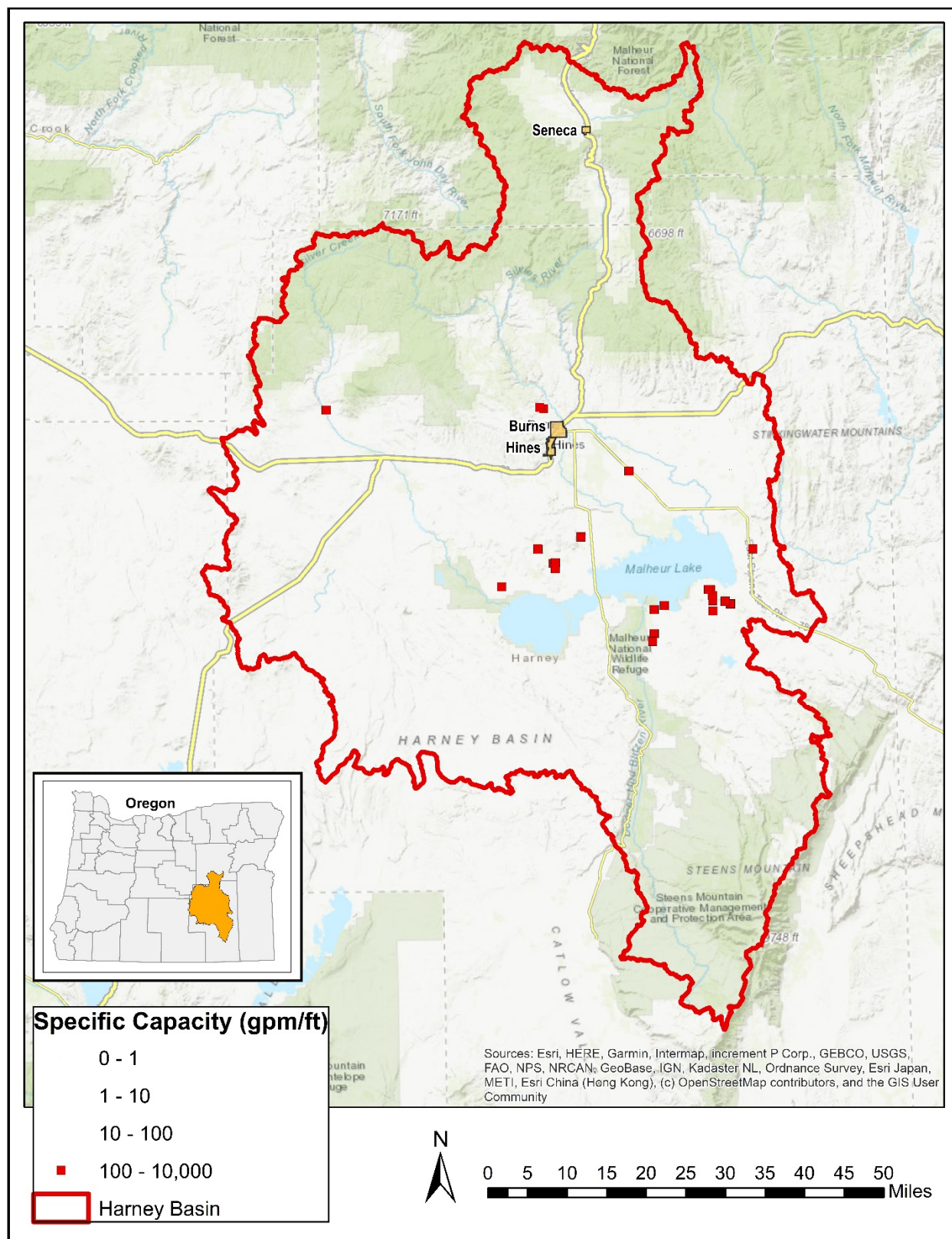


Figure K-10. Specific capacity spatial distribution map: shallower well depths, highest value range [from 498 of 1,161 well yield tests inside Harney Basin, total well depth less than 150 feet]

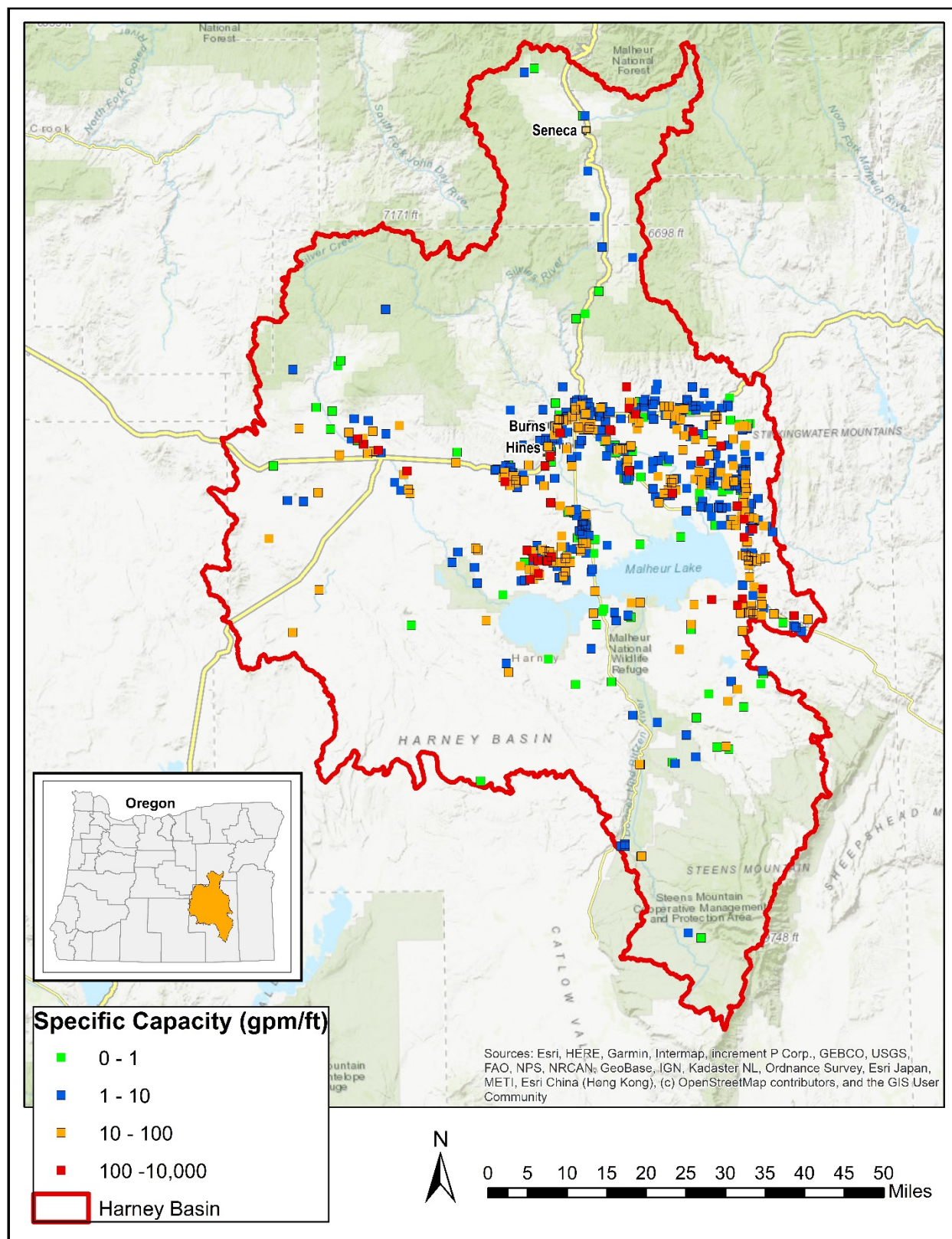


Figure K-11. Specific capacity spatial distribution map: deeper well depths, all value ranges [from 663 of 1,161 well yield tests inside Harney Basin, total well depth 150 feet or greater]

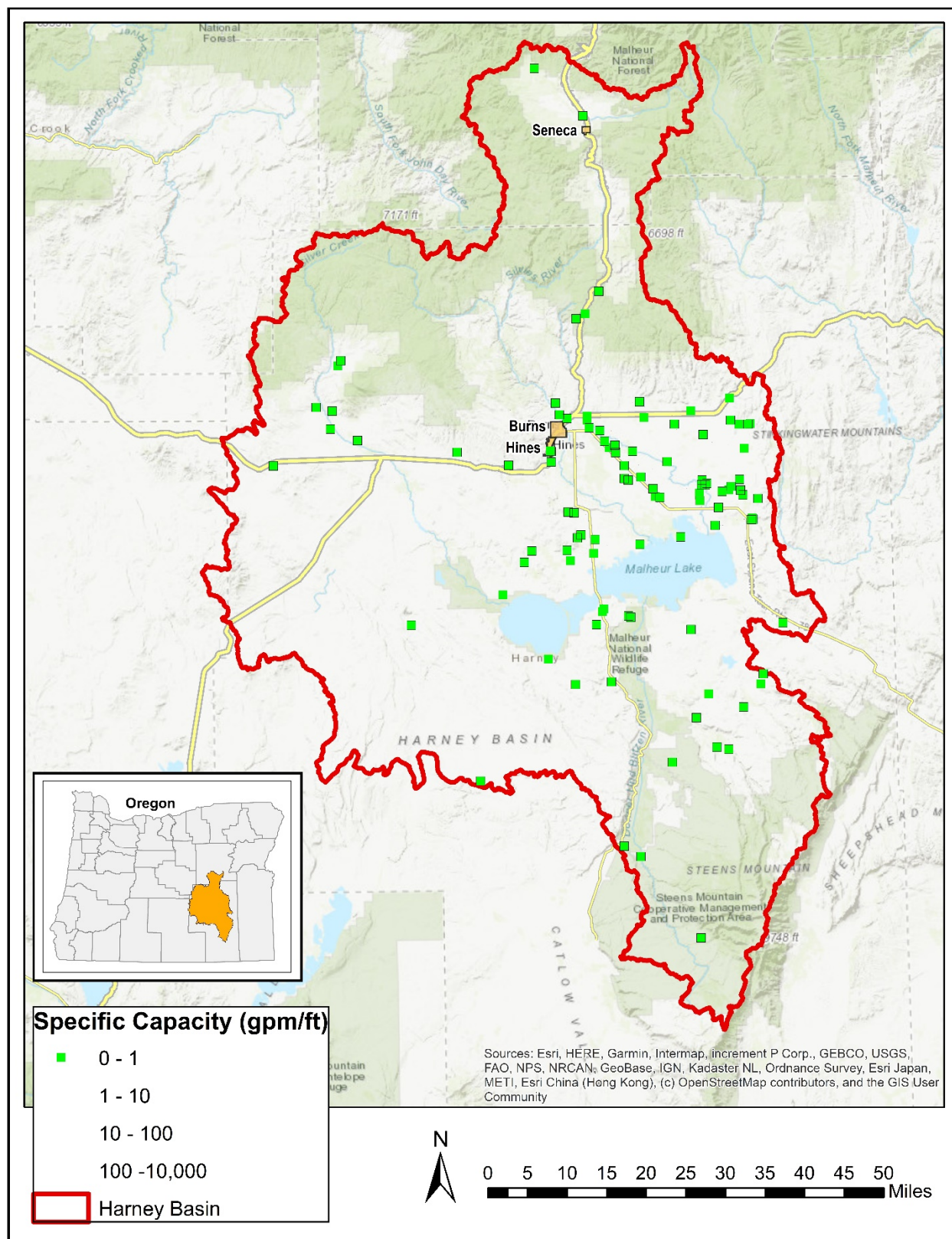


Figure K-12. Specific capacity spatial distribution map: deeper well depths, lowest value range [from 663 of 1,161 well yield tests inside Harney Basin, total well depth 150 feet or greater]

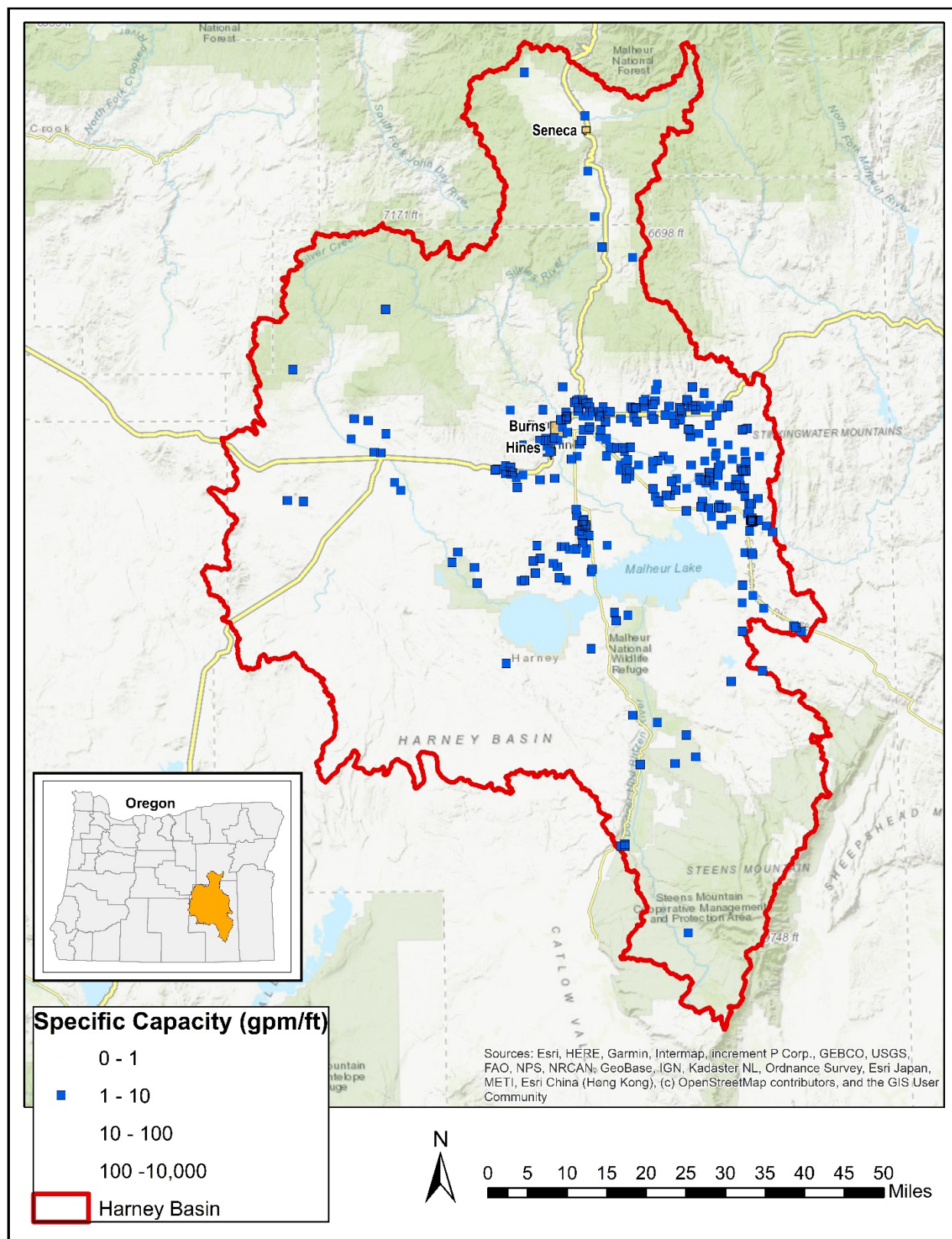


Figure K-13. Specific capacity spatial distribution map: deeper well depths, mid-low value range [from 663 of 1,161 well yield tests inside Harney Basin, total well depth 150 feet or greater]

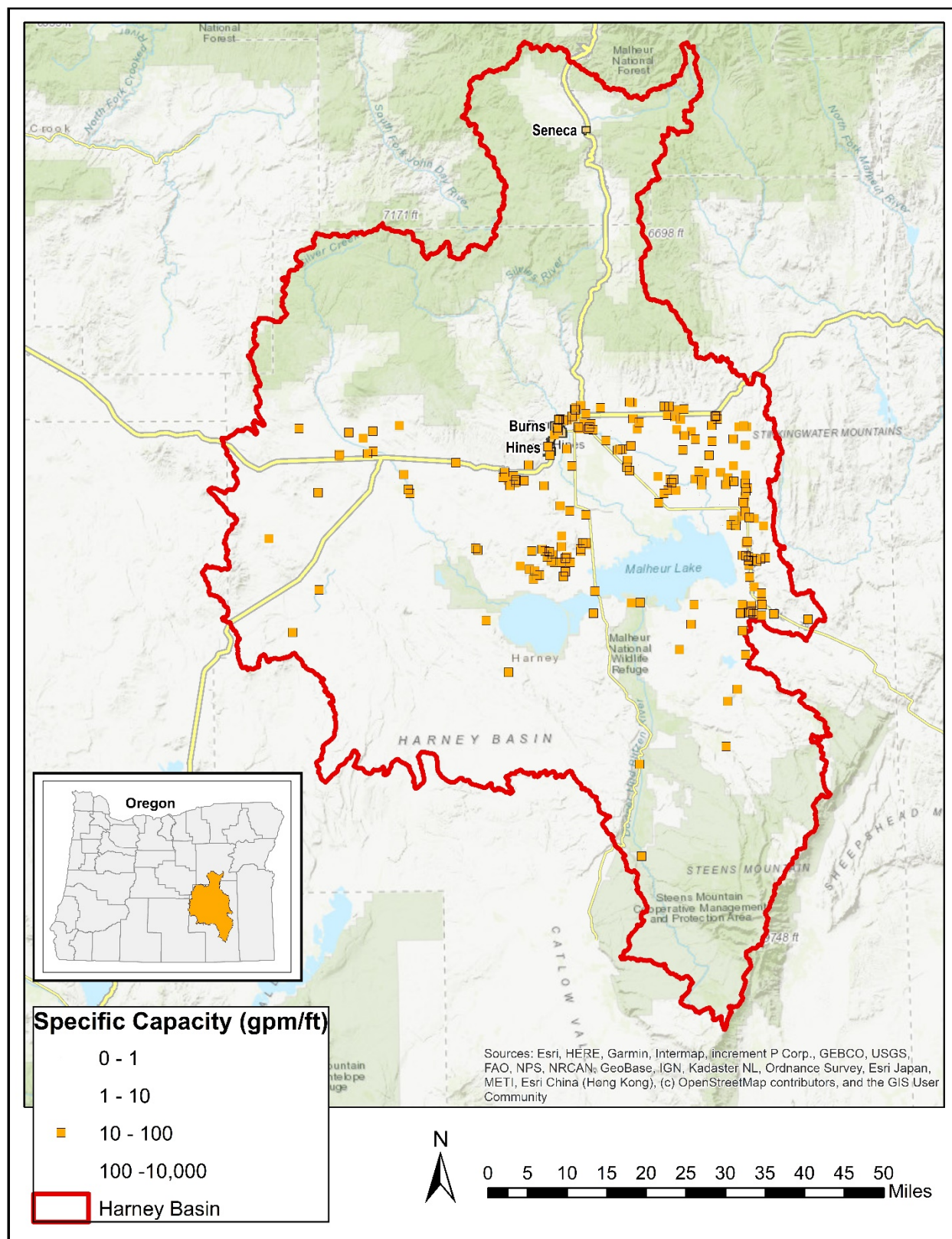


Figure K-14. Specific capacity spatial distribution map: deeper well depths, mid-high value range [from 663 of 1,161 well yield tests inside Harney Basin, total well depth 150 feet or greater]

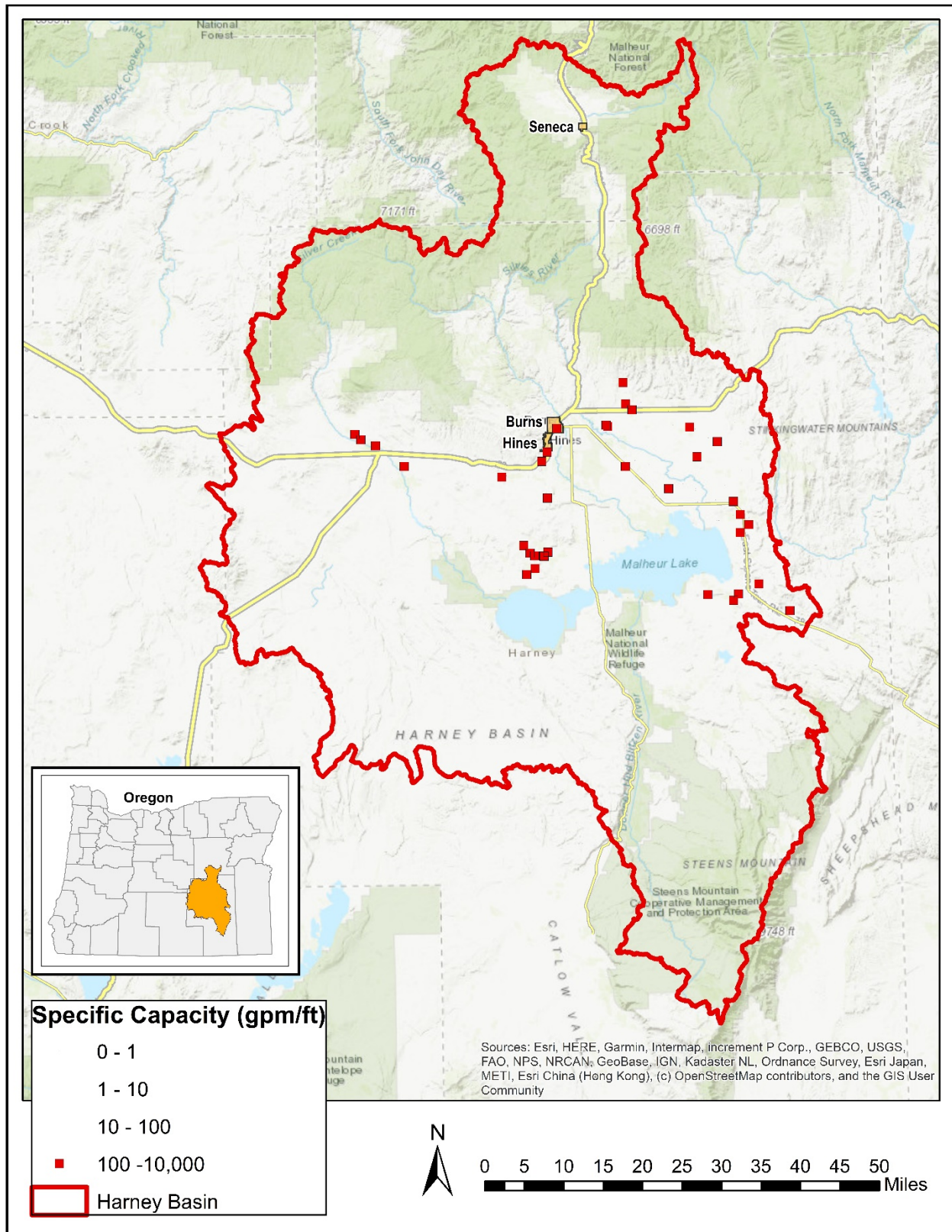


Figure K-15. Specific capacity spatial distribution map: deeper well depths, highest value range [from 663 of 1,161 well yield tests inside Harney Basin, total well depth 150 feet or greater]

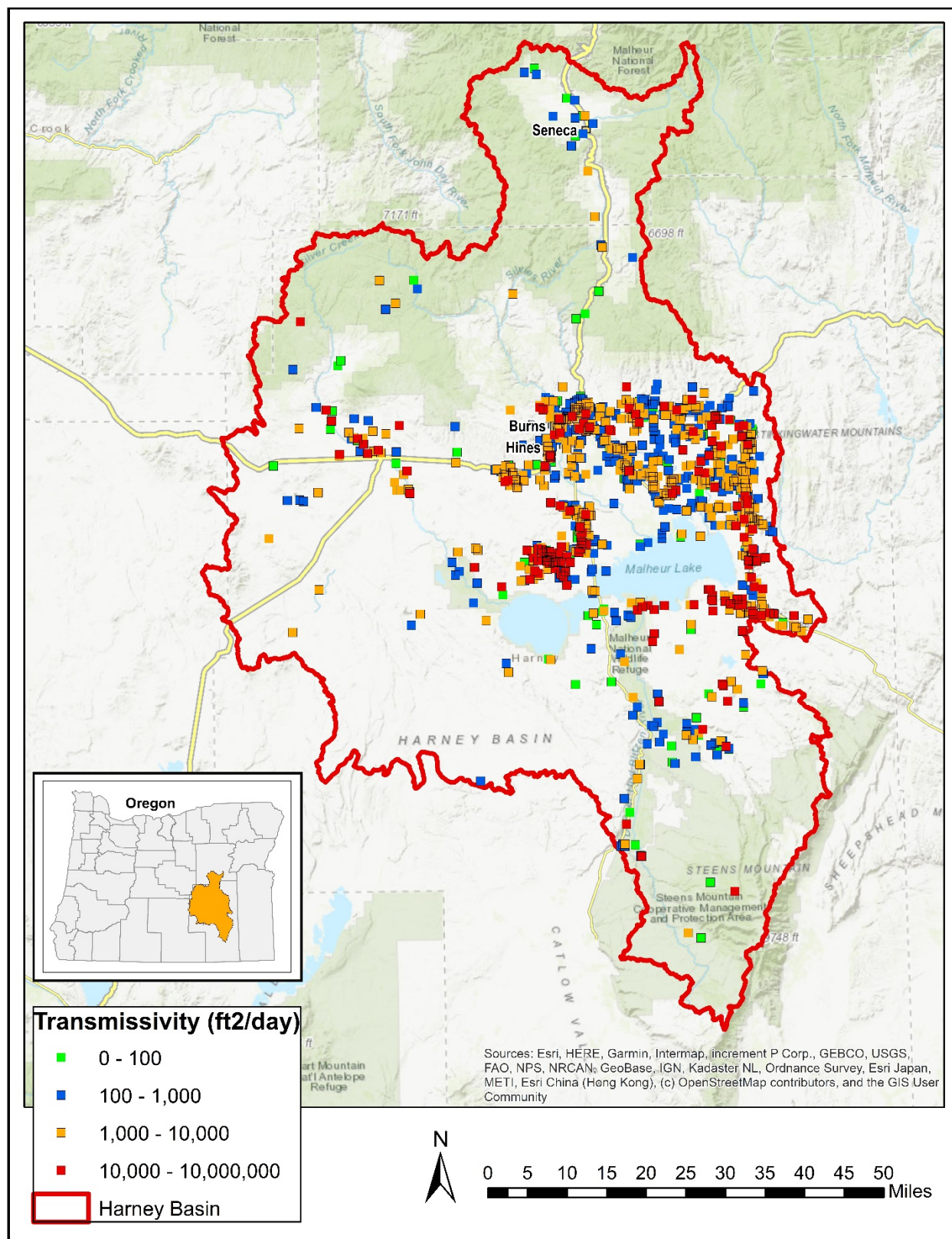


Figure K-16. Transmissivity spatial distribution map: all well depths, all value ranges [from 1,161 well yield tests inside Harney Basin]

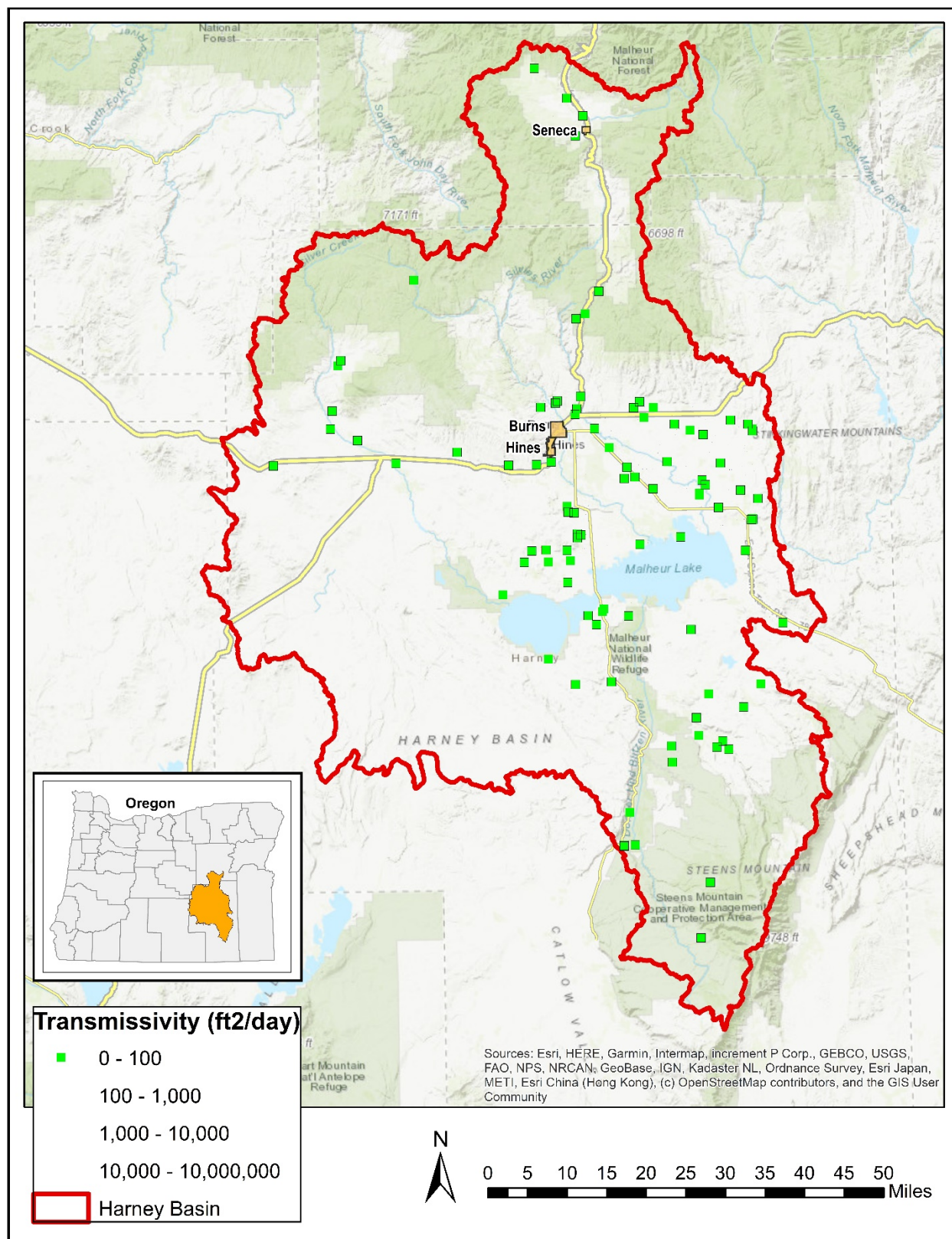


Figure K-17. Transmissivity spatial distribution map: all well depths, lowest value range [from 1,161 well yield tests inside Harney Basin]

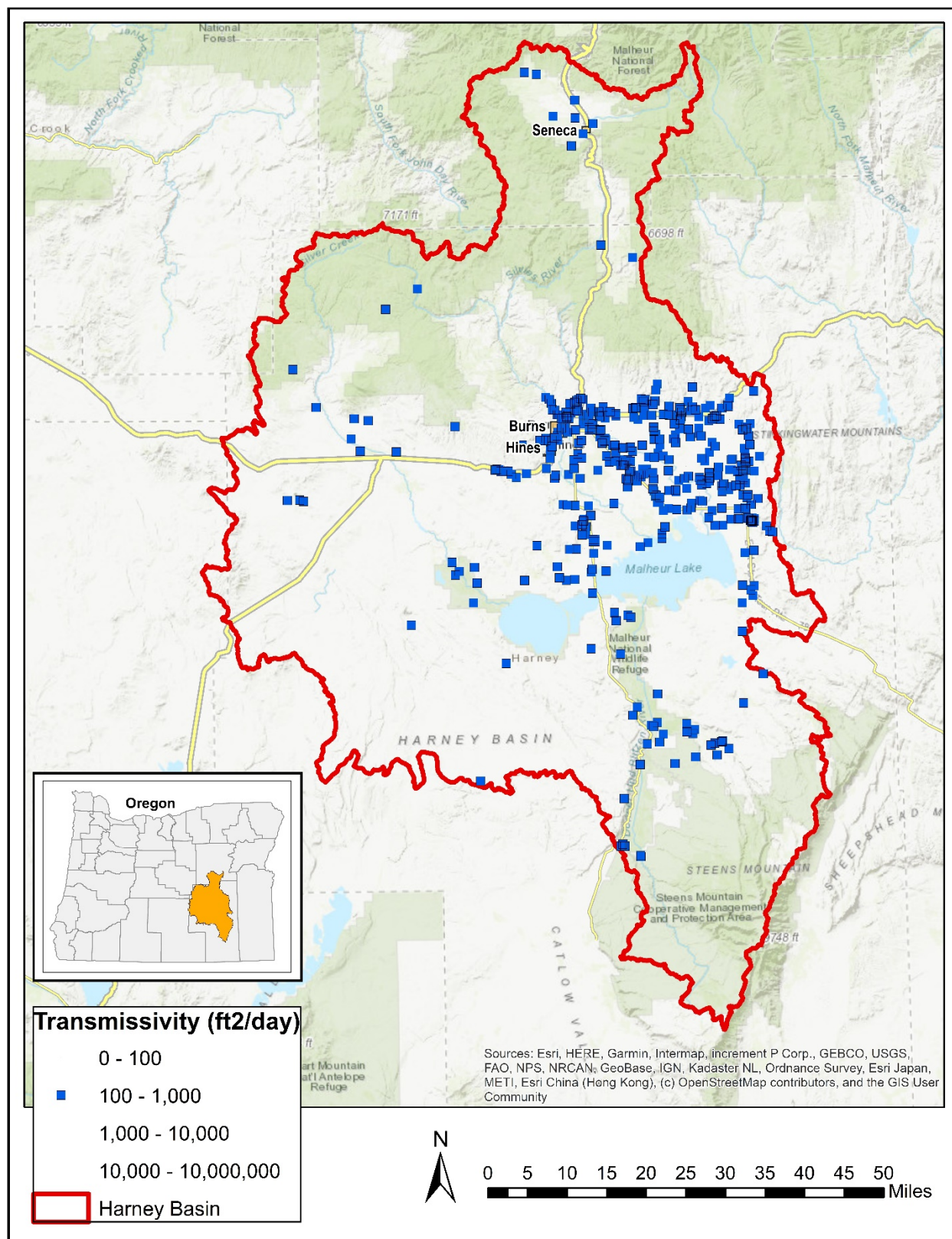


Figure K-18. Transmissivity spatial distribution map: all well depths, mid-low value range [from 1,161 well yield tests inside Harney Basin]

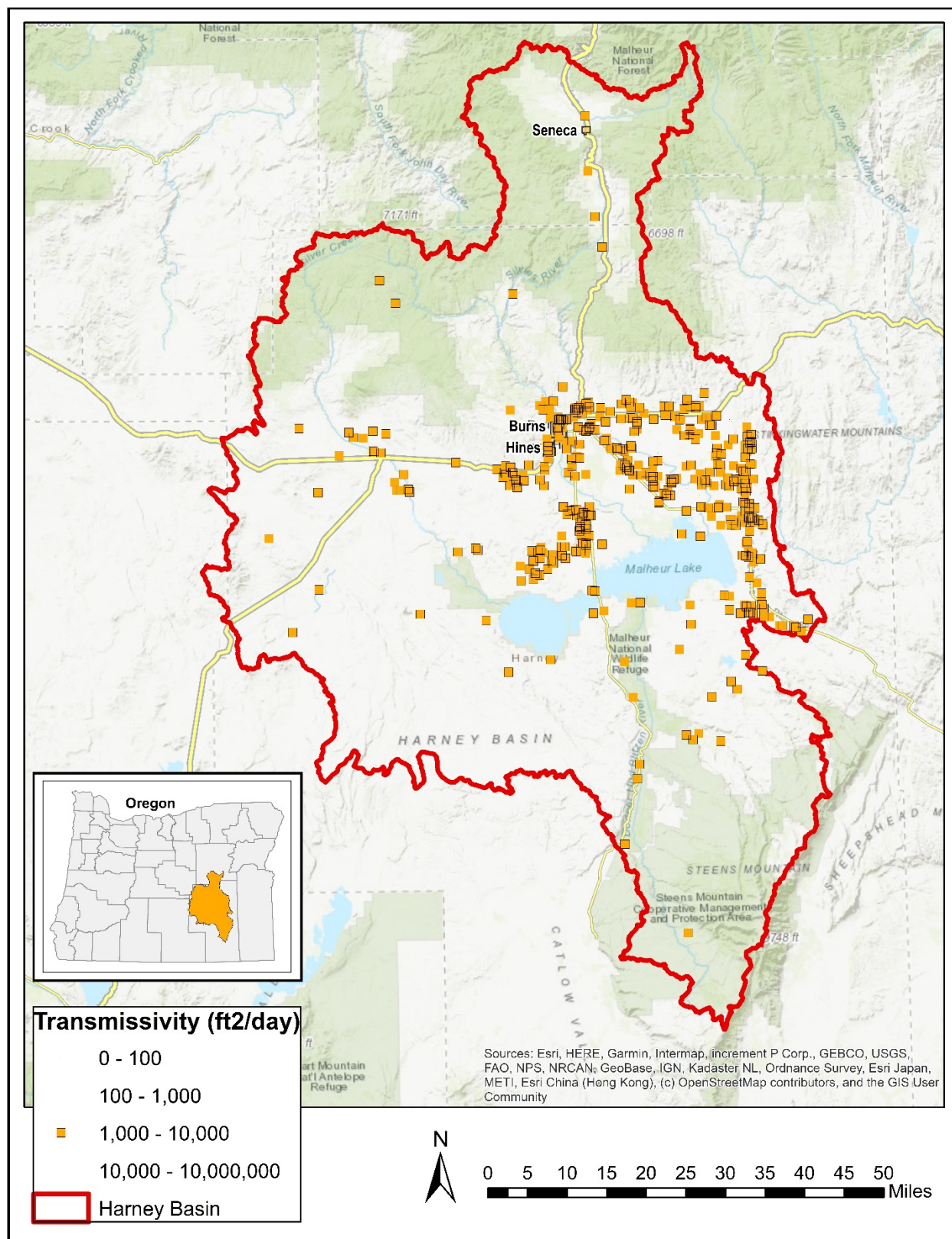


Figure K-19. Transmissivity spatial distribution map: all well depths, mid-high value range [from 1,161 well yield tests inside Harney Basin]

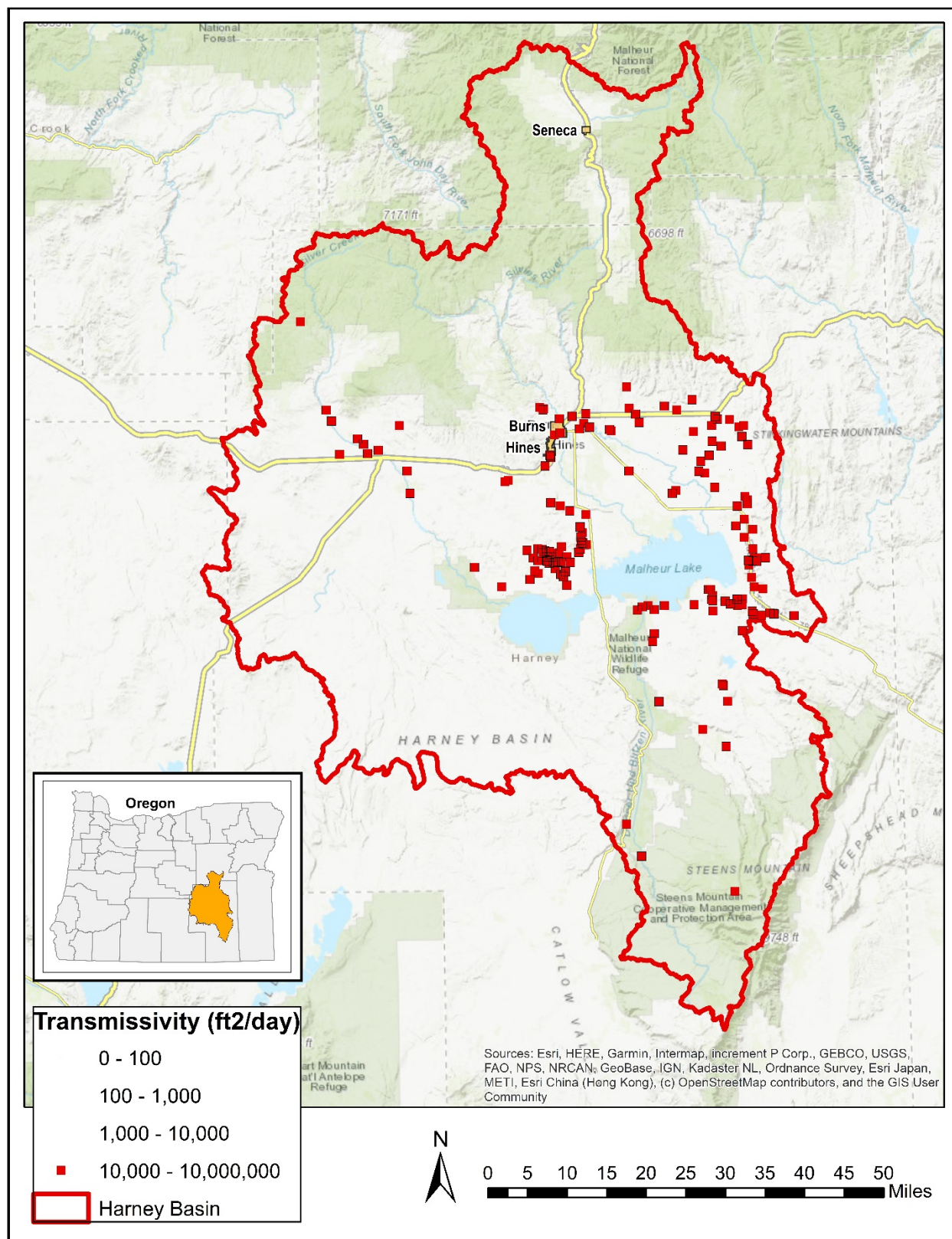


Figure K-20. Transmissivity spatial distribution map: all well depths, highest value range [from 1,161 well yield tests inside Harney Basin]

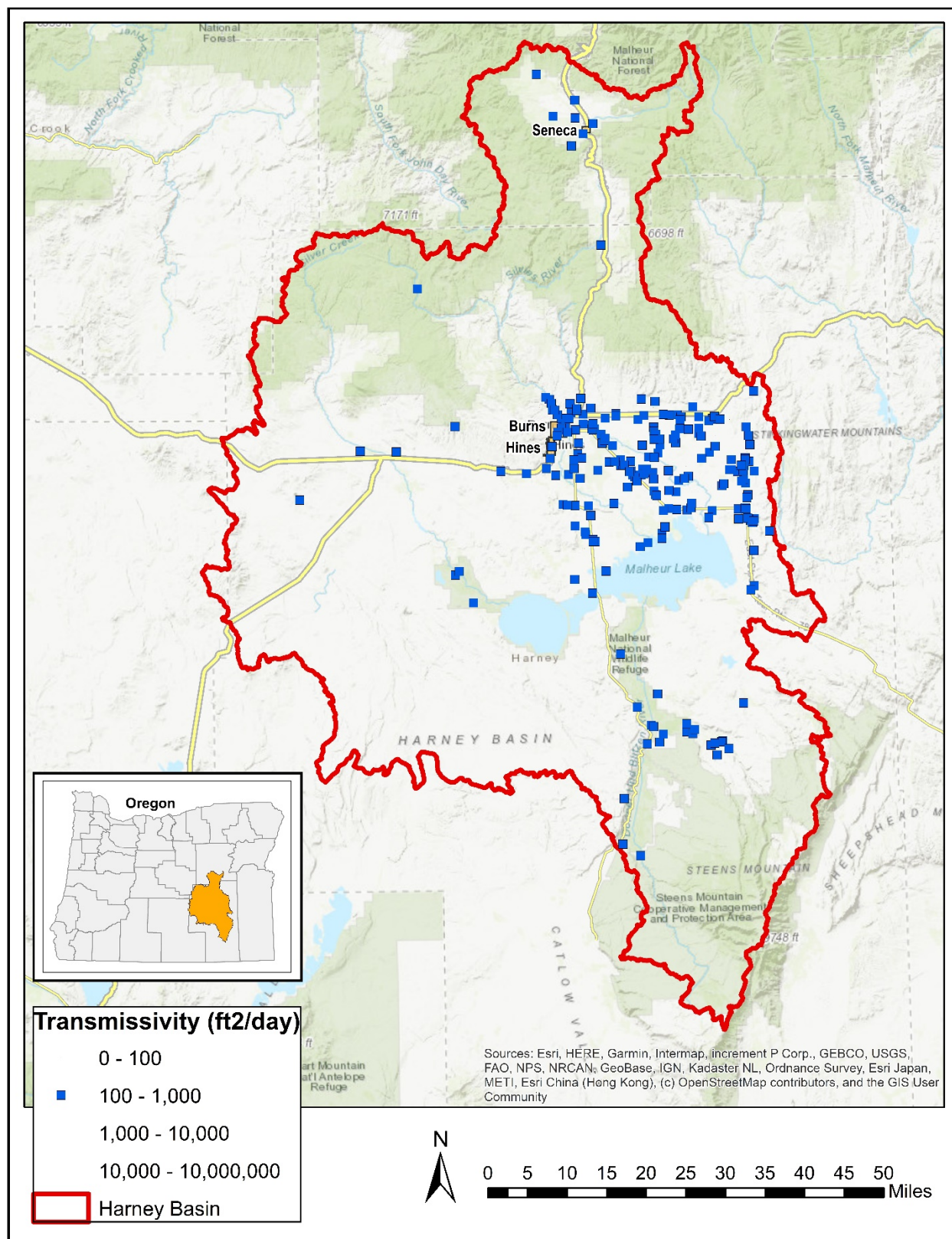


Figure K-23. Transmissivity spatial distribution map: shallower well depths, id-low value range [from 498 of 1,161 well yield tests inside Harney Basin, total well depth less than 150 feet]

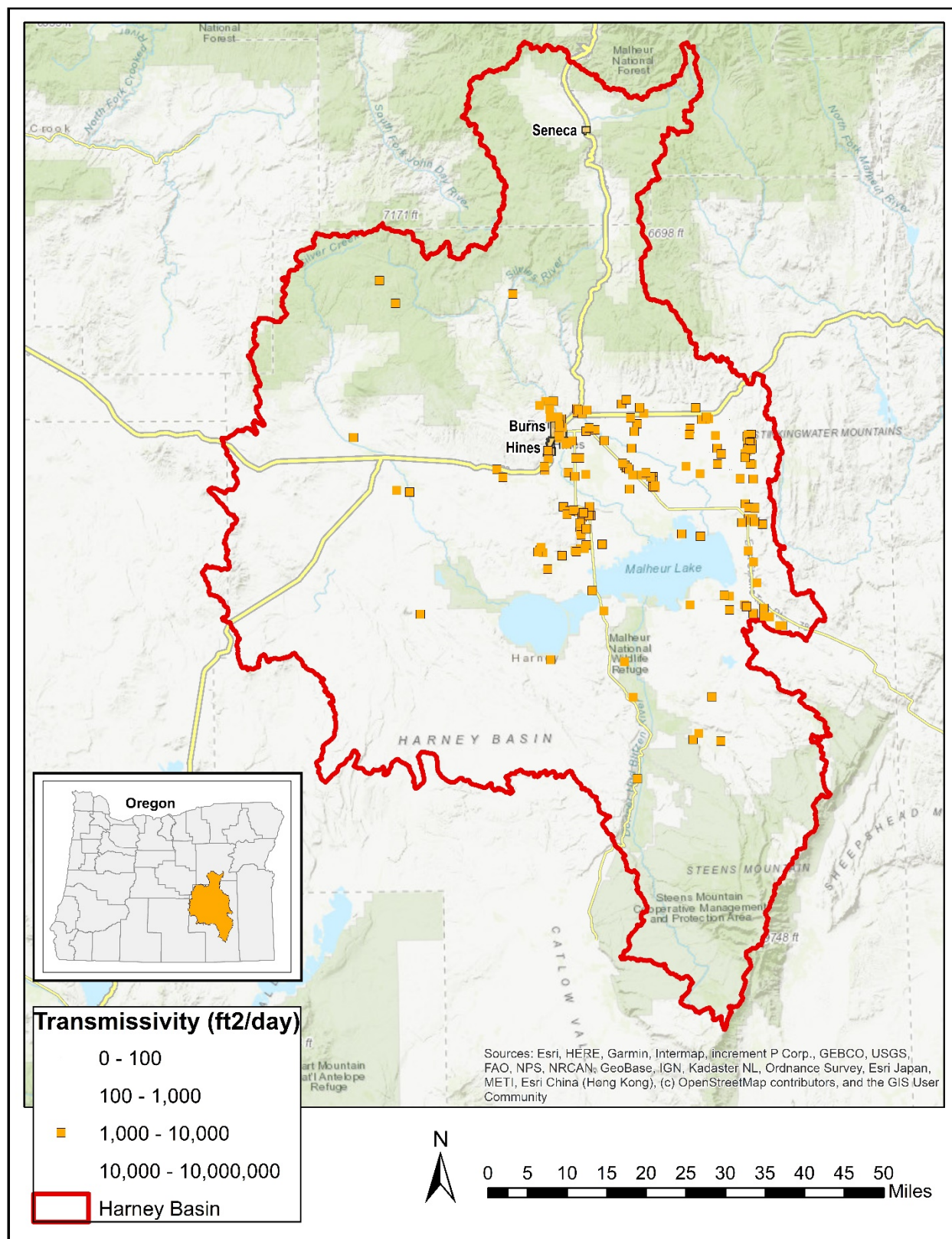


Figure K-24. Transmissivity spatial distribution map: shallower well depths, mid-high value range [from 498 of 1,161 well yield tests inside Harney Basin, total well depth less than 150 feet]

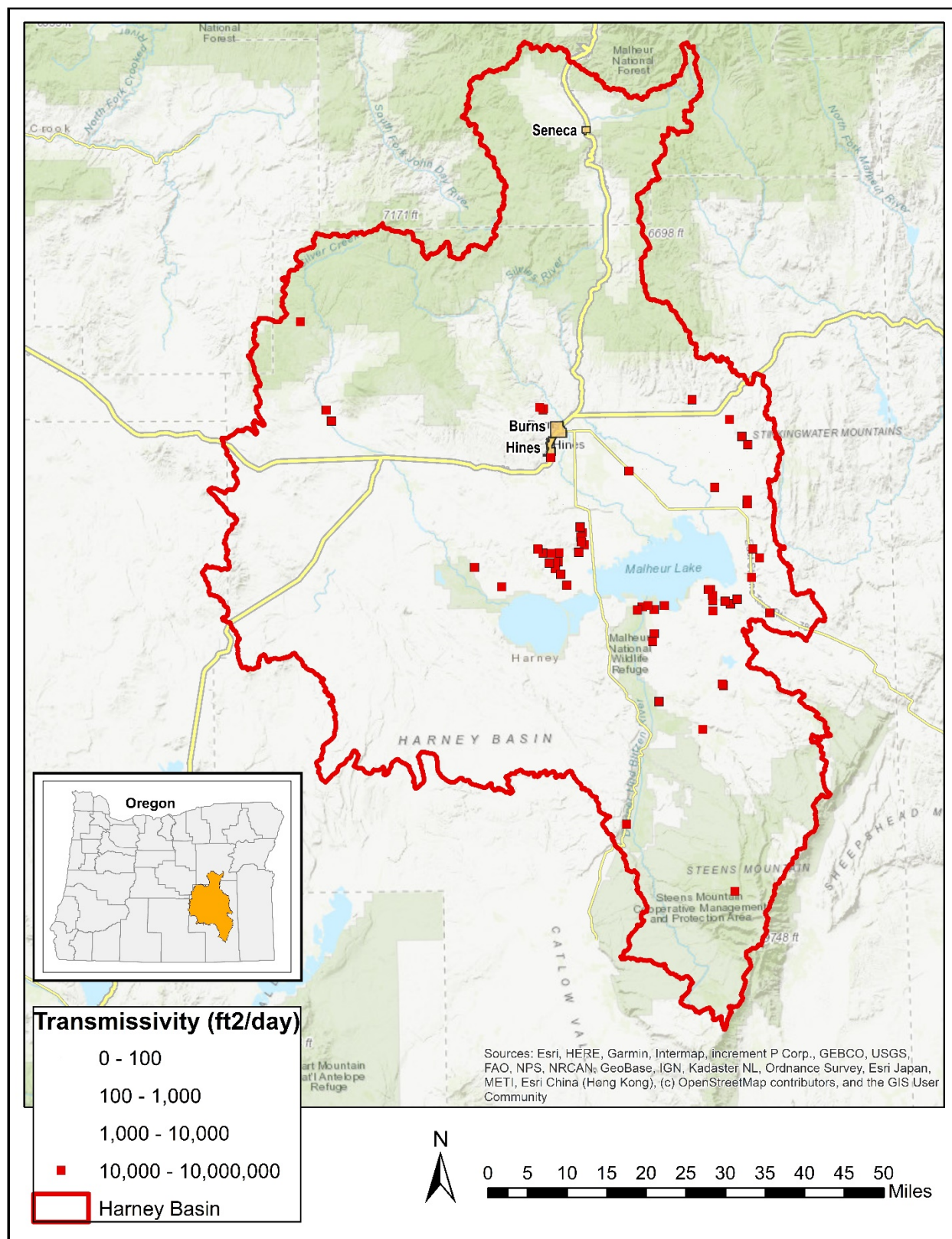


Figure K-25. Transmissivity spatial distribution map: shallower well depths, highest value range [from 498 of 1,161 well yield tests inside Harney Basin, total well depth less than 150 feet]

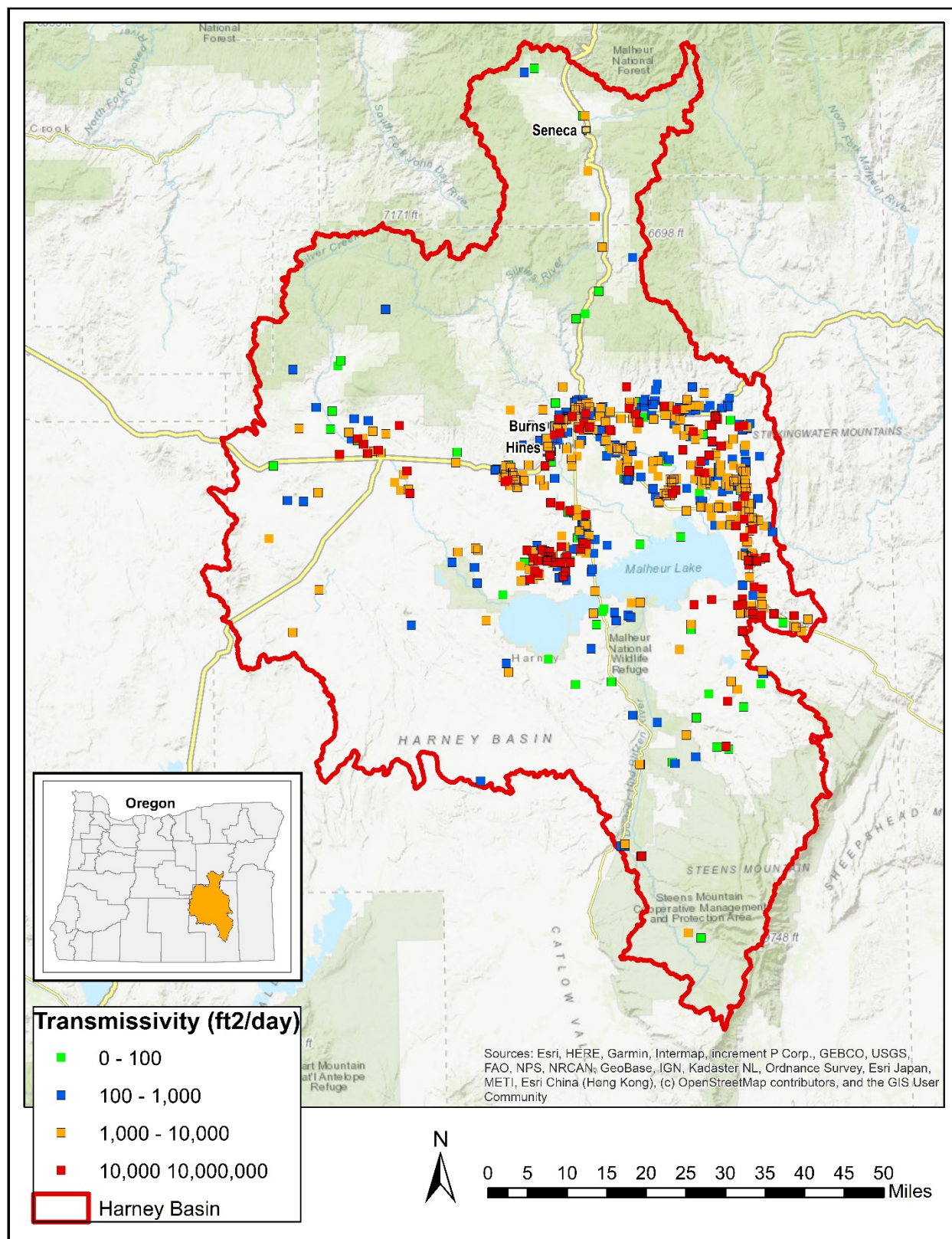


Figure K-26. Transmissivity spatial distribution map: deeper well depths, all value ranges [from 663 of 1,161 well yield tests inside Harney Basin, total well depth 150 feet or greater]

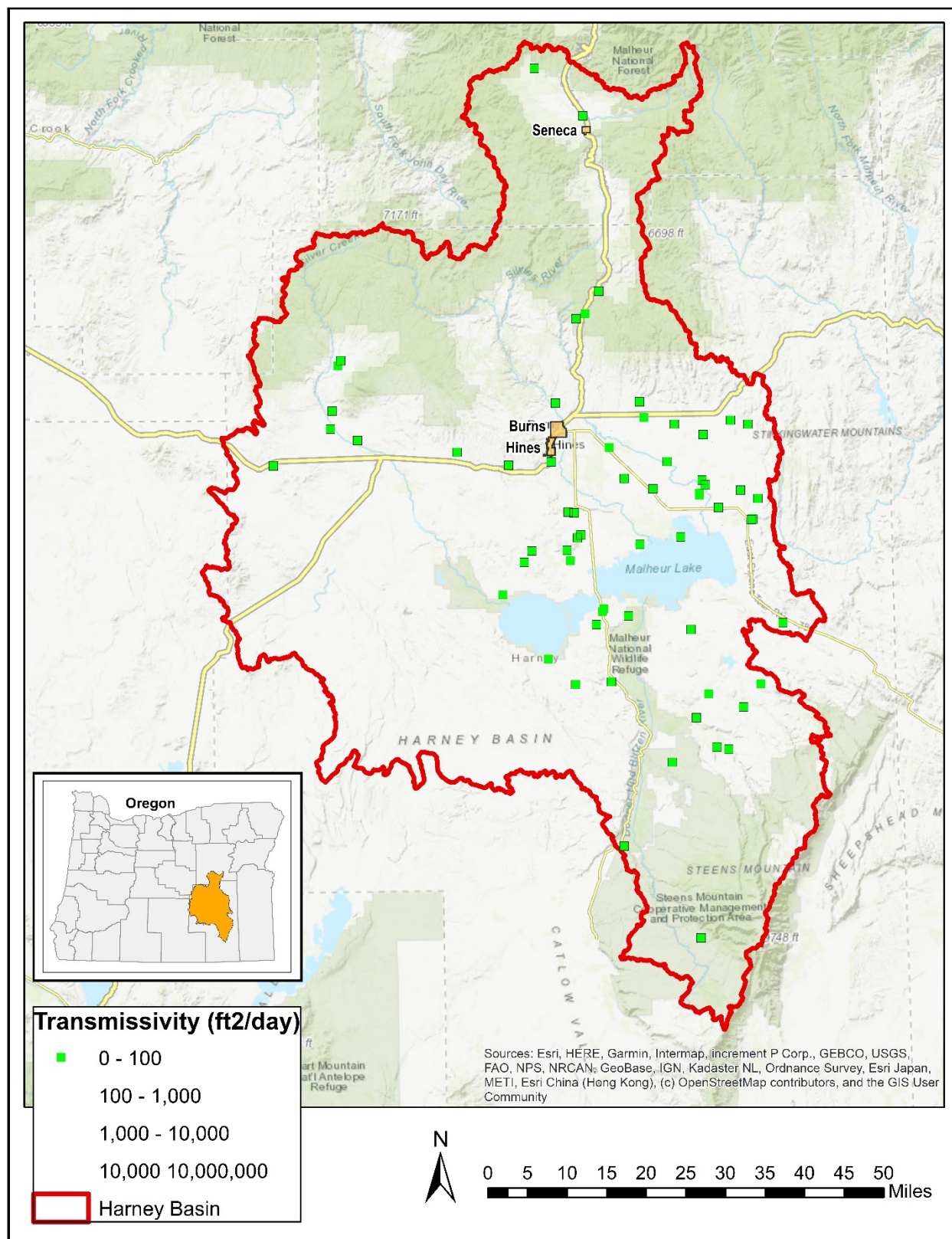


Figure K-27. Transmissivity spatial distribution map: deeper well depths, lowest value range [from 663 of 1,161 well yield tests inside Harney Basin, total well depth 150 feet or greater]

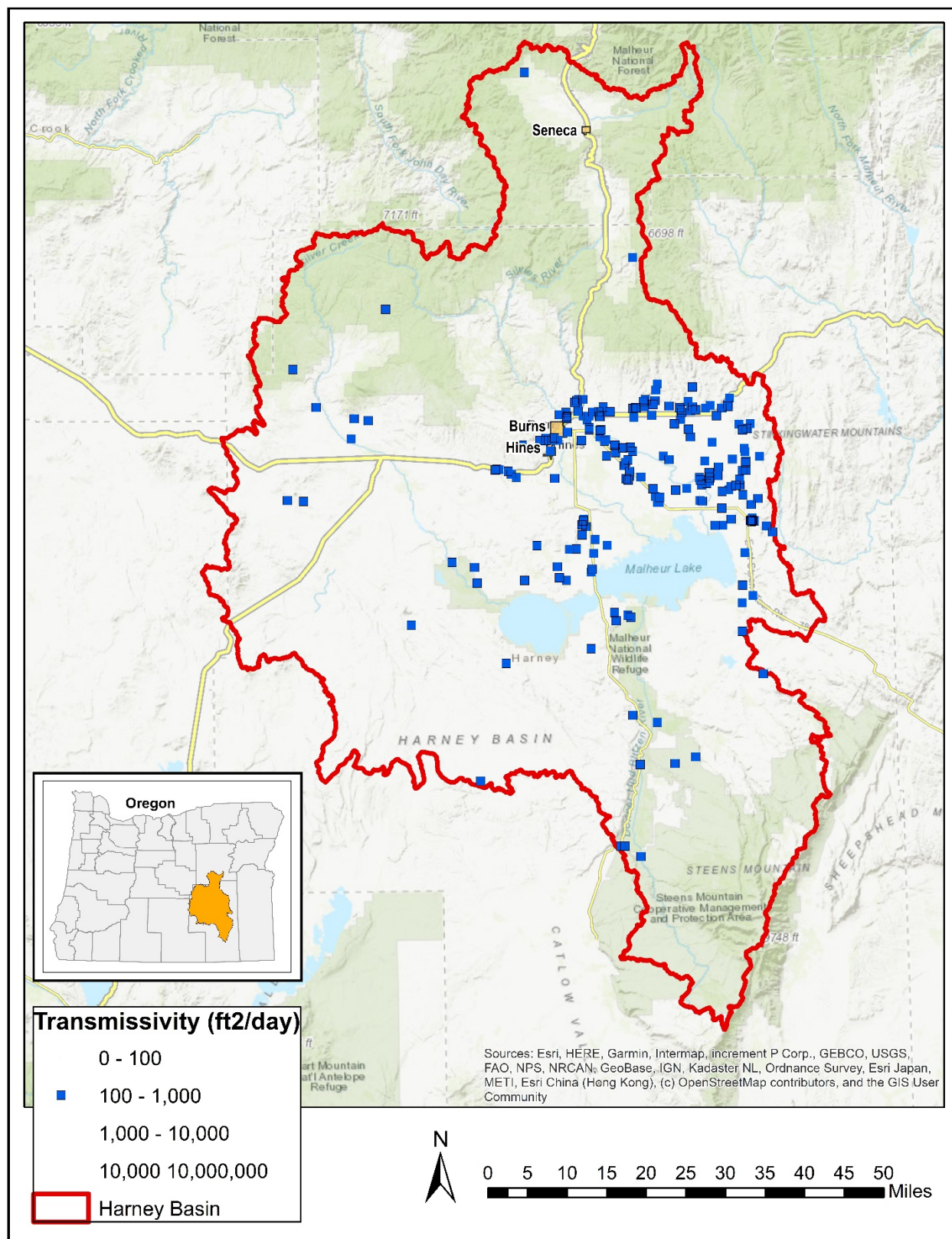


Figure K-28. Transmissivity spatial distribution map: deeper well depths, mid-low value range [from 663 of 1,161 well yield tests inside Harney Basin, total well depth 150 feet or greater]

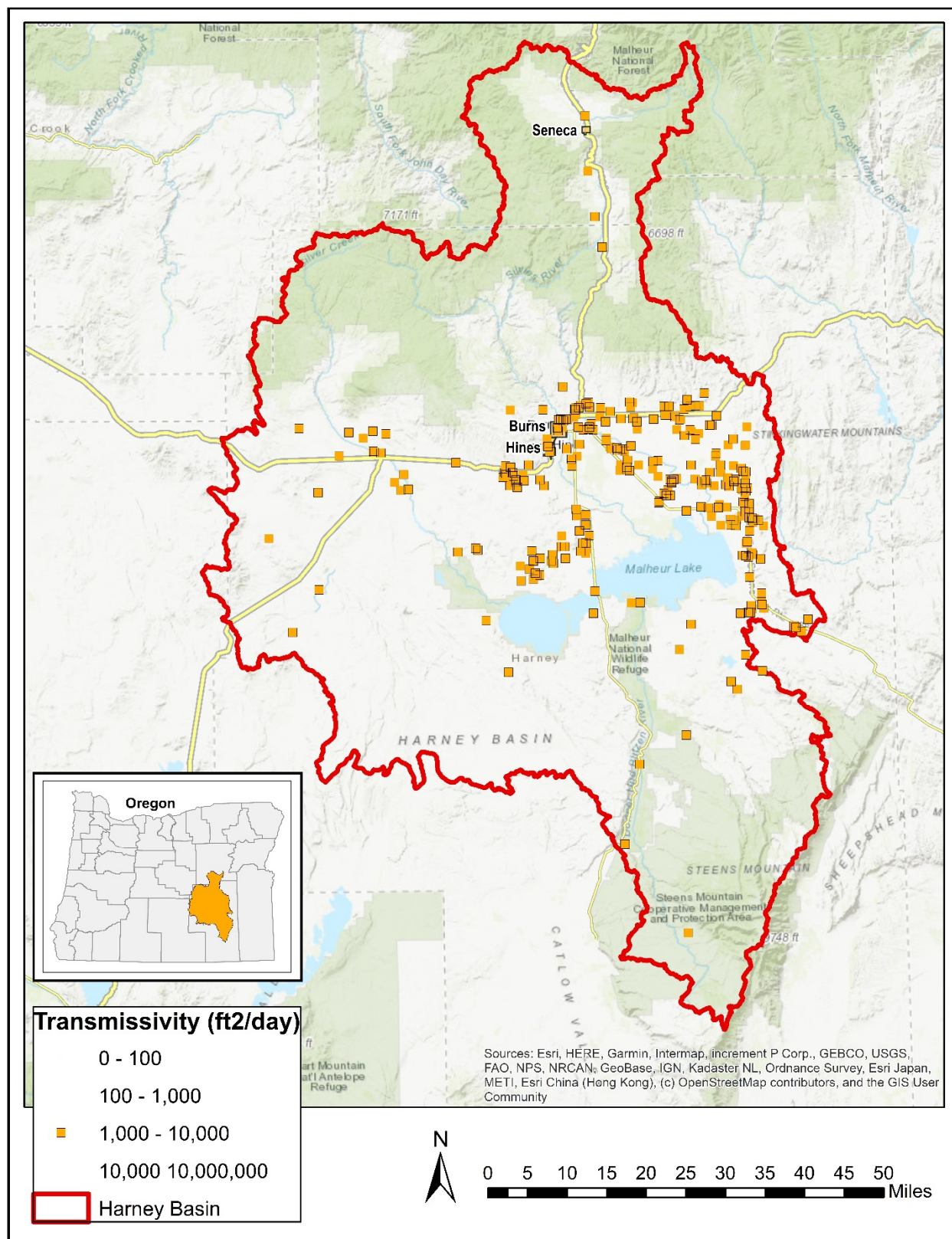


Figure K-29. Transmissivity spatial distribution map: deeper well depths, mid-high value range [from 663 of 1,161 well yield tests inside Harney Basin, total well depth 150 feet or greater]

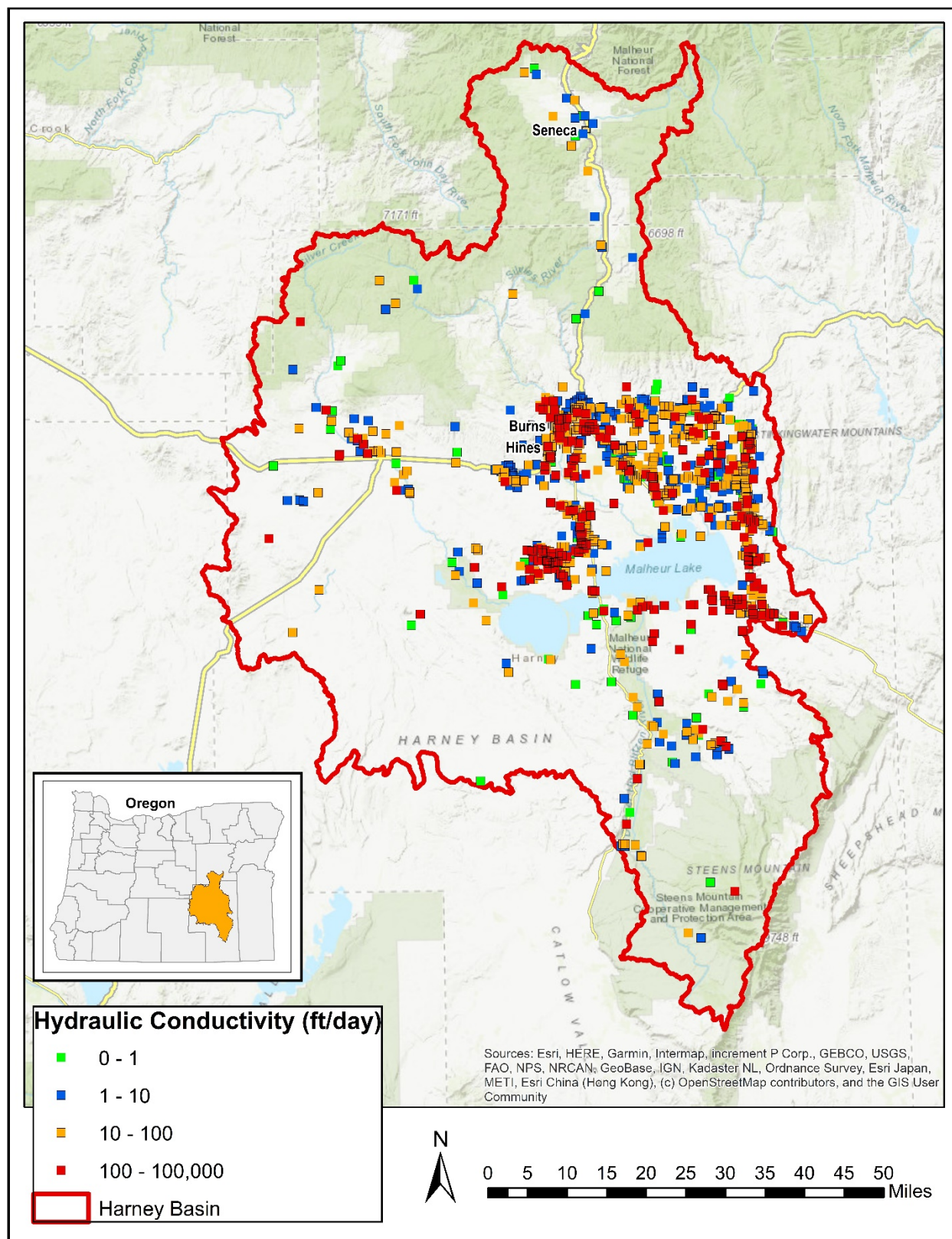


Figure K-31. Hydraulic conductivity spatial distribution map: all well depths, all value ranges [from 1,161 well yield tests inside Harney Basin]

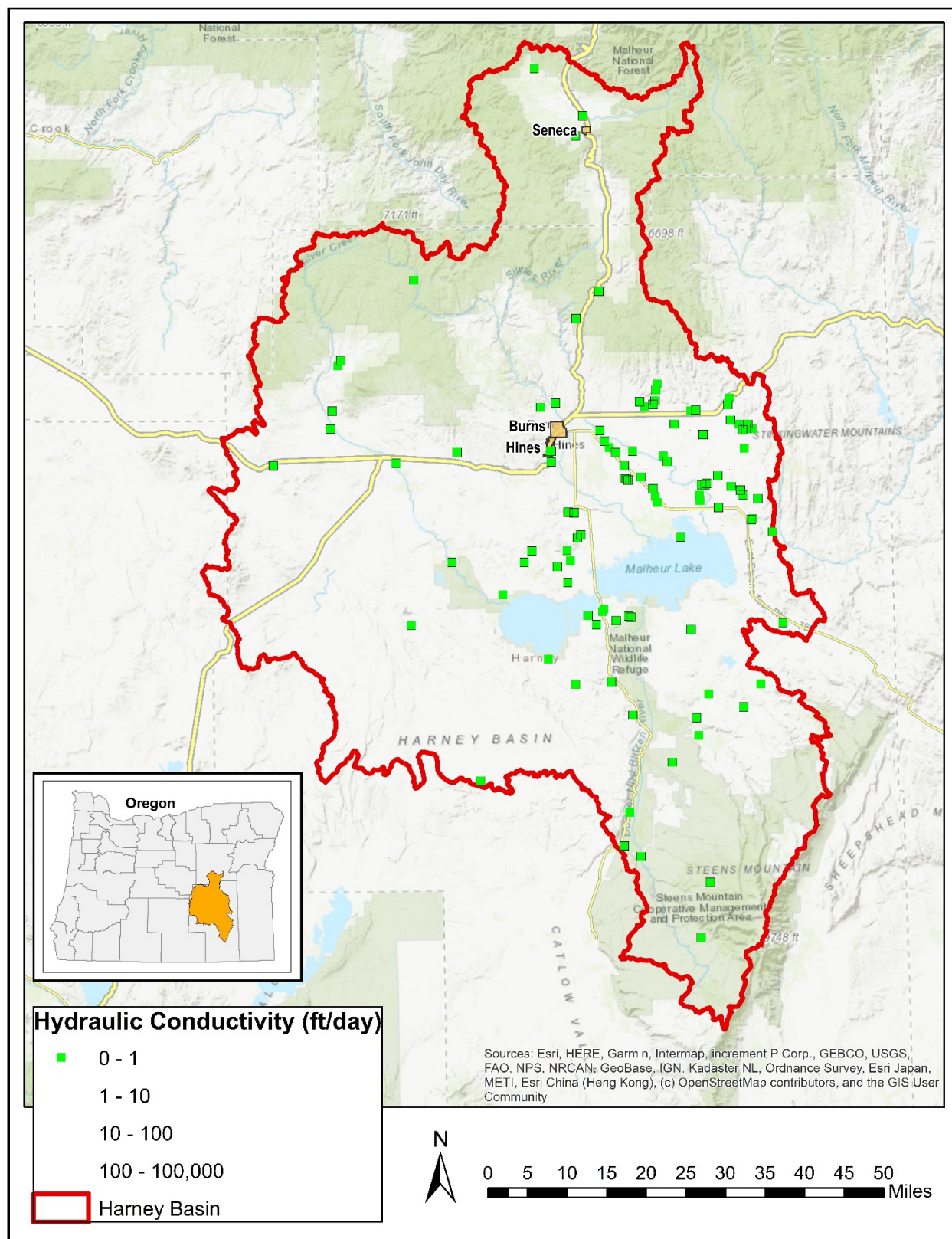


Figure K-32. Hydraulic conductivity spatial distribution map: all well depths, lowest value range [from 1,161 well yield tests inside Harney Basin]

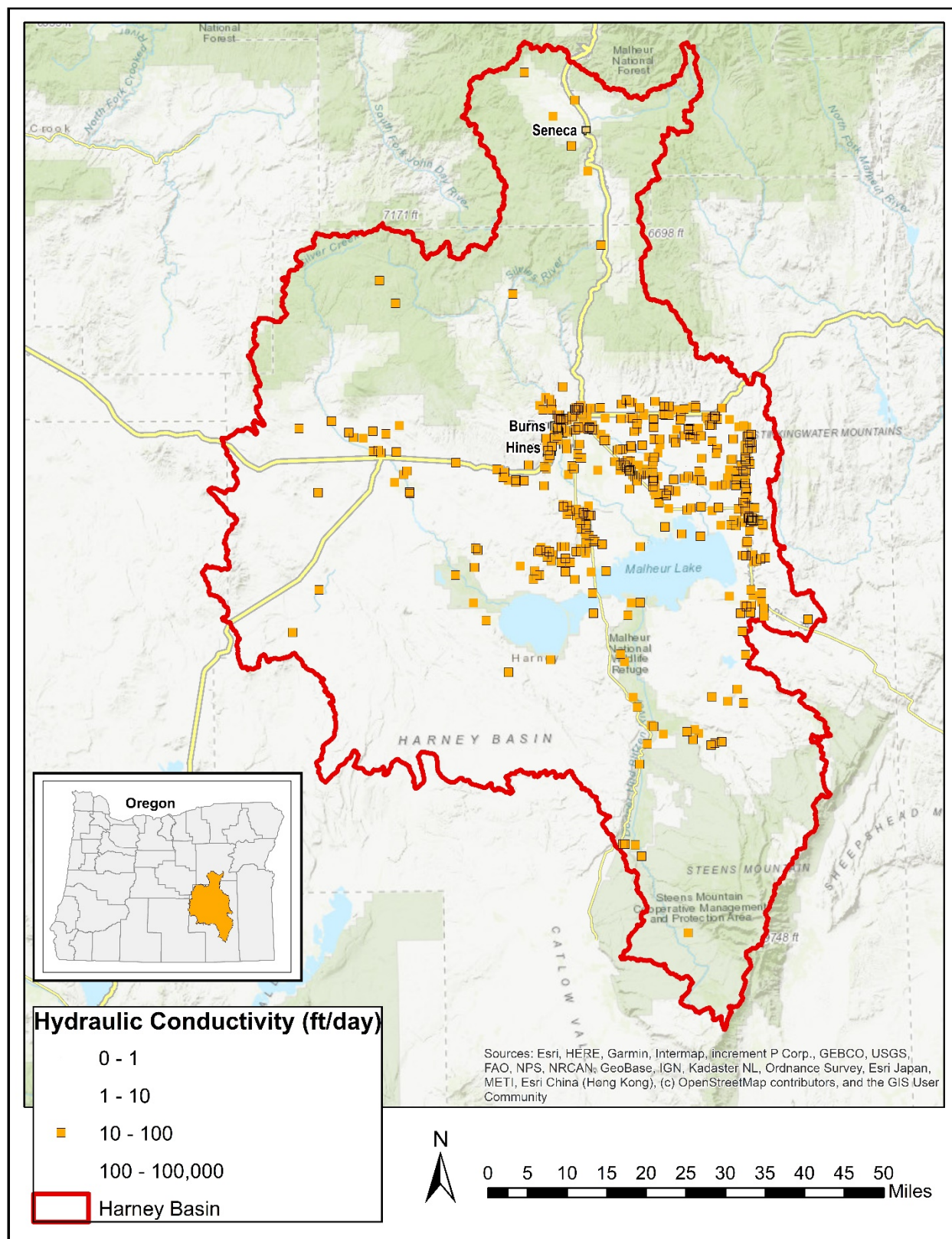


Figure K-34. Hydraulic conductivity spatial distribution map: all well depths, mid-high value range [from 1,161 well yield tests inside Harney Basin]

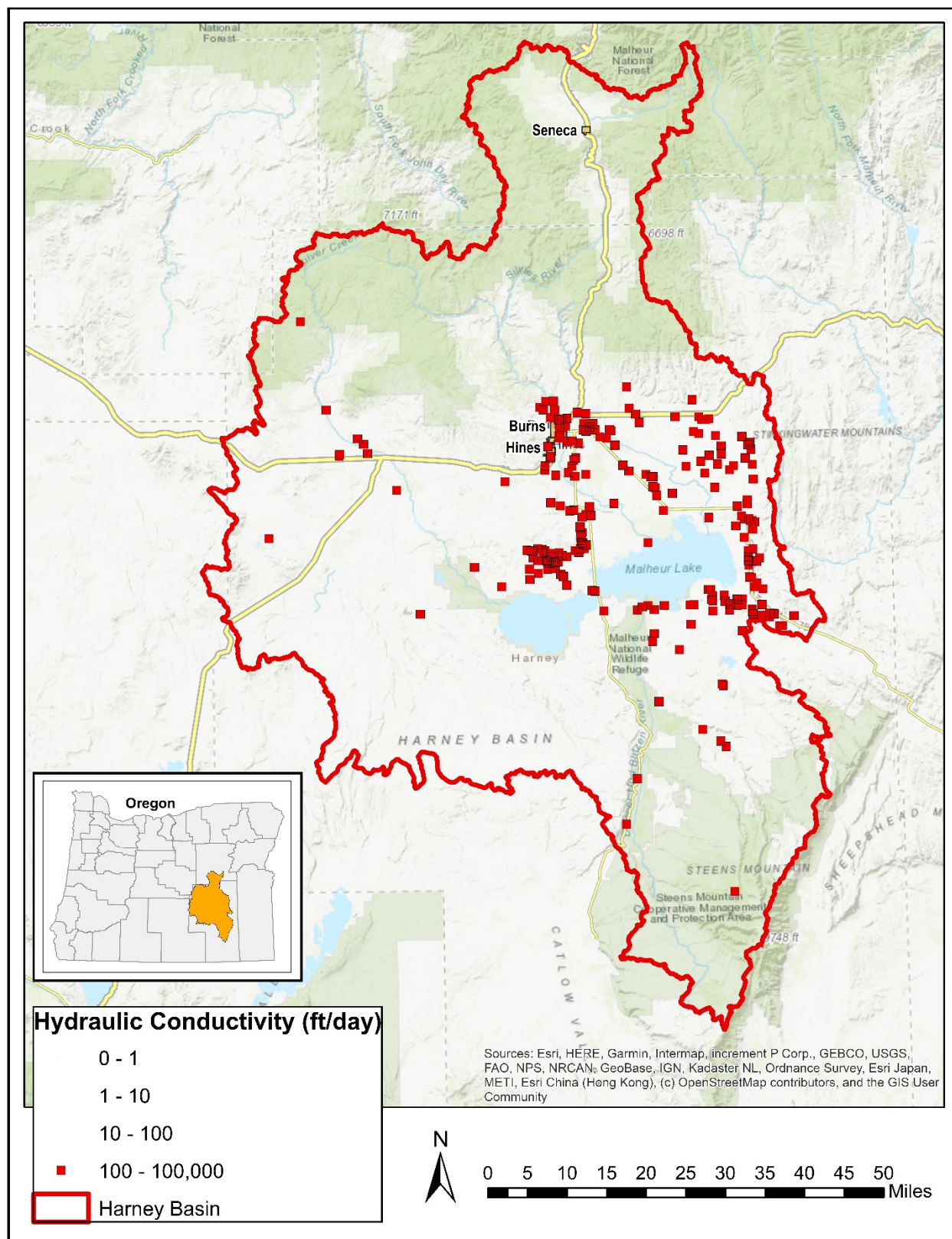


Figure K-35. Hydraulic conductivity spatial distribution map: all well depths, highest value range [from 1,161 well yield tests inside Harney Basin]

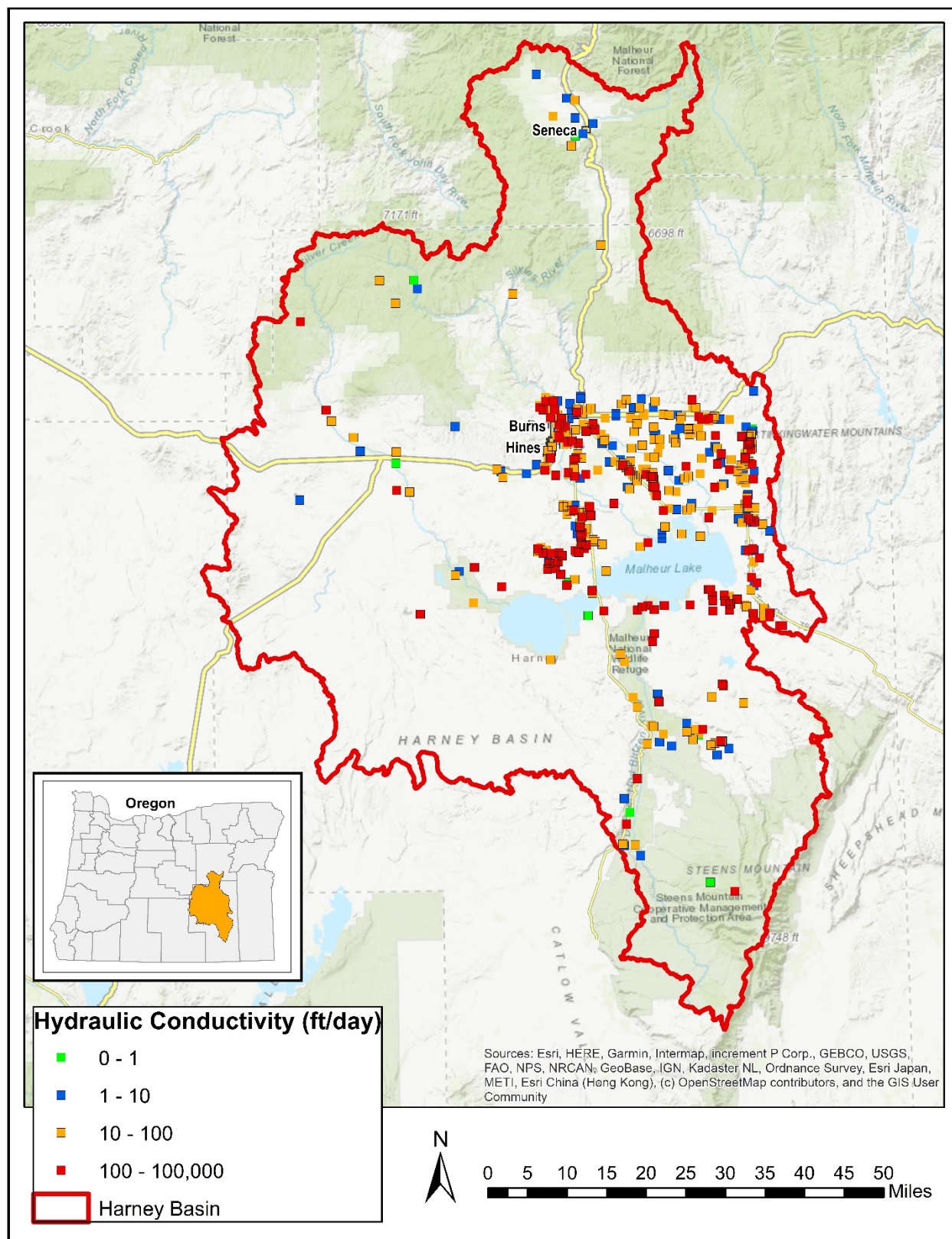


Figure K-36. Hydraulic conductivity spatial distribution map: shallower well depths, all value ranges [from 498 of 1,161 well yield tests inside Harney Basin, total well depth less than 150 feet]

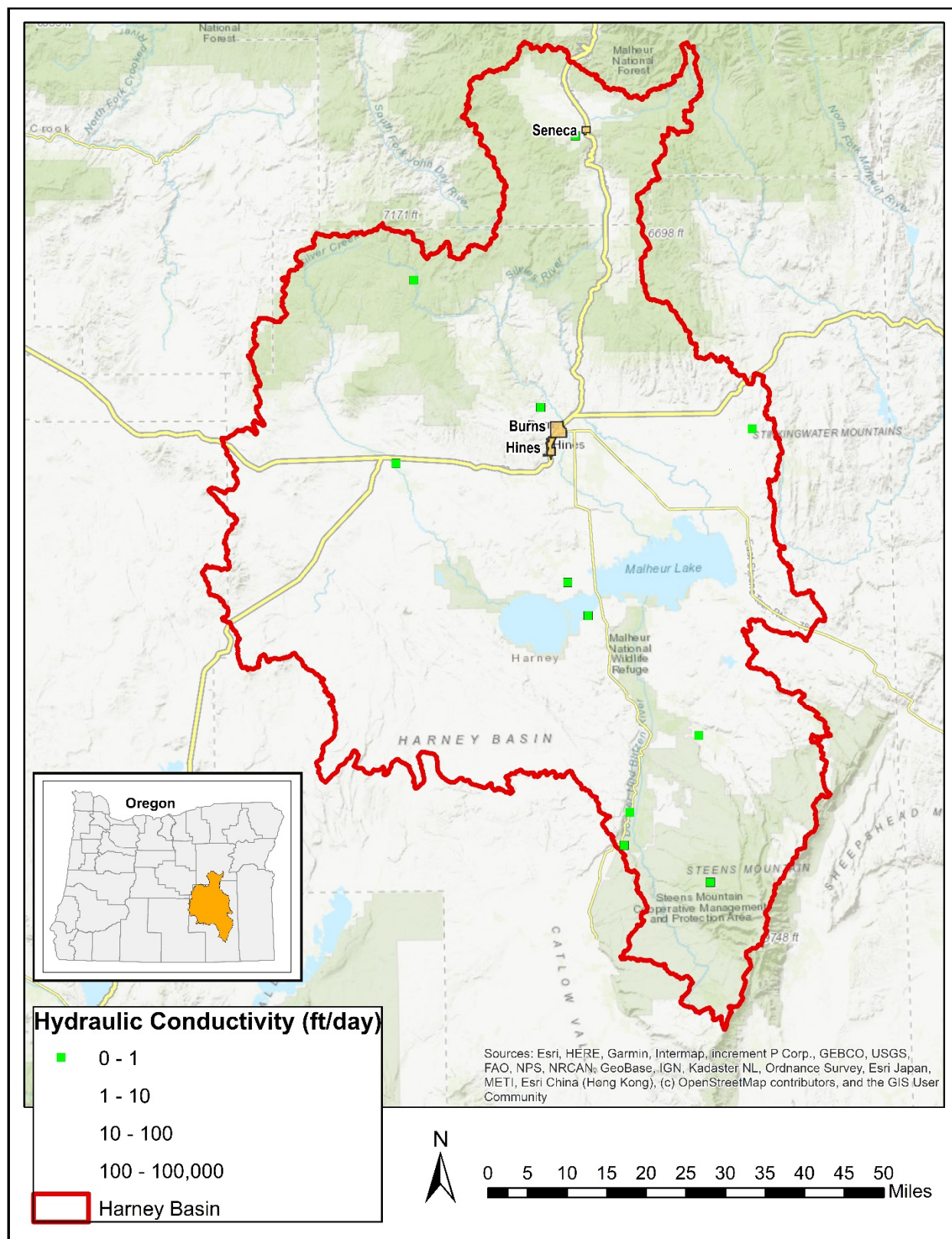


Figure K-37. Hydraulic conductivity spatial distribution map: shallower well depths, lowest value range [from 498 of 1,161 well yield tests inside Harney Basin, total well depth less than 150 feet]

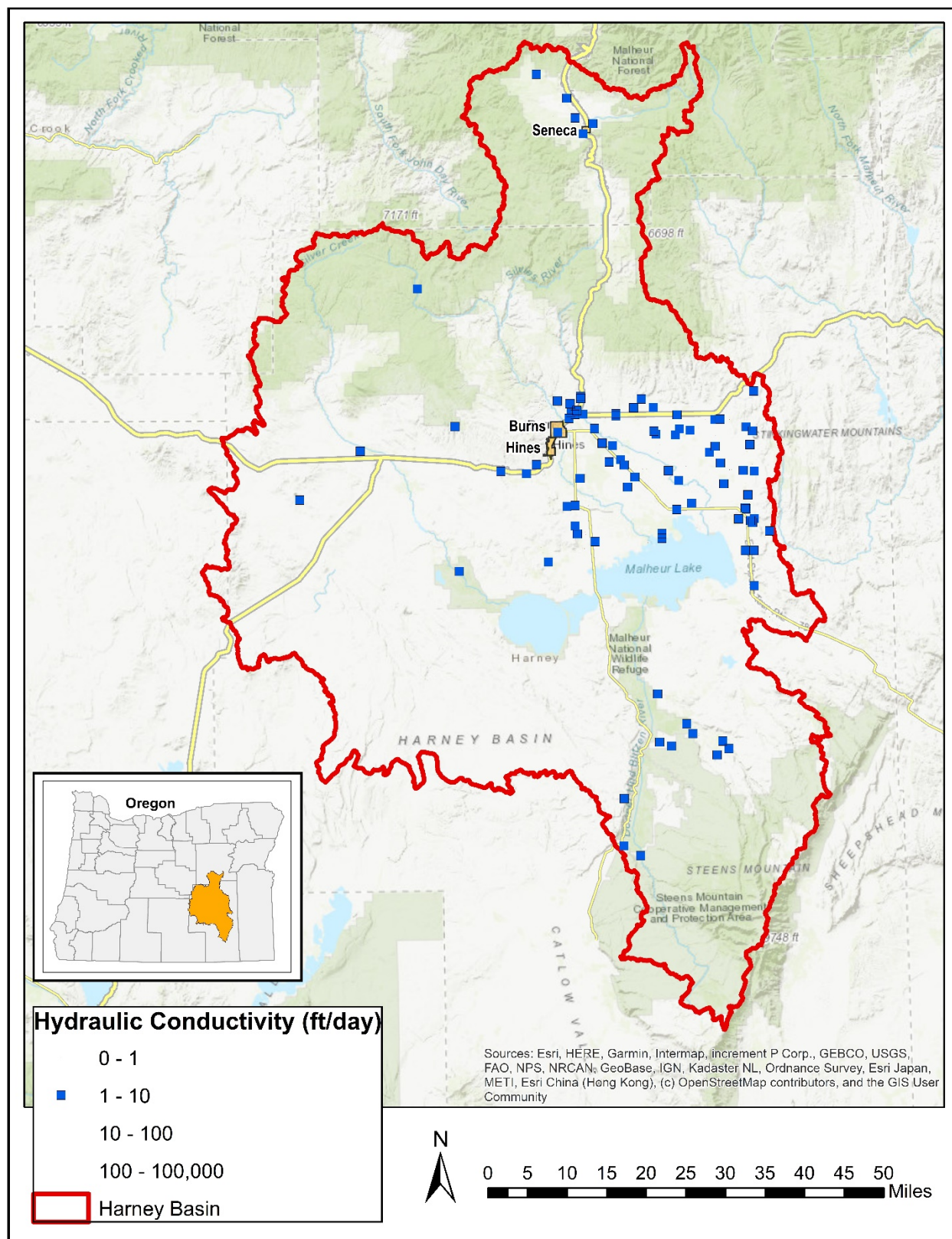


Figure K-38. Hydraulic conductivity spatial distribution map: shallower well depths, mid-low value range [from 498 of 1,161 well yield tests inside Harney Basin, total well depth less than 150 feet]

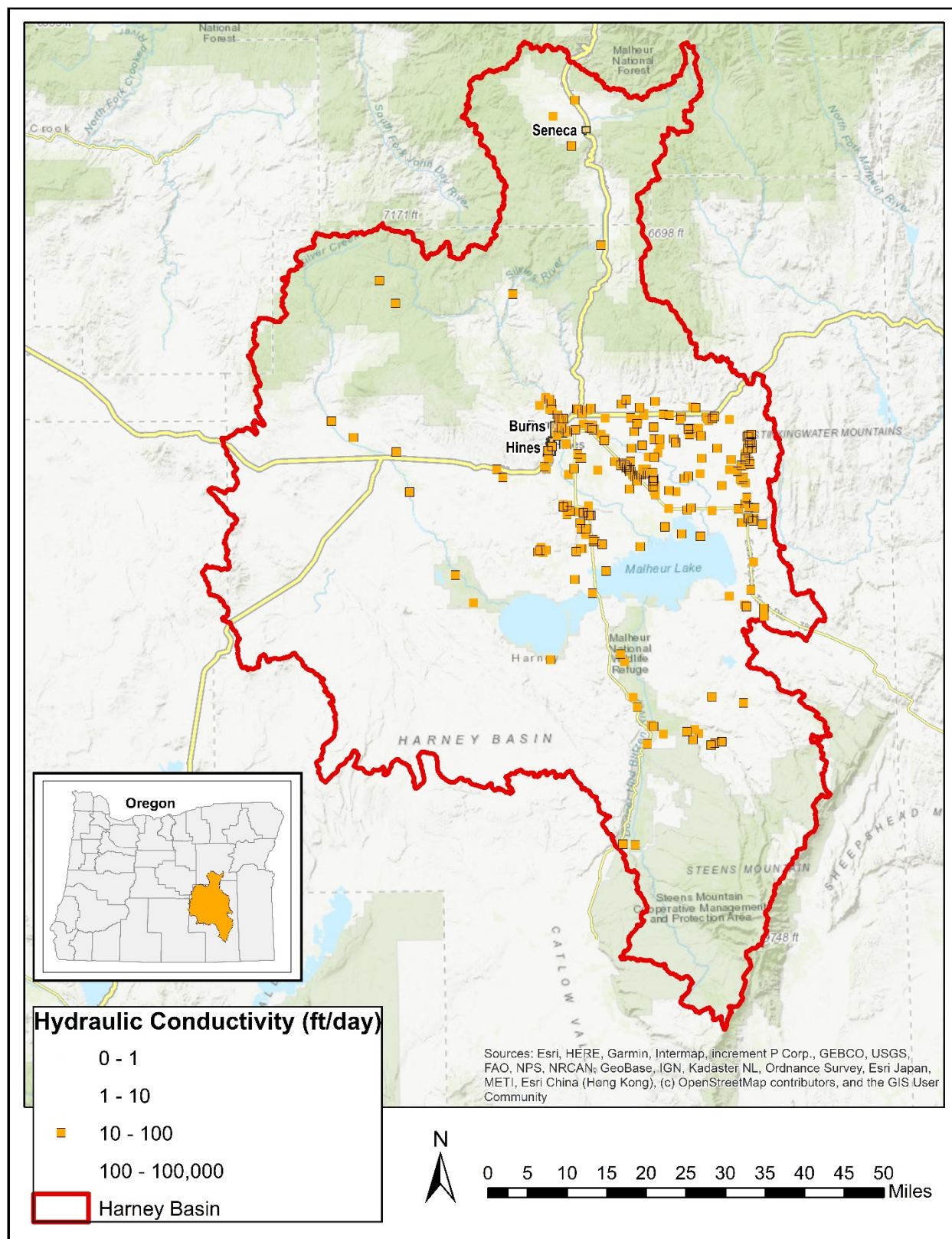


Figure K-39. Hydraulic conductivity spatial distribution map: shallower well depths, mid-high value range [from 498 of 1,161 well yield tests inside Harney Basin, total well depth less than 150 feet]

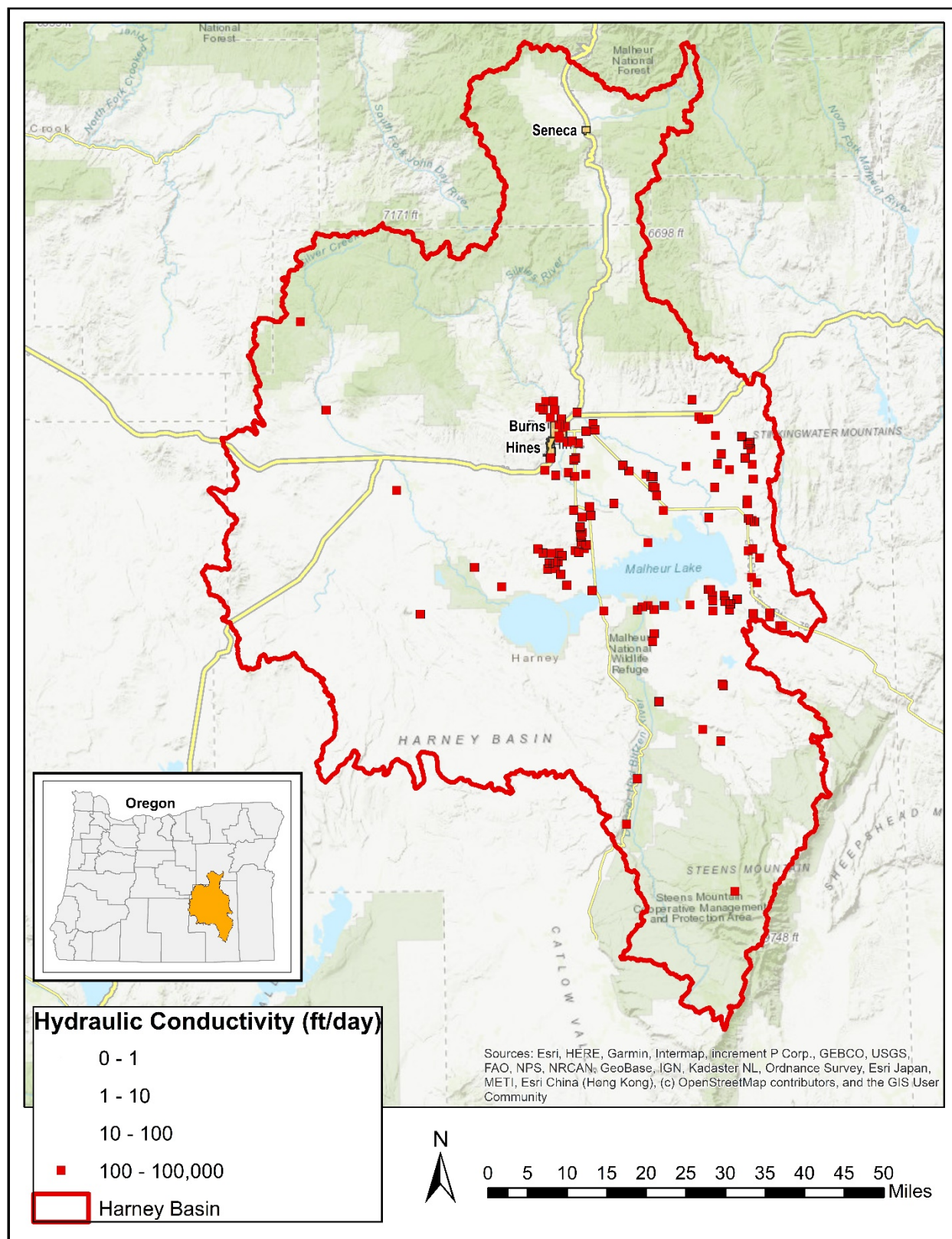


Figure K-40. Hydraulic conductivity spatial distribution map: shallower well depths, highest value range [from 498 of 1,161 well yield tests inside Harney Basin, total well depth less than 150 feet]

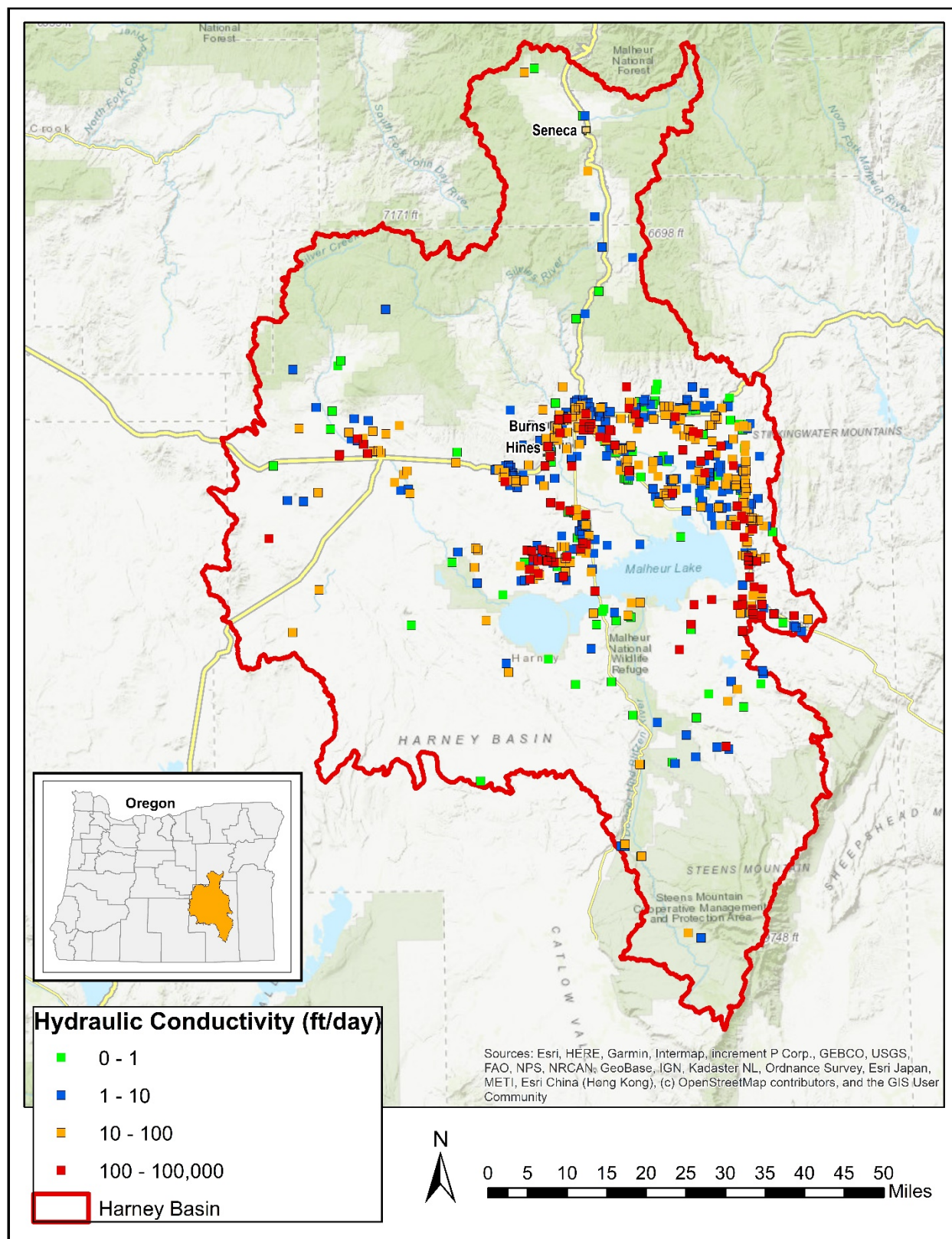


Figure K-41. Hydraulic conductivity spatial distribution map: deeper well depths, all value ranges [from 663 of 1,161 well yield tests inside Harney Basin, total well depth 150 feet or greater]

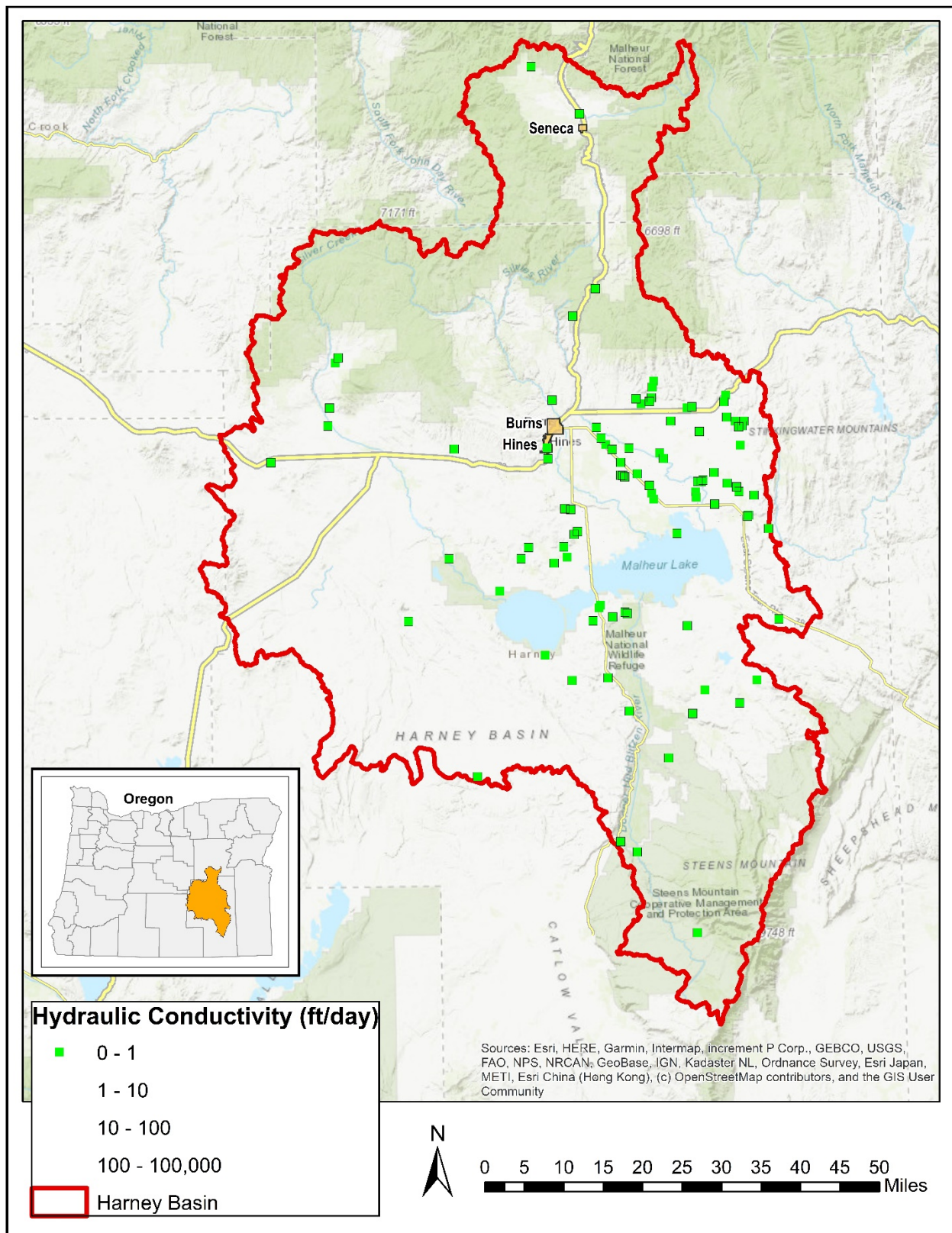


Figure K-42. Hydraulic conductivity spatial distribution map: deeper well depths, lowest value range [from 663 of 1,161 well yield tests inside Harney Basin, total well depth 150 feet or greater]

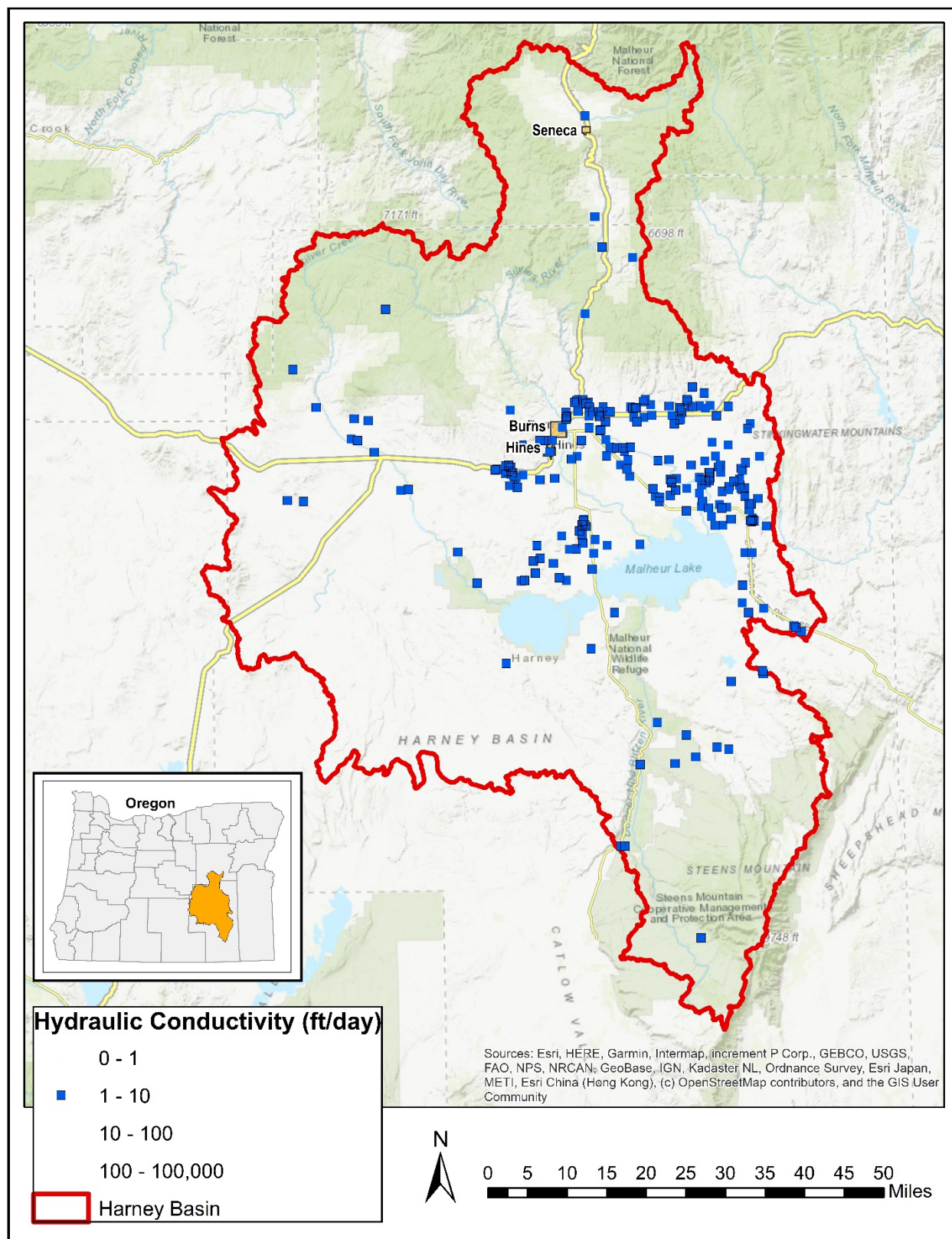


Figure K-43. Hydraulic conductivity spatial distribution map: deeper well depths, mid-low value range [from 663 of 1,161 well yield tests inside Harney Basin, total well depth 150 feet or greater]

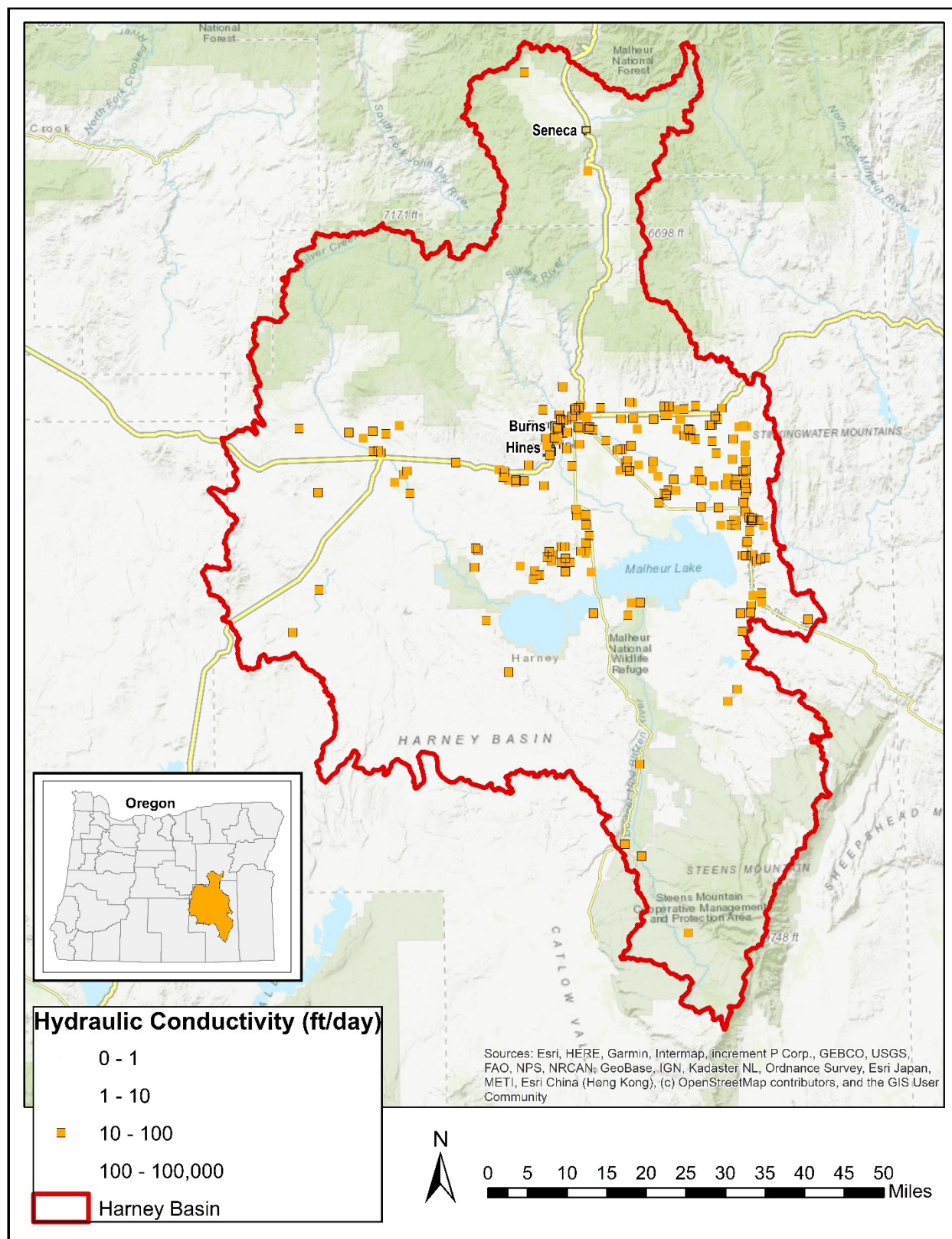


Figure K-44. Hydraulic conductivity spatial distribution map: deeper well depths, mid-high value range [from 663 of 1,161 well yield tests inside Harney Basin, total well depth 150 feet or greater]

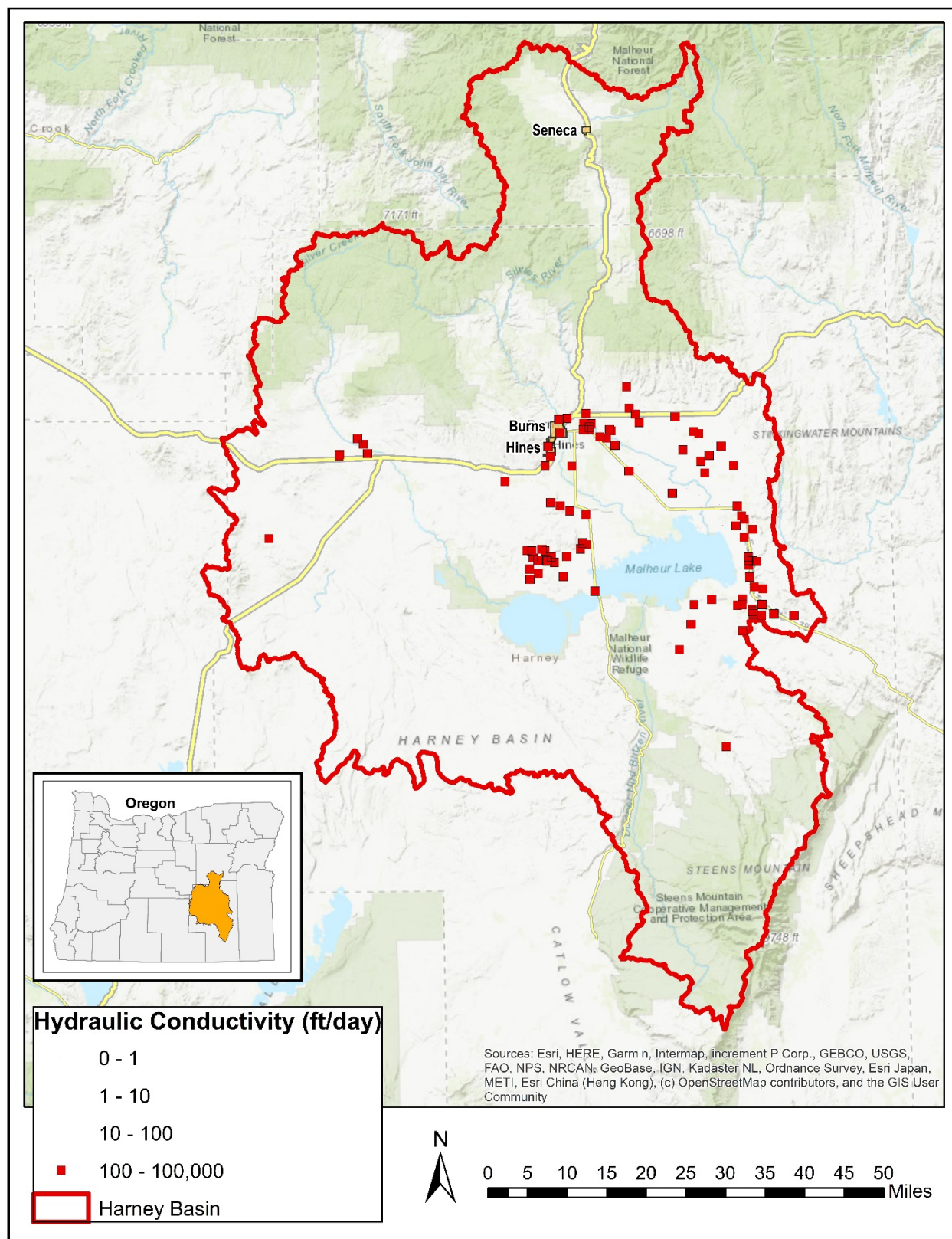


Figure K-45. Hydraulic conductivity spatial distribution map: deeper well depths, highest value range [from 663 of 1,161 well yield tests inside Harney Basin, total well depth 150 feet or greater]

Appendix L: Well Lithology Conversion to Stratigraphic Units

Well Lithology and Water Bearing Zones

Water well reports filed at the Oregon Water Resources Department (OWRD) often include a section named “well log” and a section named “static water level” (figure L-1, sections 11 and 10 respectively). The well log section is where the vertical sequence of subsurface materials (lithologic units) detected is recorded by the well driller. It includes space to describe each lithologic unit and the depth to the top and bottom of each unit. Methods to detect lithologic units vary but the most common method is collection and inspection of drill cuttings during drilling. The “static water level section” found in more recent water well report versions is where detected water bearing zones are recorded. The section includes space to note each water bearing zone, the water yield rate for each zone, the depth to the top and bottom of each zone, and a static groundwater level. A water bearing zone may include one or more lithologic units or may be a portion of a single lithologic unit. When possible or as needed, OWRD staff enter the reported lithologic and water bearing zone information into the OWRD Groundwater Information System (GWIS) database (Oregon Water Resources Department, 2019a).

Well Lithology Conversion to Stratigraphic Units

OWRD entered lithologic unit information related to 2,242 wells within and surrounding the Harney Basin into the OWRD GWIS database via a data entry process termed “lith-coding.” Of those 2,242 wells, 1,810 were identified as having associated pump tests (discussed in appendix G) and/or well yield tests (discussed in appendix I) and/or were associated with USGS Harney Basin analyses, which made them candidates for correlating their lithologic unit information to the Harney Basin stratigraphic units summarized in appendix A. Correlating the vertical sequence of lithologic units per well to stratigraphic units is termed “strat-coding.” Of the 1,810 wells, 1,495 wells were strat-coded using the reported lithology and available geologic data. The 1,495 wells are listed in table L-1. The OWRD hydrogeologist who compiled the available Harney Basin geology (Boschmann, 2021) conducted the strat-coding. The lithologic unit to stratigraphic unit correlation for each of the 1,495 wells can be found in the OWRD GWIS database (Oregon Water Resources Department, 2019a).

Page L-2

Appendix M: Well Open Interval Definitions, Calculations, and Use

This appendix presents four well “open interval” (OPI) options considered for Haney Basin groundwater investigation use: total open interval, saturated open interval, and two water-bearing open intervals (within the total OPI and within the saturated OPI). The investigation used the total open interval option to (a) calculate hydraulic conductivity values from transmissivity values, (b) identify the stratigraphic unit(s) and related hydrostratigraphic unit(s) exposed at the well open interval, and (c) assign hydraulic property values at a well location to the one or more exposed stratigraphic units and related hydrostratigraphic units. Appendix H and J lists the results.

Well Construction Data

Determining the open interval per well required acquiring well construction data from water related well reports, water right files, published reports, and other sources. That data varies in completeness, detail, and quality. Consequently, this investigation reviewed the reports, reconciled discrepancies, and/or found missing data where possible. Additionally, the construction data was entered into the Oregon Water Resources (OWRD) Groundwater Report Information Database (GRID) and/or the OWRD Groundwater Information System (GWIS) database (Oregon Water Resources Department, 2019a, 2019b) making it publicly available for queries and exports for subsequent analyses and calculations. Table M-1 shows the well construction data entry options, rules, and assumptions. The data acquired, entered, and available per well varies.

Well Construction Features Identified as Open Interval

The well construction features listed in table M-1 considered an open interval (OPI) are “filter pack” (all materials) and “open interval” (open hole, perforation, and screen only). These features and their placement in a well are interpreted as allowing horizontal groundwater flow into a well. Annular space filled with filter pack is considered as open interval (OPI) given the space remains open to allow vertical water flow between the well casing and borehole wall that eventually enters the well. Open annular space is not included as an open interval, because the open annular space can close when the borehole wall integrity fails causing the adjoining geologic materials to collapse and/or compress against the casing blocking or restricting vertical water flow between the well casing and borehole wall.

Table M-1. Well construction data options entered and publicly available via OWRD databases
[See table notes for data entry rules and assumptions used]

Well Construction Feature Type	Well Construction Material Type	Start Depth (feet)	End Depth (feet)	Diameter (inches)
Well Depth	Total Depth Drilled			
	Completed Well Depth			
Casing	PVC			
	Steel			
	Other			
	Unknown			
Liner	PVC			
	Steel			
	Other			
	Unknown			
Filter Pack	Gravel ¹			
	Sand ¹			
	Unknown ¹			
Open Interval	Open Annular Space			
	Open Hole ¹			
	Perforation ¹			
	Screen ¹			
Seal	Bentonite			
	Clay			
	Cement Grout			
	Cement			
	Mud			
	Native Material			
	Unknown			

Notes: Well Construction data entry rules and assumptions used:

¹Feature or material type considered an "open interval" for analysis

- Depths below and above land surface are entered as positive and negative numbers respectively. When groundwater levels and well construction features are considered together, the water level is a depth below land surface, not an elevation.
- Diameter values include older numbers that are rounded down and more recent non-rounded numbers corresponding to a change in GWIS that eventually allowed entering non-rounded numbers
- Unknown diameters are entered as one-inch for wells and 60-inches for sumps
- Unknown casing, seal, and/or well depths are entered as zero feet start depth and one-foot end depth. Harney Basin hydraulic property queries excluded these wells.
- Annular space is the space-gap-distance between the outermost casing and the drilled well bore wall

Table continues next page

Table M-1. (continued)

Notes: Well Construction data entry rules and assumptions used: (continued)
• Perforation, screen, and open annular intervals are generally entered in conjunction with casing intervals • All wells are required to have an open interval. Wells with casing the entire well depth (no open interval) were assigned a 0.1-foot perforation interval at the casing bottom. Harney Basin hydraulic property queries excluded these wells. • Well seal diameters are entered as 4-inches greater than the maximum casing diameter where unspecified, an assumption based on Oregon well construction rules OAR 690-210-0130 to 0150 effective 01/01/1979. • Liner diameters are assumed to be 2-inches less than the casing diameter where unspecified • Filter pack diameters are assumed to be the same as the well seal diameters where unspecified • Filter packs are assumed to begin at the bottom of the well seal when placed within the annular space. Filter packs were entered only for intervals where they were exposed to the drilled borehole wall (not inside an outer casing). • Filter packs are assumed to begin where annular space, perforations, or screen begins when placed in the space between the well liner and casing • Open hole diameters below casing are assumed to be the same as the narrowest casing diameter Wells less than 100 feet total depth with no record of casing are assumed open hole case by case. • Assume borehole diameter change occurs at half of total well depth for wells with two known borehole diameters, but no record or evidence of where the diameter change occurs. • Borehole diameters assigned for rectangular holes are an average of two adjoining sides. • An open interval should not overlap a sealed interval. • A perforation and/or screen interval may overlap a cased interval and still be an open interval provided the casing diameter is equal to or less than the perforation or screen diameter which means the perforation or screen is separated from the drilled borehole wall only by filter pack or open annular space or is in direct contact with the borehole wall.

Definition and Calculation for Total Open Interval

The total open interval (total OPI or OPI_{total}) for each well is the continuous well section that includes every open interval and any non-open interval occasionally present between the open intervals (figure M-1). The total OPI thickness calculation is shown in table M-2 (equation M-1). Definitions of the abbreviations used in table M-2 and subsequent tables in this appendix are listed in table M-3.

The total OPI calculation is the difference between the maximum OPI depth (bottom OPI depth where the entire OPI interval ends: $\max(OPI_{bottom})$) and the minimum OPI depth (uppermost OPI depth where the entire OPI interval begins: $\min(OPI_{top})$). This calculation was used instead of summing each individual OPI for two reasons. First, summing individual OPI risks double

counting where different OPI types overlap such as when a perforation OPI and a filter pack OPI are both present within the same well depth section. Second, the presence of non-open intervals between open intervals is less frequent than overlapping OPI. Consequently, the potential total OPI thickness error from double counting is greater than from including non-open intervals.

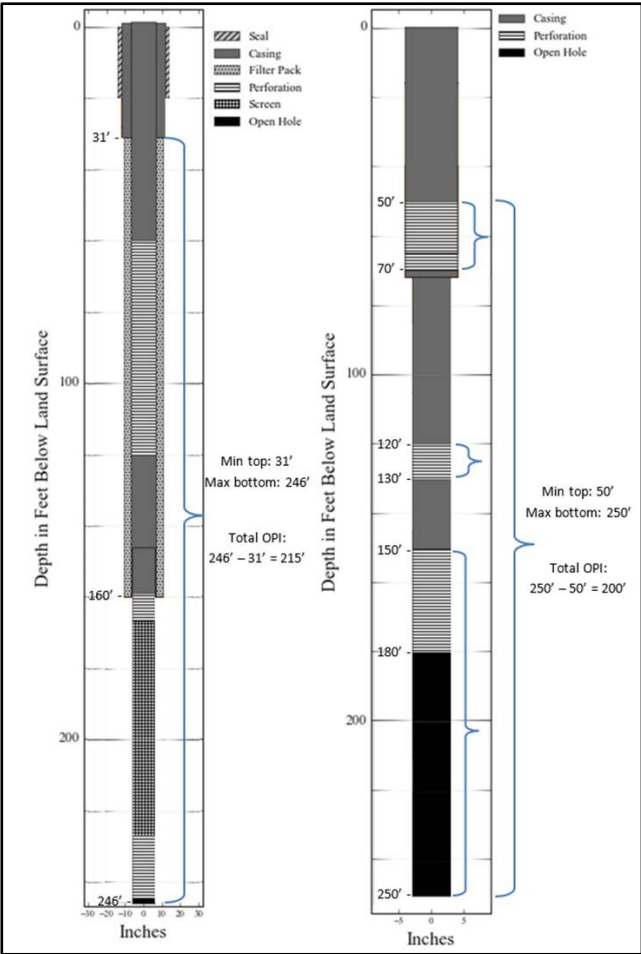


Figure M-1. Total open interval (OPI) examples with calculations

Table M-2. Logic command to calculate total open interval

OPI Variable	If $\min(\text{OPI}_{\text{top}})$	And $\max(\text{OPI}_{\text{bottom}})$	Then $\text{OPI}_{\text{total}} =$	Appendix Equation
$\text{OPI}_{\text{total}}$	$< \max(\text{OPI}_{\text{bottom}})$	$> \min(\text{OPI}_{\text{top}})$	$\max(\text{OPI}_{\text{bottom}}) - \min(\text{OPI}_{\text{top}})$	M-1

Notes:

Definitions for open interval related abbreviations are listed in table M-3

Table M-3. Definition of abbreviations used in tables M-2 to M-10 and figure M-5

Variable	Definition	Unit
OPI_{total}	Thickness of the total open interval	Thickness (height) in feet
$min(OPI_{top})$	Minimum top of open intervals within well (including open hole, perforation, screen, or filter pack)	Depth in feet
$max(OPI_{bottom})$	Maximum bottom of open intervals within well (including open hole, perforation, screen, or filter pack)	Depth in feet
SWL	Selected static water level measured in the well (Harney Basin investigation used most recent)	Depth in feet
$OPI_{saturated}$	Thickness of the saturated open interval	Thickness (height) in feet
$top(OPI_{saturated})$	Top of the saturated open interval	Depth in feet
$bottom(OPI_{saturated})$	Bottom of the saturated open interval	Depth in feet
WB	Driller defined water-bearing zone	-----
WB_{top}	Top of driller-defined water-bearing zone	Depth in feet
WB_{bottom}	Bottom of driller-defined water-bearing zone	Depth in feet
$WB_{thickness}$	Thickness of driller-defined water-bearing zone	Thickness (height) in feet
$top(WB_{open})$	Top of driller-defined water-bearing zone within the total open interval	Depth in feet
$bottom(WB_{open})$	Bottom of driller-defined water-bearing zone within the total open interval	Depth in feet
WB_{open}	Thickness of driller-defined water-bearing zone within the total open interval	Thickness (height) in feet
$top(WB_{saturated})$	Top of driller-defined water-bearing zone within the saturated open interval	Depth in feet
$bottom(WB_{saturated})$	Bottom of driller-defined water-bearing zone within the saturated open interval	Depth in feet
$WB_{saturated}$	Thickness of driller-defined water-bearing zone within the saturated open interval	Thickness (height) in feet
$sum(\quad)$	Sum total of variable within the parenthesis	Same unit as variable
$Strat_{top}$	Top of assigned stratigraphic unit	Depth in feet
$Strat_{bottom}$	Bottom of assigned stratigraphic unit	Depth in feet
$Strat_{thickness}$	Thickness of assigned stratigraphic unit	Thickness (height) in feet
$Strat_{open}$	Thickness of assigned stratigraphic unit within the total open interval	Thickness (height) in feet
$Strat_{saturated}$	Thickness of assigned stratigraphic unit within the saturated open interval	Thickness (height) in feet
$Strat_{owb}$	Thickness of assigned stratigraphic unit representing driller-defined water-bearing zones within the total open interval	Thickness (height) in feet
$Strat_{swb}$	Thickness of assigned stratigraphic unit representing driller-defined water-bearing zones within the saturated open interval	Thickness (height) in feet

Definition and Calculation for Saturated Open Interval

The saturated open interval (saturated OPI or $OPI_{\text{saturated}}$) at a well is the height of the static groundwater level (SWL) filling the total OPI section within a well (figure M-2 and M-3). Equations M-2 to M-4 in table M-4 show the saturated OPI thickness calculations. This investigation used the most recent SWL as of February 2021. The saturated OPI can range from zero to the entire total OPI at the well. It is never greater than the total OPI. The saturated OPI may vary seasonally and annually given the SWL measured at a well can vary seasonally and annually. A varying saturated OPI can occur when the SWL at a well seasonally and/or annually varies into, within, and/or beyond the total OPI section. A constant saturated OPI occurs when the SWL and its variations all occur outside the total OPI (below $\max(OPI_{\text{bottom}})$ or above $\min(OPI_{\text{top}})$).

Figures M-2 and M-3 are saturated OPI examples using a simple well where the bottom of the casing is the top of the total OPI ($\min(OPI_{\text{top}})$). In figure M-2, the SWL is below the casing bottom filling 40 feet only of the 50-foot total OPI. The saturated OPI is 40 feet using equation M-3. In figure M-3, the SWL is above the casing bottom filling the entire 50-foot total OPI and a portion of the cased interval above. The saturated OPI is limited to 50 feet maximum (equal to the total OPI, OPI_{total}) using equation M-4. Automating the decision and subsequent execution to use equation M-2 to M-4 within a computer program to calculate the saturated OPI requires a logic command summarized in table M-4.

Table M-4. Logic command to calculate saturated open interval

OPI Variable	If $\min(OPI_{\text{top}})$	And $\max(OPI_{\text{bottom}})$	Then $OPI_{\text{saturated}} =$	Appendix Equation
$OPI_{\text{saturated}}$	SWL is completely below total OPI			
	< SWL	< SWL	0	M-2
	SWL is within total OPI			
	< SWL	> SWL	$\max(OPI_{\text{bottom}}) - \text{SWL}$	M-3
	SWL is above total OPI top			
	> SWL	> SWL	$\max(OPI_{\text{bottom}}) - \min(OPI_{\text{top}})$	M-4

Notes:

Definitions for open interval related abbreviations are listed in table M-3. All variables are depth in feet.

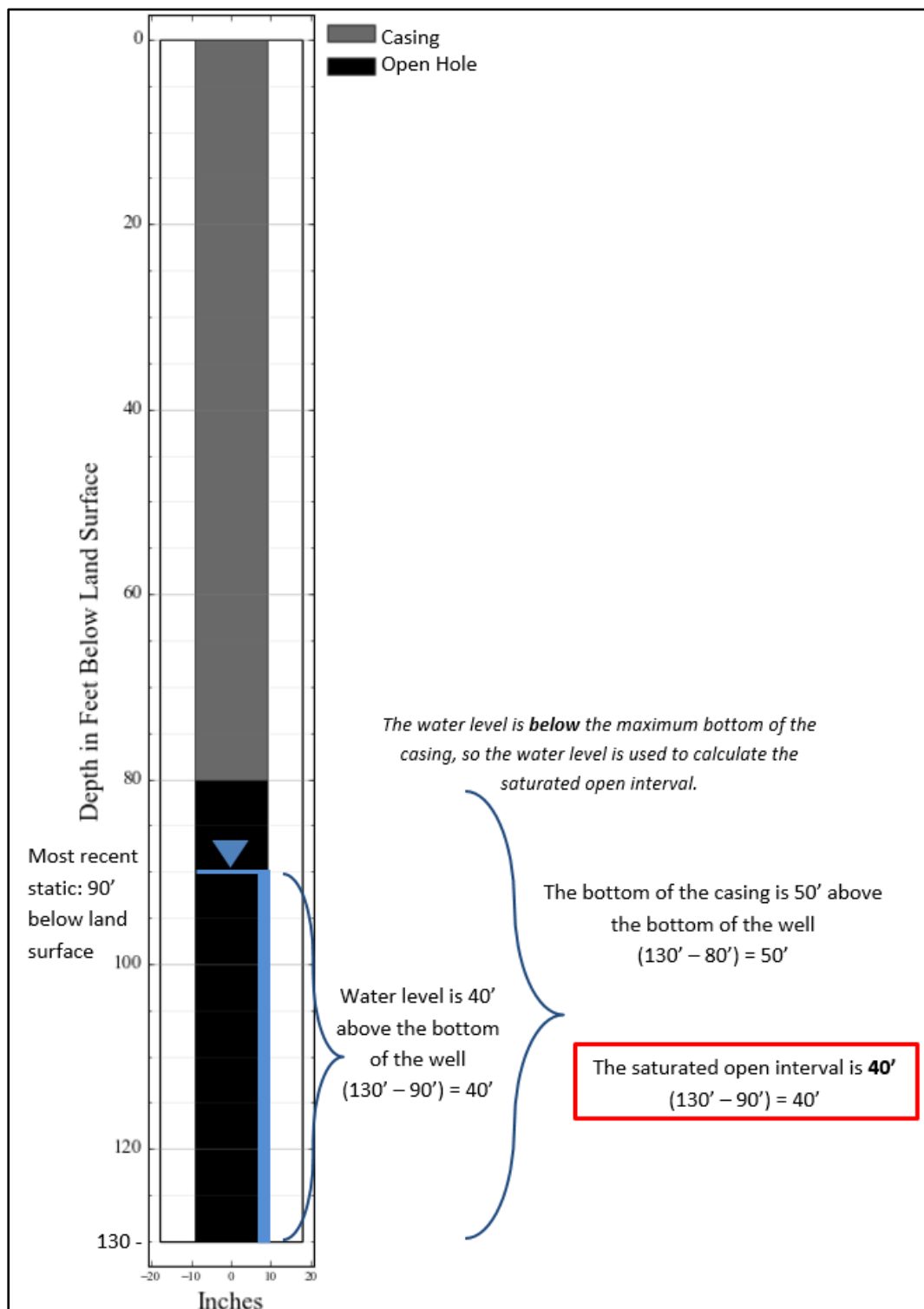


Figure M-2. Saturated open interval (OPI) example with calculations for static groundwater level below the top of the total open interval

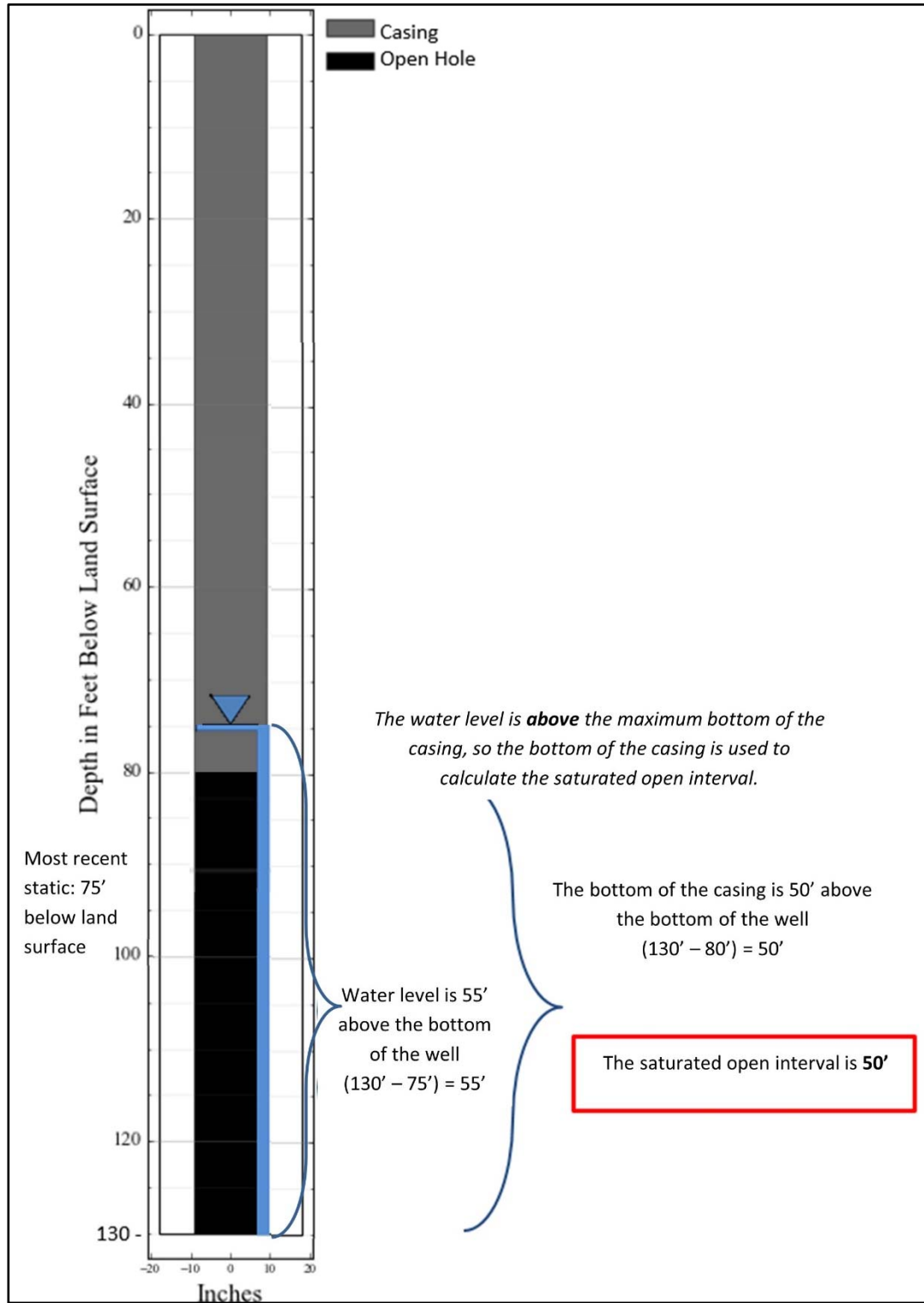


Figure M-3. Saturated open interval (OPI) example with calculations for static groundwater level above the top of the total open interval

Definition and Calculation for Water-Bearing Zone Open Interval within a Total Open Interval

Water well reports filed at OWRD can include one or more observed water bearing zones (appendix L). However, all water bearing zones at a well may or may not be listed. Some water bearing zones may not be observed or recorded for various reasons such as undetected lower yield. On some forms, the water bearing zone section is empty, but a yield is reported. Each zone reported may include one or more lithologic units or may be a portion of a single lithologic unit.

The relationship between the previously described total open interval (total OPI) and the one or more reported water bearing zones (WB) per well can vary. A reported WB may be located entirely within the total OPI, partially within the total OPI, or entirely outside the total OPI (figure M-4). The Harney Basin groundwater investigation determined for each well that had a WB reported on the well report the WB to total OPI relationship by (a) comparing the depth interval of each WB to the depth interval of the total OPI, (b) calculating per WB the WB thickness within the total open interval (WB_{open}), (c) calculating a percentage of the total OPI interval thickness for each WB_{open} , and (d) calculating a percentage of the total OPI interval thickness for all WB_{open} . Automating the decision and execution to calculate each WB_{open} thickness and percentage within a computer program requires a successive logic command summarized in table M-5.

Definition and Calculation for Water-Bearing Zone Open Interval within a Saturated Open Interval

The relationship between the previously described saturated open interval (saturated OPI) and the one or more reported water bearing zones (WB) per well can vary also. A reported WB may be located entirely within the saturated OPI, partially within the saturated OPI, or entirely outside the saturated OPI. The Harney Basin groundwater investigation determined the WB to saturated OPI relationship by (a) comparing the depth interval of each WB to the depth interval of the saturated OPI, (b) calculating per WB the WB thickness within the saturated open interval ($WB_{saturated}$), (c) calculating a percentage of the saturated OPI interval thickness for each $WB_{saturated}$, and (d) calculating a percentage of the saturated OPI interval thickness for all $WB_{saturated}$. Automating the decision and execution to calculate each $WB_{saturated}$ thickness and percentage within a computer program requires a successive logic command summarized in table M-6.

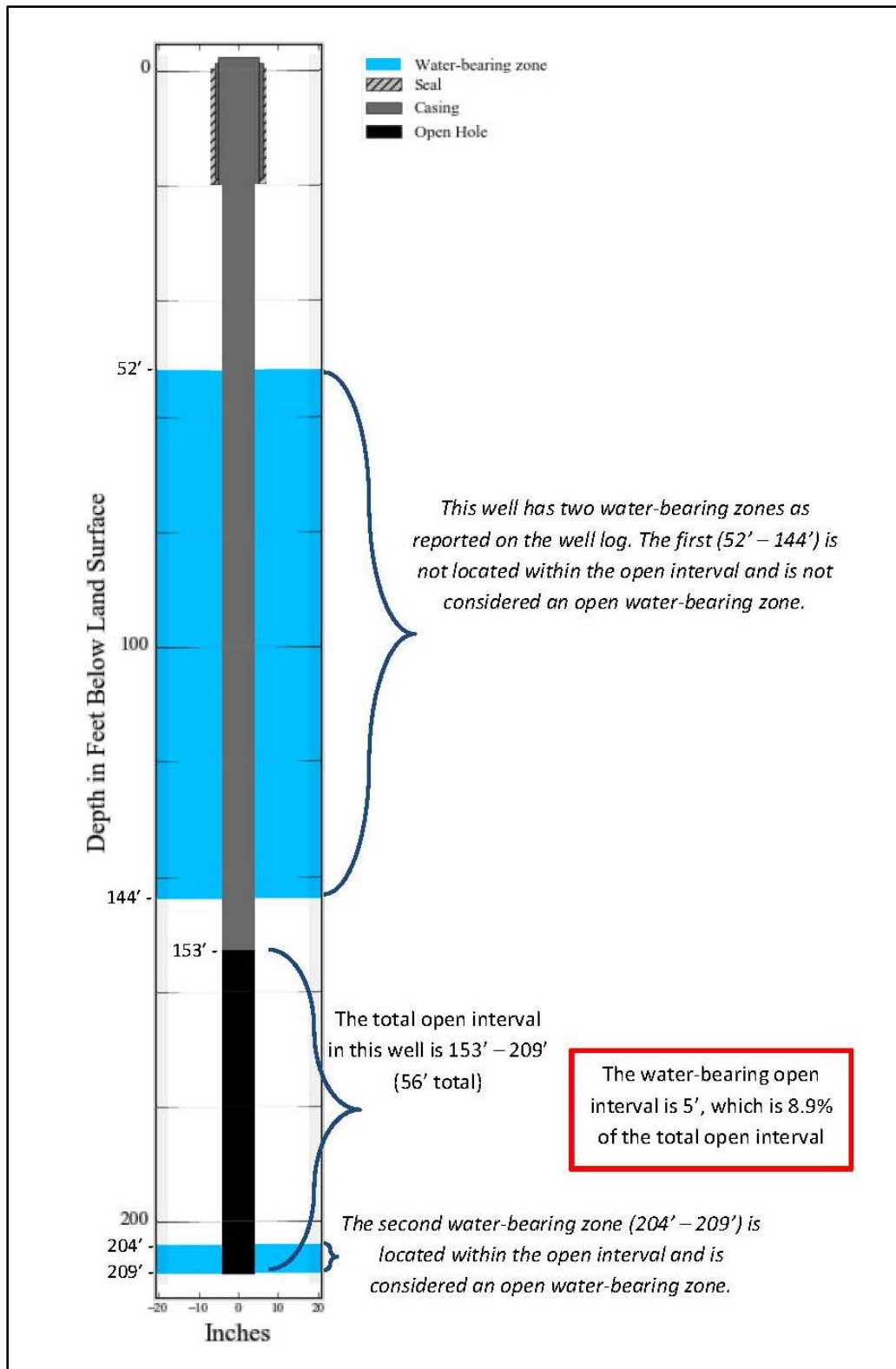


Figure M-4. Water-bearing zone open interval (OPI) within total open interval example with calculations [Calculation limited to lower water bearing zone which is inside the total open interval. No calculation for the upper water bearing zone which is outside the total open interval]

Table M-5. Logic command to calculate water bearing open interval within a total open interval

OPI Variable	If WB_{top}	And WB_{bottom}	Then $WB_{open} =$	Appendix Equation
WB_{open}	WB entirely above total OPI			
	$< \min(OPI_{top})$	$\leq \min(OPI_{top})$	0	M-5
	WB overlaps entire total OPI			
	$\leq \min(OPI_{top})$	$\geq \max(OPI_{bottom})$	$\max(OPI_{bottom}) - \min(OPI_{top})$	M-6
	WB overlaps upper portion of total OPI			
	$\leq \min(OPI_{top})$	$> \min(OPI_{top})$ $< \max(OPI_{bottom})$	$WB_{bottom} - \min(OPI_{top})$	M-7
	WB completely within total OPI			
	$> \min(OPI_{top})$ $< WB_{bottom}$	$> WB_{top}$ $< \max(OPI_{bottom})$	$WB_{bottom} - WB_{top}$	M-8
	WB overlaps lower portion of total OPI			
	$> \min(OPI_{top})$ $< \max(OPI_{bottom})$	$\geq \max(OPI_{bottom})$	$\max(OPI_{bottom}) - WB_{top}$	M-9
	WB entirely below total OPI			
	$\geq \max(OPI_{bottom})$	$> \max(OPI_{bottom})$	0	M-10
Percentage of total OPI per WB =				
$[WB_{open} / OPI_{total}] * 100$				M-11
Percentage of total OPI for all WB =				
$[\text{sum}(WB_{open}) / OPI_{total}] * 100$				M-12

Notes:

Logic command and calculation applied for each water-bearing zone identified at a well

Definitions for open interval related abbreviations are listed in table M-3. All variables are depth in feet.

Table M-6. Logic command to calculate water bearing open interval within a saturated open interval

OPI Variable	If WB_{top}	And WB_{bottom}	Then $WB_{saturated} =$	Appendix Equation
$WB_{saturated}$	WB entirely above saturated OPI			
	$< \text{top}(OPI_{saturated})$	$\leq \text{top}(OPI_{saturated})$	0	M-13
	WB overlaps entire saturated OPI			
	$\leq \text{top}(OPI_{saturated})$	$\geq \text{bottom}(OPI_{saturated})$	$\text{bottom}(OPI_{saturated}) - \text{top}(OPI_{saturated})$	M-14
	WB overlaps upper portion of saturated OPI			
	$\leq \text{top}(OPI_{saturated})$	$> \text{top}(OPI_{saturated}) < \text{bottom}(OPI_{saturated})$	$WB_{bottom} - \text{top}(OPI_{saturated})$	M-15
	WB completely within saturated OPI			
	$> \text{top}(OPI_{saturated}) < WB_{bottom}$	$> WB_{top} < \text{bottom}(OPI_{saturated})$	$WB_{bottom} - WB_{top}$	M-16
	WB overlaps lower portion of saturated OPI			
	$> \text{top}(OPI_{saturated}) < \text{bottom}(OPI_{saturated})$	$\geq \text{bottom}(OPI_{saturated})$	$\text{bottom}(OPI_{saturated}) - WB_{top}$	M-17
	WB entirely below saturated OPI			
	$\geq \text{bottom}(OPI_{saturated})$	$> \text{bottom}(OPI_{saturated})$	0	M-18
Percentage of saturated OPI per $WB_{saturated} =$				
$[WB_{saturated} / OPI_{saturated}] * 100$				M-19
Percentage of saturated OPI for all $WB_{saturated} =$				
$[\text{sum}(WB_{saturated}) / OPI_{saturated}] * 100$				M-20

Notes:

Logic command and calculation applied for each water-bearing zone identified at a well

Definitions for open interval related abbreviations are listed in table M-3. All variables are depth in feet.

Well Open Interval Option Selected for Harney Basin Groundwater Investigation

The Harney Basin groundwater investigation selected the total open interval (total OPI) option to represent the well open interval at Harney Basin wells. The total OPI was used to (a) estimate transmissivity values from well yield tests (appendices D and I, (b) calculate hydraulic conductivity values from transmissivity values, (c) identify the stratigraphic unit(s) and their correlated hydrostratigraphic unit(s) exposed at the well open interval, and (d) assign hydraulic property values at a well location to the one or more exposed stratigraphic units and their correlated hydrostratigraphic units. The primary reason the total OPI option was selected is (a) the total OPI thickness is the most reliable “known” given it is based on easily observed and reported well construction (variables for other OPI can more often be missed, undetected, or underreported), and (b) the total OPI remains constant until the well construction changes. Additionally, the total OPI yielded the most wells per stratigraphic unit for hydraulic property assignment and analyses. A potential negative consequence of using the total OPI option is that option yields the largest OPI thicknesses yielding smaller hydraulic conductivity (K) values from transmissivity (T) values given $K = T / \text{OPI thickness}$ was used to calculate hydraulic conductivity. The magnitude of this potential bias was not determined.

The other open interval options were determined to be problematic. The saturated open interval (saturated OPI) option is problematic given the saturated OPI thickness depends upon the static groundwater level (SWL) chosen. The SWL measured at a well is not constant due to seasonal and annual fluctuations, and the SWL chosen may not be concurrent for all wells. The water-bearing zone (WB) option is problematic given the potential for under-representing WB by not detecting them and/or not reporting them. Under-representation risks calculating excessively large hydraulic conductivity (K) values from transmissivity (T) values. Regardless, these other OPI options were available to the Harney Basin groundwater investigation but were not used.

Well Open Interval Use: Calculate Hydraulic Conductivity from Transmissivity

Transmissivity (T) is defined as hydraulic conductivity (K) multiplied by a thickness (b) of the groundwater flow system ($T = Kb$) (appendix B, equation B-8). Transmissivity derived from aquifer tests, pump tests, and specific capacity (well yield tests) is limited to representing the groundwater system thickness segment supplying groundwater to the well open interval (Heath, 1983). That thickness segment can be larger than the well open interval thickness as shown in

figure D-1 in appendix D when the well open interval thickness is less than the groundwater system saturated thickness. Given the groundwater system thickness segment supplying each well tested was not determined, this investigation used the total open interval thicknesses (OPI_{total}) to calculate hydraulic conductivity from available transmissivity values using equation M-21.

$$K = T / b_{OPI} = T / OPI_{total} \quad (\text{equation M-21})$$

where:

K = hydraulic conductivity

T = transmissivity

b_{OPI} = total open interval thickness = OPI_{total}

Hydraulic conductivity values calculated by the Harney Basin groundwater investigation are listed by well in the hydraulic property calculation result tables for selected aquifer-like tests and pump tests (appendix H) and for well yield tests (appendix J).

Well Open Interval Use: Calculate Stratigraphic Unit Percentage of Well Open Interval

The stratigraphic units defined in appendix A are variously exposed at a well depending on the vertical sequence of units present at a well location and the vertical placement of the open interval at the well. Calculating a stratigraphic unit's percentage of a well open interval depends upon the well open interval option chosen. The successive logic command for automating the decision and execution to calculate stratigraphic unit thickness and percentage within the four well open interval options is similar to the successive logic command previously described to calculate a water-bearing zone percentage and thickness. The logic commands and equations available for this investigation to calculate a stratigraphic unit thickness and percentage within the four well open interval options are shown in tables M-7 to M-10 and illustrated in figure M-5. This investigation used the logic command and calculation for the total open interval option summarized in table M-7 to calculate stratigraphic unit thickness and percentage for wells that were "lith-coded" and "strat-coded" as discussed in appendix L. The results are included in the hydraulic property calculation result tables for selected aquifer-like tests and pump tests (appendix H) and for well yield tests (appendix J). The stratigraphic unit names in the appendix H and J tables are abbreviated, and the percentages are noted in parentheses.

Table M-7. Logic command to calculate stratigraphic unit percentage within total open interval

Strat Variable	If Strat _{top}	And Strat _{bottom}	Then Strat _{open} =	Appendix Equation
Strat _{open}	Stratigraphic unit entirely above total OPI			
	$\leq \min(\text{OPI}_{\text{top}})$	$\leq \min(\text{OPI}_{\text{top}})$	0	M-22
	Stratigraphic unit overlaps entire total OPI			
	$\leq \min(\text{OPI}_{\text{top}})$	$\geq \max(\text{OPI}_{\text{bottom}})$	$\max(\text{OPI}_{\text{bottom}}) - \min(\text{OPI}_{\text{top}})$	M-23
	Stratigraphic unit overlaps upper portion of total OPI			
	$\leq \min(\text{OPI}_{\text{top}})$	$> \min(\text{OPI}_{\text{top}})$ $< \max(\text{OPI}_{\text{bottom}})$	$\text{Strat}_{\text{bottom}} - \min(\text{OPI}_{\text{top}})$	M-24
	Stratigraphic unit completely within total OPI			
	$> \min(\text{OPI}_{\text{top}})$ $< \max(\text{OPI}_{\text{bottom}})$	$> \text{Strat}_{\text{top}}$ $< \max(\text{OPI}_{\text{bottom}})$	$\text{Strat}_{\text{bottom}} - \text{Strat}_{\text{top}}$	M-25
	Stratigraphic unit overlaps lower portion of total OPI			
	$> \min(\text{OPI}_{\text{top}})$ $< \max(\text{OPI}_{\text{bottom}})$	$\geq \max(\text{OPI}_{\text{bottom}})$	$\max(\text{OPI}_{\text{bottom}}) - \text{Strat}_{\text{top}}$	M-26
	Stratigraphic unit entirely below total OPI			
	$\geq \max(\text{OPI}_{\text{bottom}})$	$> \max(\text{OPI}_{\text{bottom}})$	0	M-27
OPI Variable	If min(OPI _{top})	And max(OPI _{bottom})	Then OPI _{total} =	
OPI _{total}	see table M-2	see table M-2	see table M-2	M-1
Percentage of total OPI per Strat _{open} =				
$[\text{Strat}_{\text{open}} / \text{OPI}_{\text{total}}] * 100$				M-28
Percentage of total OPI for all Strat _{open} =				
$[\text{sum}(\text{Strat}_{\text{open}}) / \text{OPI}_{\text{total}}] * 100$				M-29

Notes:

Logic command and calculation applied for each occurrence of each stratigraphic unit
Definitions for abbreviations are listed in table M-3. All variables are depth in feet.

Table M-8. Logic command to calculate stratigraphic unit percentage within saturated open interval

Strat Variable	If Strat _{top}	And Strat _{bottom}	Then Strat _{saturated} =	Appendix Equation
Strat _{saturated}	Stratigraphic unit entirely above saturated OPI			
	$\leq \text{top}(\text{OPI}_{\text{saturated}})$	$\leq \text{top}(\text{OPI}_{\text{saturated}})$	0	M-30
	Stratigraphic unit overlaps entire saturated OPI			
	$\leq \text{top}(\text{OPI}_{\text{saturated}})$	$\geq \text{bottom}(\text{OPI}_{\text{saturated}})$	$\text{bottom}(\text{OPI}_{\text{saturated}}) - \text{top}(\text{OPI}_{\text{saturated}})$	M-31
	Stratigraphic unit overlaps upper portion of saturated OPI			
	$\leq \text{top}(\text{OPI}_{\text{saturated}})$	$> \text{top}(\text{OPI}_{\text{saturated}})$ $< \text{bottom}(\text{OPI}_{\text{saturated}})$	$\text{Strat}_{\text{bottom}} - \text{top}(\text{OPI}_{\text{saturated}})$	M-32
	Stratigraphic unit completely within saturated OPI			
	$> \text{top}(\text{OPI}_{\text{saturated}})$ $< \text{Strat}_{\text{bottom}}$	$> \text{Strat}_{\text{top}}$ $< \text{bottom}(\text{OPI}_{\text{saturated}})$	$\text{Strat}_{\text{bottom}} - \text{Strat}_{\text{top}}$	M-33
	Stratigraphic unit overlaps lower portion of saturated OPI			
	$> \text{top}(\text{OPI}_{\text{saturated}})$ $< \text{bottom}(\text{OPI}_{\text{saturated}})$	$\geq \text{bottom}(\text{OPI}_{\text{saturated}})$	$\text{bottom}(\text{OPI}_{\text{saturated}}) - \text{Strat}_{\text{top}}$	M-34
	Stratigraphic unit entirely below saturated OPI			
	$\geq \text{bottom}(\text{OPI}_{\text{saturated}})$	$> \text{bottom}(\text{OPI}_{\text{saturated}})$	0	M-35
OPI Variable	If min(OPI _{top})	And max(OPI _{bottom})	Then OPI _{saturated} =	
OPI _{saturated}	see table M-4	see table M-4	see table M-4	M-2 to M-4
Percentage of saturated OPI per Strat _{saturated} =				
$[\text{Strat}_{\text{saturated}} / \text{OPI}_{\text{saturated}}] * 100$				M-36
Percentage of saturated OPI for all Strat _{saturated} =				
$[\text{sum}(\text{Strat}_{\text{saturated}}) / \text{OPI}_{\text{saturated}}] * 100$				M-37

Notes:

Logic command and calculation applied for each occurrence of each stratigraphic unit
Definitions for abbreviations are listed in table M-3. All variables are depth in feet.

Table M-9. Logic command to calculate stratigraphic unit percentage within water bearing open interval within a total open interval

Strat Variable	If Strat _{top}	And Strat _{bottom}	Then Strat _{owb} =	Appendix Equation
Strat _{owb}	Stratigraphic unit entirely above WB _{open}			
	$\leq \text{top}(\text{WB}_{\text{open}})$	$\leq \text{top}(\text{WB}_{\text{open}})$	0	M-38
	Stratigraphic unit overlaps entire WB _{open}			
	$\leq \text{top}(\text{WB}_{\text{open}})$	$\geq \text{bottom}(\text{WB}_{\text{open}})$	$\text{bottom}(\text{WB}_{\text{open}}) - \text{top}(\text{WB}_{\text{open}})$	M-39
	Stratigraphic unit overlaps upper portion of WB _{open}			
	$\leq \text{top}(\text{WB}_{\text{open}})$	$\begin{matrix} > \text{top}(\text{WB}_{\text{open}}) \\ < \text{bottom}(\text{WB}_{\text{open}}) \end{matrix}$	$\text{Strat}_{\text{bottom}} - \text{top}(\text{WB}_{\text{open}})$	M-40
	Stratigraphic unit completely within WB _{open}			
	$\begin{matrix} > \text{top}(\text{WB}_{\text{open}}) \\ < \text{bottom}(\text{WB}_{\text{open}}) \end{matrix}$	$\begin{matrix} > \text{Strat}_{\text{top}} \\ < \text{bottom}(\text{WB}_{\text{open}}) \end{matrix}$	$\text{Strat}_{\text{bottom}} - \text{Strat}_{\text{top}}$	M-41
	Stratigraphic unit overlaps lower portion of WB _{open}			
	$\begin{matrix} > \text{top}(\text{WB}_{\text{open}}) \\ < \text{bottom}(\text{WB}_{\text{open}}) \end{matrix}$	$\geq \text{bottom}(\text{WB}_{\text{open}})$	$\text{bottom}(\text{WB}_{\text{open}}) - \text{Strat}_{\text{top}}$	M-42
	Stratigraphic unit entirely below WB _{open}			
	$\geq \text{bottom}(\text{WB}_{\text{open}})$	$> \text{bottom}(\text{WB}_{\text{open}})$	0	M-43
OPI Variable	If WB _{top}	And WB _{bottom}	Then WB _{open} =	
WB _{open}	see table M-5	see table M-5	see table M-5	M-5 to M-10
Percentage of WB _{open} per Strat _{owb} =				
$[\text{Strat}_{\text{owb}} / \text{WB}_{\text{open}}] * 100$				M-44
Percentage of WB _{open} for all Strat _{owb} =				
$[\text{sum}(\text{Strat}_{\text{owb}}) / \text{WB}_{\text{open}}] * 100$				M-45

Notes:

Logic command and calculation applied for each occurrence of each stratigraphic unit
Definitions for abbreviations are listed in table M-3. All variables are depth in feet.

Table M-10. Logic command to calculate stratigraphic unit percentage within water bearing open interval within a saturated open interval

Strat Variable	If Strat _{top}	And Strat _{bottom}	Then Strat _{swb} =	Appendix Equation
Strat _{swb}	Stratigraphic unit entirely above WB _{saturated}			
	$\leq \text{top}(\text{WB}_{\text{saturated}})$	$\leq \text{top}(\text{WB}_{\text{saturated}})$	0	M-46
	Stratigraphic unit overlaps entire WB _{saturated}			
	$\leq \text{top}(\text{WB}_{\text{saturated}})$	$\geq \text{bottom}(\text{WB}_{\text{saturated}})$	$\text{bottom}(\text{WB}_{\text{saturated}}) - \text{top}(\text{WB}_{\text{saturated}})$	M-47
	Stratigraphic unit overlaps upper portion of WB _{saturated}			
	$\leq \text{top}(\text{WB}_{\text{saturated}})$	$> \text{top}(\text{WB}_{\text{saturated}})$ $< \text{bottom}(\text{WB}_{\text{saturated}})$	$\text{Strat}_{\text{bottom}} - \text{top}(\text{WB}_{\text{saturated}})$	M-48
	Stratigraphic unit completely within WB _{saturated}			
	$> \text{top}(\text{WB}_{\text{saturated}})$ $< \text{bottom}(\text{WB}_{\text{saturated}})$	$> \text{Strat}_{\text{top}}$ $< \text{bottom}(\text{WB}_{\text{saturated}})$	$\text{Strat}_{\text{bottom}} - \text{Strat}_{\text{top}}$	M-49
	Stratigraphic unit overlaps lower portion of WB _{saturated}			
	$> \text{top}(\text{WB}_{\text{saturatedn}})$ $< \text{bottom}(\text{WB}_{\text{saturatedn}})$	$\geq \text{bottom}(\text{WB}_{\text{saturated}})$	$\text{bottom}(\text{WB}_{\text{saturated}}) - \text{Strat}_{\text{top}}$	M-50
	Stratigraphic unit entirely below WB _{saturated}			
	$\geq \text{bottom}(\text{WB}_{\text{saturated}})$	$> \text{bottom}(\text{WB}_{\text{saturated}})$	0	M-51
OPI Variable	If WB _{top}	And WB _{bottom}	Then WB _{open} =	
WB _{saturated}	see table M-6	see table M-6	see table M-6	M-13 to M-18
Percentage of WB _{saturated} per Strat _{swb} =				
$[\text{Strat}_{\text{swb}} / \text{WB}_{\text{saturated}}] * 100$				M-52
Percentage of WB _{saturated} for all Strat _{swb} =				
$[\text{sum}(\text{Strat}_{\text{swb}}) / \text{WB}_{\text{saturated}}] * 100$				M-53

Notes:

Logic command and calculation applied for each occurrence of each stratigraphic unit
Definitions for abbreviations are listed in table M-3. All variables are depth in feet.

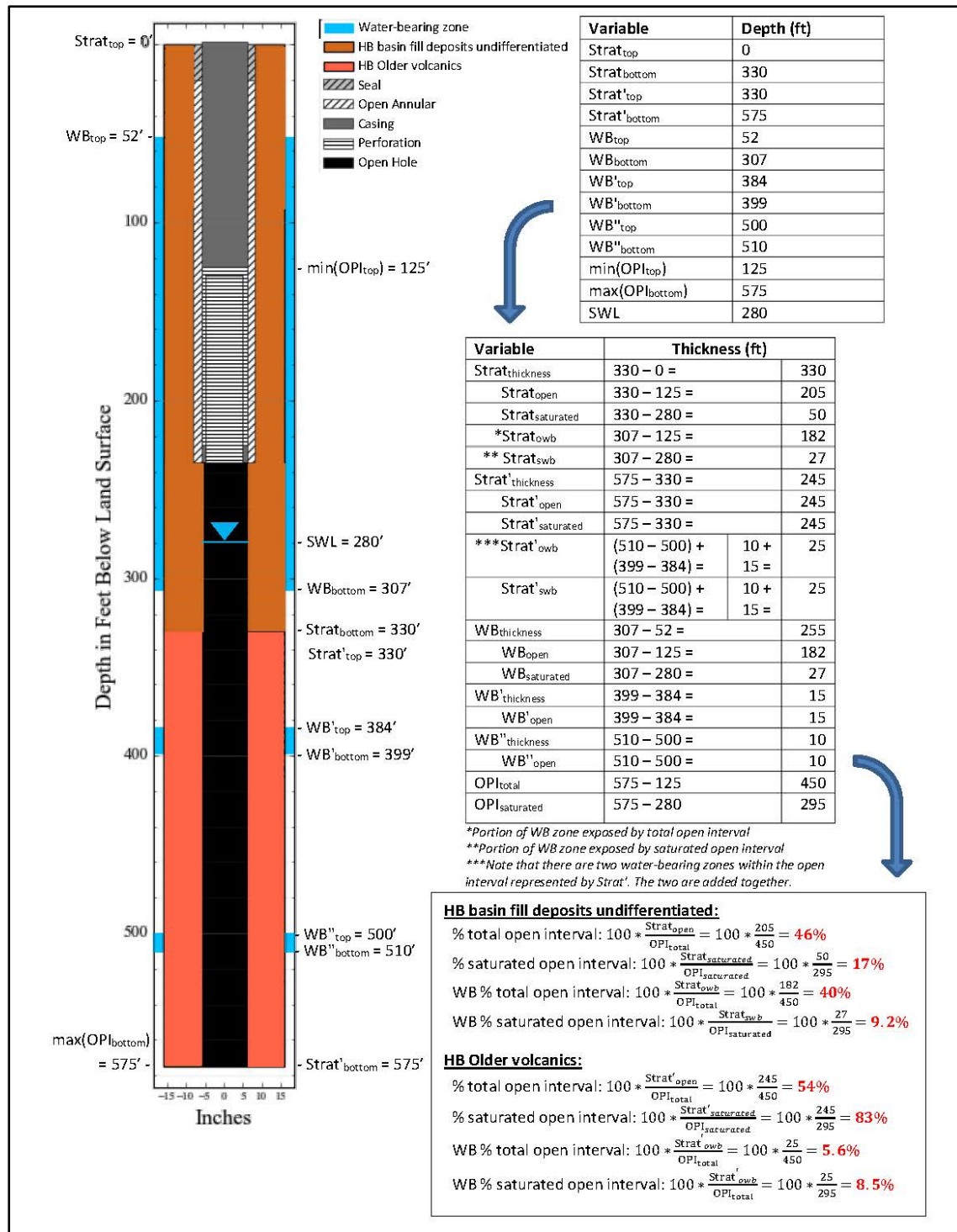


Figure M-5. Example stratigraphic unit percentage of open interval calculations for an example well [Example includes two stratigraphic units and four open interval options]

Well Open Interval Use: Calculate Hydrostratigraphic Unit Percentage of Well Open Interval

Hydrostratigraphic units as defined in the main text of this report are composed of one or more stratigraphic units, and they are variously exposed at a well depending on the vertical sequence of units present at a well location and the vertical placement of the open interval at the well. Calculating a hydrostratigraphic unit's percentage of a well open interval depends upon the well open interval option chosen. The successive logic command for automating the decision and execution to calculate a hydrostratigraphic unit thickness and percentage within the four well open interval options repeats the same successive logic command previously described for stratigraphic units. The single difference is the stratigraphic unit variable in tables 7 to 10 is replaced by a hydrostratigraphic unit variable. This investigation used the logic command and calculation for the total open interval option to calculate a hydrostratigraphic unit thickness and percentage for wells that were "lith-coded" and "strat-coded" as discussed in appendix L. The results are included in the hydraulic property calculation result tables for selected aquifer-like tests and pump tests (appendix H) and for well yield tests (appendix J). The hydrostratigraphic unit names in the appendix H and J tables are abbreviated, and the percentages are noted in parentheses.

Well Open Interval Use: Assign Hydraulic Property to Stratigraphic and Hydrostratigraphic Units

This investigation used the calculated stratigraphic unit percentage of well open intervals and calculated hydrostratigraphic unit percentage of well open intervals to assign hydraulic property values determined at each well (appendix H and J) to a single stratigraphic unit and a single hydrostratigraphic unit when the unit occupied the majority of the open interval. This investigation considered three "majority" options for making the assignment: 50 to 100 percent, 75 to 100 percent, or 90 to 100 percent of an open interval. This investigation decided to use the 90 to 100 percent of the total open interval option to maximize the likelihood the hydraulic property value assigned to a stratigraphic unit and hydrostratigraphic unit truly represents that unit.

Appendix N: Summary statistics of hydraulic property values for each Harney Basin stratigraphic unit

Table N-1. Summary statistics of specific capacity values for each Harney Basin stratigraphic unit (all data)
(See notes at end of table)

Harney Basin Stratigraphic Unit ¹		Number of Tests ³	Number of Wells ³	Specific Capacity Statistics (all data) ²											
Unit Name (alphabetical)	Unit Abbreviation							Percentile ⁸							
				Mean	Median ⁴	Minimum	Maximum	2 nd	9 th	10 th	25 th	75 th	90 th	91 st	98 th
				Specific Capacity (gpm / foot-drawdown)				Specific Capacity (gpm / foot-drawdown)							
Andesite	Ta	5	5	9.475	6.500	0.300	31.000	----	----	----	----	----	----	----	----
Basalt and andesite of Dry Mountain	Tdm	3	3	1.077	0.188	0.044	3.000	----	----	----	----	----	----	----	----
Basalt of Harney Lake	Tbh	1	1	22.500	22.500	22.500	22.500	----	----	----	----	----	----	----	----
Basin fill deposits undifferentiated ⁵	Qtsu	744	717	21.537	4.561	0.029	2,000.000	0.205	0.642	0.687	1.761	12.737	39.170	40.399	150.875
Devine Canyon Ash-flow Tuff	Tdv	7	7	30.306	1.875	0.012	94.286	0.045	0.160	0.176	0.518	57.468	77.714	79.371	90.971
Diamond Craters basalt and tephra	Qdc	0	0	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷
Drinkwater Basalt	Tdw	2	2	258.250	258.250	16.500	500.000	----	----	----	----	----	----	----	----
HLP basalt undifferentiated ⁶	HLPu	2	2	12.447	12.447	3.238	21.657	----	----	----	----	----	----	----	----
Mafic vent complexes	QTV	46	45	216.241	27.857	0.050	4,000.000	0.386	3.333	3.333	9.341	67.500	480.000	552.000	1,660.000
Mesozoic rocks	Mzu	4	4	0.110	0.125	0.011	0.181	----	----	----	----	----	----	----	----
Older volcanic rocks	Tov	11	11	54.157	3.125	0.040	510.000	0.045	0.064	0.067	0.521	20.477	30.000	78.000	414.000
Olivine basalt	Tob	1	1	16.000	16.000	16.000	16.000	----	----	----	----	----	----	----	----
Olivine basalt and andesite of Gum Boot Canyon	Tobg	2	2	24.000	24.000	8.000	40.000	----	----	----	----	----	----	----	----
Pleistocene-Pliocene basalt	QTb	1	1	0.714	0.714	0.714	0.714	----	----	----	----	----	----	----	----
Quaternary sedimentary deposits	Qs	46	46	10.022	3.333	0.133	66.667	0.206	0.573	0.586	1.018	12.651	31.579	31.579	51.667
Rattlesnake Ash-flow Tuff	Trt	22	21	25.653	2.532	0.429	400.000	0.501	0.956	1.019	1.500	5.000	11.550	21.680	274.000
Silicic lava flows and domes	Trd	10	10	10.618	3.978	0.200	40.000	0.200	0.200	0.200	1.125	14.233	31.000	31.900	38.200
Steens Basalt	Tsb	21	21	14.307	1.000	0.058	100.000	0.070	0.106	0.111	0.250	2.308	80.000	82.000	96.000
Tuffaceous sedimentary rocks and tuff	Tts	93	90	11.716	2.917	0.059	100.000	0.105	0.250	0.253	1.250	8.667	40.000	47.200	86.560
Voltage basalt	Qvb	23	22	329.679	155.556	5.294	3,300.000	5.440	7.463	7.529	30.000	225.000	500.000	513.000	2,354.000
Total		1044	1011												

Notes:
¹The stratigraphic units are described in appendix A
²All data means data related to pump tests rated good, fair, and poor and data related to well yield tests reported on water well reports including tests with a reported total drawdown of 0.00 feet (tests with 0.00 feet drawdown were assigned 0.50 feet drawdown for hydraulic property calculations)
³Some wells had multiple tests
⁴Median is the same as 50th percentile
⁵Basin fill deposits undifferentiated (Qtsu) was created for the statistical summary to account for hydraulic property values associated with reported subsurface material descriptions that were not sufficient to assign to Quaternary sedimentary deposits (Qs), Tuffaceous sedimentary rocks and tuff (Tts), or another unit
⁶HLP basalt undifferentiated (HLPu) was created for the statistical summary to account for hydraulic property values associated with reported subsurface material descriptions that were not sufficient to assign to a particular basalt unit
⁷None means no statistics
⁸No percentile is shown when the number of tests is less than 6

Appendix N: Summary statistics of hydraulic property values for each Harney Basin stratigraphic unit

Table N-2. Summary statistics of specific capacity values for each Harney Basin stratigraphic unit (poor quality pump tests excluded)
(See notes at end of table)

Harney Basin Stratigraphic Unit ¹		Number of Tests ³	Number of Wells ³	Specific Capacity Statistics (poor quality pump tests excluded) ²											
Unit Name (alphabetical)	Unit Abbreviation							Percentile ⁸							
				Mean	Median ⁴	Minimum	Maximum	2 nd	9 th	10 th	25 th	75 th	90 th	91 st	98 th
				Specific Capacity (gpm / foot-drawdown)				Specific Capacity (gpm / foot-drawdown)							
Andesite	Ta	5	5	9.475	6.500	0.300	31.000	----	----	----	----	----	----	----	----
Basalt and andesite of Dry Mountain	Tdm	3	3	1.077	0.188	0.044	3.000	----	----	----	----	----	----	----	----
Basalt of Harney Lake	Tbh	1	1	22.500	22.500	22.500	22.500	----	----	----	----	----	----	----	----
Basin fill deposits undifferentiated ⁵	Qtsu	732	717	21.404	4.500	0.029	2,000.000	0.203	0.634	0.682	1.719	12.500	36.352	40.000	152.375
Devine Canyon Ash-flow Tuff	Tdv	7	7	30.306	1.875	0.012	94.286	0.045	0.160	0.176	0.518	57.468	77.714	79.371	90.971
Diamond Craters basalt and tephra	Qdc	0	0	0.000	0.000	0.000	0.000	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷
Drinkwater Basalt	Tdw	2	2	258.250	258.250	16.500	500.000	----	----	----	----	----	----	----	----
HLP basalt undifferentiated ⁶	HLPu	0	0	0.000	0.000	0.000	0.000	----	----	----	----	----	----	----	----
Mafic vent complexes	QTV	46	45	216.241	27.857	0.050	4,000.000	0.386	3.333	3.333	9.341	67.500	480.000	552.000	1,660.000
Mesozoic rocks	Mzu	4	4	0.110	0.125	0.011	0.181	----	----	----	----	----	----	----	----
Older volcanic rocks	Tov	11	11	54.157	3.125	0.040	510.000	0.045	0.064	0.067	0.521	20.477	30.000	78.000	414.000
Olivine basalt	Tob	1	1	16.000	16.000	16.000	16.000	----	----	----	----	----	----	----	----
Olivine basalt and andesite of Gum Boot Canyon	Tobg	2	2	24.000	24.000	8.000	40.000	----	----	----	----	----	----	----	----
Pleistocene-Pliocene basalt	QTb	1	1	0.714	0.714	0.714	0.714	----	----	----	----	----	----	----	----
Quaternary sedimentary deposits	Qs	46	46	10.022	3.333	0.133	66.667	0.206	0.573	0.586	1.018	12.651	31.579	31.579	51.667
Rattlesnake Ash-flow Tuff	Trt	21	21	26.753	2.500	0.429	400.000	0.497	0.920	1.000	1.500	5.000	12.000	29.600	280.000
Silicic lava flows and domes	Trd	10	10	10.618	3.978	0.200	40.000	0.200	0.200	0.200	1.125	14.233	31.000	31.900	38.200
Steens Basalt	Tsb	21	21	14.307	1.000	0.058	100.000	0.070	0.106	0.111	0.250	2.308	80.000	82.000	96.000
Tuffaceous sedimentary rocks and tuff	Tts	90	89	11.901	2.896	0.059	100.000	0.103	0.250	0.250	1.146	8.611	41.000	49.900	87.520
Voltage basalt	Qvb	23	22	329.679	155.556	5.294	3,300.000	5.440	7.463	7.529	30.000	225.000	500.000	513.000	2,354.000
Total		1026	1008												

Notes:
¹The stratigraphic units are described in appendix A
²Includes all pump tests rated good and fair (poor are excluded) and data related to well yield tests reported on water well reports including tests with a reported total drawdown of 0.00 feet (tests with 0.00 feet drawdown were assigned 0.50 feet drawdown for hydraulic property calculations)
³Some wells had multiple tests
⁴Median is the same as 50th percentile
⁵Basin fill deposits undifferentiated (Qtsu) was created for the statistical summary to account for hydraulic property values associated with reported subsurface material descriptions that were not sufficient to assign to Quaternary sedimentary deposits (Qs), Tuffaceous sedimentary rocks and tuff (Tts), or another unit
⁶HLP basalt undifferentiated (HLPu) was created for the statistical summary to account for hydraulic property values associated with reported subsurface material descriptions that were not sufficient to assign to a particular basalt unit
⁷None means no statistics
⁸No percentile is shown when the number of tests is less than 6

Appendix N: Summary statistics of hydraulic property values for each Harney Basin stratigraphic unit

Table N-3. Summary statistics of transmissivity values for each Harney Basin stratigraphic unit (all data)
(See notes at end of table)

Harney Basin Stratigraphic Unit ¹		Number of Tests ³	Number of Wells ³	Transmissivity Statistics (all data) ²											
Unit Name (alphabetical)	Unit Abbreviation							Percentile ⁸							
				Mean	Median ⁴	Minimum	Maximum	2 nd	9 th	10 th	25 th	75 th	90 th	91 st	98 th
				Transmissivity (feet ² / day)				Transmissivity (feet ² / day)							
Andesite	Ta	5	5	2,279.268	1,453.020	51.740	7,723.110	----	----	----	----	----	----	----	----
Basalt and andesite of Dry Mountain	Tdm	3	3	222.503	29.020	6.100	632.390	----	----	----	----	----	----	----	----
Basalt of Harney Lake	Tbh	1	1	5,487.710	5,487.710	5,487.710	5,487.710	----	----	----	----	----	----	----	----
Basin fill deposits undifferentiated ⁵	Qtsu	718	696	5,873.286	977.920	3.610	661,383.230	40.498	124.387	135.051	354.798	2,907.478	9,460.557	10,167.258	41,925.986
Devine Canyon Ash-flow Tuff	Tdv	7	7	8,158.777	402.150	1.870	25,197.620	8.160	30.177	33.322	104.410	15,650.490	20,488.058	20,959.014	24,255.708
Diamond Craters basalt and tephra	Qdc	0	0	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷
Drinkwater Basalt	Tdw	2	2	78,619.245	78,619.245	3,720.580	153,517.910	----	----	----	----	----	----	----	----
HLP basalt undifferentiated ⁶	HLPu	0	0	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷
Mafic vent complexes	QTV	45	44	57,094.165	6,908.000	6.610	1,274,131.570	67.224	668.416	689.428	2,005.470	14,685.670	88,447.792	116,558.323	537,844.405
Mesozoic rocks	Mzu	4	4	18.943	21.855	1.360	30.700	----	----	----	----	----	----	----	----
Older volcanic rocks	Tov	11	11	15,807.775	640.710	5.530	148,845.110	6.736	10.957	11.560	114.840	5,808.140	9,697.000	23,611.811	121,015.488
Olivine basalt	Tob	1	1	4,100.200	4,100.200	4,100.200	4,100.200	----	----	----	----	----	----	----	----
Olivine basalt and andesite of Gum Boot Canyon	Tobg	2	2	5,376.545	5,376.545	1,906.570	8,846.520	----	----	----	----	----	----	----	----
Pleistocene-Pliocene basalt	QTb	0	0	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷
Quaternary sedimentary deposits	Qs	43	43	2,651.178	708.460	24.280	16,793.470	68.892	117.245	117.628	209.185	3,494.900	8,045.416	8,084.007	13,477.906
Rattlesnake Ash-flow Tuff	Trt	19	18	8,427.295	519.460	73.590	111,780.360	99.636	167.057	173.188	320.260	1,162.110	9,505.370	15,350.411	84,313.429
Silicic lava flows and domes	Trd	10	10	2,701.226	923.390	33.120	11,482.500	33.784	36.109	36.441	220.650	3,132.208	7,860.378	8,222.590	10,758.076
Steens Basalt	Tsb	21	21	3,943.583	215.550	8.910	29,067.210	11.970	19.832	20.650	39.690	533.620	22,066.640	22,652.686	27,439.074
Tuffaceous sedimentary rocks and tuff	Tts	88	86	3,010.349	640.245	9.620	25,884.570	14.917	41.391	44.345	237.528	1,847.785	10,267.460	11,461.030	24,153.604
Voltage basalt	Qvb	23	22	96,971.870	27,669.650	1,078.030	1,108,231.910	1,126.756	1,768.009	1,806.680	7,556.340	53,795.285	135,913.680	140,383.054	778,738.112
Total		1003	976												

Notes:

¹The stratigraphic units are described in appendix A

²All data means data related to pump tests rated good, fair, and poor and data related to well yield tests reported on water well reports including tests with a reported total drawdown of 0.00 feet (tests with 0.00 feet drawdown were assigned 0.50 feet drawdown for hydraulic property calculations)

³Some wells had multiple tests

⁴Median is the same as 50th percentile

⁵Basin fill deposits undifferentiated (Qtsu) was created for the statistical summary to account for hydraulic property values associated with reported subsurface material descriptions that were not sufficient to assign to Quaternary sedimentary deposits (Qs), Tuffaceous sedimentary rocks and tuff (Tts), or another unit

⁶HLP basalt undifferentiated (HLPu) was created for the statistical summary to account for hydraulic property values associated with reported subsurface material descriptions that were not sufficient to assign to a particular basalt unit

⁷None means no statistics

⁸No percentile is shown when the number of tests is less than 6

Appendix N: Summary statistics of hydraulic property values for each Harney Basin stratigraphic unit

Table N-4. Summary statistics of transmissivity values for each Harney Basin stratigraphic unit (poor quality pump tests excluded)
(See notes at end of table)

Harney Basin Stratigraphic Unit ¹		Number of Tests ³	Number of Wells ³	Transmissivity Statistics (poor quality pump tests excluded) ²											
Unit Name (alphabetical)	Unit Abbreviation							Percentile ⁸							
				Mean	Median ⁴	Minimum	Maximum	2 nd	9 th	10 th	25 th	75 th	90 th	91 st	98 th
				Transmissivity (feet ² / day)				Transmissivity (feet ² / day)							
Andesite	Ta	5	5	2,279.268	1,453.020	51.740	7,723.110	----	----	----	----	----	----	----	----
Basalt and andesite of Dry Mountain	Tdm	3	3	222.503	29.020	6.100	632.390	----	----	----	----	----	----	----	----
Basalt of Harney Lake	Tbh	1	1	5,487.710	5,487.710	5,487.710	5,487.710	----	----	----	----	----	----	----	----
Basin fill deposits undifferentiated ⁵	Qtsu	711	696	5,910.920	977.140	3.610	661,383.230	40.478	123.907	134.400	352.645	2,897.885	9,475.600	10,220.909	41,999.578
Devine Canyon Ash-flow Tuff	Tdv	7	7	8,158.777	402.150	1.870	25,197.620	8.160	30.177	33.322	104.410	15,650.490	20,488.058	20,959.014	24,255.708
Diamond Craters basalt and tephra	Qdc	0	0	0.000	0.000	0.000	0.000	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷
Drinkwater Basalt	Tdw	2	2	78,619.245	78,619.245	3,720.580	153,517.910	----	----	----	----	----	----	----	----
HLP basalt undifferentiated ⁶	HLPu	0	0	0.000	0.000	0.000	0.000	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷
Mafic vent complexes	QTV	45	44	57,094.165	6,908.000	6.610	1,274,131.570	67.224	668.416	689.428	2,005.470	14,685.670	88,447.792	116,558.323	537,844.405
Mesozoic rocks	Mzu	4	4	18.943	21.855	1.360	30.700	----	----	----	----	----	----	----	----
Older volcanic rocks	Tov	11	11	15,807.775	640.710	5.530	148,845.110	6.736	10.957	11.560	114.840	5,808.140	9,697.000	23,611.811	121,015.488
Olivine basalt	Tob	1	1	4,100.200	4,100.200	4,100.200	4,100.200	----	----	----	----	----	----	----	----
Olivine basalt and andesite of Gum Boot Canyon	Tobg	2	2	5,376.545	5,376.545	1,906.570	8,846.520	----	----	----	----	----	----	----	----
Pleistocene-Pliocene basalt	QTb	0	0	0.000	0.000	0.000	0.000	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷
Quaternary sedimentary deposits	Qs	43	43	2,651.178	708.460	24.280	16,793.470	68.892	117.245	117.628	209.185	3,494.900	8,045.416	8,084.007	13,477.906
Rattlesnake Ash-flow Tuff	Trt	18	18	8,885.478	690.825	73.590	111,780.360	98.189	176.760	186.645	328.660	1,195.105	12,752.615	18,272.932	85,839.370
Silicic lava flows and domes	Trd	10	10	2,701.226	923.390	33.120	11,482.500	33.784	36.109	36.441	220.650	3,132.208	7,860.378	8,222.590	10,758.076
Steens Basalt	Tsb	21	21	3,943.583	215.550	8.910	29,067.210	11.970	19.832	20.650	39.690	533.620	22,066.640	22,652.686	27,439.074
Tuffaceous sedimentary rocks and tuff	Tts	87	86	2,939.204	632.390	9.620	25,884.570	14.835	40.884	44.060	231.055	1,755.240	10,437.970	11,461.030	24,194.593
Voltage basalt	Qvb	23	22	96,971.870	27,669.650	1,078.030	1,108,231.910	1,126.756	1,768.009	1,806.680	7,556.340	53,795.285	135,913.680	140,383.054	778,738.112
Total		994	976												

Notes:

¹The stratigraphic units are described in appendix A

²Includes all pump tests rated good and fair (poor are excluded) and data related to well yield tests reported on water well reports including tests with a reported total drawdown of 0.00 feet (tests with 0.00 feet drawdown were assigned 0.50 feet drawdown for hydraulic property calculations)

³Some wells had multiple tests

⁴Median is the same as 50th percentile

⁵Basin fill deposits undifferentiated (Qtsu) was created for the statistical summary to account for hydraulic property values associated with reported subsurface material descriptions that were not sufficient to assign to Quaternary sedimentary deposits (Qs), Tuffaceous sedimentary rocks and tuff (Tts), or another unit

⁶HLP basalt undifferentiated (HLPu) was created for the statistical summary to account for hydraulic property values associated with reported subsurface material descriptions that were not sufficient to assign to a particular basalt unit

⁷None means no statistics

⁸No percentile is shown when the number of tests is less than 6

Appendix N: Summary statistics of hydraulic property values for each Harney Basin stratigraphic unit

Table N-5. Summary statistics of hydraulic conductivity values for each Harney Basin stratigraphic unit (all data)
(See notes at end of table)

Harney Basin Stratigraphic Unit ¹		Number of Tests ³	Number of Wells ³	Hydraulic Conductivity Statistics (all data) ²											
Unit Name (alphabetical)	Unit Abbreviation							Percentile ⁸							
				Mean	Median ⁴	Minimum	Maximum	2 nd	9 th	10 th	25 th	75 th	90 th	91 st	98 th
				Hydraulic Conductivity (feet / day)				Hydraulic Conductivity (feet / day)							
Andesite	Ta	5	5	52.075	23.218	0.575	183.884	----	----	----	----	----	----	----	----
Basalt and andesite of Dry Mountain	Tdm	3	3	1.106	0.121	0.036	3.162	----	----	----	----	----	----	----	----
Basalt of Harney Lake	Tbh	1	1	110.863	110.863	110.863	110.863	----	----	----	----	----	----	----	----
Basin fill deposits undifferentiated ⁵	Qtsu	692	692	88.868	19.951	0.010	5,944.709	0.225	1.175	1.477	6.042	60.882	156.550	177.064	660.214
Devine Canyon Ash-flow Tuff	Tdv	7	7	124.368	20.108	0.045	503.952	0.237	0.909	1.005	3.398	169.838	326.530	344.272	468.468
Diamond Craters basalt and tephra	Qdc	0	0	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷
Drinkwater Basalt	Tdw	2	2	3,668.018	3,668.018	25.659	7,310.377	----	----	----	----	----	----	----	----
HLP basalt undifferentiated ⁶	HLPu	0	0	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷
Mafic vent complexes	QTV	44	44	962.988	129.315	0.551	18,201.880	1.478	6.776	8.655	39.638	609.151	1,830.718	1,952.607	6,495.612
Mesozoic rocks	Mzu	4	4	0.418	0.510	0.068	0.585	----	----	----	----	----	----	----	----
Older volcanic rocks	Tov	10	10	266.033	5.551	0.020	2,325.705	0.042	0.121	0.132	0.615	71.702	421.940	612.317	1,944.952
Olivine basalt	Tob	1	1	12.853	12.853	12.853	12.853	----	----	----	----	----	----	----	----
Olivine basalt and andesite of Gum Boot Canyon	Tobg	2	2	56.795	56.795	37.327	76.263	----	----	----	----	----	----	----	----
Pleistocene-Pliocene basalt	QTb	0	0	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷
Quaternary sedimentary deposits	Qs	43	43	73.982	41.623	0.714	559.782	2.126	7.977	9.415	22.861	91.422	144.324	150.985	266.637
Rattlesnake Ash-flow Tuff	Trt	18	18	630.391	10.805	0.491	7,096.666	1.609	3.890	3.926	9.727	21.197	1,573.631	1,967.082	5,769.666
Silicic lava flows and domes	Trd	10	10	35.511	10.981	0.245	186.448	0.264	0.329	0.338	6.942	19.815	104.764	112.932	170.111
Steens Basalt	Tsb	21	21	127.118	1.146	0.041	1,922.836	0.049	0.123	0.138	0.516	4.983	72.350	181.570	1,401.082
Tuffaceous sedimentary rocks and tuff	Tts	86	86	50.221	6.223	0.020	775.167	0.070	0.218	0.260	1.068	21.081	122.627	132.161	682.836
Voltage basalt	Qvb	22	22	3,480.507	532.259	3.796	46,176.330	3.911	4.848	10.980	201.609	1,047.566	7,966.022	8,710.237	31,173.329
Total		971	971												

Notes:
¹The stratigraphic units are described in appendix A
²All data means data related to pump tests rated good, fair, and poor and data related to well yield tests reported on water well reports including tests with a reported total drawdown of 0.00 feet (tests with 0.00 feet drawdown were assigned 0.50 feet drawdown for hydraulic property calculations)
³Some wells had multiple tests
⁴Median is the same as 50th percentile
⁵Basin fill deposits undifferentiated (Qtsu) was created for the statistical summary to account for hydraulic property values associated with reported subsurface material descriptions that were not sufficient to assign to Quaternary sedimentary deposits (Qs), Tuffaceous sedimentary rocks and tuff (Tts), or another unit
⁶HLP basalt undifferentiated (HLPu) was created for the statistical summary to account for hydraulic property values associated with reported subsurface material descriptions that were not sufficient to assign to a particular basalt unit
⁷None means no statistics
⁸No percentile is shown when the number of tests is less than 6

Appendix N: Summary statistics of hydraulic property values for each Harney Basin stratigraphic unit

Table N-6. Summary statistics of hydraulic conductivity values for each Harney Basin stratigraphic unit (poor quality pump tests excluded)
(See notes at end of table)

Harney Basin Stratigraphic Unit ¹		Number of Tests ³	Number of Wells ³	Hydraulic conductivity Statistics (poor quality pump tests excluded) ²											
Unit Name (alphabetical)	Unit Abbreviation							Percentile ⁸							
				Mean	Median ⁴	Minimum	Maximum	2 nd	9 th	10 th	25 th	75 th	90 th	91 st	98 th
				Hydraulic Conductivity (feet / day)				Hydraulic Conductivity (feet / day)							
Andesite	Ta	5	5	52.075	23.218	0.575	183.884	----	----	----	----	----	----	----	----
Basalt and andesite of Dry Mountain	Tdm	3	3	1.106	0.121	0.036	3.162	----	----	----	----	----	----	----	----
Basalt of Harney Lake	Tbh	1	1	110.863	110.863	110.863	110.863	----	----	----	----	----	----	----	----
Basin fill deposits undifferentiated ⁵	Qtsu	692	692	88.868	19.951	0.010	5,944.709	0.225	1.175	1.477	6.042	60.882	156.550	177.064	660.214
Devine Canyon Ash-flow Tuff	Tdv	7	7	124.368	20.108	0.045	503.952	0.237	0.909	1.005	3.398	169.838	326.530	344.272	468.468
Diamond Craters basalt and tephra	Qdc	0	0	0.000	0.000	0.000	0.000	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷
Drinkwater Basalt	Tdw	2	2	3,668.018	3,668.018	25.659	7,310.377	----	----	----	----	----	----	----	----
HLP basalt undifferentiated ⁶	HLPu	0	0	0.000	0.000	0.000	0.000	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷
Mafic vent complexes	QTV	44	44	962.988	129.315	0.551	18,201.880	1.478	6.776	8.655	39.638	609.151	1,830.718	1,952.607	6,495.612
Mesozoic rocks	Mzu	4	4	0.418	0.510	0.068	0.585	----	----	----	----	----	----	----	----
Older volcanic rocks	Tov	10	10	266.033	5.551	0.020	2,325.705	0.042	0.121	0.132	0.615	71.702	421.940	612.317	1,944.952
Olivine basalt	Tob	1	1	12.853	12.853	12.853	12.853	----	----	----	----	----	----	----	----
Olivine basalt and andesite of Gum Boot Canyon	Tobg	2	2	56.795	56.795	37.327	76.263	----	----	----	----	----	----	----	----
Pleistocene-Pliocene basalt	QTb	0	0	0.000	0.000	0.000	0.000	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷	None ⁷
Quaternary sedimentary deposits	Qs	43	43	73.982	41.623	0.714	559.782	2.126	7.977	9.415	22.861	91.422	144.324	150.985	266.637
Rattlesnake Ash-flow Tuff	Trt	18	18	630.391	10.805	0.491	7,096.666	1.609	3.890	3.926	9.727	21.197	1,573.631	1,967.082	5,769.666
Silicic lava flows and domes	Trd	10	10	35.511	10.981	0.245	186.448	0.264	0.329	0.338	6.942	19.815	104.764	112.932	170.111
Steens Basalt	Tsb	21	21	127.118	1.146	0.041	1,922.836	0.049	0.123	0.138	0.516	4.983	72.350	181.570	1,401.082
Tuffaceous sedimentary rocks and tuff	Tts	86	86	50.221	6.223	0.020	775.167	0.070	0.218	0.260	1.068	21.081	122.627	132.161	682.836
Voltage basalt	Qvb	22	22	3,480.507	532.259	3.796	46,176.330	3.911	4.848	10.980	201.609	1,047.566	7,966.022	8,710.237	31,173.329
Total		971	971												

Notes:
¹The stratigraphic units are described in appendix A
²Includes all pump tests rated good and fair (poor are excluded) and data related to well yield tests reported on water well reports including tests with a reported total drawdown of 0.00 feet (tests with 0.00 feet drawdown were assigned 0.50 feet drawdown for hydraulic property calculations)
³Some wells had multiple tests
⁴Median is the same as 50th percentile
⁵Basin fill deposits undifferentiated (Qtsu) was created for the statistical summary to account for hydraulic property values associated with reported subsurface material descriptions that were not sufficient to assign to Quaternary sedimentary deposits (Qs), Tuffaceous sedimentary rocks and tuff (Tts), or another unit
⁶HLP basalt undifferentiated (HLPu) was created for the statistical summary to account for hydraulic property values associated with reported subsurface material descriptions that were not sufficient to assign to a particular basalt unit
⁷None means no statistics
⁸No percentile is shown when the number of tests is less than 6

Appendix O: Summary statistics of hydraulic property values for each Harney Basin hydrostratigraphic unit

Table O-1. Summary statistics of specific capacity values for each Harney Basin hydrostratigraphic unit (all data)
(See notes at end of table)

Harney Basin Hydrostratigraphic Unit ¹		Number of Tests ³	Number of Wells ³	Specific Capacity Statistics (all data) ²											
Unit Name (alphabetical)	Unit Abbreviation							Percentile ⁵							
				Mean	Median ⁴	Minimum	Maximum	2 nd	9 th	10 th	25 th	75 th	90 th	91 st	98 th
				Specific Capacity (gpm / foot-drawdown)				Specific Capacity (gpm / foot-drawdown)							
Dry Mountain lavas	DML	3	3	1.077	0.188	0.044	3.000	----	----	----	----	----	----	----	----
High Lava Plains basalt	HLP	11	10	57.202	16.000	0.306	500.000	0.306	0.306	0.306	1.976	22.079	40.000	86.000	408.000
Marine sedimentary rocks	MSR	4	4	0.110	0.125	0.011	0.181	----	----	----	----	----	----	----	----
Older basin fill	OBF	991	883	20.700	4.762	0.012	2,000.000	0.189	0.600	0.643	1.667	13.776	40.909	45.455	151.250
Proximal vent deposits	PVD	46	45	216.241	27.857	0.050	4,000.000	0.386	3.333	3.333	9.341	67.500	480.000	552.000	1,660.000
Silicic lava flows and domes	SFD	15	15	10.237	5.000	0.200	40.000	0.200	0.226	0.240	0.750	12.663	30.600	30.740	37.480
Upland volcanic rocks	UVR	32	32	28.005	1.500	0.040	510.000	0.051	0.083	0.090	0.246	9.500	75.000	82.100	255.800
Voltage Basalt	VB	23	22	329.679	155.556	5.294	3,300.000	5.440	7.463	7.529	30.000	225.000	500.000	513.000	2,354.000
Younger basin fill	YBF	46	46	10.022	3.333	0.133	66.667	0.206	0.573	0.586	1.018	12.651	31.579	31.579	51.667
	Total	1171	1060												

Notes:

¹The hydrostratigraphic units are described in the report text

²All data means data related to pump tests rated good, fair, and poor and data related to well yield tests reported on water well reports including tests with a reported total drawdown of 0.00 feet (tests with 0.00 feet drawdown were assigned 0.50 feet drawdown for hydraulic property calculations)

³Some wells had multiple tests

⁴Median is the same as 50th percentile

⁵No percentile is shown when the number of tests is less than 6

Table O-2. Summary statistics of specific capacity values for each Harney Basin hydrostratigraphic unit (poor quality pump tests excluded)
(See notes at end of table)

Harney Basin Hydrostratigraphic Unit ¹		Number of Tests ³ Number of Wells ³		Specific Capacity Statistics (poor quality pump tests excluded) ²											
Unit Name (alphabetical)	Unit Abbreviation							Percentile ⁵							
				Mean	Median ⁴	Minimum	Maximum	2 nd	9 th	10 th	25 th	75 th	90 th	91 st	98 th
		Specific Capacity (gpm / foot-drawdown)				Specific Capacity (gpm / foot-drawdown)									
Dry Mountain lavas	DML	3	3	1.077	0.188	0.044	3.000	----	----	----	----	----	----	----	----
High Lava Plains basalt	HLP	9	8	67.147	16.000	0.306	500.000	0.306	0.306	0.306	0.714	22.500	132.000	168.800	426.400
Marine sedimentary rocks	MSR	4	4	0.110	0.125	0.011	0.181	----	----	----	----	----	----	----	----
Older basin fill	OBF	972	882	20.646	4.548	0.012	2,000.000	0.178	0.588	0.631	1.667	13.333	40.290	45.455	153.625
Proximal vent deposits	PVD	46	45	216.241	27.857	0.050	4,000.000	0.386	3.333	3.333	9.341	67.500	480.000	552.000	1,660.000
Silicic lava flows and domes	SFD	15	15	10.237	5.000	0.200	40.000	0.200	0.226	0.240	0.750	12.663	30.600	30.740	37.480
Upland volcanic rocks	UVR	32	32	28.005	1.500	0.040	510.000	0.051	0.083	0.090	0.246	9.500	75.000	82.100	255.800
Voltage Basalt	VB	23	22	329.679	155.556	5.294	3,300.000	5.440	7.463	7.529	30.000	225.000	500.000	513.000	2,354.000
Younger basin fill	YBF	46	46	10.022	3.333	0.133	66.667	0.206	0.573	0.586	1.018	12.651	31.579	31.579	51.667
Total		1150	1057												

Notes:

¹The hydrostratigraphic units are described in the report text

²Includes all pump tests rated good and fair (poor are excluded) and data related to well yield tests reported on water well reports including tests with a reported total drawdown of 0.00 feet (tests with 0.00 feet drawdown were assigned 0.50 feet drawdown for hydraulic property calculations)

³Some wells had multiple tests

⁴Median is the same as 50th percentile

⁵No percentile is shown when the number of tests is less than 6

Appendix O: Summary statistics of hydraulic property values for each Harney Basin hydrostratigraphic unit

Table O-3. Summary statistics of transmissivity values for each Harney Basin hydrostratigraphic unit (all data)
(See notes at end of table)

Harney Basin Hydrostratigraphic Unit ¹				Transmissivity Statistics (all data) ²											
Unit Name (alphabetical)	Unit Abbreviation	Number of Tests ³	Number of Wells ³	Mean	Median ⁴	Minimum	Maximum	Percentile ⁵							
								2 nd	9 th	10 th	25 th	75 th	90 th	91 st	98 th
				Transmissivity (feet ² / day)				Transmissivity (feet ² / day)							
Dry Mountain lavas	DML	3	3	222.503	29.020	6.100	632.390	----	----	----	----	----	----	----	----
High Lava Plains basalt	HLP	8	7	22,209.891	3,910.390	49.820	153,517.910	49.820	49.820	49.820	1,442.383	6,327.413	52,247.937	62,374.934	133,263.915
Marine sedimentary rocks	MSR	4	4	18.943	21.855	1.360	30.700	----	----	----	----	----	----	----	----
Older basin fill	OBF	944	850	5,583.003	977.920	1.870	661,383.230	29.671	111.868	124.180	342.395	3,116.458	10,185.407	10,829.272	42,136.568
Proximal vent deposits	PVD	45	44	57,094.165	6,908.000	6.610	1,274,131.570	67.224	668.416	689.428	2,005.470	14,685.670	88,447.792	116,558.323	537,844.405
Silicic lava flows and domes	SFD	15	15	2,560.573	1,153.090	33.120	11,482.500	34.153	40.692	42.782	136.685	2,830.805	7,617.034	7,654.161	10,429.871
Upland volcanic rocks	UVR	32	32	8,021.899	276.770	5.530	148,845.110	7.626	15.510	16.969	37.738	2,501.613	20,829.676	22,681.988	74,582.812
Voltage Basalt	VB	23	22	96,971.870	27,669.650	1,078.030	1,108,231.910	1,126.756	1,768.009	1,806.680	7,556.340	53,795.285	135,913.680	140,383.054	778,738.112
Younger basin fill	YBF	43	43	2,651.178	708.460	24.280	16,793.470	68.892	117.245	117.628	209.185	3,494.900	8,045.416	8,084.007	13,477.906
	Total	1117	1020												

Notes:

¹The hydrostratigraphic units are described in the report text

²All data means data related to pump tests rated good, fair, and poor and data related to well yield tests reported on water well reports including tests with a reported total drawdown of 0.00 feet (tests with 0.00 feet drawdown were assigned 0.50 feet drawdown for hydraulic property calculations)

³Some wells had multiple tests

⁴Median is the same as 50th percentile

⁵No percentile is shown when the number of tests is less than 6

Table O-4. Summary statistics of transmissivity values for each Harney Basin hydrostratigraphic unit (poor quality pump tests excluded)
(See notes at end of table)

Harney Basin Hydrostratigraphic Unit ¹		Number of Tests ³	Number of Wells ³	Transmissivity Statistics (poor quality pump tests excluded) ²														
Unit Name (alphabetical)	Unit Abbreviation			Mean	Median ⁴	Minimum	Maximum	Percentile ⁵										
				2 nd	9 th	10 th	25 th	75 th	90 th	91 st	98 th							
				Transmissivity (feet ² / day)				Transmissivity (feet ² / day)										
Dry Mountain lavas	DML	3	3	222.503	29.020	6.100	632.390	-----	-----	-----	-----	-----	-----	-----	-----	-----		
High Lava Plains basalt	HLP	8	7	22,209.891	3,910.390	49.820	153,517.910	49.820	49.820	49.820	1,442.383	6,327.413	52,247.937	62,374.934	133,263.915			
Marine sedimentary rocks	MSR	4	4	18.943	21.855	1.360	30.700	-----	-----	-----	-----	-----	-----	-----	-----	-----		
Older basin fill	OBF	932	850	5,620.086	965.865	1.870	661,383.230	29.587	109.380	123.883	337.055	3,119.758	10,315.541	11,000.928	42,191.183			
Proximal vent deposits	PVD	45	44	57,094.165	6,908.000	6.610	1,274,131.570	67.224	668.416	689.428	2,005.470	14,685.670	88,447.792	116,558.323	537,844.405			
Silicic lava flows and domes	SFD	15	15	2,560.573	1,153.090	33.120	11,482.500	34.153	40.692	42.782	136.685	2,830.805	7,617.034	7,654.161	10,429.871			
Upland volcanic rocks	UVR	32	32	8,021.899	276.770	5.530	148,845.110	7.626	15.510	16.969	37.738	2,501.613	20,829.676	22,681.988	74,582.812			
Voltage Basalt	VB	23	22	96,971.870	27,669.650	1,078.030	1,108,231.910	1,126.756	1,768.009	1,806.680	7,556.340	53,795.285	135,913.680	140,383.054	778,738.112			
Younger basin fill	YBF	43	43	2,651.178	708.460	24.280	16,793.470	68.892	117.245	117.628	209.185	3,494.900	8,045.416	8,084.007	13,477.906			
	Total	1105	1020															

Notes:

¹The hydrostratigraphic units are described in the report text

²Includes all pump tests rated good and fair (poor are excluded) and data related to well yield tests reported on water well reports including tests with a reported total drawdown of 0.00 feet (tests with 0.00 feet drawdown were assigned 0.50 feet drawdown for hydraulic property calculations)

³Some wells had multiple tests

⁴Median is the same as 50th percentile

⁵No percentile is shown when the number of tests is less than 6

Appendix O: Summary statistics of hydraulic property values for each Harney Basin hydrostratigraphic unit

Table O-5. Summary statistics of hydraulic conductivity values for each Harney Basin hydrostratigraphic unit (all data)
(See notes at end of table)

Harney Basin Hydrostratigraphic Unit ¹				Hydraulic conductivity Statistics (all data) ²											
Unit Name (alphabetical)	Unit Abbreviation	Number of Tests ³	Number of Wells ³					Percentile ⁵							
				Mean	Median ⁴	Minimum	Maximum	2 nd	9 th	10 th	25 th	75 th	90 th	91 st	98 th
				Hydraulic Conductivity (feet / day)				Hydraulic Conductivity (feet / day)							
Dry Mountain lavas	DML	3	3	1.106	0.121	0.036	3.162	----	----	----	----	----	----	----	----
High Lava Plains basalt	HLP	8	7	946.699	31.493	0.125	7,310.377	0.125	0.125	0.125	9.671	84.913	2,270.717	2,774.683	6,302.445
Marine sedimentary rocks	MSR	4	4	0.418	0.510	0.068	0.585	----	----	----	----	----	----	----	----
Older basin fill	OBF	908	844	89.555	15.620	0.010	7,096.666	0.186	0.922	1.087	4.401	53.318	156.173	167.076	686.688
Proximal vent deposits	PVD	44	44	962.988	129.315	0.551	18,201.880	1.478	6.776	8.655	39.638	609.151	1,830.718	1,952.607	6,495.612
Silicic lava flows and domes	SFD	15	15	41.032	13.503	0.245	186.448	0.274	0.407	0.439	3.836	37.556	148.605	160.953	185.730
Upland volcanic rocks	UVR	31	31	171.929	2.157	0.020	2,325.705	0.032	0.115	0.138	0.464	15.202	210.411	332.823	2,083.984
Voltage Basalt	VB	22	22	3,480.507	532.259	3.796	46,176.330	3.911	4.848	10.980	201.609	1,047.566	7,966.022	8,710.237	31,173.329
Younger basin fill	YBF	43	43	73.982	41.623	0.714	559.782	2.126	7.977	9.415	22.861	91.422	144.324	150.985	266.637
	Total	1078	1013												

Notes:

- ¹The hydrostratigraphic units are described in the report text
- ²All data means data related to pump tests rated good, fair, and poor and data related to well yield tests reported on water well reports including tests with a reported total drawdown of 0.00 feet (tests with 0.00 feet drawdown were assigned 0.50 feet drawdown for hydraulic property calculations)
- ³Some wells had multiple tests
- ⁴Median is the same as 50th percentile
- ⁵No percentile is shown when the number of tests is less than 6

Table O-6. Summary statistics of hydraulic conductivity values for each Harney Basin hydrostratigraphic unit (poor quality pump tests excluded)
(See notes at end of table)

Harney Basin Hydrostratigraphic Unit ¹		Number of Tests ³	Number of Wells ³	Hydraulic conductivity Statistics (poor quality pump tests excluded) ²											
Unit Name (alphabetical)	Unit Abbreviation							Percentile ⁵							
				Mean	Median ⁴	Minimum	Maximum	2 nd	9 th	10 th	25 th	75 th	90 th	91 st	98 th
				Hydraulic Conductivity (feet / day)				Hydraulic Conductivity (feet / day)							
Dry Mountain lavas	DML	3	3	1.106	0.121	0.036	3.162	----	----	----	----	----	----	----	----
High Lava Plains basalt	HLP	8	7	946.699	31.493	0.125	7,310.377	0.125	0.125	0.125	9.671	84.913	2,270.717	2,774.683	6,302.445
Marine sedimentary rocks	MSR	4	4	0.418	0.510	0.068	0.585	----	----	----	----	----	----	----	----
Older basin fill	OBF	908	844	89.555	15.620	0.010	7,096.666	0.186	0.922	1.087	4.401	53.318	156.173	167.076	686.688
Proximal vent deposits	PVD	44	44	962.988	129.315	0.551	18,201.880	1.478	6.776	8.655	39.638	609.151	1,830.718	1,952.607	6,495.612
Silicic lava flows and domes	SFD	15	15	41.032	13.503	0.245	186.448	0.274	0.407	0.439	3.836	37.556	148.605	160.953	185.730
Upland volcanic rocks	UVR	31	31	171.929	2.157	0.020	2,325.705	0.032	0.115	0.138	0.464	15.202	210.411	332.823	2,083.984
Voltage Basalt	VB	22	22	3,480.507	532.259	3.796	46,176.330	3.911	4.848	10.980	201.609	1,047.566	7,966.022	8,710.237	31,173.329
Younger basin fill	YBF	43	43	73.982	41.623	0.714	559.782	2.126	7.977	9.415	22.861	91.422	144.324	150.985	266.637
Total		1078	1013												

Notes:

- ¹The hydrostratigraphic units are described in the report text
- ²Includes all pump tests rated good and fair (poor are excluded) and data related to well yield tests reported on water well reports including tests with a reported total drawdown of 0.00 feet (tests with 0.00 feet drawdown were assigned 0.50 feet drawdown for hydraulic property calculations)
- ³Some wells had multiple tests
- ⁴Median is the same as 50th percentile
- ⁵No percentile is shown when the number of tests is less than 6