Washington State Department of Ecology

Principal Aquifer Water Level Monitoring Network: Final Report

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Introduction

The National Groundwater Monitoring Network (NGWMN) is a United States Geological Survey (USGS) program established to provide national long-term groundwater quantity and quality data of principal aquifers by using existing federal, state, and local groundwater monitoring programs. The Washington State (State) Department of Ecology (Ecology) became a data provider to the NGWMN in 2016 through a two-year cooperative agreement (G16AC00365).

Ecology became a data provider because it routinely collects groundwater level measurements from a series of well networks that are used to support water use permitting activities and planning related to ambient groundwater level status and trends.

Under the original two-year agreement (G16AC00365), Ecology established the well registry, water-level, construction and lithology web services, and submitted data for 61 groundwater monitoring wells.

In October 2018, Ecology entered into a second two-year cooperative agreement (G18AC00067) with the USGS. The overall goals and objectives of this agreement were to:

(1) Submit more wells and data to the NGWMN.

(2) Maintain web services between the Ecology database and the NGWMN and keep the registry up to date.

(3) Survey select well locations already provided to the NGWMN.

(4) Perform aquifer tests to determine hydraulic connectivity at known well locations.

(5) Identify and drill new groundwater monitoring wells for the purpose of providing expanded coverage, fill data-gaps, and establish wells for the creation of a water quality web-service within the current groundwater monitoring network.

Ecology Groundwater Monitoring Program

Ecology collects groundwater level information from a state-level network of domestic, irrigation, and purpose built monitoring wells to support water use permitting activities. Ecology also uses this data for longer-term planning related to drought, and the evaluation of ambient groundwater level status and trends. Ecology also conducts groundwater quality monitoring throughout the state for a wide range of projects.

The States' annual groundwater water-level monitoring network is operated and maintained by Ecology's Water Resources Program (WRP). All data generated are entered and retained in Ecology's Environmental Information Management system (EIM) from which the data is then accessed through the NGWMN portal. The procedure that describes how the program will

conduct groundwater monitoring and adhere to quality assurance requirements is provided in the *Integrated Statewide Groundwater Monitoring Strategy* (Culhane, 2017).

There are 2,350 wells considered "candidate monitoring wells" within Ecology's WRP groundwater database in Ecology's EIM. Figure 1 shows a breakdown of the type and quantity of wells in EIM's WRP groundwater database.

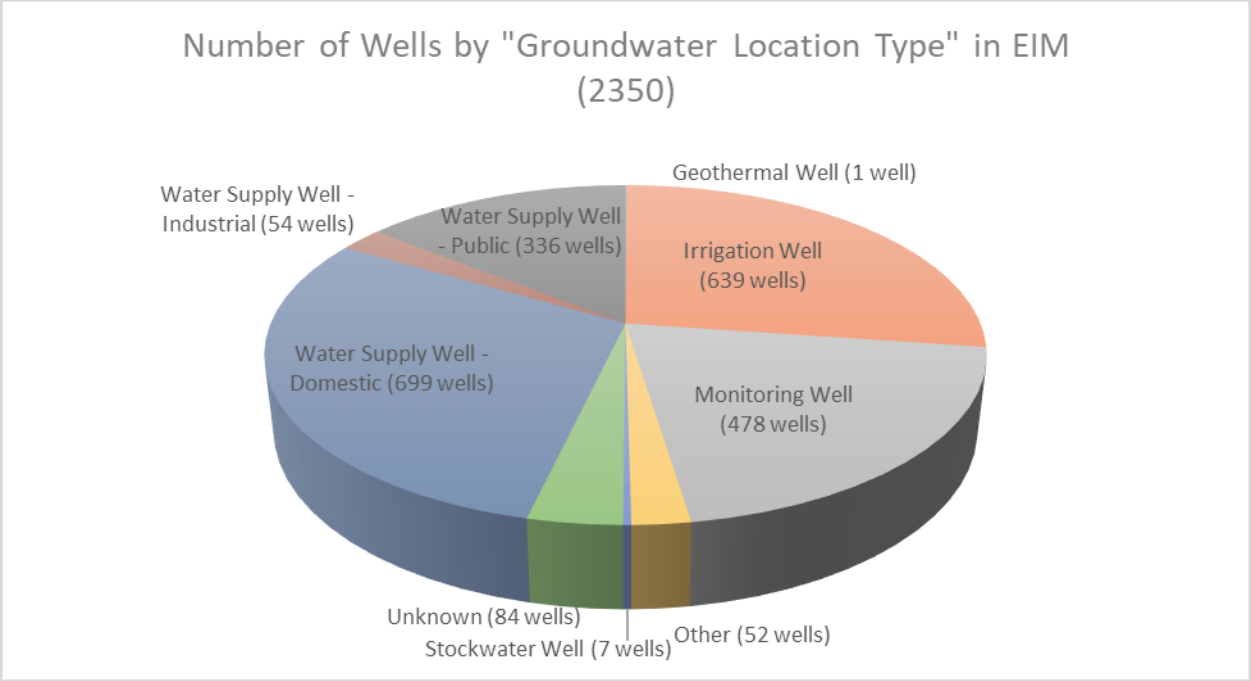

Figure 1. Distribution of wells in the Washington State Department of Ecology's Water Resources Program Environmental Information Management system groundwater database

During groundwater monitoring activities during any given year about 200 groundwater wells are monitored throughout the State. For the years 2018, 2019. 2020, and 2021, water-level measurements were collected at 318 monitoring wells. Of the 318 water-level wells, 45 well locations had transducer data uploaded to EIM. Figure 2 below is a map of Washington State with locations shown of the 318 wells as green circles, the current set of wells that have been submitted to the NGWMN are shown as yellow triangles, and the USGS Climate monitoring network are shown as red squares.

In the "Statewide Groundwater Assessment: 2017", groundwater monitoring schedules, important features that affect groundwater supply, and long range trends in water-levels for the State are discussed. The information in this document highlights where groundwater supply issues exist and shows the distribution of monitoring wells throughout the State with an emphasis on geographic regions.

Grant Activities

Cooperative agreement G18AC00067 provided funds to maintain and add wells to the NGWMN portal, evaluate well performance, fill spatial gaps in the groundwater monitoring network, and establish the beginnings of a water quality network.

Due to the COVID-19 restrictions, extensions have been requested to complete the goals and

objectives of the G18AC00067 agreement. The restrictions from COVID-19 have had far-reaching effects on the ability to get fieldwork done and when attempting to contact collaborative State and County agencies to gain access to data and field sites.

The current grant agreement began in September 2018 and was set to expire on August 31, 2020. The agreement was granted three extensions to account for delays in completion of scheduled tasks. The first extension was requested because of delays in securing easements for the selected groundwater well drilling locations. The second extension was requested because of disruption of agency operations due to the COVID-19. Drilling and other field activities were planned for the spring and summer 2020 were delayed until late fall 2020 due to work restriction implemented during COVID.

The final extension through August 30, 2021 was requested to allow for the longer than expected delays and a seasonal access restriction by the land managers at one of the well drilling sites.

Despite the restrictions, Ecology has been able to complete the tasks that are listed below with a brief summary of the progress to date.

Tasks 1: Submit 60 groundwater wells to the NGWMN portal

Under the initial agreement (G16AC00365) which ended in 2018, Ecology had submitted 61 wells to the NGWMN. These wells were selected from Ecology's existing groundwater monitoring network.

Ecology submitted an additional 80 wells under the second agreement (G18AC00067). During the second funding cycle, Ecology reached out to municipality and County organizations for potential candidate wells that could be added to the NGWMN. A total of 48 wells were added to the network during the first year of the grant and 32 wells were added during the second year. The selected wells covered regions of the State that Ecology does not have established well networks.

While updating the well registry it was discovered that not all wells submitted by non-State agencies met the NGWMN selection criteria (ACWI, 2013). Wells were either not being monitored continuously or monitoring had ended when external funding ended. Wells that do not meet the NGWMN selection criteria are in the process of being removed.

Table 1 lists the principal aquifers that are found in Washington State. The table also lists the aquifer code, aquifer location and the number of wells in each principal aquifer were added during the 2018 through 2020 grant cycle.

The NGWMN wells comprise a network structure consisting of three subnetworks. The wells added for this grant are partitioned into the subnetworks of 37 known change wells, 32 suspected change wells, and 11 background wells. Within each subnetwork, there are three monitoring categories. The monitoring categories for the 80 wells consist of 14 trend wells and 66 surveillance wells.

Table 2 is a list of each of the 80 wells that were added, coordinates, the NGWMN category and subnetwork, and the principal aquifer the well intercepts

Ecology continues to screen and refine the wells submitted to the network. More than 100 new candidate wells have been identified as potential replacement wells or for consideration as new

wells to the network. Wells that meet the NGWMN criteria will be added where spatially appropriate.

Table 1. List of Principal Aquifers, Locations, and Well Count submitted 2018 to 2020.

Principal Aquifer Name	Aquifer Code	Description	Location	No. of Wells
Columbia Plateau basaltic-rock aquifer	N600CMBPLV	Basaltic volcanic rocks	Eastern Washington	14
Columbia Plateau basin-fill aquifer	N100CMBPLB	Unconsolidated to semi-consolidated sand and gravel	Eastern Washington	20
Northern Rocky Mountains Intermontane aquifer system	S100NRMTIB	Unconsolidated to semi-consolidated sand and gravel	Eastern Washington	
Pacific Northwest basin-fill aquifer	S100NRMTIB	Unconsolidated to semi-consolidated sand and gravel	Statewide	36
Pacific Northwest volcanic-rock aquifer	N100PCFNWV	Basaltic volcanic rocks	Western Washington	
Puget Sound aquifer system	S100PGTSND	Unconsolidated to semi-consolidated sand and gravel	Western Washington	10
Willamette Lowlands aquifer system	N100WLMLWD	Unconsolidated to semi-consolidated sand and gravel	Southwest Washington	
Other rocks	N9999OTHER	Sedimentary, volcanic, metamorphic	Statewide	

Table 2. List of wells added to the NGWMN during the 2018 to 2020 grant cycle.

NGWMN ID	Location ID	Latitude	Longitude	Subnetwork	Category	Principal Aquifer
59221509	GWDB_ERO219	47.19522	-118.84936	Known change	Surveillance	N600CMBPLV
33490	AAB755	45.64641	-122.50680	Known change	Surveillance	N100PCFNWB
1033490	AAB756	45.66123	-122.69621	Known change	Surveillance	N100PCFNWB
5133490	AAB770	45.66242	-122.45613	Known change	Surveillance	N100PCFNWB
3153490	AAD458	45.67852	-122.64150	Known change	Surveillance	N100PCFNWB
4153490	AAD459	45.67865	-122.64150	Known change	Surveillance	N100PCFNWB
5153490	AAD460	45.68340	-122.64660	Known change	Surveillance	N100PCFNWB
6153490	AAD461	45.68340	-122.64660	Known change	Surveillance	N100PCFNWB
7153490	AAD462	45.70287	-122.66690	Known change	Surveillance	N100PCFNWB
8153490	AAD463	45.70287	-122.66690	Known change	Surveillance	N100PCFNWB
9153490	AAD464	45.70260	-122.65177	Known change	Surveillance	N100PCFNWB
253490	AAD465	45.71454	-122.65460	Known change	Surveillance	N100PCFNWB
1253490	AAD466	45.71454	-122.65460	Known change	Surveillance	N100PCFNWB
2253490	AAD467	45.70611	-122.65684	Known change	Surveillance	N100PCFNWB
2353490	AAD488	45.68566	-122.60761	Known change	Surveillance	N100PCFNWB
3353490	AAD490	45.67122	-122.61037	Known change	Surveillance	N100PCFNWB
4353490	AAD492	45.70706	-122.64815	Known change	Surveillance	N100PCFNWB
3273490	AAF411	45.73678	-122.52676	Known change	Surveillance	N100PCFNWB
3473490	AAF444	45.71242	-122.72351	Known change	Surveillance	N100PCFNWB
8473490	AAF449	45.74052	-122.65411	Known change	Surveillance	N100PCFNWB
6573490	AAF456	45.69994	-122.55515	Known change	Surveillance	N100PCFNWB
7573490	AAF457	45.69994	-122.57522	Known change	Surveillance	N100PCFNWB
83490	AAF460	45.72722	-122.70436	Known change	Surveillance	N100PCFNWB
1083490	AAF461	45.74340	-122.72663	Known change	Surveillance	N100PCFNWB
4083490	AAF464	45.70649	-122.61917	Known change	Surveillance	N100PCFNWB
9083490	AAF471	45.75148	-122.63058	Known change	Surveillance	N100PCFNWB
1183490	AAF473	45.77662	-122.60025	Known change	Surveillance	N100PCFNWB
6183490	AAF483	45.78849	-122.67592	Known change	Surveillance	N100PCFNWB
283490	AAF487	45.77428	-122.54065	Known change	Surveillance	N100PCFNWB
1283490	AAF490	45.77567	-122.45259	Known change	Surveillance	N100PCFNWB
2283490	AAF491	45.75534	-122.56870	Known change	Surveillance	N100PCFNWB
3283490	AAF492	45.75400	-122.54065	Known change	Surveillance	N100PCFNWB
4283490	AAF493	45.75409	-122.54060	Known change	Surveillance	N100PCFNWB
9283490	AAF502	45.67133	-122.61080	Known change	Surveillance	N100PCFNWB
1383490	AAF506	45.71680	-122.55881	Known change	Surveillance	N100PCFNWB

NGWMN ID	Location ID	Latitude	Longitude	Subnetwork	Category	Principal Aquifer
8383490	AAF529	45.80907	-122.66229	Known change	Surveillance	N100PCFNWB
9383490	AAF530	45.67746	-122.62917	Known change	Surveillance	N100PCFNWB
21393868	GWDB_ERO198	47.17939	-119.17058	Suspected change	Surveillance	N600CMBPLV
77257109	GWDB_ERO622	47.67168	-118.56595	Suspected change	Surveillance	N600CMBPLV
59326526	GWDB_ERO623	47.67168	-118.56595	Suspected change	Surveillance	N600CMBPLV
23379323	GWDB_ERO688	47.57560	-118.93541	Background	Trend	N600CMBPLV
48404228	GWDB_ERO692	47.58000	-118.27000	Background	Trend	N600CMBPLV
67652334	GWDB_ERO693	47.58000	-118.27000	Background	Surveillance	N600CMBPLV
34996000	GWDB_ERO694	47.58000	-118.27000	Background	Surveillance	N600CMBPLV
43202744	GWDB_ERO695	47.58000	-118.27000	Background	Surveillance	N600CMBPLV
93879203	GWDB_ERO696	47.58000	-118.27000	Background	Surveillance	N600CMBPLV
100018881	AEK201	47.66194	-117.36546	Suspected change	Surveillance	N100CMBPLB
100079507	AFL259	47.69460	-117.10110	Suspected change	Surveillance	N100CMBPLB
100080103	APK309	47.69797	-117.23945	Suspected change	Surveillance	N100CMBPLB
100080102	APK310	47.70066	-117.19540	Suspected change	Surveillance	N100CMBPLB
100079611	BBH401	47.73001	-117.37742	Suspected change	Surveillance	N100CMBPLB
100080547	GWDB_ERO816	47.59270	-117.71476	Suspected change	Surveillance	N600CMBPLV
100079704	GWDB_ERO817	47.65810	-117.26588	Suspected change	Surveillance	N100CMBPLB
100030322	AKT213	46.08802	-118.23721	Suspected change	Trend	N100CMBPLB
27171105	APC069	46.04925	-118.36633	Suspected change	Trend	N100CMBPLB
18846824	APC070	46.01909	-118.44122	Suspected change	Trend	N100CMBPLB
3117850	APC072	46.07206	-118.54951	Suspected change	Trend	N100CMBPLB
43503419	APK305	46.00290	-118.43590	Suspected change	Trend	N100CMBPLB
56964007	APK307	46.04305	-118.55189	Suspected change	Trend	N100CMBPLB

NGWMN ID	Location ID	Latitude	Longitude	Subnetwork	Category	Principal Aquifer
100030342	BBH623	46.02129	-118.38319	Suspected change	Trend	N100CMBPLB
100030336	BBH628	46.02753	-118.64839	Suspected change	Trend	N100CMBPLB
100030334	BBH630	46.00115	-118.59133	Suspected change	Trend	N100CMBPLB
100030346	BCE309	46.00618	-118.67111	Suspected change	Trend	N100CMBPLB
26030163	GWDB_ERO643	46.00381	-118.47281	Background	Surveillance	N100CMBPLB
37197693	GWDB_ERO644	46.00381	-118.47281	Background	Surveillance	N100CMBPLB
96523367	GWDB_ERO645	46.00381	-118.47281	Background	Surveillance	N100CMBPLB
50131278	GWDB_ERO646	46.00381	-118.47281	Background	Surveillance	N100CMBPLB
100006776	BBH470	46.70441	-117.30544	Suspected change	Trend	N600CMBPLV
100006772	GWDB_BBH471	46.70524	-117.26161	Suspected change	Trend	N600CMBPLV
2503302	GWDB_ERO698	47.58000	-118.27000	Background	Surveillance	N600CMBPLV
92303133	AGF141	48.89000	-122.50000	Suspected change	Surveillance	S100PGTSND
34291782	BCS951	48.87000	-122.45000	Suspected change	Surveillance	S100PGTSND
29425327	BCS953	48.89000	-122.47000	Suspected change	Surveillance	S100PGTSND
7305203	BCS952	48.88000	-122.47000	Suspected change	Surveillance	S100PGTSND
7594203	BCS954	48.88000	-122.50000	Suspected change	Surveillance	S100PGTSND
6005203	BCS955	48.87000	-122.53000	Suspected change	Surveillance	S100PGTSND
9005203	BCS956	48.86000	-122.55000	Suspected change	Surveillance	S100PGTSND
63905841	BCS961	48.94000	-122.56000	Suspected change	Surveillance	S100PGTSND
5235203	BCS958	48.95000	-122.51000	Suspected change	Surveillance	S100PGTSND
2335203	BCS959	48.93000	-122.52000	Suspected change	Surveillance	S100PGTSND

Task 2: Maintain web services and keep registry updated

The EIM-NGWMN web service continues to be checked and maintained. The connection between the Ecology and NGWMN is currently functional and serving data.

The web service continues to provide both discrete (manual) groundwater level measurements and daily average (transducer) measurements. All water level results are normalized to a consistent datum (NGVD88) and reported as depths to groundwater in feet below land surface.

The water quality service was added during this grant cycle. Ten water quality wells located in northwestern Washington, Whatcom County were added to the NGWMN. Data for these wells are available on the NGWMN website.

Ecology has several candidate wells for potential addition to the water quality service. Ecology monitors two areas of the State known to have elevated levels of nitrate. In Whatcom County, six new monitoring wells drilled under this grant will be added to the water quality network. Data collection for these wells will begin in March 2022. In 2021, Ecology began water quality monitoring at thirty dedicated monitoring wells in the south-central region of the State. These wells will be evaluated for potential addition to the water quality web services.

Data submitted to the NGWMN continues to be updated as the information becomes available and has met quality assurance standards.

Task 3: Survey 25 dedicated monitoring wells

Ecology continues to fill metadata gaps for current NGWMN sites. This consists of two tasks (1) provide a more accurate survey of coordinates for submitted wells, and (2) add well measuring points relative to ground surface at wells where that information is missing.

Ecology surveyed 23 wells using a Trimble Geo 7X handheld satellite global positioning system (GPS). Horizontal and vertical positioning is achieved through satellite triangulation and has a global navigation satellite system (GNSS) rated accuracy of $\pm$ 1 to 100 cm. Most of the groundwater wells in EIM have a horizontal accuracy of $\pm$100 ft and a vertical accuracy of $\pm$10 to 40 ft. The purpose of surveying existing wells is to improve the location accuracy to a sub-foot scale.

Of the 23 wells surveyed, eleven are newly drilled monitoring wells funded through G18AC00067. The 23 wells are shown in Figure 3. Well ID, coordinates, horizontal accuracy, and principal aquifer are listed in Table 3.

Ecology is committed to updating survey information for more wells in Eastern Washington now that COVID work and travel restrictions have eased.

Table 3. GPS surveyed groundwater wells, coordinates, horizontal accuracy, and principal aquifer.

NGWMN ID	Location ID	Latitude	Longitude	Horizontal Accuracy (+ft)	Principal Aquifer
7323490	AAB731	46.80751819	-123.0548022	1.0	S100PGTSND
3405243	AKB696	46.72707481	-122.9784524	1.0	S100PGTSND
100054068	APS724	48.0961136	-123.1691236	1.0	N100PCFNWB
100054152	BAF224	48.09445	-123.12386	1.0	N100PCFNWB
77890906	CRGWDB-200033	46.52036428	-120.2078683	0.1	N100CMBPLB
32816210	CRGWDB-210990	46.59287901	-120.7092563	0.1	N100CMBPLB
48646931	CRGWDB-211015	46.54974461	-120.3808575	1.0	N100CMBPLB
50375036	CRGWDB-211284	47.59961625	-119.5774316	1.0	N100CMBPLB
61359423	CRGWDB-211305	47.94580357	-119.7450786	1.0	N100CMBPLB
100033897	ECY_GREEN_MW11	48.58229226	-122.2243723	1.0	S100PGTSND
100033896	ECY_GREEN_MW6	48.64965997	-122.3244907	1.0	S100PGTSND
100033895	ECY_GREEN_MW7	48.15527063	-122.2893709	1.0	S100PGTSND
100115907	BMP064	47.55964081	-124.2849753	1.0	N100PCFNWB
100115908	BMP065	48.26380706	-124.3479188	1.0	N100PCFNWB
100115909	BMP066	48.09610864	-123.169097	1.0	N100PCFNWB
100115910	BMP060	48.99684238	-122.4561367	1.0	S100PGTSND
100119302	BNN012	48.99330079	-122.3991823	1.0	S100PGTSND
100119303	BNN013	48.99333254	-122.3784161	1.0	S100PGTSND
100119304	BNN014	48.99336837	-122.3645997	1.0	S100PGTSND
100119305	BNN015	48.99326298	-122.3326477	1.0	S100PGTSND
100119306	BNN016	48.98194536	-122.3569237	1.0	S100PGTSND
100115911	BNN010	46.477179	-122.815857	1.0	N100PCFNWB
100119301	BNN055	46.019562	-121.568599	1.0	N100CMBPLB

Task 4: Test well aquifer connectivity at 12 dedicated monitoring wells

Ecology performed aquifer tests on 12 monitoring wells. Aquifer test were performed to assess the degree of connectivity between the well and the adjacent aquifer material. Aquifer tests were conducted using a 2-inch diameter, variable speed, submersible pump. The pump was set at a steady pumping rate and drawdown was measured in the well at regular intervals. Specific capacity is calculated when the drawdown in the well achieves a steady-state at the set pumping rate. The specific capacity is calculated by dividing the pumping rate by drawdown to give a value that represents the pumping rate per foot of decline in water-level (gpm/ft).

Pump test well locations are shown in Figure 4. Well details and pump test results are listed in Table 4. All wells for which aquifer tests were performed are located in Western Washington. Selection of wells was based on accessibility and also depth of the aquifer. Many groundwater

wells in Eastern Washington are privately owned and tend to be significantly deeper than the wells in Western Washington.

The specific capacity is not reported for wells AAB740 or BNN066. AAB740 is an older carbon steel cased well with an open bottom. About 10 feet of sand has accumulated in the casing bottom and is limiting water flow into the well. There was no pumping rate at which drawdown stabilized to allow the specific capacity to be measured. Once pumping stopped, the water-level was very slow to recover. BNN066 is a new well that has a 10 foot screen located below the water-table. Drawdown in this well occurred rapidly, but unlike AAB740, the water-level recovered quickly once pumping stopped.

All wells show some degree of connectivity with the respective adjacent aquifers. Response of the wells appear to be loosely associated with the age of the well, connection to the aquifer (casing open at bottom or screened), and lithology. Based on the above criteria, wells that are older, open at the bottom, and in fine or consolidated formations tend to be less productive.

Table 4. Aquifer test wells, screen intervals, depth to water, specific capacity, and principal aquifer.

Site Name	Location ID	Top of Screen (ft bgs)[1]	Bottom of Screen (ft bgs)	Initial DTW (ft)[2]	Specific Capacity (gpm/ft)[3]	Principal Aquifer	Date
9123490	AAB714	120	125	22.45	0.33	S100PGTSND	3/20/2019
223490	AAB715	80	85	21.83	3.75	S100PGTSND	3/20/2019
1223490	AAB716	49	52	21.3	0.10	S100PGTSND	3/20/2019
7323490	AAB731	78	83	29.72	9.09	S100PGTSND	7/11/2019
4423490	AAB740	200	200	11.8	N/A	N100PCFNWB	5/14/2019
3405243	AKB696	43	53	26.35	7.50	S100PGTSND	5/17/2019
100033896	Green 6	120	120	86.47	1.05	S100PGTSND	7/16/2021
100033895	Green 7	100	100	78.85	0.24	S100PGTSND	7/15/2021
100033897	Green 11	120	120	52.44	0.18	S100PGTSND	7/15/2021
100115907	BNN064	10	20	11.84	4.00	N100PCFNWB	3/15/2021
100115908	BNN065	20	30	13.78	4.71	N100PCFNWB	3/15/2021
100115909	BNN066	45	55	31.22	N/A	N100PCFNWB	3/15/2021

[1] Below ground surface (bgs).
[2] Depth-to-water (DTW), measured from the wells' measuring point.
[3] Gallons per minute (gpm).

Task 5: Design, locate and drill 13 groundwater monitoring wells in Washington State

Under agreement G18AC00067, Ecology proposed to drill 13 new monitoring wells. In total, 12 wells sites were identified and subject to drilling. Of these locations 11 of the wells were completed in productive aquifers. One well did not encounter a viable aquifer and was abandoned. Figure 5 shows the locations of the 11 new wells relative to the Ecology NGWMN

well submissions and the USGS climate network wells. Well construction details are listed in Table 5.

Table 6 defines the NGWMN categories and subnetworks for each well. Based on subnetworks, four of the wells serve as background wells and the other seven are subject to known changes due to anthropogenic activity. All of the new wells are instrumented with pressure transducers that are continuously measuring water-levels at 4 hour intervals. Therefore, all fall in the classification of trend wells.

Installation of pressure transducers in all of the drilled wells complies with the applicable Department of Ecology Standard Operating Procedures (SOP), *Standard Operating Procedure for the use of Submersible Pressure Transducers during Groundwater Studies*, *Version 1.1* (Sinclair and Pitz, 2018).

Six monitoring wells were drilled and completed in northwest Washington's Whatcom County. The wells were installed in the regional aquifer which spans the U.S.-Canadian border. The shallow unconfined aquifer, which is a drinking water source to rural areas of the county, is composed primarily of sand and gravel outwash. The shallow depth to groundwater (typically less than 10 feet), heavy winter precipitation, and intensive agricultural land use on both sides of the border make this aquifer vulnerable to nitrate contamination. The new wells are being added to Ecology's long-term water-quality monitoring program which has been dependent on access to private domestic wells. The dedicated monitoring wells will provide water-level and water quality data for the U.S. portion of the aquifer. The wells are arranged along a 6-mile east to west transect within 1.5 miles of the border. The well locations were selected to provide water quality data along the border area to supplant data no longer provided by a Canadian monitoring program that was discontinued in 2018.

Three wells were drilled and completed on the Olympic Peninsula. Wells BNN064 and BNN065 are located in unconfined aquifers consisting of fluvial sands at both locations. These wells are located on the west side of the peninsula which has not previously hosted any groundwater monitoring wells. The role of these wells is to provide ambient water-level and monitor for climate change effects within the groundwater.

Well BNN066 is located between the towns of Port Angeles and Sequim on the Olympic Peninsula. The aquifer, which is used for municipal and domestic water supply, is in a glacial outwash composed of a coarse, unconsolidated sandy gravel. This well is completed in a shallow aquifer to a depth of 55 feet within a multi-level aquifer system. The well is located a distance of 8 feet from an adjacent deep monitoring well that reaches a depth of 289 feet. The USGS has monitored the deep well, identified as 30N/04W-15H07, since 2018. Prior to that, Ecology monitored the well from 2008 to 2018, with the Ecology designation APS724. The purpose of the shallow well is to provide water-level data in the shallow aquifer and distinguish differences in water-level and vertical gradient between the upper and lower aquifers.

The two southwest monitoring wells (BNN010, BNN055) are in areas that are intended to monitor ambient conditions and effects of climate change on groundwater. Well BNN010 is in a medium sand overlain by a consolidated glacial drift deposit. Well BNN055 is in a gravelly sand beneath a clay unit. Both aquifers are confined.

Table 5. Newly drilled monitoring wells, screen intervals, depth to water, coordinates, and principal aquifer.

NGWMN ID	Location ID	Top of Screen (ft bgs)[1]	Bottom of Screen (ft bgs)	DTW[2] (ft)	Latitude	Longitude	Principal Aquifer
Completed							
100115907	BMP064	10	20	11.00	47.5597	-124.2850	N100PCFNWB
100115908	BMP065	20	30	13.00	48.2638	-124.3479	N100PCFNWB
100115909	BMP066	45	55	32.00	48.0961	-123.1691	N100PCFNWB
100115910	BMP060	16	26	9.00	48.9968	-122.4565	S100PGTSND
100119302	BNN012	22	32	9.70	48.9933	-122.3999	S100PGTSND
100119303	BNN013	20	30	11.60	48.9933	-122.3784	S100PGTSND
100119304	BNN014	20	30	9.53	48.9934	-122.3643	S100PGTSND
100119305	BNN015	33	43	35.50	48.9933	-122.3325	S100PGTSND
100119306	BNN016	30	40	25.00	48.9820	-122.3569	S100PGTSND
100115911	BNN010	50	60	28.00	46.4772	-122.8159	N100PCFNWB
100119301	BNN055	21	31	8.15	46.0196	-121.5686	N100PCMBPLB
Abandoned							
N/A	N/A	10	20	N/A	48.8881	-121.9369	N100PCFNWB

[1] Below ground surface (bgs).
[2] Depth-to-water (DTW), measured from the wells' measuring point.

Table 6. Newly drilled wells and NGWMN category and subnetwork.

NGWMN ID	Location ID	Category	Subnetwork	Principal Aquifer
Completed				
100115907	BMP064	Trend	Background	N100PCFNWB
100115908	BMP065	Trend	Background	N100PCFNWB
100115909	BMP066	Trend	Documented Change	N100PCFNWB
100115910	BMP060	Trend	Documented Change	S100PGTSND
100119302	BNN012	Trend	Documented Change	S100PGTSND
100119303	BNN013	Trend	Documented Change	S100PGTSND
100119304	BNN014	Trend	Documented Change	S100PGTSND
100119305	BNN015	Trend	Documented Change	S100PGTSND
100119306	BNN016	Trend	Documented Change	S100PGTSND
100115911	BNN010	Trend	Background	N100PCFNWB
100119301	BNN055	Trend	Background	N100PCMBPLB
Abandoned				
N/A	N/A	N/A	N/A	N100PCFNWB

Summary

The objective of National Groundwater Monitoring Network (NGWMN) is the implementation of a long-term national groundwater quantity and quality monitoring network (ACWI, 2013). This is achieved by engaging other organizations who collect groundwater data and establishing a cooperative agreement with them. These data are shared through a web service that transfers the organization data to a common data portal. The cumulative data from all contributors is made available through a map-based interface. A defined set of data elements are requested from each of the contributors so that the ensemble product shows a consistent and uniform output from all contributors.

Two reports were required for grant G18AC00067. The one year status update report was submitted in July of 2019. This final report is the second required submission that summarizes all work done for this grant.

The Washington State Department of Ecology (Ecology) entered into a cooperative two-year agreement to provide groundwater level data, test aquifer connectivity, survey well sites, and construct new groundwater wells to enhance the NGWMN starting in 2018 and ending in 2021. Ecology completed the following tasks:

- Continued to maintain web services between the Environmental Information Management system and the NGWMN portal.
- Added 80 new wells to the NGWMN well registry.
- Established the water quality services and added 10 wells.
- Performed 12 aquifer tests to assess connectivity at the well.
- Completed surveys of 23 wells to a high spatial accuracy.
- Drilled 12 monitoring well locations and completed 11 wells to augment the monitoring network.
- Completed and submitted the final status report.

Going forward the goal is to adapt to current and possible future disruptions due to COVID-19 and changes in workflow in order to better achieve our tasks.

Tasks that are currently underway to improve and refine the NGWMN submissions include,

- Identify and remove existing wells submitted to the NGWMN that are no longer supporting groundwater monitoring activities or have been found not to satisfy the NGWMN criteria.
- Continue to fill data gaps of the existing and future wells submitted to the NGWMN.
- Identify and add new water-level and water quality wells to the network that meet the NGWMN criteria.
- Continue to identify and fill spatial gaps in the State-wide groundwater monitoring network that may be potentially part of the NGWMN.

This report was prepared and submitted in keeping with the four required elements as outlined in section 5.(b)(1)[1] of the National Groundwater Monitoring Network Terms and Conditions.

References

ACWI (2013). *A National Framework for Ground-Water Monitoring in the United States*, Subcommittee on Ground Water of the Advisory Committee on Water Information, 182. https://acwi.gov/sogw/ngwmn_framework_report_july2013.pdf

Culhane, T.J. (2017). *Water Resources Program Integrated Statewide Groundwater Monitoring Strategy*, Washington State Department of Ecology, Water Resources Program. https://fortress.wa.gov/ecy/publications/documents/1711005.pdf

Sinclair K. & Pitz C.F. (2018). *Standard Operating Procedure for the use of Submersible Pressure Transducers during Groundwater Studies, Version 1.1*, Washington State Department of Ecology, Environmental Assessment Program, EAP074. https://fortress.wa.gov/ecy/publications/documents/1803217.pdf

WDOE (2018) Statewide Groundwater Assessment: 2017, Washington State Department of Ecology, Water Resources Program, Pub. 18-11-011. https://apps.ecology.wa.gov/publications/documents/1811011.pdf

[1] 1) A comparison of actual accomplishments to the objectives of the agreement established for the budget period and overall progress in response to the performance metrics.
2) The reasons why established goals were not met, if appropriate.
3) Additional pertinent information including, when appropriate, analysis and explanation of cost overruns or high unit costs.
4) An outline of anticipated activities and adjustments to the program during the next budget period.

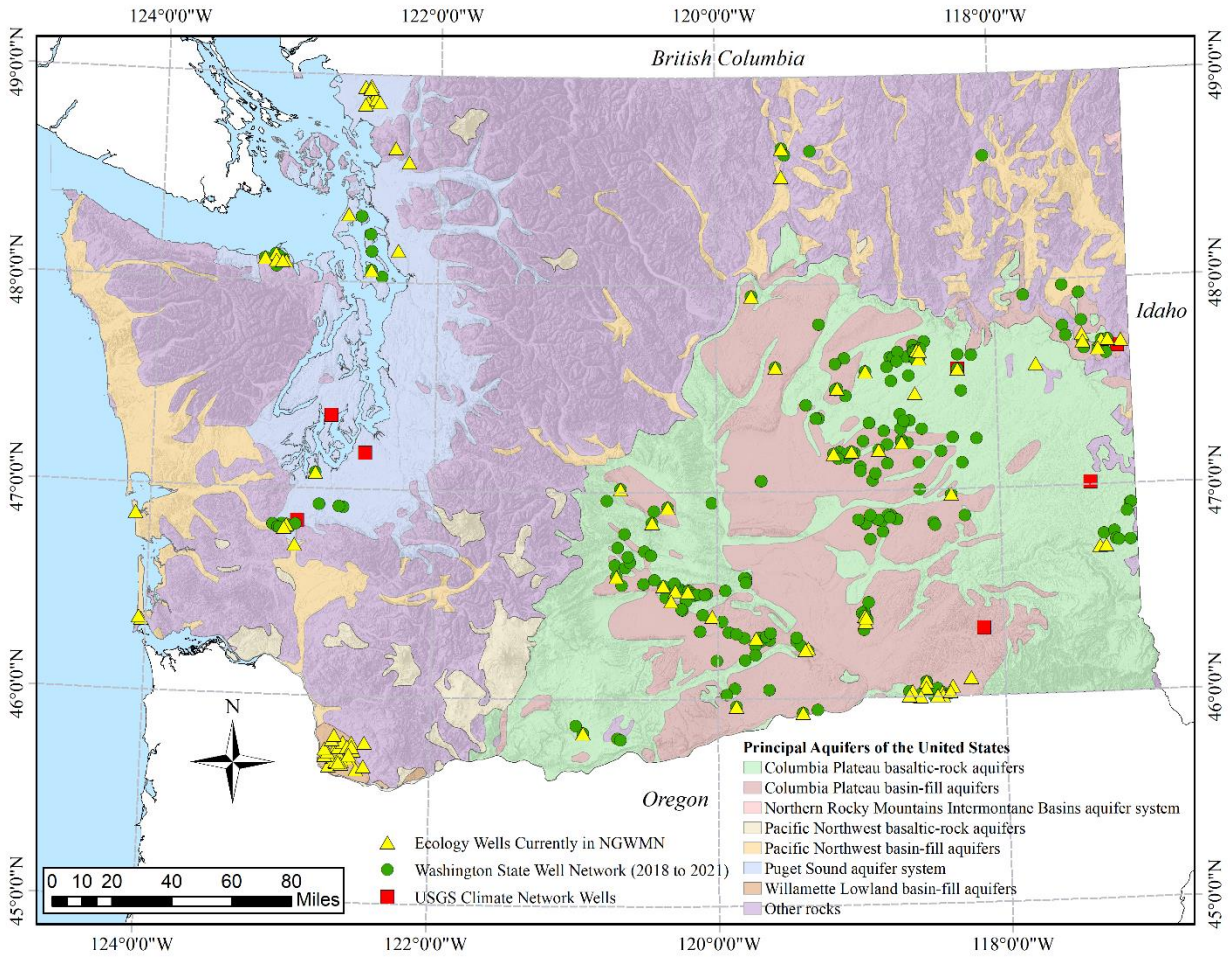

Figure 2. Washington State Department of Ecology groundwater monitoring wells water-levels measured between 2018 and 2021, the Washington State Department of Ecology wells in the National Groundwater Monitoring Network, and USGS climate network wells.

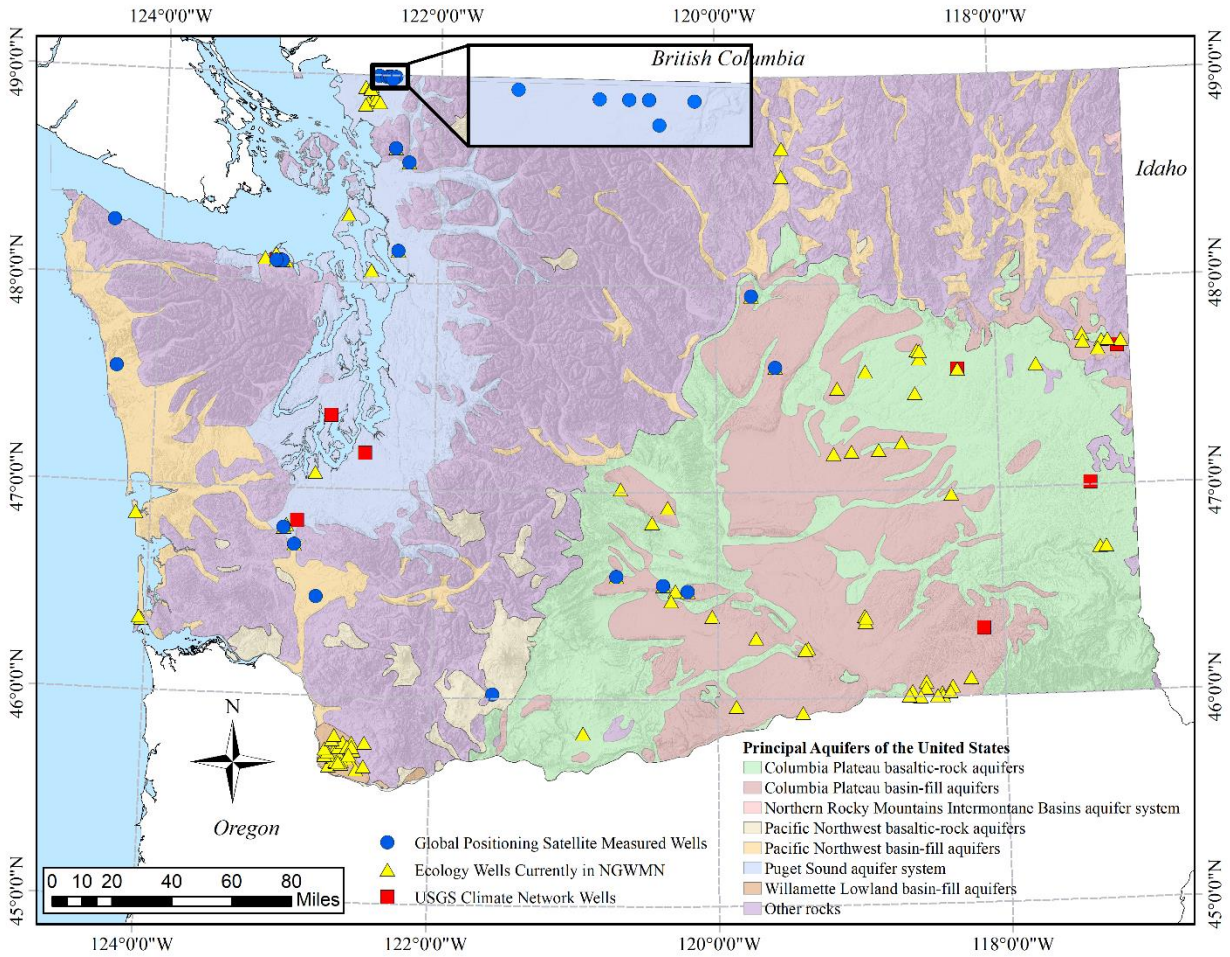

Figure 3. Washington State Department of Ecology groundwater monitoring wells in the NGWMN, locations of global positioning satellite surveyed sites, and USGS climate network wells.

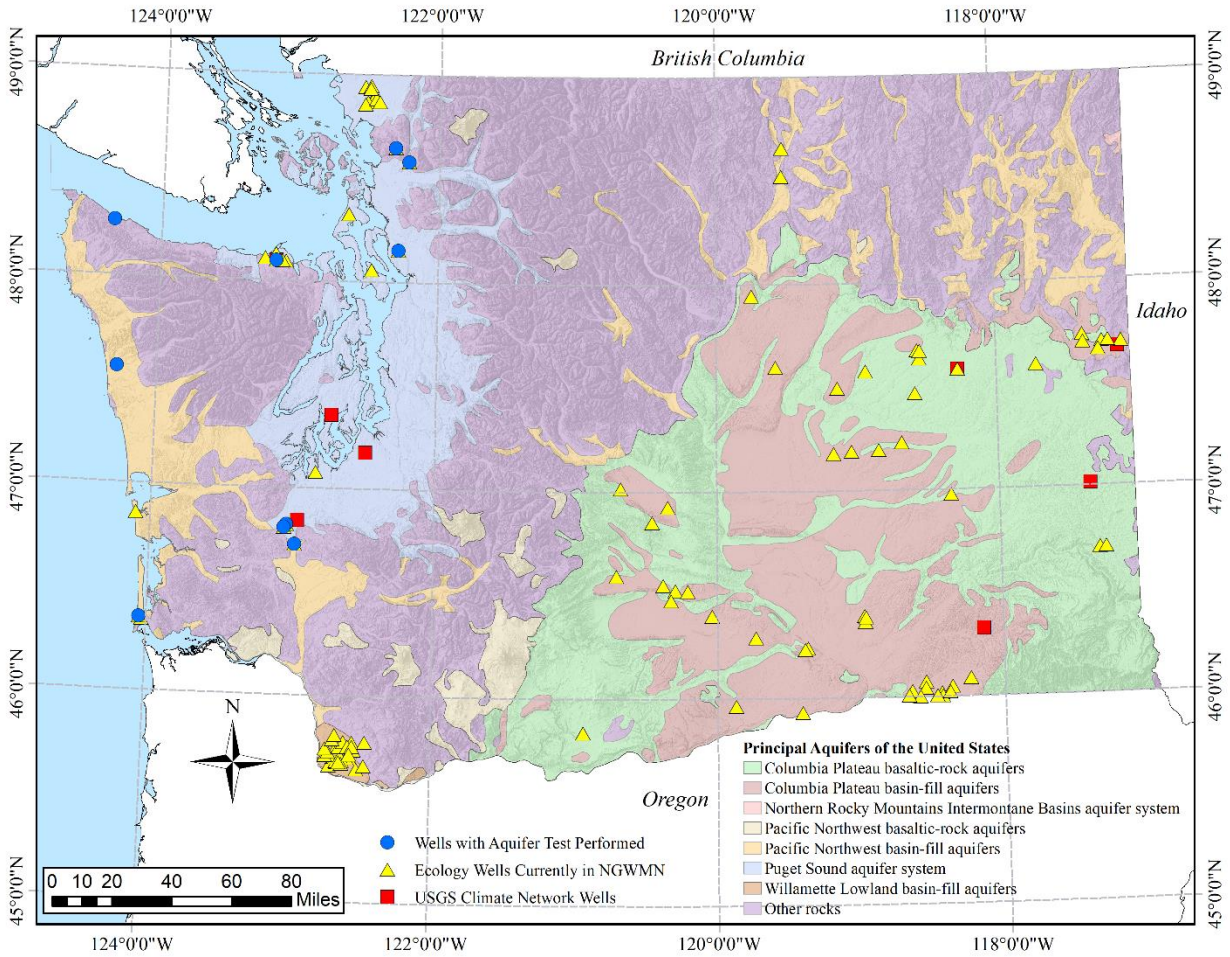

Figure 4 Washington State Department of Ecology groundwater monitoring wells in the NGWMN, locations of aquifer test wells, and USGS climate network wells.

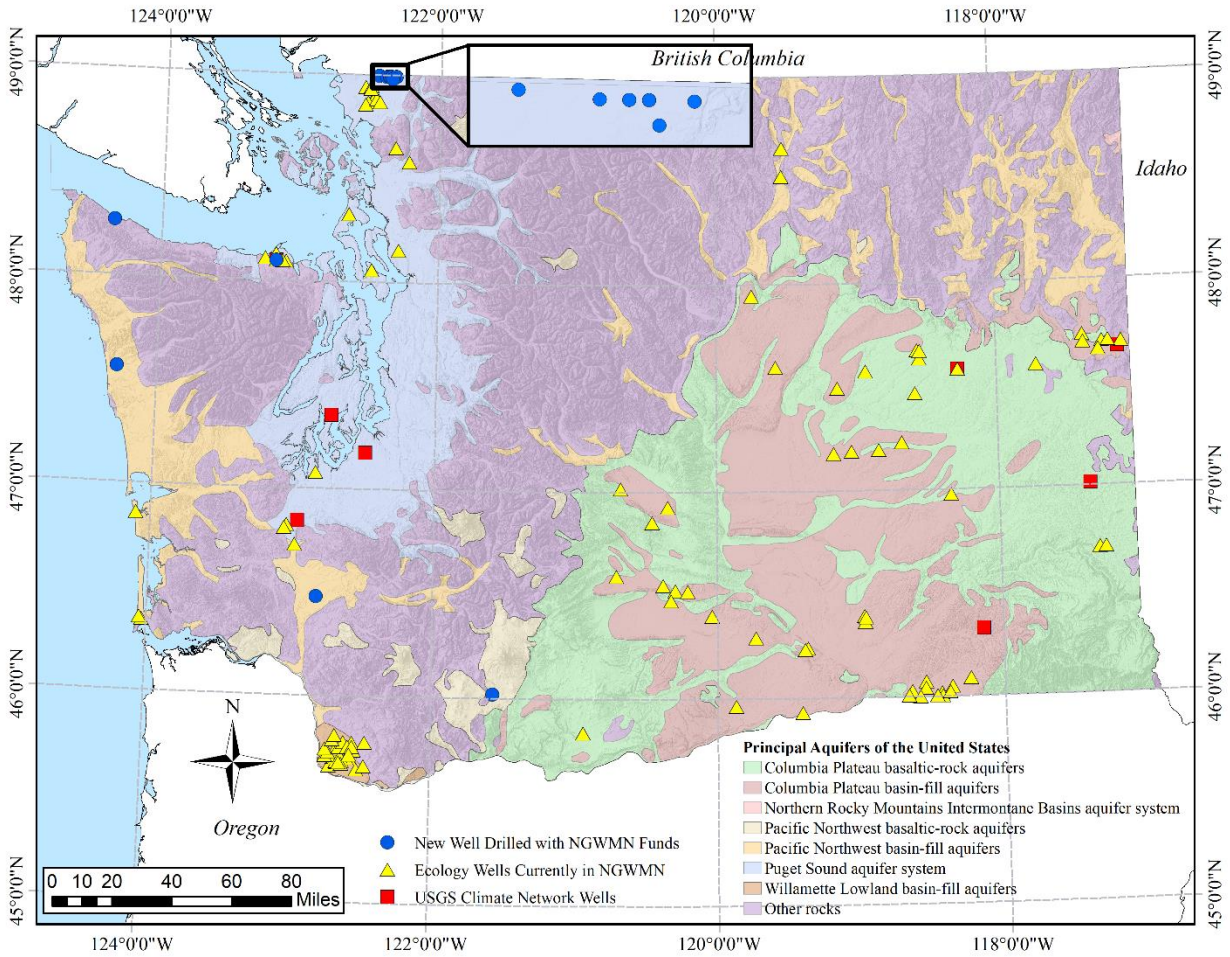

Figure 5. Washington State Department of Ecology groundwater monitoring wells in the NGWMN, locations of new wells drilled to fill data gaps, and USGS climate network wells.