WRIA 53 (Lower Lake Roosevelt Watershed)

Groundwater Inventory and Mapping Project

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Prepared for:

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Introduction

The Lower Lake Roosevelt Watershed (WRIA 53) began planning under the Watershed Planning Act (RCW 90.82) in January of 2008. The Planning Unit consists of landowners, water purveyors, governments and other interested parties. The mission statement of the planning unit is:

"To develop a plan to manage and protect the water and related resources in an environmentally and economically sound manner that is in the interest of the residents and landowners of the Lower Lake Roosevelt Watershed".

Based on that mission statement and development trends in Lincoln County, the planning unit decided to include a geographic information system (GIS) based groundwater mapping program in Phase II of the planning process.

The WRIA 53 study area includes a portion of the watershed that is located mostly within northern Lincoln County with smaller portions in northeastern Grant County, southern Ferry County, and southeastern Okanogan County (Figure 1). The portions of the watershed located in Okanogan and Ferry Counties are within the boundaries of the Colville Indian Reservation. The Colville Confederated Tribes is under a resolution to not participate in any RCW 90.82 Watershed Planning activities. Therefore, the WRIA 53 Planning Unit is focused on those portions of the watershed south of the Columbia River to characterize and develop potential planning recommendations.

The watershed encompasses approximately 326,164 acres, or approximately 509.63 square miles. The Columbia River bisects the watershed with 118,730 acres (185.52 square-miles) located north of the Columbia River, primarily within the boundaries of the Colville Indian Reservation, and 207,432 acres (324.11 square miles) located south of the Columbia River, that area which was the primary focus of this assessment. Table 1 presents a summary of the area located within each County with lands located within the Lower Lake Roosevelt Watershed. In general, the watershed encompasses that portion of the Columbia River and it is tributaries between the confluence of the Spokane River to the east and the location of Grand Coulee Dam to the west. The communities of Davenport, Lincoln, Seven Bays, and numerous smaller private housing developments are within the watershed.

TABLE 1: WRIA 53 AREA PER COUNTY			
County	***Acreage***	***Square-Miles***	***Percentage***
Lincoln	206,093	322.02	63.2
Ferry	74,542	116.47	22.8
Okanogan	44,274	69.18	13.6
Grant	1,255	1.96	0.4
TOTAL	***326,164***	***509.63***	***100***

This report presents the objectives, methodologies, description of data products, and preliminary analysis of the aquifer conditions within the southern portion (south of Columbia River) of the WRIA 53 watershed. Funding for this project was provided by the Washington State Department of Ecology (Ecology) through the RCW 90.82 Watershed Planning Grant No. G0800258.

Background

During formation of the WRIA 53 Planning Unit, the top priority of the water users in the watershed was to evaluate the sustainability of water supply within the watershed. With this priority, the Planning Unit moved forward with Phase 2, only undertaking the water quantity element of watershed planning. The WRIA 53 Planning Unit conducted the Level 1 data gathering through 2009, and completed the Phase II Level 1 Hydrogeologic Technical Assessment in September 2009. Results of the Level 1 project revealed that there was limited aquifer information available in WRIA 53 to begin aquifer sustainability planning in the watershed. In order to meet the water strategies outlined above, the following specific recommendations were developed by the WRIA 53 Planning Unit during Phase 2-Level 1 Watershed Planning (Section 7 Level 1 Technical Assessment, September 2009):

With respect to the surface water system the following is recommended:

1. *Establish flow gauging stations at selected streams and springs to better characterize water flowing into and out of the hydrologic system. Focus on the Hawk Creek drainage.*
2. *Use flow measurements to establish a baseline for comparing to future conditions.*
3. *Conduct periodic water quality measurements to better understand stream and spring health, especially as rural home density increases. Monitoring should be conducted at the locations where Ecology is conducting stream flow monitoring.*

For the aquifer systems underlying the WRIA, the Planning Unit has recommendations similar to those for surface water. These recommendations, which are driven by a general scarcity of data upon which to assess baseline conditions and trends, are as follows:

1. *Develop a groundwater monitoring plan and strategy.*
2. *Establish some groundwater level monitoring areas having both high and low well density to better track pumping effects on the 3 aquifer systems and to better characterize potential aquifer recharge conditions.*
3. *Collect aquifer pumping test data, as it becomes available, to use to better characterize aquifer physical conditions for use in evaluating long term aquifer hydrologic trends.*
4. *Conduct a limited amount of groundwater geochemical sampling in order to better understand aquifer recharge conditions and evaluate surface water/groundwater continuity.*
5. *Conduct a more detailed GIS (Geographic Information System) evaluation to inventory and map available data on ground and surface water resources and the relationship to current and future land use in WRIA 53. The goal of such an evaluation would be to collect information useful in identifying aquifer boundaries, recharge areas, high groundwater pumping areas, and potential sustainable aquifer pumping targets, and areas in which potential mining of groundwater is occurring.*
6. *Compile a GIS layer identifying where potential critical aquifer recharge areas are located.*

This GIS Groundwater Mapping project was identified as a priority in order to assure that groundwater supplies are not diminished, a potential scenario which arose from the Groundwater Management Area (GWMA) mapping project, which identified most of the basalt aquifers as having 10,000 plus year old water; suggesting that there is not a direct recharge to the aquifers from Lake Roosevelt.

The WRIA 53 Groundwater Inventory & Mapping project will produce tools to aid in decision making at all levels. A GIS will be utilized to analyze the data. For example, the maps created during this project can be used by local planning officials to implement new land use codes that reflect the water availability in the area. Also, a prospective landowner could use the data when deciding which piece of property to purchase.

The goal of this project is to create a tool so that the WRIA 53 water users can economically and responsibly use the Watershed's resources to our advantage.

Project Scope of Work

This project was comprised of five main tasks:

1. Data collection: spatial distribution and growth of groundwater wells in the watershed;
2. Analysis of Well Logs: utilizing existing well logs in the Ecology Database, document total depth of wells, static water levels, and well yields;
3. Stream flow data collection: collect stream flows at several locations on Hawk Creek;
4. Groundwater monitoring: develop a groundwater monitoring program in the watershed to track trends of groundwater levels;
5. Development potential within the watershed: use results of the technical data to begin evaluation of future growth and its impact on water resources.

A preliminary analysis was conducted as part of each task. The GIS Groundwater analysis was not intended to be comprehensive, but developed to begin a preliminary evaluation of how data and tools can be developed and used in the future to understand the hydrogeology of the watershed.

Task 1 – Data collection

The objective of this task was to begin development of a database of groundwater information in the watershed which could be used by WRIA 53 water users in the future. Databases were compiled and maintained by the Lincoln County Planning Department. Maps and graphs of the hydrogeologic information were created using the Department of Ecology's well log database. Not all well logs (especially those from the earlier years) have all the information that was needed for the project. As a result of the state of the data, these maps should be considered a starting point for analyzing wells and water availability in WRIA 53. As more data is collected, this dataset will be updated to reflect the more accurate and current data.

Well logs for the Lincoln County portion of the watershed were compiled during the Level I Technical Assessment. The Department of Ecology website allows for downloading well logs by watershed in table format, which includes coordinates that were used to create a GIS layer. The State of Washington has been receiving well logs since the 1930's; however, not all wells drilled were reported to the department.

The wells north of the Colubia River were added to the master well database table and all were imported into ArcMap. The Lincoln County wells have more complete data due to the work completed in the previous Phase 1 planning efort; the remaining well data may be improved as time and budget permit.

A review of Ecology's well database for that portion of WRIA 53 reveals approximately 600 well log records in the area. Of the Ecology well records, approximately 353 were located in Lincoln County and deemed usable for this assessment. These located wells are deemed usable because: (1) they have a clear description of location, (2) they are legible, and (3) the descriptions of well geology and construction appear to be complete and interpreted to be representative of actual conditions. Well locations as reported on the well logs are assumed to be correct as most wells were not field located for this project.

Of the approximately 353 wells used in this assessment, all but 29 are listed as domestic wells. Basic well geology and construction for 344 of these wells were imported into the Lincoln County Planning Departments database. Table 2 presents a generalized distribution these wells in the WRIA.

TABLE 2: Distribution of Groundwater Wells

TN/RE	Total wells	Non-domestic wells	Hydrogeology
25/35	1	0	
25/36	39	11	1 basement
25/37	39	7	All bslt, 1 art.
25/38	2	0	Bslt
26/34	4	0	Bslt
26/35	31	1	1 sed
26/36	49	0	1 base, 1 sed, 3 sed/bslt
26/37	13	0	4 base, 1 bslt/sed
27/32-27/33	3	0	2 bslt, 1 base
27/34	27	1	Most basement
27/35	48	4	5 base; 7 sed
27/36	22	1	6 base; 10 sed/bslt
27/37	17	0	9 base, rest mixed
28/31	33	1	Mix
28/33-28/36	16	3	Mix
	344	**29**	

The portable document format (pdf) well logs were downloaded and placed into a database at the Lincoln County Planning Department. Well log information (coordinates, total depth, geology, well yield, etc.) was downloaded into an excel spreadsheet to facilitate further analysis of the

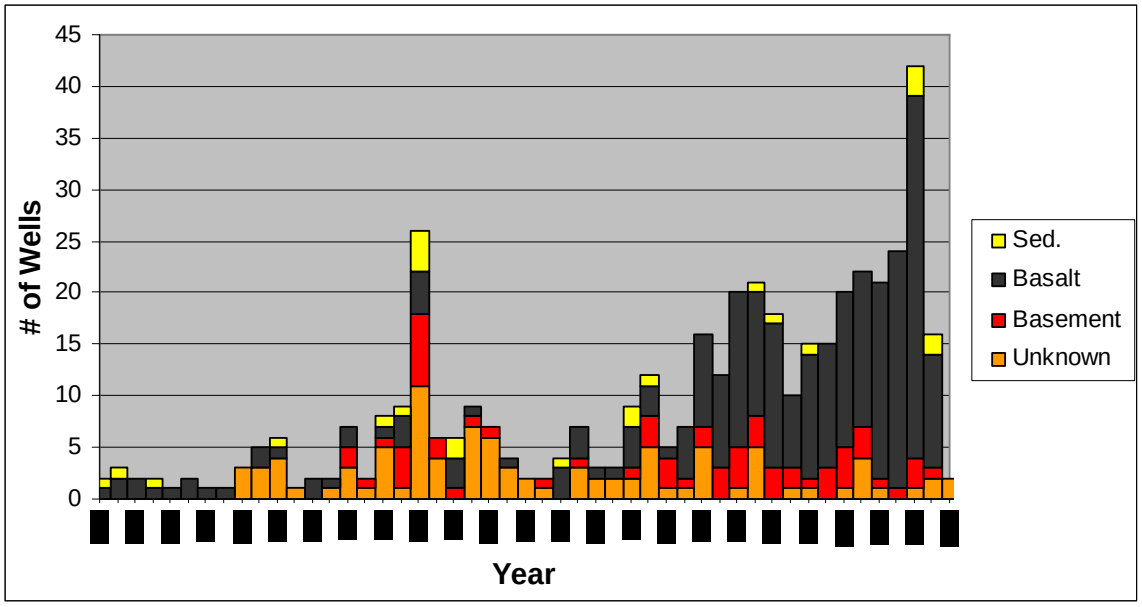
information provided for each well. This information was then utilized to conduct the GIS analysis described below.

As identified in the Phase 1 Technical Assessment (September 2009) the watershed is underlain by three basic aquifer systems: (1) a generally localized alluvial system with a high degree of hydrologic continuity with surface water, (2) the layered, generally widespread Columbia River Basalt Group (CRBG) system, and (3) a low yield, joint and fracture controlled system found within the pre-basalt basement rocks (typically granites in the southern portion of WRIA 53). Section 2 and 4 of the Phase 1 Technical Assessment provides additional information about these three systems. During analysis of the groundwater wells in the system, this project attempted to correlate only those wells founded within the same hydrogeologic system. Where multiple systems were intercepted by the groundwater well, the information was placed into the aquifer system in which the well screen was placed.

Graph 1 shows the distribution of wells drilled by year. The number of wells completed from 1940 through 1973 is not considered accurate for two reasons: 1) the practice of well drillers completing and submitting a well log to the State was not common; and 2) management of well log data changed agencies and was not the responsibility of Ecology until 1971. Data from the mid 1970's to 2009 is a better representation of the number of wells completed each year in WRIA 53.

As shown in Graph 1, prior to 1986, most wells were shallow and completed into the shallow sand and gravel aquifer, or the shallow Wanapum Basalt. In addition, during this time frame, the well logs were very generalized and did not contain detailed well completion details. Therefore, the aquifer in which the wells were screened and withdrawing groundwater is unknown.

Figure 2 presents a map of the watershed in which the groundwater wells in the southern portion of watershed are located. Only those wells which contained well construction information and in which aquifer the groundwater is being withdrawn was identified, is plotted. Figure 2 shows the distribution by year of the well completed, and from which hydrogeologic unit the groundwater is being withdrawn. Only these wells were used in the analysis outlined in the subsequent sections of this study.



Graph 1: Distribution of Groundwater Wells in Study Area by Year Drilled

Task 2 – Analysis of Well Logs

The NOI database is part of the Ecology Well Construction and Licensing System. The database contains information collected when the driller submits documentation prior to drilling a well and any report made to Ecology after the well has been drilled. The difference between this database and the well log database is that the well depth, yield, and water level are in an electronic format as opposed to just being recorded on the PDF copy of the well log. Many of the records for the NOI database also include the land parcel numbers. This coupled with the GIS data available from each county allows for more accurate location of the groundwater wells. In addition, this data can be integrated into other data sources, create spatial datasets, and analyze the data.

The next step after importing the wells into the GIS database was to analyze the spatial distribution of well depth, aquifer yield and static/potentiometric groundwater level which could be used to analyze the spatial distribution of these characteristics. This was completed by creating raster datasets using a method known as Kriging. Kriging is a geostatistical technique that is often used in soil science and geology environments.

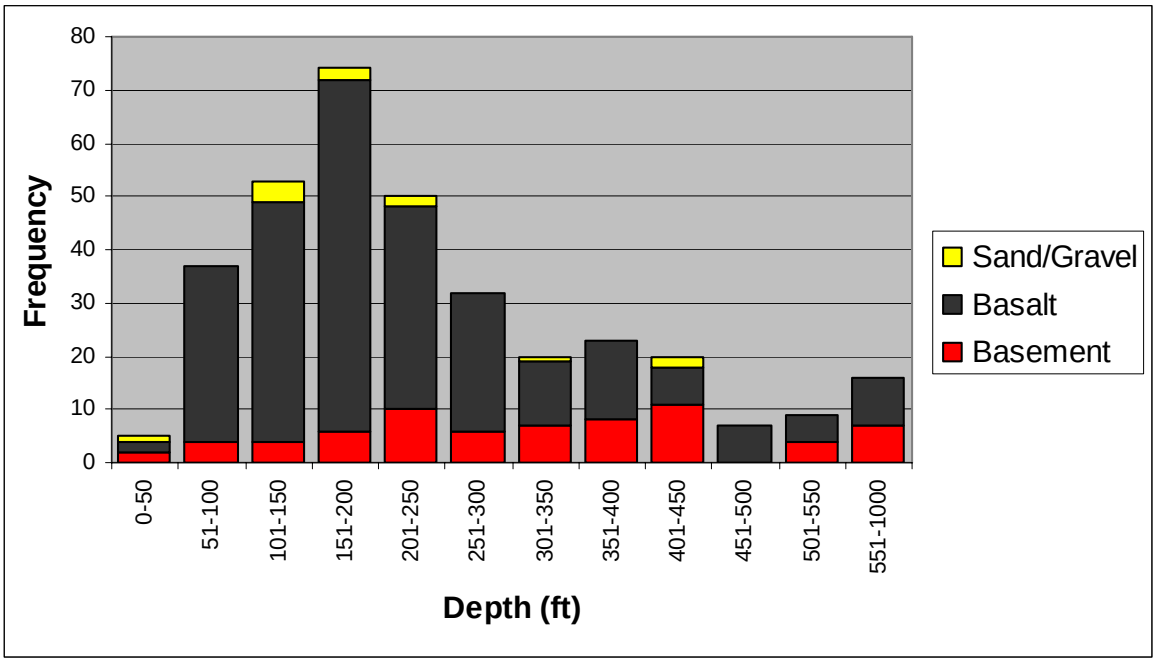
Total Depth of Groundwater Wells

An analysis was first completed on the total depth in which a well was completed. This allowed a generalized knowledge of the approximate depth a property owner would need to drill to complete a water well. This

information should be used in conjunction with static water level, as the static water level is typically higher in elevation than the depth to which the well is completed. Due to the confined and semi-confined aquifer conditions of many of the basalt and granite aquifers, a hydraulic head of tens to a hundred plus feet can occur (i.e. the pressure head on the aquifer will cause the potentiometric head or static water level to rise in the well above the depth in which the aquifer was first encountered). This information is useful to a water user by identifying what the potential depth will be required to drill a well, and to what depth a pump will need to be placed to pump the aquifer (which can be significantly shallower if the aquifer has significant hydraulic head).

Graph 2 presents a distribution of the total well depths completed in the various aquifers. This information shows that most basalt aquifers will be encountered at a depth of 50 to 300 feet. Basement aquifers (typically fractured granite) vary in depth typically from 50 to 450 feet in depth, and unconsolidated sand and gravel aquifers are most common at 50 to 250 feet in depth.

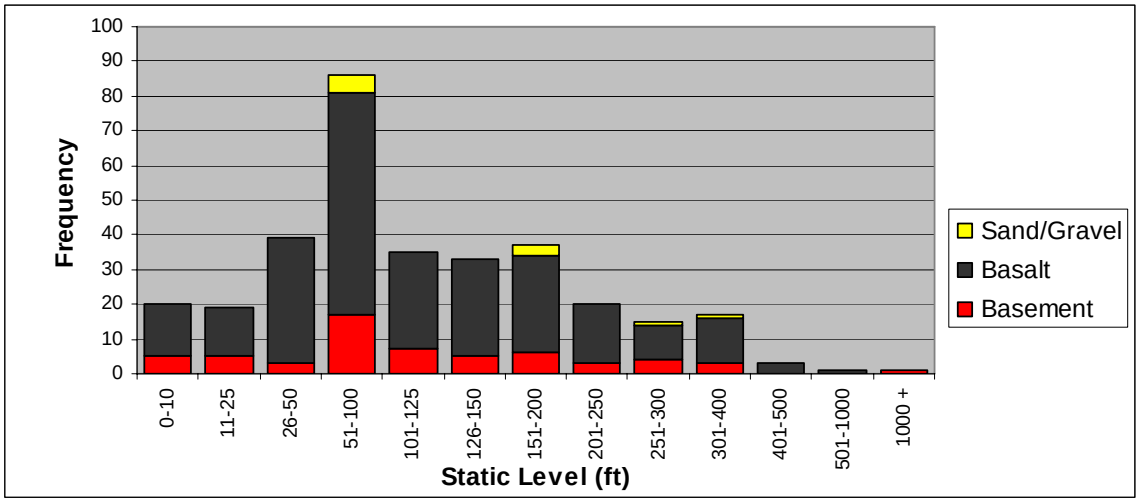
Using the GIS programming, Figure 3 presents a spatial variation of the total depth of wells throughout the watershed. Well depth is directly correlated to topography of the watershed and the type of aquifer being utilized for water production.



Graph 2: Distribution of Groundwater Wells Total Depth in Study Area

Static Water Levels in Groundwater Wells

The Static water levels in the groundwater wells were also analyzed. This information provides the depth to which the groundwater table (or potentiometric head) will be at static conditions. Graph three presents a summary of the static water levels as analyzed by depth below ground surface and hydrogeologic system. As shown on Graph 3, groundwater in the unconsolidated aquifers will typically be found at a depth of 50 to 100 feet or 150 to 200 feet. Groundwater static water levels in the basalts vary throughout the watershed, but are most commonly found from 26 to 250 feet below ground surface. Basement (mostly fractured granites) static conditions vary greatly throughout the watershed.



Graph 3: Distribution of Static Water Table in Wells in Study Area

Figure 4 presents a map showing the aquifer delineation type of wells withdrawing groundwater within the watershed. This map was developed using the well depth, static water level information, and the hydrogeologic unit within the database. The map represents a generalized representation of which hydrogeologic unit will most likely yield groundwater within a certain area of the watershed. As shown on the map, the basalt aquifers are most common throughout the watershed. Unconfined sand and gravel aquifers are most common within the drainages of the watershed. The area east of Davenport reveals mostly sand and gravel aquifers; however, it is our determination that the spatial variation program used to develop this map only had access to a few shallow wells in this area. No deep basalt wells are located throughout this area, therefore not allowing the GIS model to extrapolate out the more regional basalt aquifers. Basement rock aquifers are scattered throughout the watershed south of the Columbia River, and typically represents deeper wells with low yields.

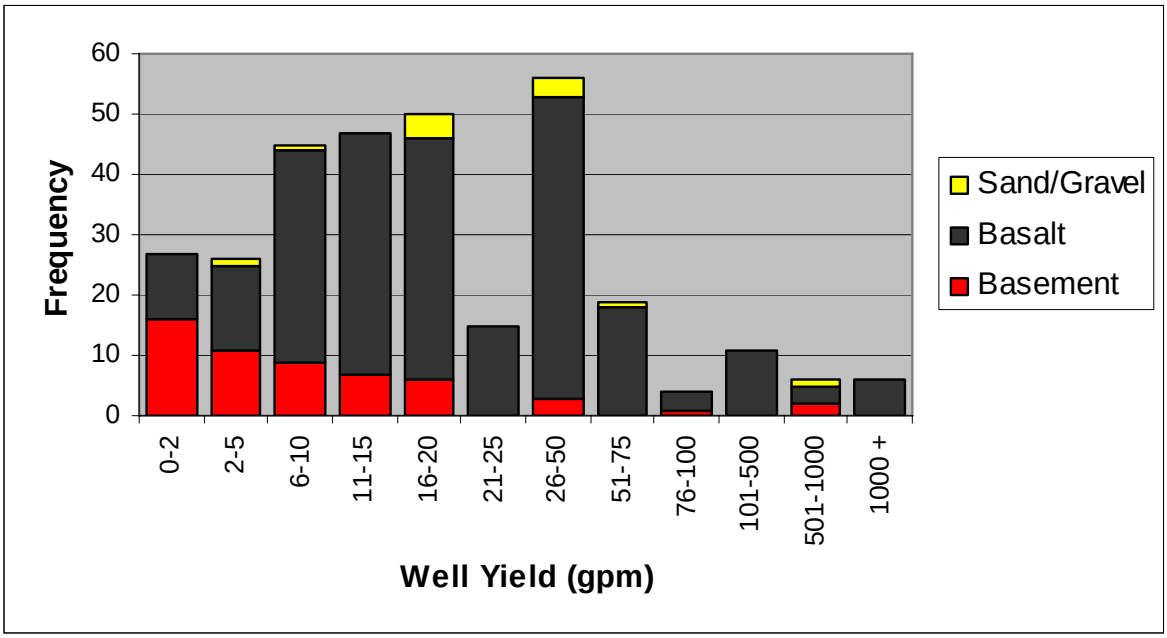
Figure 5 presents a GIS map of the static water spatial variation throughout the watershed. The map represents the static water level in all hydrogeologic units within the watershed. The map represents a generalized interpretation of the potential depth to groundwater after completion of a well. This information is useful to water users by allowing a generalized interpretation of the pump infrastructure which will be required to withdraw groundwater. As stated previously, this information should be used in conjunction with the total depth of the well.

Groundwater Yields in Wells

Groundwater well yields are the most difficult groundwater attribute to predict. Many factors can directly influence the water availability within a certain type of aquifer. Conditions such as permeability, porosity, structural controls, potential boundary conditions (e.g. valley walls in an unconfined aquifer), and facies changes (e.g. a basalt interflow of sand and gravel pinching out) will directly influence the potential yield of any given aquifer. For this task under this project, the well yields documented by the drillers at the time of drilling were used in the analysis. It should be noted that these values are yields prior to any sustained usage of the aquifer. Also, when utilizing data collected by others (e.g. air test estimates given by drillers on well logs), the quality of the well yield data is of great concern. These estimates are not based on detailed hydrogeologic studies or sustained pump tests. Past experience by the project team hydrogeologists show that the well log yields are not always accurate due to a number of factors. A primary estimate of well yield by drillers is conducting an air test, a method of using compressed air to force water out of the well, which is not considered as accurate as a pump test, and there may be an incentive for well drillers to overestimate the well yield.

To test a well yield more accurately, a minimum 4-hour pump test should be completed. The majority of wells in Lincoln County did not have an extended yield test conducted as it is not required for any building permits, as in some other counties. Therefore, the analysis of recorded well yields used in this study must be used with some limitations.

Graph 4 presents a summary of the well yields recorded on well logs within WRIA 53. As shown on this graph, there is a large variation in well yields from basalt aquifers. However, the majority of basalt aquifers yield approximately six to 75 gpm. Sand and gravel aquifers within the study area will generally yield approximately 16 to 50 gpm. Granite aquifers typically are low yielding, a result of water being derived from a fracture flow system. Fractured granite aquifers in the study area typically yield less than 20 gpm.



Graph 4: Distribution of Groundwater Yield of Wells in Study Area

The GIS analysis attempted to estimate potential aquifer yields across the watershed with the available data. The data set was configured to draw an approximate polygon around the extent of a specific hydrogeologic system, and only compute a spatial variation for the specific hydrogeologic unit within that polygon. Figure 6 shows the spatial variation of well yields throughout the watershed. As shown on the map, the lowest yielding aquifers are generally going to occur in the northwestern extent of the watershed, where the basement granitic rocks occur. Higher yield aquifers typically occur where wells are withdrawing groundwater from basalts in the central and southern portions of the watershed.

This information can be used by the watershed group and County Planning Department to begin to estimate well density and land use throughout the watershed. For example, in the areas where aquifers predominantly yield less than 10 gpm, it may be prudent to develop codes for a less development density through larger lot sizes.

Task 3 - Stream flow

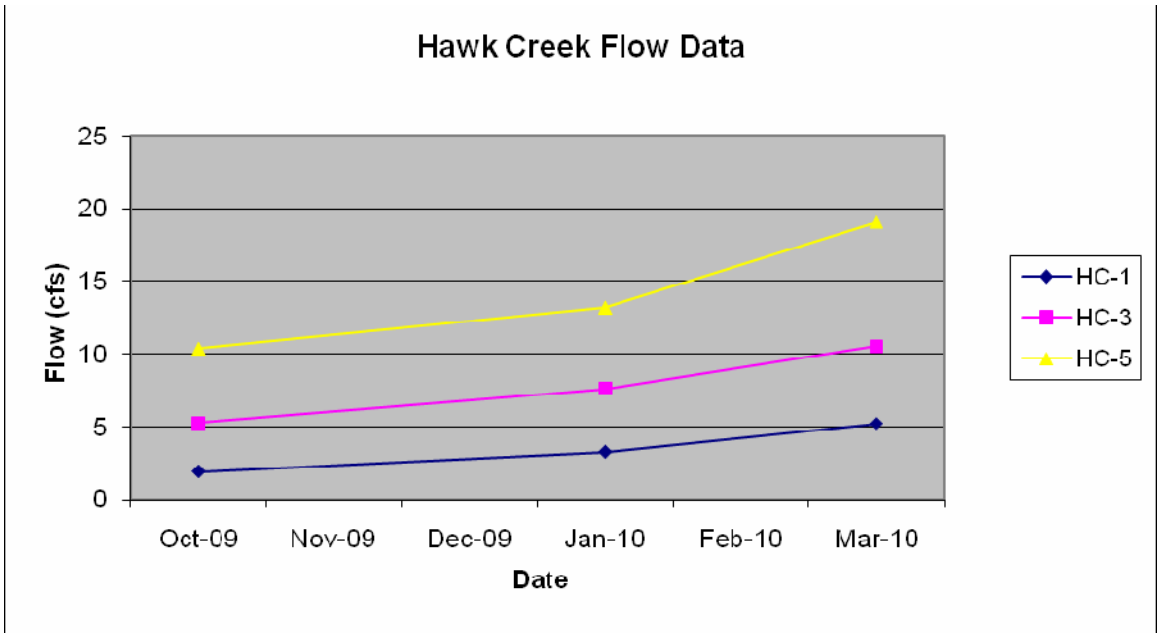
During the Phase 2 watershed planning effort, Ecology conducted some stream flow monitoring in Hawk Creek on behalf of the planning unit. Stream flow measurements were collected on October 14th, 2009, January 11th, 2010, and March 30th, 2010. The planning unit identified six potential stream monitoring locations on Hawk Creek during the

initial Phase 2 planning effort. Due to land access and stream morphology, Ecology was able to collect flow measurements at three of these locations (HC-1, HC-3, and HC-5). Locations of the monitoring stations are shown on Figure 7.

Ecology used a FlowTracker sensor to monitor flow velocity in the stream. Field data was then entered into a CPU Firmware Version 2.11. Table 3 presents a summary of the flow monitoring results collected to date. Data summery sheets are presented in Attachment A.

Table 3: Summary of Stream Flow Monitoring in Hawk Creek (all flows in cubic feet per second – cfs)			
Date	***HC-1***	***HC-3***	***HC-5***
03/30/2010	5.2151	10.5198	19.0950
01/11/2010	3.2590	7.5975	13.1940
10/14/2009	1.9122	5.2510	10.3710

As shown in Table 3 and in Graph 5, Hawk Creek appears to be a gaining stream from near the headwaters to station HC-5 which is at the bridge on Miles Creston Road. During all three monitoring dates, the stream appears to proportionally gain from each station to the next. It should be noted that all measurements collected to date have been outside of the irrigation season. The planning unit will determine whether to continue monitoring for another year.



Graph 5: Graphical Presentation of Flow Data from Hawk Creek

Task 4 – Groundwater Monitoring Program

The WRIA 53 Planning Unit also developed a groundwater level monitoring program in order to develop a database of groundwater level elevations throughout the watershed. The Lincoln County Conservation District (LCCD) is conducting the monitoring program through June 2011. The Lincoln County Planning Department solicited landowners in WRIA 53 by sending out a letter request to approximately 700 property owners in the WRIA 53 watershed. The County received responses from approximately 50 landowners, of which 70 wells were evaluated to determine if they were suitable for the groundwater level monitoring program. A list encompassing information of all the wells reviewed is presented in Attachment B. After review of the well information, property owners were requested to sign an access agreement to monitor wells. The Planning Unit and Conservation District was granted access to sixty (60) wells. Of these wells, 47 were suitable to collect groundwater level measurements. It should be noted that additional wells are being sought and added to the monitoring program as the project progresses. Figure 8 presents a map showing the location of wells that were evaluated for the study and wells that are currently being monitored for the project.

The LCCD began monitoring water levels in some wells in December 2009. An attempt is made to collect groundwater levels every six to eight weeks. To date, there are only 22 wells that have three or four measurements collected. A summary of data collected to date is presented in Appendix B. Data has only been collected for several months on the wells, and no significant trends have been identified to date. No data has been collected during the irrigation season, and defining seasonal trends will be more effective after a full year of monitoring. The project has been approved for funding through June 2011, and a summary report will be completed at that time.

Task 5 – Evaluation of potential development in WRIA 53 (Lincoln County portion only)

The purpose of Task 5 was to estimate the amount of potential future development in WRIA 53, given the current development standards; this is often known as a build out analysis. Since Lincoln County is not required to plan fully under the Growth Management Act (GMA), there is not an official minimum lot size. Lot size is driven by the ability to provide on-site water and septic systems. Five (5) and ten (10) acre lots are very popular in Lincoln County, therefore that is what was used in this evaluation. The following is how the final numbers were calculated (using a GIS):

1. All parcels within WRIA 53 were selected.
2. Removed parcels that were/could be served by a water purveyor.
3. For the remaining parcels, the following information was collected:
    a. Total acreage
    b. Value of improvements
    c. Utilization (effective parcel size/density)
4. Parcels were then separated into 5 groups:
    a. Parcels with an effective size at or below the study density (utilization less than 2) and have greater than $5,000 of improvements.
    b. Parcels with utilization less than 2 and have less than $5,000 of improvements.
    c. Parcels with utilization greater than 2 and greater than $5,000 of improvements.
    d. Parcels with utilization greater than 2 and less than $5,000 of improvements.
    e. Public Lands.
5. Final calculation was:

Potential Residential Units = (Type b parcels) + (Type c parcel utilization – 1) + (Type d parcels utilization)

Table 4 shows the results of the build out analysis, using the two different parcel sizes.

Table 4: WRIA 53 Build Out Analysis

Parcel Type	***Potential Residential Units (based on a 5 acre average)***	***Potential Residential Units (based on a 10 acre average)***
Undeveloped parcels without further subdivision potential	552	734
Undeveloped parcels that can be subdivided	26,487	12,989
Developed parcels that can be subdivided further	3,039	2,667
Total	**30,078**	**16,390**

The significance of this analysis is that each of these residential units could potentially have a separate well, potentially placing strain on the groundwater supply. One goal of this Groundwater Inventory Assessment is to identify areas with lower water availability so that the zoning and development regulations can be amended to reduce densities in areas of limited water and encourage in areas with more water and/or

water systems. The build out analysis shows that the majority of potential units come from undeveloped parcels, which most are currently in timber, farming or grazing zones.

Project Data Outputs, Conclusions and Recommendations

Raster Images

Well yield analysis
Well total depth analysis
Well static water level analysis

Map Layers (shape file format)

WRIA53_wells.shp *(this layer is used for many maps with different symbology)*
WRIA53granite_wells.shp
WRIA53basalt_wells.shp
WRIA53sediment_wells.shp

Maps

Figure 1: WRIA 53 Location and Topography (color hillshade)
Figure 2: Groundwater Wells by year drilled & geology
Figure 3: Total Depth (ft) Spatial Variation
Figure 4: Groundwater Well Aquifer Type Delineation
Figure 5: Static Water Level (ft) Spatial Variation
Figure 6: Well Yield (gpm) Spatial Variation
Figure 7: Location of Hawk Creek Stream Monitoring Locations
Figure 8: Location of Groundwater Wells being monitored

Next Steps

As stated in the introduction, it is a priority of the WRIA 53 Planning Unit to develop a complete understanding of the aquifer conditions in the watershed in order to develop appropriate land management alternatives for sustainable water supplies. This project developed the preliminary databases to initiate this goal. This project allows the Planning Unit to manage these datasets and tools to better understand the hydrogeology of the watershed. Through these data sets, the group can further delineate the spatial distribution of the permit exempt wells and an understanding of how this distribution through well characteristics (total depth, yields, and static water levels) may affect the sustainability of groundwater for the WRIA 53 water users. This may result in additional planning efforts to restrain growth in areas of limited water availability.

The following are recommendations that the Planning Unit should conduct in order to meet the goals and objectives of sustainable water supplies:

1) Continue the groundwater level monitoring program;
2) Continue development of the Hawk Creek surface water flow database;
3) Further evaluate domestic water demand patterns, and correlation to lot size development;
4) Evaluate residential water demands;
5) Continue development of the hydrogeologic database, specifically by encouraging private land owners to provide results of their pump tests to the County.