***Introduction:***

The following report presents the West Plains Hydrogeologic Database Project, and includes a project description, a review of the database development process, a description of the preliminary data analysis and a description of the data products. This project is part of Water Resource Inventory Area (WRIA) 54 Watershed Plan implementation, and was funded by Washington Department of Ecology (Ecology) Grant G1000326.

***Project Description:***

The main water supply for the West Plains area of Spokane County is the aquifer system within the lava flows and interbedded sediments of the Columbia River Basalt Group (CRBG). Hydrologists from the Spokane Office, Washington State Department of Ecology, have documented groundwater level declines, ranging from 15 to 120 feet, in the West Plains CRBG aquifers in several areas over the last decade. This data, coupled with the numerous wells reported to have been significantly deepened over the past several decades, strongly indicate that groundwater depletion is occurring and that the current rate of groundwater withdrawal in some areas of the West Plains is not sustainable. This issue was addressed in both the WRIA 54 Watershed Plan and Detailed Implementation Plan (DIP). Specifically the DIP identifies a West Plains Hydrogeology Study as a high priority immediate, term project. The West Plains Hydrogeologic database project is the initial phase of that study.

The objective of this project was to develop a database of 1,000 water well reports, which is about 20% of the existing well logs available from Ecology, within the West Plains study area (Figure 1), and perform a preliminary data analysis.

Each water well report, or database record, includes the following data (if available):

- Location – The x and y coordinates of each water well;
- Elevation – The elevation at the location of each water well;
- Lithologic Description – Description of the material encountered during drilling (e.g. sand, gravel, clay, basalt, granite, etc) and the depth at which the material was encountered.
- Stratigraphic Interpretation – Grouping of lithologic data into stratigraphic units (e.g. unconsolidated surficial deposits, basalt formations, interbedded sediments, extensive clay horizons which include altered basalt, and basement which includes older sedimentary, metamorphic and granitic rocks);
- Water Bearing Units – Description of the depth at which groundwater was encountered;
- Static Water Level – The depth to groundwater after the well is in equilibrium with the surrounding formations;
- Well Yield – The rate of groundwater withdrawal that can be sustained for an extended period of time, in gallons per minute (gpm); and
- Well Construction Details – Description of well construction including depth of well casing, perforations, or screens.

The following analyses were then performed utilizing the database :

- Development of geologic cross sections;
- Development of the surface topography and thickness of each stratigraphic unit;
- Development of a groundwater level potentiometric surface; and
- Development of well yield estimate maps.

***Database Development:***

Development of the database was done in four steps: 1) data gathering, 2) development of database structure and nomenclature, 3) data entry, and 4) data transfer and review. Most of the data gathered were from water wells located in the prairie portion of the West Plains which is underlain by the CRBG. This is because the major water producing aquifer horizon is known to occur between the Wanapum and underlying Grande Ronde Basalt, although other productive water horizons occur between the lava flows within these two formations. Basement rocks which underlie the CRBG have no interconnected aquifer system and generally produce low yield wells.

The first step in the database development was to identify the data sources. All of the data within the database was gathered from water well reports from Ecology's well log database with the exception of location and elevation. The precision of well location data included on water well reports, at best, is limited to a ¼ , ¼ section (40 acres) resolution. This level of precision often leads to errors in geologic interpretations. Therefore, more precise location data was collected.

The primary source of the well location data for the West Plains was selected from an extensive database being developed by Dr. Linda McCollum that includes the latitude and longitude of each wellhead located, gathered in the field with a GPS unit and later matched to an existing water well report. The secondary source of location data was from parcel and/or well address data, either included on the existing water well reports or added by Dr. McCollum from an ownership search of the Spokane Land Records located on the Washington State Digital Archives http://www.digitalarchives.wa.gov/Collections/TitleInfo/4 . Well coordinates were derived from that data in conjunction with existing aerial photo coverage. The elevation of each well was derived from the location data and a USGS 20 meter Digital Elevation Model (DEM).

The second step in the database development was to create a database structure and nomenclature. Each water well report includes a lithologic description. Lithologic descriptions vary widely between drillers and this disparity can be problematic for data analysis, interpretation and visualization. Therefore a standard lithologic nomenclature was developed that represents the materials found within the study area (Figure 1). Standard geologic descriptions and nomenclature were also developed for the stratigraphic units, aquifers, and well construction materials found within the study area. Table 1 shows the nomenclature used here for each data type.

The third step in the database development was a review of the 5,500 water well reports in the West Plains study area available from the Ecology website, including Dr. McCollum's updated location information for 4,065 of these water well reports. Mike Hamilton, a retired United States Bureau of Mines geologist with extensive experience within the study area, then selected 1,000 wells for data entry into an Excel Spreadsheet based on the following criteria:

1. Quality of location data available for the well i.e. field location with GPS vs. location from parcel numbers, land ownership records, etc.
2. Quality of well log descriptions with priority given to the deeper wells.
3. Only a few representative wells were selected within the densely populated sections of the study area.Figures 2 through 8 show the location of each database well.

Once a well was selected the data was entered into an Excel spreadsheet. Each depth interval with a well driller lithologic description was keyed to a standard database lithologic name. The well lithology was then interpreted to identify the depth intervals for each stratigraphic unit. Each groundwater bearing layer was designated as an aquifer horizon. This data along with well ID, location, elevation, well yield, static water level, date of well completion, and well construction was entered into an Excel spreadsheet. In addition to the standard lithologic names, a secondary field with the actual driller description was included. The 6 digit Ecology Well Log ID was utilized as the primary identifier for each database entry. This allows for easy reference to the original well log through Ecology's online well log database (http://apps.ecy.wa.gov/welllog/).

The fourth step in database development was the transfer of the data into the Rockworks program followed by a complete data review. *Rockworks,* a commercially available geological data management, analysis, and visualization software package*,* is designed to import data from an Excel spreadsheet. This step was completed by Spokane County Water Resources staff. During the importation process all typographical errors were corrected. Once the data was imported into *Rockworks* each well log was reviewed. *Rockworks* allows for review of data of one well within the context of well logs within the same vicinity, so depths of each stratigraphic unit were reviewed and minor corrections were made based on the data from surrounding wells. Also the static groundwater level was assigned to each aquifer based on the stratigraphic unit each well was completed in and which stratigraphic units had groundwater bearing layers.

Table 1 - Database Nomenclature

| Lithology | | Stratigraphy | Aquifer | Well Construction |
|---|---|---|---|---|
| Soil or overburden | Basalt, soft or decomposed | Unconsolidated | Static Groundwater Level | Casing |
| Sand, unconsolidated | Basalt, porous or vesicular | Basalt-Wanapum | Upper Sand and Gravel | Perforations |
| Gravel, unconsolidated | Basalt w/ clay or shale | Upper Latah Interbed | Basalt | Screen |
| Clay, unconsolidated | Sand, interbed | Basalt-Grande Ronde | Basement | |
| Sand and gravel, unconsolidated | Clay, interbed | Lower Latah Interbed | | |
| Basalt debris, unconsolidated | Gravel, interbed | Basement | | |
| Sand, gravel, and clay unconsolidated | Sand and gravel, interbed | | | |
| Sand and clay unconsolidated | Sand, gravel, clay, interbed | | | |
| Basalt, hard | Clay, sand, interbed | | | |
| Basalt, fractured | Basement rock | | | |
| Basalt, medium | | | | |

***Preliminary Database Analysis:***

Preliminary analysis of the data included development of the following:

- Three dimensional stratigraphic model;
- Geologic cross sections;
- Potentiometric groundwater surface maps for the Wanapum and Grande Ronde Basalt formations; and
- Spatial distribution of well yield for the Wanapum and Grande Ronde Basalt formations.

The three dimensional stratigraphic model (model) is a representation of the elevation and thickness of each stratigraphic unit throughout the study area. Six stratigraphic units were identified for the study area and are listed in Table 1. At each well the lithology was interpreted to define the top and bottom elevation of each stratigraphic unit. Inverse distance weighted interpolation was used to estimate the elevation of each stratigraphic unit between the known data points. The model was used to generate stratigraphic unit thickness maps for each formation except the basement formation (Figures 9-13). A topographic map of the surface of the basement stratigraphic unit was also developed (Figure 14).

Thirty one geologic cross sections were developed for this project using the Rockworks program. The geologic cross sections generated from this program have not been checked against existing geologic maps and therefore may differ greatly from the published geologic cross sections. Figure 19 shows the location of each cross section. The cross section includes the modeled stratigraphy, and each well along the cross section. At each well the lithology, stratigraphy, aquifer data, and well construction are displayed. The lithology displayed in each well does not always exactly match the modeled stratigraphy. The stratigraphy was modeled so that it attempted to match known data points and was fairly consistent with the present geologic understanding of the study area, such as the nature of basalt formations, sequence of major stratigraphic units, or extent of clay layers, etc. This resulted in the first attempt at a graphic representation of the basic stratigraphy at the scale of the West Plains study area, although the model does not match each of the data points.

Potentiometric groundwater surface maps were generated for both the Wanapum and Grande Ronde Basalt formations and are shown in Figures 15 and 16. As described in the Database Development section, the static groundwater level in each well was assigned to a stratigraphic unit; 491 occurrences were assigned to the Grande Ronde Basalt unit and 368 occurrences were assigned to the Wanapum Basalt unit. The static groundwater level assigned to a particular unit was used to develop a ground water elevation map. The maps were also constrained by the extent of the stratigraphic unit and the elevation of the ground surface in relation to the estimated groundwater surface elevation.

A well yield estimate map, in units of gallon per minute, was developed for both the Wanapum and Grande Ronde Basalt formations and is shown in Figures 17 and 18. Similar to the groundwater surface maps, the well yields for a particular unit were interpolated to create estimates of well yields throughout the study area.

***Recommended Future Work***

The next step that is recommended in the West Plains Hydrogeologic Study is the collection of current groundwater data including groundwater elevation and geochemical data. The West Plains Hydrogeologic Database includes data collected from wells drilled throughout the year

from the period 1955 to 2009, and while this is not an issue for geologic data, it is for groundwater elevation data. Groundwater elevation can change depending on the time of year the well was drilled, precipitation in years preceding when the well was drilled, and changes in withdrawals and return flows in the vicinity of the well location.

The groundwater elevation data currently in the West Plains Hydrogeologic Database is suitable for identifying general trends in hydraulic gradients and the general potentiometric surface of groundwater found in each stratigraphic unit. Collection of the following data will further the understanding of the groundwater flow regime within the study area:

> ***Synoptic Water Level Measurement:*** A synoptic water level measurement is the collection of water levels in multiple wells within a relatively short period of time. This type of measurement provides a snapshot of the hydraulic heads in an aquifer and is useful for mapping the potentiometric ground water surface, determining hydraulic gradients, and defining the physical boundaries of an aquifer (*Ground-Water-Level Monitoring and the Importance of Long-Term Water-Level Data, USGS 2001*).
>
> ***Monthly Water Level Measurement:*** A subset of the wells included in the synoptic water level measurement should be monitored monthly to begin to identify annual patterns in groundwater level changes.
>
> ***Continuous Water Level Measurements:*** A subset of wells included in the monthly measurements should be monitored with data loggers that measure water level and temperature every hour. This data can be used to further identify annual patterns in groundwater level changes and identify responses to precipitation events, spring runoff, and connection to surface water bodies.

The wells in the water level monitoring program should represent the study area spatially and include wells completed in each stratigraphic unit. The number of wells included in the water level monitoring program will be dependent on several factors:

- The quantity and locations of wells with suitable construction;
- The willingness of well owners to participate in the monitoring program; and
- The available budget.

In addition to a water level monitoring program, geochemical data can add to the understanding of the regional flow system. Geochemical data such as inorganic major and minor ions, stable isotopes, tritium, and carbon-14 can provide insight on the source and age of groundwater recharge, the connection of aquifers within different stratigraphic units, and the connection of ground and surface water.

***Data Products***

The following is a description of the data products developed for this project.

**Data Product Name:** *West Plains Hydrogeologic Database Data Points*
**File Name:** *Final_West_Plains_Hydrogeologic_Database.shp*
**File Type:** *Shape*
**Description:** *GIS data set that includes all data points included in the West Plains Hydrogeologic Database. This file includes the following attributes:*

- ***Well_ID****: Six digit Ecology Well ID*
- ***Easting****: x coordinate in feet, NAD 1983 UTM Zone 11N*
- ***Northing****: y coordinate in feet, NAD 1983 UTM Zone 11N*
- ***Elevation****: Land surface elevation at well location*
- ***Aquifer****: Assigned aquifer based on interpreted stratigraphy, depth of well completion and location of groundwater bearing zones. Data values are unconsolidated, Wanapum, Grande Ronde, Latah, basement, or not defined*
- ***Yield****: Well yield in gallons per minute (gpm) reported on water well report*
- ***Locate****: Method of well locations. 1 = field located GPS, 2 = parcel number and aerial photo, and 3 = parcel number.*
- ***comp_date:*** *Completion date reported on the water well report*
- ***well_depth:*** *Completed well depth reported on water well report*
- ***static_wl_*** *= Static groundwater level in feet below ground surface reported on water well report*
- ***wl_elevation*** *= Static groundwater level subtracted from elevation.*
- ***top_uncs*** *= Elevation of the top of the unconsolidated stratigraphic layer.*
- ***base_uncs*** *= Elevation of the bottom of the unconsolidated stratigraphic layer.*
- ***thk_uncs*** *= Thickness in feet of the unconsolidated stratigraphic layer.*
- ***top_wnpn*** *= Elevation of the top of the Wanapum Basalt stratigraphic layer.*
- ***base_wnpn*** *= Elevation of the bottom of the Wanapum Basalt stratigraphic layer.*
- ***thk_wnpn*** *= Thickness in feet of the Wanapum Basalt stratigraphic layer.*
- ***top_latah1*** *= Elevation of the top of the upper Latah interbed stratigraphic layer.*
- ***base_latah*** *= Elevation of the bottom of the upper Latah interbed stratigraphic layer.*
- ***thk_latah1*** *= Thickness in feet of the upper Latah interbed stratigraphic layer.*
- ***top_grnrd*** *= Elevation of the top of the Grande Ronde Basalt stratigraphic layer.*
- ***base_grnrd*** *= Elevation of the bottom of the Grande Ronde Basalt stratigraphic layer.*
- ***thk_grn****rd = Thickness in feet of the Grande Ronde Basalt stratigraphic layer.*
- ***top_Latah2*** *= Elevation of the top of the lower Latah interbed stratigraphic layer.*
- ***base_lat_1*** *= Elevation of the bottom of the lower Latah interbed stratigraphic layer.*
- ***thk_latah2*** *= Thickness in feet of the lower Latah interbed stratigraphic layer.*
- ***top bsmt*** *= Elevation of the top of the basement stratigraphic layer.*
- ***base_bsmt*** *= Elevation of the bottom of the basement stratigraphic layer.*
- ***thk_bsmt*** *= Thickness in feet of the basement stratigraphic layer.*

In addition to the data developed for this project this file includes well data from two United States Geologic Service (USGS) data sets: 1) Columbia Plateau Regional Aquifer Systems Analysis (RASA) and, 2) USGS National Water Information Systems (NWIS). These wells are denoted by C_PLAT. Data for these well only include location, elevation, and stratigraphic data.

**Data Product Name:** *West Plains Hydrogeologic Database Data Points Spreadsheet*
**File Name:** *Final_West Plains Hydrogeologic Database Spreadsheet.xlxs*
**File Type:** *Excel 2007*
**Description:** *Excel spreadsheet that includes all of the data points and attributes that are in the Final West Plains Hydrogeologic Database GIS file.*

**Data Product Name:** *West Plains Hydrogeologic Database Raster Data Set*

**File Name:** *West Plains Hydrogeologic Database Raster Data Set File Folder*
**File Type:** *ESRI File System Raster*
**Description:** *The following files are raster data sets representing the listed feature. All files are at a 500 ft grid spacing.*

- ***bsmt_tp**: Basement top elevation – grid cell values are the interpolated elevation of the top of the basement stratigraphic unit.*
- ***gnrnd_top**: Grande Ronde Basalt top elevation – grid cell values are the interpolated elevation of the top of the Grande Ronde Basalt unit.*
- ***grndrd_thk**: Grande Ronde Basalt thickness – grid cell values are the thickness of the Grande Ronde Basalt stratigraphic unit.*
- ***grndrnd_yld:** Grande Ronde Basalt well yield – grid cell values are the estimated well yield in gallons per minute derived from an interpolation of actual well yields reported for wells completed in and/or drawing from the Grande Ronde stratigraphic unit.*
- ***grrd_wl_elev:** Grande Ronde Basalt groundwater level elevation – grid cell values are the interpolated potentiometric water surface elevation for the Grande Ronde Basalt stratigraphic unit.*
- ***lw_latah_top:** Lower Latah Interbed top elevation – grid cell values are the interpolated elevation of the top of the Lower Latah Interbed stratigraphic unit.*
- ***lw_latah_thk:** Lower Latah Interbed thickness – grid cell values are the thickness of the Lower Latah Interbed stratigraphic unit.*
- ***uncs_top:** Unconsolidated top elevation – grid cell values are the interpolated elevation of the top of the unconsolidated stratigraphic unit.*
- ***uncs_thk:** Unconsolidated thickness – grid cell values are the thickness of the Unconsolidated stratigraphic unit.*
- ***up_latah_top:** Upper Latah Interbed top elevation – grid cell values are the interpolated elevation of the top of the Upper Latah Interbed stratigraphic unit.*
- ***up_latah_thk**: Upper Latah Interbed thickness – grid cell values are the thickness of the Upper Latah Interbed stratigraphic unit.*
- ***wnpn_top:** Wanapum Basalt top elevation – grid cell values are the interpolated elevation of the top of the Wanapum Basalt unit.*
- ***wnpn_thk:** Wanapum Basalt thickness – grid cell values are the thickness of the Wanapum Basalt unit.*
- ***wanapum_yld**: Wanapum Basalt well yield – grid cell values are the estimated well yield in gallons per minute derived from an interpolation of actual well yields reported for wells completed in and/or drawing from the Wanapum Basalt stratigraphic unit.*
- ***wnpm_wl_elev**: Wanapum Basalt water level elevation – grid cell values are the interpolated potentiometric groundwater surface elevation for the Wanapum Basalt stratigraphic unit.*

**Data Product Name:** *McCollum West Plains Water Well Locations*
**File Name:** *McCollum West Plains Well Location Database.xlxs*
**File Type:** *Excel 2007*
**Description:** *Database of West Plains water well locations were supplied by Dr. Linda McCollum under contract.*

**Data Product Name:** *Rockworks West Plains Hydrogeologic Database*
**File Name:** *West Plains Hydrogeologic Database Project*

**File Type:** *Rockworks 15*
**Description:** *Rockworks Hydrogeologic database. Rockworks utilizes a Microsoft Access database as the foundation for its database. The Rockworks database is an.mdb file and can be viewed in Microsoft Access.*

**Data Product Name:** *Google Earth-West Plains Hydrogeologic Database*
**File Name:** *west_plains_hydrogeo_database.kmz*
**File Type:** *Google Earth .kmz*
**Description:** *This file displays the location of each database point within Google Earth. Each point contains lithologic, stratigraphic, and aquifer data.*