CHAPTER FIVE

SUMMARY AND CONCLUSIONS

Geological Characterization Summary

The geology of the MWWVS was characterized through mapping, creation of cross sections, and fracture characterization. The results of this study were combined with results from previous studies to provide a summary of the known geology of the area. Rocks that are exposed in the area range from Proterozoic granite, gneiss and schist; Paleozoic limestone; Tertiary basalt, andesite and conglomerate; and Quaternary alluvium.

Proterozoic granite is exposed in several regions within the study area (Plate 1). Granite Mountain represents a 1.72 Ga granite pluton that was emplaced during the Proterozoic (Dewitt 1999). The location of the apex of the granite pluton is at the crest of Granite Mountain (Figure 10) as indicated by the fracture orientation and the relief of the granite complex (Larsson 1976). The absolute ages provided by the granite pre-date the Yavapai Series metamorphic complex, which has been dated at 1.61 Ga +/- 85 m.y. using Rb-Sr dating (Lanphere 1968).

The Tertiary was also a time of tectonic activity for the Mint Wash and Williamson Valley area. Extensional tectonics occurred throughout the southwestern United States during middle Tertiary time. The Mint Wash and Williamson Valley area is located within the Transition Zone, an area that accomodated the transition from the highly extended Basin and Range physiographic province to the un-extended, Colorado Plateau physiographic province. The extensional tectonics within the area are represented by the inferred normal faults indicated throughout the study area (Plate 1). Most of the contacts at these faults are Tertiary deposits in contact with Proterozoic or Paleozoic rocks.

Depositional environments include a marine depositional environment represented by the Devonian Martin Formation and the Mississippian Redwall Limestone in the northeast portion of the study area (Plate 1). There are no Paleozoic deposits throughout the rest of the study area.

Sedimentary and igneous deposition occurred during the Tertiary within the study area. The Paulden Formation and the Perkinsville unit are Tertiary fluvial conglomerates which cover most of the study area (Plate 1) (Buren 1992). Tertiary igneous rocks include latite and basalt concentrated along the eastern and southern boundaries of the study area (Plate 1).

In summary, the geologic history of the area includes the emplacement of a granite pluton with subsequent metamorphism to the north and west of the granite pluton creating the Yavapai Series metamorphic complex during the Proterozoic Eon. The Paleozoic Era was characterized with a marine environment during the Devonian and Mississippian Periods in the northeast corner of the study area. The Mesozoic Era is not represented in the Mint Wash and

Williamson Valley area, and therefore was either a non-depositional environment, the section is buried under Cenozoic deposits, or subsequent erosion has removed the Mesozoic section.

The Tertiary was a time of deposition and tectonic activity. A fluvial environment was present throughout most of the field area. Extensional tectonics were responsible for the creation of normal faults throughout the study area (Plate 1), and is assumed to be the mechanism responsible for localized volcanic deposits of latite and basalt. The Quaternary Period has had limited deposition, with deposits along ephemeral and perennial washes, with no evidence of continued tectonic activity.

Hydrogeological Characterization Summary

The ground-water system of the Mint Wash and Williamson Valley area was delineated into three distinct aquifers. The potentiometric surface map (Figure 19) shows radial flow from Granite Mountain into at least three aquifers.

The aquifer to the southeast of Granite Mountain is the Granite Basin Aquifer (Figure 36), and flows from Granite Mountain towards the southeast where it is assumed to discharge into the upper Little Chino Sub-basin. The hydrostratigraphy includes the Mint Valley Basalt overlaying Prescott Granite in the southern part of the aquifer and Paulden Conglomerate in the northern end of the aquifer. The Mint Valley unit is unconfined. The Prescott Granite and the Paulden Conglomerate may be confined due to the overlaying basalt, which has a lower average hydraulic conductivity. The bottom of the granite aquifer is assumed to be 450 feet due to the overburden weight of the rock sealing the fractures to fluid flow, and 900 feet in the lower half where Tertiary conglomerate is present (Figure 10). Aquifer properties of the Granite Basin Aquifer were estimated at a hydraulic conductivity of 88 meters/year and a storage coefficient of 0.0004 (Table 3) using average specific capacity values of wells drilled into the aquifer (Wellendorf 2000). The aquifer is assumed to be low yield relative to the other aquifers in the MWWVS due to the aquifer property values, and the small watershed area represented by the southeastern slope of Granite Mountain.

The aquifer that is to the east of the granite complex is the Mint Wash Aquifer (Figure 36), in which ground water flows from Granite Mountain toward the east and northeast, where it is assumed to discharge into the mid Little Chino Sub-basin. The hydrostratigraphy includes Prescott Granite at the upper end of the aquifer, with Paulden Conglomerate overlaying Prescott Granite at the lower end. The bottom confining layer is assumed to be 450 feet at the upper half based on the same assumptions that were established for the Granite Basin Aquifer, and 900 feet at the lower half where the conglomerate is present (Plate 1). The aquifer properties were estimated using aquifer tests. Hydraulic conductivity was estimated to be 460 meters/year. There were no valid pumping tests to estimate a value for a storage coefficient. The aquifer is assumed to produce a higher yield than the Hobbs Aquifer due to the larger surface area of the aquifer, a larger saturated thickness due to the shallow water table, and the larger watershed represented by the concave east side of Granite Mountain.

The aquifer that comprises most of the study area is the Las Vegas Aquifer, to the west and north of Granite Mountain (Figure 36). Ground water in the Las Vegas Aquifer flows from Granite Mountain and the Santa Maria Mountains towards the north to the confluence of Williamson Valley with Big Chino Valley. Ground-water flow then proceeds towards the east, to the downstream end of the Little Chino Sub-basin. The hydrostratigraphy of the Las Vegas Aquifer includes Paulden Conglomerate overlaying an assumed basement of Prescott Granite. The Paulden Conglomerate is assumed to be 900 feet thick based on preliminary interpretation of aero-magnetic data (Woodhouse 2000). The underlying Prescott Granite is assumed to be the basement due to the weight of the overriding rock sealing any ground-water conduits. Aquifer parameters were estimated using an aquifer well test within the Las Vegas Aquifer. Hydraulic conductivity was estimated to be 990 meters/year. There was insufficient data to estimate a value for the storage coefficient. The Las Vegas aquifer produces the highest yield of the three aquifers within the MWWVS. The Las Vegas Aquifer is volumetrically the largest aquifer within the MWWVS. The Las Vegas Aquifer has the largest watershed area of the MWWVS.

Ground-Water Flow Modeling Summary

The ground-water flow modeling study produced some predictive results that provide insight into the transient nature of the MWWVS. The steady-state model was calibrated to less than half (RMSE compared to head change across model area of 2.3%) of the RMSE required for the “good model” (Anderson and Woessner 1992) criteria (RMSE compared to head change across model area of 5%) with respect to measured versus calculated hydraulic head. The results of the steady-state calibration also produced a mass balance discrepancy that was over an order of magnitude less than the allowable discrepancy under the definition of a “good model”. The calibrated steady-state model results showed that recharge appears slightly more sensitive than hydraulic conductivity, and that model sensitivity is more zone-dependent than parameter-dependent. The sensitivity analyses were quantified by setting a limit of change of 5% of the total head change across the model that a parameter value could have on the RMSE of the model.

The steady-state calibration was validated with a transient calibration. The transient calibration simulated a one year period during which field data was collected for the site. Hydrographs were created for wells in each of the major hydrostratigraphic units. The hydrographs were used as a basis for the transient model calibration. Both the steady-state model and the transient model remained within the calibration criteria set forth by Anderson and Woessner (1992) for a “good model”.

Safe yield is a concept defined by ADWR (2000) as discharge through pumping not exceeding natural recharge. This was one of the scenarios simulated using the transient model.

The results indicate that safe yield would exceed sustainable yield by lowering the water table below land surface in areas that currently contain perennial or ephemeral springs, or lowering the water table below the root zone at areas that contain riparian vegetation, which is dependent on maintaining roots in the water table.

The transient model was run several times attempting to quantify a sustainable yield threshold. This yield would lower the water table to the limit of the sustainable yield criteria, but would not exceed a specified threshold. The results indicate that the sustainable yield threshold allows for approximately 15% more yield from the ground-water system then the current yield.

The calibrated transient model was extended to simulate the current condition 100 years into the future. The extension of the current condition for 100 years did not exceed the sustainable-yield threshold at any point during the extended simulation. This result implies that the current water use in the MWWVS is hydrologically and ecologically sustainable.

Water demand values for the American Ranch development were estimated in a study conducted by Clear Creek Associates (Glotfelty 2001). The water demand values presented in the Clear Creek study were added to the current water used scenario to simulate conditions including water use through the American Ranch development. Two of the five observation points within the Las Vegas Aquifer exceeded the 0.3 meter drawdown criteria established as an indicator of sustainable yield exceedance. The model indicates that the water use in the American Ranch Build Out scenario exceeds sustainable yield, but not safe yield.

Model Limitations

The model is limited by several aspects. The conceptual model was built on several values from literature as well as initial collection and analysis of data first obtained in this study. The calibration of the model to both the steady-state and transient conditions lends some confidence that the parameter values and grid setup for the model are adequate, but the lack of parameter and stress data was a limitation of the model. Data that can improve confidence in the model validation includes more aquifer tests, calculations of septic tank recharge, and a better definition of the bottom confining layer.

The predictive scenarios are limited by the lack of long-term hydrologic monitoring data. There are not enough data available to represent the climatic fluctuations of the area, nor are there exact data on the amount of water use. The predictive scenarios are more properly titled extended interpretive scenarios. Scenarios that simulate potential water use assuming that all of the remaining variables including climate are constant. Additional calibration is necessary to use this model for predictive purposes because of the influence of constant-head and general-head boundaries on the solution.

Implications

The predictive simulations imply that the MWWVS is within the sustainable yield criteria at present, and can allow for more water consumption. The scenarios also imply that the ADWR defined "safe yield" does not account for hydrological and ecological sustainability.

The model developed through this study should be used as a framework for future modeling efforts. This model was constructed from scratch, and needs to be revisited and updated in the future. The most powerful step in the use of a model of a natural system is a post-audit to quantify the accuracy of the model, and make improvements as more data becomes available.

Future Work

Several boundaries of the MWWVS need to be further developed. The bottom confining surface for all three aquifers needs to be better defined. Final interpretation of the aeromagnetic data should provide insight on the bottom confining surface of the Las Vegas Aquifer. Geophysics can possibly help determine the bottom confining surface for the Mint Wash and Granite Basin Aquifers. The boundary across the Sullivan Buttes needs to be better defined. The deep water table underneath the crest of the Sullivan Buttes has made it difficult to analyze ground-water flow across this boundary.

More aquifer tests would benefit the aquifer parameter estimation. The aquifer tests should be conducted with an observation well allowing for the estimation of storage coefficients. Several aquifer tests within each aquifer will allow for statistical validation of the aquifer parameter values used in the ground-water flow model. Variograms could be created using the results from several aquifer tests to set error limits to parameter values. The error limits would provide insight into the “goodness” of the calibrated parameter values.

Water level data, pumping averages, and precipitation data should be collected continually through several years to develop the predictive capabilities of a ground-water flow model. Data should be collected through at least one El Nino cycle to account for multi-annual climatic fluctuations. The model will need a post-audit of the transient condition to improve predictive modeling.

Individual models for each aquifer identified through this study should be produced. The models will be able to address smaller scale questions regarding ground-water flow and supply. Individual models for each aquifer should provide sensitivity analyses and sustainable yield estimates for each aquifer, which may vary between the aquifers.