GAM Run 10-007

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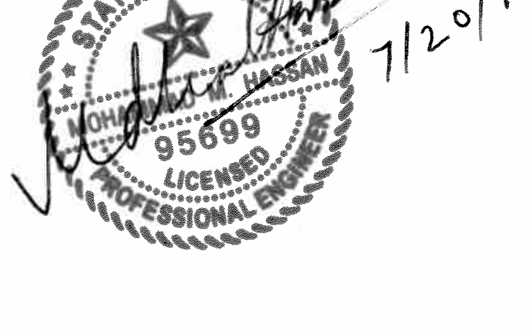

EXECUTIVE SUMMARY:

Texas State Water Code, Section 36.1071, Subsection (h), states that, in developing its groundwater management plan, a groundwater conservation district shall use groundwater availability modeling information provided by the Executive Administrator of the Texas Water Development Board in conjunction with any available site-specific information provided by the district for review and comment to the Executive Administrator. Information derived from groundwater availability models that shall be included in the groundwater management plan includes:

(1) the annual amount of recharge from precipitation to the groundwater resources within the district, if any;
(2) for each aquifer within the district, the annual volume of water that discharges from the aquifer to springs and any surface water bodies, including lakes, streams, and rivers; and
(3) the annual volume of flow into and out of the district within each aquifer and between aquifers in the district.

The purpose of this model run is to provide information to Gateway Groundwater Conservation District for its groundwater management plan. The groundwater management plan for the Gateway Groundwater Conservation District was due for approval by the Executive Administrator of the Texas Water Development Board before August 18, 2010.

This report discusses the method, assumptions, and results from model runs using the groundwater availability models for the Dockum Aquifer, the Ogallala Aquifer, the Seymour Aquifer, and the Blaine Aquifer. This report replaces GAM Run 08-57 (Oliver, 2008) due to a change of the district boundary since GAM Run 08-57 was completed. Tables 1 through 4 summarize the groundwater availability model data required by the statute, and figures 1 through 4 show the area of each model from which the values in Tables were extracted.

METHODS:

We ran the groundwater availability models for the Dockum Aquifer and (1) extracted water budgets for each year of the 1980 through 1997 period and (2) averaged the annual water budget values for recharge, surface water outflow, inflow to the district, outflow from the district, net inter-aquifer flow (upper), and net inter-aquifer flow (lower).

We ran the groundwater availability model for the Seymour and Blaine aquifers and (1) extracted water budgets for each month of the 1980 through 1999 period and (2) averaged the annual water budget values for recharge, surface water outflow, inflow to the district, outflow from the district, net inter-aquifer flow (upper), and net inter-aquifer flow (lower) for the portions of the Seymour and Blaine aquifers located within the district.

We ran the groundwater availability model for the southern portion of the Ogallala Aquifer and (1) extracted water budgets for each year of the 1980 through 2000 period and (2) averaged the annual water budget values for recharge, surface water outflow, inflow to the district, outflow from the district, net inter-aquifer flow (upper), and net inter-aquifer flow (lower) for the portions Ogallala Aquifer located within the district.

PARAMETERS AND ASSUMPTIONS:

Dockum Aquifer

- We used version 1.01 of the groundwater availability model for the Dockum Aquifer, as well as a modified groundwater model for the Dockum Aquifer described in Oliver and Hutchison (2008). Version 1.01 of the Dockum Aquifer model, described in Ewing and others (2008), was modified in order to more effectively simulate predictive conditions. See Oliver and Hutchison (2010) and Ewing and others (2008) for assumptions and limitations of the models.

- The modified model includes two active layers which represent the upper and lower portions of the Dockum Aquifer. Layer 2 represents the upper portion of the Dockum Aquifer. Layer 3 represents the lower portion of the Dockum Aquifer. Layer 1, which is active in version 1.01 of the model documented in Ewing and others (2008), was inactivated in the modified model as described in Oliver and Hutchison (2010).

- The mean absolute error (a measure of the difference between simulated and measured water levels during model calibration) for the lower portion of the Dockum Aquifer, which typically produces the most water, between 1980 and 1997 is 53 feet for the modified version of the model. This represents 2.5 percent of the hydraulic head drop across the model area.

- The MODFLOW General-Head Boundary package was used to simulate flow between the Dockum Aquifer and overlying aquifers.

- We used Groundwater Vistas version 5 (Environmental Simulations, Inc., 2007) as the interface to process model output.

- The MODFLOW Drain package was used to simulate both evapotranspiration and springs. However, the results from model grid cells representing springs were incorporated into the surface water outflow values shown in Table 1 except four (4) cells. Those cells include both evapotranspiration and springs.

Seymour and Blaine aquifers

- We used the command line Version 1.01 of the groundwater availability model for the Seymour and Blaine aquifers. See Ewing and others (2004) for assumptions and limitations of the groundwater availability model for the Seymour and Blaine aquifers.
- We used USGS MODFLOW-2000 code version 1.15.01 to run the model for the Seymour and Blaine aquifers. The GMG solver input file that accompanied the original model was modified to be consistent with the format required by version 1.15.01. The GMG input file that accompanied the original model (Ewing and others ,2004) did not include inputs for semi-coarsening, ISC, and relaxation, RELAX, parameters. Default values of 1 were used for both.
- The MODFLOW-2000 executable from Ewing and others (2004) for the Seymour and Blaine aquifers was apparently modified from standard MODFLOW-2000 to write multiple cell-by-cell budget files. In order to run the model using USGS MODFLOW-2000 version 1.15.01 and to use the output for further post-processing with ZONEBUDGET, the the stream, recharge, well, evapotranspiration, and drain files

were modified to write cell-by-cell flows to unit 50. Also, the name file was modified to explicitly specify output file names, as is required in standard MODFLOW-2000.

- The groundwater availability model includes two layers, representing the Seymour (Layer 1) and Blaine (Layer 2) aquifers. In areas where the Blaine Aquifer does not exist the model roughly replicates the various Permian units located in the study area.

- The root mean square error (a measure of the difference between simulated and actual water levels during model calibration) of the entire model for the period of 1990 to 1999 ranges from 19.6 feet (Seymour Aquifer) to 26.4 feet (Blaine Aquifer), representing one percent and three percent of the range of measured water levels respectively (Ewing and others, 2004).

- All stress periods of the groundwater availability model for the Seymour and Blaine aquifers are monthly. The current model run for 1980 through 1999, therefore, consisted of 240 individual stress periods.

Ogallala Aquifer

- We used version 2.01 of the groundwater availability model for the southern portion of the Ogallala Aquifer and the Edwards-Trinity (High Plains) Aquifer. This model is an expansion on and update to the previously developed groundwater availability model for the southern portion of the Ogallala Aquifer described in Blandford and others (2003). See Blandford and others (2008) and Blandford and others (2003) for assumptions and limitations of the groundwater availability model.

- The model includes four layers representing the southern portion of the Ogallala and Edwards-Trinity (High Plains) aquifers. The units comprising the Edwards-Trinity (High Plains) Aquifer (primarily Edwards, Comanche Peak, and Antlers Sand formations) are separated from the overlying Ogallala Aquifer by a layer of Cretaceous shale, where present.

- The mean absolute error (a measure of the difference between simulated and measured water levels during model calibration) for the Ogallala Aquifer in 2000 is 33 feet. The mean absolute error for the Edwards-Trinity (High Plains) Aquifer in 1997 is 25 feet (Blandford and others, 2008). This represents 1.8 and 3.0 percent of the hydraulic head drop across the model area for each aquifer, respectively.

- Irrigation return flow was accounted for in the groundwater availability model by a direct reduction in agricultural pumping as described in Blandford and others (2003).

- The groundwater availability model for the southern portion of the Ogallala Aquifer and the Edwards-Trinity (High Plains) Aquifer does not consider flow between these aquifers and underlying units (Blandford and others, 2008).

- We used Groundwater Vistas version 5 (Environmental Simulations, Inc., 2007) as the interface to process model output.

RESULTS:

A groundwater budget summarizes the amount of water entering and leaving the aquifer according to the groundwater availability model. Selected components were extracted from the groundwater budget for the aquifers located within the district and averaged over the duration of the calibration and verification portion of the model run (1980 through 1997 for the Dockum Aquifer, 1980 through 1999 for the Seymour and Blaine aquifers, and 1980 through 2000 for the Ogallala Aquifer) in the district, as shown in Table 1 through Table 4. The components of the modified budgets shown in Tables include:

- Precipitation recharge—This is the aerially distributed recharge sourced from precipitation falling on the outcrop areas of the aquifers (where the aquifer is exposed at land surface) within the district.

- Surface water outflow—This is the total water exiting the aquifer (outflow) to surface water features such as streams, reservoirs, and drains (springs).

- Flow into and out of district—This component describes lateral flow within the aquifer between the district and adjacent counties.

- Flow between aquifers—This describes the vertical flow, or leakage, between aquifers or confining units. This flow is controlled by the relative water levels in each aquifer or confining unit and aquifer properties of each aquifer or confining unit that define the amount of leakage that occurs. “Inflow” to an aquifer from an overlying or underlying aquifer will always equal the “Outflow” from the other aquifer.

The information needed for the district’s management plan is summarized in tables 1 through 4. It is important to note that sub-regional water budgets are not exact. This is due to the size of the model cells and the approach used to extract data from the model. To avoid double accounting, a model cell that straddles a political boundary, such as district or county boundaries, is assigned to one side of the boundary based on the location of the centroid of the model cell. For example, if a cell contains two counties, the cell is assigned to the county where the centroid of the cell is located (see figures 1 to 4).

The areas from which water budgets were extracted were different for each layer of the groundwater availability model for the Seymour and Blaine aquifers. In layer 1, all active model cells within the district were used, representing the Seymour Aquifer. In Layer 2, only those active cells within the district representing the Blaine Aquifer were used. Active model cells within the district representing other Permian sediments were excluded in Layer 2. Net flows within the district from the Blaine to the other Permian sediments and from the other Permian sediments to the Blaine are included in the last row of table 3.

Comparison of the groundwater availability models for the Dockum Aquifer

A portion of the Dockum Aquifer is located at the southwest corner of the district in Motley County. There are two different models that represent Dockum Aquifer. The first one is version 1.01 of the groundwater availability model for the Dockum Aquifer by Ewing, J.E., and others (2008). A modification of the original model was done by Oliver, W. and Hutchison, W.R. (2010). We ran both models to justify our water budget results.

The estimated annual amount of recharge from precipitation to the district from the Dockum Aquifer model (version 1.01) is 618 acre-feet per year; the modified version of the model shows that the recharge is 619 acre-feet per year.

The estimated annual amount of discharge from the aquifer to the surface water from the Dockum Aquifer model (version 1.01) is 1,633 acre-feet per year; on the other hand the modified version of the model shows that the discharge is 1,160 acre-feet per year.

The estimated annual volume of flow into the district for the Dockum Aquifer model (version 1.01) is 2,617 acre-feet per year; and the modified version of the model shows that the flow into the district is 1,190 acre-feet per year.

The estimated annual volume of flow out of the district from the Dockum Aquifer model (version 1.01) is 890 acre-feet per year; and the modified version of the model shows that the flow out of the district is 760 acre-feet per year.

The modified version of the Dockum Aquifer model is believed to better represent flow between the Ogallala Aquifer and the Dockum Aquifer. Therefore, the modified version of the Dockum Aquifer model was used to meet the management plan requirements (see Table 1 for a summary).

Table 1: Summarized information required for the Gateway Groundwater Conservation District's groundwater management plan for the Dockum Aquifer. All values are reported in acre-feet per year. All numbers are rounded to the nearest 1 acre-foot. Reported flow estimates include both fresh and brackish waters present in the aquifers.

Management Plan requirement	Aquifer or confining unit	Results
Estimated annual amount of recharge from precipitation to the district	Dockum Aquifer	619
Estimated annual volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams, and rivers	Dockum Aquifer	1,160
Estimated annual volume of flow into the district within each aquifer in the district	Dockum Aquifer	1,190
Estimated annual volume of flow out of the district within each aquifer in the district	Dockum Aquifer	760
Estimated net annual volume of flow between each aquifer in the district	Net flow entering Dockum Aquifer from Ogallala Aquifer	133

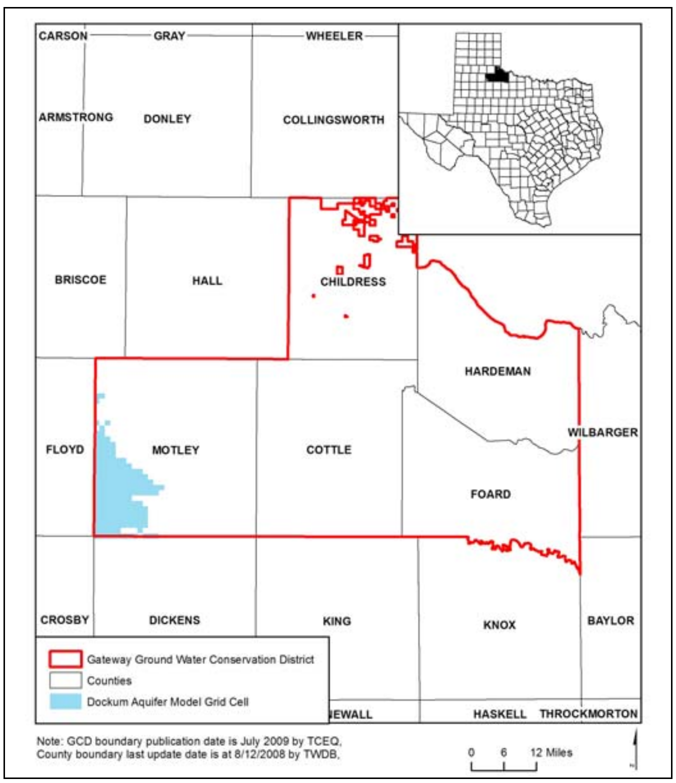

Figure 1: Area of the groundwater availability model for the Dockum Aquifer from which the information in Table 1 was extracted (the aquifer extent within the Gateway Groundwater Conservation District boundary).

Table 2: Summarized information required for the Gateway Groundwater Conservation District's groundwater management plan for the Seymour Aquifer. All values are reported in acre-feet per year. All numbers are rounded to the nearest 1 acre-foot. Reported flow estimates include both fresh and brackish waters present in the aquifers.

Management Plan requirement	Aquifer or confining unit	Results[1]
Estimated annual amount of recharge from precipitation to the district	Seymour Aquifer	48,643
Estimated annual volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams, and rivers	Seymour Aquifer	5,191
Estimated annual volume of flow into the district within each aquifer in the district	Seymour Aquifer	792
Estimated annual volume of flow out of the district within each aquifer in the district	Seymour Aquifer	7,145
Estimated net annual volume of flow between each aquifer in the district	Net flows entering Seymour from Blaine and other Permian Units	8,046

Note 1: A mass balance error of one percent or less is normally considered acceptable for water budgets extracted from numerical flow models (Anderson and Woessner, 1992); however, the water budgets for some stress periods of the groundwater availability model for the Seymour and Blaine aquifers exceeded one percent. After investigating the cause and several alternative approaches to defining the water budget it was determined that, after averaging all 240 stress periods together, the results are reasonable and appropriate for the purposes of the district's management plan.

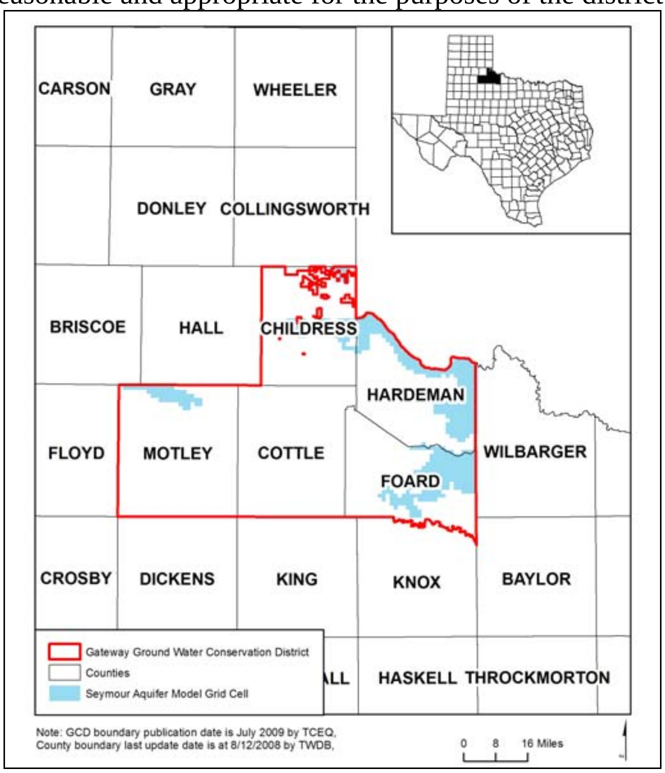

Figure 2: Area of the groundwater availability model for the Seymour Aquifer from which the information in Table 2 was extracted (the aquifer extent within the Gateway Groundwater Conservation District boundary).

Table 3: Summarized information required for the Gateway Groundwater Conservation District's groundwater management plan for the Blaine Aquifer. All values are reported in acre-feet per year. All numbers are rounded to the nearest 1 acre-foot. Reported flow estimates include both fresh and brackish waters present in the aquifers.

Management Plan requirement	Aquifer or confining unit	Results
Estimated annual amount of recharge from precipitation to the district	Blaine Aquifer	47,067
Estimated annual volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams, and rivers	Blaine Aquifer	17,164
Estimated annual volume of flow into the district within each aquifer in the district	Blaine Aquifer	18,811
Estimated annual volume of flow out of the district within each aquifer in the district	Blaine Aquifer	13,795
Estimated net annual volume of flow between each aquifer in the district	Net flows leaving Blaine into overlying Seymour Aquifer	7,056
	Net flows leaving Blaine into the Permain Unit	14,026

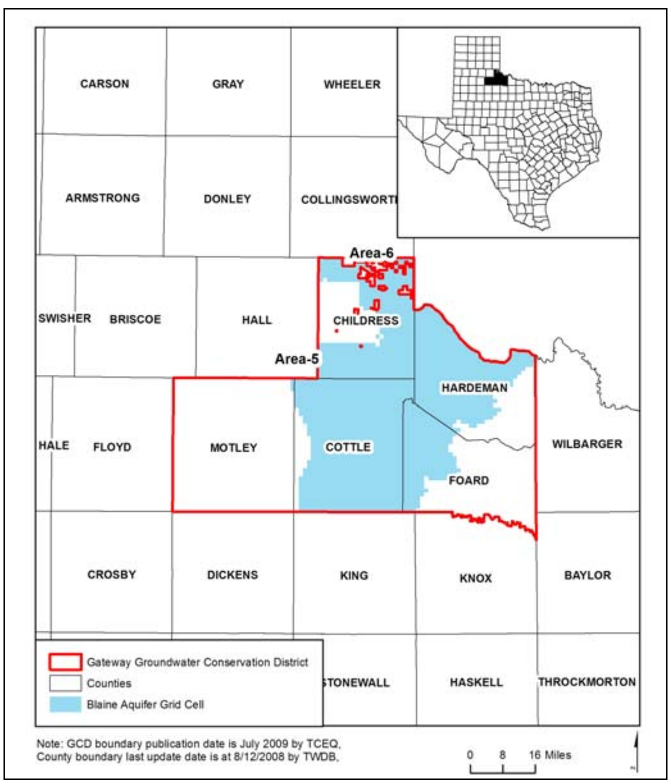

Figure 3: Area of the groundwater availability model for the Blaine Aquifer from which the information in Table 3 was extracted (the aquifer extent within the Gateway Groundwater Conservation District boundary).

Table 4: Ogallala Aquifer's summarized information required for the Gateway Groundwater Conservation District's groundwater management plan. All values are reported in acre-feet per year. All numbers are rounded to the nearest 1 acre-foot. Reported flow estimates include both fresh and brackish waters present in the aquifers.

Management Plan requirement	Aquifer	Results
Estimated annual amount of recharge from precipitation to the district	Ogallala Aquifer	404[1]
Estimated annual volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams, and rivers	Ogallala Aquifer	0[2]
Estimated annual volume of flow into the district within each aquifer in the district	Ogallala Aquifer	1,895
Estimated annual volume of flow out of the district within each aquifer in the district	Ogallala Aquifer	2,742
Estimated net annual volume of flow between each aquifer in the district	Net flow leaving Ogallala Aquifer to Dockum	133

Note: 1) Irrigation return flow was accounted for in the model by a direct reduction in agricultural pumping as described in Blandford and others (2003). This value is higher than what was reported in Groundwater Availability Model Run 08-47 (Oliver, 2008) due to the correction associated with irrigation return flow.
2) The model does not include any major springs, lakes, streams, or rivers within the district.

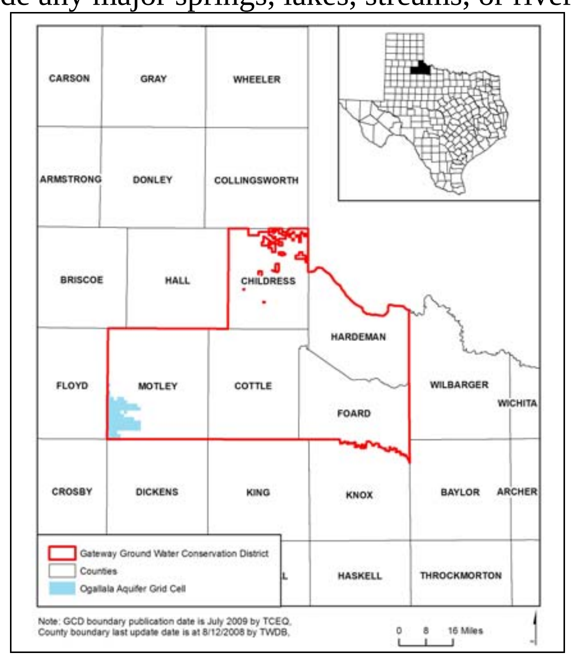

Figure 4: Area of the groundwater availability model for the Ogallala Aquifer from which the information in Table 4 was extracted (the aquifer extent within the Gateway Groundwater Conservation District boundary).

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