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DRAFT TECHNICAL MEMORANDUM

To:	Groundwater Conservation Districts in Groundwater Management Area 10
From:	Wade Oliver, P.G., INTERA James Pinkard, INTERA Neil Deeds, PhD, PE, INTERA
Date:	May 19, 2016
RE:	**Development of an Analytic Element Tool to Evaluate the Trinity Aquifer in Hays County, Texas**

INTRODUCTION:

The Trinity Aquifer in Groundwater Management Area 10 (GMA 10) has become a target for significant groundwater development in recent years. While there has been increased interest in the Trinity Aquifer, there does not yet exist a groundwater availability model for groundwater conservation districts (GCDs) to use for the development of desired future conditions (DFCs). During the initial round of joint planning in 2010, the Texas Water Development Board used a simple spreadsheet-based approach for estimating modeled available groundwater based on the desired future conditions established by GMA 10. Due to the increased emphasis on the aquifer as a resource, and additional information that has become available, the GCDs in GMA 10 commissioned this study to better understand the relationship between pumping and aquifer impacts and help guide the development of desired future conditions. Figure 1 shows the extent of GMA 10.

The purpose of this technical memorandum is to document the evaluation of potential hydrogeologic impacts to the upper and middle sections of the Trinity Aquifer and their component units (upper and lower Glen Rose, Hensel, and Cow Creek). Our analysis primarily relies on the results of recent pumping tests completed at the Electro Purification (EP) well field in central Hays County (Figure 2). For this analysis we have used the modeling code TTIM. TTIM is useful for evaluating impacts at the well-scale, though it does contain simplifications from the level of detail that is included in a typical MODFLOW-based groundwater availability model. Additional information about TTIM and the approach used in this study are presented below. This includes development of the conceptual model of groundwater flow, development and calibration of the analytic element numerical model for the aquifer in Hays County, and several predictive simulations showing potential impacts to the aquifer from proposed groundwater production at the EP well field.

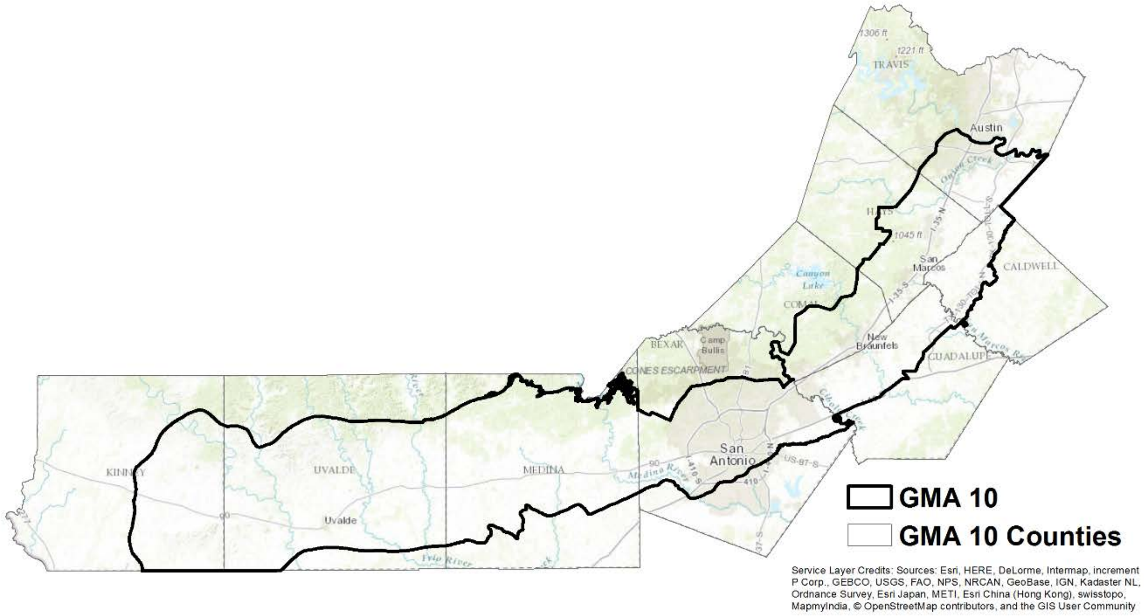

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Figure 1. Groundwater Management Area 10 in Central Texas

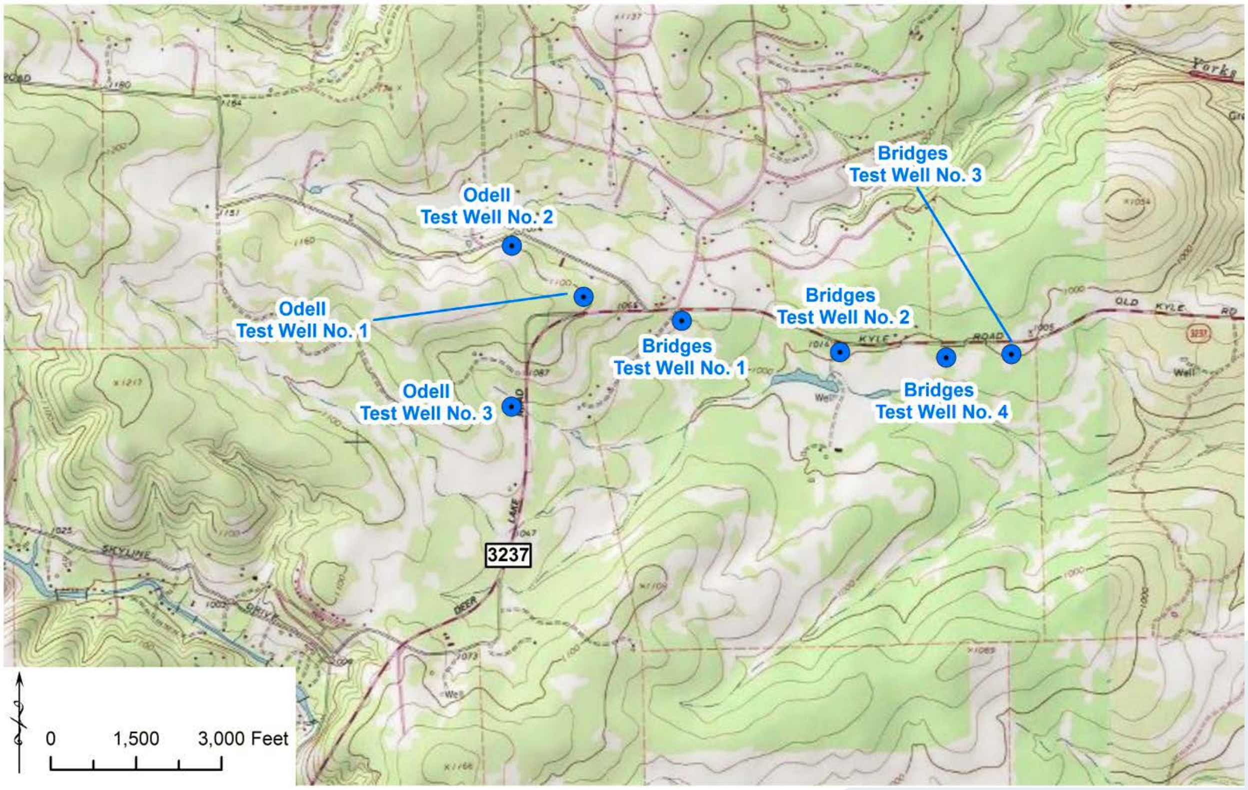


Figure 2. Electro Purification Well Field Layout (from WRGS, 2015)

APPROACH:

Groundwater model development typically includes definition of the conceptual model of groundwater flow prior to designing and calibrating the model for use in predictive simulations. The conceptual model of flow describes the current understanding of aquifer hydrogeology given available information and the purpose of the project. For this evaluation, we sought to better understand the hydraulic properties such as hydraulic conductivity and storativity and the degree of hydraulic connection between the various units within the Trinity Aquifer as well as the overlying Edwards (Balcones Fault Zone) Aquifer. The numerical model is the representation of this conceptual model of the aquifer in the computer code. All models, by definition, are simplifications of reality. When developed and applied appropriately, however, they can be very useful in increasing the level of understanding about how the aquifer works, defining those characteristics of the aquifer that most determine how it responds to pumping and assisting decision-makers tasked with developing groundwater management policies.

CONCEPTUAL MODEL:

The Trinity Aquifer in GMA 10 underlies the Edwards (Balcones Fault Zone) Aquifer. The Trinity Aquifer includes the upper and lower Glen Rose units, the Hensel, the Cow Creek, and the Sligo and Hosston formations of the Lower Trinity. The Hammett Shale is a confining unit that separates the Middle Trinity from the Lower Trinity. These units is shown in the stratigraphic chart in Figure 3. Large scale development at the EP well field is planned for the Cow Creek portion of the aquifer. One of the key purposes of this analysis is to better understand the potential impact that pumping of the Cow Creek could have on the overlying Lower Glen Rose and Edwards (Balcones Fault Zone) Aquifer.

To assist in the development of the conceptual model for the Trinity Aquifer, Barton Springs/Edwards Aquifer Conservation District (BSEACD) provided INTERA with pumping test information and estimated aquifer thicknesses for the EP well field. As these pumping tests were performed on many different wells, they represent a valuable source of information for understanding the aquifer in the area. Details of these pumping tests are documented in WRGS (2015). Additional information on the Trinity Aquifer nearby was also provided by BSEACD, including pumping test results at the Ruby Ranch and Needmore properties. These are documented in Mikels (2010) and WRGS (2016), respectively.

The primary aquifer in GMA 10 is the Edwards (Balcones Fault Zone) Aquifer. The Balcones Fault Zone is an area of extensive southeast to northeast trending faulting that extends through the Edwards and Trinity Aquifers. These faults can enhance dissolution and creation of karst features, create pathways for flow between aquifer units, or in some cases restrict flow across fault boundaries. Figure 4 shows a cross-section along the Blanco River in Hays County from Hunt and others (2015). Most relevant to the current study, the occurrence of faulting can inhibit the flow of groundwater down-dip. For a detailed description of the hydrogeology of the Trinity Aquifer in the study area, see Wierman and others (2010).

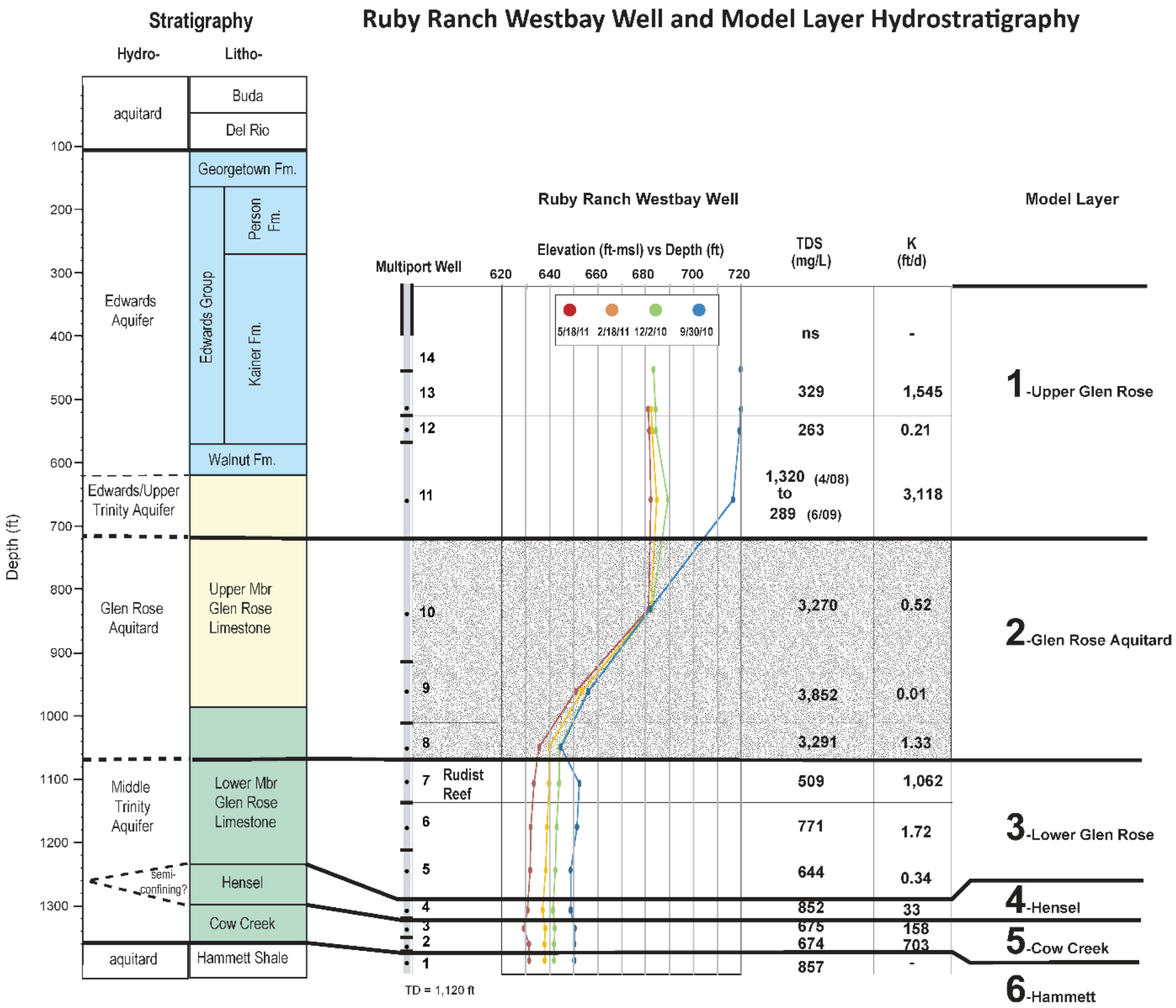


Figure 3. Stratigraphic chart, Ruby Ranch Westbay well, and model layer hydrostratigraphy

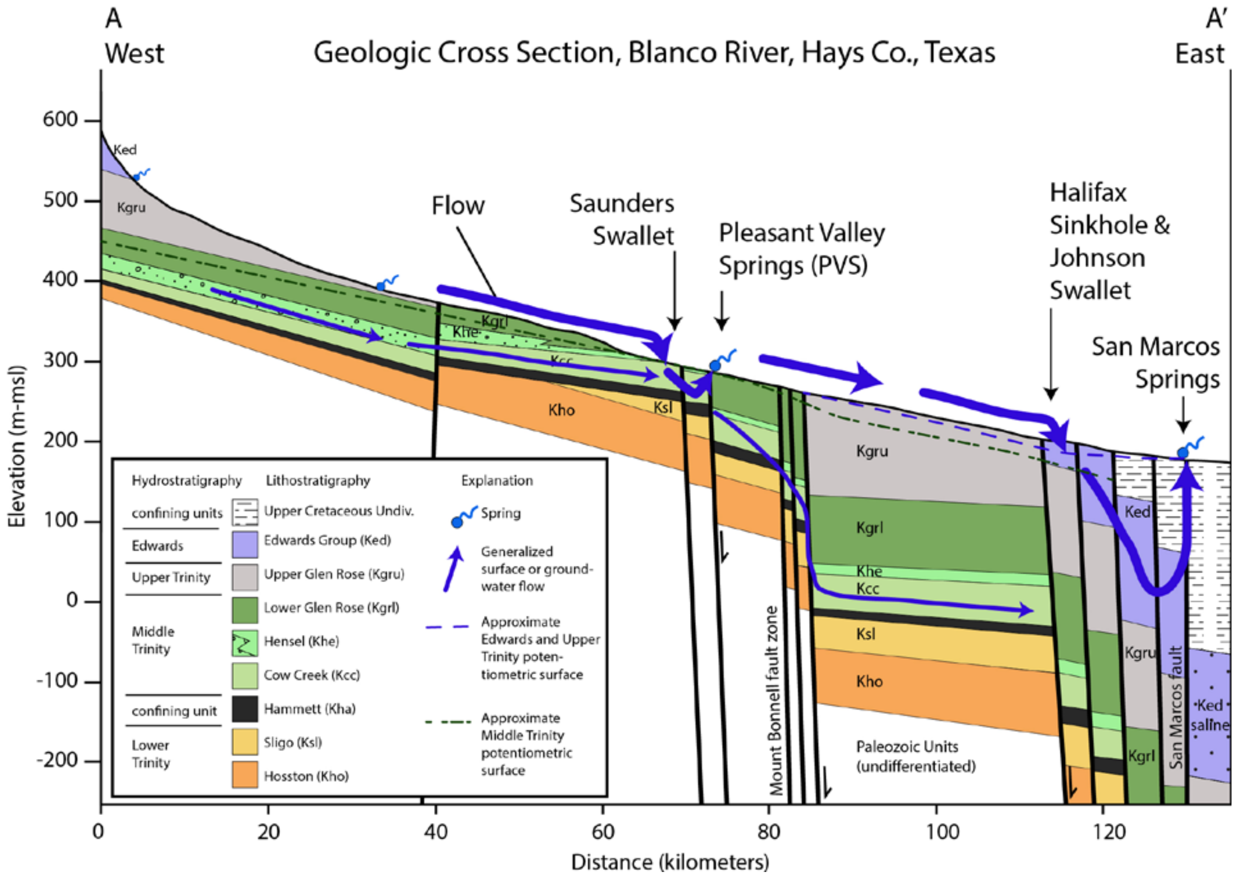


Figure 4. Geologic cross-section along the Blanco River in Hays County (from Wierman and others, 2010).

NUMERICAL MODEL:

Model Code:

The code chosen for this analysis is the transient analytic element groundwater modeling code known as TTIM (Bakker, 2015). TTIM was selected because it contains many characteristics that are key to this analysis including the ability to calibrate to pumping tests and evaluate drawdowns at a local scale for aquifers overlying and underlying the pumping unit (Cow Creek). A TTIM analytic element model can be developed much more cost effectively than a MODFLOW groundwater availability model. However, there are characteristics of the aquifer that are not simulated as part of the TTIM analysis. For instance, a MODFLOW groundwater availability model has aquifer properties that can vary spatially. A TTIM model assumes uniform aquifer properties horizontally within a particular unit. Similarly, a MODFLOW model can incorporate spatially varying aquifer structure and thickness. A TTIM model assumes uniform aquifer thickness. MODFLOW groundwater models have user-defined cell sizes. For the Texas Water Development Board's groundwater availability models, this is typically 1 mile x 1 mile. By contrast, a TTIM model is not limited by a user-defined cell size. Instead, the water level change (drawdown) is calculated at user-defined locations. That is, it can calculate drawdown at individual wells.

Given these differences in the assumptions and limitations of each of the modeling codes, MODFLOW is typically better suited for large, regional-scale groundwater resource evaluations. With its ability to evaluate impacts at individual well sites, TTIM is typically better suited for more local scale evaluations. For this reason, the results shown in this study are limited to the portion of Hays County in Groundwater Management Area 10.

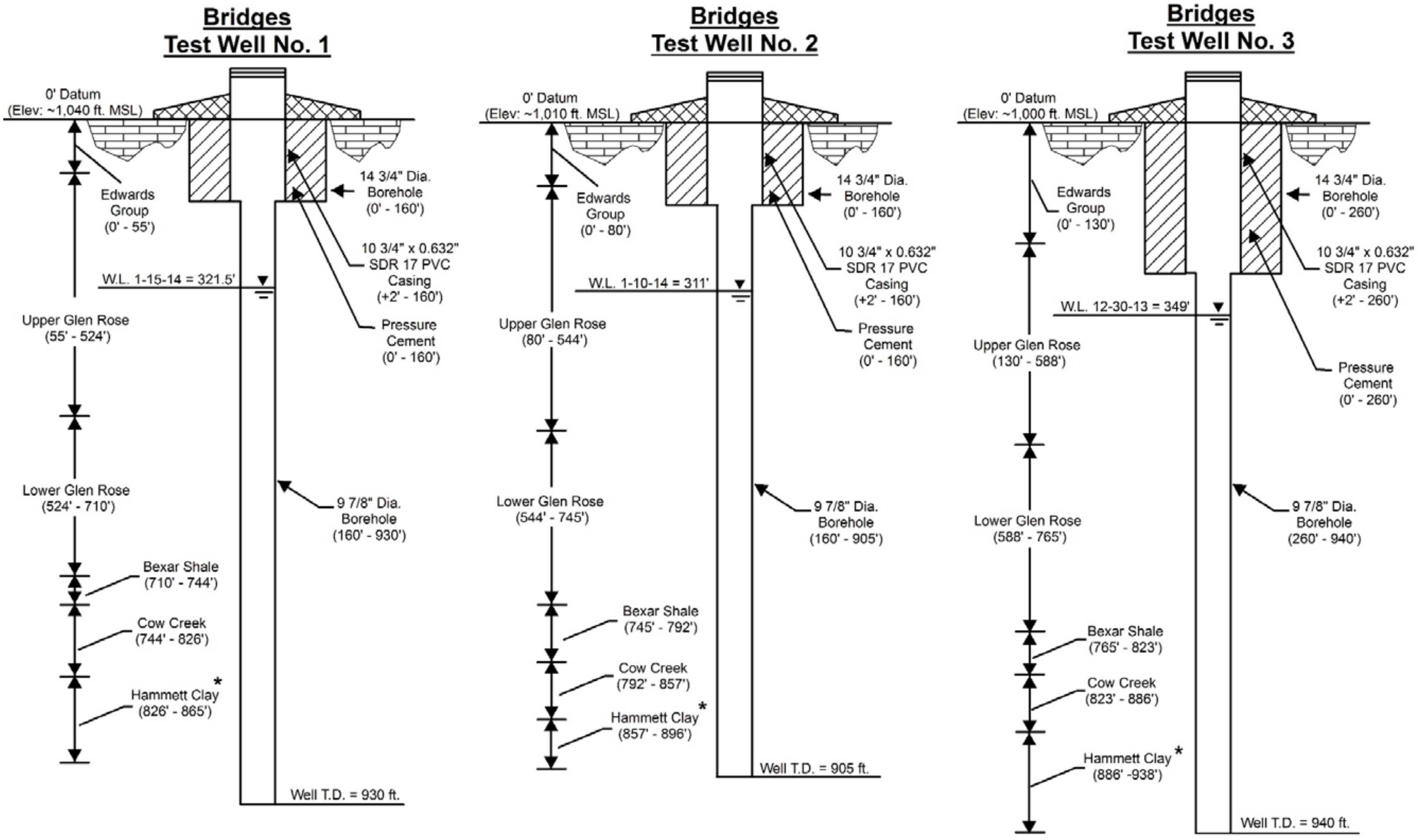
Model Calibration:

The model calibration focused on matching the aquifer test results at the EP well field in central Hays County near the boundary between Groundwater Management Area 9 (GMA 9) and GMA 10. We used the parameter estimation code PEST (Watermark, 2004) to aid in the matching of drawdowns in the pumping tests during model calibration. When using PEST, each of the model parameters are adjusted within a reasonable range to better match observed drawdowns. The model set up including layer thicknesses and aquifer properties is shown in Table 1. During calibration, the specific storage and horizontal and vertical hydraulic conductivities were adjusted.

Table 1. Model layering setup and mid-point calibrated hydraulic properties

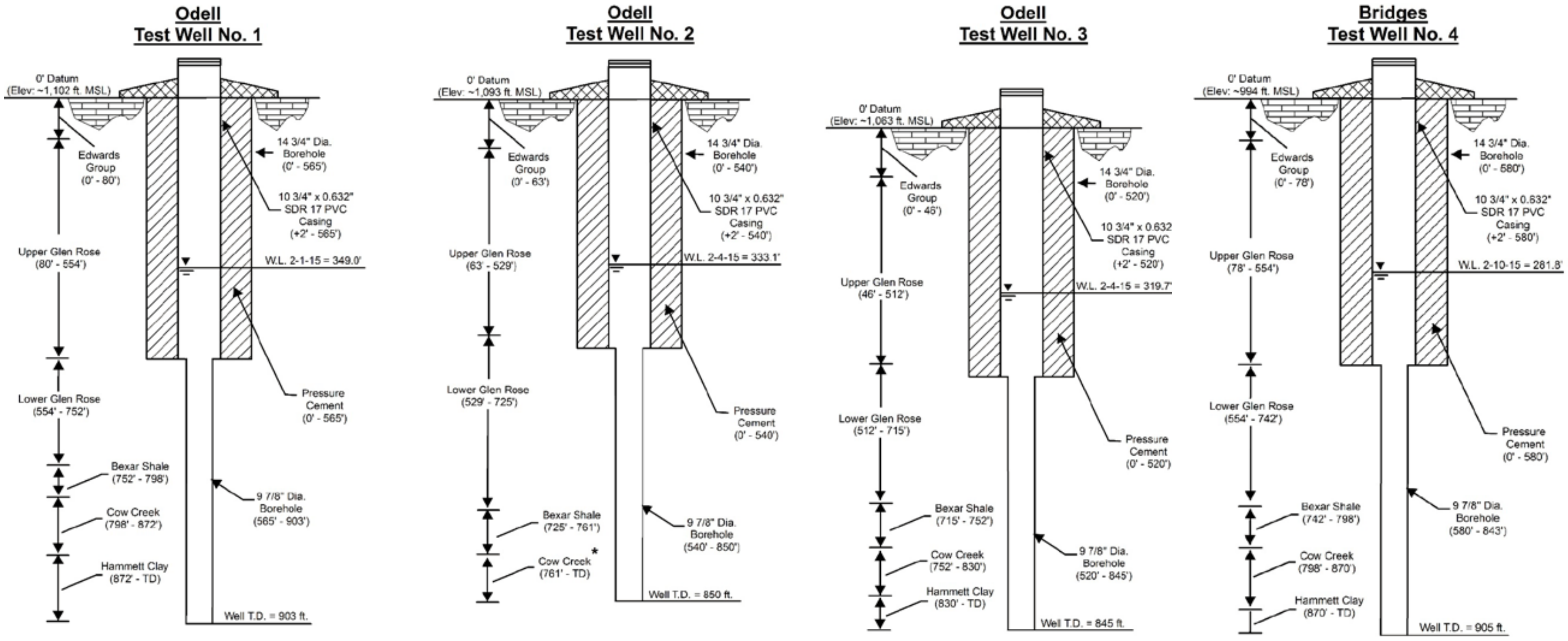
Unit	Thickness (ft)	Horizontal K (ft/d)	Transmissivity (ft^2/d)	Vertical Anisotropy	Specific Storage
Edwards	65	1.00E+01		5.00E-01	7.94E-07
Upper Glen Rose	470	1.74E-03		1.68E-02	1.50E-05
Lower Glen Rose	195	2.33E-01	45.5	4.91E-01	3.29E-07
Hensel	45	1.00E-04	0.0	1.00E-02	1.52E-04
Cow Creek	75	6.06E+00	454.3	6.58E-02	1.00E-07
Hammett	50	5.00E-07		1.00E-02	1.00E-04

The current well completions for the EP well field are open hole. During the pumping tests it was assumed that a majority of the pumping was sourced from the Cow Creek with a small amount from the Lower Glen Rose. As shown in Figure 5, the Bridges 1, Bridges 2 and Bridges 3 wells have some completion into and below the Hammett Clay. After discussions with BSEACD staff, we conclude it is reasonable to assume that the Hammett Clay and underlying Lower Trinity do not contribute significantly to water produced from the Bridges wells in the EP well field. For predictive simulations, it is our understanding that the wells will be completed to only produce from the Cow Creek.



Notes:
- Well profiles created with information from downhole geophysical surveys.
- Figure for schematic purposes; not drawn to scale.
* = Borehole filled in to a shallower depth than T.D. due to sloughing from the Hammet Clay

Figure 5. EP well field well completion diagrams (from WRGS, 2015).



Notes:
- Well profiles created with information from downhole geophysical surveys.
- Figure for schematic purposes; not drawn to scale.
* = Borehole filled in to a shallower depth than T.D. due to sloughing from the Hammett Clay

Figure 5. Continued.

The goal of the calibration was to match aquifer test results – to the extent possible – acknowledging that mismatches will occur due to heterogeneity in the aquifer. In order to better reflect aquifer impacts of an active pumping well, we normalized the drawdown targets so shorter periods with high drawdown carried as much weight as longer periods with little to no drawdown.

The test and observation well setup for the EP well field are shown in Table 2 (WRGS, 2015). We have removed all aquifer test results associated with the Bridges 3 well. This well does not appear to have a significant hydraulic connection to the other wells completed in the Cow Creek in the EP well field. As shown in Table 2, the Bridges 3 well had the lowest well yield (48 gallons per minute). The well also exhibited very little drawdown when used as an observation well during the pumping tests for Bridges 1 and Bridges 2. During the Bridges 1 test, no drawdown was observed in Bridges 3 which was 1.1 miles away. During the Bridges 2 test, only 2.6 feet of drawdown was observed at a distance of just over half a mile. Bridges 1 was also observed during the Bridges 2 pumping test at approximately the same distance (half mile). Bridges 1 showed 23.5 feet of drawdown during this test, approximately 10 times as much as was observed in Bridges 3.

Table 2. EP test and observation well pumping rates and drawdowns (from WRGS, 2015). All test and observation well results associated with Bridges 3 were omitted from the current analysis.

Pumping Well	Pumping Rate gpm (MGD)	Observation Well 1 (Distance from Pumping Well)	Observation Well 1 Drawdown	Observation Well 2 (Distance from Pumping Well)	Observation Well 2 Drawdown in feet
Bridges Test Well No. 1 (B-1)	435 (0.63)	B-3 (1.1 miles)	0 feet		
Bridges Test Well No. 2 (B-2)	333 (0.48)	B-1 (0.54 miles)	23.5 feet	B-3 (0.57 miles)	2.6 feet
Bridges Test Well No. 3 (B-3)	48 (0.07)				
Bridges Test Well No. 4 (B-4)	66 (0.09)	B-2 (0.35 miles)	4.7 feet	B-1 (0.64 miles)	0 feet
Odell Test Well No. 1 (O-1)	95 (0.14)	O-3 (0.44 miles)	8.7 feet	B-1 (0.33 miles)	7.5 feet
Odell Test Well No. 2 (O-2)	300 (0.43)	O-1 (0.29 miles)	22.7 feet	O-3 (0.54 miles)	14.3 feet
Odell Test Well No. 3 (O-3)	175 (0.25)	O-1 (0.44 miles)	9.9 feet	B-1 (0.64 miles)	20.4 feet

The calibrated hydraulic parameters are also shown in Table 1. The calibrated hydraulic conductivity of the Cow Creek is approximately 6 feet per day. The horizontal hydraulic conductivity of the Hensel is that of a confining unit at 10^{-4} feet per day. Because water levels in wells only completed in units shallower than the Cow Creek were not observed during these tests, the calibrated hydraulic parameters in the lower and upper Glen Rose units are not well constrained. For the lower Glen Rose and Cow Creek, the mid-point calibration results indicate approximately 90 percent of the transmissivity of the Middle Trinity is in the Cow Creek (454.3 ft^2/d for the Cow Creek, compared to 45.5 ft^2/d for the Lower Glen Rose). This is in-line with the conceptual model of flow for the aquifer in which the Cow Creek is the primary source of water produced.

Vertical anisotropy of the Hensel is a key parameter in this analysis as it strongly influences the degree to which pumping in the Cow Creek affects water levels in the overlying lower Glen Rose. A discussion of the sensitivity of the results to changes in the vertical anisotropy of the Hensel is included later in this memorandum.

Figure 6 through Figure 11 show a comparison of the model-predicted drawdowns to the measured drawdowns for the Bridges and Odell wells during calibration. Due to horizontal anisotropy in the aquifer and other heterogeneities, the model predicted drawdowns have significant variations from the observed drawdowns for several of the wells. For example, Bridges 1 has a model predicted drawdown greater than the observed drawdown during the aquifer test. However, Bridges 2 has a model-predicted drawdown less than the observed drawdown during its aquifer test. As shown for Bridges 1, the modeled drawdowns when Bridges 1 was used as an observation well more closely match observed drawdowns.

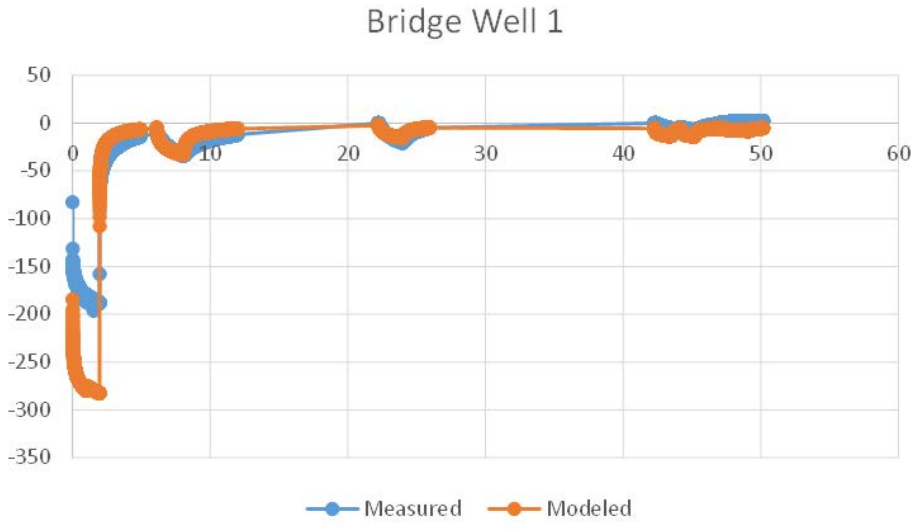


Figure 6. Comparison of measured to modeled drawdowns (in feet) for the Bridges 1 well.

Figure 7. Comparison of measured to modeled drawdowns (in feet) for the Bridges 2 well.

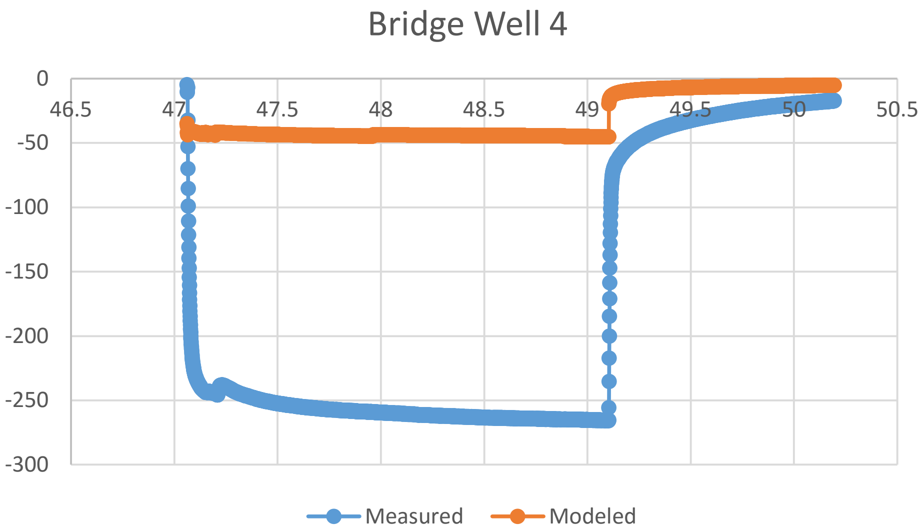


Figure 8. Comparison of measured to modeled drawdowns (in feet) for the Bridges 4 well.

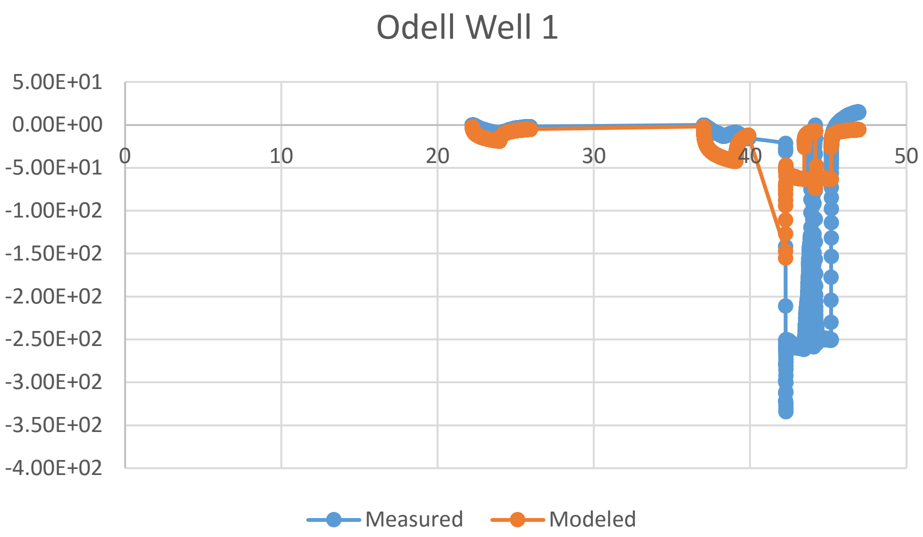


Figure 9. Comparison of measured to modeled drawdowns (in feet) for the Odell 1 well.

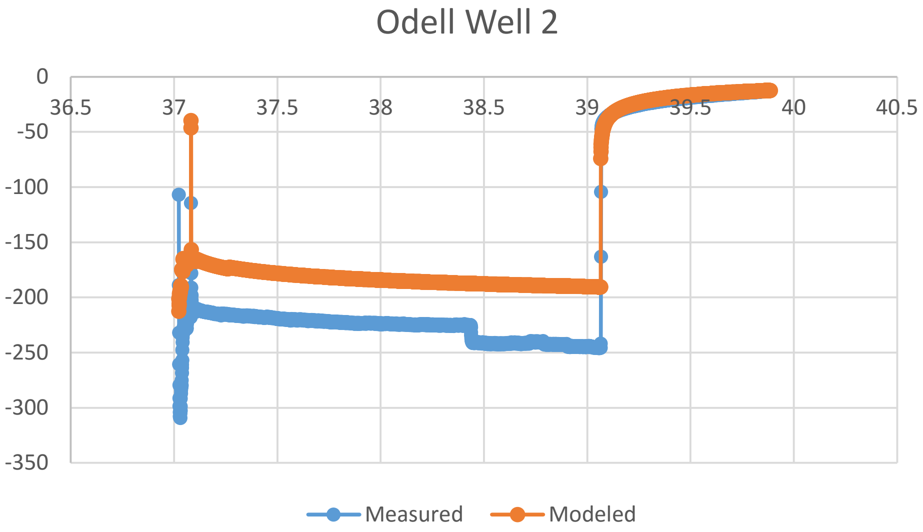


Figure 10. Comparison of measured to modeled drawdowns (in feet) for the Odell 2 well.

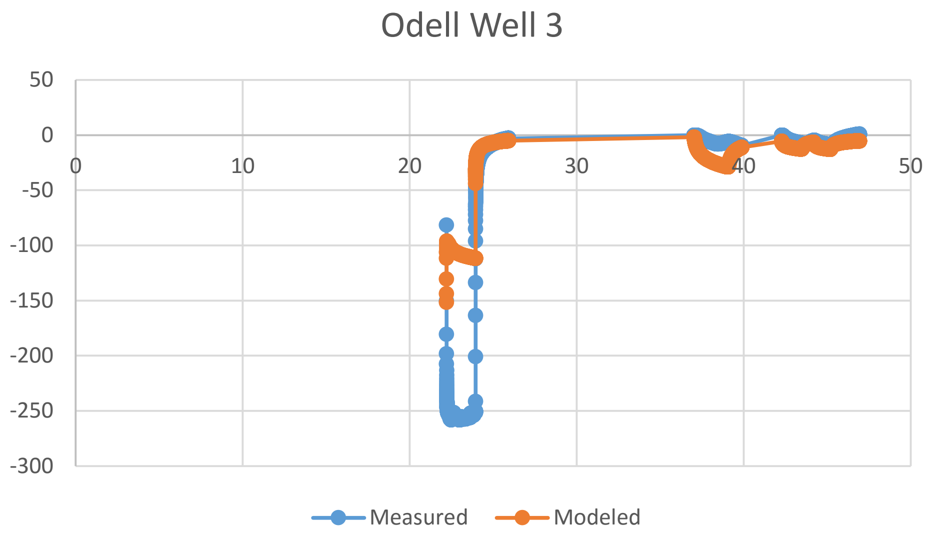


Figure 11. Comparison of measured to modeled drawdowns (in feet) for the Odell 3 well.

PREDICTIVE SIMULATIONS:

With the model calibrated to aquifer test results at the EP well field, the model was then used to evaluate the potential impacts to the units of the Trinity and overlying Edwards (Balcones Fault Zone) aquifers under a range of pumping scenarios. The predictive scenarios were chosen in coordination with the groundwater conservation districts in GMA 10. The results of these predictive scenarios are shown in Table 3 and Table 4. Cross-sections of drawdown in the Cow Creek, lower Glen Rose, and Edwards aquifers are shown in the Appendix.

Scenario Parameters:

Each of the scenarios described below use the same hydraulic properties and contain pumping from the same wells at the EP well field. The time period for each of the simulations is 50 years, consistent with the time period for the joint planning and regional water planning processes. The primary differences between the scenarios relate to the goal of the scenario – whether it is a specified pumping scenario or whether the scenario aims to achieve a specific drawdown at the well field or in GMA 10 in Hays County. The Bridges 1 well was chosen to represent drawdowns in the EP well field because of its location at the center of the field and because it had the highest pumping rate among the EP wells.

For the vertical anisotropy of the Hensel, scenarios 1 through 5 reflect the mid-point calibration with a vertical anisotropy of 0.01. Because of the sensitivity of the model results to the vertical hydraulic conductivity of the Hensel, scenarios 6 through 10 reflect the same five pumping/drawdown scenarios for a case in which the vertical anisotropy is 1.0. While this represents an anisotropy 100 times higher than the mid-point calibration, it is still a fairly restrictive unit because the horizontal hydraulic conductivity of the Hensel is 10^{-4}.

Scenario 1: Pumping of 2.47 Million Gallons Per Day

WRGS (2015) indicates that the expected productivity of the EP well field after the Bridges 3 well is plugged will be approximately 2.47 million gallons per day (1,717 gallons per minute). This conclusion comes from the well yields from the aquifer tests, a stated desire to keep the water level 60 feet above the top of the Cow Creek, and a “safety factor” of 25 percent. In this pumping scenario we applied the 2.47 million gallons per day to the well field by assigning pumping proportionally to the well yield established during the aquifer test. As shown in Table 3, the drawdown that occurs in the Cow Creek with this level of pumping is 805 feet after 50 years. Given the water level in the Cow Creek and the depth of the formation, this level of drawdown could not be achieved as the water level would be below the bottom of the aquifer.

Due to the restrictive nature of the Hensel in the mid-point calibration results, the impacts to the overlying lower Glen Rose in this scenario are relatively small. As shown in Table 3, the drawdown for the lower Glen rose is estimated to be only 6 feet after 50 years. Similarly, no drawdown is observed in this scenario in the Edwards (Balcones Fault Zone) Aquifer.

Scenario 2: Drawdown to 60 Feet Above the Cow Creek Top

For the second scenario we adjusted the pumping for the EP well field so that the resulting drawdown in the Cow Creek matches the stated goal in (WRGS, 2015) of keeping the water level 60 feet above the top of the Cow Creek unit. This condition results in a pumping rate for the field of 773 gallons per minute and a drawdown of 362 feet in the Cow Creek. As in Scenario 1, the drawdown impact to overlying units is limited. While this pumping achieves the stated goals for the well field in terms of drawdown, it is 55 percent less pumping than is estimated in WRGS (2015).

Scenario 3: Drawdown to the Cow Creek Top

Scenario 3 is similar to Scenario 2 except that the drawdown goal is set at the top of the Cow Creek. This 60 feet of additional drawdown compared to Scenario 2 is associated with 128 gallons per minute of additional pumping – totaling 901 gallons per minute for the field with 422 feet of drawdown in the Cow Creek.

Scenario 4: Drawdown to the Top of the Lower Glen Rose

For Scenario 4 the drawdown goal was set at the top of the lower Glen Rose. This represents the level of drawdown in the Cow Creek that could significantly affect water availability in the lower Glen Rose if there is significant communication between the two formations. The pumping that achieves this 182 feet of drawdown in the Cow Creek is 389 gallons per minute. As with the higher pumping scenarios, drawdown impacts to shallower formations are limited.

Scenario 5: Drawdown of 25 Feet for GMA 10 Portion of Hays County

Scenario 5 differs from scenarios 1 through 4 in that drawdown is calculated not at the center of the EP well field (Bridges 1), but as an average over the portion of Hays County in GMA 10. The drawdown was calculated not just for the Cow Creek portion of the Trinity Aquifer, but for the Trinity Aquifer as a whole consistent with desired future conditions being considered by the groundwater conservation districts in GMA 10. To calculate the Trinity Aquifer average drawdown the water level declines in each unit of the Trinity Aquifer (upper Glen Rose, lower Glen Rose, Hensel and Cow Creek) were weighted by the transmissivity of each unit (i.e. the product of the hydraulic conductivity and the aquifer thickness).

The aerial drawdown was calculated using TTIM by dividing the portion of GMA 10 in Hays County into one square mile blocks. Pumping was then adjusted iteratively until the Trinity Aquifer average drawdown inside the 298 square mile area matched the proposed desired future condition of an average drawdown of 25 feet. The pumping associated with this scenario was slightly more than Scenario 4 – 400 gallons per minute.

As described above, one limitation of TTIM is that it assumes constant horizontal hydraulic conductivity throughout a particular unit. Though it could not be incorporated into the model, one of the components of the conceptual model for the Trinity Aquifer is that, due to faulting and other heterogeneities, the horizontal hydraulic conductivity is greater along the strike of the Balcones Fault Zone (southwest to northeast) than along the dip of the aquifer (northwest to southeast). This horizontal anisotropy would lead to greater drawdowns along strike and lesser drawdowns along dip than the model predicts. A comparison of the modeled drawdowns to a conceptual representation of how anisotropy could affect drawdown contours is shown in Figure 12.

Table 3. Predictive simulation drawdowns (in feet) for scenarios 1 through 5 with a vertical anisotropy ratio for the Hensel of 0.01.

Hensel Vertical Hydraulic Conductivity Scenario	Hensel Vertical Hydraulic Conductivity = 10^{-6} feet/day				
Aquifer Impact Scenario	Scenario 1: 2.47 MGD	Scenario 2: 60 ft Above Cow Creek Top	Scenario 3: Cow Creek Top	Scenario 4: Lower Glen Rose Top	Scenario 5: GMA 10 Hays DFC 25 ft
EP Well Field Cow Creek Pumping Rate	1717 gpm	773 gpm	901 gpm	389 gpm	400 gpm
Drawdown Location	**Center of Proposed EP Well Field (Bridges 4 Well)**				
Edwards	0	0	0	0	0
Upper Glen Rose	-1	0	0	0	0
Lower Glen Rose	-6	-3	-3	-1	-2
Hensel	-60	-27	-32	-14	-14
CowCreek	-805	-362	-422	-182	-188
Trinity Average	*-731*	*-329*	*-384*	*-166*	*-170*
Drawdown Location	**Average for GMA 10 in Hays County**				
Edwards	0	0	0	0	0
Upper Glen Rose	0	0	0	0	0
Lower Glen Rose	-3	-1	-2	-1	-1
Hensel	-12	-6	-6	-3	-3
CowCreek	-118	-53	-62	-27	-28
Trinity Average	*-108*	*-49*	*-57*	*-24*	*-25*

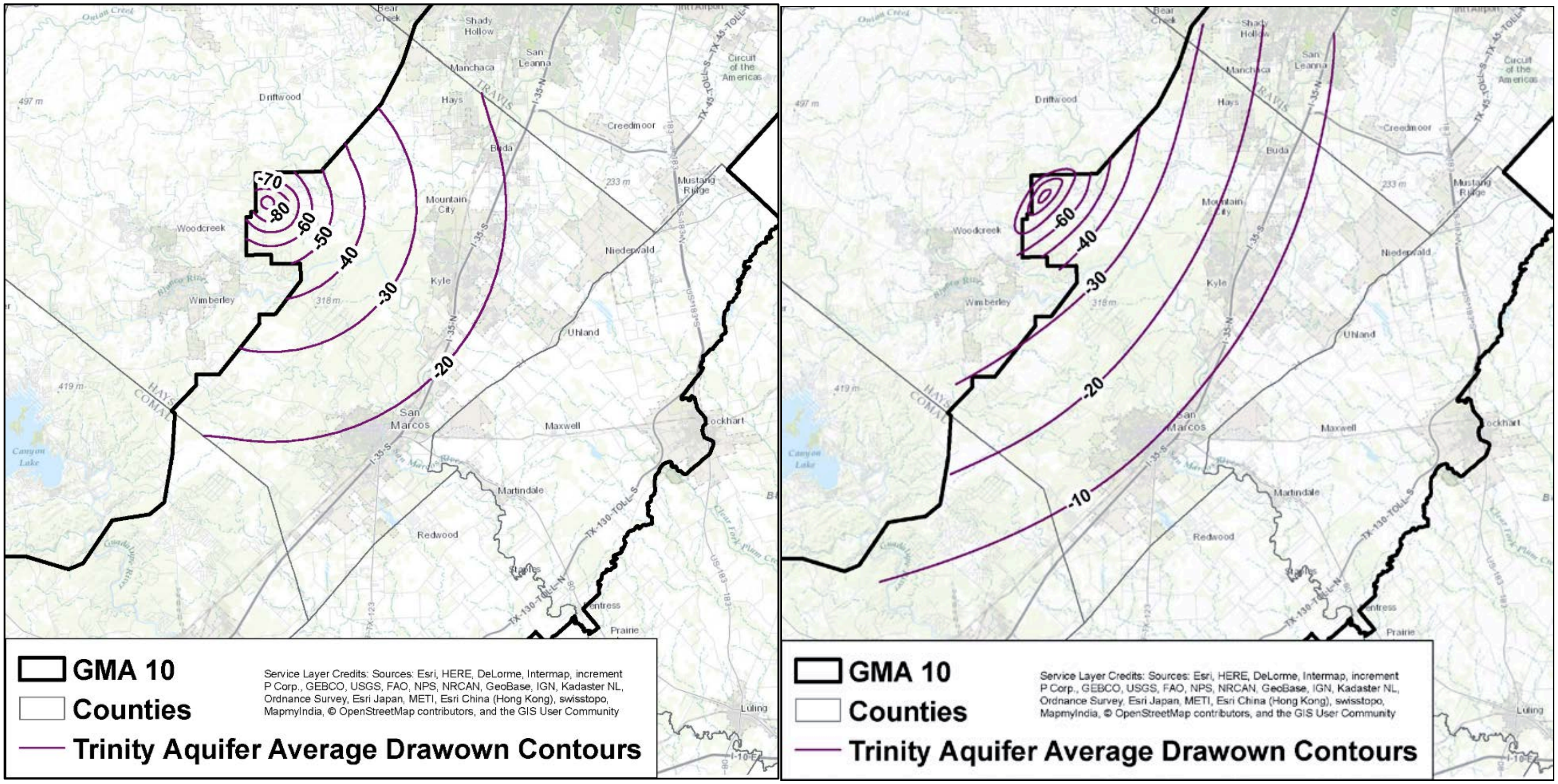


Figure 12. Comparison of modeled Trinity Aquifer average drawdown contours (left) to elongated contours designed to conceptually represent the effect of horizontal anisotropy (right).

Scenarios 6 through 10: Vertical Anisotropy of 1.0 for the Hensel

As mentioned above, the impacts of pumping in the Cow Creek on overlying units such as the lower Glen Rose are strongly influenced by the vertical anisotropy of the Hensel. The calibrated value for vertical anisotropy used in scenarios 1 through 5 above is 0.01. Since the horizontal hydraulic conductivity of the Hensel is 10^{-4} feet per day, the model vertical hydraulic conductivity used in scenarios 1 through 5 is 10^{-6} feet per day. This reflects a conceptual model of the Hensel as a highly confining unit, though because there were no observation wells in the shallower units during the EP pumping test, there is not a high degree of confidence in this calibrated value. Figure 13 shows the drawdown that would occur in the Cow Creek and lower Glen Rose units with pumping of 1,717 gallons per minute (2.47 million gallons per day) for different values of vertical hydraulic conductivity for the Hensel. As shown in Figure 13, higher values of vertical hydraulic conductivity in the Hensel lead to reduced drawdown impacts in the Cow Creek and increased drawdown impacts in the lower Glen Rose (and other overlying units).

Scenarios 6 through 10 are identical in purpose to scenarios 1 through 5 except that the vertical anisotropy of the Hensel has been increased to 1.0. This reflects a vertical hydraulic conductivity for the unit of 10^{-4} feet per day.

Table 4. Predictive simulation drawdowns (in feet) for scenarios 6 through 10 with a vertical anisotropy ratio for the Hensel of 1.0.

Hensel Vertical Hydraulic Conductivity Scenario	Hensel Vertical Hydraulic Conductivity = 10^{-4} feet/day				
Aquifer Impact Scenario	Scenario 6: 2.47 MGD	Scenario 7: 60 ft Above Cow Creek Top	Scenario 8: Cow Creek Top	Scenario 9: Lower Glen Rose Top	Scenario 10: GMA 10 Hays DFC 25 ft
EP Well Field Cow Creek Pumping Rate	1717 gpm	917 gpm	1069 gpm	461 gpm	1175 gpm
Drawdown Location	**Center of Proposed EP Well Field (Bridges 4 Well)**				
Edwards	-4	-2	-2	-1	-2
Upper Glen Rose	-41	-22	-26	-11	-28
Lower Glen Rose	-220	-118	-137	-59	-151
Hensel	-360	-192	-224	-97	-246
CowCreek	-679	-363	-423	-182	-465
Trinity Average	*-636*	*-340*	*-396*	*-171*	*-435*
Drawdown Location	**Average for GMA 10 in Hays County**				
Edwards	-2	-1	-1	-1	-1
Upper Glen Rose	-5	-3	-3	-1	-3
Lower Glen Rose	-33	-17	-20	-9	-22
Hensel	-34	-18	-21	-9	-23
CowCreek	-37	-20	-23	-10	-25
Trinity Average	*-37*	*-20*	*-23*	*-10*	*-25*

Table 4 shows the results of scenarios 6 through 10. In scenario 6, the 1,717 gallons per minute results in 679 feet of drawdown in the Cow Creek and 220 feet of drawdown in the lower Glen Rose. As the drawdown impacts are distributed across more aquifer units with the higher vertical anisotropy, the pumping rates associated with the drawdown conditions of scenarios 7, 8 and 9 are higher than the pumping rates for scenarios 2, 3 and 4. The most significant difference in these scenarios is in Scenario 10 which reflects the Trinity Aquifer average drawdown of 25 feet for GMA 10 in Hays County. The Scenario 10 pumping of 1,175 gallons per minute is nearly 3 times the pumping of Scenario 5.

A key takeaway from Figure 13 and a comparison of scenarios 1 through 5 to scenarios 6 through 10 is that the drawdown results and productivity of the EP well are very sensitive to the Hensel vertical hydraulic conductivity.

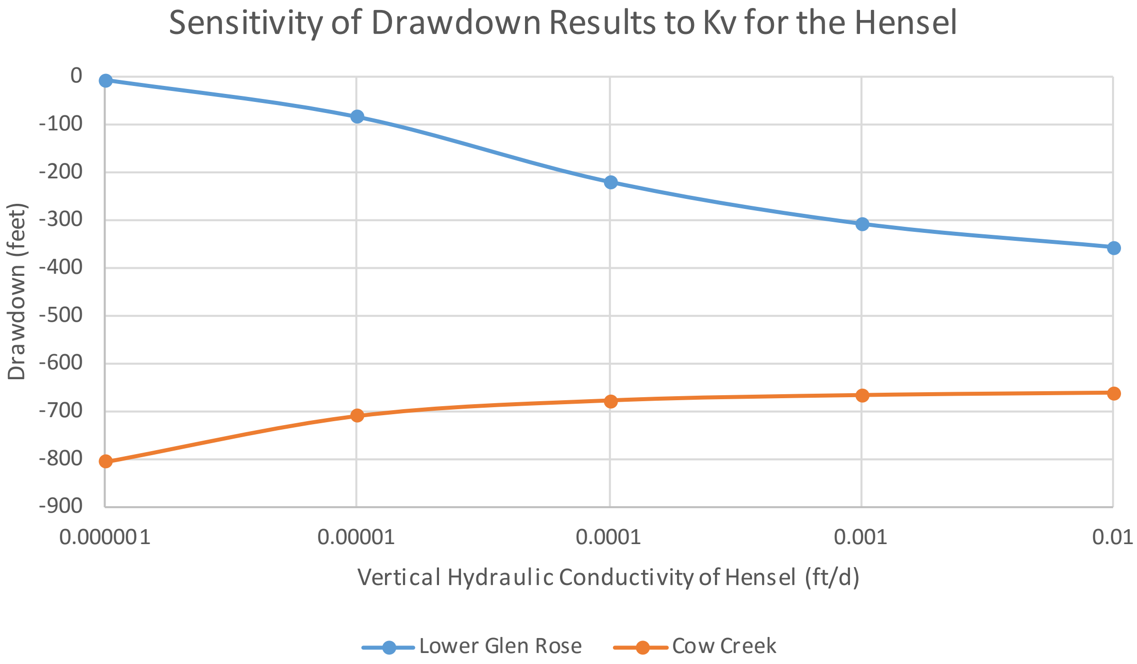


Figure 13. Sensitivity of Cow Creek and lower Glen Rose drawdown to the vertical hydraulic conductivity of the Hensel. Assumes pumping in the EP well field of 2.47 million gallons per day. Drawdowns after 50 years shown for Bridges 1 well.

LIMITATIONS:

All modeling studies inherently have simplifications and limitations to their applicability. This analysis is no different. As described above, the modeling code selected for this analysis (TTIM) is better suited to local/well field-scale analyses than for large, regional-scale analysis such as GMA 10. For this reason, the largest scale of impacts we have presented here is for the portion of GMA 10 in Hays County.

TTIM does not directly account for recharge from precipitation to the aquifer, though because it assumes an infinite aquifer extent, it allows for lateral flow – and increases in lateral flow – that would be observed in a system connected to an up-dip recharge area. At the time of this writing, the Texas Water Development Board is in the process of soliciting qualifications from firms to develop a groundwater availability model covering the Trinity Aquifer throughout GMA 10. While the analysis presented here has limitations, particularly as it relates to drawdowns over large areas, it is our opinion that this is the best tool available to evaluate impacts to the Trinity aquifer and its component units. During the next round of joint planning (2021) it is likely that a more comprehensive tool will be available for regional scale analyses.

REFERENCES:

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APPENDIX

Drawdown Profiles for Predictive Pumping Scenarios 1 through 10

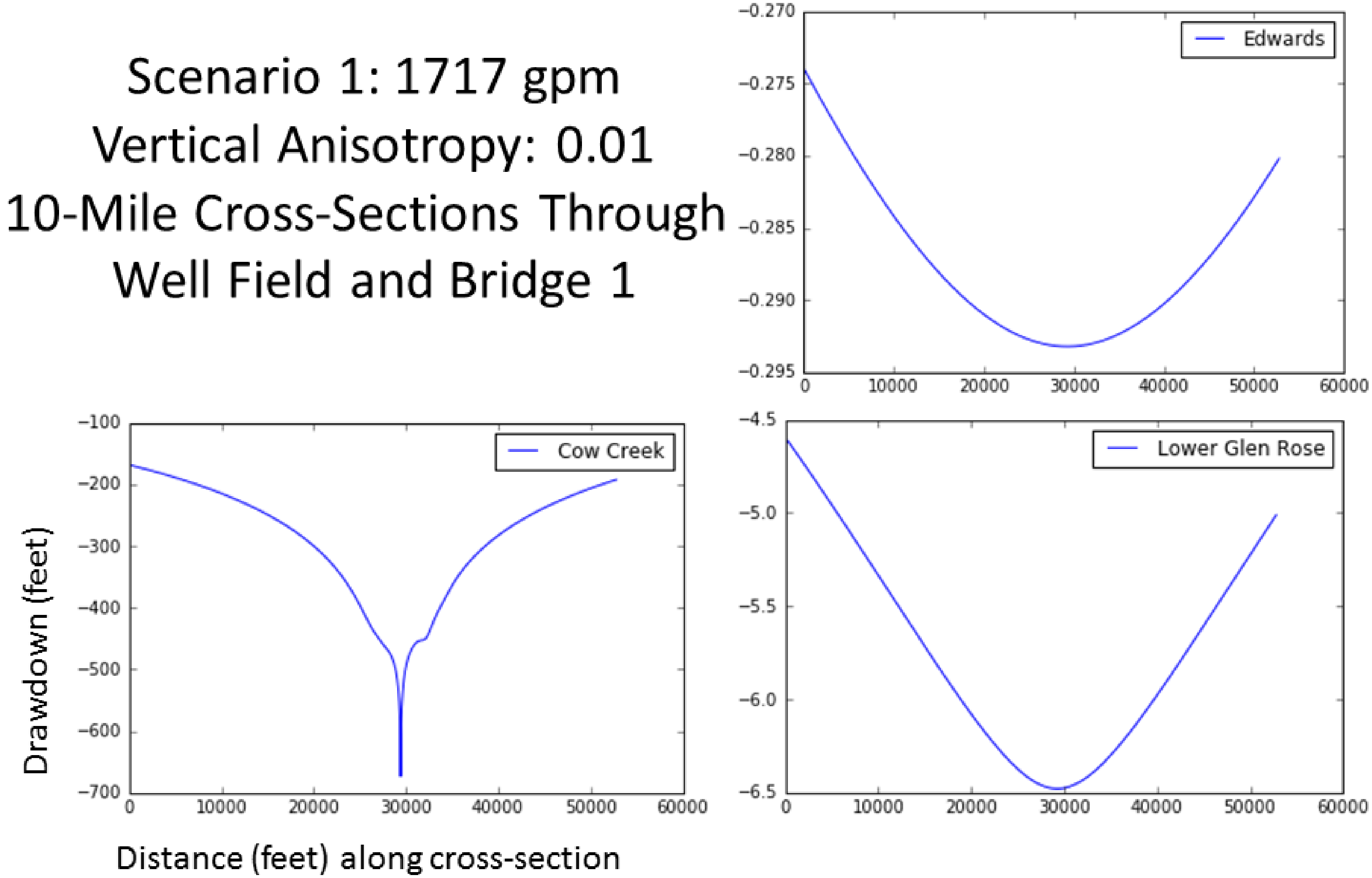
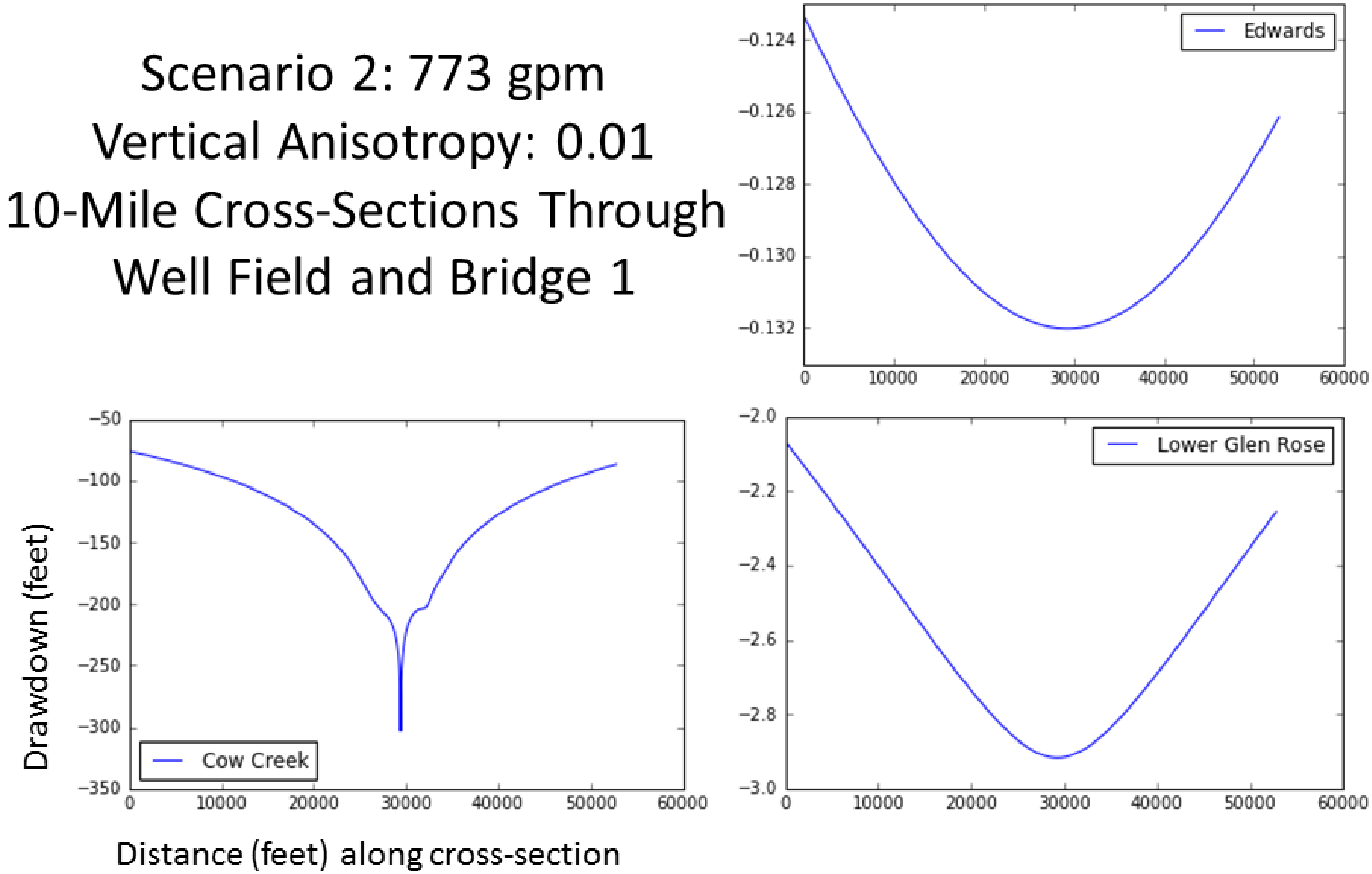
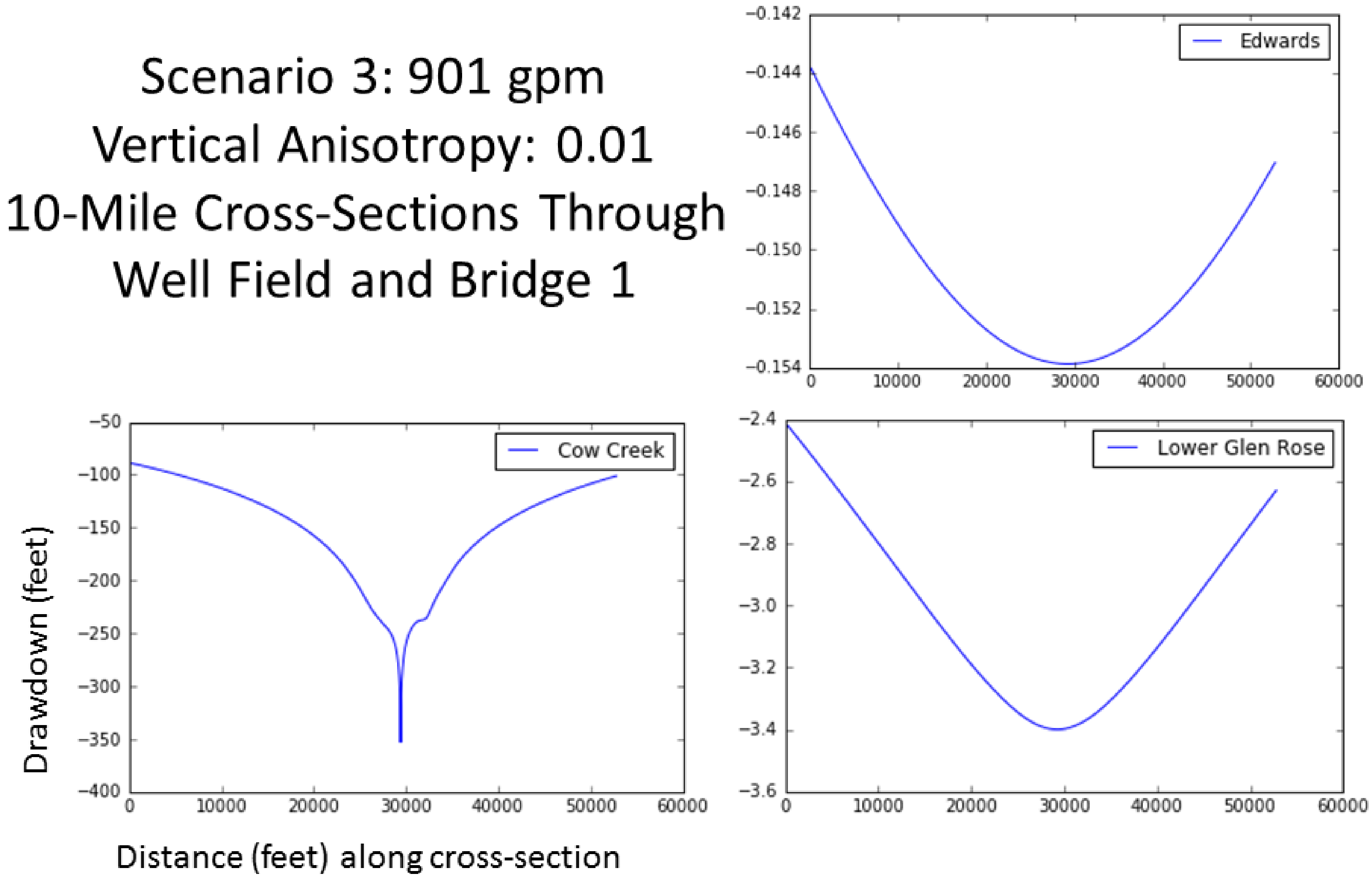


Figure A-1. Drawdown profiles for Scenario 1 across a 10-mile cross-section through the EP well field.



Scenario 2: 773 gpm
Vertical Anisotropy: 0.01
10-Mile Cross-Sections Through
Well Field and Bridge 1

Figure A-2. Drawdown profiles for Scenario 2 across a 10-mile cross-section through the EP well field.



Scenario 3: 901 gpm
Vertical Anisotropy: 0.01
10-Mile Cross-Sections Through
Well Field and Bridge 1

Figure A-3. Drawdown profiles for Scenario 3 across a 10-mile cross-section through the EP well field.

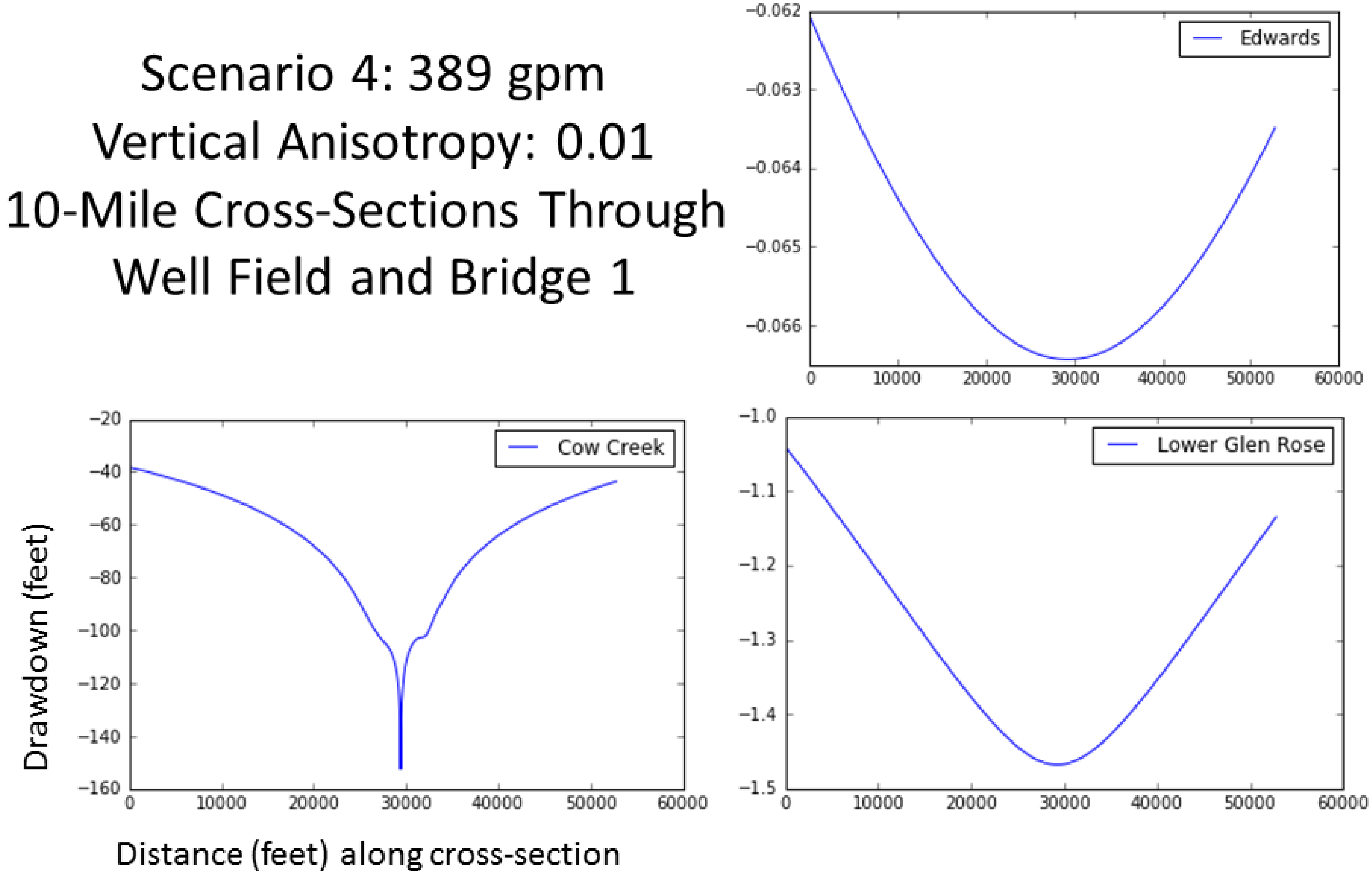
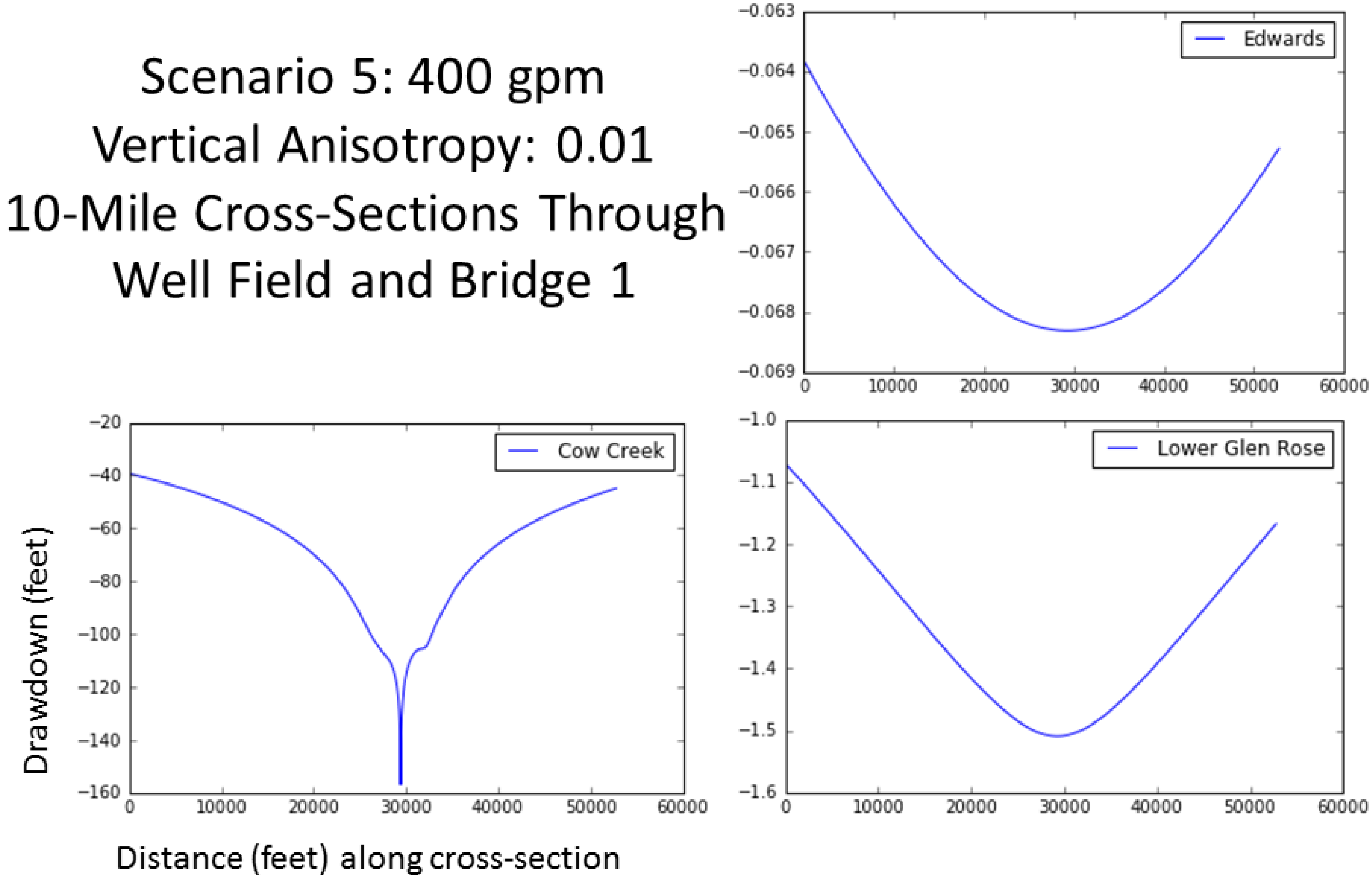


Figure A-4. Drawdown profiles for Scenario 4 across a 10-mile cross-section through the EP well field.



Scenario 5: 400 gpm
Vertical Anisotropy: 0.01
10-Mile Cross-Sections Through
Well Field and Bridge 1

Figure A-5. Drawdown profiles for Scenario 5 across a 10-mile cross-section through the EP well field.

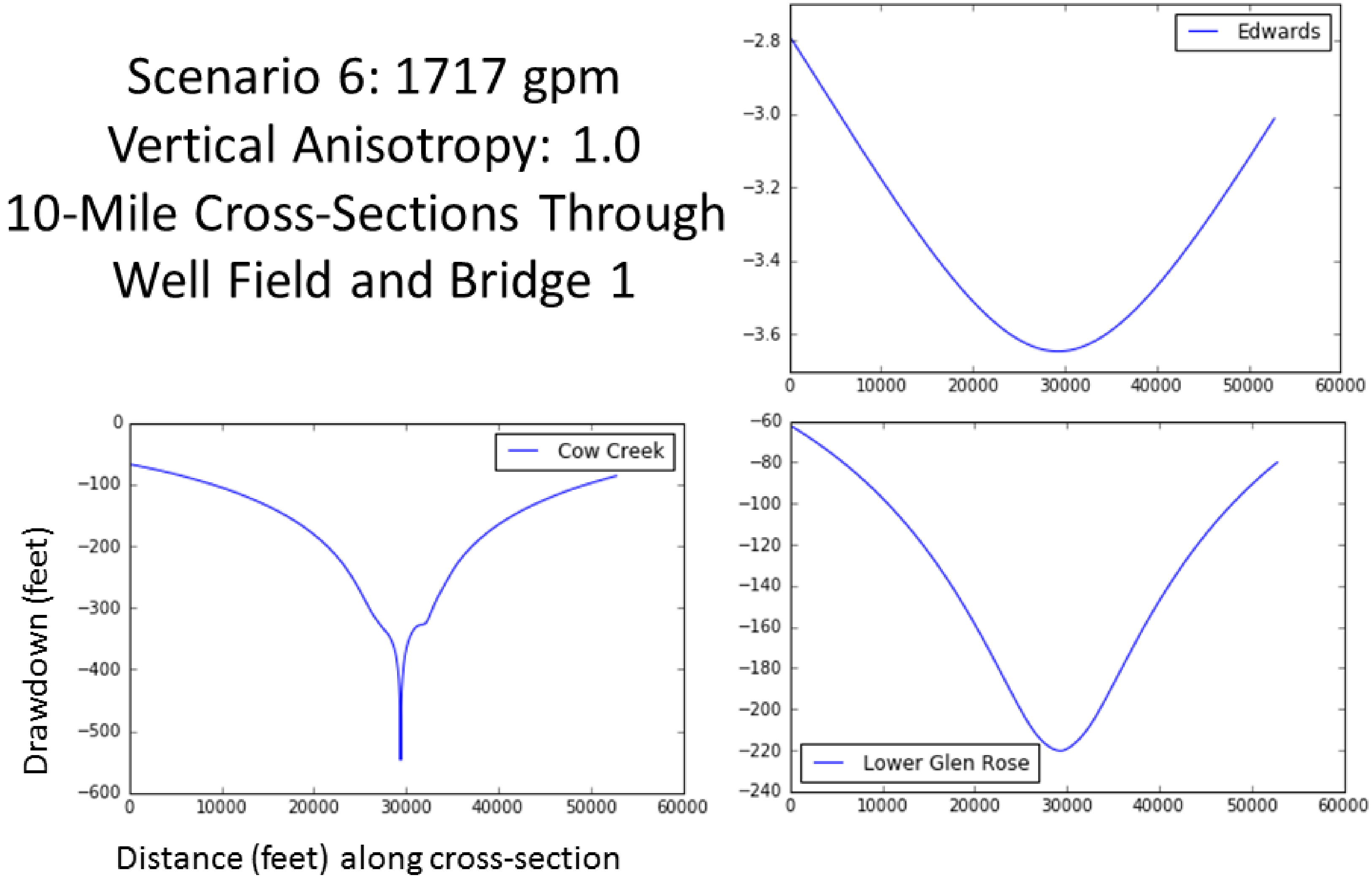


Figure A-6. Drawdown profiles for Scenario 6 across a 10-mile cross-section through the EP well field.

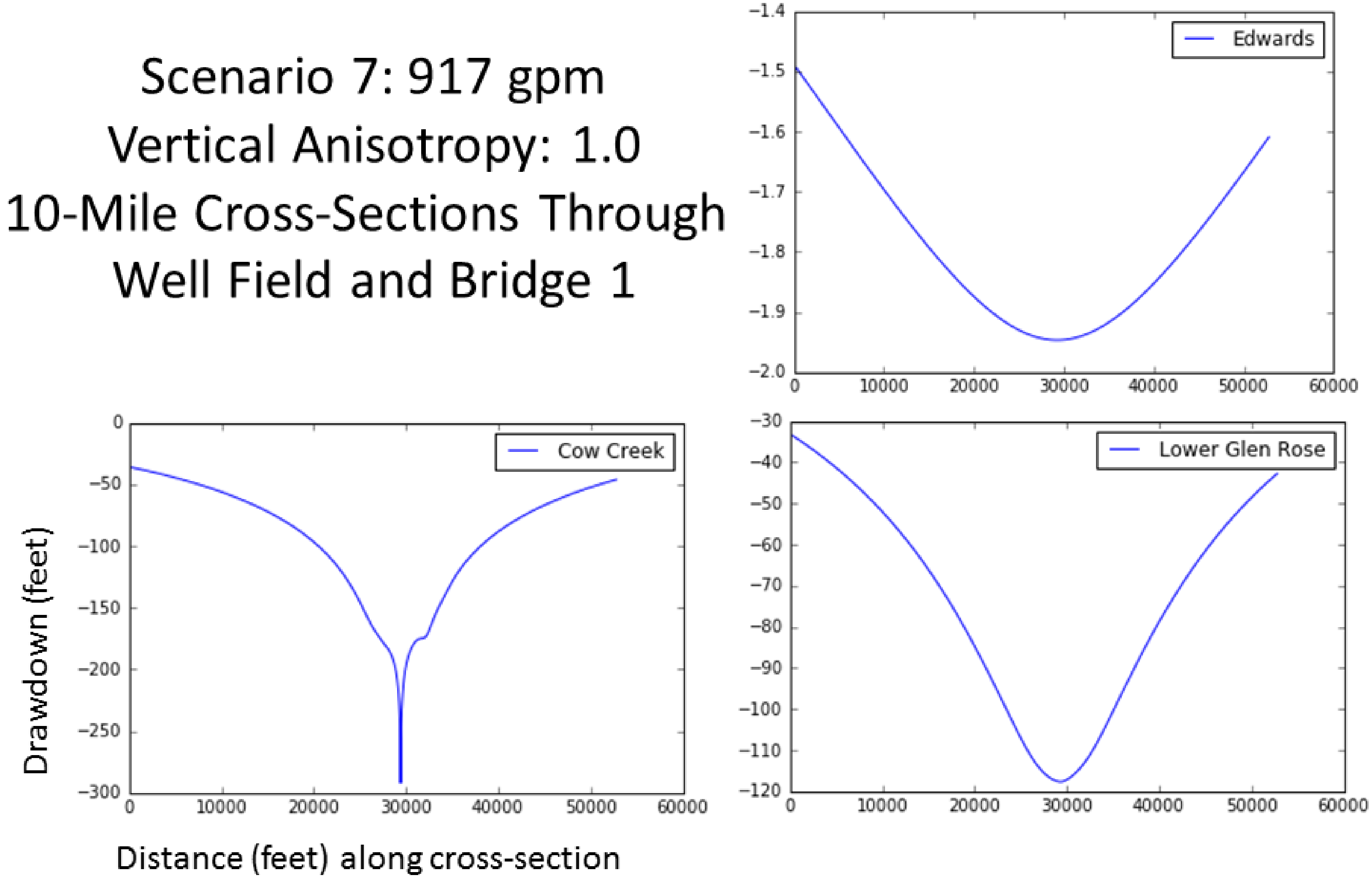

Scenario 7: 917 gpm
Vertical Anisotropy: 1.0
10-Mile Cross-Sections Through
Well Field and Bridge 1

Figure A-7. Drawdown profiles for Scenario 7 across a 10-mile cross-section through the EP well field.

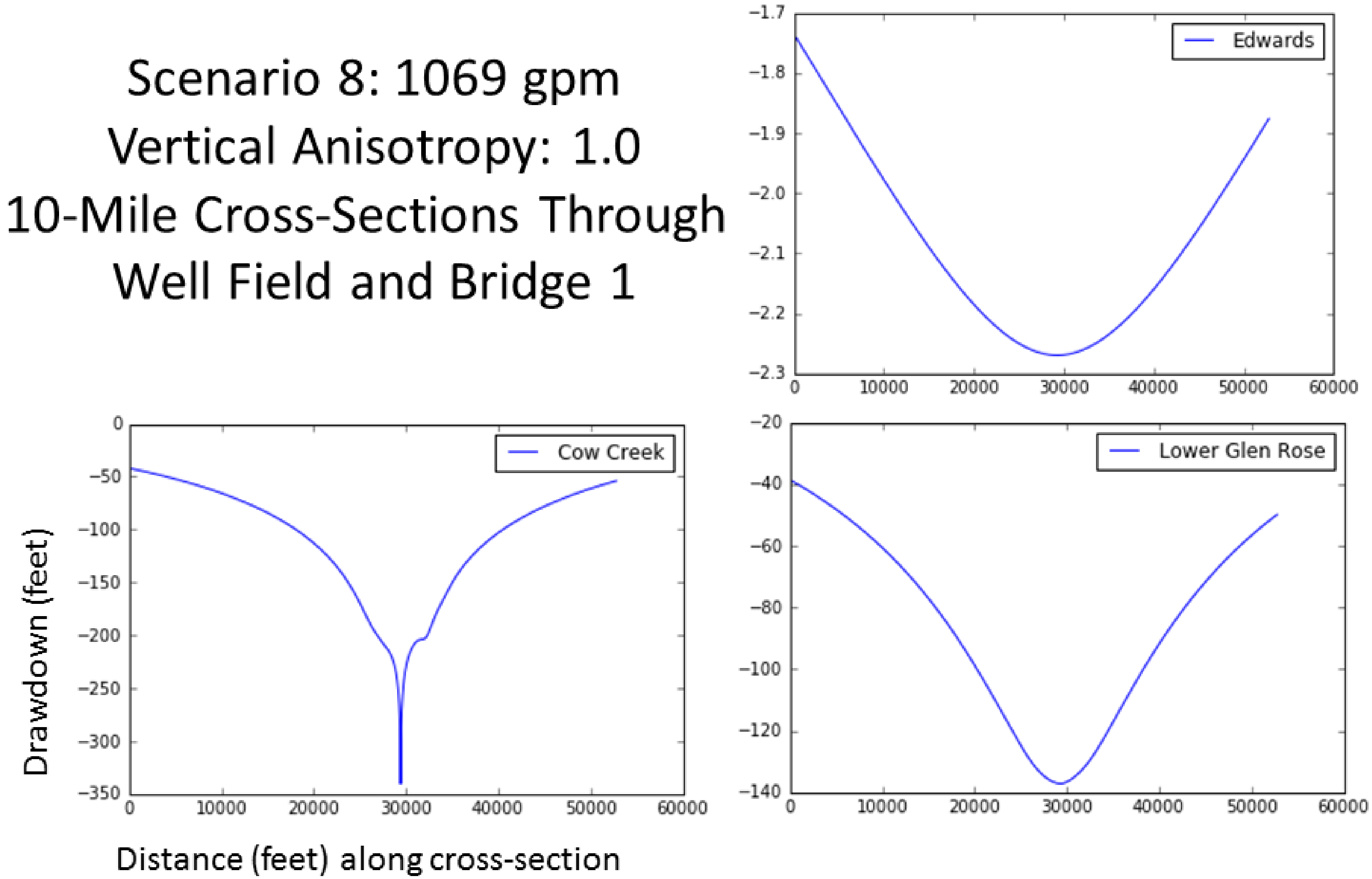


Figure A-8. Drawdown profiles for Scenario 8 across a 10-mile cross-section through the EP well field.

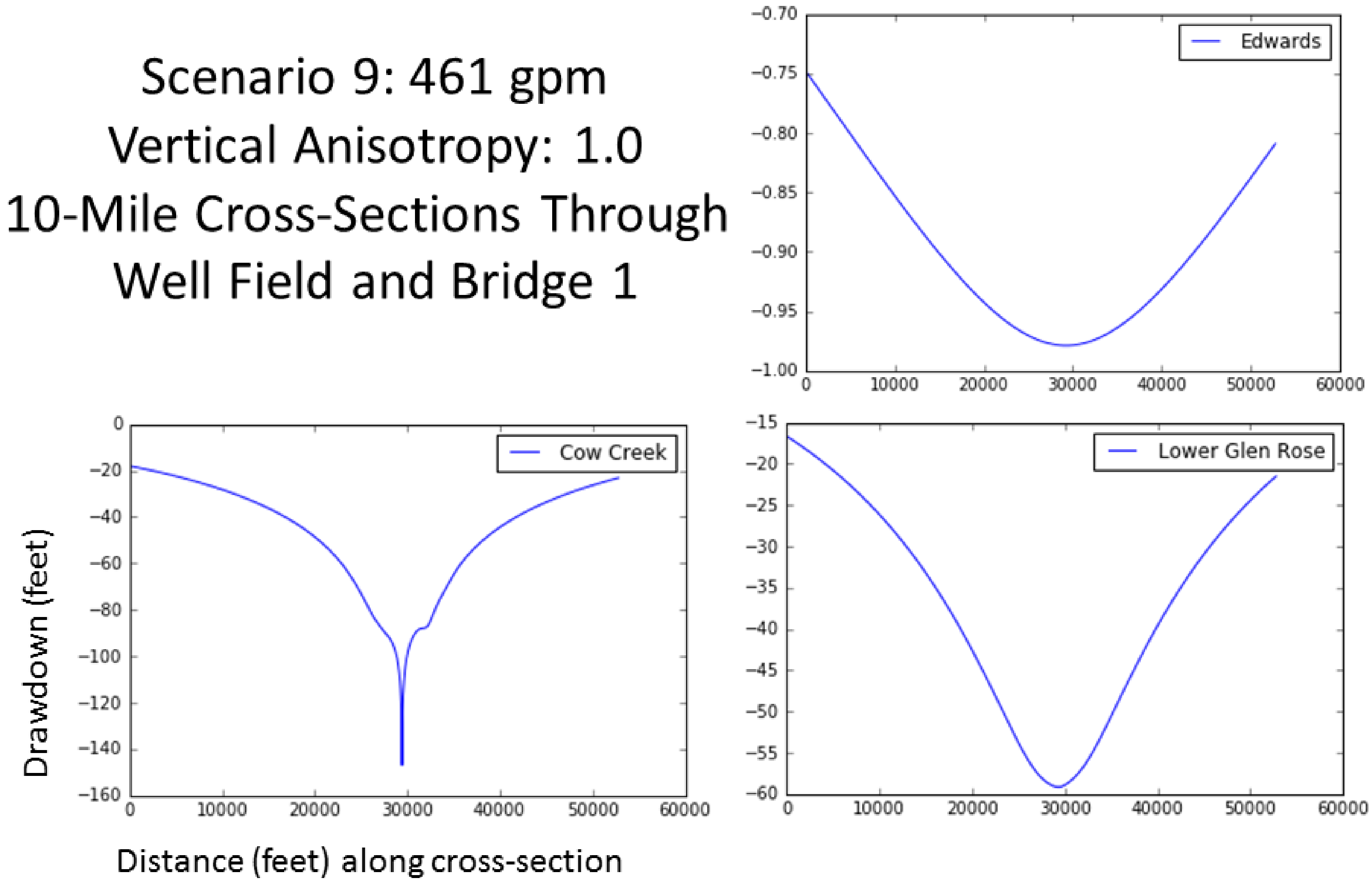
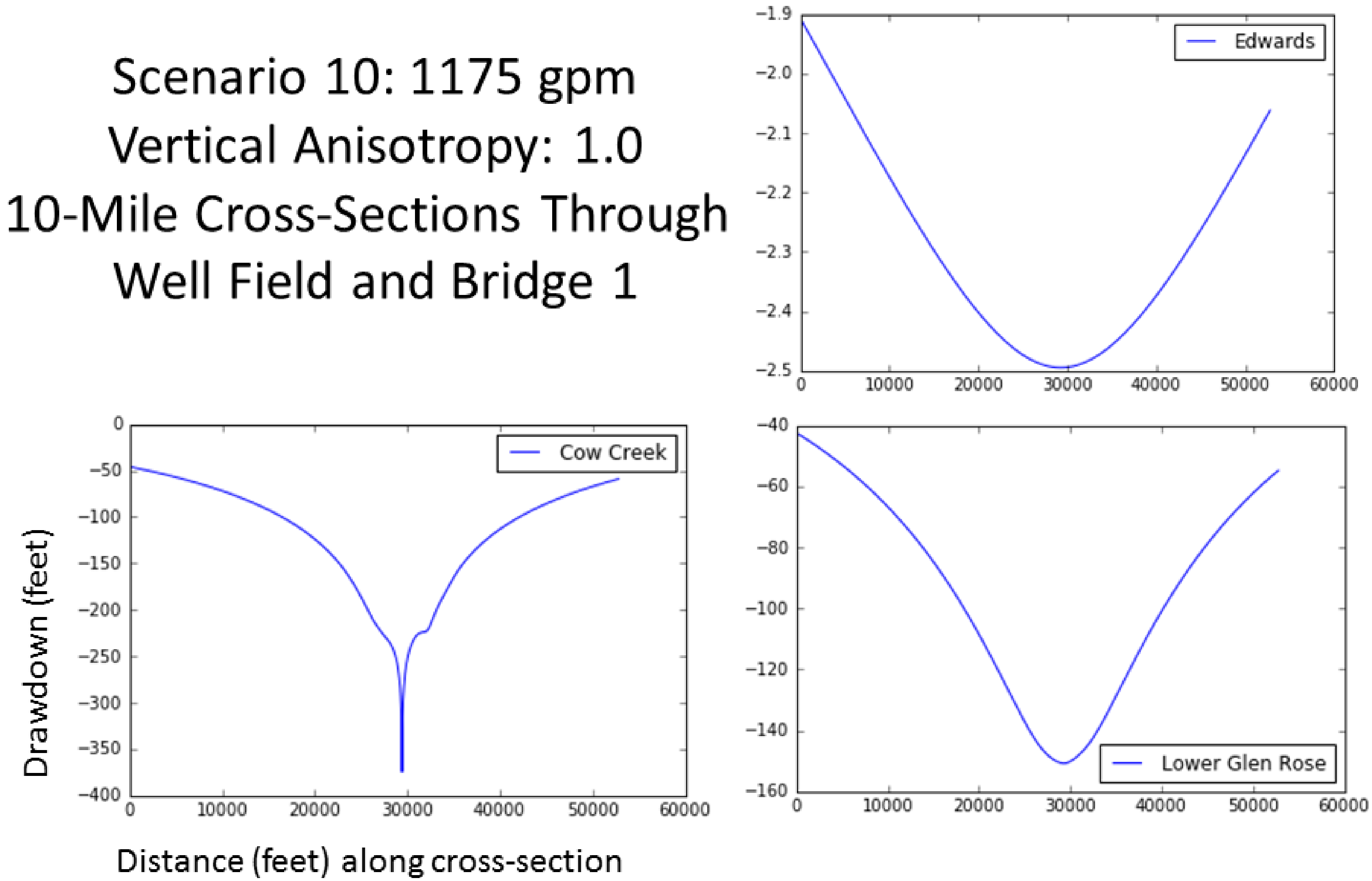


Figure A-9. Drawdown profiles for Scenario 9 across a 10-mile cross-section through the EP well field.



Scenario 10: 1175 gpm
Vertical Anisotropy: 1.0
10-Mile Cross-Sections Through
Well Field and Bridge 1

Figure A-10. Drawdown profiles for Scenario 10 across a 10-mile cross-section through the EP well field.