Phase II Hydrogeologic Investigation Report
Collector Well Siting Study

prepared for

Ameren Corporation
Ameren-UE

June 2008

Project No. 46691

prepared by

Burns & McDonnell Engineering Company, Inc.
Kansas City, Missouri

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June 30, 2008

Mr. Tom Grothe
Ameren-UE
Callaway Plant
PO Box 620
Fulton, MO 65251-0620

Phase II Hydrogeologic Investigation Report
Collector Well Siting Study
46691

Dear Mr. Grothe:

We are pleased to present the attached final report for Phases 1 and 2 of the hydrogeologic investigation addressing the suitability of the Missouri River alluvial aquifer for providing a groundwater supply source for the Callaway County plant.

The Phase 1 report, previously submitted as a draft for your review, is also included as Appendix A of the Phase 2 report

Phase 1 consisted of test drilling at seven locations and was completed in order to select the most appropriate sites for more detailed hydrogeologic investigation as part of Phase 2. Phase 2 consisted of aquifer pumping tests at two locations, both of which demonstrated the suitability of those sites for potential collector well locations.

The Phase 2 report includes a description of the investigations performed, data collection and analysis, an estimate of collector well yields, and conceptual design for a typical collector well.

As always, Burns & McDonnell appreciates the opportunity to be of service to Ameren-UE. Please do not hesitate to contact me (816-822-3887, phigg@burnsmcd.com) or Dave Stous (816-822-3088, dstous@burnsmcd.com) if you have any comments or questions.

Sincerely,

Patrick J. Higgins, R.G.
Project Manager

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INDEX AND CERTIFICATION

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Certification

I hereby certify, as a Professional Engineer in the state of Missouri, that the information in the document was assembled under my direct personal charge. This report is not intended or represented to be suitable for reuse by the Ameren-UE or others without specific verification or adaptation by the Engineer. This certification is made in accordance with the provisions of the laws and rules of the State of Missouri under Missouri Administrative Code.

David Stous

BMcD, David Stous, P.E., P.G.
Date: June 30, 2008
(Reproductions are not valid unless signed, dated, and embossed with Engineer's seal)

STATE OF MISSOURI
DAVID H. STOUS
NUMBER
E-17239
REGISTERED PROFESSIONAL ENGINEER

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EXECUTIVE SUMMARY

The primary purpose of this Phase II Hydrogeologic Investigation effort is to confirm that the hydrogeologic characteristics of the Missouri River alluvial aquifer near the Callaway Plant will support the installation of collector wells that will supply the quantity and quality of water needed for Callaway. This effort included test hole drilling, the performance of two, 72-hour aquifer pumping tests, water quality analysis, and analysis of the pumping test data to estimate well capacity and develop a conceptual design. The tests indicated that aquifer conditions at both sites are very suitable for the installation of high capacity collector wells. While both test sites were suitable, Ameren has recently negotiated the purchase of the property around the TW-01 site. Since the aquifer testing results indicate that this site can supply the necessary volume of water, our results will concentrate on this site. The estimated well yield at site TW-01 is shown below:

Table ES 1
Design Yield

Average summer	37 MGD (26,000 gpm)
Test conditions	32 MGD (22,000 gpm)
Average winter	25 MGD (17,000 gpm)

Because of the large potential yield capacity, our proposed conceptual well design consists of a 20-foot inside diameter concrete caisson constructed to bedrock and fourteen 200-foot laterals installed in two tiers. Burns & McDonnell recommends the construction of three such collector wells to provide a makeup water supply of approximately 50,000 gpm for two units at the Callaway Nuclear Plant.

The analysis indicates water supply from the collector wells could be 85 percent river water and 15 percent aquifer water during most of the year. During winter months with cold river water, there may be a larger percentage of aquifer water. Based upon water samples from the river and the aquifer, the design water supply from the collector wells would be as shown below. In reviewing the following it is important to understand that actual water chemistry will vary from the design water chemistry. The design water chemistry is a hypothetical analysis that serves as a design tool.

Table ES 2
Design Water Quality

Constituents	Design	Range	
Cations			
Calcium, ppm	72.32	69.10	75.54
Magnesium, ppm	22.90	22.42	23.38
Potassium, ppm	5.89	5.78	6.00
Sodium, ppm	50.60	48.40	52.81
Anions			
Chloride, ppm	10.03	9.03	11.04
Fluoride, ppm	0.50	0.50	0.51
Nitrate, ppm as Nitrogen	4.29	3.86	4.72
Silica, ppm	14.22	13.35	15.10
Miscellaneous			
Iron, ppb	1,304.51	882.82	1,726.21
Manganese, ppb	136.44	97.20	175.68
pH	7.95	7.91	7.99

Based upon the aquifer flow parameters and the design water analysis, water treatment is likely to be required during well development. Initially high iron concentrations are expected to decline with time as river water is drawn through the river bed and replaces the native aquifer water. Burns & McDonnell is in the process of performing water chemistry tasks that will identify with greater certainty the type and quantity of water treatment that may be required. These results will be addressed separately from this report.

* * * * *

1.0 INTRODUCTION

Ameren Corporation (Ameren) is preparing a Combined License Application (COLA) for submittal to the Nuclear Regulatory Commission for the construction and operation of a second unit at the Callaway Nuclear Plant in Callaway County, Missouri. As part of the COLA, a hydrogeologic investigation is being completed to evaluate the possibility of using horizontal collector wells to supply the cooling water for the existing and proposed units. Burns & McDonnell is pleased to provide this report to address the methods, analysis, and conclusions related to Phase II of the hydrogeologic investigation for the proposed collector wells along the Missouri River. All figures and appendices referenced in the text are presented at the end of this report.

During Phase I of the hydrogeologic investigation, seven test borings were advanced to bedrock in order to determine the depth, approximate saturated thickness, and geologic composition of the of the Missouri River alluvium near the existing surface water intake that currently supplies cooling water to Unit 1. Monitoring wells were installed at each boring location to obtain static water level observations and to allow measurement of water levels during aquifer pumping tests to be conducted as part of Phase II of the project. Water quality samples were obtained from these monitoring wells in August of 2007. Locations of the monitoring wells are shown in Figure 1 and labeled FMW-06 through FMW-12. Geologic logs and a geologic cross section through the investigation area are included in the Phase I Investigation Report, included in this report as Appendix A.

Data including depth to bedrock and grain size of the geologic material obtained from Phase I test drilling was used during Phase II to select two test well locations (TW-01 Site & TW-02 Site) and to design the test wells. The locations of the aquifer test sites are presented in Figure 1. Eighteen observation wells were also installed (nine at each test well Site) to obtain additional data used to analyze the aquifer flow characteristics. A 72-hour constant-rate aquifer pumping test was completed at each site to estimate the potential yield of a collector well.

* * * * *

2.0 TEST WELL AND OBSERVATION WELL INSTALLATION

Drilling for Phase II was performed between October 1 and November 12, 2007. During Phase II, a total of two test wells (TW-01 & TW-02) and 18 test borings were drilled at the test Sites shown in Figure 1. Selected Phase II activities including drilling and construction of both test wells were observed by a Burns & McDonnell geologist. All of the drilling activities were observed by a Burns & McDonnell archeologist to verify that no cultural resources were disturbed during the investigation.

Cahoy Well & Pump Service (Cahoy) of Fredericksburg, Iowa completed all test well and observation well drilling. At each Site, a test well and six observation wells were drilled to bedrock. Two shallow observation wells were installed to a depth of approximately 50 feet below grade (fbg) and one bedrock observation well was installed 40 feet into the bedrock unit below the alluvial aquifer to monitor the vertical flow and interaction between the alluvial and bedrock aquifers. Figures 2 and 3 are plan views showing the layout of the wells at the TW-01 and TW-02 Sites, respectively.

Each boring location was first drilled from 0 to 20 fbg with 10-inch diameter hollow stem augers and sampled with a Central Mine Equipment (CME) continuous sampler, so that any evidence of cultural resources would be clearly visible. After the first 20 feet were drilled with hollow stem augers, temporary surface casing was set and the well was drilled to total depth using reverse rotary or direct rotary methods.

Cahoy completed all observation well drilling using hollow stem auger and mud rotary techniques. Each observation well was constructed with 20 feet of 2-inch diameter, Schedule 40 machine-slotted (0.010-inch) PVC screen set at the bottom and completed with solid Schedule 40 PVC casing to the ground surface. A gravel pack was placed alongside the screen extending up to a depth of approximately 5 to 10 feet above the top of screen, and a minimum 3-foot thick bentonite chip seal was placed above the gravel pack. A bentonite slurry grout was then pumped in to fill the borehole to grade. Borehole total depths ranged from approximately 52 to 138 fbg. All wells were registered with and approved by Missouri Department of Natural Resources. Following construction, each observation well was developed by air lifting to remove drilling fluid from the area around the well screen and to enhance communication between the well screen and the aquifer. A summary of the well construction information is included as Table 2.1.

Table 2.1
Well Construction Information Summary

Well No.	Diameter	Drilled Depth	Top of Screen	Bottom of Screen
TW-01	12	95	54	94
OB01-01	6	97	64	84
OB01-02	2	96	76	96
OB01-03	2	99	79	99
OB01-04	2	96	76	96
OB01-05	2	98	75	95
OB01-06	2	97	75	95
OB01-S1	2	52	30	50
OB01-S2	2	52	30	50
OB01-B1	2	137	117*	137*
TW-02	12	95	50	90
OB02-01	6	97	74	94
OB02-02	2	97	77	97
OB02-03	2	96	76	96
OB02-04	2	97	77	97
OB02-05	2	98	77	97
OB02-06	2	97	74	94
OB02-S1	2	52	30	50
OB02-S2	2	52	30	50
OB02-B1	2	138	118	138

**OB01-B1 was completed as an open borehole (without screen and gravel pack) during TW-01 testing.*

At each test well location, Cahoy drilled a 24-inch diameter borehole to bedrock using reverse rotary techniques. A test well was then constructed of 12-inch diameter steel casing with 40 feet of continuous wire-wrap steel screen with 0.020-inch openings. A gravel pack was placed alongside the screen extending up to a depth of approximately 5 to 10 feet above the top of screen, and a minimum 3-foot thick bentonite chip seal was placed above the gravel pack. A cement grout was then pumped in to fill the borehole to grade. Following construction, the test well was developed by air lifting, bailing, surging, and then pumping with a submersible pump. This development procedure continued until the well water was observed to be clean after starting and stopping the pump several times. Total well development time was approximately 13.5 hours for TW-01 and 10 hours for TW-02. Geologic logs for the test wells are included in Appendix B.

A field survey was conducted at each Site. Burns & McDonnell personnel used a surveying level to determine the elevation of the top of casing of each test well and observation well in relation to an arbitrary Site datum.

* * * * *

3.0 AQUIFER TESTING PROCEDURES

3.1 BACKGROUND DATA

Aquifer and Missouri River levels were monitored throughout the investigation to evaluate the hydraulic connection between the river and the aquifer, and to observe any water level trends during the pumping tests that might impact the analysis and results.

A LevelTROLL® 700 data logger was installed in monitoring well FMW-10. FMW-10 is located approximately halfway between the two Sites, and well beyond the radius of influence of the pumping wells. Data collected from this well was used to evaluate changes in the aquifer water level that were not associated with the pumping activities in the two wells. The LevelTROLL® recorded groundwater level data every 15 minutes from October 2 to November 28, 2007.

3.2 STEP TESTS

Step-rate pumping tests were conducted on both test wells using a submersible pump in order to determine the efficiency of the test wells and to determine the pumping rate for each constant-rate test. The flow rate was measured using a free discharge orifice weir (10-inch pipe, 8-inch orifice) fitted with a manometer tube. The discharge from the test well flowed overland to the Missouri River.

The step tests consisted of four or five steps in which the pumping rate increased with each subsequent step. During each step the well was pumped at a constant-rate until the pumping water level became relatively stable. Water levels in the test well were recorded by Cahoy personnel throughout the step tests. At each Site substantial measures were taken to minimize the potential for erosion from the discharge.

3.3 CONSTANT-RATE TESTS

Following the step-rate testing, water levels in the aquifer were allowed to recover for a minimum of 12 hours before a 72-hour constant-rate test was initiated. During each constant-rate test, water levels were monitored manually in the test well using an electric water level meter. Water levels in the observation wells were constantly measured with pressure transducers and recorded at regular intervals using In-Situ®, Inc. Hermit 3000® and LevelTROLL® 700 computerized data recorders. Manual measurements were also collected at intervals with an electric water-level meter as a backup to the electronic instruments. The flow rate was monitored manually and with a pressure transducer connected to the Hermit 3000®. Changes in barometric pressure were monitored and recorded by the Hermit 3000®. The

Missouri River stage was monitored with an In-Situ, Inc. LevelTROLL® 500, set in a stilling well in the river near each test Site.

After 72 hours of pumping the wells were shut down and the aquifer water level recovery was monitored. Each test well and the observation wells were monitored in the same manner as during the pumping portion of the test. The river stage was also monitored during the recovery portion of the test.

3.4 WATER QUALITY SAMPLING

Water quality samples were collected from the discharge of the pumping well at three intervals during the constant-rate test in order to evaluate changes in the water quality over time. Temperature, conductivity, and pH of the discharge were measured at the beginning, middle and end of the test. For comparison, temperature measurements were collected in the Missouri River. Samples were collected 2.5 hours, approximately 30 hours, and 71 hours after pump start-up. Sample analysis results are attached as Appendix C of this report.

* * * * *

4.0 AQUIFER TESTING ACTIVITIES

4.1 WELL TW-01 TESTING

TW-01 was step tested on November 7, 2007. Four steps were completed, at 797, 1205, 1580, and 1691 gallons per minute (gpm). Results of the step-rate test indicated that the highest pumping rate that could reliably be sustained for 72-hours in TW-01 was approximately 1600 gpm. Therefore a pumping rate of approximately 1600 gpm was selected for the 72-hour constant rate test.

The 72-hour constant-rate pumping test on TW-01 was started at 8:00 a.m. on November 8, 2007. TW-01 was pumped at a constant-rate of 1594 gpm with only minor fluctuations until 8:00 a.m. on November 11, when the pump was shut down and the recovery portion of the test began. Recovery was monitored until 8:00 a.m. on November 12.

During the test, the Missouri River stage dropped approximately 0.8 feet, which dewatered the stilling well and the LevelTROLL® 500 which was monitoring the river stage. The river level dropped below the pressure transducer at approximately 2:00 p.m. on November 8. The LevelTROLL® 500 was reinstalled in the stilling well at a greater depth at 12:15 p.m. on November 9, and adjustments were made to the data to correct for the change in the level of the transducer.

Water quality samples were collected at three intervals during the constant-rate test. The first sample was collected at 10:30 a.m. on November 8, the second at 1:00 p.m. on November 9, and the third at 7:00 a.m. on November 11. Each of the samples was stored on ice and either delivered by Burns & McDonnell personnel or shipped to the laboratory for analysis.

4.2 WELL TW-02 TESTING

A step test was completed on TW-02 on November 3, 2007. Five steps were completed, at 797, 1205, 1580, 2021, and 2044 gallons per minute (gpm). Results of the step-rate test indicated that a continuous pumping rate of approximately 1900 gpm could be sustained for the 72-hour constant-rate pumping test at TW-02.

The 72-hour constant-rate pumping test on TW-01 was started at 8:00 a.m. on November 14, 2007. TW-02 was pumped at a constant-rate of 1906 gpm with only minor fluctuations until 8:00 a.m. on November 17, when the pump was shut down and the recovery portion of the test began. Recovery was monitored until 3:30 p.m. on November 17.

Water quality samples were collected at three intervals during the constant-rate test. The first sample was collected at 10:30 a.m. on November 8, the second at 3:10 p.m. on November 9, and the third at 7:25 a.m. on November 11. Each of the samples was stored on ice and either delivered by Burns & McDonnell personnel or shipped to the laboratory for analysis.

* * * * *

5.0 INVESTIGATION RESULTS

The following paragraphs describe the analysis of the observation well and test well construction data and the results of the aquifer testing completed at the site.

5.1 OBSERVATION WELL AND TEST WELL CONSTRUCTION

The materials encountered in the test borings at the site were Missouri River alluvium consisting of a generally coarsening-downward sequence of inter-bedded layers of fine to coarse sand. The upper 10 feet of the formation is a mixture of silt, clay and sand that transitions to fine to medium grained sand. From approximately 10-60 fbg, the formation is primarily sand with some gravel. The lower 40 feet of the formation is a poorly sorted mixture of sand and gravel with some cobbles. Based on the visual observations during drilling and geophysical logs from Phase I, there were no significant layers or lenses of fine-grained materials that could potentially restrict groundwater flow encountered in any test boring at depths greater than 30 fbg. Bedrock underlying the sand and gravel consists of dolomite and was encountered at depths ranging from 95 to 99 fbg.

Groundwater was measured at each Site prior to starting any test pumping activities and averaged approximately 20 fbg. The saturated thickness of the aquifer is approximately 75 to 80 feet. A generalized geologic profile along the line of the test borings for the TW-01 Site is presented in Figure 4, and for TW-02 Site in Figure 5.

5.2 BACKGROUND DATA

The Missouri River was monitored using the USGS gages at Booneville and Jefferson City. In addition, a LevelTROLL® 500 was installed in a stilling well in the river adjacent to each test Site for the duration of each pumping test. Figure 6 is a graph showing the groundwater level data collected from FMW-10, the Missouri River data from the USGS gage at Jefferson City and the local river data for each test.

Aquifer water levels monitored in FMW-10 indicate a good hydraulic connection to the Missouri River and rapid response to changes in the river stage. The Jefferson City gage data indicates that the Missouri River stage declined approximately 0.8 feet during the TW-01 test and approximately 0.4 feet during the TW-02 test. Aquifer water levels at FMW-10 during those same periods declined approximately 0.7 feet and 0.4 feet, respectively.

5.3 STEP-RATE TESTS

Step-rate tests were completed in each test well as described above. Results of the step tests were used to calculate the specific capacity (pumping rate divided by drawdown) of each test well in order to determine the appropriate flow rate for the constant-rate pumping test. Specific capacity and drawdown for each step are presented in Table 5.1.

Table 5.1
Step Test Data Summary

Test Well TW-01

Step No.	Q (gpm)	Drawdown (feet)	Specific Capacity (gpm/ft)
1	797	14.56	54.7
2	1205	22.67	53.2
3	1580	33.10	47.7
4	1691	37.00	45.7

Test Well TW-02

Step No.	Q (gpm)	Drawdown (feet)	Specific Capacity (gpm/ft)
1	825	33.11	24.9
2	1205	38.00	31.7
3	1609	42.20	38.1
4	2021	48.20	41.9
5	2044	48.45	42.2

5.4 72-HOUR CONSTANT-RATE TESTS

Two 72-hour constant-rate pumping tests were completed as described in the previous section. Due to the decline in the Missouri River Level, the aquifer static water level also declined. This decline is apparent in the observation well water level data and results in the appearance of increased drawdown. The data from the observation wells was corrected for the drop in aquifer water level by subtracting the value of the decline in the aquifer water level at FMW-10 at a given time from the observation well data at that same time.

Graphs of the recorded water level data corrected for the decline in the river and aquifer water levels during the TW-01 test are presented in Figure 7, and for TW-02 in Figure 8. In general, water levels recorded electronically closely match those recorded manually. Gage data from the USGS stream gage in Jefferson City correlated well with the Site stage measurements. Drawdown contours at the TW-01 Site from the end of the 72-hour test are presented in Figure 9 and for the TW-02 Site in Figure 10.

5.5 ANALYSIS

Transmissivity is defined as the rate at which water is transmitted through a unit width of aquifer under a unit hydraulic gradient. Storativity, also known as the storage coefficient, is the volume of water an aquifer releases or takes into storage per unit surface area of the aquifer per unit change in head.

The distance to the line source of recharge is a computational method for considering infiltration from an adjacent river or lake. It simplifies calculations of infiltration of river water through an area of streambed by assuming the recharge is from a line at a distance "a" from the pumping well. The "a" distance is a parameter used in the estimate of collector well yield. Calculations of "a" are based on image well theory developed by Theis. For this analysis, data is recorded from two lines of observation wells, one parallel to the river and one perpendicular to the river.

Aquifer parameters of transmissivity (T) and storativity (S) were calculated from pumping test data using computational methods developed by Theis (1935), Cooper and Jacob (1946), Neuman (1972, 1974), and Rorabaugh (1956). In general, time-drawdown analyses (Theis, Neuman) will give better indications of aquifer conditions near the pumping well and distance-drawdown analyses (Cooper and Jacob) give better indications of conditions near the edge of the cone of depression. Additionally, the distance to the line source of recharge "a" was calculated using methods developed by Rorabaugh.

Results of the calculations of T and S are presented in Table 5.2. Pumping test data and calculations are presented in Appendix D.

Using the Rorabaugh method, the apparent "a" distance along the line of observation wells parallel to the river for the TW-01 Site under test conditions is approximately 1000 feet. The apparent "a" along the perpendicular line of observation wells for the TW-02 Site is approximately 825 feet. This difference indicates varying transmissivity in the area of the test, which is confirmed by the varying depth to bedrock and varying estimates of transmissivity from the time-drawdown analyses at the individual observation wells.

Table 5.2
Aquifer Analysis Results
Time-Drawdown Analysis

Test Well TW-01

Well Nos.	Average Transmissivity (gpd/ft)	Storage (unitless)
OB01-01 to -06	548,300	0.0129
OB01-01,-05,-06	489,400	0.0071
OB01-02,-03	500,000	0.0267

Test Well TW-02

Well Nos.	Average Transmissivity (gpd/ft)	Storage (unitless)
OB02-01 to -06	632,800	0.0007
OB02-01,-05,-06	562,500	0.0009
OB02-02,-03	550,600	0.0005

Distance-Drawdown Analysis
Line of Wells Parallel to River

Test Well TW-01

Test Elapsed Time	Transmissivity (gpd/ft)	Storage (unitless)
24 hours	466,000	0.155
48 hours	464,900	0.215
72 hours	462,500	0.262

Test Well TW-02

Test Elapsed Time	Transmissivity (gpd/ft)	Storage (unitless)
24 hours	363,900	0.155
48 hours	372,400	0.282
72 hours	375,500	0.417

Distance-Drawdown Analysis
Line of Wells Perpendicular to River

Test Well TW-01

Test Elapsed Time	Transmissivity (gpd/ft)	Storage (unitless)
24 hours	426,200	0.118
48 hours	429,500	0.152
72 hours	436,000	0.169

Test Well TW-02

Test Elapsed Time	Transmissivity (gpd/ft)	Storage (unitless)
24 hours	426,100	0.190
48 hours	431,000	0.203
72 hours	434,000	0.482

Because there is some variation in apparent hydraulic conditions at the test Sites, conservative values were selected for considering collector well yield estimates. These values are summarized in Table 5.3.

Table 5.3
Aquifer Hydraulic Characteristics Summary

	TW-01 Site	TW-02 Site
Transmissivity	450,000 gpd/ft	400,000 gpd/ft
Distance to Line Source of Recharge	1000 feet	825 feet
Saturated Thickness	78 feet	77 feet
Hydraulic Conductivity (K)	5770 gpd/ft^2	5195 gpd/ft^2
Storativity (S)	0.179	0.208

5.6 ESTIMATED COLLECTOR WELL YIELD

Estimates of potential collector well yield were made using methodology developed by Hantush and Popadopulos (1962). The method considers the theoretical drawdown under steady-state pumping conditions in a collector well located adjacent to a river and constructed in an unconfined aquifer.

In addition to aquifer parameters determined from the pumping test, potential collector well yield is also dependent on several design and seasonal river factors. These include available drawdown, river level and water temperature. The river level will impact the amount of water that will flow from the river to the subsurface and influence the static water level. Temperature will impact the viscosity of water moving through the river bed and aquifer. A 1-degree Fahrenheit change in water temperature will change the effective permeability of the aquifer by 1½ percent. The average June to August water temperature of the Missouri River at Hermann, Missouri is approximately 77° F and the average winter water temperature is approximately 40° F. Groundwater temperatures will moderate the temperature of the water moving through the river bed to the collector well. The effective value of transmissivity will change due to changes in viscosity at varying water temperatures which will impact calculations of the distance to the line of recharge and estimates of well yield. Design parameters and assumptions for seasonal yield are listed in Table 5.4.

Table 5.4
Collector Well Design Parameters

Conditions	Test Conditions	Summer Low Flow	Winter Average Flow
Grade, ft. msl (from USGS topo map)	520 ±	520 ±	520 ±
Top of Sand, ft. msl	510	510	510
Base of Aquifer, ft. msl	422	422	422
Centerline of Upper Tier of Laterals, ft. msl	434	434	434
Inside Diameter of Caisson	20	20	20
Saturated Thickness	76	77	76
Static Water Level, ft. msl	498	499	498
Hydraulic Conductivity, gpd/ft^2 (temperature corrected)	5770	6710	4950
Radius of Lateral, ft.	0.5	0.5	0.5
Design Distance to Line Source of Recharge, ft	1000	900	1200
Average Lateral Length, ft.	200	200	200
Number of Laterals	14	14	14
Aquifer Water Temperature, °F	57	68	45
Minimum Design Pumping Level, ft. msl	444	444	444

Calculated yield and drawdown for test, summer and winter conditions are shown in Figure 11. Yield calculations are presented in Appendix E and the calculated maximum yields for each set of seasonal conditions are summarized in Table 5.5.

Table 5.5
Design Yield

Average Summer	37 MGD (26,000 gpm)
Test conditions	32 MGD (22,000 gpm)
Average winter	25 MGD (17,000 gpm)

Due to the variability of the aquifer materials, actual yield of a collector well may be higher or lower depending on materials encountered during installation of the collector well laterals.

Analysis of the pumping test data indicates that the Missouri River alluvium at both of the test well sites is capable of providing the necessary yield for a large capacity collector well. Both the Missouri River and the groundwater aquifer will contribute water to a well. Initially, a higher percentage of water will come from the aquifer, but as the pumping duration increases more water will infiltrate from the river. Using the test well data, it is estimated that when steady-state conditions develop, approximately 85 percent of the water pumped will come from induced infiltration of river water and 15 percent will be groundwater originating as infiltration of precipitation through the upper soil horizons (Appendix E). The actual percentage of river/aquifer water will also vary with season due to changing water temperature, river stage, and aquifer water levels. Current knowledge of riverbed infiltration characteristics indicate that the ratio of river water to aquifer water content will be highest in the summer and lowest in the winter.

Actual river/aquifer percentages will depend on several factors including:

- Distance from the well to the river
- Duration of pumping
- Geology of the subsurface sediments impacted by pumping (radius of influence will be larger than during the test pumping)
- Changing water temperature of the river, resulting in changing permeability of the river bed

5.7 WATER QUALITY

During the 72-hour pumping test, the temperature, conductivity, and pH of the discharge were measured at the beginning, middle and end of the test. For comparison, temperature measurements were collected in the Missouri River. Table 5.6 summarizes the field parameter data from the two tests. The field parameter data was collected for verification, but as expected there was not much variation in the results. Although the Missouri River alluvium at the Sites is highly transmissive, at these test rates and durations the River's influence on the field parameters was negligible.

Table 5.6
Field Parameter Data

Well No.	Sample Time (after test start)	pH	Temperature (°F)	Conductivity (µS)
TW-01	2.5 hours	6.9	58.8	1000
	29 hours	7.0	58.4	1000
	71 hours	6.9	58.1	1010
TW-02	2.5 hours	7.1	57.5	760
	33 hours	7.1	58.0	740
	71 hours	7.4	58.0	730

Discharge samples were collected at three intervals during each test to evaluate the quality of water for the proposed use by Ameren. The samples were placed in a cooler with ice and shipped to Pace Analytical Laboratories, Inc. in Lenexa, Kansas for analysis. Selected parameter results from the laboratory analyses are presented in Table 5.7. The results indicate that with the exception of dissolved iron, the levels of the constituents analyzed are within typical ranges found in groundwater from alluvial aquifers in the area. Laboratory reports are included in Appendix C.

Table 5.7
Laboratory Analysis Results Summary

Constituents	Design	Range	
Alkalinity, ppm as CaCO3	259.62	245.93	273.31
Aluminum, ppb	19.91	17.91	21.90
Ammonia, ppm as N	0.19	0.17	0.21
Arsenic, ppb	2.81	2.53	3.09
Barium, ppb	379.28	339.52	419.03
Beryllium, ppb	0.49	0.44	0.54
Bicarbonate, ppm	259.62	245.93	273.31
Cadmium, ppb	2.11	1.90	2.32
Calcium, ppm	72.32	69.10	75.54
Carbon dioxide, ppm	3.46	3.11	3.80
Carbonate, ppm	4.34	3.90	4.77
Chloride, ppm	10.03	9.03	11.04
Chromium, ppb	2.44	2.19	2.68
Cobalt, ppb	2.52	2.27	2.77
COD, ppm	27.36	24.63	30.10
Copper, ppb	3.35	3.01	3.68
Fluoride, ppm	0.50	0.50	0.51
Hardness, ppm as CaCO3	225.64	221.66	229.61
Iron, ppb	1,304.51	882.82	1,726.21
Lead, ppb	13.42	12.08	14.77
Magnesium, ppm	22.90	22.42	23.38
Manganese, ppb	136.44	97.20	175.68
Mercury, ppb	0.96	0.87	1.06
Molybdenum, ppb	10.00	9.00	11.00
Nickel, ppb	2.35	2.11	2.58
Nitrate, ppm as Nitrogen	4.29	3.86	4.72
Nitrite, ppm as Nitrogen	0.03	0.03	0.03
Nitrogen, ppm	2.53	2.28	2.78
Noncarbonate hardness, ppm as CaCO	56.56	53.23	59.89
Orthophosphate, ppm	0.29	0.27	0.32
pH	7.95	7.91	7.99
Phosphorus, ppm	0.33	0.30	0.36
Potassium, ppm	5.89	5.78	6.00
Selenium, ppb	2.07	1.86	2.27
Silica, ppm	14.22	13.35	15.10
Silver, ppb	0.80	0.72	0.88
Sodium, ppm	50.60	48.40	52.81
Specific conductance, µs/cm	722.30	718.89	725.72
Strontium, ppb	531.79	521.94	541.63
Sulfate, ppm	148.02	141.21	154.84
TDS, ppm	560.79	559.25	562.33
TOC, ppm	13.37	12.71	14.03
TSS, ppm	17.33	15.60	19.07
Turbidity, NTU	109.34	109.25	109.43
Zinc, ppb	14.42	12.97	15.86

5.8 CONCEPTUAL DESIGN

During the course of this study, Ameren successfully negotiated the purchase of the property that the TW-01 site is located on. While the aquifer characteristics at both sites were acceptable for constructing high-capacity collector wells, the right-of-way and property access issues are now significantly reduced at this site. For this reason, the conceptual design is directed towards constructing the wells on the TW-01 site.

The results of the test drilling and aquifer testing indicate that a collector well capable of yielding approximately 17,000 to 26,000 gpm can be developed at the TW-01 location. The transmissivity of the aquifer at the site is estimated to be 450,000 gpd/ft. The preliminary design recommendations for collector wells at this site to meet the expected plant demand are listed in Table 5.8 and shown in Figure 12.

Table 5.8
Collector Well Preliminary Design

Caisson inside diameter, feet	20
Caisson outside diameter, feet	25
Total length of caisson (below grade), feet	100
Total length of caisson (above grade), feet	23
Number of laterals (2 tiers, 7 laterals per tier)	14
Centerline of upper tier of laterals (below grade), feet	92
Minimum Length of laterals (each)	
Screen, feet	190
Blank, feet	10
Lateral Diameter, inches	12
Screen Entrance Velocity, ft/min	< 2.0
Screen Slot Size (estimated), inches	0.10*
Minimum distance between caissons, feet	1500

**Screen slot size will vary according to data collected during installation of the laterals.*

The top of the caisson should extend to above the 500-year flood elevation of 543, which is about 23 to 24 feet above grade at this location.

Laterals should extend 200 feet from the caisson, if possible. The screens should be of stainless steel, wire-wrapped construction. This design allows a large open area per lineal foot of screen permitting low water entrance velocity, which will help reduce screen fouling. The estimated amount of open area for each collector well screen is 1.32 ft2/linear foot. Assuming 14 laterals with 190 feet of screen each (10 feet of blank near the caisson) and the amount of open area, the mechanical capacity of the proposed collector well would be approximately 26,000 gpm.

Mechanical capacity is the maximum quantity of water that can pass through the well screens at a velocity of 2.0 feet per minute, assuming a 50% blockage of the screen open area. The mechanical capacity should be greater than the estimated aquifer yield to allow slow entrance velocity during standard operation, which should help to prolong periods between well maintenance. This number will vary with actual lateral length and slot size installed.

The 14 laterals should be placed in 2 tiers and spaced within a 225-degree arc generally facing the Missouri River (see Figure 12).

5.9 WATER RIGHTS

Water rights are not needed in Missouri. However, large water users are required to report yearly usage to the Missouri Department of Natural Resources.

* * * * *

6.0 CONCLUSIONS AND RECOMMENDATIONS

A water supply from horizontal collector wells can be developed at the Site to provide the estimated plant demand of 50,000 gpm. Based on the design conditions, three wells will be required to meet this demand. However, due to the variability of the aquifer materials, the actual yield of a collector well may be higher or lower depending on materials encountered during installation of the collector well laterals.

Based on the levels of total dissolved solids, the water will likely not require treatment prior to use by the plant. Treatment of the water supply from the collector wells may be required to reduce iron concentrations present in the supply. It is anticipated that the iron concentrations from the collector well field will reduce over time and may eventually not require any treatment before use at the plant.

* * * * *

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* * * * *

FIGURES

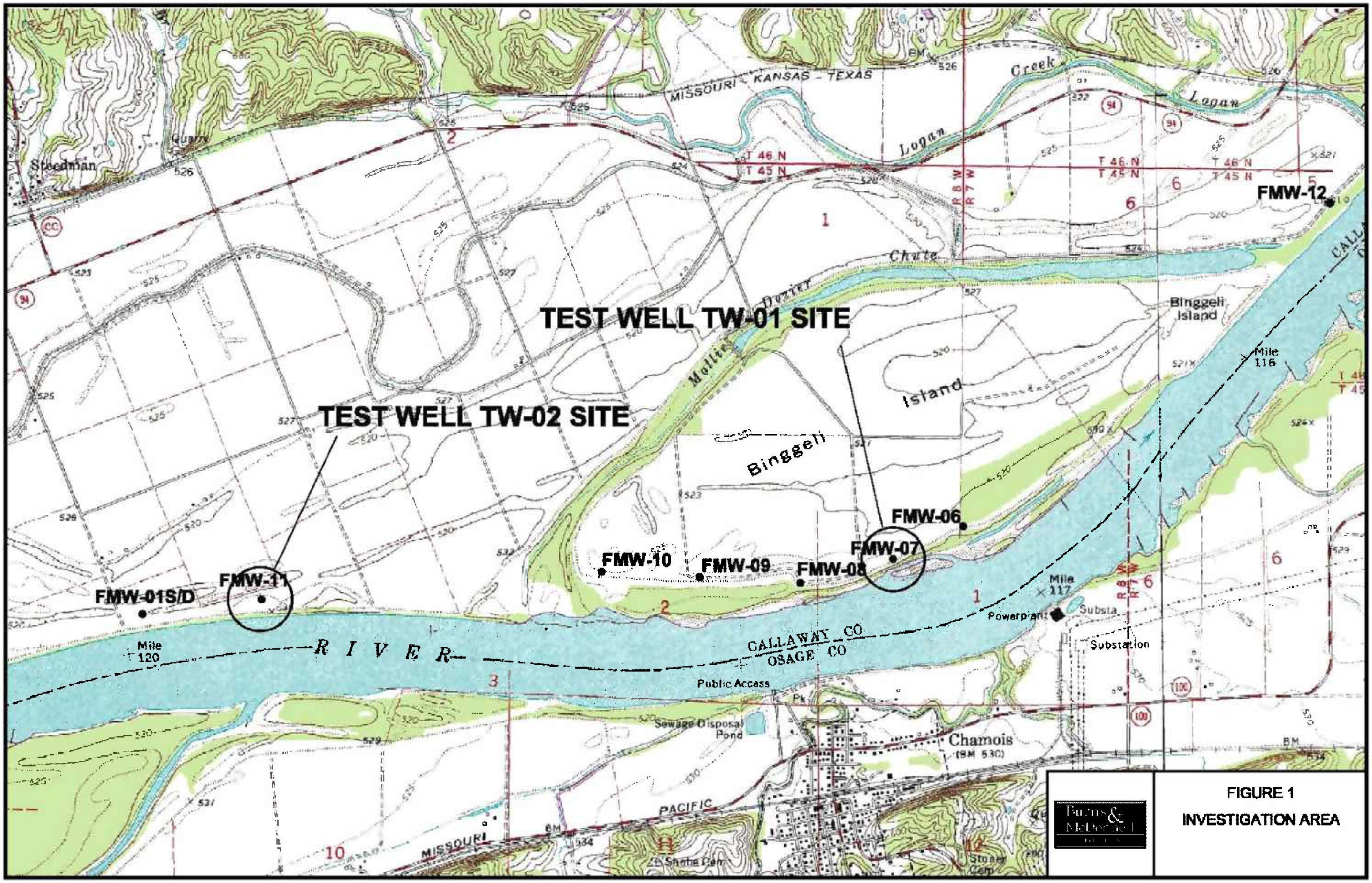

FIGURE 1
INVESTIGATION AREA

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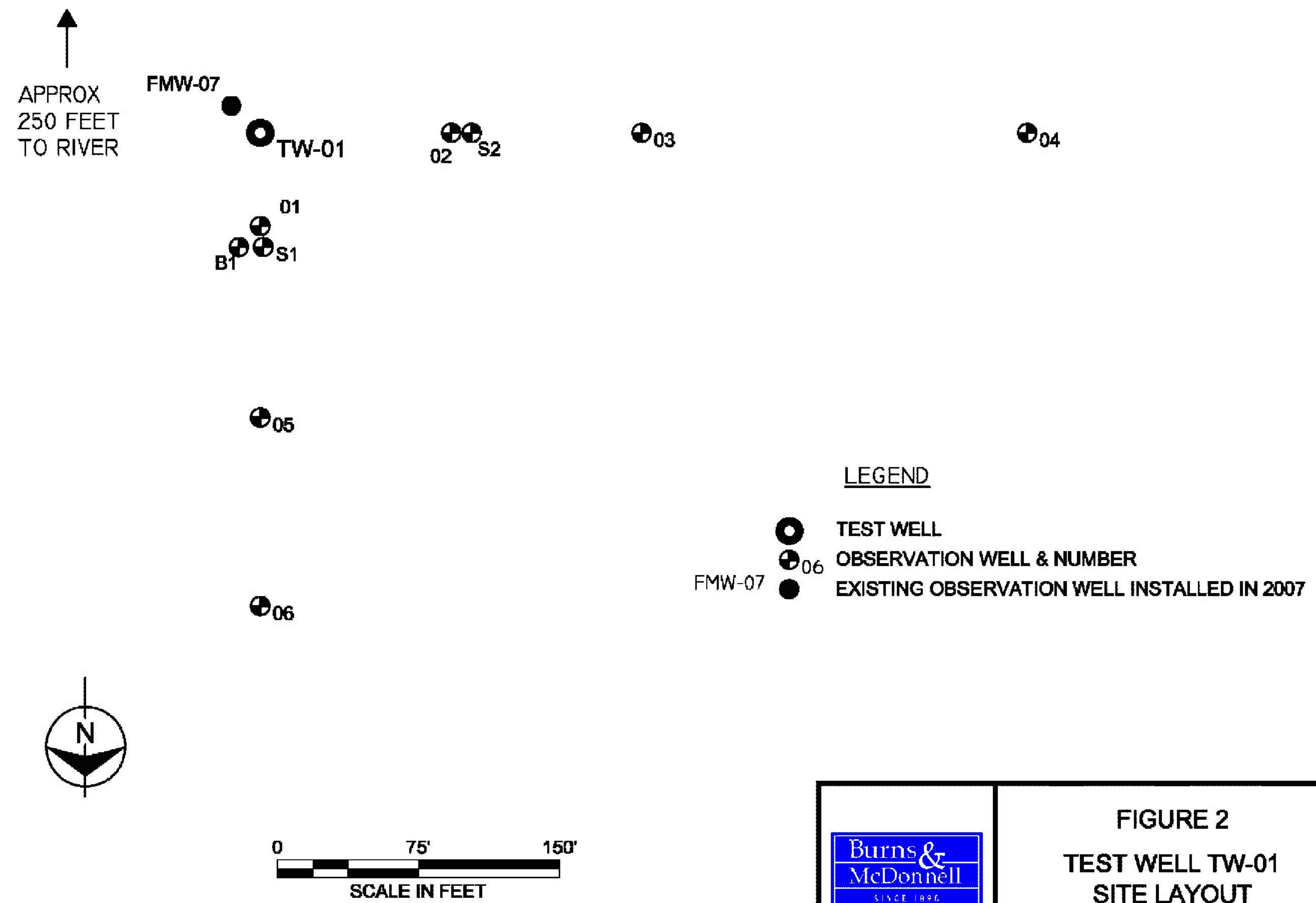

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FIGURE 2

TEST WELL TW-01
SITE LAYOUT

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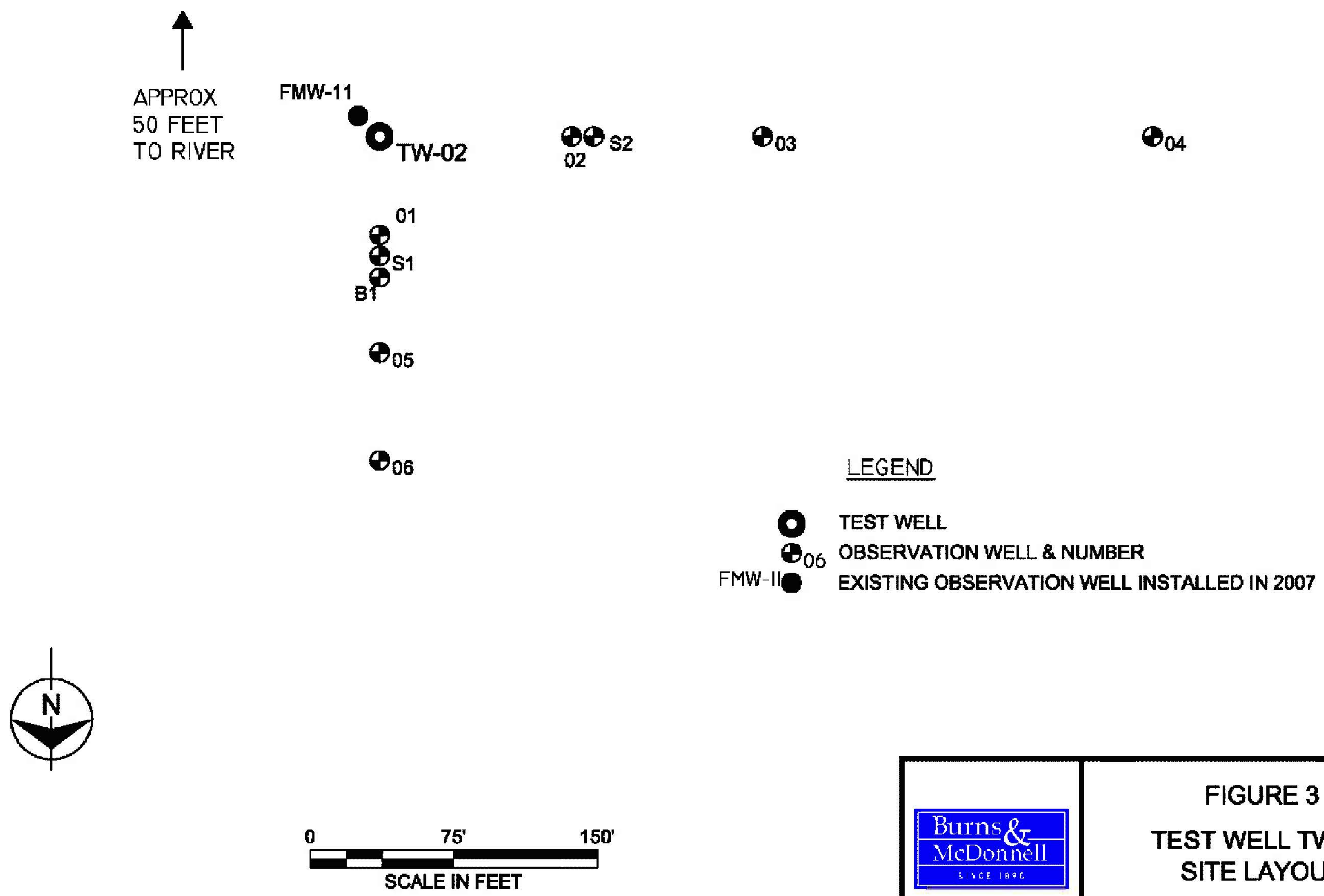

FIGURE 3

TEST WELL TW-02
SITE LAYOUT

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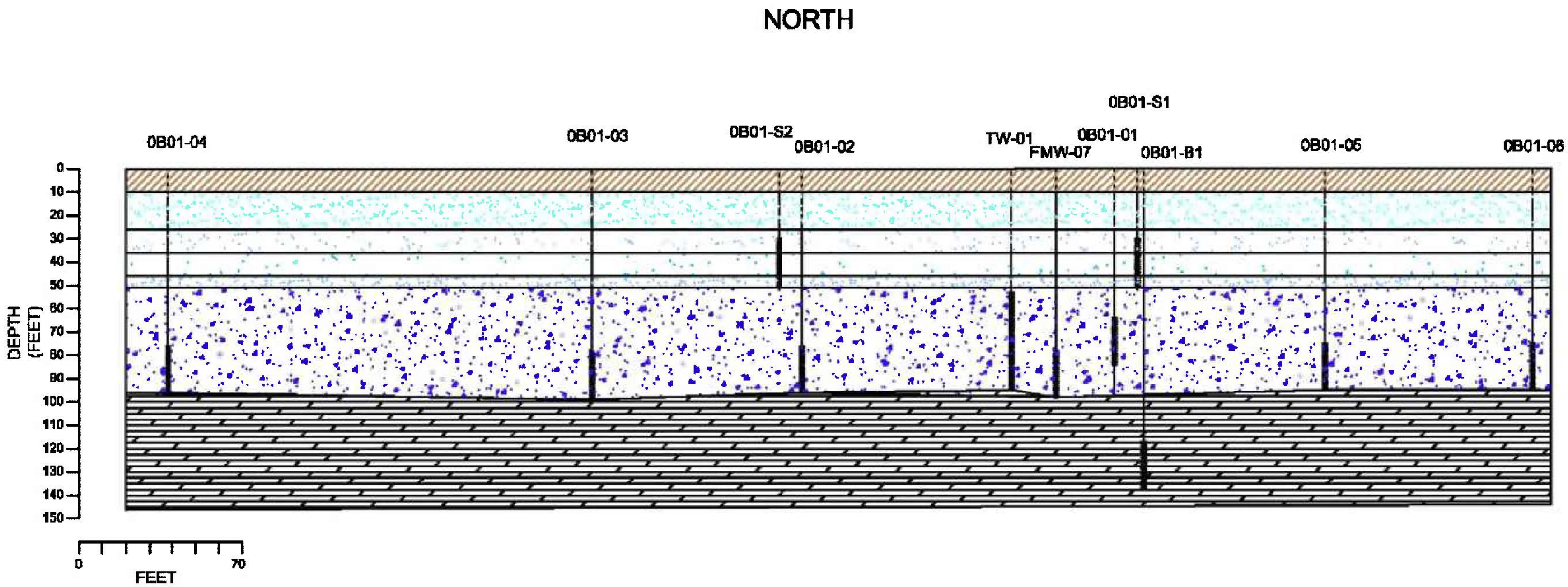

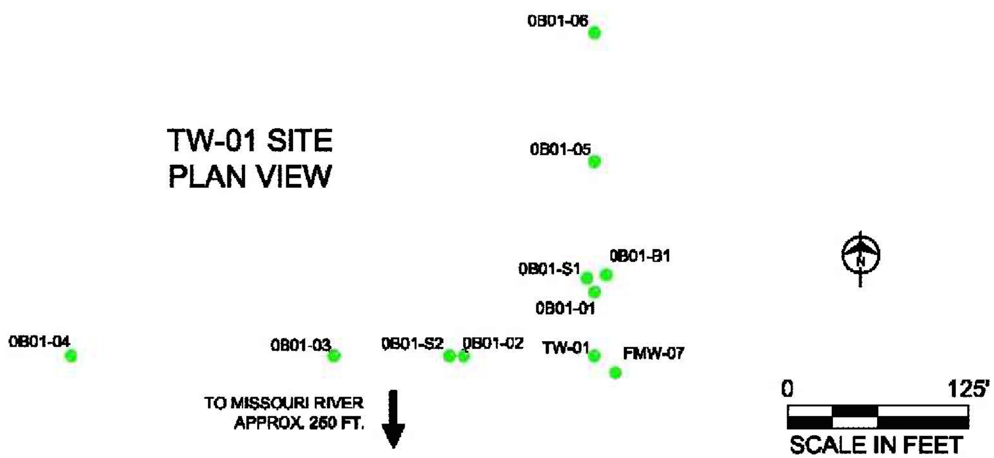

SILT & CLAY

FINE SAND

FINE TO MEDIUM SAND

MEDIUM SAND

COARSE SAND

BEDROCK

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FIGURE 4

TW-01 SITE CROSS SECTION

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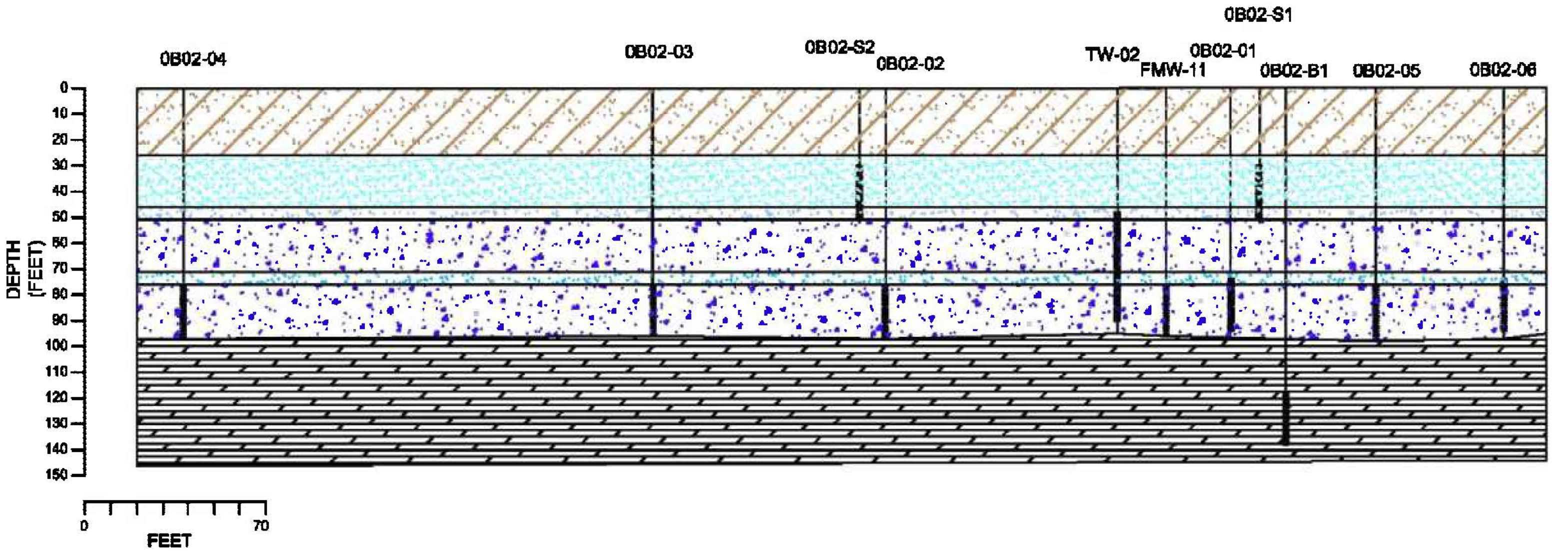
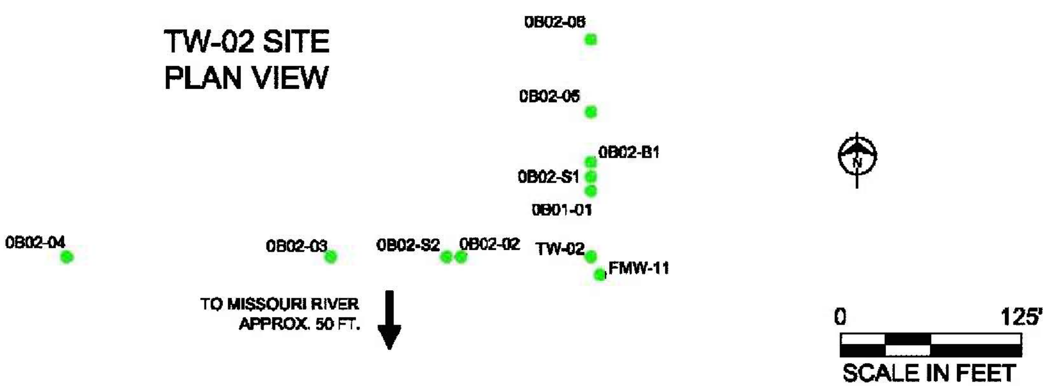
NORTH



TW-02 SITE PLAN VIEW



SANDY SILT & CLAY

MEDIUM SAND

FINE SAND

COARSE SAND

FINE TO MEDIUM SAND

BEDROCK

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FIGURE 5

TW-02 SITE CROSS SECTION

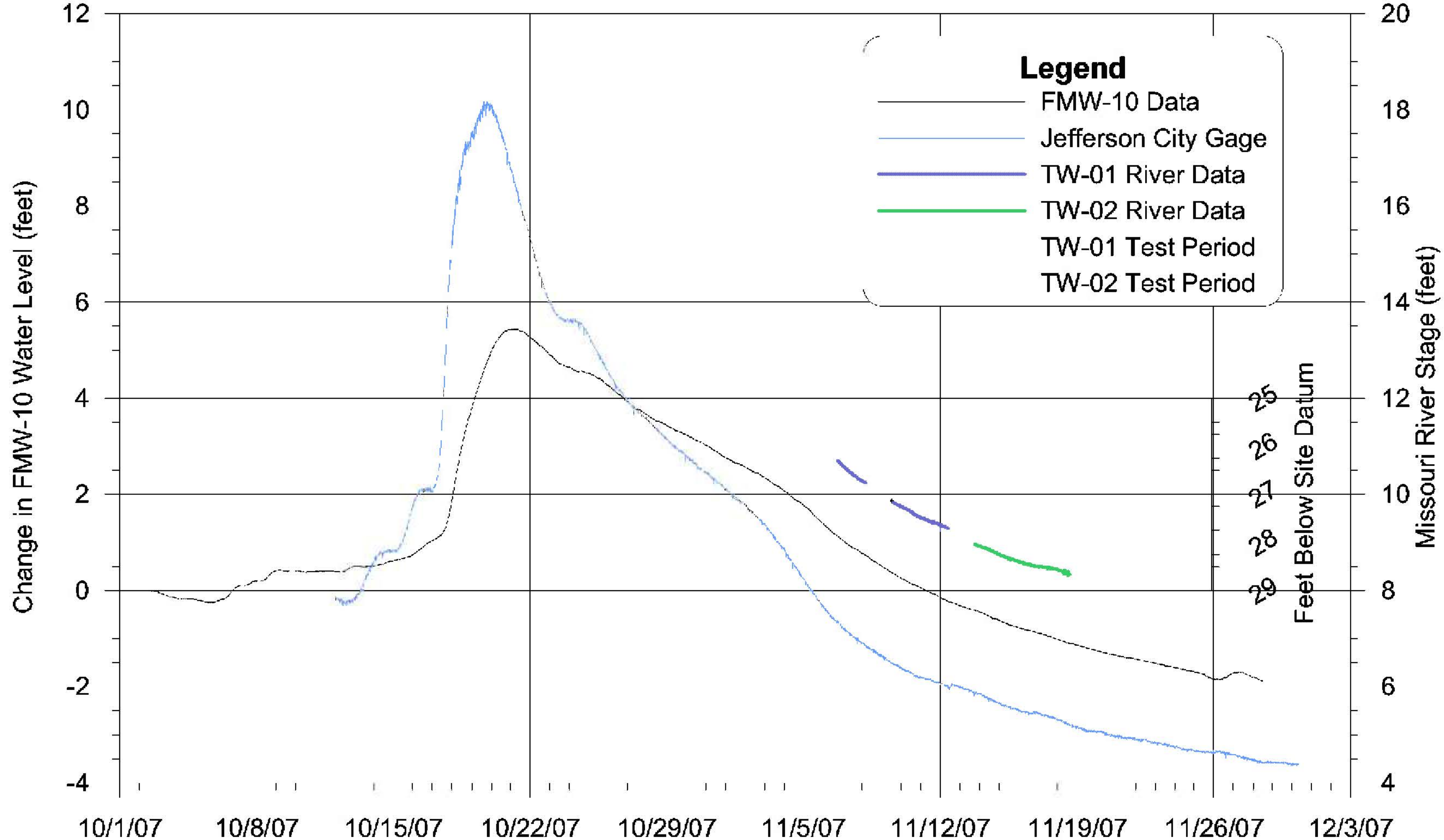

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Figure 6

Missouri River & Aquifer Water Levels

River Aquifer Data.grf 1/4/08

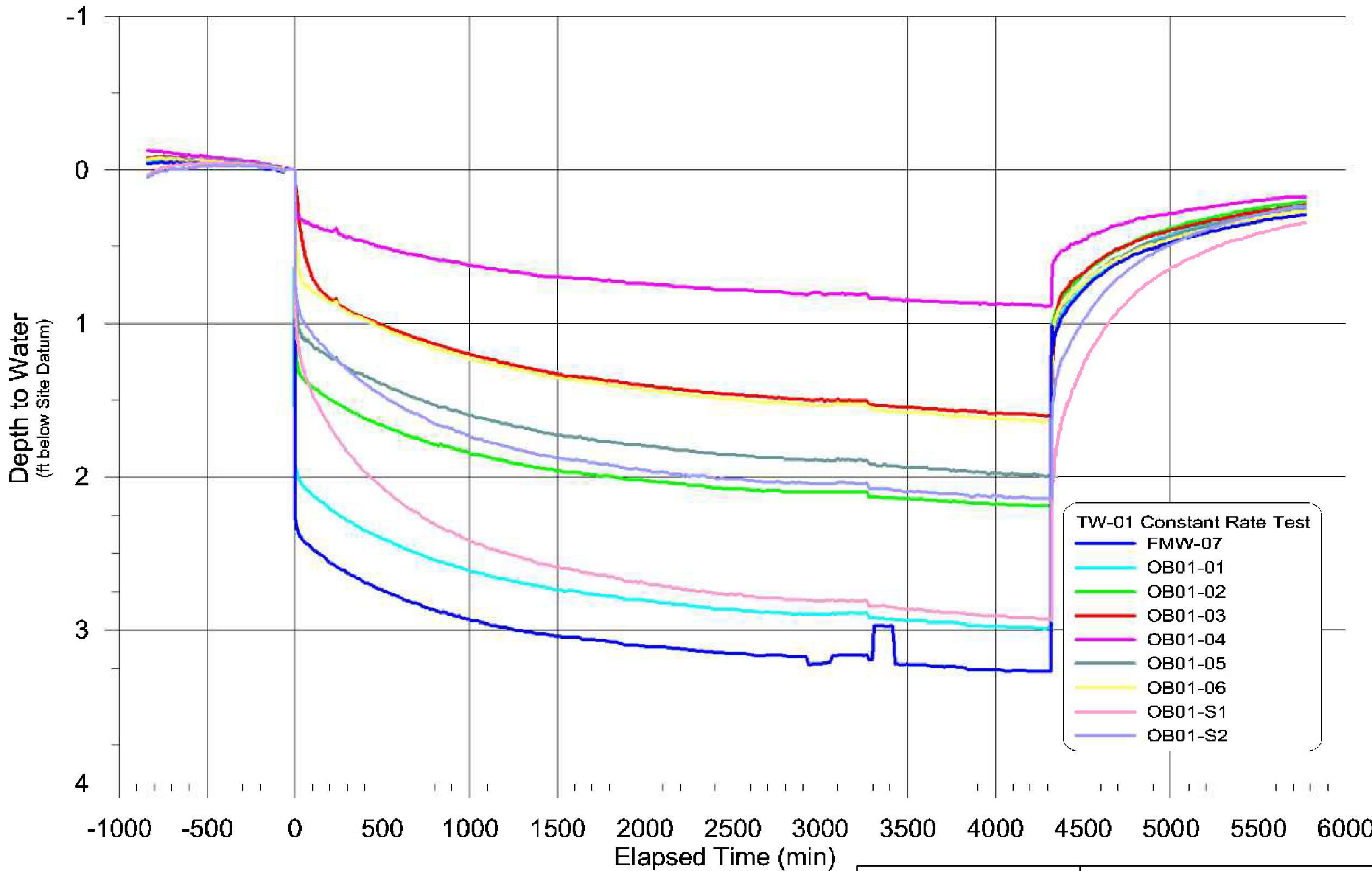

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Figure 7

TW-01
Constant Rate Test
Observation Well Data

TW-01 Complete Corrected.grf 12/19/07

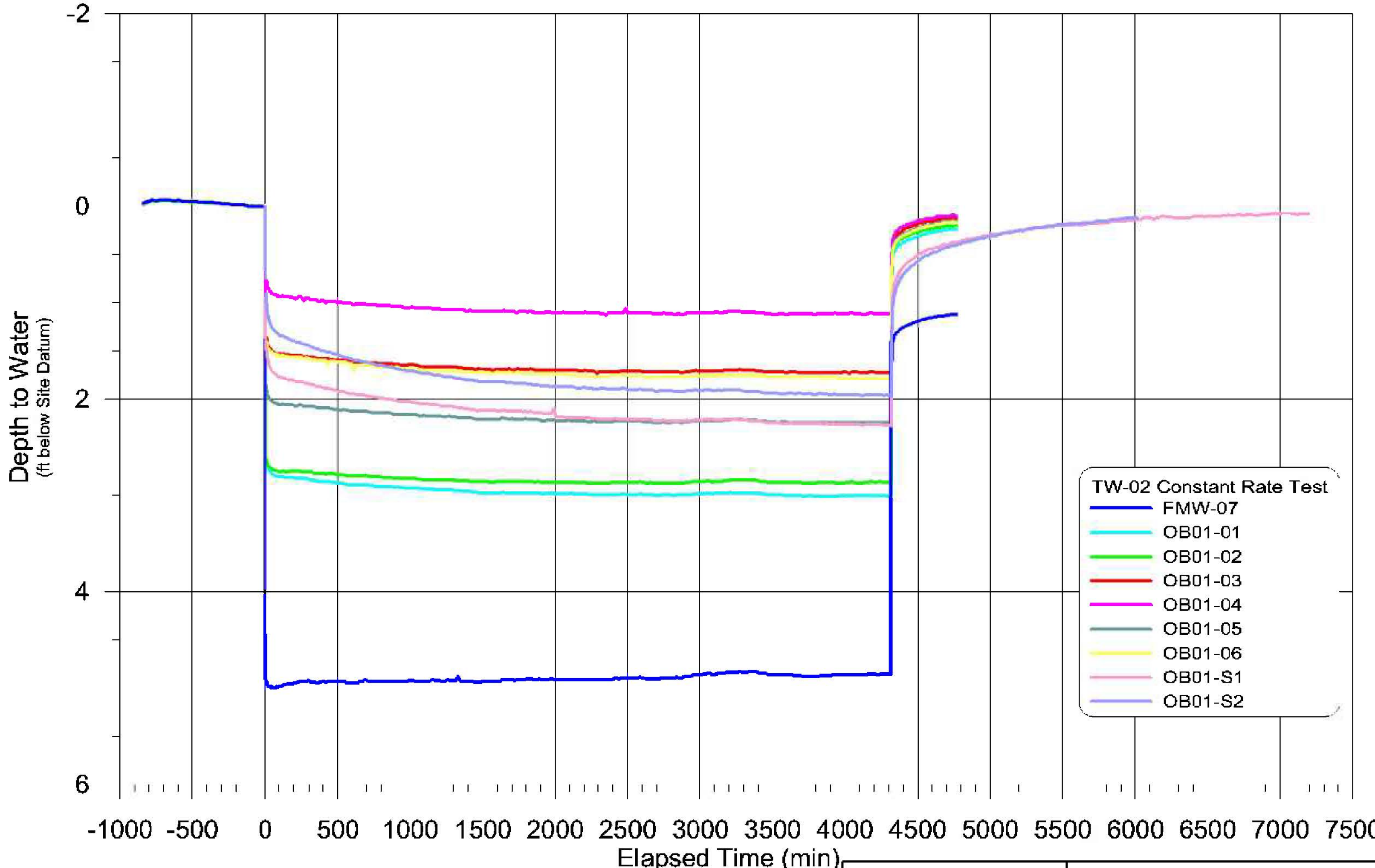

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Figure 8

TW-02
Constant Rate Test
Observation Well Data

TW02 Complete Corrected.grf 6/10/08

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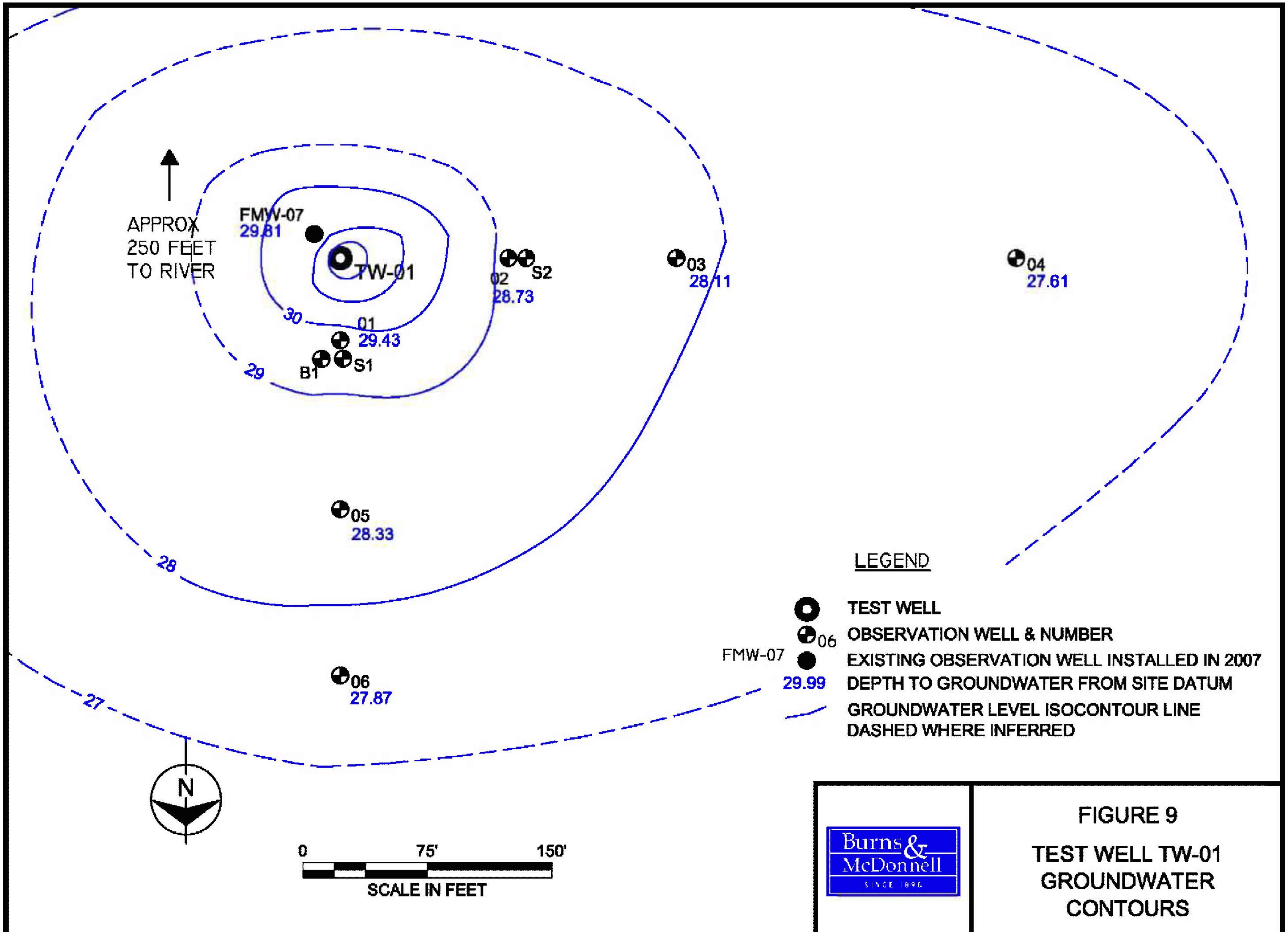

FIGURE 9

TEST WELL TW-01
GROUNDWATER
CONTOURS

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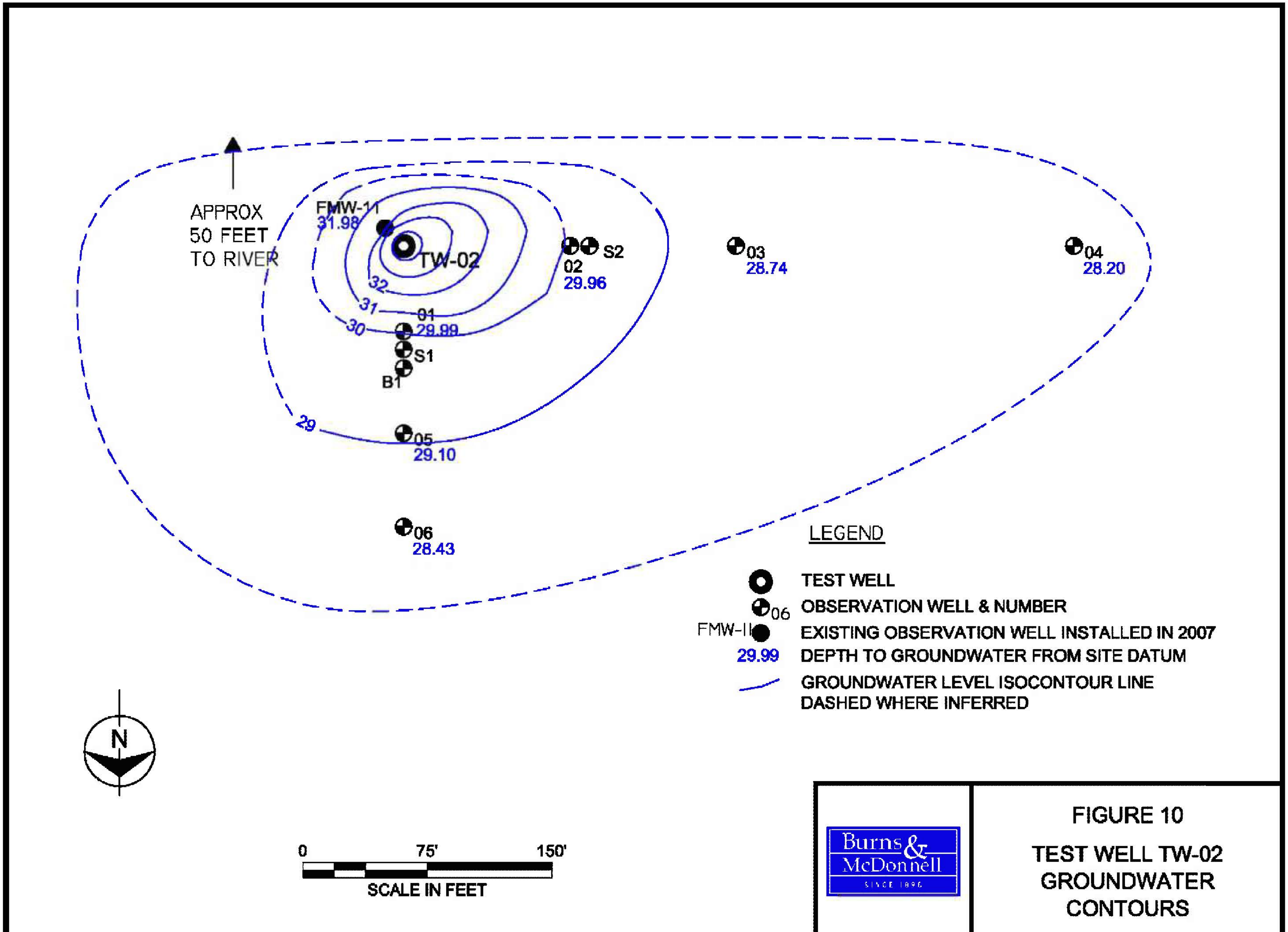

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FIGURE 10

TEST WELL TW-02
GROUNDWATER
CONTOURS

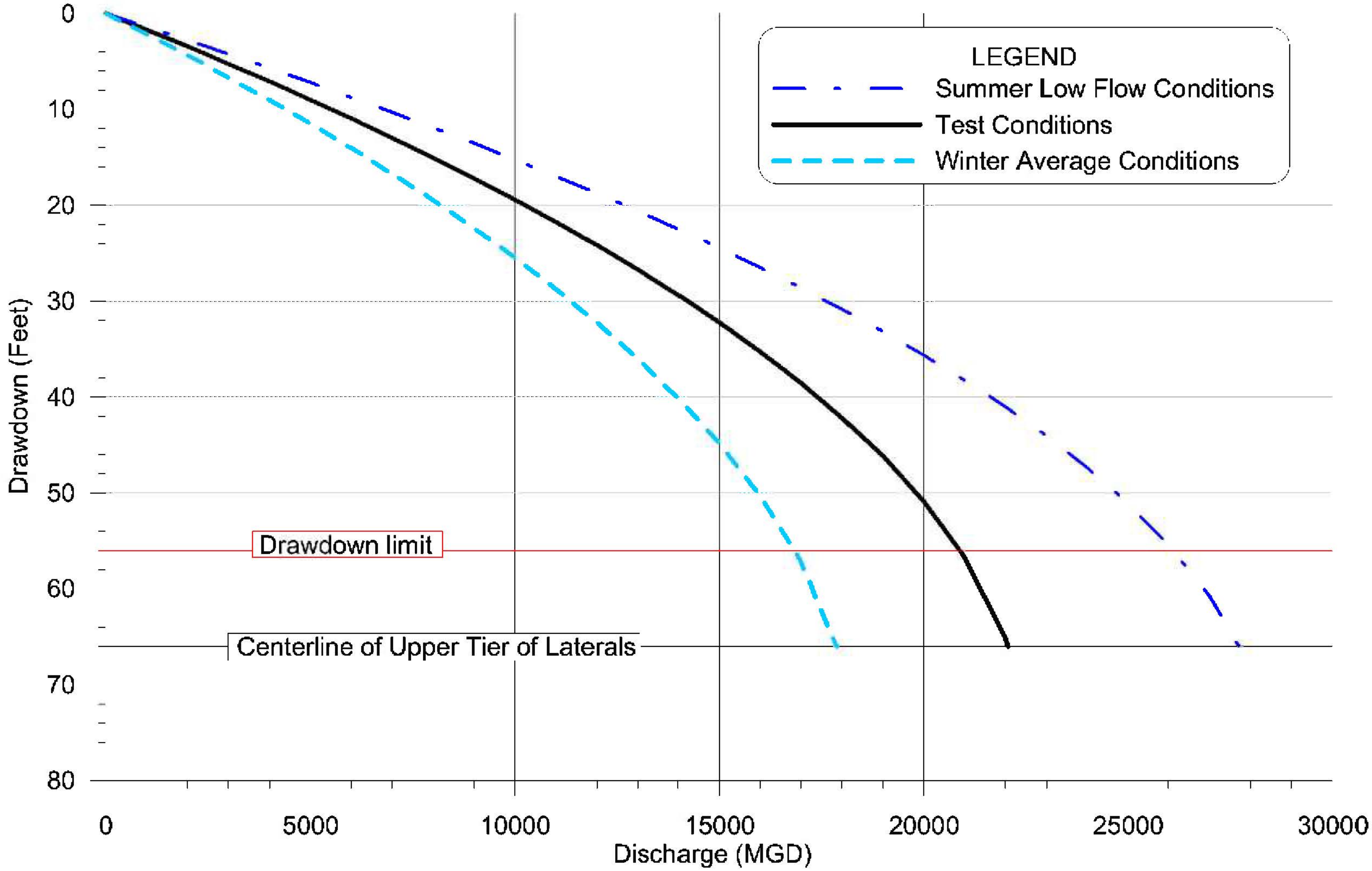

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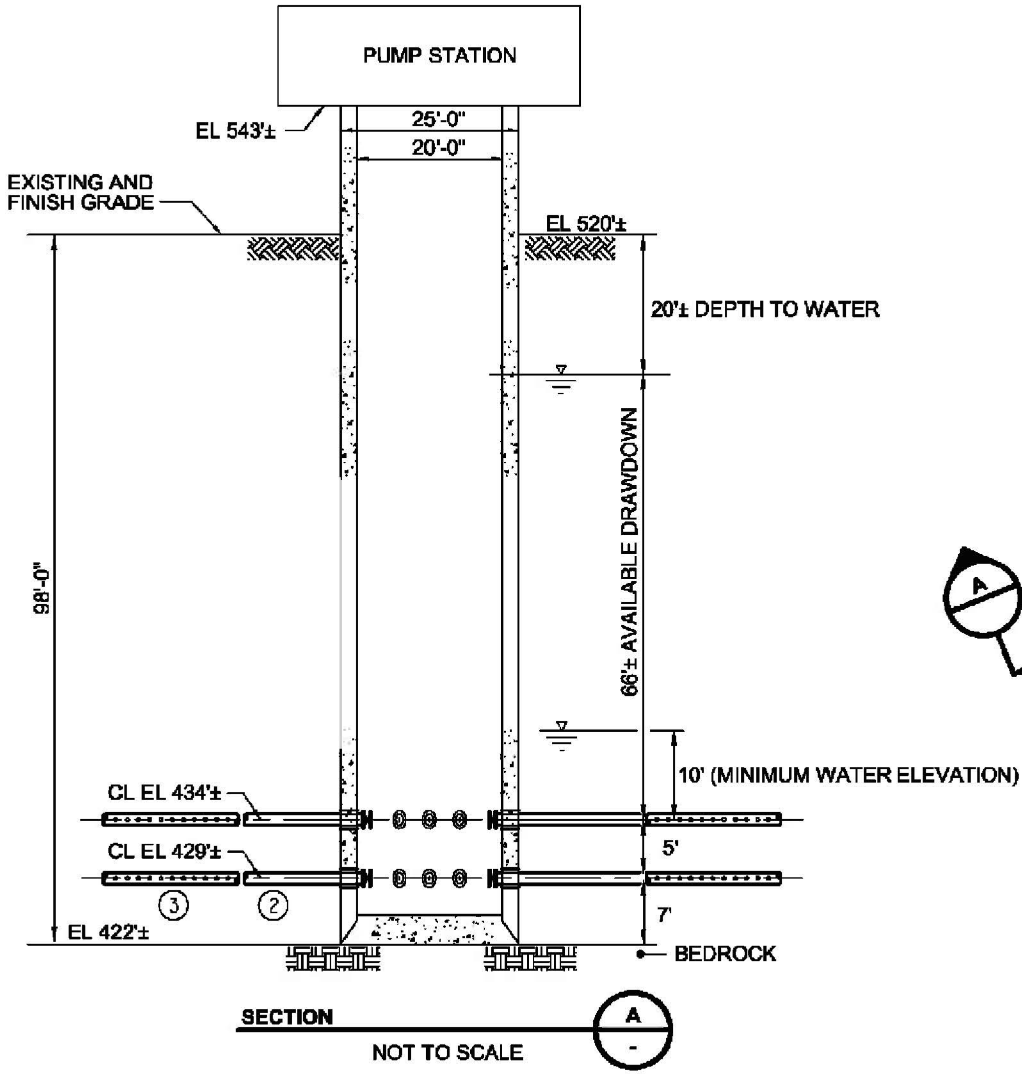
Figure 11

Estimated
Collector Well Yield
Callaway Plant

CWyield.grf 1/7/08



NOTES:

1. ADDITIONAL SPARE PORTS TO BE LOCATED BY CONTRACTOR.
2. 10 FEET BLANK SECTION MEASURED FROM INSIDE FACE OF CAISSON.
3. MINIMUM DESIGN LENGTH OF EACH LATERAL IS 200 FEET FROM INSIDE FACE OF CAISSON.

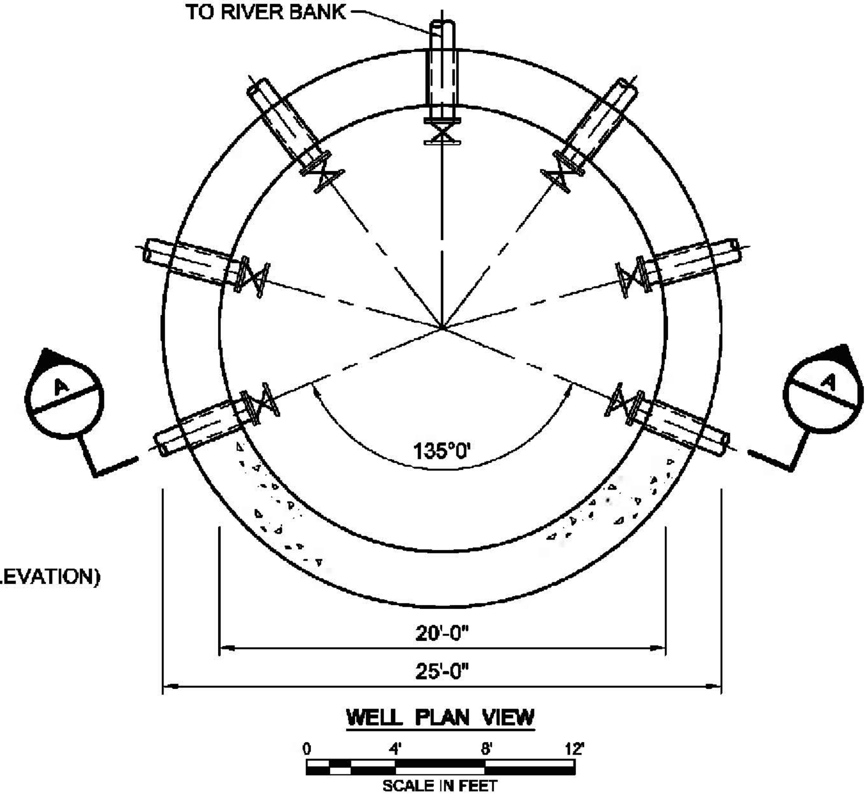


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Figure 12
PRELIMINARY COLLECTOR WELL DESIGN
AMEREN CALLAWAY

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APPENDIX A

PHASE I INVESTIGATION REPORT

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Date: September 6, 2007

To: Tom Grothe – Ameren Corporation

From: Pat Higgins, Paul McCormick

Re: Phase I Test Drilling at Callaway Nuclear Plant, Callaway County, Missouri

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Ameren Corporation (Ameren) is preparing a Combined License Application (COLA) for submittal to the Nuclear Regulatory Commission for the construction and operation of a second unit at the Callaway Nuclear Generating Station in Callaway County, Missouri. As part of the COLA, a hydrogeologic investigation is being completed to evaluate the possibility of using horizontal collector wells to supply the cooling water for the existing and proposed units.

During Phase I of the hydrogeologic investigation, seven test borings were advanced to bedrock in order to determine the depth and approximate saturated thickness of the Missouri River alluvial aquifer near the existing surface water intake that currently supplies cooling water to unit number 1. Monitoring wells were installed at each boring location to obtain static water level observations, water quality samples, and allow measurement of water levels during aquifer pumping tests, to be conducted during Phase 2 of the project. Locations of the monitoring wells are shown in Figure 1 and labeled FMW-06 through FMW-12.

Presented in this memo are the methods, findings, and conclusions related to Phase 1 of the hydrogeologic investigation.

Test Drilling and Well Construction Procedures

Prior to drilling, the boring sites were evaluated by MACTEC to determine if any cultural resources or wetlands would be impacted. A surface electromagnetic survey was performed at each boring site. If the electromagnetic survey indicated the potential for

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buried artifacts, a MACTEC archaeologist was present during drilling to examine the cuttings and ensure that no cultural resources were disturbed. No evidence of cultural resources were identified in borings FMW-06 through FMW-12.

Seven test borings were drilled in July and August of 2007 and completed as monitoring wells. The test boring locations are shown in Figure 1 as FMW-06 through FMW-12. Aquadrill, Inc. of Swisher, Iowa completed all drilling and well construction work using hollow stem auger and mud rotary drilling techniques, under the direction of Paul C. Rizzo Associates, Inc. of Pittsburg, Pennsylvania. A Burns & McDonnell geologist was present at the site to observe the fieldwork and prepare drilling logs for each boring.

Each boring was drilled from 0 to 20 feet below grade (fbg) with 10-inch diameter hollow stem augers and sampled with a CME continuous sampler, so that any evidence of cultural resources would be clearly visible. After the first 20 feet were drilled with hollow stem augers, temporary surface casing was set and a 6-inch diameter borehole was drilled to bedrock using mud rotary methods. The geology was logged by a Burns & McDonnell geologist based on the drill cuttings collected from each five-foot interval. Drilling logs for each boring are presented in Attachment 1. Subsequently, geophysical logging consisting of natural gamma, spontaneous potential, and single point resistivity methods was completed in each borehole. The geophysical logs for each boring are presented in Attachment 2. Grain-size distribution analysis was performed on four representative samples of aquifer materials collected from each of the test borings by Alpha-Omega Geotech of Kansas City, Kansas. Results of the grain size analyses for each boring are presented in Attachment 3.

Each test boring was completed as a monitoring well with a steel protective cover. Each monitoring well was constructed with 20 feet of 2-inch diameter, Schedule 40 machine-slotted (0.010-inch) PVC screen set at the bottom and completed with solid Schedule 40

PVC casing to the ground surface. A gravel pack was placed alongside the screen extending up to a depth of approximately 5 to 10 feet above the top of screen, and a minimum 3-foot thick bentonite chip seal was placed above the gravel pack. A bentonite slurry grout was then pumped in to fill the borehole to grade. FMW-12 was completed with an above-ground protective casing, and the remaining wells were completed with flush-mounted steel protective manhole cover. A concrete pad approximately two feet square was them poured around the protective casing..

Following construction, the monitoring wells were developed by surging, air-lifting, and pumping the well to remove drilling fluid from the area around the well screen and enhance communication between the well and the aquifer. Development was completed in two sessions at each well. Each well was airlifted, disinfected with chlorine and allowed to sit overnight. The next day the well was airlifted again until the well water was observed to be reasonably clean a short time after starting the pump.

Investigation Results

The materials encountered in the test borings at the site were Missouri River alluvium consisting of inter-bedded layers of fine to coarse sand from approximately 10-60 fbg, underlain by approximately 40 feet of fine to coarse grained sand with some fine gravel. Based on the visual observations during drilling and the geophysical logging, clay layers were not encountered in any test boring at depths greater than 26 fbg. Bedrock underlying the sand and gravel consists of dolomite and was encountered at depths ranging from 95 to 101.5 fbg. Groundwater was encountered in each boring at a depth of approximately 12 fbg. The saturated thickness of the aquifer is approximately 83 to 90 feet.

Figure 2 is a cross section through the aquifer developed using the data from the seven test holes and FMW-1 D and FSB-03. The cross section indicates that the aquifer material in the study area is coarsest near FMW-07 and FMW-06. A larger proportion of fine grained materials is found at the west end of the study area near FMW-11 and at the east end of the study area near FMW-12.

Each borehole was logged using geophysical methods to assist in identifying and locating any layers of fine-grained materials (silt and clay) that might be present in the subsurface. Geophysical logging consisted of natural gamma, spontaneous potential, and single-point resistivity methods. Both the geophysical logging and the visual observations of the samples during drilling confirmed that there are not significant layers of fines present at depths greater than 40 fbg. The grain-size distribution analyses also support this conclusion, indicating an average of 1.4 percent fines (material smaller than 200-mesh sieve) in any of the samples, with a range of 0.3 to 3.7 %.

Groundwater samples were collected from the monitoring wells on August 22, 2007. The samples were submitted to Pace Laboratories for analysis. The results of the analysis will be used for permitting and design in the event that it is decided to move forward with the construction of horizontal collector wells. Analysis of the samples is currently in progress.

Conclusions and Recommendations

The anticipated water supply demand for each unit is approximately 25,000 gallons per minute or 36 million gallons per day. Phase 1 testing continues to indicate that this demand can potentially be obtained from two or three horizontal collector wells. Grain size analyses and observation of the saturated aquifer thickness indicate that the Missouri River alluvial aquifer in the study area is likely suitable for development of a series of collector wells capable of meeting the plant's water supply requirement.

Two pumping tests are recommended for Phase 2, in order to better evaluate the aquifer characteristics and estimate the yield of a series of horizontal collector wells in the study area. Several of the borings had to be moved because the property owners denied access to their property. As a result, several of the borings (FMW-11 and FMW-12) are substantially farther from the other borings than originally planned. Two tests are necessary due to the distance between the borings and the variations in the grain-sizes throughout the study area.

Phase 2 will consist of the installation of two test pumping wells (each capable of yielding 1,000 to 1,500 gallons per minute to sufficiently stress the aquifer), and nine additional piezometers at each site. A 72-hour pumping test will be performed at each test well location. The first test well is proposed to be installed at the site of monitoring well FMW-07. Based on visual observation and grain-size analysis this location had the coarsest material in the study area. The second test well is proposed to be installed near FMW-11, which had a higher proportion of finer-grained sands. After completion of the testing activities, the test wells and piezometers will be abandoned in accordance with Missouri Department of Natural Resources regulations.

If you have any questions or comments regarding these investigations, please do not hesitate to contact us.

FIGURES

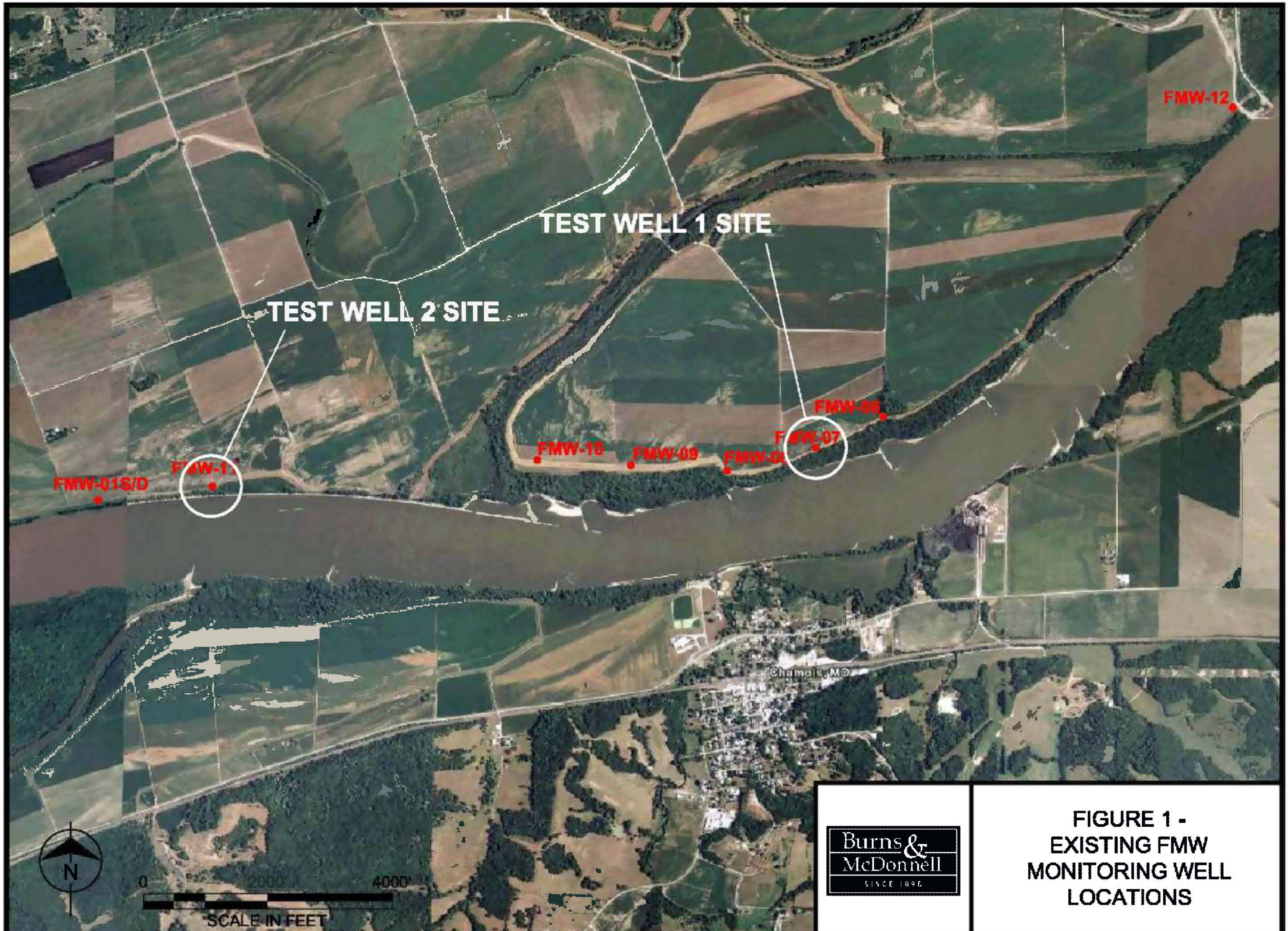

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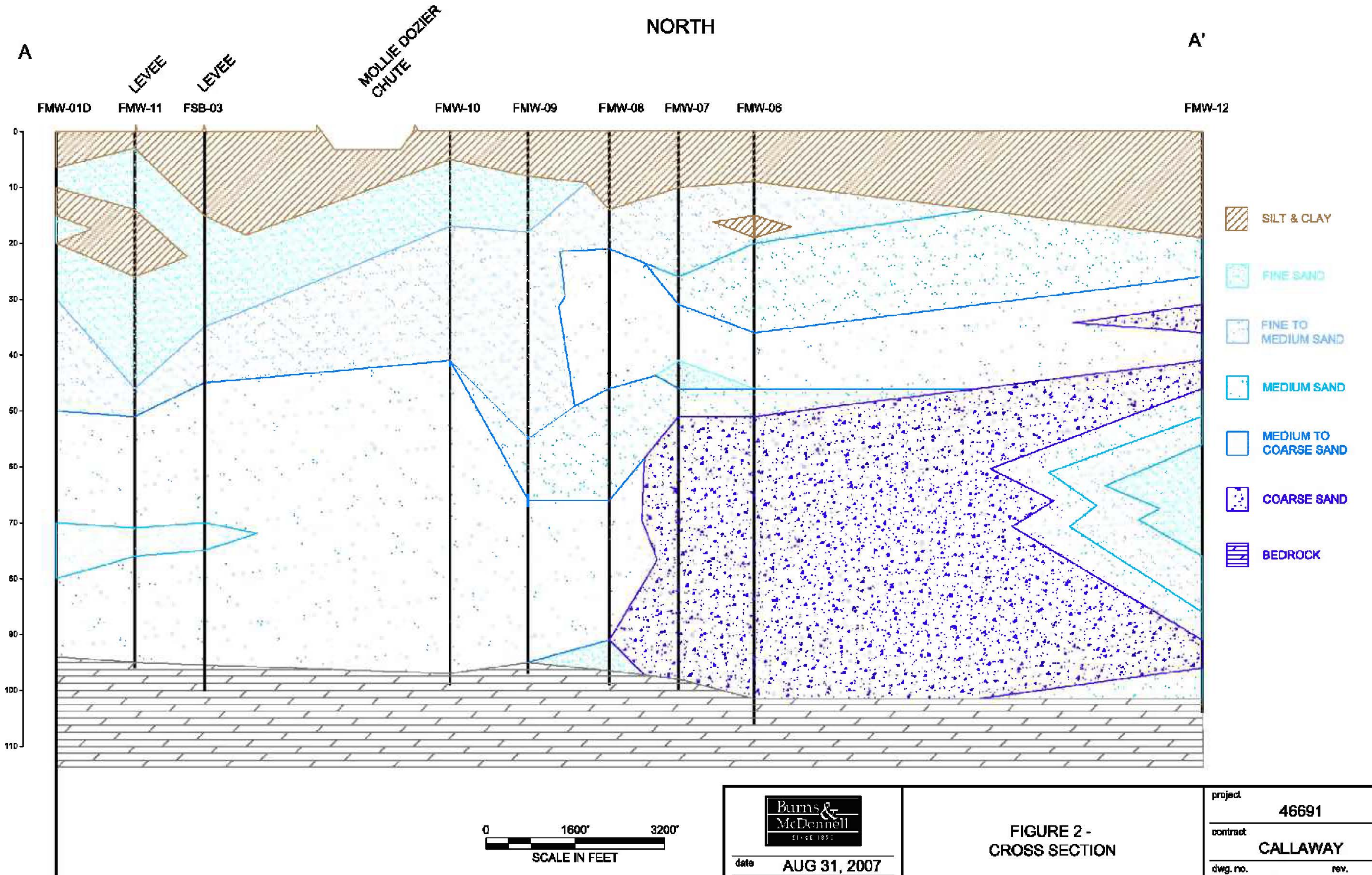
FIGURE 1 -
EXISTING FMW
MONITORING WELL
LOCATIONS



Burns & McDonnell

date AUG 31, 2007

designed P. MCCORMICK

FIGURE 2 -
CROSS SECTION

project 46691

contract CALLAWAY

dwg. no. 2

rev. –

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