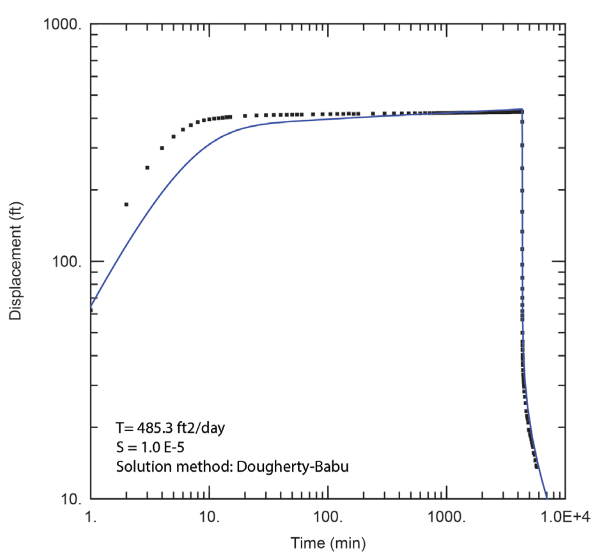
Barton Springs
Edwards Aquifer
CONSERVATION DISTRICT

Guidelines for Hydrogeologic Reports and Aquifer Testing



Barton Springs/Edwards Aquifer Conservation District
Hays, Caldwell, and Travis Counties, Texas

Board Adopted - April 10, 2025

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Cover
Photograph of pumping well in Kingsville City from the Goliad Sands pumping 700 gpm. Photo shows the orifice weir for measuring the flow rate, photo from Joe Vickers. Chart is an example of analytical solution used to estimate aquifer parameters for a Middle Trinity irrigation well (Onion Creek Golf Course well; August 2015).

I. Introduction

In accordance with the Barton Springs/Edwards Aquifer Conservation District's (District) Rules and Bylaws (Rules), Permit applicants seeking to export groundwater out of the District, to obtain a major amendment or a minor amendment (Rule 3-1.9(F)(G), or to permit a new nonexempt well with an annual pumpage volume of more than 2,000,000 gallons from the Edwards Aquifer or more than 650,000 gallons for the Trinity Aquifers, shall conduct an aquifer test and submit to the District a current Hydrogeological Report (Report) addressing the potential impacts associated with the proposed groundwater production or export. The Report is a required component of all administratively complete applications for such requested authorizations. District Rules define the Hydrogeologic Report as follows:

> *"a report, prepared by a Texas licensed geoscientist or a Texas licensed engineer in accordance with the District's guidance document, Guidelines for Hydrogeologic Reports and Aquifer Testing (Guidelines), which identifies the availability of groundwater in a particular area and formation and assesses the response of an aquifer to pumping over time and the potential for unreasonable impacts."*

Hydrogeologic studies provide essential baseline information for water-resource management for both the District and the permittee. Aquifer tests are a key component of hydrogeologic studies, however as Butler (2009) states, "an assessment of the response of an aquifer to pumping over the long term should not solely depend on information from a pumping test of limited duration; one must use other information on the regional hydrogeology, and so forth, to make that determination." These guidelines are intended to assist professionals involved in planning and conducting the aquifer test and also address the key elements of the Report that include other information such as regional hydrogeology or local hydrogeologic boundary conditions.

An aquifer test work plan shall be prepared prior to conducting an aquifer test. Results of the aquifer test will be included in the Hydrogeological Report. Both the aquifer test work plan and Report need to be prepared by a Texas licensed professional geoscientist or engineer. Planning and implementation of the aquifer test shall be closely coordinated with the District to ensure that the proposed report is consistent with District standards and expectations specified in these guidelines. Prior to the commencement of the aquifer test, the applicant (or applicant's designated representative) shall have a meeting to discuss the proposed aquifer test work plan that shall be prepared pursuant to the Guidelines for Aquifer Test Work Plans (Design and Operation) (**Appendix A**). A written aquifer test work plan shall be submitted to the General Manager for review and approval prior to commencement of the test and shall include the required information for aquifer test work plans as specified in these guidelines. Once approved by the District, the aquifer test shall be conducted and the Report completed pursuant to the approved work plan and these guidelines. The applicant is responsible for all costs associated with the aquifer test.

The Report shall provide findings and conclusions addressing the response of an aquifer to pumping over time and the potential for causing unreasonable impacts. Applicants may not rely solely on reports previously filed with or prepared by the District. Deviation from these guidelines may occur only with prior District approval (see variance section below).

The District's Aquifer Science Team will evaluate the application to determine whether there is potential for unreasonable impacts (as define by District Rule) and produce findings in accordance with the process specified in District Rule 3-1.4.G. The evaluation of the potential for unreasonable impacts will apply the best available science and be performed on the basis of the Report, the aquifer test, and other factors relevant to the proposed production from the subject well/well field including but not limited to:

a. local geology and aquifer conditions including water quality;
b. construction and location of the subject well/well field;
c. target production zone, production capacity, and proposed production rate of the subject well/well field;
d. construction/completion of existing wells in the area of influence;
e. drawdown over time and distance attributed to pumping from the subject well/well field;
f. drawdown attributed to drought conditions and seasonal increases in pumping from existing wells;
g. drawdown attributed to pumping from existing wells and from future domestic and livestock wells;
h. proposed production relative to the Modeled Available Groundwater;
i. projected impacts on the relevant Desired Future Condition(s); and
j. projected impacts to regional surface water resources (springs and streams).

Permit applications may be deemed incomplete due to Reports that do not meet the District's minimum standards or deviate significantly from these guidelines without prior District approval. An applicant who incurs costs related to conducting an aquifer test knowingly bears the risk that the permit request may be denied or modified.

II. Purpose and Scope of Hydrogeologic Reports and Aquifer Testing

Based on the scale of the requested permit volume, the District has established Classed requirements as they pertain to aquifer tests and associated Reports (Table 1). Generally, the Class 3 aquifer tests will require more extensive monitoring and data collection than tests for Class 1 and 2. Class 3 aquifer tests will require a monitoring well network plan and the installation of one or more scientific monitor wells. For Class 1 aquifer tests, an abbreviated single well test (specific capacity) may suffice, however, monitoring of nearby wells may be required if existing wells are accessible and adequate for monitoring.

Table 1: Test Classes for Aquifer Testing and Hydrogeologic Report Requirements (3-1.4.D).

Test Class	Aquifer Test and Report Requirements	Anticipated Production Volume
0	None	<650,000 gallons per year for Trinity Aquifer OR <2,000,000 gallons per year for Edwards Aquifer
1	Abbreviated aquifer test and Report	650,000 to 2,000,000 gallons per year for the Trinity Aquifer OR 2,000,000 to 12,000,000 gallons per year for the Edwards Aquifer
2	Hydrogeologic Report, and aquifer test <u>may</u> require installation of new scientific monitor wells if existing wells are not available or adequate for monitoring.	2,000,000 to 40,000,000 gallons per year for the Trinity Aquifer OR 12,000,000 to 40,000,000 gallons per year for the Edwards Aquifer
3	Hydrogeologic Report, and aquifer test <u>will</u> require monitoring well network plan and installation of one or more scientific monitor wells.	>40,000,000 gallons per year for all aquifers

Class 1 Abbreviated Aquifer Test and Report

The purpose of the Class 1 tests and Reports is to establish baseline information of the well and aquifer (yield, parameters, water quality). The Class 1 tests and Reports are intended for wells that pump a relatively small volume and have a low risk for unreasonable impacts. Key elements of the Class 1 Abbreviated Aquifer Test and Report include:

1. **Estimated aquifer properties:** Transmissivity needs to be calculated from an aquifer test using the standards outlined in these guidelines. Often these will be single-well (specific capacity) tests, however monitoring of nearby wells may be required if existing wells are readily accessible and adequate for monitoring. Storativity should be calculated if sufficient monitor well response is measured.

2. **Estimated extent and magnitude of well interference:** The report should address the short- and long-term impacts from the anticipated pumping on existing surrounding water wells. This can be done with simple distance-drawdown graphs (e.g. Cooper-Jacob) that project the effects of up to 7 years of pumping.

3. **Water quality:** The report should document and establish water chemistry of the groundwater produced at the end of the test, which at a minimum includes field parameters (conductivity, temperature, pH) and possibly laboratory results (common ions and anions, nutrients).

Class 2 and 3 Hydrogeologic Test and Report

Class 2 and 3 tests and reports are intended for those well systems that have proposed pumping volumes greater than 2,000,000 gallons per year (see Table 1). Accordingly, the purpose is to make an assessment of the short- and long-term potential for unreasonable impacts to the regional aquifer system and existing surrounding water wells from the proposed pumping. An aquifer test is a key part of that evaluation, but other relevant hydrogeologic data, as described above, may also be evaluated, if available.

> *Note: The difference between Class 2 and 3 Aquifer Test and Hydrogeologic Report is the monitoring well network plan (**Appendix B**) and installation of scientific monitor wells for the aquifer test. Class 2 testing will require the installation of monitor wells only if existing wells in the study area are not available or adequate for monitoring. In contrast, Class 3 testing requires a monitoring well network to be established by the installation of at least one or more new scientific monitor well for a test and identifying a sufficient amount of existing wells adjacent to the well or well field. A second monitor well may be required to measure the effects in different aquifers or in different locations of a widespread wellfield. The Class 3 testing requirements are intended to ensure the best possible test and data collected for these large permit requests, and that the aquifer can be monitored for impacts on a long-term basis if/when the requested well production is approved and underway. The new scientific monitor wells shall serve as a component of the "monitoring well network plan" submitted with the aquifer test work plan as required by the rules (3-1.4.D). The monitoring well network plan must be approved by the District and the monitoring wells shall be installed and/or identified prior to the commencement of the aquifer test.*

Key elements of the Class and 3 Hydrogeologic Test and Report include:

1. **Estimated aquifer properties:** Hydrogeologic parameters including *transmissivity* and *storativity* need to be calculated from an aquifer test using appropriate published analytical models. Additionally, the Report should also identify the presence of boundary conditions such as barriers to groundwater flow, recharge, and other factors inherent to the aquifer or hydrologic conditions that may influence pumping over time.

2. **Estimated extent and magnitude of interference:** The Report should address the short and long-term impacts from the pumping on existing surrounding water wells. The Report should contain a map of the maximum measured drawdown from the aquifer test for the surrounding monitored wells. In addition, projected future drawdown from analytical models shall be done for at least 7 years. Future drawdown models should also include pumping from other known pumping centers within a 5-mile radius of the test well, including existing permitted wells pumping at their full permitted volume. Results will be used to evaluate the potential for unreasonable impacts to existing surrounding water wells.

3. **Water quality:** The Report should document water chemistry and detectable trends during the aquifer testing. The Report should discuss the risk of water quality changes due to pumping. In cases where pumping or ASR injection wells are located near the Edwards Aquifer's saline zone boundary, or where significant inter-aquifer flow could induce waters of differing and distinguishable water quality, further evaluations may be required. Results will be used to evaluate the potential for unreasonable impacts to the quality of water in existing surrounding water wells or the aquifer.

4. **Estimated impacts to regional water resources:** Regional water resources include aquifers, springs, and surface streams. The Report should attempt to quantify the short- and long-term impacts from the pumping on these water resources and Desired Future Conditions (DFCs) for the relevant aquifer(s). Results will be used to evaluate the potential for unreasonable impact to DFCs, regional aquifer conditions, springflows, or base flows to surface streams.

Variances to Hydrogeologic Reports and Aquifer Test

The District may consider a variance from certain requirements. Technical information and a memorandum from a Texas licensed geoscientist or engineer supporting and documenting the rationale for the variance shall be submitted to the General Manger for consideration. Factors that may be considered include:

1. Relatively low requested production volume;
2. Sufficient data exist for the well or vicinity (e.g. existing hydrogeologic reports or aquifer tests);
3. Low potential for unreasonable impacts; and

4. Other relevant factors.

Deviations from the guidelines and/or the work plan requirements (**Appendix A**) can occur with approval from District Aquifer Science staff, which should be noted and described in the submitted work plan.

III. Hydrogeologic Report Outline

Below is a suggested outline of topics, tables, and figures that should be included in the Hydrogeologic Report (Report). Class 1-3 Reports need to address their respective topics described in the Section II above. (However, the Class 1 Abbreviated Hydrogeologic Report is, by its nature, a more concise document and does not address all the elements outlined below.)

A. Summary, Results and Conclusions

i) Description of the type of permit request, aquifer (target production zone), use type, volume, and other relevant factors.
ii) Conclusions of the Report as they relate to the purpose described in Section II.

B. Description of the Pumping Well Site and Water System

i) Description and map of the project area, the location of the well site(s), and system configuration including the location and volume of water-storage facilities.
   - Figure*: sketch (map) of the test site*
     - *Note*: *Describe and map potential interference from nearby pumping wells.*

ii) Description of the current and anticipated annual pumping demands, including typical pumping schedules, such as, frequency, duration, peak demand hours, and pumping rates of the pumped well(s).

C. Hydrogeology and Conceptual Model (Class 2 and 3 only, except where indicated)

The data sources for this section should be the best available information, properly cited from the literature, and integrated with the data collected from this study.

i) Provide a description of the hydrogeologic conceptual model of the aquifer and well site. Discuss or provide:
     - Relevant hydrogeologic aspects of the aquifer, such as aquifer conditions (e.g. confined, semi-confined, unconfined), hydrostratigraphy, faulting, and boundary conditions (recharge or barriers).
     - Map of wells (exempt and nonexempt), surface ponds or reservoirs, major karst features, springs, or any other source of recharge and discharge for the project well site and surrounding area of influence. Data sources should include all publically available databases coupled with field reconnaissance or survey investigations.
     - Regional hydrogeologic elements such as recharge, flow, and discharge should be addressed in the conceptual model. Concepts such as pumping equilibrium, changes in storage, and capture related to pumping should be discussed.
   - *Figures: Regional and local scale geologic and potentiometric maps*
   - *Figures: Study area geologic and hydrogeologic cross sections*
     - The role of karst and fracturing and faulting in the conceptual model should also be directly discussed in addition to the heterogeneity and anisotropy of the aquifer and well field.

ii) Detailed well hydrostratigraphy and completion/construction information need to be presented in the Report. This should include geophysical logs of the pumping wells (required), and monitor wells (required for all wells used in a Class 3 monitoring well network plan).
   - *Figures: Pumping and monitor well hydrostratigraphy and well completion diagrams.*
      - Well inventories, drilling and geophysical logs, pump depths, casing/annular seal specs, state well reports, and other relevant records should be included in the appendices of the report.
      - Electronic files (PDF and/or .WCL) of geophysical logs should be made available. Geophysical logs should include gamma ray, resistivity, and caliper.

iii) Potentiometric maps should be prepared showing the elevations of the potentiometric surface(s) of the aquifer(s) proposed for usage or that could be impacted.
      - Regional potentiometric maps can be based on existing or published data, while more local potentiometric maps should be based on water-level measurements taken prior to the aquifer test for the tested aquifer and, to the extent possible, all relevant aquifers that could be subject to capture.
   - *Figure: Regional and local potentiometric maps*

D. Aquifer Test Work Plan and Results

i) Aquifer Test Work Plan. Summarize the aquifer test design and operation outlined in **Appendix A**, and approved by the District.
      - *Note: Complete time-discharge records of the pumped well and water-level records of the pumped and monitor wells should be put into an appendix (and provided in digital format).*

ii) Aquifer test results. Discuss pre-test trends and water levels during the pumping and recovery phases as they might relate to influences from recharge, barometric effects, and other pumping wells. Any problems or inconsistencies with pumping rates or measurements must be discussed and documented.
   - *Figure: Map of the maximum measured drawdown during aquifer test. If more than one well is pumped, the sum of the maximum drawdown from each test must be presented. Maximum drawdown determinations may need to be adjusted for regional water-level trends.*
   - *Figures: Annotated hydrographs (arithmetic or non-log) water-level elevations versus time for all the data from each well.*
   - *Figures: Hydrographs of nearest stream flow, springflow, and rainfall station data covering a period of three months prior to the aquifer test through the recovery period.*

E. Analyses of Aquifer Test Data and Parameter Estimation

i) This section should describe the methods used and analytical model selected to estimate aquifer parameters.
      - All data manipulation (trend-correction) should be clearly described.

- *Table: Summary of input parameters used in the analytical solutions (pumping rate, aquifer thickness, distances, well construction details etc.)*
- *Figures: Annotated semi-log and log-log graphs of measured drawdown versus time in pumping and monitor wells. Include select theoretical curves (analytical models) used to calculate the parameters.*
  - *Methods should include straight-line (Cooper and Jacobs, 1946) and type curve models such as Theis (1935) or other analytical models. If numerous plots are generated, they can be put into an appendix.*

ii) Storativity should only be calculated from monitor well (not pumping well) data. Data from monitor wells farthest out generally result in the best estimates of storativity (Butler and Duffield, 2015; Butler, 2009).

iii) Deviations from these theoretical curves must be discussed and may include effects from: hydraulic boundaries (recharge and no flow), partial penetration, fluctuating pumping rate, delayed yield, leakage, atmospheric responses, regional water-level trends, and interference from other wells.

- *Table: Summary table of estimated aquifer parameters and methods. This should provide a range of results based on various selected methods. The preferred or averaged result and model should be indicated. A comparison to other published or nearby aquifer test values should be included.*

F. Potential Unreasonable Impacts Analysis (Class 2 and 3 only, except where indicated)

The effects of pumpage on wells and on the aquifer must be evaluated and discussed in this section as they relate to the potential for unreasonable impacts. Aquifer parameters selected for the evaluation should be representative of the potentially impacted area. Discuss the rationale of the parameters selected for the analyses.

Well interference (Class 1-3)

i) Discuss and map the estimated extent (area of influence) and magnitude of well interference on existing surrounding wells.

ii) Discuss and consider construction and location of the subject well/well field; target production zone, production capacity, and proposed production rate of the subject well/well field; construction/completion of existing wells in the area of influence; drawdown attributed to drought conditions and seasonal increases in pumping from existing wells; and drawdown attributed to pumping from existing wells and from future domestic and livestock well.

- *Figure: A plan view map of theoretical maximum drawdown for at least 7 years shall be shown on the final maps and cross sections. For Class 2 and 3, theoretical maximum drawdown should include cumulative modeled drawdown of any permitted pumping centers within a 5-mile radius of the test well.*
- *Figure: Chart showing the forecast of distance-drawdown from the pumping well for 1 week, 1 year, and 7 years. Cooper-Jacob plots are recommended.*

- *Figure: Hydrogeologic cross section (showing geologic formations and well completions, etc.) showing theoretical drawdown for at least 7 years.*

Impacts to regional water resources

i) Discuss the requested production volume in context with the Modeled Available Groundwater (MAG) and the DFC.
ii) Discuss potential short- and long-term impacts from the pumping on freshwater resources including springs and baseflow to surface streams.
iii) Discuss regional numerical or other analytical models and results relevant to the permit.

Changes in water quality

i) Document and discuss any water-quality changes that may have occurred due to pumping during the test.
   - Analytical results from the laboratory should be provided as appendices.
   - *Table: Summary of laboratory water-chemistry results. Should include comparison to EPA and TCEQ standards, in addition to other regional averages.*
   - *Figure: Plots showing water level, temperature, and conductivity during test.*

G. Supplemental Information

Due to the test-specific nature of these investigations, additional information can enhance the results and evaluation of the data. Below are some items that could be considered within the scope of work for the hydrogeologic studies and report:

- *Numerical modeling*
- *Dye tracing*
- *Surface geophysics*
- *Down-hole camera surveys*
- *Other reports or unpublished information or data.*

IV. Select References

Alley, William M., 2009, Update on Guidance for the Preparation, Approval, and Archiving of Aquifer-Test Results. Office of Groundwater Technical Memorandum 2009.01 <https://water.usgs.gov/admin/memo/GW/gw09.01.html>

Butler, J., 2009, Pumping Tests for Aquifer Evaluation—Time for a Change? Groundwater, Volume 47, Issue 5, September/October 2009, Pages: 615–617.

Butler, J. and G. Duffield, 2015, Aquifer Testing for Improved Hydrogeologic Site Characterization featuring AQTESOLV and the In-Situ Level TROLL, Course Notes, D. Kelleher (ed), Fort Collins, Colorado, October 27 and 28, 2015, 511 pages.

Cooper, H.H. and C.E. Jacob, 1946, A generalized graphical method for evaluating formation constants and summarizing well field history. Am. Geophys. Union Trans. Vol. 27, pp. 526-534.

Driscoll, F.R., 1986, Groundwater and Wells. Second Edition. Johnson Screens, St. Paul, Minnesota. Pp. 1089.

Hunt, B.B., B.A. Smith, J. Kromann, D. Wierman, and J. Mikels, 2010, Compilation of Pumping Tests in Travis and Hays Counties, Central Texas: Barton Springs Edwards Aquifer Conservation District Data Series report 2010-0701, 12 p. + appendices <http://www.bseacd.org/uploads/BSEACD_DS_2010-0701.pdf>

Kruseman, G.P., and N.A. de Ridder, 1991, Analysis and Evaluation of Pump Test Data, Second Edition, ILRI, Netherlands. Pp. 377

Theis, C.V., 1935, The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage. Trans. Amer. Geophys. Union, Vol. 16, pp. 519-524.

Appendix A: Guidelines for Aquifer Test Work Plans (Design and Operation)

The aquifer test plan shall be submitted to the District prior to the test and should briefly address the key aspects outlined below. These guidelines will be used as a checklist during the pre-test meeting with the applicant or their consultant. The aquifer test work plan must be approved by the District Staff prior to commencement of the test.

Aquifer test design and operation should generally follow those discussed in Driscoll (1986) or other published resources.

1. **Initiation, Duration and Pumping Rate**
    a) Aquifer tests for most aquifers (especially the Edwards) should not be conducted during or immediately after significant rain or recharge events, because of the rapid change in water levels that often follows.
        - *Note: aquifer tests may occur during recharge events for deeply confined aquifers if the pre- and post-test data are sufficient to document trends.*

    b) Testing schedules should be coordinated with other area pumping wells to avoid interferences that could result in misleading or uncertain results.
    c) The test shall be designed to pump a minimum of three times the daily equivalent of the requested annual permitted volume (Table 2). Pumping tests should be a minimum of 48 hours duration for Class 1 and 72-hours duration for Class 2 and 3 permits. Longer duration pumping tests (four to five times the daily equivalent) are encouraged and could be required where the risk of impacts, or encountering aquifer boundaries, is high.
        - *Note: the duration of the test, rather than the pumping rate, increases the scale of the test (distance of measureable drawdown). The pumping rate has less of an effect on the scale of the test, but increases the ability to distinguish water-level fluctuation noise. In addition, unconfined aquifers generally result in slower response and need longer pumping durations for measured responses in monitor wells (Butler and Duffield, 2015). Longer test durations and larger pumping volumes should be considered if it is anticipated the permit would increase sometime in the future, such that the test would not need to be repeated.*

Table 2. Example duration calculation of a Class 3 aquifer test

Annual Permit Request (gal)	**Daily equivalent (gal)**	**Pumping target volume (gal)**	**Testing Rate: 72 hours**	**Testing Rate: 96 hours**
100,000,000	274,000	3 x 274,000= 822,000	190.3 gallons-per-minute	142.8 gallons-per-minute

d) The aquifer test should be a constant-rate test. Well testing (step tests) should be performed prior to the aquifer test (allowing for recovery) in order to properly size the pump and estimate the optimal well yield for the test. Well testing should ideally be done prior to the final work plan.
   - *Note: Pumping rates should be measured frequently to verify that a constant discharge rate is being achieved. If a flow meter is used to measure flow, it should be calibrated prior to the test and verified using another calculation method, such as an orifice weir or by the time required to fill a storage vessel of known volume.*

e) Waste of the discharge should be avoided as much as possible, particularly during low water-level conditions in the aquifer and should be routed to storage tanks or to other water systems when possible. If the water must be discharged to surface drainages off-site, the pumped water should be routed so that it does not recharge into the tested aquifer in the vicinity of the pumping or monitor wells during the test. Discharge onto adjoining properties needs to be considered and avoided if possible, especially when it involves flooding and/or poor quality water. The applicant shall discuss the fate of discharged water in the work plan.

2. Aggregate Well Fields

a) If the study involves the assessment of two or more pumping wells, each well may be pumped separately to measure their combined effects. If the wells are sufficiently close, it may be possible to pump the wells simultaneously.

3. Well Completion (3-1.20)

a) All proposed pumping wells must be completed and equipped for the ultimate planned use or, at minimum, completed and equipped to isolate the target production zone for the ultimate planned use and production rate. Observation wells may be required. The applicant is responsible for all cost associated with the design, engineering, well construction, and other related expenses. The use of test wells must be approved by the District.

   - *Note: If the conversion of the test wells to final production involves significant modifications (well diameter, acidization, etc.) then a special condition of the permit, if granted, may be included to require a re-test of select wells after final completion to demonstrate the data can be reproduced. If the test of wells after final completion results in significant differences in aquifer parameters and measured response to surrounding wells, the full aquifer test may need to be repeated and the permit subject to staff-initiated amendments based on a new aquifer test.*

4. Number and Location of Monitor Wells

a) Monitor wells should be selected radially around the pumping well and include wells completed in the same aquifer.
   - *Provide a detailed map of pumping, monitor, and area wells.*
   - *Use analytical models (Cooper-Jacob) to help forecast distance and potential magnitude of drawdown to monitor wells using published aquifer parameters.*

b) For Class 2 and 3, some monitor wells may be selected that are in different aquifers to evaluate the potential for inter-aquifer communication.

c) Ultimately, it may be necessary for the Class 2 testing, which have a significant risk of unreasonable impacts, to install one or more monitor wells in the absence of existing well-suited monitor wells.

d) For Class 3, the aquifer test work plan shall also include a monitoring well network shall be established by installing one or more new monitor wells and identifying a sufficient number of existing wells adjacent to the well or well field prior to the commencement of the aquifer test in accordance with the District approved monitoring well network plan. The final monitoring well network plan and aquifer test work plan must be approved by the District (Appendix B).

5. Water-Level Data

a) Pre-aquifer test water-level measurements should be collected starting at least 1 week prior to pumping.

b) Post-test data collection in all wells should continue through the recovery phase, which should be about as long as the pumping phase.
   - *Note: recovery data often results in the best data for parameter estimation as head loss due to well construction is minimized (Butler and Duffield, 2015).*

c) Select monitor wells should be measured beyond the recovery period of the pumping phase to establish regional and local water-level trends and to observe any delayed response to pumping.
   - *Note: It is preferable that recovery lasts two to three times the duration of the pumping for complete recovery and also to measure trends.*

d) All water-level measurements should be within 0.1 feet precision. The use of automated data loggers and vented pressure transducers should be used whenever possible. The automated data should be verified with manual e-line measurements if the risk of hanging up the e-line is low.

e) Other means such as airlines or sonic meters, are generally discouraged from use but may be allowed as backup measurements.

f) All water-level data must be submitted in the report and made available in digital format (spreadsheet).

g) Care should be exercised to prevent (bacterial) contamination of monitor wells.

Note: The District may be able to provide continuous data from relevant existing monitor wells, and provide logistical support to identify, make introductions, and possibly assist with monitoring if time and resources allow.

6. Water Quality Data

a) Samples for major ions, nutrients, and other trace elements at the end of the test.
   - *Note: the list of parameters should be provided in the work plan.*

b) Field parameters (temperature, conductivity, pH) should be monitored throughout the test with tabular results provided in the appendices.

Appendix B: Monitoring Well Network Plan Outline

Class 3 testing requires a monitoring well network to be established by the installation of at least one or more new scientific monitor wells for a test and identifying a sufficient amount of existing wells adjacent to the well or well field. A second monitor well may be required to measure the effects in different aquifers or in different locations of a widespread wellfield. The Class 3 requirement is meant to ensure the best possible test and data collected for these large permit requests. Scientific monitor wells serve as a component of the "monitoring well network plan" submitted with the aquifer test work plan as required by the rules (3-1.4.D). Scientific monitor well(s) drilled under the Class 3 requirement have two intended functions: 1) to provide data during an aquifer test to satisfy the requirements of a Class 3 hydrogeologic report, and 2) to provide long-term monitoring of well field production after a the production permit has been issued. Scientific monitor well(s) should not be pumping wells. The applicant is expected to facilitate access to scientific monitoring well(s) for District staff as long as their associated production permit is active. The monitoring well network plan must be approved by the District and the monitoring wells shall be installed and/or identified prior to the commencement of the aquifer test.

A. Goal and purpose of project

Summarize and state the purpose and goal of the monitoring network. Include figures showing well network locations (including proposed and existing wells) and rationale for well locations.

B. Design and Construction

Provide information on the well design on each monitor well. Include figures and tables showing the construction and completion of each new well. Information should include: State well reports if available, geophysical data, downhole video, non-pumping and pumping water levels, well and casing depth and diameter, pump depth, or schematics for proposed modifications.

C. Monitoring well specifications and installation

Provide information on the monitor well including:

- Designated hydrogeologist/engineer and well drilling contractor.
- Schedule for completion of work.
- Assurances that the District can maintain access to the monitoring well network and equipment.
- Parties responsible for maintaining, repairing, and equipping the monitoring well network.