San Gorgonio Pass Water Agency
A California State Water Project Contractor
1210 Beaumont Avenue • Beaumont, CA 92223
Phone (951) 845-2577 • Fax (951) 845-0281

April 1, 2019

Dear Consultant:

You have been selected to receive the enclosed Request for Proposal package to develop a Groundwater Sustainability Plan for the San Gorgonio Pass Subbasin of the Coachella Basin. The RFP package was developed by the San Gorgonio Pass GSP Working Group, a consortium of six water purveyors and three Groundwater Sustainability Agencies (the San Gorgonio Pass GSA, the Verbenia GSA, and the Desert Water Agency GSA). The six parties are the Agency, the City of Banning, Banning Heights Mutual Water Company, Cabazon Water District, Mission Springs Water District, and Desert Water Agency. In addition, the Morongo Band of Mission Indians contributed to development of the RFP.

The entire RFP package, identical to this one, will be posted on our web site, sgpgsas.org, by the end of this week. The package includes the RFP, a map of the subbasin, the Work Plan for the Agency's SGMA grant, and two technical memoranda related to a model that has previously been developed for the subbasin.

The RFP includes a timetable for submitting questions, submitting a final proposal, interviews (if required), and award of contract. It is anticipated that the Agency board will consider award of contract at its June 17 meeting.

The Agency is the recipient of a SGMA grant from DWR for development of a GSP in the amount of $1 million. All costs over and above this will be shared by the six parties mentioned above. The grant includes a Work Plan, which is the basis for the scope of services in this RFP. The Work Plan is included as Exhibit A to the RFP. The Work Plan for Component 2 of the grant is the applicable one for this RFP.

If you have any specific questions related to the RFP, please submit them per the RFP by the given deadline. Written answers to all questions will be provided to all recipients of this RFP. We invite you to consider submitting a proposal for this work.

Very truly yours,

Jeffrey W Davis

Jeff Davis
General Manager

Request for Proposals

DEVELOP GROUNDWATER SUSTAINABILITY PLAN FOR THE SAN GORGONIO PASS SUB-BASIN AREA

San Gorgonio Pass Water Agency

In partnership with

Desert Water Agency
Mission Springs Water District
Cabazon Water District
City of Banning
Banning Heights Mutual Water Company
(known collectively as the "GSP Working Group")

Deadline to submit proposals is: May 10, 2019

I. PROJECT BACKGROUND

In 2017, the San Gorgonio Pass Water Agency (Agency) joined the Cabazon Water District, the City of Banning, and the Banning Heights Mutual Water Company to form the San Gorgonio Pass Sub-Basin Groundwater Sustainability Agency (SGP-GSA). At the same time, the Agency joined the Mission Springs Water District (MSWD) to form the Verbenia Groundwater Sustainability Agency (Verbenia-GSA), and the Desert Water Agency (DWA) formed the Desert Water Agency Groundwater Sustainability Agency (DWA-GSA). In addition, each of the GSA's established that they will coordinate and cooperate with other GSAs in the San Gorgonio Pass Sub-Basin (SGPSB). Following, these entities have joined together through the San Gorgonio Pass Groundwater Sustainability Plan Working Group (GSP Working Group) to develop a Groundwater Sustainability Plan (GSP) for the SGPSB of the Coachella Valley Basin. The SGPSB has been identified as a medium priority basin by the California Department of Water Resources (DWR) (2015 initial priority and the 2018 update). The group is required to submit a final GSP to the DWR by January 31, 2022.

The Sustainable Groundwater Management Act (SGMA) went in effect on January 1, 2015. SGMA requires governments and water agencies of high and medium priority basins, as determined by DWR, to halt overdraft and bring groundwater basins into balanced levels of pumping and recharge. Under SGMA, these basins must reach sustainability within 20 years of implementing their respective GSP's. For medium priority basins, such as the SGPSB, 2042 is the deadline for sustainability. SGMA implementation began with a process to identify the unmanaged basins, or basins not adjudicated, throughout the State of California and establishing a priority. For each of these unmanaged basins that were identified with a critical, high and medium priority, one or more GSA's are required to be established to prepare one or more GSP's. A portion of the San Gorgonio Pass Sub-basin is located in the adjudicated Beaumont Storage Unit (also known as the Beaumont Basin), and will not be managed by the SGPSB GSP pursuant to Water Code Section 10720.8. The Morongo Band of Mission Indian's (MBMI) reservation lands overlie more than half of the sub-basin and will not be managed by the SGPSB GSP. The GSP working group is charged with developing a GSP for the SGPSB, excluding the Beaumont Basin and the MBMI reservation.

Before formation of the GSA's, the Agency had worked with the United States Geological Survey (USGS) to model a portion of the SGPSB known as the Cabazon Storage Unit. The Cabazon Storage Unit covers a majority of the SGPSB as defined by DWR in Bulletin 118. Various separate and distinct canyon basins are also included in the SGPSB, as is a portion of the Banning Storage Unit and Banning Bench Storage Unit. These basins were not included in the USGS model of the Cabazon Storage Unit.

As part of the recently completed (2018) San Gorgonio Integrated Regional Water Management Plan (SGIRWMP), the Agency, in conjunction with the City of Banning, Cabazon Water District, and Banning Heights Mutual Water Company, expanded the

USGS model to include the approximate boundaries of the SGPSB, and also incorporated a rainfall/runoff model. This new model, known as the San Gorgonio Integrated Watershed and Groundwater Model (SGIWGM), is complete but not yet calibrated. For this reason, it should be considered as an incomplete model at this time. Exhibit B and Exhibit C are two technical memoranda that describe this model.

The SGIWGM is hampered by a paucity of groundwater level data, especially in the eastern portion of the SGPSB. In an effort to remedy this paucity of data, the Agency applied for and received a Sustainable Groundwater Planning Grant, through DWR, to drill up to three monitoring wells in the eastern portion of the SGPSB. Work on these monitoring wells is ongoing but no data will be available until at least May or June 2019.

The Morongo Band of Mission Indians (MBMI), a federally recognized tribal reservation is located completely within the boundaries of the SGPSB. While the MBMI has worked closely with the GSP Working Group in the initial stages of SGMA, it elected to not be a participating member of any of the GSAs. As a federally recognized Native American tribe, the MBMI is exempt from SGMA as identified in Water Code section 10720.3. The MBMI is not required to report groundwater data on its tribal lands, however it is required to submit annual surface water filings related to its State surface water rights.

II. PROJECT DESCRIPTION

The SGPSB underlies the eastern half of the Agency's service area and a small portion of the western jurisdictional boundary of Desert Water Agency and Mission Springs Water District. Figures 1 through 3show the SGPSB boundary, along with various agency and GSA boundaries.

The City of Banning, the Banning Heights Mutual Water Company, the Cabazon Water District, and the Mission Springs Water District each pump water from the SGPSB to meet retail water demands. In addition, Robertson's Ready Mix is a major pumper. The MBMI has wells in the SGPSB as well but no data has been made available from those wells. The MBMI also has a wastewater treatment plant that has discharged into the Cabazon Storage Unit since 2003. The Agency and DWA are the water importers for their service areas and as such are charged with bringing imported water to the portion of the SGPSB within their respective boundaries should it be required.

Based on data available to the Agency, approximately 8,200 acre-feet of water were pumped from the SGPSB in 2017. Data regarding safe yield are not available at this time, although the intent of the USGS model and the SGIWGM is to eventually estimate safe yield. The lack of adequate data from the eastern portion of the SGPSB, where there are virtually no wells, as well as the presence of the MBMI reservation, make it difficult to establish an accurate water budget and safe yield.

Implementation of SGMA provides an opportunity to fill in the gaps in data and to develop a management strategy for the SGPSB. Key information is not available at this time. This includes a water budget, a safe yield, and other information required by SGMA as part of a GSP. One key piece of information that is not known is the amount of water flowing out of the SGPSB past Fingal Point to the remaining portions of the Coachella Valley Basin. It is believed that this flow varies based on groundwater elevation in the SGPSB and Indio Sub-Basin (ISB). Available data indicate that groundwater in the SGPSB have declined significantly over the past decade. However, this is not well understood and could be a natural phenomenon. It is believed that the SGPSB operates on a lengthy cycle of gradually draining over a number of years, and then rapidly filling over a fewer number of years, during wetter periods. The lack of data makes it difficult to determine if this is the case and more difficult to develop a management strategy for the SGPSB.

Key information and analysis needed in order to develop a GSP include, but is not limited to, the following:

Evaluate Supplies and Demands. The essential issue is to identify the difference, or gap, between supply and demand (current and future).

Establish Sustainability Goals for the SGPSB including the amount of water needed to bridge any gap between supplies and demands, including an additional amount for reliability ("reliability factor"); and measurement and tracking of identified sustainability indicators.

Identify and Evaluate Management Actions that may be implemented to address any gaps in supplies and demands and achieve the established sustainability goals by year 2042. Options will be evaluated based upon feasibility, potential efficacy, cost, and other factors.

Identify and Assess Impacts of the GSP to applicable County and City General Plans and the water resources-related plans and programs within the SGPSB.

Implement the Plan and Adaptive Management. This involves building the necessary institutional agreements, processes, and administrative framework to put the GSP into action, to measure progress, and to make course changes if necessary.

Establish Framework for Local Management of Groundwater Resources. All of the actions above will be undertaken in a collaborative manner to insure that beneficial users of the SGPSB have a voice in the success of the GSP.

III. SCOPE OF SERVICES

Develop Draft and Final Groundwater Sustainability Plan (GSP) for the San Gorgonio Pass Sub-Basin (SGPSB)

Using the information generated in Tasks 1, 2, and 3 as outlined in the Grant **Component 2** Work Plan (see ***Exhibit A*** for further details), consultant shall prepare an administrative draft GSP for circulation, review and comment by the GSP Working Group and stakeholders. This will also be a "check-in" point with DWR. Based on comments, consultant shall prepare a draft GSP as identified and described in Task 2 below. Thereafter, a maximum of six public hearings will be held to receive comments on the draft GSP. The comments received on the draft GSP will be considered by the GSA's and individual water agency boards prior to incorporation into the final GSP and plan adoption. Consultant shall incorporate any comments as necessary into the final GSP.

Generally, the work performed by consultant will include, but not be limited to, the following tasks, which are correlated with tasks from the grant work plan (Exhibit A):

1. Meet with the GSP Working Group to obtain pertinent information and references for use in preparation of (not in implementation of) the GSP. Meet as needed or as directed to provide updates during preparation of the SP. It is anticipated that monthly meetings with the GSP Working Group will be required for at least the first six months.
2. Analyze the available information and develop draft chapters of the GSP as described in Task 2 of the Grant Work Plan
3. Identify projects and management actions to achieve the sustainability goal as described in Task 2 of the Grant Work Plan. Work with the GSP Working Group to establish how many projects, programs, or policies are necessary to achieve sustainability in the basin.
4. Define an Implementation Plan per Task 2 of the Grant Work Plan in conjunction with the GSP Working Group.
5. Describe Existing and Planned Monitoring Network and evaluate its ability to monitor each of the sustainability indicators for the SGPSB area. See Task 2 of the Grant Work Plan.
6. Develop framework for Data Management System (DMS) database once the SGIWGM model is completed and calibrated, the existing and planned monitoring network has been assessed, and the template for reporting has been developed, per Task 1 of the Grant Work Plan. Develop a DMS database specification sheet along with a cost estimate in the form of a memorandum for review and comment by the GSP Working Group.
7. Integrate established governance structure of the GSA's into the GSP.
8. Hold, coordinate, and present materials for a maximum of four stakeholder outreach workshops. Facilitate outreach meetings to best meet SGMA requirements for GSP development outreach, and inclusion of various stakeholders including disadvantaged and underrepresented communities, per Task 4 of the Grant Work Plan. Assume free use of Agency Administration Building for this work.
9. Prepare final GSP document and handle all filings and administrative procedures through final approvals by DWR and the State Water Resources Control Board . Verify and confirm that the GSP meets all requirements as set forth in Water Code § 10727.2., and additional requirements where applicable.
10. Develop a water budget for the SGPSB using existing data, as well as newly generated data from monitoring wells completed in 2019.

11. Review, update, and calibrate the SGIWGM as needed to make its accuracy consistent with that of Exhibit B. Exhibit C includes recommendations on how to achieve this level of calibration.

Once finalized, all electronic files must be submitted to the Agency in the latest editions of the following software programs: Microsoft Excel, Microsoft Word, Adobe Acrobat and Microsoft Project. No other electronic file format will be accepted without written approval from the Agency.

IV. PROPOSAL SCHEDULE

Date	Event
4/1/19	Release of Request for Proposal (RFP)
4/19/19	RFP Questions Due
5/3/19	Response to Questions
5/10/19	Deadline for Agency Receipt of Proposals
5/20/19	Notice of Interviews (optional)
5/29/19	Interviews (optional)
6/17/19	Board of Directors Approval/Award Contract

V. TEAM

Proposer (Consultant) is responsible for assembling a team which meets all of the requirements outlined in this RFP.

VI. MEETINGS

Consultant will conduct all meetings necessary to complete this project. Monthly meetings with the GSP Working group are anticipated for at least the first six months. At least four stakeholder meetings will be required, along with a maximum of six public meetings on the draft GSP. Meetings with individual members of the GSP Working Group may also be required to gather and analyze existing data, explore current governance structures, etc. Some of these meetings with individual members may be accomplished via telephone.

VII. PROJECT SCHEDULE

The proposal shall include a detailed, project schedule which shows the project tasks. The schedule will be reviewed and finalized with the Consultant prior to start of the project. Once the schedule has been finalized, no extension will be allowed unless the extension has been requested, in writing, and approved by the Agency before a submittal deadline. Failure to submit required work by scheduled deadlines may result in cancellation of the remainder of the contract and all outstanding invoices. Should cancellation occur, all materials collected and/or developed during the process will become property of the Agency.

VIII. PROPOSAL REQUIREMENTS

a) **Body of the proposal** (may not exceed 15 pages in length with a minimum font size of 12 point)
   i) Table of Contents
   ii) Project Understanding. A clear statement of the project.
   iii) Project Approach. The project approach shall include a detailed description of all the tasks needed for successful completion of the project and shall follow the general outline provided in the Scope of Services section above.
   iv) Organizational chart illustrating the individuals who will actually work on the project complete with names, firm names, addresses, telephone numbers, email addresses and chain of responsibility (qualifications are to be provided in the appendix, see below).
   v) Project Schedule
   vi) Any other information that may assist the GSP Working Group in making its determination in the selection process: Consultant is encouraged to include any other information that will help the GSP Working Group make its selection.
   vii) Fee schedule: Fee schedule shall be organized to follow the general tasks in the Scope of Services. Services outlined in each proposal must comply with all requirements set forth in this RFP. The costs shall provide hourly rates and hours to complete each task, including sub-consultant's hourly rates and hours, and any other costs for a complete project including estimated reimbursables. The level of effort and associated costs are to be easily understood by the GSP Working Group. The Agency accepts no responsibility for costs incurred by any individual or firm submitting a proposal pursuant to this RFP. The proposal must include a complete and fixed price. If the scope of services requires modification during the course of the work, the Agency, in consultation with the other members of the GSP Working Group, will determine whether to amend the current agreement or to issue a subsequent RFP for additional services. The price specified must remain firm and irrevocable for 90 days following the RFP submission date. All proposals become property of the Agency and will not be returned.

b) **Appendix**

   i) Qualifications, licenses, certificates and resumes for all persons, including sub-consultants that will actually work on the project. Please limit individual experience to similar projects. For each project, highlight the name(s) of each individual on the project team for this proposal. Please include reference(s) (be sure they are current).

Six (6) hardcopies and a PDF version (can be submitted via email) of the proposal must be received by the proposal submission deadline. Please submit your proposals to:

Jeff Davis
General Manager
San Gorgonio Pass Water Agency
1210 Beaumont Avenue
Beaumont, CA 92223

All questions regarding this RFP must be submitted in writing via email by 4:30 pm, April 19, 2019 to the following email address: jdavis@sgpwa.com. Answers may be sent via email and/or regular mail to the entire distribution list for this RFP by May 3, 2019.

IX. INTERVIEW

Interviews may be scheduled with selected firms following initial review of the proposals and will take place on the date specified in the Proposal Schedule above. Interview must be attended by the actual team members that will work on the project including any sub-consultants. The interview will include an approximate 20-30 minute presentation by the project team followed by a question and answer period.

X. EVALUATION PROCESS AND CRITERIA

Evaluation of proposals shall be based upon a competitive selection process. Review and evaluation of the submitted proposals will be based upon the following criteria:

a) Project approach (20)

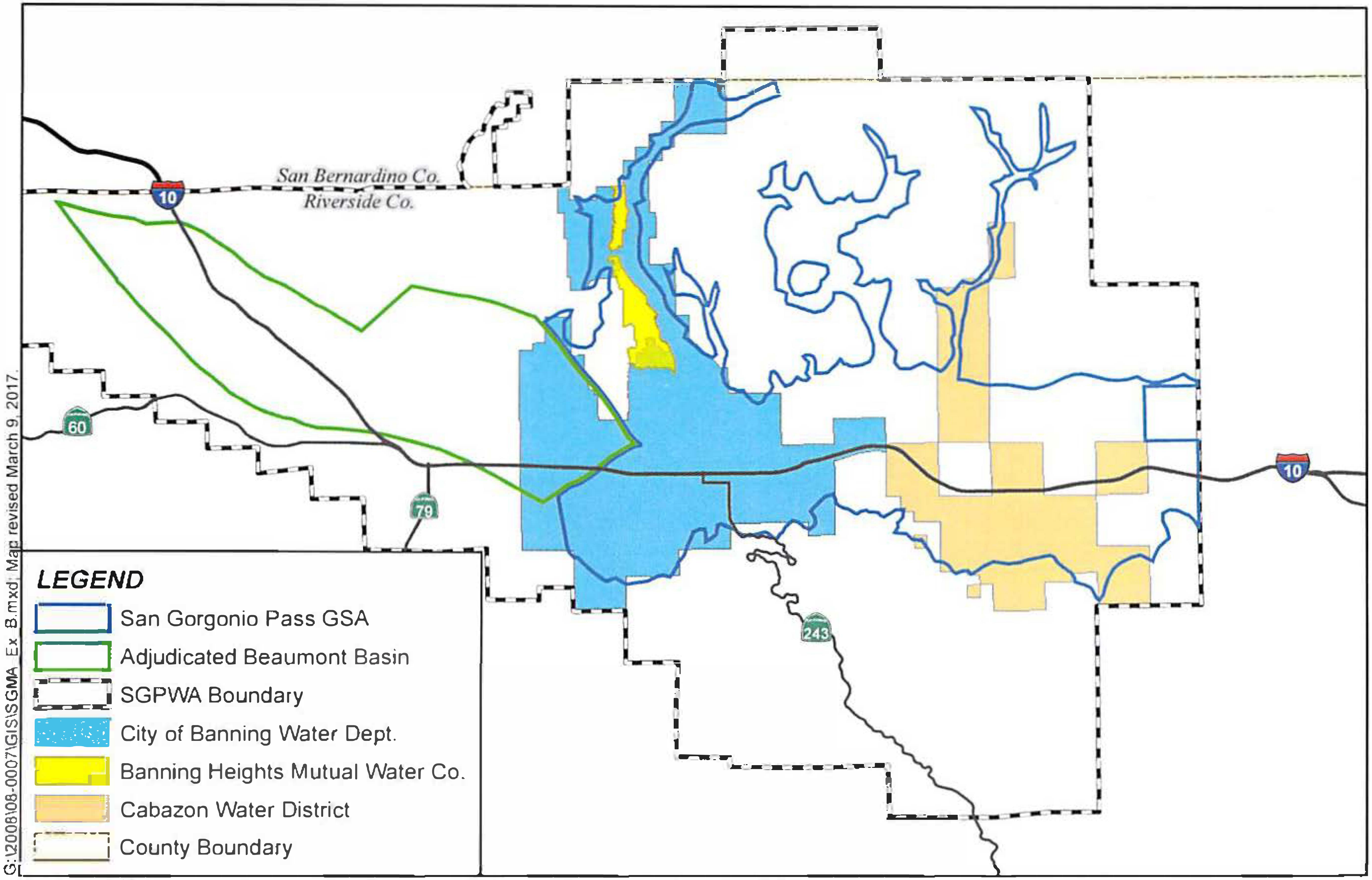
b) Experience on similar projects and/or projects of similar complexity and size (40)

c) Demonstrated ability to perform the tasks outlined in this RFP efficiently and accurately (30)

d) Fee (10)

e) Interview presentation – optional (10)

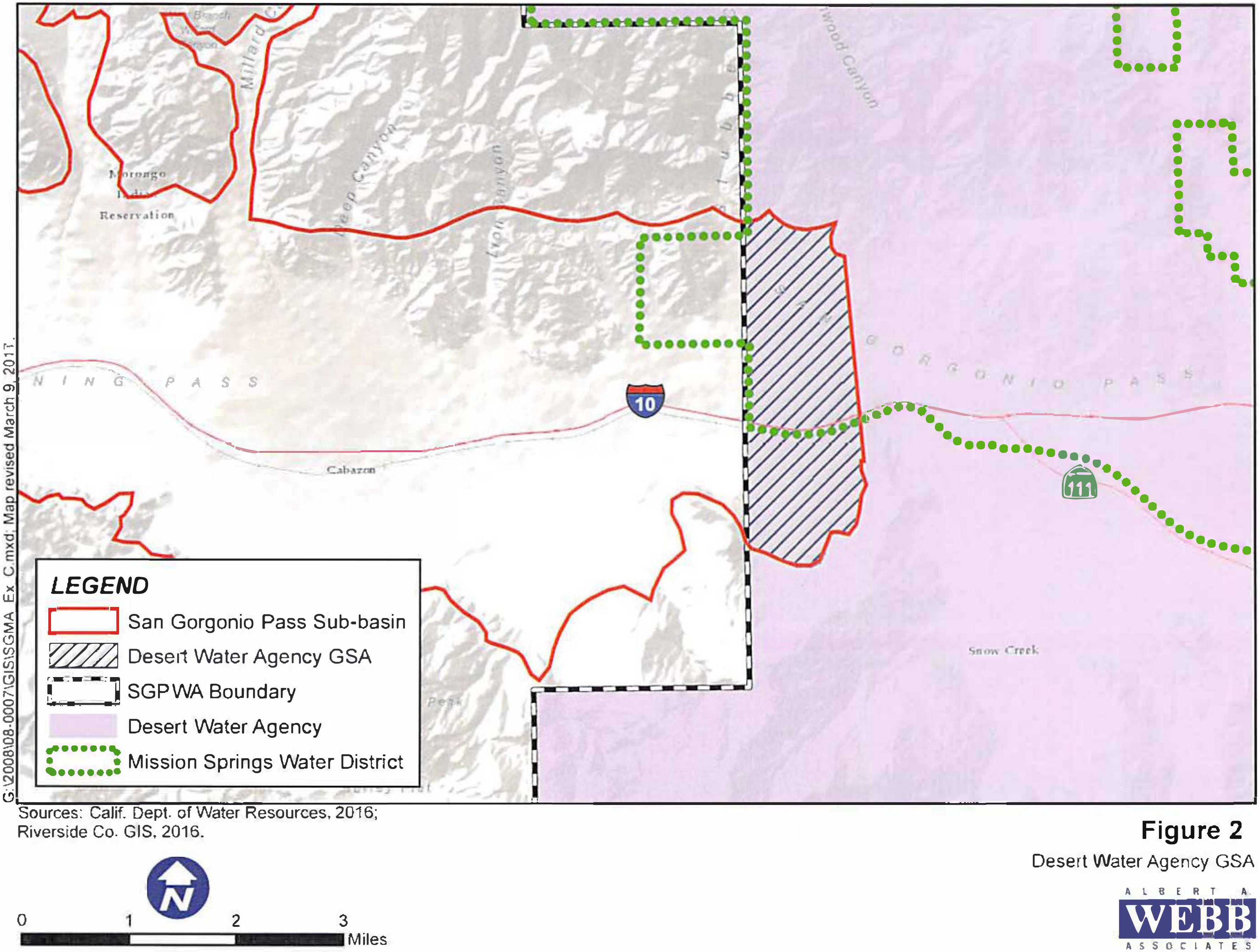
The Agency reserves the right to issue additional RFPs, to modify or to abandon this project before award of contract.



Sources: Calif. Dept. of Water Resources, 2016; LAFCO 2010; Riverside Co. GIS, 2017.

Figure 1

SGP GSA Portion of Sub-basin



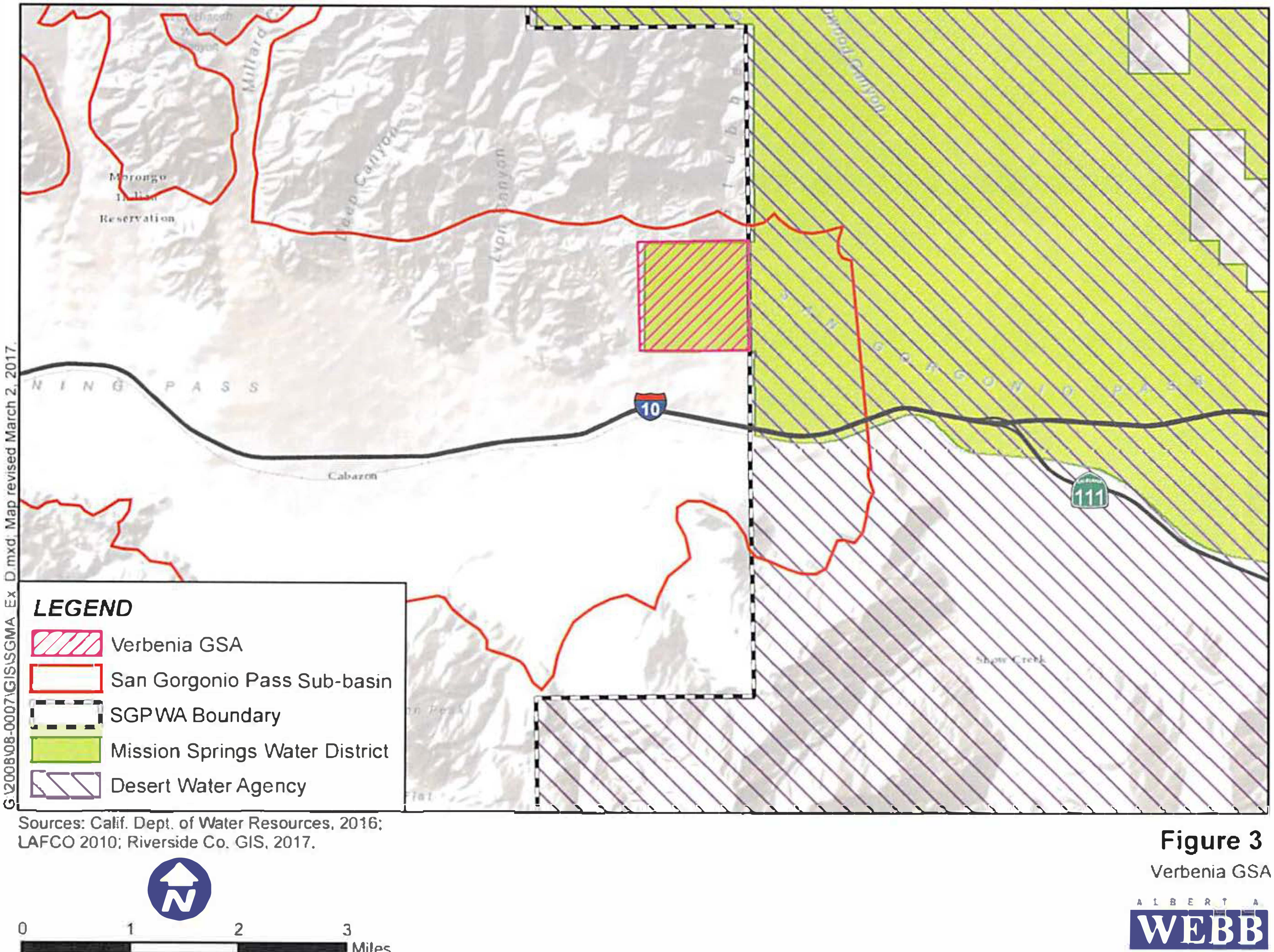
G:\2008\08-0007\GIS\SGMA_Ex_C.mxd; Map revised March 9, 2017.

Sources: Calif. Dept. of Water Resources, 2016;
Riverside Co. GIS, 2016.

Figure 2

Desert Water Agency GSA

ALBERT A. WEBB ASSOCIATES



Sources: Calif. Dept. of Water Resources, 2016; LAFCO 2010; Riverside Co. GIS, 2017.

Figure 3
Verbenia GSA

ALBERT A. WEBB ASSOCIATES

Exhibit "A" – 2017 Sustainable Groundwater Planning Grant Program: Work Plan

EXHIBIT A
WORK PLAN

Project Title: San Gorgonio Pass Subbasin Groundwater Sustainability Plan and Implementation

Project Description: The Grantee's San Gorgonio Pass Subbasin GSP and Implementation Project (Project) includes two components. First, the implementation project is to install approximately nine to fifteen monitoring wells on approximately three sites located on the east side of the San Gorgonio Pass Subbasin (Subbasin) where virtually no data exists regarding water levels. The sites are located In SDACs within the Subbasin and one in the adjacent Indo Subbasin. Second, is the preparation of a GSP for the Subbasin that meets the criteria of SGMA by January 2022. The San Gorgonio Pass Subbasin (DWR Basin No. 7-021.04) is located within the Coachella Valley Groundwater Basin in Riverside County.

The resulting GSP will incorporate appropriate Best Management Practices (BMPs) as developed by DWR and will result in a more complete understanding of the groundwater Subbasin to support long-term sustainable groundwater management. The Work Plan consists of the following components which outline the scope of work, including tasks and project deliverables:

Component 1: Monitoring Wells Installation and Site Development
Component 2: San Gorgonio Pass Subbasin GSP Development

Component 1: Monitoring Wells Installation and Site Development

Category (a): Grant and Component 1 Administration
Manage and comply with the Grant Agreement requirements and develop supporting grant documents. Complete administrative responsibilities associated with the Project, such as coordinating with DWR, partnering agencies, the United States Geological Survey, and owners of the well sites. Prepare and submit invoices to DWR, compile invoice backup information, and manage contracts and budgets associated with the Grant Agreement. Prepare and submit quarterly Progress Reports, a Component Completion Report, and a Grant Completion Report. All reports will meet generally accepted professional standards for technical reporting and the requirements outlined in Exhibit F of this Grant Agreement.

Deliverables:
- Environmental Information Form (EIF)
- Progress Reports
- Invoices and associated backup documentation
- Final Component 1 Completion Report
- Final Grant Completion Report

Category (b): Stakeholder Engagement
Conduct public meeting to inform and coordinate with local stakeholders about the location of the monitoring wells and the value they bring to the Subbasin. Coordinate with the San Gorgonio Pass (SGP) GSA to incorporate the installation of the proposed wells into the monitoring program for the Subbasin, and to include them in the adaptive management of the Subbasin.

Deliverables:
- Summaries of the public meeting on the monitoring wells included in the Progress Report(s)

Category (c): Planning/Environmental/Design

Task 1: Planning, Environmental, Design, Permitting, and Procurement

Conduct activities for planning, environmental, and design of the monitoring wells and any required site development or improvements. Perform site evaluation, including, but not limited to, Geographical Information System (GIS) work, geotechnical evaluations, site visits, and other analyses required to select sites and prepare for design. A technical memorandum will be prepared that incorporates the results of the site evaluation and supporting planning documents and analyses. Prepare final design of the wells and conduct meetings between USGS, and the planning and design team(s).

All drilling and other required permits, including necessary equipment and materials will be obtained as set forth in Paragraph 14 of this Agreement. A Notice of Exemption will be filed for this project, filed with the appropriate County Clerk and submitted to DWR's Project Manager in accordance with Paragraph D.7 of his Agreement.

Deliverables:

- Final site evaluation technical memorandum
- Final designs for monitoring well installation
- Final permits
- Notice of Exemption and other appropriate environmental document(s)
- Meeting summaries included in the Progress Report(s)

Task 2: Project Monitoring Plan

Develop and submit a Project Monitoring Plan, as described in Paragraph 18 of this Agreement, for the new monitoring wells installed within the Subbasin. This plan shall incorporate items defined and listed in Exhibit K.

Deliverables:

- Project Monitoring Plan

Category (d): Construction/Implementation

Task 3: Drilling and Construction

Drill and construct approximately nine to fifteen monitoring wells. Each of the approximately three monitoring well sites will have approximately three to five wells. Construction activities include site preparation, tailing disposal, and mobilization/demobilization. Following site preparation, borehole drilling and well construction will begin. This task also includes management and disposal of waste solids and fluids and well development. Finally, this task includes demobilization of field equipment, site cleanup following construction, and establishing site security.

Deliverables:

- Award of Contract
- Notice to Proceed
- Photo Documentation of Construction activities included in progress report(s)

Task 4: Site Management, Data Collection, and Analysis

Establish site security, develop a detailed description of lithology and sequence-stratigraphic unit assignments, track the measurement of depth-to-water in each well, complete a high-precision reference mark survey, and complete geophysical logging at each site.

Deliverables:

- Geophysical logging reports for all well sites

Task 5: Data and Construction Documentation
Compile the data collected, conduct quality assurance checks on the data, complete well and site reporting, engage in correspondence, and compile a project archive. Also included in this task will be the preparation of well construction reports for submittal to DWR.

Deliverables:
- Copy of the Notice of Completion for all well sites.
- Well design and construction reports

Component 2: San Gorgonio Pass Subbasin GSP Development

Category (a): Component 2 Administration
Manage the administrative responsibilities associated with Component 2, such as coordinating with DWR, partnering agencies, and consultants. The Grantee will prepare and submit information for Component 2 in relevant quarterly progress reports, and a Component Completion Report. All reports will meet generally accepted professional standards for technical reporting and the requirements outlined in Exhibit F of this Agreement.

Deliverables
- Component information included in relevant Progress reports
- Final Component 2 Completion Report

Category (b): GSP Development
Task 1: Data Management System (DMS)
Develop a DMS that can store and report information relevant to the development or implementation of the GSP and monitoring of the subbasin. Compile relevant data required to define sustainability, set sustainability criteria, develop required water budgets, and evaluate options for obtaining and maintaining groundwater basin sustainability. Develop the needs and criteria for a DMS to serve the Subbasin. Identify what kinds of data will be included in the DMS, set quality control criteria and processes, and develop a plan for implementing the DMS. Obtain input from the Subbasin GSA member agencies, along with stakeholder input at a stakeholder DMS workshop. Organize GPS data into standardized data sets using common formats for groundwater data, and link GPS data to a Geographical Information System (GIS) geodatabase. All data compiled into the DMS will undergo quality control checks, reconciled to standardized benchmarks. Create the DMS system, including data entry and quality control of data available at the time of implementation.

Deliverables:
- Technical memorandum describing DMS

Task 2: Prepare GSP Chapters:
Prepare the GSP to include, at a minimum, the sections listed and described below. The GSP will meet SGMA regulations and DWR requirements and will build upon activities outlined in the Grant Agreement. Provide summaries of the GSP development activities in the Progress Reports.

1. Basin Setting and Flow Modeling
   Define the characterization of the Subbasin, including the evaluation of historical and current hydrologic and hydraulic data and development of hydrologic data to be used for the HCM. The San Gorgonio Integrated Watershed and Groundwater Model (SGIWGM) is being updated as part of the City of Banning IRWM Grant Agreement No. 4600011932. The updated flow model will be the basis for the hydrogeologic conceptual model (HCM); however, the development of the HCM will be separate and distinct from the updated flow model. Develop and calibrate a HCM using the updated SGIWGM as a base and analyze groundwater conditions to support sustainable groundwater management. The HCM will describe the structural and physical characteristics that govern

groundwater occurrence, flow, storage, and quality and will cover the entire Subbasin. Develop and analyze a water budget that will show the inflows to the Subbasin, along with existing and potential export of groundwater from the Subbasin for historical, existing, and expected future conditions, including Subbasin interflows with the adjacent Indio Subbasin, and change in volume of groundwater storage. Complete an analysis of the Subbasin and its water budget and determine the approximate safe annual yield of water extracted from the Subbasin.

2. Monitoring Network
   Review historical and current monitoring programs to identify potential representative monitoring sites, including wells that have been long monitored and deemed suitable for the CASGEM program, as well as the new monitoring well sites constructed under Component 1. Representative monitoring sites will be evaluated and documented in terms of distribution and density, suitability to monitor sustainability indicators, and representation of general conditions in an area. Evaluate the monitoring network established for the GSP. Develop a monitoring program that will define performance criteria for the monitoring network and develop a plan for obtaining data to evaluate against performance criteria.

   Develop the GSP sections for Description of Monitoring Protocols and Data and Reporting Standards. Sections will include technical standards, data collection methods, and other procedures or protocols to ensure reliable and comparable data and methodologies.

3. Sustainability Goals and Indicators
   Build on the hydrogeologic conceptual model, groundwater conditions, and water budgets to identify and evaluate Sustainable Management Criteria. The GSP will include a description of the decision process for establishment of the sustainable management criteria, along with the sustainable management criteria and measurable objectives. Additionally, undesirable results will be defined, along with minimum thresholds.

4. Projects and Management Action
   Develop and analyze projects and management actions to achieve the identified sustainability goal (and interim goals). The gap between current groundwater conditions and sustainability goals will be identified, and an implementation program will be developed to close this gap. The implementation program will form the Management Actions and Projects sections of the GSP.

5. Implementation Plan
   Develop the implementation plan for the GSP. This task includes developing steps for implementation, a plan schedule (including annual reporting, periodic evaluations, and five-year updates), and a fiscal strategy for implementing the GSP. Additionally, it will include estimated costs for implementing the GSP, Project and Management Actions, and the Monitoring Network and potential improvements. The Implementation Plan will also address how the GSP will be evaluated for different reporting requirements.

6. Executive Summary, Introduction, Plan Area, and Administrative Information
   Develop outstanding GSP items that include a description of the geographic area covered by the GSP, as well as a description of governance and administration. Describe the management structure for the SGP-GSA, Desert Water Agency-GSA, and Verbenia GSA, as well as the Subbasin GSP, along with the legal authority for member agencies to form a GSA and manage Subbasin groundwater. The roles and responsibilities of each of the Subbasin GSAs will be defined.

Deliverables:

- Summaries of activities included as an attachment in the Progress Reports
- Draft GSP
- Proof of Final GSP submittal to DWR

Task 3: Financing
Prepare a financing plan that will evaluate potential alternatives for obtaining necessary implementation funding. This task will identify opportunities to secure additional funding that may be used to assist the GSAs in developing a meaningful financial plan that addresses the economic realities of the region while providing the basis for implementing the proposed programs and projects included in the final GSP.

Deliverables:

- Final Financing Plan

Category (c): Stakeholder Engagement
Task 4: Website Development and Public Outreach Workshops
Develop a website for the SGP-GSA to house information about the SGP-GSA, the GSP, and the DMS. The website will host GSP sections for public review and comment.

Prepare and distribute general outreach materials, notices, and updates as progress is made on development of the GSPs and the tasks described through the work plan. Prepare an Stakeholder Outreach and Communications Plan. Conduct public workshops across the SGP-GSA region to improve access by different populations. Some or all these public workshops may be held jointly with TAC workshops.

Deliverables:

- Public Workshop Meeting summaries included in Progress Reports as attachment(s)
- Stakeholder Outreach and Communications Plan

Task 5: Intra-Basin Coordination (San Gorgonio Pass Subbasin)
Provide technical support for coordinating technical analyses across the San Gorgonio Pass Subbasin. This task will involve coordination efforts between the three GSAs within the Subbasin: SGP-GSA, Verbenia GSA, and Desert Water Agency GSA. Conduct technical workshop meetings that will keep GSA personnel and stakeholders informed of the ongoing technical analyses as appropriate for the given audience.

Deliverables:

- Technical Workshops meeting summaries included in Progress Reports as attachment(s)

Task 6: Inter-Basin Coordination
Provide technical support for coordinating technical analyses across the neighboring subbasin. The San Gorgonio Pass Subbasin (7-021.04) is adjacent to the Indio Subbasin (7-021.01), part of the Coachella Valley Groundwater Basin. Conduct coordination meetings with the adjacent Indio Subbasin. These meetings will focus on key aspects of the technical work that require inter-basin coordination.

Deliverables:

- Inter-Basin Coordination meeting summaries included in Progress Reports as attachment(s)

Exhibit "B" - SGIWGM Technical Memorandum

Technical Memorandum

San Gorgonio Integrated Watershed and Groundwater Model (SGIWGM)

Prepared For: City of Banning and SGPWA

Prepared by: Reza Namvar, David Liu

Date: February 7, 2018

Table of Contents

1. Introduction
   1.1. Acknowledgments
2. Regional Groundwater Basin Description
3. Existing San Gorgonio Pass Area Models
   3.1. San Gorgonio Pass Watershed Model (SGPWM)
   3.2. Banning Canyon and Cabazon Groundwater Model (BC&CGM)
4. San Gorgonio Integrated Watershed and Groundwater Model (SGIWGM)
   4.1. Watershed Model of SGIWGM (PRMS)
   4.2. Groundwater Model of SGIWGM (MODFLOW)
   4.3. Linked Model Runtime
   4.4. Model Calibration
5. Summary and Recommendations
6. References

Acronyms

BC&CGM	Banning Canyon and Cabazon Groundwater Model
CD	Cumulative Departure from Mean
CIMIS	Caligornia Irrigation Management Information System
GSFLOW	Groundwater and Surface Water Flow
INFILv3	USGS INFILtration version model code
IRWM	Itegrated Regional Water Management
LCMMP	California Land Cover Mapping and Monitoring Program
LM	Lower Groundwater Model
MBMI	Morongo Band of Mission Indians
MODFLOW	U.S. Geological Survey Modular Finite-Difference Flow Model
MODFLOW-NWT	MODFLOW Newton-Raphson Formulation for MODFLOW-2005 Model
NLCD	National Land Cover Data
PET	Potential Evapotranspiration
PRMS	Precipitation-Runoff Modeling System
SFR	Stream Flow Routing Package for MODFLOW Model
SGIWGM	San Gorgonio Integrated Watershed and Groundwater Model
SGPWM	San Gorgonio Pass Watershed Model
STATSGO	State Soil Geographic Database
SU	Storage Unit
UM	Upper Groundwater Model

1 Introduction

The San Gorgonio Integrated Regional Water Management (IRWM) Plan development process included three adjunct technical tasks to help improve the understanding of the San Gorgonio Region's water management needs and opportunities. These planning efforts were funded through a Proposition 1 IRWM Planning Grant award in 2017.

Initially conceived as a groundwater model update, Task 7 within the Region's IRWM planning award evolved into a task focused on combining existing watershed and groundwater models into an integrated surface and groundwater model that could be used to better understand the relationship between surface and groundwater systems.

Based upon review of the existing groundwater and watershed models of the San Gorgonio Pass area, limits of the current models, the availability of the model data and files, the goals of modeling tasks, and the schedule of this project, the Groundwater Group recommended linking the existing groundwater and surface models and developing a new integrated surface water and groundwater model. This Technical Memorandum (TM) presents the results of the work completed for development of the new coupled surface water and groundwater model.

The purpose of the San Gorgonio Integrated Watershed and Groundwater Model (SGIWGM) is to summarize the work performed under Task 7: Updates to San Gorgonio Pass Subbasin Groundwater Model and consists of the following sections:

1. **Introduction** – Provides the purpose and content of the TM and acknowledges the technical support provided for performing this task.
2. **Groundwater Basin Description** – Provides a brief description of the model area.
3. **Existing San Gorgonio Pass Models** – Briefly describes the existing USGS models that were used to develop the linked watershed and groundwater model for the Cabazon and Banning Canyon subbasins.
4. **San Gorgonio Integrated Watershed and Groundwater Model (SGIWGM)** – Provides a description of SGIWGM.
5. **Summary and Recommendations** – Summarizes the work performed and the model developed under this task and recommendations for future updates and application of the model.

1.1 Acknowledgments

The authors acknowledge the individuals and agencies in the project area that contributed technical support and data to this work. The technical support and review of the modeling work by the Groundwater Group are gratefully acknowledged. The Groundwater Group consisted of the following members:

- Jeff Davis – San Gorgonio Pass Water Agency
- Art Vela – City of Banning
- Luis Cardenas – City of Banning
- Bob Krieger – Cabazon Water District
- Larry Ellis – Banning Heights Mutual Water Company

Allen Christensen of the U.S. Geological Survey provided significant technical information and support for this study. He provided data, reports and draft model files that were used to build the coupled surface water and groundwater model of the Cabazon and Banning Canyon subbasins.

2 Regional Groundwater Basin Description

The San Gorgonio IRWM Region overlies parts of the San Gorgonio Pass Groundwater Basin (also known as the San Gorgonio Pass Subbasin of the Coachella Valley Hydrologic Unit, as defined in DWR Bulletin 118). As shown in Figure 1, the San Gorgonio Groundwater Basin includes five hydraulically connected groundwater storage units (SU) of:

- Banning SU
- Banning Bench SU
- Banning Canyon SU
- Cabazon SU
- Beaumont Basin

The Banning, Cabazon, and Beaumont storage units are the most productive storage units because of the presence of thick layers of saturated aquifer. Surface runoff from the higher elevations and the canyon storage units recharges the downstream groundwater storage units. The existing groundwater model covers the Banning Canyon and Cabazon SUs. However, the existing surface water model covers the entire San Gorgonio Pass watershed.

The San Gorgonio Pass watershed area is bounded by Little San Gorgonio Peak (9,524 ft) and the San Bernardino Mountains to the north and San Jacinto Peak (10,825 ft) and the San Jacinto Mountains to the south. Land surface altitudes range from a low of 660 feet (200 m) in the valley of the Indio subbasin along the eastern boundary of the study area to a high of 9,524 feet (2,900 m) at the summit of Little San Gorgonio Peak. The southern part of the study area includes the San Jacinto Mountains which reach an altitude of 10,825 feet (3,300 m) at the summit of San Jacinto Peak.

Similar to other parts of southern California, precipitation falls primarily between October and May. The San Gorgonio Pass area experiences periods of great variability in recharge and runoff in response to variability in precipitation. As a result, the streamflow is generally ephemeral to intermittent and the episodic stream flows that discharge from higher elevations quickly infiltrate the permeable alluvial fill of the groundwater basin.

Based on spatially interpolated daily precipitation and air temperature from a network of 134 climate stations in southern California, spatially, averaged for water years 1913-2012, rainfall ranges from a minimum of about 9 inches per year (in/yr), on the valley floor at the Indio subbasin along the eastern boundary of the study area to a maximum of about 38 in/yr at the summit of Little San Gorgonio Peak (Hevesi and Christensen, 2015). Average precipitation in the San Gorgonio Pass area is 19.5 in/yr. Average potential evaporation (PET) for the San Gorgonio Pass area is about 63 inches per year (in/yr) (CIMIS, 2005) with a minimum average monthly PET of less than 2 inches for December and January and a maximum average monthly PET of about 9.5 inches for July. The easternmost part of the project area has a higher average PET of 71 in/yr while the westernmost part of the project area has a lower average PET of 55 in/yr.

Water level data from several wells in the study area are available, mostly for recent years (Figure 2). Very limited streamflow data is available for the study area. The peaks in water levels are associated with increases in precipitation and stream flows. The wells in the Banning Canyon SU and western parts of the Cabazon SU show more correlation to increased stream flows than the wells in the eastern half of Cabazon SU.

3 Existing San Gorgonio Pass Area Models

There are two USGS models developed for areas within the San Gorgonio Pass that were used to develop the SGIWGM. The first model is an existing USGS watershed model of the entire San Gorgonio Pass area (San Gorgonio Pass Watershed Model or SGPWM) that was published in 2015 (Hevesi and Christensen, 2015). The second model is an unpublished groundwater model that is being developed by USGS for the Banning Canyon and Cabazon SUs. The draft files of this groundwater model were provided by USGS to SGPWA for use in development of the SGIWGM as part of this project. This model is expected to be released in 2018 (Christensen, 2017). These two models, briefly described below, were used to develop the SGIWGM (described in Section 4).

3.1 San Gorgonio Pass Watershed Model (SGPWM)

The San Gorgonio Pass Watershed Model (SGPWM) is a daily precipitation-runoff model developed by USGS to estimate spatially and temporally distributed recharge for the groundwater basins in the entire San Gorgonio Pass area (Hevesi and Christensen, 2015). The SGPWM area is shown in Figure 3. The recharge and stream flows estimated by SGPWM were used to define the boundary conditions for groundwater models of the area.

3.1.1 Model Grid

The model area of SGPWM covers 265 square miles (about 170,000 acres) and includes three watersheds: San Timoteo Creek draining to the west, Potrero Creek draining to the south, and San Gorgonio River draining to the east. The SGPWM was developed using the USGS INFILtration version 3.0 (INFILv3) model code. A uniform grid with 150-meter (492 feet) cell size and 30,595 active model cells was used to account for spatial variability in climate and watershed characteristics that includes high relief and rugged topography. The SGPWM includes seven layers consisting of six layers to represent the root zone and one layer to represent a perched zone beneath the root zone.

3.1.2 Simulation Period

The SGPWM was used to simulate precipitation and runoff in the project area and to develop a water budget, including recharge and runoff, for water years 1913 to 2012. A 45-month (3.75 years, starting January 1, 1909) model initialization period was used for reducing uncertainty associated with the initial conditions.

3.1.3 Model Parameters

Model parameters defining the physical characteristics of the San Gorgonio Pass area consisted of topography, land cover, soils, geology, and root zone.

The land cover parameters used in this model consist of percent imperviousness, percent canopy cover, and 28 different land cover types. The percent imperviousness and canopy cover were estimated by using the 2001 National Land Cover Data (NLCD) (Homer et al., 2007). The land cover types were identified by using data from the California Land Cover Mapping and Monitoring Program (LCMMP), South Coast Project Area July 2002, Fire and Resource Assessment Program of California Department of Forestry and Fire Protection.

A total of ten (10) different soil types are included in the SGPWM model. Soil types were estimated using the State Soil Geographic Database (STATSGO) digital map and associated tables (U.S. Department of Agriculture, 1994). The soil parameters include soil porosity, residual water content, a drainage function coefficient, and upper and lower vertical saturated hydraulic conductivities (Hevesi, et al., 2003).

Daily precipitation and air temperature input were interpolated by using a modified inverse-distance-squared interpolation method and available climate records from a network of 134 climate stations throughout Southern California.

3.1.4 Model Calibration and Results

The SGPWM model was calibrated by comparing simulated and observed monthly mean streamflow, annual mean streamflow, and average monthly mean streamflow at five USGS stream gages in and near the model area.

The long-term average water budgets simulated by the SGPWM model for water years 1913-2012 indicated that the model area receives an average of 279,800 acre-feet per year (AFY) of precipitation and loses 215,700 AFY to evapotranspiration; a difference of 64,100 AFY. The model estimated that 44,400 AFY of precipitation is recharged in the area and 13,600 AFY becomes runoff leaving the model area; resulting in a total of 58,000 AFY. The remaining 6,100 AFY is contributed to sublimation and root zone storage change.

3.2 Banning Canyon and Cabazon Groundwater Model (BC&CGM)

USGS is developing the BC&CGM to evaluate the effects of pumping and climate on the long-term availability of groundwater in the Banning Canyon and Cabazon SUs. No publication have been released for this modeling work; however, USGS provided draft BC&CGM model files to SGPWA to be used for development of the SGIWGM. A brief description of the BC&CGM is provided in this subsection.

BC&CGM uses the same model grid that was used for the SGPWM (Figure 3). However, only the cells in the Banning Canyon and Cabazon SUs are kept active in the BC&CGM. BC&CGM has a uniform grid with 150-meter (492 feet) cell size. BC&CGM grid and SGPWM grid size and orientation were matched to provide a more efficient coupling of the surface and groundwater models.

BC&CGM consists of two models: the Upper Groundwater Model (UM) and the Lower Groundwater Model (LM). Both models are built based on USGS modular finite difference groundwater flow model (MODFLOW) and simulate a 100-year period of 1913 to 2012 using monthly stress periods. During each stress period of one month, all model stresses, such as stream flows, remain constant. This results in dampening the effects of short duration high stream flows by averaging daily variations of stream flows to average monthly stream flows. UM covers the Banning Canyon and Cabazon SUs while LM covers the Cabazon SU only. The stream flows and stream aquifer interaction are simulated in the UM and infiltration of precipitation and stream seepage into the bottom layer of the UM is passed on to the LM as recharge. Wells and groundwater extraction are included in the LM only. These models are further described below.

3.2.1 Upper Groundwater Model (UM)

The Upper Groundwater Model (UM) with an active area of 21,620 acres covers the Banning Canyon and Cabazon SUs (Figure 4).

Stream Simulation

Major streams including the San Gorgonio River and its tributaries are simulated in the UM using the MODFLOW Stream Flow Routing package (SFR) (Figure 5). Stream inflows are added to the SFR at boundaries of the UM where streams enter the active groundwater model area. The average total stream inflow to the UM is 57,600 AFY for the 1983-2012 period. The source of this information is not known since the model is not yet published. Thirty-year average annual stream inflows at forty (40) inflow locations are shown in Table 1. The stream inflow locations not listed in Table 1 did not provide any inflows during 1983-2012 simulation period.

Boundary Conditions

The UM connection to the surrounding area is through boundary conditions that consist of stream inflows and recharge from precipitation. Recharge from precipitation and stream seepage are added to the top layer of the model and the resulting infiltration of groundwater from top layer to bottom layer of UM is passed on to LM. The accounting of this infiltration is done using DRraiN package (DRN) in the UM and Unsaturated Zone Flow package (UZF) in the LM. Figure 6 shows distribution of the average recharge rates from UM to LM.

Faults

As shown in Figure 4, two faults are simulated in the Banning Canyon SU by the UM. The first one is in the middle of the Banning Canyon and the second one is located at the boundary of Banning Canyon and Cabazon SUs. No other faults are simulated in the UM. These two faults are set to be semi-impermeable in the UM.

Model Layers

The UM has two layers with the top layer (Layer 1) having an average thickness of about 200 feet and the lower layer (Layer 2) having a thickness of 1000 feet to 2000 feet, extending down to zero elevation (Figure 7). Layer 1 represents the upper 200 feet of aquifer material. Layer 2 is added to the model to collect the infiltration from Layer 1 by using the drain package (DRN).

Aquifer Parameters

Aquifer parameters of the UM are grouped into two zones (Figure 8). Aquifer parameters within each zone are set to be constant. Table 2 provides the values of aquifer parameters used in the UM. Aquifer parameter values are assumed to be calibrated values and were not changed in developing the linked watershed/groundwater model.

3.2.2 Lower Groundwater Model (LM)

The Lower Groundwater Model (LM) covers the Cabazon SU. The LM receives inflow from the UM and is hydraulically connected to the Banning SU on the west and Indio subbasin of the Coachella Basin on the east.

Boundary Conditions

The model connection to the surrounding area is through boundary conditions that consists of inflow from Banning SU on the west and outflow to Coachella groundwater basin on the east (Figure 9). Inflow from Banning SU is set to be constant at a rate of about 2,400 AFY for the 1983-2012 period; however, the outflow to Coachella is variable and depends on groundwater levels at the eastern boundary of the model. The annual average outflow at the eastern model boundary is 20,170 AFY for the 1983-2012 period. The numbers on Figure 9 represent the 100-year (1913 to 2012) average boundary flow rates at these two boundaries.

Recharge from precipitation and stream seepage are added to the top layer of the UM. The infiltration of groundwater from top layer to bottom layer of UM is then passed on to LM. The accounting of this infiltration is done in the UM using the DRN package and in the LM using the UZF package.

Faults

Five faults are simulated in the Cabazon SU (Figure 9). Two faults are in the western half of the LM and three faults are near the eastern boundary of the model. Similar to the UM, these faults are set to be semi-impermeable in the LM.

Model Layers

The LM has three layers with each of the top two layers having average thicknesses of about 500 feet. The lower layer (Layer 3) with a maximum thickness of about 1,500 feet is only present at deeper parts of the aquifer (Figure 10).

Aquifer Parameters

Aquifer parameters of the LM are grouped into several zones (Figures 11 and 12). Aquifer parameters within each zone are set to be constant. Table 3 provides the values of aquifer parameters used in the LM. Aquifer parameters are assumed to be calibrated values and were not changed in developing the SGIWGM.

Groundwater Extraction

Groundwater extraction in the Cabazon SU is simulated in the LM (Figure 12). The size of the circles in Figure 13 are scaled based on average monthly pumping rates of each well. Average annual groundwater extraction is 1,126 AFY for the 1983-2012 period. Some of the extraction wells of the City of Banning are not represented in the LM; however, other City of Banning wells that are located within the model area were added to the linked watershed/groundwater model as described in Section 4.

4 San Gorgonio Integrated Watershed and Groundwater Model (SGIWGM)

The SGPWM and BC&CGM developed by USGS use INFILv3 and MODFLOW-NWT model codes, respectively. These model codes are stand-alone codes and are not set up to be coupled. However, the Groundwater and Surface water FLOW (GSFLOW) model code, available from USGS, is a coupled surface water model and groundwater model that was used for development of the linked watershed and groundwater models of the San Gorgonio Pass area.

GSFLOW consists of two coupled model codes of the Precipitation-Runoff Modeling System (PRMS) and MODFLOW (Figure 14). PRMS model code is similar to INFILv3 model code. Data files of the SGPWM were converted from INFILv3 to PRMS model code. Similarly, the UM and LM data files were transferred to the groundwater model of GSFLOW (Figure 15).

For each model cell, PRMS calculates the runoff quantity for each cell based on precipitation rates falling on the cell. Based on surface elevation of each cell, the runoff is routed to downstream cells using a cascading algorithm (Figure 16) and then the runoff is directed to creeks and streams in the model area (Figure 17). Stream flows are then directed downstream and towards the boundaries of the model. When the stream flows calculated by the PRMS model reach the beginning of the streams in the groundwater model (i.e. beginning of the SFR nodes), the streamflows are passed from the PRMS model to the MODFLOW (SFR package) (Figure 18). From this point on, stream flows are routed downstream in the SFR package and streams are in hydraulic connection with the groundwater system and may lose to or gain from groundwater based on hydraulic gradient between the stream and groundwater.

After building the PRMS and MODFLOW models in GSFLOW, the resulting SGIWGM was run as a coupled model. Development of the PRMS and MODFLOW components of the GSFLOW model is described in the following subsections.

4.1 Watershed Model of SGIWGM (PRMS)

The Precipitation-Runoff Modeling system (PRMS) is a computer model that simulates the hydrologic cycle by accessing variability in climate, geology and human activities. PRMS is used as the watershed model of the SGIWGM developed for this task.

The SGPWM was developed by using the INFILv3 code. The grid cell size and geometry were selected to match the grid used for groundwater modeling of the SGP area. There are 30,592 active grid cells in this model, effectively covering the entire San Gorgonio Pass Watershed. The SGPWM separated the San Gorgonio Pass Watershed into three subbasins, the San Gorgonio River (SGR), the San Timoteo Creek (STC), and the Potrero Creek (PTC). To maintain consistency in the conversion from INFILv3 to PRMS, the SGPWM grid size, geometry, and subbasin identification were used in the PRMS model.

4.1.1 Data Transfer from INFILv3 to PRMS

ComparedCompared to the INFILv3, the PRMS model has simpler and fewerfewer required input parameters. There are two required input parameters to run the PRMS model, spatially distributed daily precipitation and temperature. The PRMS model can estimate the precipitation and temperature data from climate stations or read existing data from user input. The latter option was selected to reduce the variability of model results between INFLv3 and PRMS. The precipitation data was generated from the INFILv3 model, then it was formatted to PRMS input format. Unlike the precipitation data, the INFILv3 code uses climate station data to estimate spatially distributed daily temperature for its internal calculation only, and it lacks the capability to output of temperature data. Therefore the temperature interpolation was done using a Fortran code outside of the model with the temperature estimation equation presented in the INFILv3 manual *(USGS, 2008)*. Stream segments were added directly from the INFILv3 model since both models share the same grid property and geometry. The SGPWM includes a cascade path for runoff routing. The cascade path was slightly modified to ensure the flow paths were linked to the SFR package of the groundwater model correctly.

PRMS and INFILv3 models use different methods for simulation of some of the hydrological processes, therefore results of the two models may not be exact. To minimize the difference between the result, other optional inputs for the PRMS model such as spatially distributed daily potential evapotranspiration, ground perviousness, surface slope, aspect, soil type, vegetation cover type, and surface elevation were used. Some parameters were transferred directly; others had to be reclassified. The soil type in the INFILv3 model has 10 categories while PRMS only has 3. The soil types from the INFILv3 model were reclassified into either sand, loam, or clay by using the USDA Texture Classification method. INFILv3 has 28 categories for vegetation cover, the PRMS model can only have 5 categories. The reclassification of the 28 categories was done by identifying the properties of the vegetations and matching with the most appropriate PRMS categories. As with the spatially distributed daily precipitation data, the potential evapotranspiration data was generated by the INFILv3 simulation. This output was reformatted and used in the PRMS model as an input to further reduce the variance of the two models.

4.1.2 PRMS Results

The PRMS model is capable of outputting spatially distributed data. The precipitation (Figure 19), potential evapotranspiration (Figure 20), impervious areas (Figure 21) and temperature (Figure 22) maps were generated to compare with the INFILv3 maps found in the SGPWM model report. The map outputs from the PRMS model have a similar distribution as the map outputs found in the SGPWM model report.

More outputs from the PRMS model were generated for calibration. The evapotranspiration, runoff, and recharge data were generated for comparison between the SGPWM and PRMS models. Since the models use different approaches to estimate the hydrological cycles, minor differences between the model outputs were expected. The annual evapotranspiration (Figures 23 and 24), runoff (Figures 25 and 27), and recharge (Figures 26 and 28) for water years 1983-2012 were generated. The 30-year pattern of each graph was compared with the similar graph found in the SGPWM report. PRMS simulated recharge for 1993 (a wet year) and 2004 (a dry year) are presented in Figures 29 and 30, respectively. The patterns are the same for the two models.

4.2 Groundwater Model of SGIWGM (MODFLOW)

The MODFLOW component of the GSFLOW model was built based on data and information obtained from the UM and LM models. The UM and LM models were combined into one single groundwater model to simulate the Banning Canyon and Cabazon SUs. This combined groundwater model is briefly described below.

Model Layers

The MODFLOW model of GSFLOW has four layers: Layer 1 is the top layer of UM, Layer 2 is the top layer of LM, Layer 3 is the middle layer of LM, and Layer 4 is the bottom layer of LM. Figure 32 presents an east-west profile of the MODFLOW model along Interstate 10. No changes were made to layer elevations and thicknesses. Part of the model that covers the Banning Canyon has a single layer that is identical to top layer of the UM.

Linkage of PRMS and MODFLOW models in GSFLOW

The PRMS model simulates the stream flows from higher elevations in the model area and passes the stream flows to the MODFLOW model at the starting locations of streams in the SFR package (Figure 33). Figure 34 shows a comparison of stream inflows used in the GSFLOW groundwater model and those of the INFILv3 and UM models. Average annual total stream inflows for SGIWGM, INFILv3, and UM models are 35,200 AFY, 34,700 AFY, and 57,600 AFY, respectively. The SGIWGM stream inflows were calibrated against the INFILv3 model rather than the UM since the INFILv3 model is published. Thirty-year average annual stream inflows of UM, INFILv3, and SGIWGM models at forty (40) inflow locations are shown in Tables 1, and 4, respectively. The stream inflow locations not listed in these tables did not have any inflows during the 1983-2012 simulation period.

Groundwater Extraction

Review of the wells used in the LM model for groundwater extraction indicated that several municipal wells of the Morongo Band of Mission Indians (MBMI) and City of Banning are not included in the BC&CGM. Location and pumping data of these wells were collected, and the wells were added to SGIWGM. Figure 35 show the location of the new wells included in the SGIWGM in addition to the existing model wells shown in Figure 13.

Artificial and Incidental Recharge

An average of 1,500 AFY of Whitewater River stream flows are transferred into the model area. About a third of this water is released into the San Gorgonio River in the northern parts of the Banning Canyon to recharge groundwater and the rest is used to meet the municipal demands.

There are three general areas in the Cabazon SU that are on septic systems, Banning, Morongo, and Cabazon. Additionally, there are two wastewater treatment plants (WWTPs), one for MBMI and the other for the City of Banning. Incidental recharge from the WWTPs and areas on septic systems are included in the SGIWGM.

Figure 36 shows the location and rates of the artificial and incidental recharges as simulated in the SGIWGM.

4.3 Linked Model Runtime

GSFLOW is a complex hydrological model that simulates many components of the hydrologic cycle. As such, it has a much larger runtime compared to the runtime of models that only simulate part of the hydrologic cycle (such as MODFLOW for groundwater flow simulation or PRMS for precipitation-runoff simulation). SGPWM and BC&CGM both have a 100-year (1913-2012) simulation period to capture predevelopment conditions of the model area.

Different approaches were taken to reduce the model runtimes and have calibration completed by the deadline of December 2017. The SGPWM and the UM and LM models are developed for a 100-year (1913-2012) simulation and as such the SGIWGM was also initially developed for the 1913-2012 period. This 100-year run of SGIWGM takes several days to complete which makes it impractical to calibrate within the timeframe of this project.

To improve run times, the SGIWGM was modified to run for a 30-year (1983-2012) simulation period. This shorter simulation period allows shorter model runtimes while maintaining the capability to simulate recent 30-year conditions in the Banning Canyon and Cabazon SUs. The 30-year simulation time resulted in a shorter,impractical simulation time (Table 5).

Water flow in the San Gorgonio Pass area is from higher elevations and watersheds towards the groundwater basins and storage units with no areas of reverse flow paths identified. Based on these hydrological characteristics of the project area, the SGIWGM was run as PRMS only and MODFLOW only runs to evaluate the impact on model runtimes. Stream inflows from PRMS model were imported into the MODFLOW before running it. The 30-year PRMS-only simulation had a runtime of less than 30 minutes (Table 5) while the MODFLOW-only simulation runtime was reduced to about 3 days. However, when the MODFLOW was run as a standalone model outside of GSFLOW, the runtime was reduced to less than 5 hours (Table 5). The SGIWGM model was run using the following sequence:

1. Run PRMS model as a standalone run
2. Extract stream flows from PRMS model
3. Import stream flows into MODFLOW model
4. Run MODFLOW as a standalone run

Use of this efficient methodology resulted in timely model development and calibration.

4.4 Model Calibration

The SGIWGM calibration consisted of three major steps- streamflow calibration, groundwater elevation calibration, and groundwater outflow calibration to Coachella Basin.

Streamflow Calibration

As very limited measured stream flow data is available for the San Gorgonio Pass area, stream flow calibration consisted of comparing SGIWGM stream flows to INFILv3 stream flows. INFILv3 model is a USGS published model and its simulated stream flows were used as reference for SGIWGM model stream flow calibration. Table 4 presents the simulated stream flows of INFILv3 and SGIWGM. Model parameters of SGIWGM were adjusted to obtain stream flows close to those of INFILv3. In general, simulated stream flows for most streams of both models are very close. SGIWGM and INFILv3 generate different stream flows for four streams (inflow locations 6, 21, 54, and 59). Comparing the catchment areas of these streams indicates stream flows simulated by SGIWGM for these locations are more comparable to the corresponding catchment areas. Thus, no changes were made to the SGIWGM parameters to match the INFLv3 model stream flows. As data sources of UM model stream flows are not known at this time, no attempt was made to match GSFLOW stream flows to the UM stream flows.

Groundwater Elevation Calibration

Groundwater elevations are very sensitive to stream flows and stream-aquifer interaction processes in the San Gorgonio Pass area. Additionally, aquifer parameters such as hydraulic conductivity and storage parameters could impact the simulated groundwater elevations. It was assumed that the aquifer parameters of the UM and LM models are calibrated parameters and provide a close representation of field values. Thus, no changes were made to the aquifer properties of the model.

Groundwater elevation calibration was concentrated on stream-aquifer interaction parameters, mainly the streambed conductance and vertical hydraulic conductivity of the unsaturated zone beneath the streams in the Banning Canyon and Cabazon SUs. These two parameters were manually adjusted until a reasonable match was obtained between observed and simulated groundwater elevations at 21 calibration wells (Figure 37). There are 10 calibration wells in the Banning Canyon SU and 11 calibration wells in the Cabazon SU. Most wells have observed data for the 10 years of model simulation period - with 7 wells with 30 years of groundwater elevation data in the Banning Canyon SU and only 3 wells with 30 years of groundwater elevation data in the eastern parts of Cabazon SU. The hydrographs of simulated and observed groundwater elevations for the 21 calibration wells are presented in Figures 38a to 38u. Comparing these hydrographs with those of UM and LM models show a better calibration for SGIWGM model. In general, hydrographs show more fluctuations in Banning Canyon wells as a result of high stream-aquifer interaction in this area. SGIWGM hydrographs follow the pattern of precipitation and streamflow fluctuations during wet and dry periods. The final calibrated value of the streambed conductivity is 650 ft/day and vertical hydraulic conductivity of the unsaturated zone beneath the streams ranges from 0.5 to 5.3 ft/day, respectively.

Groundwater Outflow to Coachella Basin

The annual average simulated groundwater outflow to the Coachella Basin by the LM model is estimated to be 20,170 AFY for the 1983-2012 period. This outflow rate seems to be higher than the rate that is generally thought to be leaving the Cabazon SU towards the Coachella Basin. The general head boundary conductance at the eastern boundary of the Cabazon SU was manually adjusted until a reasonable outflow rate was obtained at this model boundary. The calibrated groundwater outflow to the Coachella Basin is 11,025 AFY. The actual quantity of outflow to Coachella Basin is not known and previous studies have used a wide range of values for this outflow. Installation of monitoring wells and collection of water level data at this area would provide valuable data for a more accurate estimation of the groundwater outflow to Coachella Basin. When new data becomes available, it will be incorporated in the future updates of the SGIWGM.

5 Summary and Recommendations

An integrated watershed and groundwater model (SGIWGM) of the San Gorgonio Pass watershed and Banning Canyon and Cabazon SUs was developed using GSFLOW modeling platform of USGS. The SGIWGM was built based on existing SGPWM of USGS and unpublished BC&CGM that is under development by USGS. The SGIWGM was calibrated to stream flows, groundwater elevations, and groundwater outflow to the Coachella Basin. Calibration results show a good qualitative and quantitative match between simulated and observed/estimated values.

The GSFLOW model is a regional model that could be used for the following:

- **Detailed Local Hydrogeologic Investigations** – There are extensive silty-sand units in parts of the Cabazon SU that may generate temporary perching conditions or reduce vertical groundwater movementflow. When additional hydrogeologic information becomes available, the model could be refined for the areas of interest for better understanding of the local conditions and use of the model for detailed local impact of projects. However, the effects of these low permeability units are localized and are not expected to impact the capability of the model to simulate the regional groundwater levels.

- **Simulation of Water Resources Management Projects** – Various IRWMP or SGMA projects that involve groundwater recharge or groundwater pumping in the Banning Canyon and Cabazon SUs could be simulated using the SGIWGM.
- **Climate Change Impact Analysis** – SGIWGM simulates the precipitation-runoff process in the San Gorgonio Pass area and could be used to evaluate the impact of climate change on precipitation rates and patterns and the resulting runoff rates and how the long-term availability of groundwater is impacted.

6 References

California Irrigation Management and Information System (CIMIS), 2005. Meteorological data: California Department of Water Resources and University of California at Davis. www.cimis.water.ca.gov

Christensen, A.H., 2018. U.S. Geological Survey. Personal Communications.

Hevesi, J.A., Flint, A.L., and Flint, L.E., 2003. Simulation of net infiltration using a distributed parameter watershed model for the Death Valley regional flow system, Nevada and California: U.S. Geological Survey Water-Resources Investigation Report 03-4090, 104p., http://pubs.usgs.gov/wri/wri034090

Hevesi, J.A., and Christensen, A.H., 2015. Estimating natural recharge in San Gorgonio Pass watersheds, California, 1913-2012: U.S. Geological Survey Scientific Investigation Report 2015-5122, 74p. https://pubs.er.usgs.gov/publication/sir20155122 .

Homer, C., Dewitz, J., Fry, J., Coan, M., Hossain, N., Larson, C., Herold, N., McKerrow, A., VanDriel, J.N., and Wickham, J., 2007. Completion of the 2001 National Land Cover Database for the Conterminous United States: Photogrammetric Engineering and Remote Sensing, v. 73, no. 4, p. 337-341. http://www.asprs.org/a/publications/pers/2007journal/april/highlight.pdf

Markstrom, S.L., Niswonger, R.G., Regan, R.S., Prudic, D.E., and Barlow, P.M., 2008. GSFLOW-Coupled groundwater and surface water flow model based on the integration of the Precipitation-Runoff Modeling System (PRMS) and the Modular Ground-Water Flow Model (MODFLOW-2005): U.S. Geological Survey Techniques and Methods 6-D1, 240p.

U.S. Geological Survey, 2008, Documentation of computer program INFIL3.0—A distributed-parameter watershed model to estimate net infiltration below the root zone: U.S. Geological Survey Scientific Investigations Report 2008–5006, 98 p.

Table 1 – Average Annual Stream Inflows for UM

Inflow Location Name	Inflow Location	30yr Average (AFY)	Inflow Location Name	Inflow Location	30yr Average (AFY)
Upper San Gorgonio Canyon	1	1,620	Stubbe Canyon	43	1,075
Upper San Gorgonio Canyon	2	3,950		46	65
Lower San Gorgonio Canyon	4	950		47	70
Lower San Gorgonio Canyon	6	6,700		48	115
Potrero Creek	8	60	Cottonwood Canyon	49	13,670
Potrero creek	9	3,260		50	810
	10	90		51	535
Hathaway Creek	11	1,540	Brown Creek	52	4,655
	12	35		54	220
Millard Canyon	13	3,750		57	25
	14	50		59	200
	16	120		63	105
Montgomery Creek	17	260		65	235
Banning Bench	18	130		66	175
	19	260		68	25
Smith Creek	21	425	Jenson Creek	69	1,735
	24	30		71	10
	26	160		76	635
	28	30		79	190
	29	45		80	130
	31	30		84	30
	34	495		85	745
	35	145	Falls Creek	86	7,400
	37	60	Snow Creek	87	450
	38	60		88	25
Total			57,600 AF/yr		

Table 2 – Aquifer Parameters for UM

Aquifer Parameters	Layer 1		Layer 2
Region ID	**10**	**11**	**11**
Kh (ft/day)	32.8	98.4	98.4
Kv (ft/day)	32.8	16.4	32.8
Sy	0.06	0.3	0.3
SS	0.00001		0.00001

Kh – Horizontal Hydraulic Conductivity
Kv – Vertical Hydraulic Conductivity
Sy – Specific Yield
SS – Specific Storage

Table 3 – Aquifer Parameters for LM

Aquifer Parameters	Layer 1					Layer 2				Layer 3
Region ID	**31**	**32**	**33**	**34**	**35**	**4**	**41**	**42**	**43**	**5**
Kh (ft/day)	1	12	50	60	5	17	6	49	.03	.06
Kv (ft/day)	63	65	65	44	65	6	20	.04	.28	.00
Sy	.04	.10	.05	.20	.15	.07	.07	.07	.07	N/A
SS	.00001					.0000000878				.00001

Kh – Horizontal Hydraulic Conductivity
Kv – Vertical Hydraulic Conductivity
Sy – Specific Yield
SS – Specific Storage

Table 4 - Average Annual Stream Inflows for SGPWM and SGIWGM

Inflow Location Name	Inflow Location	SGPWM 30yr Average (AFY)	SGIWGM 30yr Average (AFY)	Difference (AFY)	Inflow Location Name	Inflow Location	SGPWM 30yr Average (AFY)	SGIWGM 30yr Average (AFY)	Difference (AFY)
Upper San Gorgonio Canyon	1	1,280	1,670	-390	Stubbe Canyon	43	570	1,000	-430
Upper San Gorgonio Canyon	2	3,210	4,475	-1,265		46	2	40	-38
Lower San Gorgonio Canyon	4	400	955	-555		47	0	20	-20
Lower San Gorgonio Canyon	6	3,715	30	3,685		48	0	50	-50
Potrero Creek	8	10	30	-20	Cottonwood Canyon	49	250	660	-410
Potrero creek	9	810	3,510	-2,700		50	0	5	-5
	10	3	45	-42		51	90	450	-360
Hathaway Creek	11	365	1,620	-1,255	Brown Creek	52	3,075	5,075	-2,000
	12	0	40	-40		54	3,210	90	3,120
Millard Canyon	13	2,325	4,350	-2,025		57	0	7	-7
	14	0	13	-13		59	7,410	4	7,406
	16	0	130	-130		63	30	35	-5
Montgomery Creek	17	0	265	-265		65	80	80	0
Banning Bench	18	0	90	-90		66	65	55	10
	19		180	-180		68	0	9	-9
Smith Creek	21	240	1,950	-1,710	Jenson Creek	69	1,210	1,370	-160
	24	1	3	-2		71	0	4	-4
	26	365	80	285		76	440	310	130
	28	0	10	-10		79	85	110	-25
	29	365	5	360		80	0	1	-1
	31	20	15	5		84	0	4	-4
	34	215	340	-125		85	210	325	-115
	35	20	100	-80	Falls Creek	86	4,570	5,340	-770
	37	40	35	5	Snow Creek	87	15	170	-155
	38	0	20	-20		88	0	4	-4
SGPWM Total:			34,700 AF/yr						
SGIWGM Total:			35,200 AF/y						

Table 5 – SGIWGM Runtimes

	GSFLOW - Coupled	GSFLOW – PRMS Only	GSFLOW – Groundwater Only	PRMS – Standalone	Groundwater (MODFLOW) – Standalone
30-year simulation	> 5 days	< 30 minutes	~ 3 days	< 30 minutes	< 5 hours

Figure 1 – San Gorgonio Groundwater Basin Storage Units

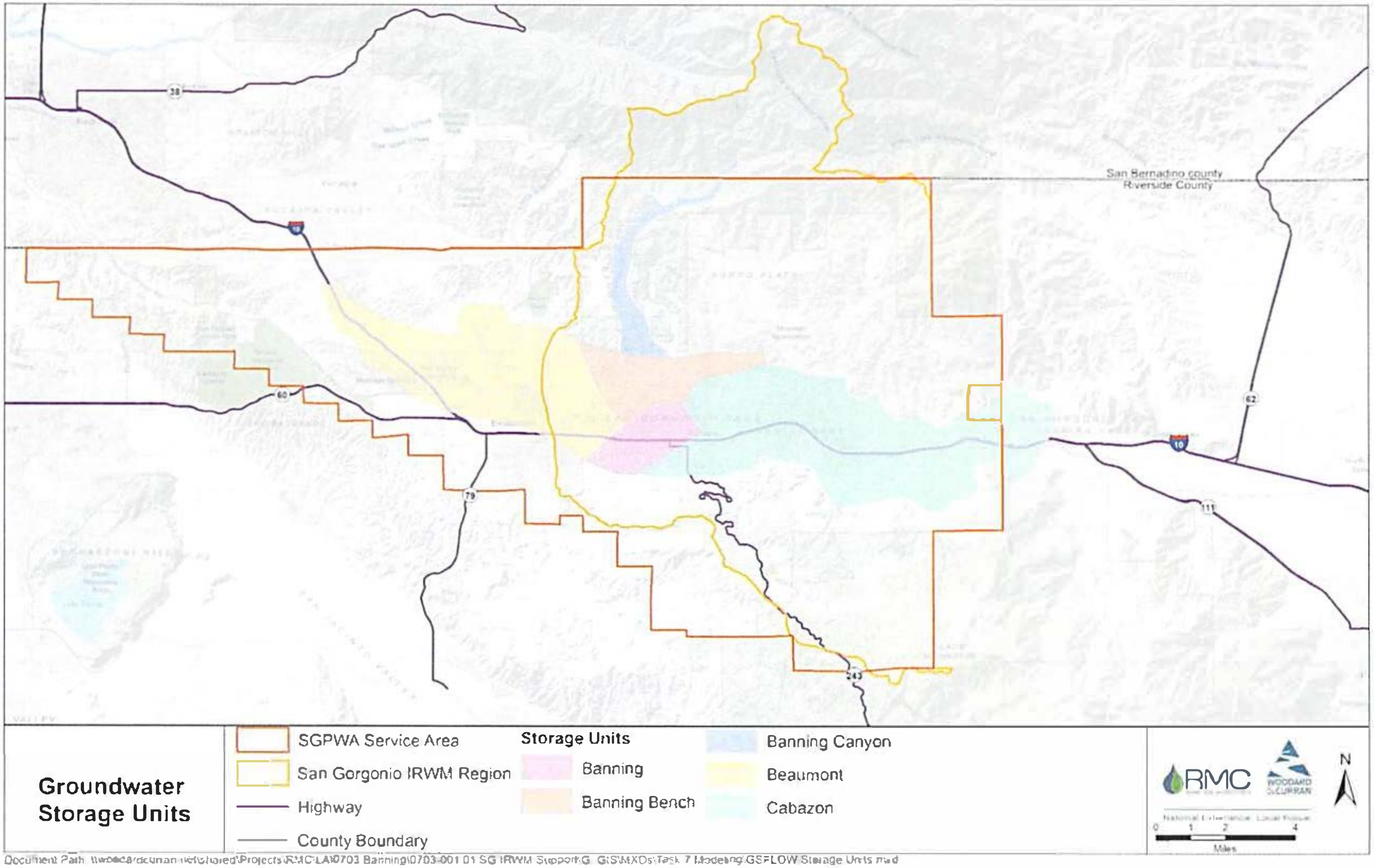
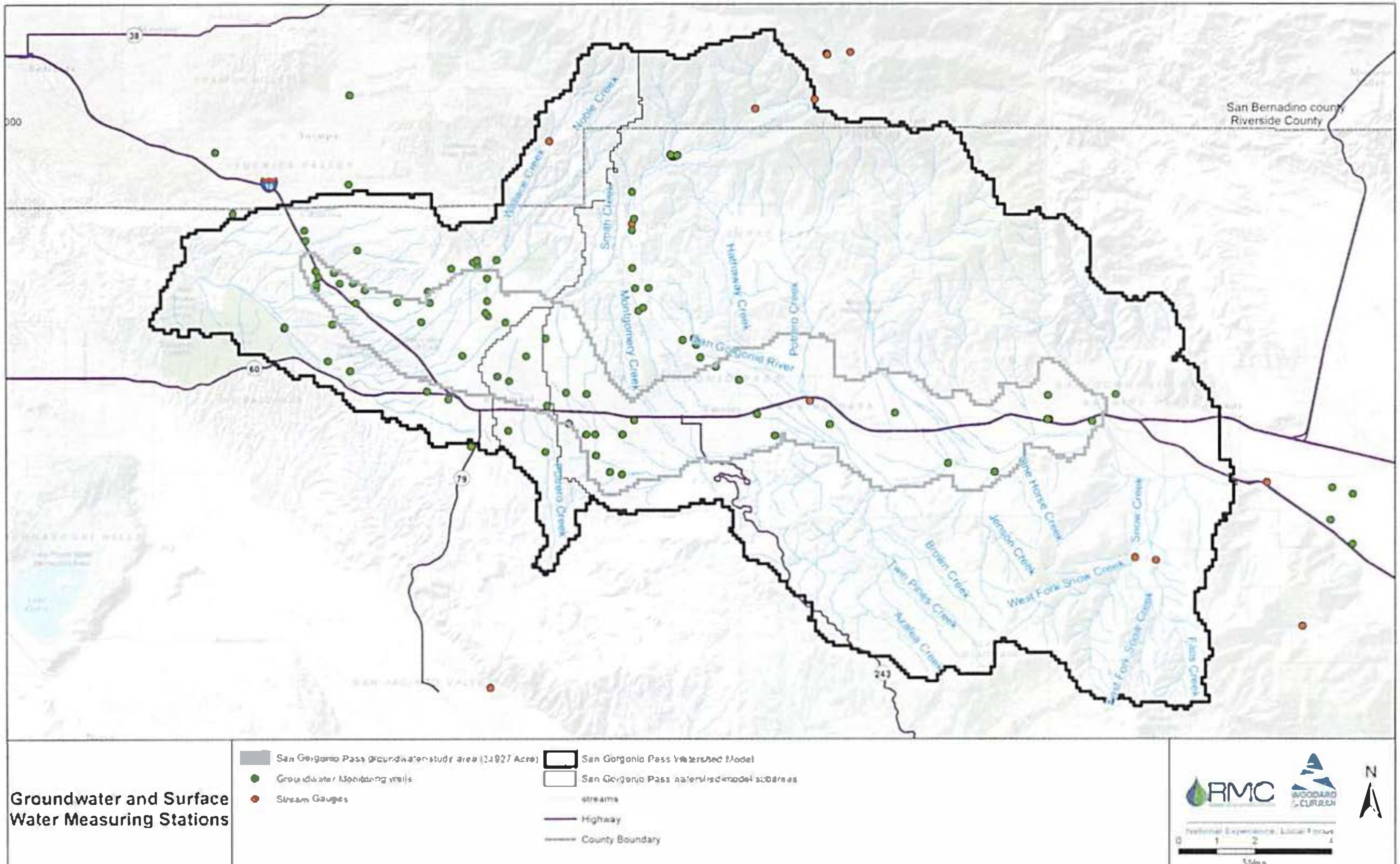


Figure 2 – Location of sites with groundwater and surface water data.



Document Path: \\woodardcurran.net\shared\Projects\RMC\LA\0703 Banning\0703-001.01 SG IRWM Support\G. GIS\MXDs\Task 7 Modeling\Groundwater and Surface Water Measuring stations.mxd

Figure 3 – USGS San Gorgonio Pass Study Area

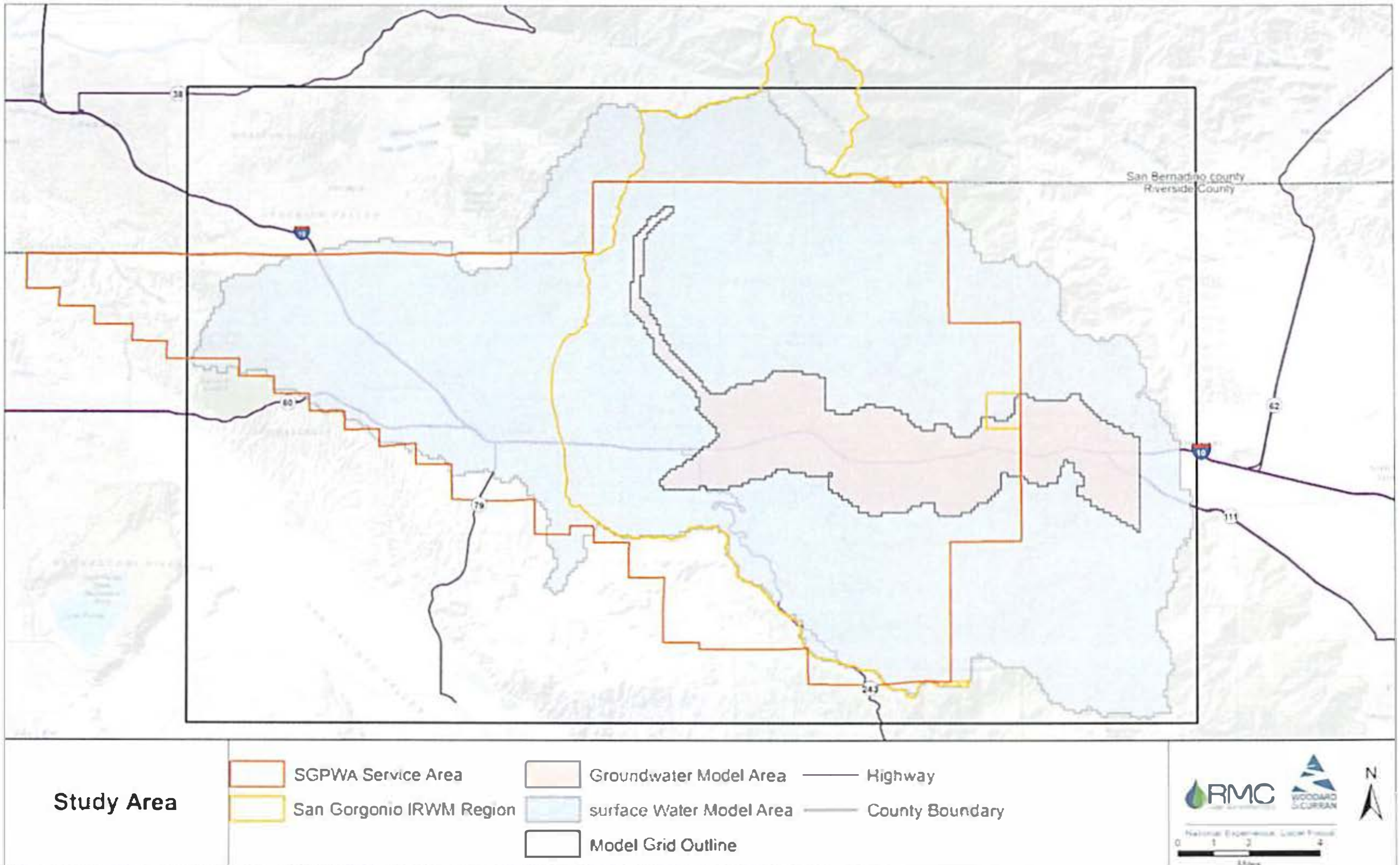


Figure 4 – UM Features

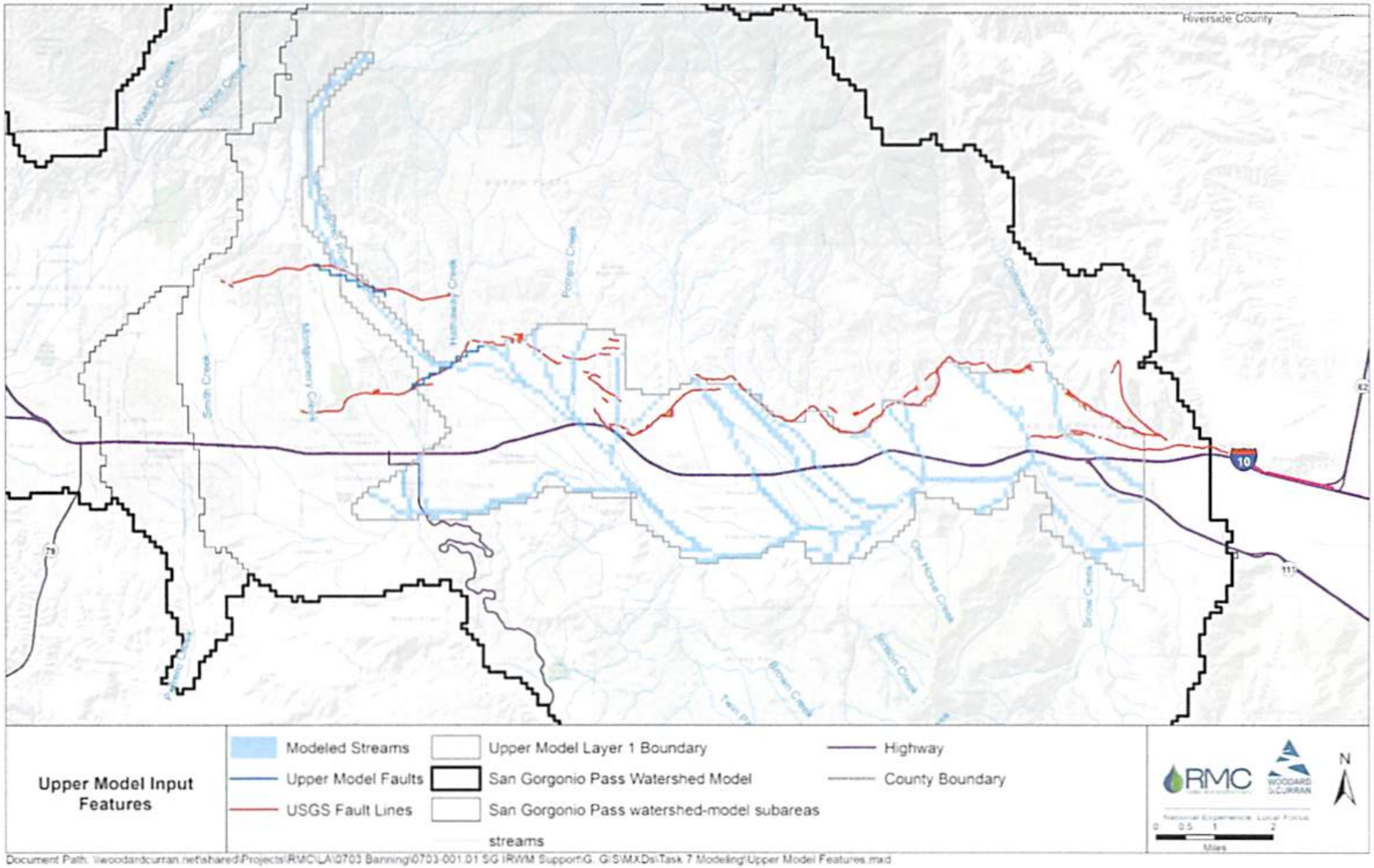


Figure 5 - Stream Inflow Locations for the UM

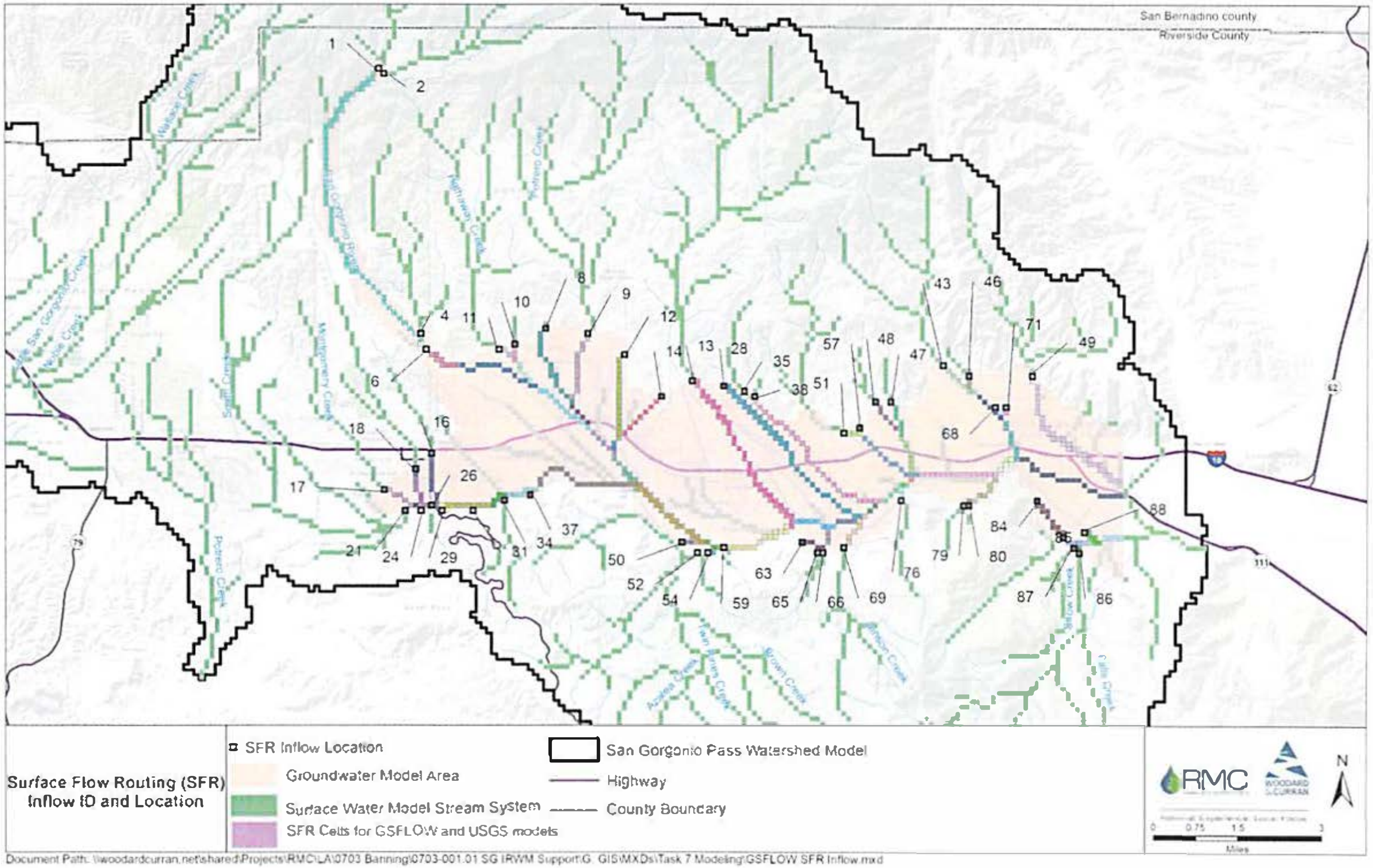


Figure 6 – Recharge Rates from UM to LM

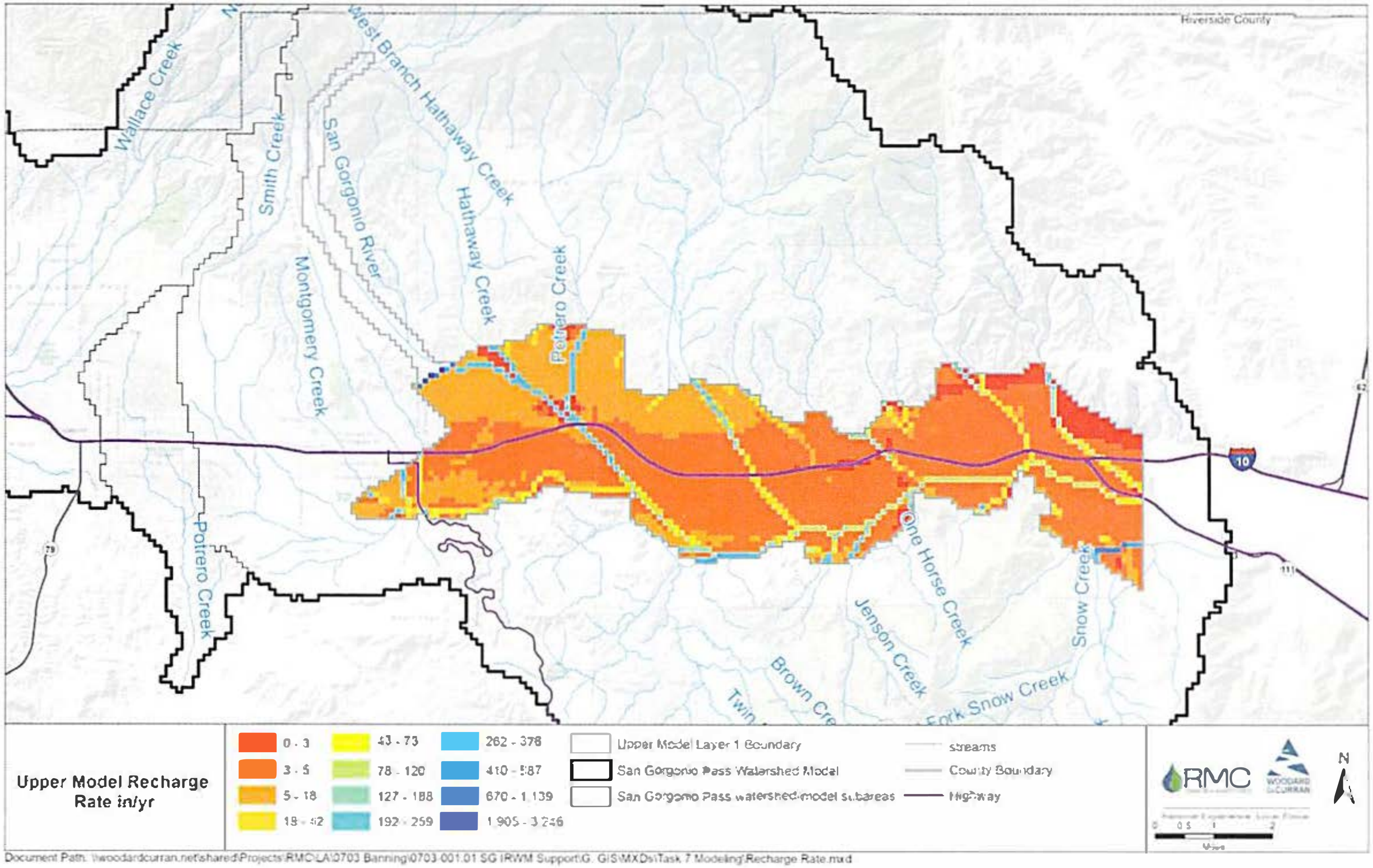


Figure 7 – UM Cross Section A4-A4'

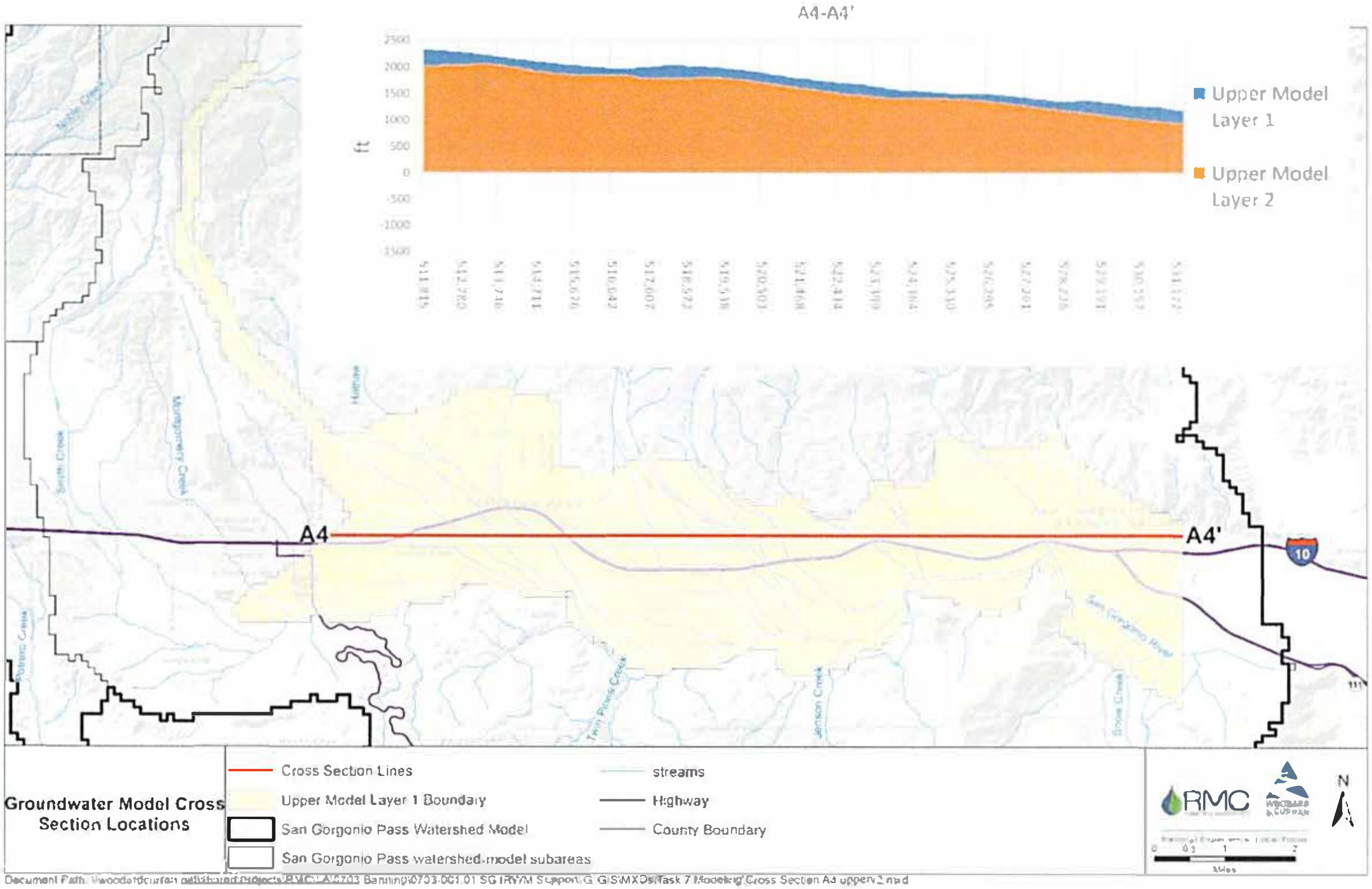
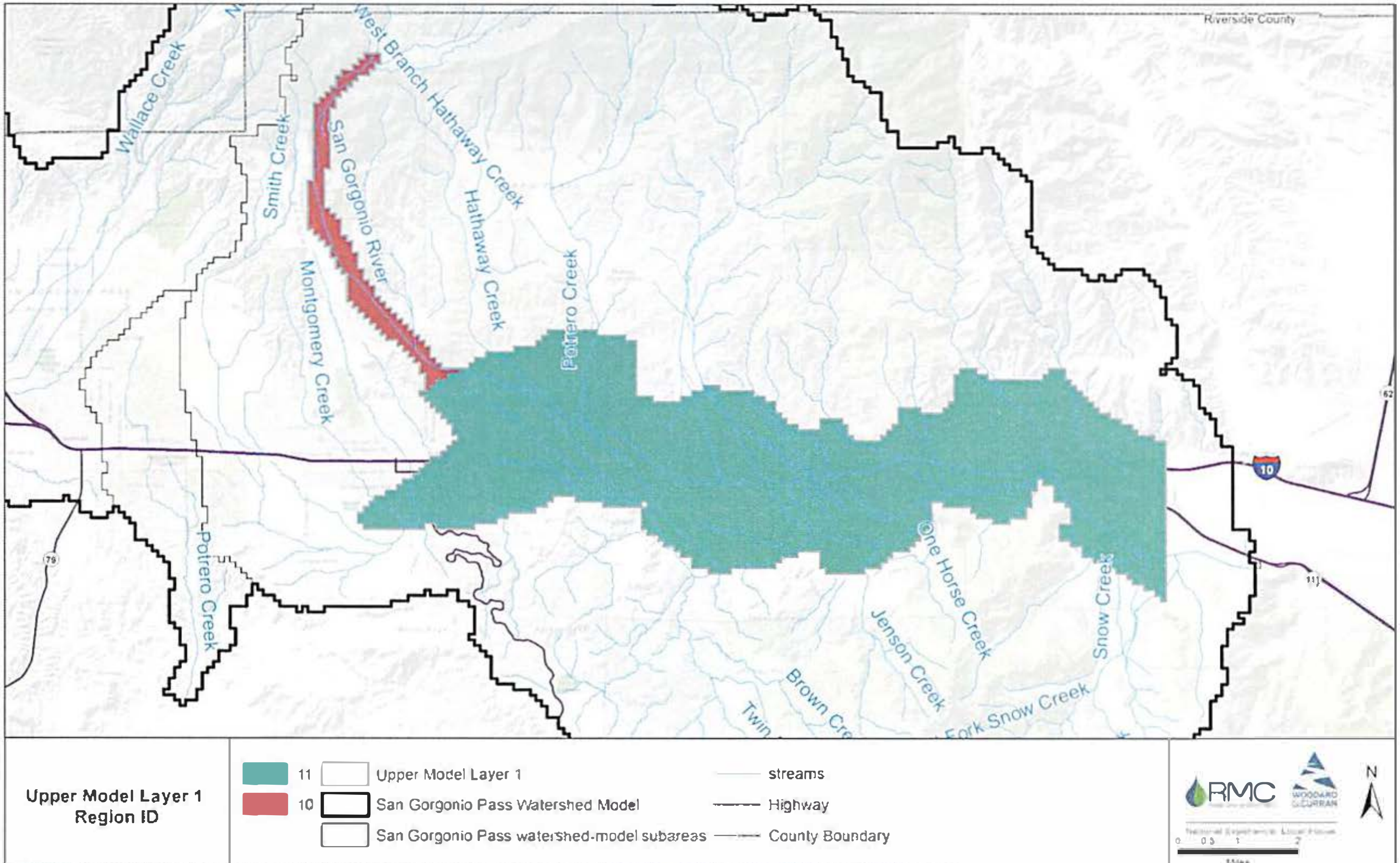


Figure 8 – Aquifer Parameter Zones for UM



Document Path: \\woodardcurran.net\shared\Projects\RMC\LA\0703 Banning\0703-001.01 SG IRWM Support\G. GIS\MXDs\Task 7 Modeling\Upper Model Layer 1 Region ID.mxd

Figure 9 – LM Features

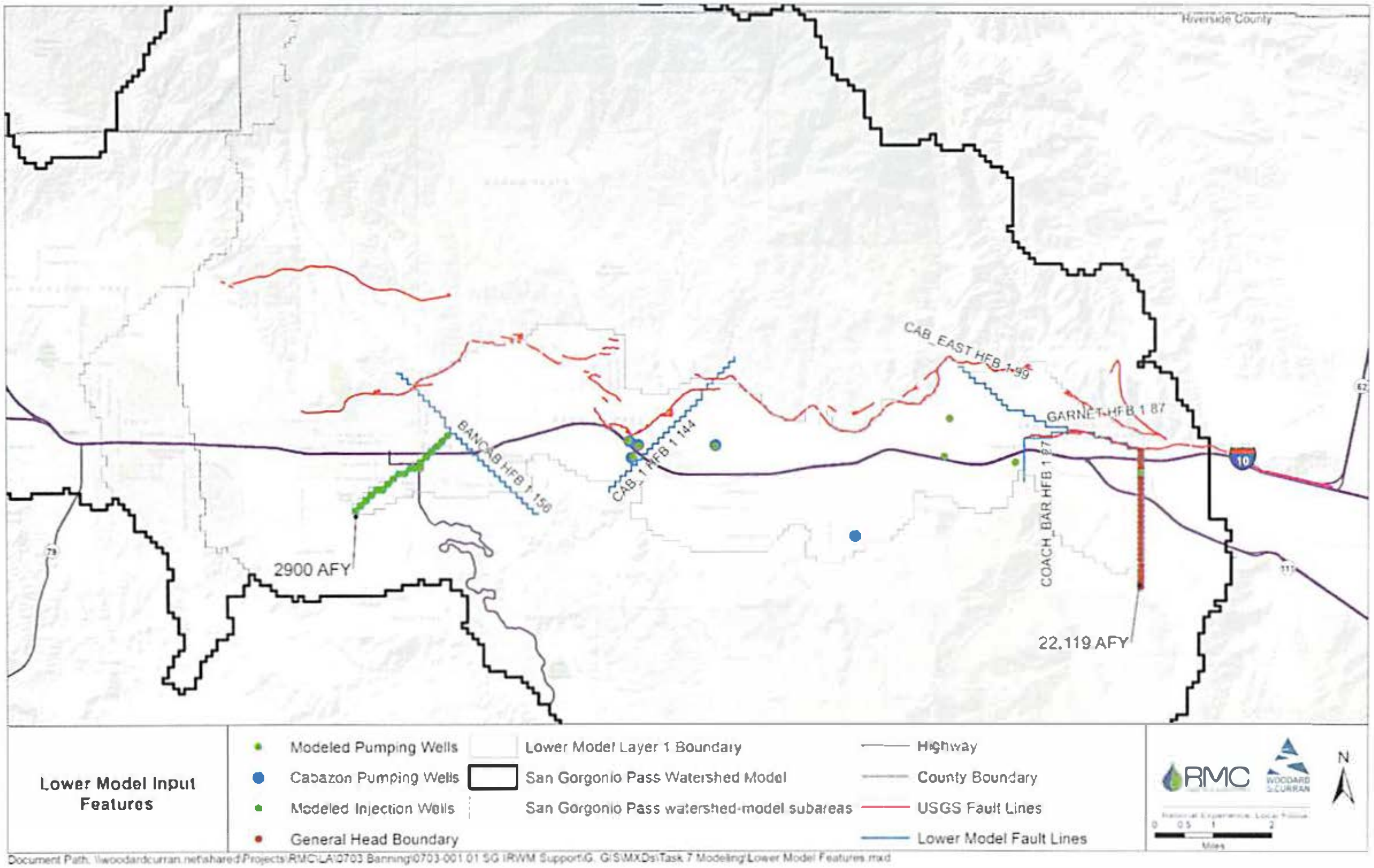


Figure 10 – LM Cross Section A4-A4'

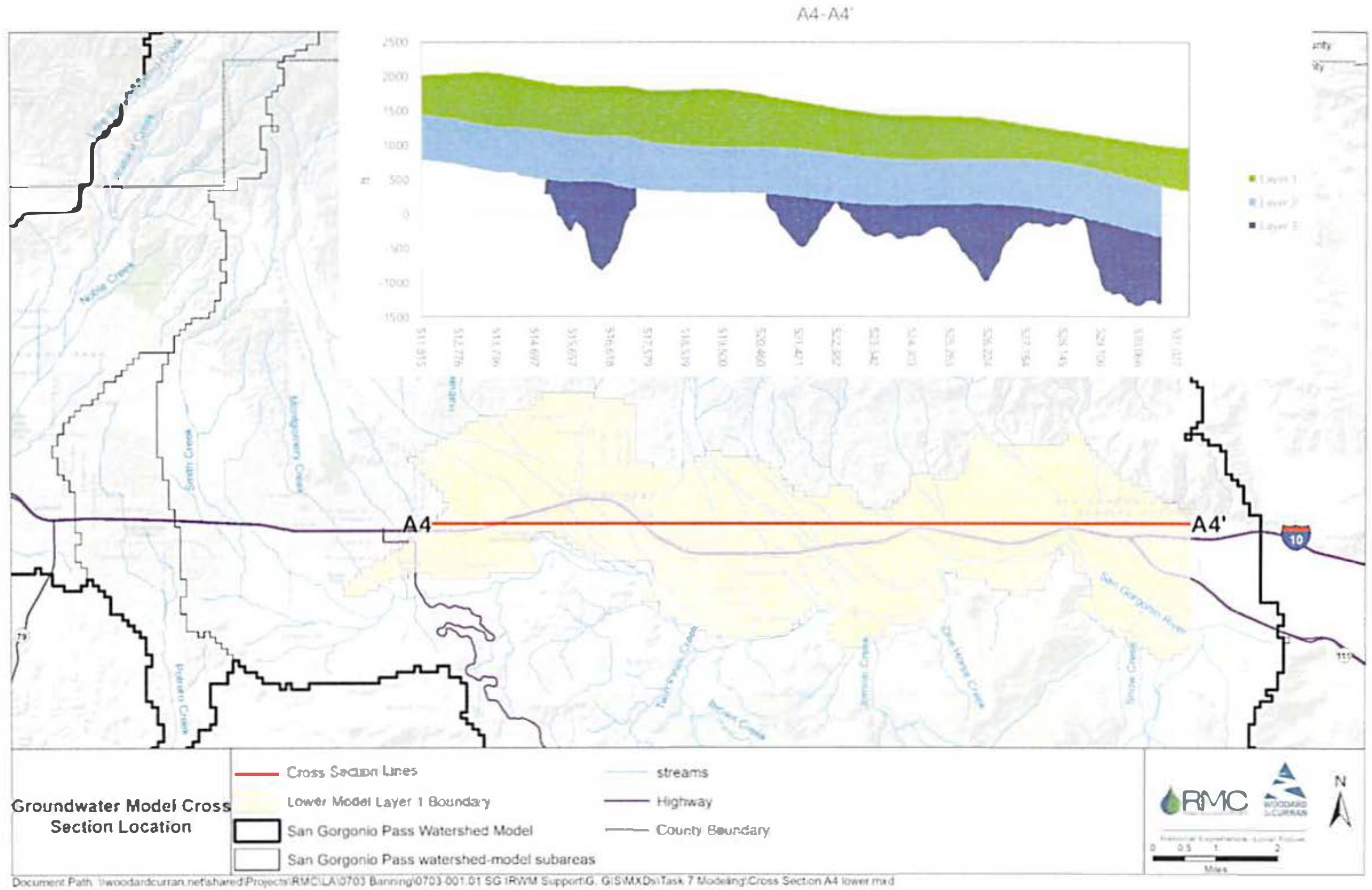
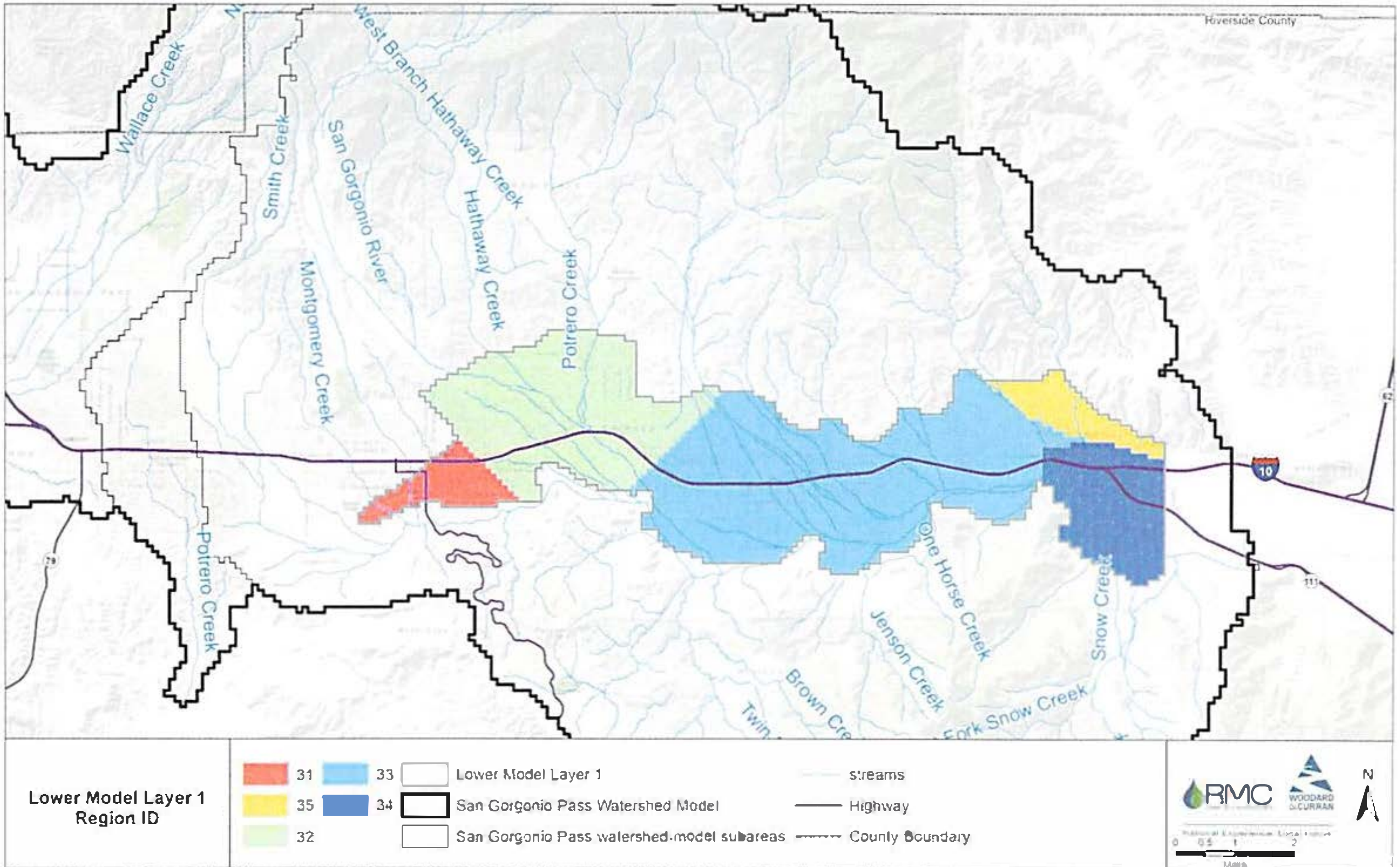


Figure 11 – Aquifer Parameter Zones for Layer 1 of LM



Document Path: \\woodardcurran.net\shared\Projects\RMC\LA\0703 Banning\0703-001.01 SG IRWM Support\G. GIS\MXDs\Task 7 Modeling\Lower Model Layer 1 Region ID.mxd

Figure 12 – Aquifer Parameter Zones for Layer 2 of LM

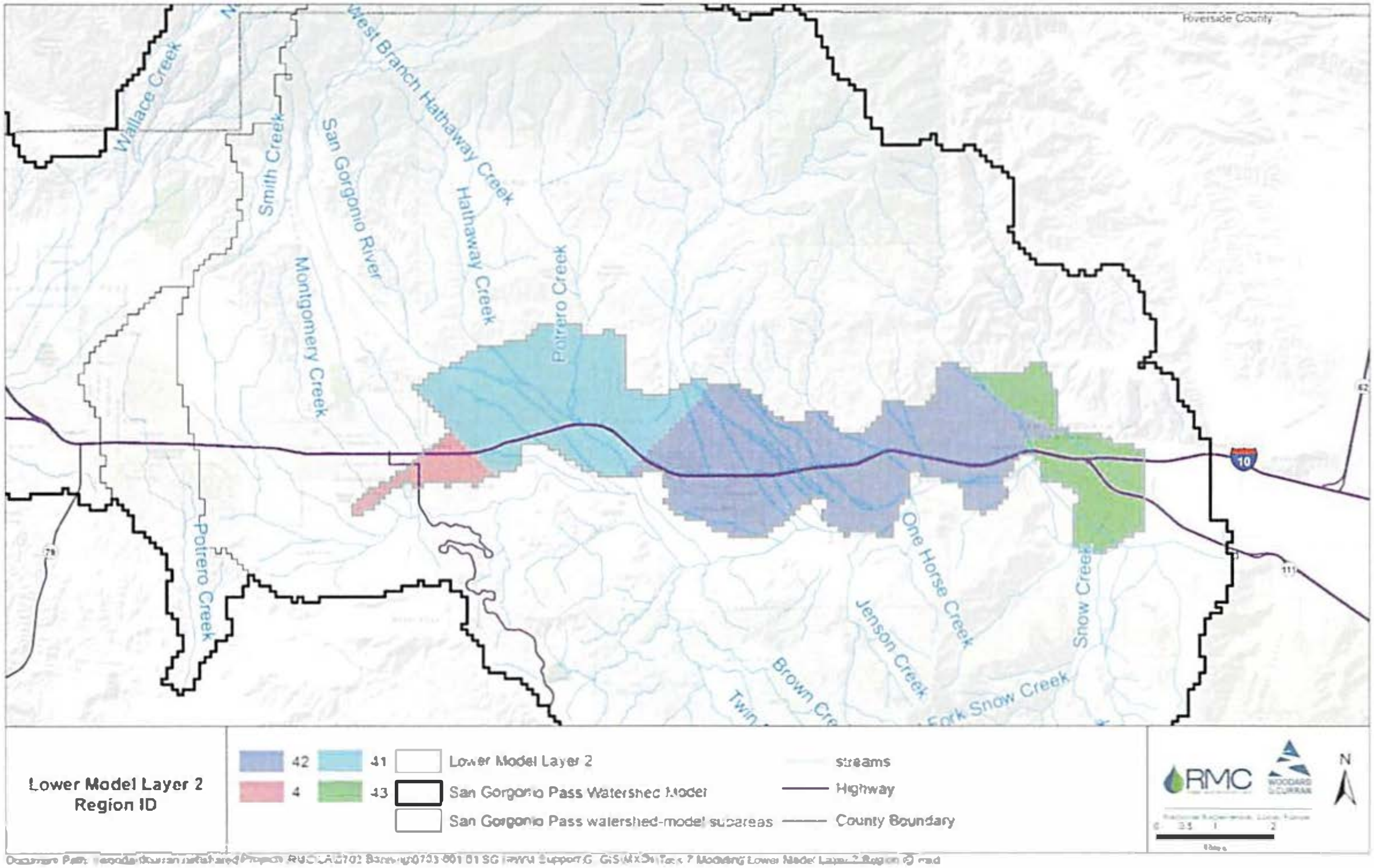
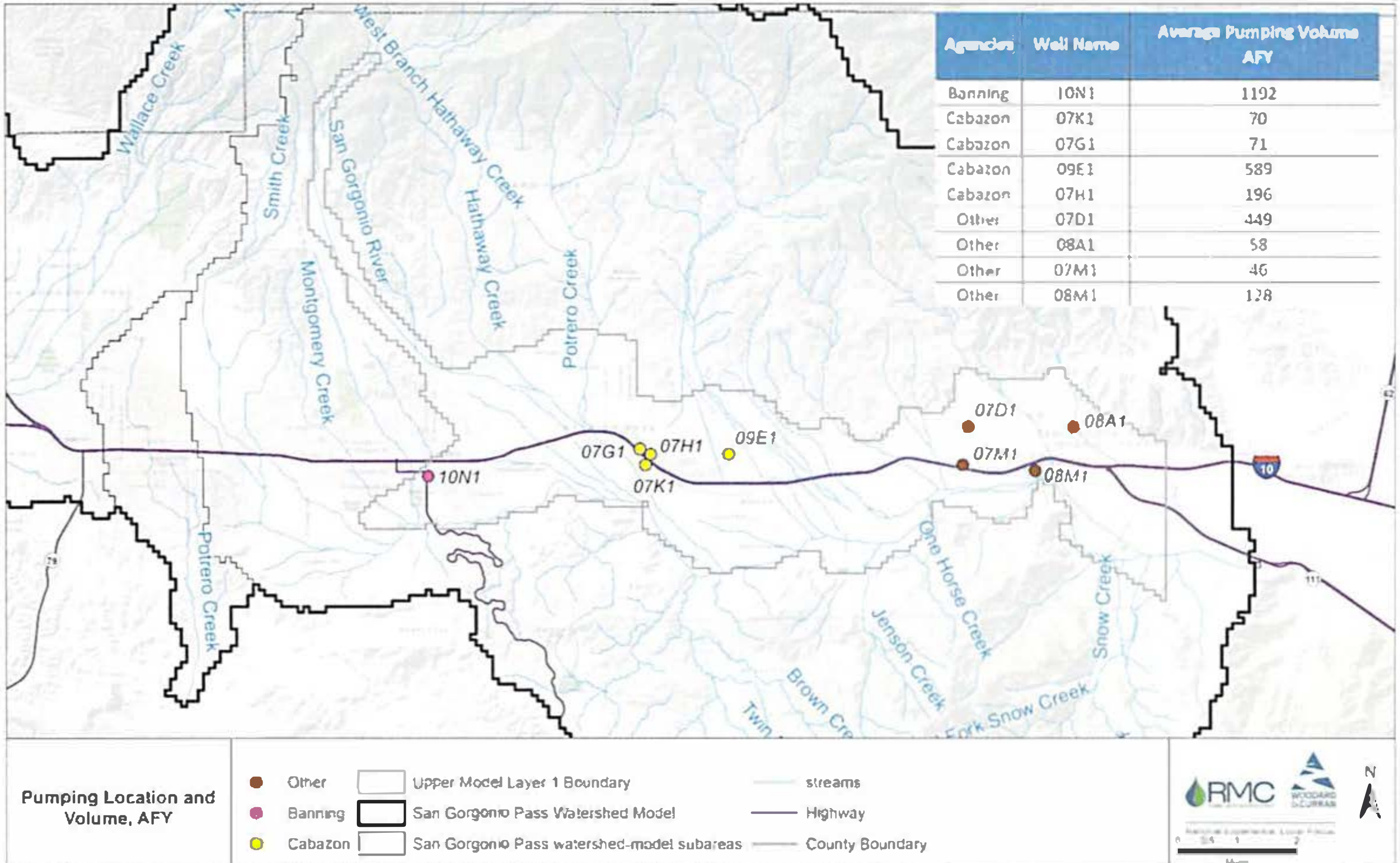


Figure 13 – Location of Wells and Average Pumping Rates for 2010-2012 period in LM



Agencies	Well Name	Average Pumping Volume AFY
Banning	10N1	1192
Cabazon	07K1	70
Cabazon	07G1	71
Cabazon	09E1	589
Cabazon	07H1	196
Other	07D1	449
Other	08A1	58
Other	07M1	46
Other	08M1	128

Figure 14 – Schematic Diagram of the Exchange of Flow Among the Three Regions in GSFLOW (Markstrom, et al. 2008)
(The Dependency on soil moisture and head in the computation of flow among the regions also is shown)

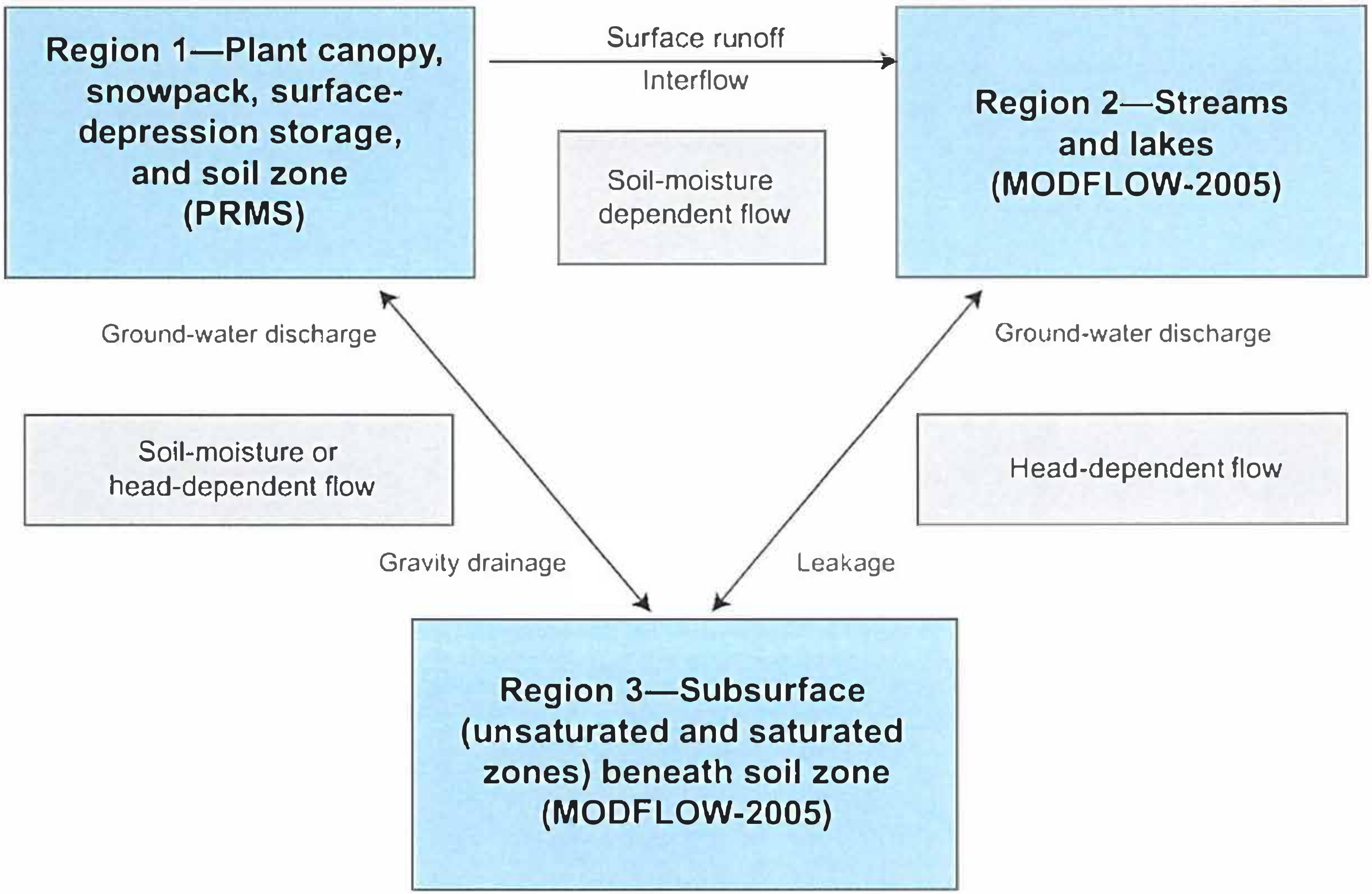


Figure 15 – SGIWGM Components of Surface Water (PRMS) and Groundwater Model (MODFLOW)

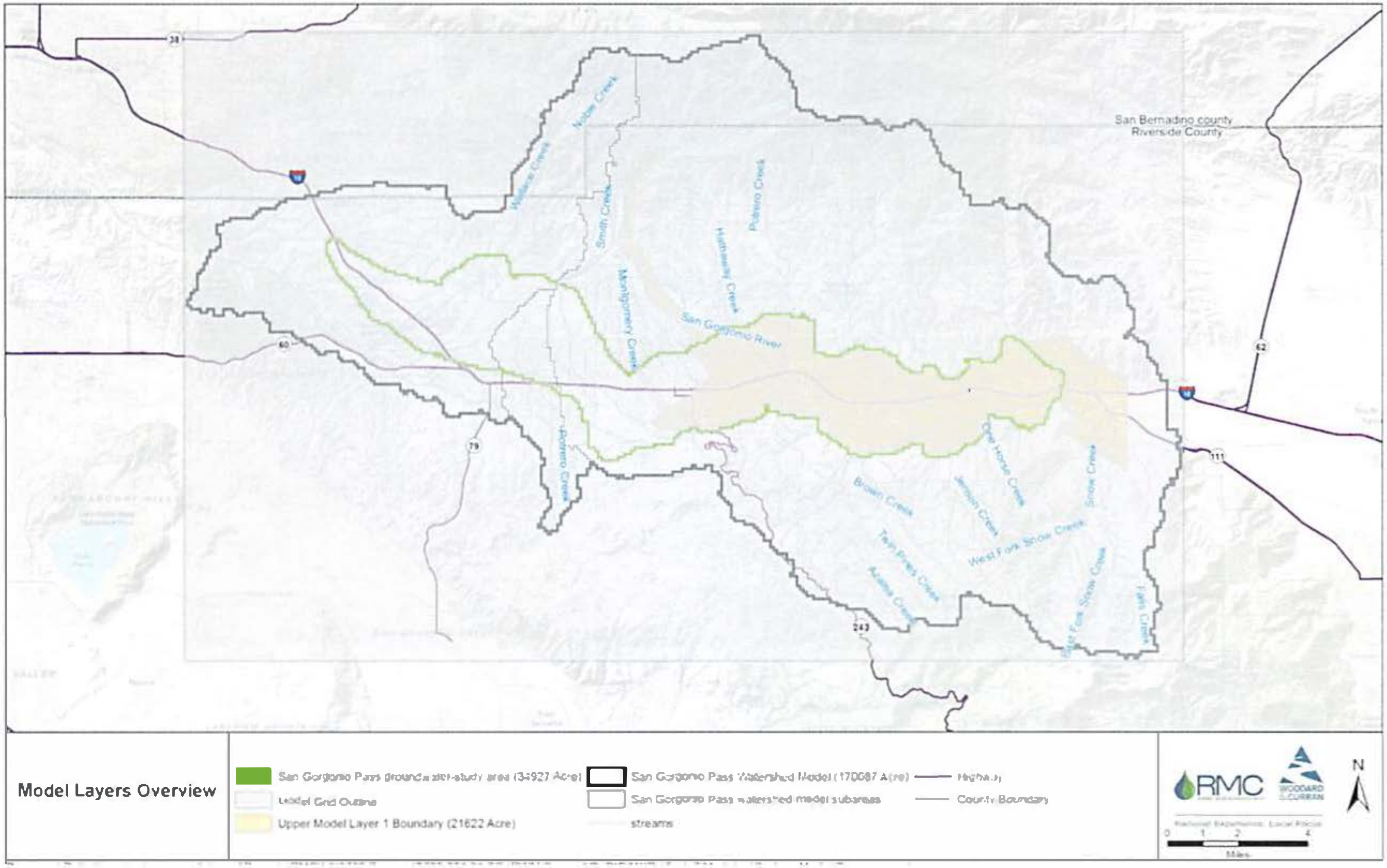


Figure 16 – SGIWGM Flow Cascade Configuration

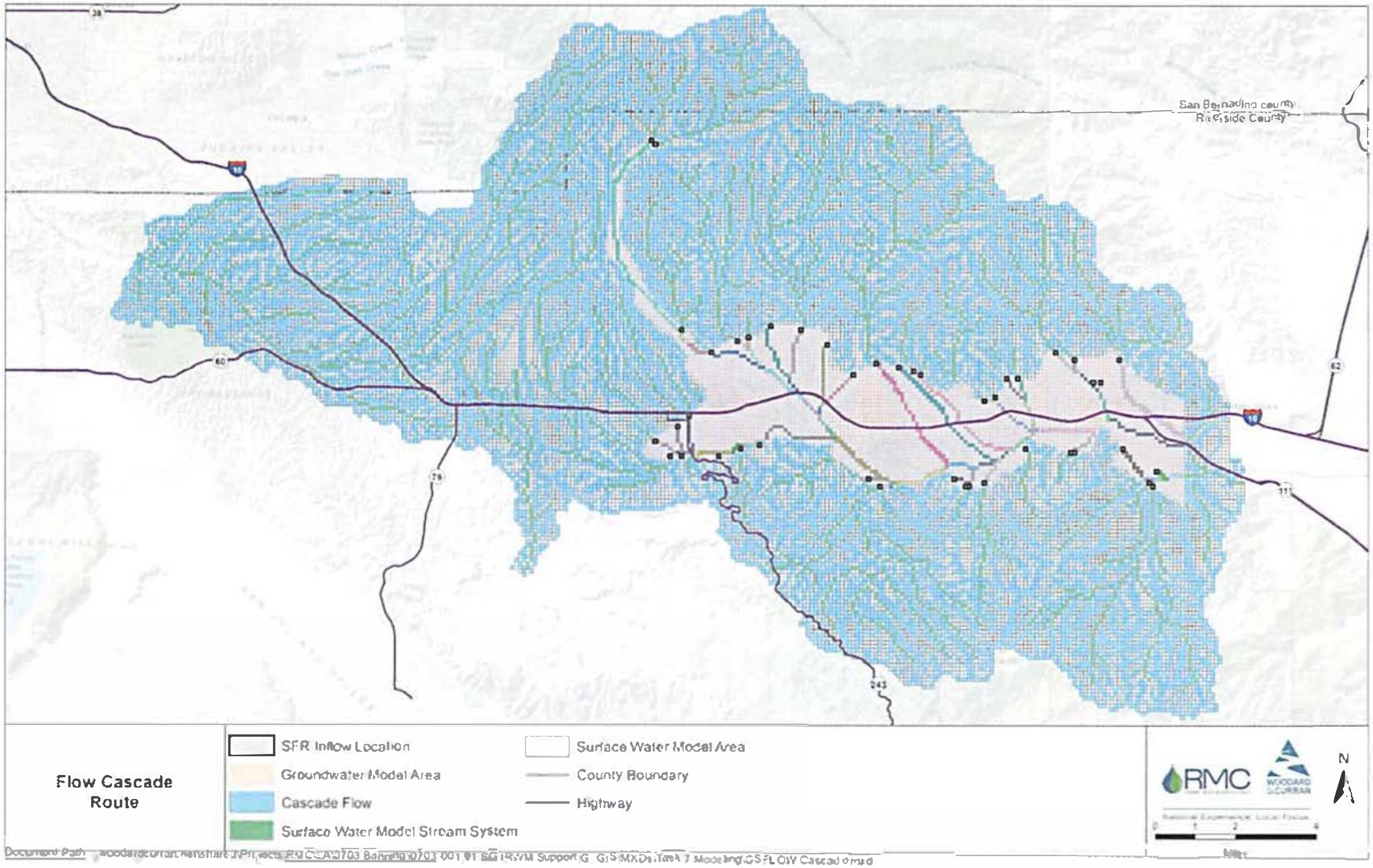


Figure 17 – SGIWGM Stream Configuration

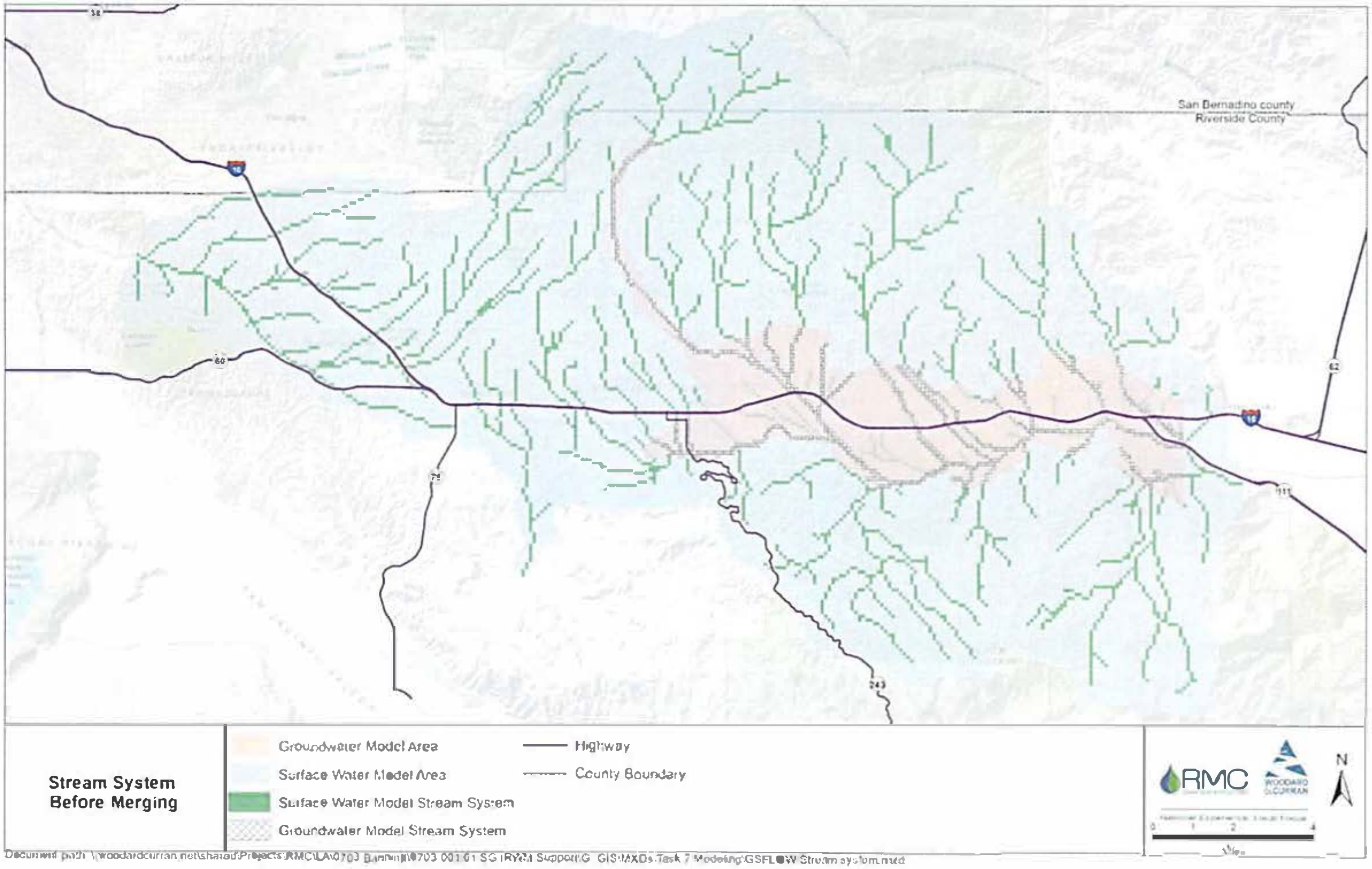


Figure 18 – SGIWGM Streamflow Inflow Locations

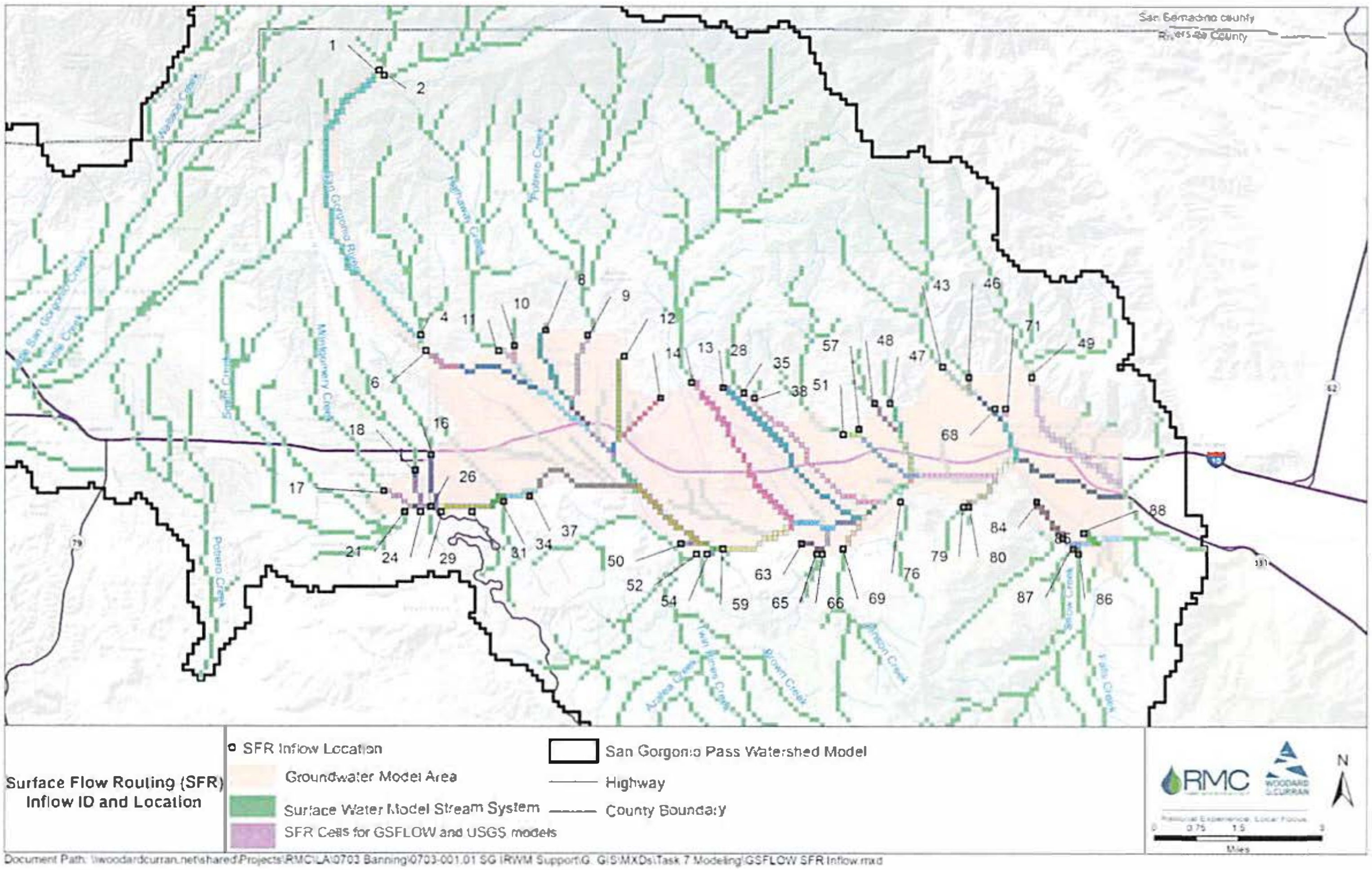
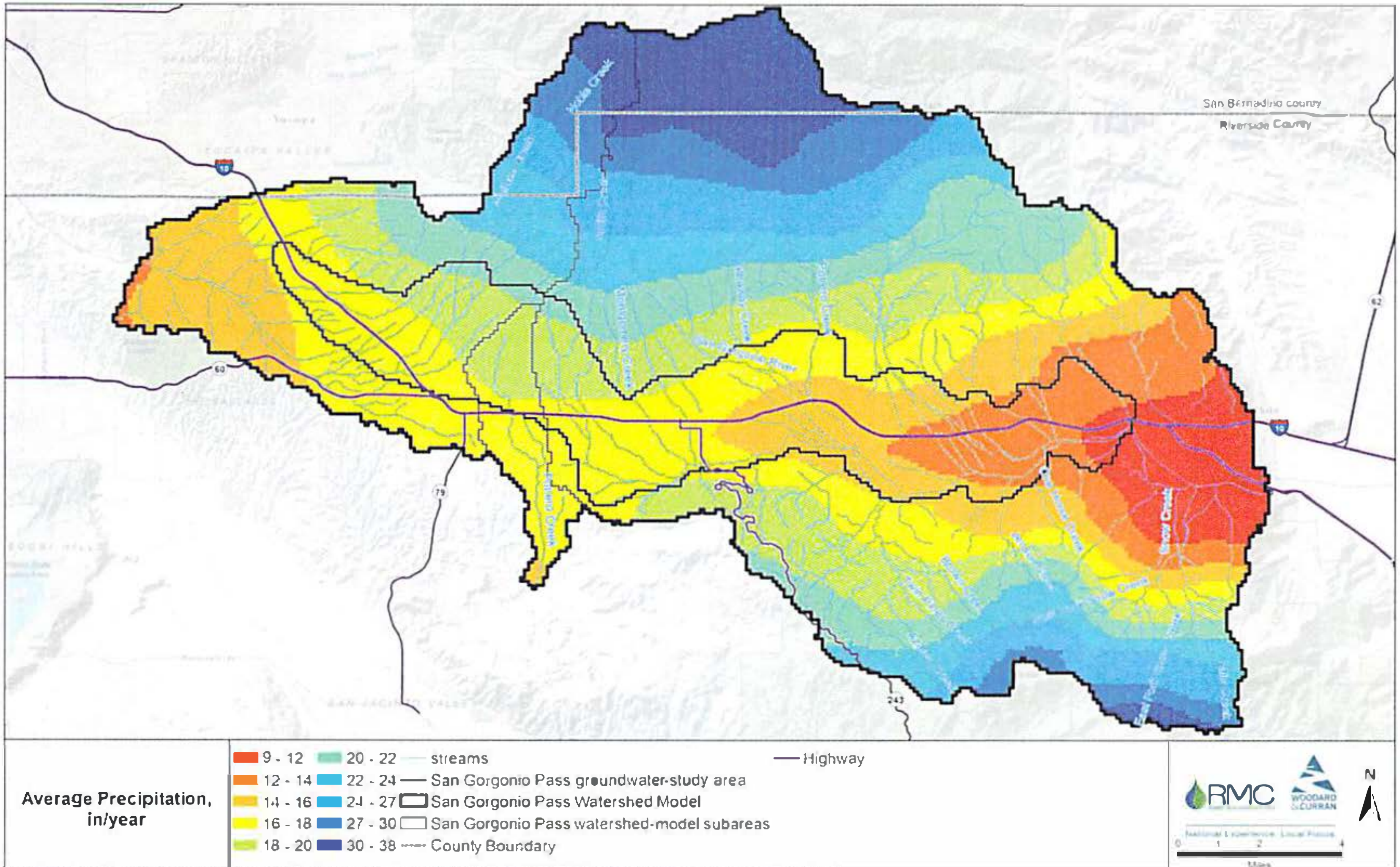
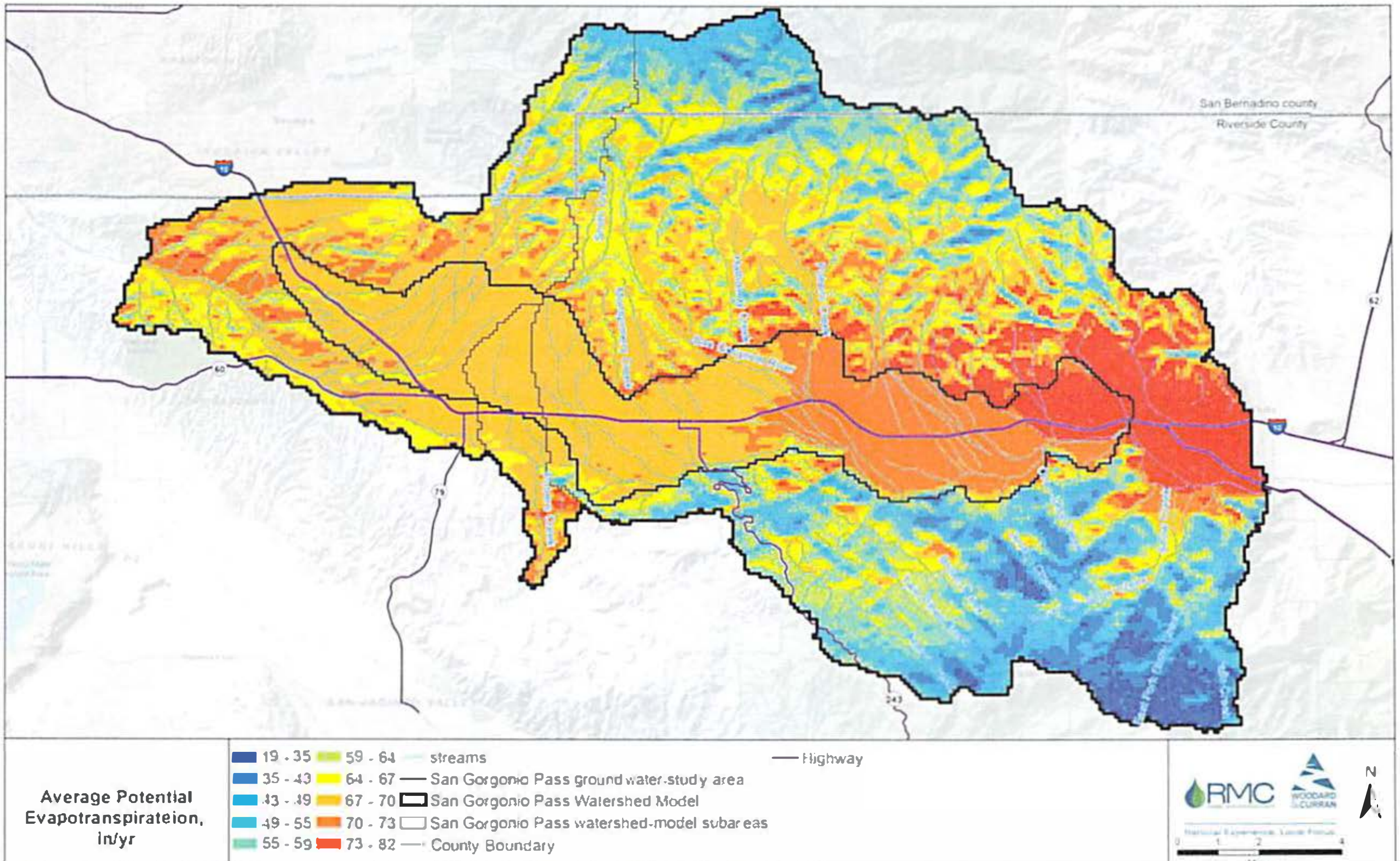


Figure 19 – PRMS Average Precipitation (30 years, 1983-2012)
(Note: Groundwater study area refers to USGS model)



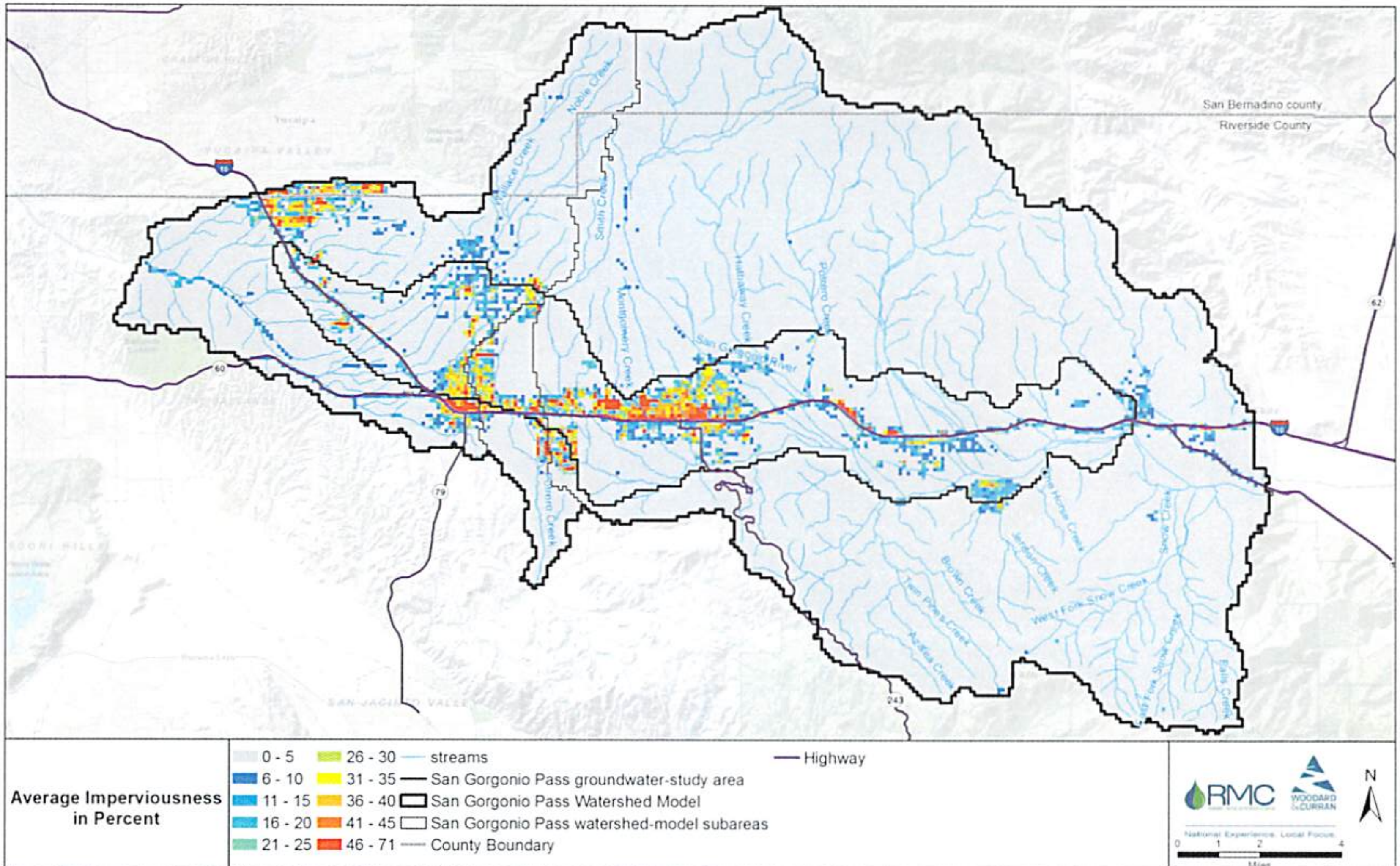
Document Path: \\woodardcurran.net\shared\Projects\RMC\LA\0703 Banning\0703-001.01 SG IRWM Support\G_GIS\MXDs\Task 7 Modeling\PRECRIP.mxd

Figure 20 – PRMS Average Potential Evapotranspiration (30 years, 1983-2012)
(Note: Groundwater study area refers to USGS model)



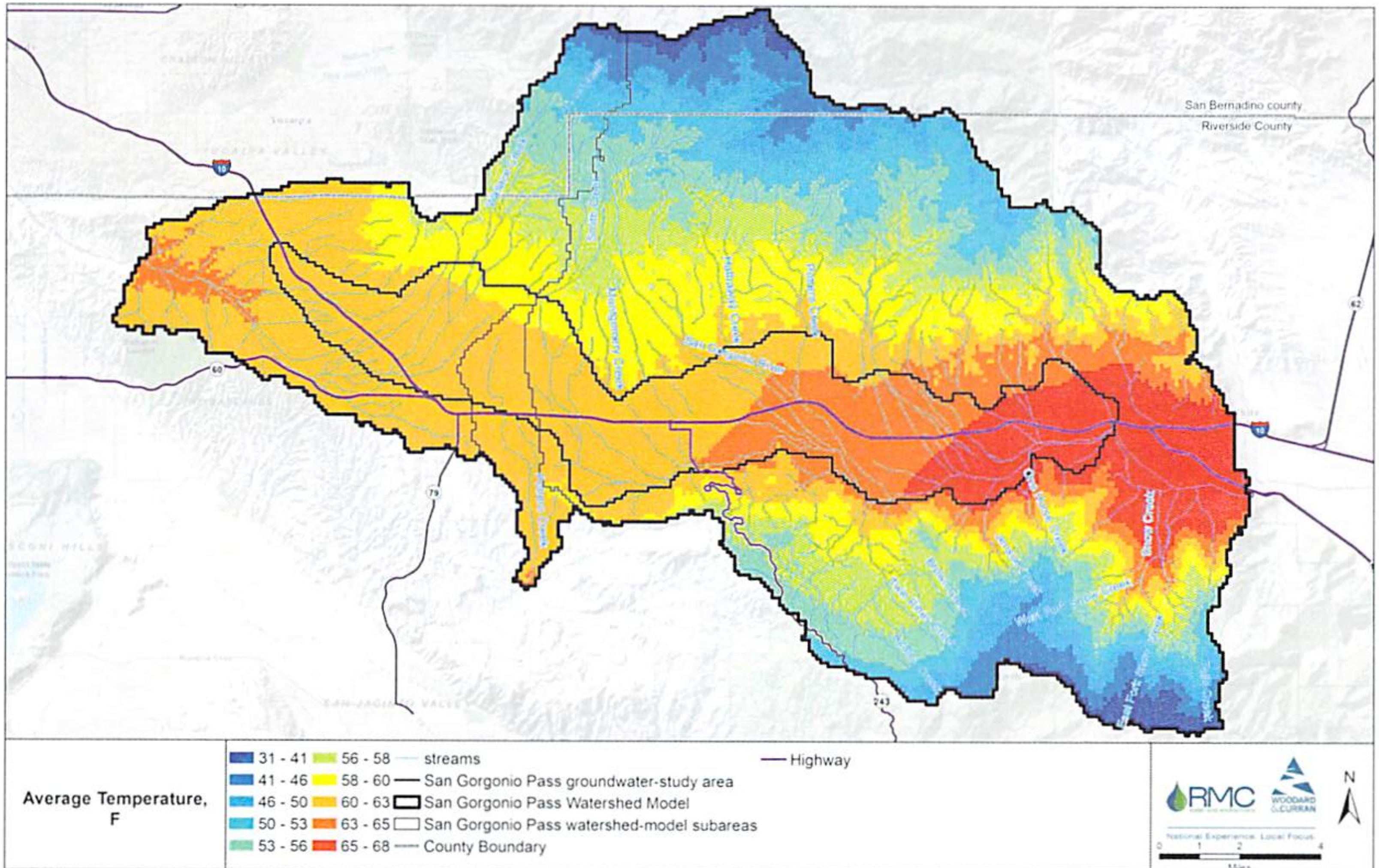
Document Path: \\woodardcurran.net\shared\Projects\RMC\LA\0703 Banning\0703-001.01 SG IRWM Support\G GIS\MXDs\Task 7 Modeling\POTET.mxd

Figure 21 – PRMS Average Imperviousness (%)
Year 2001 Data



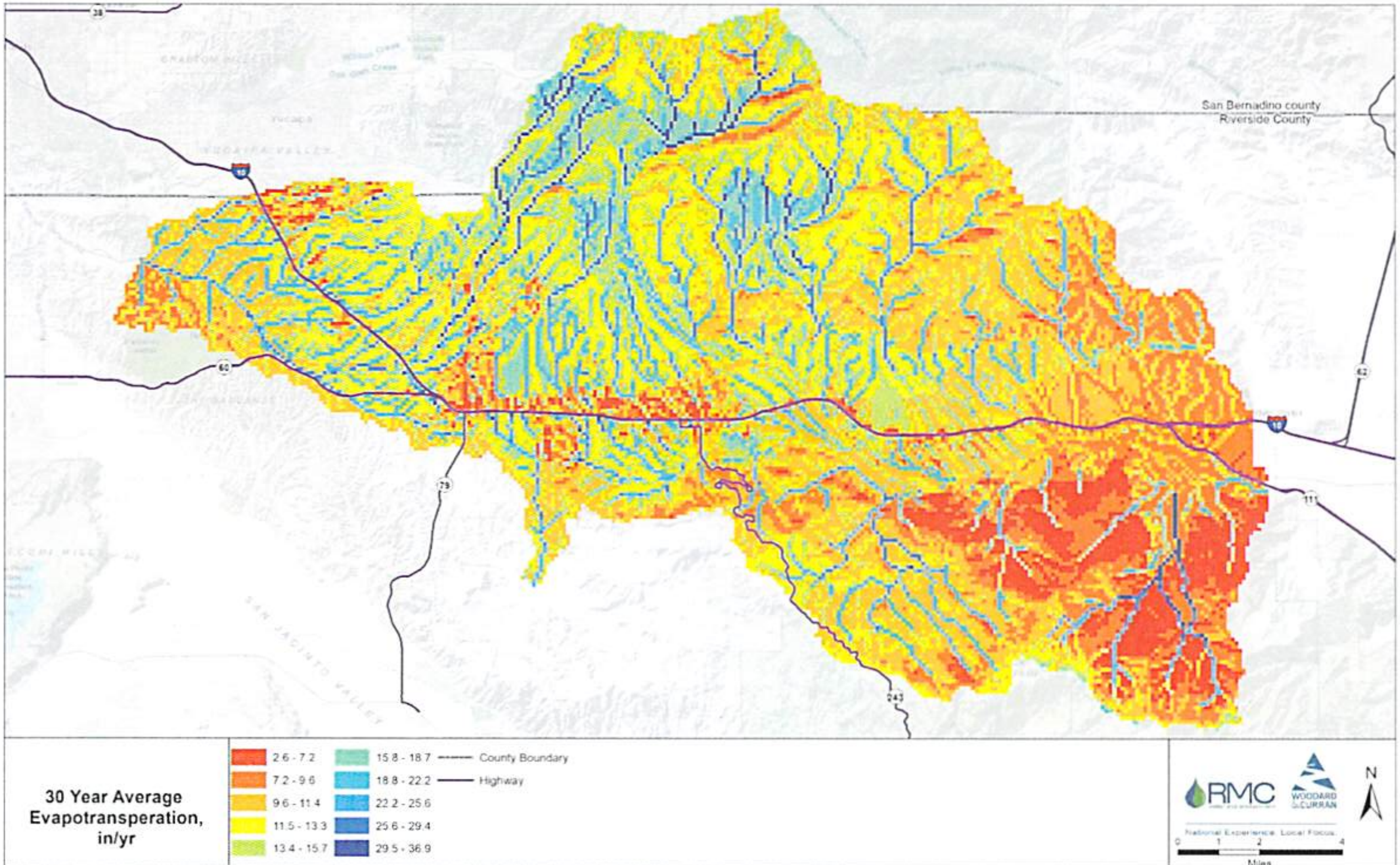
Document Path: \\woodardcurran.net\shared\Projects\RMC\LA\0703 Banning\0703-001.01 SG IRWM Support\G. GIS\MXDs\Task 7 Modeling\imperv.mxd

Figure 22 – PRMS Average Temperature, °F (30 years, 1983-2012)
(Note: Groundwater study area refers to USGS model)



Document Path: \\woodardcurran.net\shared\Projects\RMC\LA\0703 Banning\0703-001.01 SG IRWM Support\G. GIS\MXDs\Task 7 Modeling\Temperature.mxd

Figure 23 – PRMS Average ET, in/yr (30 years, 1983-2012)



Document Path: \\woodardcurran.net\shared\Projects\RMC\LA\0703 Banning\0703-001.01 SG IRWM Support\G. GIS\MXDs\Task 7 Modeling\GSFLOW ET (fig 22).mxd

Figure 24 – PRMS Simulated Annual ET, average across all model cells (in/yr)
(Annual cumulative departure from mean annual rain (CD) is provided as a reference)

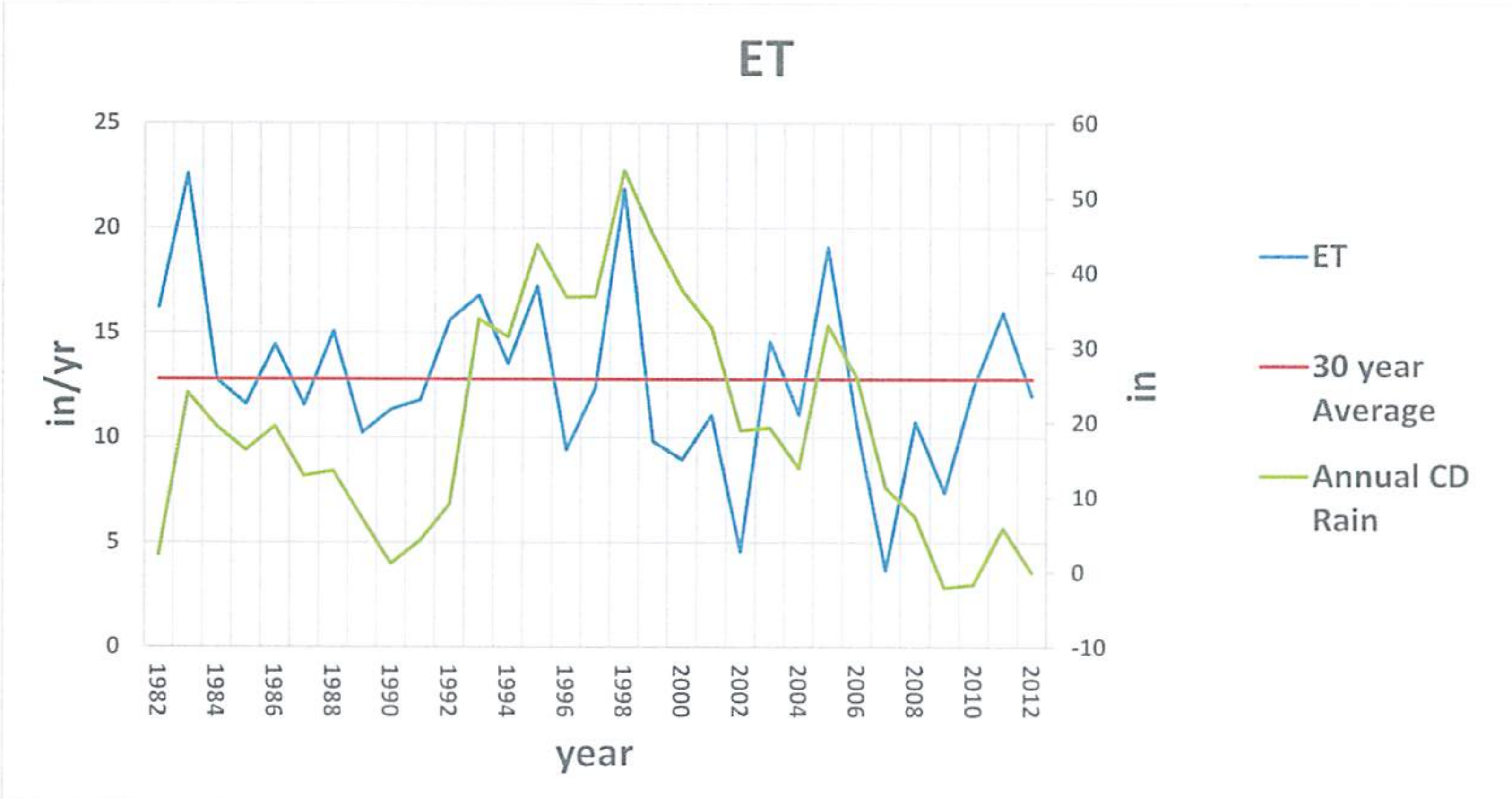


Figure 25 – PRMS Simulated Annual Runoff, average across all model cells (in/yr)
(Annual cumulative departure from mean annual rain (CD) is provided as a reference)

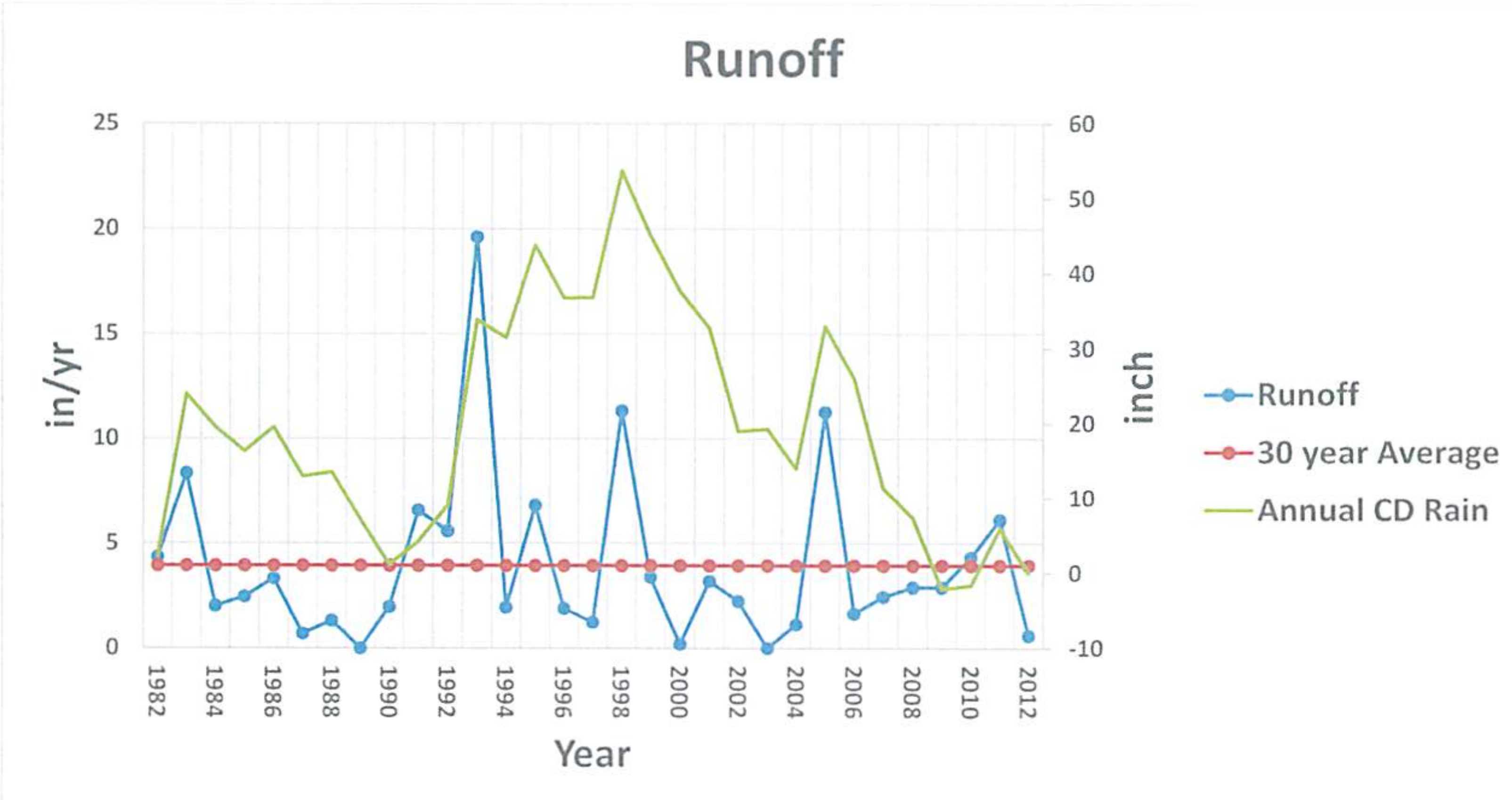


Figure 26 – PRMS Simulated Annual Recharge, average across all model cells (in/yr)
(Annual cumulative departure from mean annual rain (CD) is provided as a reference)

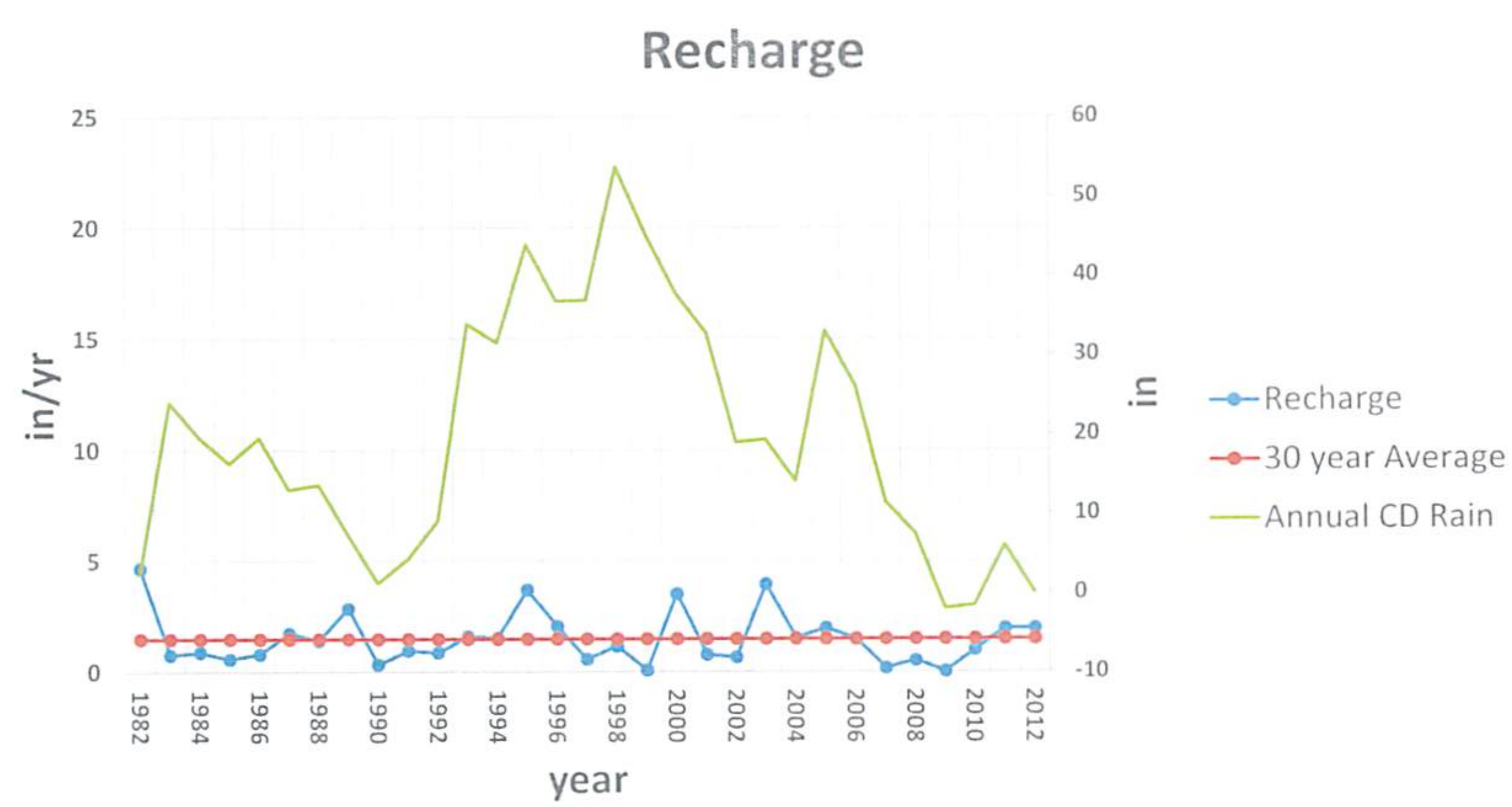
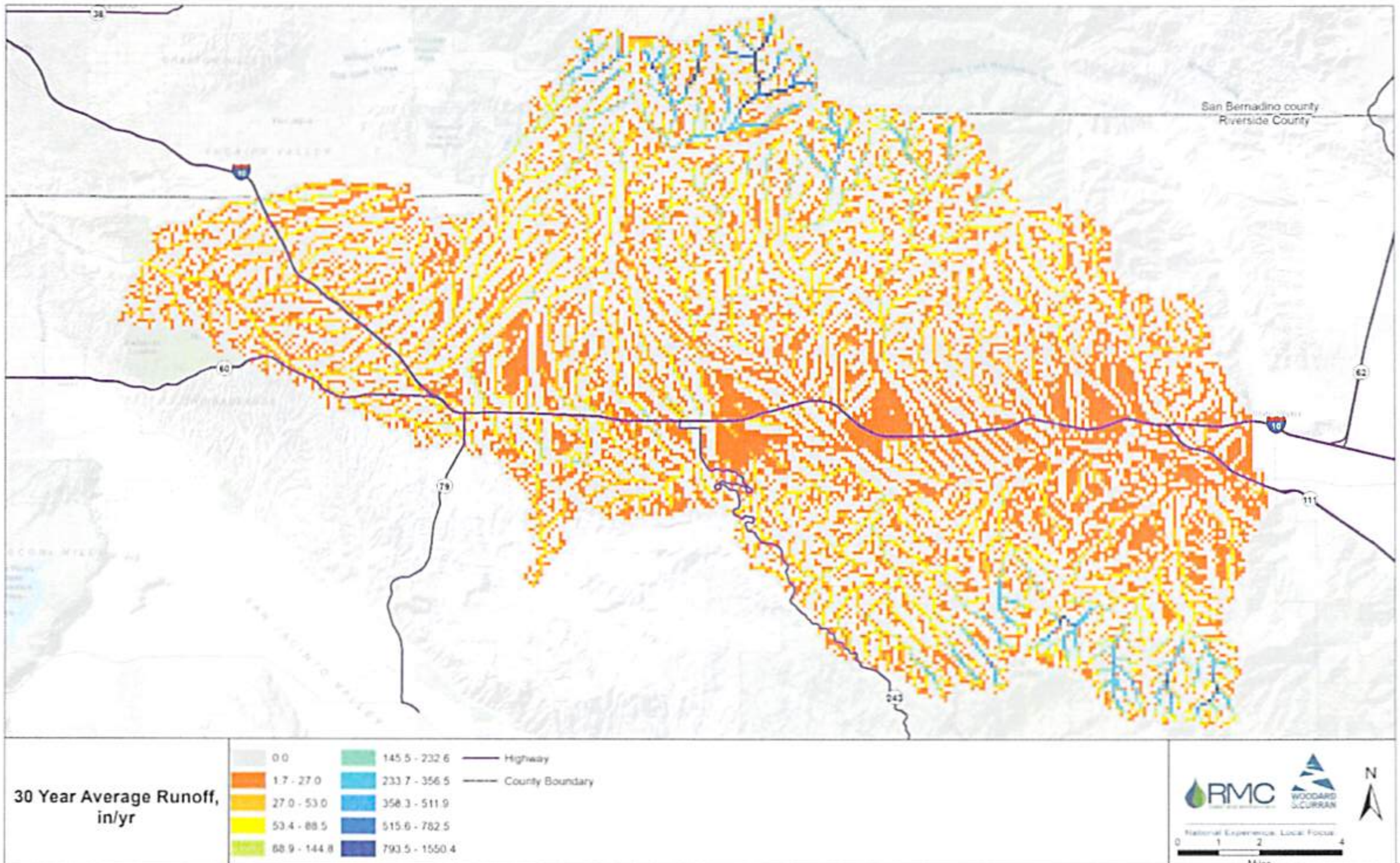
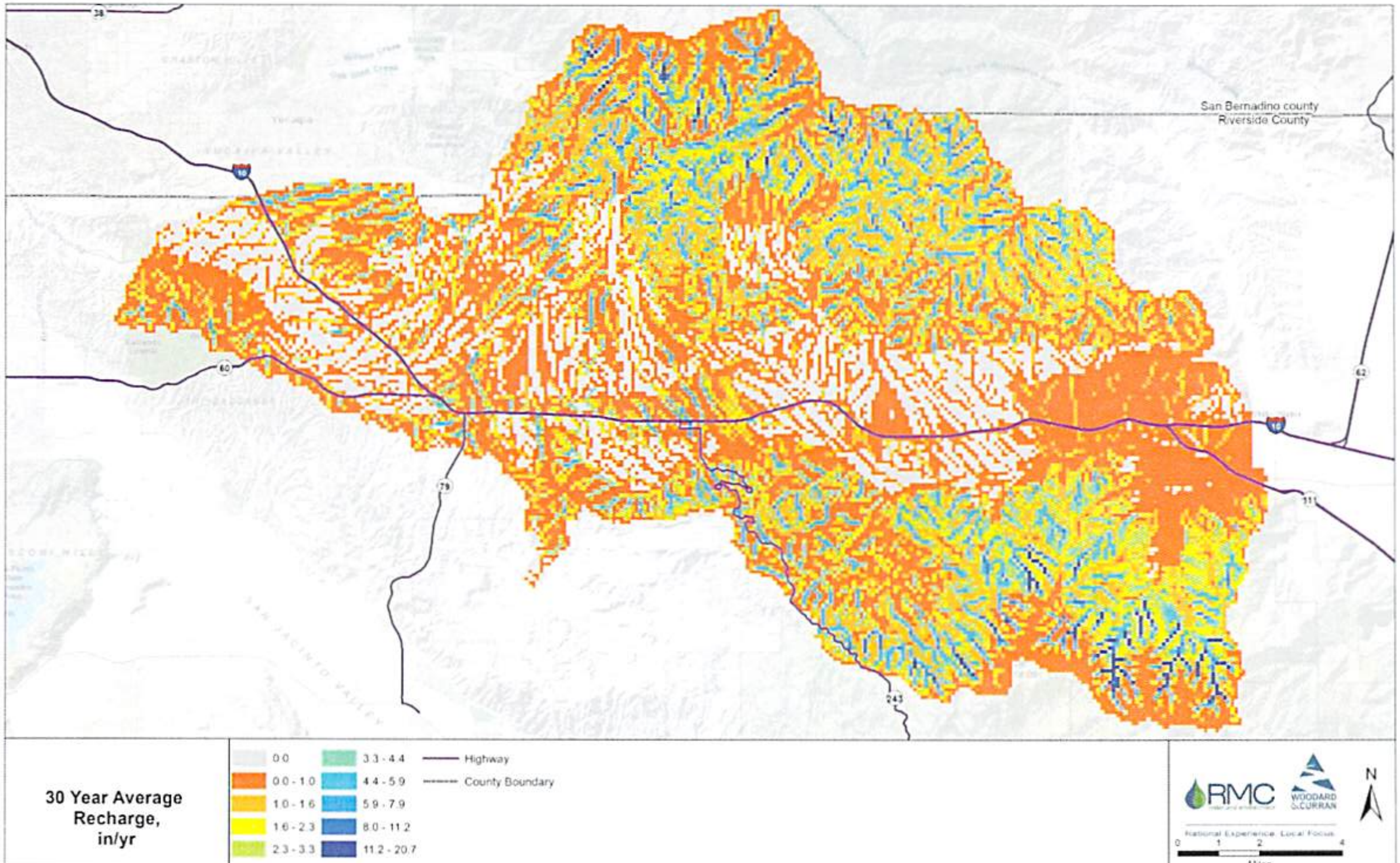


Figure 27 – PRMS Average Runoff, in/yr (30 years, 1983-2012)



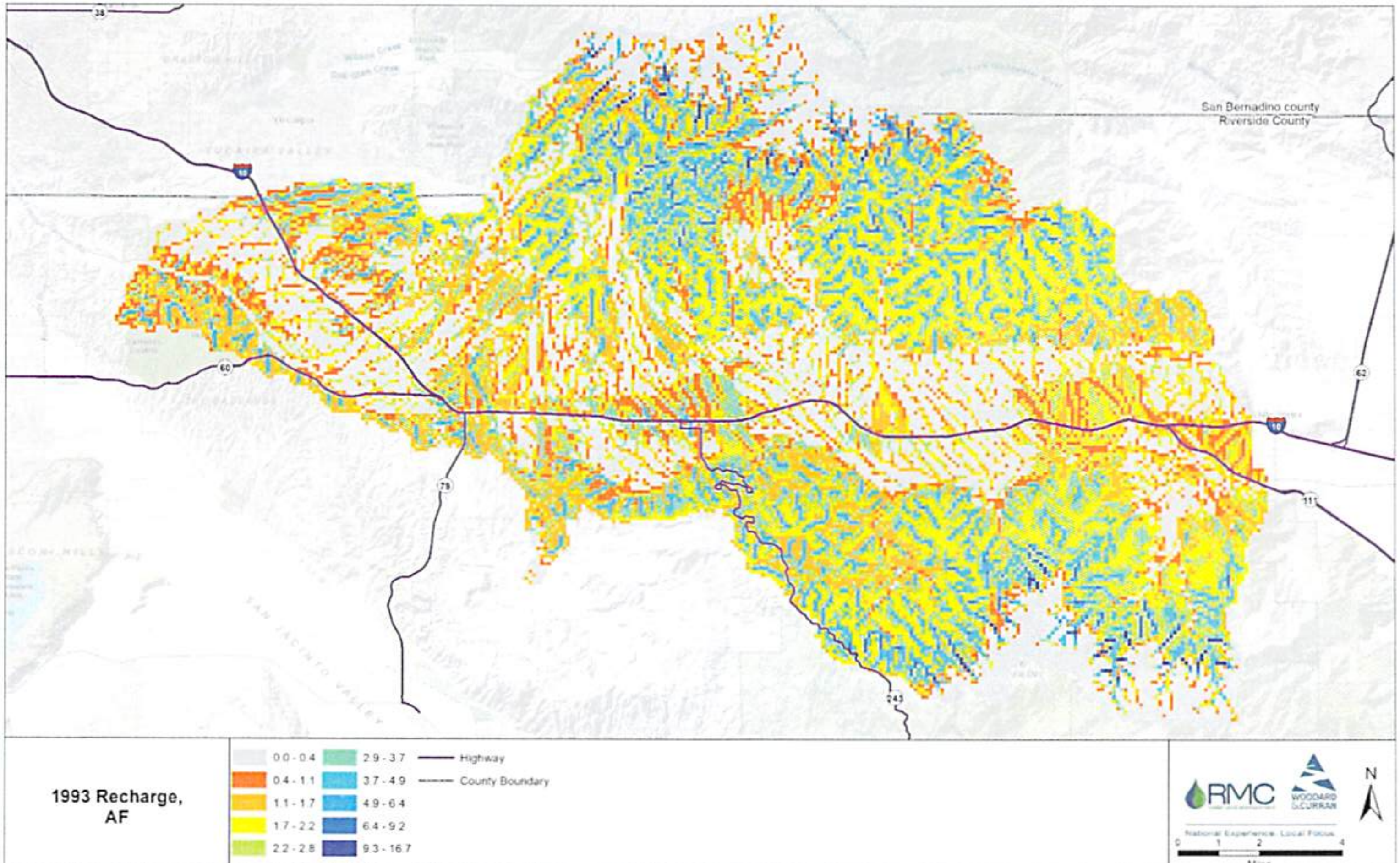
Document Path: \\woodardcurran.net\shared\Projects\RMC\LA\0703 Banning\0703-001.01 SG IRWM Support\G. GIS\MXDs\Task 7 Modeling\GSFLOW runoff (fig 23).mxd

Figure 28 – PRMS Average Recharge, in/yr (30 years, 1983-2012)



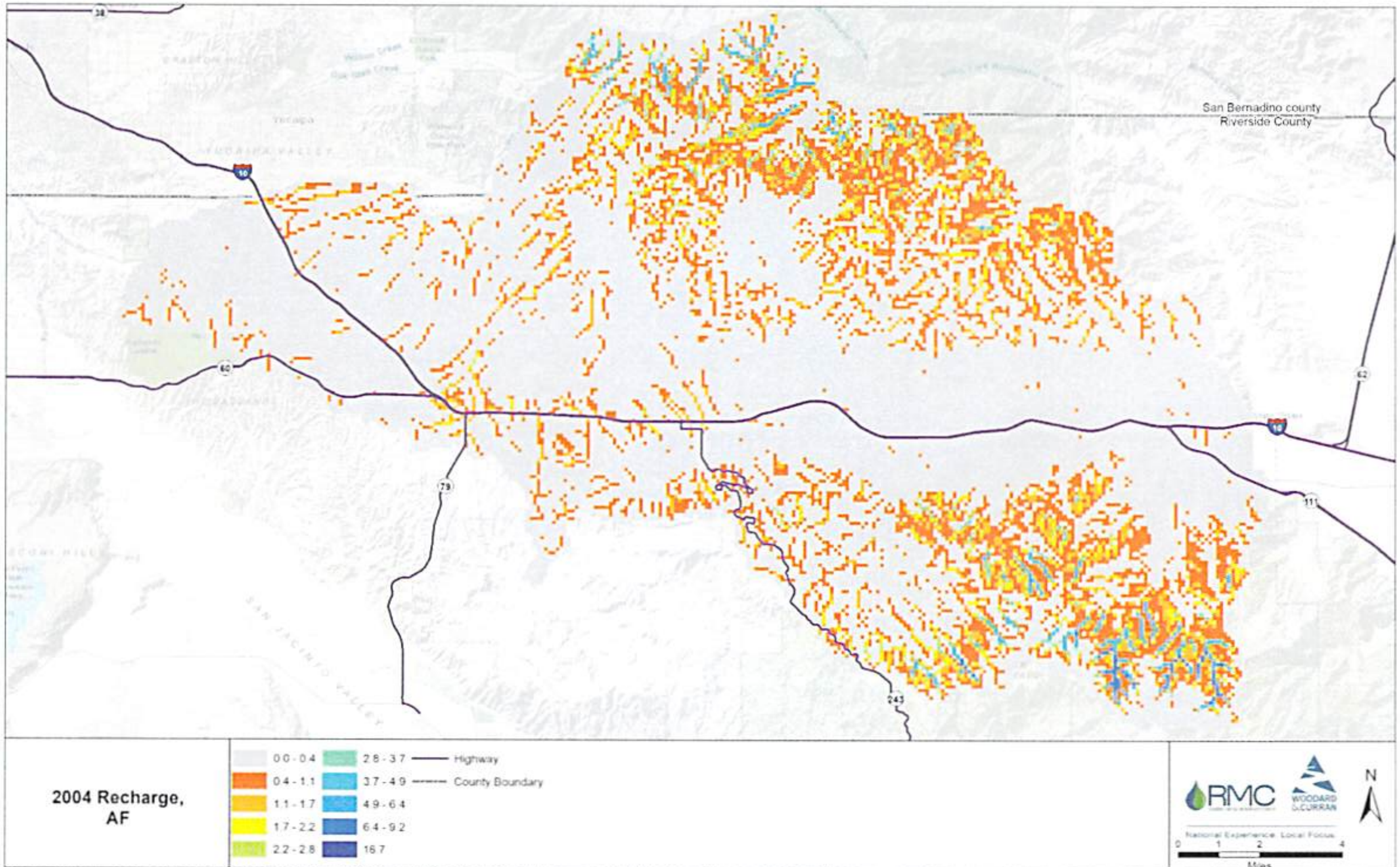
Document Path: \\woodardcurran.net\shared\Projects\RMC\LA\0703 Banning\0703-001.01 SG IRWM Support\G. GIS\MXDs\Task 7 Modeling\GSFLOW recharge (fig 24).mxd

Figure 29 – PRMS Simulated Recharge for 1993 Wet Year, AF/model cell



Document Path: \\woodardcurran.net\shared\Projects\RMC\LA\0703 Banning\0703-001.01 SG IRWM Support\G. GIS\MXDs\Task 7 Modeling\GSFLOW 1993 recharge (fig 28a).mxd

Figure 30 – PRMS Simulated Recharge for 2004 Dry Year, AF/model cell



Document Path: \\woodardcurran.net\shared\Projects\RMC\LA\0703 Banning\0703-001.01 SG IRWM Support\G. GIS\MXDs\Task 7 Modeling\GSFLOW 2004 recharge (fig 28b).mxd

Figure 31 – PRMS Simulated Runoff compared to INFILv3 Simulated Runoff, AFY
(PRMS simulated an average of 35,200 AFY runoff. INFILv3 simulated an average of 34,700 AFY runoff)
(Annual cumulative departure from mean annual rain (CD) is provided as a reference)

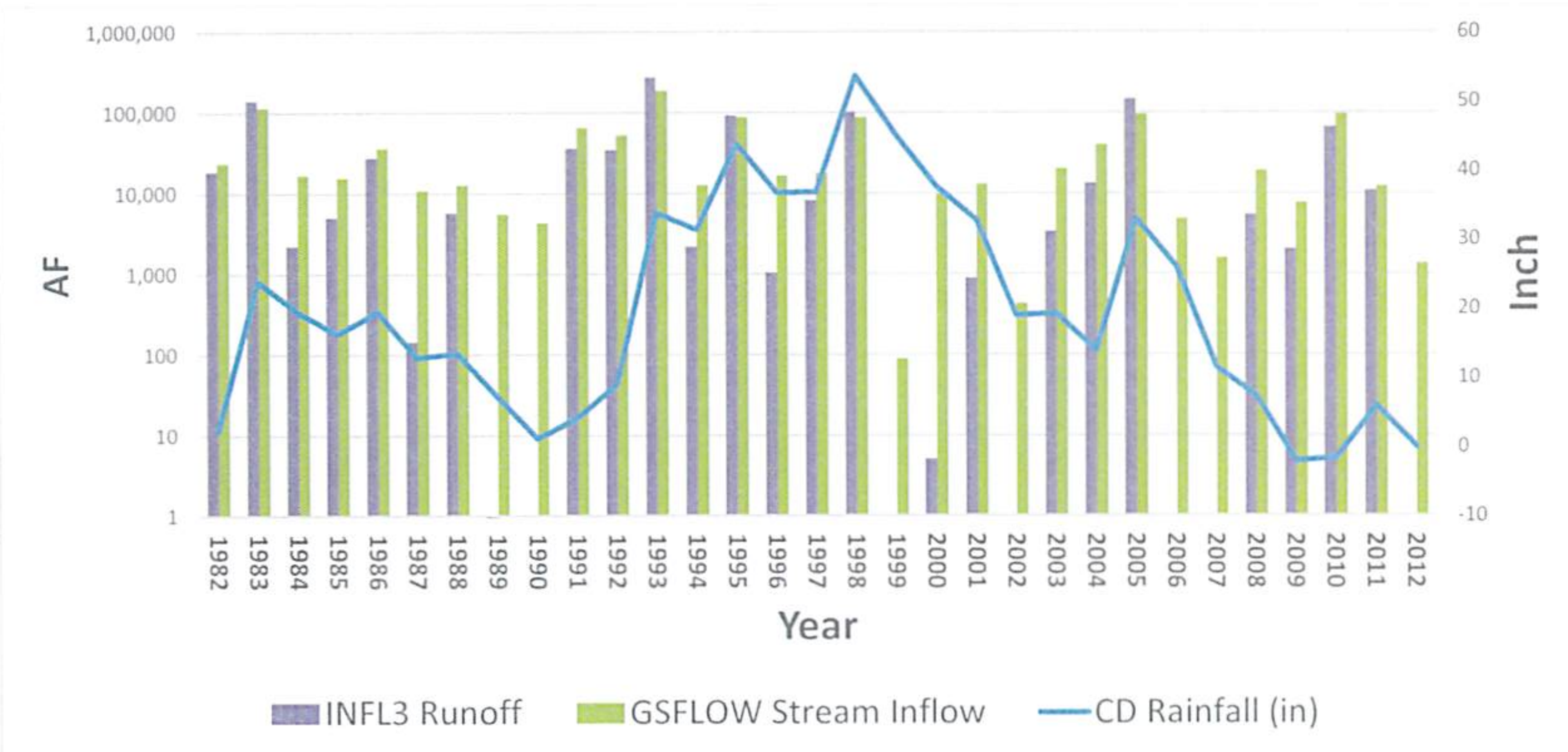


Figure 32 – SGIWGM Cross Section A4-A4'

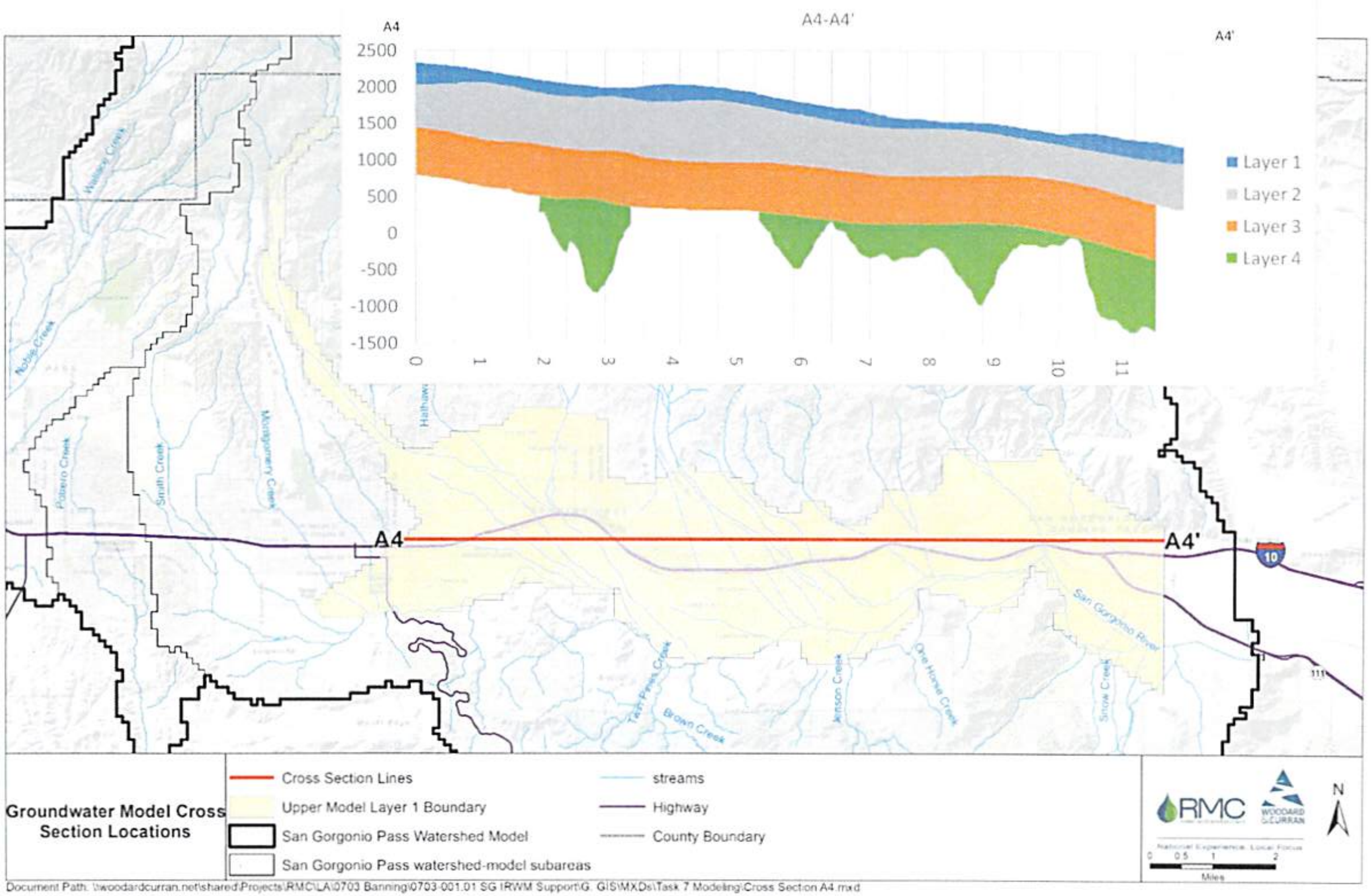


Figure 33 – SGIWGM SFR Inflow Locations

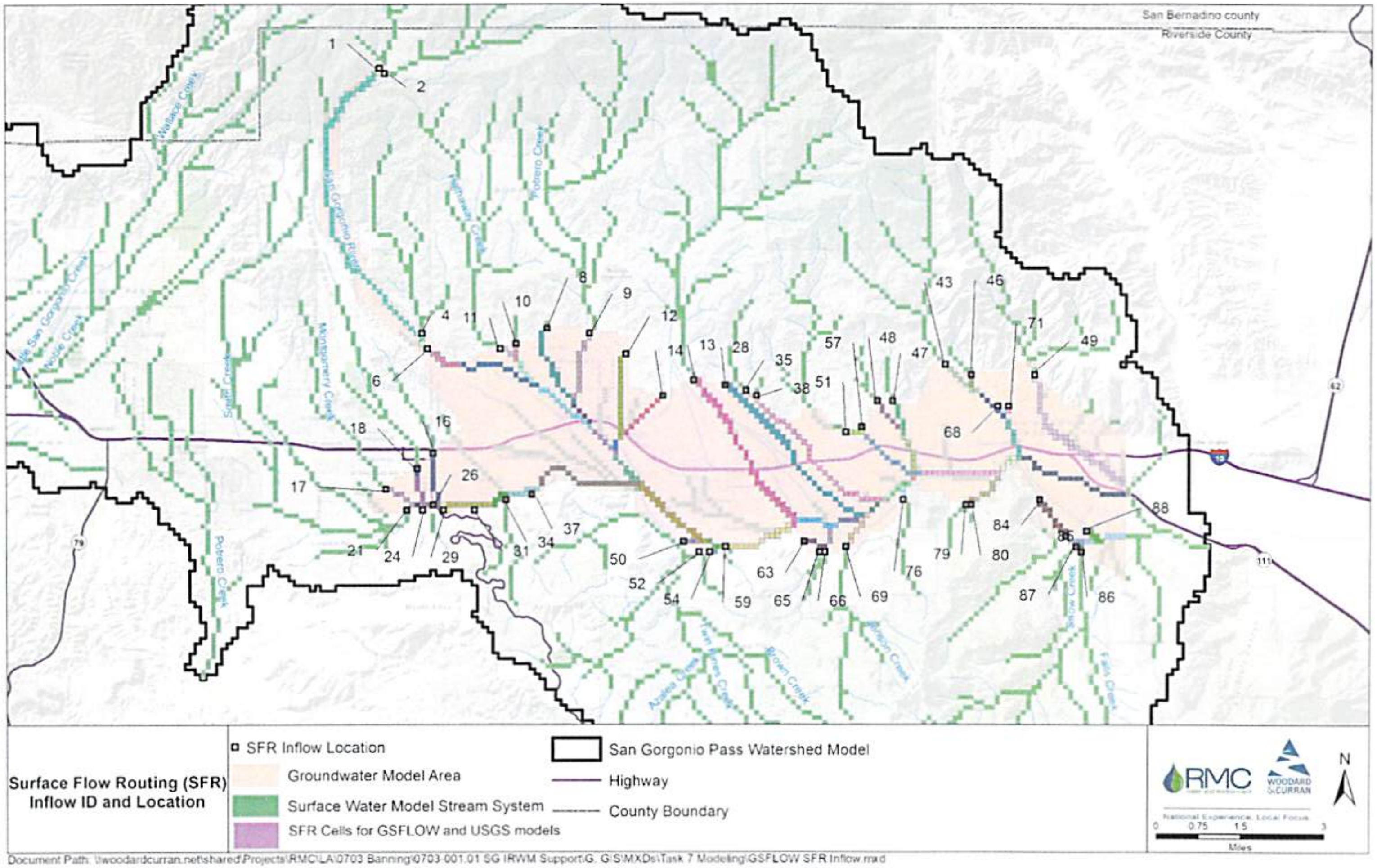


Figure 34 – SGIWGM Stream Inflow Compared to INFILv3 and UM Stream Inflows
(Annual cumulative departure from mean annual rain (CD) is provided as a reference)

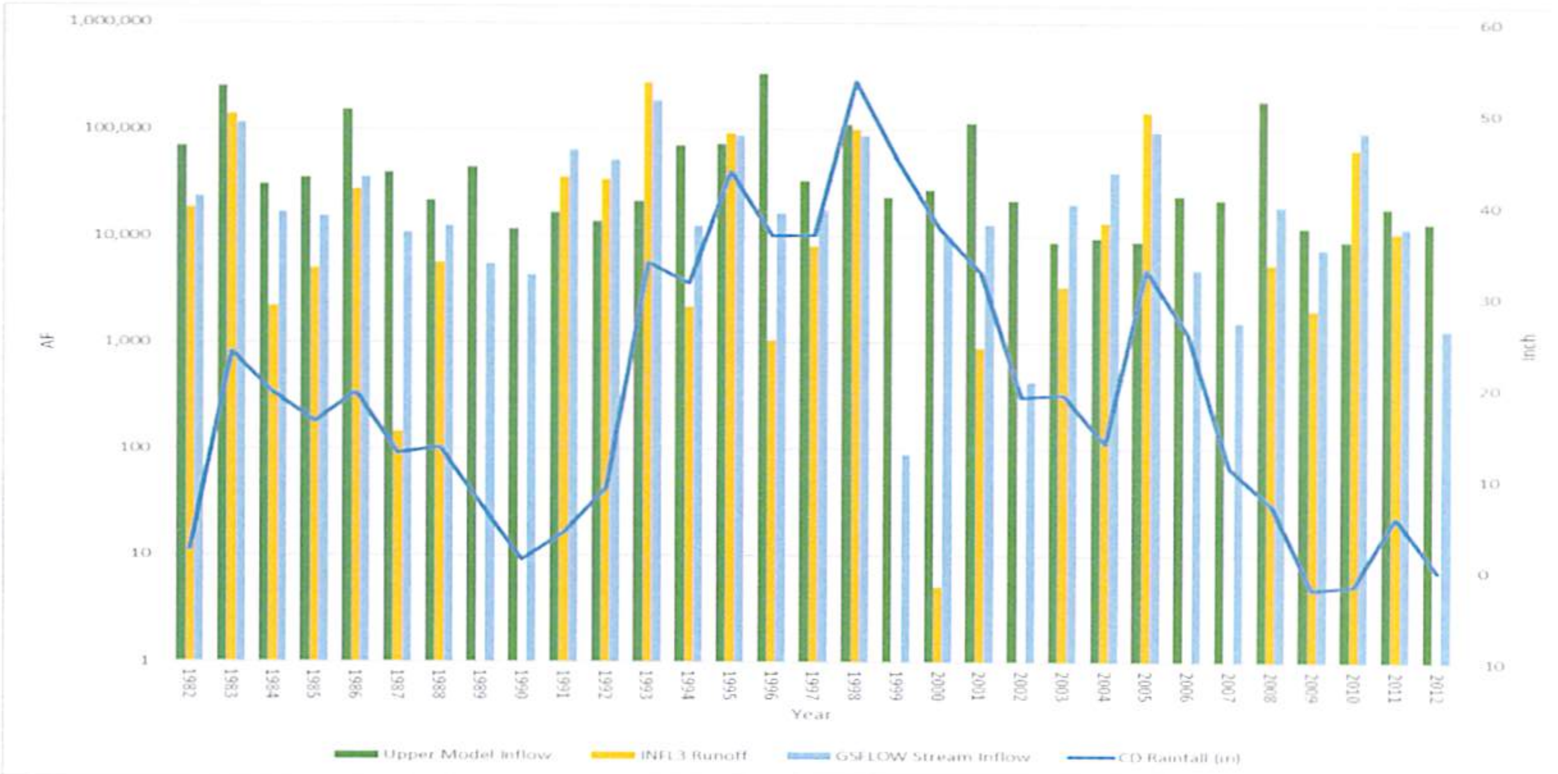


Figure 35 – Location of New Wells in the SGIWGM in Addition to the Wells Shown in Figure 13

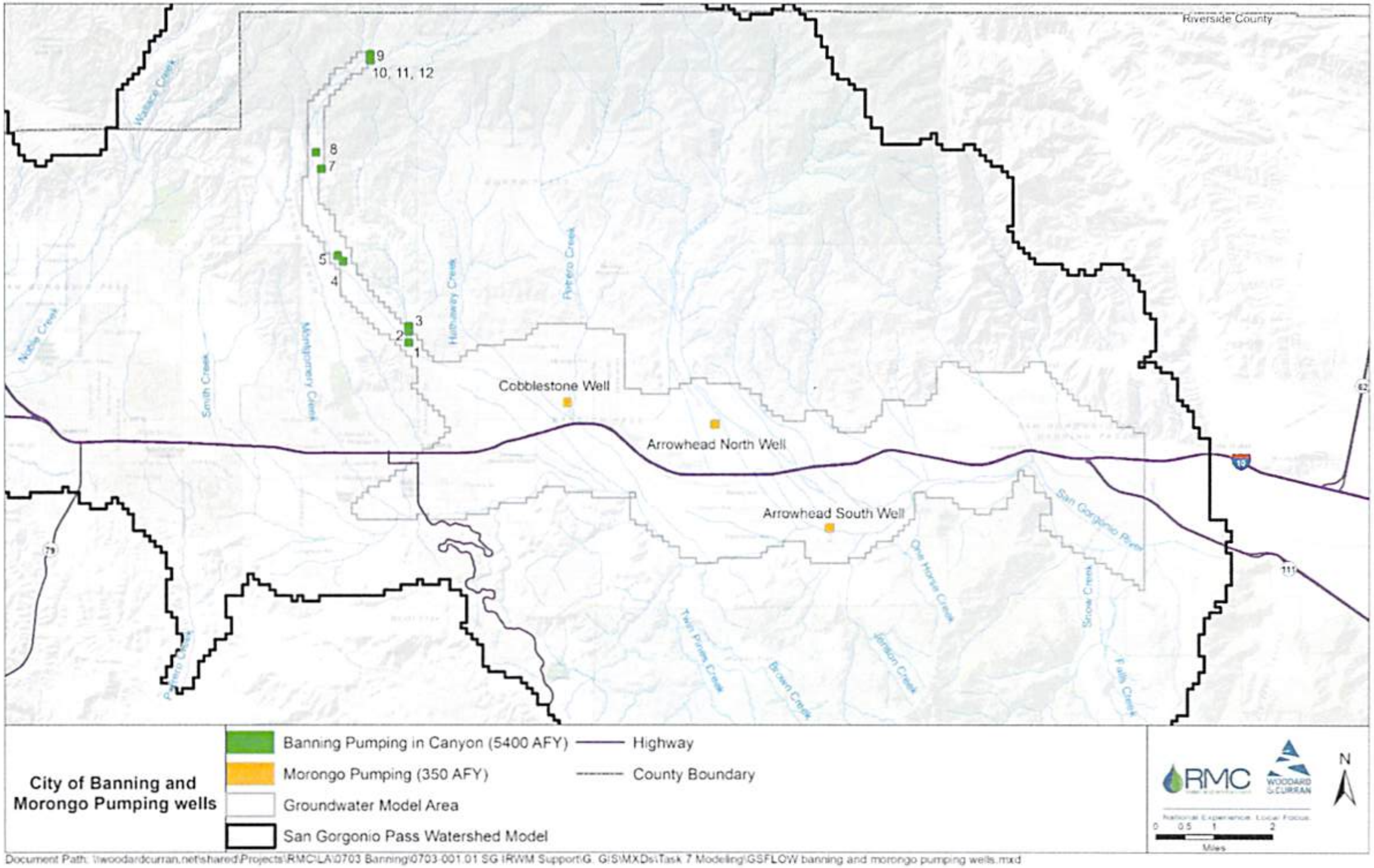
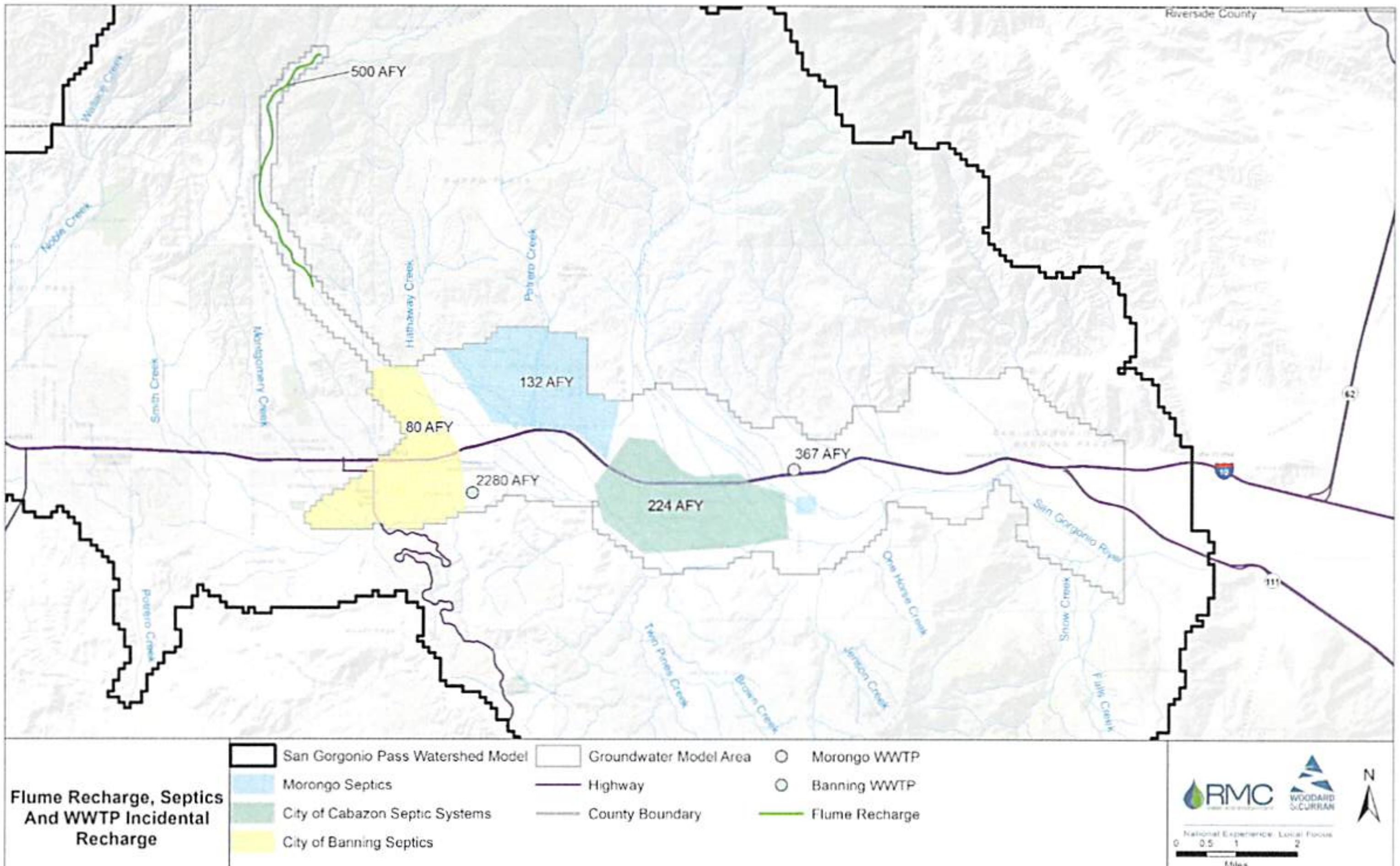
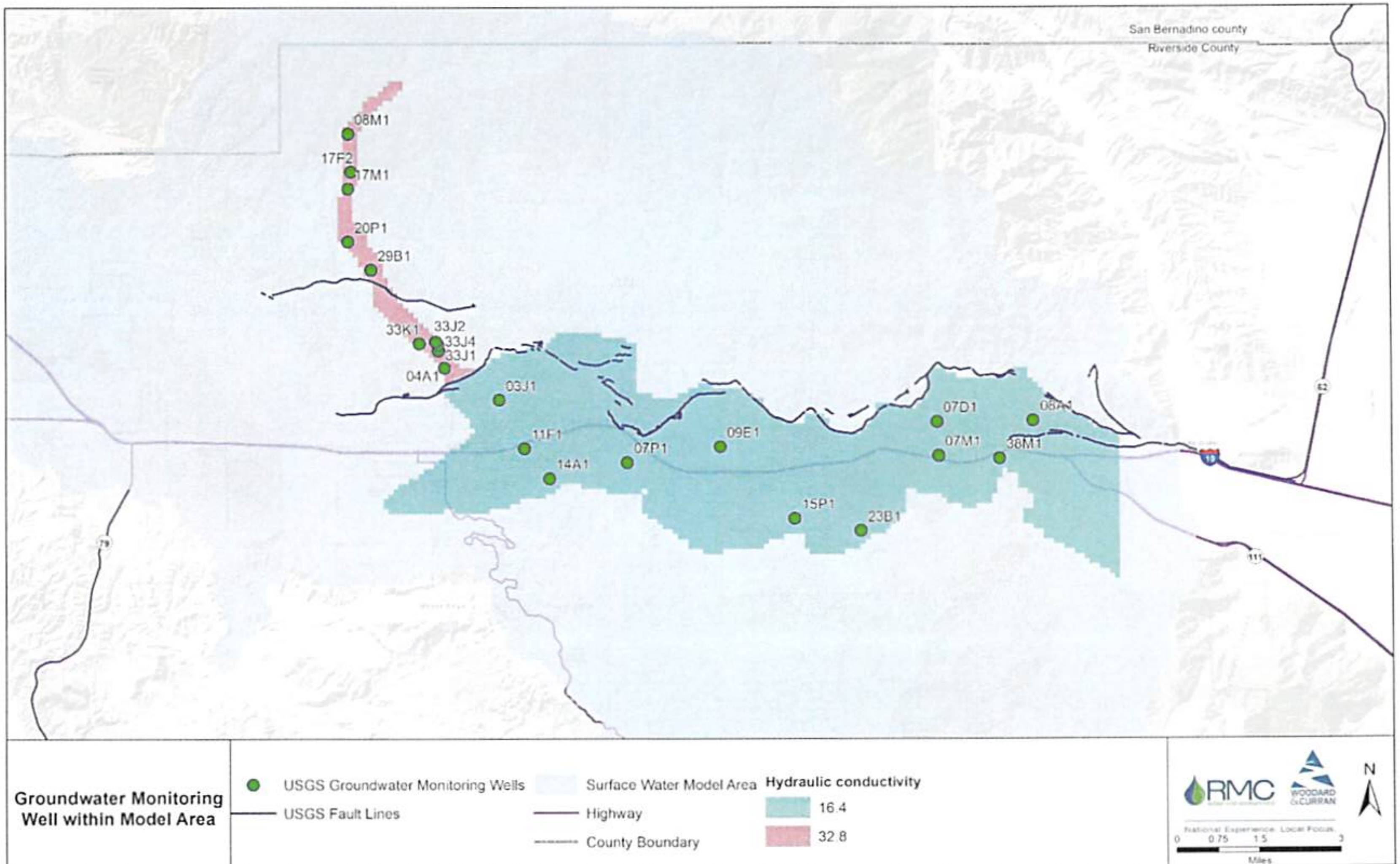


Figure 36 –Artificial and Incidental Recharge Locations
(Note: City of Banning septic incidental recharge rate was adjusted based on area covered by SGIWGM. Banning WWTP incidental recharge rate was adjusted from 2016 reported in the Recycled Water Study report down to 2,280 AFY to reflect the lower population of the simulation period)



Document Path: \\woodardcurran.net\shared\Projects\RMC\LA\0703 Banning\0703-001.01 SG IRWM Support\G. GIS\MXDs\Task 7 Modeling\GSFLOW Septics.mxd

Figure 37 – Location of Groundwater Monitoring Wells Used for Calibration of SGIWGM



Document Path: \\woodardcurran.net\shared\Projects\RMC\LA\0703 Banning\0703-001 01 SG IRWM Support\G. GIS\MXDs\Task 7 Modeling\GSFLOW 24 Monitoring wells2.mxd

Figure 38a - Hydrograph of Simulated and Observed Groundwater Elevations

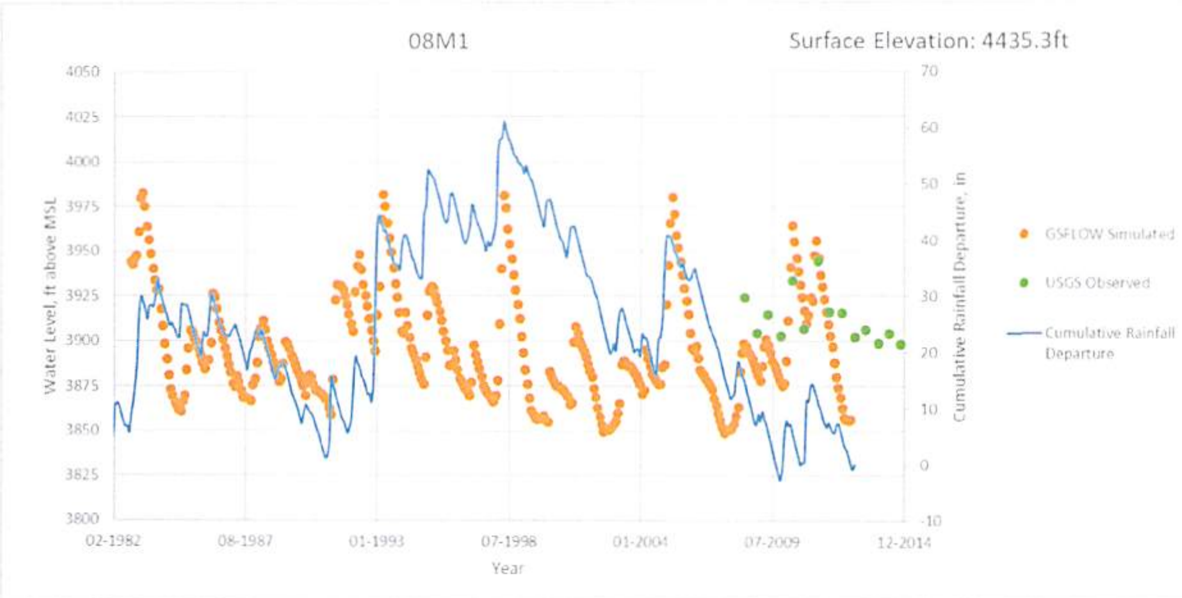


Figure 38b - Hydrograph of Simulated and Observed Groundwater Elevations

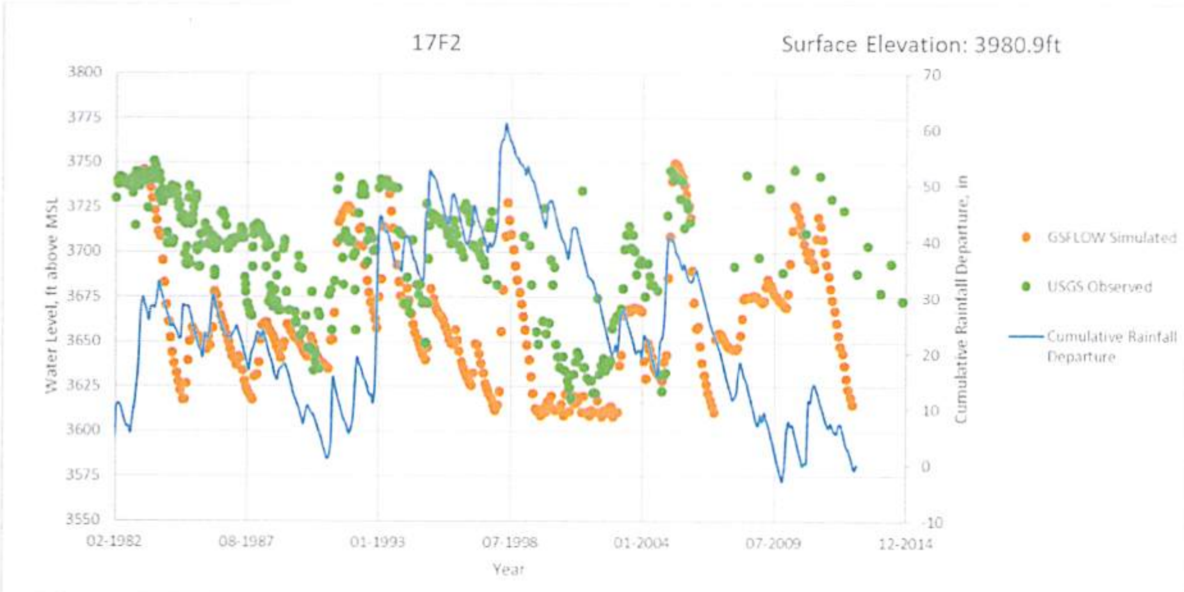


Figure 38c - Hydrograph of Simulated and Observed Groundwater Elevations

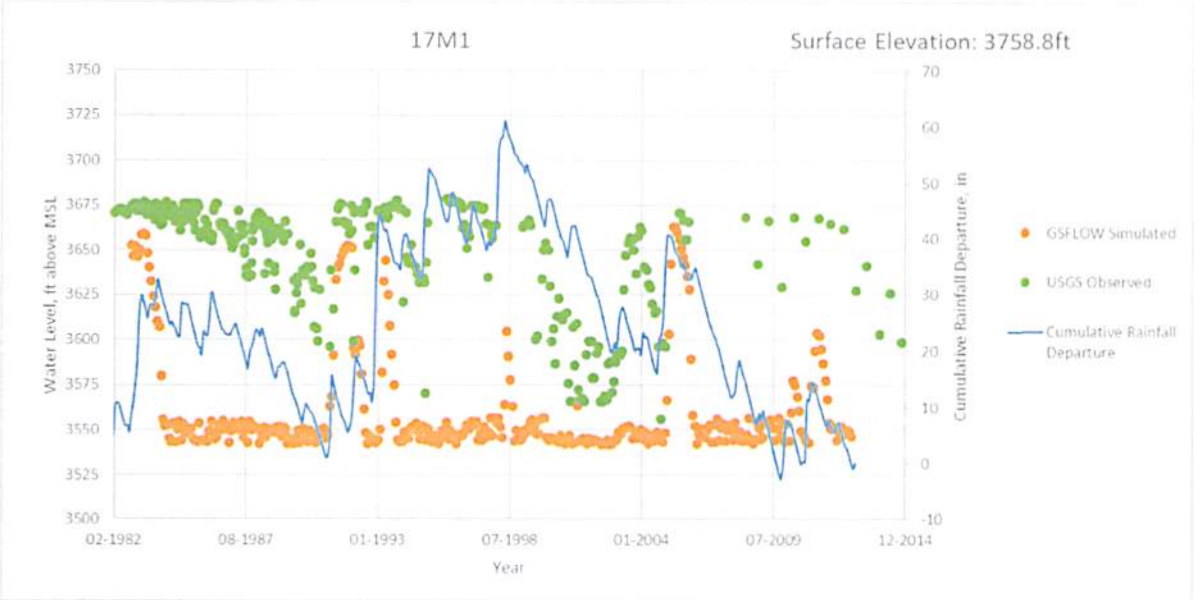


Figure 38d - Hydrograph of Simulated and Observed Groundwater Elevations

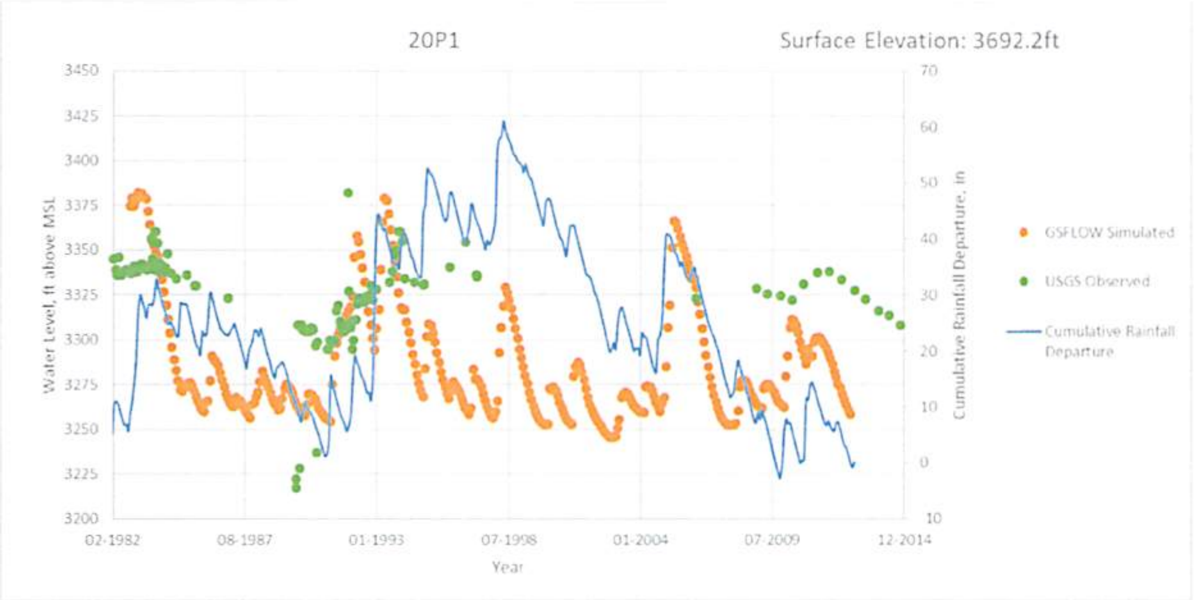


Figure 38e - Hydrograph of Simulated and Observed Groundwater Elevations

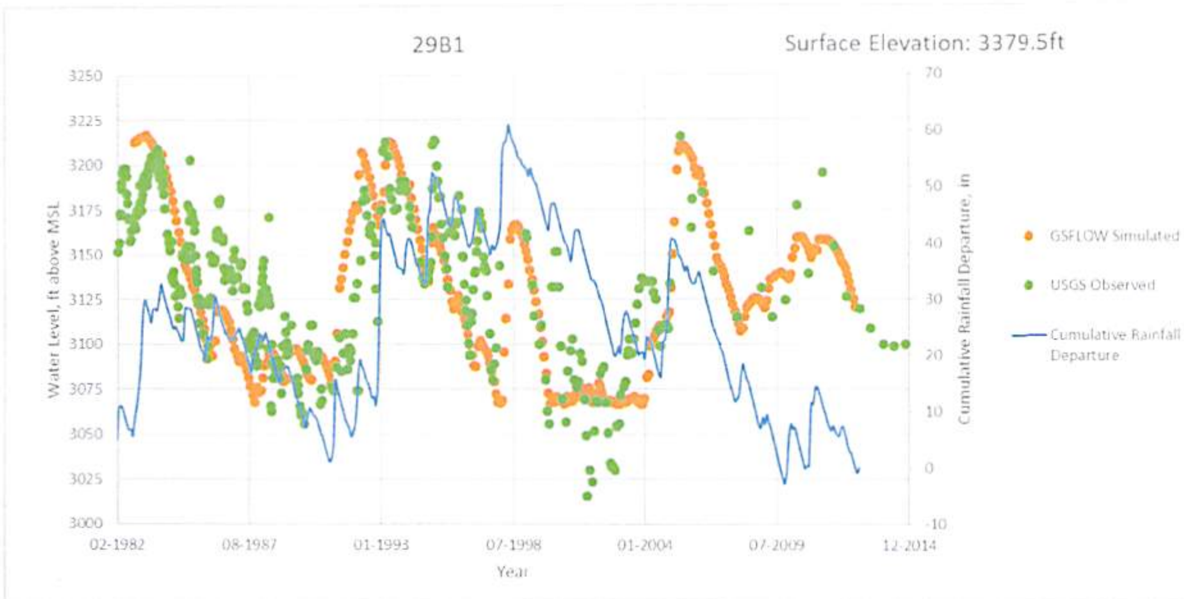


Figure 38f - Hydrograph of Simulated and Observed Groundwater Elevations

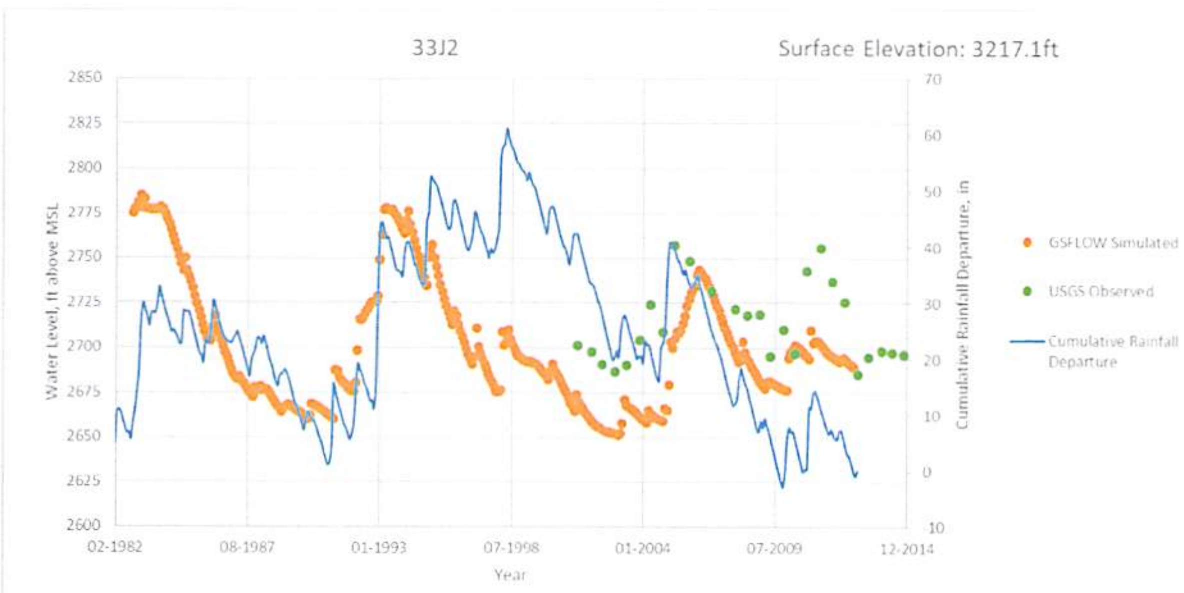


Figure 38g - Hydrograph of Simulated and Observed Groundwater Elevations

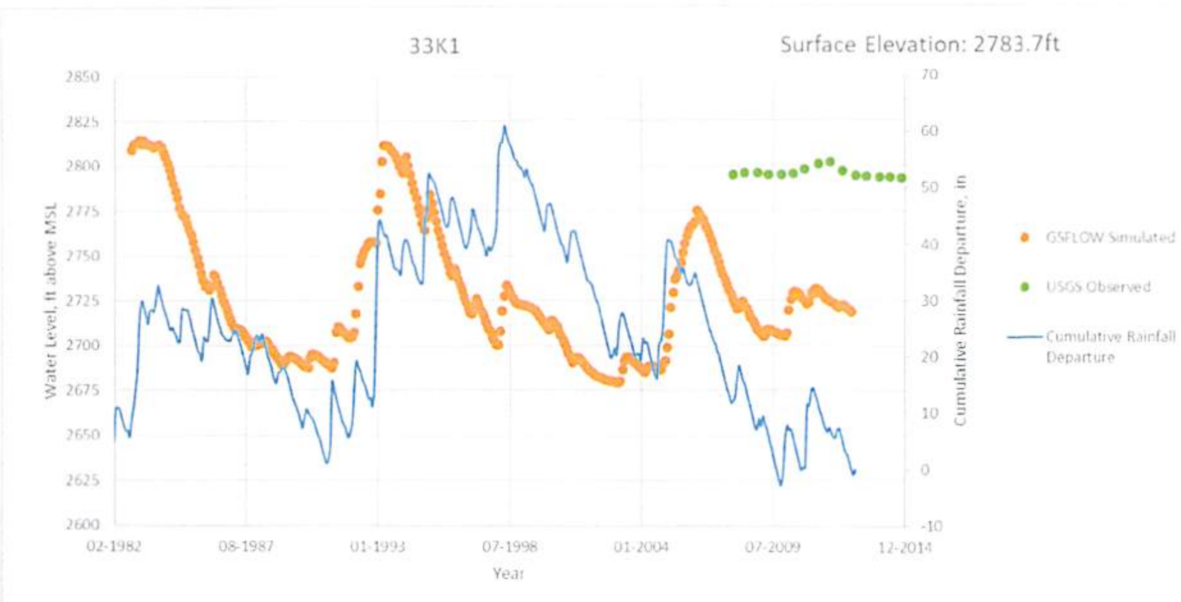


Figure 38h - Hydrograph of Simulated and Observed Groundwater Elevations

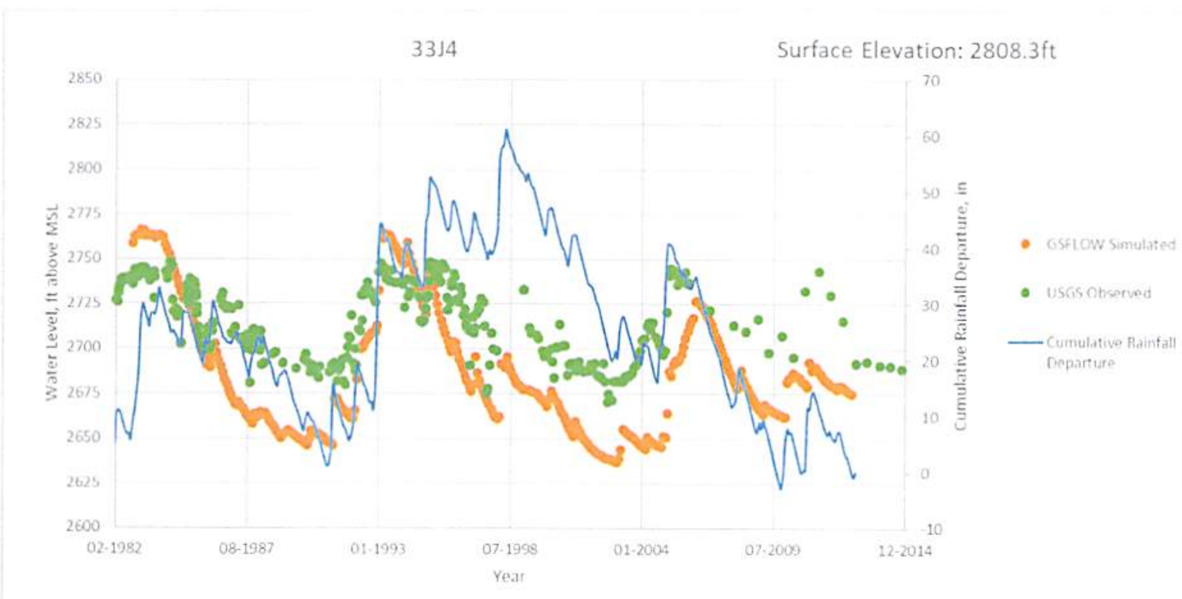


Figure 38i - Hydrograph of Simulated and Observed Groundwater Elevations

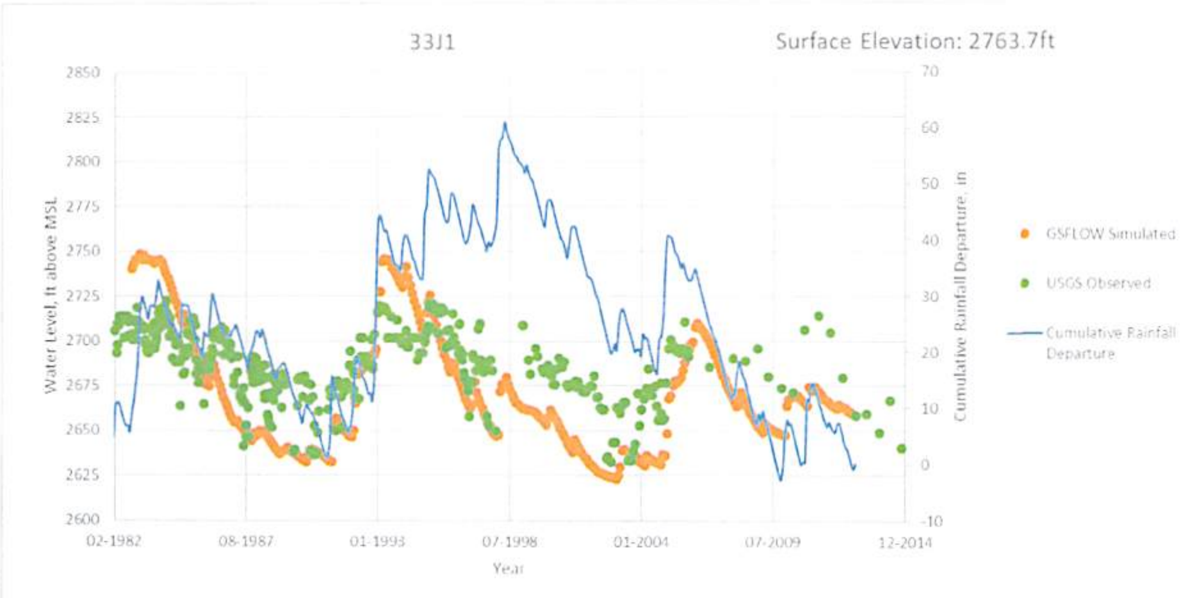


Figure 38j - Hydrograph of Simulated and Observed Groundwater Elevations

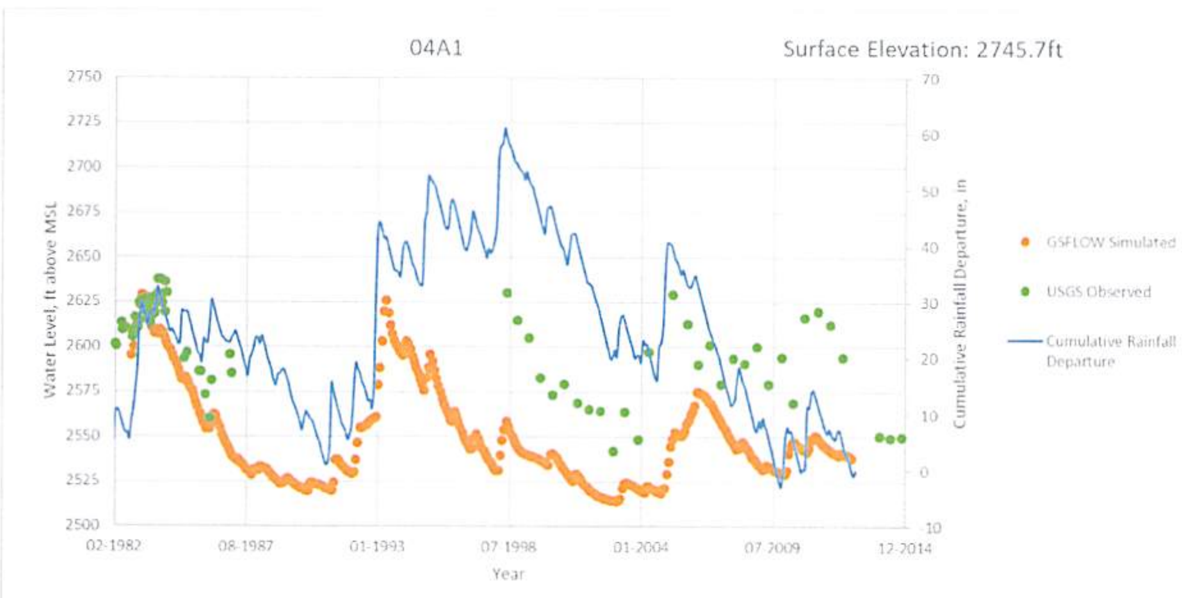


Figure 38k - Hydrograph of Simulated and Observed Groundwater Elevations

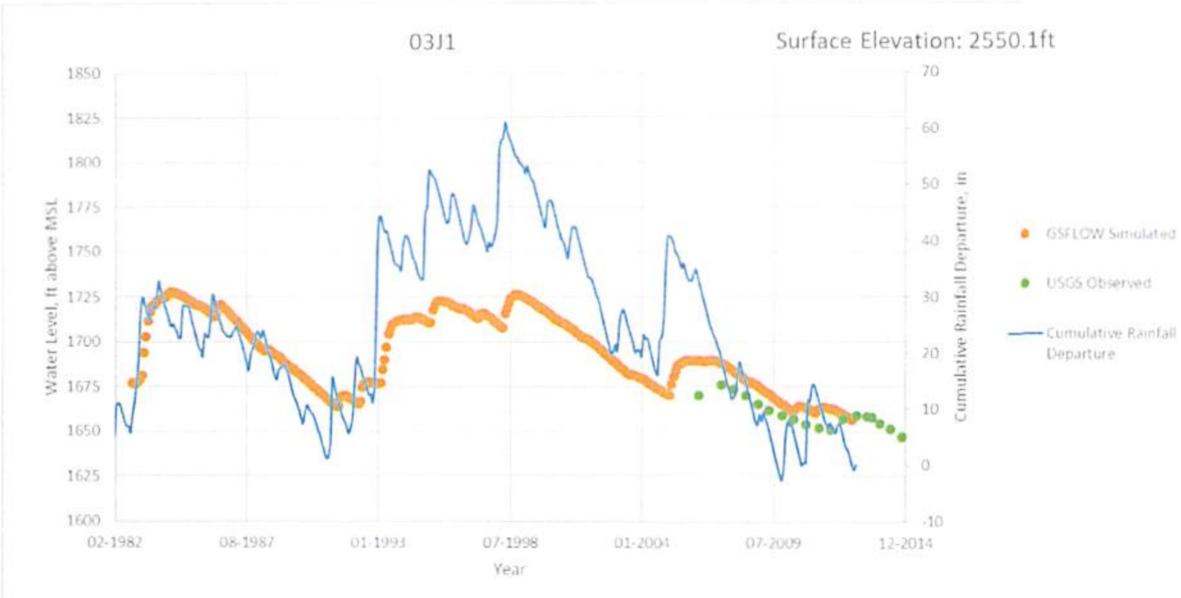


Figure 38l - Hydrograph of Simulated and Observed Groundwater Elevations

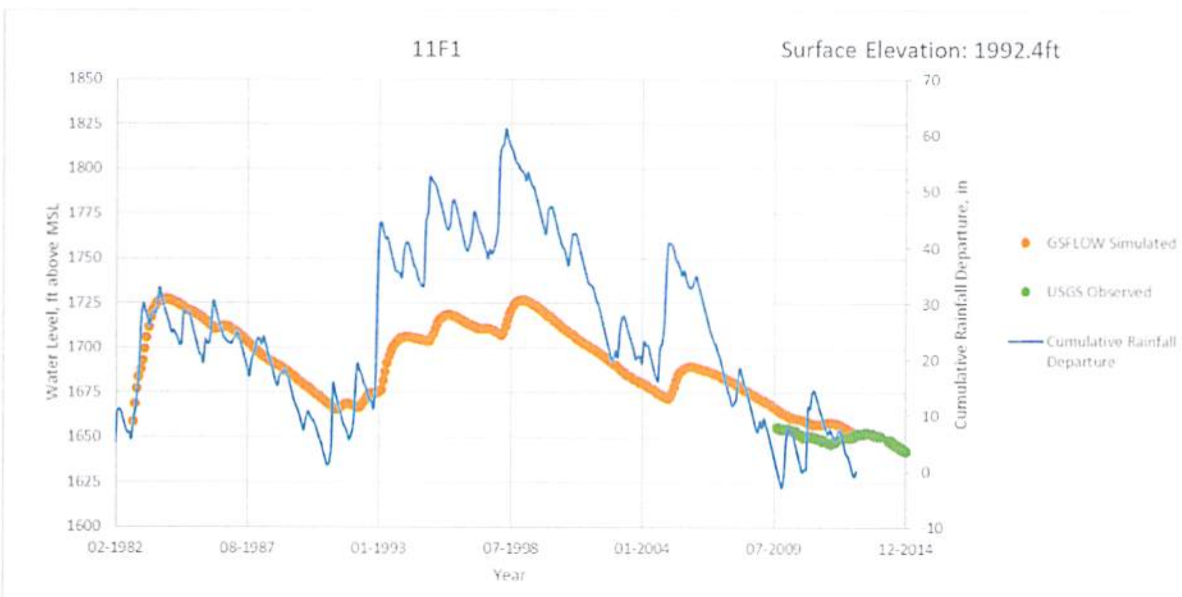


Figure 38m - Hydrograph of Simulated and Observed Groundwater Elevations

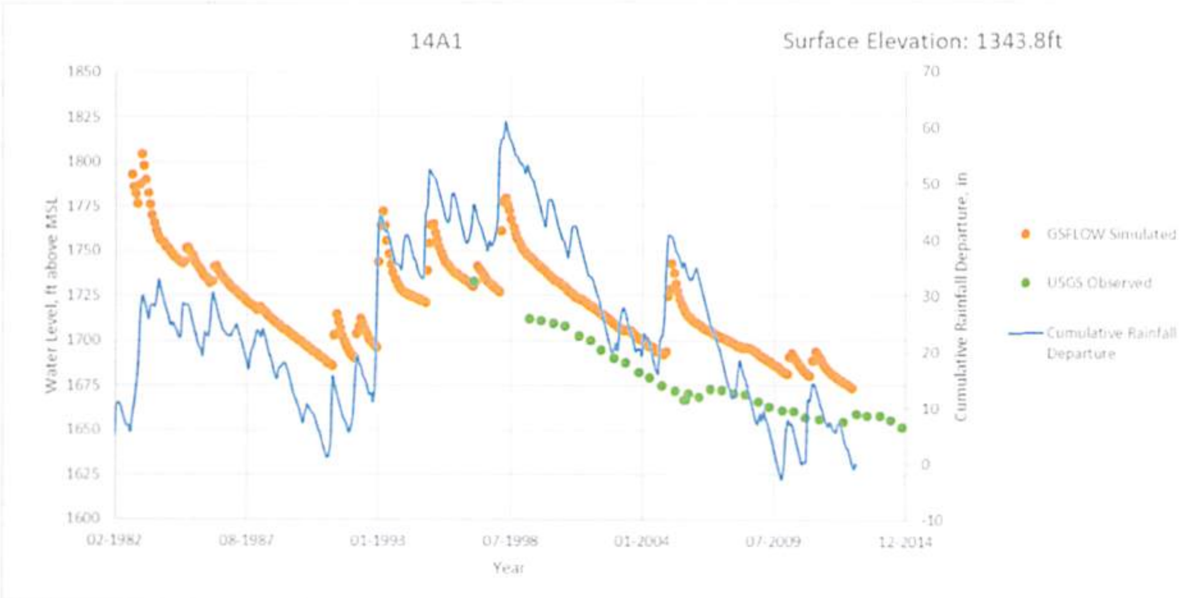


Figure 38n - Hydrograph of Simulated and Observed Groundwater Elevations

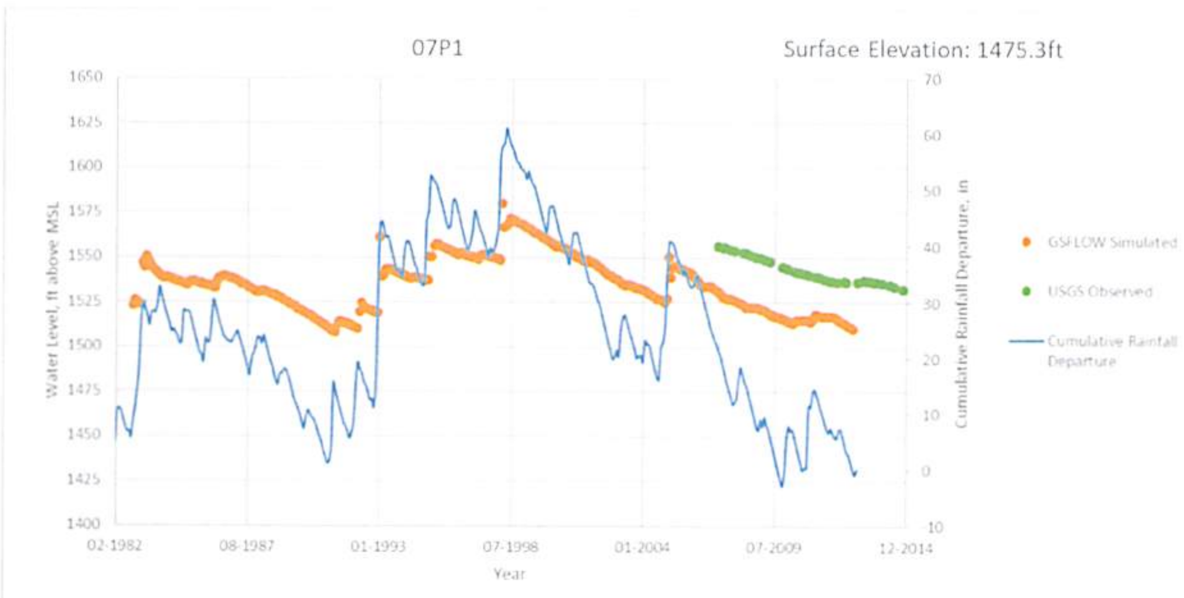


Figure 38o - Hydrograph of Simulated and Observed Groundwater Elevations

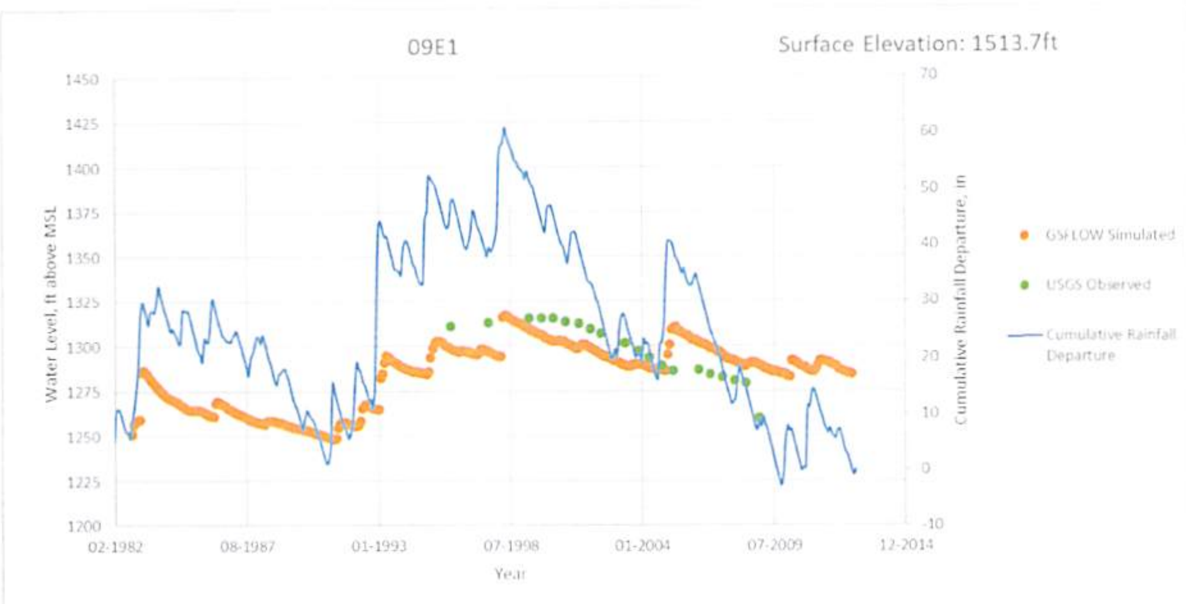


Figure 38p - Hydrograph of Simulated and Observed Groundwater Elevations

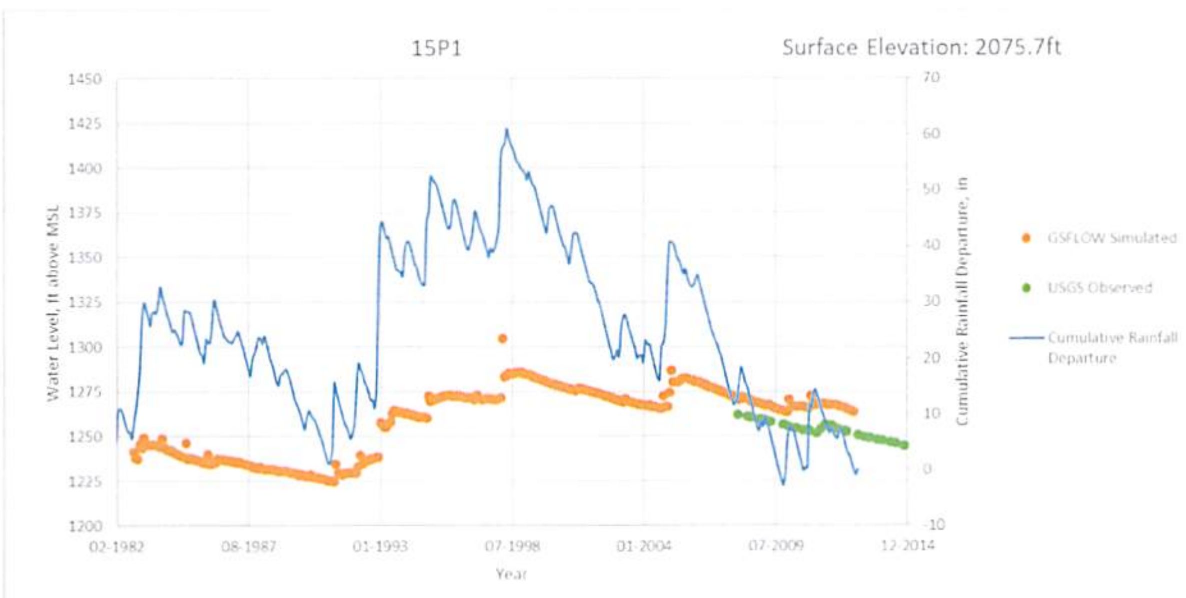


Figure 38q - Hydrograph of Simulated and Observed Groundwater Elevations

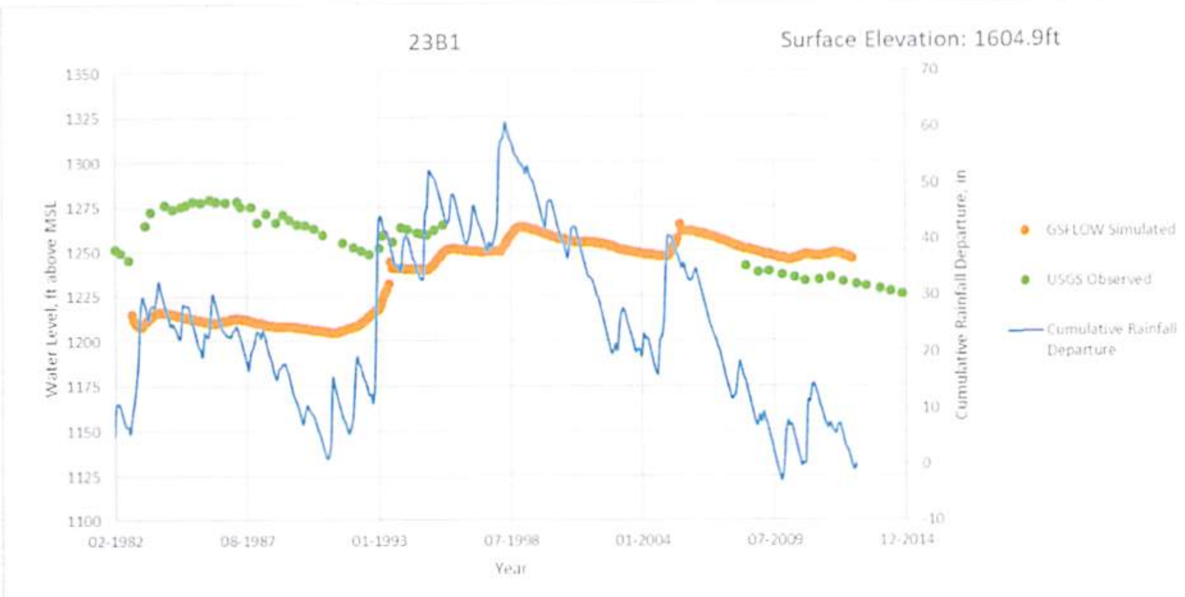


Figure 38r - Hydrograph of Simulated and Observed Groundwater Elevations

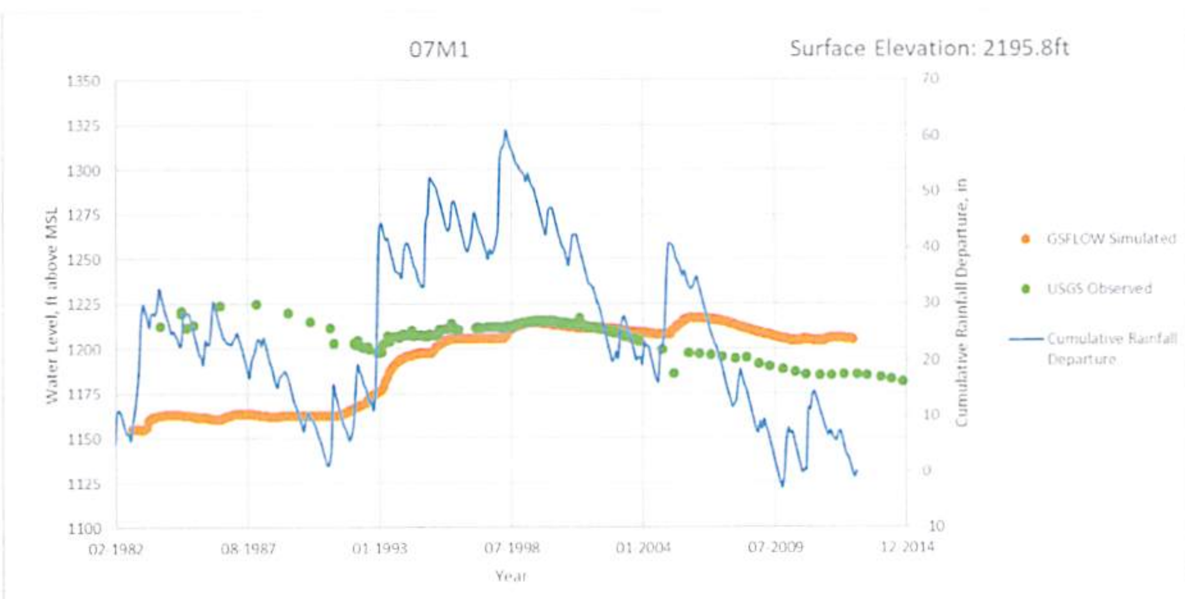


Figure 38s - Hydrograph of Simulated and Observed Groundwater Elevations

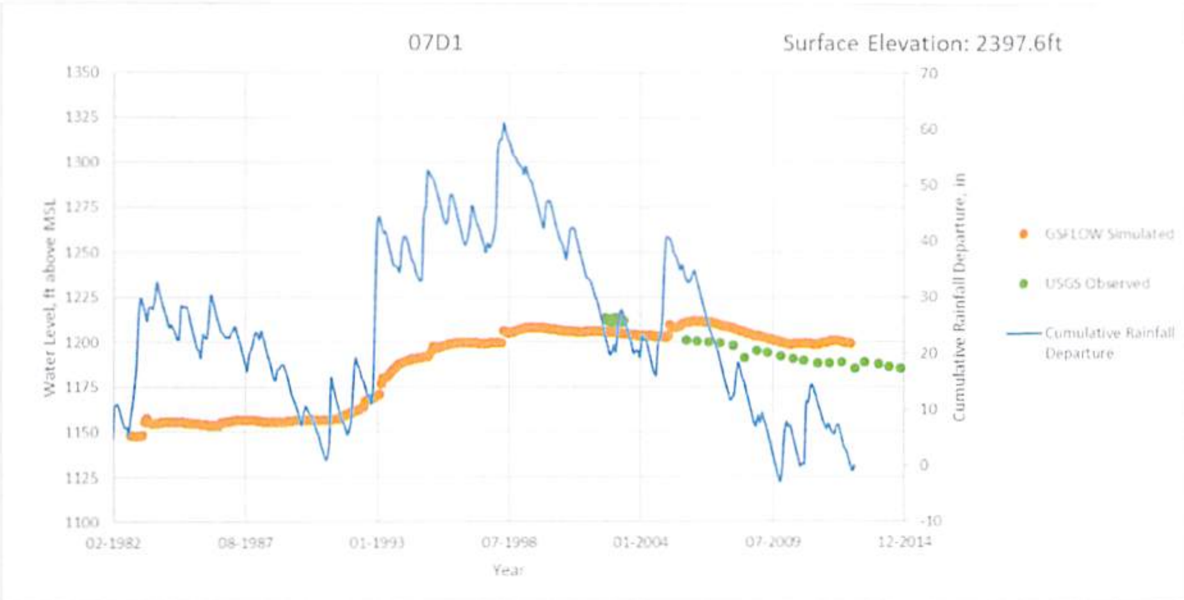


Figure 38t - Hydrograph of Simulated and Observed Groundwater Elevations

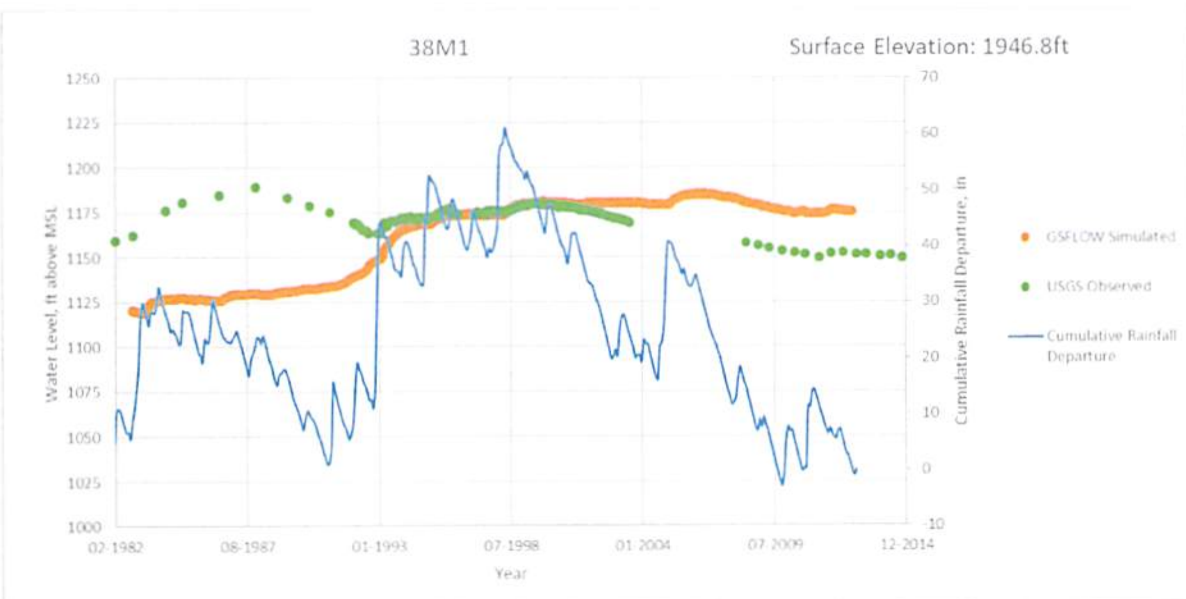


Figure 38u - Hydrograph of Simulated and Observed Groundwater Elevations

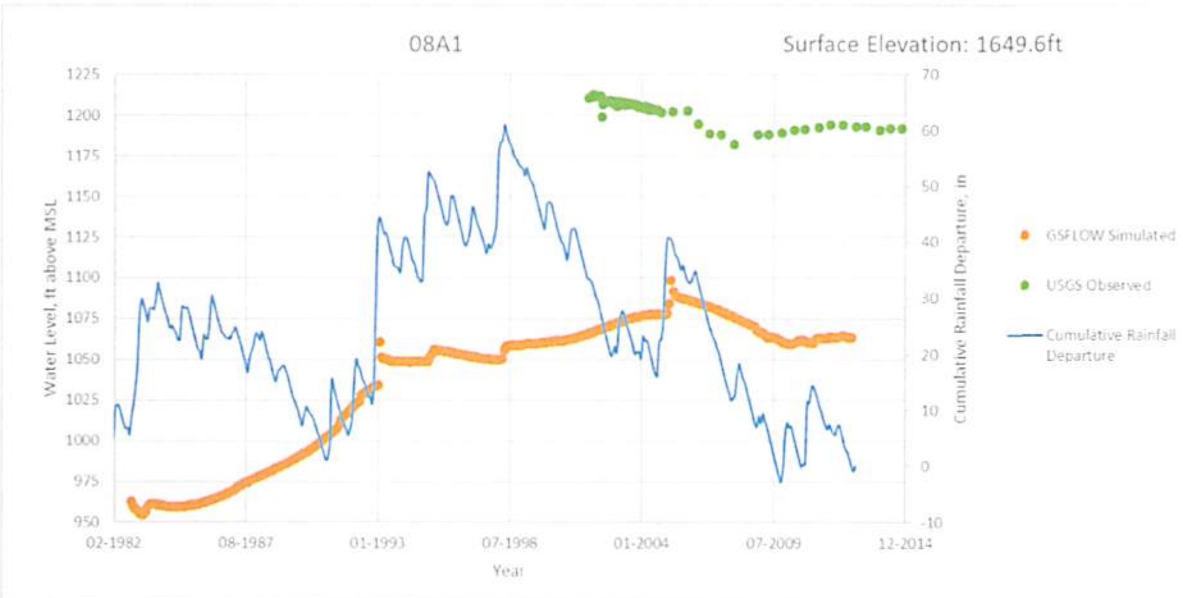


Exhibit C – Expansion of SGIGWM

San Gorgonio Integrated Watershed and Groundwater Model (SGIWGM)

Appendix A: Expansion of the SGIWGM

Prepared For: City of Banning and SGPWA

Prepared by: Benjamin Bass, Ph.D., EIT, Woodard & Curran

Reviewed by: Reza Namvar, Ph.D., PE; Mesut Cayar, Ph.D., Woodard & Curran

Date: December 3, 2018

Table of Contents

1. Introduction
2. Data Sources and Defining the SGIWGM Expansion Area
3. Updates to the SGIWGM Groundwater Model
    - 3.1. Fault Properties
    - 3.2 Aquifer Thickness
    - 3.3. Aquifer Parameters
    - 3.4. Initial Heads (Water Levels)
    - 3.5. Groundwater Production and Injection
    - 3.6. Septic Areas
4. Representation of Streamflow in the SGIWGM
5. SGIWGM Simulation Results
    - 5.1. General Results
    - 5.2. Simulated and Observed Water Levels
6. Expanded SGIWGM Calibration
7. References

1. Introduction

The existing San Gorgonio Integrated Watershed and Groundwater Model (SGIWGM) in the main TM covers the Cabazon and Banning Canyon subbasins of the San Gorgonio groundwater basin (**Figure 1**). While the San Gorgonio Pass Watershed Model (SGPWM) covers the entire San Gorgonio groundwater basin, the SGIWGM only cover the Cabazon and Banning Canyon subbasins. This appendix presents the work completed by Woodard & Curran to expand the SGIWGM to cover the remaining parts of the San Gorgonio Pass groundwater basin, which includes Banning and Banning Bench subbasins and Hathaway, Potrero, and Millard Canyons, in addition to a portion of the Beaumont basin.

2. Data Sources and SGIWGM Expansion Area

The SGPWM already covers the entire San Gorgonio groundwater basin. As a result, only the groundwater (MODFLOW) component of the SGIWGM required expansion. To represent the expansion area the following data were required:

i. Basin Boundaries and Location of Faults
ii. Aquifer Thickness (Layer Elevations)
iii. Aquifer Parameters
    a. Horizontal and Vertical Hydraulic Conductivity (K_h and K_v)
    b. Specific Yield (Sy)
    c. Specific Storage (SS)
iv. Initial Head (1983 water year water levels)
v. Pumping Wells and Recharge Locations and Rates
vi. Septic Areas

Figure 2 shows the coverage area of the primary data sources collected to guide the expansion of the groundwater model. Data collected includes a gravity survey (USGS Draft Study 2017) that estimates total aquifer thickness and was used to guide the development of the USGS Banning Canyon and Cabazon Groundwater Model (BC&CGM). This gravity survey was performed by USGS for most of the San Gorgonio Pass groundwater basin; however, data in the canyons are limited. A Banning and Beaumont groundwater model (BBGM) was developed by USGS (Rewis et al., 2006) using MODFLOW 96. Most data needed to update the Banning and Beaumont section of the SGIWGM is available from this study; however, differences between the BBGM and the SGIWGM groundwater model are outlined in **Table 1**.

Prior to expanding the groundwater model, faults in the study area were reviewed to determine if the expansion area had a geologic boundary. **Figure 3** shows USGS faults and faults as defined in the BBGM. The F4 and F5 faults of the BBGM shown in Beaumont, to the west of San Gorgonio Pass groundwater basin, were used to define the western boundary of the SGIWGM because they are non-leaky faults that serve as a no flow boundary condition. Faults 6 and 7 from the BBGM were defined in the SGIWGM as internal leaky barriers to flow. **Figure 4** demonstrates the existing SGIWGM groundwater model and the extent of the expansion area.

The simulation period of the original SGIWGM is 100 years (1913-2012). However, this 100-year run of the original SGIWGM required several days to complete and was impractical to complete to calibrate the model within the project schedule. To improve the run times, the original SGIWGM was modified to run for a 30-year (1983-2012) calibration period. The simulation period from October 1st, 1982 (water year 1983) to September 30th, 2012 (water year 2013) used in the main TM was not modified. To put the simulation period's rainfall and other atmospheric variables into perspective **Figure 5a and 5b** show annual averages of precipitation, air temperature, snowfall, and potential evapotranspiration in the SGPWM basin area. The average precipitation for the 100-year period from 1913 to 2012 is 19.5 inches/year and the 30-year period from 1983 to 2012 is 18.3 inches/year. This shows that the selected calibration period hydrology is adequately representative of the long-term hydrology of the model area.

3. Updates to the SGIWGM Groundwater Model

3.1 Fault Properties

Simulated faults and their hydraulic characteristics are shown in **Figure 6**. New faults (and their hydraulic conductivities) from the BBGM include faults 2,4, and 5. In addition to including faults from the BBGM, faults defined by USGS (U.S. Geological Survey and California Geological Survey, 2006) were used to guide the extension of existing faults in the original model into the expansion areas (i.e. faults 1, 3, 9, 10, 12). The same hydraulic characteristics were applied to the extended faults as the original faults they extend from. Faults that were added along the original models boundary include faults 6, 9, 10, and 12.

3.2 Aquifer Thickness

After defining the final extent of the SGIWGM expansion based on faults present in the study area, the model's aquifer thickness was defined as shown in **Figure 7**. A gravity survey completed by USGS (Draft Study 2017) was used to guide the aquifer thickness for the majority of the expansion area. For expansion areas beyond the extent of the gravity survey, aquifer thickness was extrapolated from the existing model. For the portion of Banning Canyon outside of the gravity survey, the same thickness of the existing SGIWGM was applied (150 ft.). For Potrero Canyon, a thickness of 500 ft. was applied across most of the canyon since the gravity survey showed a thickness of 500 ft. and the depth to bottom of the wells in the middle of the canyon is roughly 500 ft. For Millard and Hathaway canyons, only the upper aquifer or surficial deposits were represented in the SGIWGM groundwater model, similar to that for Banning Canyon, and their thickness was defined as 325 ft. This is true for Banning Bench as well where the gravity survey shows a greater thickness than that considered productive aquifer. The same thickness as Banning Canyon (150 ft.) was applied to Banning Bench based on estimates of saturated thickness of Banning Bench from a GEOSCIENCE study (2011).

In addition to defining total aquifer thickness (i.e. the elevation of the bottom of the aquifer defined by the gravity survey), the elevation of each model layer was defined in the expanded area by extrapolating from the existing model. Model cross-sections developed at the locations shown in **Figure 8** are shown in **Figures 9, 10, and 11.** For reference, the layers defined in the SGIWGM correspond to the lithology described in USGS Draft Study 2017, and includes Surficial Deposits (Holocene to Pleistocene, Layer 1), Younger Upper Sedimentary Deposits (Pleistocene, Layer 2), Younger Lower Sedimentary Deposits (Pleistocene, Layer 3), and Older Sedimentary deposits (Pleistocene to Pliocene, Layer 4).

3.3 Aquifer Parameters

Aquifer parameter zones were subsequently defined for each layer of the groundwater model. Each zone allows for the definition of unique aquifer parameters. The zones for each layer of the SGIWGM expanded groundwater model are shown in **Figures 12 to 15**, representing layers 1 through 4 respectively. Zones that are not defined in subsequent layers (i.e. defined in Layer 1, but not Layer 2) indicate subsequent aquifer layers are not existent or negligible in terms of aquifer productivity and thus not included.

The aquifer parameters defined include horizontal conductivity (K_h, ft/day), vertical conductivity (K_v, ft/day), specific yield (Sy, decimal fraction), and specific storage (SS, unitless). While these parameters were defined using best available information, the values can be modified during calibration in the future phases of the SGIWGM development. **Figure 16** demonstrates the variation in horizontal hydraulic conductivity throughout the top layer of the SGIWGM. **Table 2** summarizes the aquifer parameters that were defined for each layer. Aquifer parameters for Banning and Beaumont were defined based on information from the BBGM (Rewis et al., 2006); however, since the BBGM only represents the most productive first 2 layers, parameters for the subsequent, less productive, layers (layers 3 and 4) were set equal to values defined for Cabazon. Aquifer parameters for South Banning were set equal to the values defined for Banning. Lacking additional information, parameters for Banning Bench were set equal to the average of the values for Banning and Banning Canyon given its location between these two areas. Values in the expanded portions of Cabazon and Banning Canyon, were set equal to the neighboring areas of the existing model. Hydraulic conductivity for Potrero Canyon was defined based on a USGS study (Pimentel and Christensen, 2002), and specific storage and yield were set equal to the values defined for Banning Canyon. Finally, lacking further information, the hydraulic conductivity for Hathaway and Millard Canyons was set equal to the average of Banning Canyon and Potrero Canyon, while the specific storage and yield were set equal to the values defined for Banning Canyon.

3.4 Initial Heads (Water Levels)

The initial head, which must be set for each grid cell for the start date of the model simulation (1983 water year, henceforth simply referred to as 1983), was defined based on the BBGM for Banning and Beaumont and by extrapolating head values from the existing model into other expansion areas. The only well with observed data near 1983 in the expansion area is located in Potrero Canyon and was used to define head in Potrero Canyon. To obtain head from the BBGM, the model was simulated for its entire 1926-2003 simulation period and head values at the start of 1983 water year were obtained and projected from BBGM's grid onto SGIWGM's grid for the Banning and Beaumont expansion areas. Based on USGS (Rewis et al., 2006), heads simulated in the BBGM had a root mean square error of 14.4 ft compared to observed water levels. This was considered the most reliable source of information for initial head due to lack of observed water levels in the study area for 1983. The defined initial head for the expanded model is shown in **Figure 17**.

3.5 Groundwater Production and Injection

The production and injection rates are defined on a daily time-step for the SGIWGM groundwater model. Average rates in acre-feet per year (AFY) for the group of wells shown in **Figure 18** is based on years when wells were active during the simulation period of the model (1983-2013). The production wells for Banning were obtained from the City of Banning on a monthly time-step from 1990-1997, 1999-2013 and on an annual time-step from a groundwater modeling study completed by Thomas Harder & Co. (2015) for 1983-1990, 1998. Production wells were also obtained (on annual time-step) for Beaumont from Thomas Harder & Co. (2015) for the years 1983-2012, with 2013 values set equal to 2012. Annual injection rates for the Noble Creek Recharge Facility located in Beaumont, which began operating in 2006, was additionally obtained from Thomas Harder & Co. (2015). Production wells for Banning Bench were obtained on an annual time-step from Morongo Band of Mission Indian's Water Department.

Production and injection well data from Thomas Harder & Co. (2015) were on an annual time-step, so wells in Banning (for years 1983-1990 and 1998), Beaumont (for entire simulation period), and Banning Bench (a single well for entire simulation period) were distributed to monthly values based on the historical percentage of pumpage by month based on data from the City of Banning wells from 2004 to 2013 shown in **Figure 19**. The injection site's annual rates were distributed uniformly across each month. Finally, daily values for pumping and injection were obtained by dividing monthly rates by the number of days within a given month.

Finally, as shown in **Figure 18**, flow from west of the modeled area was represented by introducing 4,350 AFY at a constant rate along the western boundary of the model in Beaumont. This is an estimated rate and will be adjusted during the model calibration. If flows are found to occur out of the modeled area during calibration, due to increases in head from the Noble Creek recharge facility, the positive value of 4,350 AFY can be made negative at any of the grid cells defined as boundary inflow along the western boundary of the model.

3.6 Septic Areas

In addition to production wells and injection and recharge facilities, recharge from septic areas was added to the SGIWGM for the expanded area as shown in **Figure 20**. Septic areas were identified from the BBGM for Banning and Beaumont. For Banning Bench, developed/residential areas were identified using satellite imagery. Recharge rates from septic grid cells (500x500 ft) in Banning and Beaumont were set to 10.7 AFY, which is the average recharge for the original model's septic areas. For Banning Bench, recharge at septic grid cells (500x500 ft) was set equal to 0.68 AFY which was defined so recharge from all of the septic areas in Banning Bench equaled the minimum annual production rates for Banning Bench of 5 AFY. The total recharge for each septic area and incidental recharge from wastewater treatment plants is shown in **Figure 21**.

4. Representation of Streamflow in the SGIWGM

After updating the groundwater component of the SGIWGM, the stream locations in the surface water model represented by the groundwater model were updated. The streams represent the original SGIWGM streams in addition to any tributaries or upstream segments in the new expansion area. These new streams were then used to update the number of streams and segments in the Precipitation-Runoff Modeling System (PRMS) and the stream locations in the flow cascade file and groundwater cascade file of PRMS. The updated flow cascade route for the surface water model is shown in **Figure 22**. The PRMS was then simulated to obtain surface runoff to the stream network at the inflow (upstream) locations of the main reaches and tributaries of the groundwater model (MODFLOW). Daily time-step data from PRMS was defined at the inflow locations of MODFLOW shown in **Figure 23**, and then the groundwater model simulation was used to represent subsequent surface-groundwater interactions as described in Section 4 of the main report. **Table 3** lists the average inflow rates for each stream inflow location.

In addition to stream inflows, PRMS simulated recharge from precipitation was added to the groundwater model as discussed in section the main TM.

5. SGIWGM Simulation Results

5.1 General Results

The expanded SGIWGM simulation time was 2.5 hours. The simulation was performed as a standalone groundwater model (MODFLOW) that utilized PRMS streamflow results rather than running the models with Groundwater and Surface Water FLOW (GSFLOW) which requires significantly longer runtimes as discussed in Section 4.3 of the main TM. **Figure 24** displays simulated heads near the beginning of the simulation on October 31st, 1982 (1983 water year), near the middle of the simulation on October 31st, 1998, and at the end of the simulation on September 30th, 2012.

5.2 Simulated and Observed Water Levels

Figure 24 shows the locations of monitoring wells that were selected for comparison of simulated and observed water levels. These hydrographs show the current uncalibrated status of the expanded SGIWGM model. The calibration of the SGIWGM in the next phase of the model expansion will result in an improved match of simulated and observed water levels. Comparisons of the SGIWGM simulated heads and observed water levels at the selected wells are shown in **Figures 26a-26t** for the original model area and **Figures 27a-27j** for the expanded model area. Figures in the original model area include the original SGIWGM's simulated results for comparison against the expanded SGIWGM.

6. Expanded SGIWGM Calibration

The calibration status of the expanded SGIWGM has changed as a result of the expansion of the model into the new areas in the Cabazon groundwater basin and eastern Beaumont. Expanded SGIWGM calibration will need to be improved to its original calibration status before the model could be used for development of water budgets and analysis of water resources projects and management actions. The calibration process of the expanded SGIWGM would be similar to the original calibration of the model specified in Subsection 4.4 of the main TM. In summary, the calibration of the expanded SGIWGM would consist of the following:

- Streamflow Calibration – Very limited measured stream flow data is available for the San Gorgonio Pass area. Thus, in addition to comparing the simulated and limited observed stream flows, the expanded SGIWGM stream flows will be compared to the INFILv3 model stream flows. INFILv3 model is a published USGS model and its simulated stream flows will be used as reference for SGIWGM stream flow calibration.
- Stream-Aquifer Interaction – Groundwater elevations are very sensitive to stream flows and stream-aquifer interaction processes in the San Gorgonio Pass groundwater basin. Special attention will be given to values and distribution of streambed conductance and vertical hydraulic conductivity of the unsaturated zone beneath the streams to simulate the aquifer response to short duration and high flow rate stream flows in the model area.
- Groundwater Elevation Calibration – Aquifer parameters such as hydraulic conductivity, storage parameters, and seepage from streams as well as conductance of various faults in the model area will be adjusted to simulate groundwater elevations that are adequately close to the observed water levels. Seasonal variations and long-term trends of groundwater elevations in the model area will be matched.
- Groundwater Outflow to Coachella Basin – Groundwater outflow to the Coachella Basin at the eastern boundary of the SGIWGM is an important part of the water resources management in the model area. USGS will be installing up to three monitoring wells at the eastern boundary of the groundwater basin to monitor and quantify the groundwater outflow through the eastern boundary of the basin. Limited groundwater level data from USGS investigation may become available during the model calibration. Timing of this data will be beyond the calibration period of 1983-2012 but it will be used to qualitatively improve the estimation of the groundwater flow at the eastern boundary of the model.
- Sensitivity Analysis – Numerous aquifer and stream parameters are estimated in the SGIWGM. A sensitivity analysis will be conducted to evaluate the effectiveness of the model parameters and identify the major model parameters for simulation of the groundwater and surface water flows in the model area. Sensitivity analysis may be based on automated methods such as Parameter Estimation (PEST) or other industry standard methods.

- Parameters Update – The expanded SGIWGM has numerous zones for aquifer properties and parameters. During model calibration these parameter zones will be evaluated and if necessary new parameter zones with new aquifer parameter values will be defined. These new zone may include the northern section of Cabazon separated by faults and other areas of the model.
- Data Gaps – During the calibration process, some areas of the model may be identified where model performance during and after calibration is poorer than other areas. The reason for poor calibration status is often due to a poorly defined conceptual model of the area or lack of sufficient data. Such areas will be identified and recommended for further data collection efforts.
- Additional Monitoring Wells - The location of proposed well monitoring sites on the east end of the SGIWGM are shown in **Figure 24**. Each well site will have three to five monitoring wells. While these sites will start to record water levels in 2019, which is beyond the simulation period of the SGIWGM, the observed water levels will be compared to the simulated hydrographs. Adjustments to model parameters will be made, if necessary, to ensure trends in simulated hydrographs agree with trends in observed water levels. The simulated hydrographs at these well locations are shown in **Figures 28a-28c**.

7. References

Everett, R.R and Christensen, A.H. (USGS Draft Study, 2017). Geology, Groundwater Hydrology, and Geochemistry of the Cabazon and Banning Storage Units, San Gorgonio Pass Area, Riverside County, California.

GEOSCIENCE (2011). Maximum Perennial Yield Estimates for the Banning and Cabazon Storage Units, and Available Water Supply from the Beaumont Basin. Prepared for City of Banning.

Rewis, D.L., Christensen, A.H., Matti, J.C., Hevesi, J.A., Nishikawa, T., and Martin, P. (2006). Geology, Ground-Water Hydrology, Geochemistry, and Ground-Water simulation of the Beaumont and Banning Storage Units, San Gorgonio Pass Area, Riverside County, California. USGS Scientific Investigation Report 2006-5026.

Thomas Harder & Co. (2015). Beaumont Basin Watermaster: 2013 Reevaluation of the Beaumont Basin Safe Yield.

U.S. Geological Survey California Geological Survey, 2006. Quaternary fault and fold database for the United States, accessed 9/15/2018, from USGS web site: http//earthquake.usgs.gov/hazards/qfaults/.

Table 1: Major Differences Between BBGM and Groundwater Component of SGIWGM

	Banning and Beaumont Groundwater Model (USGS 2006)	Groundwater Component of SGIWGM
Software	MODFLOW 96	MODFLOW-NWT
# of Layers	2	4
Cell Size	1000x1000 ft	492x492 ft (150x150 m)
Simulation Period	1926-2003	1983-2013 (Water Years)
Time-Step	Monthly	Daily

Table 2: Aquifer Parameters defined for each Layer

Aquifer Parameter	Layer 1								
Zone	10	11	12	13	14	15	16	17	18
Region	Banning Canyon	Cabazon	Potrero Canyon	Hathaway Canyon	Millard Canyon	Banning	South Banning	Banning Bench	Beaumont
Kh (ft/day)	32.8	98.4	8.9	20.8	20.8	10.0	10.0	21.4	30.0
Kv (ft/day)	32.8	16.4	8.9	20.8	20.8	0.1	0.1	16.5	0.3
Sy	0.06	0.3	0.06	0.06	0.06	0.05	0.05	0.055	0.05
SS	0.00001								

Aquifer Parameter	Layer 2								
Zone	31	32	33	34	35	36	37	38	39
Region	SE Banning	West Cabazon	Cabazon	SE Cabazon	NE Cabazon	Potrero Canyon	Banning	South Banning	Beaumont
Kh (ft/day)	1.5	12.8	50.8	60.4	5.2	12.8	2.0	2.0	2.0
Kv (ft/day)	44.1	65.6	65.6	44.1	65.6	65.6	0.02	0.02	0.02
Sy	0.04	0.1	0.053	0.2	0.15	0.1	0.06	0.06	0.06
SS	0.0001								

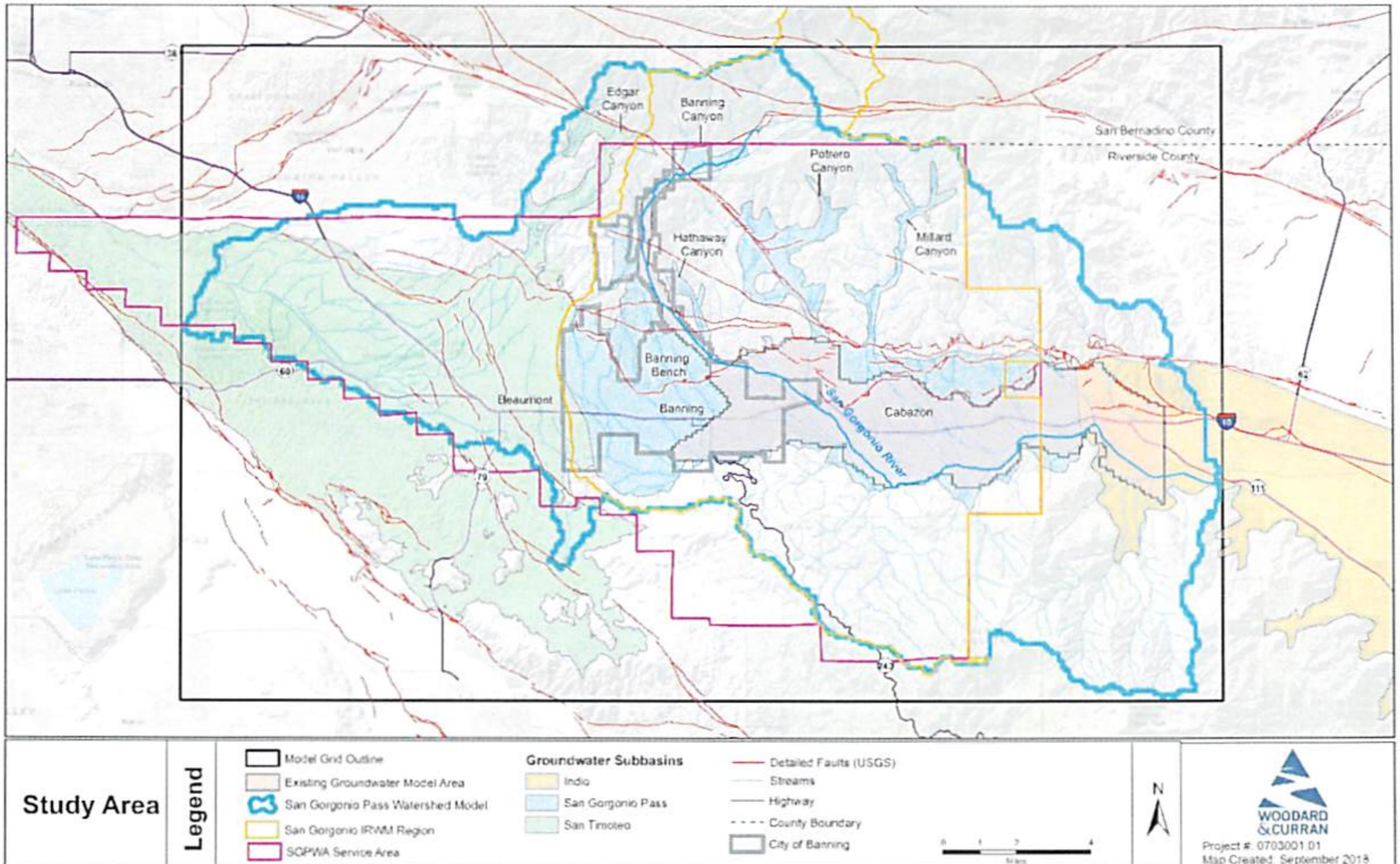
Aquifer Parameter	Layer 3						
Zone	4	41	42	43	44	45	46
Region	East Cabazon	SE Banning	West Cabazon	Cabazon	Banning	South Banning	Beaumont
Kh (ft/day)	0.03	17.4	6.1	49.2	0.06	0.06	0.06
Kv (ft/day)	0.3	6.5	20.3	0.04	0.005	0.005	0.005
Sy	0.068						
SS	0.00000009						

Aquifer Parameter	Layer 4	
Zone	5	52
Region	Cabazon	Banning/Beaumont
Kh (ft/day)	0.06	0.06
Kv (ft/day)	0.005	0.005
Sy	0.068	
SS	0.0001	

Table 3: Average Annual Streamflows for SGIWGM

Inflow Location Name	Inflow Location	Average (AFY) for Simulation Period (1983-2013)	Inflow Location Name	Inflow Location	Average (AFY) for Simulation Period (1983-2013)
	1	181	Potrero Canyon	56	606
	2	45		57	41
Wallace/Noble Creek	3	1890	Potrero Canyon	58	294
	4	1557		59	7
	5	26		60	14
	6	169		61	493
	7	102	Millard Canyon	62	38
	8	19	Millard Canyon	63	39
	9	18	Brown Creek	64	4574
Smith Creek	10	483	Millard Canyon	65	140
	11	24	Millard Canyon	66	288
	12	32		68	5
	13	61		70	118
	14	32	Millard Canyon	71	227
	15	32	Millard Canyon	73	86
Montgomery Creek	16	46	Millard Canyon	74	795
Smith Creek	17	32	Millard Canyon	75	263
Banning Bench	18	35		77	99
Banning Bench	19	24		79	19
Hathaway Creek	20	369	Millard Canyon	80	135
	21	22	Millard Canyon	81	70
	23	69		82	19
Banning Canyon	25	1412		83	362
Hathaway Tributary	28	151		84	13
	29	35		85	36
Banning Canyon	32	108		88	66
Hathaway Tributary	33	77		90	8
	35	29	Jenson Creek	92	1418
	36	6		95	14
Banning Canyon	37	257		96	7
	38	15		97	14
Banning Canyon	39	2128		100	17
Banning Canyon	41	436		103	322
	43	351		105	1147
	44	1675		106	9
	45	46		107	61
Potrero Canyon	46	123	Stubbe Canyon	109	12
	48	34		110	35
	49	17		114	4
	50	14		116	4
	51	31		117	332
Potrero Canyon	52	139	Cottonwood Canyon	118	680
Potrero Canyon	53	138	Snow Creek	120	173
Potrero Canyon	54	116	Falls Creek	121	5520
	55	14		123	4
Total			31,248 AFY		

Figure 1: Study Area



Document Path: \\woodardcurran.net\shared\Projects\RMC\LA\0703 Banning\0703-001.01 SG IRWM Support\G. GIS\MXDs\Task 7 Modeling\Ben Model Updates\For_Figures_Modify_Sparingly\1_Ben_GSFLOW Model Area Updates_4.mxd

Figure 2: Data Available for Updating Groundwater Model

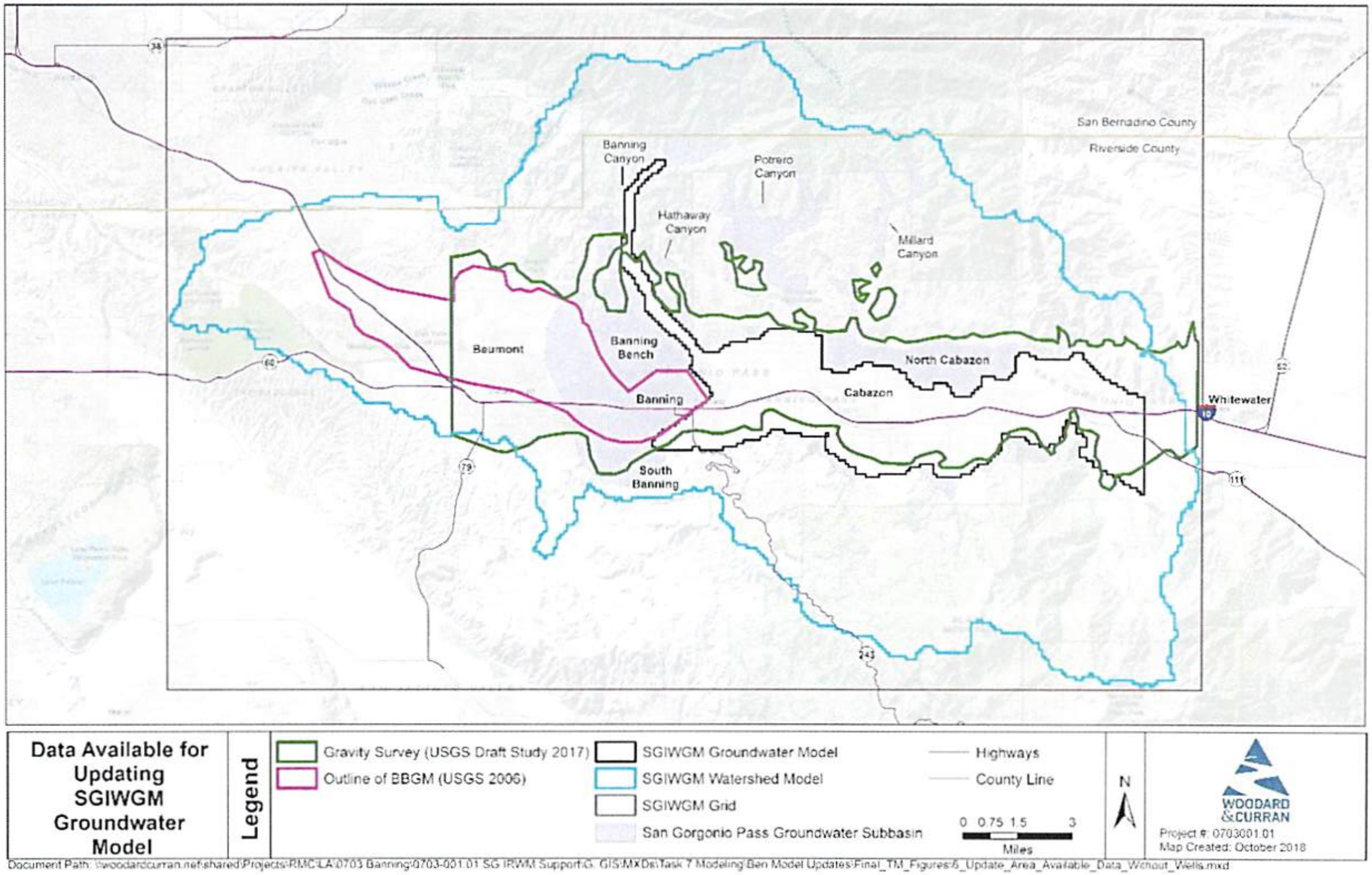
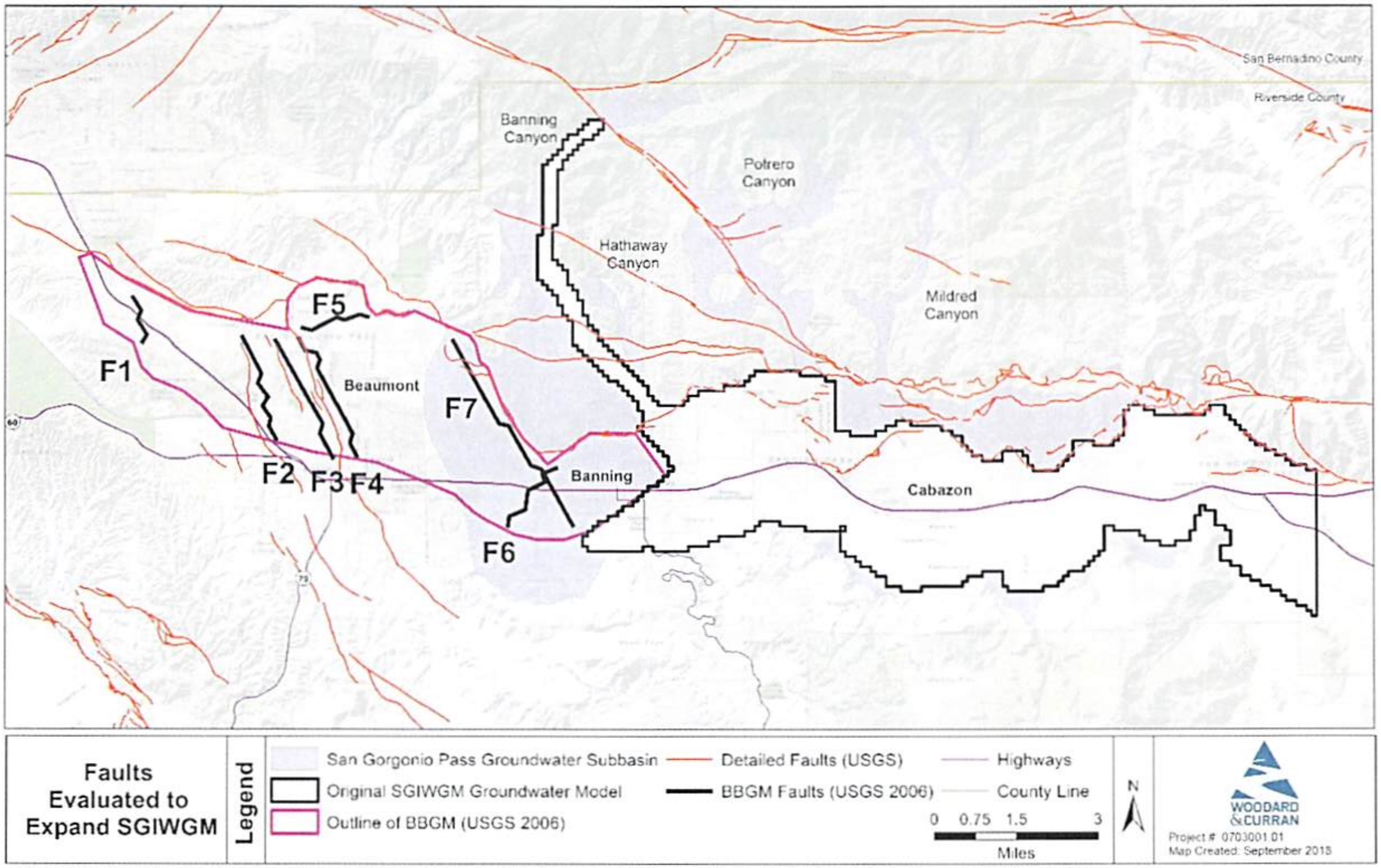


Figure 3: Faults Evaluated to Define Extent of Model Expansion



Document Path: \\woodardcurran.net\shared\Projects\RMC\LA\0703 Banning\0703-001.01 SG IRWM Support\G. GIS\MXDs\Task 7 Modeling\Ben Model Updates\Final_TM_Figures\10_USGS_and_BBGM_Faults.mxd

Figure 4: Expansion Area Based on Fault Boundary

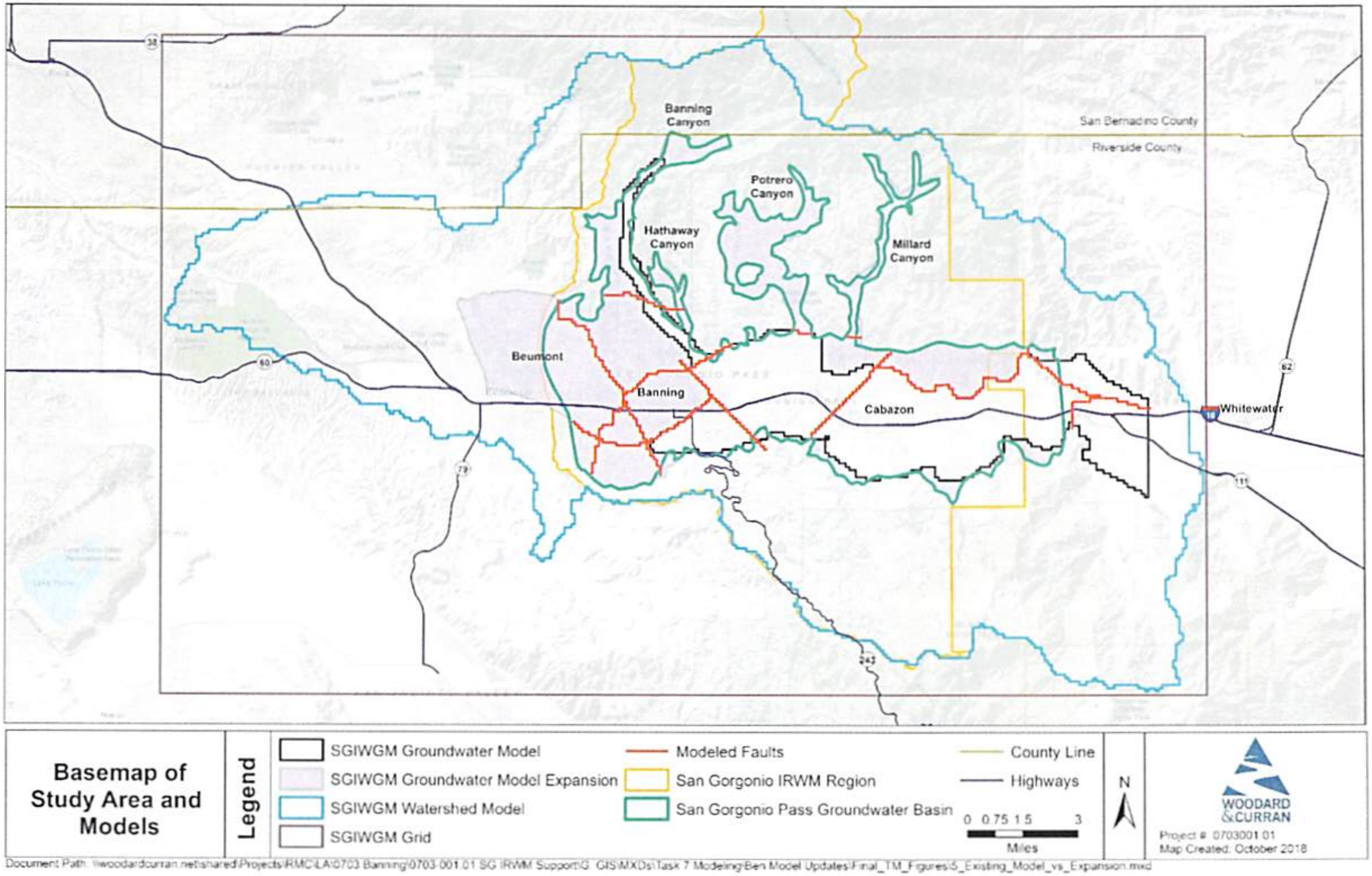


Figure 5a: Historical Atmospheric Record (Source Rewis et al. 2006)

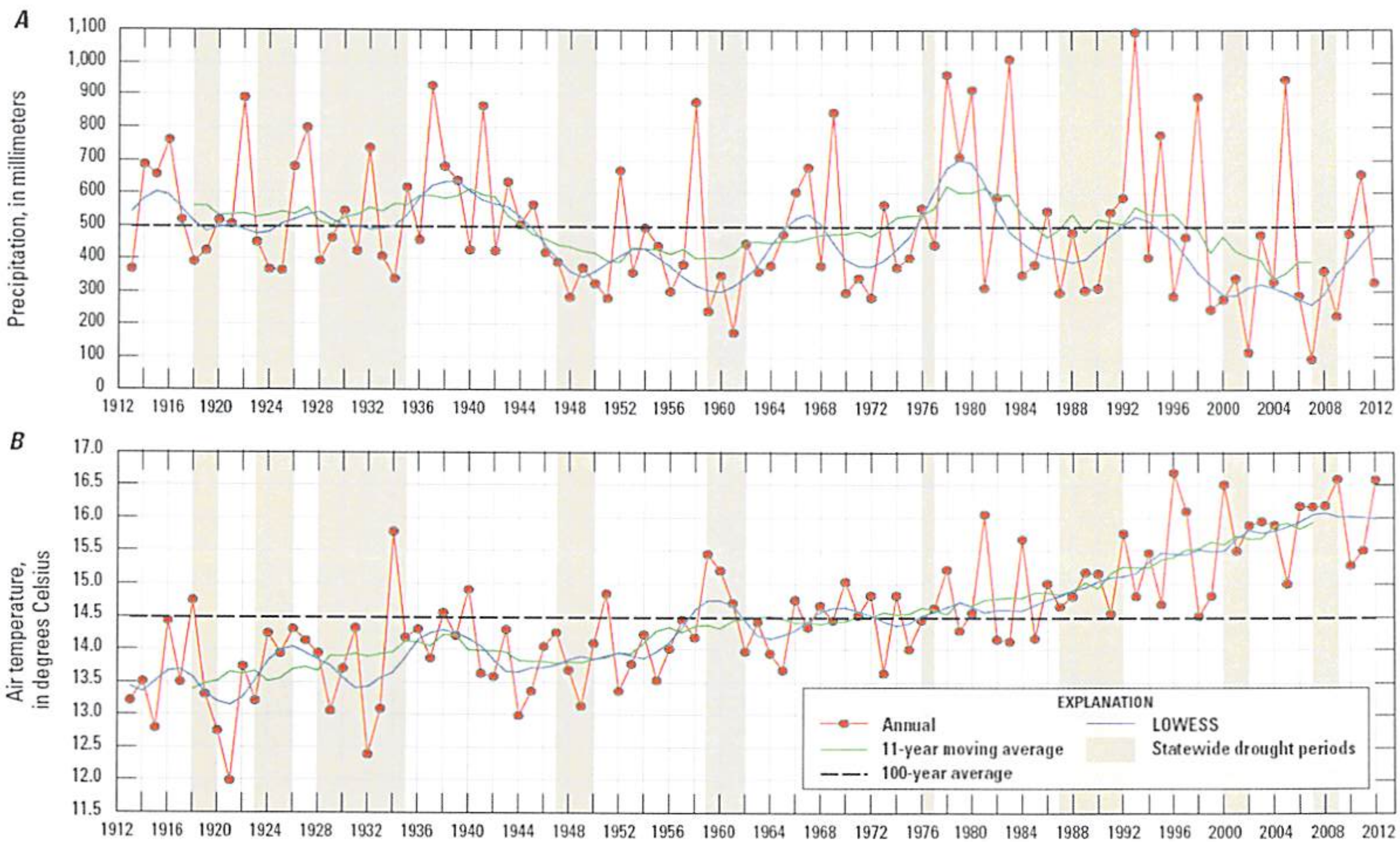


Figure 5b: Historical Atmospheric Record (Source Rewis et al. 2006)

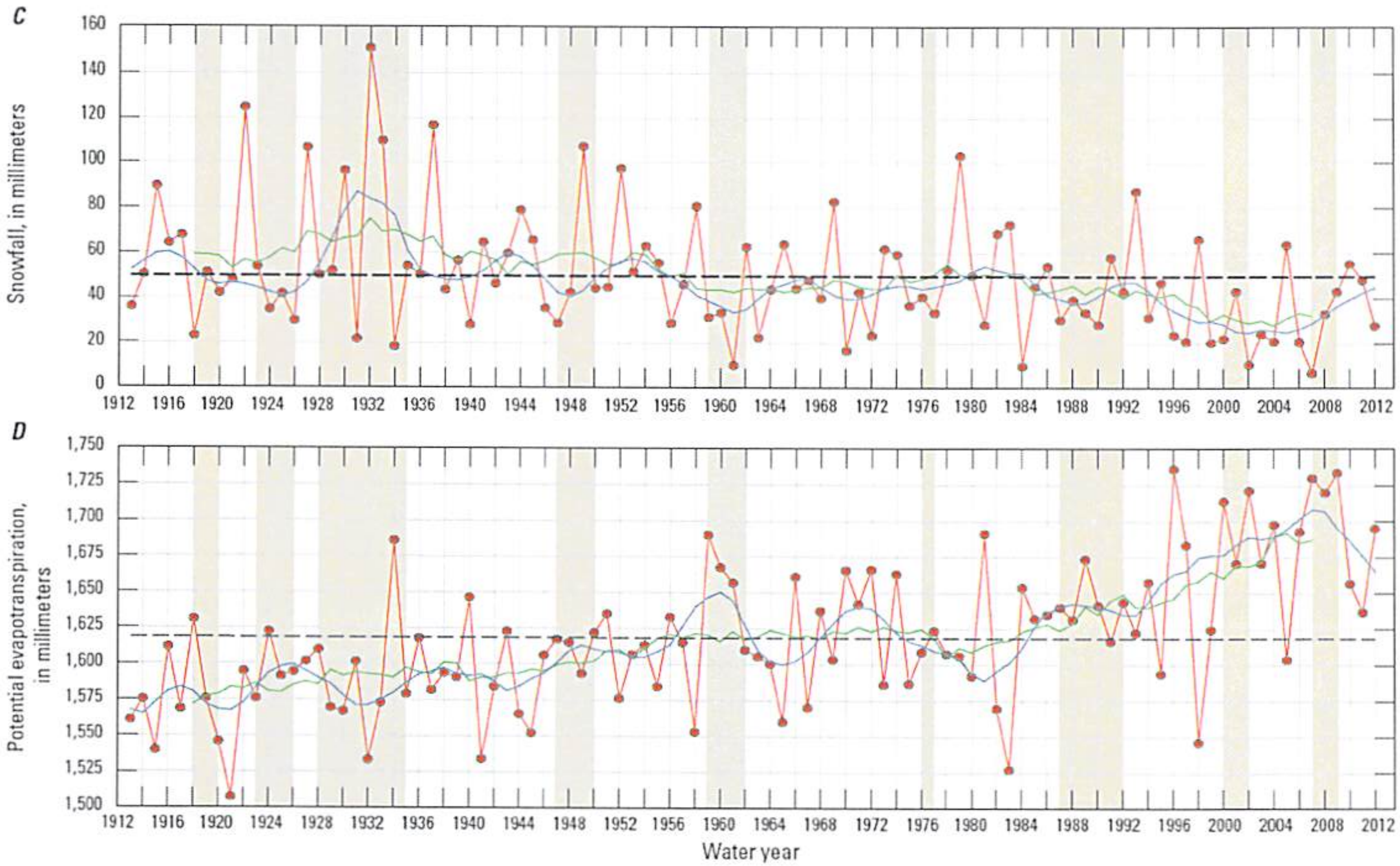
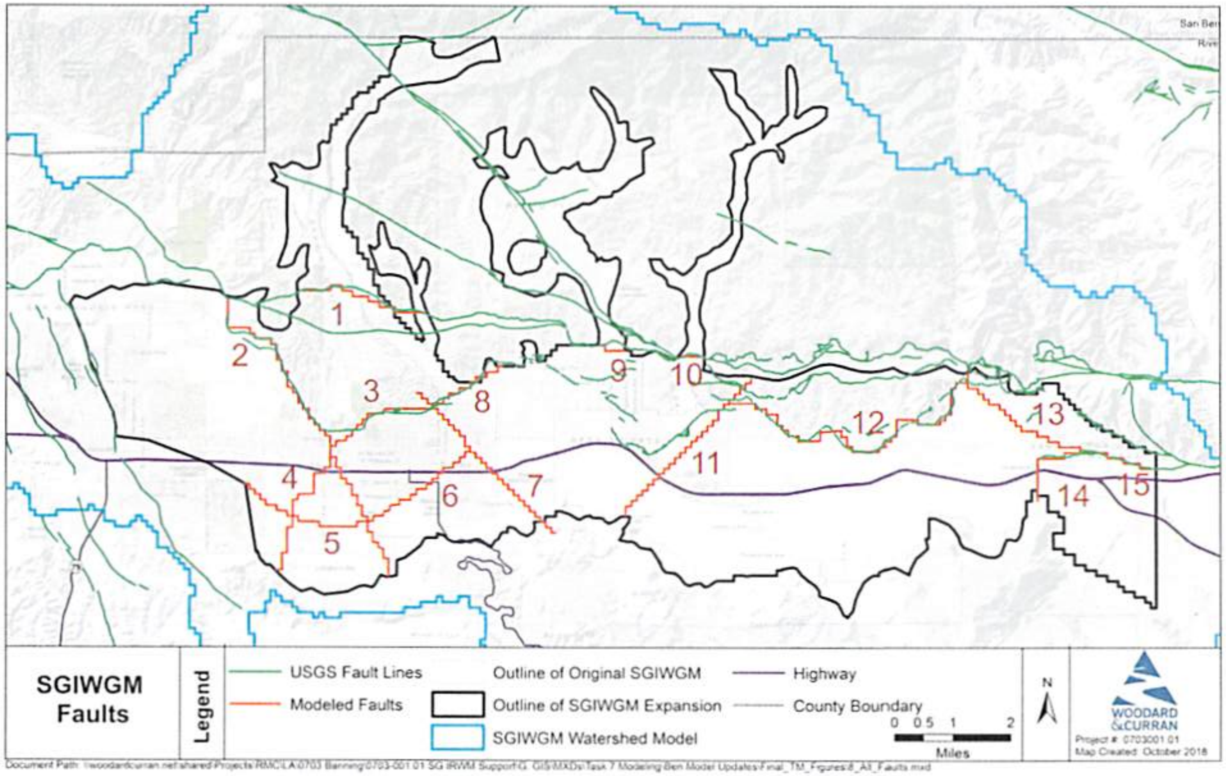


Figure 6: Fault Properties



Fault Number	Hydraulic Conductivity (ft/d)
1	3.00E-03
2	6.00E-04
3	2.00E-03
4	7.00E-04
5	6.00E-04
6	6.00E-04
7	2.00E-03
8	2.00E-03
9	3.00E-03
10	3.00E-03
11	5.91E-04
12	1.71E-02
13	1.71E-02
14	1.53E-05
15	3.41E-01

Figure 7: Total Aquifer Thickness for SGIWGM Groundwater Model

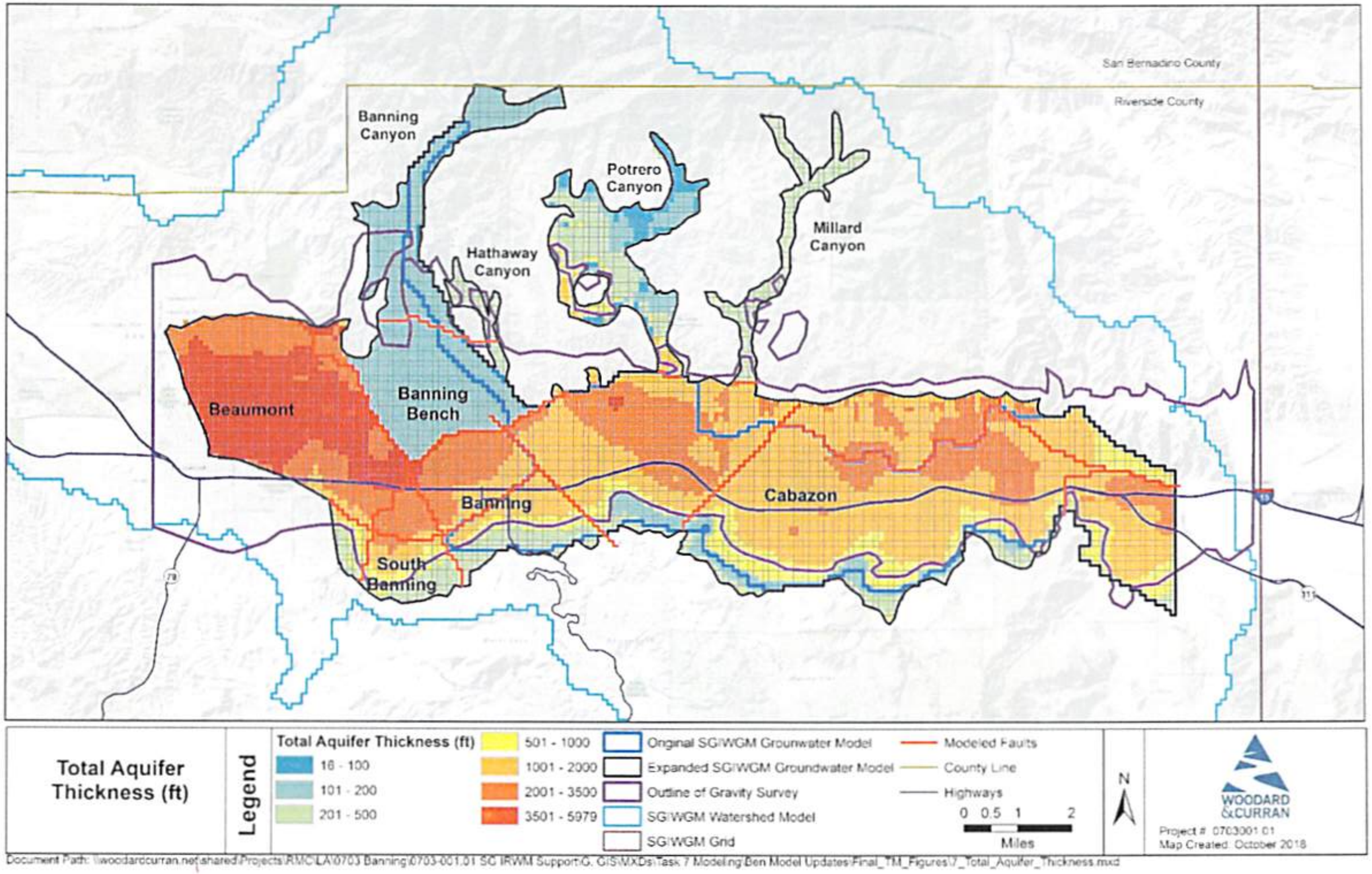


Figure 8: Location of Cross-Sections

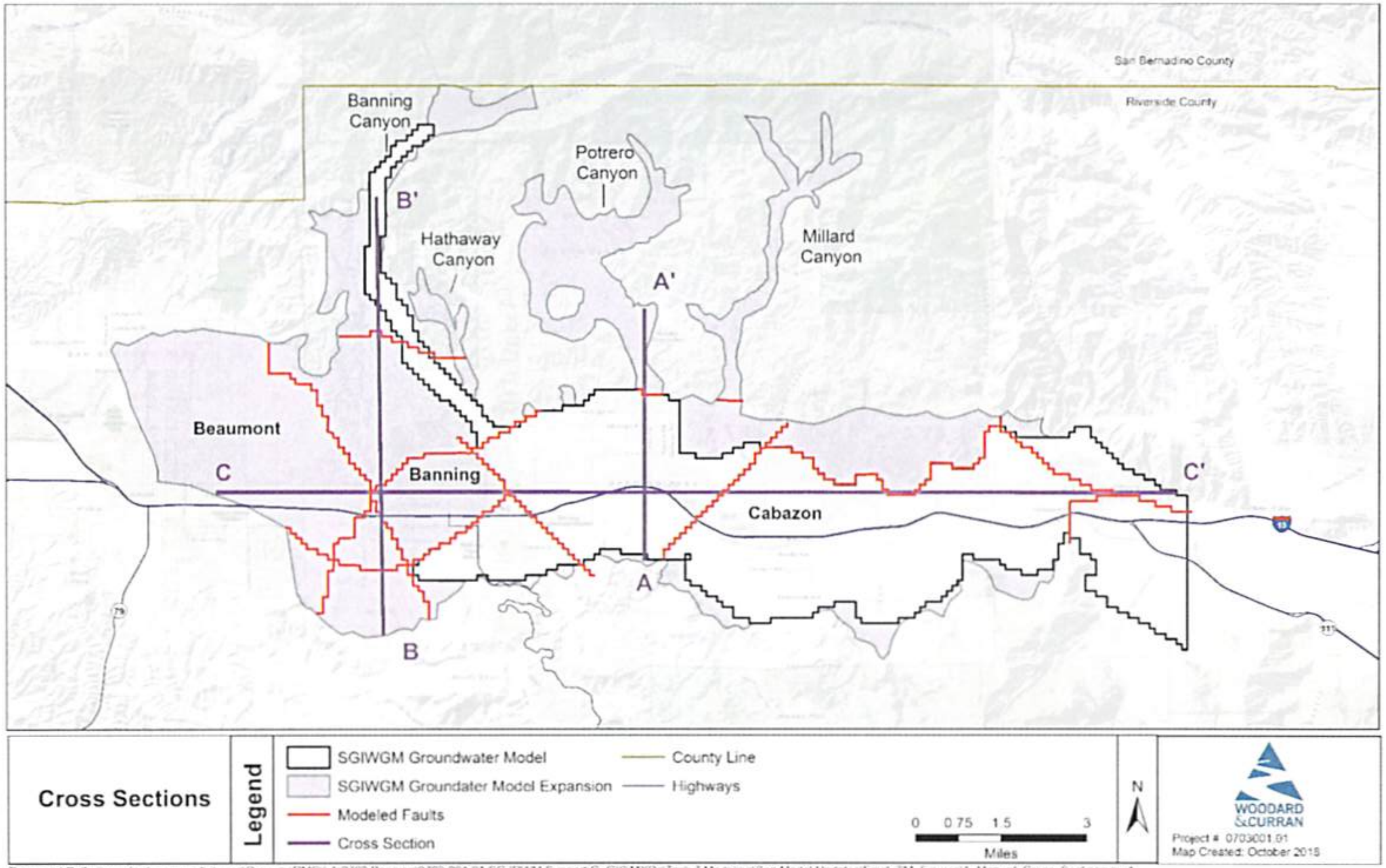


Figure 9: Cross-Section A-A' (Cabazon to Potrero Canyon, S-N)

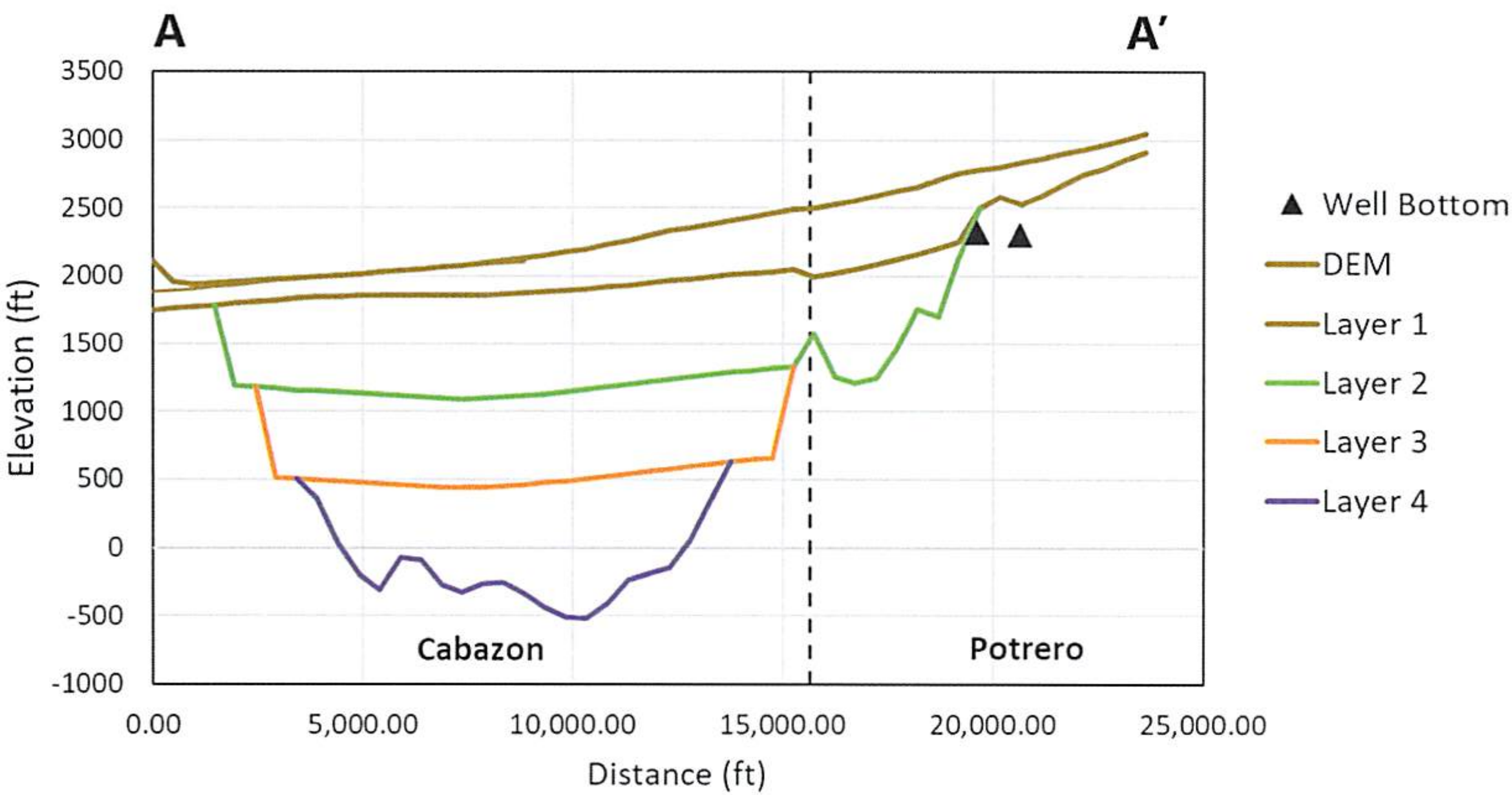


Figure 10: Cross-Section B-B' (Banning to Banning Bench/Canyon, S-N)

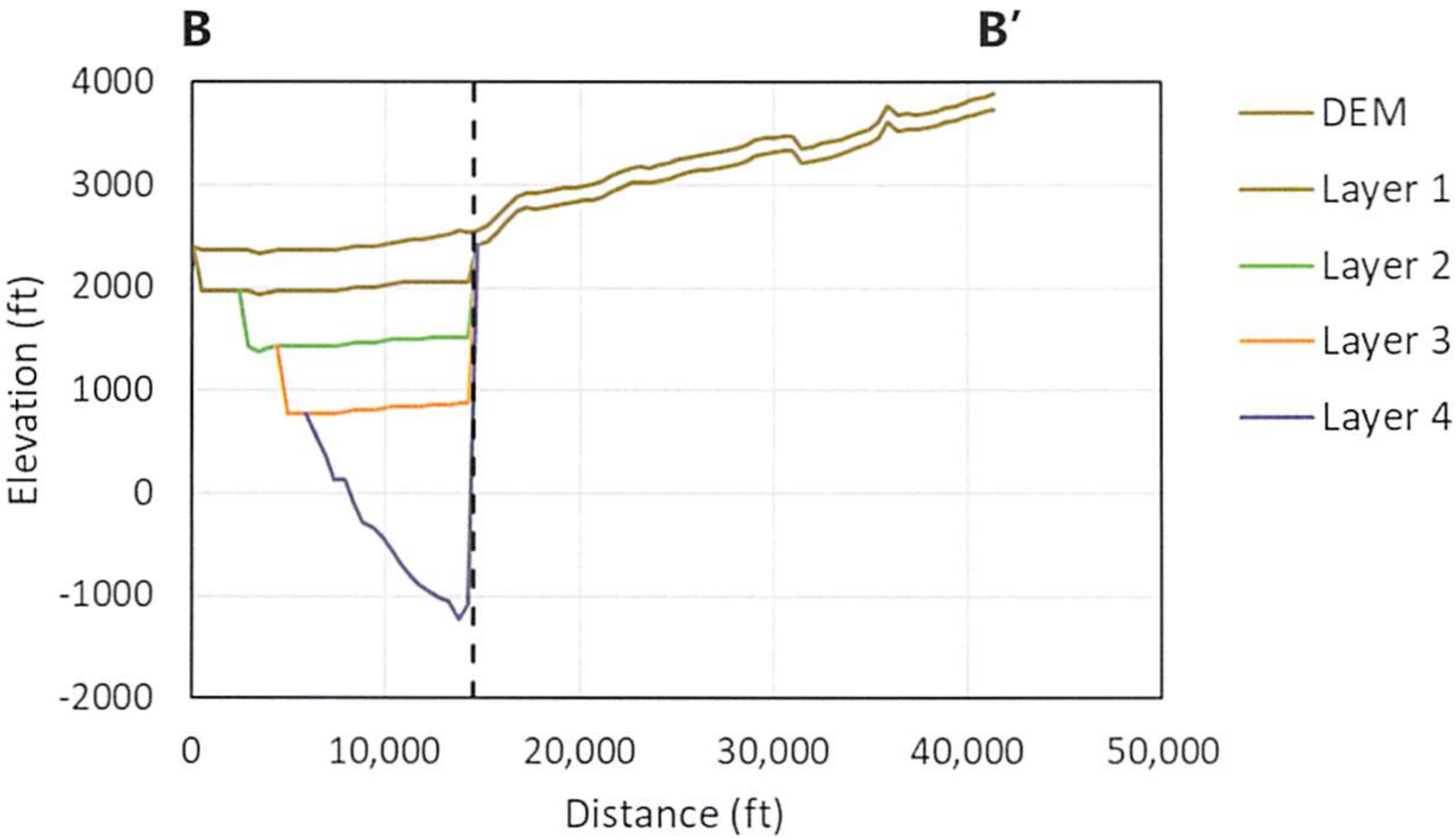


Figure 11: Cross-Section C-C′ (Beaumont to Cabazon, W-E)

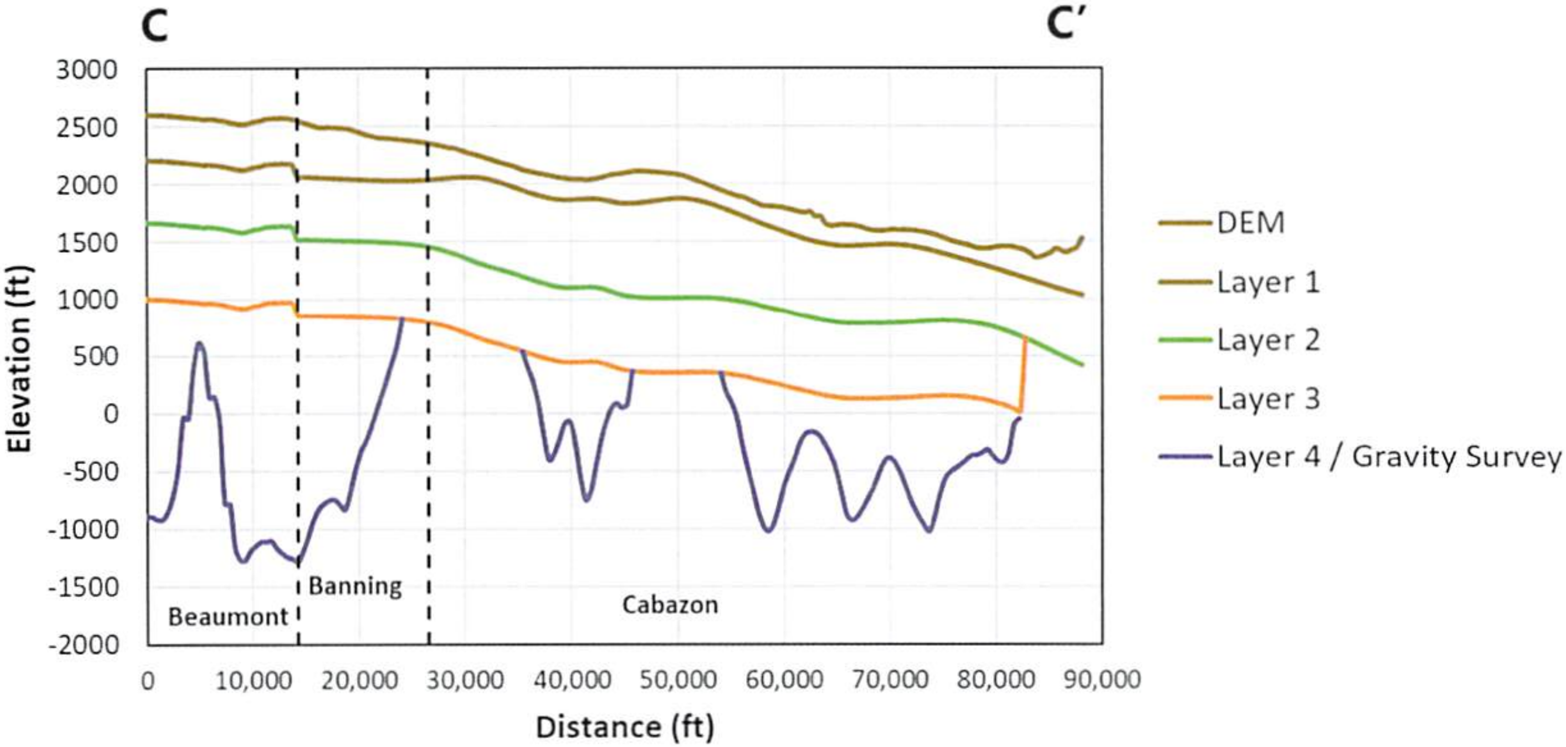


Figure 12: Layer 1 Aquifer Zones

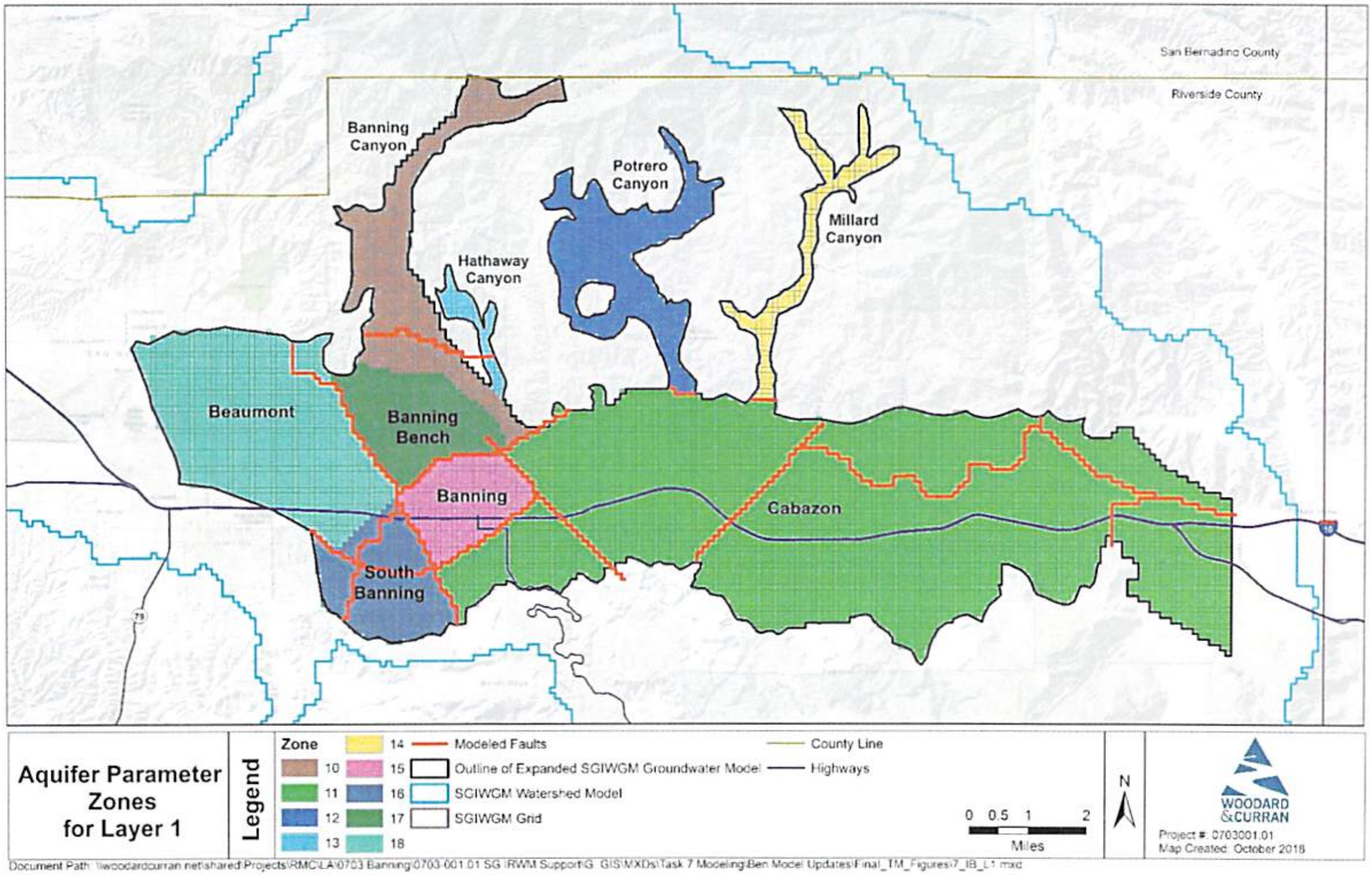


Figure 13: Layer 2 Aquifer Zones

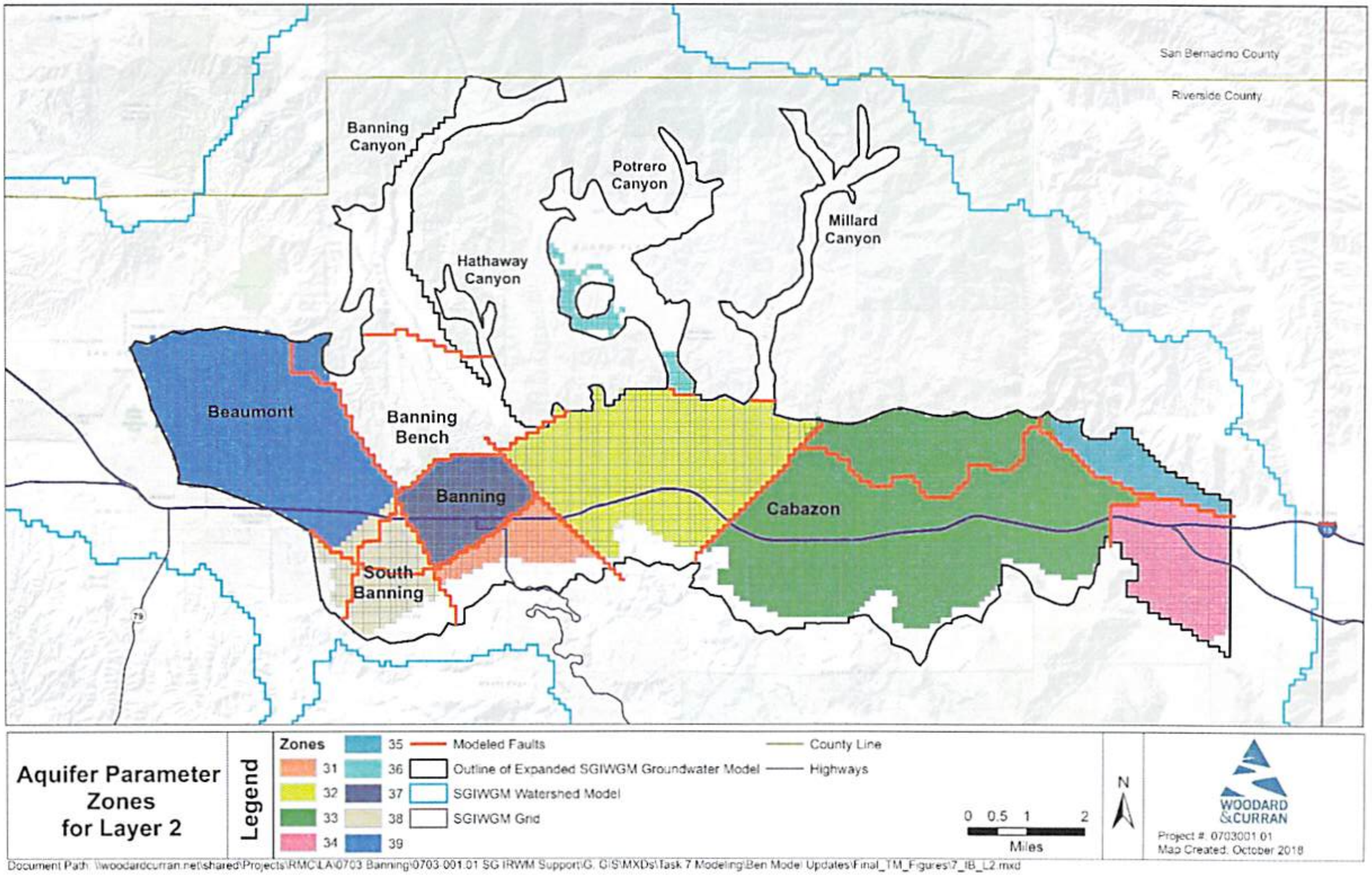


Figure 14: Layer 3 Aquifer Zones

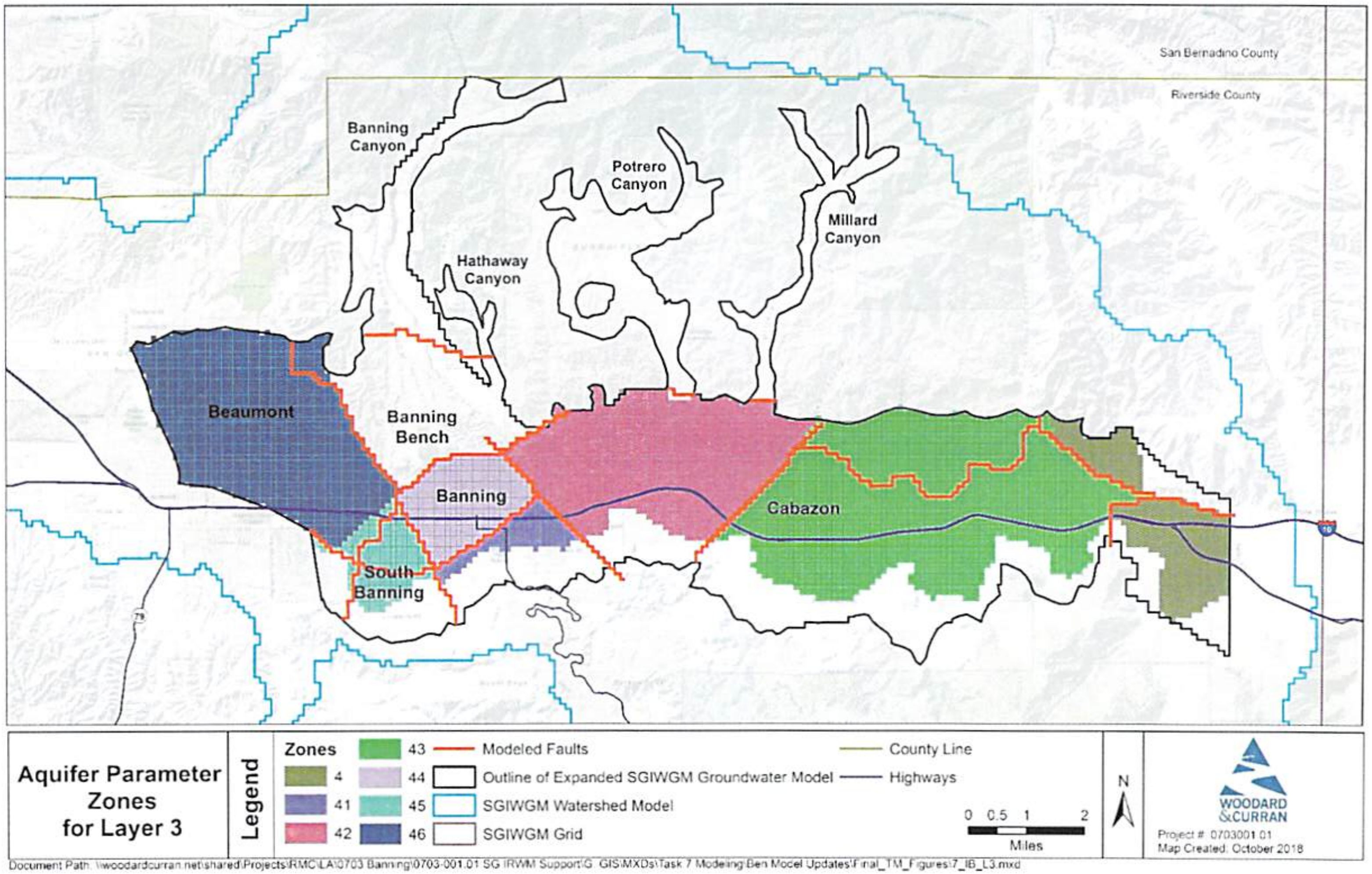


Figure 15: Layer 4 Aquifer Zones

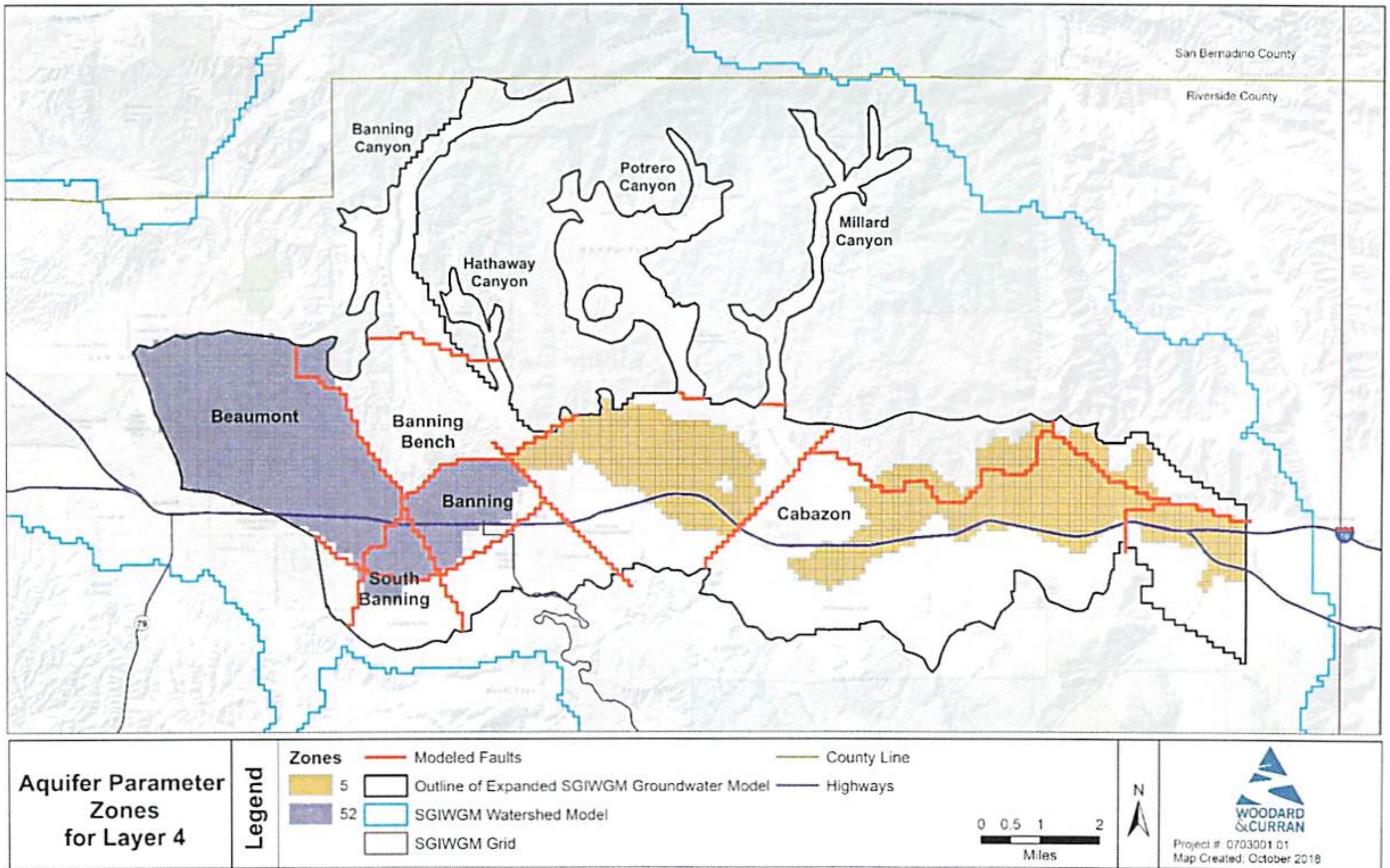


Figure 16: Layer 1 Horizontal Hydraulic Conductivity

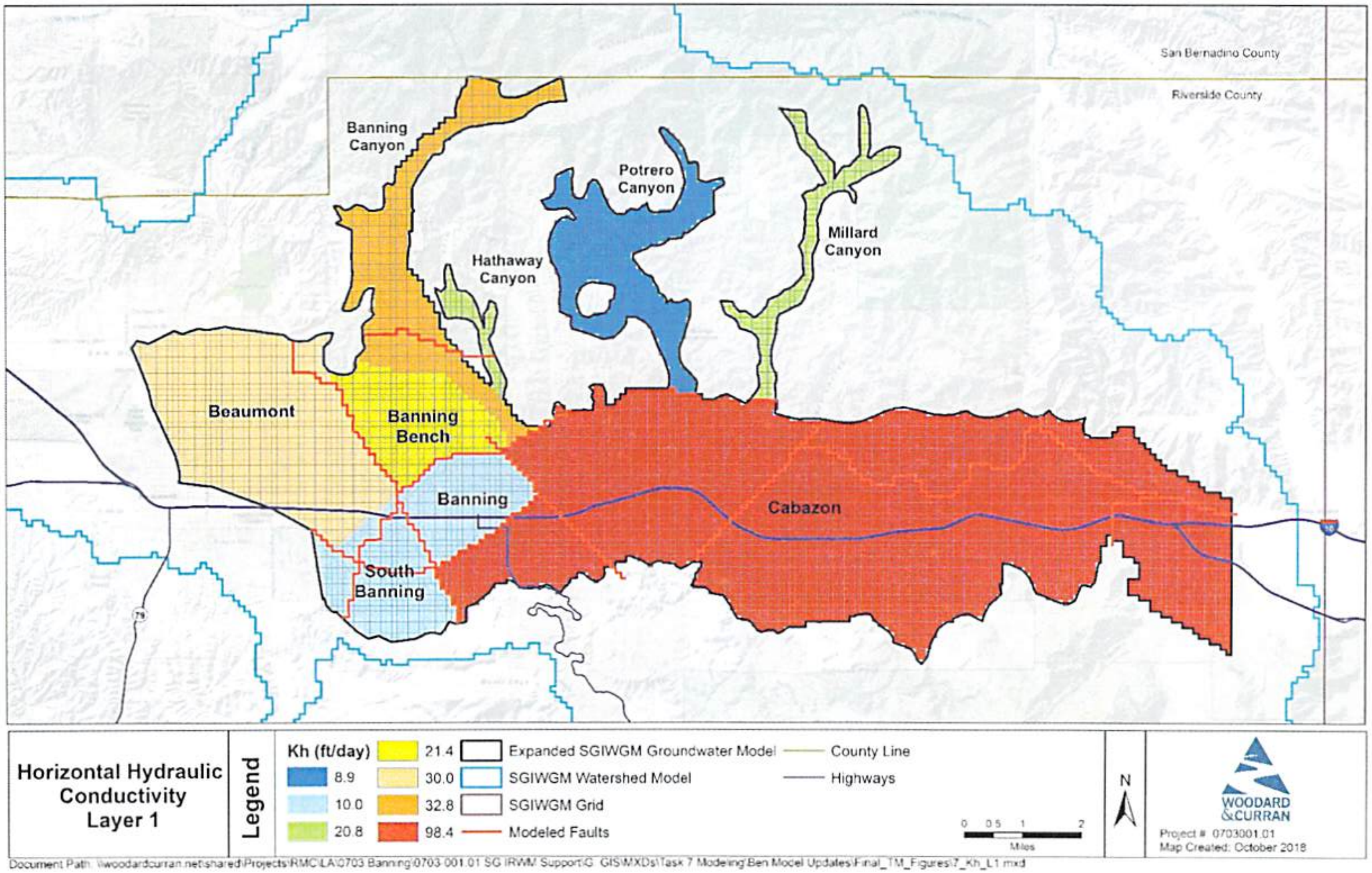


Figure 17: Initial Heads (October 1st, 1982)

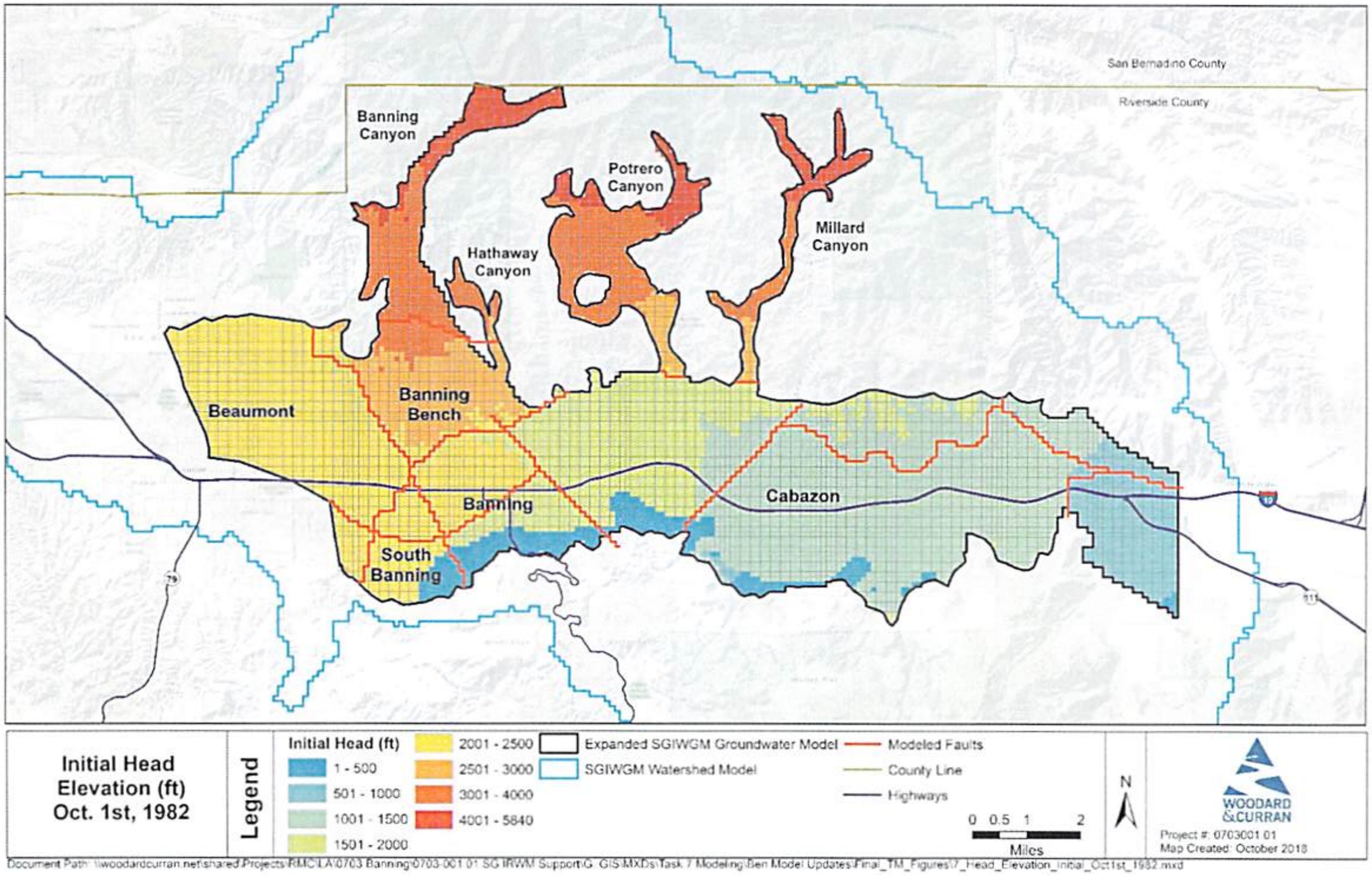


Figure 18: Average Production and Injection Rates (AFY) for Simulation Period

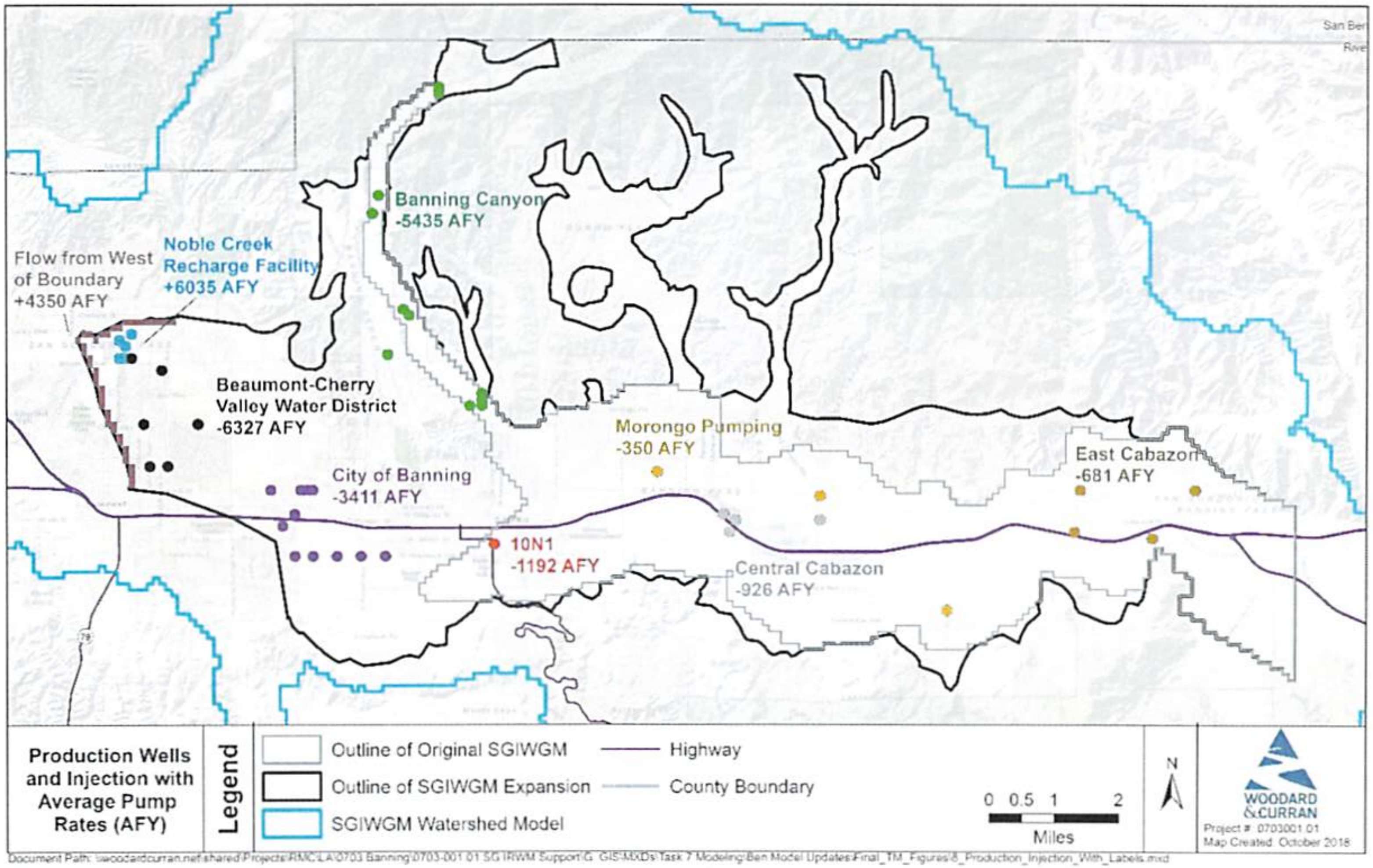


Figure 19: Monthly Pumpage Percentage

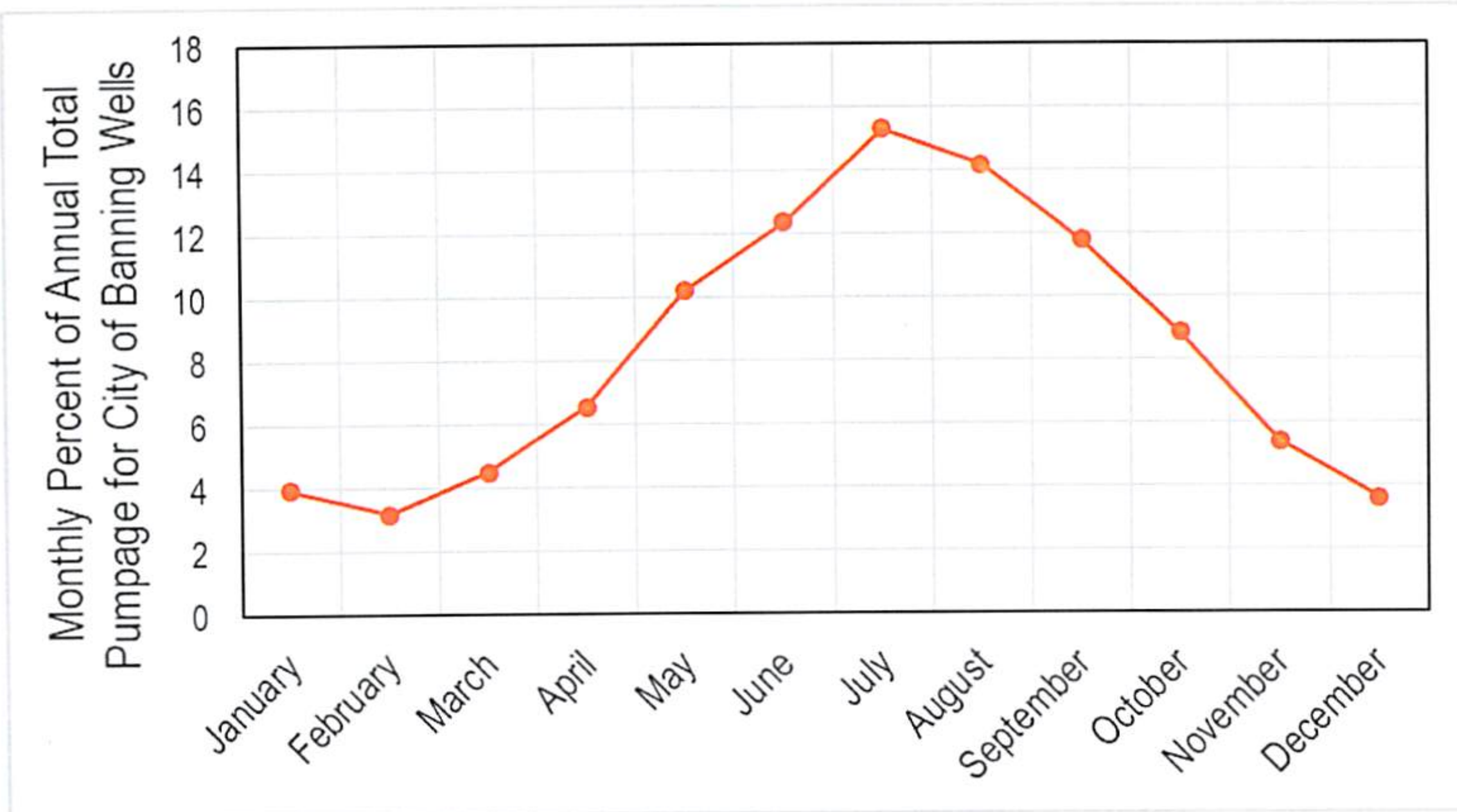


Figure 20: Model Features

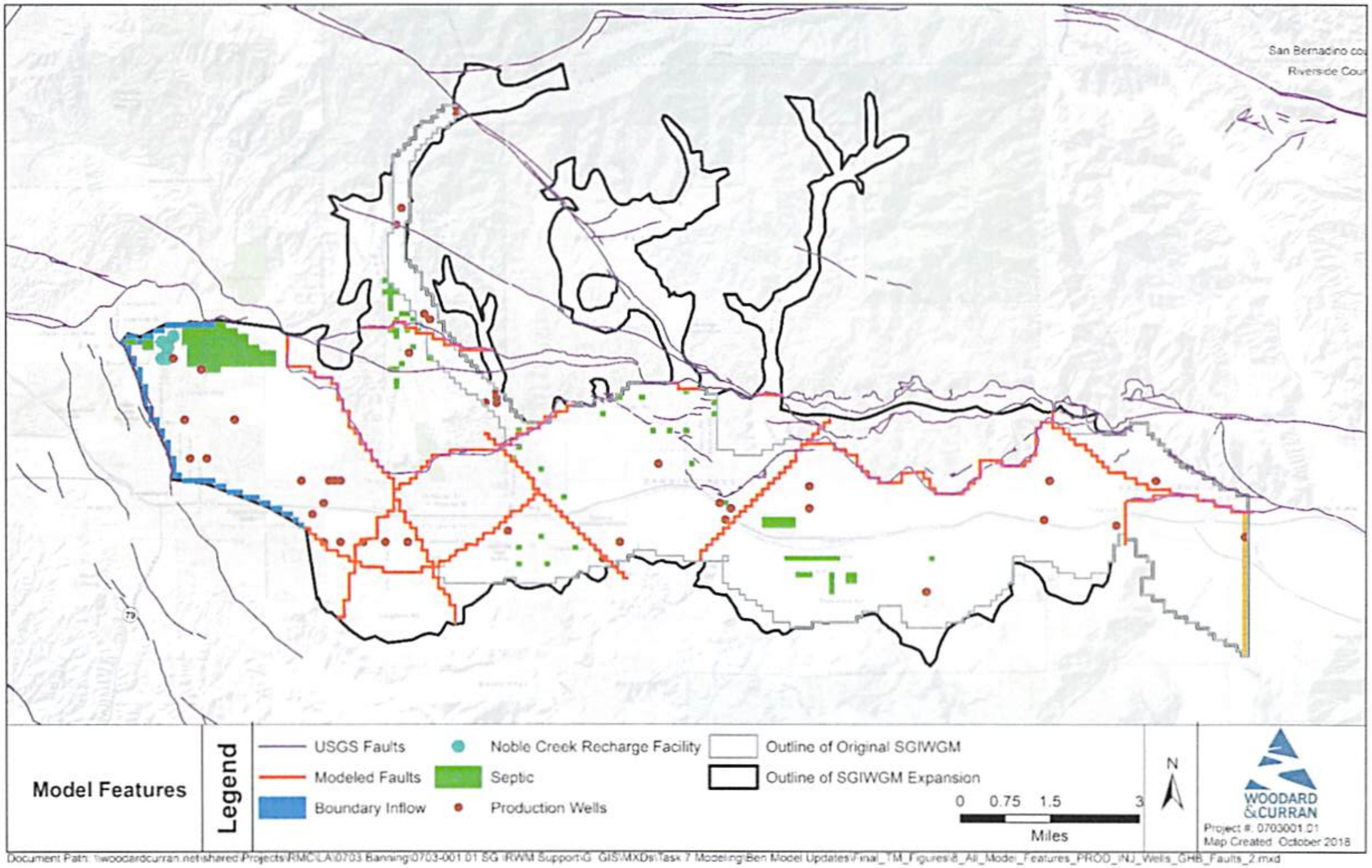


Figure 21: Septic and WWTP Recharge

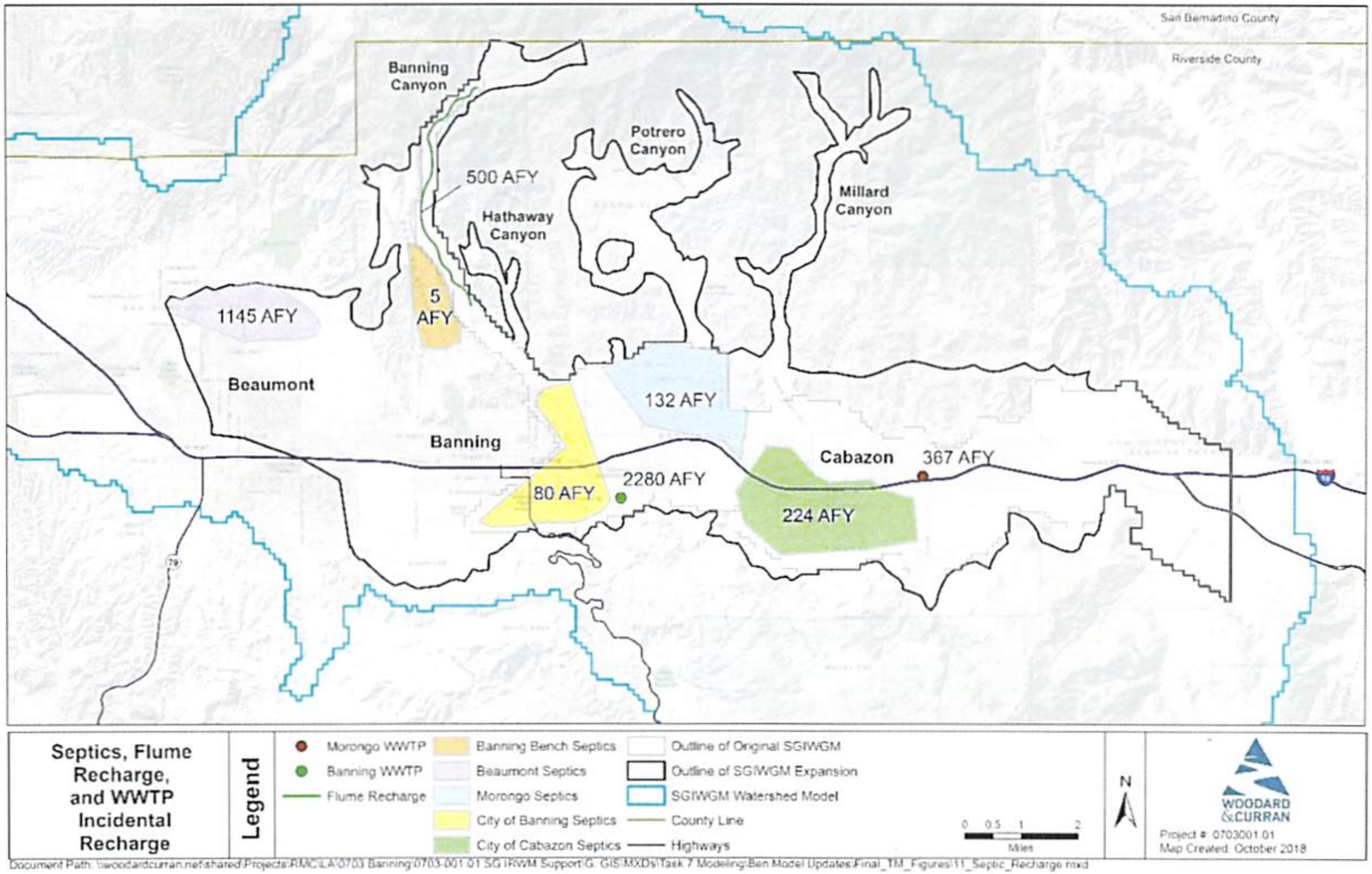


Figure 22: Flow Cascade Route

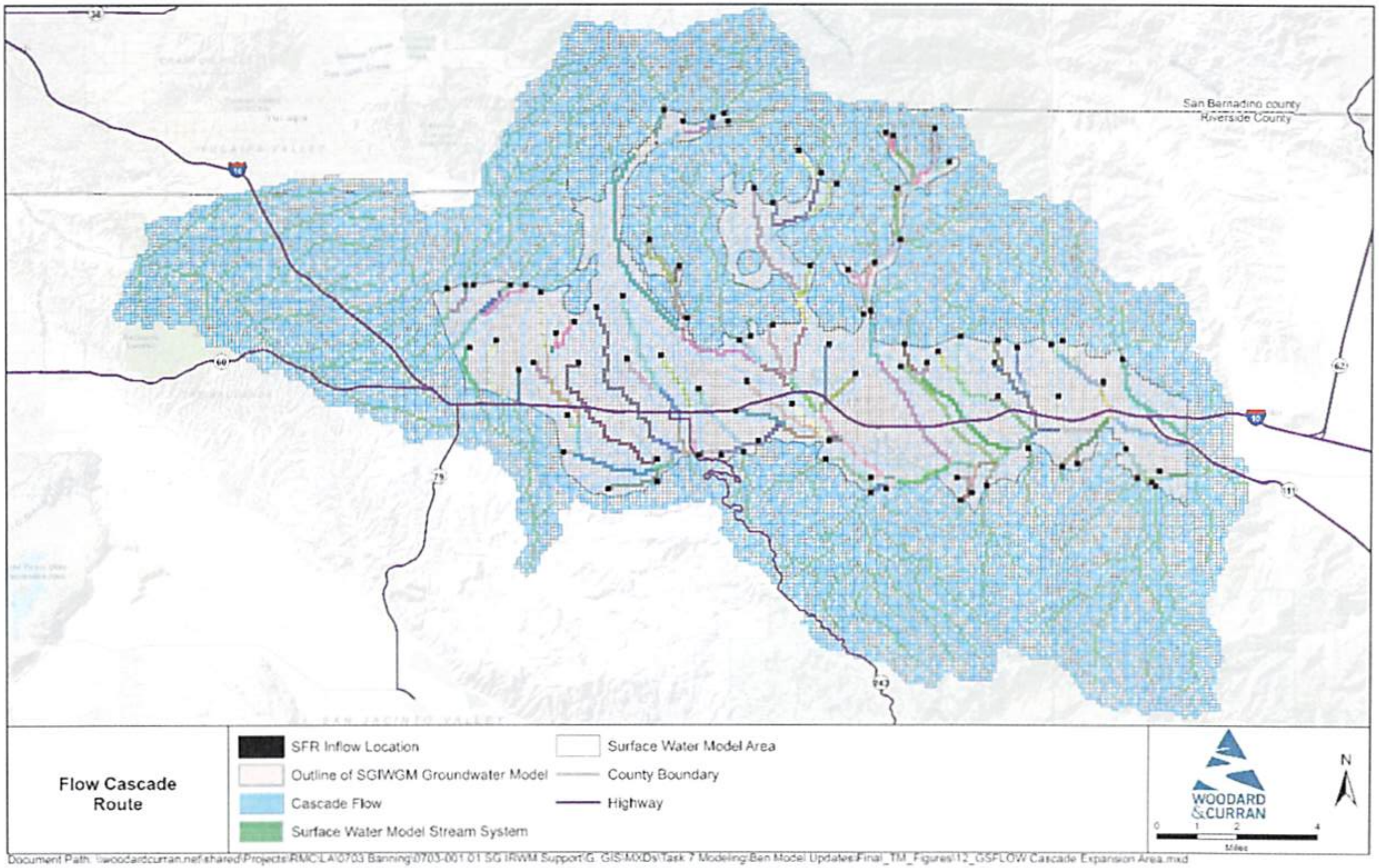


Figure 23: SGIWGM Stream Inflow Locations

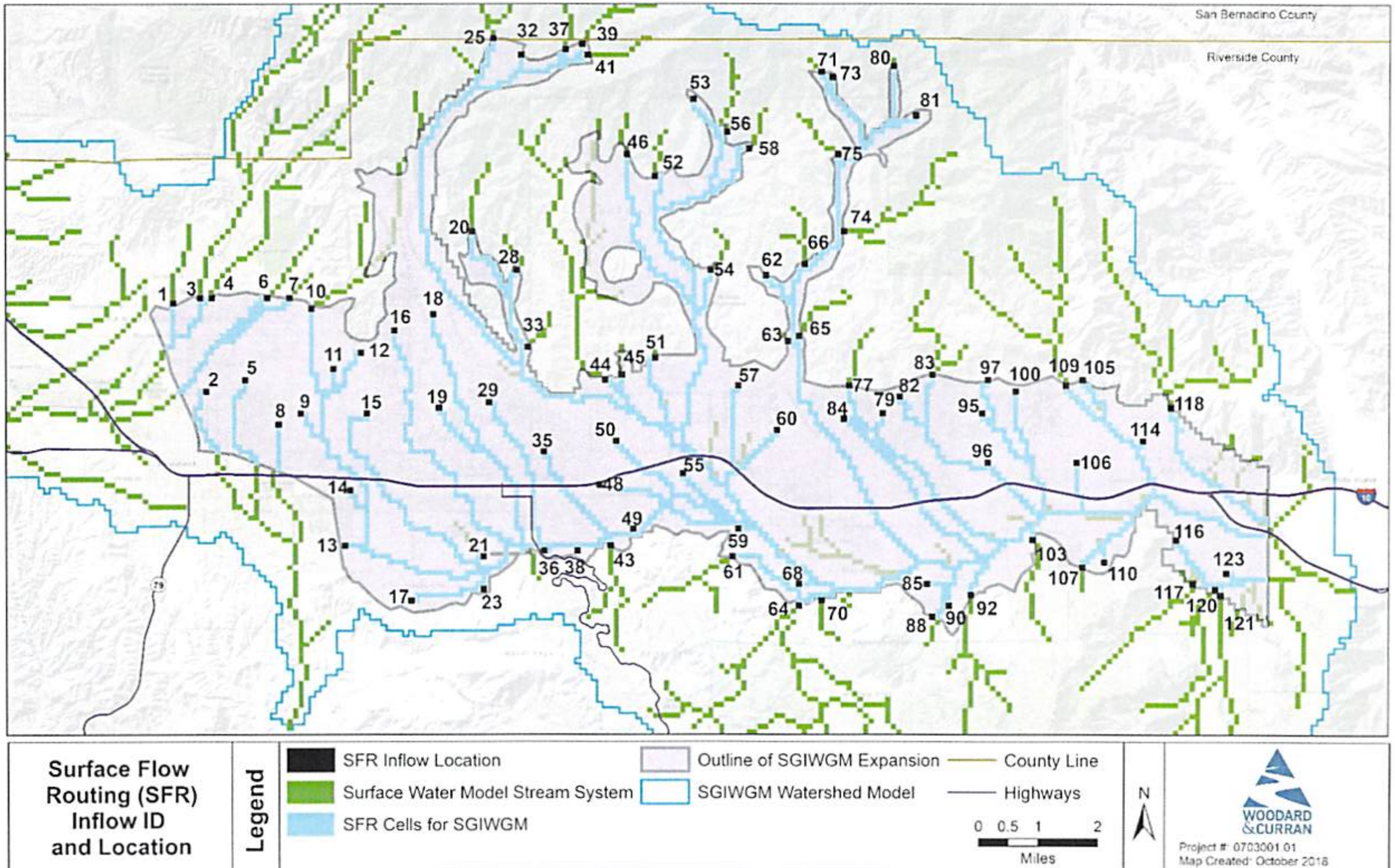
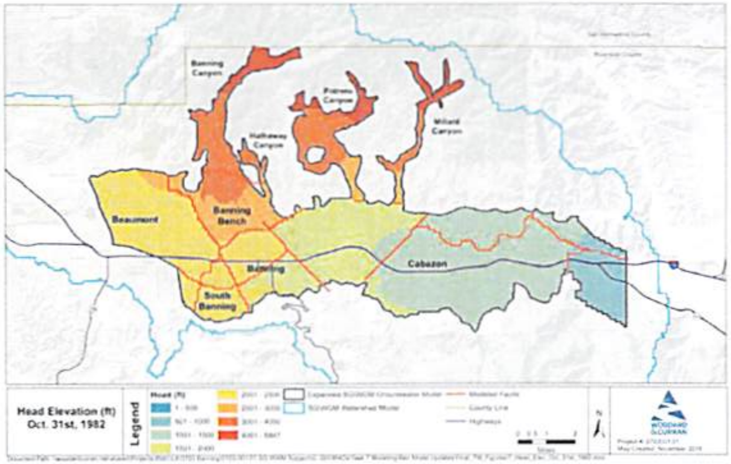
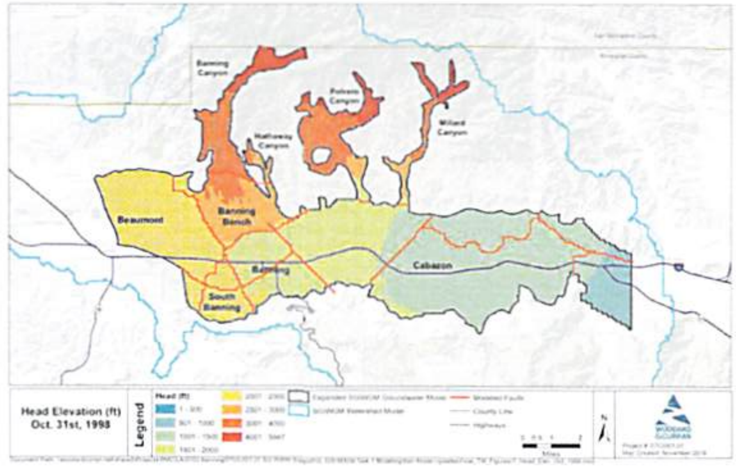


Figure 24: Comparison of Simulated Heads at Different Time-Steps

October 31st, 1982



October 31st, 1998



September 30th, 2012

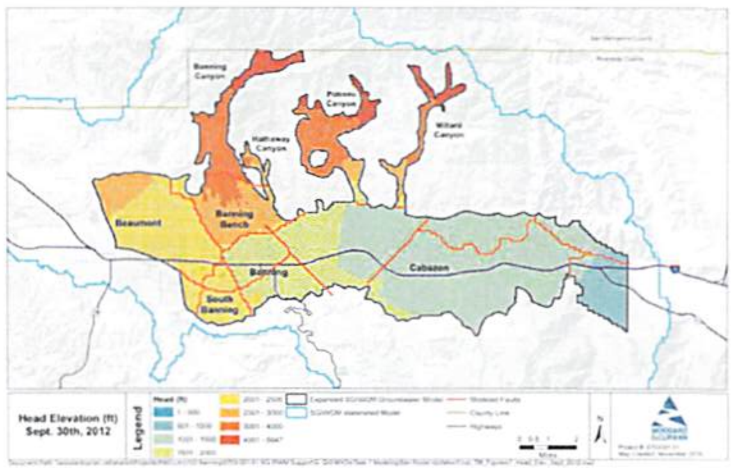


Figure 25: Monitoring Wells Selected for Calibration of Expanded SGIWGM

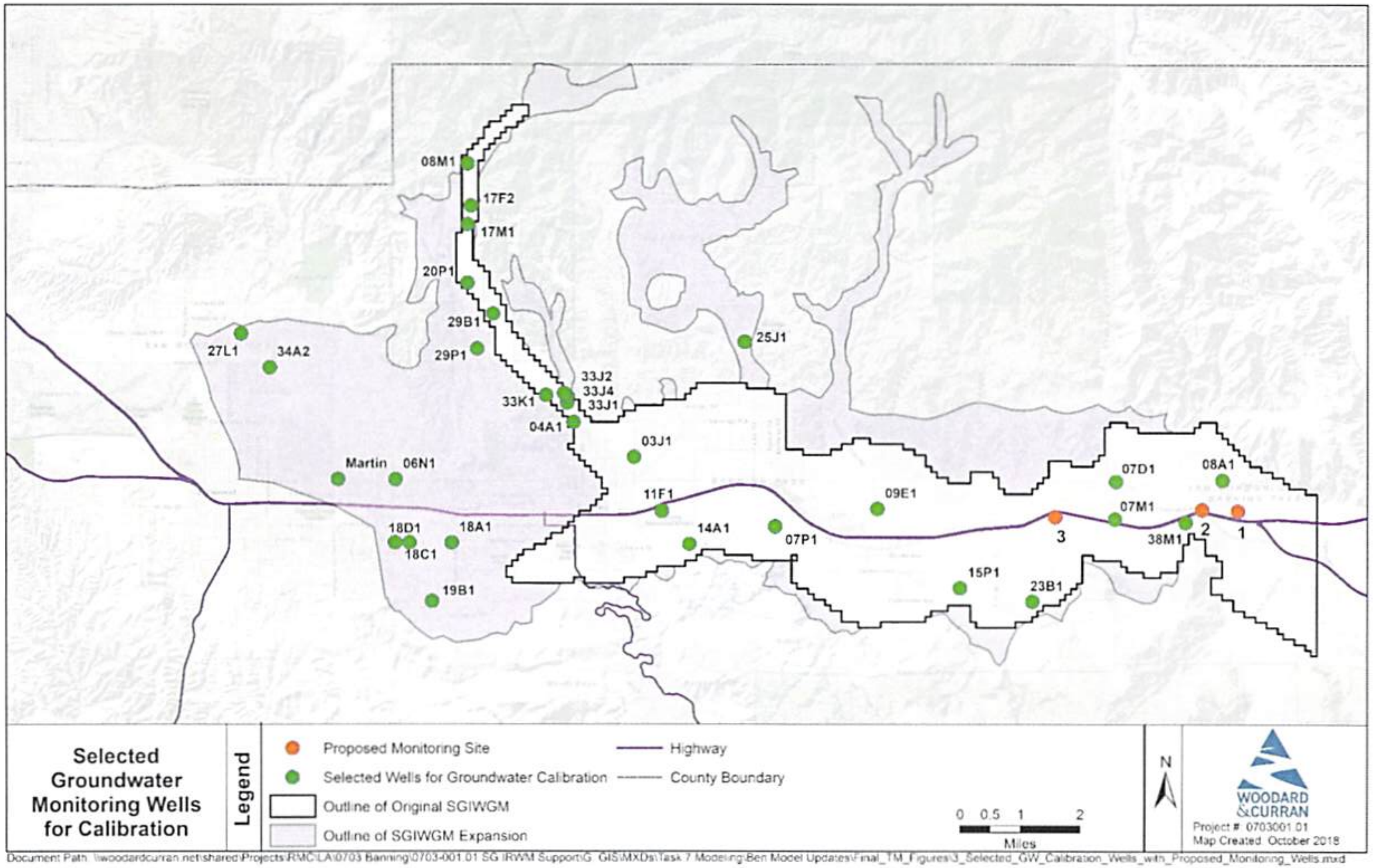


Figure 26a

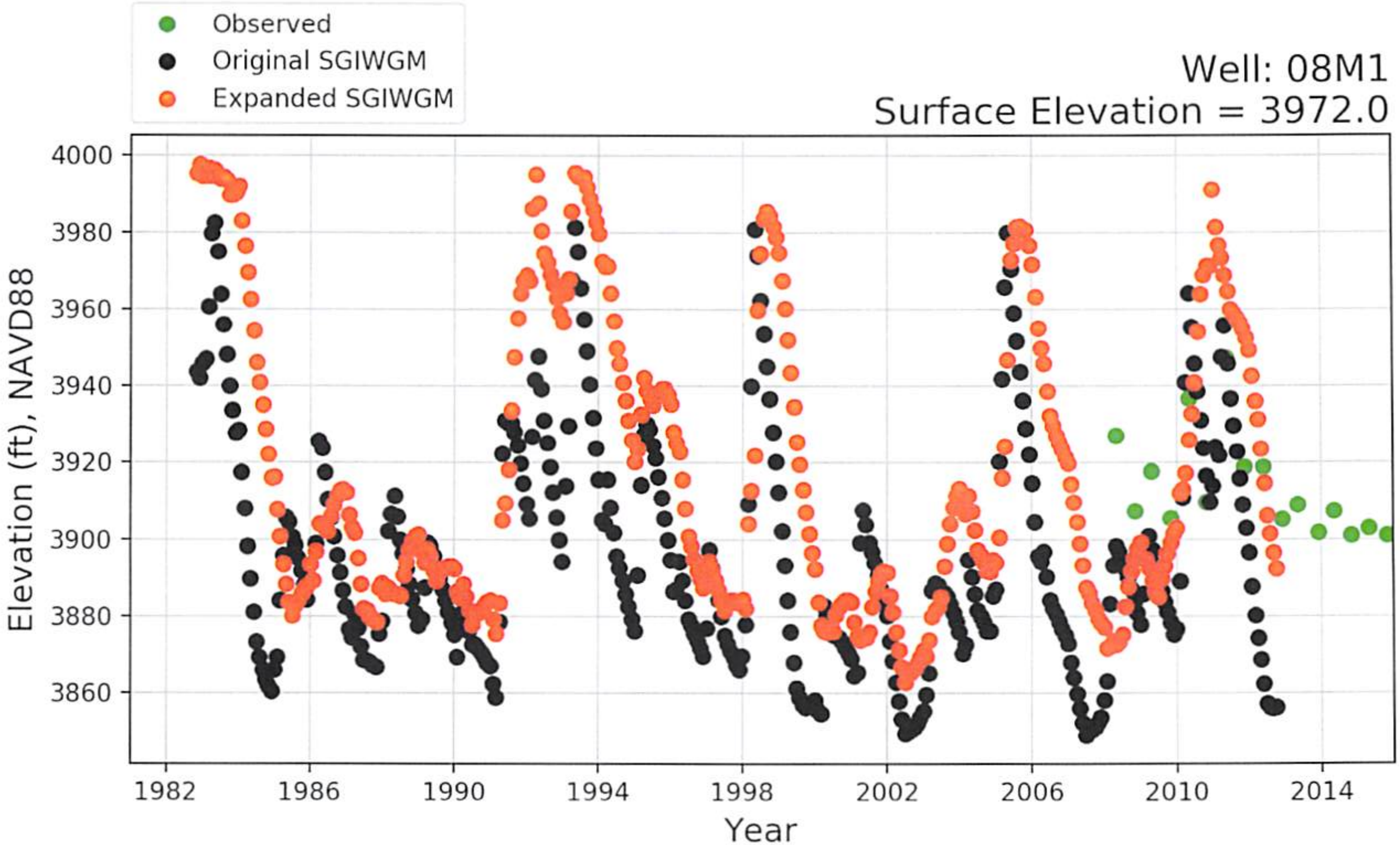
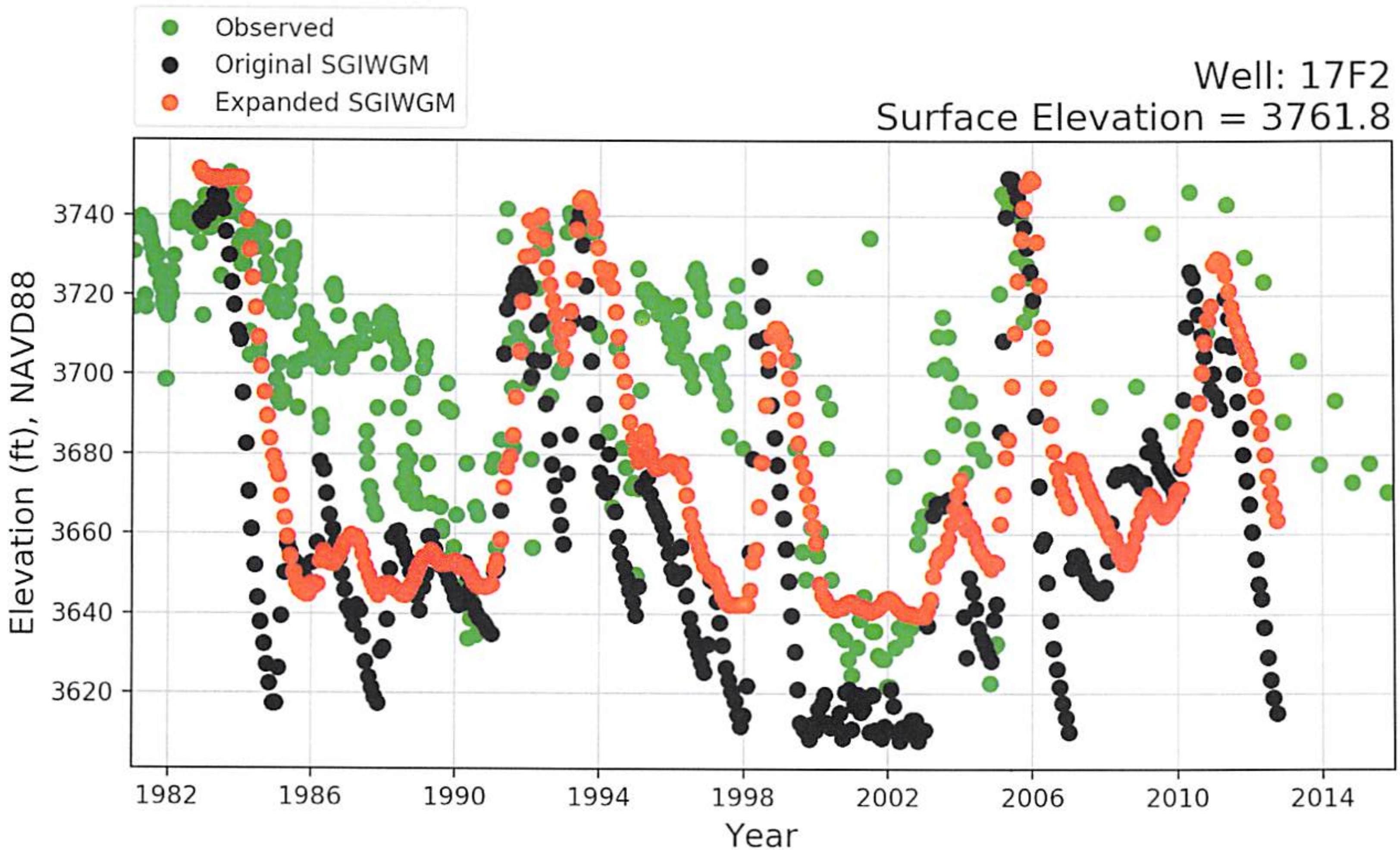

Observed
Original SGIWGM
Expanded SGIWGM
Well: 08M1
Surface Elevation = 3972.0
Elevation (ft), NAVD88
4000
3980
3960
3940
3920
3900
3880
3860
1982
1986
1990
1994
1998
2002
2006
2010
2014
Year

Figure 26b



Observed
Original SGIWGM
Expanded SGIWGM
Well: 17F2
Surface Elevation = 3761.8
Elevation (ft), NAVD88
3740
3720
3700
3680
3660
3640
3620
1982
1986
1990
1994
1998
2002
2006
2010
2014
Year

Figure 26c

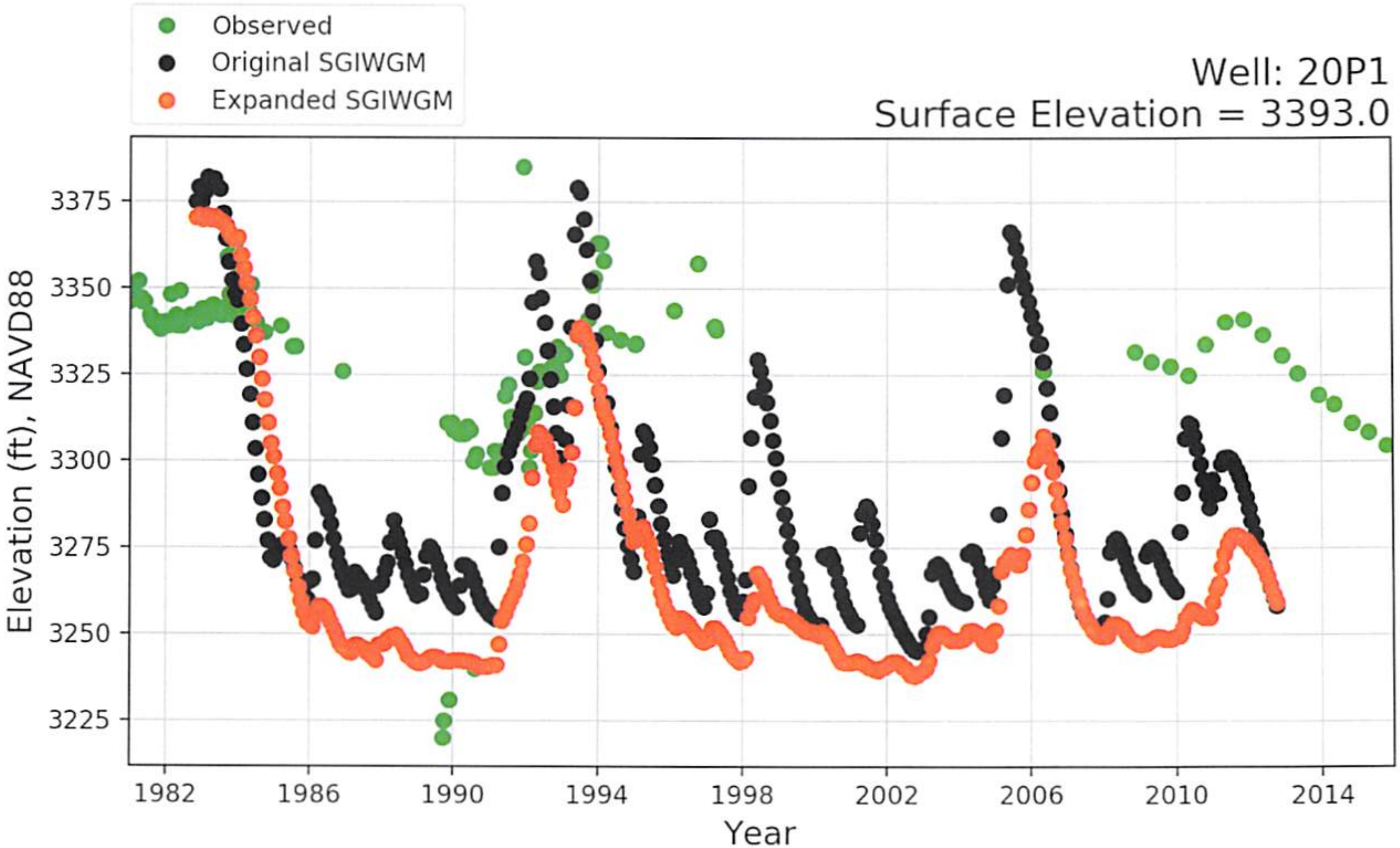

Observed
Original SGIWGM
Expanded SGIWGM
Well: 20P1
Surface Elevation = 3393.0
Elevation (ft), NAVD88
3225
3250
3275
3300
3325
3350
3375
1982
1986
1990
1994
1998
2002
2006
2010
2014
Year

Figure 26d

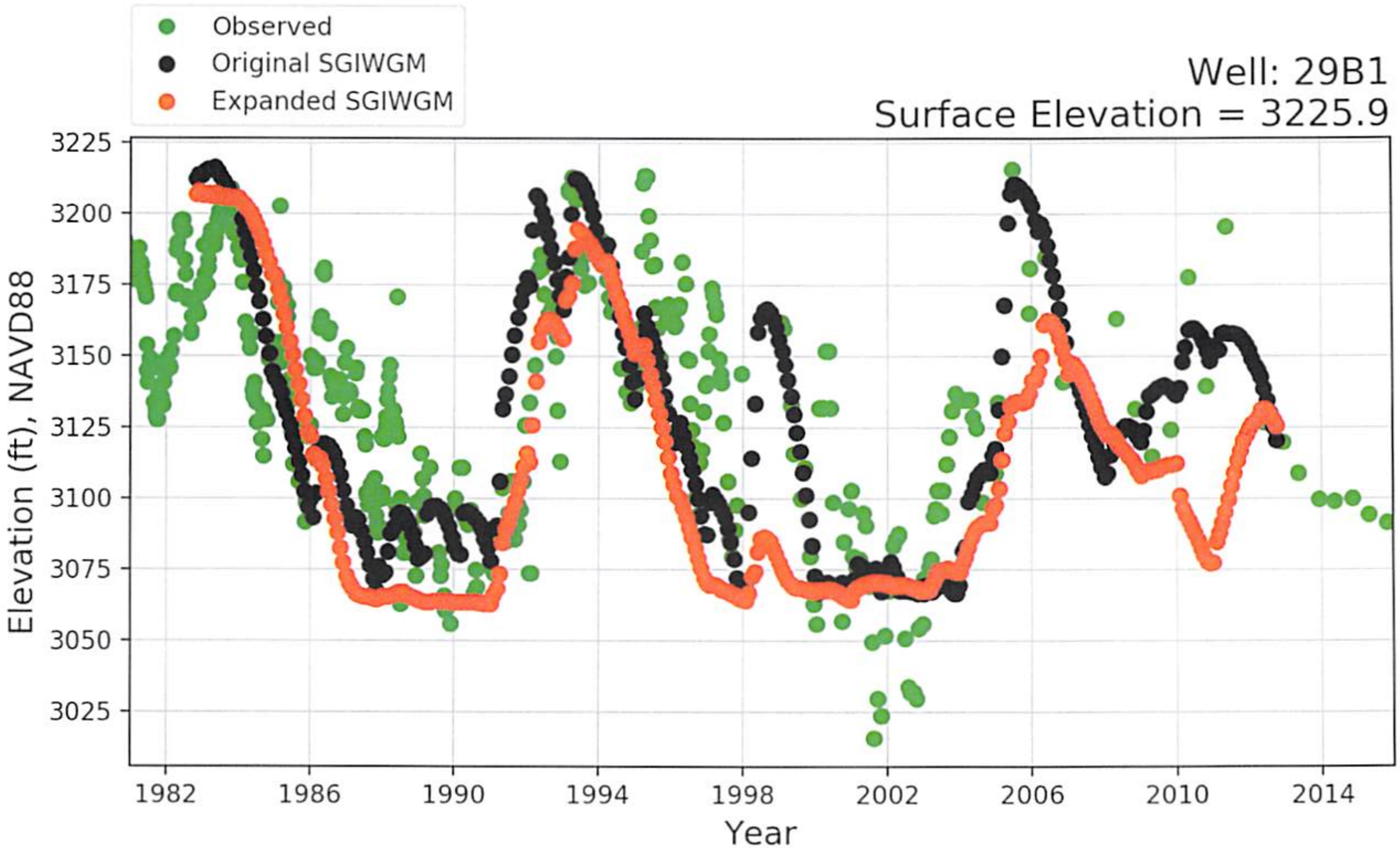

Observed
Original SGIWGM
Expanded SGIWGM
Well: 29B1
Surface Elevation = 3225.9
Elevation (ft), NAVD88
3225
3200
3175
3150
3125
3100
3075
3050
3025
1982
1986
1990
1994
1998
2002
2006
2010
2014
Year

Figure 26e

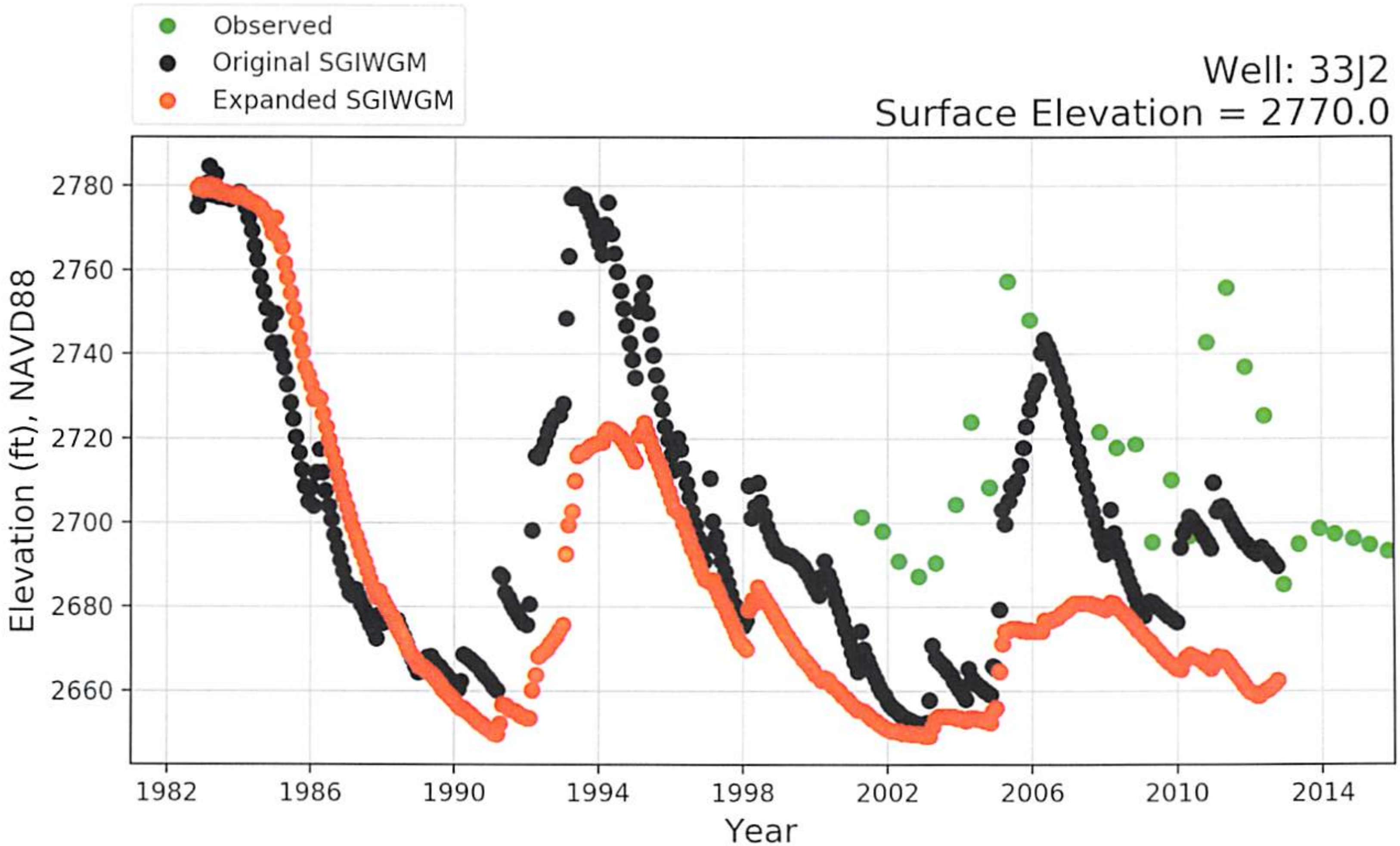

Observed
Original SGIWGM
Expanded SGIWGM
Well: 33J2
Surface Elevation = 2770.0
Elevation (ft), NAVD88
2780
2760
2740
2720
2700
2680
2660
1982
1986
1990
1994
1998
2002
2006
2010
2014
Year

Figure 26f

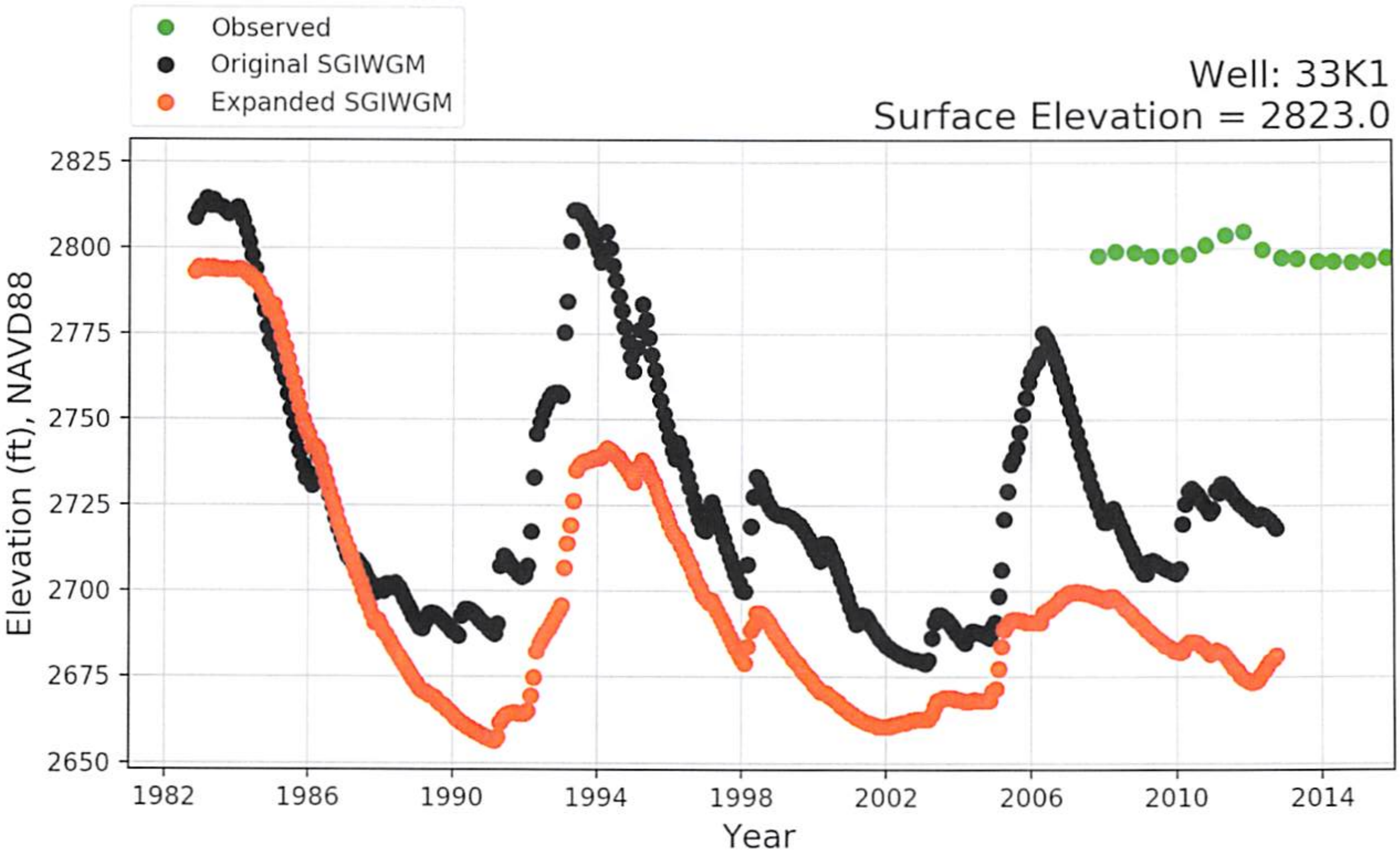

Observed
Original SGIWGM
Expanded SGIWGM
Well: 33K1
Surface Elevation = 2823.0
Elevation (ft), NAVD88
2825
2800
2775
2750
2725
2700
2675
2650
1982
1986
1990
1994
1998
2002
2006
2010
2014
Year

Figure 26g

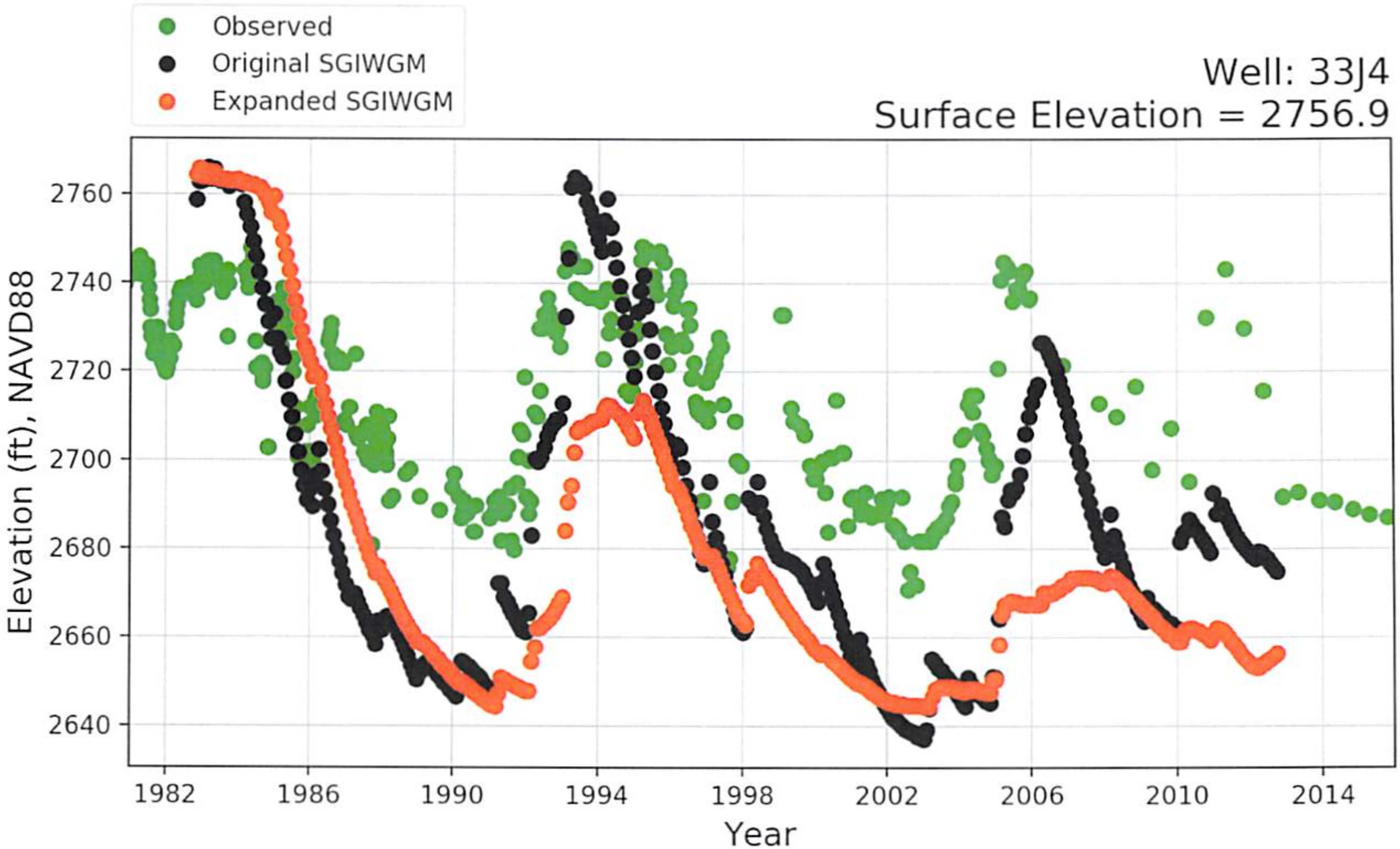
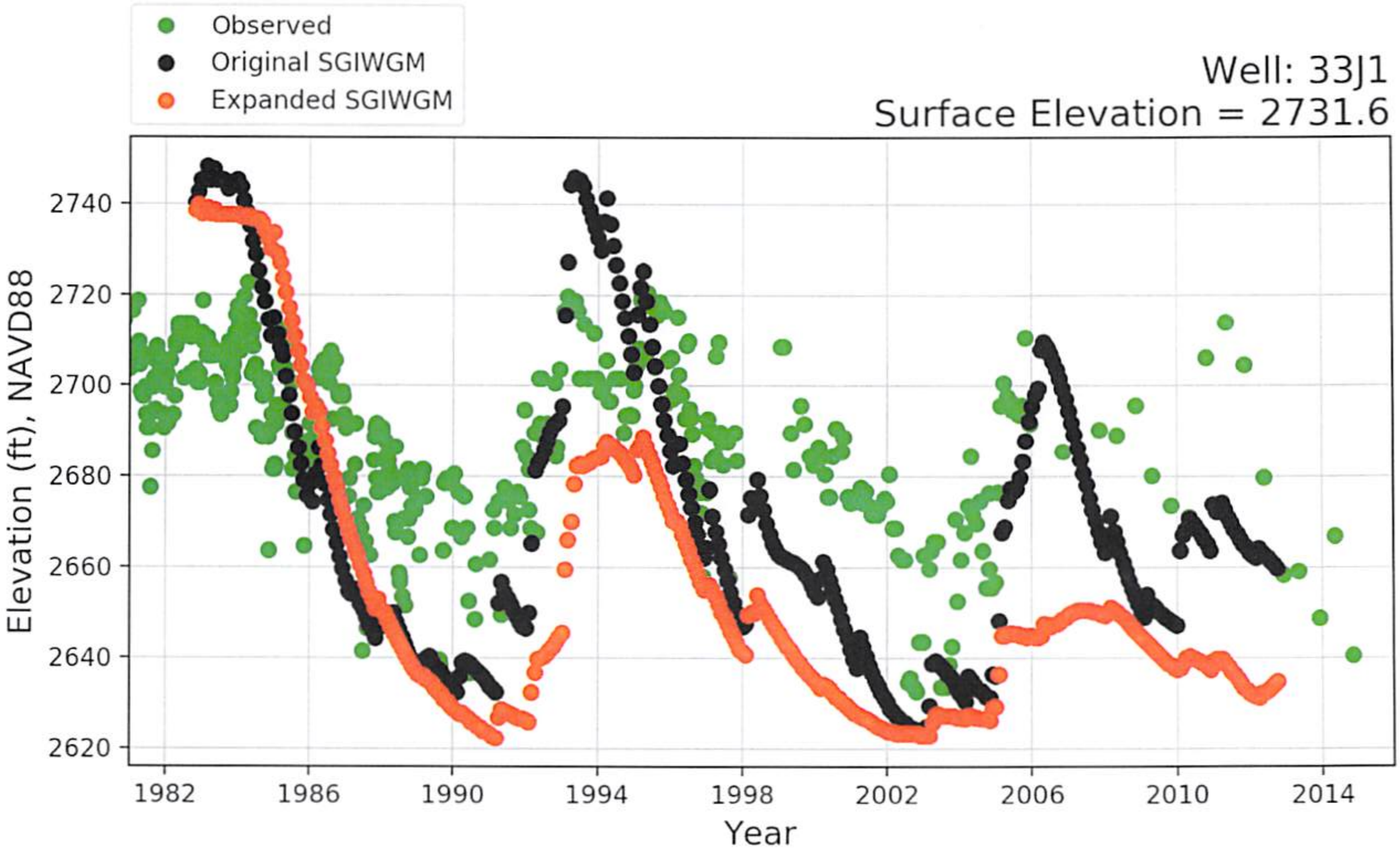

Observed
Original SGIWGM
Expanded SGIWGM
Well: 33J4
Surface Elevation = 2756.9
Elevation (ft), NAVD88
2760
2740
2720
2700
2680
2660
2640
1982
1986
1990
1994
1998
2002
2006
2010
2014
Year

Figure 26h



Observed
Original SGIWGM
Expanded SGIWGM
Well: 33J1
Surface Elevation = 2731.6
Elevation (ft), NAVD88
2740
2720
2700
2680
2660
2640
2620
1982
1986
1990
1994
1998
2002
2006
2010
2014
Year

Figure 26i

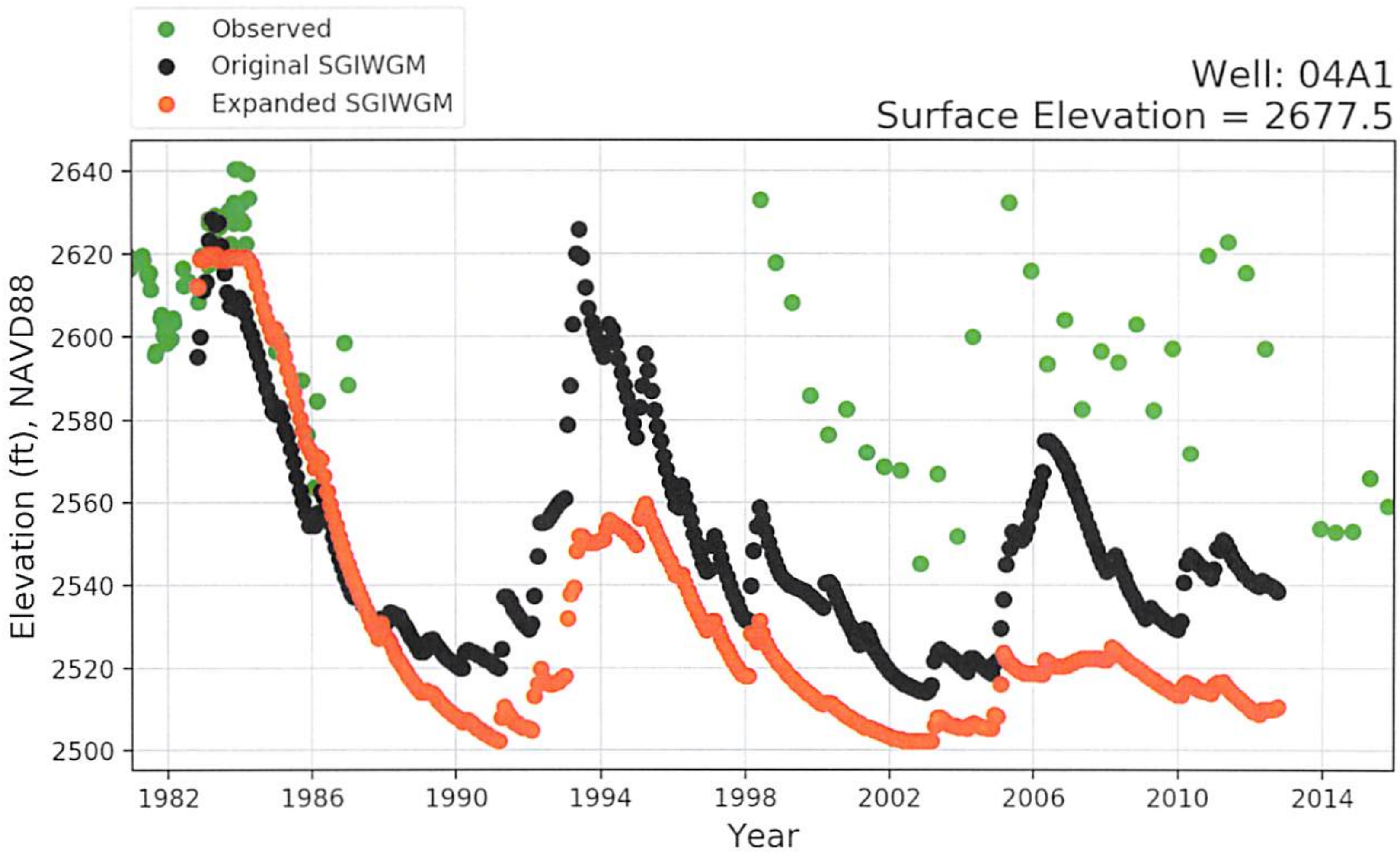

Observed
Original SGIWGM
Expanded SGIWGM
Well: 04A1
Surface Elevation = 2677.5
Elevation (ft), NAVD88
2640
2620
2600
2580
2560
2540
2520
2500
1982
1986
1990
1994
1998
2002
2006
2010
2014
Year

Figure 26j

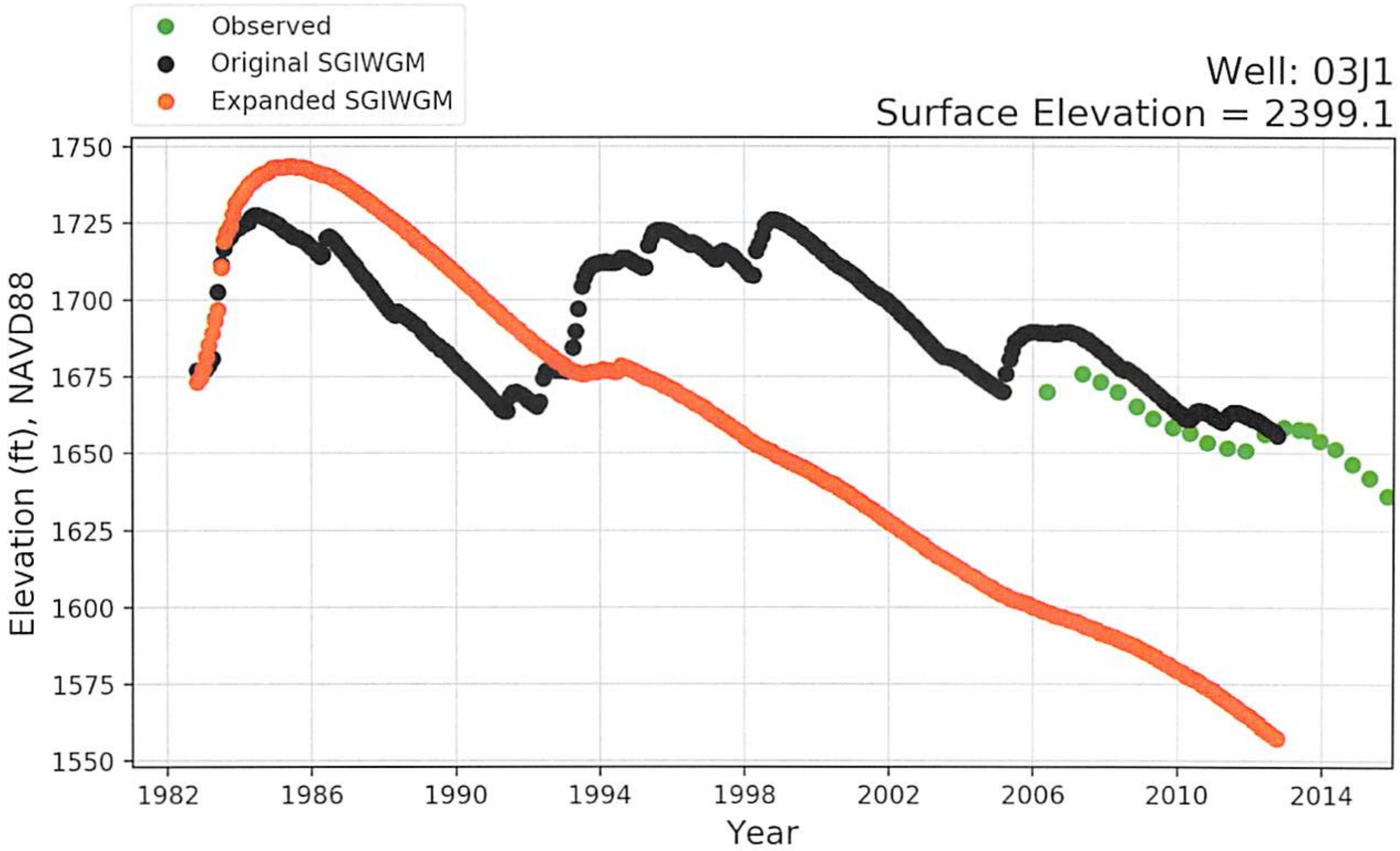

Observed
Original SGIWGM
Expanded SGIWGM
Well: 03J1
Surface Elevation = 2399.1
Elevation (ft), NAVD88
1750
1725
1700
1675
1650
1625
1600
1575
1550
1982
1986
1990
1994
1998
2002
2006
2010
2014
Year

Figure 26k

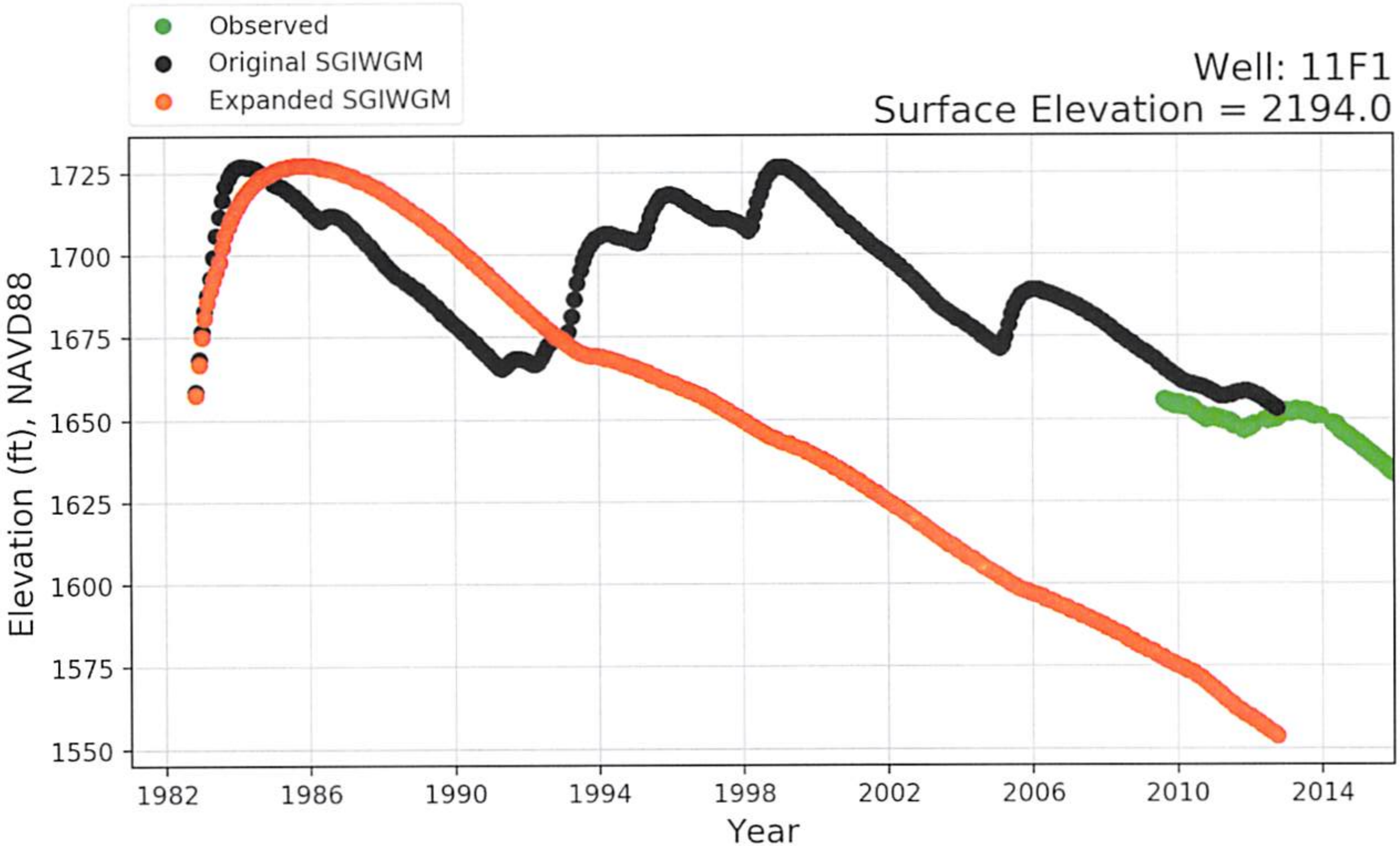
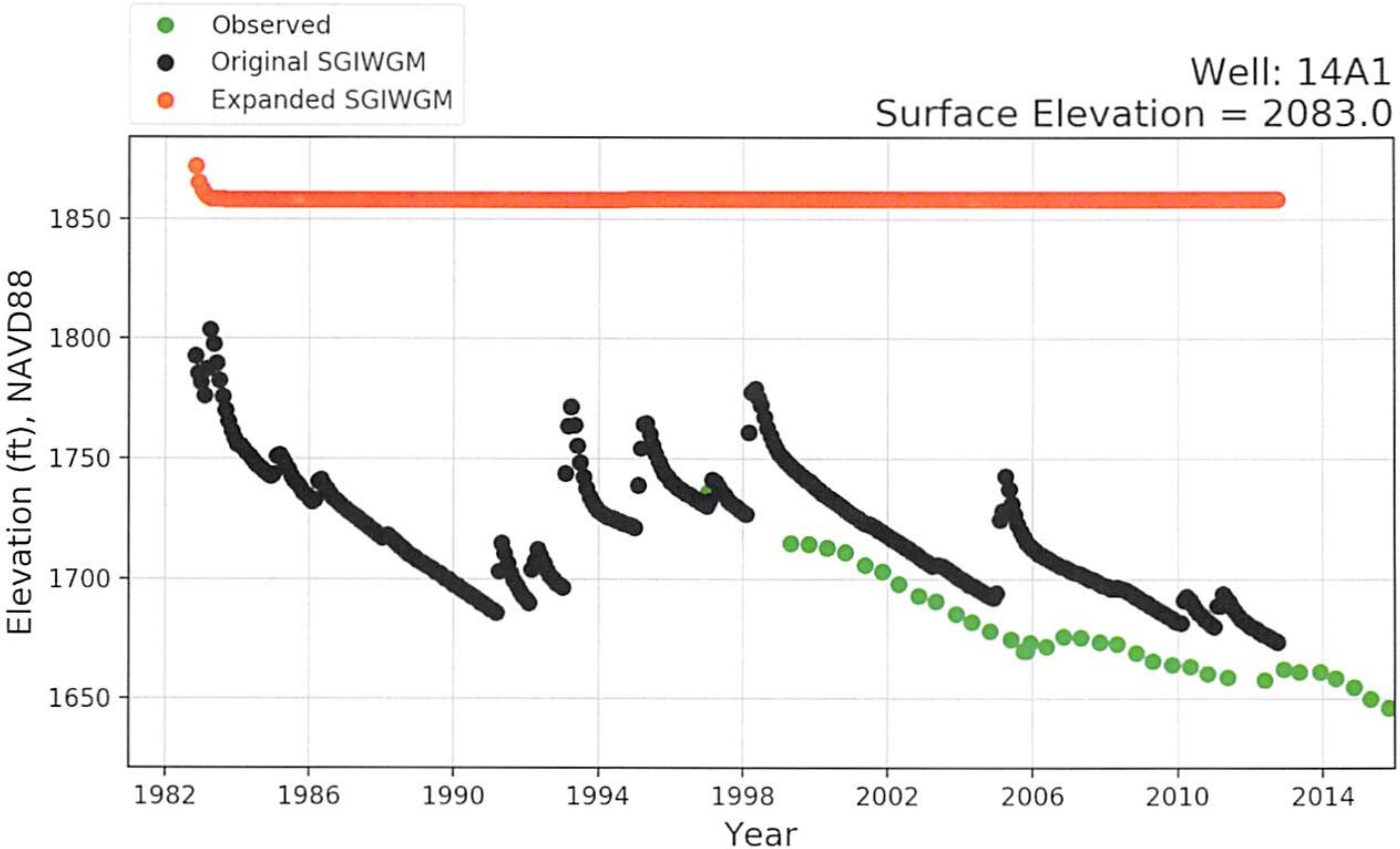

Observed
Original SGIWGM
Expanded SGIWGM
Well: 11F1
Surface Elevation = 2194.0
Elevation (ft), NAVD88
1725
1700
1675
1650
1625
1600
1575
1550
1982
1986
1990
1994
1998
2002
2006
2010
2014
Year

Figure 26l



Observed
Original SGIWGM
Expanded SGIWGM
Well: 14A1
Surface Elevation = 2083.0
Elevation (ft), NAVD88
1850
1800
1750
1700
1650
1982
1986
1990
1994
1998
2002
2006
2010
2014
Year

Figure 26m

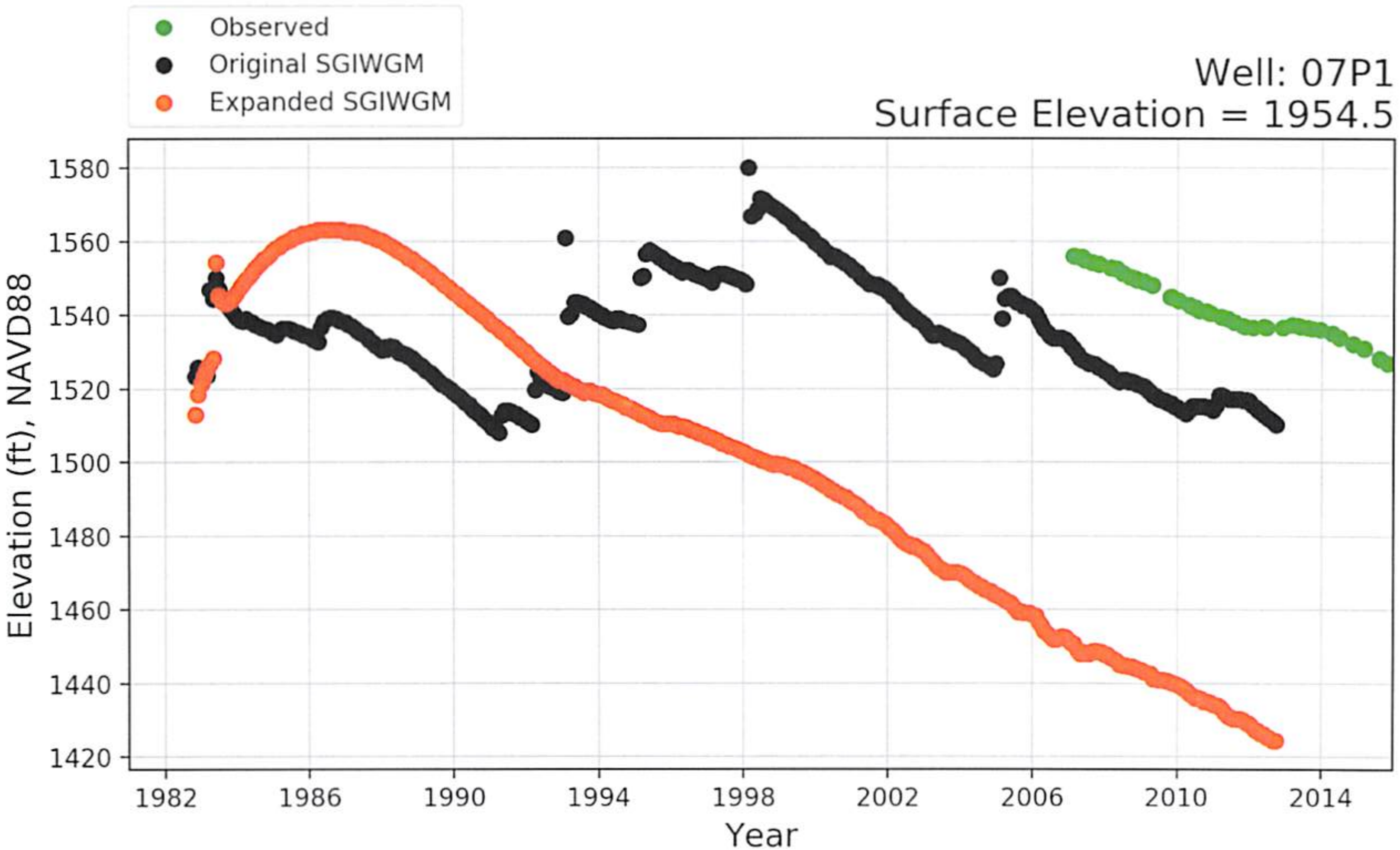
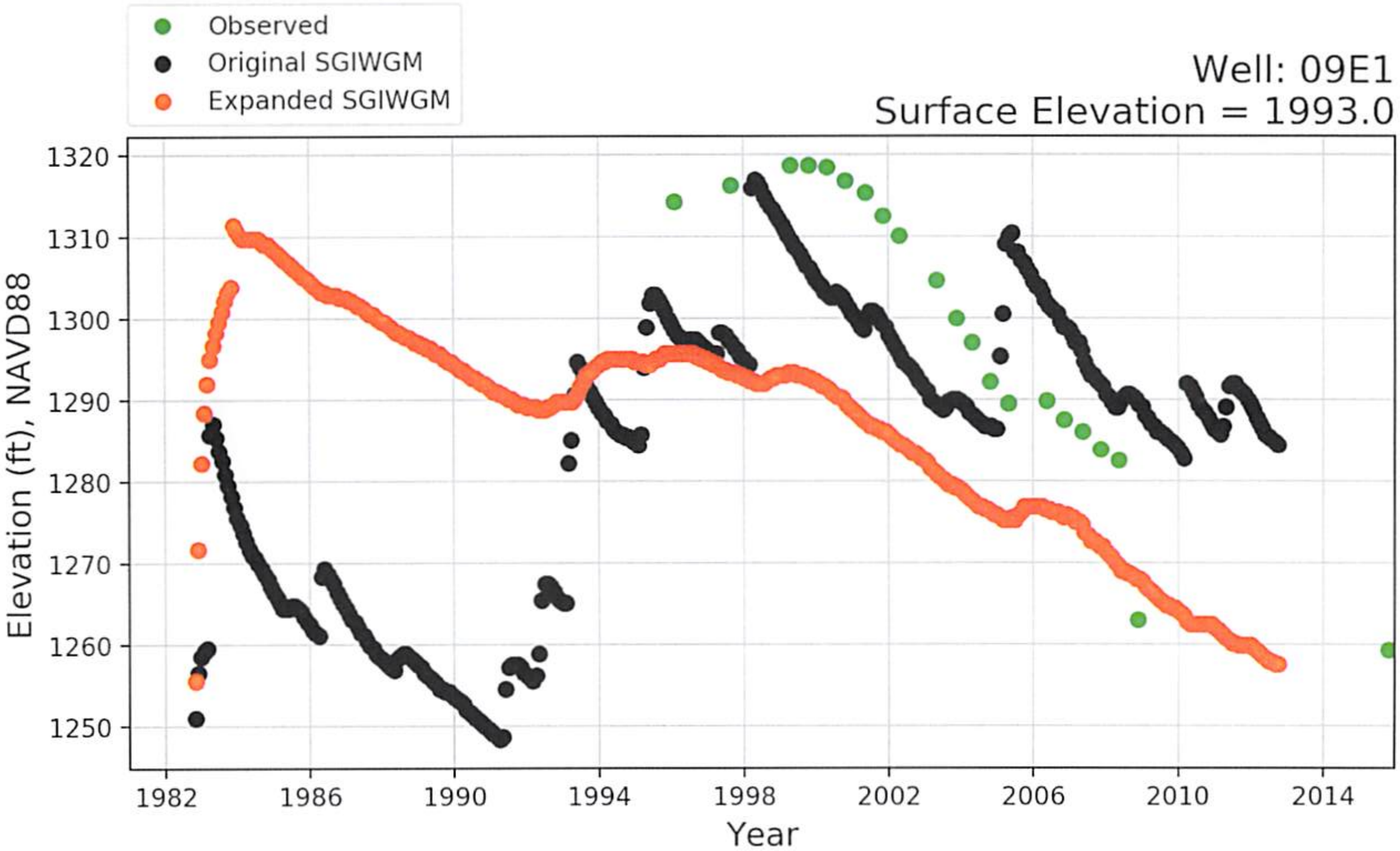

Observed
Original SGIWGM
Expanded SGIWGM
Well: 07P1
Surface Elevation = 1954.5
Elevation (ft), NAVD88
1580
1560
1540
1520
1500
1480
1460
1440
1420
1982
1986
1990
1994
1998
2002
2006
2010
2014
Year

Figure 26n



Observed
Original SGIWGM
Expanded SGIWGM
Well: 09E1
Surface Elevation = 1993.0
Elevation (ft), NAVD88
1320
1310
1300
1290
1280
1270
1260
1250
1982
1986
1990
1994
1998
2002
2006
2010
2014
Year

Figure 26o

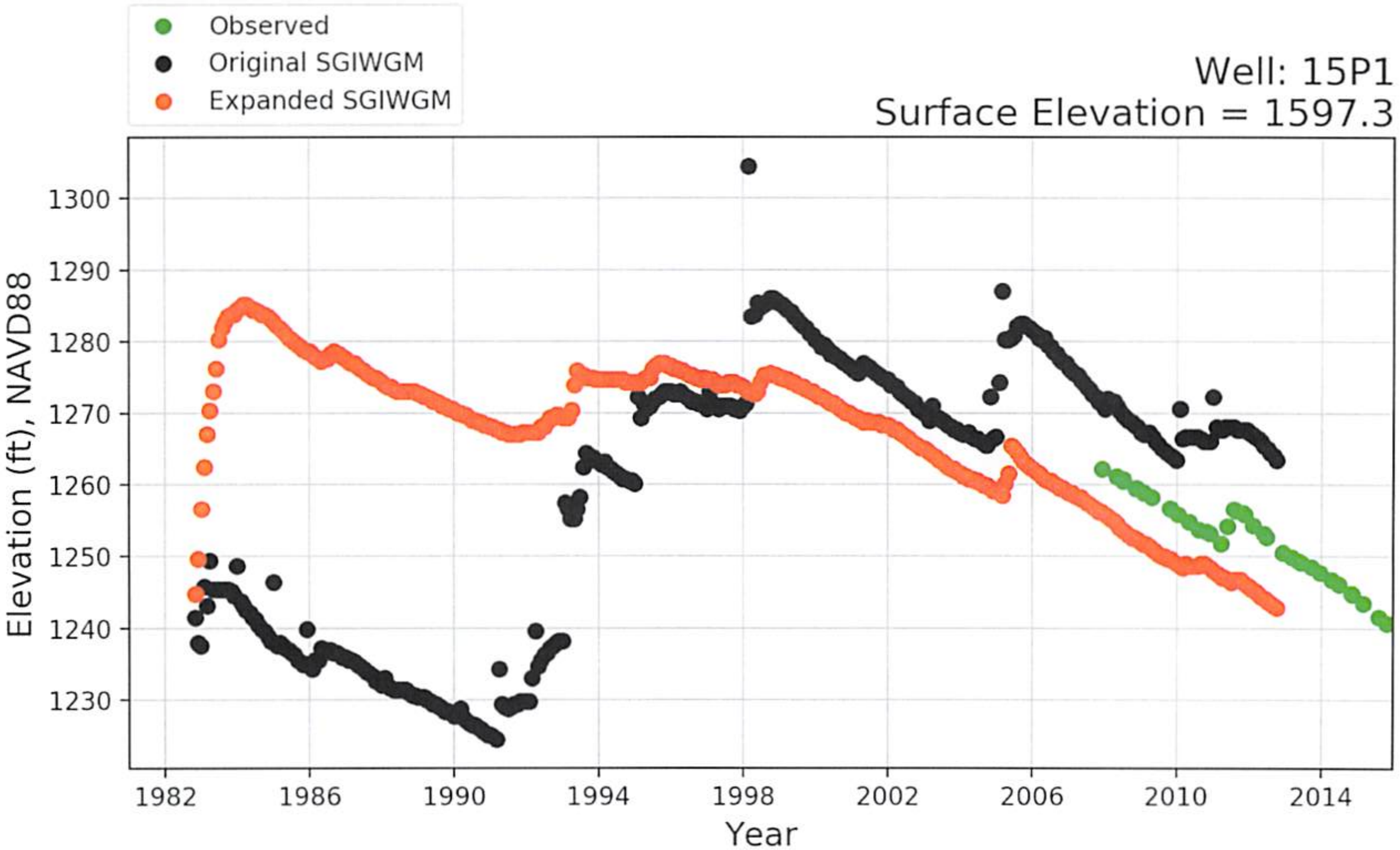

Observed
Original SGIWGM
Expanded SGIWGM
Well: 15P1
Surface Elevation = 1597.3
Elevation (ft), NAVD88
1300
1290
1280
1270
1260
1250
1240
1230
1982
1986
1990
1994
1998
2002
2006
2010
2014
Year

Figure 26p

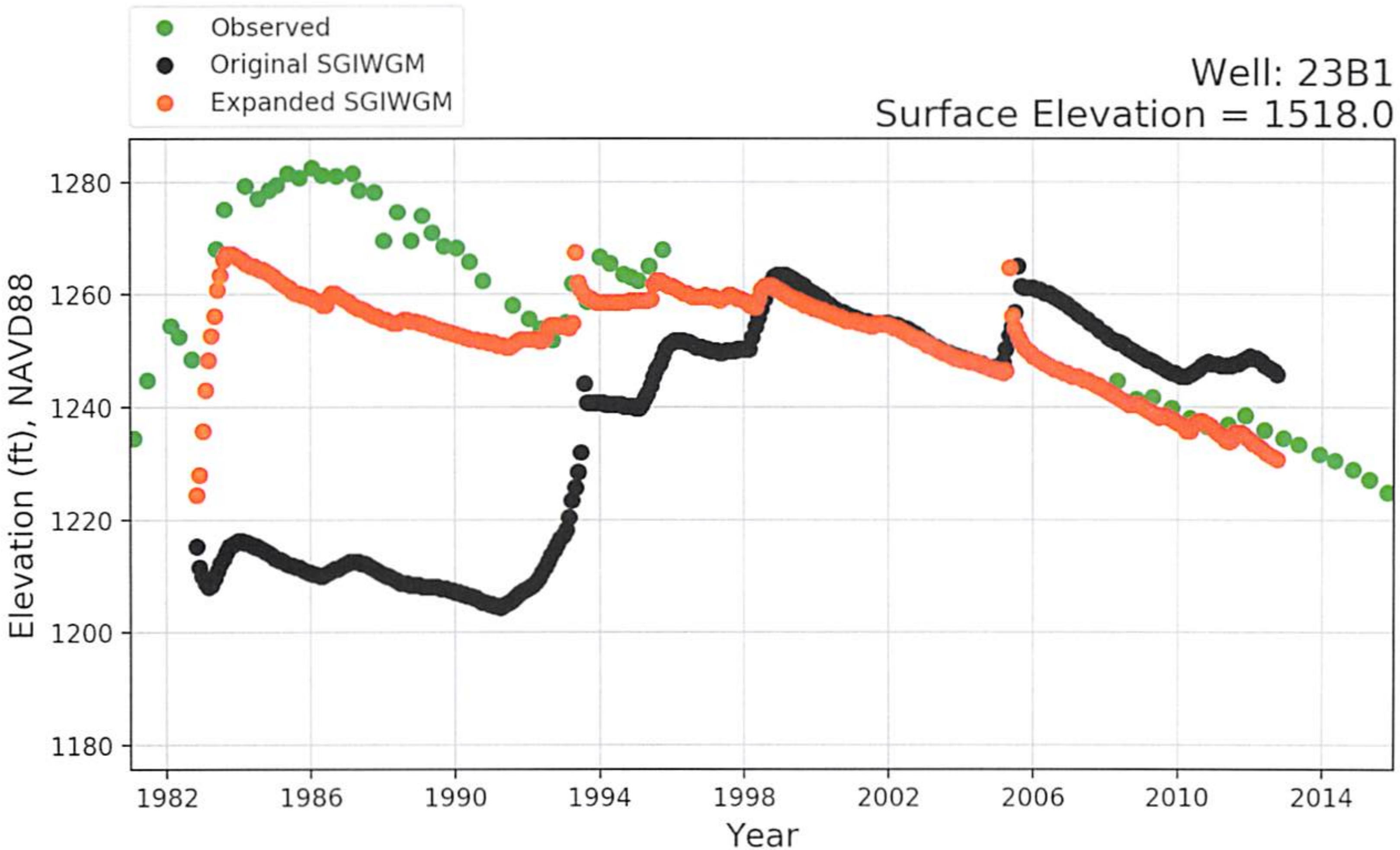

Observed
Original SGIWGM
Expanded SGIWGM
Well: 23B1
Surface Elevation = 1518.0
1280
1260
1240
1220
1200
1180
Elevation (ft), NAVD88
1982
1986
1990
1994
1998
2002
2006
2010
2014
Year

Figure 26q

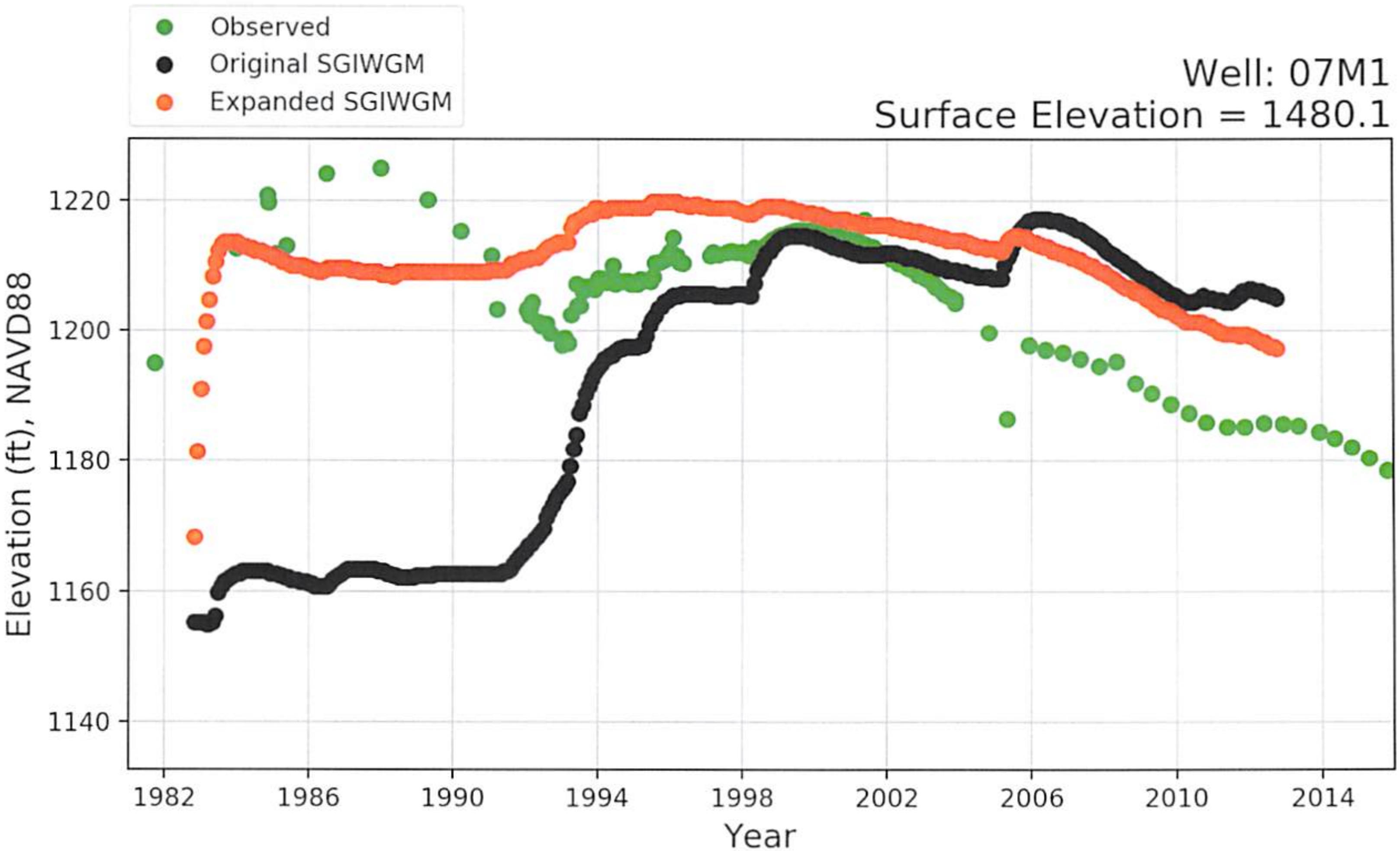
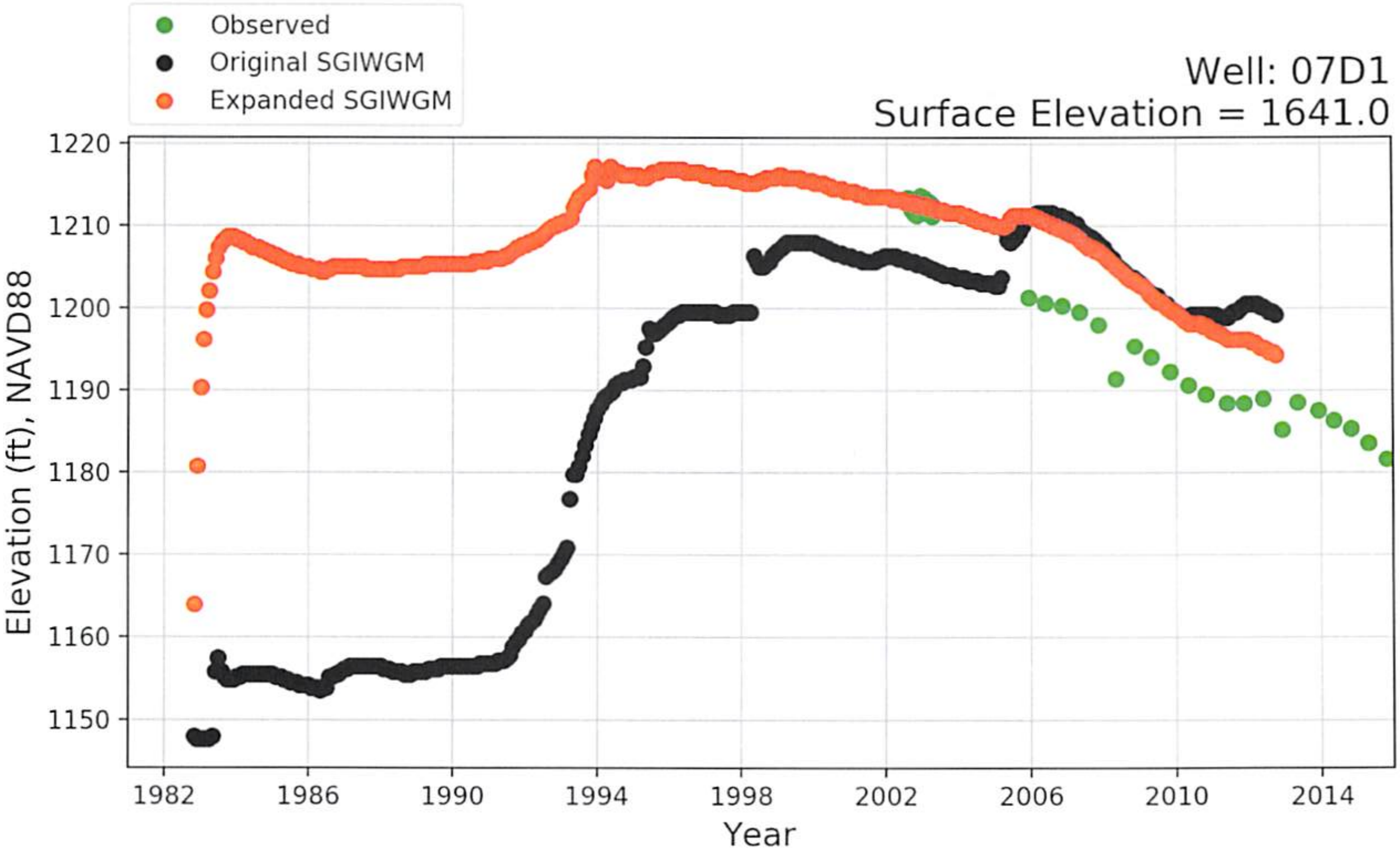

Observed
Original SGIWGM
Expanded SGIWGM
Well: 07M1
Surface Elevation = 1480.1
Elevation (ft), NAVD88
1220
1200
1180
1160
1140
1982
1986
1990
1994
1998
2002
2006
2010
2014
Year

Figure 26r



Observed
Original SGIWGM
Expanded SGIWGM
Well: 07D1
Surface Elevation = 1641.0
Elevation (ft), NAVD88
1220
1210
1200
1190
1180
1170
1160
1150
1982
1986
1990
1994
1998
2002
2006
2010
2014
Year

Figure 26s

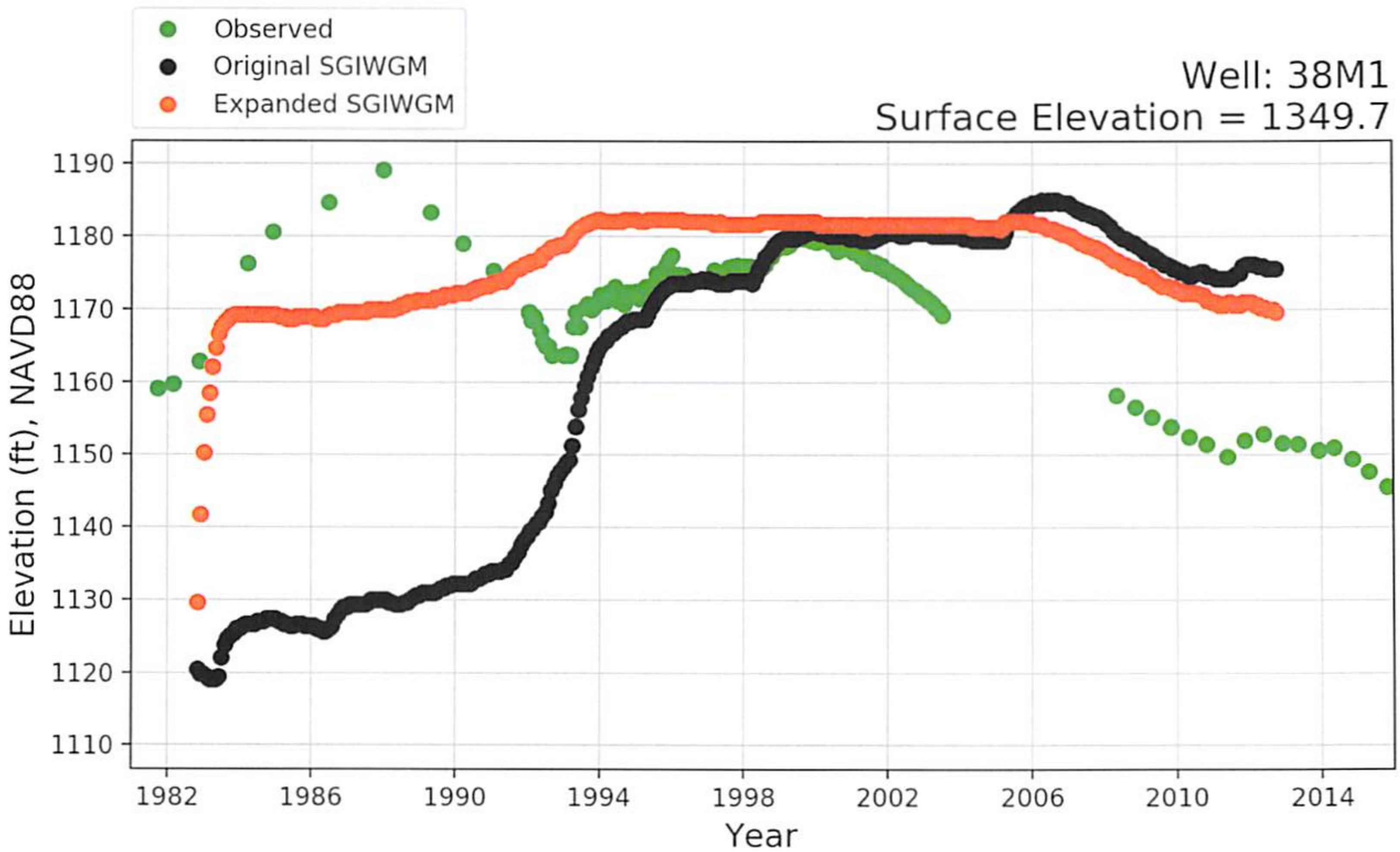

Observed
Original SGIWGM
Expanded SGIWGM
Well: 38M1
Surface Elevation = 1349.7
1190
1180
1170
1160
1150
1140
1130
1120
1110
Elevation (ft), NAVD88
1982
1986
1990
1994
1998
2002
2006
2010
2014
Year

Figure 26t

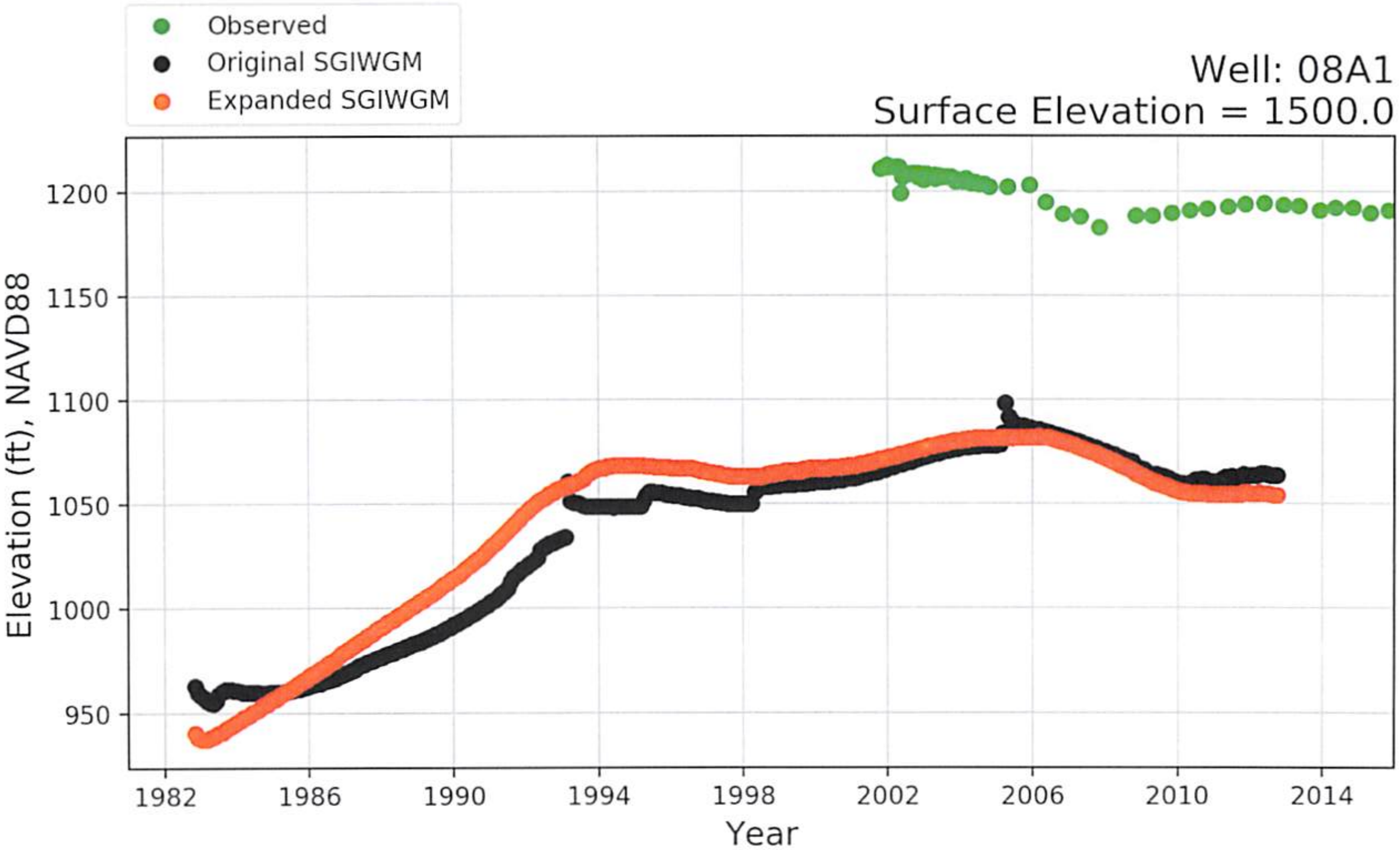

Observed
Original SGIWGM
Expanded SGIWGM
Well: 08A1
Surface Elevation = 1500.0
Elevation (ft), NAVD88
1200
1150
1100
1050
1000
950
1982
1986
1990
1994
1998
2002
2006
2010
2014
Year

Figure 27a

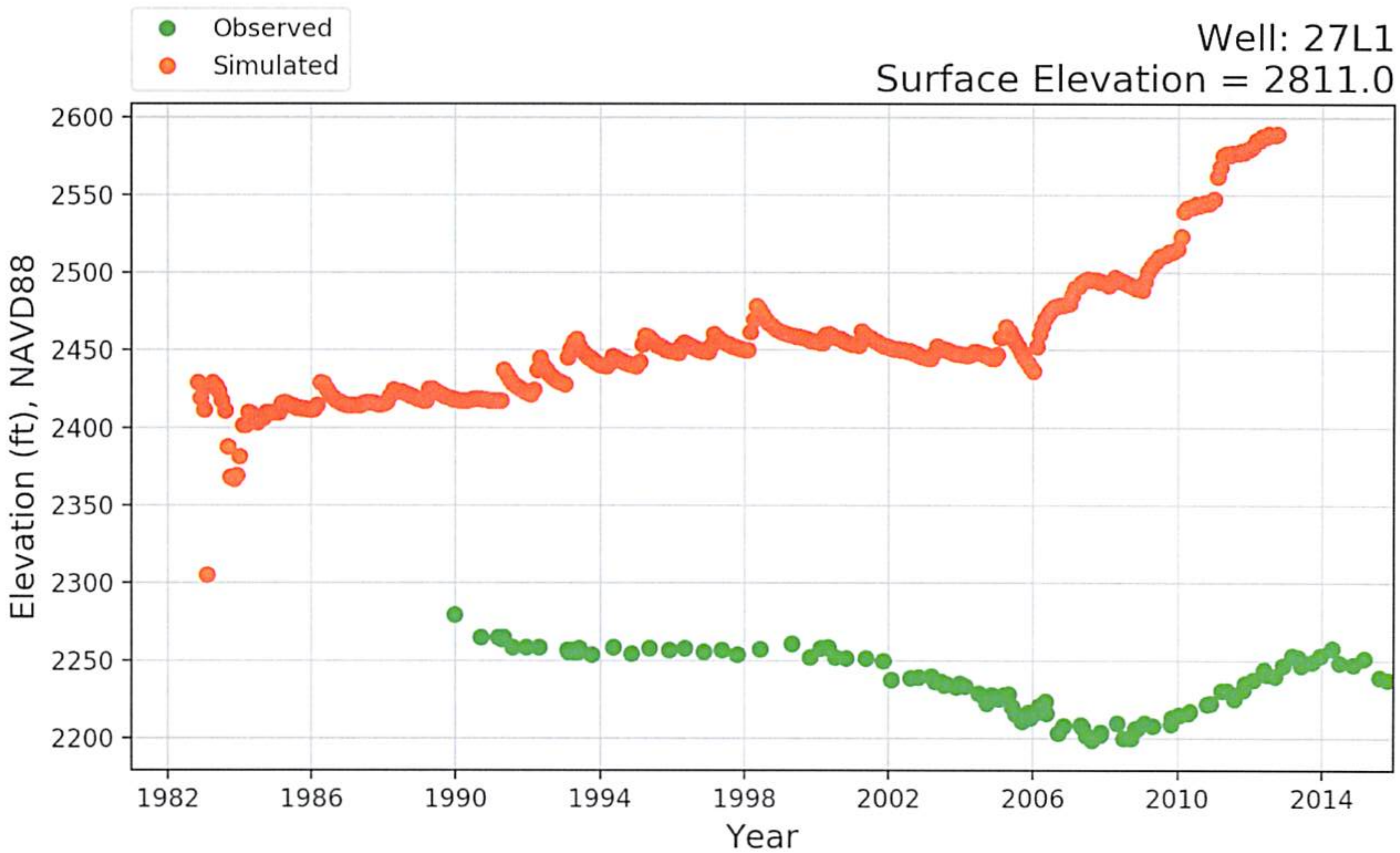

Observed
Simulated
Well: 27L1
Surface Elevation = 2811.0
Elevation (ft), NAVD88
2600
2550
2500
2450
2400
2350
2300
2250
2200
1982
1986
1990
1994
1998
2002
2006
2010
2014
Year

Figure 27b

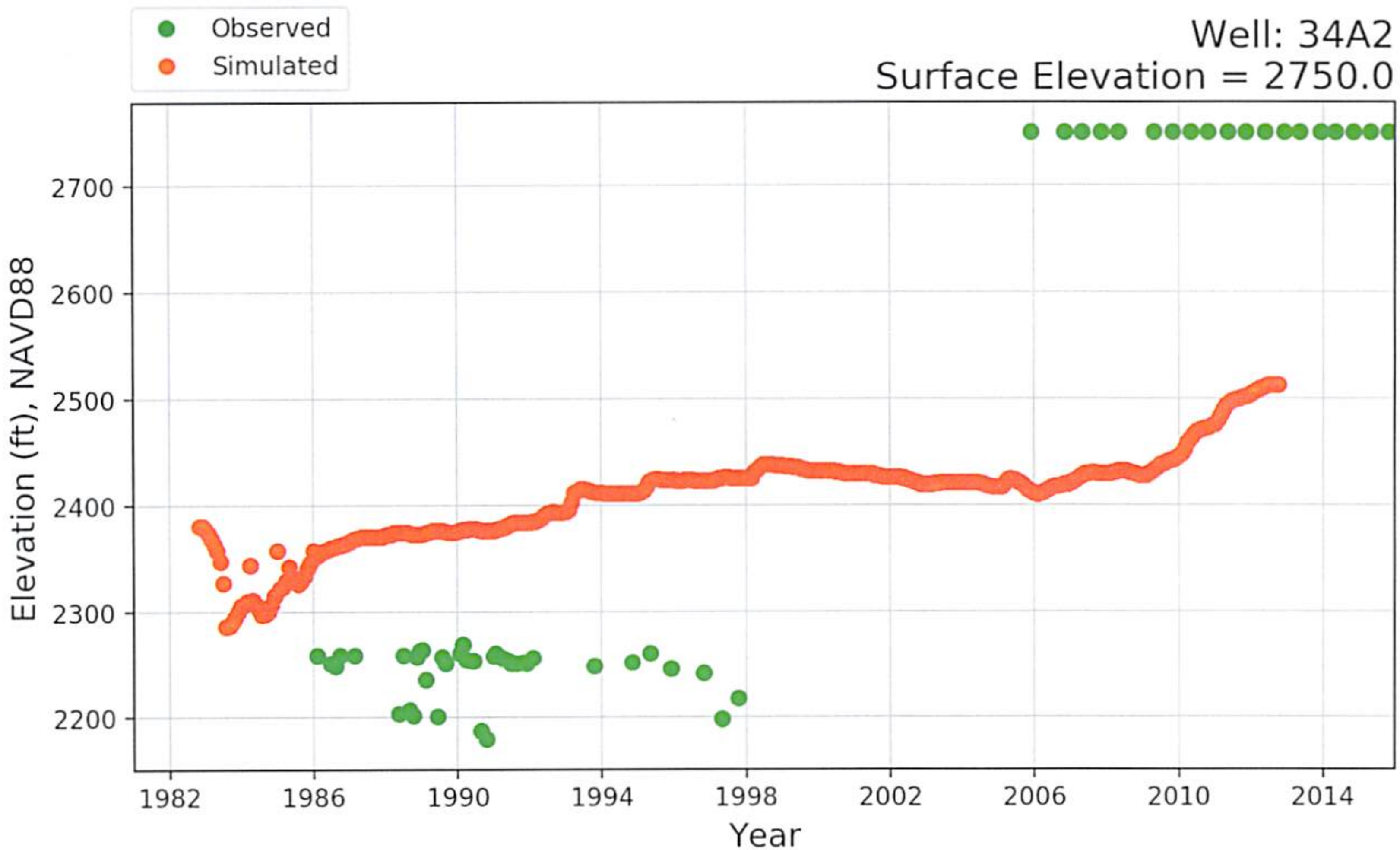

Observed
Simulated
Well: 34A2
Surface Elevation = 2750.0
Elevation (ft), NAVD88
2700
2600
2500
2400
2300
2200
1982
1986
1990
1994
1998
2002
2006
2010
2014
Year

Figure 27c

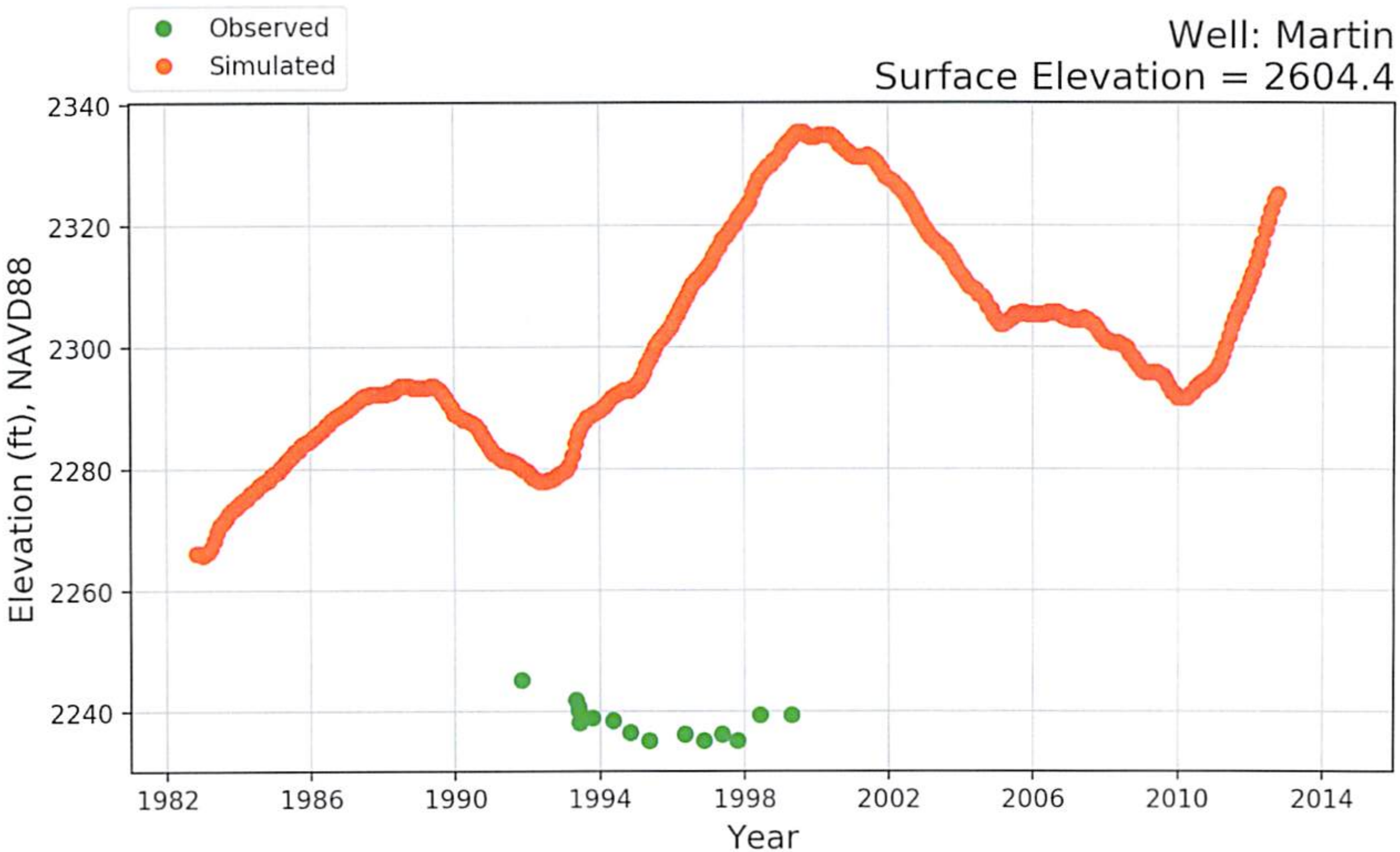

Observed
Simulated
Well: Martin
Surface Elevation = 2604.4
2340
2320
2300
2280
2260
2240
Elevation (ft), NAVD88
1982
1986
1990
1994
1998
2002
2006
2010
2014
Year

Figure 27d

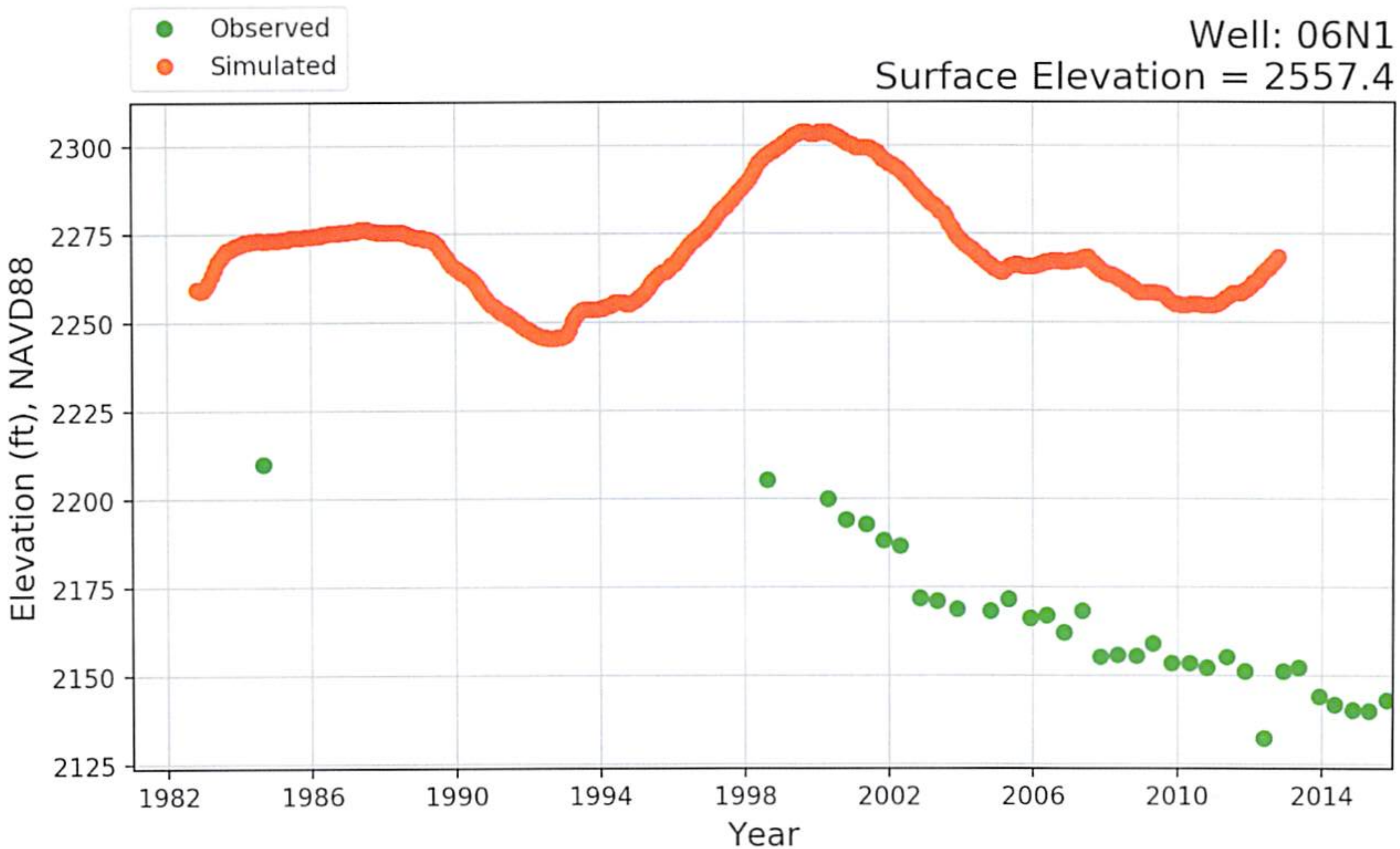

Observed
Simulated
Well: 06N1
Surface Elevation = 2557.4
Elevation (ft), NAVD88
2300
2275
2250
2225
2200
2175
2150
2125
1982
1986
1990
1994
1998
2002
2006
2010
2014
Year

Figure 27e

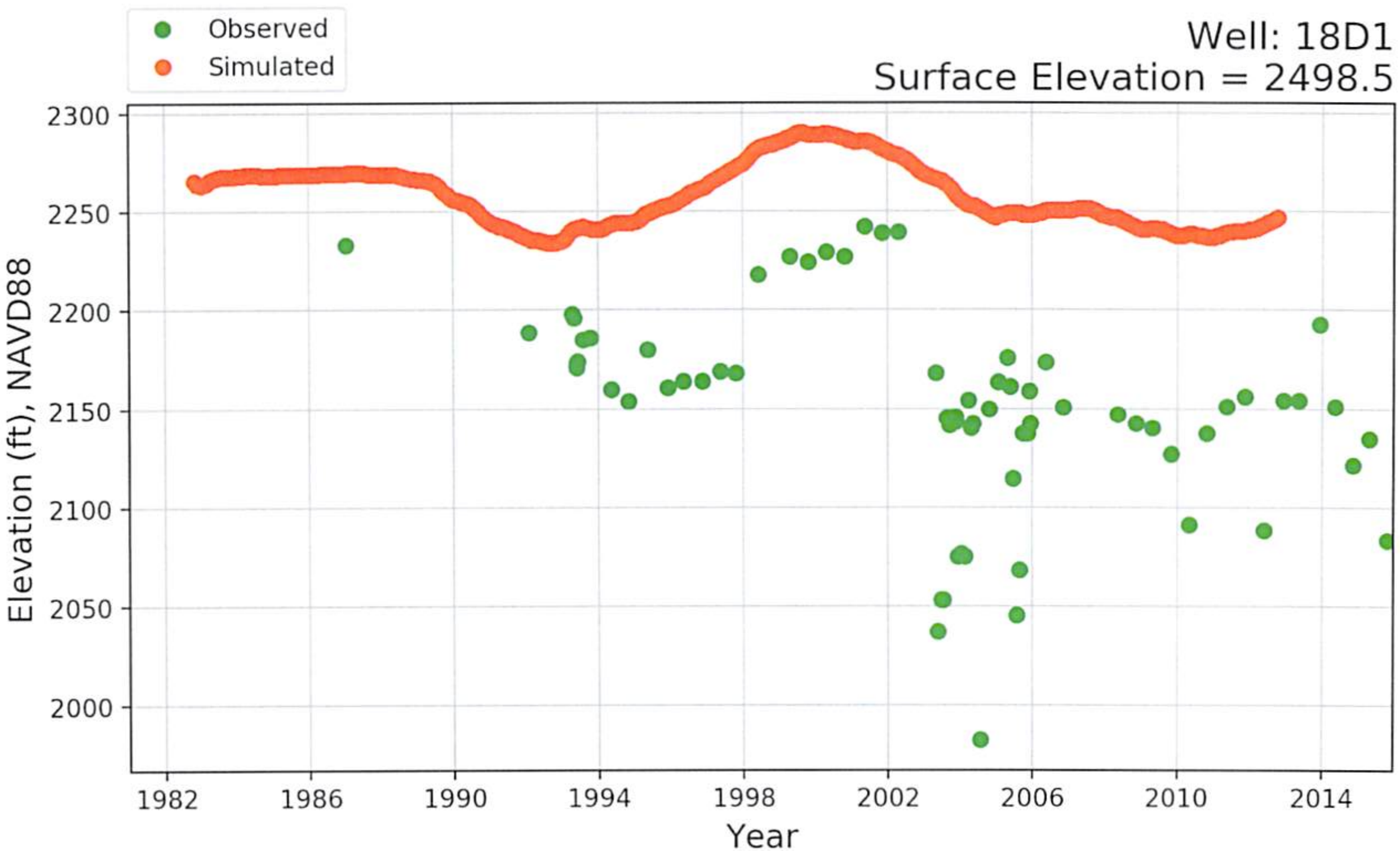

Observed
Simulated
Well: 18D1
Surface Elevation = 2498.5
2300
2250
2200
2150
2100
2050
2000
Elevation (ft), NAVD88
1982
1986
1990
1994
1998
2002
2006
2010
2014
Year

Figure 27f

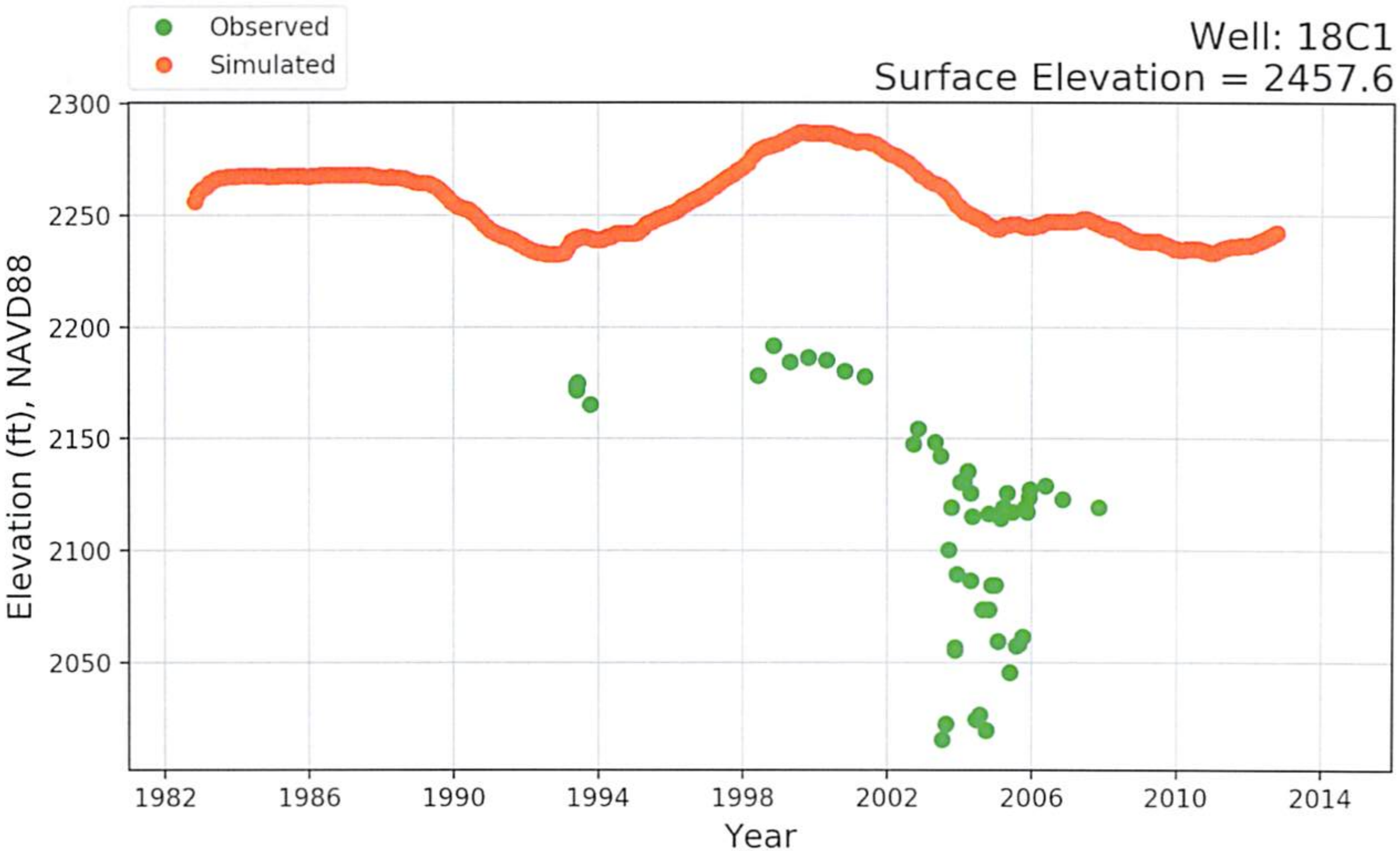

Observed
Simulated
Well: 18C1
Surface Elevation = 2457.6
2300
2250
2200
2150
2100
2050
Elevation (ft), NAVD88
1982
1986
1990
1994
1998
2002
2006
2010
2014
Year

Figure 27g

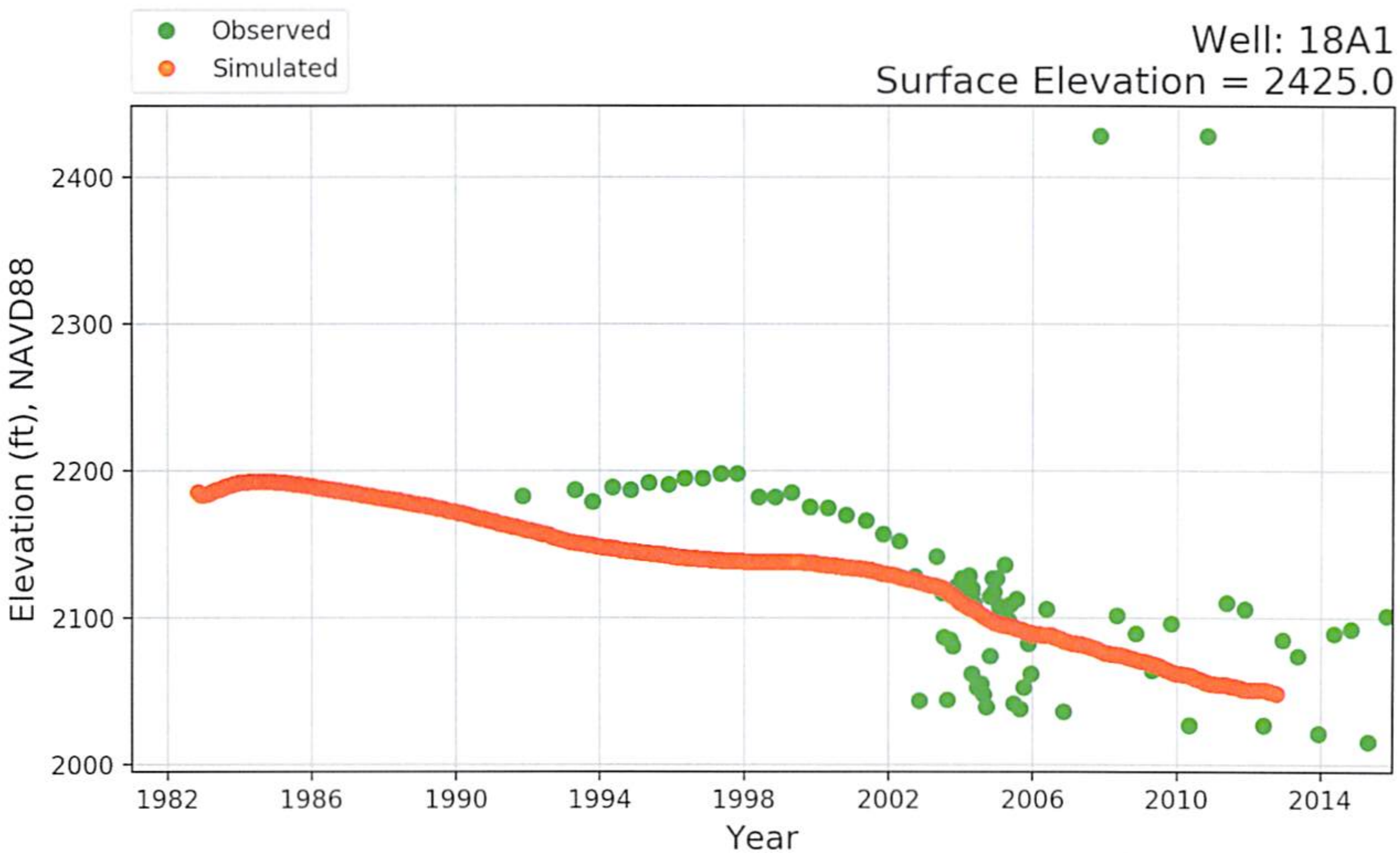

Observed
Simulated
Well: 18A1
Surface Elevation = 2425.0
Elevation (ft), NAVD88
2400
2300
2200
2100
2000
1982
1986
1990
1994
1998
2002
2006
2010
2014
Year

Figure 27h

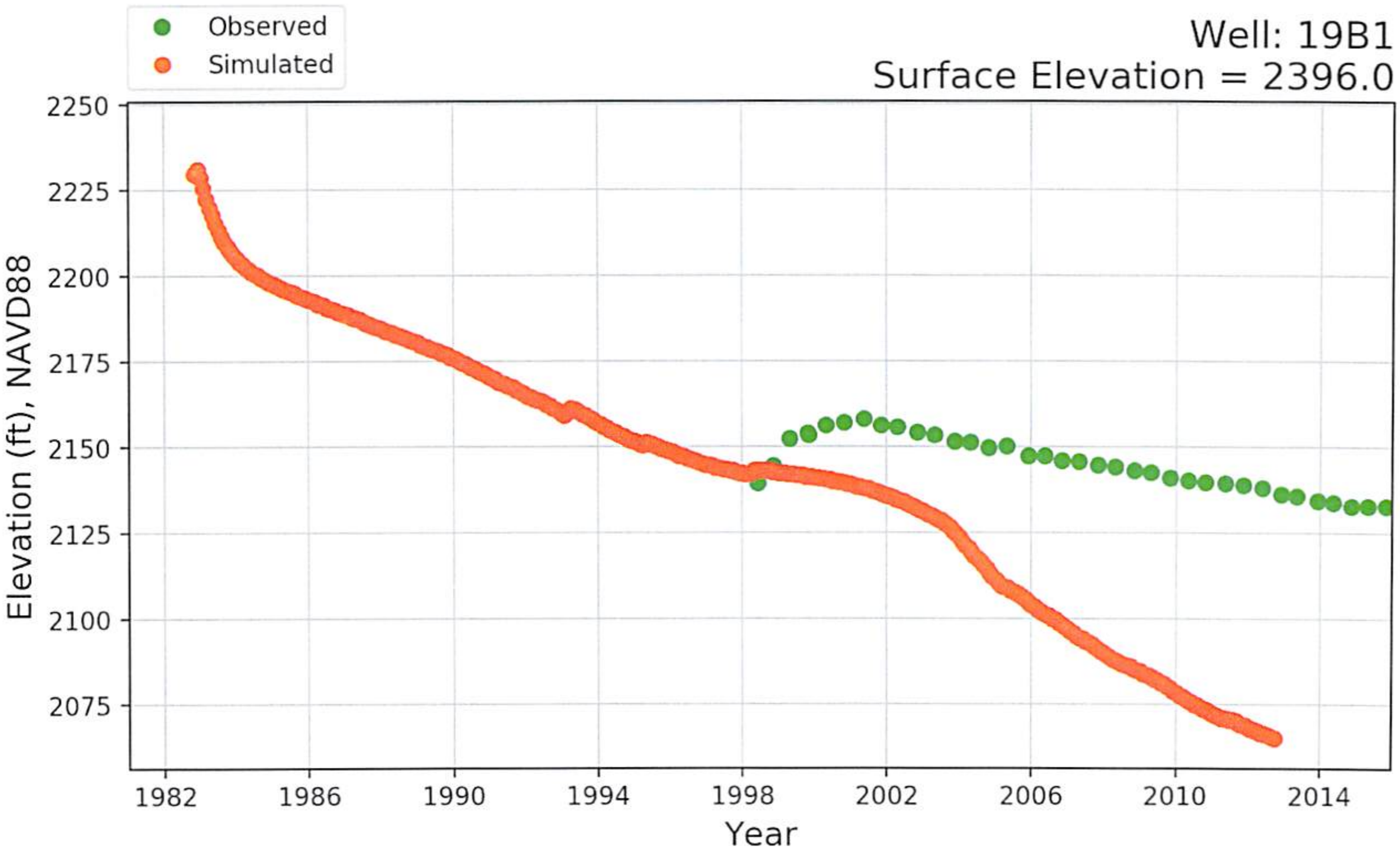

Observed
Simulated
Well: 19B1
Surface Elevation = 2396.0
2250
2225
2200
2175
2150
2125
2100
2075
Elevation (ft), NAVD88
1982
1986
1990
1994
1998
2002
2006
2010
2014
Year

Figure 27i

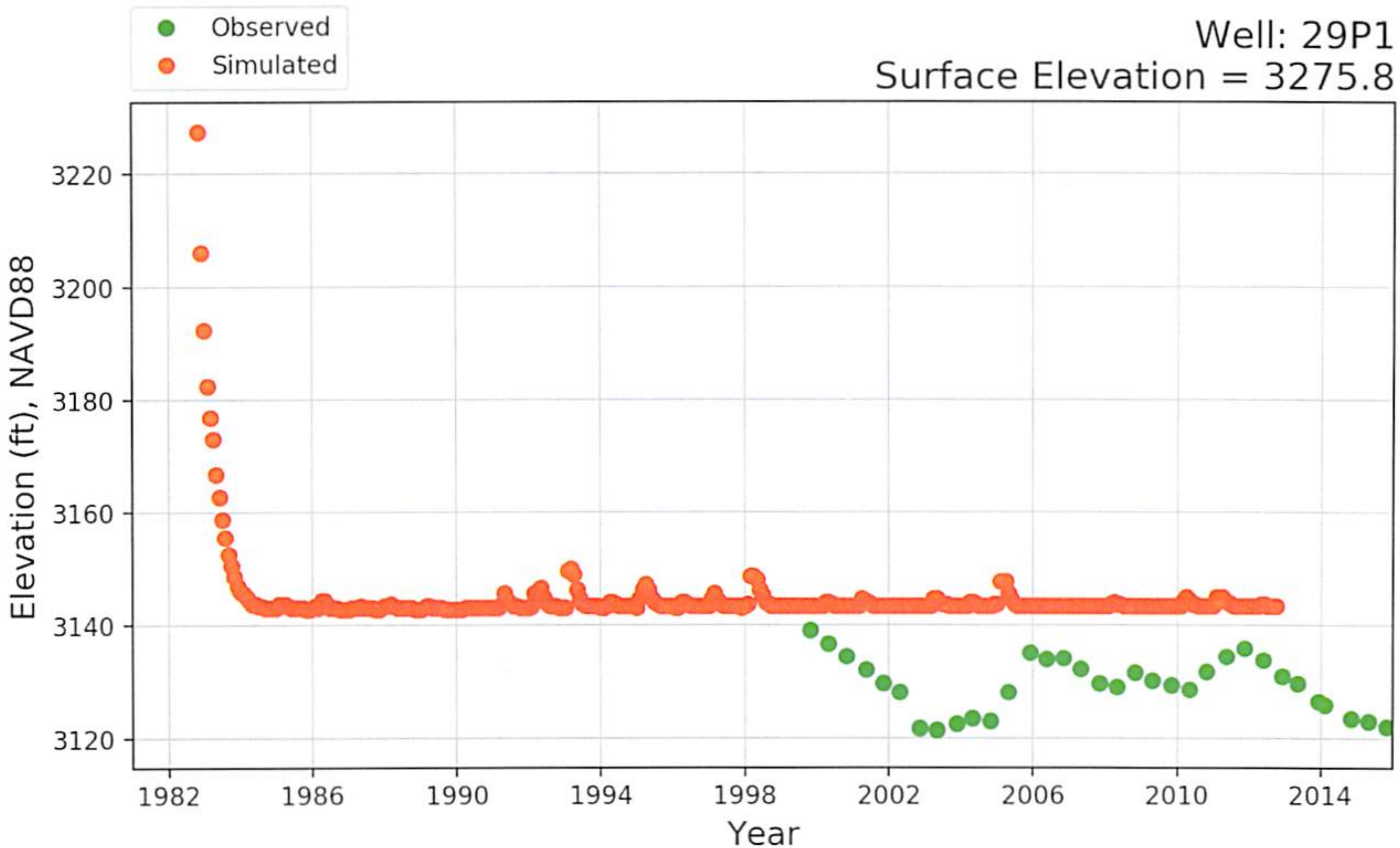

Observed
Simulated
Well: 29P1
Surface Elevation = 3275.8
Elevation (ft), NAVD88
3220
3200
3180
3160
3140
3120
1982
1986
1990
1994
1998
2002
2006
2010
2014
Year

Figure 27j

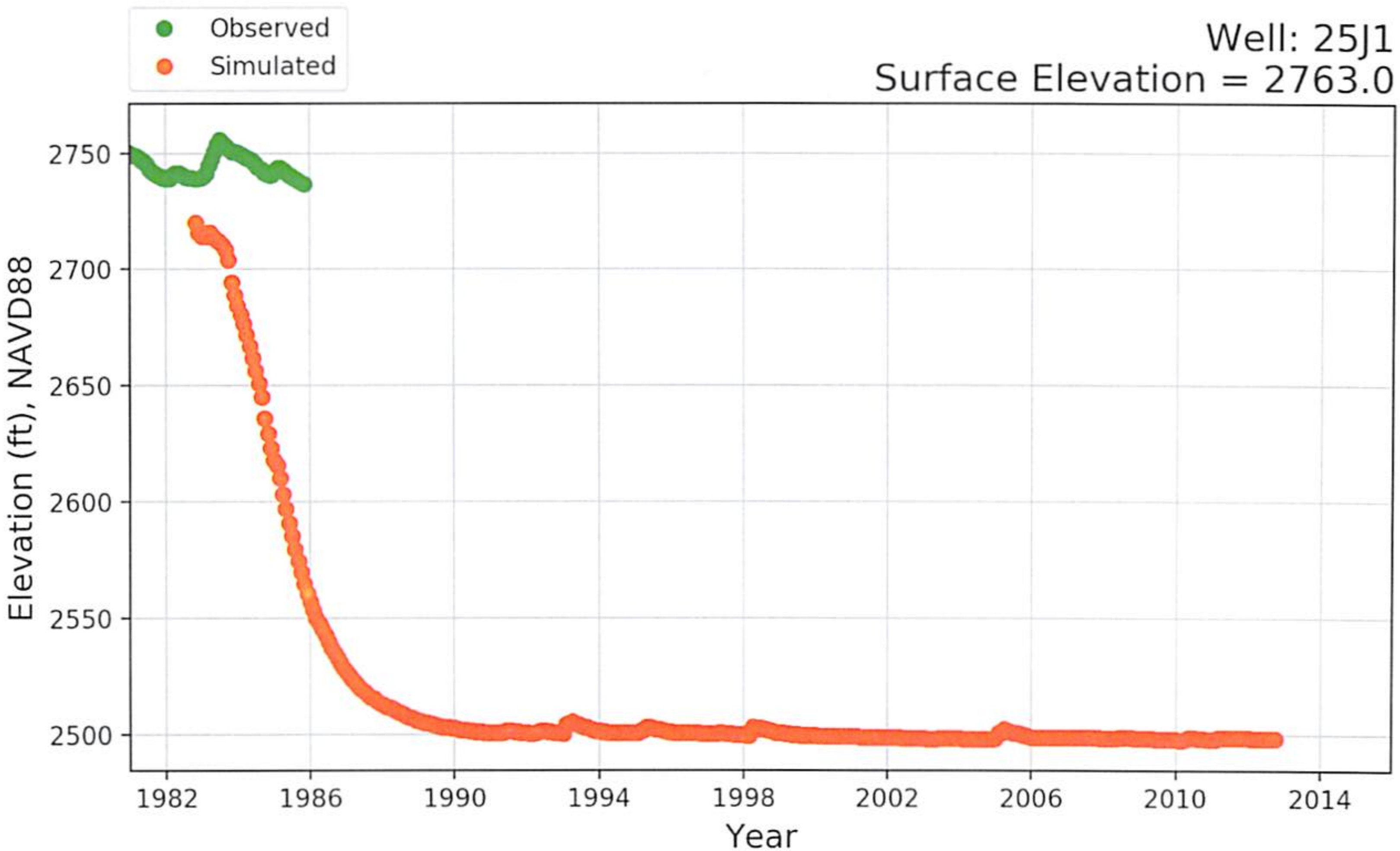

Observed
Simulated
Well: 25J1
Surface Elevation = 2763.0
Elevation (ft), NAVD88
2750
2700
2650
2600
2550
2500
1982
1986
1990
1994
1998
2002
2006
2010
2014
Year

Figure 28a

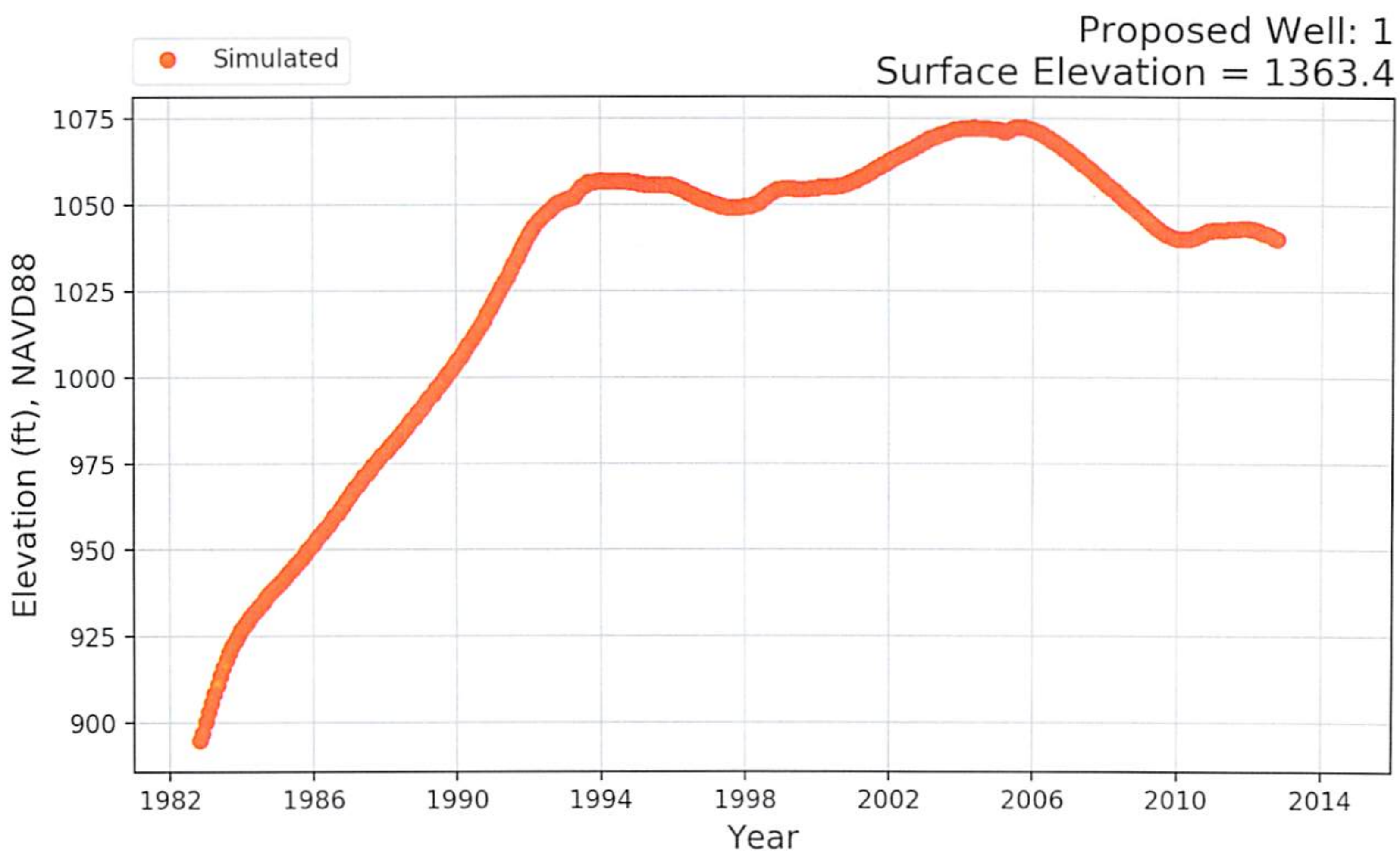

Simulated
Proposed Well: 1
Surface Elevation = 1363.4
Elevation (ft), NAVD88
1075
1050
1025
1000
975
950
925
900
1982
1986
1990
1994
1998
2002
2006
2010
2014
Year

Figure 28b

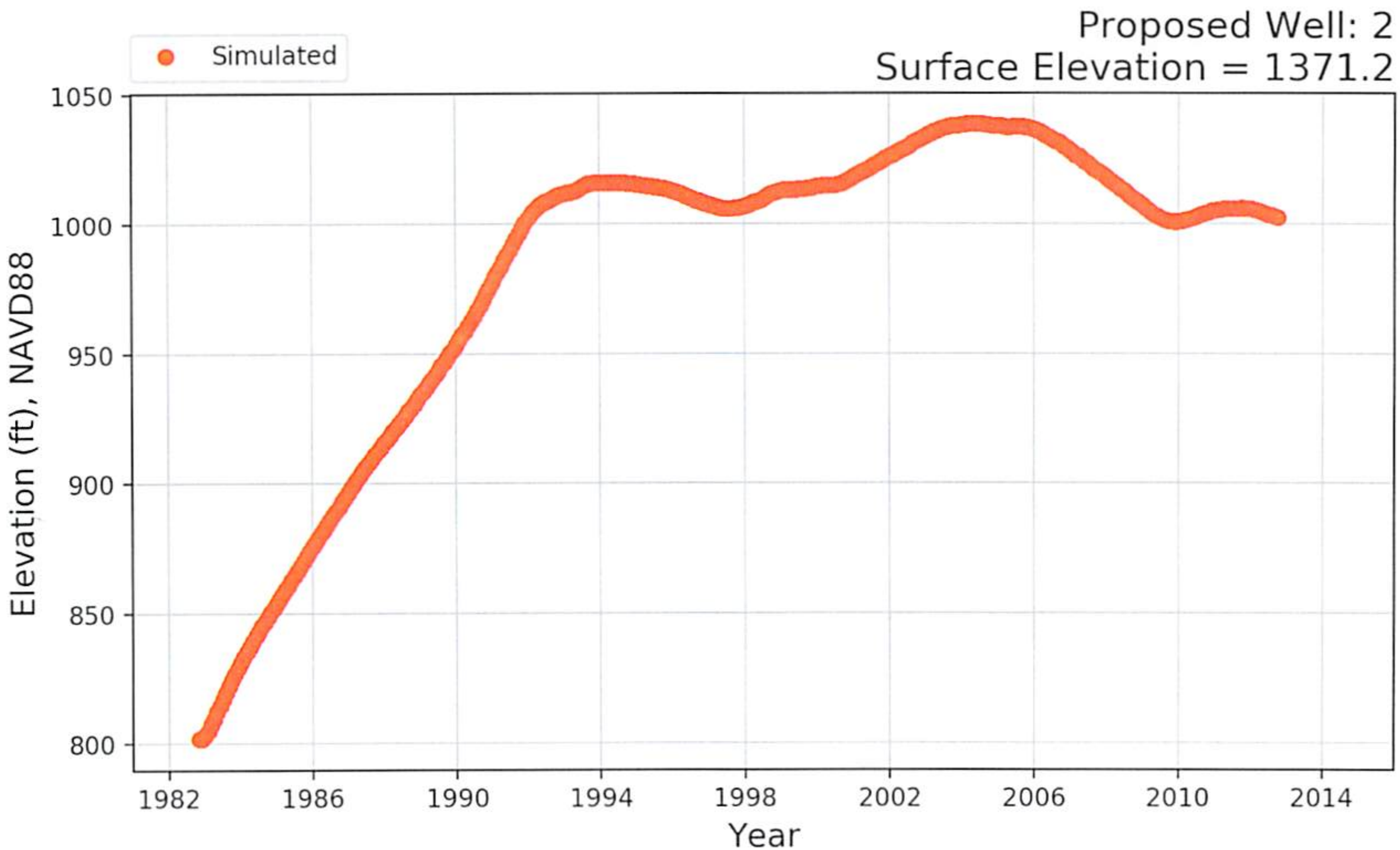
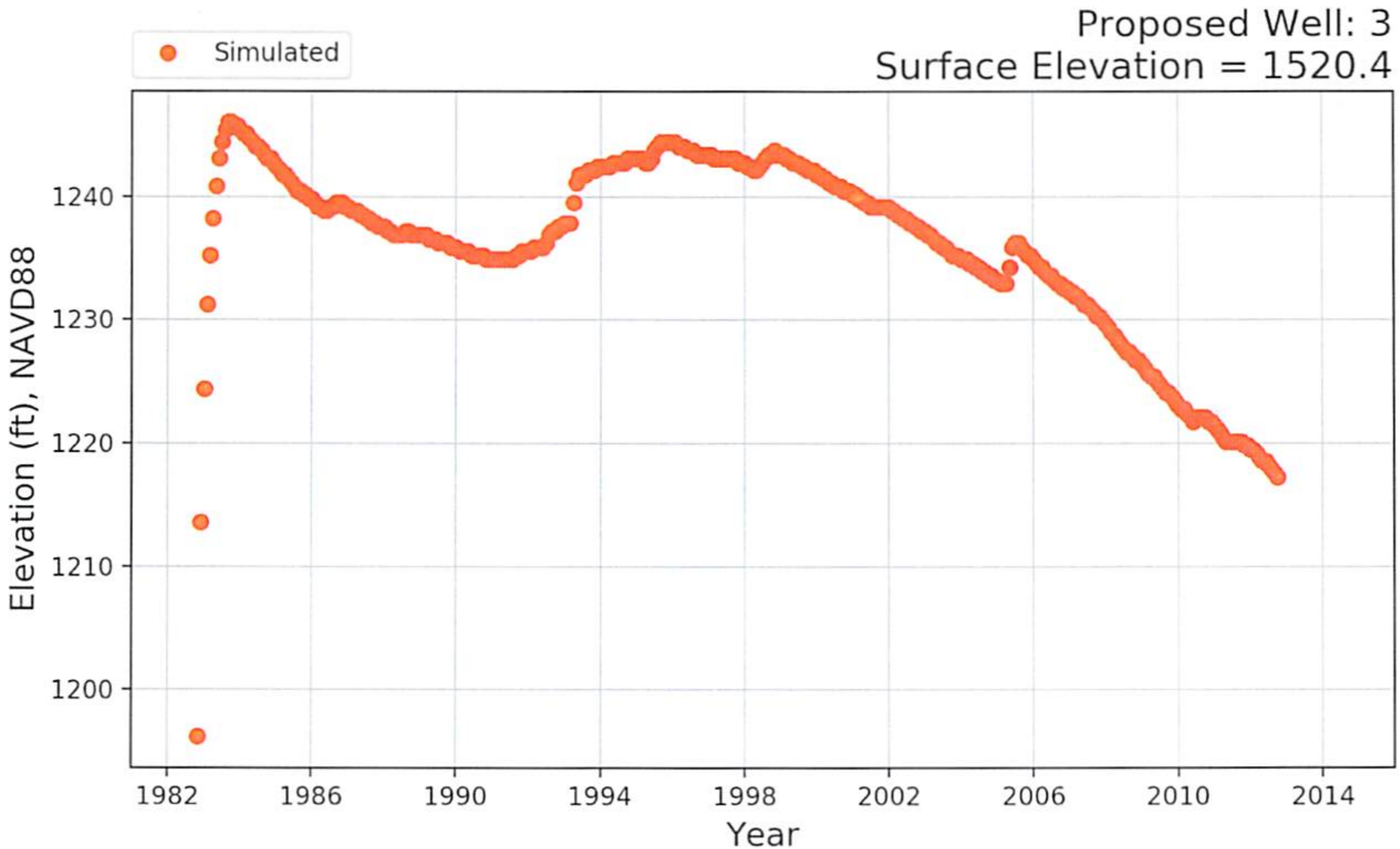

Simulated
Proposed Well: 2
Surface Elevation = 1371.2
1050
1000
950
900
850
800
Elevation (ft), NAVD88
1982
1986
1990
1994
1998
2002
2006
2010
2014
Year

Figure 28c


Simulated
Proposed Well: 3
Surface Elevation = 1520.4
Elevation (ft), NAVD88
1240
1230
1220
1210
1200
1982
1986
1990
1994
1998
2002
2006
2010
2014
Year