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TECHNICAL MEMORANDUM

To: Kim Adamson, Soquel Creek Water District
Ralph Bracamonte, Central Water District

From: Cameron Tana and Derrik Williams

Date: January 23, 2015

Subject: Work Plan

Soquel-Aptos Area Groundwater Model

This memorandum provides the work plan for completing the Soquel-Aptos Area groundwater model. This work plan is based on two scoping meetings held on October 28 and December 1, 2014. This work plan describes the tasks required to develop a groundwater model with the uses and capabilities described in the attached memorandum (HydroMetrics WRI, 2015).

One primary direction from the scoping meetings is to use the U.S. Geological Survey (USGS) model code GSFLOW (Markstrom et al., 2008) that is a fully integrated watershed-groundwater model. GSFLOW will be used because simulating surface water-groundwater interaction is a top priority use of the model.

This work plan has a major change from the tasks listed in our July 10, 2014 proposal to the Basin Implementation Group (BIG). The July 10 proposal proposed using the existing Precipitation-Runoff Modeling System (PRMS) watershed model for the Soquel-Aptos Area (HydroMetrics WRI, 2011) and integrating it directly with a MODFLOW groundwater model to create a GSFLOW model. The USGS provided guidance as part of the scoping process and recommended that the PRMS watershed model be based on a rectangular grid, rather than the sub-watershed discretization used by the existing PRMS model. Therefore, we will need to create a grid based PRMS model, although we will leverage the previous work by using data sets input into the existing PRMS model.

Additional changes from the proposal will be noted in the task list.

TEAM MEMBERS

The principals of HydroMetrics WRI, Derrik Williams and Cameron Tana, will lead the work in the roles of technical lead and project manager, respectively. Senior hydrogeologist Georgina King will lead land use analysis and transfer of information from the existing PRMS model to the grid-based model. Our staff groundwater modelers are Stephen Hundt and Hanieh Haeri. If additional modelers are added to the team, we will provide resumes.

Based on a reference from the USGS, we are subcontracting with Huntington Hydrologic, Inc. (Huntington) to efficiently develop a grid based PRMS model. Justin Huntington, the principal of Huntington Hydrologic, is a research professor at the Desert Research Institute and is a PRMS and GSFLOW expert.

Mike Cloud will also join our team to assist with developing the hydrogeologic subsurface structure. Before retiring from Santa Cruz County, Mike developed a detailed knowledge of the basin's hydrogeology and we plan to leverage that knowledge.

The U.S. Geological Survey (USGS) will continue to provide support for this effort under separate contract with the Basin Implementation Group. Linda Woolfenden will provide guidance for the modeling effort on conference calls every other week, review of reports, and participation in Technical Review Committee meetings. Richard Niswonger will upgrade GSFLOW to incorporate the seawater intrusion package SWI2. Lorrie and Alan Flint will develop climate data for the calibration period and climate scenarios to incorporate in model simulations of future conditions.

The following tasks make up the work plan. Several tasks detail interim deliverables to be reviewed by the Technical Review Committee that will also be used as milestones for project progress. Task 1 is the scoping task that concludes with Basin Implementation Group acceptance of this work plan and formation of the Technical Review Committee.

TASK 2. DEVELOP MODEL OF SURFACE SYSTEM

2.1 DEFINE MODEL GRID FOR GROUNDWATER MODEL

The model grid for the surface system needs to match the model grid for the groundwater system. HydroMetrics WRI will first define a reasonable model grid for the groundwater system. The model grid will consider important aspects of the conceptual model, including:

- Identifying model boundaries. The model boundary will be similar to the existing PRMS model (Figure 1) with revisions most likely in the southeast corner and how far it extends offshore.
- Honoring watershed boundaries
- Acknowledging the groundwater management area boundary
- Acknowledging and incorporating the Central Water District (CWD) model grid (HydroMetrics WRI and Kennedy/Jenks, 2014), though highly discretized areas of the CWD grid will likely be made more coarse for this larger model
- Honoring existing and potential well locations
- Honoring geologic structures
- Maintaining reasonable simulation times

2.2 REFINE MODEL GRID FOR PRMS AND DEFINE STREAM/SUB-WATERSHED NETWORK

In addition to the preliminary grid created for the groundwater system, the model grid for the surface system will be based on the ground surface digital elevation model (DEM) and stream network. HydroMetrics WRI will compile the stream network map and the streamflow gauge locations from the previous PRMS work into a Geographic Information System (GIS) GeoDatabase. HydroMetrics WRI will also compile daily streamflow data for the gauges.

The preliminary model grid and stream GeoDatabase will be transferred to Huntington. Huntington will refine and modify the grid as necessary to promote an accurate and efficient surface water simulation. Huntington will refine the grid and define the stream/sub-watershed network based on the grid by:

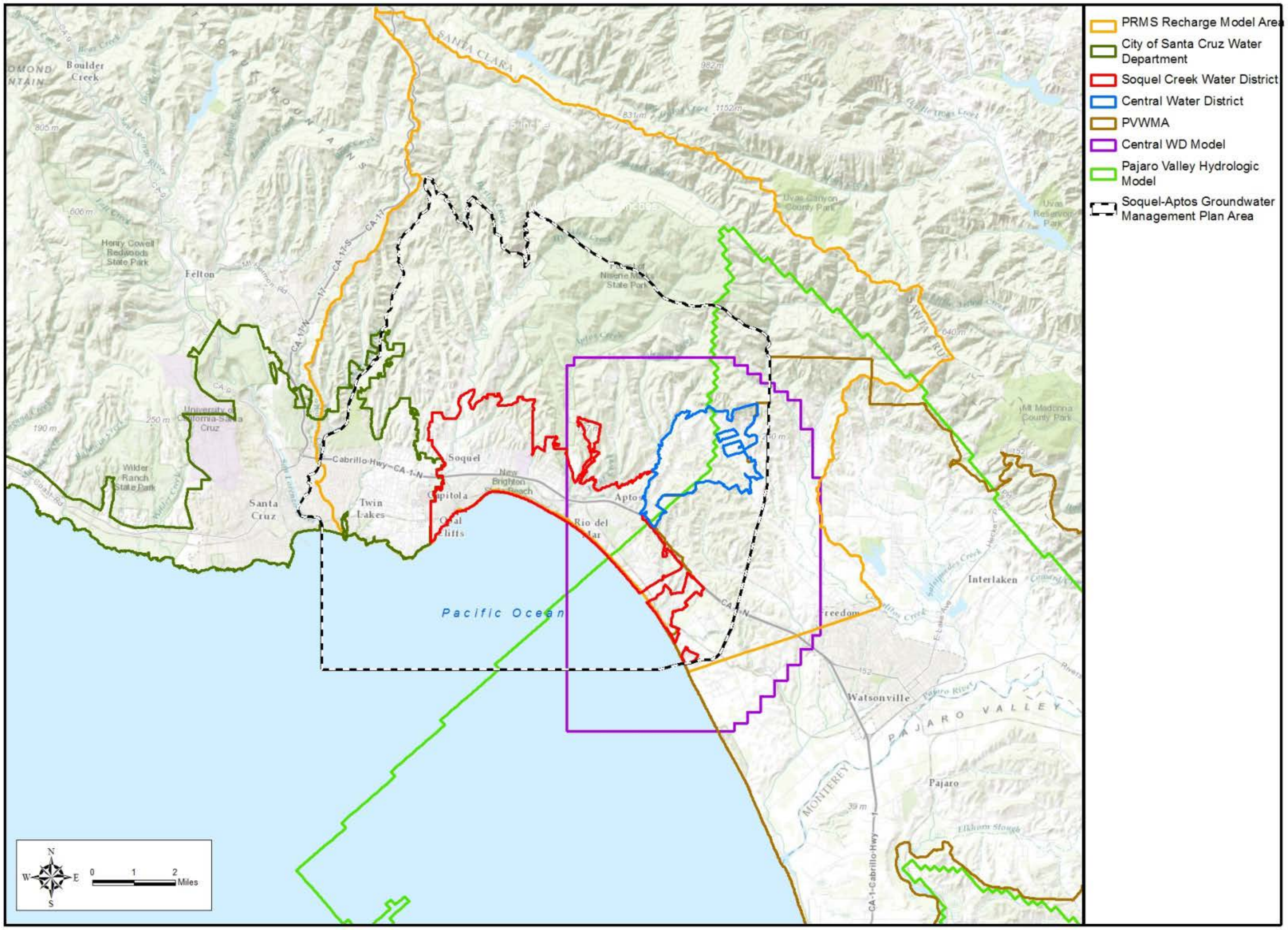

Figure 1. Existing Model Boundaries

- Resampling an existing DEM to the Grid
- Overlaying stream and stream gauge locations and adjusting DEM, stream locations, and grid as necessary
- Developing the grid-based stream network and cascade network
- Creating sub-watersheds at each gauge and mapping to grid
- Creating a map of the MODFLOW Streamflow Routing Package (SFR) stream segments with reach ordering.

The result will be the final grid and stream network used for the GSFLOW model. This grid will be used for modeling the surface system in Task 2 as well as the subsurface system in Task 3.

2.3 COMPILE LAND SURFACE DATA FROM SUB-WATERSHED BASED PRMS FOR DEVELOPMENT OF GRID BASED PRMS

For the existing sub-watershed based PRMS model, spatially distributed parameters were based on available spatial data sets, zone-based calibration to streamflows, and default values recommended by USGS documentation of PRMS (USGS, 2011). HydroMetrics WRI will compile these datasets into a GIS Geodatabase for Huntington to use in defining initial grid-based parameter values.

The four spatial data sets that will be compiled are the surface outcrop of geology (Johnson et al., 2004, Cloud, 2006, Brabb, 1997), USGS 30 meter gridded land use/land cover (USGS, 2007), SSURGO soils database (NRCS, 2009), and USGS tree canopy density (USGS, 2007). A spatial data set with the four geology-based calibration zones will be compiled with the calibrated values. The default values used will also be compiled.

Huntington will use these data sets to assign initial parameter values to the model grid cells, efficiently making use of the previous PRMS effort and calibration.

2.4 CLIMATE DATA FOR GRID-BASED PRMS

For this model, we will use available station data for rainfall and spatially distribute the data using the PRISM dataset. This differs from the existing PRMS, for which we distributed data from individual weather stations based on distance inverse weighting. Using the PRISM dataset for historical climate simulations will be more consistent with the datasets that will be developed to simulate different climate change scenarios (Task 5.2). HydroMetrics WRI will compile individual weather station data. Huntington will use the station data and PRISM dataset to calculate precipitation parameters and map them to the grid cells.

We also plan to directly input spatially distributed temperature, solar radiation and evapotranspiration data into PRMS. In most PRMS applications, including our existing PRMS, model parameters are calibrated to regional solar radiation and evapotranspiration data averaged over longer timescales than the daily results provided by PRMS. The USGS will develop spatially distributed daily data for input into PRMS by Huntington. This methodology will be consistent with methodology used for climate change scenarios (Task 5.2).

2.5 LAND USE ANALYSIS FOR WATER USE AND RETURN FLOW

An important part of the basin's water balance is water use by non-agency pumpers and return flow from all users. The return flow occurs at the surface and can both recharge the basin or flow to streams so this source of water needs to added to the PRMS model of the surface system. We performed a land use analysis for the CWD model using assumptions in Johnson et al. (2004). We propose to expand the land use analysis from the CWD model to the entire basin, and update the assumptions in Johnson et al. (2004) with more current and local information. This analysis will involve the following steps.

- Revise water use factors and return flow assumptions for more current and local information.
- Extend GIS analysis of land use from CWD model to entire basin. We plan to apply the current land use over the entire model period. We will either assume current non-agency water use applies to the entire period or apply a simple factor to account for changes in water use over time.
- Evaluate water use and return flow by land use zone.
- Calculate system losses based on zones served by water supply and sewer systems

HydroMetrics WRI will compile return flow estimates by land use zone in a GIS Geodatabase. Huntington will map water applied at the surface to the model grid cells. System losses that occur below the surface will likely be added directly to groundwater using the recharge package.

2.6 DRAFT TECHNICAL MEMO AND REVIEW OF PRMS INPUTS *(MILESTONE)*

We will summarize the work in Tasks 2.1-2.5 in a draft technical memorandum. An interim draft technical memorandum will first be reviewed by the USGS. The technical memorandum will be revised based on USGS comments and provided to funding partners and Technical Review Committee (TRC) members two weeks prior to a scheduled meeting. HydroMetrics WRI will present the memorandum at the meeting and receive feedback from the TRC. The USGS will also attend the meeting.

2.7 CONSTRUCT GRID-BASED PRMS FOR GSFLOW

Huntington will use the grid-based GeoDatabases from GIS created in Tasks 2.2 through 2.5 to create PRMS input files: including the parameter and control files. Huntington will create the data file containing streamflow for all gauges. Huntington will then make initial PRMS runs, debug, and analyze initial results.

2.8 CALIBRATE PRMS

In order to facilitate integration with MODFLOW in GSFLOW, the grid-based PRMS model will be calibrated to measured steamflows. HydroMetrics WRI will use the Parameter Estimation (PEST) software (Watermark, 2005) to achieve a calibration that is adequate to proceed with the GSFLOW integration. This includes creation of PEST files based on PRMS files.

TASK 3. DEVELOP MODEL OF SUBSURFACE SYSTEM

3.1 SUBSURFACE STRUCTURE FOR MODEL

HydroMetrics WRI and Mike Cloud will develop the hydrogeologic structure of the GSFLOW model based on our existing understanding of the Soquel-Aptos basin hydrostratigraphy. Mapped contacts originally developed by Johnson et al. (2004), and updated by Mike Cloud will form the basis of the hydrostratigraphic layering. Modifications to the mapped contacts will include

- Merging layers used in CWD model.
- Extending layers to the western outcrop boundaries
- Adding layers for deeper Purisima and related units
- Merging units if defensible

Terrace deposits cap the dipping hydrostratigraphy in the coastal area of the Soquel-Aptos basin. As part of this task, we will develop and implement a conceptual model for modeling the terrace deposits. The implementation may be similar to that used for the Potomac aquifer modeled by Phillips (1987).

In consultation with Huntington and USGS, an alluvium layer along the stream network will be added as necessary to simulate groundwater-surface water interaction. A layer to simulate future recharge basins may also be added if artificial surface recharge is a likely groundwater management alternative.

The Zayante fault will be simulated as a horizontal flow barrier. Mike Cloud will help determine whether the Zayante fault should be implemented in only the model layers simulating the Purisima Formation, or the model layers representing both the Purisima and Aromas Formations.

The geologic structure north of the Zayante Fault is undifferentiated Purisima Formation as well as other more consolidated formations. This subsurface area needs to be modeled as part of the integrated GSFLOW model. Based on our current conceptual model, groundwater flow in this area is not significant for groundwater management of the Soquel-Aptos area. Therefore, we will simulate this area as simply as possible. We will likely extend layers across the Zayante Fault to the northern watershed boundary parallel to the ground surface and possibly deactivate lower layers.

HydroMetrics WRI and Mike Cloud will also evaluate and revise the conceptual model for the Aromas coastal area. Groundwater levels observed in the area appear inconsistent with the current conceptual model for the Aromas Red Sands formation.

HydroMetrics WRI will develop the layer surfaces and fault locations, and enter these data into the Groundwater Vistas groundwater modeling graphical user interface.

3.2 DEFINE BOUNDARY CONDITIONS

Boundary conditions must be defined along all lateral edges of the model, as well as the top and bottom of the model. These boundary conditions define how groundwater flows across the boundaries of the model. Transient boundary conditions will be developed for each month between 1984 and 2014. A steady-state initial boundary condition will also be developed, using average boundary conditions for the 1984 through 2014 time period. This is the same approach used in the CWD model.

The main steady state boundary condition are the outcrops below Monterey Bay, which will likely be simulated with general head boundaries representing sea level. The main transient boundary condition to be developed is the boundary with Pajaro Valley, which will consist of extending the groundwater level based boundary developed for the CWD model in time and space. Other boundary conditions are likely to be no-flow with source of water flow only coming from the surface system. HydroMetrics WRI will compile and create datasets for the boundary conditions and enter the boundary conditions into Groundwater Vistas.

3.3 DEVELOP PUMPING TIME SERIES

Groundwater pumping is the primary way in which groundwater leaves the Soquel- Aptos basin. The majority of pumping is municipal. Historic municipal pumping rates are available from the city of Santa Cruz, SqCWD, and CWD. Averages for steady-state initial conditions will be based on an estimate of average pumping prior to 1984. These data will be incorporated directly into the model at the location of the pumping wells.

Where possible, additional individual wells for small water systems will be simulated. These may include the Cabrillo College well, the Seaside Golf Course well, the Seaside Greens well, and wells of mutual water companies. Pumping amounts for these wells may be based on historical records recorded by Santa Cruz County, County records of number of connections, and/or land-use based water use estimates (Task 2.5). The well locations and depths may need to be estimated.

For these wells with readily identified screen intervals, the Multi-Node Well (MNW2) package will be used to allow the model to calculate distribution of pumping between layers. HydroMetrics WRI will create the package outside of Groundwater Vistas to simulate multiple screen intervals, but also store well locations and pumping data in Groundwater Vistas.

Additional private pumping will be based on the land-use based water use estimates (Task 2.5). The pumping will be distributed over the land use zones and assumed to be relatively shallow pumping. Our plan is to use MODFLOW's Recharge package to incorporate pumping as negative recharge applied to the top active layer.

3.4 DRAFT TECHNICAL MEMO AND REVIEW OF MODFLOW INPUTS *(MILESTONE)*

We will summarize the work in Tasks 3.1-3.3 in a draft technical memorandum. An interim draft technical memorandum will first be reviewed by the USGS. The technical memorandum will be revised based on USGS comments and provided to funding partners and Technical Review Committee (TRC) members two weeks prior to a scheduled meeting. HydroMetrics WRI will present the memorandum at the meeting and receive feedback from the TRC. The USGS will also attend the meeting.

3.5 COMPILE GROUNDWATER LEVEL CALIBRATION DATA

The primary data for calibration of the groundwater model will be groundwater levels. HydroMetrics WRI will compile groundwater level data used in the Annual Review and Report (HydroMetrics WRI, 2014) for model calibration. Any logger data will be averaged to daily or greater intervals. HydroMetrics WRI will set up files to use Parameter Estimation (PEST) software to calibrate the groundwater model.

3.6 CREATE RECHARGE PACKAGE BASED ON HRU BASED PRMS

The USGS has recommended that an initial calibration of MODFLOW be performed prior to integration into GSFLOW. In order to perform an initial calibration of MODFLOW, we will use the results from the existing sub-watershed based PRMS model to estimate recharge. The existing PRMS results are for 1984-2009 so initial MODFLOW runs will be limited to that time frame. HydroMetrics WRI will map the results to the model grid similar to what was done for the CWD model . Estimates of return flow and system losses (Task 2.5) will also be added to recharge package. As done for the CWD model, the steady state initial conditions will be based on a 1984-2009 average. The recharge package will be added to Groundwater Vistas.

3.7 ROUGHLY CALIBRATE MODFLOW (1984-2009) USING EXISTING PRMS RAINFALL RECHARGE

To facilitate integration with PRMS in GSFLOW, the interim MODFLOW model will be calibrated so that general groundwater levels relative to streams and ground surface are simulated accurately. HydroMetrics WRI will use the Parameter Estimation (PEST) software to achieve this rough calibration.

TASK 4. DEVELOP INTEGRATED MODEL

4.1 IMPLEMENT SFR AND UZF PACKAGES

The main packages connecting PRMS and MODFLOW in GSFLOW are the streamflow routing (SFR, Prudic et al., 2004) and unsaturated zone flow (UZF, Niswonger et al., 2006) packages. Huntington will create the SFR and UZF packages based on information from Task 2.2. HydroMetrics WRI will test the packages in MODFLOW. HydroMetrics WRI and Huntington will also meet to discuss the MODFLOW development, and for Huntington to transfer to HydroMetrics WRI the codes that create model inputs including SFR and UZF.

4.2 CREATE GSFLOW

The grid-based PRMS model and MODFLOW model will be integrated into a GSFLOW model. Huntington will perform the initial linkage and testing to produce reasonable results and eliminate convergance errors. The recharge package will be revised to remove sources applied at the surface in the PRMS model.

4.3 DRAFT TECHNICAL MEMO AND REVIEW OF GSFLOW INTEGRATION *(MILESTONE)*

We will summarize the work to finalize development of PRMS, MODFLOW and integrate into GSFLOW (Tasks 2.7-2.8, 3.5-3.7, and 4.1-4.2) in a draft technical memorandum. An interim draft technical memorandum will first be reviewed by the USGS. The technical memorandum will be revised based on USGS comments and provided to funding partners and Technical Review Committee (TRC) members two weeks prior to a scheduled meeting. HydroMetrics WRI will present the memorandum at the meeting and receive feedback from the TRC. The USGS will also attend the meeting.

4.4 CALIBRATE GSFLOW

HydroMetrics WRI will calibrate the integrated GSFLOW model to groundwater levels and streamflows using PEST software. The model will be calibrated to a level of accuracy that justifies use of the model to evaluate groundwater model alternatives effects on basin recovery, coastal groundwater levels, and streamflows.

4.5 IMPLEMENT SWI2 CODE IN GSFLOW

The seawater interface package SWI2 is not currently implemented in GSFLOW. A USGS developer of GSFLOW will implement and test SWI2 into GSFLOW.

4.6 IMPLEMENT AROMAS AND PURISIMA SEAWATER INTERFACES USING SWI2 IN GSFLOW

A priority use of the model is to predict future movement of the seawater interface even in areas such as the Purisima Formation, where the interface has not yet been observed. We will implement the sharp-interface package (SWI2) for MODFLOW. HydroMetrics WRI will approximate the interface location in the Aromas over time and use the approximate initial condition in the model. Approximated changes over time will be used to check against model results. HydroMetrics WRI will map an assumed interface in the Purisima that will facilitate simulations evaluating minimum travel time of the interface to production wells in the Purisima. This assumed interface will be implemented in the SWI2 package.

4.7 TECHNICAL REVIEW OF GSFLOW CALIBRATION AND SWI2 IMPLEMENTATION *(MILESTONE)*

We will summarize the calibration of the GSFLOW model and implementation of SWI2 (Tasks 4.4-4.6) in a draft technical memorandum. An interim draft technical memorandum will first be reviewed by the USGS. The technical memorandum will be revised based on USGS comments and provided to funding partners and Technical Review Committee (TRC) members two weeks prior to a scheduled meeting. HydroMetrics WRI will present the memorandum at the meeting and receive feedback from the TRC. The USGS will also attend the meeting.

TASK 5. MODEL SIMULATIONS

5.1 DEVELOP CLIMATE CHANGE SCENARIOS

The scoping meetings identified a need to use the groundwater model to assess the effect of climate. The USGS will create datasets for climate data to import into the GSFLOW model representing possible climate change futures. The USGS will downscale four future climate scenarios (LOCA AR5) at daily time steps to the resolution of the model grid.

5.2 EVALUATE GROUNDWATER MANAGEMENT ALTERNATIVES WITH MODEL

The calibrated GSFLOW model will be used to evaluate groundwater management alternatives. Based on the current understanding of management options for the Basin Implementation Group, HydroMetrics WRI will outline up to five alternatives in a draft technical memorandum for funding partners to review before implementation. The alternatives will include variations on some combination of the following:

- Overall pumping quantities
- Pumping rates and locations, including pumping coordination
- Availability of supplemental supplies, specifically supplies that are recharged or injected
- Non-agency pumping, including alternative water use factors

One or two of the five alternatives may be developed into model simulations based on input from the funding partners. HydroMetrics WRI will implement the alternatives into GSFLOW simulations based on the 1984-2014 calibration hydrology but with initial conditions representing the end of 2014.

HydroMetrics WRI will evaluate results for the model runs of alternatives for the following:

- Comparing groundwater levels to established protective elevations for preventing seawater intrusion
- Time for basin recovery i.e. time for groundwater levels to rise to protective elevations
- Effects on stream flow
- Movement of seawater interface

Based on groundwater model results, HydroMetrics WRI will recommend groundwater management alternative for further evaluation.

5.3 RUN RECOMMENDED ALTERNATIVE WITH CLIMATE CHANGE SCENARIOS

HydroMetrics WRI will input the climate scenarios developed in Task 5.1 into GSFLOW using consistent technique to Task 2.4 and run the recommended alternative from Task 5.2 with the four climate change scenarios. Model results to be evaluated are the same as Task 5.2.

5.4 EVALUATE PREDICTIVE UNCERTAINTY FOR RECOMMENDED ALTERNATIVE

There is uncertainty in model results even with a calibrated model. HydroMetrics WRI will use the PEST software to estimate the uncertainty of the results for the recommended alternative.

5.5 DRAFT TECHNICAL MEMO AND REVIEW OF MODEL SIMULATIONS *(MILESTONE)*

We will summarize the setup and results of model simulations (Tasks 5.1-5.4) in a draft technical memorandum. An interim draft technical memorandum will first be reviewed by the USGS. The technical memorandum will be revised based on USGS comments and provided to partner agencies and Technical Review Committee (TRC) members two weeks prior to a scheduled meeting. HydroMetrics WRI will present the memorandum at the meeting and receive feedback from the TRC. The USGS will also attend the meeting.

TASK 6. FINAL MODEL REPORT

HydroMetrics WRI will compile previous technical memorandums detailing model construction into a draft final report. The report serves as both a record of the models' development, and as reference documents for future model users. At a minimum, the model documentation should include the information outlined by authors such as Anderson and Woessner (1992). The report will include revisions of previous technical memorandums based on Technical Review Committee comments. The draft report will be provided to staff of partner agencies. The report will be revised based on comments of staff and submitted to the Basin Implementation Group for review and approval. HydroMetrics WRI will present the study to the BIG.

BUDGET

The revised cost estimate for this work plan is attached. The overall cost estimate of $591,000 is higher than what was presented in our July 10, 2014 proposal for the following reasons.

1. The recommended strategy to develop a grid-based PRMS and calibrate PRMS and MODFLOW separately before integration requires more effort than presented in the proposal.
2. The proposal did not include USGS costs for guidance, implementatation of SWI2 in GSFLOW, and development of data sets to facilitate climate change scenarios.
3. The plan to simulate climate change scenarios also requires greater effort from HydroMetrics WRI and Huntington to implement.

The cost estimate for fiscal year 2014-2015 of approximately $193,500 is within the amount Soquel Creek Water District has budgeted for the fiscal year. The purchase order issued to HydroMetrics WRI was for the full fiscal year budget and will need to be reduced $26,000 to fund the USGS's efforts for the fiscal year. The cost estimate for fiscal year 2015-2016, including USGS costs, is $397,850.

SCHEDULE

The following table shows the work plan schedule for tasks grouped by the draft technical memorandums and technical review committee meetings that serve as milestones for the project.

Months	**Task Nos.**	**Tasks**
Feb - May 2015	2.1-2.5	Develop PRMS Inputs
Mar - June 2015	3.1-3.3	Develop MODFLOW Inputs
June 2015	*2.6*	*Draft Memo and TRC Meeting on PRMS Inputs*
July 2015	*3.4*	*Draft Memo and TRC Meeting on MODFLOW Inputs*
July - Aug 2015	2.7-2.8	Construct and Calibrate PRMS (Tasks 2.7-2.8)
July - Sep 2015	3.5-3.7	Calibrate Interim MODFLOW (Tasks 3.5-3.7)
Sep – Oct 2015	4.1-4.2	Integrate GSFLOW (Tasks 4.1-4.2)
Nov 2015	*4.3*	*Draft Memo and TRC Meeting on GSFLOW Integration*
Nov 2015 – Jan 2016	4.4	Calibrate GSFLOW
July 2015 – Jan 2016	4.5-4.6	Implement SWI2 (Tasks 4.5-4.6)
Feb 2016	*4.7*	*Draft Memo and TRC Meeting on Calibration and SWI2*
Oct 2015 – Apr 2016	5.1-5.4	Model Simulations
May 2016	*5.5*	*Draft Memo and TRC Meeting on Model Simulations*
June 2016	6.1-6.2	Final Report

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Cost Estimate for Scope of Professional Services to Mid County Basin Groundwater Model

Tasks	HydroMetrics WRI Hours							Huntington Hydrologic		Cost	ODC	HydroMetrics WRI PO		U.S. Geological Survey	
	Derrik Williams	Cameron Tana	Georgina King	Staff	Staff	Admin	Mike Cloud	Justin Huntington	Staff			FY 2014-2015 TOTAL	FY 2015-2016 TOTAL	FY 2014-2015 TOTAL	FY 2015-2016 TOTAL
	Technical Lead	Project Manager	Land Use Analysis Lead	Groundwater Modeler	Hydrologist/ GIS	Office Support	Geologist	PRMS/GSFLOW Expert	Watershed Modeler						
Rates per hour	$195	$175	$165	$125	$100	$60	$150	$138	$110	($)	($)	($)	($)	($)	($)
Task 1 Scoping Effort															
1.1 Scoping Meetings (assume 2)	16	24	0	0	0	0	0	0	0	$ 7,320	$ 350	$ 7,670	$ -	$ 5,000	$ -
1.2 Draft Memorandum on Potential Model Uses	2	16	4	0	2	0	0	0	0	$ 4,050	$ -	$ 4,050	$ -	$ -	$ -
1.3 Develop Work Plan and Revise Cost and Schedule	4	24	8	0	4	0	0	0	0	$ 6,700	$ 100	$ 6,800	$ -	$ 2,000	$ -
Task 1 Subtotal	*22*	*64*	*12*	*0*	*6*	*0*	*0*	*0*	*0*	*$ 18,070*	*$ 450*	*$ 18,520*	*$ -*	*$ 7,000*	*$ -*
Task 2 Develop Model of Surface System															
2.1 Define Model Grid for Groundwater Model	3	6	0	12	0	0	0	0	0	$ 3,135	$ 350	$ 3,485	$ -	$ -	$ -
2.2 Refine Model Grid for PRMS and Define Stream/Subwatershed Netwo	3	8	16	8	0	0	0	11	32	$ 10,658	$ -	$ 10,658	$ -	$ -	$ -
2.3 Compile Land Surface Data from Sub-Watershed Based PRMS	3	8	20	0	0	0	0	11	4	$ 7,238	$ -	$ 7,238	$ -	$ -	$ -
2.4 Climate Data for PRMS	2	4	4	0	4	0	0	10	38	$ 7,705	$ -	$ 7,705	$ -	$ 10,000	$ -
2.5 Land Use Analysis for Water Use and Return Flow	16	40	60	40	200	0	0	4	8	$ 46,450	$ -	$ 46,450	$ -	$ -	$ -
2.6 Draft Technical Memo and Review of PRMS Inputs	16	24	24	8	40	0	0	20	12	$ 20,350	$ 794	$ 21,144	$ -	$ 9,000	$ -
2.7 Construct Grid-Based PRMS for GSFLOW	8	16	20	8	0	0	0	44	30	$ 18,010	$ -	$ -	$ 18,010	$ -	$ -
2.8 Calibrate PRMS	8	20	12	60	0	0	0	26	8	$ 18,995	$ -	$ -	$ 18,995	$ -	$ -
Task 2 Subtotal	*59*	*126*	*156*	*136*	*244*	*0*	*0*	*126*	*132*	*$ 132,540*	*$ 1,144*	*$ 96,679*	*$ 37,005*	*$ 19,000*	*$ -*
Task 3 Develop Model of Sub-surface System															
3.1 Develop Sub-surface Hydrogeologic Structure	12	20	8	60	0	0	60	15	8	$ 26,603	$ -	$ 26,603	$ -	$ -	$ -
3.2 Define Boundary Conditions	12	16	0	80	0	0	0	0	0	$ 15,140	$ -	$ 15,140	$ -	$ -	$ -
3.3 Develop Pumping Time Series	4	8	0	24	40	0	0	2	0	$ 9,455	$ -	$ 9,455	$ -	$ -	$ -
3.4 Draft Technical Memo and Review of MODFLOW Inputs	16	24	0	48	20	0	10	0	0	$ 16,820	$ 200	$ -	$ 17,020	$ -	$ 3,000
3.5 Compile Groundwater Level Calibration Data	4	8	0	16	40	0	0	0	0	$ 8,180	$ -	$ -	$ 8,180	$ -	$ -
3.6 Create Recharge Package Based on HRU Based PRMS	4	16	24	8	0	0	0	0	0	$ 8,540	$ -	$ -	$ 8,540	$ -	$ -
3.7 Roughly Calibrate Subsurface MODFLOW	12	20	0	80	0	0	0	8	0	$ 16,940	$ -	$ -	$ 16,940	$ -	$ -
Task 3 Subtotal	*64*	*112*	*32*	*316*	*100*	*0*	*70*	*25*	*8*	*$ 101,678*	*$ 200*	*$ 51,198*	*$ 50,680*	*$ -*	*$ 3,000*
Task 4 Develop Integrated Model of Surface and Sub-surface Systems															
4.1 Implement SFR and UZF Package	4	8	0	16	0	0	0	42	0	$ 9,955	$ 594	$ -	$ 10,549	$ -	$ -
4.2 Create GSFLOW	8	16	0	20	0	0	0	24	0	$ 10,160	$ -	$ -	$ 10,160	$ -	$ -
4.3 Draft Technical Memo and Review of GSFLOW Integration	16	24	0	40	0	0	0	16	0	$ 14,520	$ 594	$ 200	$ 15,114	$ -	$ 6,000
4.4 Calibrate GSFLOW	20	60	0	200	40	0	0	40	0	$ 48,900	$ -	$ -	$ 48,900	$ -	
4.5 Implement SWI2 Code in GSFLOW	4	8	0	0	0	0	0	0	0	$ 2,180	$ -	$ -	$ 2,180	$ -	$ 29,371
4.6 Incorporate Density Dependence for Seawater Intrusion	24	60	0	120	0	0	0	0	0	$ 30,180	$ -	$ -	$ 30,180	$ -	$ -
4.7 Draft Technical Memo and Review of GSFLOW Calibration and SWI2	16	24	0	40	20	0	0	16	0	$ 16,520	$ 594	$ 200	$ 17,114	$ -	$ 6,000
Task 4 Subtotal	*92*	*200*	*0*	*436*	*60*	*0*	*0*	*138*	*0*	*$ 132,415*	*$ 1,782*	*$ 400*	*$ 134,197*	*$ -*	*$ 41,371*
Task 5 Model Simulations															
5.1 Develop Climate Change Scenarios	4	8	0	16	0	0	0	0	0	$ 4,180	$ -	$ -	$ 4,180	$ -	$ 33,000
5.2 Evaluate Groundwater Management Alternatives and Scenarios	16	60	0	120	0	0	0	0	0	$ 28,620	$ -	$ -	$ 28,620	$ -	$ -
5.3 Run Selected Alternative Runs with Climate Change Scenarios	8	24	0	60	0	0	0	4	0	$ 13,810	$ -	$ -	$ 13,810	$ -	$ -
5.4 Evaluate Predictive Uncertainty for Preferred Alternative	8	24	0	40	0	0	0	0	0	$ 10,760	$ -	$ -	$ 10,760	$ -	$ -
5.5 Draft Technical Memo and Review of Model Simulations	16	24	0	40	0	0	0	0	0	$ 12,320	$ -	$ -	$ 12,320	$ -	$ 6,000
Task 5 Subtotal	*52*	*140*	*0*	*276*	*0*	*0*	*0*	*4*	*0*	*$ 69,690*	*$ -*	*$ -*	*$ 69,690*	*$ -*	*$ 39,000*
Task 6 Final Model Report															
6.1 Final Draft Report	12	24	12	48	20	0	4	0	0	$ 17,120	$ -	$ -	$ 17,120	$ -	$ 2,000
6.2 Final Report	2	4	2	8	4	16	0	0	0	$ 3,780	$ -	$ -	$ 3,780	$ -	$ -
Task 6 Subtotal	*14*	*28*	*14*	*56*	*24*	*16*	*4*	*0*	*0*	*$ 20,900*	$ -	*$ -*	*$ 20,900*	*$ -*	*$ 2,000*
TOTAL	*303*	*670*	*214*	*1220*	*434*	*16*	*74*	*293*	*140*	*$ 475,293*	*$ 3,576*	*$ 166,797*	*$ 312,472*	*$ 26,000*	*$ 85,371*
												TOTAL FISCAL YEAR BUDGET		*$ 192,797*	*$ 397,843*