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SENT VIA: EMAIL

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SUBJECT: Response to Comments from Appropriative Pool following 2025 Safe Yield Reevaluation Calibration Workshop #1

Dear Todd:

This letter documents our responses to the Appropriative Pool's comments following the May 29, 2024 workshop[1] regarding the calibration and uncertainty analysis of the 2025 Chino Valley Model (2025 CVM) as part of the ongoing 2025 Safe Yield Reevaluation. Thomas Harder and Company (TH&Co; Jim Van De Water, PG, CHG and Thomas Harder, PG, CHG) submitted the comments on behalf of the Appropriative Pool (AP) in a letter dated June 28, 2024.

TH&CO COMMENTS AND RESPONSES

Comment 1

In response to discussions between representatives of the AP and CBW, Tom Harder and I participated in a video conference call with Garrett and Eric on April 15, 2024 (hereafter referred to as "the April 15th call"). The purpose of the call was to discuss uncertainty analysis and provide recommendations. Based on what was presented at the workshop, it appears that WY has genuinely considered our recommendations and has implemented some to varying degrees as discussed during the April 15th call.

Response:
No response required.

Comment 2

Our primary comment is that too few parameters are being used for the uncertainty analysis. We are also of the opinion that a knowledgeable third-party reviewer of the control file familiar with [PESTPP-IES (IES)] (e.g., USGS personnel, PEST developers) would support our claim that there are too few parameters being used. The main strength of using IES is that it allows the user to vary a virtually unlimited number

[1] 5/29/2024 Workshop Agenda; 5/29/2024 Workshop Presentation

parameters to assess uncertainty. In general, the more parameters that are varied, the less likely it is that uncertainty will be underestimated.

Response:

It is important to clarify the definitions of parameters related to the IES process (IES parameters). IES parameters can impact many model parameters if they are scalar multipliers applying to a time series at multiple cells (e.g., how we vary areal recharge) or pilot points whose values are interpolated for cells between the pilot points (e.g., how we vary aquifer properties). Using this methodology, most of the model parameters are allowed to vary in every active model cell.

Mathematically, the IES method scales independently of the number of parameters varying in the ensemble due to the empirical calculation of the Jacobian matrix. However, the computational time of implementing more IES parameters increases with the number of the parameters, as the sizes of the Jacobian matrix and the parameter ensemble matrix increase as a function of the number of parameters.[2] In our experience, a 9-fold increase in the number of parameters results in about a 1.5-fold increase in the computational time, given the same number of realizations. Computational constraints require the modeler to balance the benefit of increasing IES parameters with the increased computational cost.

To respond to this comment, we increased the number of IES parameters and the number of realizations to ensure that we have adequately captured uncertainty in the model. From the May 29th and August 6th workshop, we have simulated and presented results of the following IES configurations:

1. 2,700 IES parameters, 100 realizations (resulting in 88 final realizations)
2. 2,700 IES parameters, 400 realizations (resulting in 335 final realizations)
3. 25,300 IES parameters, 400 realizations (resulting in 316 final realizations)

We demonstrated in the August 6, 2024 workshop[3] that increasing the number of realizations (i.e., comparing the results of configurations 1 and 2) increases the range of net recharge and water budget components (uncertainty). We also demonstrated that increasing the number of IES parameters (i.e., comparing the results of configurations 2 and 3) does not materially increase the uncertainty. We simulated other configurations that were not presented at the workshop, including a configuration with 160,000 parameters and 400 realizations. However, we ran into limitations in computational time and/or memory with our current resources.

Through these modeling efforts, we believe our configuration of 25,300 IES parameters and 316 final realizations represents a reasonable and appropriate range of plausible, calibrated model realizations with an appropriate degree of uncertainty.

Comment 3

In essence, when a modeler does not vary a parameter, he/she is claiming that:

a. "I know the value of the fixed parameter with complete precision. That is, I am 100 percent certain of its value with complete confidence. Ultimately, I have prior knowledge that is perfectly inerrant with respect to this parameter value"; and/or

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[2] See formulas 8 and 9 in White et al. (2020)

[3] Slides from the August 8, 2024 Workshop

b. "I know with absolute confidence that the prediction of interest is completely insensitive to this parameter".

There are very few, if any, parameters for which these claims can be made. Metered pumping is a possible example of a "certain parameter", although even it too carries some uncertainty due to equipment error, operator error, transmission/transcription error, etc. Claims regarding sensitivity cannot be made a priori as it follows that the people who coded the model (e.g., USGS personnel) felt the need to include the parameter. That is, if a parameter exists in the model, the USGS personnel must believe it may carry some importance with respect to model predictions.

Response:
We agree with these statements; omitting variability in critical parameters can lead to an incomplete understanding of the system. The 2022 Safe Yield Reset Methodology was developed to improve the understanding of and ability to vary parameters. We are varying most model parameters during the uncertainty analysis process, including aquifer properties in every active cell. However, we have simplified the generation of these parameter fields by using pilot points and the Kriging method, which reduces the computational burden while allowing us to capture the uncertainty and variability in model parameter fields.

Comment 4

Evaluating uncertainty is the primary function of IES. In using too few parameters, one runs the risk of winding up with a range of safe yield values that is unreasonably narrow, which could lead to unwelcome surprises down the line when the model is used as a decision-making tool. With less than 3,000 parameters as presented in the workshop, there is little to be gained in using IES as compared to regular PEST. During the April 15th call, WY shared the control file on-screen and it appears that they have added approximately 2,000 parameters since their initial effort. While this is a step in the right direction, there are still too few parameters being used in the IES setup. In general, a rule of thumb that we've employed is to use 50,000 to 100,000 parameters per model layer.

Response:
Please see our response to Comment 2. Each pilot point is an IES parameter and varied during the model calibration process. As a result of using the Kriging method to interpolate pilot point values to model cells, aquifer parameters in all model cells varied during the model calibration process. In addition to pilot points, additional IES parameters include the hydraulic conductivity of faults and streambed as well as scalar multipliers for mountain front Inflow, boundary inflow from adjacent basins, DIPAW, and Potential ET.

We believe that we have addressed this comment with the updates that we have made since the May 29, 2024 workshop and our run varying 25,300 PESTPP-IES parameters and generating 316 realizations.

Comment 5

As part of the update to the CVM (Slide 8), it is our understanding that:

a. The Cucamonga Barrier has been moved to the west from its original location in order to achieve a better fit to measured groundwater elevations in that general area;

b. the time period of 1978 to 1991 was removed from the CVM to reduce model runtimes resulting in a new history matching period of Water Year 1992 through Water Year 2022 (i.e., October 1, 1991 through September 30, 2022); and

c. the HYDRUS and R4 models were updated.

Response:
Regarding (a), the Cucamonga Barrier was moved from its original location due to the analysis of recent InSAR data indicating that the Cucamonga Barrier is in a different location than was estimated previously.

(b) is correct, except we use Fiscal Year (July 1 through June 30) rather than Water Year.

Regarding (c), the HYDRUS model was not updated. We only revised the interpretation of the results to develop a smoother distribution of lag time estimates across the basin. The R4 model was not recalibrated, but the hydrology was extended through FY 2022.

Comment 6

Was the HSPF model updated?

Response:
The HSPF model was not recalibrated, but the hydrology was extended through FY 2022.

Comment 7

As shown on Slide 13, the target wells appear to be uniformly distributed laterally across the Basin and we were told (Slide 12) that measured values used for history matching ("observations") are evenly distributed over time. How many calibration wells are in each of five model layers (i.e., how many are in Layer 1, how many are in Layer 2, and so on?). How many observations are in each of these model layers?

Response:
A total of 107 calibration wells were used for Chino Basin, Cucamonga Basin, Spadra Basin, and Six Basins. A total of 77 calibration wells locates within Chino Basin; 5 wells in Cucamonga Basin; 2 wells in Spadra Basin, and 18 wells in the Six Basins.

Most wells in Chino Basin are only screened in the first model layer. A few wells are screened in multiple model layers. Below is a list of number of wells screened in each of the five model layers:

Layer 1: 72 wells

Layer 2: 17 wells

Layer 3: 32 wells

Layer 4: 10 wells

Layer 5: 24 wells

A total of 7954 observations were selected as calibration targets; 7664 of them are head observations and 290 are flow observations at the station below Prado Dam.

Comment 8

How many groundwater elevation observations and how many surface water flow observations are being used to calibrate the model?

Response:
We have included 7,664 groundwater elevation observations from 107 wells (77 of which are in the Chino Basin). We have included 290 surface water flow observations of monthly flows in the Santa Ana River at Prado Dam. Some of the available surface water flow observations were not used due to the errors and uncertainty introduced aggregating daily flow into monthly values.

Comment 9

How many surface water locations are used to calibrate the model?

Response:
Only one surface water location was used to calibrate the groundwater-flow model (Santa Ana River at Below Prado Dam). The R4 model was calibrated for the 2020 Safe Yield Recalculation based on two surface water locations (Cucamonga Creek and Chino Creek); for the 2025 SYR, the R4 model was validated by comparing the simulated streamflow for FY 2019 through 2022 to the measured streamflow.

Comment 10

On Slide 27, PEST++-IES (IES) is introduced, and it is stated there are 2,245 pilot points and 2,701 adjusted parameters. It is further stated on this slide "Models with many adjusted parameters tend to produce extreme parameter values and artifacts due to over-fitting". Slide 28 is then shown as examples of over-fitting.

Response:
We have used "overfitting" differently than is typically understood in a groundwater modeling context. We used "overfitting" here to mean that IES generated unrealistic patterns of heterogeneity (e.g., horizontal hydraulic conductivity) given our prior knowledge of the hydrostratigraphy.

Comment 10a

We respectfully disagree that 2,701 parameters qualifies as 'many' for a model as large and complex as the CVM. The primary author of IES commonly parameterizes every model cell – an approach that likely results in an IES setup containing several hundred thousand and perhaps more than a million parameters for a large-scale model. When the parameters in the various MODFLOW input files are considered (e.g., aquifer properties, fault permeabilities, streambed thicknesses and conductivities, flows and/or heads at perimeter boundaries, pumping at unmetered/unknown wells associated with historical agricultural pumping) and head boundaries - all of which are uncertain to some degree - and especially those whose parameters vary over time and are specified for multiple layers, one can quickly amass several hundreds of thousands of parameters within an IES framework. It is worth noting that IES was primarily created for this very purpose (in addition to streamlining uncertainty analysis). That is, IES was created to free the modeler from making the highly subjective choice of selecting which parameters to vary and which parameters to not vary as IES can process a virtually unlimited number of parameters. In summary, a general rule when using IES is: "If there's any doubt, let the parameter vary".

Response:
Please see responses to Comments 2 and 4.

Comment 10b

How many pilot points are assigned to each layer? TH&Co generally sets pilot points in every other cell to every fourth model cell, depending on our computing resources.

Response:
The following is a list of numbers of pilot points in the five model layers by the type of aquifer parameters. The density of pilot points for hydraulic conductivities varied based on the density of observation wells. Please note that these numbers increased in later model runs after the 5/29 workshop.
Horizontal hydraulic conductivity: 145, 75, 62, 23, 37
Vertical hydraulic conductivity: 89, 75, 61, 23, 37
Specific yield: 920, 0, 0, 0, 0
Specific storage: 0, 188, 188, 161, 161

Comment 10c

How many parameters are varied in each layer?

Response:
Each pilot point is a parameter and varied during the model calibration process. As a result of using the Kriging method to interpolate pilot point values to model cells, aquifer parameters in all model cells varied during the model calibration process. In addition to pilot points, additional parameters include the hydraulic conductivity of faults and streambed as well as scalar multipliers for mountain front Inflow, boundary inflow from adjacent basins, DIPAW, and Potential ET.

Comment 10d

With respect to extreme parameter values, we do not believe this is related to the number of parameters. Rather, we recommend that the lower and upper bounds for offending parameters specified in the control file simply be restricted to WY's liking. Doing so will result in a narrower range over which IES is allowed to vary the parameter. (It should be kept in mind that restricting the range increases the chance parameter bounds may be hit and other parameters will therefore be called upon by IES to assume a surrogate role to make up for this shortcoming.)

Response:
Since the preliminary findings in the May 29th workshop, we have revised the lower and upper bounds of the parameters.

Comment 10e

It is not clear what is meant by 'artifacts' but it may refer to the 'bullseye' patterns shown on Slide 28. We recommend using more pilot points and one or more covariance matrices to smooth out these patterns. Without covariance matrices, the parameter values at the pilot points are spatially independent of each other and this is not likely the case. That is, values of aquifer parameters (e.g., hydraulic conductivity) at adjacent pilot points are expected to be similar whereas those separated by large distances are not.

Response:
We have generated covariance matrices using the PPCOV code of the PEST Groundwater Utilities based on the pilot points.

Comment 10f

It is unclear to us whether the model is indeed overfit as this would require inspection of the history matching hydrographs, an example of which is provided as Slide 35, and possibly subdivision of the calibration dataset into training data and test data. In our opinion, Slide 35 does not demonstrate overfitting nor does Slide 36.

Response:
We agree that the analyses presented do not suggest that the model is overfitting the match between simulated and observed data. In our selection of the observed data, we made an effort to select representative observations that would limit the risk of overfitting.

Comment 11

Slide 30 is informative and lists the parameters that are varied by IES to calibrate the model and generate the realizations for the uncertainty analysis.

Response:
This was provided as background and does not require a response.

Comment 11a

Areal groundwater recharge multiplier: Is the multiplier parameterized for each stress period? Over what range is the multiplier allowed to vary?

Response:
The multiplier is allowed to vary each year (12 stress periods) over the range of 0.8 to 1.2.

Comment 11b

Boundary inflow multiplier: Is the multiplier varied for each stress period and layer? Is it varied on a cell-by-cell basis or are the individual flow cells somehow grouped? Over what range is the multiplier allowed to vary? This is a good opportunity to significantly increase the number of parameters in the IES setup as this parameter is likely to: a) exert considerable influence on model predictions and b) be highly uncertain.

Response:
The multiplier is varied for each layer, but not each stress period, over the range of 0.1 to 5. The individual flow cells are grouped based on the segments shown in slide 19 of the May 29th workshop presentation.

Comment 11c

Max ET rate multiplier: Is the multiplier parameterized for each stress period? Over what range is the multiplier allowed to vary?

Response:
The max ET rate varies for each stress period over the range of 0.8 to 1.2.

Comment 11d

Streambed conductivity: Are other stream parameters parameterized (e.g., streambed thickness, roughness coefficient, upstream and downstream widths)? It is noted that the last three in the parenthesized list are uncertain and can be varied for each stress period.

Response:
No, streambed conductivity is the only variable IES parameter.

Comment 11e

Is horizontal anisotropy included in the IES setup? Given that hydraulic conductivity along model grid rows ("Kx") is an IES parameter (i.e., it is considered uncertain), it logically follows that the hydraulic conductivity along model grid columns ("Ky") should also be an IES parameter.

Response:
Anisotropy is not included in the IES setup. The hydraulic conductivity is assumed to be isotropic.

Comment 12

Subsidence is reportedly a concern for the Chino Basin. Is subsidence included in the model (e.g., via MODFLOW's 'SUB' package) and/or the IES setup? If not, it is unclear to us how the model can be used as a decision-making tool with respect to subsidence and which parameters are compensating to account for release from storage/uptake into storage due to compaction/expansion of compressible units.

Response:
Subsidence is not included in the model. The use of the SUB package has been considered in the past; the Ground-Level Monitoring Committee directed Watermaster to use the one-dimensional compaction models to simulate aquifer compaction as the tool for simulating aquifer system compaction. In the past, we have used groundwater levels as a proxy for determining projected risk of new land subsidence. For the 2025 SYR, we propose to use a similar methodology that we will detail at a workshop this fall.

CONCLUSION

Many of TH&Co's comments and suggestions were addressed in the August 6, 2024 workshop[4] discussing revisions to the calibration and uncertainty analysis of the 2025 CVM. As outlined in our response to Comment 2, we have incorporated TH&Co's comments by developing alternative combinations of parameters and realizations to ensure we have captured the appropriate degree of uncertainty in our understanding and simulation of the Chino Basin. We look forward to a continued dialog with the peer review committee, and we will include all comments and responses in the final 2025 SYR report. Please let us know if you have any questions or concerns regarding the above comments and responses.

Sincerely,
WEST YOST

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Eric Chiang, PhD
Principal Engineer II

cc: Edgar Tellez-Foster, PhD; Andy Malone, PG

[4] 8/6/2024 Workshop Agenda; 8/6/2024 Workshop Presentation