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Stibnite Gold Project

Stibnite Hydrologic Site Model (SHSM) Sensitivity Analysis

Prepared for

Perpetua Resources Idaho, Inc.

Valley County, Idaho

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Brown AND Caldwell

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List of Abbreviations

ARM	absolute residual mean
BC	Brown and Caldwell
cfs	cubic feet per second
cfs^2	cubic feet per second squared
EC	Existing Condition
EFSFSR	East Fork of the South Fork of the Salmon River
ft	foot/feet
ft^2	square foot
ft/d	feet per day
HCSM	Hydrological Conceptual Site Model
K	hydraulic conductivity
LHS	Latin Hypercube Sampling
OAT	one-at-a-time
Perpetua Resources	Perpetua Resources Idaho, Inc.
RM	Residual Mean
RMSE	Root Mean Squared Error
SGP	Stibnite Gold Project
SHSM	Stibnite Hydrologic Site Model
SSE	Sum of Squared Errors
Sy	specific yield
USGS	United States Geological Survey

Executive Summary

Brown and Caldwell (BC) prepared this report on behalf of Perpetua Resources Idaho, Inc., formerly Midas Gold Idaho, Inc., to summarize results of a sensitivity analysis for the Stibnite Hydrologic Site Model (SHSM; BC 2021). This sensitivity analysis is in response to several agency comments (comments included in Appendix B) on the Stibnite Gold Project Stibnite Hydrologic Site Model Refined Modified Proposed Action (ModPRO2) Report (BC 2021). The goal of the sensitivity analysis is to expand the range of bedrock hydraulic conductivity (K) and specific yield (S_y) values in the bedrock transition zone, shallow bedrock, and deep bedrock zones in the SHSM to quantify differences in simulated groundwater levels, streamflow, and pit dewatering flow rates.

The sensitivity analysis consisted of varying either the hydraulic conductivity (K) or specific yield (S_y) within the bedrock transition zone, shallow bedrock, and deep bedrock while keeping all other aquifer parameters in the calibrated SHSM the same. Bedrock K values were increased using multiplication factors of 5, 10, and 50, and decreased using multiplication factors of 0.2, 0.1, and 0.02. Bedrock S_y values were increased by a multiplication factor of 2 and decreased by a multiplication factor of 0.5. The sensitivity analysis simulations are compared to the measured historical site data and residual (error) statistics are calculated to assess how well each simulation is calibrated since the simulations modify calibrated SHSM parameters.

Overall, the sensitivity analysis shows that small changes in bedrock K values result in small or negligible differences in simulated groundwater elevations, streamflow, and pit dewatering rates, and moderate changes in SHSM bedrock parameters did not yield meaningful differences in simulated dewatering rates. The significant differences in simulated groundwater levels, streamflow, and pit dewatering rates result when increasing bedrock K values by an order of magnitude or larger in the shallow bedrock and deep bedrock. In these simulations, the modified parameter values result in a model that is biased and does not sufficiently represent the measured site data. Thus, the projected dewatering rates simulated by the calibrated ModPRO2 SHSM as presented in the SGP Stibnite Hydrologic Site Model Refined Modified Proposed Action (ModPRO2) Report (BC 2021) are reliable projections of future conditions.

It is shown in this report that the calibrated Existing Conditions (EC) SHSM represents the minimum head and stream baseflow error achievable with the ranges of K and S_y in this analysis. This confirms that the endpoints of the allowable parameter ranges for the bedrock transition zone, shallow bedrock, and deep bedrock in the EC SHSM calibration procedure are justifiable. Moreover, increasing those values do not change the analysis or results presented in the SGP Stibnite Hydrologic Site Model Refined Modified Proposed Action (ModPRO2) Report (BC 2021).

Section 1

Introduction

This report was prepared by Brown and Caldwell (BC) on behalf of Perpetua Resources Idaho, Inc. (Perpetua Resources), formerly Midas Gold Idaho, Inc. (Midas Gold), to summarize results of a sensitivity analysis for the Stibnite Hydrologic Site Model (SHSM). The SHSM was developed to assess potential impacts to groundwater and surface water within the Stibnite Gold Project (SGP) study area and predict open pit dewatering needs. Details regarding the development and calibration of the SHSM and the assessment of potential mine plan impacts are presented in the SGP Stibnite Hydrologic Site Model Refined Modified Proposed Action (ModPRO2) Report (BC 2021).

The goal of the sensitivity analysis is to expand the range of bedrock hydraulic conductivity (K) and specific yield (S_y) values in the bedrock transition zone, shallow bedrock, and deep bedrock zones in the SHSM to quantify uncertainty in simulated groundwater elevation, streamflow, and pit dewatering flow rates. The sensitivity analysis is in response to agency comments received regarding the SHSM and the corresponding SGP Stibnite Hydrologic Site Model Refined Modified Proposed Action Report (BC 2021). A main concern identified in the agency comments is the upper bound of the range of bedrock transition zone, shallow bedrock, and deep bedrock K values sampled during the calibration procedure for the SHSM (Stantec comment numbers 1, 5, 51, 53, and 63; United States Environmental Protection Agency comment numbers 70, 71, and 72). Therefore, the sensitivity analysis contains more cases where bedrock K in these zones is increased rather than decreased. The expanded range of bedrock K and S_y values in the SHSM will test whether moderate changes in model parameters yield meaningful difference in simulated dewatering rates (See Stantec comment 1).

This sensitivity analysis follows the one-at-a-time (OAT) method in which one model input parameter in the SHSM is changed while keeping all others the same. The OAT approach allows for model results to be easily compared to the original SHSM and any differences will be due to the single parameter change.

In applying the OAT method to the SHSM, it is important to ensure that any parameter change results in a simulation that is consistent with the Hydrological Conceptual Site Model (HCSM; BC 2021). Following the HCSM (BC 2021), bedrock in the SHSM is represented by three layers where the hydraulic conductivity decreases with depth. The sensitivity analysis focuses on the bedrock transition zone (layer 3), the shallow bedrock (layer 4), and the deep bedrock (layer 5). To ensure that the bedrock hydraulic conductivity values decrease with depth in the sensitivity analysis the following parameter changes are applied to layers 3, 4, and 5:

- Increase K by multiplication factors of 5, 10, and 50 for the bedrock transition zone (layer 3)
- Increase K by multiplication factors of 5, 10, and 50 for the bedrock transition zone and shallow bedrock (layers 3 and 4)
- Increase K by multiplication factors of 5, 10, and 50 for the bedrock transition zone, shallow bedrock, and deep bedrock (layers 3, 4, and 5)
- Decrease K by multiplication factors of 0.2, 0.1, and 0.02 (i.e., division factors of 5, 10, and 50) in the bedrock transition zone, shallow bedrock, and deep bedrock (layers 3, 4, and 5)

In the sensitivity analysis the vertical anisotropy ratio is preserved. For all bedrock layers the ratio is one-to-one, thus the vertical K values are also increased and decreased by the same factors as listed above.

For the sensitivity analysis of S_y the following parameter changes are applied to layers 3, 4, and 5:

- Increase and decrease S_y by a multiplication factor of 2 and 0.5, respectively, in the bedrock transition zone (layer 3)
- Increase and decrease S_y by a multiplication factor of 2 and 0.5, respectively, in the shallow bedrock (layer 4)
- Increase and decrease S_y by a multiplication factor of 2 and 0.5, respectively, in the deep bedrock (layer 5)
- Increase and decrease S_y by a multiplication factor of 2 and 0.5, respectively, in the bedrock transition zone, shallow bedrock and deep bedrock (layers 3, 4, and 5)

The calibrated hydrogeological parameters for the Existing Conditions (EC) SHSM are provided in Table 1-1. The spatial distribution of K and S_y in the bedrock layers of the SHSM is shown in Figure A-1 through Figure A-6 in Appendix A. Details regarding the calibration procedure are in BC 2021, Appendix A. Briefly, the SHSM calibration procedure used combinations of hydrogeologic parameters (K and S_y) generated using a standard Latin Hypercube Sampling (LHS) algorithm. The minimum and maximum parameter bounds in the LHS were informed by measured site data for K and literature values for S_y. In addition, the parameter ranges conform to the HCSM in that the bedrock K is highest in the bedrock transition zone (layer 3) and decreases with depth for all combinations of parameters in the LHS. For example, the range of K values for the shallow bedrock (layer 4) are not allowed to be higher than the bedrock transition zone (layer 3) or lower than the deep bedrock K values (layer 5). Monte Carlo simulations were conducted for each LHS parameter set. The relative performance of each Monte Carlo simulation was evaluated using statistical evaluation of the difference between simulated and observed values of groundwater elevation and stream baseflow. The set of parameters with the smallest differences indicated by the statistical measure of error between groundwater elevations and late-season stream baseflow was selected as the calibrated EC SHSM parameter set. The EC SHSM K values of 0.2 feet per day (ft/d), 0.1 ft/d, and 0.03 ft/d for the bedrock transition zone, shallow bedrock, and deep bedrock, respectively, are consistent with the geometric mean of 0.05 ft/d for all the bedrock K measurements at the site (BC 2021, Appendix A).

Table 1-1. SHSM Calibrated Aquifer Parameters

Hydrogeologic Unit	Hydraulic Conductivity (ft/d)	Vertical Anisotropy Ratio[1]	Specific Yield	Specific Storage (ft)
Layer 1				
Alluvium/Overburden	12.0	10:1	0.20	1.0E-07
Gestrin Feature 1.1[2]	12.0	10:1	0.05	1.0E-07
Gestrin Feature 1.2	8.0	20:1	0.01	1.0E-07
Layer 2				
Alluvium/Overburden	12.0	10:1	0.20	1.0E-07
Gestrin Feature 2.1	100.0	100:1	0.05	1.0E-07
Gestrin Feature 2.2	8.0	10:1	0.05	1.0E-07
Gestrin Feature 2.3	0.2	1:1	0.05	1.0E-07
Layer 3				
Bedrock Transition Zone	0.2	1:1	0.04	1.0E-07
Gestrin Feature 3.1	3.0	1:1	0.04	1.0E-05
Layer 4				
Shallow Bedrock	0.1	1:1	0.006	1.0E-07

Hydrogeologic Unit	Hydraulic Conductivity (ft/d)	Vertical Anisotropy Ratio[1]	Specific Yield	Specific Storage (ft)
Metaseds	0.5	1:1	0.006	1.0E-07
MCFZ	1.0E-04	1:1	0.025	1.0E-04
Layer 5				
Deep Bedrock	0.03	1:1	0.002	1.0E-07
Metaseds	0.15	1:1	0.002	1.0E-07
MCFZ	1.0E-04	1:1	0.025	1.0E-04

Notes:

[1]horizontal conductivity:vertical conductivity

[2]Label suffixes are included to identify refined hydraulic conductivity or specific yield parameter zones associated with the Gestrin feature in each layer

Abbreviations:

ft = foot/feet

ft/d = feet per day

MCFZ = Meadow Creek Fault Zone

SHSM = Stibnite Hydrologic Site Model

The parameter values for each simulation in the sensitivity analysis are provided in Table 1-2. The naming convention for the sensitivity analysis simulations in Table 1-2 is to identify the layers affected by the multiplication factor and list the multiplication factor next to the parameter that is varied. For example, “Layer 3 Bedrock 5K” means that the bedrock transition zone K is multiplied by a factor of 5, whereas “Layers 3, 4, & 5 Bedrock 0.5S_y” means that S_y in the bedrock transition zone, shallow bedrock, and deep bedrock is multiplied by a factor of 0.5. It is noted that increasing the K values by multiplication factors of 5, 10, and 50 in the bedrock transition zone and shallow bedrock result in K values that include the high end of range of measured K values. In the simulations where the bedrock transition zone is increased by a factor of 50, the resulting K value is 10 ft/d, which is near to the calibrated K value of 12 ft/d for the alluvium layers in the SHSM. Therefore, in these simulations the bedrock transition zone is effectively treated as the alluvium and cannot be increased significantly higher to maintain consistency with the HCSM. In the simulations where the bedrock transition zone, shallow bedrock, and deep bedrock are increased by a factor of 50 the simulation is numerically unstable and thus there are no results for that simulation.

Table 1-2. Sensitivity Analysis Simulation Bedrock Parameters

Sensitivity Analysis Simulations	Bedrock Transition Zone		Shallow Bedrock		Deep Bedrock	
	Hydraulic Conductivity (ft/d)	Specific Yield	Hydraulic Conductivity (ft/d)	Specific Yield	Hydraulic Conductivity (ft/d)	Specific Yield
EC SHSM	0.2	0.04	0.1	0.006	0.03	0.002
Layer 3 Bedrock 5K	1.0	0.04	0.1	0.006	0.03	0.002
Layer 3 Bedrock 10K	2.0	0.04	0.1	0.006	0.03	0.002
Layer 3 Bedrock 50K	10.0	0.04	0.1	0.006	0.03	0.002
Layers 3 & 4 Bedrock 5K	1.0	0.04	0.5	0.006	0.03	0.002
Layers 3 & 4 Bedrock 10K	2.0	0.04	1.0	0.006	0.03	0.002
Layers 3 & 4 Bedrock 50K	10.0	0.04	5.0	0.006	0.03	0.002
Layers 3, 4 & 5 Bedrock 5K	1.0	0.04	0.5	0.006	0.15	0.002

Sensitivity Analysis Simulations	Bedrock Transition Zone		Shallow Bedrock		Deep Bedrock	
	Hydraulic Conductivity (ft/d)	Specific Yield	Hydraulic Conductivity (ft/d)	Specific Yield	Hydraulic Conductivity (ft/d)	Specific Yield
Layers 3, 4 & 5 Bedrock 10K	2.0	0.04	1.0	0.006	0.3	0.002
Layers 3, 4 & 5 Bedrock 50K[1]	10.0	0.04	5.0	0.006	1.5	0.002
Layers 3, 4, & 5 Bedrock 0.2K	0.04	0.04	0.02	0.006	0.006	0.002
Layers 3, 4, & 5 Bedrock 0.1K	0.02	0.04	0.01	0.006	0.003	0.002
Layers 3, 4, & 5 Bedrock 0.02K	0.004	0.04	0.002	0.006	0.0006	0.002
Layer 3 Bedrock 2S_y	0.2	0.08	0.1	0.006	0.03	0.002
Layer 3 Bedrock 0.5S_y	0.2	0.02	0.1	0.006	0.03	0.002
Layer 4 Bedrock 2S_y	0.2	0.04	0.1	0.012	0.03	0.002
Layer 4 Bedrock 0.5S_y	0.2	0.04	0.1	0.003	0.03	0.002
Layer 5 Bedrock 2S_y	0.2	0.04	0.1	0.006	0.03	0.004
Layer 5 Bedrock 0.5S_y	0.2	0.04	0.1	0.006	0.03	0.001
Layers 3, 4, & 5 Bedrock 2S_y	0.2	0.08	0.1	0.006	0.03	0.004
Layers 3, 4, & 5 Bedrock 0.5S_y	0.2	0.02	0.1	0.012	0.03	0.001

Notes:

[1] Parameter increase resulted in numerical instabilities

Abbreviations:

EC SHSM = Existing Condition Stibnite Hydrologic Site Model

ft/d = feet per day

Since the sensitivity analysis simulations use K and S_y parameter modifications based on the calibrated EC SHSM parameters the sensitivity analysis simulations are expected to produce differences between the measured data and corresponding model outputs that are not minimized. Thus, the sensitivity analysis simulations would not be considered calibrated. This is an important consideration and means that calibration statistics are a useful measure of sensitivity when interpreting the results presented in the following sections.

Section 2

Existing Conditions Sensitivity

The calibrated EC SHSM serves as the base case for the sensitivity analysis. The sensitivity analysis simulations are compared directly to the measured site data and the EC SHSM. The comparison to the measured site data provides a measure of the degree of calibration for each sensitivity analysis simulation. The comparison of each sensitivity analysis simulation to the EC SHSM provides a measure of model sensitivity to each parameter change.

2.1 Groundwater Elevations

The groundwater elevation residuals (observed data minus simulated data) are used to quantify the differences in groundwater elevations. Positive and negative residuals indicate the observed groundwater elevations are underpredicted and overpredicted, respectively, by the sensitivity analysis simulation. SHSM sensitivity to bedrock K and specific yield variations are discussed here.

2.1.1 Groundwater Elevations Sensitivity to Bedrock K

The groundwater residuals for the set of sensitivity analysis simulations where K was varied are presented in Figure 2-1 for the alluvium monitoring wells and Figure 2-2 for the bedrock monitoring wells. In the simulations that are insensitive to the parameter change, the results do not change and therefore the data points are plotted under the EC SHSM data and are not visible. Generally, the EC SHSM is sensitive to both the increases and decreases in bedrock K values, with greater sensitivity to increases than decreases in bedrock K.

For most of the simulations in which bedrock K is increased there is an increase in the magnitude of residuals at most of the alluvium and bedrock wells. The notable exception is the Layer 3 Bedrock 5K case where the EC SHSM is not sensitive to the change in K from 0.2 ft/d to 1 ft/d in the bedrock transition zone. This is not surprising since the increase in K is relatively small, and the bedrock transition zone is only 20 ft thick which means the resulting impact to the transmissivity value in this simulation is also relatively small in comparison to layers 4 and 5 overall transmissivity. The large increases in positive residuals and decreases in negative residuals in all other cases indicate that increased K in the bedrock layers of the EC SHSM cause the groundwater heads to be lower than in the calibrated EC SHSM and therefore not as well calibrated. This is expected since an increase in K results in less resistance to flow and allows the groundwater elevations to relax to lower elevations. The nearly universal upward shift of the sensitivity analysis simulation residuals for the cases where K is increased introduces a model bias in which these simulations underestimate the measured groundwater elevations in both the alluvium and bedrock.

In the simulations where K is decreased in the bedrock layers, both the alluvium and bedrock groundwater residuals are relatively insensitive for the 0.2K and 0.1K simulations. In the 0.02K simulation the residuals tend to shift up in the alluvium wells indicating an overall decrease in simulated groundwater elevations in the alluvium and shift down in the bedrock wells, resulting in a simulation that is not as well calibrated as the EC SHSM. In all the simulations in which bedrock K is decreased, there is one bedrock well in which the sensitivity simulations overestimate the measured head significantly more than in the calibrated EC SHSM.

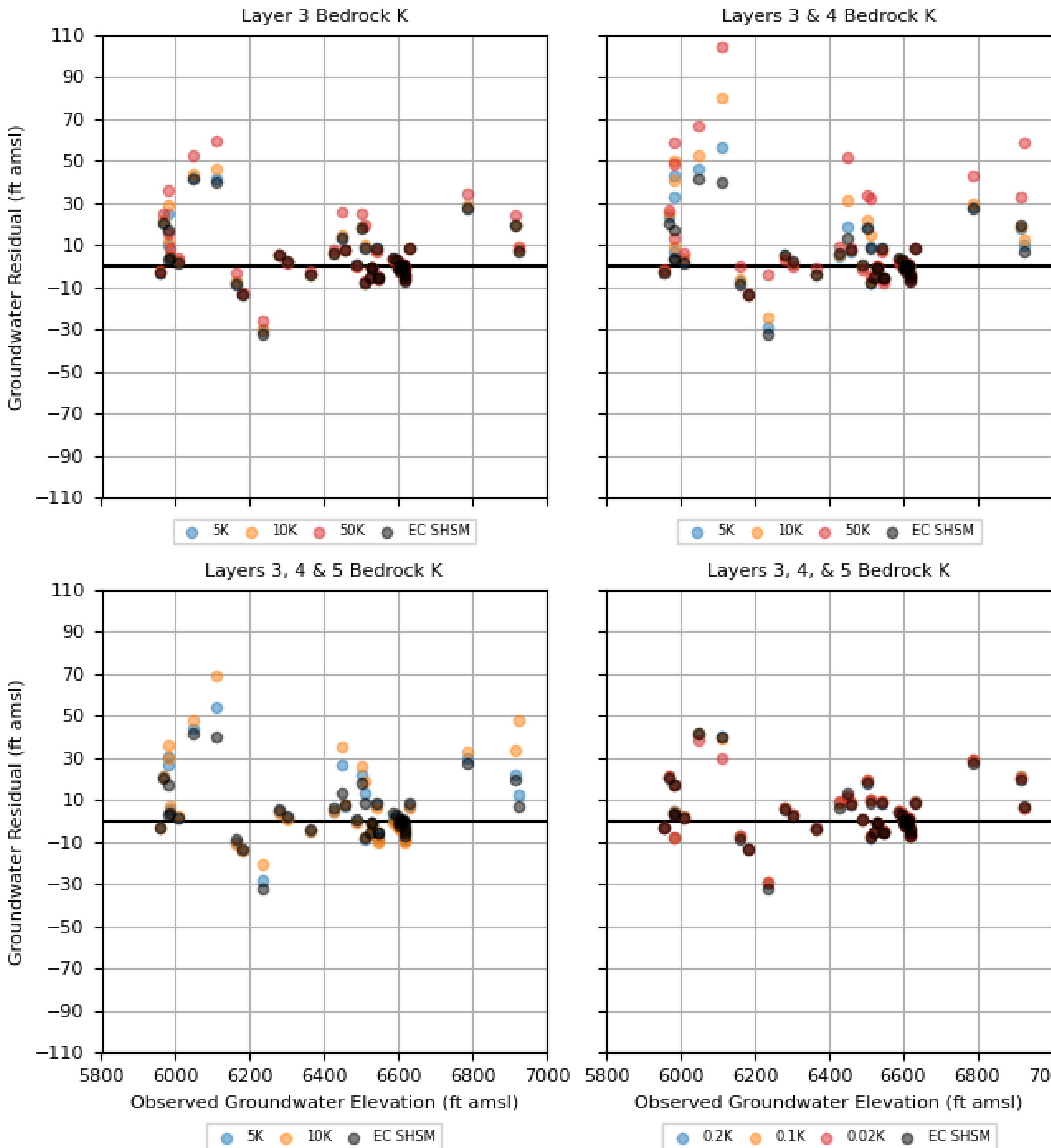

Figure 2-1. Groundwater Residuals of Bedrock K Sensitivity Analysis at the Alluvium Monitoring Wells

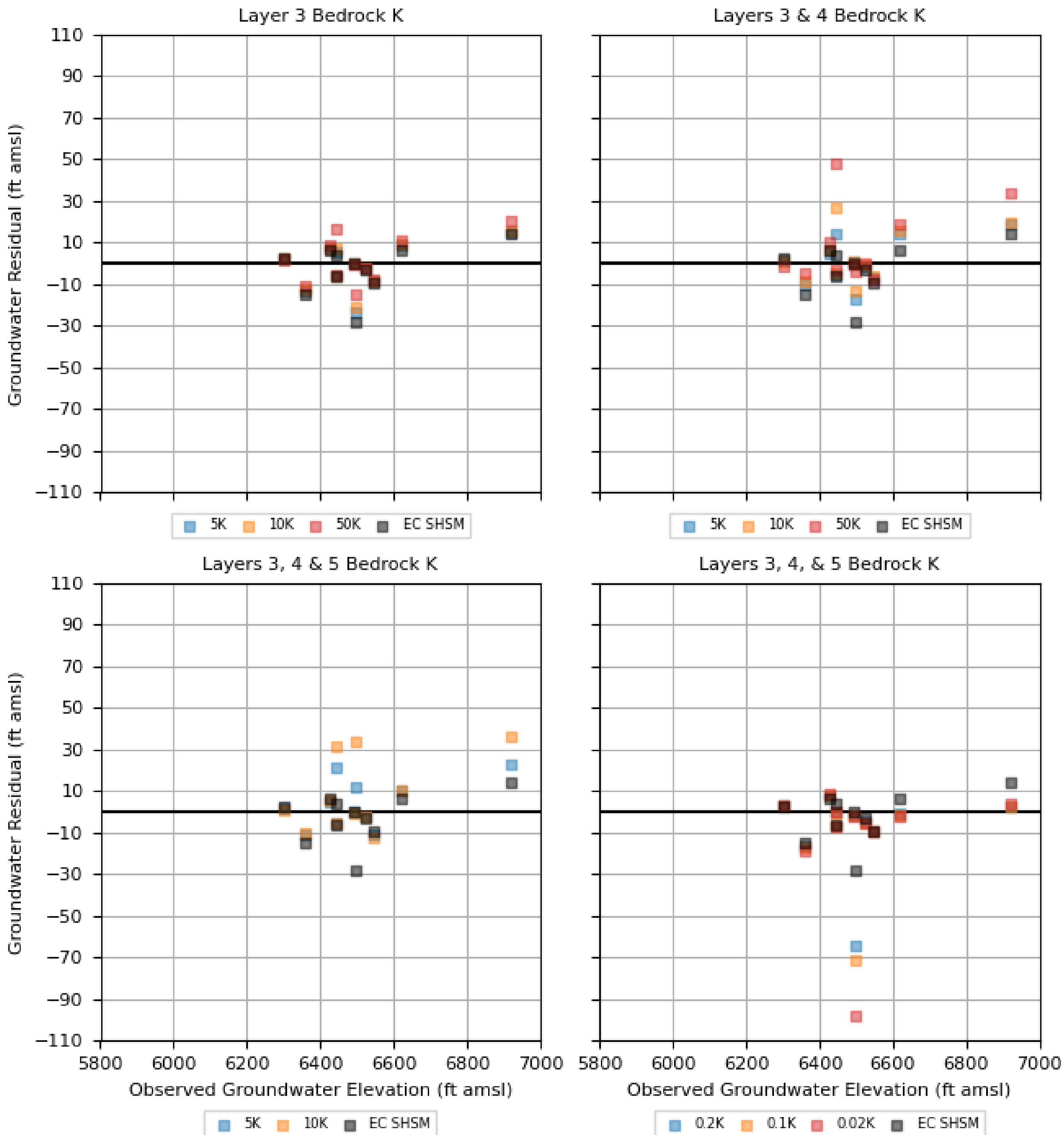

Figure 2-2. Groundwater Residuals of Bedrock K Sensitivity Analysis at the Bedrock Monitoring Wells

2.1.2 Groundwater Elevations Sensitivity to S_y

The groundwater residuals for the set of sensitivity analysis simulations where S_y was varied are presented in Figure 2-3 for the alluvium monitoring wells and Figure 2-4 for the bedrock monitoring wells. In the simulations that are insensitive to the parameter change, the results do not change and therefore the data points are plotted under the EC SHSM data and are not visible. Generally, the EC SHSM is insensitive to both the increases and decreases of bedrock Sy in the alluvium and bedrock monitoring wells.

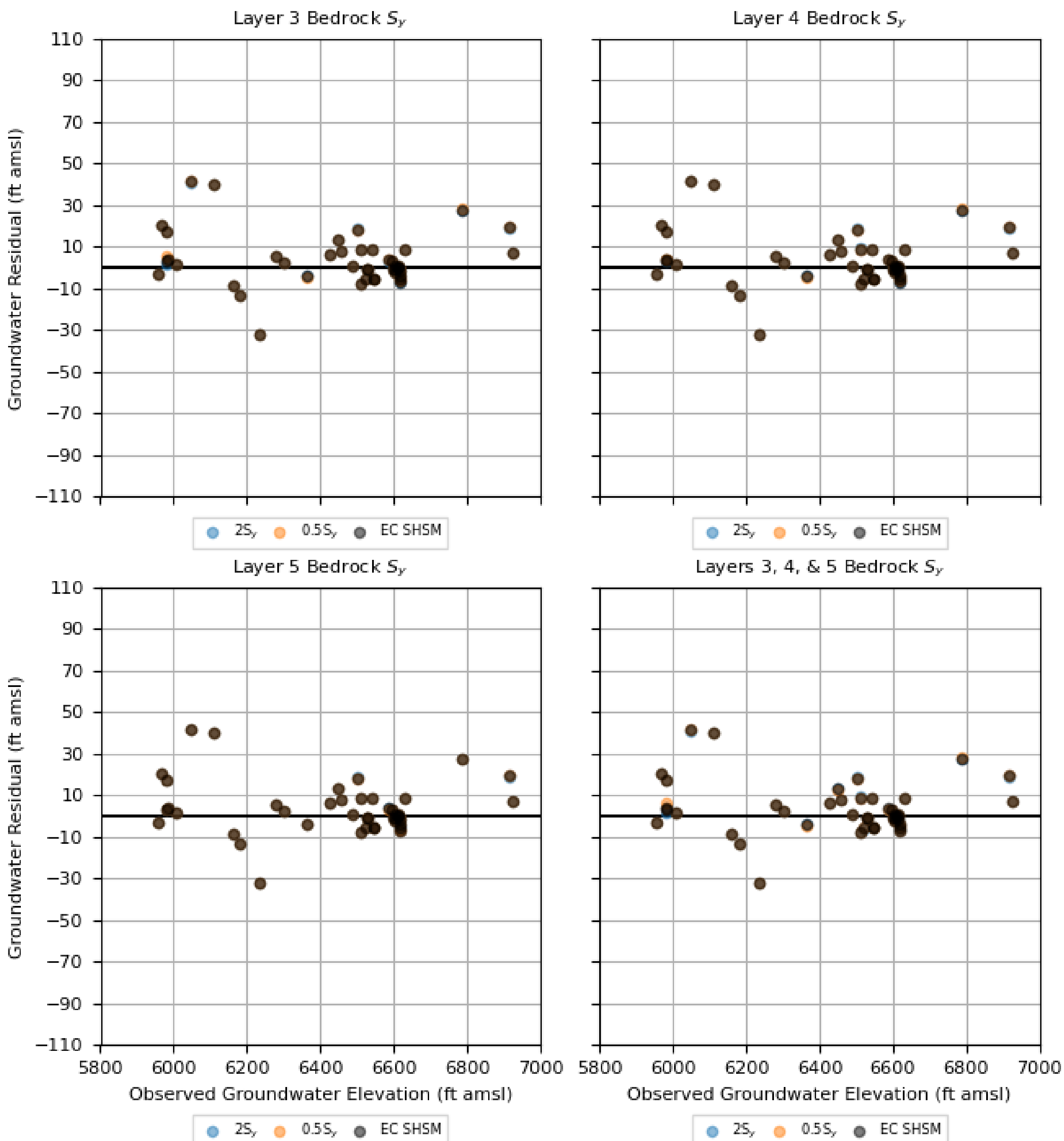

Figure 2-3. Groundwater Residuals of Bedrock S_y Sensitivity Analysis at the Alluvium Monitoring Wells

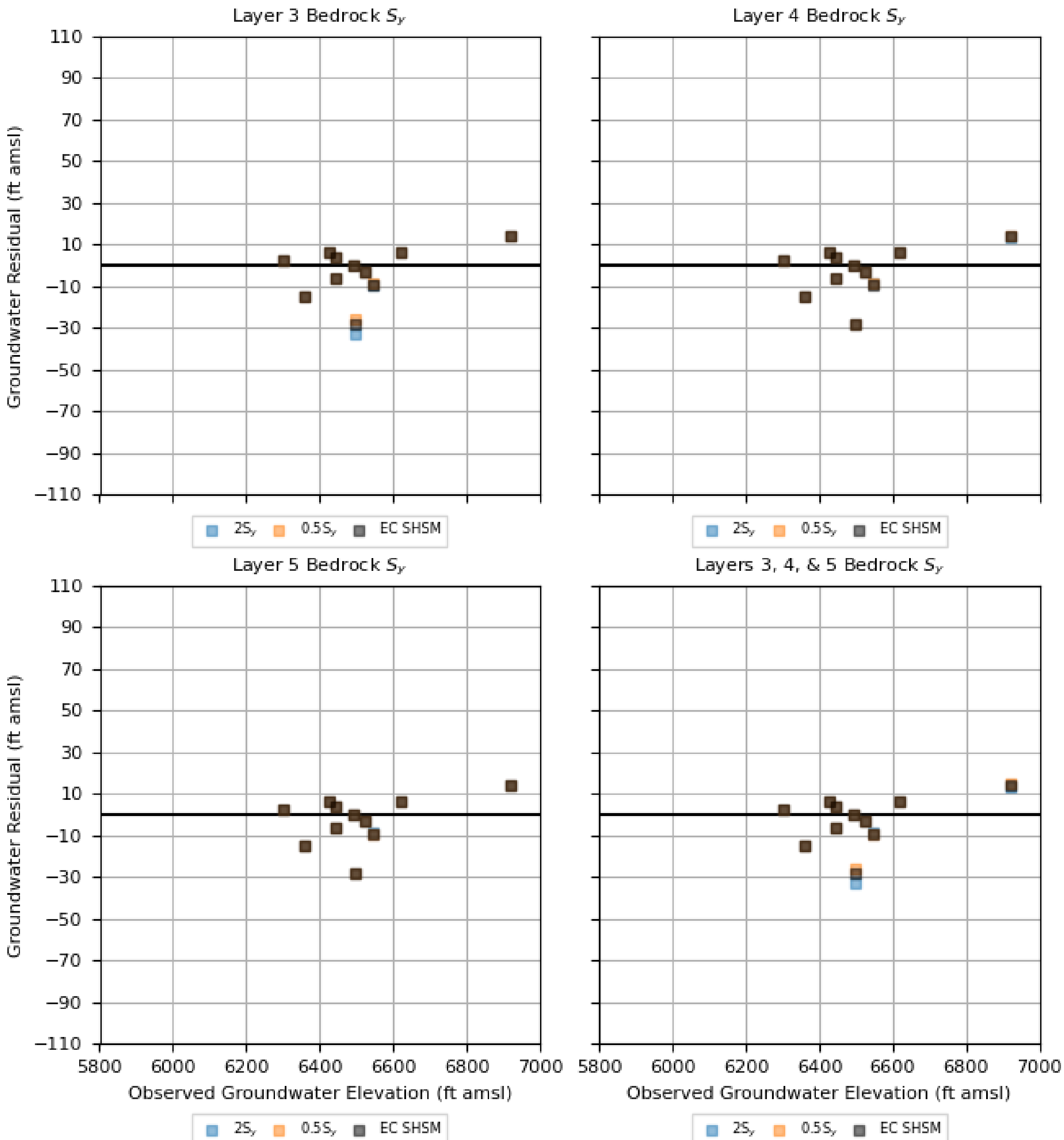

Figure 2-4. Groundwater Residuals of Bedrock S_y Sensitivity Analysis at the Bedrock Monitoring Wells

The groundwater residual summary statistics for the sensitivity analysis simulations are provided in Appendix A, Table A-1. The summary statistics include:

- Residual Mean (RM) — the average of the differences between the observed and SHSM simulated values.
- Absolute Residual Mean (ARM) — the average of the absolute values of the differences between the observed and SHSM simulated values.

- Sum of Squared Errors (SSE) — the sum of the square of the differences between the observed and SHSM simulated values.
- Root Mean Squared Error (RMSE) — the square root of the average of squared differences between the observed and SHSM simulated values.
- Scaled RMSE — the RMSE divided by the total change in measured head, which is a measure of how well the model simulates groundwater elevation gradients.

The sensitivity analysis summary statistics provide an aggregate description and quantification of the residuals shown on Figure 2-1 through Figure 2-4. In all simulations where the bedrock K is increased the summary statistics worsen in comparison to the EC SHSM case, especially in the cases where K values are increased by factors of 10 and 50. In the cases where K is decreased the RM improves indicating that, on average, these simulations underestimate the measured groundwater elevations slightly less than the EC SHSM. However, all other summary statistics worsen, particularly the scaled RMSE, indicating that overall, these simulations do not represent the groundwater elevations as well as the calibrated EC SHSM. This degradation in the scaled RMSE means that these simulations of decreased K values do not represent the groundwater gradients as well as the EC SHSM. There are no notable differences in the summary statistics for the S_y sensitivity simulations, reiterating that the SHSM simulated groundwater elevations are insensitive to changes in S_y.

2.2 Streamflow

Streamflow from the EC SHSM sensitivity analysis simulations are compared to measured streamflow at five United States Geological Survey (USGS gages that have measured streamflow data in the calibration period of 2011 to 2019 (Figure A-7 in Appendix A). Figure 2-5 through Figure 2-9 show the comparison between simulated and measured streamflow for the sensitivity analysis simulations where bedrock K is varied. In the simulations that are insensitive to the parameter change, the results do not change and therefore the data points are plotted under the EC SHSM data and are not visible. The dotted lines in Figure 2-5 through Figure 2-9 indicate the sensitivity analysis simulations that have significant discrepancies with the measured groundwater elevations or stream baseflow and are thus not considered well calibrated models.

The simulated streamflow is largely insensitive to increases of K by factors of 5, 10, or 50 in the bedrock transition zone (layer 3) at all five USGS gage locations. Increases of bedrock K by factors of 5 or 10 in layers 3 and 4 do not cause a significant change in simulated streamflow at all five USGS gage locations. The increase of K by a factor 50 in layers 3 and 4 causes a significant decrease in simulated stream baseflow at USGS Gage 13310800 that greatly underestimates the measured stream baseflow while decreasing simulated baseflow to a lesser extent at the other gages. The increase of bedrock K by factors of 5 and 10 in layers 3, 4, and 5 result in simulated stream baseflow that underestimates measured values at USGS Gage 13310800; at all other gages simulated stream baseflow is increased as compared to the calibrated EC SHSM and in most simulations, the model overestimates the measured stream baseflow at these locations. In the simulations where K is decreased in layers 3, 4, and 5, the simulated stream baseflow decreases at all five gage locations as compared the EC SHSM. However, in the 0.2K and 0.1K simulations the decreases in simulated stream baseflow are small and still represent the measured data. In the 0.02K simulation the decreases in simulated baseflow are notable and generally underestimates the measured baseflow at all gages.

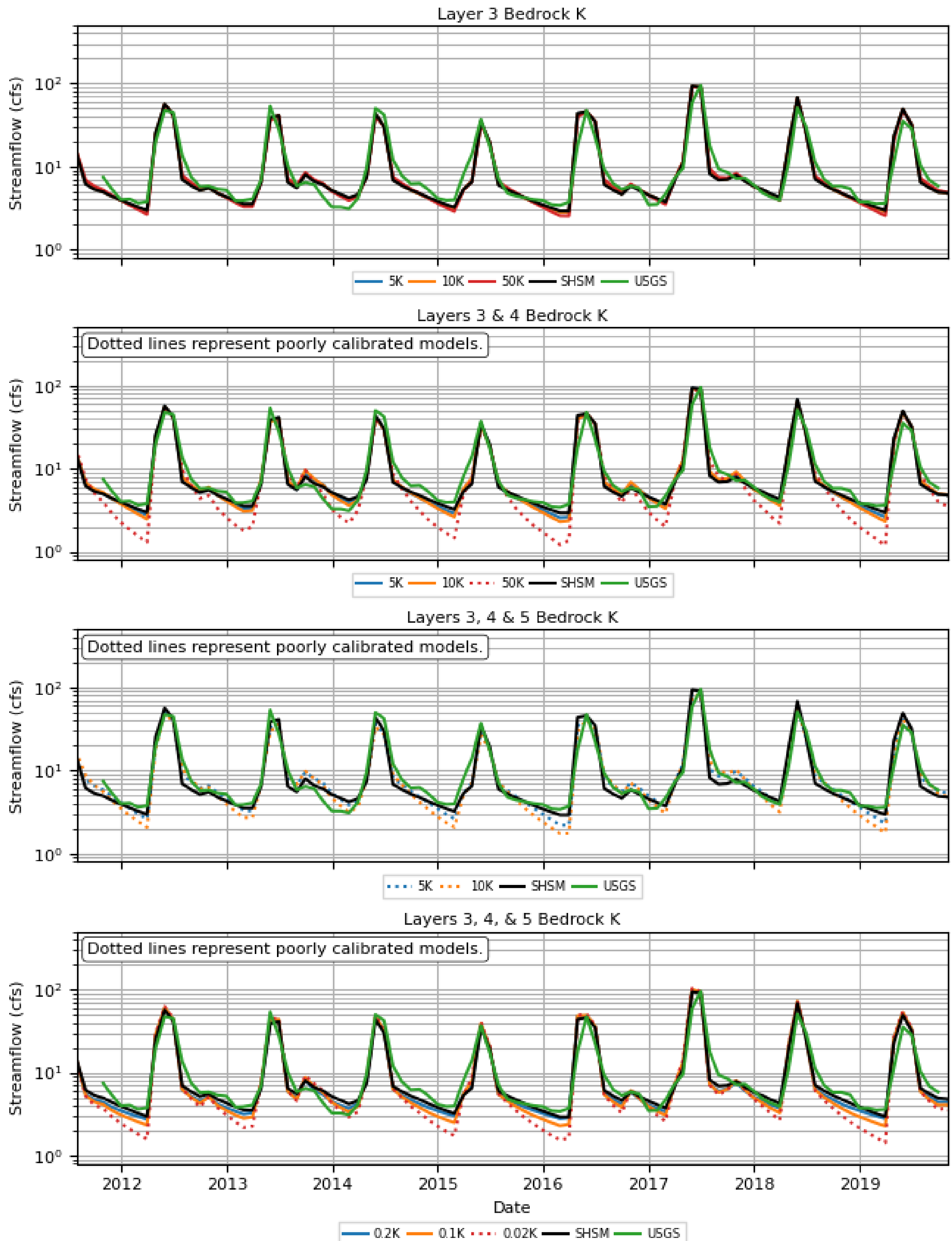

Figure 2-5. Bedrock K Sensitivity Analysis Measured and Simulated Streamflow at USGS Gage 13310800 (EFSFSR Upstream of Meadow Creek) Comparison

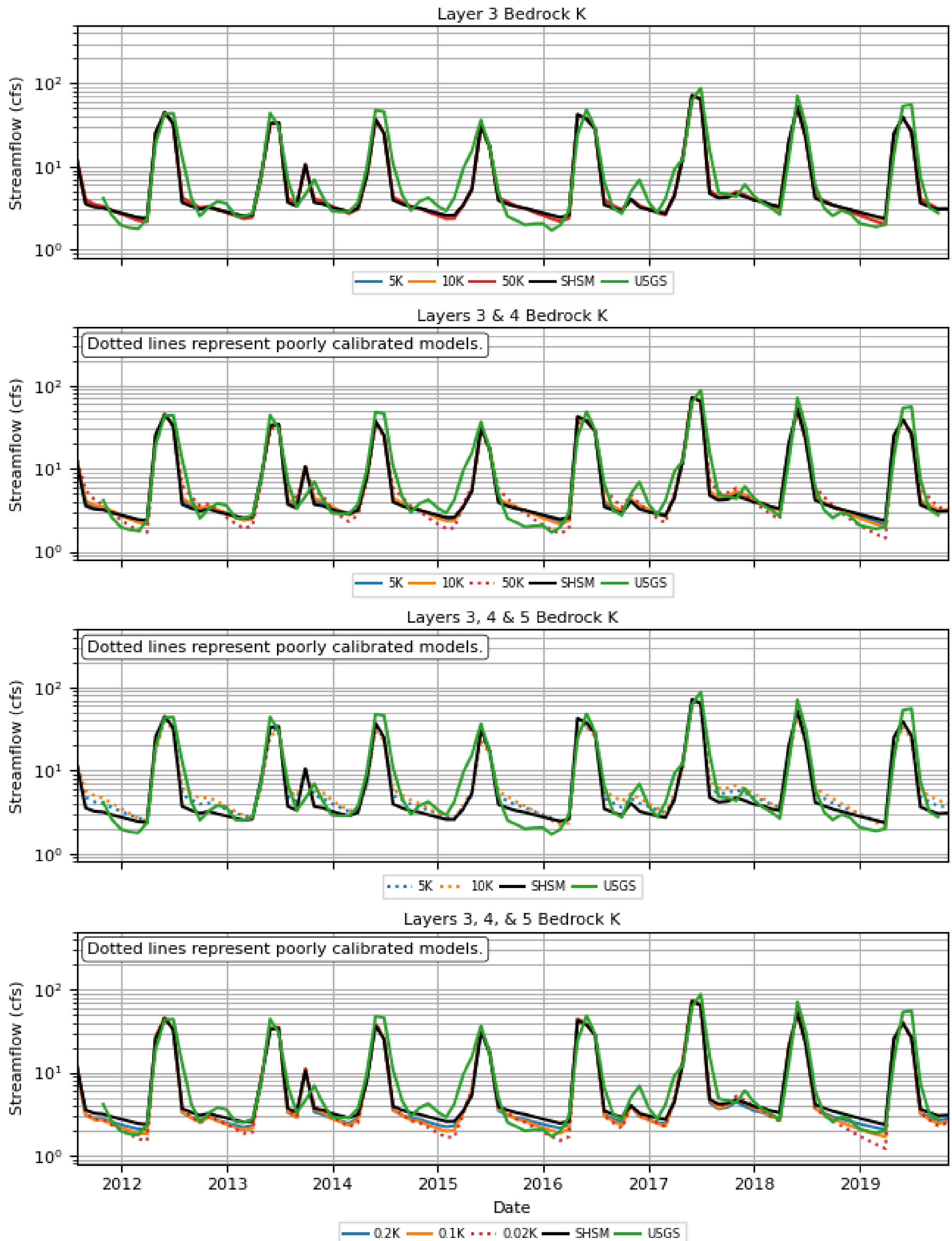

Figure 2-6. Bedrock K Sensitivity Analysis Measured and Simulated Streamflow at USGS Gage 13310850 (Meadow Creek) Comparison

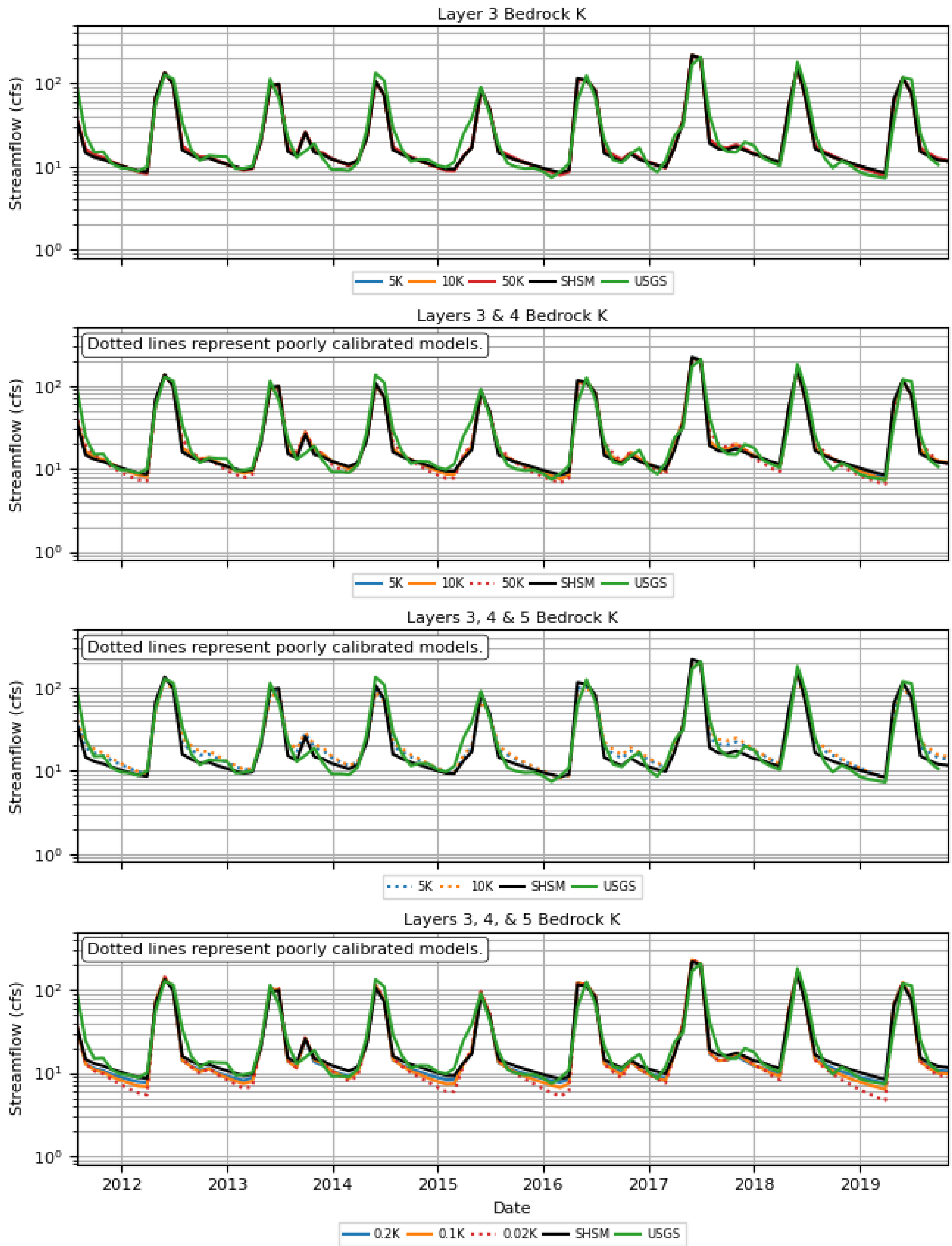

Figure 2-7. Bedrock K Sensitivity Analysis Measured and Simulated Streamflow at USGS Gage 13311000 (EFSFSR at the Box Culvert) Comparison

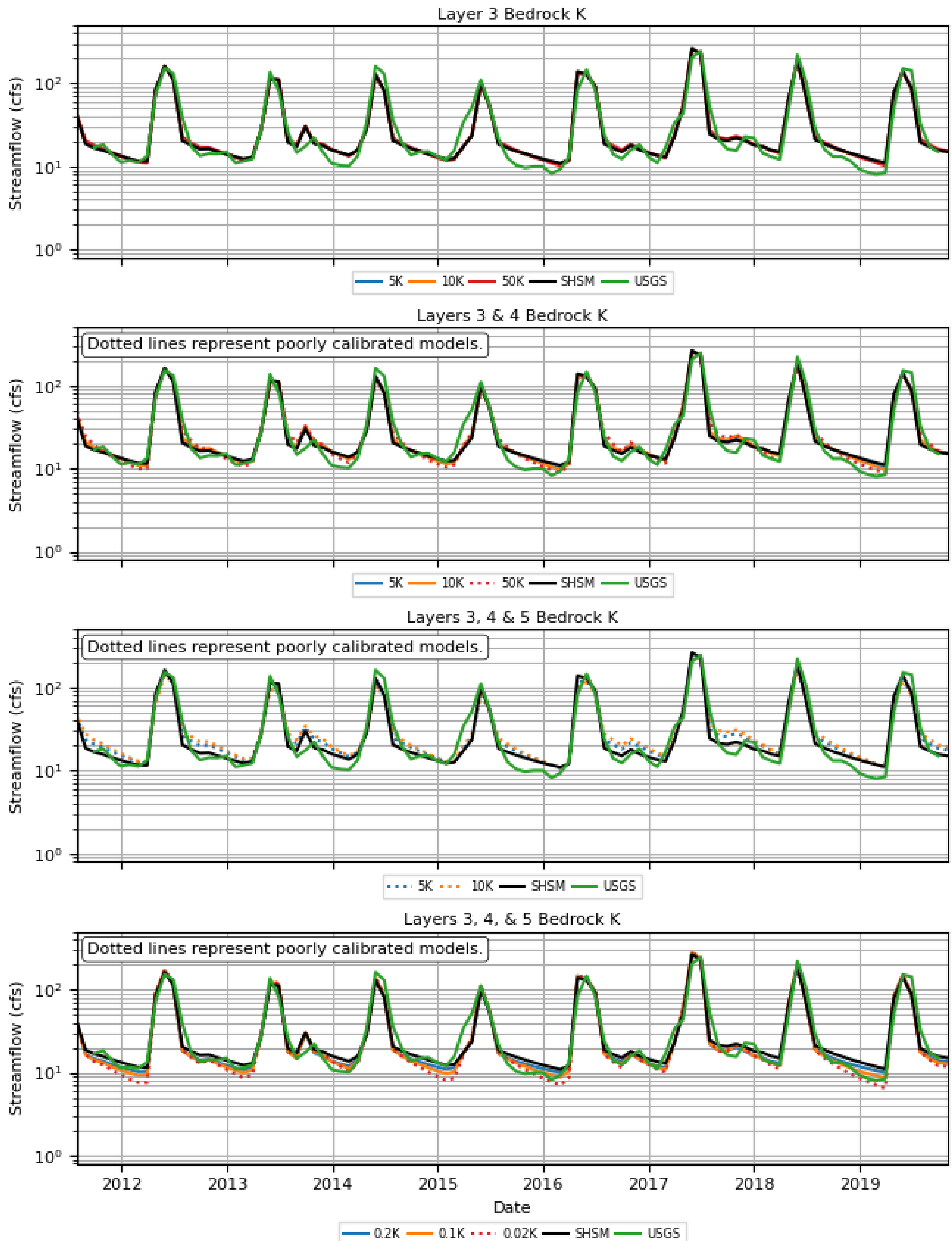

Figure 2-8. Bedrock K Sensitivity Analysis Measured and Simulated Streamflow at USGS Gage 13311250 (EFSFSR Upstream of Sugar Creek) Comparison

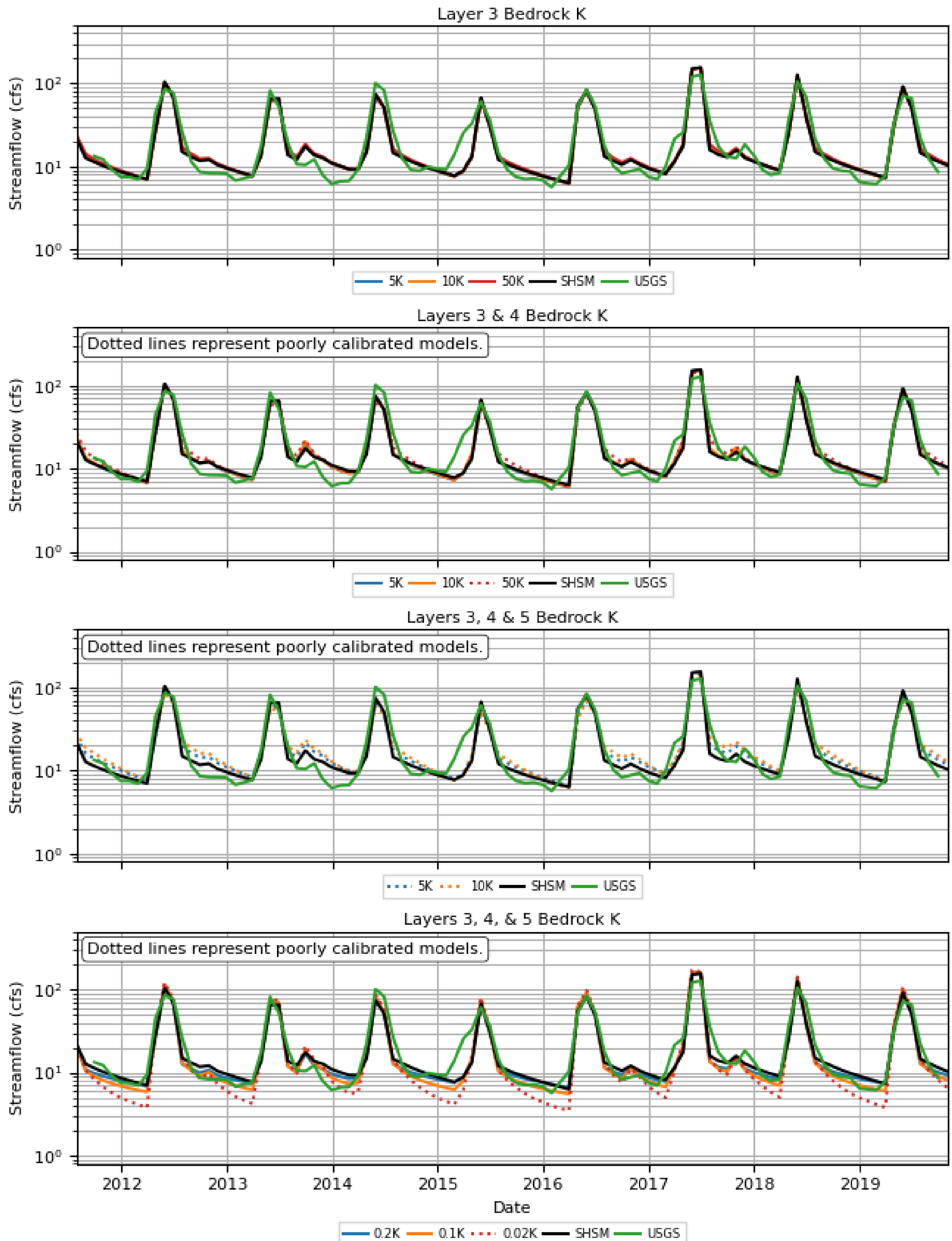

Figure 2-9. Bedrock K Sensitivity Analysis Measured and Simulated Streamflow at USGS Gage 13311450 (Sugar Creek Upstream of EFSFSR) Comparison

Figure 2-10 through Figure 2-14 show the comparison between simulated and measured streamflow for the sensitivity analysis simulations where bedrock S_y is varied. In the simulations that are insensitive to the parameter change, the results do not change and therefore the data points are plotted under the EC SHSM data and are not visible. In the simulations where Sy is increased or decreased in only Layer 3, only Layer 4, and only Layer 5 the simulated stream baseflow does not change significantly at any gage locations. At all gage locations the simultaneous increase in S_y in layers 3, 4, and 5 causes a small increase in simulated stream baseflow as compared to the EC SHSM, whereas the simultaneous decrease in S_y in layers 3, 4, and 5 causes a small decrease in simulated stream baseflow as compared to the EC SHSM.

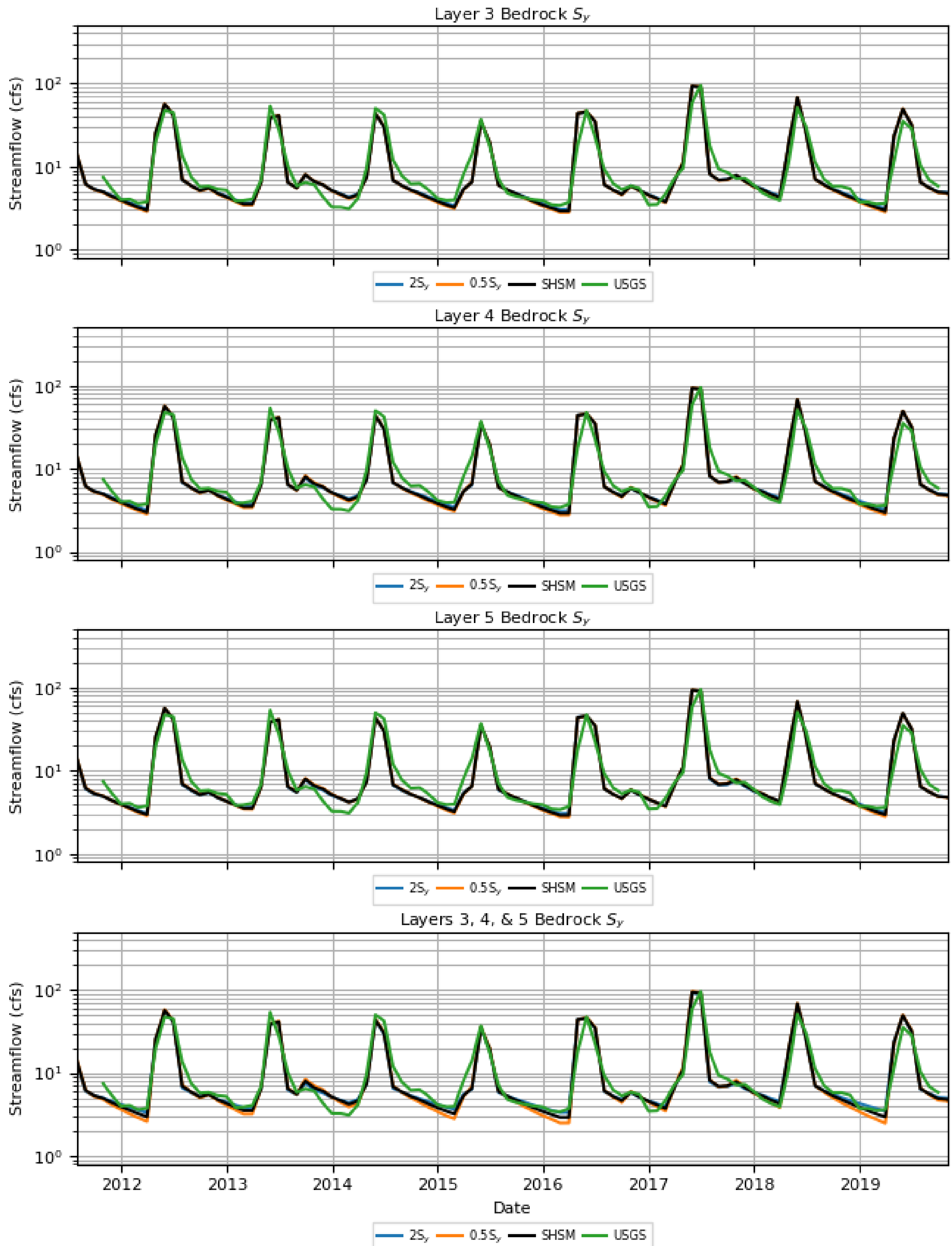

Figure 2-10. Bedrock S_y Sensitivity Analysis Measured and Simulated Streamflow at USGS Gage 13310800 (EFSFSR Upstream of Meadow Creek) Comparison

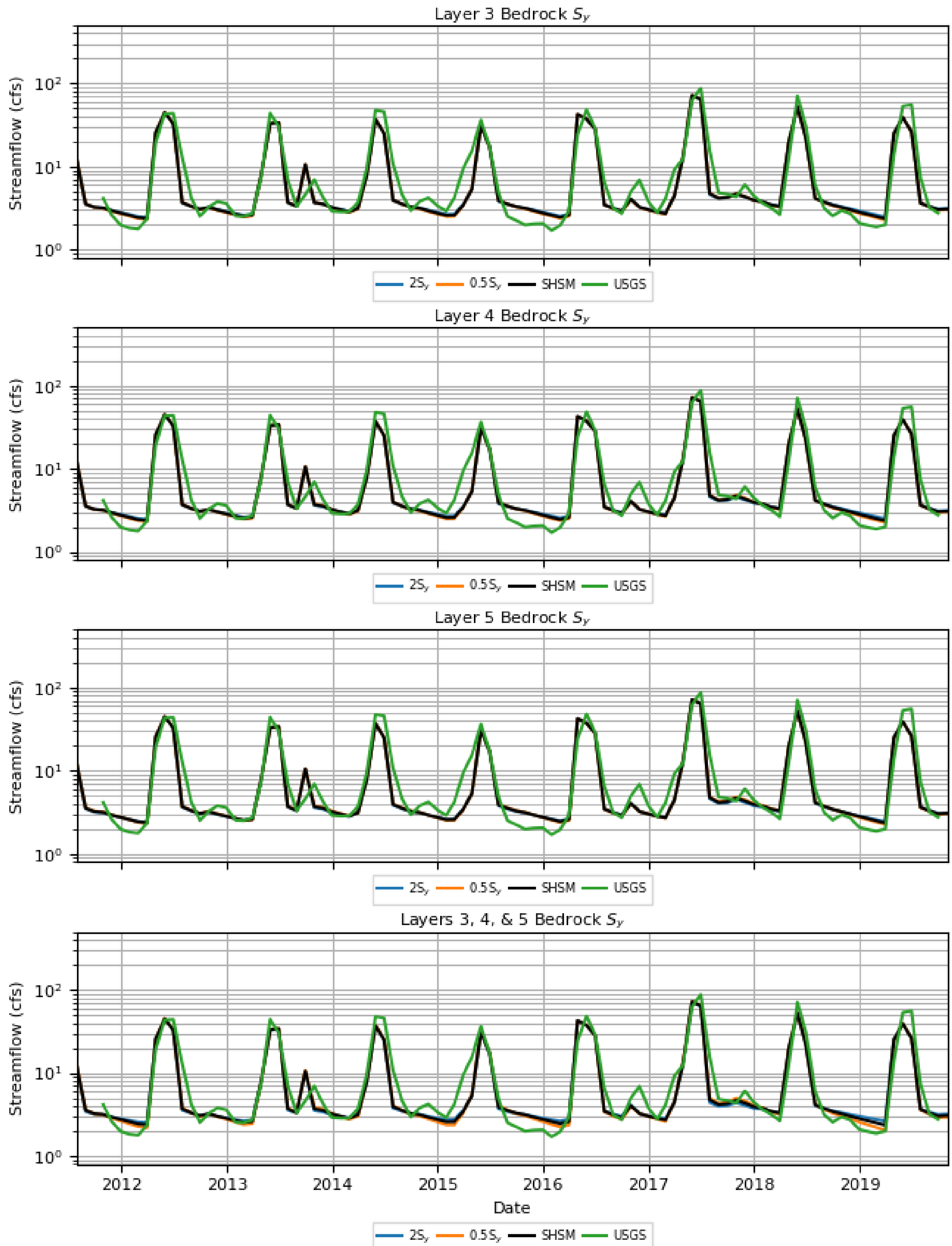

Figure 2-11. Bedrock S_y Sensitivity Analysis Measured and Simulated Streamflow at USGS Gage 13310850 (Meadow Creek) Comparison

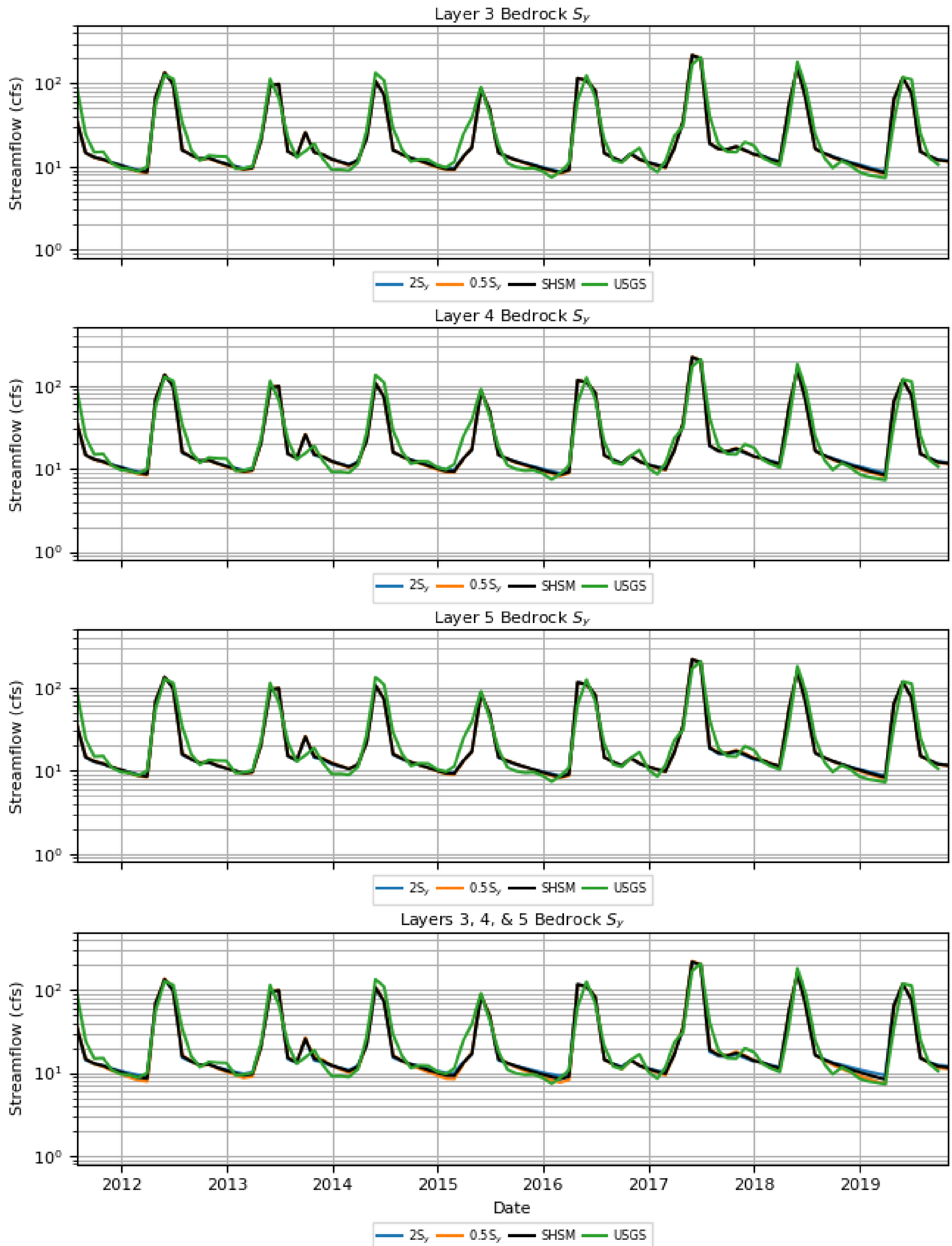

Figure 2-12. Bedrock S_y Sensitivity Analysis Measured and Simulated Streamflow at USGS Gage 13311000 (EFSFSR at the Box Culvert) Comparison

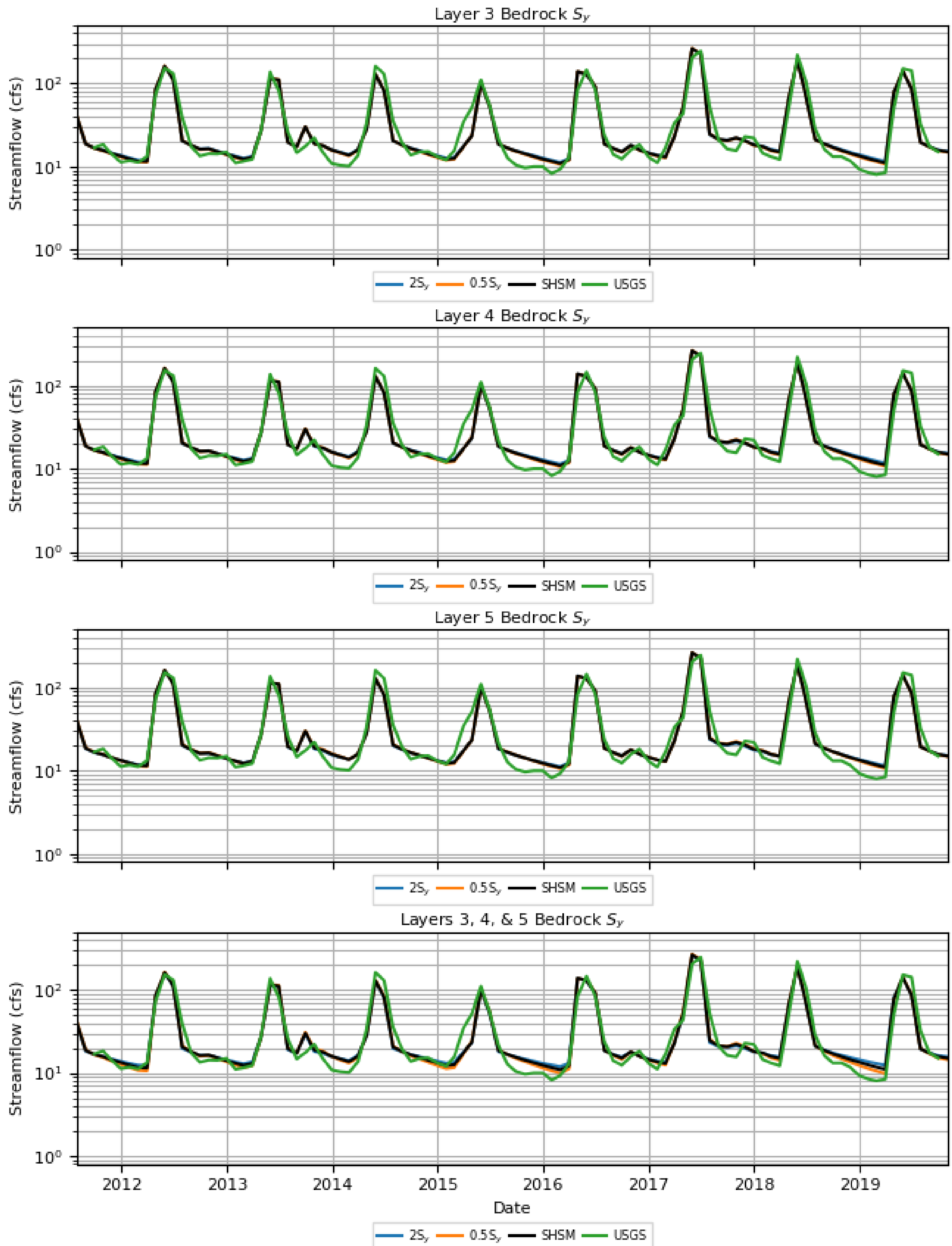

Figure 2-13. Bedrock S_y Sensitivity Analysis Measured and Simulated Streamflow at USGS Gage 13311250 (EFSFSR Upstream of Sugar Creek) Comparison

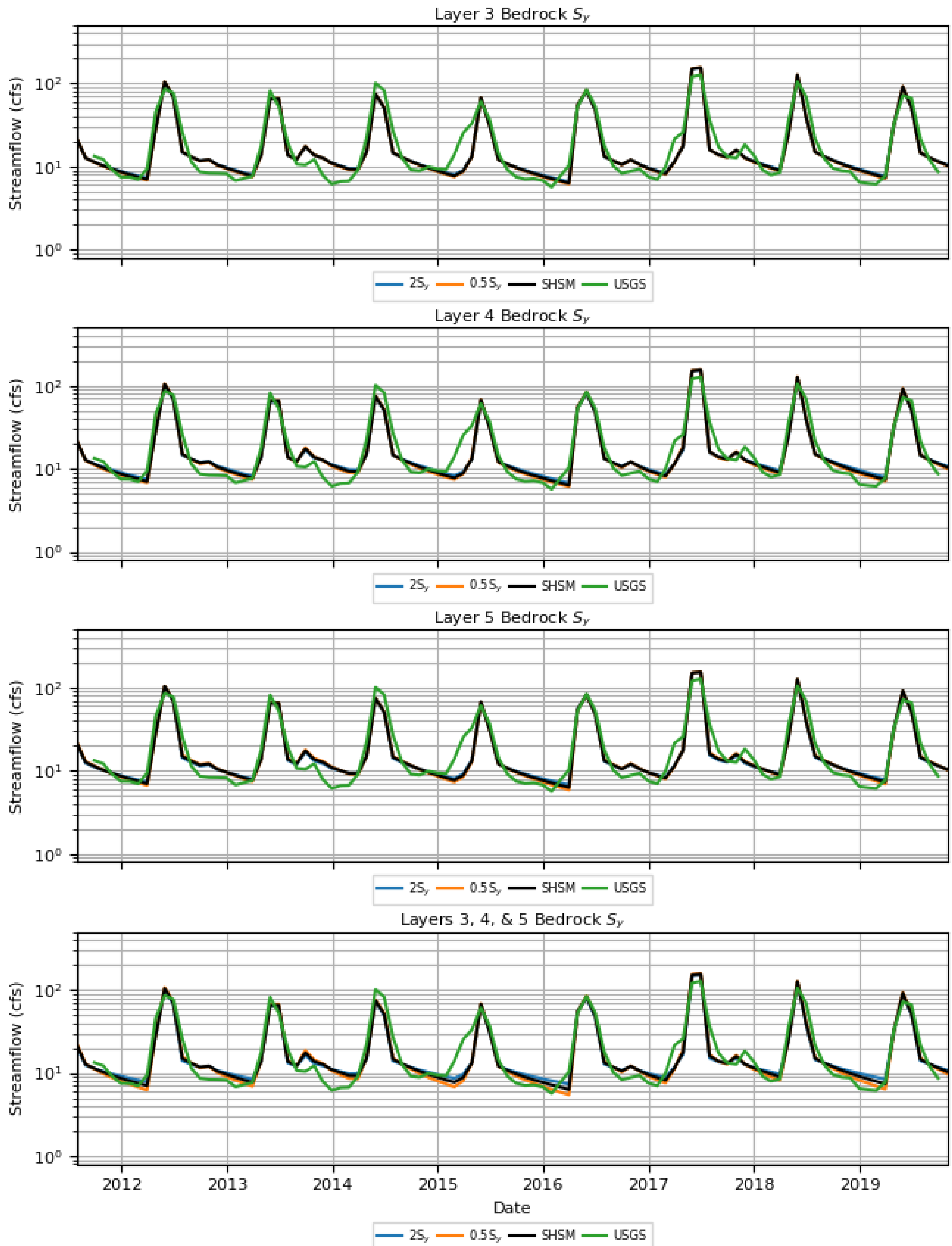

Figure 2-14. Bedrock S_y Sensitivity Analysis Measured and Simulated Streamflow at USGS Gage 13311450 (Sugar Creek Upstream of EFSFSR) Comparison

The stream baseflow residual summary statistics are provided in Table A-2 of Appendix A. The summary statistics are calculated as an aggregate of all five USGS gages for the October, November, December, January, and February months from 2011 through 2019. The summary statistics do not change significantly for the simulations where bedrock K is increased in layer 3 by factors of 5, 10, and 50 and the simulations where bedrock K is increased in layers 3 and 4 by factors of 5 and 10. The summary statistics deteriorate for the simulations in which K is increased in layers 3 and 4 by a factor of 50 and K is increased in layers 3, 4, and 5 by factors of 5 and 10. In the simulations where bedrock K decreases by a factor 0.2 and 0.1 the summary statistics do not change significantly while the multiplication factor 0.02 cause the summary statistics to degrade. In all simulations in which S_y is increased or decreased the summary statistics change marginally.

There are a few simulations for which the summary statistics show improvements compared to the summary statistics for the EC SHSM (e.g., layer 4 decreases S_y by a factor of 0.5; layers 3, 4, and 5 decrease S_y by a factor of 0.5), however these improvements are small and within model uncertainty.

2.3 Existing Conditions Summary

The comparison of simulated groundwater elevation residuals, simulated streamflow, and summary statistics shows that the SHSM is sensitive to variations in K and is insensitive to variations in S_y. Increases or decreases to bedrock K and S_y values result in SHSM simulations that are less representative of the measured groundwater elevations and the measured stream baseflow as compared to the calibrated EC SHSM. Indeed, the simulations where layers 3 and 4 increase K by a factor of 50 and where layers 3, 4, and 5 increase K by factors of 5 and 10 result in poorly calibrated models that on average significantly underestimate the measured groundwater elevations at the site.

This sensitivity analysis demonstrates that, for all simulations, variations in bedrock K and S_y from the calibrated SHSM result in similar or poorer calibration performance in both groundwater elevation and stream baseflow. Although the original Mote Carlo calibration did not cover the higher values of the estimated bedrock K values, the sensitivity analysis demonstrates that inclusion of higher bedrock K values does not result in a better calibrated model and that there is no bias in the calibrated EC SHSM toward low bedrock K values. Further, the overall sensitivity of this model is reasonable and expected and there are no substantially different combinations of input parameters that would result in a more closely calibrated model and thereby potentially change predictions of future mine impacts.

Section 3

ModPRO2 Comparative Analysis

The ModPRO2 SHSM simulates the mine plan described in the Refined Modified Proposed Action (ModPRO2) Alternative (Midas Gold 2020). This ModPRO2 SHSM evaluates a 14-year period (mine years -2 through 12) consistent with the mine construction and operations period. The ModPRO2 SHSM uses the calibrated EC SHSM aquifer parameters (Table 1-1) and serves as the base case simulation for the comparative analysis. The ModPRO2 comparative analysis focuses on how the changes in bedrock K and S_y influence simulated dewatering rates at the three proposed pits.

3.1 Pit Dewatering

This section presents the comparative analyses of the dewatering rates for the Yellow Pine, Hangar Flats, and West End pits. Simulated Yellow Pine pit and Hangar Flats pit dewatering rates are generally sensitive to bedrock K. However, note that bedrock K values that deviate from the values established in the calibrated EC SHSM are expected to simulate groundwater heads and streamflow that are less representative of site data. The values used for this comparison of predicted pit dewatering rates have been shown to result in poor calibration performance and an uncalibrated model (Section 2). These comparisons are therefore intended to provide a response to review questions regarding the relative sensitivity of the predicted dewatering rates to changes in aquifer parameters. Because none of the comparative simulations are based on calibrated K or S_y values the resulting dewatering rate estimates have no value in evaluating potential mine dewatering behavior or mine impacts.

3.1.1 Yellow Pine Pit

The simulated Yellow Pine pit dewatering rates for the ModPRO2 comparative analysis simulations where the bedrock K is varied are presented in Figure 3-1. In the simulations that are insensitive to the parameter change, the results do not change and therefore the data points are plotted under the SHSM data and are not visible. In layer 3, an increase of bedrock K by factors of 5 or 10 has no impact on the simulated dewatering rates and an increase of bedrock K by a factor of 50 results in a marginal increase in dewatering rates. For the cases where layers 3 and 4 bedrock K is increased by factors of 5 and 10 there is a small increase in dewatering rates. When the bedrock K's in layers 3 and 4 are increased by a factor of 50, there is a significant increase in simulated dewatering rates. Similarly, an increase of bedrock K by factors of 5 and 10 in layers 3, 4, and 5 results in significantly increased simulated dewatering rates. In the cases where the bedrock K values are decreased there is a small decrease in dewatering rates during mine years 2 through 6 and a small increase in mine years 7 through 10.

The simulated Yellow Pine pit dewatering rates for the ModPRO2 comparative analysis simulations where the bedrock S_y is varied are presented in Figure 3-2. In the simulations that are insensitive to the parameter change, the results do not change and therefore the data points are plotted under the SHSM data and are not visible. The simulated dewatering rates at Yellow Pine pit are generally insensitive to the changes in S_y in the comparative analysis.

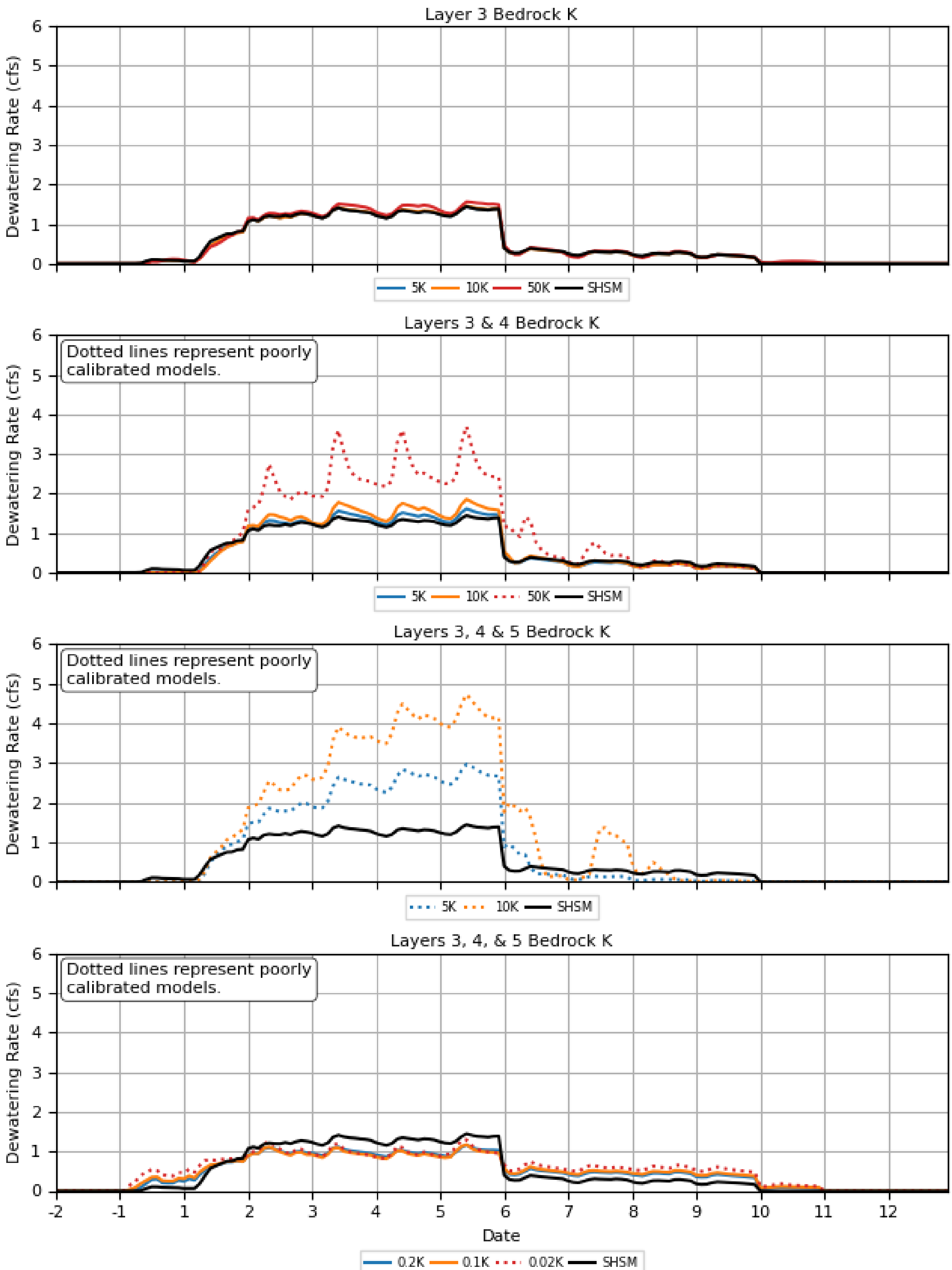

Figure 3-1. Simulated Dewatering Rates of Bedrock K Sensitivity Analysis at Yellow Pine Pit

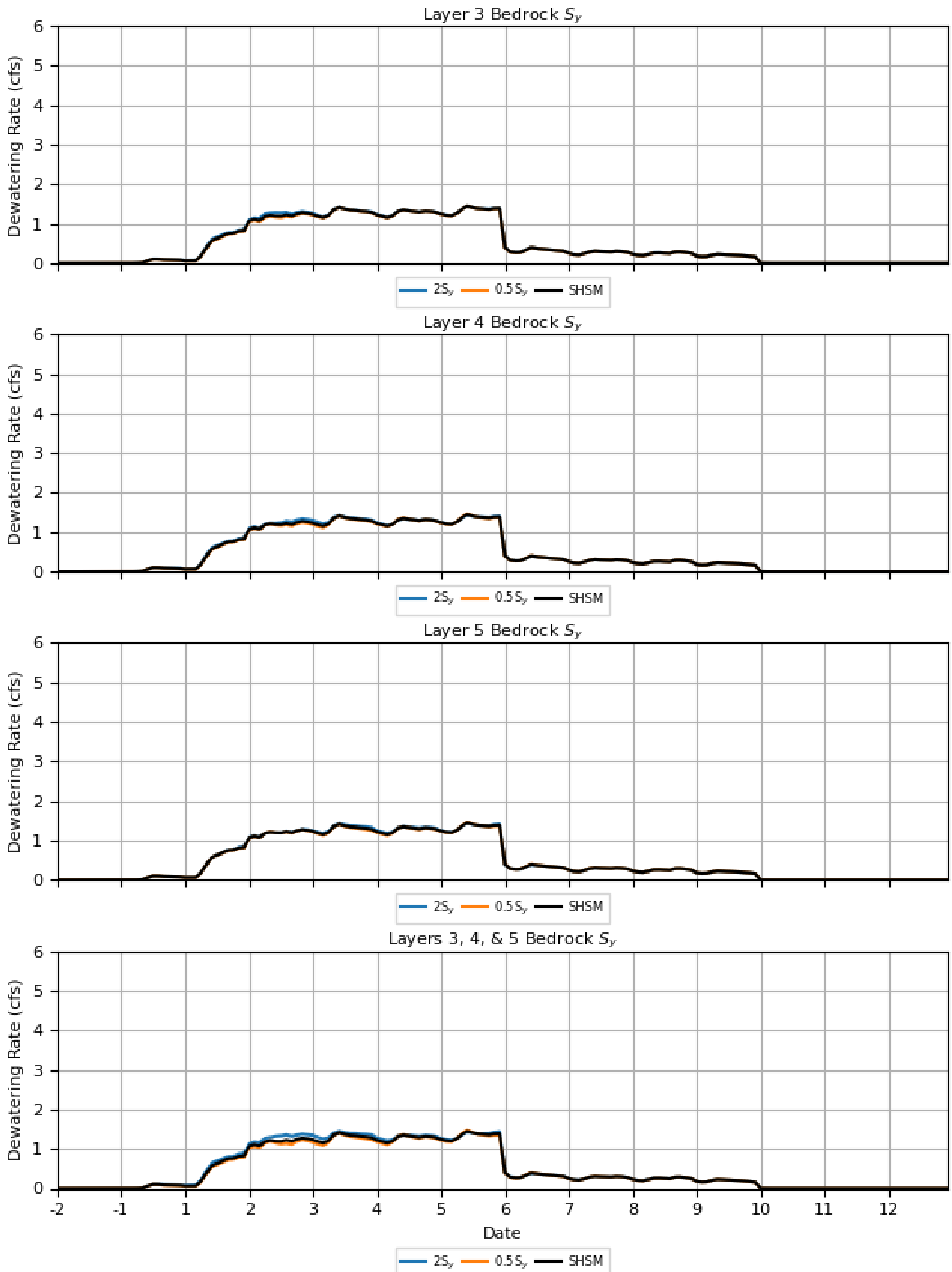

Figure 3-2. Simulated Dewatering Rates of Bedrock S_y Sensitivity Analysis at Yellow Pine Pit

3.1.2 Hangar Flats Pit

The simulated Hangar Flats pit dewatering rates for the ModPRO2 comparative analysis simulations where the bedrock K is varied are presented in Figure 3-3. In the simulations that are insensitive to the parameter change, the results do not change and therefore the data points are plotted under the SHSM data and are not visible. In layer 3 an increase of bedrock K by factors of 5 and 10 has only minor impacts on the simulated dewatering rates and an increase of bedrock K by a factor of 50 causes an approximately 0.5 cubic feet per second (cfs) increase in dewatering rates for mine years 5 and 6. For the simulations where layers 3 and 4 bedrock K values are increased by factors of 5 and 10 there is a small increase in dewatering rates. When the bedrock K values in layers 3 and 4 are increased by a factor of 50, there is a significant increase in the simulated dewatering rate. Similarly, an increase of bedrock K by factors of 5 and 10 in layers 3, 4, and 5 results in significantly increased simulated dewatering rates. In the simulations where the bedrock K values are decreased there is a small decrease in dewatering rates.

The simulated Hangar Flats pit dewatering rates for the ModPRO2 comparative analysis simulations where the bedrock S_y is varied are presented in Figure 3-4. In the simulations that are insensitive to the parameter change, the results do not change and therefore the data points are plotted under the SHSM data and are not visible. The simulated dewatering rates at Hangar Flats pit are not sensitive to the changes in S_y in the comparative analysis.

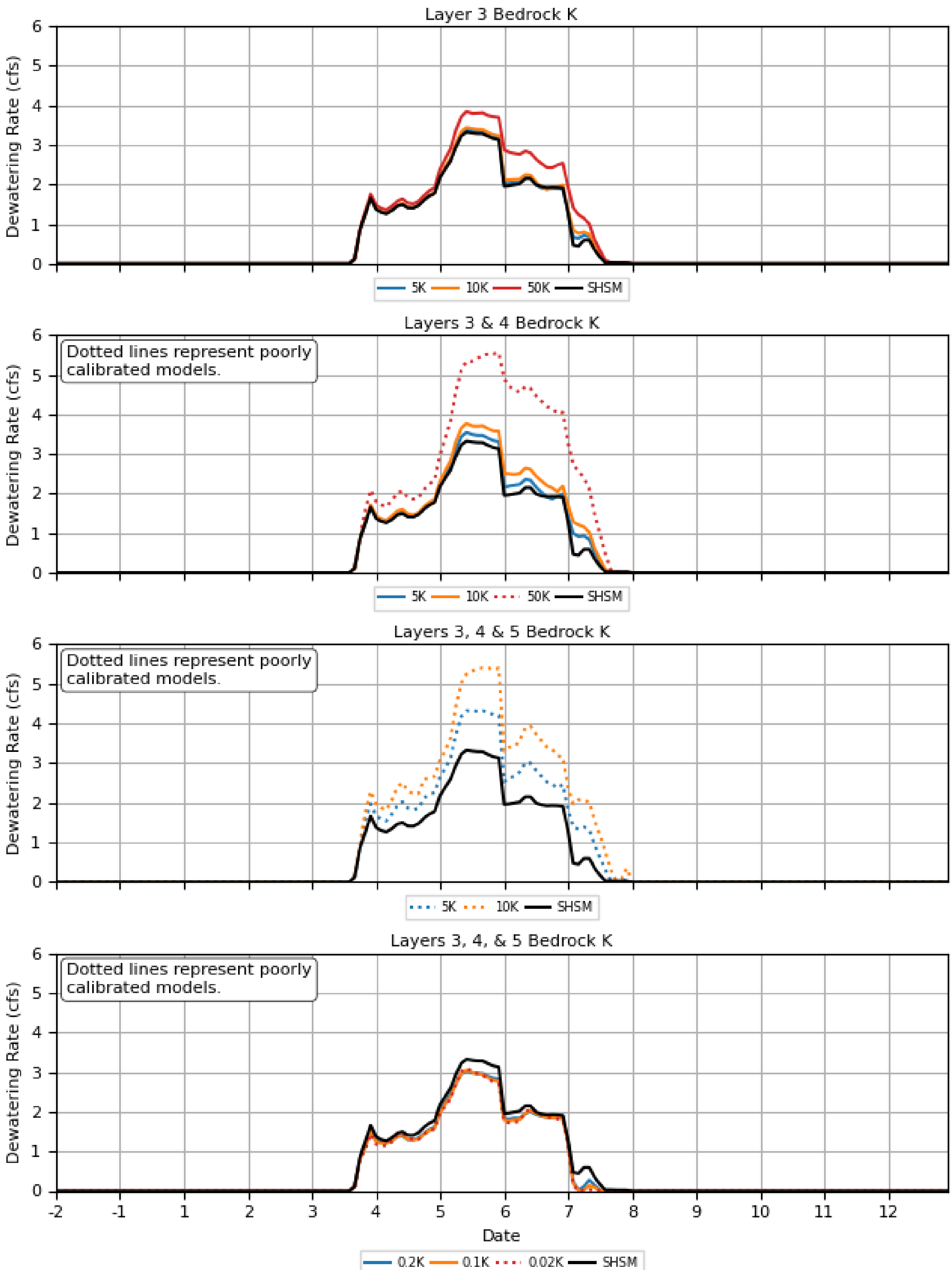

Figure 3-3. Simulated Dewatering Rates of Bedrock K Sensitivity Analysis at Hangar Flats Pit

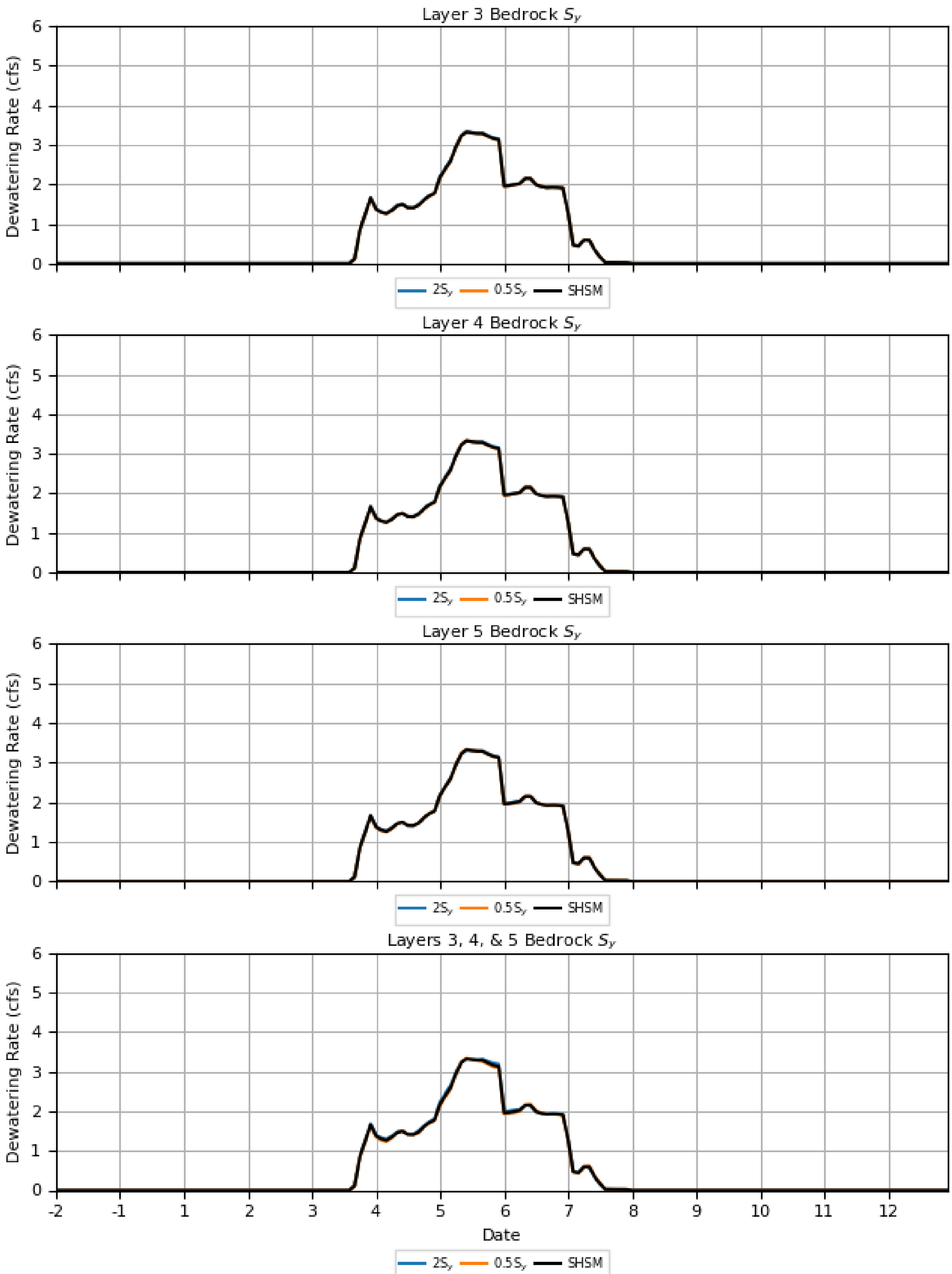

Figure 3-4. Simulated Dewatering Rates of Bedrock S_y Sensitivity Analysis at Hangar Flats Pit

3.1.3 West End Pit

The West End pit intersects the bedrock transition zone in layer 3 and the metaseds in layers 4 and 5. In the HCSM the metaseds are conceptualized to have a higher K value than the surrounding shallow bedrock and deep bedrock in layers 4 and 5, respectively, due to the vertical bedding and fracturing observed in that area. For this reason, the K values in the metaseds in layers 4 and 5 are not varied in this comparative analysis.

The simulated West End pit dewatering rates for the ModPRO2 comparative analysis simulations where the bedrock K is varied are presented in Figure 3-5. In the simulations that are insensitive to the parameter change, the results do not change and therefore the data points are plotted under the SHSM data and are not visible. The West End pit dewatering rates are only slightly sensitive to bedrock K variations in two of the sensitivity analysis simulations. In the simulation where bedrock K in layers 3, 4, and 5 is increased by a factor of 10, there is a small decrease in dewatering rates. This is due to the increase in K in the bedrock transition zone which lowers the groundwater elevations, resulting proportionally less of the pit walls being below the water table, and thus in less dewatering. In the simulation where bedrock K in layers 3, 4, and 5 is decreased by a factor of 50, there is a small increase in simulated dewatering rates due to the decrease in K in the bedrock transition zone, resulting in a slightly higher groundwater elevation in West End pit. Both simulations have already been shown to be poorly calibrated, thus it is anticipated that increases or decreases in the metaseds K values in layers 4 and 5 would deteriorate the calibration ever further.

The simulated West End pit dewatering rates for the ModPRO2 comparative analysis simulations where the bedrock S_y is varied are presented in Figure 3-6. In the simulations that are insensitive to the parameter change, the results do not change and therefore the data points are plotted under the SHSM data and are not visible. The simulated dewatering rates at West End pit are not sensitive to the changes in S_y in the comparative analysis.

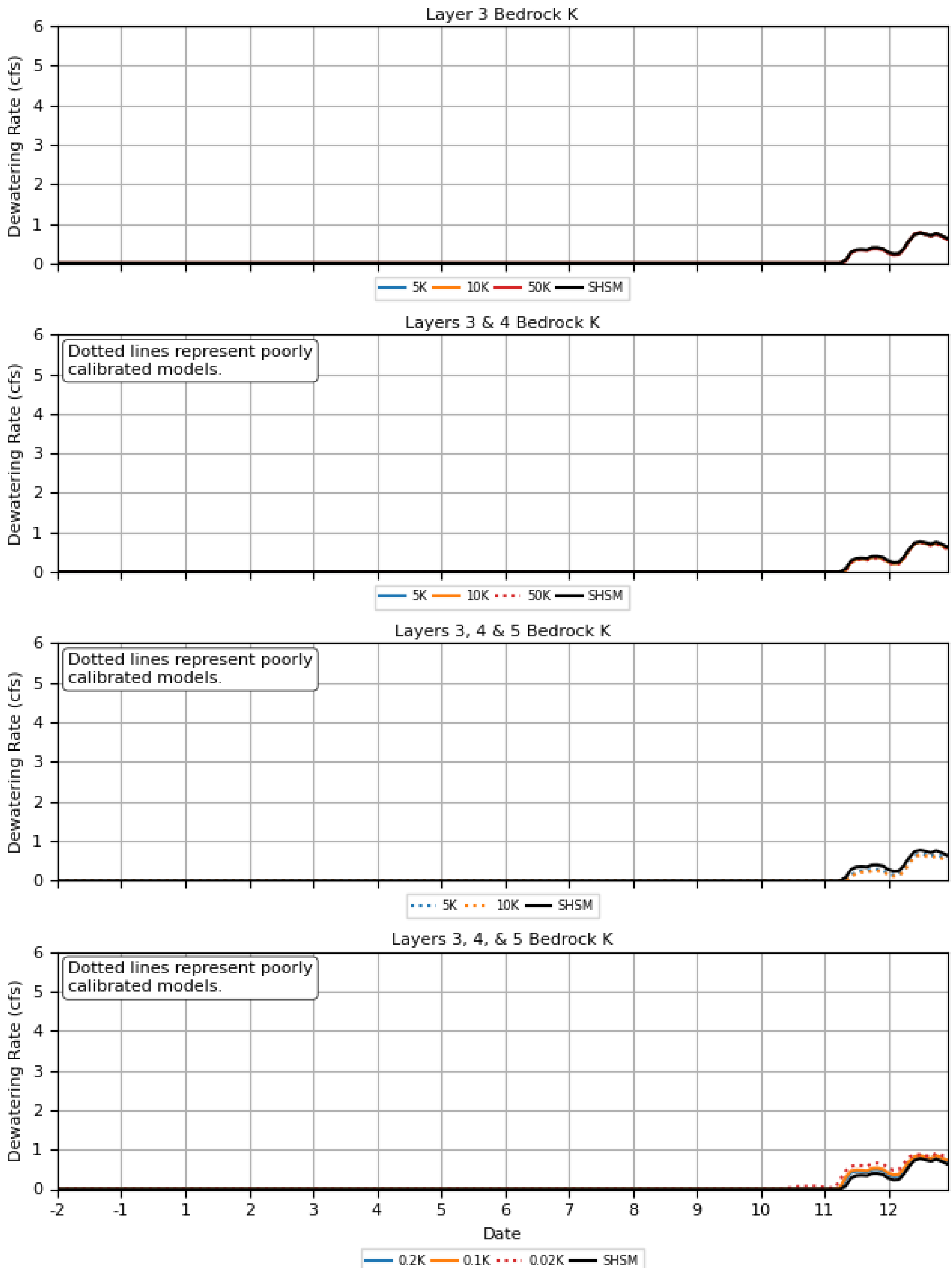

Figure 3-5. Simulated Dewatering Rates for Bedrock K Sensitivity Analysis at West End Pit

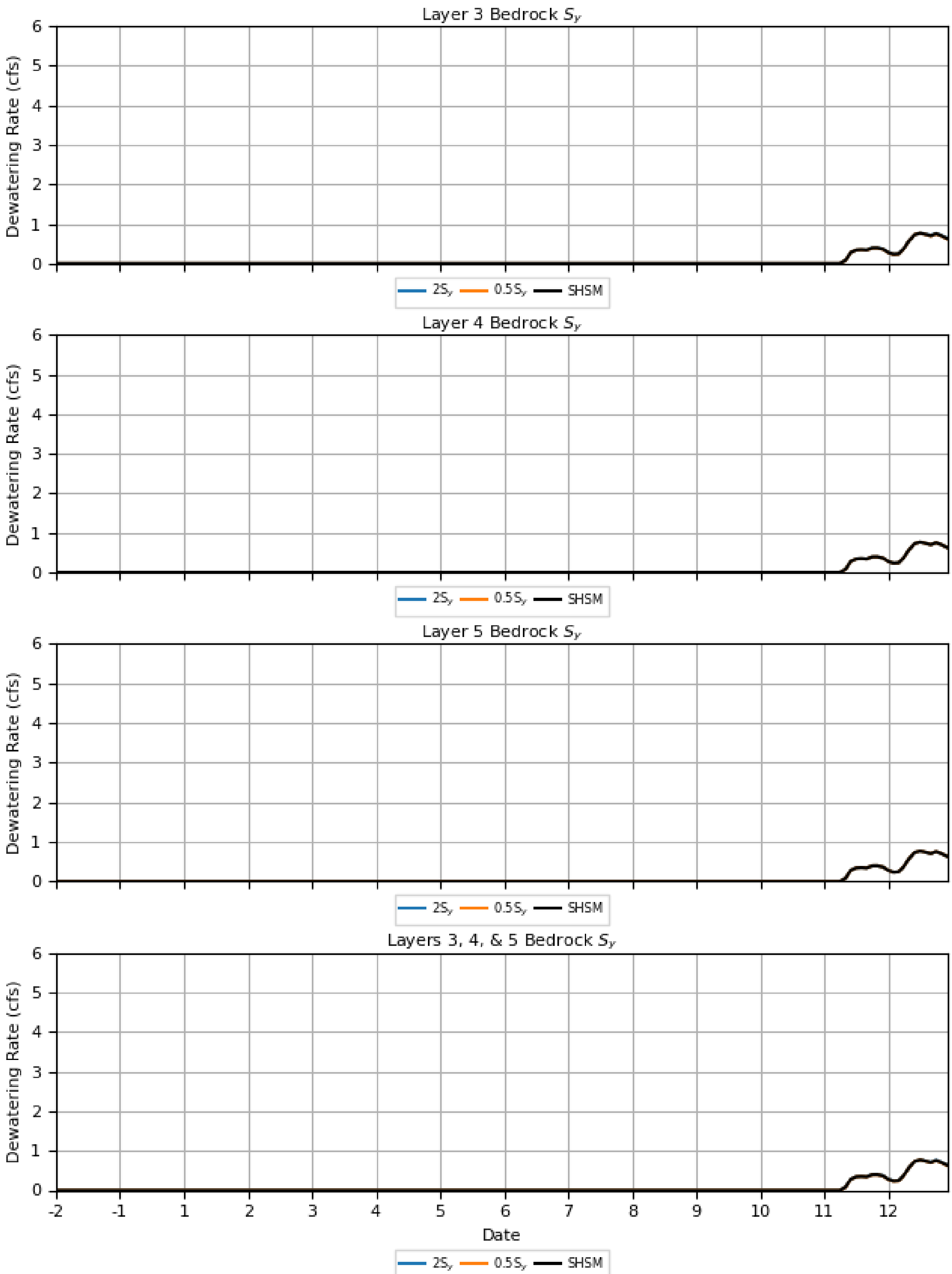

Figure 3-6. Simulated Dewatering Rates for Bedrock S_y Sensitivity Analysis at West End Pit

Section 4

Summary

A sensitivity analysis has been conducted for the bedrock transition zone, shallow bedrock, and deep bedrock input parameter values of K and Sy for the SHSM. The sensitivity analysis included model simulations that varied the bedrock K and Sy input values for the EC and ModPRO2 SHSM. The sensitivity analysis was specifically designed to focus more on higher K values in the bedrock transition zone, shallow bedrock, and deep bedrock to address comments received during the agency comment period on the SHSM. The results of the sensitivity analysis simulations were compared to calibration data to evaluate the degree of calibration and compared to the corresponding calibrated SHSM to assess the degree of sensitivity.

Results from the EC SHSM sensitivity simulations are summarized as follows:

- In the case where the bedrock K values are increased by a factor of 50 in layers 3, 4, and 5, the K values of 10 ft/d in the bedrock transition zone, 5 ft/d in the shallow bedrock, and 1.5 ft/d in the deep bedrock led to numerical instabilities and the simulation failed to converge.
- Simulated groundwater elevations are most sensitive to the large factors of 10 and 50 increases in bedrock K values.
- In all cases where groundwater elevations are notably sensitive to increases in bedrock K values, the increased K values led to a decrease in simulated groundwater elevations that worsen the calibration summary statistics and introduce an underestimation bias in both the alluvium and bedrock monitoring wells.
- Simulated groundwater elevations are sensitive to the decreases in bedrock K values, most notably in the bedrock monitoring wells where the decrease causes a small increase in simulated groundwater elevations.
- Simulated groundwater elevations are not sensitive to the increases or decreases in S_y applied in this sensitivity analysis.
- Simulated stream baseflows are most sensitive to the large factors of 10 and 50 increases in bedrock K values; at the 13310800 and 13310850 gages the stream baseflow decreases due to the increase in bedrock K values, however this sensitivity to increased bedrock K values decreases at gages that are down valley on the EFSFSR and Sugar Creek.
- Simulated stream baseflows at all gages are sensitive to the decreases in bedrock K values, exhibiting a decrease in simulated stream baseflow as compared to the EC SHSM.
- Simulated stream baseflows at all gages are not sensitive to the increases or decreases in S_y applied in this sensitivity analysis.

Overall, it was shown that the calibrated EC SHSM represents the minimum head and stream baseflow error achievable with the ranges of K and S_y in this analysis. The sensitivity analysis K values were specifically set to values higher than those used in original calibration effort and higher than any measured value at the site. Therefore, the maximum values of the parameter ranges for the bedrock transition zone, shallow bedrock, and deep bedrock in the EC SHSM calibration procedure are justifiable and increasing those values does not change the analysis or results presented in the SGP Stibnite Hydrologic Site Model Refined Modified Proposed Action (ModPRO2) Report (BC 2021).

Results from the ModPRO2 SHSM comparative simulations are summarized as follows:

- At Yellow Pine pit, where bedrock K in layers 3 and 4 are increased by a factor of 50 and when the bedrock K in layers 3, 4, and 5 are increased by factors of 5 and 10, there is a significant increase in simulated dewatering rates that is an artifact of the high, poorly calibrated K values.
- At Yellow Pine pit, in the simulations where bedrock K values are decreased there is a small decrease in dewatering rates during mine years 2 through 6 and a small increase in mine years 7 through 10.
- At Hangar Flats pit, an increase of bedrock K by a factor of 50 in the bedrock transition zone causes an approximately 0.5 cfs increase in dewatering rates for mine years 5 and 6.
- At Hangar Flats pit, where the bedrock K in layers 3 and 4 are increased by a factor of 50 and where the bedrock K in layers 3, 4, and 5 are increased by factors of 5 and 10, there is a significant increase in simulated dewatering rates that is an artifact of the high, poorly calibrated K values.
- At Hangar Flats pit, in the cases when the bedrock K values are decreased there is a small decrease in dewatering rates.
- At West End pit, the dewatering rates are largely insensitive to increases and decreases in bedrock K values in the bedrock transition zone, shallow bedrock, and competent bedrock since the West End pit is in the metaseds in the SHSM, and much of it lies above the groundwater table.
- At all three pits, the simulated dewatering rates are insensitive to increases and decreases in the bedrock S_y values.

Overall, small changes in bedrock K values in the SHSM result in small or negligible differences in simulated groundwater levels, streamflow, and pit dewatering rates. It was shown that moderate changes in SHSM bedrock parameters did not yield meaningful differences in simulated dewatering rates. The only significant differences in simulated groundwater levels, streamflow, and pit dewatering rates are a result of increasing bedrock K values by an order of magnitude or larger in the shallow bedrock and deep bedrock. In these simulations where K values are increased by an order of magnitude of larger, the parameter values result in a model that is biased and does not sufficiently represent the measured site data, whether one considers observed streamflow, observed groundwater levels, or measured K from slug, pump, and packer tests in boreholes. Thus, the projected dewatering rates simulated by the original ModPRO2 SHSM and presented in in the SGP Stibnite Hydrologic Site Model Refined Modified Proposed Action (ModPRO2) Report (BC 2021) are reliable projections of future conditions.

Section 5

Limitations

This document was prepared solely for Perpetua Resources in accordance with professional standards at the time the services were performed and in accordance with the contract between Perpetua Resources and Brown and Caldwell dated January 1, 2021. This document is governed by the specific scope of work authorized by Perpetua Resources; it is not intended to be relied upon by any other party except for regulatory authorities contemplated by the scope of work. We have relied on information or instructions provided by Perpetua Resources and other parties and, unless otherwise expressly indicated, have made no independent investigation as to the validity, completeness, or accuracy of such information.

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Section 6

References

Brown and Caldwell, 2021. *Stibnite Hydrologic Site Model Refined Modified Proposed Action (ModPRO2) Report*, Prepared for Perpetua Resources Idaho, Inc., April.

Midas Gold, 2020. *Refined Proposed Action ModPRO2*, December.

Appendix A: Additional Figures and Tables

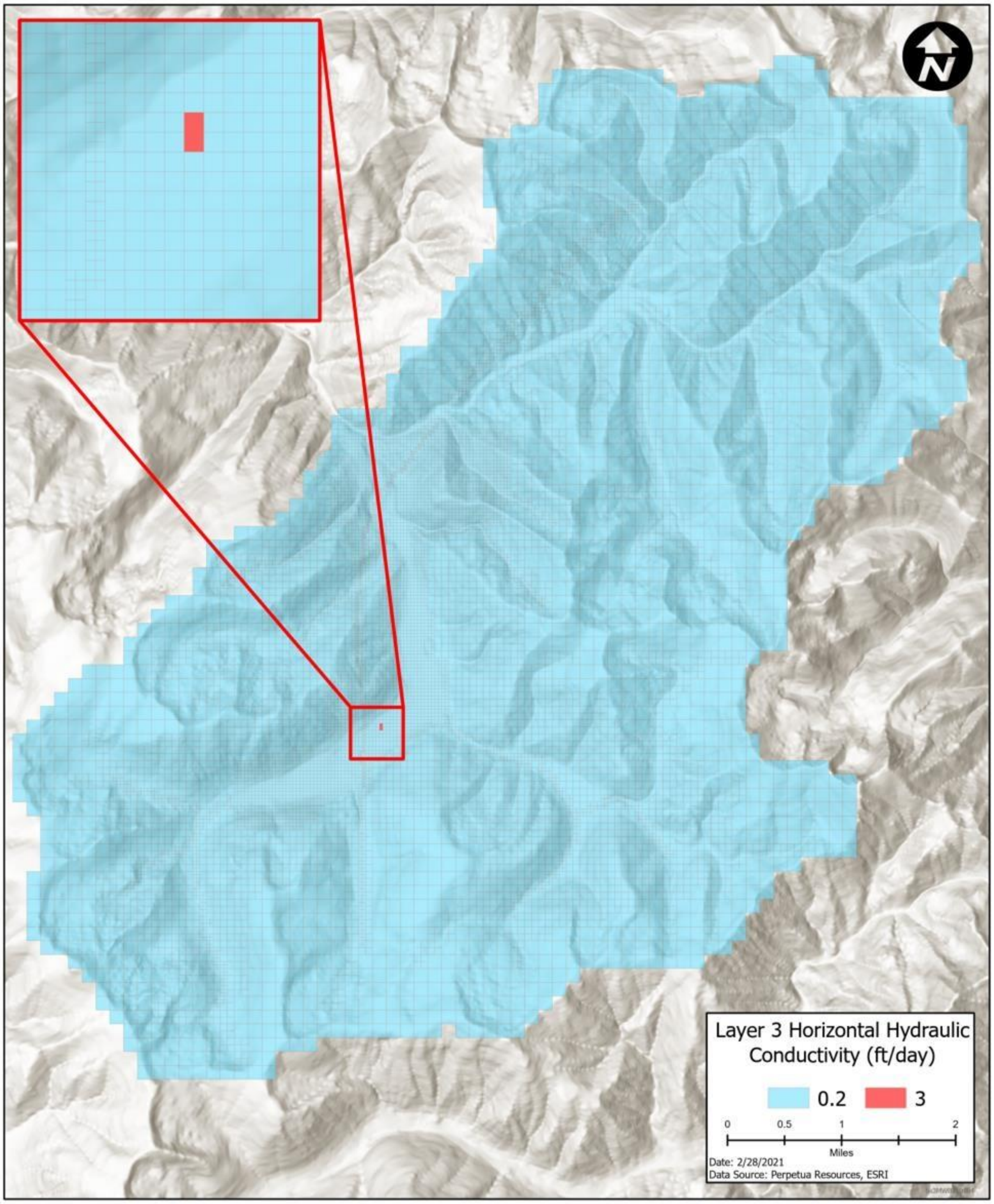

Figure A-1. SHSM Layer 3 Horizontal Hydraulic Conductivity Field

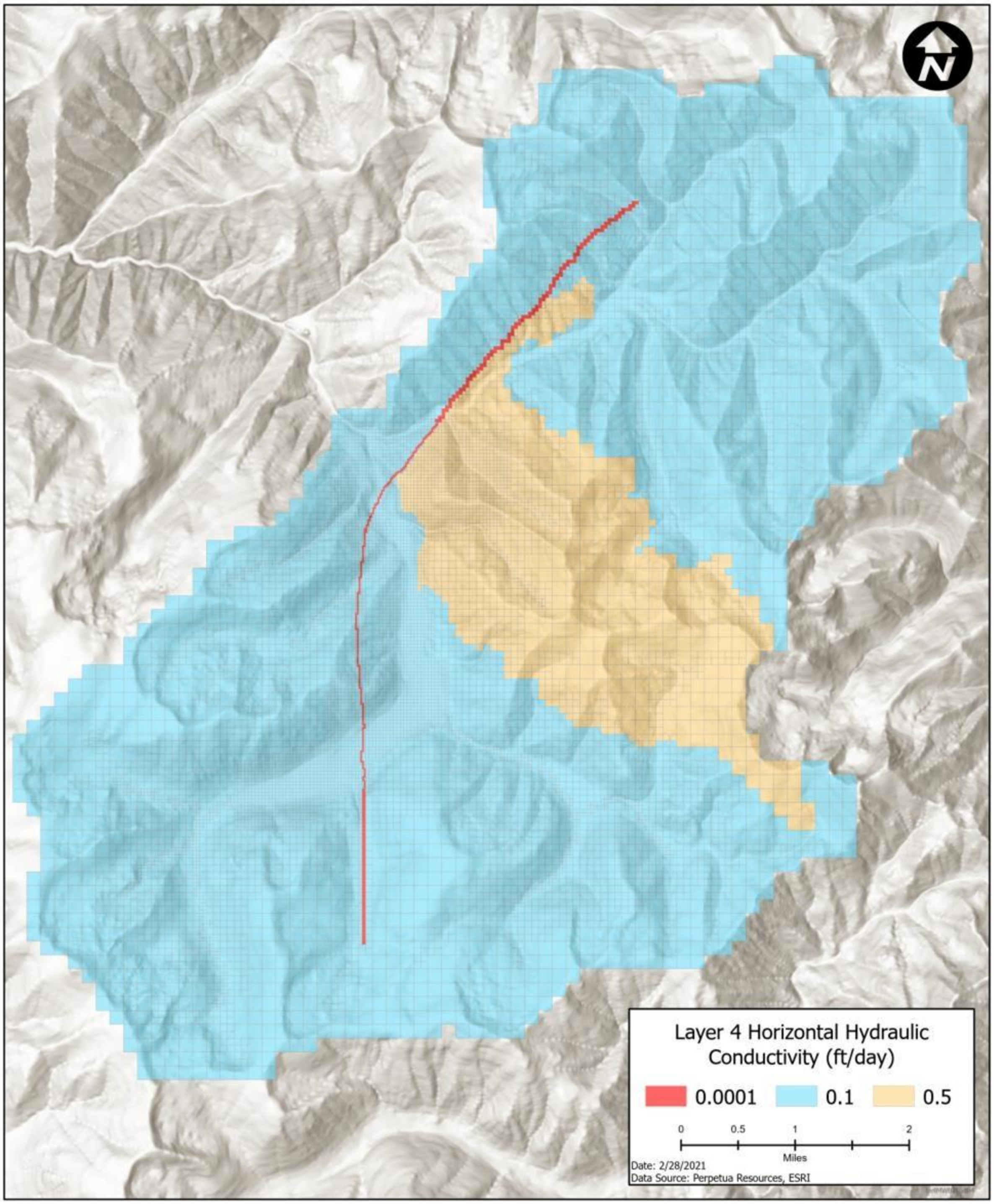

Figure A-2. SHSM Layer 4 Horizontal Hydraulic Conductivity Field

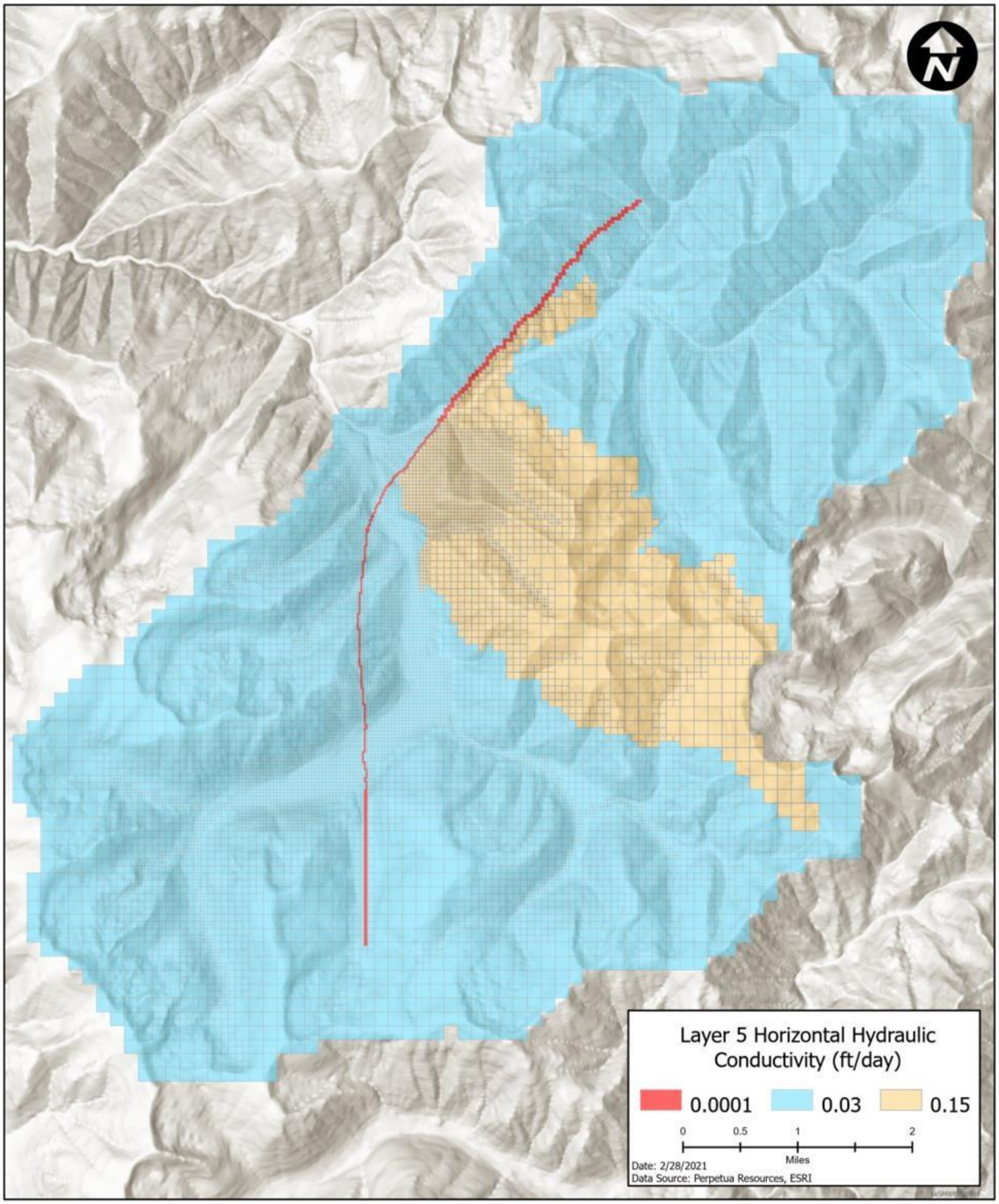

Figure A-3. SHSM Layer 5 Horizontal Hydraulic Conductivity Field

Figure A-4. SHSM Layer 3 Specific Yield

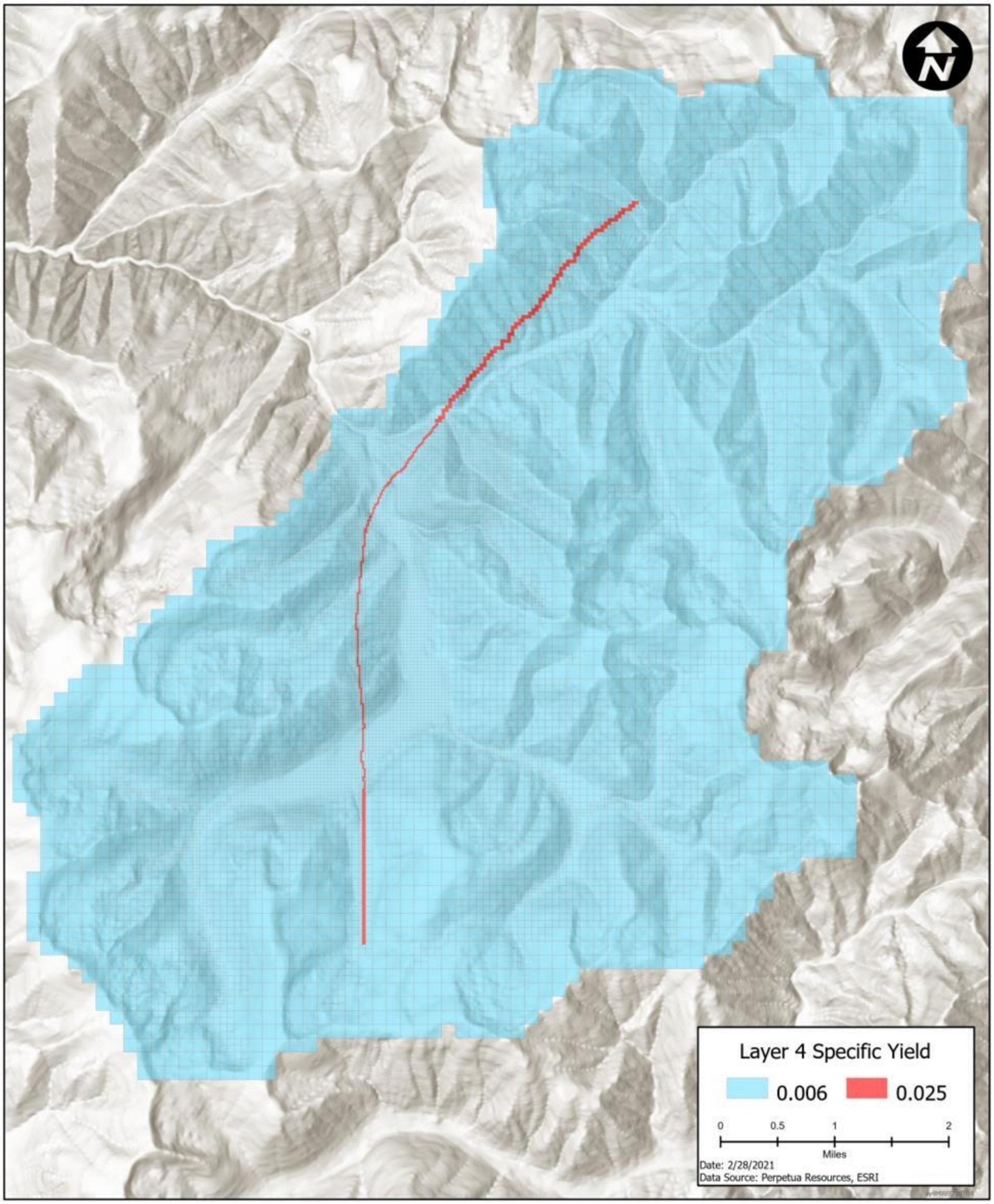

Figure A-5. SHSM Layer 4 Specific Yield

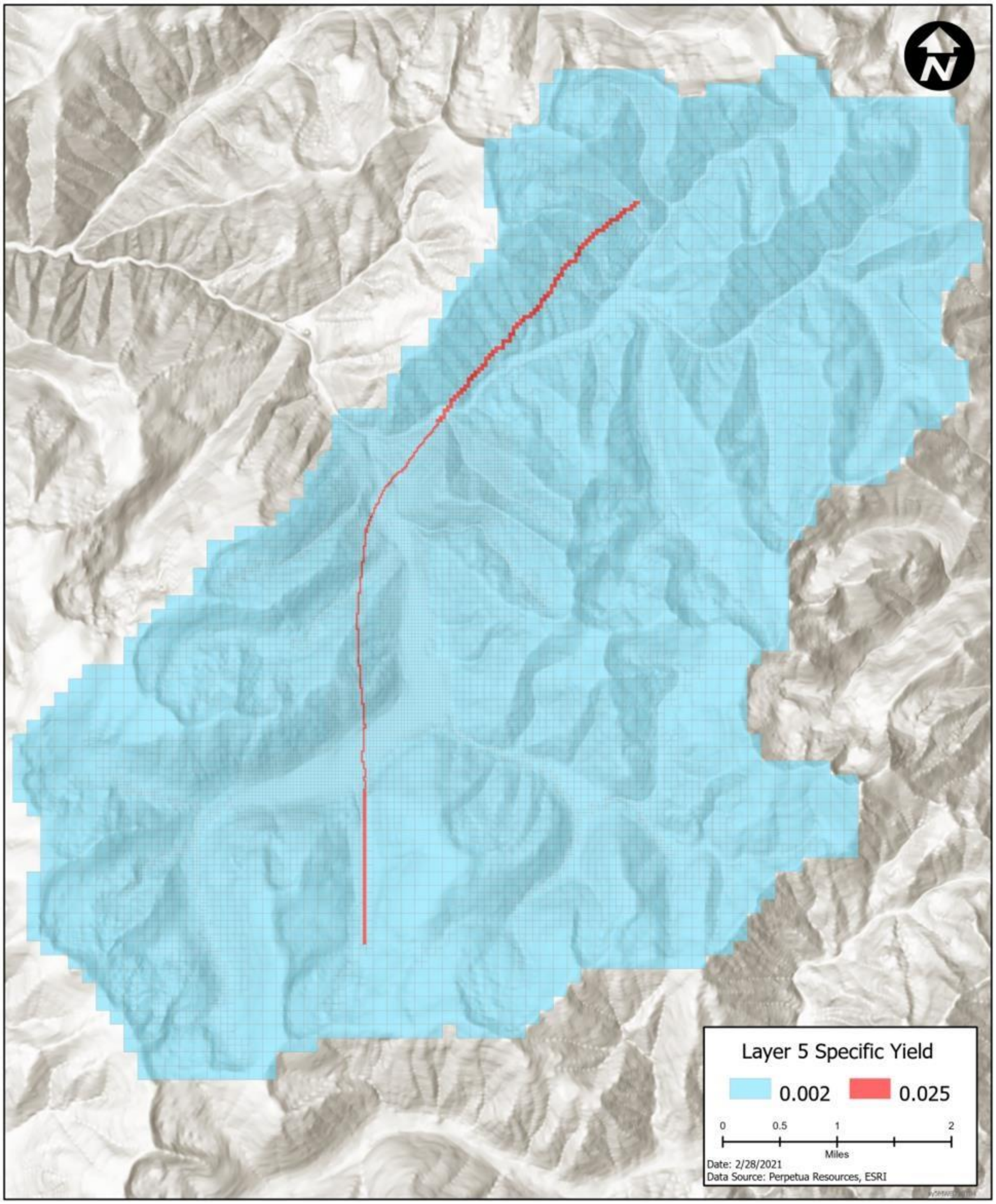

Figure A-6. SHSM Layer 5 Specific Yield

Table A-1. EC SHSM Sensitivity Analysis Groundwater Residual Summary Statistics

	RM (ft)	ARM (ft)	SSE (ft2)	RMSE (ft)	Maximum Residual (ft)	Minimum Residual (ft)
EC SHSM	2.4	8.7	9183.2	12.9	41.3	-32.0
Layer 3 Bedrock 5K	3.1	9.0	9628.6	13.2	42.4	-31.0
Layer 3 Bedrock 10K	3.6	9.2	10435.0	13.8	46.2	-30.1
Layer 3 Bedrock 50K	5.7	10.5	14937.4	16.5	60.0	-25.9
Layers 3 & 4 Bedrock 5K	5.0	10.2	13780.2	15.8	56.2	-28.9
Layers 3 & 4 Bedrock 10K	6.9	11.6	20320.8	19.2	80.4	-24.7
Layers 3 & 4 Bedrock 50K	11.8	14.9	38242.6	26.4	104.4	-13.3
Layers 3, 4 & 5 Bedrock 5K	4.7	10.5	13165.6	15.5	54.0	-27.9
Layers 3, 4 & 5 Bedrock 10K	6.9	13.3	21990.7	20.0	69.2	-20.6
Layers 3, 4 & 5 Bedrock 50K	Simulation contains numerical instabilities and fails to converge.					
Layers 3, 4, & 5 Bedrock 0.2K	1.6	9.2	12423.6	15.0	42.0	-64.1
Layers 3, 4, & 5 Bedrock 0.1K	1.4	9.4	13429.0	15.6	41.4	-71.5
Layers 3, 4, & 5 Bedrock 0.02K	0.6	9.7	17090.1	17.6	38.4	-97.9
Layer 3 Bedrock $2S_v$	2.3	8.7	9415.4	13.1	41.2	-32.9
Layer 3 Bedrock $0.5S_v$	2.5	8.7	9105.6	12.9	41.4	-32.0
Layer 4 Bedrock $2S_v$	2.4	8.6	9154.3	12.9	41.3	-31.9
Layer 4 Bedrock $0.5S_v$	2.4	8.7	9204.6	12.9	41.4	-32.1
Layer 5 Bedrock $2S_v$	2.4	8.7	9177.6	12.9	41.3	-32.0
Layer 5 Bedrock $0.5S_v$	2.4	8.7	9176.4	12.9	41.3	-32.0
Layers 3, 4, & 5 Bedrock $2S_v$	2.3	8.7	9384.8	13.1	41.2	-33.1
Layers 3, 4, & 5 Bedrock $0.5S_v$	2.5	8.7	9121.1	12.9	41.4	-32.0

Abbreviations:

ARM = absolute residual mean

EC SHSM = Existing Condition Stibnite Hydrologic Site Model

ft = foot/feet

ft2 = square foot

RM = residual mean

RMSE = root mean squared error

SHSM = Stibnite Hydrologic Site Model

SSE = sum of squared errors

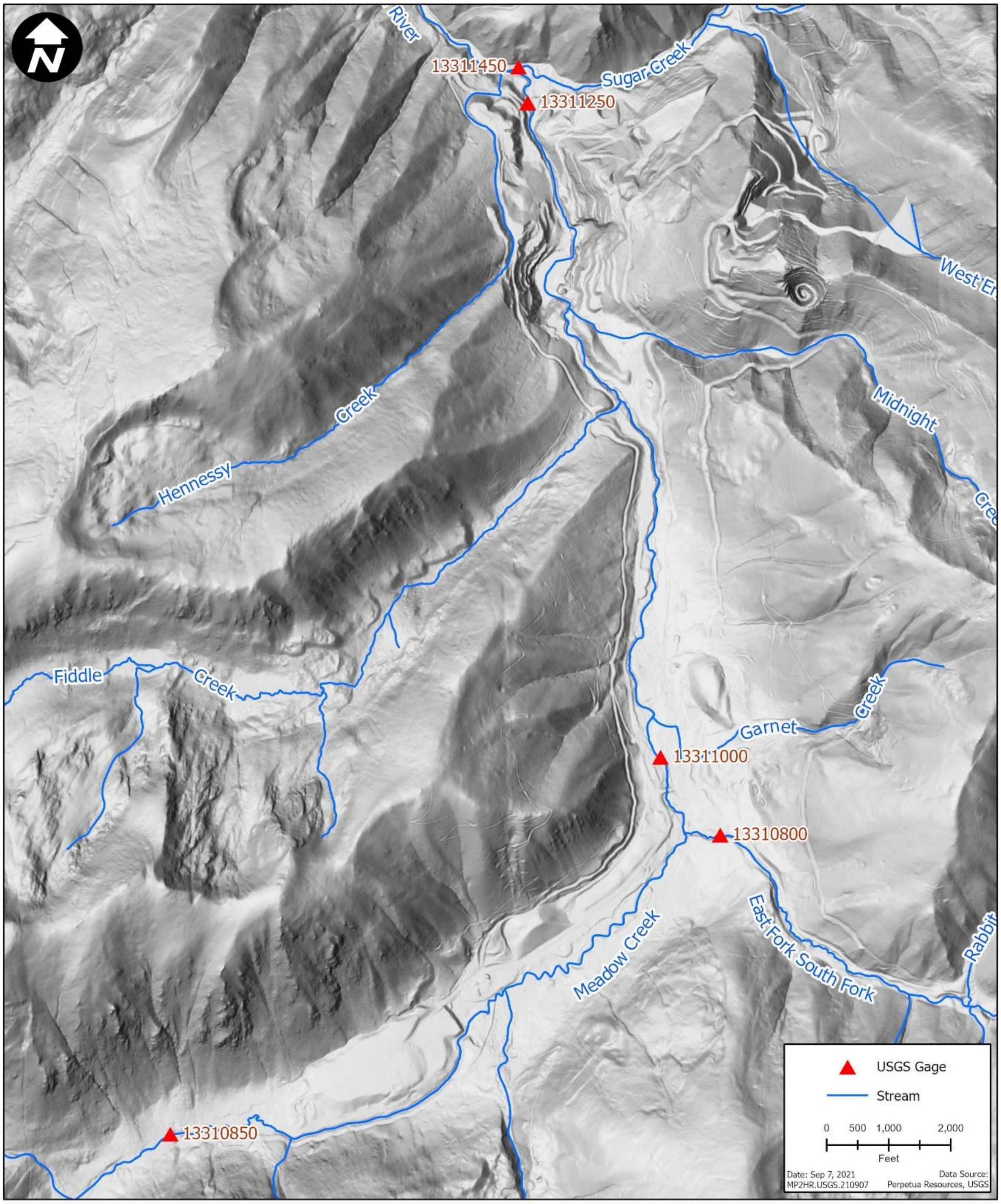

Figure A-7. USGS Gage Locations

Table A-2. EC SHSM Sensitivity Analysis Baseflow Residual Summary Statistics

Sensitivity Analysis Simulations	RM (cfs)	ARM (cfs)	SSE (cfs^2)	RMSE (cfs)	Maximum Residual (cfs)	Minimum Residual (cfs)
EC SHSM	-0.4	1.5	796.3	2.0	6.2	-6.5
Layer 3 Bedrock 5K	-0.3	1.5	788.9	2.0	6.3	-6.7
Layer 3 Bedrock 10K	-0.3	1.5	783.4	2.0	6.3	-6.8
Layer 3 Bedrock 50K	-0.4	1.5	794.9	2.0	6.2	-7.6
Layers 3 & 4 Bedrock 5K	-0.3	1.5	769.1	2.0	6.6	-8.2
Layers 3 & 4 Bedrock 10K	-0.3	1.5	802.2	2.0	6.6	-9.2
Layers 3 & 4 Bedrock 50K	0.2	1.7	990.1	2.2	6.5	-10.1
Layers 3, 4 & 5 Bedrock 5K	-1.5	2.0	1535.7	2.8	5.9	-12.3
Layers 3, 4 & 5 Bedrock 10K	-1.8	2.4	2232.3	3.3	6.3	-15.4
Layers 3, 4 & 5 Bedrock 50K	Simulation contains numerical instabilities and fails to converge.					
Layers 3, 4, & 5 Bedrock 0.2K	0.5	1.4	804.2	2.0	7.2	-4.7
Layers 3, 4, & 5 Bedrock 0.1K	1.0	1.6	940.1	2.2	7.7	-5.6
Layers 3, 4, & 5 Bedrock 0.02K	1.7	2.1	1467.2	2.7	9.8	-6.3
Layer 3 Bedrock $2S_y$	-0.5	1.5	836.6	2.0	6.0	-6.5
Layer 3 Bedrock $0.5S_y$	-0.2	1.5	768.4	2.0	6.4	-6.5
Layer 4 Bedrock $2S_y$	-0.5	1.6	859.1	2.1	5.7	-6.1
Layer 4 Bedrock $0.5S_y$	-0.2	1.4	757.9	1.9	6.5	-6.8
Layer 5 Bedrock $2S_y$	-0.3	1.5	802.2	2.0	6.0	-6.0
Layer 5 Bedrock $0.5S_y$	-0.3	1.5	790.9	2.0	6.6	-7.0
Layers 3, 4, & 5 Bedrock $2S_y$	-0.6	1.6	909.1	2.1	5.8	-5.7
Layers 3, 4, & 5 Bedrock $0.5S_y$	0.0	1.4	744.0	1.9	7.1	-7.2

Abbreviations:

ARM = absolute residual mean

cfs = cubic feet per second

cfs^2 = cubic feet per second squared

EC SHSM = Existing Condition Stibnite Hydrologic Site Model

RM = residual mean

SSE = sum of squared errors

Appendix B: SHSM Sensitivity Analysis Agency Comments

No.	Agency Comment	Perpetua Resources Response
STANTEC COMMENTS		
1	The numerical groundwater flow model relies on limited measurements of hydraulic properties, particularly in the bedrock units. Therefore, hydraulic properties are largely simulated as uniform by layer with some localized variations for the Gestrin Feature in Layers 1, 2 and 3 and the Metaseds and Meadow Creek Fault Zone in Layers 4 and 5. Model calibration is achieved in part by spatially varying recharge applied to the near-uniform modeled hydraulic layers. While selection of the hydraulic parameter values is unbiased in the calibration process, the selected parameter values are more dependent on calculated recharge values than direct hydraulic parameter measurements (with the exception of the Gestrin Feature in Layers 1, 2 and 3). When utilized for model predictions such as dewatering of the Yellow Pine Pit, moderate changes in model parameters can yield meaningful differences in the predicted pit dewatering rates and area of dewatering drawdown effect. These differences in predictions have knock-on implications for other project aspects such as indirect effects on Groundwater Supported Ecosystems and the volume of supplemental water needed for consumptive use requirements. The absence or uncertainty in direct hydraulic parameter measurements would benefit from a model sensitivity analysis, particularly in assessing potential implications for water supply and water treatment designs. This model uncertainty in predicting water quantity impacts to environmental resources could then be addressed via design of the water resources monitoring and associated mitigation measures.	Sections 3.4.2 and 4.1 have been added to Appendix A of the report to provide more detail regarding the hydraulic conductivity data at the site and the correspondence of Stibnite Hydrologic Site Model (SHSM) parameters to this data. Three lines of evidence that do not support the statement, “the selected parameter values are more dependent on calculated recharge values than direct hydraulic parameter measurements (with the exception of the Gestrin Feature in Layers 1, 2, and 3).” are: 1. The hydraulic conductivity values in the SHSM are in the range of measured values at the site. We have added Sections 3.4.2 and 4.1 to Appendix A provide more detail regarding the agreement between the SHSM hydrogeologic parameters and the measured data. 2. The recharge values applied in the model are seasonal and primarily result in seasonal increases in groundwater elevations in the SHSM model. 3. Figures 4-16 through 4-21 in Appendix A show that the SHSM represents the measured groundwater elevations with +/- 5 feet during the dry seasons when recharge has a small influence on groundwater elevations. Note the locations of the wells in figures 4-16 through 4-21 cover the extent of the Meadow Creek and East Fork of the South Fork of the Salmon River (EFSFSR) valleys within the study area. Overall, it is clear with these three lines of evidence that the SHSM represents the measured K values and captures the measured groundwater elevations. The recharge in the SHSM is primarily responsible for the seasonal groundwater elevation peaks shown on Figures 4-16 through 4-21, that correspond to the timing of the measured seasonal groundwater elevation peaks. Model uncertainty will be addressed in the forthcoming sensitivity analysis.
5	Include a sensitivity analysis on the updated model similar to the sensitivity analysis performed on the previous model. Include model predicted groundwater drawdown contours that reflect the range of model predictions determined by the sensitivity analysis.	The range of model predictions will be provided in the forthcoming sensitivity analysis.
51	Modifications to the numerical groundwater flow model have resulted in a prediction of decreased dewatering rates for the Yellow Pine Pit (i.e., revised hydraulic conductivity parameters, recharge distribution, Meadow Creek Fault Zone incorporation). Consider describing the effect of the Meadow Creek Fault Zone on predicted dewatering rates. If the decrease in predicted dewatering rates is tied to the incorporation of the fault zone, the report should bolster the interpretation of the fault as a flow barrier by including items such as quantitative or semi-quantitative observations of groundwater level differences across the fault zone, locations of observed artesian conditions, and/or borehole observations of gouge or lithologic discontinuity in the fault zone. If the predicted decrease is tied more to the revised hydraulic conductivity and recharge distribution, a sensitivity analysis around the hydraulic conductivity and recharge rates utilized in the model is warranted. Alternatively, measurements of hydraulic conductivity in the Yellow Pine Pit area could be provided.	A preliminary simulation without the Meadow Creek Fault Zone (MCFZ) was conducted to quantify the MCFZ impacts on simulated dewatering estimates and similar dewatering rates were simulated with and without the MCFZ. A paragraph has been added to the end of Section 4.1. The simulated decrease in dewatering volume is tied to the refined hydrological conceptual site model and refined hydraulic parameters. Sections 3.4.2 and 4.1 in Appendix A have been added to better illustrate the correspondence of the updated hydraulic parameters with the available hydraulic conductivity measurements at the site. Section 1.1 in Appendix A has been added and contains a detailed description of the refined hydrologic conceptual site model. A sensitivity analysis is being conducted and will be delivered when it is complete.
53	Despite the lower predicted dewatering production rates, the predicted areal extent of groundwater drawdown around the Yellow Pine and West End pit increased. Is this increased extent of drawdown attributed to increased hydraulic conductivity of the bedrock units or changes in the model application of recharge?	Along with model parameter refinements, the SHSM includes updates associated with the refined ModPRO2. In the ModPRO2 the areal extent of the Yellow Pine and West End pits have increased. Also, the West End pit is 40 feet deeper than in the PRO and ModPRO. Both updates to the mine plan will result in changes to the simulated extent of the drawdown contours. The SHSM refinements also include both a decrease and increase in bedrock hydraulic conductivity depending on the location. For example, in Layer 2 of the previous model the Moderately Fractured Bedrock hydraulic conductivity was 3 feet per day (ft/d) and the Non-fractured Bedrock was 0.00175 ft/d. In the SHSM, the bedrock is represented by Layers 3, 4, and 5 with 0.2 ft/d, 0.1 ft/d and 0.03 ft/d, respectively. The parameter updates are consistent with the

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		available site data. Sections 3.4.2 and 4.1, and Figure 4-3 have been added to Appendix A to better demonstrate the correspondence of the model parameters to those measured on the site. Overall, the SHSM refinements result in a decrease of the water available and lower the saturated thickness in the bedrock layers, lowering the transmissivity, which contributes to the extended drawdown contours. The effect of changing the hydraulic conductivity in the bedrock layers on the extent of drawdown contours and magnitude of dewatering will be quantified in the forthcoming sensitivity analysis.
APPENDIX A		
63	The calibration ranges for bedrock hydraulic conductivity used in Table 4-3 do not cover the many of the average bedrock hydraulic conductivity measurements reported in Tables 4-4 and 4-5. Please explain why the range of values considered in the calibration had a maximum lower than the average reported field observations.	The maximum range of values used in the bedrock layers of the models (Layers 3, 4, and 5) is not lower than the average reported field observations. The bedrock transition zone (Layer 3) of the SHSM is conceptualized to represent the fractured bedrock throughout the Study Area. The maximum hydraulic conductivity for layer 3 is 2 ft/d, slightly lower than the maximum measured value of 4.9 ft/d in Table 4-4 and the value of 5.9 ft/d in Table 4-5. The maximum of 2 ft/day in layer 3 was chosen to represent the higher end of the bedrock hydraulic conductivity measurements. Layers 4 and 5 are conceptualized to represent a decrease in hydraulic conductivity with depth. The calibrated hydraulic conductivities of layers 3, 4, and 5 are 0.2 ft/d, 0.1 ft/d and 0.03 ft/d, respectively, whereas the geometric mean of the measured hydraulic conductivity values is 0.05 ft/d. See the newly added Figure 4.3 of Appendix A. Overall, the SHSM captures the processes within the Study Area on average. Section 1.1 has been added to Appendix A to describe the HCSM. The HCSM describes the layering of the model and how it fits with the geology of the Study Area. Section 3.4.2 and Section 4.1 have been added to Appendix A to clarify how the calibrated hydraulic conductivity values for the bedrock compare with the measured data in the Study Area. A sensitivity analysis will further address higher hydraulic conductivity in the bedrock layers of the SHSM.
USEPA COMMENTS		
70	What are other big ticket items/significant issues for Forest Service to raise to Perpetua for the aquifer test report or ModPRO2 hydrological modeling? The Existing Conditions Model (Appendix A of the ModPro2 hydrologic model report) uses a range of hydraulic conductivity calibration parameters (Table 4-3). The range should be expanded to include results of large scale aquifer testing in favor of microscale formation tests (slug tests and packer tests). Bedrock hydraulic conductivity calibration range is an order of magnitude lower than values obtained from aquifer testing, and calibration residuals (Figure 4-13 and Table 4-7) confirm that calibration metrics are biased by the relatively lower hydraulic conductivities used for the calibration. Use of the calibrated model to forecast the pumping rate for dewatering the open pits could significantly underpredict the amount necessary during operations.	The ranges of the bedrock hydraulic conductivity consider the data from both aquifer tests (2013 and 2019), as well as the slug tests and packer tests. In the SHSM, the bedrock is represented by layers 3 through 5. The maximum range of hydraulic conductivity for layer 3 is 2 ft/d. This is lower than 4.5 ft/d by approximately a factor of 2 not an order of magnitude. Layer 3, the bedrock transition zone, in the SHSM is designed to represent the fractured bedrock observed in the rock quality designation (RQD) data, thus it has a higher maximum range for hydraulic conductivity. The lower maximum values for the hydraulic conductivity in layers 4 and 5 follow the hydrologic conceptual site model and observations in that the hydraulic conductivity decreases with depth. The conceptual model is aligned with all available site data. Slug tests and packer tests are completely adequate and appropriate for aquifer characterization over larger scales when the tests are spatially distributed over the larger scale of interest as they are in this case. The slug tests and packer tests are located near the Hangar Flats pit, Yellow Pine pit and West End pit areas. Slug tests and packer tests are the most appropriate testing method available when testing low conductivity zones [Bliss & Rushton 1984; Palmer and El-Idrysy 2015; Butler 2019]. In regional scale hydrogeological testing using spatially distributed, discrete measurements of hydraulic conductivity, averaging all the discrete values using the geometric mean is an appropriate method [Warren & Price 1961; King 1987; Selvadurai & Selvadurai 2014]. Pumping tests are not well suited for regional scale characterization of hydraulic conductivity in low permeability formations since they require constant pumping rates which are difficult to sustain at the low flow rates available in low permeability formations. This often leads to monitoring well drawdown responses that are limited in magnitude and require long test times to develop. Moreover, pumping tests do not directly measure hydraulic conductivity. They estimate transmissivity and storage coefficient through curve matching with an analytical solution. Hydraulic conductivity can then be estimated from transmissivity values using an assumed value for saturated thickness in the test zone (Neuzil 1986; Renard 2005; Mejia et al. 2009).

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		We do not observe a bias in the calibration residuals or metrics. Figure 4-14 shows the simulated groundwater elevation at 4 of the bedrock monitoring wells is lower than the measured values and simulated groundwater elevations at 5 of the wells are higher than measured values. At the remaining well, the difference between the simulated and measured groundwater elevation is close to zero. As stated in the text, Figure 4-14 demonstrates that the model heads are not biased low or high in both the alluvium and bedrock. Moreover, the calibrated hydraulic conductivities for layers 3, 4 and 5 are 0.2 ft/d, 0.1 ft/d and 0.03 ft/d, respectively. The geometric mean of the slug test and packer test data is 0.04 ft/d, whereas the geometric mean of the slug test, packer test, and aquifer test data is 0.05 ft/d. We have added Section 1.1 to the Appendix to better explain the refined hydrologic conceptual site model. Also, Sections 3.4.2 and 4.1 have been added to Appendix A to clarify how the calibrated hydraulic conductivity values for the bedrock compare with the measured data in the Study Area. A sensitivity analysis will further address higher hydraulic conductivity in the bedrock layers of the SHSM.
71	What are your initial thoughts of the use of the ModPRO2 hydrological model for the EIS? Model objectives include (1) input to the water balance model for estimating stream flows and (2) forecasting mine operations such as dewatering, pumping water for operations and disposal of wastewater through RIBs. Calibration of the alluvial aquifer and stream flow (objective 1) appears to be completed; calibration of the bedrock aquifer, however, does not consider the best available data and is problematic.	Calibration of the bedrock and alluvial aquifers uses the best available data, and individual and overall calibration results are improved versus the previous model. Please see response to comment 1 of USEPA Comments. Also see Sections 1.1, 3.4.2, and 4.1 that have been added to Appendix A to better clarify the refinements contained in the SHSM and the correspondence to data available at the site.
72	Note that there is no need to wait for additional aquifer tests to expand the calibration range for hydraulic parameters for the bedrock aquifer. This can be done now by calibrating to the range of transmissivity values observed in aquifer test results. Results may indicate that, as suggested in previous modeling, water wells are not needed to supplement operations and RIBs are needed to dispose of excess water.	Please see response to comment 70 above. A sensitivity analysis is currently being conducted to test higher hydraulic conductivity values in the bedrock layers of the SHSM.