Technical Memorandum

June 1, 2012

Revisions: Drawdown at U.S. Forest Service Selected Monitoring Points
Myers Rosemont Groundwater Model Report

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Prepared for: Pima County and Pima County Regional Flood Control District

The U.S. Forest prepared and released a draft environment impact statement (DEIS) for the proposed Rosemont Copper Mine (USFS 2011). The proposed mine includes extensive dewatering and future pit lake development. Myers (2010, 2008) developed a groundwater model on behalf of Pima County to predict the impacts to the groundwater flow system to be caused by developing the mine.

The DEIS presented predictions from three groundwater models, including Myers (2010). However, the USFS could not include output from Myers (2010) at certain locations because they had not requested the specific data. In a 3/2/12 memorandum from the Forest Supervisor to the Pima County Administrator, the USFS requested "groundwater levels or water level drawdown over time" for a list of sites, as shown in Table 1; this had been developed in a 3/22/12 technical memorandum. In a 5/3/2012 memorandum, the Forest Supervisor requested hydrographs for the sites in Table 1; the Forest Supervisor also requested hydrographs of sensitivity analyses. This technical memorandum replaces the previous memorandum and presents a series of drawdown graphs, appended below, showing both the predicted drawdown hydrographs, the base case, and hydrographs showing the sensitivity analysis.

Simulated drawdown was determined for each of the sites as follows. The sites were added as monitoring wells for all six model layers to the groundwater model, based on the location as mapped on USGS 1:24000 maps; the USFS had not provided exact coordinates. The model was run exactly as described in Myers (2010) so that the drawdown at the new locations could be determined. The simulation includes 20 years of pit development and dewatering followed by 10,000 years of pit lake recovery. Drawdown was estimated based on simulated water levels for time periods that most closely corresponds with the times reported in Tables 54 through 58 in USFS (2011). It is necessary to use the time that most closely corresponds because time stepping increases the length of the step by a multiplier which does not compute in even years. The estimates are very accurate because the water levels changes between the time steps bracketing the desired year were very small.

Sensitivity analysis determines which parameter zones the model is most sensitive to. It is common to complete a sensitivity analysis by varying one or more parameters simultaneously and comparing a goodness of fit statistic to the calibrated value. In this way, it can be determined to which parameters or parameter zones the model is most sensitive. Sensitivity analysis was completed for steady state (Myers 2010). The request for a set of hydrographs is a request for the sensitivity of specific storage and specific yield. This model had not been calibrated in transient mode to a set of observed head values, therefore there is no test statistic that can be calculated. The model can be assessed as to how the model results change with respect to parameters or parameter zones.

Initial testing (not shown) revealed that drawdown at a point is most sensitive to the storage or specific yield parameter zone in which the observation point is located, with little to no variation in the hydrograph due to varying adjacent parameter zones. For this reason, sensitivity has been determined, based on steady state initial conditions, by changing the entire suite of parameters as follows. All specific yield, Sy, zones have been simultaneously multiplied by 1.2, .8, .6, and .4 and hydrographs for observation points determined. The same has been done for the Ss zones, except the multiplication factors are 10, 5, .5, .1, .05, .01, and .005. The two storage coefficient types have not been altered together for any simulations.

Table 1 presents the results of the analysis as requested by the USFS. The reported drawdown is for model layer 1, chosen because it represents the water table which would more likely affect the spring and stream flow.

Figures showing drawdown at the various sites in Table 1, plus a site just downgradient of the pit and forming pit lake (Myers 2010), are appended to the end of this technical memorandum. These figures show drawdown in the uppermost active model layer, either layer 1 or 2, and layer 5. At least two figures are used to present the graphs to represent different time scales, 10,000 years, and 150 years; a 30-year period is additionally presented for two sites. Variability at 1000 years can be discerned from the 10,000 year graph. Differing vertical scales are also used to improve the detail where necessary.

Drawdown can differ between the water table and deeper layers because of the difference in controlling storage coefficients, specific yield for the upper layer, and specific storage at depth where artesian conditions control the flow. Layer 5 is not shown at several locations, Gardner Canyon, Singing Valley, Hilton Ranch, Gardner Cienega Confluence, and Empire Gulch, because the drawdown is very similar to that in layer 1 and there is little difference in that drawdown based on different storage coefficients.

Drawdown at most sites reaches equilibrium after some long period, with variation for storage coefficient and in some cases layer. Storage coefficient controls the time to equilibrium, or how fast water level at a site responds, more than the ultimate drawdown, although there are differences. This is because as the system approaches equilibrium, the storage coefficients become less important because little water is drawn from or enters storage. Generally, the lower specific storage or specific yield causes a faster responce, meaning the drawdown spreads faster. At Scholfield Spring, layer 1, for example, the drawdown reaches 2 feet within 150 years for specific yield being 40 percent of the base case for which drawdown is 0.5 feet; after 1000 years, drawdown is 50 feet while the base case is about 20 feet. The long-term drawdown is about 60 feet for each value. Similar effects can be observed for other sites.

Drawdown at Scholfield Springs, layer 5, is about half that in layer 1. At Rosemont Springs, the drawdown in layer 5 is about 50% more than in layer 1. This reflects a different proximity to the pit, with Rosemont Springs being much closer to the pit, less than a mile, whereas Scholfield Springs is about 2.5 miles from the pit. There are also differences in geology at different layers. Drawdown at Barrell Spring is about the same in each layer.

Drawdown at several sites, including most apparently Scholfield Spring, Rosemont Spring, and Downgradient Pit, decreases after a peak which occurs between 1000 and 2000 years. This means that the water level decreases to a maximum within that time period and then recovers. The primary sites are closest to the forming pit lake and thus reflect the rising pit lake. The effect is most noticeable for the lower specific yield sensitivity runs which reflects that lower specific yield causes the water table to respond faster, both declining due to stress and recovering as the stress subsides.

Table 1: Drawdown with time from the end of mining at selected locations at the Rosemont Copper Project.

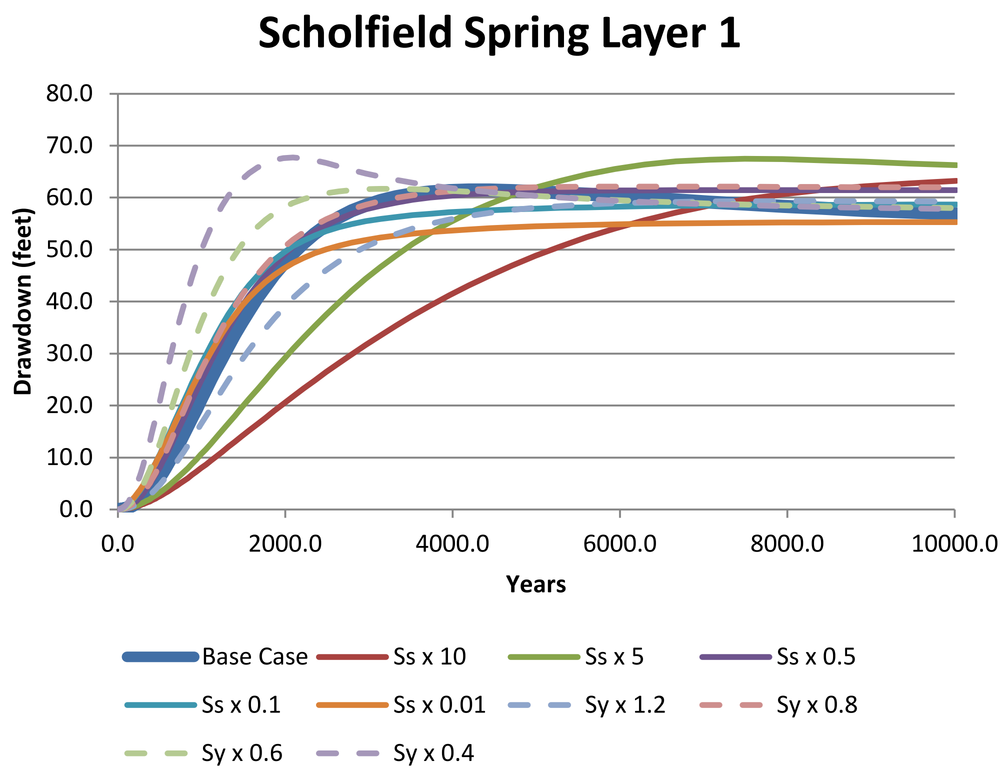
				Years after mining			
Location	Row	Column	End of Mining	20	50	150	1000
Empire Gulch Springs	14	20	0	0	0.2	0.3	4.3
Gardner Canyon (nr area of perennial flow)	17	24	0	0	0	0.1	2.2
Cienega Creek (gage 09484550)	1	21	0	0	0	0	0.2
Hilton Road residences	5	13	0	0.8	1.6	3.6	13.2
Cienega Creek (original station)	5	22	0	0	0	0	0.3
Barrel Spring (not requested)	7	12	1.5	2.3	3.2	5.4	17.7
Gardner/Cienega Confluence	8	24	0	0	0	0.1	2.2
Scholefield Springs	9	7	0	0	0.1	0.6	19.8
Rosemont Spring	18	8	4.5	11	19.5	42.9	112.1
Singing Valley North residences	22	15	0.1	0.2	0.6	2.3	13.9
Confluence of Davidson Canyon/Cienega Creek	northeast of model domain						
Reach 2 Spring in Davidson Canyon	northeast of model domain						
Corona de Tucson residences	northwest of model domain						
Fig Tree Spring	west of model domain						
Sycamore Spring	west of model domain						
Rueles Spring	west of model domain						
Helvetia Spring	west of model domain						

REFERENCES

Myers, T. 2010. Technical Memorandum, Updated Groundwater Modeling Report, Proposed Rosemont Open Pit Mining Project. Prepared for Pima County and Pima County Regional Flood Control District.

Myers, T., 2008. Hydrogeology of the Santa Rita Rosemont Project Site, Numerical Groundwater Modeling of the Conceptual Flow Model and Effects of the Construction of the Proposed Open Pit. Prepared for Pima County Regional Flood Control District, April 2008.

U.S. Forest Service (USFS). 2011. Draft Environmental Impact Statement for the Rosemont Copper Project. U.S. Forest Service, Tucson, AZ.


Scholfield Spring Layer 1
80.0
70.0
60.0
50.0
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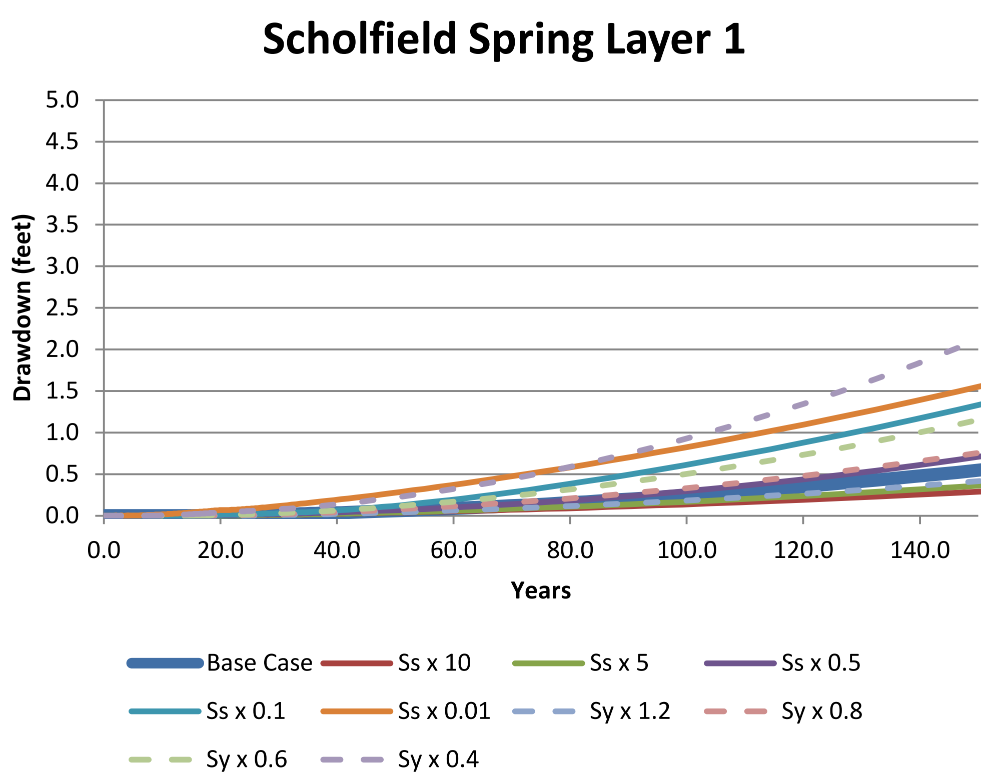
30.0
20.0
10.0
0.0
Drawdown (feet)
0.0
2000.0
4000.0
6000.0
8000.0
10000.0
Years
Base Case
Ss x 10
Ss x 5
Ss x 0.5
Ss x 0.1
Ss x 0.01
Sy x 1.2
Sy x 0.8
Sy x 0.6
Sy x 0.4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4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
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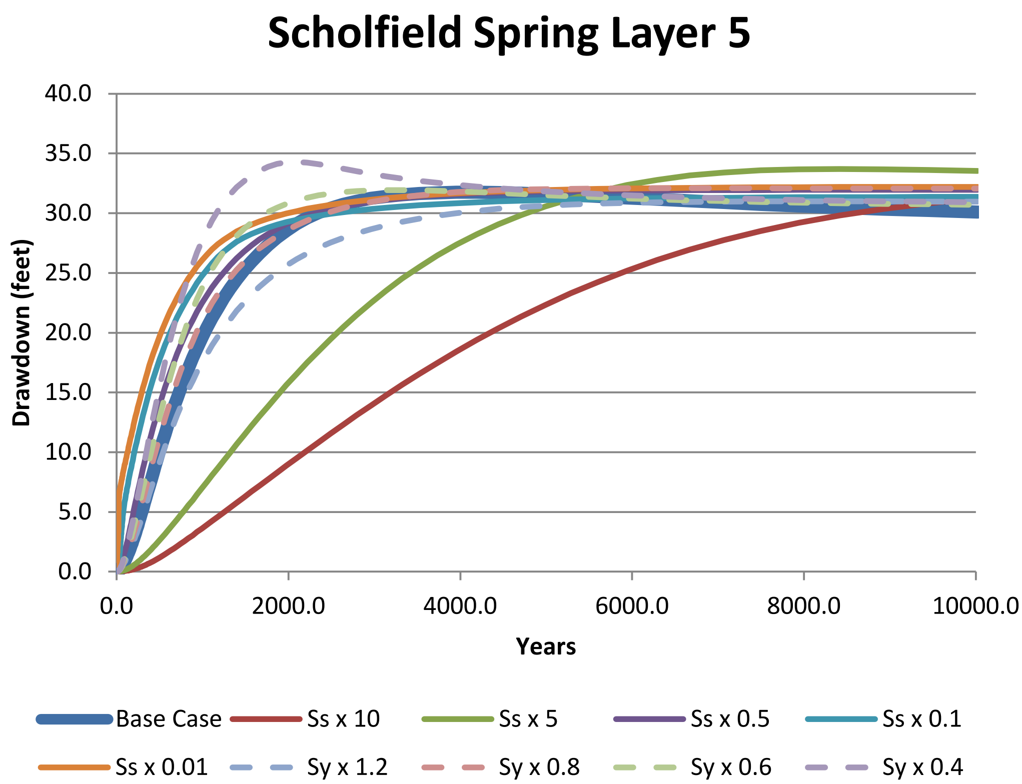
0.0
Drawdown (feet)
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
Years
Base Case
Ss x 10
Ss x 5
Ss x 0.5
Ss x 0.1
Ss x 0.01
Sy x 1.2
Sy x 0.8
Sy x 0.6
Sy x 0.4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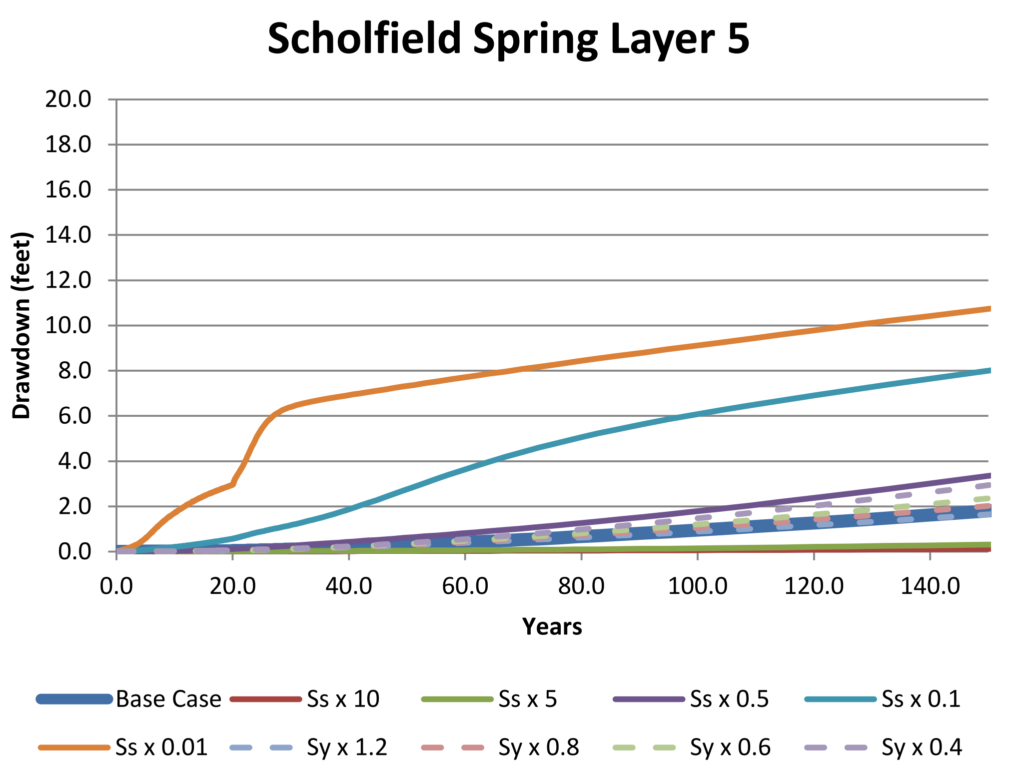
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Drawdown (feet)
0.0
2000.0
4000.0
6000.0
8000.0
10000.0
Years
Base Case
Ss x 10
Ss x 5
Ss x 0.5
Ss x 0.1
Ss x 0.01
Sy x 1.2
Sy x 0.8
Sy x 0.6
Sy x 0.4


Scholfield Spring Layer 5
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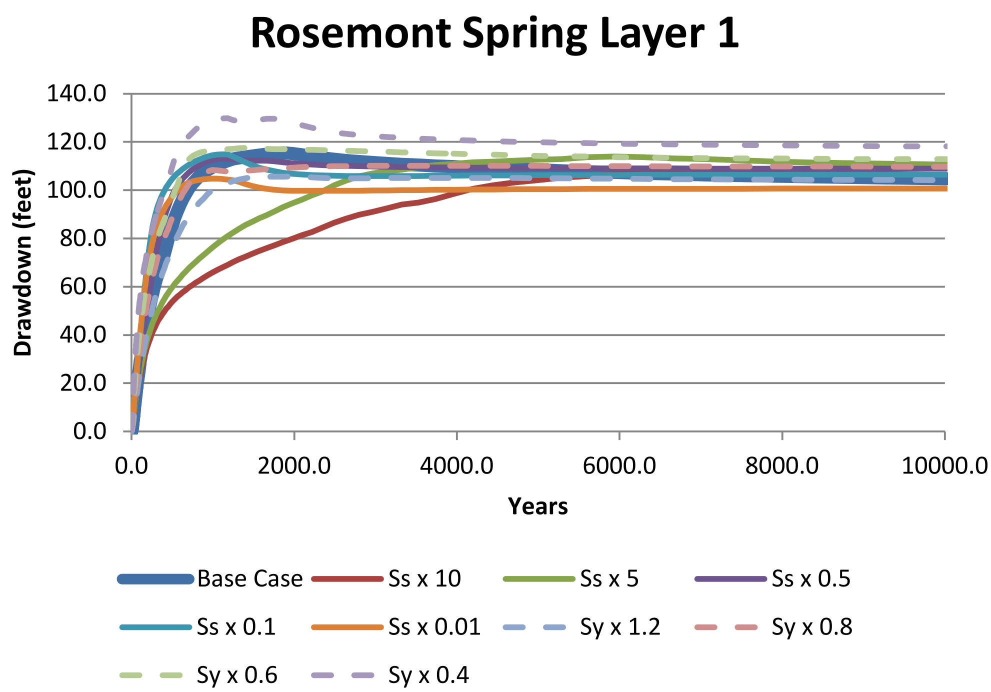
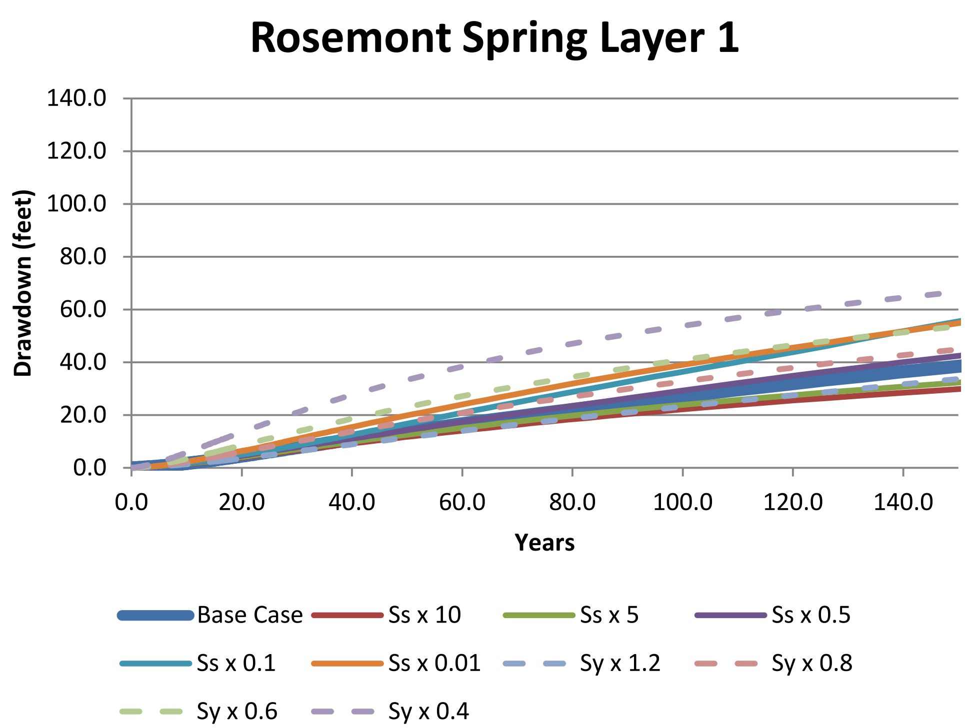
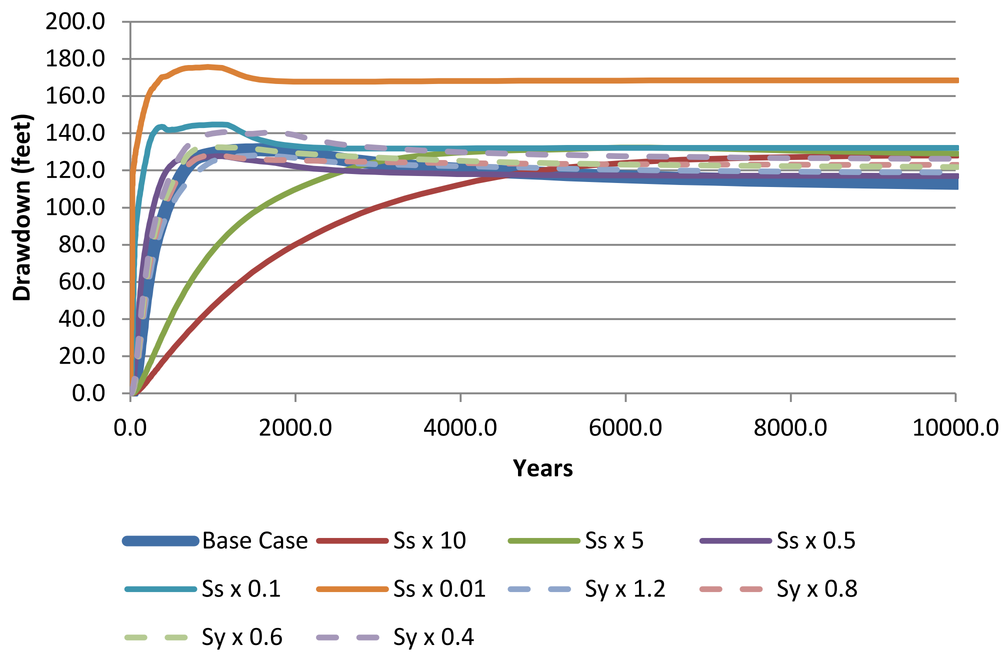
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Drawdown (feet)
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
Years
Base Case
Ss x 10
Ss x 5
Ss x 0.5
Ss x 0.1
Ss x 0.01
Sy x 1.2
Sy x 0.8
Sy x 0.6
Sy x 0.4

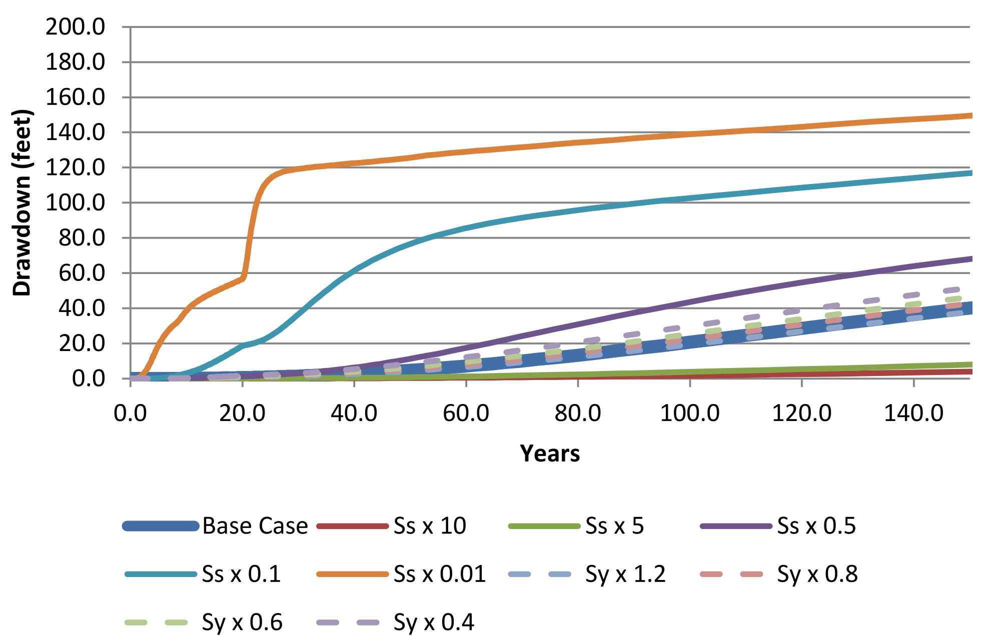

Rosemont Spring Layer 1
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
Drawdown (feet)
0.0
2000.0
4000.0
6000.0
8000.0
10000.0
Years
Base Case
Ss x 10
Ss x 5
Ss x 0.5
Ss x 0.1
Ss x 0.01
Sy x 1.2
Sy x 0.8
Sy x 0.6
Sy x 0.4

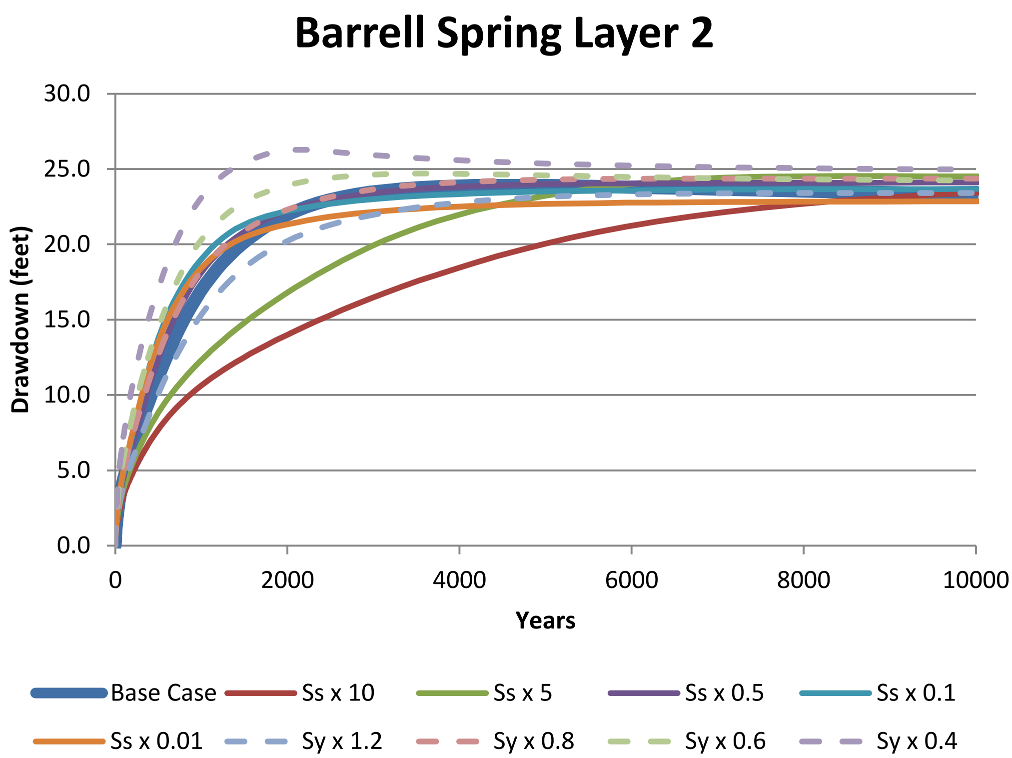

Rosemont Spring Layer 1
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
Drawdown (feet)
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
Years
Base Case
Ss x 10
Ss x 5
Ss x 0.5
Ss x 0.1
Ss x 0.01
Sy x 1.2
Sy x 0.8
Sy x 0.6
Sy x 0.4

Rosemont Spring Layer 5

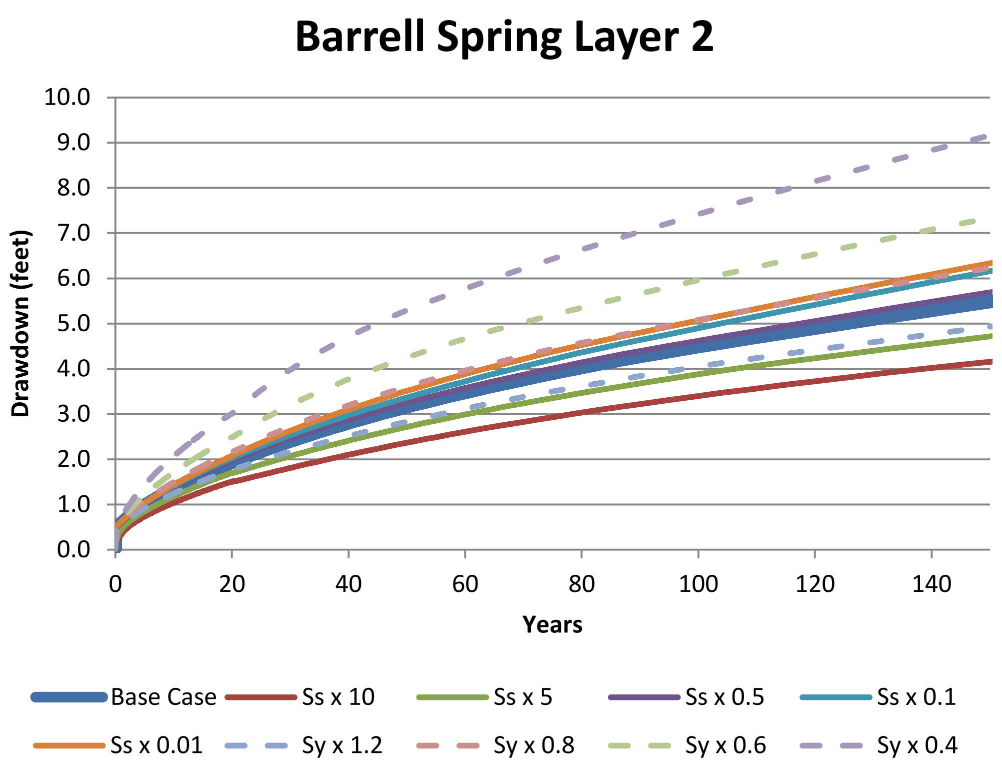


Rosemont Spring Layer 5

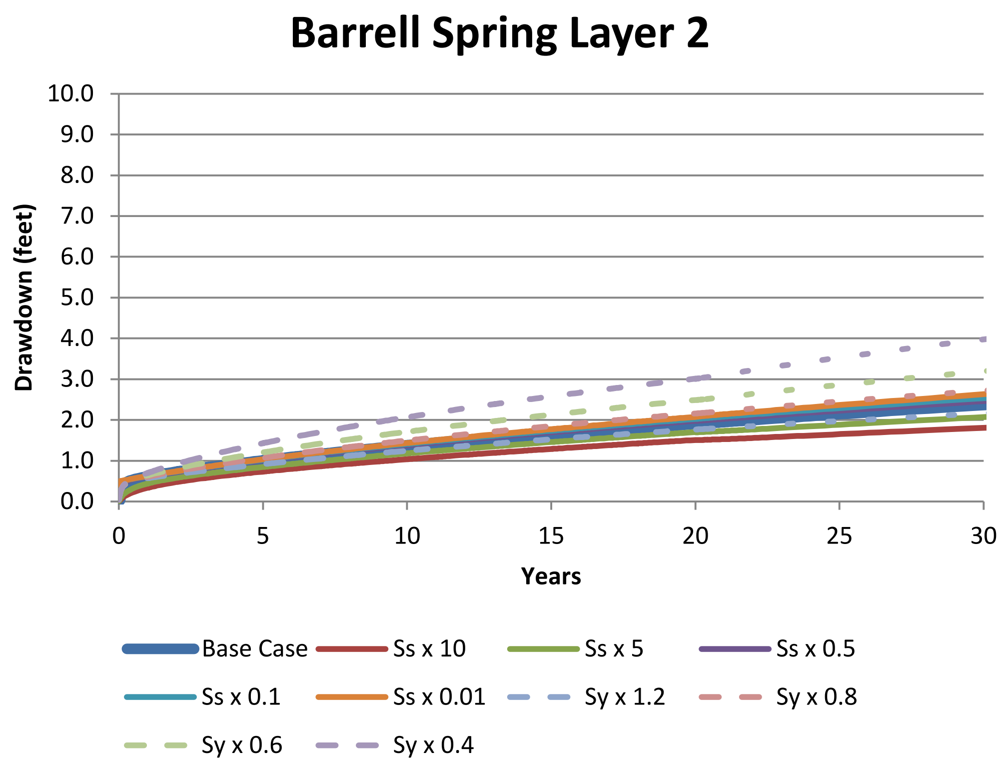


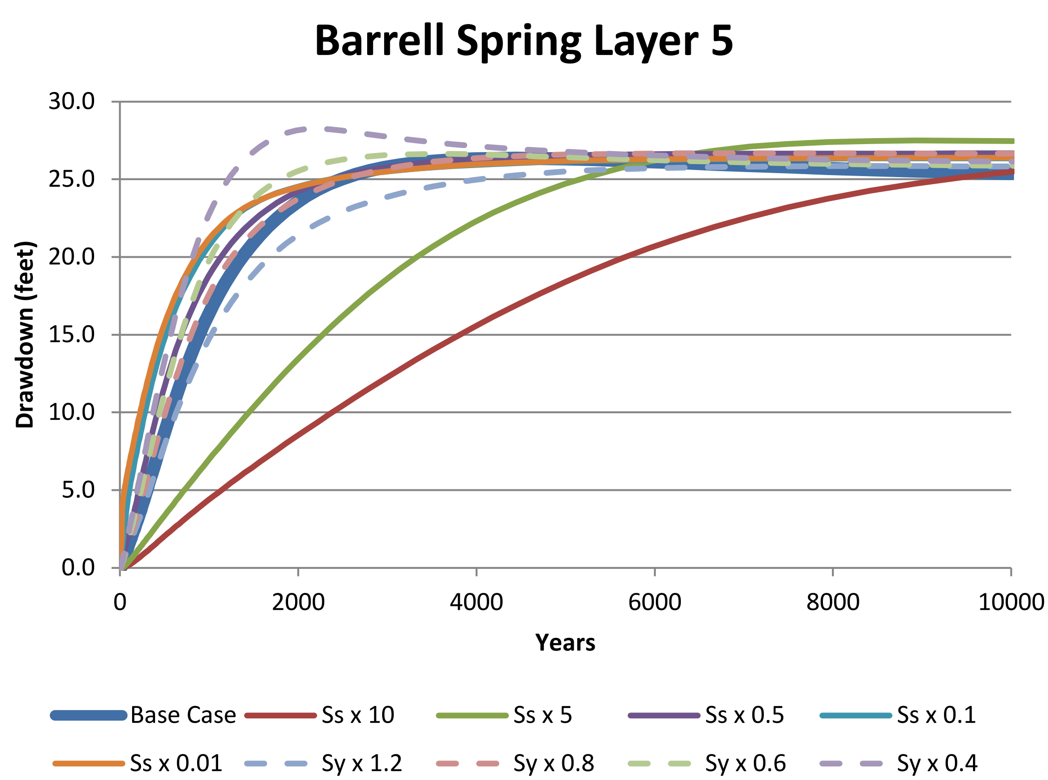


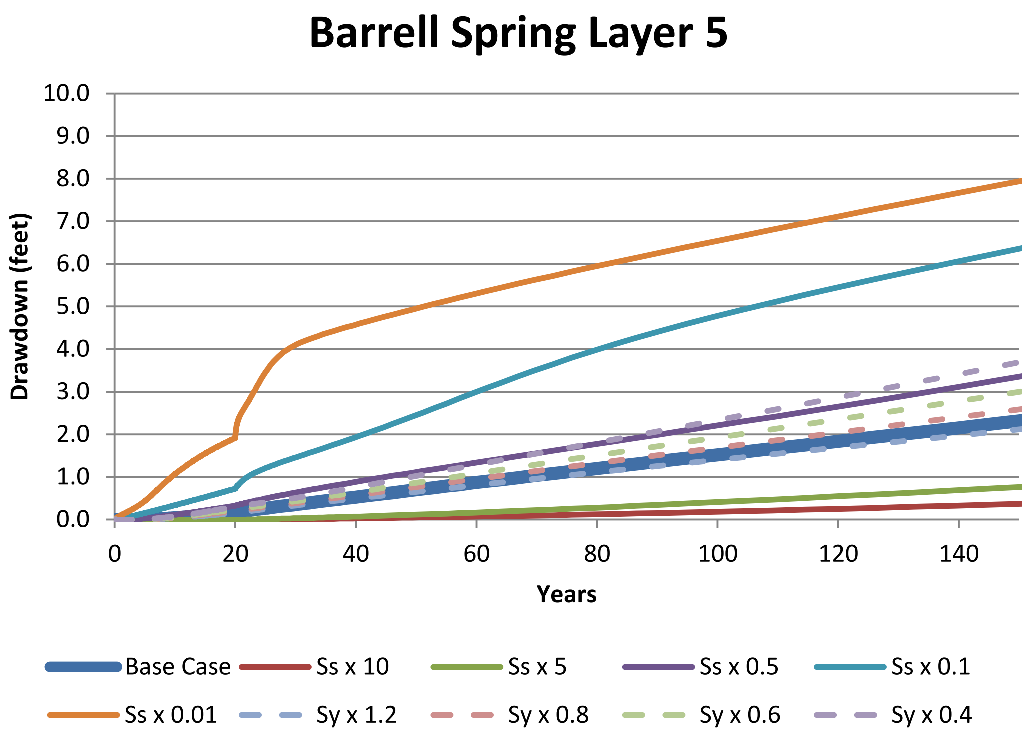
Barrell Spring Layer 2
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Drawdown (feet)
0
2000
4000
6000
8000
10000
Years
Base Case
Ss x 10
Ss x 5
Ss x 0.5
Ss x 0.1
Ss x 0.01
Sy x 1.2
Sy x 0.8
Sy x 0.6
Sy x 0.4

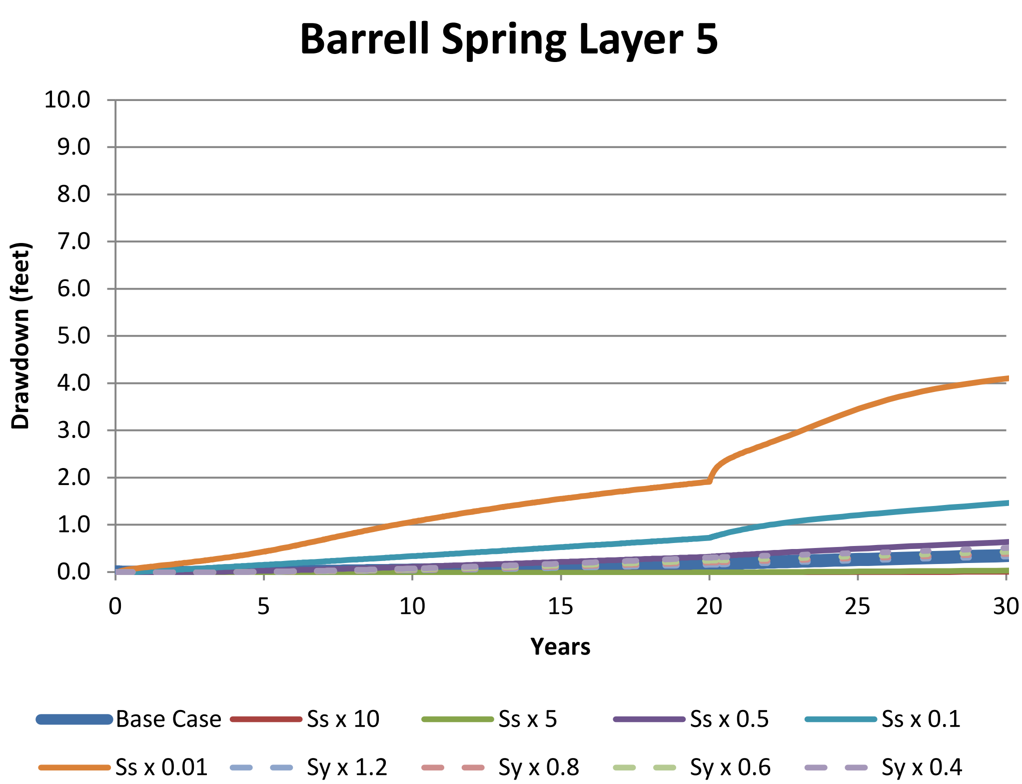


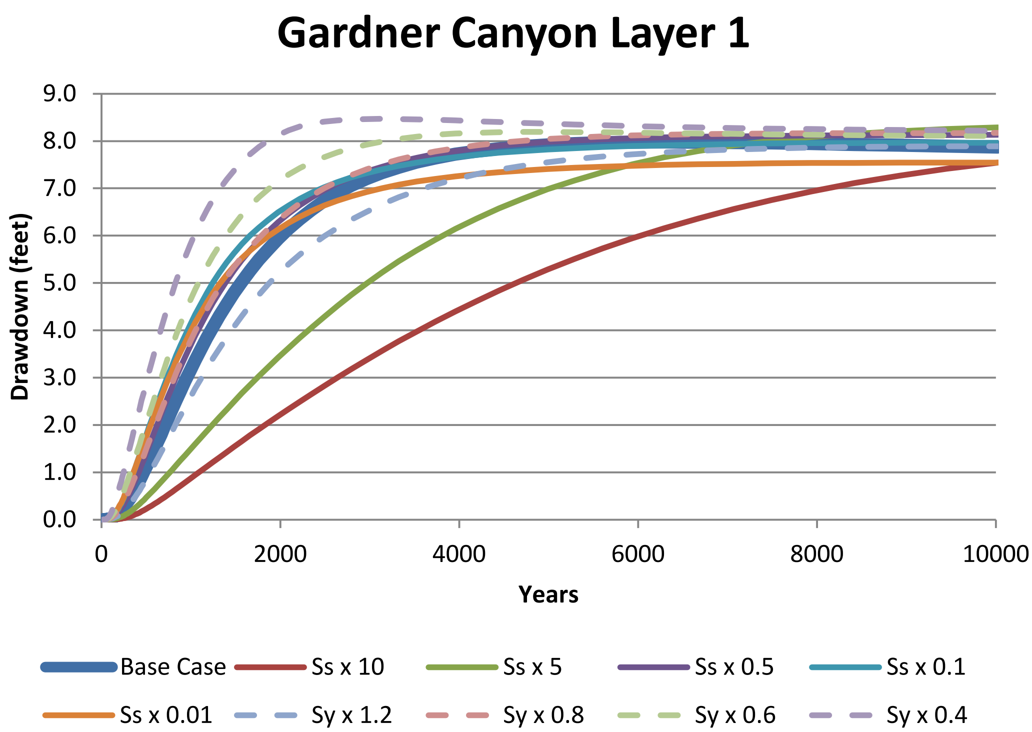
Barrell Spring Layer 2
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Drawdown (feet)
0
20
40
60
80
100
120
140
Years
Base Case
Ss x 10
Ss x 5
Ss x 0.5
Ss x 0.1
Ss x 0.01
Sy x 1.2
Sy x 0.8
Sy x 0.6
Sy x 0.4

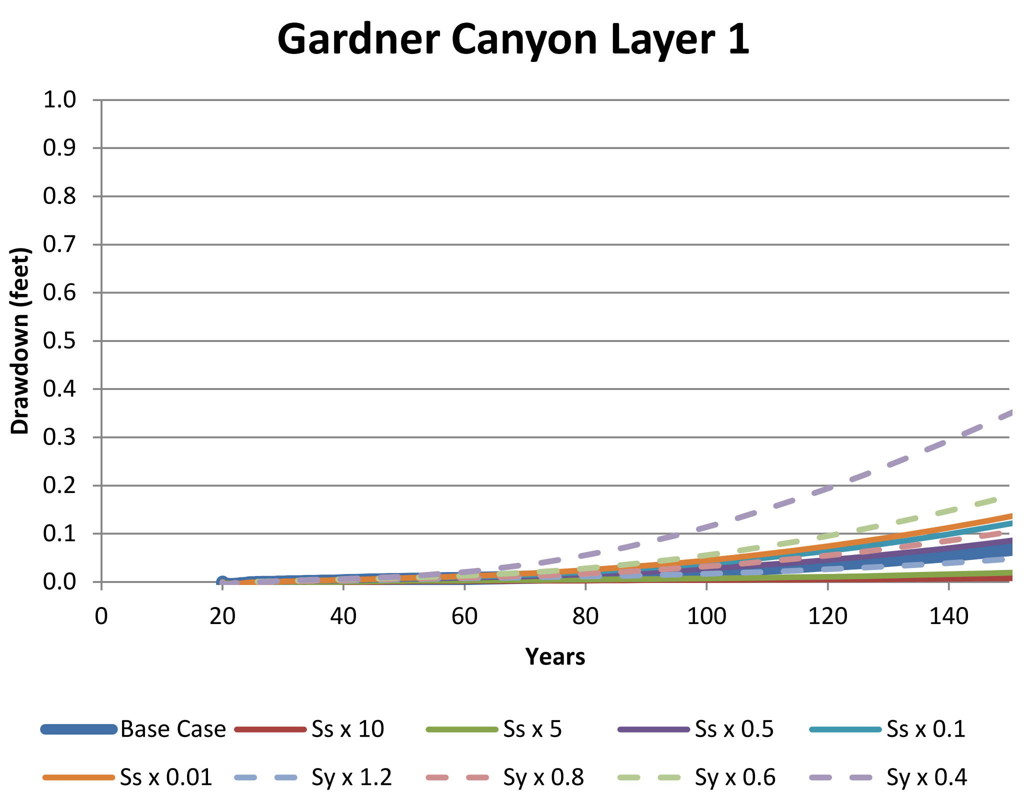

Barrell Spring Layer 2
Drawdown (feet)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
5
10
15
20
25
30
Years
Base Case
Ss x 10
Ss x 5
Ss x 0.5
Ss x 0.1
Ss x 0.01
Sy x 1.2
Sy x 0.8
Sy x 0.6
Sy x 0.4


Barrell Spring Layer 5
Drawdown (feet)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0
2000
4000
6000
8000
10000
Years
Base Case
Ss x 10
Ss x 5
Ss x 0.5
Ss x 0.1
Ss x 0.01
Sy x 1.2
Sy x 0.8
Sy x 0.6
Sy x 0.4


Barrell Spring Layer 5
Drawdown (feet)
Years
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
20
40
60
80
100
120
140
Base Case
Ss x 10
Ss x 5
Ss x 0.5
Ss x 0.1
Ss x 0.01
Sy x 1.2
Sy x 0.8
Sy x 0.6
Sy x 0.4


Barrell Spring Layer 5
Drawdown (feet)
Years
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
5
10
15
20
25
30
Base Case
Ss x 10
Ss x 5
Ss x 0.5
Ss x 0.1
Ss x 0.01
Sy x 1.2
Sy x 0.8
Sy x 0.6
Sy x 0.4


Gardner Canyon Layer 1
Drawdown (feet)
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
2000
4000
6000
8000
10000
Years
Base Case
Ss x 10
Ss x 5
Ss x 0.5
Ss x 0.1
Ss x 0.01
Sy x 1.2
Sy x 0.8
Sy x 0.6
Sy x 0.4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Drawdown (feet)
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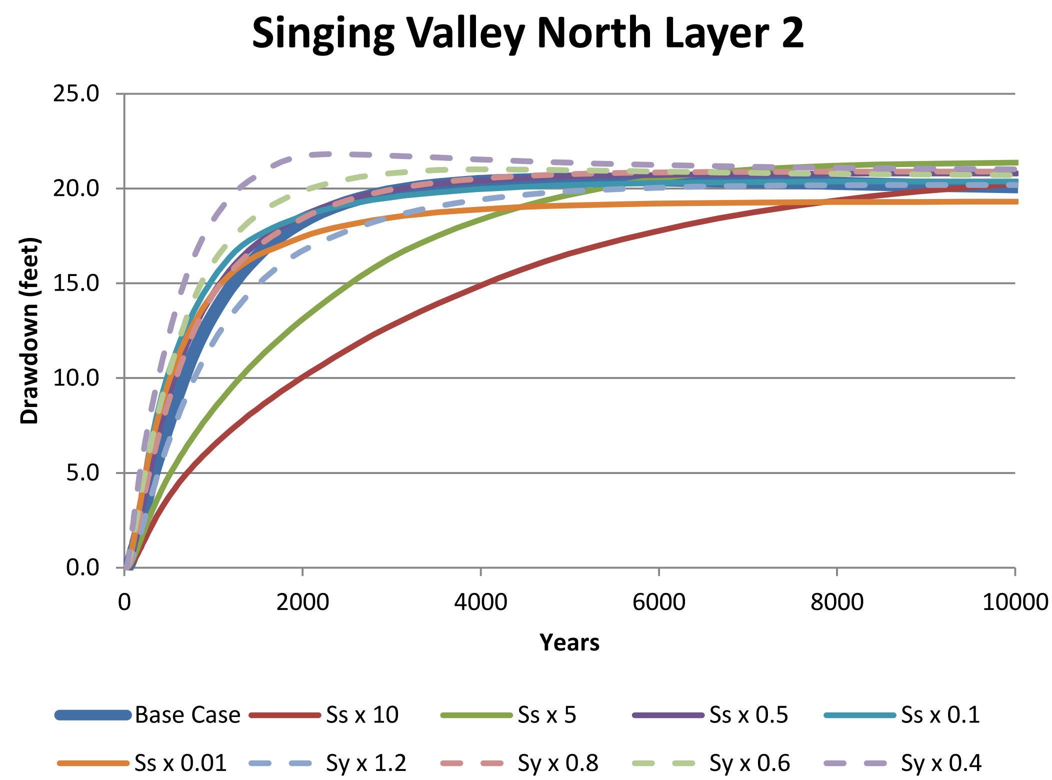
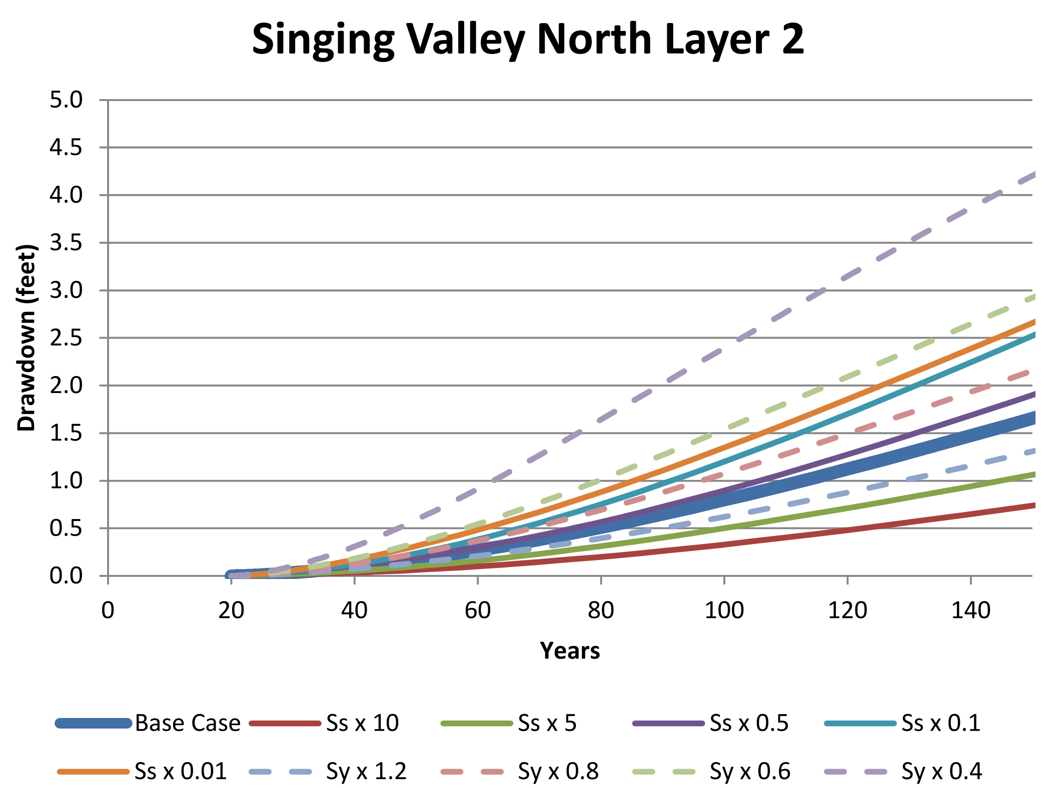
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
Years
Base Case
Ss x 10
Ss x 5
Ss x 0.5
Ss x 0.1
Ss x 0.01
Sy x 1.2
Sy x 0.8
Sy x 0.6
Sy x 0.4


Singing Valley North Layer 2
25.0
20.0
15.0
10.0
5.0
0.0
Drawdown (feet)
0
2000
4000
6000
8000
10000
Years
Base Case
Ss x 10
Ss x 5
Ss x 0.5
Ss x 0.1
Ss x 0.01
Sy x 1.2
Sy x 0.8
Sy x 0.6
Sy x 0.4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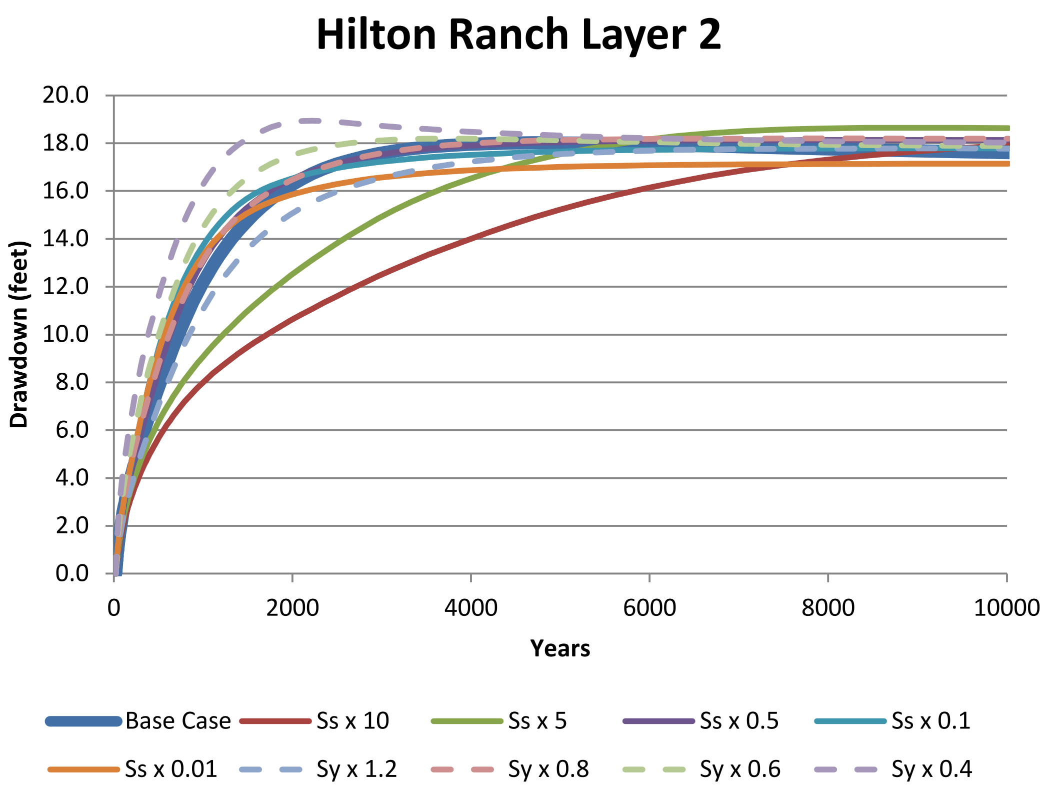
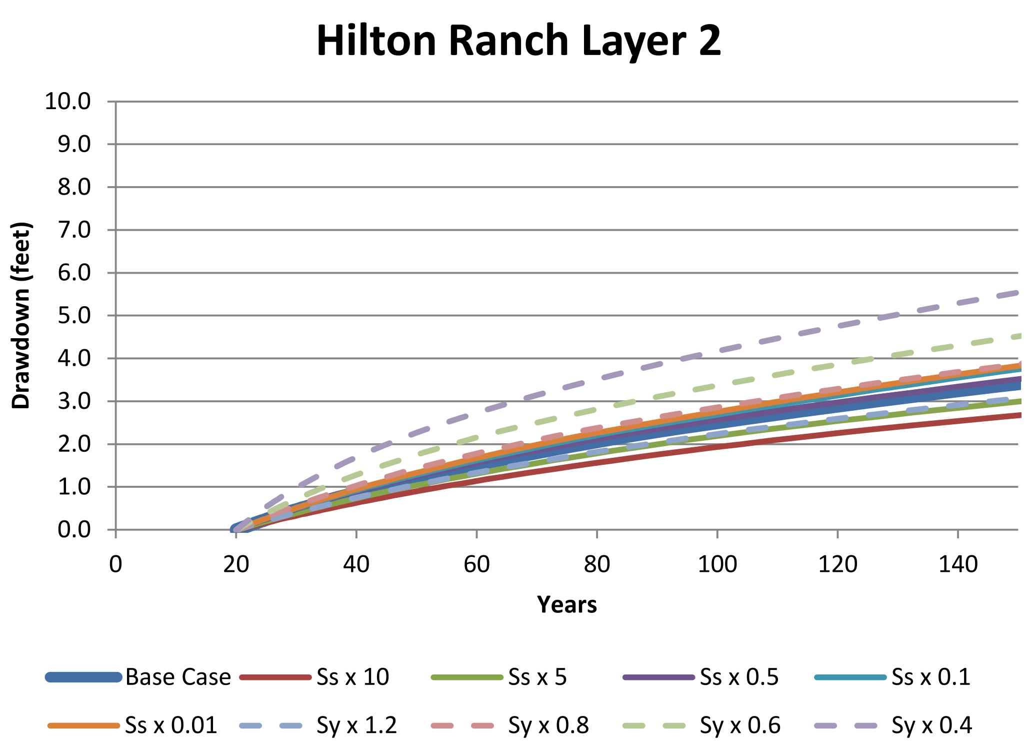
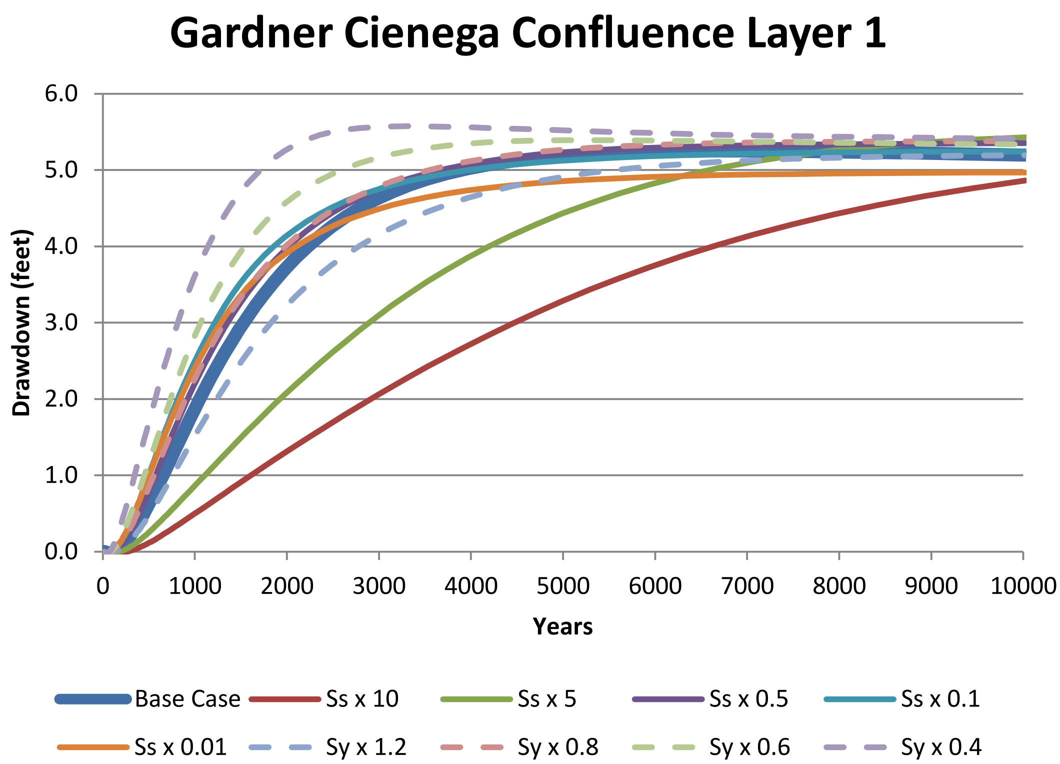
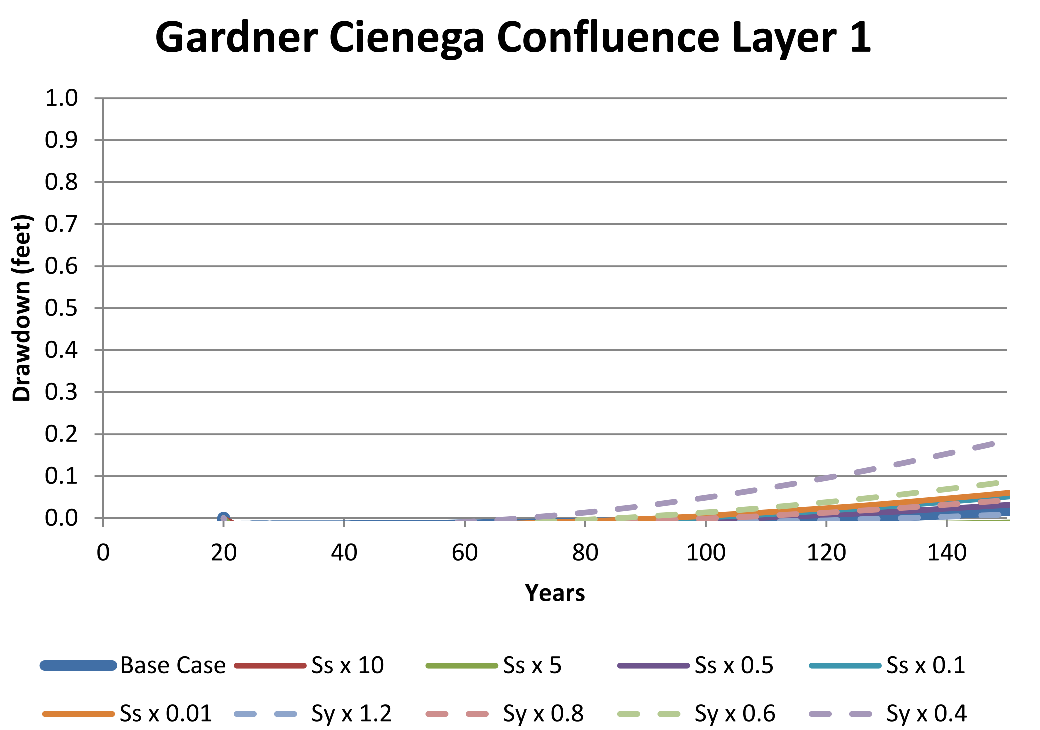
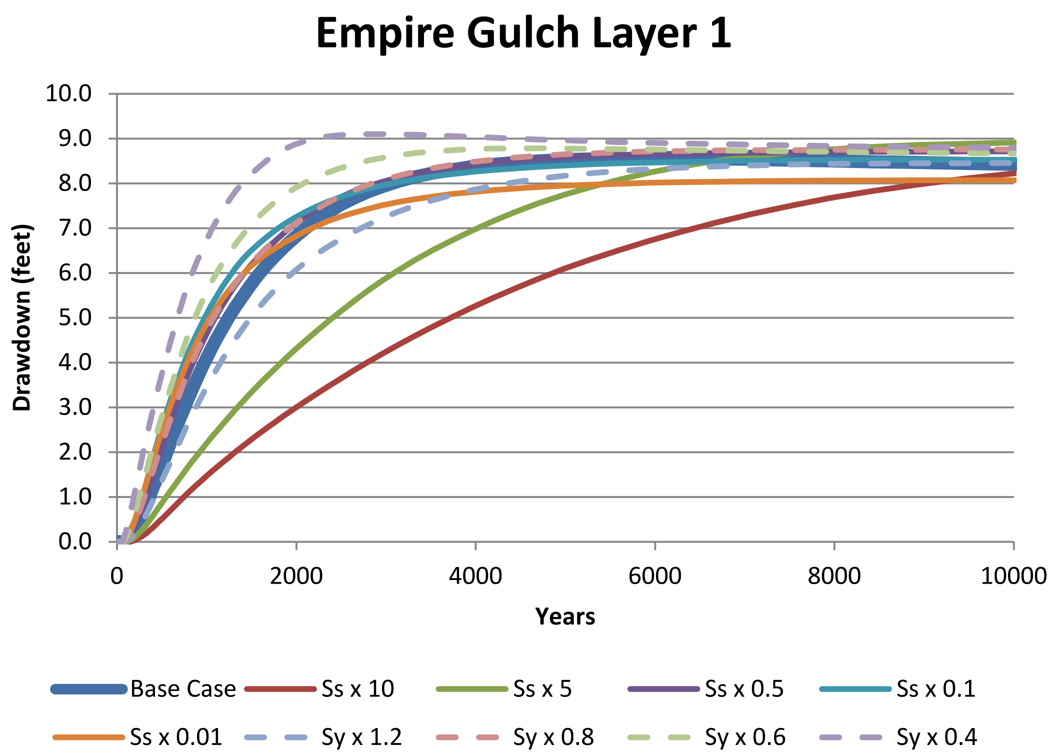
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Drawdown (feet)
0
20
40
60
80
100
120
140
Years
Base Case
Ss x 10
Ss x 5
Ss x 0.5
Ss x 0.1
Ss x 0.01
Sy x 1.2
Sy x 0.8
Sy x 0.6
Sy x 0.4

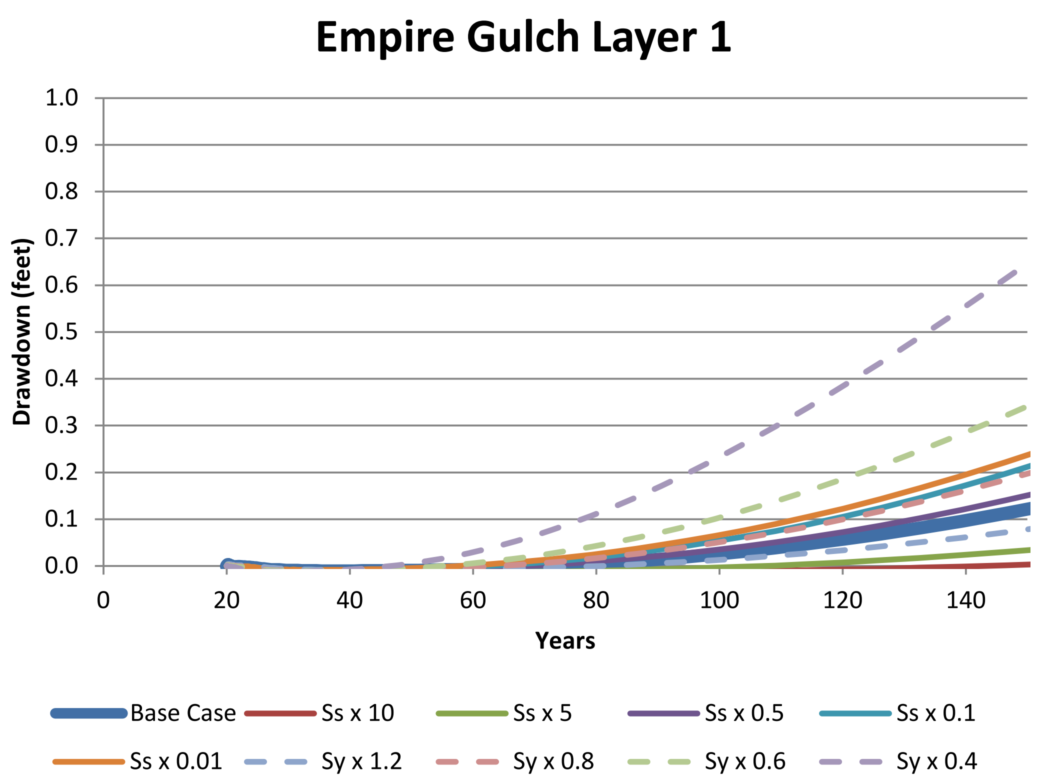

Hilton Ranch Layer 2
Drawdown (feet)
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0
2000
4000
6000
8000
10000
Years
Base Case
Ss x 10
Ss x 5
Ss x 0.5
Ss x 0.1
Ss x 0.01
Sy x 1.2
Sy x 0.8
Sy x 0.6
Sy x 0.4

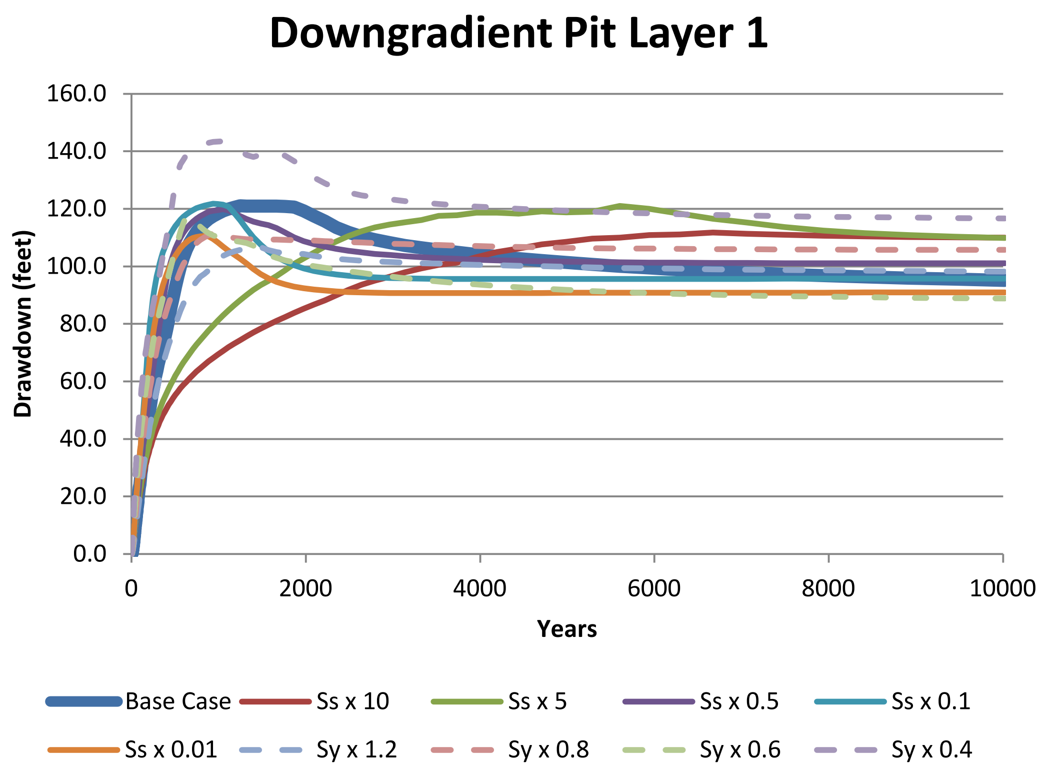

Hilton Ranch Layer 2
Drawdown (feet)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
20
40
60
80
100
120
140
Years
Base Case
Ss x 10
Ss x 5
Ss x 0.5
Ss x 0.1
Ss x 0.01
Sy x 1.2
Sy x 0.8
Sy x 0.6
Sy x 0.4

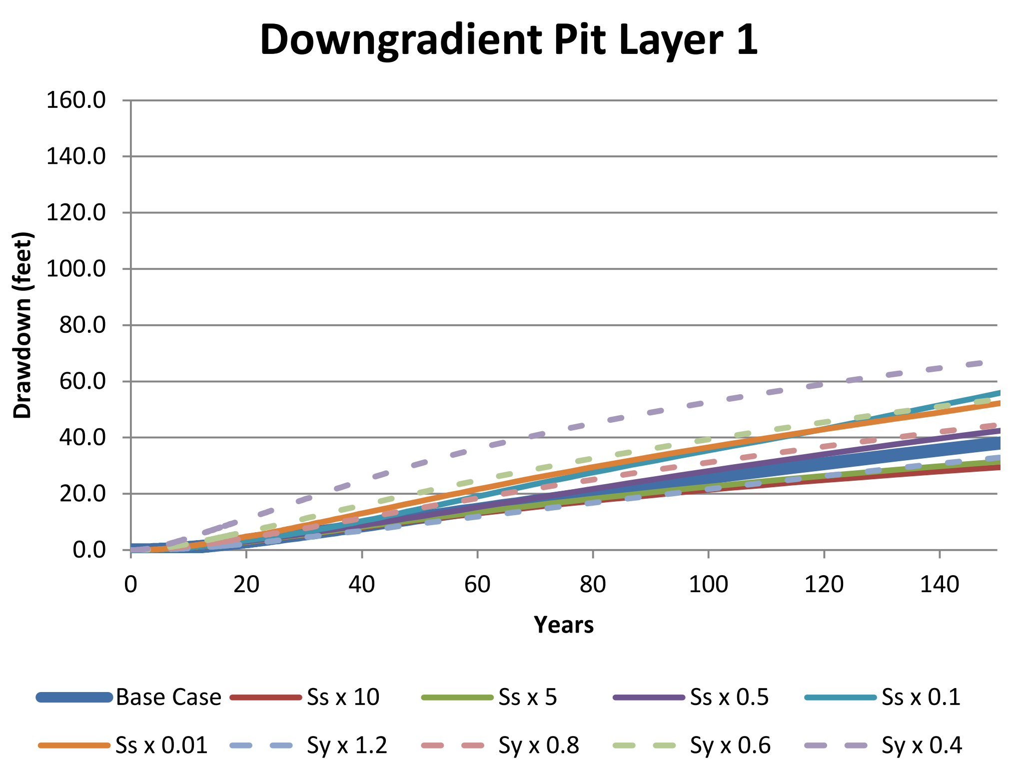

Gardner Cienega Confluence Layer 1
Drawdown (feet)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
Years
Base Case
Ss x 10
Ss x 5
Ss x 0.5
Ss x 0.1
Ss x 0.01
Sy x 1.2
Sy x 0.8
Sy x 0.6
Sy x 0.4

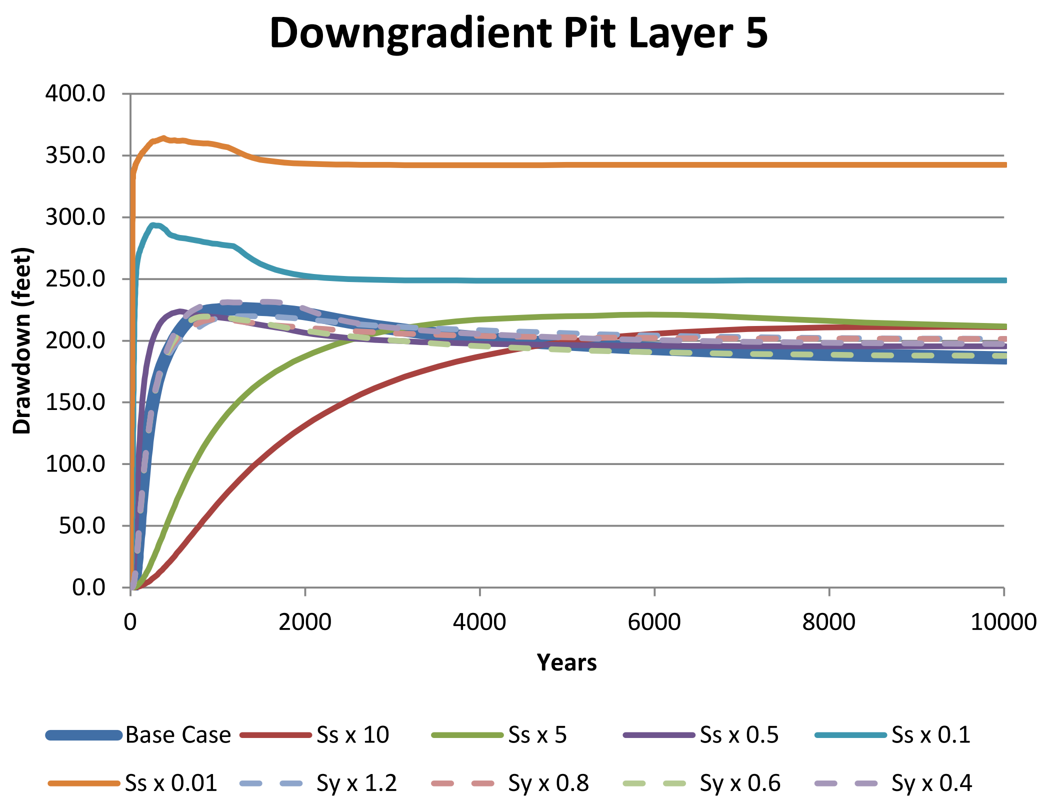

Gardner Cienega Confluence Layer 1
Drawdown (feet)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
Years
Base Case
Ss x 10
Ss x 5
Ss x 0.5
Ss x 0.1
Ss x 0.01
Sy x 1.2
Sy x 0.8
Sy x 0.6
Sy x 0.4

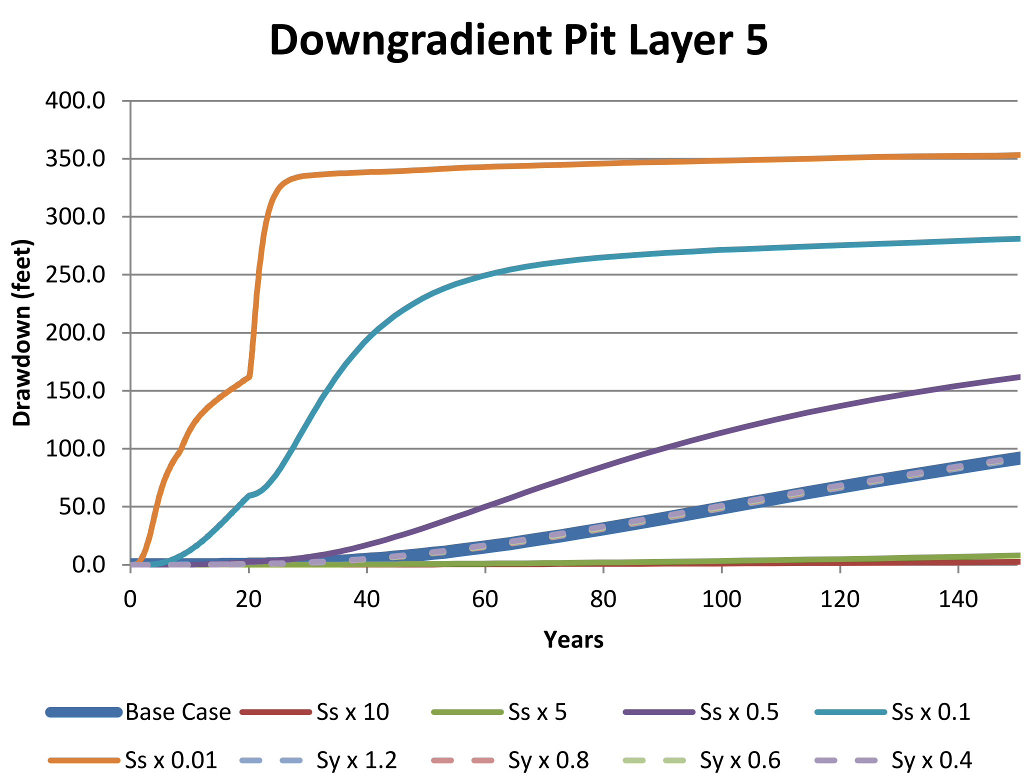

Empire Gulch Layer 1
Drawdown (feet)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0
2000
4000
6000
8000
10000
Years
Base Case
Ss x 10
Ss x 5
Ss x 0.5
Ss x 0.1
Ss x 0.01
Sy x 1.2
Sy x 0.8
Sy x 0.6
Sy x 0.4


Empire Gulch Layer 1
Drawdown (feet)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
20
40
60
80
100
120
140
Years
Base Case
Ss x 10
Ss x 5
Ss x 0.5
Ss x 0.1
Ss x 0.01
Sy x 1.2
Sy x 0.8
Sy x 0.6
Sy x 0.4


Downgradient Pit Layer 1
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
Drawdown (feet)
0
2000
4000
6000
8000
10000
Years
Base Case
Ss x 10
Ss x 5
Ss x 0.5
Ss x 0.1
Ss x 0.01
Sy x 1.2
Sy x 0.8
Sy x 0.6
Sy x 0.4


Downgradient Pit Layer 1
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
Drawdown (feet)
0
20
40
60
80
100
120
140
Years
Base Case
Ss x 10
Ss x 5
Ss x 0.5
Ss x 0.1
Ss x 0.01
Sy x 1.2
Sy x 0.8
Sy x 0.6
Sy x 0.4


Downgradient Pit Layer 5
Drawdown (feet)
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
0
2000
4000
6000
8000
10000
Years
Base Case
Ss x 10
Ss x 5
Ss x 0.5
Ss x 0.1
Ss x 0.01
Sy x 1.2
Sy x 0.8
Sy x 0.6
Sy x 0.4


Downgradient Pit Layer 5
Drawdown (feet)
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
0
20
40
60
80
100
120
140
Years
Base Case
Ss x 10
Ss x 5
Ss x 0.5
Ss x 0.1
Ss x 0.01
Sy x 1.2
Sy x 0.8
Sy x 0.6
Sy x 0.4