Rocky Mountain
ENVIRONMENTAL
ASSOCIATES, INC.

Supplement to
Technical Report on ESPAM2.0 Modeling Issues

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INTRODUCTION

On October 1, 2012, Rocky Mountain Environmental Associates, Inc. (RMEA) prepared a document titled "Technical Report on ESPAM2.0 Modeling Issues" (Report). It was submitted to IDWR in behalf of Fremont Madison Irrigation District as an expert report in the Rangen case. Subsequently, Idaho Department of Water Resources (IDWR) discovered a mistake in the input data to ESPAM2.0. IDRW has since withdrawn ESPAM2.0 and replaced with ESPAM2.1, which was calibrated after correcting the mistake.

This document is supplementary to the original Report. It has two purposes:

1. It presents comparisons between ESPAM2.0 and ESPAM2.1, to show that the modeling results in the Report are not substantially affected by the differences induced by correcting the mistake;
2. It presents an additional illustration supporting an assertion on page C6 of Appendix C of the original Report.

Comparisons Between ESPAM2.0 and ESPAM2.1

Dr. Allan Wylie of Idaho Department of Water Resources presented a slide presentation entitled "ESPAM2.0 – E121025A001" at the Eastern Snake Hydrologic Modeling Committee (ESHMC) meeting on November 9, 2012.[1] Figure 1 shows the comparison

1 http://www.idwr.idaho.gov/Browse/WaterInfo/ESPAM/meetings/2012_ESHMC/11_9_2012/Wylie_ESPAM2_ESPAM21_Nov2012.pdf

of ESPAM2.0, ESPAM2.1 and target data for the Ashton to Rexburg reach, which is the reach nearest Fremont Madison Irrigation District. Figure 2 shows the comparison for the Rangen reach, which includes the Rangen diversion among others. In the figures, ESPAM2.1 is referenced as E121025A001. The blue line represents the target data, the green line represents ESPAM2.0, and the red line represents ESPAM2.1. Where the red line is not visible, it is obscured by the green ESPAM2.0 line.

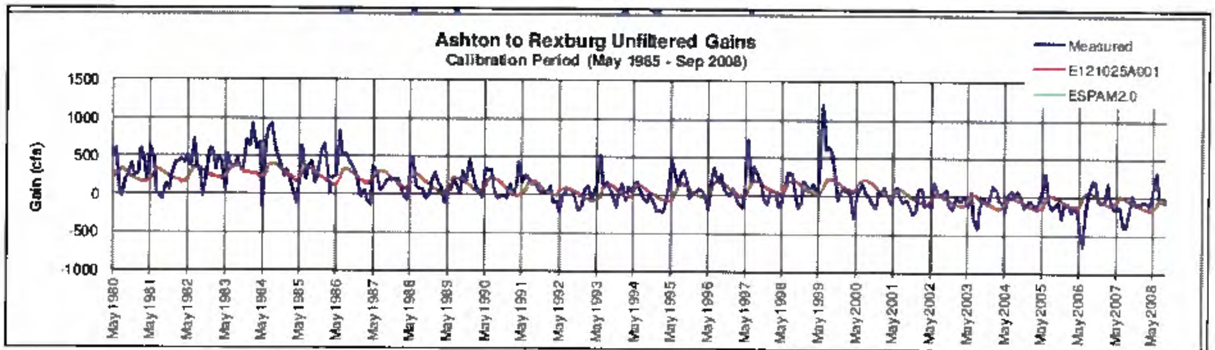


Figure 1. ESPAM2.0 and ESPAM2.1, Ashton to Rexburg, from Dr. Allan Wylie's presentation slide 4.

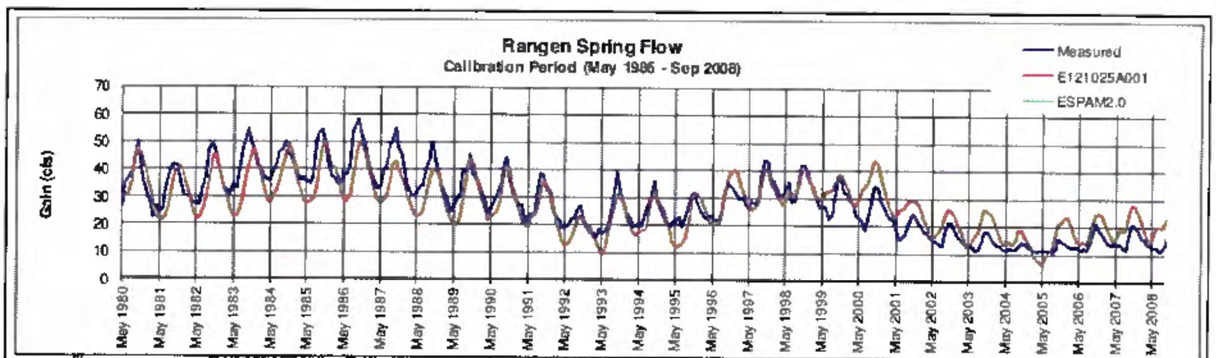


Figure 2. ESPAM2.0 and ESPAM2.1, Rangen reach. From Dr. Wylie's slide 59.

These figures and the other slides in Dr. Wylie's presentation indicate that the differences between ESPAM2.0 and ESPAM2.1 representations are small relative to the ESPAM2.0 results relied upon in the Report. It is my professional judgment that ESPAM2.0 modeling in the Report is adequately representative of expected ESPAM2.1 results, for the context of the Report.

Additional Illustration

The Report asserts on page C6 of Appendix C that that "Demonstrating the ability to respond to this large, diffuse, distant flux does not at all guarantee that the model can correctly respond to a small, concentrated, nearby stress." Figure 3 below illustrates a hypothetical geometric arrangement of two springs (1 and 2), two wells (B and C) and

a distant large area that also affects the springs (A). The single most important feature of the hypothetical aquifer is that there is a region of low-permeability materials between Well C and Spring 1, or alternately, that there are preferential flow pathways between the vicinity of Well B and Spring 1, and between the vicinity of Well C and Spring 2.

The analysis assumes that distant region A includes irrigation, wells, springs, water bodies, recharge sources and other features not explicitly represented in the Figure. Figure 4 shows the time series of the hydraulic signal from the combined hydraulic effects in region A, while Figure 5 shows the time series of pumping at the two wells. Accompanying file "Supplemental_Figures.xls" contains all the calculations underlying the figures and the example.

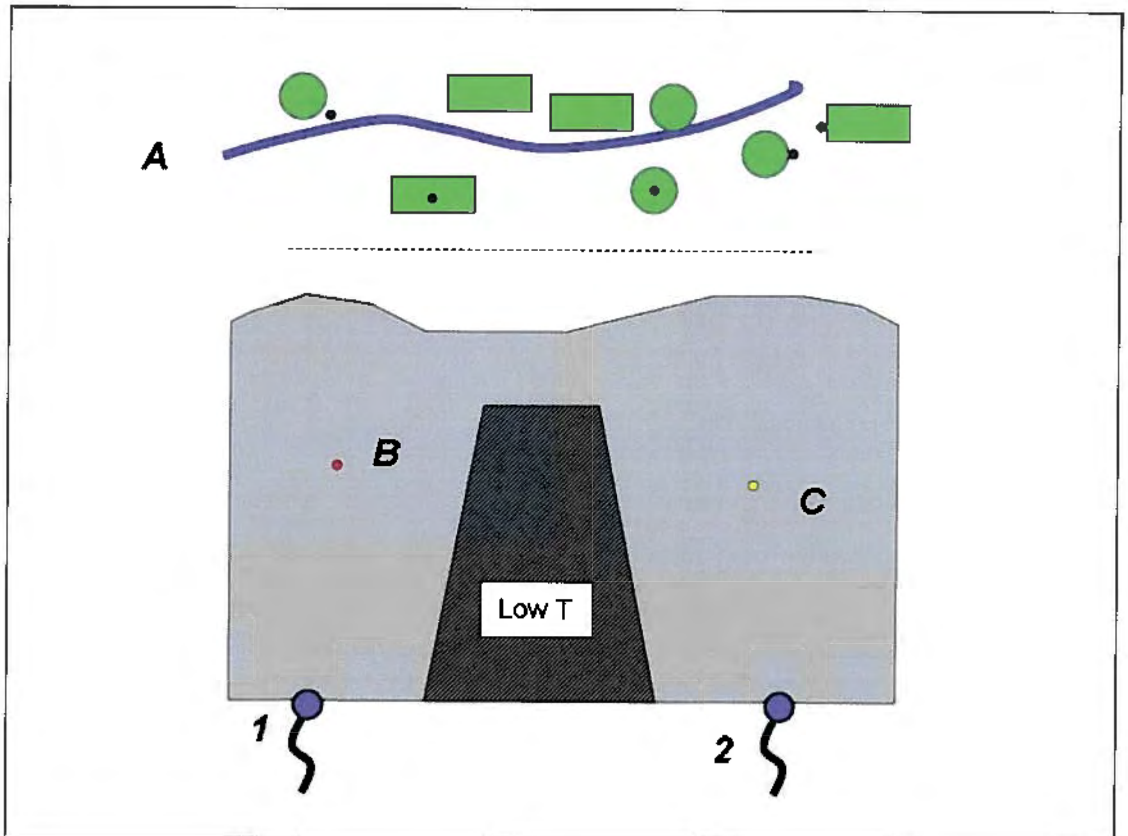


Figure 3. Geometry of the hypothetical aquifer, springs and wells.

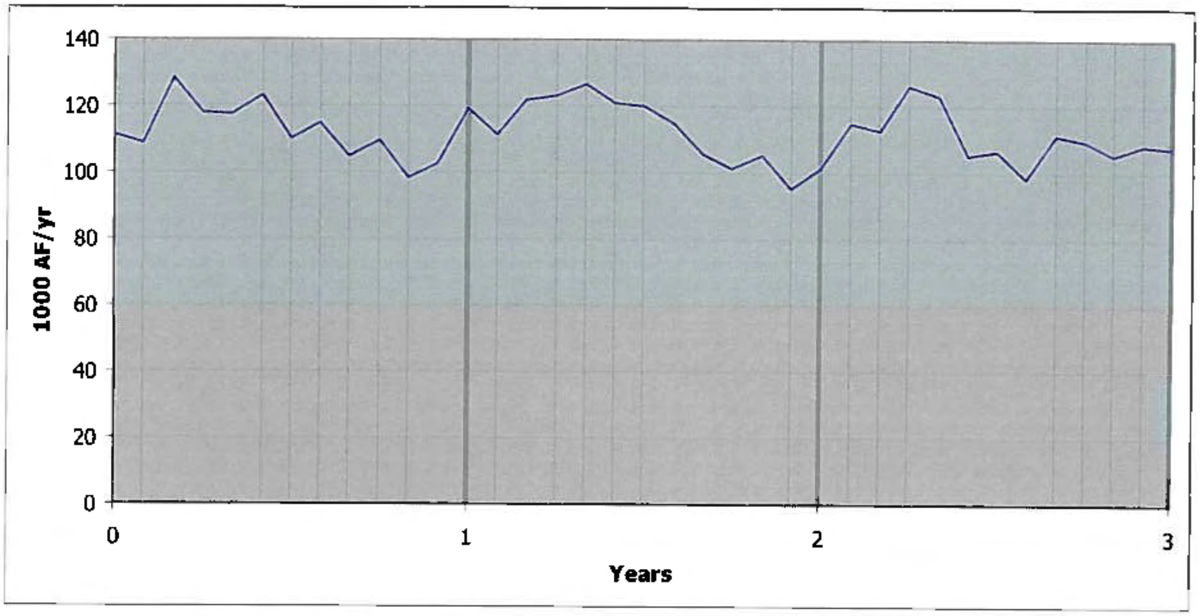


Figure 4. Time series of hypothetical net effect from region A.

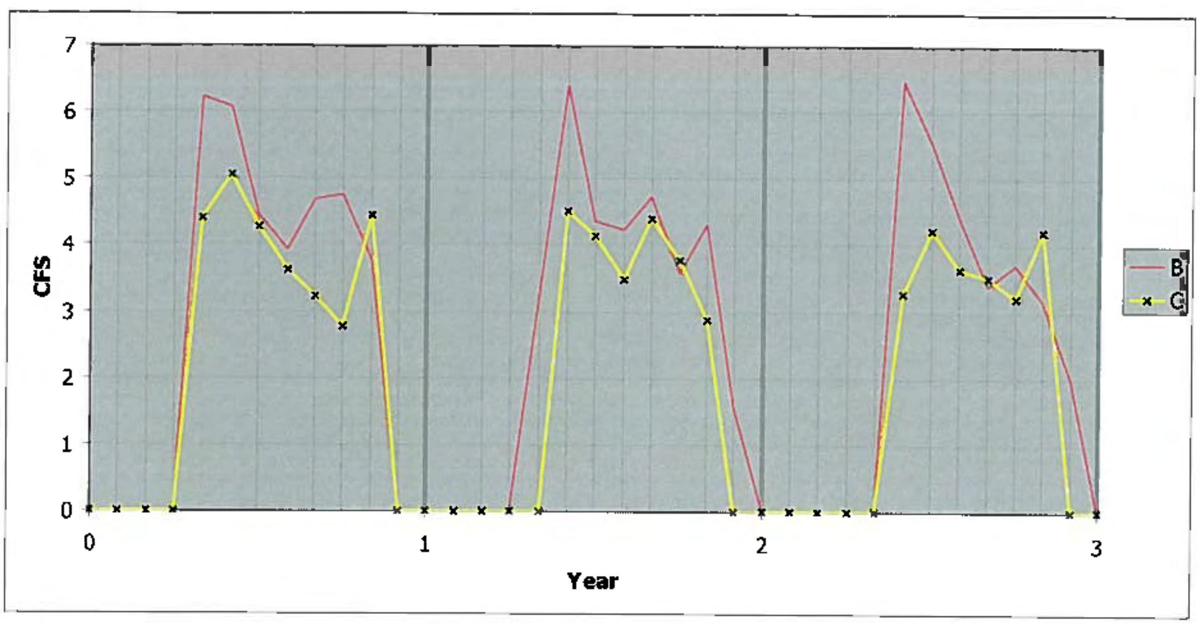


Figure 5. Hypothetical time series of well pumping.

Equation 1 is the hypothetical true expression of the relationships between net effect from region A, the pumping at the two wells, and the discharge at Spring 1.[2]

$$Q1 = 0.33\ A - 0.95\ B - 0.01\ C + 0 \quad (1)$$

[2] For simplicity, temporal delays are omitted from the illustration.

where Q1 = Discharge at Spring 1, cubic feet per second
A = net recharge in region A, 1000 acre feet per year
B = pumping at well B, cubic feet per second
C = pumping at well C, cubic feet per second

The steady-state response function for Well B is 0.95, indicating that 95% of curtailment at well B would benefit Spring 1. However, the steady-state response function for Well C is only 0.01, or one percent.

Figure 2 illustrates the geometry that would of necessity be represented if the distance between the wells and the springs were smaller than the inter-pilot-point distance. It differs from Figure 1 in omitting the low-permeability region, or alternately, in omitting the preferential flow pathways. The entire region containing the wells and springs would be considered a uniform porous medium, perhaps with a smooth gradation of aquifer properties across the region.

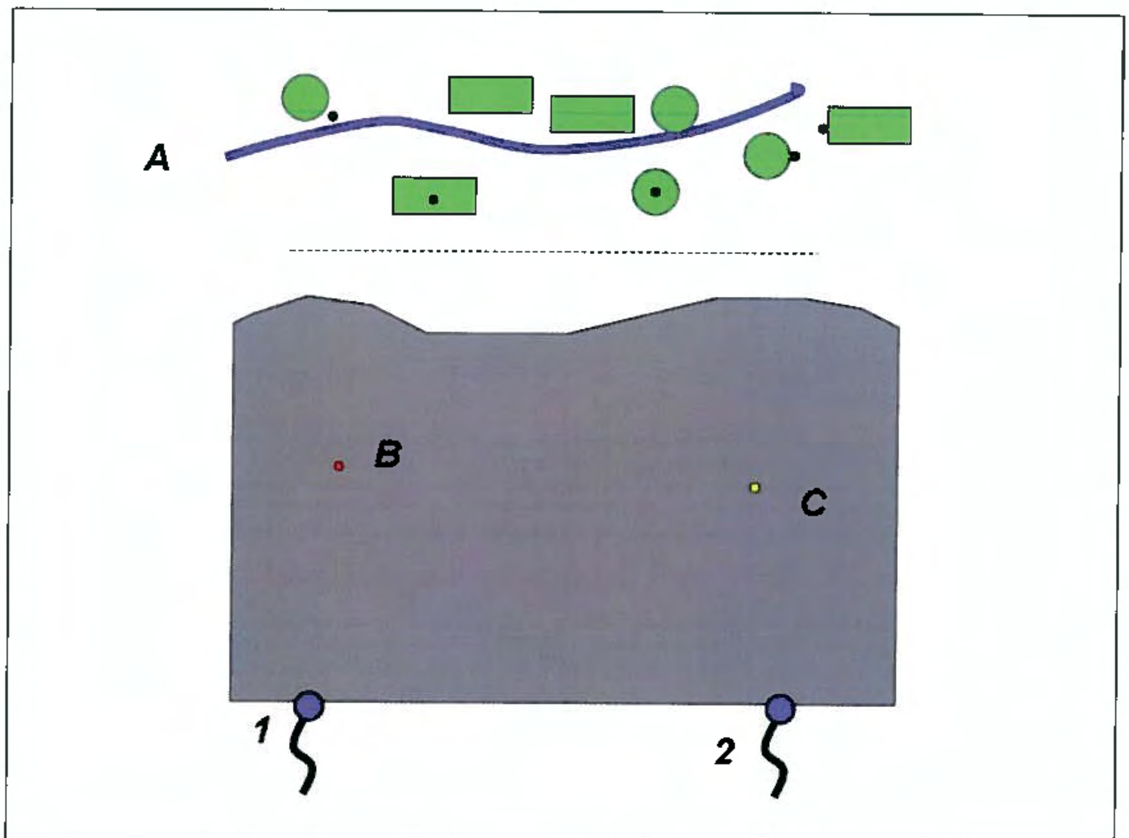


Figure 6. Model representation of the hypothetical aquifer.

Equation 2 is a calibrated equation compatible with the representation of Figure 6; the relative effects of Well B and Well C are constrained by distances and a uniform

representation of aquifer properties. All parameters are manually calibrated to minimize the sum of differences between estimated (i.e. produced by the estimated parameters in Equation 2) and observed (i.e. produced by the correct parameters in Equation 1) values, with an attempt to visually match the seasonal amplitude. The coefficient for parameter A was purposely made different from the actual to represent practical limitations of modeling and to illustrate that calibration can often overcome such imprecision with compensation elsewhere.

$$Q1 = 0.2\,A - 0.5\,B - 0.2\,C + 13.7 \qquad (2)$$

The response function for Well B is 0.50 and the response function for Well C is 0.20.

Figure 7 shows the calibration results. Visually, the fit is arguably better than the actual ESPAM2.1 results illustrated in Figure 1 and Figure 2. The calibration statistics are also reasonable; the mean error is less than one percent of the spring discharge and the root mean square error is approximately four percent. Nevertheless, the calibrated response functions differ greatly; the calibrated steady-state response fraction for Well B is approximately half the "true" value, while the calibrated response fraction for Well C is twenty times the "true" value.

This means that this illustrative model is capable of correctly reproducing results when both Well B and Well C are operating in their customary fashion, but it is not capable of correctly representing the isolated effects of either well.

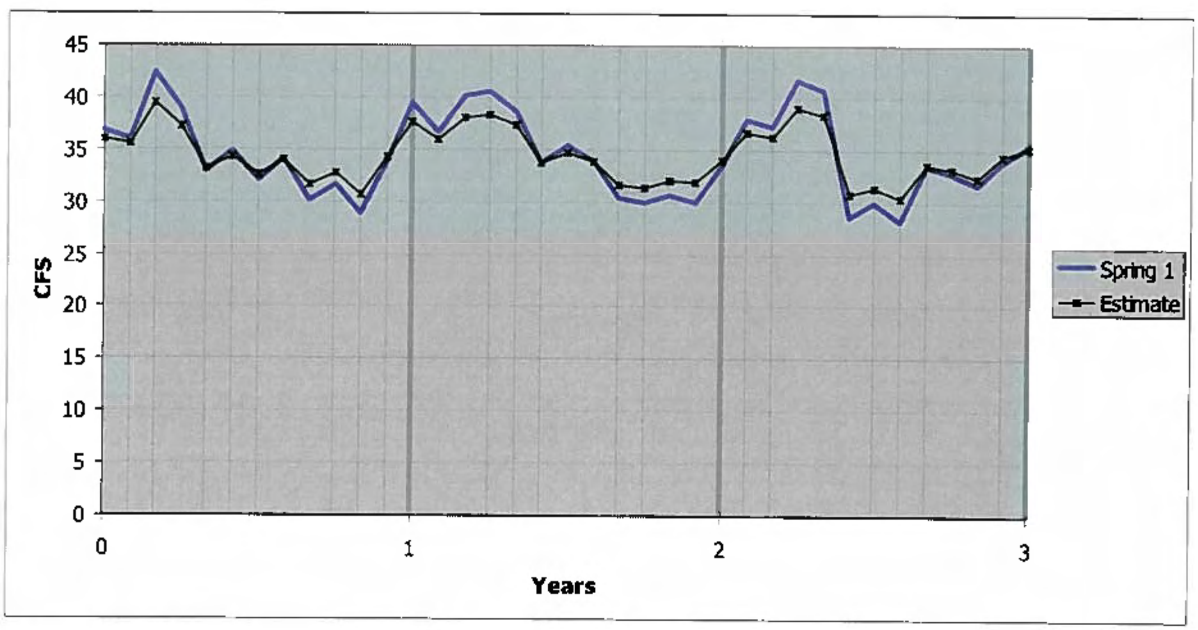


Figure 7. Hypothetical calibration match. "Spring 1" shows the results of Equation 1, while "Estimate" represents the results of manually-fitted Equation 2.

This result is consistent with characteristics that the illustration shares with ESPAM2.1:

1. The hydrologic features near the springs share temporal characteristics of discharge or recharge (i.e. the temporal water-use pattern of Well B is similar to that of Well C) during the calibration period;
2. An important influence on spring discharge propagates from a distant, broad region;
3. A local geological feature exists at a finer spatial scale than can be represented with the available distribution of pilot points.

The illustration demonstrates that a good calibration to good local data can still fail to produce an accurate representation of response functions to single springs. While we cannot assert that this occurs in all cases within the ESPAM2.1 model, we have no available tools to demonstrate that it does *not* occur in any particular case or location. We only know that the conceptual model of a uniform porous medium with gradual gradation in properties is consistent with an expectation of a broad, uniform seepage face and inconsistent with the observation of large, individual springs separated by expanses of dry canyon wall.

Given the tools, data and resources available, representation as a uniform porous medium was a defensible modeling choice. However, that choice should temper expectations of the spatial scale of applicability of modeling estimates.

CONCLUSION

This supplement offers two important conclusions. First, the differences between ESPAM2.0 and ESPAM2.1 do not appear to substantially change the model results relied upon in the Report. Second, an illustration provides clarification and support of the statement in the Report that "Demonstrating the ability to respond to this large, diffuse, distant flux does not at all guarantee that the model can correctly respond to a small, concentrated, nearby stress."

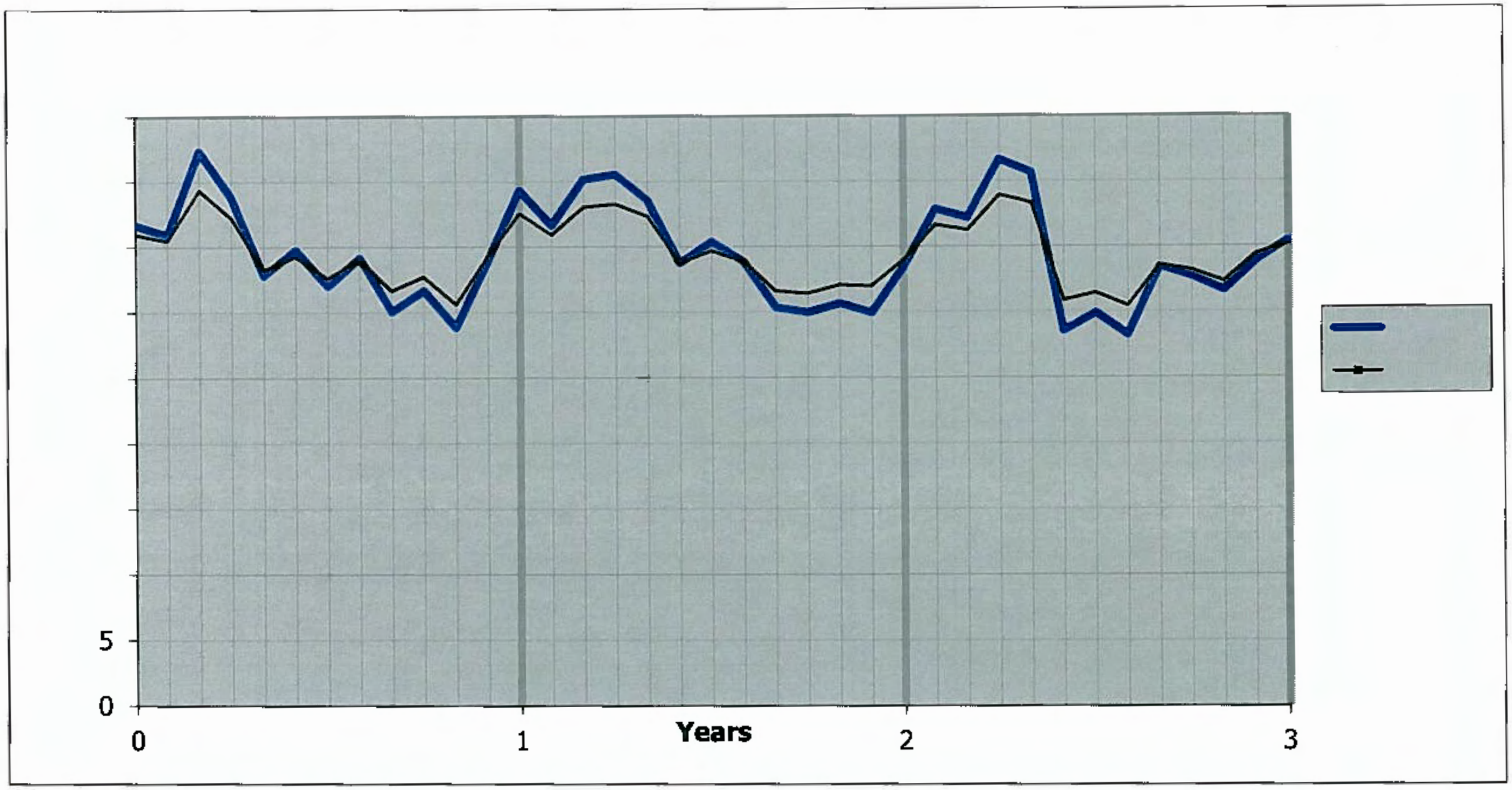
Calib_Para	13.7
Mean Err	-0.0727
Mean Err °	-0.00211
RMSE	1.416279
RMSE %	0.041072

s)	Time	A	B	C	Spring 1	Estimate	Err	Err2
0	0	111.293	0	0	36.72668	35.95859	-0.76808	0.589954
1	0.083333	108.8266	0	0	35.91279	35.46533	-0.44746	0.200223
2	0.166667	128.3572	0	0	42.35788	39.37144	-2.98644	8.918808
3	0.25	117.6753	0	0	38.83284	37.23505	-1.59779	2.552919
4	0.333333	117.478	6.221354	4.401573	32.81345	33.20461	0.391166	0.153011
5	0.416667	123.0174	6.068063	5.049706	34.78059	34.25951	-0.52108	0.271525
6	0.5	109.9296	4.452054	4.265903	32.00465	32.60671	0.602058	0.362474
7	0.583333	114.9909	3.916821	3.614133	34.18986	34.01693	-0.17293	0.029904
8	0.666667	104.6769	4.691565	3.236152	30.05402	31.64236	1.588342	2.522829
9	0.75	109.7369	4.747665	2.766845	31.67521	32.72017	1.044957	1.091935
10	0.833333	98.36459	3.772334	4.449309	28.83211	30.59689	1.764785	3.114464
11	0.916667	102.7901	0	0	33.92073	34.25802	0.337289	0.113764
12	1	119.2742	0	0	39.36049	37.55484	-1.80565	3.260369
1	1.083333	111.1078	0	0	36.66557	35.92156	-0.74401	0.553554
2	1.166667	121.7515	0	0	40.178	38.0503	-2.1277	4.527089
3	1.25	122.8547	0	0	40.54205	38.27094	-2.27111	5.157936
4	1.333333	126.3064	3.255187	0	38.58869	37.33369	-1.255	1.575027
5	1.416667	120.8021	6.394574	4.517931	33.74468	33.75956	0.014873	0.000221
6	1.5	119.8893	4.345269	4.130953	35.39417	34.67904	-0.71513	0.511404
7	1.583333	114.8631	4.225298	3.493131	33.85585	33.86134	0.005491	3.02E-05
8	1.666667	105.666	4.730072	4.392706	30.3323	31.58963	1.257333	1.580886
9	1.75	101.2156	3.576582	3.781424	29.96559	31.39855	1.432962	2.053379
10	1.833333	105.4028	4.304759	2.884398	30.66456	32.0513	1.386741	1.92305
11	1.916667	95.17052	1.569265	0	29.91547	31.94947	2.034002	4.137162
12	2	101.3258	0	0	33.4375	33.96515	0.52765	0.278415

1	2.083333	114.767	0	0	37.87312	36.6534	-1.21971	1.487698
2	2.166667	112.7802	0	0	37.21745	36.25603	-0.96142	0.924331
3	2.25	126.2373	0	0	41.65832	38.94746	-2.71085	7.34872
4	2.333333	123.2039	0	0	40.6573	38.34079	-2.31651	5.366229
5	2.416667	105.1649	6.468929	3.279955	28.52613	30.84252	2.316391	5.365669
6	2.5	106.5881	5.516977	4.234155	29.89061	31.41231	1.521694	2.315553
7	2.583333	98.3231	4.420862	3.642705	28.21038	30.42565	2.215271	4.907427
8	2.666667	111.2748	3.388723	3.5031	33.46638	33.55998	0.093609	0.008763
9	2.75	109.7506	3.698718	3.203744	32.67187	33.16	0.488138	0.238279
10	2.833333	105.0556	3.167577	4.205447	31.61711	32.28625	0.66914	0.447749
11	2.916667	108.4239	2	0	33.87987	34.38477	0.504898	0.254922
12	3	107.4294	0	0	35.45169	35.18588	-0.26582	0.07066

Rand_A	Rand_B	Rand_C	Rand_1
0.564648	0.886059	0.003829	0.716484
0.191332	0.809466	0.681525	0.926255
0.984848	0.268294	0.121591	0.514212
0.383764	0.624047	0.414695	0.50015
0.440889	0.677664	0.017774	0.680288
0.900871	0.784032	0.524853	0.438121
0.496478	0.226027	0.382952	0.380596
0.999543	0.208411	0.307067	0.494166
0.666856	0.778795	0.301088	0.1375
0.986843	0.873832	0.133422	0.04305
0.351242	0.31918	0.907667	0.379753
0.389504	0.977178	0.50621	0.412451
0.963711	0.025629	0.424333	0.92018
0.305389	0.855262	0.168582	0.455396
0.654563	0.093816	0.091572	0.772572
0.642734	0.389348	0.847375	0.201548
0.882308	0.822174	0.601024	0.866816
0.790107	0.947287	0.258965	0.193665
0.994467	0.172635	0.315476	0.703655
0.993153	0.362649	0.246565	0.096525
0.716315	0.798049	0.879366	0.275545
0.560781	0.288291	0.640712	0.657846
0.703153	0.585392	0.125211	0.919967
0.008526	0.865442	0.907135	0.785203
0.066288	0.373345	0.18226	0.685491

0.488351	0.417754	0.480149	0.779456
0.205996	0.412324	0.295193	0.842377
0.811866	0.761583	0.549846	0.10663
0.727184	0.956719	0.767045	0.296711
0.008244	0.984465	0.342825	0.676583
0.329406	0.758489	0.367078	0.164038
0.166155	0.460431	0.321352	0.403636
0.996754	0.127374	0.434563	0.056977
0.987528	0.349359	0.351872	0.381901
0.685795	0.016801	0.785736	0.369773
0.671193	0.393167	0.382184	0.410939
0.371469	0.634129	0.659045	0.973298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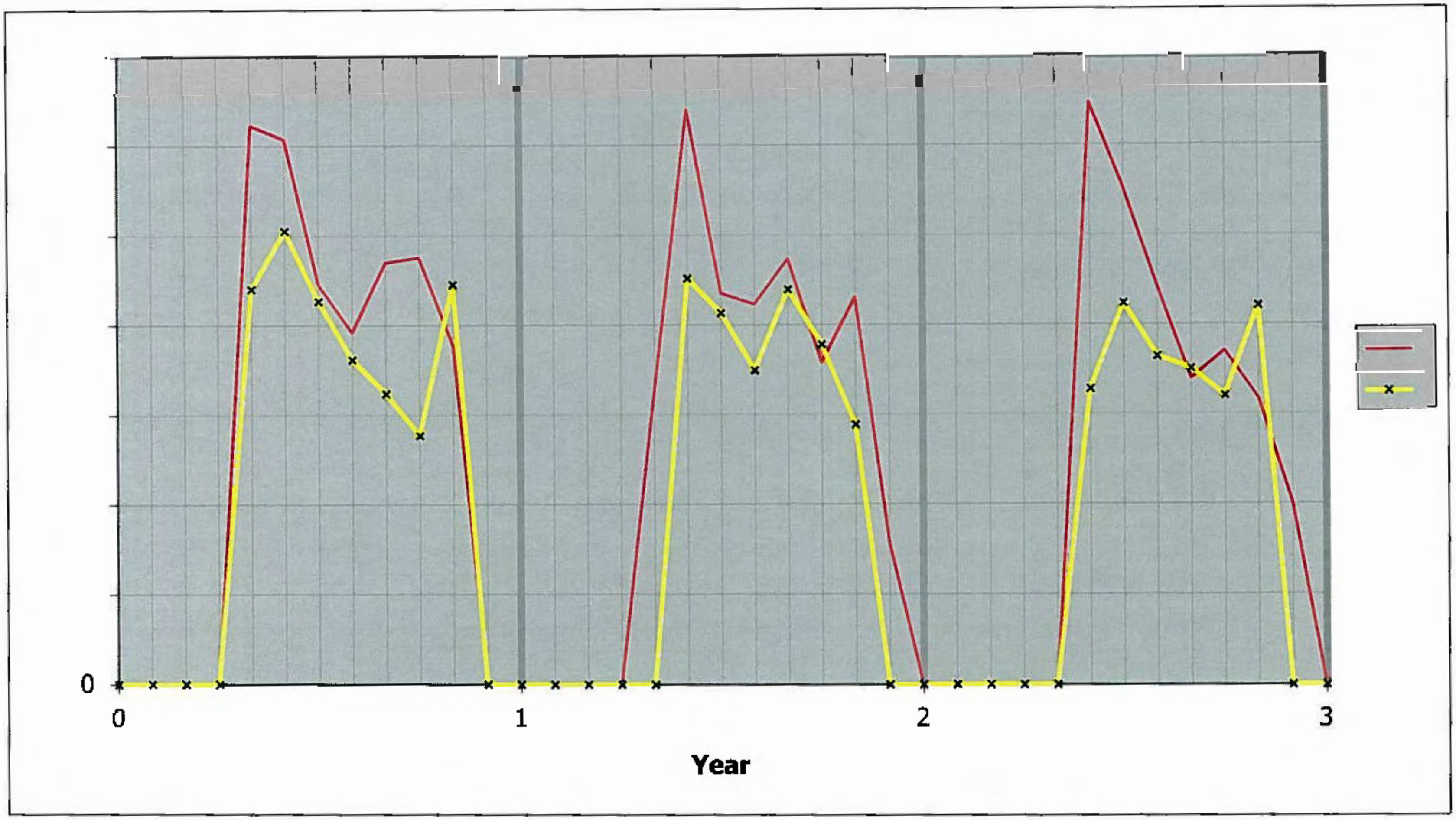
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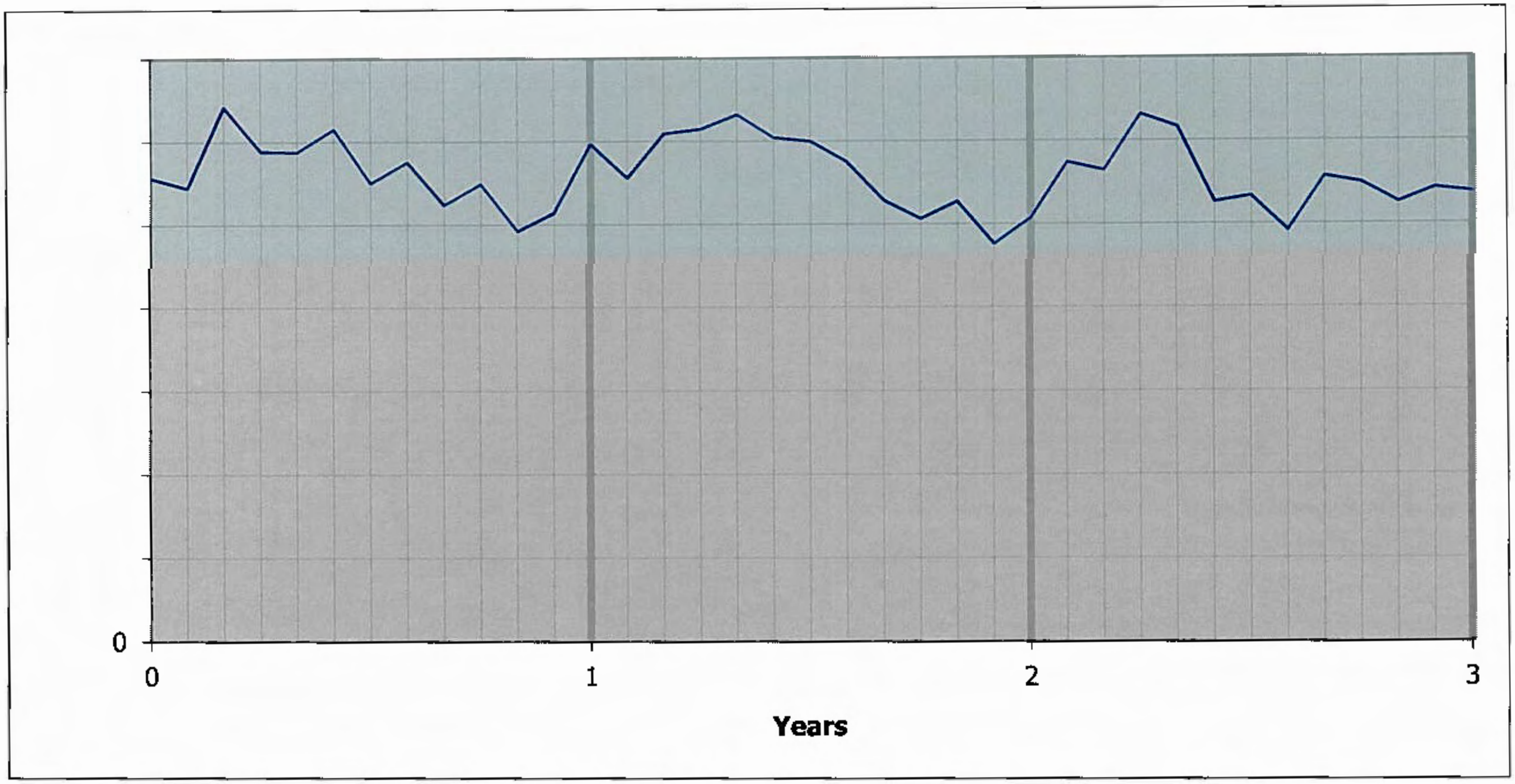
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