SURREBUTTAL TESTIMONY OF STEFFEN MEHL

1. I am a professor of Civil Engineering at California State University, Chico, where I routinely teach courses in fluid mechanics, hydrology, and hydraulics. I have a Bachelor of Science in Environmental Resources Engineering from California State University, Humboldt, and a Master of Science and Doctor of Philosophy in Civil Engineering from University of Colorado, Boulder.

2. A copy of my resume, which accurately describes my education and experience, was previously submitted as Exhibit SCWA-41.

PURPOSE AND SUMMARY OF TESTIMONY

3. For the surrebuttal phase of Part 1 of the California Water Fix (CWF) hearing, Sacramento County Water Agency asked me to prepare testimony and exhibits responding to the Petitioners' rebuttal testimony of Gwen Buchholz (DWR – 80).

4. In her rebuttal testimony, Ms. Buchholz states:

> Groundwater model results in the BDCP/CWF EIR/EIS, Figure 7-14, show that a maximum reduction of 5 feet in groundwater elevations along the Sacramento River would occur due to operations of the five intakes under Alternative 1B and that the changes in groundwater elevations would not affect groundwater near Interstate 5, which is the western boundary of Zone 40. The results would be similar under the proposed Alternative 4A as can be determined by comparing the minimum Sacramento River flows under Alternatives 1B and 4A. (DWR 80, 18:25-28 -- 19:1-3.)

On cross-examination, when asked whether newer groundwater modeling conducted by Petitioners for the Final EIR/EIS would have been more relevant to an assessment of groundwater impacts under Alternative 4A, Ms. Buchholz stated that she believes Alternative 1B is adequate to indicate the effects of Alternative 4A. (April 25, 2017, Vol. 36, 75:9-17.)

5. Based on Ms. Buchholz's testimony, I reviewed the ability of Petitioners' existing groundwater models to properly evaluate the CWF's impacts on groundwater resources in the South American Subbasin. I evaluated the existing CVHM-D model under different scenarios to consider whether they appropriately represent impacts on groundwater in the South American Subbasin. I carefully evaluated Petitioners' CVHM-D model because Ms. Buchholz's testimony indicates that she relied on the results of the No Action Alternative (NAA) and Alternative 1B (Alt 1B) scenarios to form the opinions in her rebuttal testimony and these scenarios were analyzed using the CVHM-D model. My testimony highlights numerical issues with the CVHM-D model, and, how the

models, in their current state, would simulate a potential impact on stream leakage in the South American Subbasin.

6. I analyzed the potential impacts of Alternative 1B (the preferred alternative is Alternative 4A, but Ms. Buchholz indicated that Alternative 1B would have similar impacts because Alternative 4A and 1B modeling with the CWF operating show similar flows in the Sacramento River downstream of the proposed North Delta Diversions) on the groundwater resources in the South American Subbasin without modification of the physical representation (i.e. no changes in the boundary or flux representation) of the CVHM-D model. As explained later, I only modified the convergence criterion for the numerical solution to investigate the reliability of the simulated results. Using the CVHM-D model without modification, I evaluated potential impacts on stream leakage along the Sacramento River.

BACKGROUND

7. In my testimony submitted on August 31, 2016, as part of the Sacramento County Water Agency's case in chief, I concluded that the available groundwater models are not suitable in their current form to evaluate the general water balance, in particular stream leakage, for the Sacramento river downstream of the CWF diversion with respect to the potential impacts of the CWF on groundwater and stream/aquifer interactions. (See SCWA-50 and SCWA-51.) In response to Petitioners' rebuttal testimony, this surrebuttal testimony describes the detailed analysis I performed on the CVHM-D model to evaluate its accuracy and therefore its suitability to assess potential impacts on stream/aquifer interactions and groundwater resources in the South American Subbasin. I also analyze the CVHM-D convergence criteria and water balance errors, and compare different alternatives and their impacts on groundwater pumping.

EVALUATION OF PETITIONERS' CVHM-D MODEL

8. To evaluate the reliability of the Petitioners' analysis of the potential impacts of the CWF on stream/aquifer interactions and on the groundwater resources in the South American Subbasin, I carefully analyzed the simulated results of the Petitioners' CVHM-D model. As stated in my previous testimony, the CVHM-D model was developed to simulate impacts of dewatering operations during CWF construction and would need refinements to accurately evaluate the impacts of the CWF on stream leakage and groundwater storage. Based on this knowledge, I analyzed the accuracy of the numerical solution of the CVHM-D model which directly affects the accuracy of the simulated results.

9. I've evaluated water budget convergence issues in CVHM-D and analyzed differences in the water budget and water use components in the NAA and Alt1B scenarios. The water budget is an overall accounting of the flows into and out of the system, which should balance if the numerical solution to the governing equations is accurate. Figures 1, 2, 3, and 4 show the most significant evidence in my analysis.

10. Figure 1 shows the percent rate discrepancy in the water budget at each stress period for CVHM-D NAA & Alt1B and CVHM NAA. This discrepancy is an indicator of how precisely the governing mathematical equations in the models were solved. As stated earlier, the water budget is an accounting of the flow of water into and out of the system, which should balance at each simulated time step. Generally, some amount of discrepancy between inflows and outflows occurs due to numerical tolerances and the rule of thumb is that simulations with flow rate discrepancies less than 1% are considered adequate. Simulations with discrepancies between inflows and outflows greater than 1% can indicate that the numerical solution failed to converge with enough precision and/or that other problems exist related to the model conceptualization or design and that the simulated results are not reliable. (Anderson, Woessner, and Hunt, 2015, Applied Groundwater Modeling, pp. 99-100 [Exh. SCWA-201]; Reilly, T.E., Harbaugh, A.W., 2004, Guidelines for evaluating ground-water flow models: U.S. Geological Survey Scientific Investigations Report 2004-5038, pp. 20-21 [Exh. SCWA-202]). As depicted in Figure 1, the CVHM-D NAA & Alt1B scenarios exceed the 1% budget error threshold 57% and 59% of the time, respectively, whereas the CVHM –NAA is always below the 1% threshold. Over half of the simulated results in the CVHM-D NAA & Alt1B models are associated with large budget errors and indicate unacceptably large inaccuracies in the simulated results. These inaccuracies can manifest in numerical anomalies, as described below. Furthermore, there is no guarantee that these numerical inaccuracies occur in a predictable or consistent way between model scenarios which makes comparative analysis between models problematic. Therefore, using the different scenarios only in a comparative way, as stated by Ms. Buchholz on cross examination (April 25, 2017, Vol. 36, 68:13-21), does not guarantee that the comparison provides correct and reliable results.

11. Figure 2 shows the differences in the water budget components as calculated by CVHM-D for the South American Subbasin. The net groundwater/surface water exchange seems consistently positive, which would suggest a decrease in stream leakage in the Alternative 1B scenario. Also, the net inter-subregional flow presents significant differences in how water will be exchanged between neighboring subbasins compared to the NAA scenario. More specifically, the South American Subbasin seems to be receiving significantly more water and/or delivering significantly less water from/to the surrounding regions under the Alt1B scenario.

12. Ms. Buchholz states that "groundwater adjacent to the Sacramento River between Intake 1 and Rio Vista would decline up to 5 feet." (DWR-80, 20:15-16.) During cross examination, Ms. Buchholz emphasized that the model revealed changes from zero to five feet. (April 25, 2017, Vol. 36, 60:12-14, 63:9). Based on the results shown in Figures 1 and 2, we analyzed the changes in South American Subbasin groundwater elevations in the two scenarios. Figure 3 graphically represents the maximum groundwater head (level) differences in all 10 CVHM-D model layers. The maximum head difference between the NAA and Alternative 1B is 13.4 m in January of 1969 (approx. 44 ft), which is much larger than the 5 foot maximum (approx. 1.5 m) stated in Ms. Buchholz's testimony. As shown in Figure 3, maximum head differences larger than 5ft occur 34 times throughout the simulation period. During cross-examination, Ms. Buchholz stated that the maximum head difference of up to 5 feet mentioned above was verified by checking the output files. (April 25, 2017, Vol. 36, 60:14-17].) Figure 4 presents a screenshot of the output files (obtained from the original CVHM-D files provided by the Petitioners) for the simulated heads for NAA and Alt1B and the location that corresponds to the maximum difference has been highlighted. Figure 5 shows where the maximum head difference is happening along the Sacramento River, downstream of the NDD.

13. I question whether the modeled changes in groundwater levels of 0-5 feet are even reliable given the head closure criterion used in the CVHM-D model. The numerical precision for the groundwater head solution in the CVHM-D model is set to 1 m. This means that any purported change in level of less than 1m is unreliable because the model considers the solution adequate once groundwater level changes are within +/-1m. Therefore, the differences that Ms. Buchholz cites are within the noise of the model and thus have questionable reliability. The rule of thumb is to use a head closure criterion that is one order of magnitude smaller than the desired level of accuracy (McDonald and Harbaugh, 1988, pp. 2-23, A modular three-dimensional finite-difference ground-water flow model. Techniques of Water-Resources Investigations, Book 6. U.S. Geological Survey [Exh. SCWA-203].) Based on this rule of thumb, the criterion should have been set at approximately 0.1 m. As a comparison, the regional CVHM model used a head closure criterion of 0.3 m.

14. The substantial number of budget errors exceeding the standard threshold of 1% (See Figure 1) and the large head differences in 1969 and 1998 (See Figure 3) indicate numerical instabilities in the model and call into question the reliability of the simulated results. Based on these results and on the budget discrepancies, it is my opinion that some numerical anomalies occur in the model simulation. Therefore, I checked the closure criteria (precision to which the CVHM-D model is simulated) used for heads and river discharge, which can cause the budget convergence issues mentioned above.

15. In the CVHM model, the closure criteria are set at 0.3 m for heads and at 100 m for the stream depth (DLEAK). In the CVHM-D model, the closure criterion for heads was increased to 1 m which decreases the accuracy of the solution, despite using a refined grid. From the MODFLOW manual, DLEAK is "a real value equal to the tolerance level for stream depth used in computing leakage between each stream reach and active model cell. Value is in units of length. Usually a value of 0.0001 is sufficient when units of feet or meters are used in model." (Prudic, D.E., Konikow, L.F., and Banta, E.R., 2004, A new streamflow-routing (SFR1) package to simulate stream aquifer interaction with MODFLOW-2000: U.S. Geological Survey Open-File Report 2004-1042, pp. 40-41 [Exh. SCWA-204].) Note that the value used in the CVHM-D model is much larger than what is recommended, which can compromise the fidelity with which the model can simulate stream/aquifer interactions.

16. Considering my original testimony highlighted the need to better understand the impacts of stream/aquifer interactions on the South American Subbasin due to the changes in the streamflows in the Sacramento River, I performed a comparison of the NAA and alternative 1B results with DLEAK=25.

17. Figure 6 a and b show the difference in the water budget in the South American Subbasin between CVHM-D Alt 1B with DLEAK=100 and CVHM-D Alt 1B with DLEAK=25 and between CVHM-D NAA with DLEAK=100 and CVHM-D NAA with DLEAK=25. If the value of DLEAK of 100 were sufficiently small to lead to a numerically precise solution, then decreasing DLEAK to 25 would produce only minor changes in the simulated results. Instead, Figure 6 a and b show that the volume of water exchanged between groundwater and surface water is significantly affected by changing the DLEAK coefficient. For example, the difference in stream/aquifer interaction is over 30,000 acre-ft in 1998 just by changing the precision of the model for representing streamflows. This indicates that the simulated results have a large amount of noise and even their use in a comparative analysis is questionable.

18. In her rebuttal testimony, Ms. Buchholz states:

> It should be noted that Figure 7-14 provides results for operations of Intakes 1 through 5 under Alternative 1B. However, the results would be similar under the proposed Alternative 4A as can be determined by comparing the minimum Sacramento River flows under Alternatives 1 and 4A. As shown in Appendix 5A, Section C of the BDCP/CWF EIR/EIS, changes in Sacramento River monthly flows downstream of the North Delta Diversions as compared to the No Action Alternative are similar for the evaluation of Alternative 1B and Alternative 4A (see Tables C-21-14 and C-60-6, respectively). (DWR-80, p. 20:19-26.)

19. On cross-examination, Ms. Buchholz stated that it was appropriate to conclude that groundwater level changes would be the same under Alternative 4A and 1B because water levels downstream of the North Delta Diversions are similar and that the only variable that changes between the NAA and action alternatives is Sacramento River flow. (April 25, 2017, Vol. 36, 64:7-10.) When asked whether water use and the source of that water use in the South American Subbasin are the same in Alternative 1B and 4A, Ms. Buchholz responded that such use is the same in all of the CVHM-D alternatives. (April 25, 2017, Vol. 36, 65:13-14.)

20. In response, I evaluated Alternative 1C and Alternative 1B, and noted differences in agricultural groundwater pumping. (I used Alternative 1C to demonstrate the differences between models because it is my understanding that Petitioners have not modeled potential groundwater impacts associated with Alternative 4A operations. [April 25, 2017, Vol. 36, 74:14-25—75:1-8].) I agree that the municipal pumping does not change in the different CWF alternatives, but the agricultural pumping is internally calculated by the model and it depends on the flow in the entire system. Figure 7 shows the comparison between the agricultural pumping estimated by Alternative 1C and Alternative 1B for the agricultural pumping estimated by the two alternatives for the South American Subbasin. The model calculates the agricultural pumping as a function of landuse, availability of surface water, soil moisture and other factors, and therefore the estimated pumping can be different for each scenario and strongly connected to the other terms of the water budget, such as stream leakage and interbasin flow.

IMPACT ON RIVER/AQUIFER INTERACTION IN THE SACRAMENTO RIVER

21. Ms. Buchholz states that "[o]verall, based on information prepared for Zone 40 groundwater conditions and results from groundwater monitoring presented in the BDCP/CWF EIR/EIS, it does not appear that operations of the North Delta Diversions would substantially affect groundwater recharge in Zone 40." (DWR-80, 20:27-28 -- 21:1-2.) Ms. Buchholz, however, acknowledges that "groundwater in the groundwater basin that includes Zone 40 is recharged from rivers (Cosumnes, American, and Sacramento rivers)." (DWR-80, 19:14-16.) Thus, a change in stream/aquifer interaction between these rivers and the South American Subbasin has the potential to adversely impact Zone 40.

22. I extracted stream leakages from the CVHM-D NAA and Alternative 1B budgets and compared the two to understand the impact of the CWF on stream leakage in the Sacramento River. Given the modeling inaccuracies cited previously, I consider this a qualitative assessment. As shown in Figure 2, the water exchanged with the neighboring basins is affected by the different scenarios. Figure 8a represents the cumulative difference in stream leakage from the Sacramento River along the entire length adjacent to the South American Subbasin, and Figure 8b just the length downstream of the last intake of the North Delta Diversion. Of note are the large

cumulative differences, with most of this occurring downstream of the North Delta Diversion. The positive cumulative difference combined with mostly negative leakage (gaining stream) along this portion of the Sacramento River indicates the Alt1B scenario has more water draining from the aquifer into the Sacramento River than the NAA. Again, this should only be considered a qualitative analysis. To draw more quantitative conclusions on the impact, it is necessary to refine the model such that numerical anomalies in the model that I demonstrated above are mitigated.

CONCLUSION

23. As stated in my previous testimony, the CVHM-D model requires refinements such that it is suitable for analyzing potential CWF impacts on stream/aquifer interactions. The numerical precision of the model is insufficient to accurately assess impacts on stream/aquifer interactions and groundwater resources because: 1) large water budget errors, indicating that the simulated results are internally inconsistent by not balancing inflows with outflows, 2) large differences in heads (over 40 feet, which is much larger than the maximum difference stated by Ms. Buchholz), and 3) large differences in stream leakage when changing the DLEAK value which controls the precision of the simulated stream flows. The simulated results using the CVHM-D models have a large amount of noise within each model that is unpredictable. This makes comparative analyses between model scenarios problematic because the model does not have the fidelity to separate what is an actual difference versus a numerical artifact (i.e., poor signal to noise ratio). Nevertheless, even with these anomalies, a qualitative analysis of stream leakage effects using Alternative 1B shows a potential adverse effect on stream leakage to the South American Subbasin during CWF operations. It is possible that this significant cumulative change in stream leakage could adversely affect Zone 40 groundwater resources.

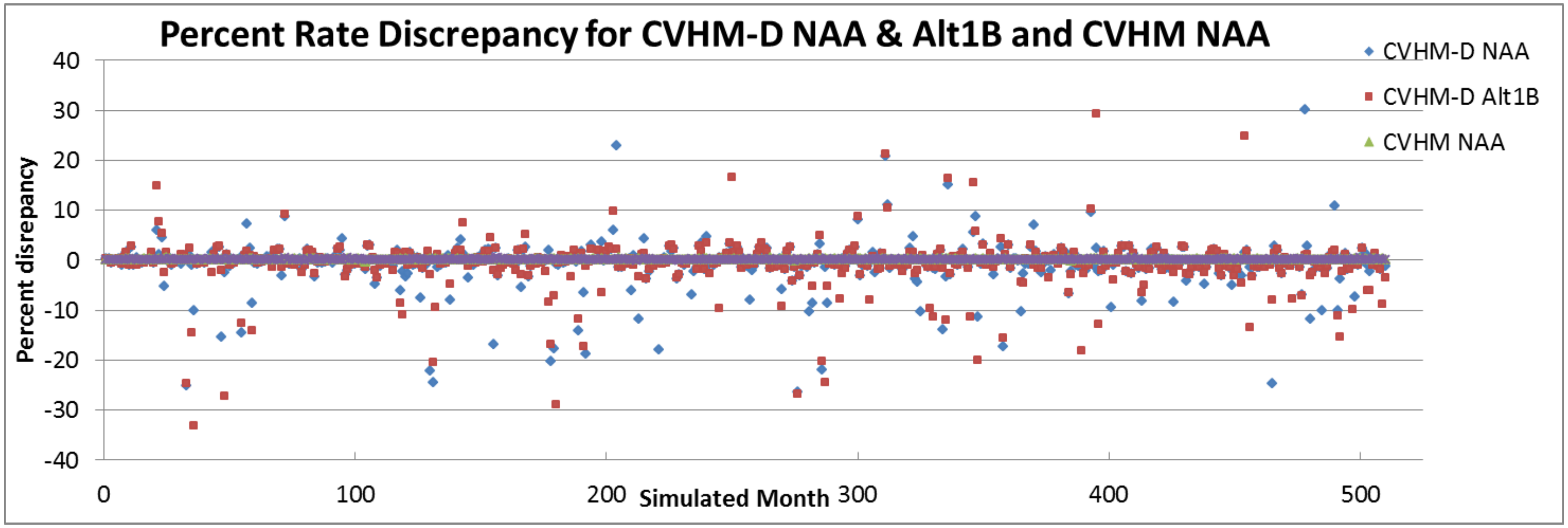


Figure 1: Water budget errors for each simulated month from the main MODFLOW output file (the listing file) for CVHM-D NAA, CVHM-D Alt 1B, and CVHM NAA.

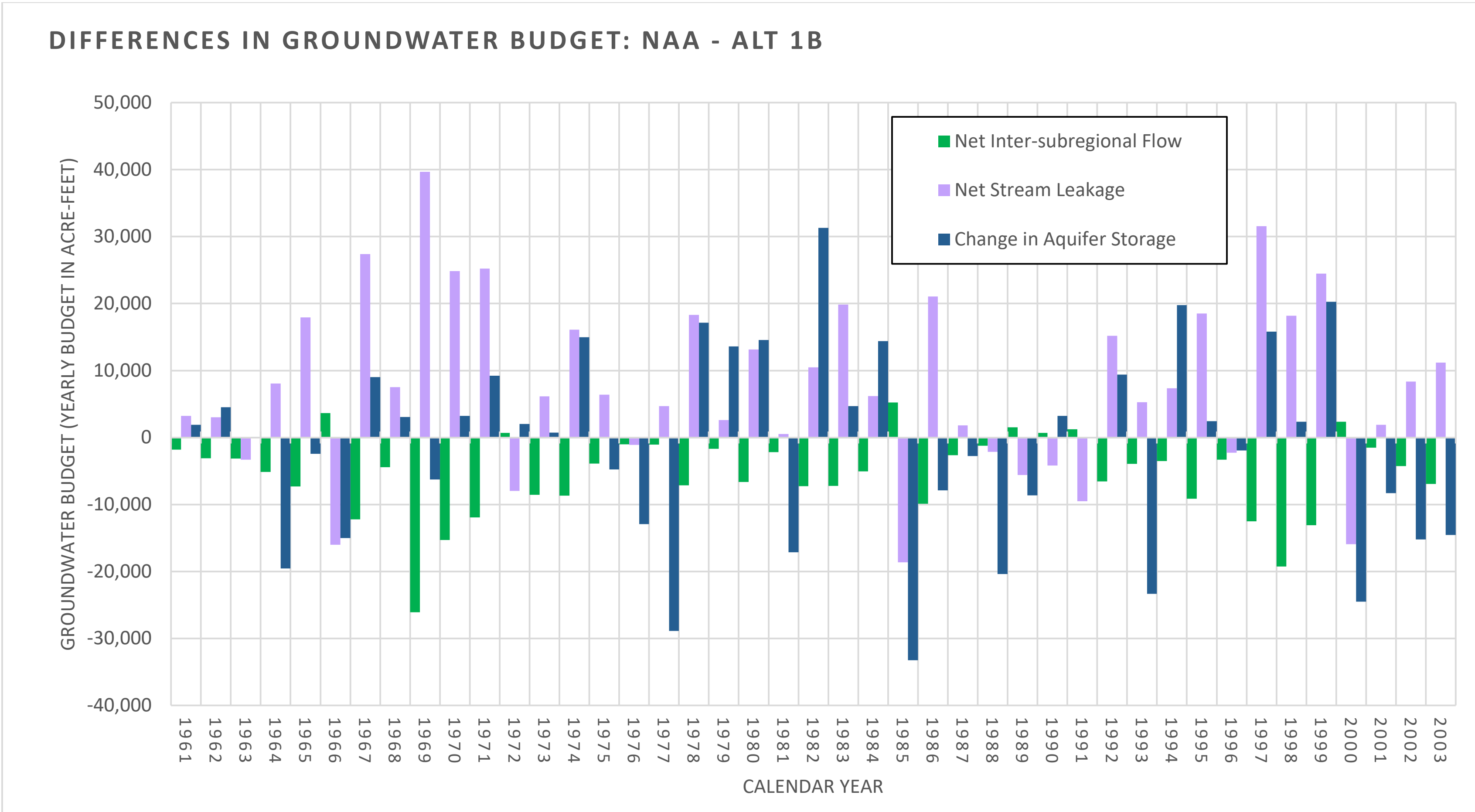


Figure 2: Comparison of the water budget components in the No Action Alternative (NAA) and the Alternative 1B scenarios within the South American Subbasin.

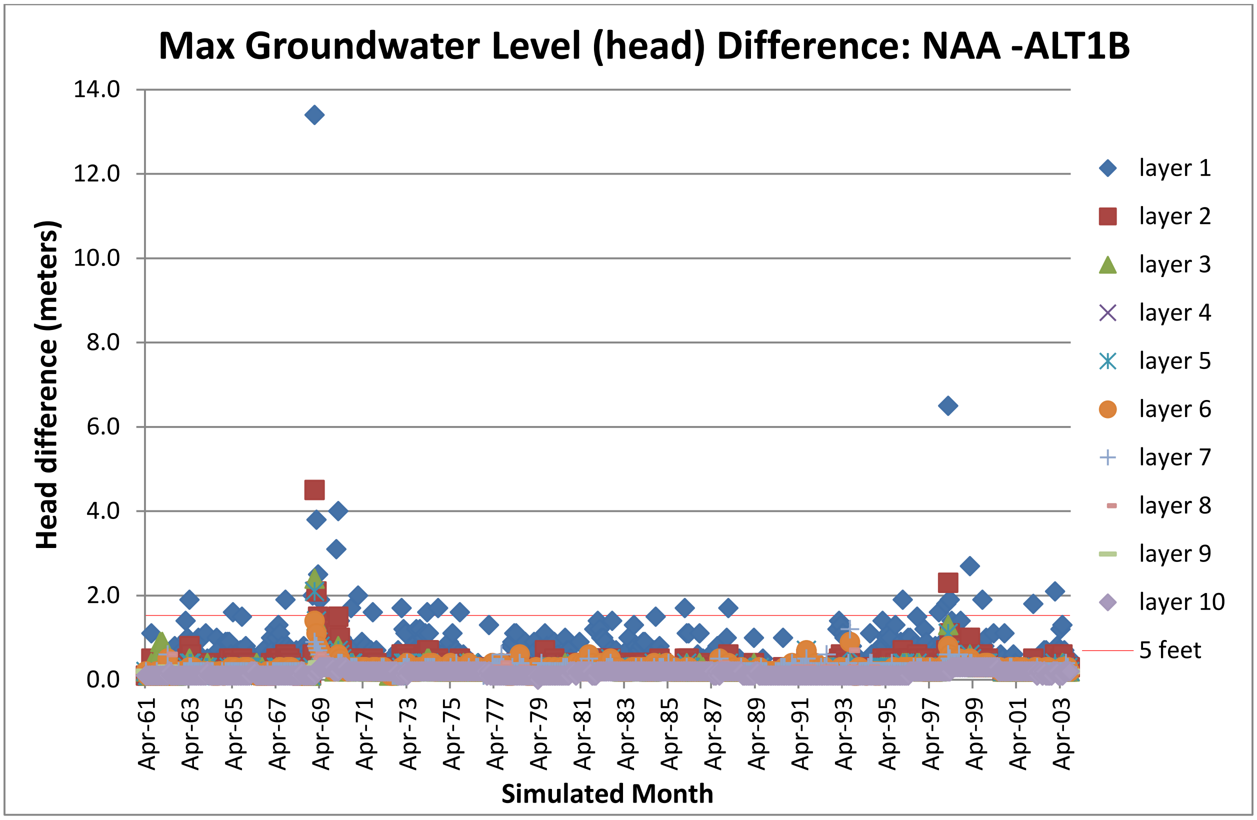
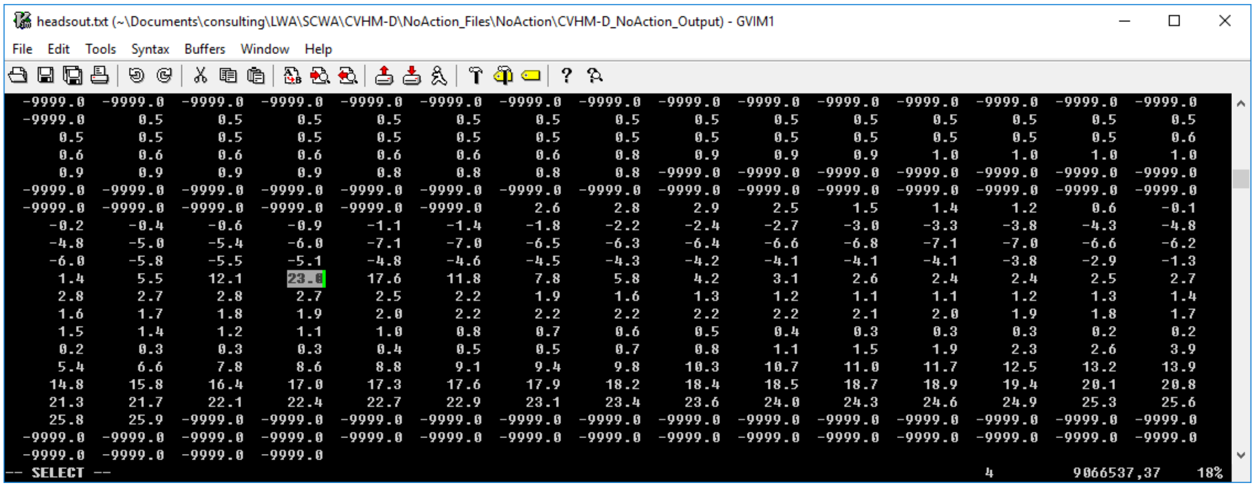


Figure 3: Using the CVHM-D model: max difference in hydraulic head between the No Action Alternative (NAA) and the Alternative 1B scenarios in the South American Subbasin



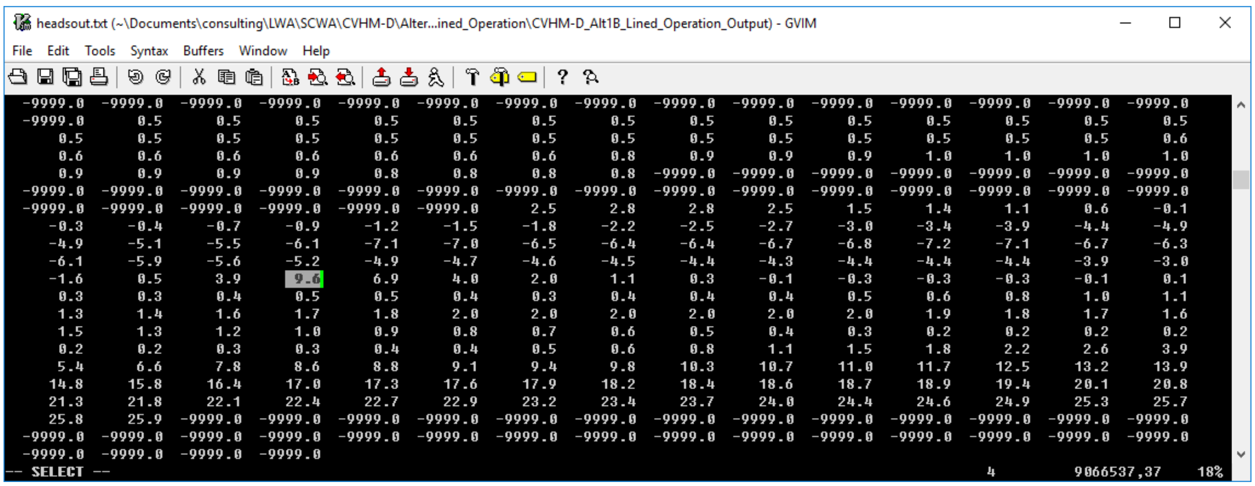


Figure 4: Screenshots of CVHM-D output files for NAA and Alternative 1B. Highlighted numbers represent the groundwater level in the same location in the two different scenarios. The difference corresponds to the 13.4 m mentioned above.

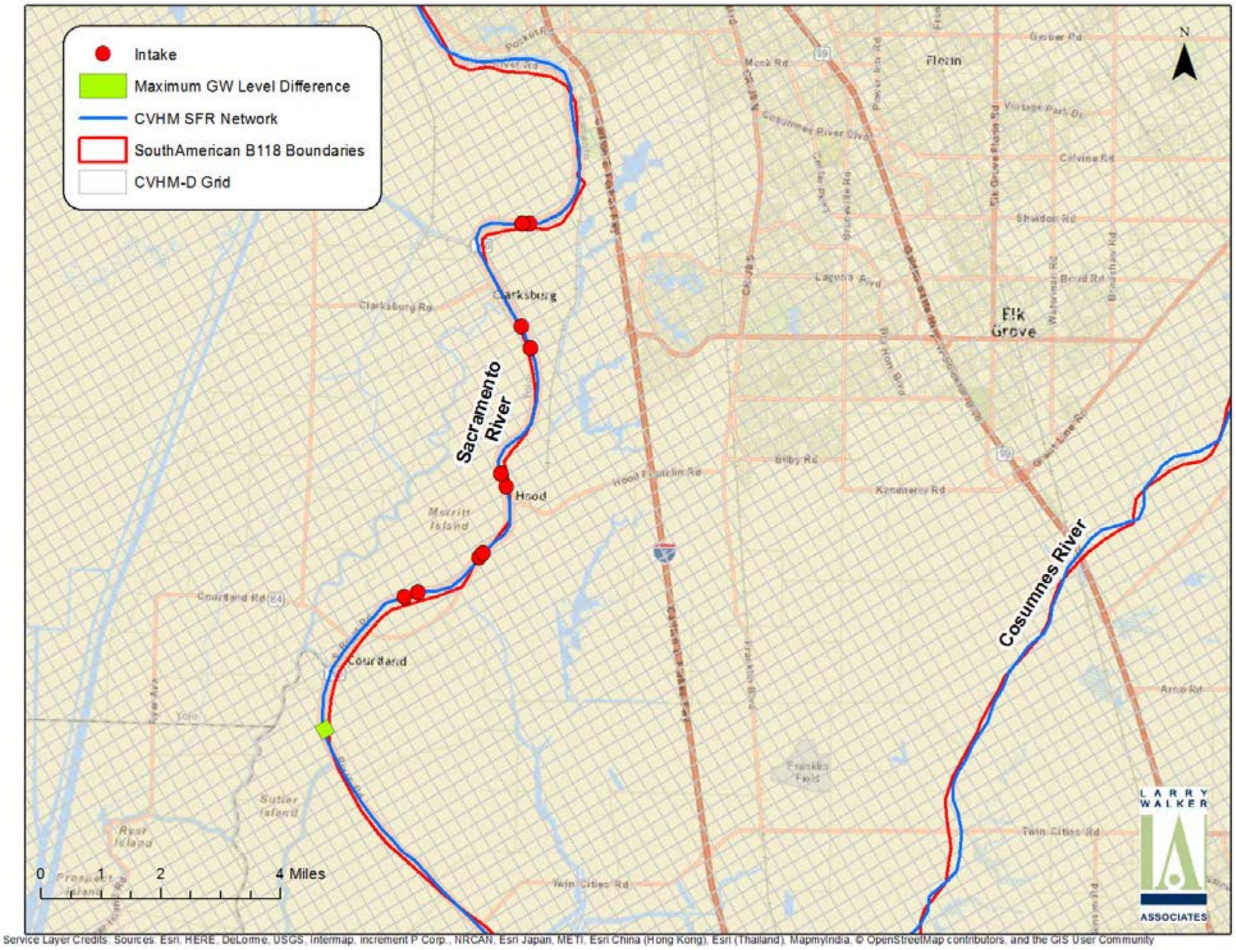


Figure 5: Location of maximum difference in groundwater levels between CVHM-D NAA and Alt1B simulations shown as a green square. Red circles show the NDD intakes.

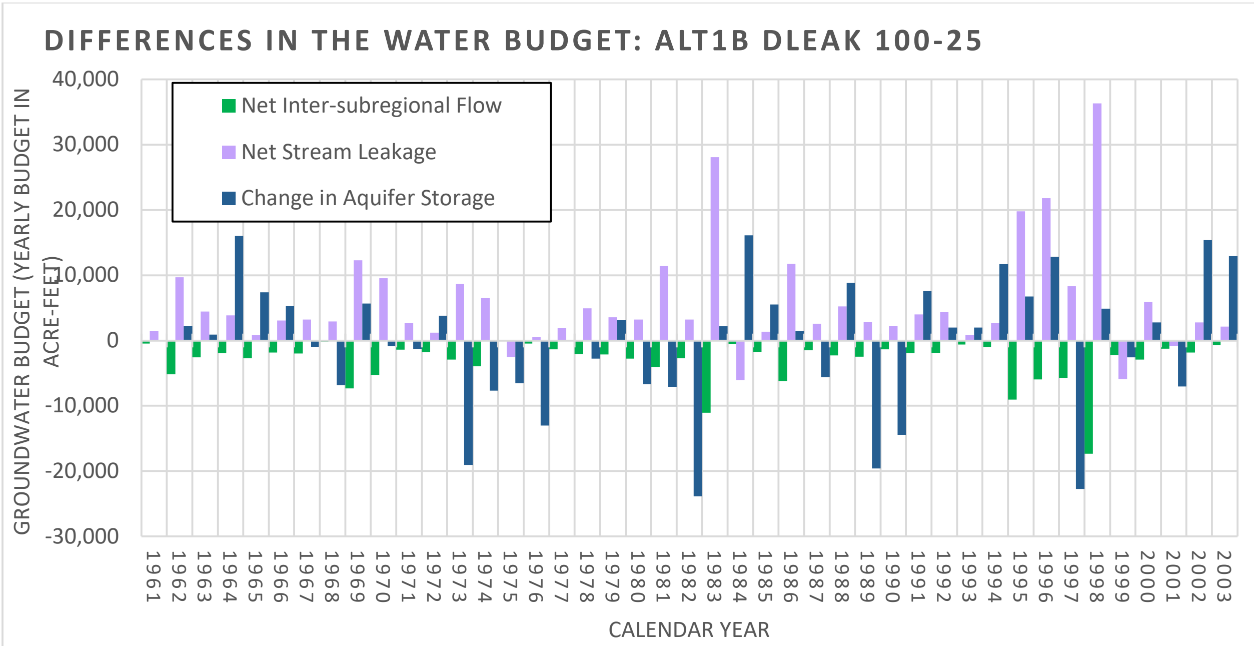


Figure 6 a: Using the CVHM-D model: comparison in water use components obtained with the CVHM-D model with DLEAK = 100 and DLEAK = 25 for the NAA. The budget components are calculated for the South American Subbasin.

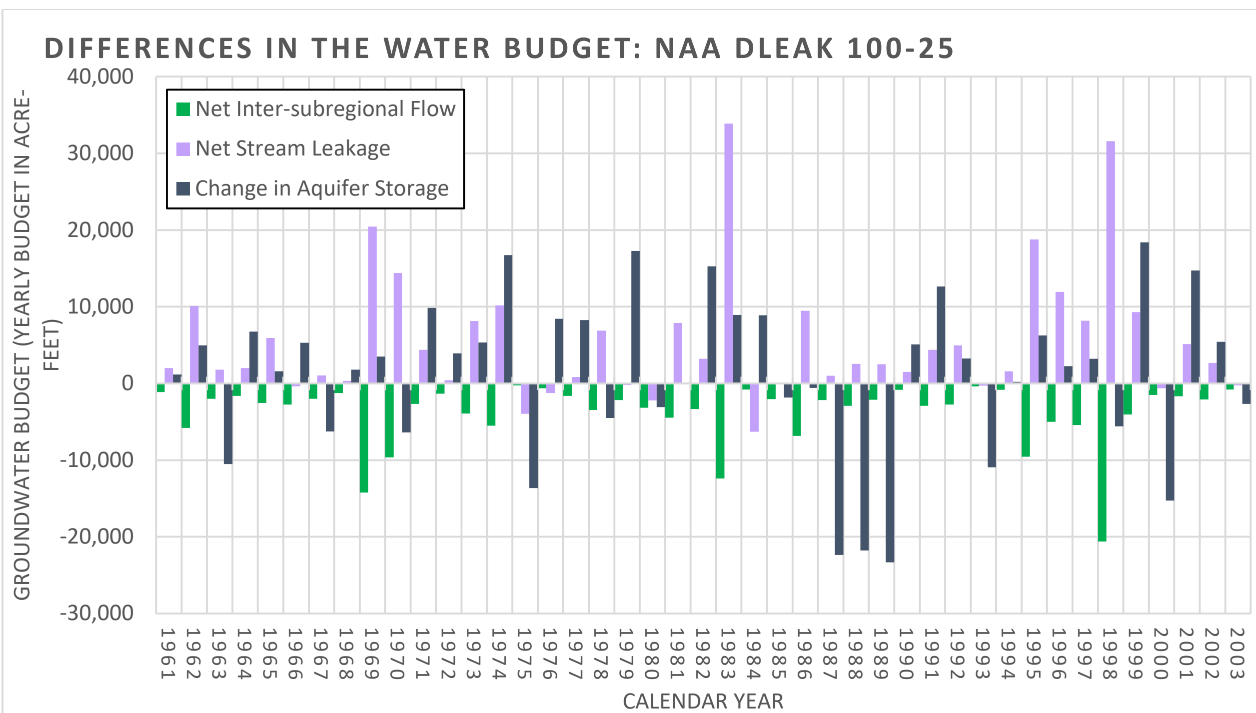


Figure 6 b: Using the CVHM-D model: comparison in water use components obtained with the CVHM-D model with DLEAK = 100 and DLEAK = 25 for the Alternative 1B scenario. The budget components are calculated for the South American Subbasin.

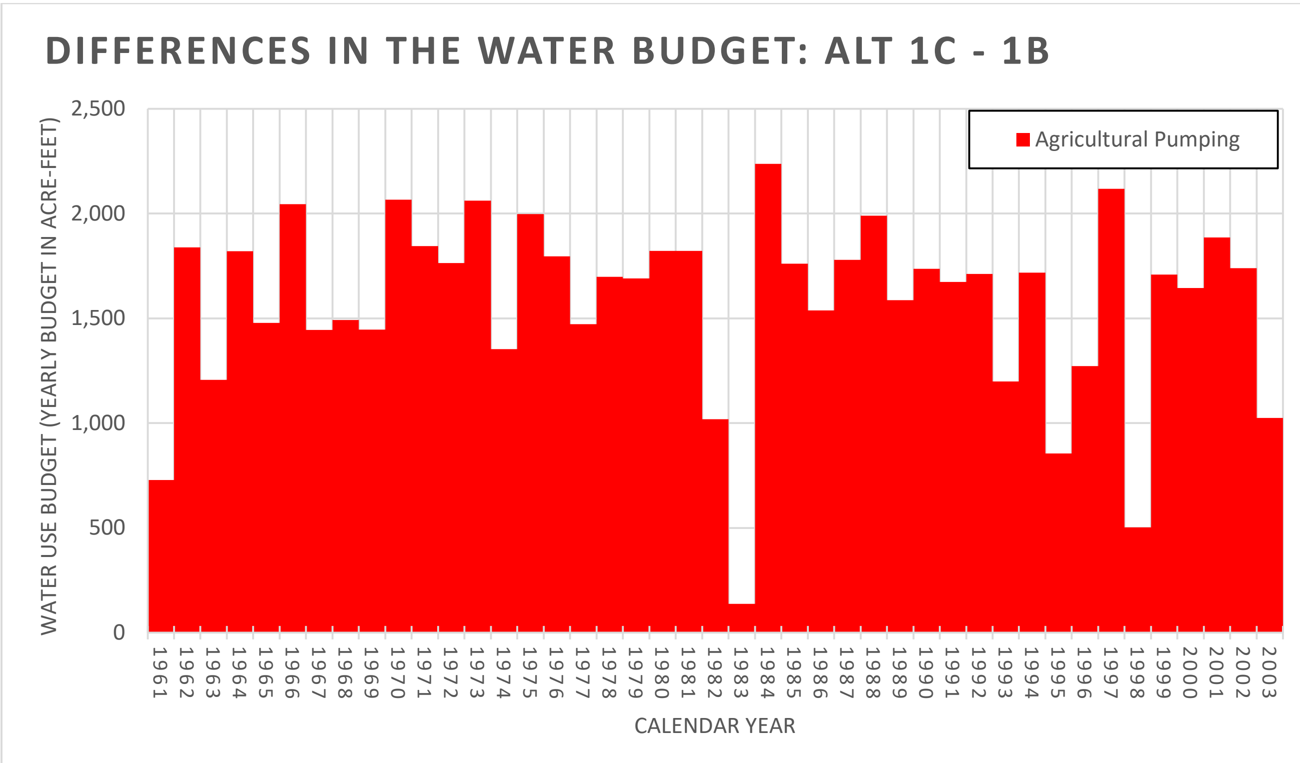


Figure 7: Comparison in the estimated agricultural pumping using Alternative 1C and Alternative 1B for the South American Subbasin.

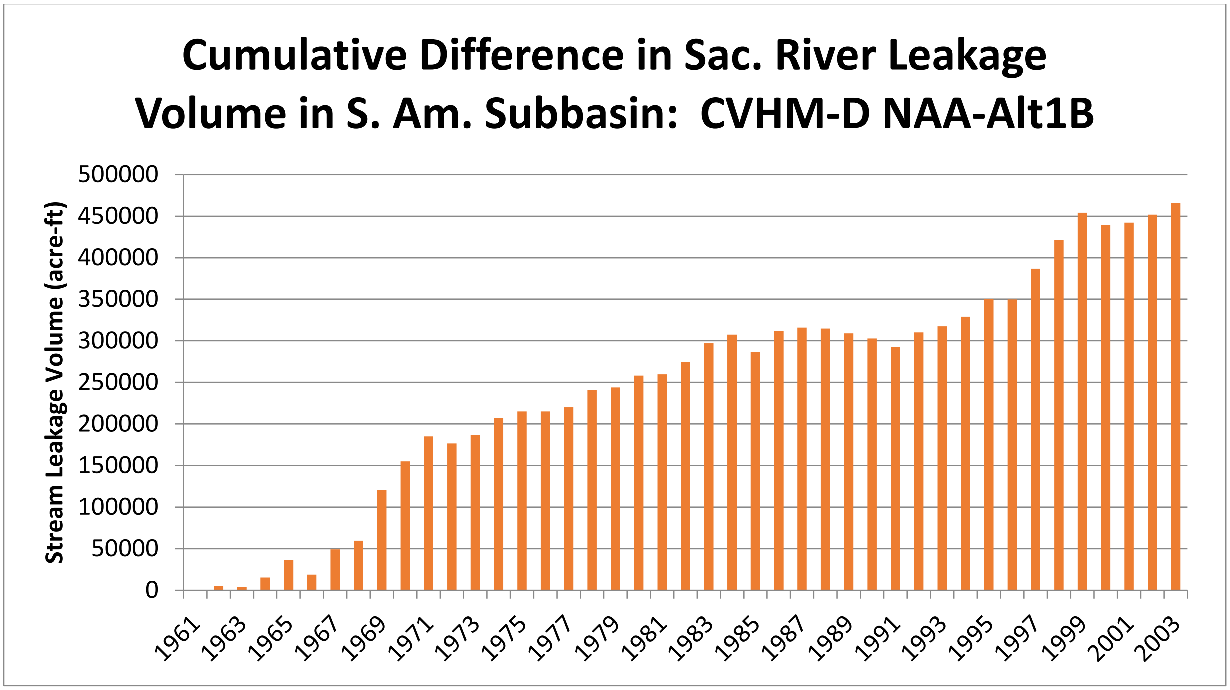


Figure 8 a) Cumulative difference in the volume of the Sacramento River leakage between CVHM-D NAA and CVHM-D Alt1B.

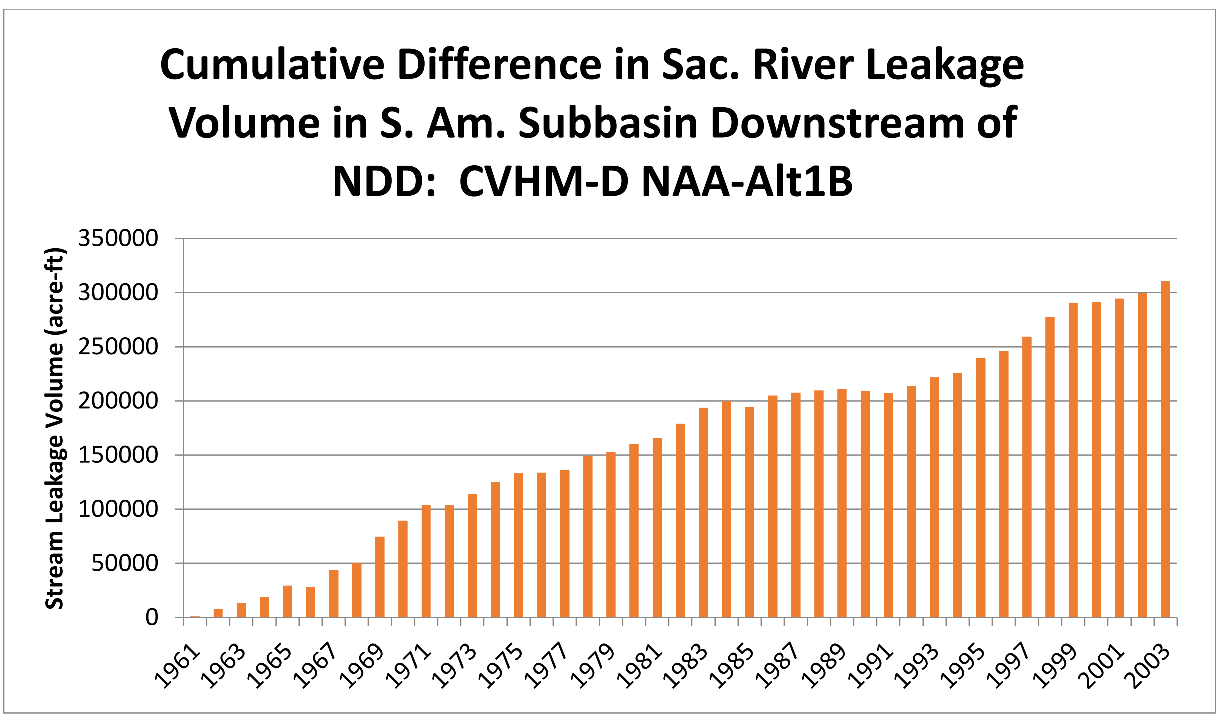


Figure 8 b) Cumulative difference in the volume of the Sacramento River leakage between CVHM-D NAA and CVHM-D Alt1B only in the portion of the Sacramento river downstream of the NDD.