Closure to "Optimal Operation of Multireservoir Systems: State-of-the-Art Review" by John W. Labadie

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The discusser presents a convincing argument that this state-of-the-art review should have given more attention to analytical optimization methods for multireservoir systems. However, the fact remains that these methods are primarily relegated to academic (albeit interesting) exercises. We can certainly gain useful insights into reservoir operations by employing analytical approaches, but the complexity and highly regulated nature of most real-world multireservoir systems tends to thwart their practical application. It is the imposition of complex constraints and regulations that conflict with the use of these methods, and I am unaware of any real-world system where these techniques are being applied.

The discusser criticizes this state-of-the-art review for not including other management options, while referencing examples of papers he believes should have been included in the review. The scope of this review was clearly stated as focusing on management and operations for multireservoir systems; whereas, the papers cited by the discusser include topics such as policy analysis, capital investment, and infrastructure improvement. These are certainly important issues, but are beyond the intended scope of the original paper. I would agree that studies dealing with conjunctive use of surface and groundwater could have been included, but many of these, such as the cited article by Cai et al. (2003), use simplified "tank models" for groundwater basins, which means they can be treated in the optimization much like another type of reservoir. In this case, the studies included in the review would certainly be applicable.

I agree with the discusser that dramatic advances in computer technology have allowed a greater degree of realism in reservoir system optimization, a point that was actually emphasized in the review. However, does this mean that computational efficiency is no longer a concern in reservoir system optimization? I think not! The "curse of dimensionality" associated with the application of dynamic programming, although abated somewhat, remains a daunting challenge. Solution of large-scale integer and mixed integer programming problems is still difficult, in spite of the remarkable improvements in computer hardware and the algorithms that we devise to run on them. Real-time control of reservoir systems provides an additional stress on computational efficiency by imposing clock-time restrictions. Combining simulation and optimization can also be computationally formidable, particularly when attempting to embed fully dynamic, unsteady flow hydraulic simulation models in the system optimization. The discusser's contention that computational limits have receded "… faster than increasing demands for greater model complexity…" is an interesting observation, but likely unsupportable.

Certainly, a major hypothesis of this review was that the optimal coordinated operation of reservoir systems is better than operating projects independently. The discusser disagrees with this, and cites one of his own studies as an example. However, I take issue with the statement that "there are occasions where fairly complex multireservoir basins have been found to operate as well, or perhaps even better, without coordination." First, the notion that reducing flexibility and coordination in reservoir operations can actually improve performance is certainly counterintuitive, and I would challenge the discusser to find studies other than his own that would support this assertion. I would agree that disaggregating a multireservoir system into subsystems might indeed reveal that certain subsystems separated by long distances would require little coordination. This is a far cry, however, from the claim that uncoordinated operations can be as good as or better than fully integrated management. Exploring the cited study (Needham et al. 2000) offered as proof of this contention reveals that coordinated solutions were indeed better than the uncoordinated solutions in all cases, except that improvement of the coordinated operations was only slightly better in certain instances. The authors then add the rather subjective performance measure of "easiest to implement" to support the assertion that the uncoordinated operations were better. However, solutions closest to the optimal coordinated solution still involved various levels of coordination among reservoirs included in the subsystems. One could take issue with the fact that this study employed piecewise linear penalty functions, with the assumption that minimizing total penalties produced the optimal operation. However, many of the penalties are arbitrarily specified, leaving one to wonder if different penalty structures and solution methodologies not relying on linearization of nonlinear system characteristics might have produced different results. I would offer one of my own studies (Shim et al. 2002) as a counterexample to the discusser's assertion.

I am in wholehearted agreement with the remaining points raised by the discusser in his discussion. Many of these are restatements of concepts that I attempted to elucidate in the review, but perhaps failed to communicate them as well as they could have been. I appreciate the discusser's unique insights on these issues.

References

Cai, X., McKinney, D., and Lasdon, L. (2003). "Integrated hydrologic-agronomic-economic model for river basin management." *J. Water Resour. Plan. Manage.*, 129(1), 4–17.

Needham, J., Watkins, D., Lund, J., and Nanda, S. (2000). "Linear programming for flood control on the Iowa and Des Moines Rivers." *J. Water Resour. Plan. Manage.*, 126(3), 118–127.

Shim, K.-C, Fontane, D., and Labadie, J. (2002). "Spatial decision support system for integrated river basin flood control." *J. Water Resour. Plan. Manage.*, 128(3), 190–201.