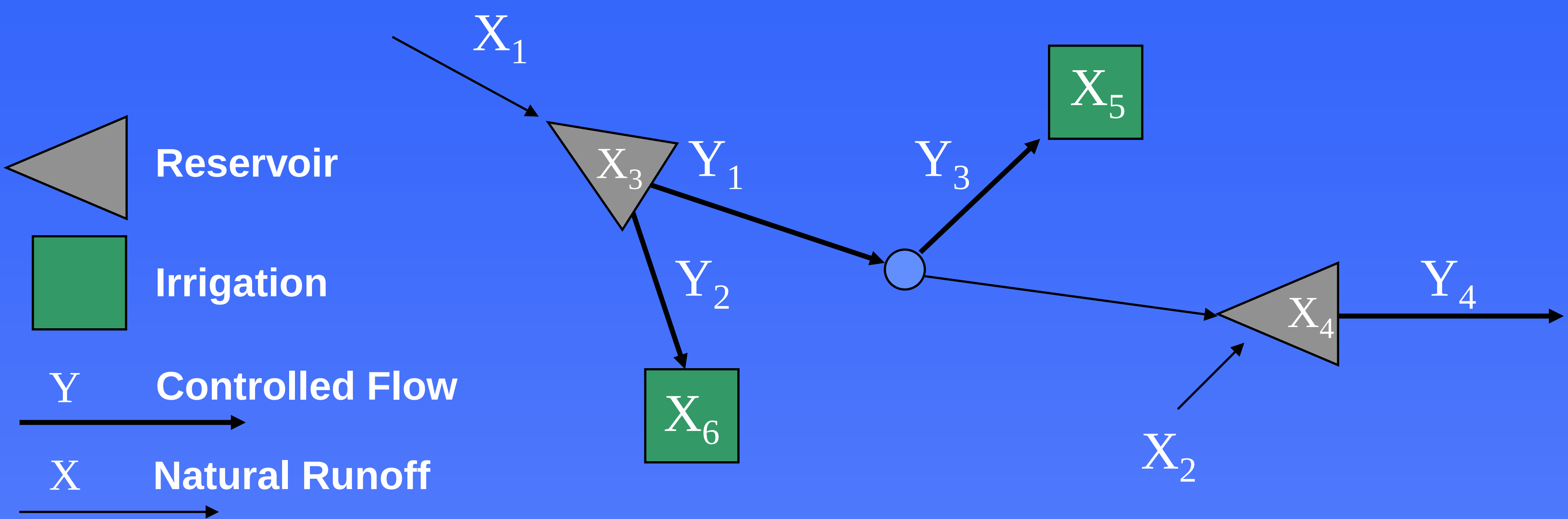
Conjunctive Optimization of Supply and Demand in River Basin Modeling

1. Introduction to Basin Management Models
2. Some Important Modeling Issues:
   - Current Modeling Practices
   - Simultaneous Optimization of Supply and Demand
   - Time Step Length
   - Need for agreement on minimum technical specifications and benchmarks
3. Conclusions and Recommendations

Introduction to Basin Management Models (BMM)



1. BMM simulate decision making process
2. BMM are either:
   - Rule Based (rely on the use of “if-else” rules);
   - Optimization Based, e.g. Maximize $\sum \sum Y_{i,t} P_i$

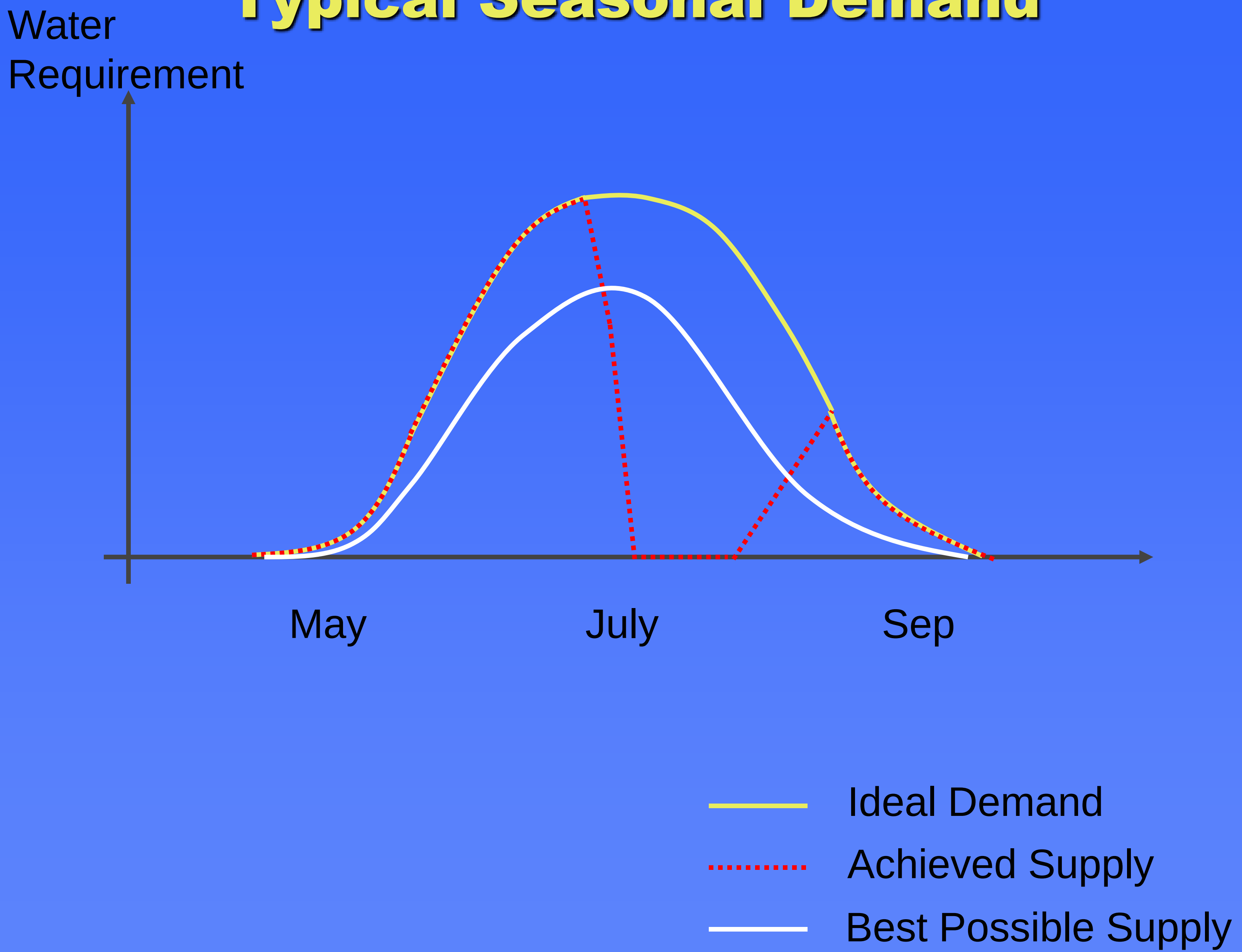
The Purpose and Typical Use of BMMs

The purpose of a BMM is to help us find the best operating regimes for various input scenarios

The use of BMM makes sense only if the obtained solution is better than the solution we would get using the rule of thumb (analogy with computer chess games)

The onus is on modelers to provide evidence that their model solutions are better than the rule of thumb

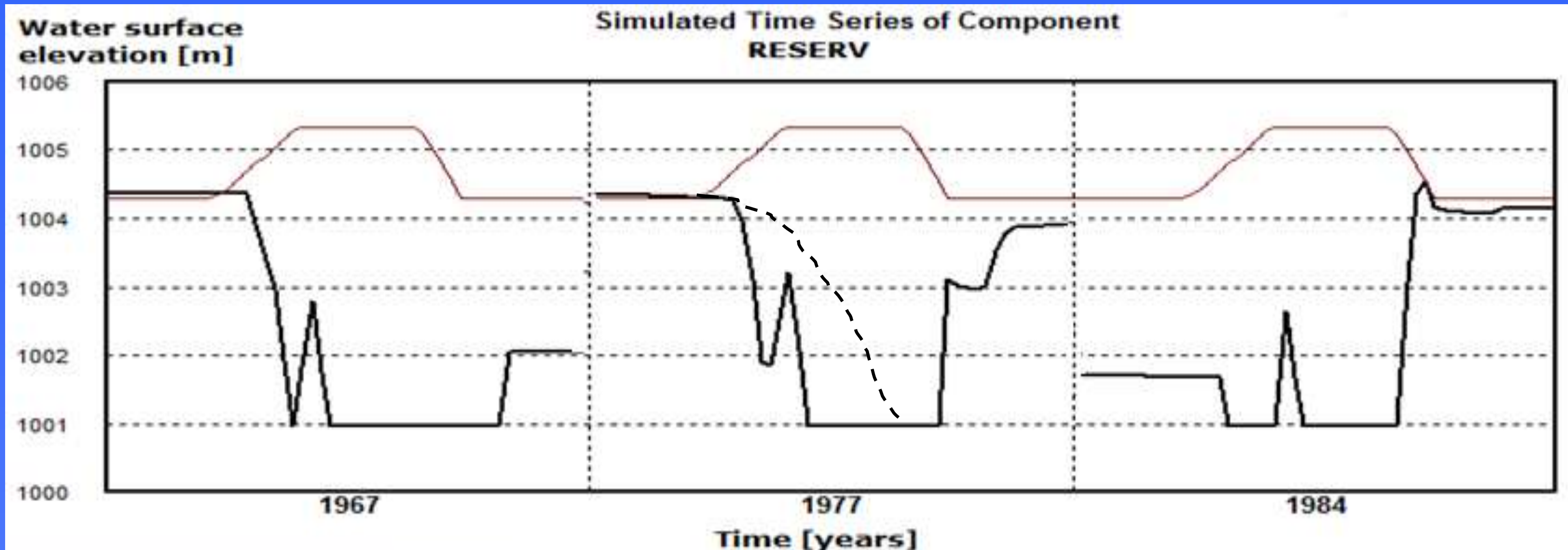
Typical Seasonal Demand

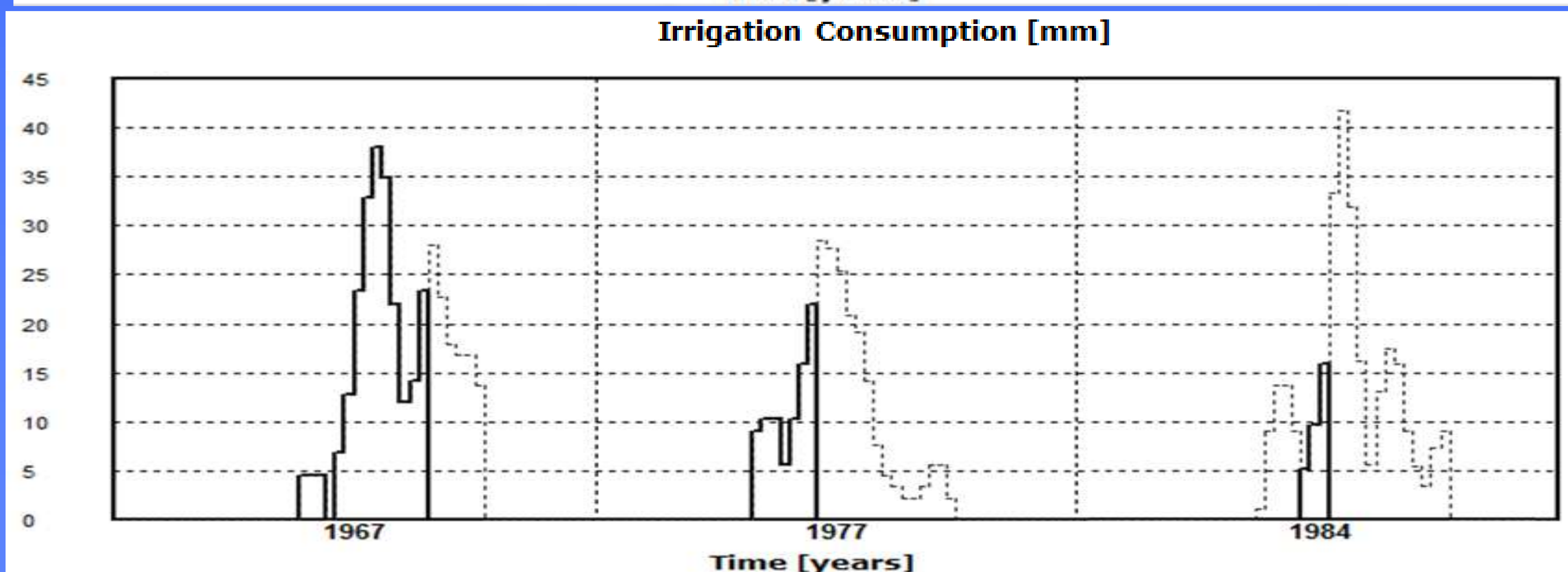


Current Modeling Practices

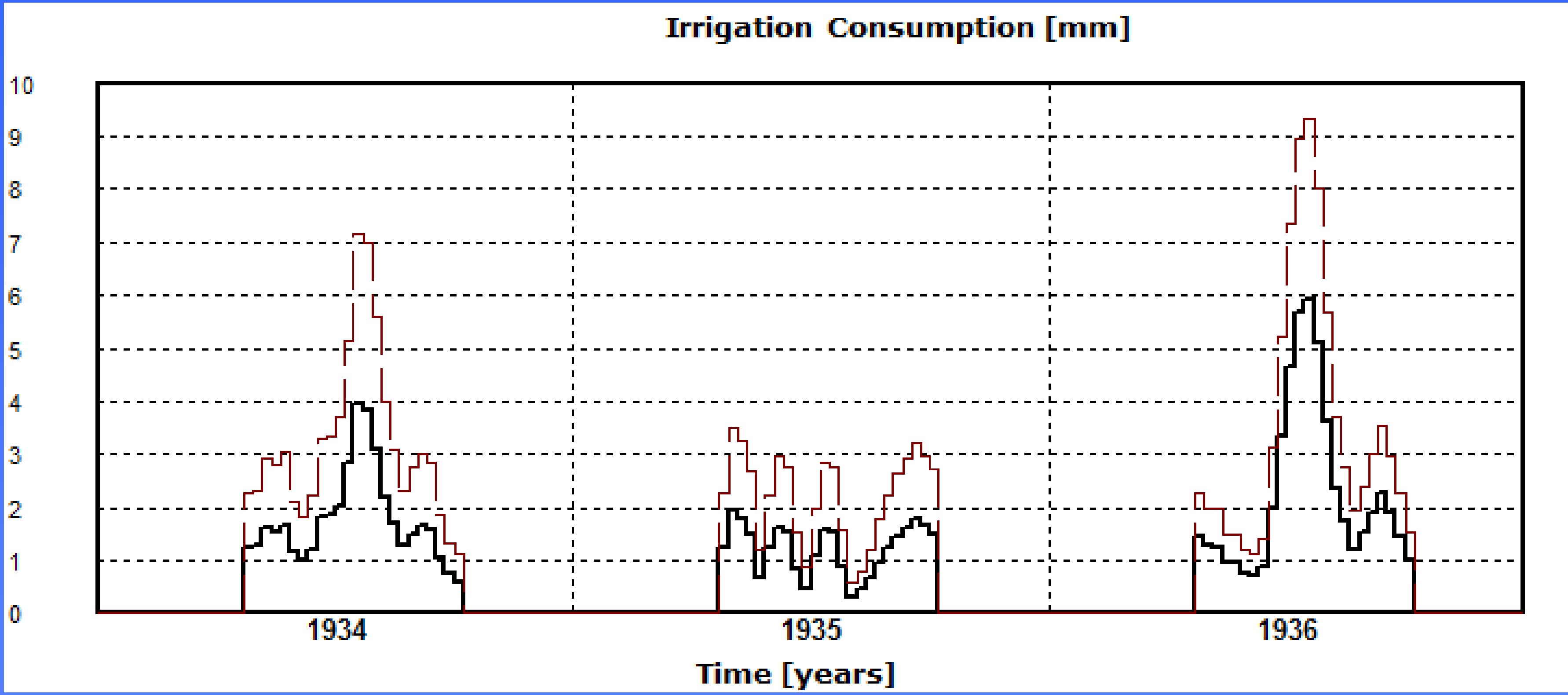
1. Reservoir operating rules are the same for every year, and they are arbitrarily defined by the modeler;
2. Model is typically run in single time step (STO) mode; and,
3. Water demands are based on full licenses (adjusted for precipitation) for each time step. There is no hedging of demands.

Modeling Results under STO Mode

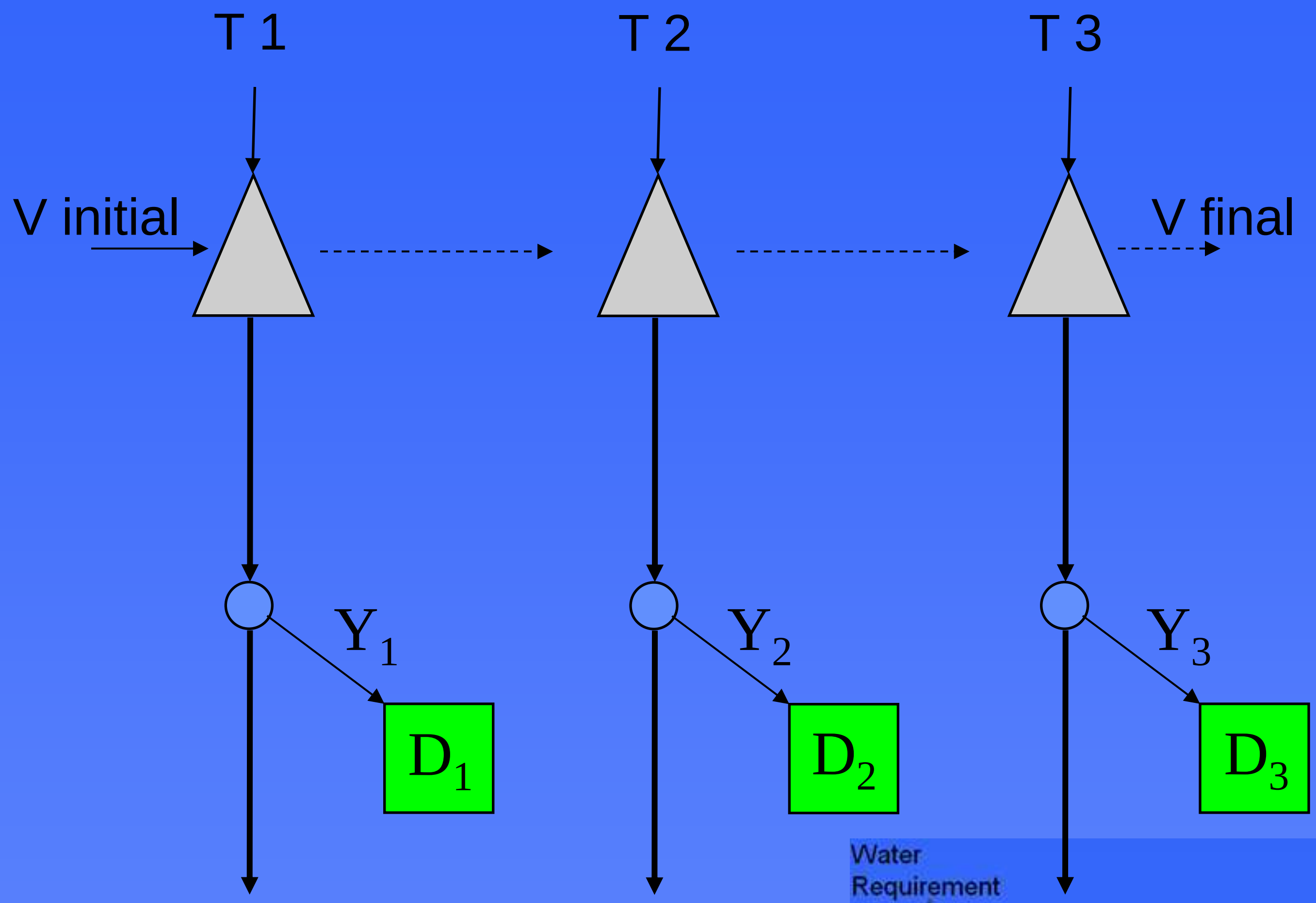




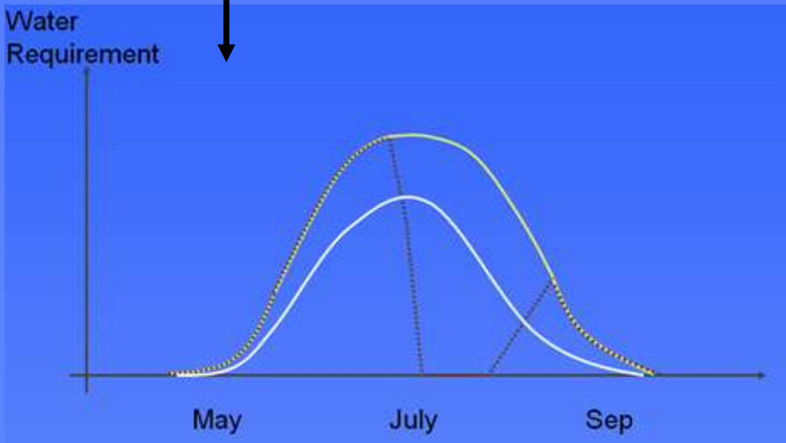
Modeling Results based on Demand Optimization



Multiple Time Step Optimization (MTO)



$$\frac{Y_t}{D_t} = \frac{Y_{t+1}}{D_{t+1}} \qquad for\ t = 0, n-1$$



Shortcomings of MTO

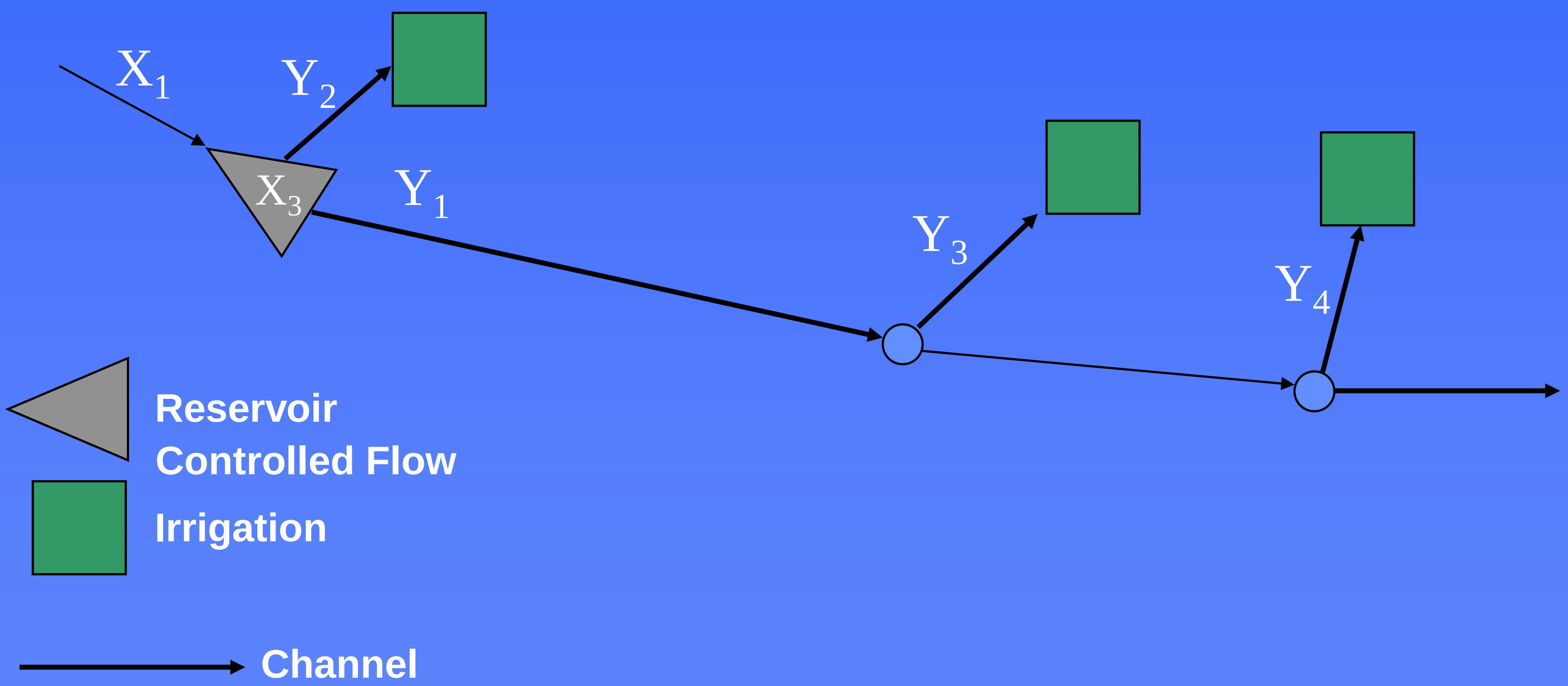
- Much larger solution networks with longer solution times;
- MTO runs are much more difficult to debug if something goes wrong; and,
- When used in combination with some constraints that require binary variables, the solution times may be prohibitive.

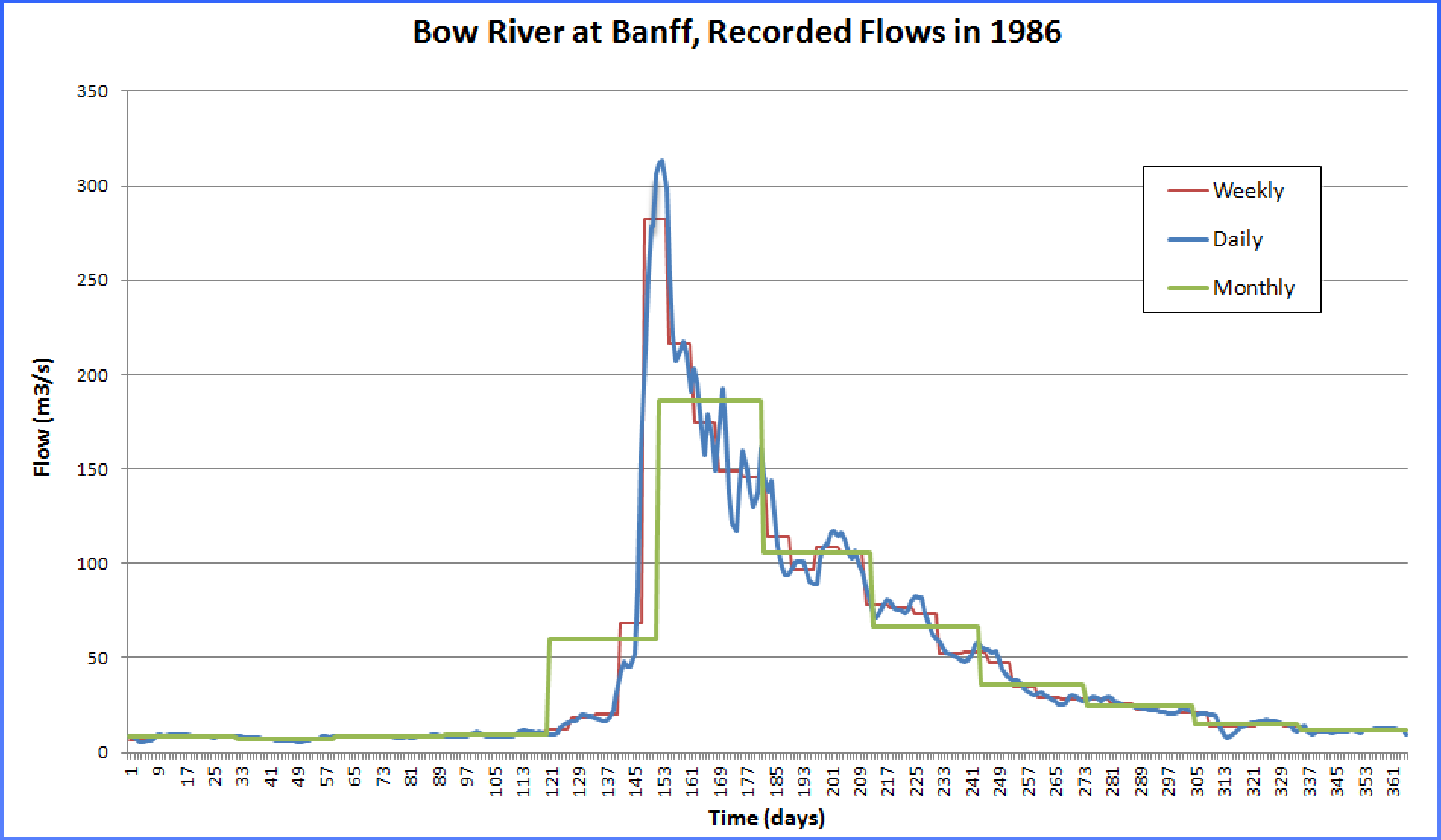
Benefits of MTO

- Solutions include perfect reservoir operating regime developed uniquely for each year by the model;
- Solutions include optimal demand reduction in dry years for all time steps within a year which is a better reflection of the actual management practices; and,
- Solutions over many years provide good basis for inferential development of seasonal operating rules

Time Step Length

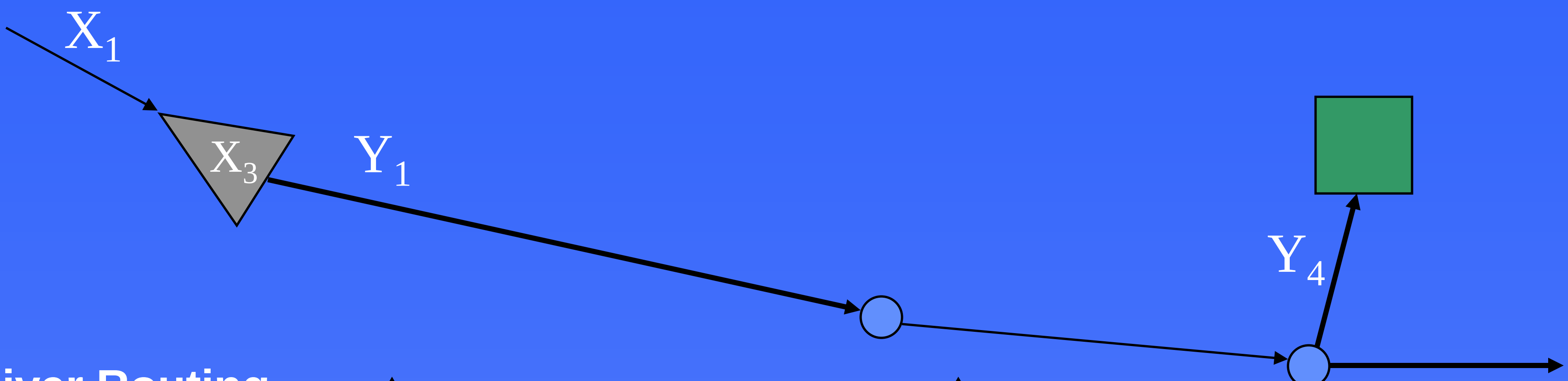
It is assumed that water can reach any user from the most upstream source within a time step. This restricts modeling of large basins to monthly time steps.



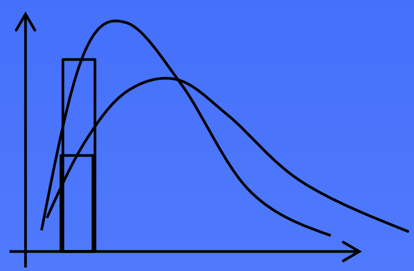


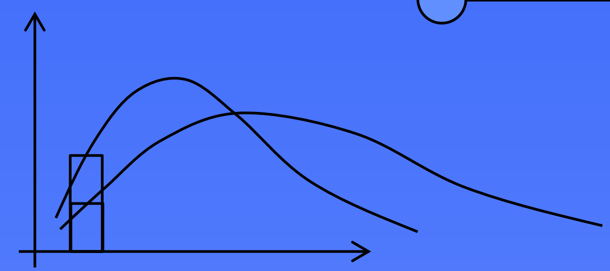
Monthly inflow hydrographs are much easier to manage. The same basins modeled with monthly and weekly time steps showed up to 28% difference in spills.

Problems with Channel Routing Constraints

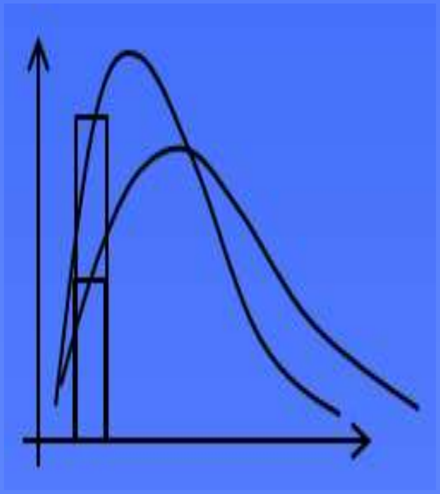


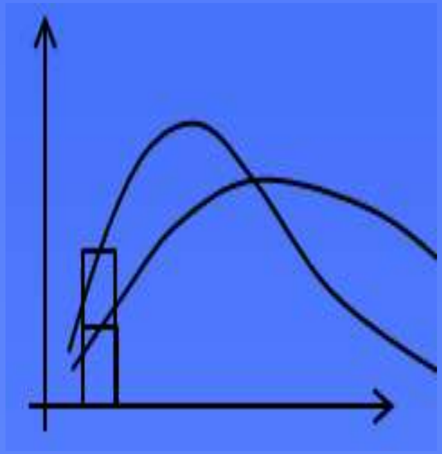
River Routing Effects under normal reservoir release:





River Routing Effects under increased reservoir release:





Time Step Length

Inclusion of hydrologic channel routing as a constraint to optimization requires daily time steps, which introduces problems:

- **model floods the river valley to reduce the downstream deficits[1];**
- **There is no published solution to this problem (which does not mean that there is no solution); and,**
- **Modeling of small (daily) time steps can be done by setting the storage outflow to a fixed user defined value, which turns off the powerful optimization engine that no longer drives the storage releases.**

[1]Ilich, N. 2008. Shortcomings of Linear Programming in Optimizing River Basin Allocation. Water Res. Research, Vol. 44.

Time Step Length

There should be guidelines on:

- establishing the proper time step length (not too long to avoid problem with the spills, not too short to avoid problems with routing);
- how to model time steps which are shorter than the total travel time through the basin; and,
- how to model hydrologic river routing within the optimization framework, can it be done within the LP framework and if so, how? The routing coefficients do change with significant flow variations over the year.

$$O_i = C_0 I_i + C_1 I_{i-1} + C_2 O_{i-1}$$

Min Tech. Specifications: List of Constraints

- Storage outlet structure
- Diversion at a weir
- Net Evaporation on Reservoirs
- Return flow channels
- Diversion license volume limit per year
- Apportionment volume limit per year
- Channel routing (?)
- Equal deficit constraints

Model Constraints

There should be guidelines on:

- Establishing which constraints are important and by how much they affect the quality of solutions if they are not modeled;
- How individual constraints should be formulated and included in the model; and,
- Problems with constraints should be formulated as benchmark tests and their solutions should be published such that every model vendor can verify their results by re-running the benchmarks.

Model Objectives

Objective Function: $\sum \sum Y_{i,t} P_i$

A universally accepted algorithm that determines suitable priority factors *Pi* for a given system based on:

a) Network configuration

b) Priorities

c) Constraints

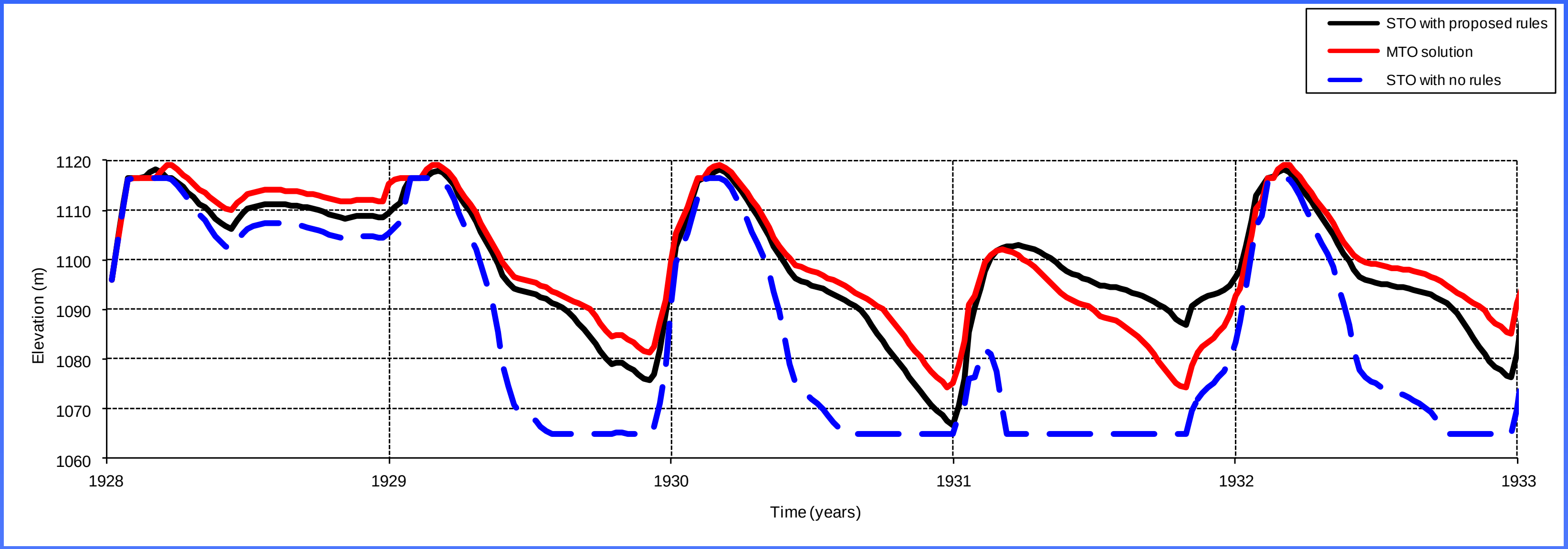
has yet to be devised. It would be useful to the practitioners.

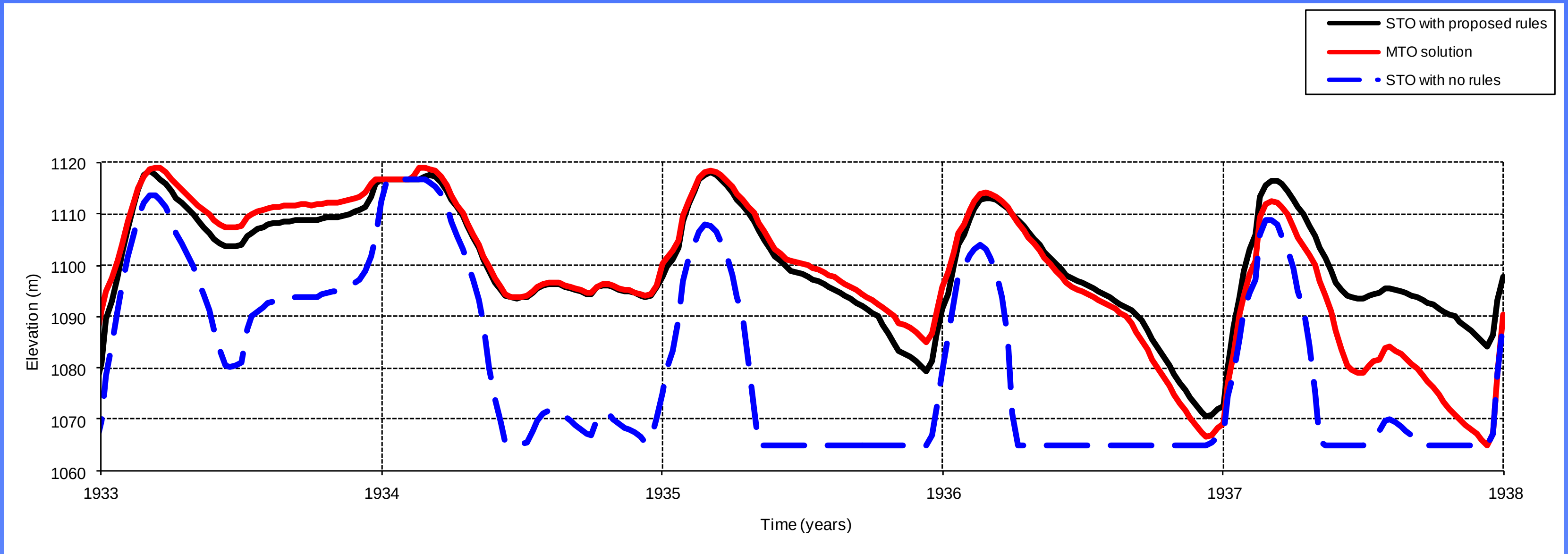
Summary of Desirable Research Objectives

Further research is needed to address the following issues:

a) How to model time steps that are shorter than the entire basin travel time
b) Importance of MTO solution framework
c) Agreement on which constraints are important and how they should be modeled
d) A universal algorithm that finds suitable payout (cost) factors based on network configuration and established priorities
e) General agreement on modeling approach aimed to derive short term operating rules that would be easy to understand and implement.

Use of MTO in Development of Rule Curves Storage Levels for three Scenarios (1928-1937)





The End