##### RIPARIAN FORMULATION

## for all basins, *k*

### Basin proportions *Pk* are between 0 and 1.

## for all *i* users, in each basin *k*

### Each user’s allocation *Ai* is user *i*’s basin proportion *Pk*, of *i*’s demand *ui*.

## for all *i* users that are within each basin *k*

### Mass Balance: within every basin *k*, the sum of all users’ allocations are less than or equal to flow *vk* in basin *k*, less any environmental instream flow requirement *ek*.

## for all basins *j* and all basins *k*

### Upstream basin proportions *Pi* cannot exceed downstream basin proportions *Pk*.

## for all users, *i*

### A basin penalty *wk* is applied that increases with the ratio of the number of users *ni* upstream of basin *k*, to the number of users at the watershed outlet *ni at basin outlet*.

## Why?

#### Because if upstream basins are not allowed to exceed downstream basins, then some offset is required so that downstream basins are not allocated more than upstream, to conform with the riparian doctrine of shared shared shortage.

## for all basins, *k*

### The basin scalar *α* is the minimum of the ratios between downstream penalties *wk* and basin-wide demands *uk*.

## Why?

#### Because.

# Objective Function:

## For all users *i*, and all basins, *k*

### Minimize shortage (left term) + but make the slightly modified sum of basin proportions as large as possible (right term).

##### APPROPRIATIVE FORMULATION

## for all users, *i*

### Each appropriative user’s allocation *Ai* must be between 0 and her reported demand *ui*

## for all users *i*, in all upstream basins *k*

### Mass Balance: the sum of all appropriative allocations *Ai,appropriative* that are in basin *k*, must be less than or equal to available flow *vk*, less any environmental instream flow requirement *ek*, less the sum of all upstream riparian allocations, *Ai,riparian*.

# Objective Function:

## for all users, *i*

### Minimize the difference between demand and allocation, or shortage, (*ui* – *Ai*) weighted by the inverse of the priority of user *i*.