## 1. Setup

Dimensions:

- Time ($t$): Currently yearly, solved independently
- Counties ($r$): 3121 in CONUS
- Crops ($c$): 9 (alfalfa, other hay, summer barley, winter barley, maize, sorghum, soybeans, spring wheat, winter wheat)
- Gauges ($g$): 22 559 nodes in the water network
- Canals ($p$): 21 598 extraction links between gauges and counties
- Edges ($e$): 18 561 county-to-county transportation connections

Optimization parameters:

- Conjunctive Use: $\text{Pumping}_{rt}$ $(1000m^3/year)$
- Conjunctive Use: $\text{Withdrawals}_{pt}$ $(1000m^3/year)$
- Agriculture: $\text{IrrigatedArea}_{rct}$ $(Ha)$
- Agriculture: $\text{RainfedArea}_{rct}$ $(Ha)$
- Transportation: $\text{Imported}_{ect}$ ($Lb$ or $Bu$ by crop)
- Market: $\text{InternationalSales}_{rct}$ ($Lb$ or $Bu$ by crop)

Constraint variables:

- Water Network: $\text{Outflows}_{gt}$ $(1000m^3/year)$
- Conjunctive Use: $\text{SWBalance}_{rt}$ $(1000m^3/year)$
- Market: $\text{Available}_{rct}$ ($Lb$ or $Bu$ by crop)
- Market: $\text{DomesticCropBalance}_{rct}$ ($Lb$ or $Bu$ by crop)

## 2. Agriculture

Parameters:

- LogIrrigatedYield$_{rc}$: intercept of statistical model (later add temperatures)
- WaterDemand$_c$ $(mm)$: Water requirement by crop
- Precipitation$_{rt}$ $(mm)$

Equations:

$$Production_{rct} = IrrigatedArea_{rct} e^{LogIrrigatedYield_{rc}} + Rainfed Area_{rct} e^{LogIrrigatedYield_{rc} - b_{rc} min(0, WaterDemand_c - Precipitation_{rt})}$$

$$Irrigation_{rt} = IrrigatedArea_{rct} min(0, WaterDemand_c - Precipitation_{rt})/100$$

## 3. Conjunctive Use

Parameters:

- PumpingCost$_{rt}$ $(USD/1000m^3)$: Currently \$100 / 1000 $m^3$ everywhere

Equations:

$$SWBalance_{rt} = DomesticWaterUse_{rt} + Irrigation_{rt} - Pumping_{rt} - \sum_{p \in P(r)} Withdrawals_{pt} > 0$$

$$PumpingSpending_{rt} = Pumping_{rt} PumpingCost_{rt}$$

## 4. Domestic Demand

Parameters:

- Population$_{rt}$ $(people)$: From census (later from SSPs)
- WaterPerPerson $(m^3/year)$: 575 liter/year
- CropPerPerson$_c$ $(Lb/year$ or $Bu/year$ by crop): In daily units, 1 Lb hay, 0.005 Bu barley, 0.05 Bu maize, 0.01 Lb sorghum, 0.02 Bu soybeans, 0.05 Bu wheat

Equations:

$$DomesticWaterUse_{rt} = WaterPerPersonPopulation_{rt}$$

$$DomesticCropDemand_{rct} = CropPerPerson_{c}Population_{rt}$$

## 5. Market

Parameters:

- DomesticPrices$_c$ ($USD/Lb$ or $USD/Bu$ by crop): \$0.046 / Lb hay, \$2.62 / Bu barley, \$4.08 / Bu maize, \$4.44 / Lb sorghum, \$9.51 / Bu soybeans, \$4.92 / Bu wheat
- InternationalPrices$_c$ ($USD/Lb$ or $USD/Bu$ by crop): DomesticPrices$_c$ / 2

Equations:

$$Available_{rct} = Production_{rct} + RegionImports_{rct} - RegionExports_{rct} > 0$$

$$Revenue_{rct} = Available_{rct}DomesticPrices_{c} + (InternationalPrices_{c} - DomesticPrices_{c})InternationalSales_{rct}$$

$$DomesticCropBalance_{rct} = Available_{rct} - InternationalSales_{rct} - DomesticCropDemand_{rct} < 0$$

## 6. Transportation

Parameters:

- EdgeCost$_{et}$ ($USD/m^3$): Set to \$0.76 everywhere (40' container = 76.5 $m^3$, Average rate is \$1.58 per mile, Distance from SF to NYC is 2906 miles, Counties crossed is $.5X^2 = 3121$, or 79; Average distance between counties = 37 mile
- VolumeCrop$_c$ ($m^3/Lb$ or $m^3/Bu$ by crop): 0.0018 for pound crops, 0.035 for bushel crops

Equations:

$$RegionImports_{rct} = \sum_{e \in I(r)} Imported_{ect}$$

$$RegionExports_{rct} = \sum_{e \in E(r)} Imported_{ect}$$

$$TransitCost_{ect} = EdgeCost_{et} VolumeCrop_{c} Imported_{ect}$$

## 7. Water Network

Parameters:

- Runoff$_{rt}$ $(1000 m^3/year)$: From VIC, scaled by area of county

Equations:

$$Added_{gt} = \frac{1}{N(R(g))} Runoff_{R(g),t}$$

$$Outflows_{gt} = Added_{gt} - Withdrawals_{gt} + \sum_{g \in U(g)} Outflows_{gt}$$