Developing Mine Water Balance Models for Extreme Environments

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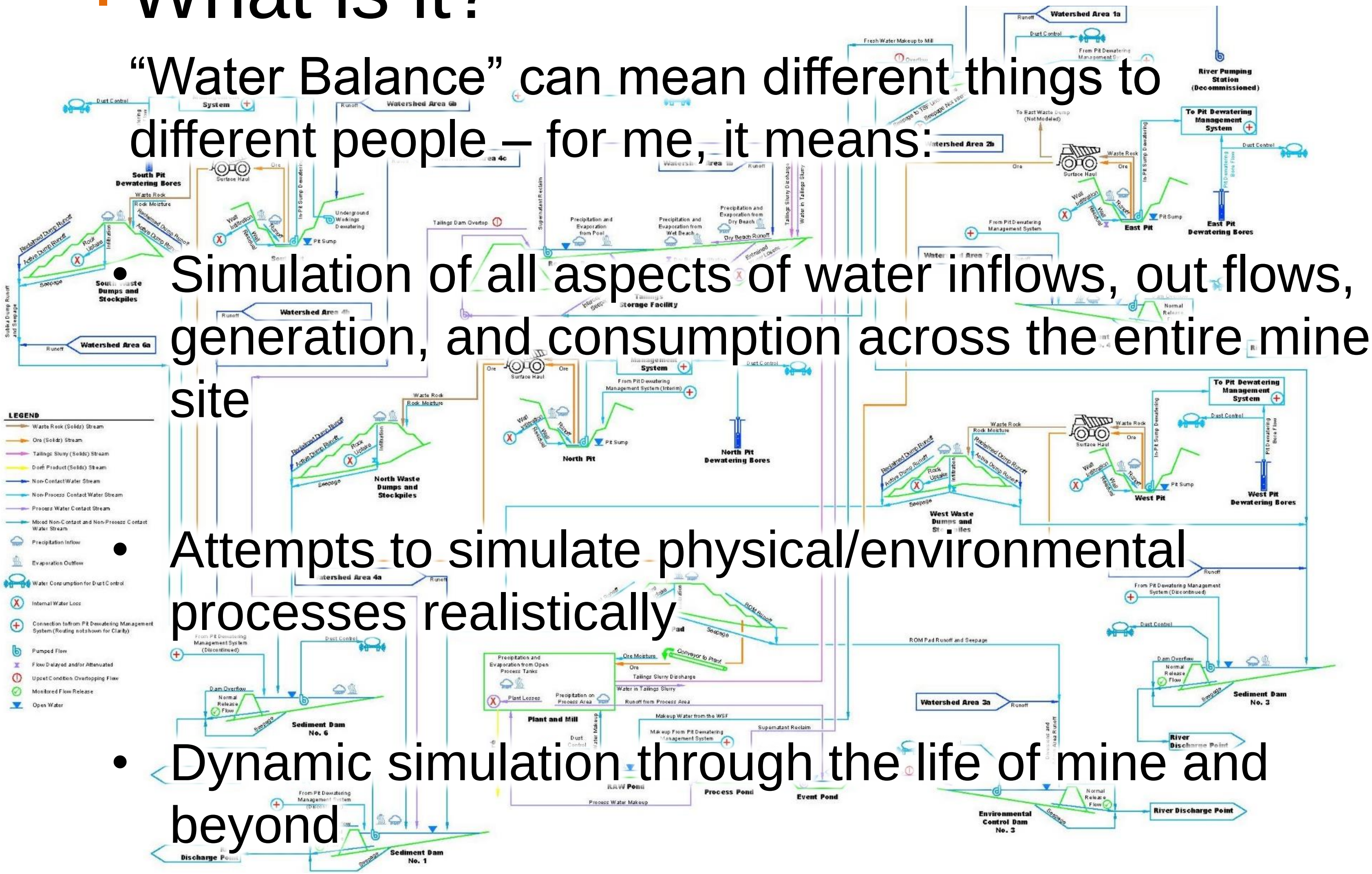
Water Balance Modeling
What is it?

"Water Balance" can mean different things to different people – for me, it means:

- Simulation of all aspects of water inflows, out flows, generation, and consumption across the entire mine site
- Attempts to simulate physical/environmental processes realistically
- Dynamic simulation through the life of mine and beyond



Water Balance Modeling
Why?

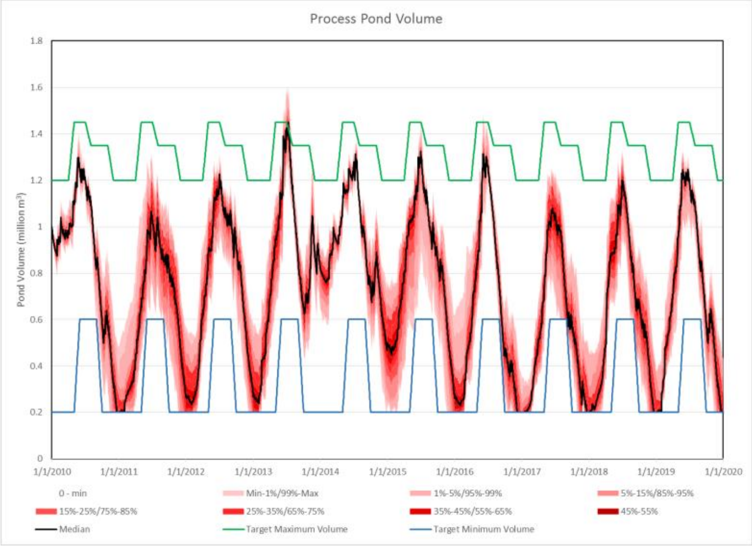
Why do we need a site-wide water balance?

- Understand water use across the whole site
- Quantify water use where it can't be directly measured
- Examine the impacts of extreme conditions

Operational Site-Wide Water Balance in West Africa

Extreme wet/dry cycles (monsoon and harmattan)

- Monthly precipitation totals can go from 400 mm in November to 0 mm in January
- Pond inventory management becomes critical
- Model had to include complex operating logic to maintain adequate freeboard during the wet season, yet ensure availability of water during the dry season



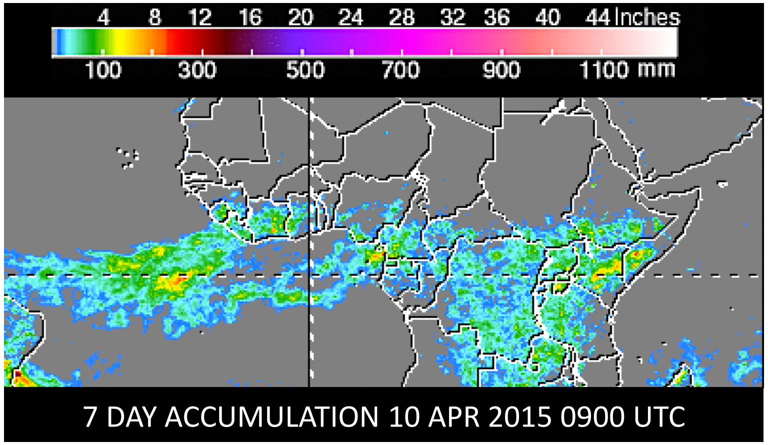
So How Do We Incorporate Climate Data Appropriately?

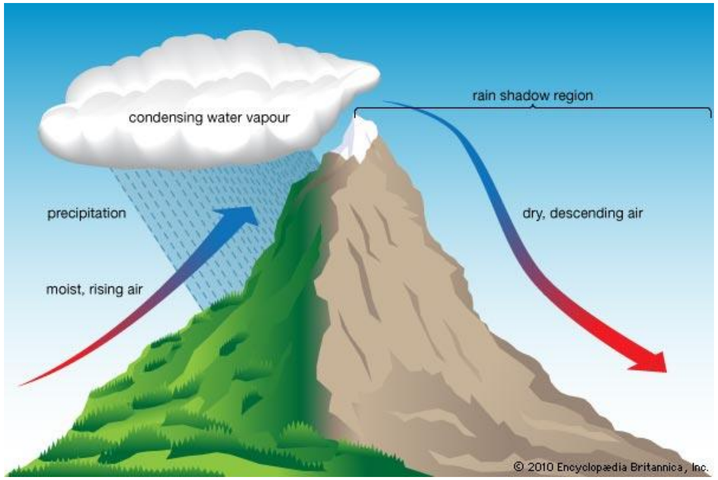
A lot of things go into a water balance, but it's really important to get this part right

- Climate components are usually the largest uncertainty that is out of our control
    - Precipitation
    - Evaporation
    - Temperature
    - Solar radiation

Site Specific Climate Data

- Obtaining historic data
  - Onsite or nearby climate stations
  - Gridded climate sets (i.e. TRMM)





- Extrapolating data to the mine site
  - Orographic effects
  - Sea temperature oscillations (aka La Niña, El Niño)
  - Changing climate trends

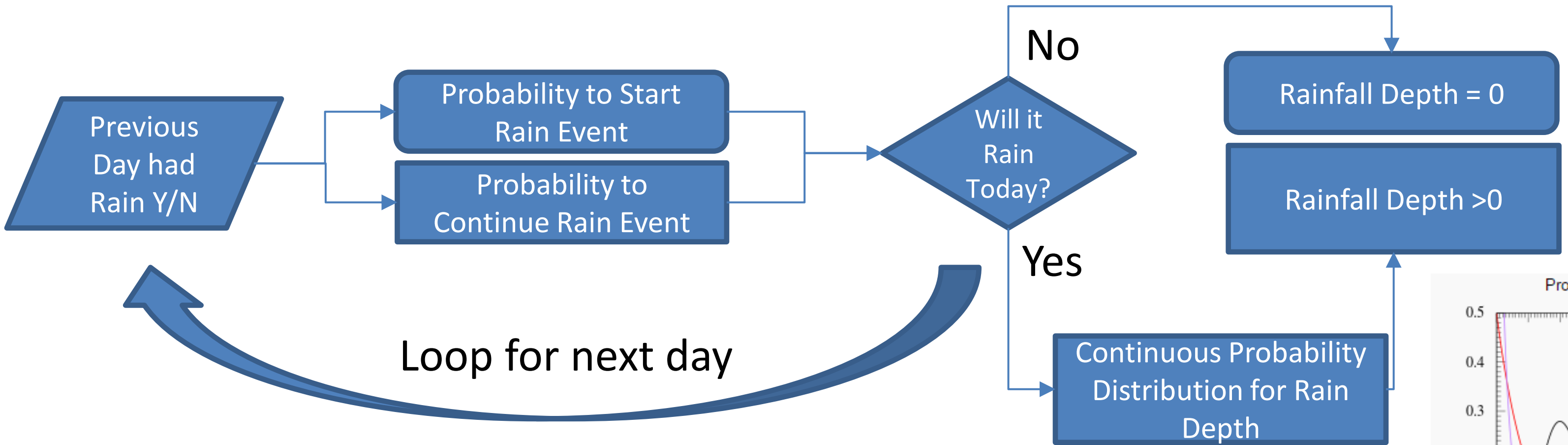
Using the Climate Data in Water Balances

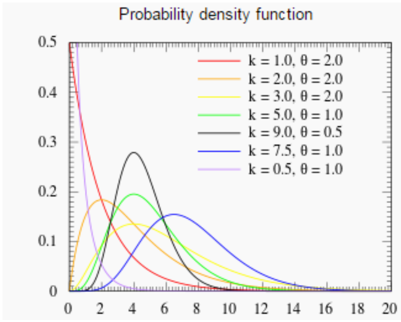
- Average year / wet year / dry year
  - Simplistic and often over conservative
- Repeat historic records
  - Does the record include the extremes?
- Reshuffle historic records
  - Did you lose any cyclic patterns or trends?
- Synthetic climate
  - Fitted distribution(s) that can extend the data set to generate extremes, can superimpose cycles or trends

Generating Synthetic Climate

A synthetic climate generator implies a probabilistic (actually stochastic) model

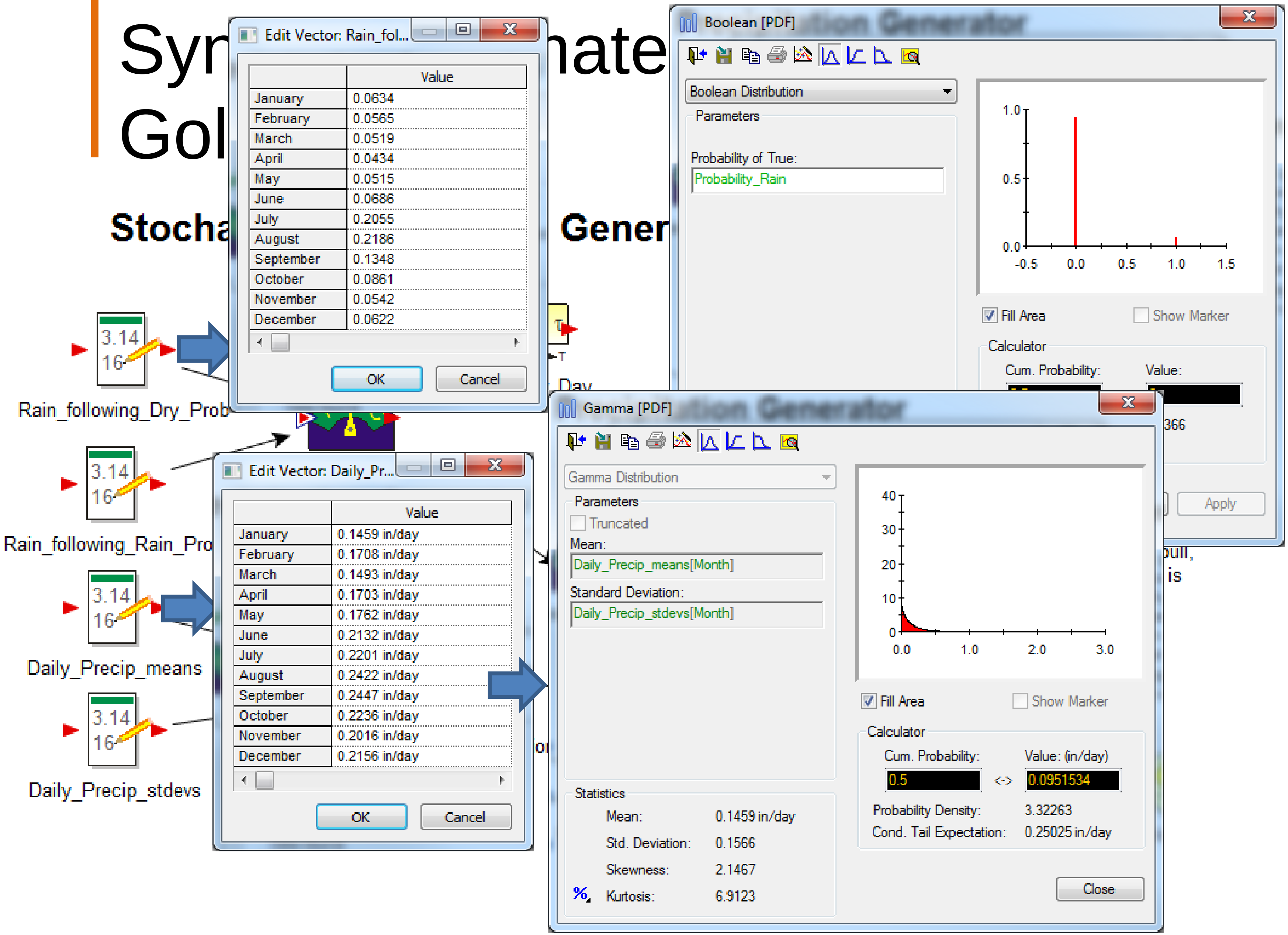
- I'm fond of the WGEN synthetic climate generator – a second order Markov chain model





Syn... nate... Gol...

Stocha... Gener...

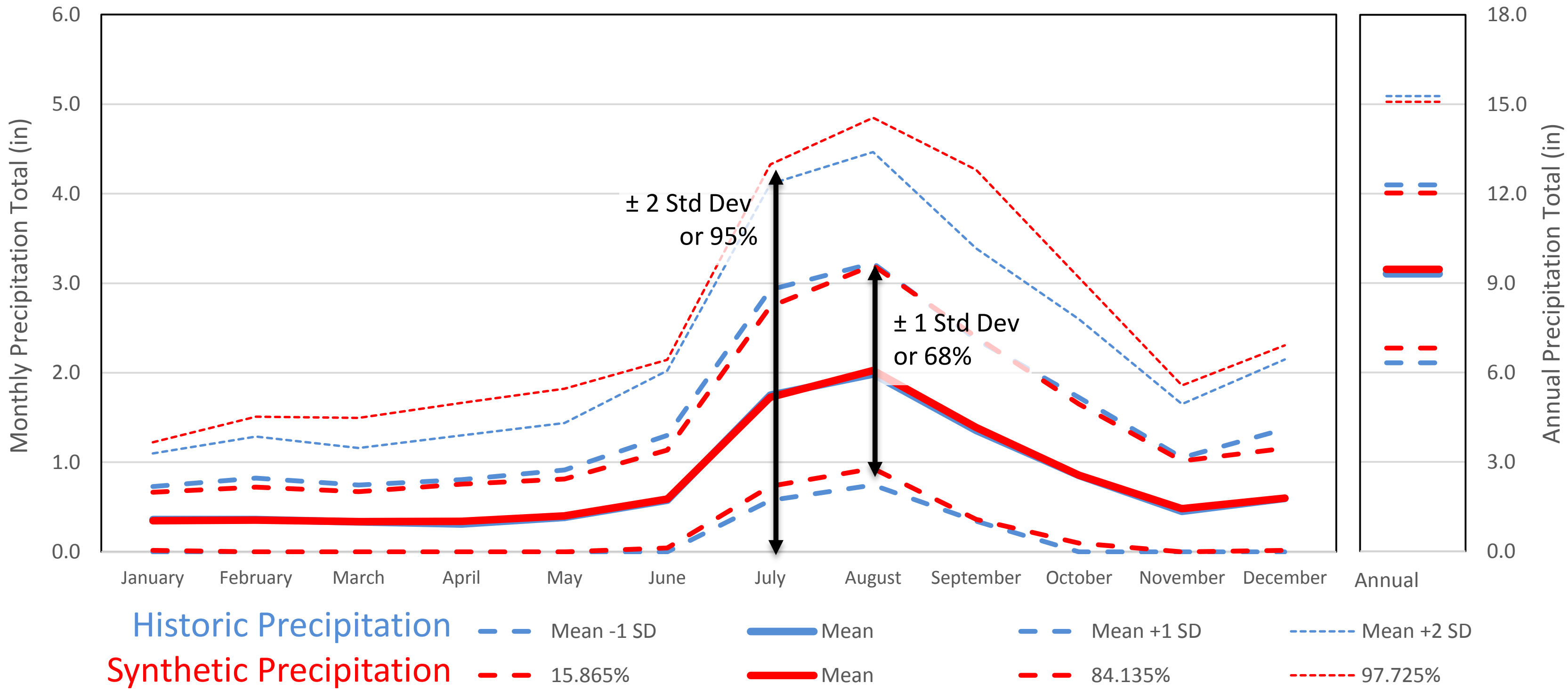


	Value
January	0.0634
February	0.0565
March	0.0519
April	0.0434
May	0.0515
June	0.0686
July	0.2055
August	0.2186
September	0.1348
October	0.0861
November	0.0542
December	0.0622

	Value
January	0.1459 in/day
February	0.1708 in/day
March	0.1493 in/day
April	0.1703 in/day
May	0.1762 in/day
June	0.2132 in/day
July	0.2201 in/day
August	0.2422 in/day
September	0.2447 in/day
October	0.2236 in/day
November	0.2016 in/day
December	0.2156 in/day

Stochastic Precipitation Modeling

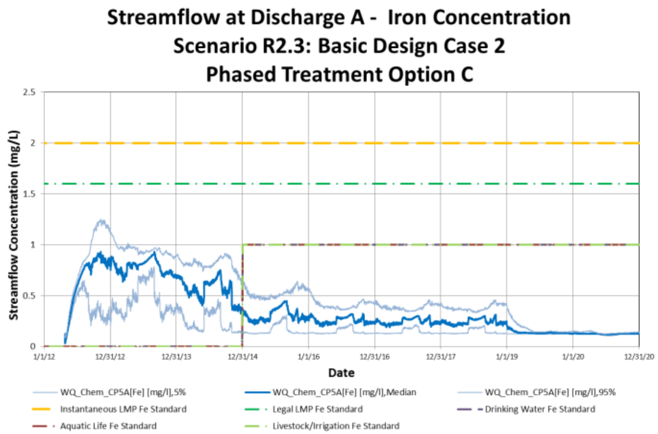
The proof of the pudding: does the daily synthetic model result in appropriate monthly and annual values?



Water and Mass Balance Model to Predict Off-site Water Quality

Model development highlighted need for increasing level of detail in runoff simulations

- Original model focus was on process waters only with runoff from undisturbed watersheds as a ‘FYI only’
- Subsequently incorporated water quality downstream of treated water discharges
- Highlighted need for increasingly higher detail and accuracy in surrounding watershed runoff calculations



Finding the Right Level of Detail – Top Down Modeling

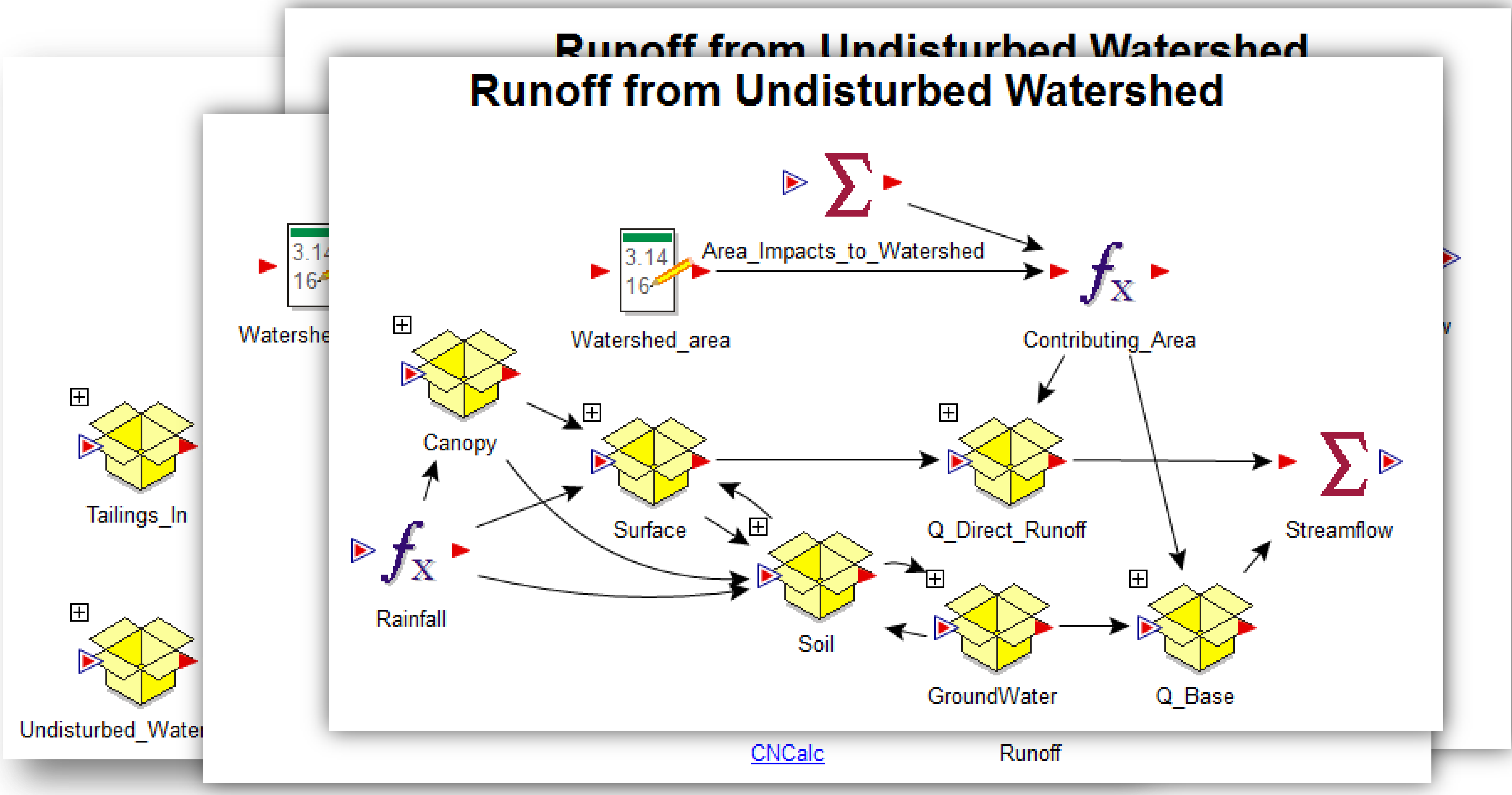
Knowing where to focus the model development effort is important

- Too simple — but….
  - Easy to build
  - Minimal data needs
  - Misrepresents system
  - Difficult to calibrate

- Too complex — but..
  - Better accuracy
  - Easier to defend
  - Resource intensive
  - Data intensive

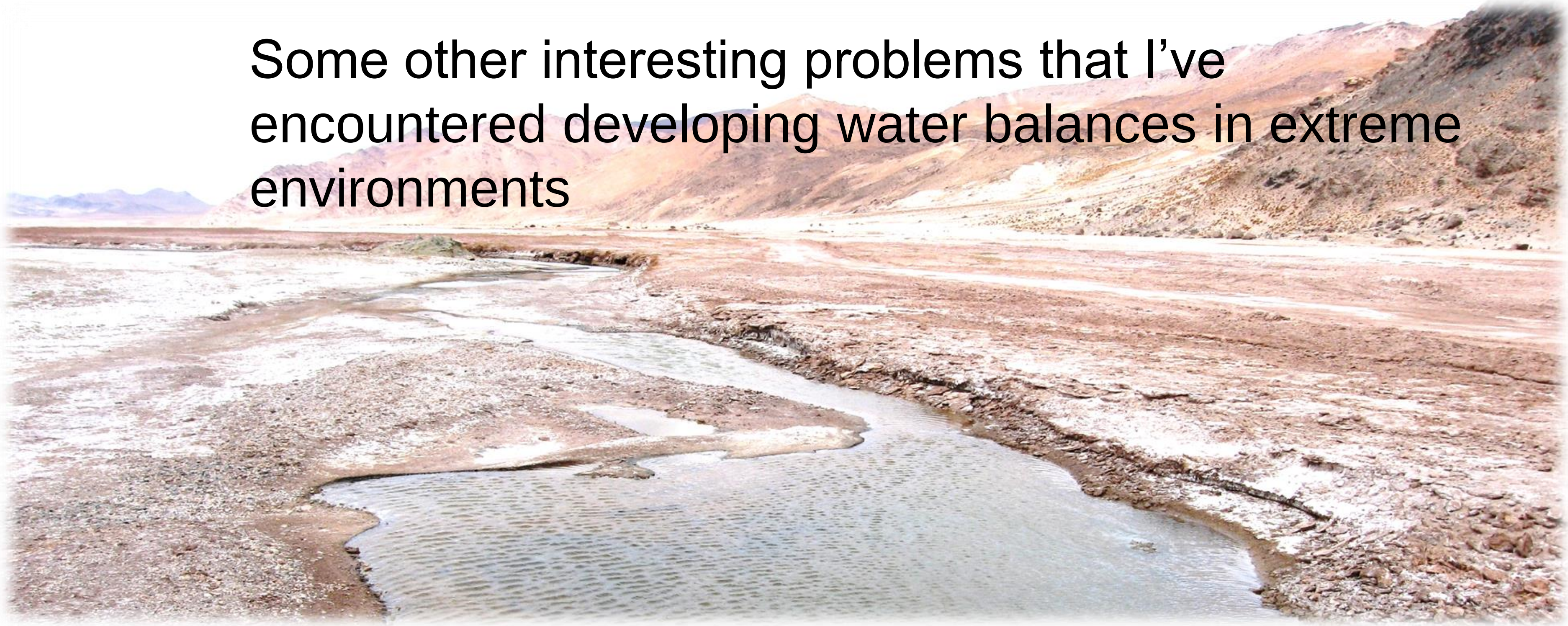
Find the balance by experience and trial and error

Example of Top Down Construction



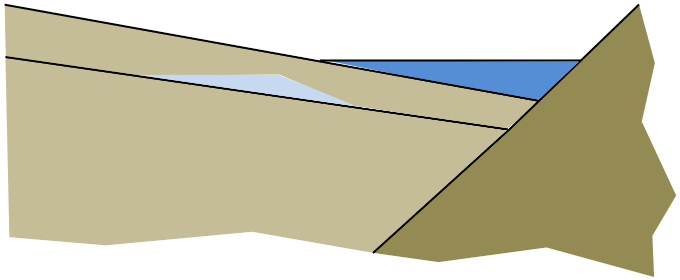
Water Balance Modeling in Extreme Environments

Some other interesting problems that I’ve encountered developing water balances in extreme environments



Ice pack formation in tailings impoundment

- Tailings pool would freeze during the winter
- Limited availability of water in the winter, surplus of water in the spring
- Ice flows would be covered by tailings, resulting in permanently entrained ice
- Model tracked water bound as ice in different areas of the TSF, noting when deposition in those areas would cover the ice floes



Evaporation From Warm Process Discharges in Winter

- Process discharges included water from warmer heap solutions
- Resulted in a warm, permanently open water zone in the pool during winter
- Modeling evaporation from this area required an arbitrary potential evaporation value to account for cold dry air and warm open water surface

Loss of Pond Capacity Due to Blowing Sand

- Blowing sand from dust storms would be captured in the process ponds, displacing pond capacity
- Model had to include loss of pond capacity and cleanout schedule

The End