# Flaming Gorge Operational Rules Outline for the Midterm Probabilistic Model

Revisions:

* Rev. 1, 27 January 2010: Cameron Bracken
* Rev. 2, 3 February 2010: Cameron Bracken
* Rev. 3, 16 February 2010: Cameron Bracken
* Rev. 4, 15 March 2010: Cameron Bracken
* Rev. 5, 28 March 2010: Cameron Bracken
* Rev. 6, 1 June 2010: Cameron Bracken
* Rev. 7, 3 June 2010: Cameron Bracken
* Rev. 8, 8 June 2010: Cameron Bracken
* Rev. 9, 28 June 2010: Cameron Bracken
* Rev. 10, 14 July 2010: Cameron Bracken

## Data

### Data Object

FlamingGorgeData

* 1963 - Present historic Data for definitions of hydrologic classification
* HydrologicClassPercentileLimits: Look up tables for Hydrologic Classification Wet, Moderately Wet, Average, Moderately Dry, Dry (based on quantile of obs or fc)
  + Dry: > 90%
  + Moderately Dry: 90% - 70.1%
  + Average: 70% - 30%
  + Mod Wet: 30% - 10.1%
  + Wet: < 10%
* May1TargetElevation: Table for May 1 Upper Limit Drawdown Elevation
* BaseFlowMagnitudeLimits: Base flow limits and ramp down rates for each classification
* Manual input Feb-May flows and usage flag indicating special case year
* DaysAtBypassCapacity: Required days at bypass release
  + Dry: NA (Never bypass in dry years)
  + Moderately Dry: 3
  + Average: 5
  + Mod Wet: 7
  + Wet: 21
* YampaDaysAbove14000ForBypass
  + Dry: NA (Never bypass in dry years)
  + Moderately Dry: 12
  + Average: 10
  + Mod Wet: 8
  + Wet: NA (Always bypass in wet years)
* DaysAtPowerPlantCapacity: Required days at Power Plant Capacity
  + Dry: 0 – 7
  + Moderately Dry: 7 - 14
  + Average: 14 - 28
  + Mod Wet: 28 – 42
  + Wet: 42 +
* Slots for All proportions, remaining days at ppc
  + PreviousMonthProportion
  + RampUpProportion
  + PPCProportion
  + RampDownProportion
  + RemainingProportion
* RampUpRate: Spring Ramp up rate, 2000 cfs
* PowerPlantCapacity: 4600 cfs
* BypassRelease: 8600 cfs

### Other Data

* YampaNearMaybelle: Yampa Forecast
* GreenAboveFG: inflow

### Required User Data Input

* Reach Intervening Flows for entire run length
* Initial Reservoir Storage
* If the model is starting in a spring flow month, the previous flow proportions and remaining days at power plant capacity
* Start end end year for calculating hydrologic clasifications for both the yampa and the green
* TBD: Projected Demands

## Rules

In order of priority

### RIP Adjusted Release Request

*Execution Constraint*: None

*Description*: Manual entry in first year of model run. Highest priority.

### Shift Water for Power Generation \*\*

*Execution Constraint*: January - April

*Description*: In special cases of Dry-Mod Dry and releases are minimum, use manually input values for Feb-May flow.

\*\* Only used in special cases when flag is set in FG data object

* Take calculated base flow releases and lower them in January and February
* Possible to switch off shifting from January.

### Spring Flow Operations

*Execution Constraint*: May - July (depending on classification)

*Description*: Sets the spring release to meet power plant capacity and control flooding. Higher priority than Base flow operations. August is not included because it will always be handled by the base flow operations rule. Any of the components of the monthy flow when splitting (ppc, downramping and baseflow) may be zero. E.g. downramping and baseflow are zero when the whole month is at ppc.

C:\Documents and Settings\bracken\My Documents\My Dropbox\FGReleaseTypes.emf

**Figure 1**: Flaming Gorge Spring Release Types

PreviousProportion \* PreviousBaseFlowRelease +

RampUpProportion \* AverageRampUpRelease +

PPCProportion \* PowerplantCapacity +

BypassProportion \* BypassRelease

RampDownProportion \* AverageRampDownRelease +

RemainingProportion \* BaseFlowMagnitude

* Get base flow release from previous timestep
* Get Average ramp up release knowing proportion (i.e. number of days to reach peak and then average)
* Get Power Plant Capacity flow using GetMaxReleaseGivenInflow
* Get Ramp Down release by similar calculation in ramp up.
* Get Base flow magnitude from hydrologic classification and lookup table
* Proportions are calculated by proportion rules
* Checking if total volume in month is enough to meet peak flow requirement.

*Slots Set*: FlamingGorge.Outflow

### March-April Release to Meet ULDE

*Execution Constraint*: March or April

*Description:* Break the restriction of steady flow and release whatever necessarry to meet the May 1 ULDE. This means breaking out of the base flow limits.

(Current Storage – May1 Target Storage + March Inflow + April Inflow)/ 2 months

*Slots Set*: FlamingGorge.Outflow

### Base flow Operations

*Execution Constraint*: June - February

*Description*: Depending on the model start month, set steady base flow based on the hydrologic classification in order to meet the May 1 ULDE. If steady flow is outside of the base flow limits then constrain to the limits. Only set June, July if downramping has completely finished in the previous month. In In june and July since the obs volume is not available use the forecasted volume to set the base flow.

Set Release to the steady flow within the base flow limits that will get the closest to the May 1 ULDE

* Overlap with spring flow rule since ramp down month is variable
* Relies on previous proportions being set.
* If model is starting in June, July or August, check if base flow operations have started and either continue base flow or start it

*Slots Set*: FlamingGorge.Outflow

### Set Remaining Proportion

*Execution Constraint*: May - July

*Description*: In a given spring flow month, if ramping down has finished before the end of the month the remaining portion of the month must be base flow.

* 1 - ∑(All other proportions)

Slot Set: FlamingGorgeData.RemainingProportion

### Set Ramp Down Proportion

*Execution Constraint*: May - July

*Description*: In a given spring flow month, if no more days remain at power plant capacity, then compute the time necessary to ramp down to base flow.

* In May:
  1. Start Ramp down in dry years
  2. Do not start ramp down
* In June:
  1. Continue ramp down and finish
  2. Start ramp down and finish
  3. Start ramp down and do not finish
* In July:
  1. Continue ramp down and finish
  2. Start ramp down and finish
  3. Start ramp down and do not finish

*Slots Set*: FlamingGorgeData.RampDownProportion

### Set Power Plant Capacity Proportion

*Execution Constraint*: May - July

*Description*: In a given spring flow month, if no more days remain at power plant capacity, then compute the time necessary to ramp down to base flow. Power plant capacity is a surrogate for explicitly setting peak flows.

* In May 3 cases:

1.No ppc because ramping takes all 7 days (Only applies to extreme cases)

- PPCProportion = 0

2. PPC for the rest of the month after ramp up or

- PPCProportion = Remaining time in May after ramping up occurs

3. PPC completely finishes (Only in extreme dry years)

- PPCProportion = Only the portion of the month that will deplete the PPCDays

* In June:

1. Start PPC and finish (if ramping took all of may)

- PPCProportion = portion of the month that will deplete the PPCDays less the days at bypass which count as days at ppc

- Reduce RemainingPPCDays to zero

2. Start/Continue PPC and do not finish

- PPCProportion = 1 – BypassProportion

- Reduce RemainingPPCDays by number of days in June

3. PPC Previously finished (Extreme Low flow years)

- PPCProportion = 0

* In July:

1. Continue PPC and finish with no time left (extreme wet years)

- PPCProportion = all of month less the time to downramp

- Reduce RemainingPPCDays to zero

- Increase outflow above PPC (bypass) for the amount of time necessary to meet ULDE

2. Continue PPC and finish with time to spare

- PPCProportion = portion of the month that will deplete the PPCDays

- Reduce RemainingPPCDays to zero

3. PPC previously finished

- PPCProportion = 0

*Slots Set*: FlamingGorgeData.PPCProportion

### Set Bypass Proportion

*Execution Constraint*: June, July

*Description*: In all year types besides dry it may be necessary to bypass depending on the number of Yampa days above 14000 cfs. In these cases, bypass would be used to meed flow recommendations. In extreme Wet years, power plant capacity for all of June and July may not be enough to prevent overtopping and therefore bypass is necessary.

* If the spring hydrologic classification is mod dry, ave, or mod wet and the Flaming gorge April-July volume is greater than 860,000 ac-ft (an emperical threshold from the data) then use the regression in Figure to determine the number of days required to bypass (up to the max days at bypass given in YampaDaysAbove1400ForBypass).

**Figure 2**: Regression used to determine Yampa Days above 14000 cfs

*Slots Set*: FlamingGorgeData.BypassReleaseProportion

### Set Ramp Up Proportion

*Execution Constraint*: May

*Description*: Determine the amount of time to ramp up from base flow to power plant capacity. Assume May 23 ramp up date, 2000 cfs/day, for simplicity never let ramp up push into June.

* In May: RampUpProportion = DaysToRampUp() / NumDaysInMay
* Otherwise : RampUpProportion = 0

*Slots Set*: FlamingGorgeData.RampUpProportion

### Set Previous Proportion

*Execution Constraint*: May

*Description*: This is fixed at 22/30 for May only

*Slots Set*: FlamingGorgeData.PreviousProportion

### Set Days at Power Plant Capacity

*Execution Constraint*: March - July

*Description*: Sets the number of days at power plant capacity given the Spring hydrologic classification. Interpolate between limits of current Yampa hydrologic classification based on the yampa hydrologic classification. Also initializes the remaining days at power plant capacity to be the same as the total days.

*Slots Set*: FlamingGorgeData.PPCDays, FlamingGorgeData.RemainingPPCDays

### Spring Flow Hydrologic Classification

*Execution Constraint*: January - July

*Description*: Use forecast of April-July Volume to determine the hydrologic classification for the given month (for both FG and Yampa)

Loop through upper limits of Classifications

IF Exceedance Prob of forecast Apr-Jul Vol is < upper limit of Class

THEN SpringHClass = i

* In any particular month, classify based on following season forecasted April - July unregulated inflow.
* When running from different start dates, the hydrologic classification may change from month to month but will not change during a single run

*Slots Set*: FlamingGorgeData.SpringHClass, FlamingGorgeData.YampaHClass

### Base Flow Hydrologic Classification

*Execution Constraint*: June - February

*Description*: Use observed April-July for classification.

Loop through upper limits of Classifications

IF Exceedance Prob of observed flow is < upper limit of Class

THEN BaseFlowHClass = i

* Classification will not change from spring classification during a single run
* Between runs with start dates August-December, classification will not change
* In June and July treat the forecast as the observed in order to get an estimate of volume and set classification
* May vary between runs with start dates Jan - July since incomplete or no observations are available

*Slots Set*: Sets FGData.BaseFlowHClass

### Set Percent Exceedance

*Execution Constraint:* None

*Description*: Use the percent rank function to calculate the exceedance probability of

1 – Number of data points falling below current value

*Slots Set*: FlamingGorgeData.AprJulPercentExceedanceSpringFlow, FlamingGorgeData.AprJulPercentExceedanceBaseFlow FlamingGorgeData.YampaAprJulPercentExceedance

### Initilize Proportions

*Execution Constraint:* None

*Description*: Sets all proportions to zero at the current time step to avoid NaN errors.

*Slots Set*: FlamingGorgeData.PreviousMonthProportion,

FlamingGorgeData.RampUpProportion, FlamingGorgeData.BypassProportion, FlamingGorgeData.PPCProportion, FlamingGorgeData.RampDownProportion, FlamingGorgeData.RemainingProportion

### Calculate April to July Volume Monthly

*Execution Constraint*: None

*Description*: Set the April – July volume for in a monthy series slot for easy access by other rules. Calculate the next season volume of Flaming Gorge and the Yampa for spring flow rules and the previous season volume for the base flow rules. For spring flow operations we are interested in the april - july volume for the upcoming season, all the way into August we may be refering to this number. This number is needed in march to determine releases to meet the ULDE. For base flow operations we are interested in the available observed volume in the previous april - july season. Since base flow may actually start in june calculate this number then.

If March

Calculate the FG unregulated inflow volume of current year for spring flows

If April

Calculate the Yampa unregulated inflow volume of current year for spring flows

If May

Calculate the FG unregulated inflow volume of current year for base flows

Otherwise

Set slaots to the same values as the previous timestep

*Slots Set*: FlamingGorgeData.AprJulyVolumeSpringFlow, FlamingGorgeData.AprJulyVolumeBaseFlow, FlamingGorgeData.YampaAprJulyVolume

### Calculate April to July Volume Annual Slot

*Execution Constraint*: Beginning of Run

*Description*: Loop through all years of data calculate the Apr - July Volume (Using SumFlowsToVolume). Will be used by "Set April to July Percent Exceedance".

FOREACH Year in model run

AprJulyVol = SumFlowsToVolume( April - July of Current year )

*Slots Set*: FlamingGorgeData.AprJulyVolume

## Functions

NUMERIC GetDownrampRate( NUMERIC Class )

*Arguments*:

Class

An integer [1,5] representing the current hydrologic classification

*Description*: Returns the downramping rate based on given hydrologic classification. The function interpolates based on the actual flow percentile.

*Value*: The Peak flow to base flow downramping rate in flow/day

NUMERIC DaysToRampUp( NUMERIC flow )

*Arguments*:

Flow

The flow to ramp up from

Class

Hydrologic classification to determine ramping rate

*Description*: Returns the number of days necessary to ramp up to power plant capacity.

* Uses the inflow on the current timestep and ramping rate
* rounded up to the nearest day so slight overestimation can occur.

*Value*: The Peak flow to base flow downramping rate in flow/day