Appendix C - Capability Determination for Daily Cycle Hydro Generator Assets

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I. DAILY CYCLE HYDRO GENERATORS

Calculations will use daily mean river flow rate data over a 20-year historical period. The flow duration data will be constructed from the most relevant United States Geological Survey ("USGS") flow gage, with appropriate scaling to account for differences in drainage area. Ratings for such resources are established and updated in calendar years that are evenly divisible by five. Capability will include the effects of natural stream flow, pondage, and eligible upstream storage. Details of these capability calculations are contained in Section II of this Appendix.

A non-Intermittent Power Resource daily cycle hydro asset summer Seasonal Claimed Capability (SCC) Audit value is calculated from the average of the four summer monthly ratings (June - September), and the winter SCC Audit value is calculated using the average of the eight winter monthly ratings (October - May).

The following variables must be defined prior to calculating the monthly capability. All data must be provided by the Lead Market Participant (Lead MP) except for flow and gage data, which will be provided by the ISO staff.

Max. Capacity - power, in kW, produced when the ***Flow at Max. Capacity*** passes through the Generators at the station. ***Max. Capacity*** represents an average value that properly takes into account typical differences in head experienced under normal operating conditions.

Flow at Max. Capacity - the amount of water flow, in cubic feet per second (cfs), required to produce the power specified in **Max. Capacity**.

Conversion Factor - kilowatts of power produced at the station per cfs of flow. The default value of ***Conversion Factor*** is ***Max. Capacity*** / ***Flow at Max. Capacity***, however, the Lead MP may supply an alternative value that is more representative of typical operating conditions.

Minimum Flow - the minimum amount of water flow, in cfs, needed to support power production. Station power production is assumed to be zero whenever the flow is less than ***Minimum Flow***.

USGS Flow Gage - the most relevant USGS flow gage.

Flow at Gage - the amount of water flow, in cfs, at the gage that is surpassed 50% of the time during the month, based on 20 years of flow data for the month. Daily cycle hydro capability calculations will use daily mean river flow rate data, over a 20-year historical period. The monthly flow rate used will be the 50th percentile value of the full set of daily mean values for that month over the 20-year historical period (i.e., the value that is exceeded for 50% of the time during the month). For example, for the month of June, the number of daily mean flow rate data points would be 20 (years) * 30 (days) = 600. These 600 daily mean flow rates for the month of June would be sorted, lowest to highest. The flow rate assumed for that month would be the 50th percentile value (value number 300 out of 600, i.e., 50% of the values are lower than this value and 50%

of the values are higher than this value). The flow estimates will be updated in calendar years that are evenly divisible by 5. ISO staff will provide this information.

Gage Drainage Area - the stream natural drainage area, in square miles, at the gage. ISO staff will provide this information.

Station Drainage Area - the stream natural drainage area, in square miles, at the station.

Unusable Flow - the minimum amount of water flow, in cfs, required at all times that is unavailable for generation, in order to maintain sufficient flow in a structure such as (but not limited to) a diversion canal. Leakage is also included in this factor.

Usable Flow - the minimum amount of water flow, in cfs, required at all times, but is available for generation during generation periods.

For Governance Participants claiming supplemental pond storage at the station, the following must be provided:

kWh in Full Pond - the energy produced, in kWh, if the water in the pond between maximum (full) and minimum pond elevation limits is used to generate at ***Max. Capacity*** without using any natural inflow. In effect, it is the electrical energy equivalent of the pond. ***kWh in Full Pond*** is assumed to be Cubic Feet of Usable Pond * ***Conversion Factor*** / 3600.

For Governance Participants claiming supplemental upstream storage, the ***kWh in Upstream Pond*** is calculated in accordance with the Section II of this Appendix.

kWh in Upstream Pond - the amount of energy produced, in kWh, if the water in upstream storage is used to generate power of the amount in ***Max. Capacity*** at the lower station without using any natural flow. In effect, it is the electrical energy equivalent of the upstream storage. This model will create an equivalent pond at the station for the upstream storage.

The following are calculations that will be used during the station evaluation:

NOTE
x = y means x is assigned the value y

Monthly Capability - the monthly station rating, in kW, which will ultimately be determined by this process.

Test Hours - the number of hours simulated as a demonstration test period. The demonstration test period is two hours for Winter Period months (i.e., October - May), and four hours for Summer Period months (i.e., June - September).

Flow at Station - the amount of monthly water flow at the station, in cfs, which is surpassed 50% of the time during the month.

Flow at Station = Flow at Gage * Station Drainage Area / Gage Drainage Area.

Hours in Full Pond - hours of generation available from a full pond without use of natural flow when generating at ***Max. Capacity***. ***Hours in Full Pond*** represents the usable water between maximum (full) pond and minimum pond elevation requirements.

Hours in Full Pond = ***kWh in Full Pond*** / ***Max. Capacity***

Hours in Upstream Pond - hours of generation available from upstream storage without use of natural flow when generating at ***Max. Capacity***.

Hours in Upstream Pond = ***kWh in Upstream Pond*** / ***Max. Capacity***

The following steps are repeated for each month to determine capability for daily cycle hydro generating stations:

a. Assign the station maximum capability if the natural monthly water flow at the station is greater than what the station requires at maximum generation. If the station meets this criterion, no further evaluation is needed.

If ***Flow at Station*** > (***Flow at Max. Capacity*** + ***Unusable Flow***)

Then ***Monthly Capability*** = ***Max. Capacity***

If ***Flow at Station*** < (***Flow at Max. Capacity + Unusable Flow***)

Then proceed to (b.)

b. If step (a.) determined there is insufficient natural monthly water flow at the station, the natural water flow shortage needs to be determined.

Natural Flow Shortage = ***Flow at Max. Capacity*** + ***Unusable Flow*** - ***Flow at Station***

If pond storage is claimed, go to step c.

If pond storage is not claimed, but upstream storage is claimed, go to step e.

If neither pond storage nor upstream storage is claimed, go to step h.

c. Since the station has insufficient monthly natural water flow for ***Max. Capacity***, and there is a pond at the station, the number of hours that the pond will supplement the natural monthly water flow needs to be determined. It is assumed that the station will generate at maximum output while the pond is supplementing the natural water flow.

Hours of Supplementary Pond = (***Hours in Full Pond*** * ***Flow at Max.***

Capacity / ***Natural Flow Shortage***)

d. If the number of hours that the pond supplements the natural monthly water flow is greater than the test period, assign the station maximum capability provided that the monthly natural water flow will refill the pond for a demonstration the same time on the following day.

If ***Hours of Supplementary Pond*** > ***Test Hours***

Then, ***Monthly Capability*** = ***Max. Capacity***

and go to step i to perform a refill check.

If pond supplement is insufficient for ***Max. Capacity***, and upstream storage is claimed, go to e.

If pond supplement is insufficient for ***Max. Capacity*** and upstream storage is not claimed, go to h.

e. The station has insufficient natural water flow, and insufficient (or no) pond storage, and the station has upstream water storage. This algorithm simplifies upstream storage by modeling it as an extension of the pond at the station. The variable ***kWh in Upstream Pond*** contains constraints related to the output of the upstream storage, and transit time.

Hours of Supplementary Upstream Storage = ***Hours in Upstream Pond*** * ***Flow at Max. Capacity*** / ***Natural Flow Shortage***

f. Constrain the ***Hours of Supplementary Upstream Storage*** so that it only provides energy after the pond at the station is depleted.

If ***Hours of Supplementary Upstream Storage*** > ***Test Hours*** - ***Hours of Supplementary Pond***

Then ***Hours of Supplementary Upstream Storage*** = ***Test Hours*** - ***Hours of Supplementary Pond***

g. The station will be at maximum capability if the pond and upstream storage supplement the natural monthly water flow for the entire test period.

If (***Hours of Supplementary Pond*** + ***Hours of Supplementary Upstream Storage***) = ***Test Hours***

Then ***Monthly Capability*** = ***Max. Capacity***

and go to step i to perform a refill check.

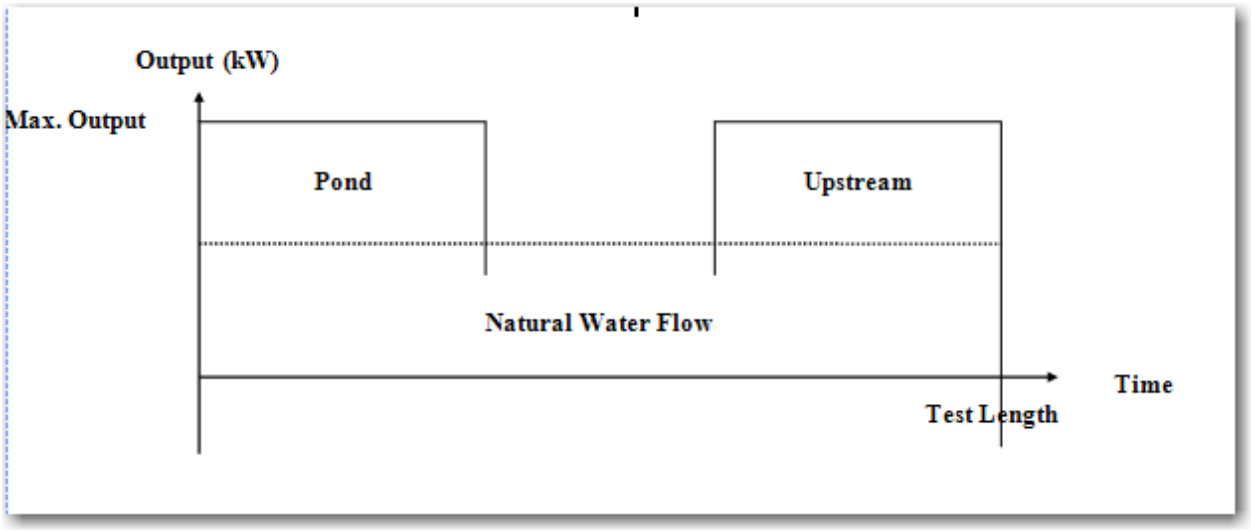
If this step is reached, maximum generation cannot be sustained throughout the simulated test period. The generation will be computed in three (3) parts:

h.

- Generation that is produced by:
  - natural flow,
  - the pond, and
  - upstream storage.

Diagram 1 shows what each part of the calculation represents:

Diagram 1: Time Profile of Station Output



The calculations for each are:

Natural Flow:

Case 1: (***Flow at Station*** - ***Unusable Flow***) ≥ ***Minimum Flow***
Generation = (***Flow at Station*** - ***Unusable Flow***) * ***Test Hours*** * ***Conversion Factor***

Case 2: (***Flow at Station*** - ***Unusable Flow***) < ***Minimum Flow***
Generation = (***Flow at Station*** - ***Unusable Flow***) * (***Hours of Supplementary Pond*** + ***Hours of Supplementary Upstream Storage***) * ***Conversion Factor***

Pond Supplement:

It is assumed that the station generates at ***Max. Capacity***.
Generation = ***Hours of Supplementary Pond*** * ***Natural Flow Shortage*** * ***Conversion Factor***

Upstream Storage:

It is assumed that the station generates at ***Max. Capacity***.

Generation = ***Hours of Supplementary Upstream Storage*** * ***Natural Flow Shortage*** * ***Conversion Factor***

The ***Monthly Capability*** rating is then determined as the sum of the energies derived from each source divided by the number of hours in the test.

Monthly Capability = (Natural Flow Generation + Pond Supplement Generation + Upstream Storage Generation) / ***Test Hours***.

i. Upon reaching this refill check step, the ***Monthly Capability*** is correct, provided that the pond and upstream storage used can be refilled by natural flow if the same test was repeated on the same hour of the following day. For simplicity, it is assumed that the same natural flow will refill both the pond and upstream storage.

The refill check assumes that minimum possible water use occurs in between simulated test periods. The total outflow of water passing through and around the station is calculated:

OutFlow = (***Test Hours*** *__Flow at Station__) + (***Natural Flow Shortage*** * (***Hours of Supplementary Pond*** + ***Hours of Supplementary Upstream Storage***)) + ((24 - ***Test Hours)*** * (***Unusable Flow*** + ***Usable Flow***))

(***Test Hours*** *__Flow at Station__) represents the water passing through the generator station during the test.

(***Natural Flow Shortage ** (***Hours of Supplementary Pond*** + ***Hours of Supplementary Upstream Storage***)) represents the supplemental pondage and upstream storage used during the test period.

((24 - ***Test Hours)*** * (***Unusable Flow*** + ***Usable Flow***)) represents the water which must pass the station in between test periods on successive days.

j. If ***OutFlow*** does not exceed the natural inflow during a day (24 * ***Flow at Station***), then the ***Monthly Capability*** previously calculated is correct. If ***OutFlow*** exceeds the daily inflow, then the ***Monthly Capability*** is scaled downward to honor the refill requirement as follows:

Monthly Capability = ***Monthly Capability*** * (24 * ***Flow at Station***) / ***OutFlow***

k. The SCCs are calculated as follows:

Summer SCC **=** Average of four summer ***Monthly Capabilities*** (June – September)

Winter SCC **=** Average of eight winter ***Monthly Capabilities*** (October – May)

II. UPSTREAM STORAGE MODEL

The upstream storage model is a “no spill” model, which assumes that all ponds in the river system are full at the start of the modeling period. It models a “slug” of water being released and moving downstream. By the time the slug of water moves downstream to reach the facility being rated, the flow rate is assumed to be equal to the smallest flow for maximum generation among all intermediary generators including the upstream facility whose contribution is being computed.

The model computes a contribution from each upstream storage facility for each 30-minute interval within the test period. These contributions include the flow limitations in the river system as described above, the flow to achieve maximum generation at the station being rated, the hours of storage in the upstream pond for the upstream facilities, and the transit times to the station being rated.

First, each upstream generator contribution is determined in each 30-minute interval assuming an infinite pond size at the upstream storage facility. Then the cumulative unconstrained energy from the upstream facility is computed as the test period progresses. Then, an energy limit is computed for each upstream facility based on the hours of storage in the upstream pond when the upstream station generates at maximum, the transit time to the station being rated, the flow for maximum generation at the station being rated, and the maximum generation at the station being rated.

The cumulative energy delivery from an upstream storage facility to the station being rated with a 30-minute resolution is then constrained by the effective energy limit for the upstream storage energy ultimately produced at the station being rated.

Contributions in each 30-minute interval from relevant upstream storage facilities are then summed, and the kWh of effective upstream storage is ultimately computed.

A. Required Information

The following information must be provided for the **station being rated**:

Max. Capacity of Rated Station - the output of the station being rated, in kW, corresponding to the maximum flow.

Max. Capacity of Rated Station - the output of the station being rated, in kW, corresponding to the maximum flow.

The following information is needed for **each upstream facility**:

Max. Capacity of Upstream Facility - power, in kW, produced when the ***Flow at Max. Capacity of Upstream Facility*** passes through the generators at the upstream station.

Max. Capacity of Upstream Facility represents an average value that properly takes into account typical differences in head experienced under normal operating conditions.

kWh in Upstream Storage Facility - the amount of energy produced, in kWh, if the water in upstream storage is used to generate power at the upstream facility of the amount specified in ***Max. Capacity of the Upstream Facility*** without using any natural flow.

Flow at Max. Capacity of Upstream Facility - the amount of water flow, in cfs, required to produce the power specified in ***Max. Capacity of Upstream Facility***.

Hours of Supplementary Upstream Storage - the hours for which the pond of the upstream facility can sustain full output without any natural flow. This is used to ensure that the energy limitations of the upstream storage facility are respected within the methodology.

Hours of Supplementary Upstream Storage = kWh in Upstream Storage Facility / Max. Capacity of Upstream Facility

Transit Time - The time, in hours, required for water from the upstream storage facility to reach the pond of the station being evaluated. In order to simulate simultaneous requests for maximum generation for the same peaking period, upstream storage is assumed to be unavailable for generation for the station being studied until the ***Transit Time*** expires. An upstream pond cannot supplement the station being examined if ***Transit Time*** is greater than ***Test Hours***.

Test Hours - the number of hours simulated as a demonstration test period.

Minimum Flow at Max. Capacity - when computing the kWh available to the station being rated from an upstream storage facility, ***Minimum Flow at Max. Capacity*** is the smallest value found among the flows for maximum capacity for the upstream storage facility being evaluated for its contribution and that of any intermediary stations. This is the means by which the no-spill requirement of the model is enforced.

B. Calculations

1. **Compute the contribution from each upstream facility in each 30-minute interval of the test period.** The contribution is set to zero if the 30-minute interval is such that the slug of water being modeled will not arrive during the interval due to the ***Transit Time***. If the transit time is such that there is some overlap with the interval, then for simplicity it is assumed that the slug of water is fully available in the interval. For example, a transit time of 59 minutes renders that upstream storage unavailable for the first 30-minute interval, and then fully available during subsequent intervals. When the upstream storage is available to provide energy in a 30-minute interval, its energy is computed by multiplying the maximum capacity of the station being rated by the ratio of the most restrictive maximum flow in the path from the upstream storage to the flow

for maximum output at the station being rated. This energy is constrained by the maximum capacity of the station being rated. These calculations do not include any energy limitations of the upstream storage.

Kilowatt-Half Hours from Upstream Pond =

Lesser of

Max. Capacity of Rated Station * (Minimum Flow at Max. Capacity / Flow at Max. Capacity of Rated Station)

And

Max. Capacity of Rated Station

2. **Compute cumulative energy for each upstream storage facility.** For each 30-minute interval, compute the cumulative energy that would be delivered from the upstream storage as if it had an infinite pond size, as time progresses through the test period.

3. **Determine energy limit for each upstream storage facility.** Categorize the energy limit determination into one of four mutually exclusive scenarios. The energy limit is computed based on rules applicable to each scenario.

Scenario A applies when the most constraining upstream flow for the upstream facility exceeds or equals the flow for maximum generation at the station being rated, and this condition will persist from the time the transit time expires until the test period expires. In Scenario A, the energy limit equals

Energy Limit A = Max. Capacity of Rated Station * (Test Hours – Transit Time)

Scenario B applies when the most constraining upstream flow for the upstream facility exceeds or equals the flow for maximum generation at the station being rated, but this condition will not persist from the time the transit time expires until the test period expires. This scenario recognizes that the water arriving at the station being rated from the upstream facility in excess of that needed for maximum generation at the station being rated will be “ponded” at the station for use after the inflow from upstream storage goes to zero. Full output at the station being rated is assumed for the lesser of these two periods:

Time B =

Lesser of

Test Hours – Transit Time

And

Hours of Supplementary Upstream Storage + (Hours of Supplementary Upstream Storage * ((Minimum Flow at Max. Capacity – Flow at Max. Capacity of Rated Station) / Flow at

Max. Capacity of Rated Station))

Energy Limit B = Max. Capacity of Rated Station * Time B

Scenario C occurs when the constrained upstream flow is less than the flow required for maximum generation at the station being rated, but that lesser flow is sustainable through to the end of the test period once it arrives at the station being rated. In Scenario C, the energy limit is computed as:

Energy Limit C = Max. Capacity of Rated Station * (Minimum Flow at Max. Capacity / Flow at Max. Capacity of Rated Station) * (Test Hours – Transit Time)

Scenario D occurs when the constrained upstream flow is less than the flow required for maximum generation at the station being rated, but that lesser flow is NOT sustainable through to the end of the test period once it arrives at the station being rated. In Scenario D, the energy limit is computed as:

Energy Limit D = Max. Capacity of Rated Station * (Minimum Flow at Max. Capacity / Flow at Max. Capacity of Rated Station) * Hours of Supplementary Upstream Storage

4. **Apply energy limits for each upstream facility.** Apply the energy limits by comparing the cumulative unconstrained (from a total upstream storage energy perspective) initial energy assignments with the applicable energy limit from the upstream storage. The initial energy assignment is unaltered if the energy limit has not been met. However, if the cumulative energy in the 30-minute interval surpasses the energy limit, then the initial energy assignment is reduced sufficiently to honor the energy constraint.

5. **Sum up the contributions within each 30-minute interval from each upstream facility in the model.** The sum of the contributions in each 30-minute interval is capped by the maximum capacity of the station being rated.

6. **Determine the *kWh in Upstream Pond* for use in calculations.** Sum up the capped energy values in each 30-minute interval, multiplying by two to convert kW-half hours to kWh, to determine the usable upstream storage.

NOTE

Upstream ponds without generators can be used by determining the hours of supplemental upstream storage at the maximum allowable outlet flow and by using that maximum allowable outlet flow in determining the Minimum Flow at Max Capacity.

III. OP-23 APPENDIX C REVISION HISTORY

Rev No.	Date	Reason
Rev 0	09/01/13t	Initial version
Rev 0.1	07/06/15	Periodic review performed requiring no changes;
Rev 0.2	04/18/17	Periodic review performed by procedure owner requiring no changes; Added required corporate document identity to all page footers;
Rev 0.3	01/09/19	Periodic review performed by procedure owner requiring no changes; Made administrative changes required to publish a Minor Revision;
Rev 0.4	12/14/20	Periodic review performed by procedure owner requiring no changes; Made administrative changes required to publish a Minor Revision;
Rev 0.5	12/12/22	Periodic review performed by procedure owner requiring no intent changes; Added clarification on page 4 regarding steps for each month to determine capability for daily cycle hydro generating stations; Minor edits; Made administrative changes required to publish a Minor Revision.