Description and Methodology of the Cumulative Diversion Analysis (CDA) Output Package

The Water Availability Tool (WAT) has been developed following the guidelines outlined in the Policy for Maintaining Instream Flows in Northern California Coastal Streams. This document describes the materials produced and exported following the successful creation of a cumulative diversion analysis in the WAT

Acronyms

WAT - Water Allocation Tool
CDA - Cumulative Diversion Analysis
USGS - United States Geological Survey
POD - Point of Diversion
POI - Point of Interest
POA - Point of Analysis
PRISM - Parameter-elevation Regressions on Independent Slopes Model
NHD - National Hydrography Dataset
CFS - Cubic Feet per Second
GIS - Geographic Information System
WSR - Water Supply Report
eWRIMS - Electronic Water Rights Information Management System
MBF - Minimum bypass flow
FMF - February median flow
MCD - Maximum Cumulative Diversion

Overview

It is recommended that readers review [appendix B of the Policy for Maintaining Instream Flows in Northern California Coastal Streams] for reference of the following files.

Following the completion of a Cumulative Diversion Analysis (CDA), users can be emailed a .zip file named CDA_Output_Package.zip which contains all analysis output files. The files are intended to be inserted by the user into a document with supplementary spreadsheets for submission in support of a new application for a water right to the regulator. The files included in the download package are:

- senior_diverters_upstream_of_gage_raw_B.5.2.1-A3.csv
  - Senior diverters upstream of gage, as provided from eWRfMS. This csv will be downloaded, reviewed and uploaded by the user.
- senior_diverters_upstream_of_gage_edited_B.5.2.1-A3.csv
  - Uploaded edited senior diverters upstream of gage, with additional column yearly_total_diversion_af.
- senior_diverters_upstream_of_gage_water_year_total_diversion_B.5.2.1-A3.csv
  - List of total diversion from upstream diverters in all water years of record.
- gage_streamflow_mean_annual_flow_rate_B.5.2.1-A4.csv
  - Annual flow, impairment and values prorated to POI's
- peaks_over_threshold_time_series_B.5.2.3-A_*.csv
  - Represents the time series generation for the peaks-over-threshold implementation (policy section B.5.2.3)
- peaks_over_threshold_B.5.2.3-A_*.csv
  - List of peaks used in the peaks over threshold calculations
- peaks_over_threshold_results_poi_*.csv / maximum_cumulative_diversion_gage.csv
  - Lists the results of the peaks over threshold calculations
- initial_calculations_and_regional_criteria_or_user_thresholds_mbf_mcd_fmf_B.5.2.1-A4.csv

    - Threshold table (minimum bypass flow, maximum cumulative diversion, February median, etc.) as viewed on the site
- daily_flow_study_senior_diveters_poi*_B.5.3.2.csv
    - Contains senior diverter information used in the daily flow study (similar to senior_diverters_upstream_of_gage_edited)
- daily_flow_study_time_series_poi_*_B.5.3.1-B.5.3.3.csv
    - Shows the time-series involved with the daily flow study
- daily_flow_study_summary_B.5.3.4_poi_*_.csv
    - As displayed in the application, this shows the full output for the daily flow study with month exceedances for each POI using minimum bypass flow
- daily_flow_study_summary_B.5.3.5_poi_*.csv
    - As displayed in the application, this shows the full output for the daily flow study with 1.5-year daily peak flow values calculated using peaks over threshold, and monthly deltas
- february_median_flow_time_series_B.5.3.6_poi_*.csv
    - Time series of exceedances of the February median flow (for class II POI's downstream of a class III POD).
- daily_flow_study_summary_B5.3.6_poi_*.csv
    - As displayed in the application, this shows the full output for the daily flow study with month exceedances for each POI using February median flow
- Unimpaired_annual_gage_comparison.png
    - Bar chart of unimpaired vs impaired yearly flow volume at gage in acre-feet
- distinct_flood_events_gage/poi*.png
    - Graph of log-log fitted graph using data from peaks over threshold calculation.

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Data Sources & Preprocessing

The contents of the output package are compiled from the analysis of streamflow records from the United States Geological Survey (USGS). Only records from gages within or nearby (and representative of) the policy area are used. Gages on irrigation canals, conveyances around powerhouses, rivers with very large catchment basins, or with less than 10 water years are excluded. The streamflow records included in the final results are filtered to only include data from complete water years (defined as October 1 to September 30).

Candidate gages for watersheds are chosen using a variety of datasets, including average annual precipitation data from 1991-2020 from PRISM. More information about how candidate gages are selected can be found in the *Watershed Candidates Calculations* document.

The base hydrography used in this project is the NHDPlus high-resolution data set[1]. For further guidance, a user manual is available[2]. Watershed boundaries contained within the WAT have been derived from the NHDPlus high-resolution data by the project team.

Gage Diverters

Gage Senior Diverters Unedited

Table name: senior_diverters_upstream_of_gage_raw_B.5.2.1-A3.csv
Table description: This table contains a list of the senior diverters within the watershed upstream of the user-selected gage from the WSR. It includes all of the fields required for calculating seasonal demand, and from seasonal demand the daily diversion values are derived.
The following steps reflect the data source of this table:

1. Data is sourced and combined from https://data.ca.gov/dataset/water-rights and https://data.ca.gov/dataset/california-water-rights-uses-and-seasons. Also, as an additional data source for riparian water rights, the reported data from https://data.ca.gov/dataset/california-water-rights-water-use-reported is integrated. The linkage between the datasets is established through the 'application_number' and 'wr_water_right_id' columns.
2. All "senior diverters" within the watershed upstream of the gage are selected using a spatial intersect GIS function.
3. All stream segments on the downstream flow path are identified and given the 'analysis_label' = 'Downstream Flow Path' and all stream segments that branch off the downstream flow path are given the 'analysis_label' = 'Upstream of Downstream Flow Path'. All stream segments are given incrementing integers from upstream to downstream in the 'order_upstream_to_downstream' column.
4. All clipped "senior diverters" are then associated with a stream segment from step 3 by the following rules; if the senior diverter is within 1 mile of a stream segment and the

[1] https://pubs.usgs.gov/publication/ofr20191096
[2] https://pubs.usgs.gov/of/2019/1096/ofr20191096.pdf

senior diverter “source_name” is similar to the stream segment “gnis_name”, then it is associated with the matching stream segment, otherwise, the “senior diverter” is snapped to the nearest stream segment.

5. All clipped “senior diverters” from step 2 that are only within the upstream watershed of the Gage are identified and given the ‘analysis_label’ = ‘Upstream of Gage’ and a new incrementing integer starting at 1 overwrites the ‘order_upstream_to_downstream’ column. All other values (not upstream of gage) are then dropped.
6. As a post-processing step, water rights with water_right_status as one of “Canceled”, “Closed”, “Completed”, “Rejected”, “Revoked” or “Withdrawn” are filtered out of the table, and the “order_upstream_to_downstream” is re-created to address any gaps
7. Comments are added addressing edge cases with Riparian, Frost Protection, Irrigation, and Inactive water rights. See “comments” column below.

Column Name	**Column Type**	**Description**
analysis_label	Text E.g. Upstream of Gage	This is a tool-generated column. This column is primarily used by the tool to identify relative locations of senior diverters upstream of the proposed gage in the WSR section. However, for the gage it is simple enough to just filter to the diverters upstream of the gage and give the label “Upstream of Gage”. ● Upstream of Gage ○ Label assigned for senior diverters upstream of the user’s selected gage.
order_upstream _ to_downstream	Integer E.g. 1	This column is auto-populated with an ordered, unique integer representing the order of the senior diverter from furthest upstream to furthest downstream. This field is required to calculate upstream demand accurately at the Gage.
application_ number	Text E.g. A000016	Automatically populated by the tool using data from https://data.ca.gov/dataset/water-rights.
appl_pod	Text E.g. A000016_01	Automatically populated by the tool using data from https://data.ca.gov/dataset/water-rights.
wr_water_right_i d	Integer E.g. 100	Automatically populated by the tool using data from https://data.ca.gov/dataset/water-rights.
water_right_type	Text E.g. Appropriative E.g. Statement of Div and Use	Automatically populated by the tool using data from https://data.ca.gov/dataset/water-rights.

Column Name	Column Type	Description
water_right_ status	Text E.g. Licensed E.g. Inactive	Automatically populated by the tool using data from https://data.ca.gov/dataset/water-rights. If this value is ““Canceled”, “Closed”, “Completed”, “Rejected”, “Revoked” or “Withdrawn”, the water right is not included in the senior diverters, as the water right is not actively diverting water. Also, if this value is “Inactive”, a comment is added to the csv indicating further investigation should be performed.
application_ primary_owner	Text E.g. EAGLE CREEK PACIFIC, LLC	Automatically populated by the tool using data from https://data.ca.gov/dataset/water-rights.
pod_type	Text E.g. Point of Direct Diversion E.g. Point of Onstream Storage	Automatically populated by the tool using data from https://data.ca.gov/dataset/water-rights.
pod_count	Text E.g. 1	Automatically populated by the tool using data from https://data.ca.gov/dataset/water-rights.
source_name	Text E.g. UNNAMED STREAM	Automatically populated by the tool using data from https://data.ca.gov/dataset/water-rights.
latitude	Numeric E.g. 38.8295	Automatically populated by the tool using data from https://data.ca.gov/dataset/water-rights.
longitude	Numeric E.g. -123.2383	Automatically populated by the tool using data from https://data.ca.gov/dataset/water-rights.
drainage_area_ sqmi	Number E.g. 0.24533	Automatically populated by the tool. It reflects the area of the upstream watershed associated with the stream to which the senior diverter location was snapped. For detailed information

Column Name	Column Type	Description
		on the snapping logic applied to senior diverters and their association with streams, refer to the documentation linked here.
annual_precip_in	Number E.g. 46.125008	Automatically populated by the tool. It reflects the average annual precipitation (1991-2020) of the upstream watershed associated with the stream to which the senior diverter location was snapped. The data source of the precipitation data set is PRISM (https://prism.oregonstate.edu/).
use_codes	Text E.g. 'Domestic It is permissible to include multiple use codes within a single cell. For instance, 'Domestic, Stockwatering' is an acceptable format.	Automatically populated by the tool using the data from https://data.ca.gov/dataset/california-water-rights-uses-and-seasons and https://data.ca.gov/dataset/water-rights related together using 'application_number'.
priority_date	Date of the form yyyy-mm-dd E.g. 1965-01-01	Automatically populated by the tool using data from https://data.ca.gov/dataset/water-rights. Data is pulled from the field priority_date, if it's empty then receipt_date, then finally application_acceptance_date is used for a given diverter.
direct_div_season_start_month	Integer (1-12) E.g. 6	Direct Diversion Season Start Month Automatically populated by the tool using data by extracting **month** from 'direct_div_season_start' within https://data.ca.gov/dataset/water-rights.
direct_div_season_start_day	Integer (1-31) E.g. 30	Direct Diversion Season Start Day Automatically populated by the tool using data by extracting **day** from 'direct_div_season_start' within https://data.ca.gov/dataset/water-rights.
direct_div_season_end_month	Integer (1-12) E.g. 1	Direct Diversion Season End Month Automatically populated by the tool using data by extracting **month** from 'direct_div_season_end' within https://data.ca.gov/dataset/water-rights.

Column Name	Column Type	Description
direct_div_ season_end_ day	Integer (1-31) E.g. 20	Direct Diversion Season End Day Automatically populated by the tool using data by extracting **day** from 'direct_div_season_end' within https://data.ca.gov/dataset/water-rights.
storage_season _start_month	Integer (1-12) E.g. 1	Storage Season Start Month Automatically populated by the tool using data by extracting **month** from 'storage_season_start' within https://data.ca.gov/dataset/water-rights.
storage_season _start_day	Integer (1-31) E.g. 1	Storage Season Start Day Automatically populated by the tool using data by extracting **day** from 'storage_season_start' within https://data.ca.gov/dataset/water-rights.
storage_season _end_month	Integer (1-12) E.g. 1	Storage Season End Month Automatically populated by the tool using data by extracting **month** from 'storage_season_end' within https://data.ca.gov/dataset/water-rights.
storage_season _end_day	Integer (1-31) E.g. 1	Storage Season End Day Automatically populated by the tool using data by extracting **day** from 'storage_season_end' within https://data.ca.gov/dataset/water-rights.
max_storage_af	Numeric E.g. 100.1	Storage Amount (Acre-feet) Automatically populated by the tool using max_storage from https://data.ca.gov/dataset/water-rights. No unit conversion is performed by the tool as the units are assumed to be in Acre-feet as the column description in the Data Dictionary states: "The maximum annual amount of water requested to be placed into storage in any given year."
face_amount_af	Numeric E.g. 100.1	Maximum annual use limitation when it is less than the face value of the permit of license (Acre-feet) Automatically populated by the tool using multiple fields from https://data.ca.gov/dataset/water-rights. The tool automatically calculates this number by first determining 'face_value_af,' which involves converting 'face_value_amount' to acre-feet using 'face_value_units.' Subsequently, the tool populates this entry with 'max_dd_ann'

Column Name	Column Type	Description
		when it is not zero and is less than 'face_value_af'; otherwise, 'face_value_af' is used. This calculation follows the policy guidelines which states that the following information is required for each POD associated with each senior diverter: (B.1.2.4) “Maximum annual use limitation when it is less than the face value of the permit of license”
max_rate_of_ diversion_cfs	Numeric E.g. 0.0164872666	Maximum Rate of Diversion (cubic feet per second) Automatically populated by the tool using multiple fields from https://data.ca.gov/dataset/water-rights. The tool automatically calculates this number by first determining 'direct_diversion_rate_cfs' and ‘max_rate_of_diversion_cfs’ which involves converting ‘direct_diversion_rate’ to cubic feet per second using ‘direct_div_rate_unit' and converting ‘max_rate_of_diversion` to cubic feet per second using ‘max_rate_of_div_unit`. Subsequently, the tool populates this entry with ‘max_rate_of_diversion_cfs’ when it is not zero; otherwise, 'direct_diversion_rate_cfs' is used. These steps were taken to follow the policy guidelines which state that the following information is required for each POD associated with each senior diverter: (B.1.2.2) “Direct diversion rate, unless a maximum rate of diversion is imposed as a term on the permit or license, in which case the maximum rate of diversion should be used.”
minimum_ bypass_flow_cfs	Numeric E.g. 0.01	Minimum Bypass Flow (cubic feet per second) if imposed or specified in the water right permit of license. When downloading the csv, this field is unpopulated, as it lacks existence in the data source from which the tool extracts information.
seasonal_ demand_af	Numeric E.g. 230.4	Senior Diverter Seasonal Demand (Acre-feet) within the proposed project’s season of diversion.
overwrite_ seasonal_ demand_af_ justification	Text E.g. Adjusted seasonal demand to reflect correspondence with a state water board engineer.	Overwrite Seasonal Demand (Acre-feet) justification. This field is provided for the user to justify, detailing the method used to populate the field and the rationale behind overriding the tool's seasonal demand calculation.

Column Name	Column Type	Description
comments		This column is designated for user record-keeping purposes. There are a few warnings which are auto-populated to highlight edge cases for the user: - “Warning: Frost Protection in use_codes but senior diverter's diversion season has no overlap with frost season.” - “Warning: Irrigation in use codes but senior diverter's diversion and storage season has no overlap with summer irrigation season.” - “Warning: Inactive water right. Look into EWRIMS data for more information!” - “Warning: Riparian water right with storage, ensure this is accurate.” - “Likely out of order, this WR is on an isolated stream reach and therefore cannot be accurately ordered”

Gage Senior Diverters Edited

Table name: senior_diverters_upstream_of_gage_edited_B.5.2.1-A3.csv
Table description: This table has many of the same columns as senior_diverters_upstream_of_gage_raw_B.5.2.1-A3.csv. This table represents the necessary information to calculate the tool value: yearly_total_diversion_af. It is important to know the yearly diversion of a particular water right in order to simulate unimpaired conditions for flow at the gage.

Column Name	Column Type	Description
application_ number	Text E.g. A000016	Automatically populated by the tool using data from https://data.ca.gov/dataset/water-rights.
water_right_type	Text E.g. Appropriative E.g. Statement of Div and Use	Automatically populated by the tool using data from https://data.ca.gov/dataset/water-rights.
water_right_ status	Text E.g. Licensed E.g. Inactive	Automatically populated by the tool using data from https://data.ca.gov/dataset/water-rights.

Column Name	Column Type	Description
face_value_amount	Numeric E.g. 100.1	Corresponds to column 'face_amount_af' in senior_diverters_upstream_of_gage_raw_B.5.2.1-A3.csv
priority_date	Date of the form yyyy-mm-dd E.g. 1965-01-01	Automatically populated by the tool using data from https://data.ca.gov/dataset/water-rights. Data is pulled from the field priority_date, if it's empty then receipt_date, then finally application_acceptance_date is used for a given diverter.
diversion_rate_cfs	Numeric E.g. 0.0164872666	Corresponds to column "max_rate_of_diversion_cfs" from senior_diverters_upstream_of_gage_raw_B.5.2.1-A3.csv
yearly_total_diversion_af	Numeric E.g. 50.2	Calculated value describing the total demand of the senior diverter. There are 3 main contributors to this value. 1. **Storage Demand**. This value represents the storage water usage of the senior diverter. This is the max_storage_af value from 2. **Direct Diversion Demand**. This value represents the directly diverted water usage of the senior diverter. This is simply calculated by subtracting the face_value_amount from the storage demand 3. **Frost demand.** This value is calculated using the max_rate_of_diversion_cfs. It is assumed that 10 hours of frost protection diversion happens every other day between March 15th and April 30th. This value is defaulted to 0 if "Frost Protection" is **not** one of the use_codes. yearly_total_diversion_af is calculated as the sum of the 3 values above.

Senior Diverters Upstream of Gage Total Diversion

Table name: senior_diverters_upstream_of_gage_water_year_total_diversion_B.5.2.1-A3.csv
Table description: This table contains the data from the water years of record, starting from the earliest start of the time series or the first diverter's start based on the first full water year after its first priority_date (from Gage Senior Diverters Edited) and ending with the current last full water year. Each year has an associated total diversion value in acre-feet.

Column Name	Column Type	Description
water_year	Year E.g. 1970	Represents the water year (October 1 - September 30th) of record.
total_diversion_af	Numeric E.g. 6.1	This column is populated with the total_diversion from **all senior diverters** upstream of the gage for each year. This data is generated from senior_diverters_upstream_of_gage_edited_B.5.2.1-A3.csv, generated from the sum of the associated diverters with priority_dates that indicate activity for that year.

Gage Impaired vs Unimpaired Comparison Plot

File Name: Unimpaired_annual_gage_comparison.png
Description: The gage impaired vs unimpaired comparison bar chart illustrates the differences between the gage yearly flow data when impaired and unimpaired for each water year of record. The data from senior_diverters_upstream_of_gage_water_year_total_diversion_B.5.2.1-A3.csv is used to generate the unimpaired gage values. This unimpaired gage data is used throughout the CDA, as a baseline of unimpaired conditions to be scaled to POI's, to calculate the minimum bypass flow and to calculate maximum cumulative diversion.

Description of Equations & Assumptions to Derive Intermediate Values - Gage Senior Diverters

The following section outlines the calculations that are completed to generate intermediate values found in senior_diverters_upstream_of_gage_water_year_total_diversion_B.5.2.1-A3.csv. Furthermore, it outlines assumptions that are made when generating these values so applicants and application reviewers can be clear about assumptions and how they change the tool outputs.
Note: If a user elects to use gage data without unimpairing with senior diversions, none of the below data and calculations are necessary.

Frost Demand in Acre-Feet

Description: Demand associated with frost protection water usage.
Equation:
$$demand = max\_rate\_of\_diversion\_cfs \ * \ 3600 \ * \ 10\, hours \ * \ overlapping\_days/2 \ / \ 43560\ (cf/acre)$$
Assumptions:

All overestimations of this value cause **more** calculated streamflow to be available at the POD and POIs (easier to meet policy, more assumed demand causes higher gauge unimpairment) and underestimations cause **less** calculated streamflow to be available (more difficult to meet policy).

- It is assumed that frost demand is applied every other day between March 15 and April 30th, for 10 hours a day
    - This assumption could cause an underestimation of frost demand in February, the first half of March, and May where there could potentially be diversions for frost

Storage Demand in Acre-Feet

Description: Gage Senior Diverter Demand Associated with Storage
Equation:

If the senior diverter's storage season is within the winter policy season:

$$demand_{day} = max\_storage\_af / overlapping\_days\_of\_storage\_and\_policy$$

If the senior diverter's storage season is outside of the winter policy season:

$$demand_{day} = max\_storage\_af \ / \ days\_of\_storage \ (length\ of\ storage\ season)$$

Assumptions:
All overestimations of this value cause **more** calculated streamflow to be available at the POD and POIs (easier to meet policy, more assumed demand causes higher gauge unimpairment) and underestimations cause **less** calculated streamflow to be available (more difficult to meet policy).

- Storage demand is applied uniformly over its storage season
    - This could cause an under-or-overestimation of storage demand overlapping the proposed project
- Storage demand is applied only within the policy season if the policy season overlaps the diverter storage season
    - This could cause overestimation of storage demands within the policy season and underestimation of storage demands outside of the policy season
- Reservoirs are empty at the beginning of the storage season and full at the end of the storage season
    - This could cause an overestimation relative to actual storage demands

Direct Diversion Demand in Acre-Feet

Description: Demand associated with water usage for direct diversion.
Equation:
If the diverter use codes use_codes **do not** only have "Irrigation" or "Irrigation" and "Frost Protection":

$$demand = diversion\_per\_day * overlapping\_proposed\_and\_days\_of\_direct\_diversion$$

If the diverter use codes use_codes **do not** only have "Irrigation" or "Irrigation" and "Frost Protection": days_outside_policy

$$days\_outside\_policy = days\_of\_diversion - overlapping\_days\_of\_direct\_diversion\_and\_policy\_season$$
$$dayratio = overlapping\_proposed\_and\_days\_of\_direct\_diversion / days\_outside\_policy\ (above)$$
$$demand = diversion\_amount\_af * dayratio\ (above)$$

Assumptions:
All overestimations of this value cause **more** calculated streamflow to be available at the POD and POIs (easier to meet policy, more assumed demand causes higher gauge unimpairment) and underestimations cause **less** calculated streamflow to be available (more difficult to meet policy).

- Diverter demand occurs equally over the course of the senior diverter's diversion season
    - This could overestimate or underestimate the overlapping demand as diversions may vary on a yearly basis
- Diverters strictly follow irrigation guidelines for only diverting outside of the policy season if irrigating
    - This could overestimate the diversions for the given diverter outside of the policy season and underestimate the value within the policy season
- Diverters do not follow minimum bypass flow requirements or other streamflow-based analyses, they divert up to their maximum over their season
    - This would likely over-estimate the demand, as the water right holder may be bound to leave more water in the stream than the estimated diversion
- Diverter's face_amount_af value (used to derive diversion_amount_af, and diversion_per_day) is accurate and represents the total diversion to both storage and direct diversion
    - Changes in this value could cause under-or-overestimation of diversions. Users are directed to double check this value before submitting senior diverters due to its critical nature

Total Demand in Acre-Feet

Description: Total demand from water used for direct diversion, frost protection, and storage for gage upstream diverters. Values for this data point are derived from those in the Senior Diverters With Seasonal Demand Calculation csv.
Equation:

This value is derived from the frost demand, storage demand, and direct diversion.

$$total\_demand_{day} = frost\_demand_{day} + storage\_demand_{day} + direct\_diversion\_demand_{day}$$

If seasonal demand > face_amount_af, then scale the daily values so they sum to face_amount:

$\Sigma total\_demand_{day} > face\_amount\_af$ then
$total\_demand_{day} = total\_demand_{day} * face\_amount\_af / \Sigma total\_demand_{day}$

Assumptions:
All overestimations of this value cause **more** calculated streamflow to be available at the POD and POIs (easier to meet policy, more assumed demand causes higher gauge unimpairment) and underestimations cause **less** calculated streamflow to be available (more difficult to meet policy).

- Diverter's face_amount_af value (used to derive diversion_amount_af, and diversion_per_day) is accurate and represents the total diversion to both storage and direct diversion
    - Changes in this value could cause under-or-overestimation of diversions. Users are directed to double check this value before submitting senior diverters due to its critical nature
- All assumptions from frost, storage, and direct diversion demand apply to this value

Unimpairing Gage Data with Total Demand

Description: Using the above time-series, methodology is described to unimpair the gage time-series with its upstream diverters, which are added into the gage time-series after they have begun diverting using the field *priority_date* from the above file. The first full water year of diversions after the priority_date is taken as the source to know a diverter is diverting.
Equation:
Then, all of the diversions are summed to get a total upstream demand value. Diversion start dates are taken into consideration with respect to the date being analysed.
$upstream\_diverter\_demand_{date} = \Sigma\, diverter\_total\_demand_{date}\,(date > priority\_date_{full\_water\_year})$

The senior diverters timeseries is then generated for each date by adding the upstream diverter demand to the observed streamflow
$gage\_unimpaired\_timeseries_{date} = gage\_streamflow_{date} + upstream\_diverter\_demand_{date}$
Assumptions:
All overestimations of this value cause **more** calculated streamflow to be available at the POD and POIs (easier to meet policy, more gage streamflow scales to more POI or POD sreamflow) and underestimations cause **less** calculated streamflow to be available (more difficult to meet policy).

- The diverter start dates are an accurate way to measure streamflow accumulation over time
    - Using all diversions over time instead of adding in as they appear will cause **more** calculated streamflow to appear
- All assumptions from total_demand in acre-feet apply to this value

Peaks Over Threshold

The policy section describing the peaks over threshold method is policy section B5.2.3. Peaks over threshold is a process to find instantaneous peak flows over a time series, and then using these peaks to find the 1.5-year instantaneous peak flow, which is required for:

1. Finding the maximum cumulative diversion for each POI using the gage data
2. Evaluating the reduction in natural flow variability for section B5.3.5 of the daily flow study.

Peaks Over Threshold Time Series

Table name:peaks_over_threshold_time_series_B.5.2.3-A_*.csv

Table description: The time series to indicate the methodology and results of the peaks over threshold method. This time series represents finding the peaks. The time series data it pulled from the gage daily streamflow data, which was obtained from the USGS hydrography dataset.

Column Name	Column Type	Description
date	Date E.g. 01-10-1961	Day to be analyzed, the time range is pulled from the user's selected gage historical data.
daily_flow	Number E.g. 6.1	The daily flow value for the day of analysis.
is_peak	Binary (0/1)	If the current daily flow is greater than the two days before and after, it is said to be a local maximum or a peak. This column is 1 if the current day is a local maximum.
peak_value	Number E.g. 6.1	This is the daily flow value if the day is a peak (is_peak = 1)

Sorted Peaks Table

Table name:peaks_over_threshold_B5.2.3-A_*.csv

Table description: This table contains all of the peaks identified in peaks_over_threshold_time_series_B.5.2.3-A_*.csv, sorted and presented for the peaks over threshold analysis. There is also a "recurrence interval" included in each of these, which uses the Weibull formula as found in policy section B5.2.3A:

Column Name	Column Type	Description
rank	Integer E.g. 2	Rank of the peak, with largest peak having rank = 1
daily_peak_flow_cfs	Number E.g. 6547.82	The daily flow value for peak day of analysis.
recurrence_interval	Number E.g 7.5	Recurrence interval as found using the below formula (Weibull formula) $T = (N + 1)/m$ *T= recurrence interval* *N = record length (total number of years in peaks_over_threshold_time_series_B.5.2.3-A_*.csv)* *M = rank of the peak (sorted highest to lowest, highest peak rank = 1)*

Peaks and Recurrence Intervals Plot

File name: distinct_flood_events_gage/poi_*.png

Table Description: Graph of log-log fitted graph using data from peaks_over_threshold_B5.2.3-A_*.csv. Plots the recurrence_interval on the x-axis and the instantaneous peak flow on the y-axis. A line of best fit is drawn, and the value at the 1.5-year recurrence interval is indicated on the plot.

Peaks Over Threshold Results

Table name:peaks_over_threshold_results_poi_*.csv / maximum_cumulative_diversion_gage.csv

Table description: Since peaks_over_threshold is used in both the maximum cumulative diversion calculations and the daily flow study, the resulting files are named differently for the two. This table represents the peaks over thresholds results, using both a value interpolated from the table peaks_over_threshold_B5.2.3-A_*.csv and the value from the line of best fit on the plot distinct_flood_events_gage/poi_*.png. This table also indicates the threshold value used for the analysis, which was selected so that there were an average of three events per year.

Column Name	Column Type	Description
table_derived	Number E.g. 1789.009	Table derived 1.5-year instantaneous peak flow for the gage or POI. This value is either pulled directly from the table in sorted_peaks if there is an entry at exactly 1.5 years, or is derived from the average of the two values on either side of 1.5 years.
curve_fit	Number E.g. 1582.5	Curve fit value for 1.5 year instantaneous peak flow. This is the value displayed in the peaks and recurrence intervals plot, and is derived from a line of best fit on the log-log plot distinct_flood_events_*.png
threshold	Number E.g 7	Threshold value chosen so that peak flows have a minimum recurrence_interval of ⅓ of a year. This is the smallest value in peaks_over_threshold_B5.2.3-A_*.csv.

Description of Equations & Assumptions to Derive Intermediate Values - Peaks Over Threshold

The following section outlines the calculations that are completed to generate intermediate values found in the above files. Furthermore, it outlines assumptions that are made when generating these values so applicants and application reviewers can be clear about assumptions and how they change the tool outputs.

Finding Peaks

Description: Methods used to find peaks in historical gage unimpaired time series, or the point of interest time series. Peaks are necessary for the method of peaks over threshold.
Equation: A sliding window formula is used to find peaks in a time series. The value is_peak at each time slice is derived from the following equation:

$$is\_peak_n = 1\ if\ val_n > \{val_{n-2}, val_{n-1}, val_{n+1}, val_{n+2}\}\ else\ 0$$

Assumptions:
Overestimations in the number of peaks does not cause a significant change in the results of the peaks over thresholds calculations as the threshold is always determined by the number of years in the time series data set. Underestimations, however, could cause significant differences as fewer peaks would cause a perhaps lower threshold to be selected, and this may cause a lower 1.5-year peak flow in some cases.

- It is assumed that a local peak among 5 data points is sufficient to call a peak
    - If a stricter analysis is necessary, the peak flow could end up lower as fewer peaks would be selected

- This assumption allows for more peaks, which likely causes a more stable analysis

Sort Peaks & Determine Threshold

Description: Methods used to find the threshold amongst the peaks determined by the methods above.
Equation: Sorting is done using general sorting algorithms. Once the peaks are determined, the threshold is then found by doing time_series_length:

$$threshold = peak_n \; if \; n = 3 * time\_series\_years, \; else \; peak_{max(n)}$$

Assumptions:
Overestimations in the threshold value would cause a more skewed analysis towards higher peak values. This may cause a higher 1.5-year peak flow to be estimated, the maximum cumulative diversion or instream flow variability calculation will be higher and therefore the analysis will assume **more** streamflow is available at the POD and POI's. Underestimations would cause the converse effect.

- The above formula assumes that the found peaks from above can be used as a source of truth for finding the threshold. If the found peaks are therefore incorrect or not strict enough, the threshold could be underestimated. This could cause **less streamflow to** appear available than there is in reality.

Thresholds Table Data

Table name:
initial_calculations_and_regional_criteria_or_user_thresholds_mbf_mcd_fmf_B.5.2.1-A4.csv
Table Description: This table contains the thresholds table data as displayed to the user on the site. This table represents a meaningful point of review for the user. The thresholds table data is vital for the analysis conducted in the daily flow study.

Column Name	Column Type	Description
location	Text E.g. Gage	Contains the location being analyzed, which is one of: - "Gage" - "POD" - "POI <id>"
stream_class	Integer E.g. 2	User-selected stream class of the POD or POI, in the range 1-3. This value is omitted for the Gage.
position_relative_to_ula	Text E.g "Below or At"	Contains the user-entered value for anadromy position. Is either "Above" or "Below or at".

area_sqmi	Number E.g. 37.198306	Drainage area of the upstream watershed of the gage, POD or POI. This value is populated automatically by the tool using USGS and NHD data.
average_annual_precipitation_in	Number E.g. 46.6209	Average annual precipitation of the Gage, POD or POI. This value is populated automatically by the tool using USGS and NHD data.
mean_annual_flow_volume_af	Number E.g. 137.84	Total average annual flow volume at the Gage, POD or POI in acre-feet. This value is populated automatically by the tool for gages using USGS and NHD data. For POIs and PODs, the gage value is multiplied by the below ratio to obtain this value.
mean_annual_flow_volume_cfs	Number E.g 45.67	Average flow volume rate in cubic-feet per second at the Gage, POD or POI. This value is populated automatically by the tool for gages using USGS and NHD data. For POIs and PODs, the gage value is multiplied by the below ratio to obtain this value.
ratio	Number E.g. 0.15	Ratio calculated from the drainage area (area_sqmi) and the average annual precipitation (average_annual_precipitation_in) using the following formula: $Ratio = area_{POI}/area_{Gage} * precipitation_{POI} / precipitation_{Gage}$
rc_mbf_cfs	Number E.g 3451.67	Regional Criteria (tool-calculated) minimum bypass flow. Value is calculated by performing the following calculation on the mean_annual_flow_volume_cfs: **If area_sqmi is less than or equal to 1 square mile:** $mbf = 9 * mean\ annual\ flow\ cfs$ **If area_sqmi is between 1 and 321 square miles:** $mbf = 8.8 * (mean\ annual\ flow\ cfs) * (area)^{-0.47}$ **If area_sqmi is greater than or equal to 321 square miles:** $mbf = 0.6 * mean\ annual\ flow\ cfs$ *See the policy Appendix B5.2.2 for the derivation of the above calculation*
up_mbf_cfs	Number E.g. 4531.78	User-Provided Minimum Bypass flow in the tool. Note that for class II POI's, this value must be greater than or equal to fmf_cfs
rc_mcd_cfs	Number E.g. 53.4	Regional Criteria (tool-calculated) maximum cumulative diversion. Value is calculated using the 1.5-year instantaneous peak flow calculated as curve_fit in maximum_cumulative_diversion_gage.csv. This value is stated to be 5 percent of the instantaneous peak flow of the gage, which is then scaled using the ratio above to each POI.
up_mcd_cfs	Number E.g. 67.9	User-Provided maximum cumulative diversion in the tool.

fmf_cfs	Number E.g. 24.1	February median flow value as calculated by the tool. Calculated by finding the median value of the gage's records in february, and multiplying by the ratio above.

Description of Equations & Assumptions to Derive Intermediate Values - Peaks Over Threshold

The following section outlines the calculations that are completed to generate intermediate values found ininitial_calculations_and_regional_criteria_or_user_thresholds_mbf_mcd_fmf_B.5.2.1-A4.csv. Furthermore, it outlines assumptions that are made when generating these values so applicants and application reviewers can be clear about assumptions and how they change the tool outputs.

Streamflow Scaling Ratio

Description: Ratio used to scale gaged streamflow to given project or POI. Values for this data point are derived from geospatial analysis of nhdplusid watersheds and public precipitation datasets.
Equation:

$$streamflow\_scaling\_ratio = wa_{pod}/wa_{gage} * map_{pod}/map_{gage}$$

Where wa = watershed area and map = mean annual precipitation.

Assumptions:
All overestimations of this value cause **more** calculated streamflow to be available at the POD and POIs (easier to meet policy) and underestimations cause the converse effect (more difficult to meet policy).

- The [NHDPlus High-Res] dataset is trusted as a source of truth for watershed sizes for catchments, and catchments are broken down based on intersections with points of diversion and gages for calculations. These intersections are estimated as the closest point on the catchment streamflow to the diverter.
    - Based on the intersection point and the geometry of the river, this could cause an over-or-under-estimation of the watershed for the diverter based on the geometry of the stream segment

Minimum Bypass Flow

Description: Minimum bypass permitted in the stream to allow spawning, rearing, and passage for fish species.
Equation:

If area_sqmi is less than or equal to 1 square mile:

$$mbf = 9 * mean\ annual\ flow\ cfs\ (gage) * streamflow\_scaling\_ratio\backslash$$

If area_sqmi is between 1 and 321 square miles:

$$mbf = 8.8 * (mean\ annual\ flow\ cfs\ (gage) * streamflow\_scaling\_ratio) * (area)^{-0.47}$$

If area_sqmi is greater than or equal to 321 square miles:

$$mbf = 0.6 * mean\ annual\ flow\ cfs\ (gage) * streamflow\_scaling\_ratio$$

Assumptions:
An overestimation of minimum bypass flow would cause **more** calculated streamflow to be available at the POD and POIs as more water use would be permitted. Underestimation would cause the converse effect.

- The mean annual flow value at the gage is determined from USGS stream statistics from QA/QC'd USGS data. These flows have a high determinance on the minimum bypass flow. Users are recommended to use gages with more recent data and longer periods of record to smooth any variation in this dataset
- The streamflow scaling ratio's assumptions about watershed size carry over into this data point as the scaling ratio is used heavily in the above formula

Maximum Cumulative Diversion

Description: Maximum Cumulative Diversion is the maximum permitted diversion at a given point. It is determined from the results of the peaks over threshold calculation.
Equation: The maximum cumulative diversion is determined as follows:
1.5_year_instantaneous_peak

$$mcd = 0.05 * 1.5\_year\_instantaneous\_peak$$

Assumptions:
Any assumptions or estimation in the peaks over threshold results would cause the same estimation to happen to the maximum cumulative in a linear fashion (i.e. a 5% variability in the peaks over threshold output causes a 5% variability in the mcd output)

February Median Flow

Description: February Median Flow is used for analysis of class III points of interest. It is determined entirely based on historical gage flow, scaled using the streamflow scaling ratio to the POI.

Equation:

A statistical median is found from the gage dataset scaled with the scaling ratio for all values in February. gage_timeseries

$$fmf \ = \ Median(gage\_timeseries_{february} \ * \ streamflow\_scaling\_ratio)$$

Assumptions:
An overestimation of february median would cause **more** calculated streamflow to be available at the POD and POIs as more water use would be permitted. Underestimation would cause the converse effect.

- The mean annual flow value at the gage is determined from USGS stream statistics from QA/QC'd USGS data. These flows have a high determinance on the minimum bypass flow. Users are recommended gages with more recent data and longer periods of record to smooth any variation in this dataset
- The streamflow scaling ratio's assumptions about watershed size carry over into this data point as the scaling ratio is used heavily in the above formula

Daily Flow Study

The daily flow study represents the overall results of the cumulative diversion analysis. The values in the thresholds table, along with the gage unimpaired time series, are all used to create the daily flow study outputs. The daily flow study values represent the impact of the project on the days of its diversion in its project season.

Daily Flow Study Senior Diverters

Table name:daily_flow_study_senior_diveters_poi*_B.5.3.2.csv
Table description: The senior diverters upstream of a POI in the daily flow study represent the largest impairment to the POI. The daily flow study relies on creating **daily** impairments for each diverter and the user's proposed project. This table represents the yearly impairment, broken down by day, for each of the senior diverters upstream of the POI and the user's project. Note that all of the data here is pulled from the user-uploaded senior diverters from the WSR section of the WAT.

Column Name	Column Type	Description
application_ number	Text E.g. A000016	Automatically populated by the tool using data from https://data.ca.gov/dataset/water-rights.
order_upstream _to_downstream	Number E.g. 1	This is a tool-generated column described in Order Description. This column is auto-populated with an ordered, unique integer representing the order of the senior diverter from furthest

		upstream to furthest downstream. This field is required to calculate upstream demand accurately at the Proposed POD and all senior diverters along the flow path (also known as the Points of Analysis). The tool prioritizes the ordering of senior diverters as follows: those with an 'analysis_label' of 'Upstream of POD' first, followed by 'Proposed POD', and then the remaining senior diverters with 'analysis_label's of 'Upstream of Downstream Flow Path', 'Downstream Flow Path', and 'Inside Project Extent' are appended in their respective order.

analysis_label	Text E.g. Upstream of POD	This is a tool-generated column. This column is primarily used by the tool to identify relative locations of senior diverters upstream of the proposed POD, senior diverters which are along the downstream flow path, and senior diverters which are upstream of the senior diverters along the flow path. This column can also be thought of as a way to describe the position of the point of diversion relative to the proposed POD and the senior diverters along the flow path. The field supports the water supply report requirement to perform analysis at the Proposed POD as well as at senior diverters along the downstream flow path. There are 5 possible values for 'analysis_label': ● Upstream of POD ○ Label assigned for senior diverters upstream of the Proposed Point of Diversion (POD). ● Proposed POD ○ Label assigned and populated with the selected Proposed POD. ● Downstream Flow Path ○ POA stands for Point of Analysis. This label is assigned if the tool considers the senior diverter to be on the downstream flow path (therefore a WSR Point of Analysis). The tool automatically considers senior diverters on the downstream flow path if the senior diverter is either within 1 mile of the downstream flow path and the senior diverter 'source_name' is similar to the downstream flow path stream name, or, the downstream flow path is the nearest stream to the senior diverter. ● Upstream of Downstream Flow Path ○ The label is assigned if the tool determines that the senior diverter is upstream of another senior diverter with the 'analysis_label' of 'Downstream Flow Path'. ● Inside Project Extent ○ Label assigned if the senior diverter is within the watershed upstream of the most downstream segment of the downstream flow path but not upstream of any identified senior diverter with an 'analysis_label' of 'Downstream Flow Path'. Senior diverters with this label will not be used in any subsequent senior seasonal demand calculations. Water rights with this 'analysis_label' have been included in this table for completeness. For example, in case the tool has assigned an 'analysis_label' incorrectly, they are included and it is up to the user to relabel them

		appropriately so they are used in the calculations correctly.
frost	Text E.g “Yes” or “No”	Whether the senior diverter requires diversions for frost protection.
notes	Text E.g. “”	Optional column to add any additional notes for water board submission.
face_amount_af	Numeric E.g. 100.1	Maximum annual use limitation when it is less than the face value of the permit of license (Acre-feet) Automatically populated by the tool using multiple fields from https://data.ca.gov/dataset/water-rights. The tool automatically calculates this number by first determining 'face_value_af,' which involves converting 'face_value_amount' to acre-feet using 'face_value_units.' Subsequently, the tool populates this entry with 'max_dd_ann' when it is not zero and is less than 'face_value_af'; otherwise, 'face_value_af' is used. This calculation follows the policy guidelines which states that the following information is required for each POD associated with each senior diverter: (B.1.2.4) “Maximum annual use limitation when it is less than the face value of the permit of license”
max_rate_of_ diversion_cfs	Numeric E.g. 0.0164872666	Maximum Rate of Diversion (cubic feet per second) Automatically populated by the tool using multiple fields from https://data.ca.gov/dataset/water-rights. The tool automatically calculates this number by first determining 'direct_diversion_rate_cfs' and ‘max_rate_of_diversion_cfs’ which involves converting ‘direct_diversion_rate’ to cubic feet per second using ‘direct_div_rate_unit' and converting ‘max_rate_of_diversion` to cubic feet per second using ‘max_rate_of_div_unit`. Subsequently, the tool populates this entry with ‘max_rate_of_diversion_cfs’ when it is not zero; otherwise, 'direct_diversion_rate_cfs' is used. These steps were taken to follow the policy guidelines which state that the following information is required for each POD associated with each senior diverter: (B.1.2.2) “Direct diversion rate, unless a maximum rate of diversion is imposed as a term on the permit or license, in which case the maximum rate of diversion should be used.”
pod_type	Text E.g. Point of Direct	Automatically populated by the tool using data from https://data.ca.gov/dataset/water-rights.

	Diversion E.g. Point of Onstream Storage	
onstream_storage	Text E.g. “Yes” or “No”	“Yes” if pod_type = Point of Onstream Storage. Indicates whether the point of diversion diverts to onstream storage.
max_storage_af	Numeric E.g. 100.1	Storage Amount (Acre-feet) Automatically populated by the tool using max_storage from https://data.ca.gov/dataset/water-rights.
direct_div_season_start	Date E.g. 05/01/2019	Diversion season start date for the senior diverter. Automatically populated by the tool using https://data.ca.gov/dataset/water-rights. The year field is populated so that the storage season always occurs entirely within 2019, or between 2018 and 2019 if in multiple years.
direct_div_season_end	Date E.g. 10/31/2019	Diversion season end date for the senior diverter. Automatically populated by the tool using https://data.ca.gov/dataset/water-rights. The year field is populated so that the storage season always occurs entirely within 2019, or between 2018 and 2019 if in multiple years.
days_of_diversion	Numeric E.g. 184	Calculated value as the number of days (inclusive) between direct_div_season_start and direct_div_season_end.
storage_season_start	Date E.g. 12/15/2018	Storage season start date for the senior diverter. Automatically populated by the tool using https://data.ca.gov/dataset/water-rights. Matches with storage_season_start_month and storage_season_start_day from senior_diverters_unedited.csv. The year field is populated so that the storage season always occurs entirely within 2019, or between 2018 and 2019 if in multiple years.
storage_season_end	Date E.g. 03/31/2019	Storage season end date for the senior diverter. Automatically populated by the tool using https://data.ca.gov/dataset/water-rights. Matches with storage_season_end_month and

		storage_season_end_day from senior_diverters_unedited.csv. The year field is populated so that the storage season always occurs entirely within 2019, or between 2018 and 2019 if in multiple years.
days_of_storage	Numeric E.g. 107	Calculated value as the number of days (inclusive) between storage_season_start and storage_season_end.

Daily Flow Study Comparison Time Series

Table name:daily_flow_study_time_series_poi*_B.5.3.1-B.5.3.3.csv

Table description: This table contains the dates that have been analyzed as part of the daily flow study. It contains the unimpaired flow data at the gage, POI, and the necessary impaired time-series to create the minimum bypass flow analysis for section B5.3.4 of the policy.

Column Name	Column Type	Description
date	Date E.g. 01-10-1961	Day of time series.
gage_flow	Number E.g. 2.56	Unimpaired Gage flow, generated from the methodology of unimpairing streamflow above.
<application_id>_face_value_af	Number E.g 8.5	Face value of an upstream diverter, given as reference for the maximum diversion over the year for the diverter.
<application_id>_daily_diversion_cfs	Number E.g. 0.06	Average estimated diversion rate of the diverter, generated by the methodology and equations mentioned below.
<application_id>_daily_diversion_af	Number E.g. 0.4	Daily diversion in acre-feet for the diverter if the diversions are made at the above daily_diversion_cfs rate.
<application_id>_total_yearly_diversion_af	Number E.g. 1.2	The total diversion so far in the current water year for the given senior diverter. Equals the sum of the daily_diversion_af values.
senior_diverters_total_diversion_af	Number E.g. 1.5	The sum of all senior diverters daily diversion_af values
senior_diverters_diversion_rate_cfs	Number E.g. 0.008724	Diversion rate of all senior diverters. Users can inform themselves of these values by analysing values from daily_flow_study_senior_diveters_poi*_B.5.3.2.csv. However, the maximum diversion is such that the impaired flow at the poi is 0 (diverting all unimpaired flow).

pod_diversion_af	Number E.g. 1.435	Calculated project diversion on given date, in acre-feet
pod_diversion_cfs	Number E.g. 2.673	Calculated project diversion rate on given date, in cfs.
poi_flow_unimpaired_cfs	Number E.g. 0.379	Unimpaired flow at the POI. This value is obtained by multiplying the gage_mean_daily_flow_cfs by the ratio in initial_calculations_and_regional_criteria_or_user_thresholds_mbf_mcd_fmf_B.5.2.1-A4.csv
poi_flow_impaired_wth_senior_diverters_cfs	Number E.g. 0.312	Flow at the POI impaired by diverters. This is equal to poi_flow_unimpaired_cfs - senior_diverters_diversion_rate_cfs.
poi_flow_impaired_with_senior_diverters_plus_proposed_cfs	Number E.g. 0.302	Flow at the POI impaired by diverters and the user-proposed project. This is equal to poi_flow_impaired_wth_senior_diverters_cfs minus the user's entered diversion rate if in the user's diversion season.
minimum_bypass_flow_cfs	Number E.g. 875	Minimum bypass flow value, either the user-entered or tool-calculated values as indicated by up_mbf_cfs or rc_mbf_cfs from initial_calculations_and_regional_criteria_or_user_thresholds_mbf_mcd_fmf_B.5.2.1-A4.csv.
poi_unimpaired_flow_meets_or_exceeds_mbf	Binary (0/1) E.g. 0	Whether the unimpaired flow meets or exceeds the minimum bypass flow. = 1 if poi_flow_unimpaired_cfs >= minimum_bypass_flow_cfs = 0 otherwise
poi_impaired_flow_meets_or_exceeds_mbf	Binary (0/1) E.g. 0	Whether the impaired flow with senior diverters meets or exceeds the minimum bypass flow. = 1 if poi_flow_impaired_wth_senior_diverters_cfs >= minimum_bypass_flow_cfs = 0 otherwise
poi_impaired_flow_plus_proposed_meets_or_exceeds_mbf	Binary (0/1) E.g. 0	Whether the impaired flow with senior diverters and the proposed project meets or exceeds the minimum bypass flow. = 1 if poi_flow_impaired_with_senior_diverters_plus_proposed_cfs >= minimum_bypass_flow_cfs = 0 otherwise
in_project_season	Binary (0/1) E.g. 0	Whether the given date is in the user's project season. Only values in the user's project season are used to generate daily_flow_study_summary_B.5.3.4_poi*.csv and february_median_flow_time_series_B.5.3.6_poi_*.csv However, all values are used to generate daily_flow_study_summary_B.5.3.5_poi*.csv.

Spawning, Rearing and Passage Daily Flow Study Summary

Table name:daily_flow_study_summary_B.5.3.4_poi*.csv
Table description: Summary of results from the minimum bypass flow section (policy section B5.3.4) of the daily flow study. This will indicate whether a proposed project “contributes to reductions in instream flows necessary for spawning, rearing and passage”.

Column Name	Column Type	Description

metric	Text
	E.g.
	“Number of Days…”
		Describes the metric analyzed in this row. The metrics are:
		1. Number of Days Unimpaired Flow Meets or Exceeds MBF
		    a. The sum for each month of the values in daily_flow_study_time_series_poi*_B.5.3.1-B.5.3.3.csv column poi_unimpaired_flow_meets_or_exceeds_mbf where in_project_season is 1
		2. Number of Days Impaired with Senior Diverters Meets or Exceeds MBF
		    a. The sum for each month of the values in daily_flow_study_time_series_poi*_B.5.3.1-B.5.3.3.csv column poi_impaired_flow_meets_or_exceeds_mbf where in_project_season is 1
		3. Number of Days Impaired with Senior Diverters and Project Meets or Exceeds MBF
		    a. The sum for each month of the values in daily_flow_study_time_series_poi*_B.5.3.1-B.5.3.3.csv column poi_impaired_flow_plus_proposed_meets_or_exceeds_mbf where in_project_season is 1
		4. Percent change in the number of days flow is above MBF (unimpaired and impaired without project)
		    a. Percent difference for each month of metrics 1 and 2 above
		5. Percent change in the number of days flow is above MBF (unimpaired and impaired with the project)
		    a. Percent difference for each month of metrics 1 and 3 above

Month columns	Integer/Numeric E.g. 14	There is a separate column for each month of the user’s diversion season and the rows in each column represent a metric for that month from the above list of metrics. The first three metrics (Number of Days…) are integer values greater than or equal to 0 as they represent a count of days The final two metrics (Percent change…) are percentage values between 0 and 100.

Natural Flow Variability Daily Flow Study Summary

Table name:daily_flow_study_summary_B.5.3.5_poi*.csv

Table description: This table represents the results of the daily flow study section B5.3.5. This will indicate whether a proposed project "contributes to reductions in instream flows needed for the maintenance of natural flow variability".

Column Name	Column Type	Description
location	Integer E.g. 1	The ID of the POI as displayed in the application, indicating this is the POI under analysis.
1.5 Year Daily Peak Flow Unimpaired	Number E.g. 665.43	1.5-year unimpaired daily peak flow at the POI as calculated in the peaks over threshold method. This will correspond with the curve_fit value in peaks_over_threshold_results_poi_<id>_unimpaired.csv
1.5 Year Daily Peak Flow Impaired with Senior Diverters	Number E.g. 663.17	1.5-year impaired daily peak flow with diverters at the POI as calculated in the peaks over threshold method. This will correspond with the curve_fit value in peaks_over_threshold_results_poi_<id>_impaired.csv
1.5 Year Daily Peak Flow Impaired with Senior Diverters and Projects	Number E.g. 663.01	1.5-year impaired daily peak flow with diverters and the proposed project at the POI as calculated in the peaks over threshold method. This will correspond with the curve_fit value in peaks_over_threshold_results_poi_<id>_impaired_with_pod.csv
Calculation B.5.3.5-2a 1	Number E.g. 0.0065	Calculated value using the above 1.5-year instantaneous peak flow values, this value is equal to: $1 - (1.5\ year\ unimpaired)/(1.5\ year\ impaired\ diverters)$
Calculation B.5.3.5-2b 1	Number E.g 0.0451	Calculated value using the above 1.5-year instantaneous peak flow values, this value is equal to: $1 - (1.5\ year\ unimpaired)/(1.5\ year\ diverters\ \&\ project)$ If this value is less than 0.05 (5 percent), the natural flow variability can be maintained.
Change in instream flow	Number E.g 0.0029	Difference between calculation B5.3.5.-2a 1 and calculation B5.3.5-2b 1. If this value is 0, it indicates that the natural flow variability can be maintained (i.e. the proposed project does not cause a change in the instantaneous peak flow).

February Median Comparison Time Series

Table name: february_median_flow_time_series_B.5.3.6_poi_*.csv

Table description: This table contains the dates that have been analyzed as part of the February median flow analysis of the daily flow study. It contains the unimpaired flow data at the gage, POI, and the necessary impaired time-series to create the minimum bypass flow analysis for section B5.3.6 of the policy. Its data and style are similar to daily_flow_study_time_series_poi*_B.5.3.1-B.5.3.3.csv, except it uses February median flow instead of minimum bypass flow. Note that this table only exists when a February median analysis is necessary, where a POI is on a class II river downstream of a class III project.

Column Name	Column Type	Description
date	Date E.g. 01-10-1961	Day of time series.
gage_flow	Number E.g. 2.56	Unimpaired Gage flow, generated from the methodology of unimpairing streamflow above.
<application_id>_face_value_af	Number E.g 8.5	Face value of an upstream diverter, given as reference for the maximum diversion over the year for the diverter.
<application_id>_daily_diversion_cfs	Number E.g. 0.06	Average estimated diversion rate of the diverter, generated by the methodology and equations mentioned below.
<application_id>_daily_diversion_af	Number E.g. 0.4	Daily diversion in acre-feet for the diverter if the diversions are made at the above daily_diversion_cfs rate.
<application_id>_total_yearly_diversion_af	Number E.g. 1.2	The total diversion so far in the current water year for the given senior diverter. Equals the sum of the daily_diversion_af values.
senior_diverters_total_diversion_af	Number E.g. 1.5	The sum of all senior diverters daily diversion_af values
senior_diverters_diversion_rate_cfs	Number E.g. 0.008724	Diversion rate of all senior diverters. Users can inform themselves of these values by analysing values from daily_flow_study_senior_diveters_poi*_B.5.3.2.csv. However, the maximum diversion is such that the impaired flow at the poi is 0 (diverting all unimpaired flow).
pod_diversion_af	Number E.g. 1.435	Calculated project diversion on given date, in acre-feet
pod_diversion_cfs	Number E.g. 2.673	Calculated project diversion rate on given date, in cfs.
poi_flow_unimpaired_cfs	Number E.g.	Unimpaired flow at the POI. This value is obtained by multiplying the gage_mean_daily_flow_cfs by the ratio in

	0.379	initial_calculations_and_regional_criteria_or_user_thresholds_mbf_mcd_fmf_B.5.2.1-A4.csv
poi_flow_impaired_wth_senior_diverters_cfs	Number E.g. 0.312	Flow at the POI impaired by diverters. This is equal to poi_flow_unimpaired_cfs - senior_diverters_diversion_rate_cfs.
poi_flow_impaired_with_senior_diverters_plus_proposed_cfs	Number E.g. 0.302	Flow at the POI impaired by diverters and the user-proposed project. This is equal to poi_flow_impaired_wth_senior_diverters_cfs minus the user's entered diversion rate if in the user's diversion season.
february_median_flow_cfs	Number E.g. 875	Minimum bypass flow value, either the user-entered or tool-calculated values as indicated by fmf_cfs from initial_calculations_and_regional_criteria_or_user_thresholds_mbf_mcd_fmf_B.5.2.1-A4.csv.
poi_unimpaired_flow_meets_or_exceeds_fmf	Binary (0/1) E.g. 0	Whether the unimpaired flow meets or exceeds the February median flow. = 1 if poi_flow_unimpaired_cfs >= february_median_flow_cfs = 0 otherwise
poi_impaired_flow_meets_or_exceeds_fmf	Binary (0/1) E.g. 0	Whether the impaired flow with senior diverters meets or exceeds the February median flow. = 1 if poi_flow_impaired_wth_senior_diverters_cfs >= february_median_flow_cfs = 0 otherwise
poi_impaired_flow_plus_proposed_meets_or_exceeds_fmf	Binary (0/1) E.g. 0	Whether the impaired flow with senior diverters and the proposed project meets or exceeds the February median flow. = 1 if poi_flow_impaired_with_senior_diverters_plus_proposed_cfs >= february_median_flow_cfs = 0 otherwise
in_project_season	Binary (0/1) E.g. 0	Whether the given date is in the user's project season. Only values in the user's project season are used to generate daily_flow_study_summary_B.5.3.4_poi*.csv and february_median_flow_time_series_B.5.3.6_poi_*.csv However, all values are used to generate daily_flow_study_summary_B.5.3.5_poi*.csv.

February Median Daily Flow Study Summary

Table name:daily_flow_study_summary_B.5.3.6_poi*.csv

Table description: Summary of results from the minimum bypass flow section (policy section B5.3.4) of the daily flow study. This will indicate whether a proposed project "impacts the February median flow on class II streams". Note that this table only exists when a February median analysis is necessary, where a POI is on a class II river downstream of a class III project.

Column Name	Column Type	Description
metric	Text E.g. “Number of Days…”	Describes the metric analyzed in this row. The metrics are: 6. Number of Days Unimpaired Flow Meets or Exceeds FMF a. The sum for each month of the values in daily_flow_study_time_series_poi*_B.5.3.1-B.5.3.3.csv column poi_unimpaired_flow_meets_or_exceeds_fmf where in_project_season is 1 7. Number of Days Impaired with Senior Diverters Meets or Exceeds FMF a. The sum for each month of the values in daily_flow_study_time_series_poi*_B.5.3.1-B.5.3.3.csv column poi_impaired_flow_meets_or_exceeds_fmf where in_project_season is 1 8. Number of Days Impaired with Senior Diverters and Project Meets or Exceeds FMF a. The sum for each month of the values in daily_flow_study_time_series_poi*_B.5.3.1-B.5.3.3.csv column poi_impaired_flow_plus_proposed_meets_or_exceeds_fmf where in_project_season is 1 9. Percent change in the number of days flow is above FMF (unimpaired and impaired without project) a. Percent difference for each month of metrics 1 and 2 above 10. Percent change in the number of days flow is above FMF (unimpaired and impaired with project) a. Percent difference for each month of metrics 1 and 3 above
Month columns	Integer/Numeric E.g. 14	There is a separate column for each month of the given project and the rows in each column represent a metric for that month from the above list of metrics. The first three metrics (Number of Days…) are integer values greater than or equal to 0 as they represent a count of days The final two metrics (Percent change…) are percentage values between 0 and 100.

Description of Equations & Assumptions to Derive Intermediate Values - Daily Flow Study

The following section outlines the calculations that are completed to generate intermediate values found in the daily flow study output files. Furthermore, it outlines assumptions that are made when generating these values so applicants and application reviewers can be clear about assumptions and how they change the tool outputs.

Daily Frost Diversion Time Series in Acre-Feet

Description: Demand associated with frost protection water usage, at daily time intervals.
Equation:

Frost demand is determined for a given day using the following equation:
$demad_{day} = max\_rate\_of\_diversion\_cfs * 3600 * 10\,hours\,/\,43560\,(cf/acre)$
This demand is then applied on a daily basis to the days assumed to have frost diversion to generate a time series. These dates are every other day between March 15 and April 30.

If a diverter is only using water for storage during the policy season, the frost demand is only applied during the policy season from March 15th to March 31st.
Assumptions:
Overestimations of this value could cause project requirements to be **more** calculated streamflow to be available at the POD and POIs as more water use would be permitted, and underestimations cause **less** calculated streamflow to be available at the POD and POIs (easier to meet policy).

- It is assumed that frost demand is applied for 8 days between March 15 and 31st, for 10 hours a day (per policy section B.2.1.4 (3))
    - This assumption could cause an underestimation of frost demand in February, April, and May where there could potentially be diversions for frost
    - Also, this assumption could cause additional impacts as one month of the daily flow study (March) would be more heavily impacted than the others for the analysis of demand for Spawning, Rearing, and Passage. This could cause a project to not meet requirements only in March due to frost demand

Daily Storage Diversion Time Series in Acre-Feet

Description: Diverter Demand Associated with Storage, at daily time intervals.
Equation:

If the diverter’s storage season overlaps the winter policy season:

$$demand_{day} = max\_storage\_af\ /\ overlapping\_days\_of\_storage\_and\_policy$$

This demand is then applied each day of the storage season which overlaps the winter policy season.

If the diverter’s storage season does not overlap the winter policy season:

$$demand_{day} = max\_storage\_af\ /days\_of\_storage\ (length\ of\ storage\ season)$$

This daily demand value is then applied to each day of the diverter's storage season.

Assumptions:
All overestimations of this value cause **less** calculated streamflow to be available at the POD and POIs(more difficult to meet policy) and underestimations cause **more** calculated streamflow to be available at the POD and POIs (easier to meet policy).

- It is assumed that storage demand is applied uniformly over its storage season
    - This could cause an under-or-overestimation of storage demand overlapping the proposed project, depending on the dates of the project
    - This could cause an overestimation of the number of days that senior diverters are diverting above minimum bypass flow requirements as an average demand does not take into account minimum bypass flow at the given diverter
- Storage demand is applied only within the policy season if the policy season overlaps the diverter storage season
    - This could cause overestimation of storage demands within the policy season and underestimation of storage demands outside of the policy season
- Reservoirs are empty at the beginning of the storage season and full at the end of the storage season
    - This could cause an overestimation relative to actual storage demands, as reservoirs may not be empty at the beginning of a storage season

Daily Direct Diversion Time Series

Description: Demand associated with water usage for direct diversion as a daily time series.
Equation:

First, a total diversion calculation is done to find the total usage to direct diversion

$$total\_diversion \ = face\_amount\_af \ - max\_storage\_af$$

If the diverter use codes use_codes **do not** only have "Irrigation" or "Irrigation" and "Frost Protection":

$$demand_{day} = total\_diversion \,/\, days\_of\_diversion \ (length\ of\ diversion\ season)$$

This daily demand is then applied across the diversion season specified in the senior diverters upload.

If the diverter use codes use_codes **do not** only have "Irrigation" or "Irrigation" and "Frost Protection": days_outside_policy

$$days\_outside\_policy \ = days\_of\_diversion \ - \ overlapping\_days\_of\_direct\_diversion\_and\_policy\_season$$
$$demand_{day} = total\_diversion \,/\, days\_outside\_policy$$

Assumptions:
All overestimations of this value cause project requirements to be **less** calculated streamflow to be available at the POD and POIs (more difficult to meet policy) and underestimations cause project requirements to be **more** calculated streamflow to be available at the POD and POIs (easier to meet policy).

- Diverter demand occurs equally over the course of the senior diverter's diversion season
    - This could overestimate or underestimate the overlapping demand as diversions may vary on a yearly basis
    - This could cause an overestimation of the number of days that senior diverters are diverting above minimum bypass flow requirements as an average demand does not take into account minimum bypass flow at the given diverter
- Diverters strictly follow irrigation guidelines for only diverting outside of the policy season if irrigating
    - This could overestimate the diversions for the given diverter outside of the policy season and underestimate the value within the policy season
- Diverters do not follow minimum bypass flow requirements or other streamflow-based analyses, they divert up to their maximum over their season
    - This would likely over-estimate the demand, as the water right holder may be bound to leave more water in the stream than the estimated diversion
- Diverter's face_amount_af value (used to derive diversion_amount_af, and diversion_per_day) is accurate and represents the total diversion to both storage and direct diversion
    - Changes in this value could cause under-or-overestimation of diversions. Users are directed to double check this value before submitting senior diverters due to its critical nature

Diversion for Onstream Dams: Fill and Spill Method

Description: An onstream dam presents significant impairments to flow in a stream while it is filling its reservoir. Since it impairs the stream directly and does not pull water from the stream, this allows water rights holders to fully impair the stream above the minimum bypass flow associated with their license.
This method is used if a senior diverters "pod_type" is "Point of Onstream Storage"
Equation:

The unimpaired gage time series is scaled to the dam's location using a streamflow scaling ratio:
$streamflow\_scaling\_ratio \ = \ wa_{dam}/wa_{gage} \ * \ map_{pod}/map_{gage}$

Where wa = watershed area and map = mean annual precipitation.
$unimpaired\_flow_{dam} \ = \ unimpaired\_flow_{gage} \ * \ streamflow\_scaling\_ratio$

For each day in the gage time series of record, the impaired flow at the diverter is then calculated by subtracting the demand from senior diverters upstream of the dam impaired_streamflow.

$$impaired\_streamflow_{date} = unimpaired\_streamflow_{dam} - upstream\_diverter\_demand_{date}$$

Note: The above process must be done iteratively, and diversions are calculated in order using the field order_upstream_to_downstream from daily_flow_study_senior_diveters_poi*_B.5.3.2.csv.

The demand from the diverter is then calculated to be the streamflow, summing over the course of a year until the dam's face_value is reached.

Minimum_bypass_flow at the dam is said to be 0 if there is no minimum bypass in the associated water license.

Over the course of a water year, and a diverters storage season:

If

$$total\_demand_{year} + (impaired\_streamflow_{date} - minimum\_bypass\_flow) < face\_amount\_af$$

Then:

$$dam\_demand_{date} = impaired\_streamflow_{date} - minimum\_bypass\_flow$$

Otherwise:

$$dam\_demand_{date} = face\_amount\_af - total\_demand_{year}$$

And

$total\_demand_{year}$ will have the daily demand added to it

Assumptions:

All overestimations of this value cause **less** calculated streamflow to be available at the POD and POIs (more difficult to meet policy) and underestimations cause project requirements to be **more** calculated streamflow to be available at the POD and POIs (easier to meet policy).

- The above method that an onstream storage is empty at the beginning of its diversion season and then takes all of the streamflow available above its minimum bypass flow to fill its reservoir immediately.
    - This could cause overestimations in the amount of water used closer to the beginning of a dam's diversion season, and less water to be available later on in a dam's season
- The above method also assumes that dams have no channels available to route excess water, they simply fill their reservoirs and then overflow into further streamflow
    - This could cause overestimations in the amount of water used closer to the beginning of a dam's diversion season, and less water to be available later on in a dam's season

Total Daily Diversion Time Series For Senior Diverters

Description: Overall Diversion for a senior diverter upstream of a Senior Diverter broken down by day over a water year.

Equation:

The time series from frost, storage and diverter demand above are all extended with 0 demand outside of their associated demand seasons. These time series are then summed together. This is done only for non-dam diverters, i.e. if the diverter's pod_type is not "Point of Onstream Storage"

$total\_demand_{day} = frost_{day} + diversion_{day} + storage_{day}$

For all days in a water year (Oct 1 - Sep 30th)

Assumptions:

All overestimations of this value cause **less** calculated streamflow to be available at the POD and POIs (more difficult to meet policy) and underestimations cause project requirements to be **more** calculated streamflow to be available at the POD and POIs (easier to meet policy).

- Diverter's face_amount_af value (used to derive diversion_amount_af, and diversion_per_day) is accurate and represents the total diversion to both storage and direct diversion
    - Changes in this value could cause under-or-overestimation of diversions. Users are directed to double check this value before submitting senior diverters due to its critical nature
- All assumptions from frost, storage, and direct diversion demand apply to this value

Impairing POI with Diverter Time Series Over Time

Description: Given a time series of diverters generated above, create a time series representing the impairments of diverters over time on the scaled time series at the POI. Note: a time series for the POI with all senior diverters and a time series further impaired by the project diversion are both generated. project_demand

Equation:

First the unimpaired streamflow at the POI at each date must be estimated using the gaged data and streamflow scaling ratio

$unimpaired\_streamflow\_poi_{date} = unimpaired\_streamflow\_gage_{date} * streamflow\_scaling\_ratio$

Then, all of the diversions are summed to get a total upstream demand value..

$upstream\_diverter\_demand_{date} = \Sigma\, diverter\_demand_{date}$

The senior diverters timeseries is then generated for each date by subtracting the upstream diverter demand from the unimpaired streamflow

$poi\_senior\_diverters\_timeseries_{date} = unimpaired\_streamflow\_poi_{date} - upstream\_diverter\_demand_{date}$

Finally, the senior diverter timeseries taking into account project demands is generated by subtracting project demand from the poi time series.

$$poi\_senior\_diverter\_project\_timeseries_{date} = poi\_senior\_diverters\_timeseries_{\ date} - project\_demand_{date}$$

Assumptions:
Any overestimations in these demand sums will cause **less** calculated streamflow to be available at the POD and POIs (more difficult to adhere to policy), and underestimations will cause **more** calculated streamflow to be available at the POD and POIs**.**

- Any assumptions in the total daily diversion time series and their associated changes would change linearly with this value (i.e. a 5% variability in the total daily diversion time series output could cause a 5% variability in the mcd output)
- Any assumptions made about the observed gage data or streamflow scaling ratio would change linearly with this value