



NEON USER GUIDE TO STAGE-DISCHARGE RATING CURVES (NEON.DP4.00133)

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CHANGE RECORD

REVISION	DATE	DESCRIPTION OF CHANGE
A	01/11/2018	Initial Release
B	10/19/2020	Updated to reflect algorithm changes and additional input and output data tables
B.1	04/20/2021	Added information on data tables processed as part of the Stream morphology map (DP4.00131.001) and Bathymetric and morphological maps (DP4.00132.001) data product that are now published in this data product. Updated information on geolocation input data.
C	03/08/2022	Updated section 5.2 Data Revision with latest information regarding data release
D	10/06/2022	Added information pertaining to the geo/bat_AISsiteSurveyResultFile tables
E	03/06/2024	Updated to detail new L4 discharge input data table structure
F	04/29/2025	Removed 'Algorithm Theoretical Basis' section (now published in NEON.DOC.005403)



TABLE OF CONTENTS

1	DESCRIPTION	1
1.1	Purpose	1
1.2	Scope	1
2	RELATED DOCUMENTS AND ACRONYMS	2
2.1	Associated Documents	2
2.2	Acronyms	2
3	DATA PRODUCT DESCRIPTION	3
3.1	Spatial Sampling Design	3
3.2	Temporal Sampling Design	4
3.3	Variables Reported	4
3.4	Spatial Resolution and Extent	5
3.5	Temporal Resolution and Extent	5
3.6	Associated Data Streams	5
3.7	Product Instances	5
3.8	Data Relationships	5
4	DATA QUALITY	7
4.1	Data Entry Constraint and Validation	7
4.2	Data Revision	8
4.3	Uncertainty	8
4.4	Quality Flagging	8
5	REFERENCES	8

LIST OF TABLES AND FIGURES

Table 1	List of input data for Stage-Discharge Rating Curves.	4
Table 2	List of geolocation inputs for Stage-Discharge Rating Curves. Staff gauge and discharge transect geolocation data may contain multiple named locations (e.g., SITE.AOS.gauge.b, SITE.AOS.gauge.c). At Toolik Lake inflow/outflow locations, SITE will equal TOOK.inflow and TOOK.outflow, respectively.	4
Figure 1	An example rating curve (red line) with parametric uncertainty (light red shading). Blue line and shading represent "prior" rating curve and parametric uncertainty using information based on hydraulic controls only, respectively. Picture taken from "Rating Curve" documentation for BaRatinAGE (Le Coz, 2013; Le Coz, 2014).	3



1 DESCRIPTION

1.1 Purpose

This document provides an overview of the data included in this NEON Level 4 data product, which is generated from Level 1 OS data, and associated metadata. In the NEON data products framework, the raw data collected in the field (i.e. staff gauge and discharge measurements from a single collection event) are considered the lowest level (Level 0). Raw data that have been quality checked and simple metrics that emerge from the raw data are considered Level 1 data products. Level 4 data products rely on inputs of any level data, often L1 or higher, and may involve calculations that use data collected over a range of spatial or temporal scales.

The text herein provides a discussion of measurement theory and implementation, data product provenance, quality assurance and control methods used, and approximations and/or assumptions made during L4 data creation.

1.2 Scope

This document describes the steps needed to generate the L4 data product Stage-discharge rating curves (NEON.DP4.00133) - the parameters that describe the relationship between staff gauge measurements and discharge measurements made over a range of dates and flow conditions - and associated metadata from input data and calculations. This document also provides details relevant to the publication of the data products via the NEON data portal, with additional detail available in the file, NEON Data Variables for Stage-Discharge Rating Curves (DP4.00133.001) (AD[03]), provided in the download package for this data product.

This document describes the process for performing custom calculations derived from L1 discharge field collection data (NEON.DP1.20048; stage and discharge data), L1 level 4 discharge input data (DP1.00133.001; hydraulic control, AIS site survey, and rating curve identification data), geolocation data, and previous L4 Stage-discharge rating curves data. For information on the raw stage and discharge data that are ingested and processed for this data product, see NEON User Guide to Discharge Field Collection (DP1.20048.001) (AD[07]) and NEON Data Validations for Discharge Field Collection (DP1.20048.001) (AD[08]), which are available for download with Discharge field collection (DP1.20048.001) data package. The Level 4 discharge input data (DP1.00133.001) data product is not an independently published data product. The data transitioned in the DP1.00133.001 data product are published in this data product. Please note that raw or lower level source data products (denoted by 'DP0') may not always have the same numbers (e.g., '20048') as the corresponding L1 or L4 data product.



2 RELATED DOCUMENTS AND ACRONYMS

2.1 Associated Documents

AD[01]	NEON.DOC.000001	NEON Observatory Design (NOD) Requirements
AD[02]	NEON.DOC.002652	NEON Level 1, Level 2 and Level 3 Data Products Catalog
AD[03]	NEON.DOC.005403	Algorithm Theoretical Basis Document (ATBD): Stage-Discharge Rating Curves and Continuous Discharge
AD[03]	NEON.DP4.00133.001_variables.csv	NEON Data Variables for Stage-Discharge Rating Curves (DP4.00133.001)
AD[04]	NEON.DOC.001152	NEON Aquatic Sampling Strategy
AD[05]	NEON.DOC.000008	NEON Acronym List
AD[06]	NEON.DOC.000243	NEON Glossary of Terms
AD[07]	NEON_streamDischarge_userGuide.pdf	NEON User Guide to Discharge Field Collection (DP1.20048.001)
AD[08]	NEON.DP1.20048.001_validation.csv	NEON Data Validations for Discharge Field Collection (DP1.20048.001)

2.2 Acronyms

Acronym	Definition
Q	Discharge
H	Stage height
m	Meters
MCMC	Markov Chain Monte Carlo
BaM	Bayesian Modeling
BaRatinAGE	Bayesian Rating Curve Advanced Graphical Environment
UI	User Interface



3 DATA PRODUCT DESCRIPTION

The Stage-discharge rating curves (DP4.00133.001) data product provides a rating curve that describes the relationship between staff gauge and discharge measurements at stream, river, and lake inflow/outflow locations each water year (October 1st - September 30th). The relationship developed for the rating curve is used for computing the Continuous discharge (DP4.00130.001) data product. An example rating curve that was plotted for a range of discharge (y-axis) and stage values (x-axis) is plotted below (Figure 1).

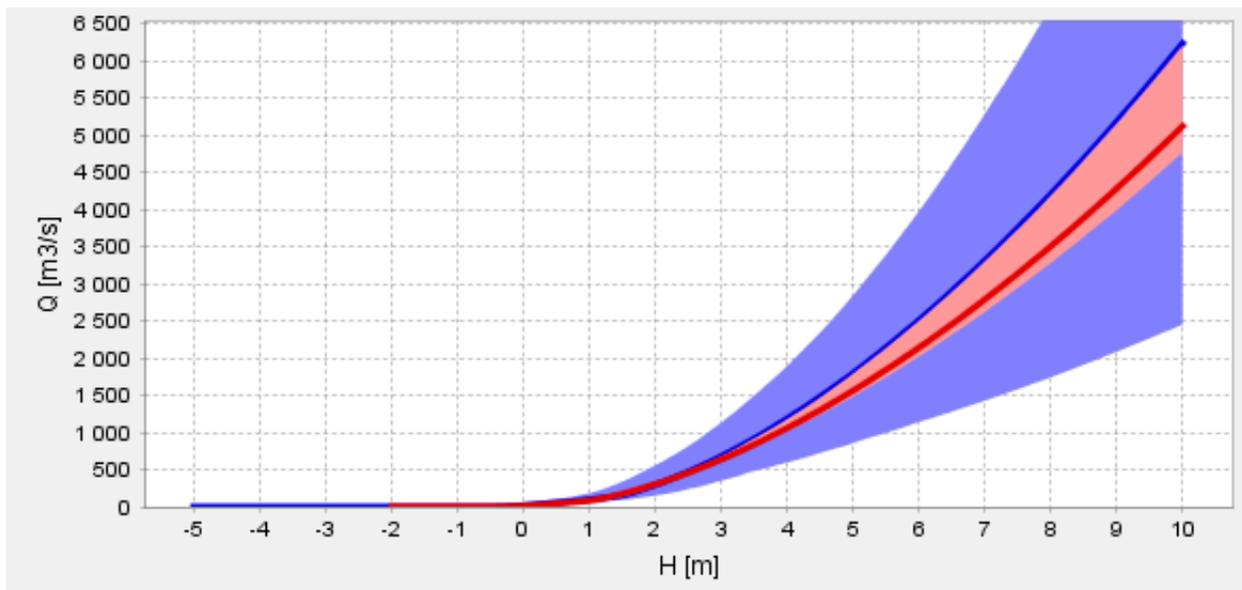


Figure 1: An example rating curve (red line) with parametric uncertainty (light red shading). Blue line and shading represent "prior" rating curve and parametric uncertainty using information based on hydraulic controls only, respectively. Picture taken from "Rating Curve" documentation for BaRatinAGE (Le Coz, 2013; Le Coz, 2014).

3.1 Spatial Sampling Design

A stage-discharge rating curve is developed at the site level (except for Toolik Lake, where two stations will have rating curves produced, the inflow and outflow to the lake) using data collected at the same spatial scale as the discharge and stage measurements, which are measured at all wadeable stream sites on a run or riffle near sensor set #1 or sensor set #2 and near the buoy at river sites. Point measurements of water depth and velocity are made along the transect from one bank to the other using a wading rod and attached velocity meter (at wadeable stream sites and Toolik Lake inflow and outflow) or acoustic Doppler current profiler instrumentation (at wadeable streams, non-wadeable rivers, and Toolik Lake inflow and outflow). If a discharge cross-section or staff gauge is re-located, a new rating curve may be developed for a site if the hydrologic data is no longer directly comparable to the existing set of stage and discharge measurements.

As much as possible, sampling occurs in the same locations over the lifetime of the Observatory. However,



Table 1: List of input data for Stage-Discharge Rating Curves.

Data Source	DPID	table
L1 Discharge field collection data	DP1.20048.001	dsc_fieldData
L1 Level 4 discharge input data	DP1.00133.001	sdr_c_controllInfo
L1 Level 4 discharge input data	DP1.00133.001	sdr_c_priorParameters
L1 Level 4 discharge input data	DP1.00133.001	sdr_c_curveIdentification

Table 2: List of geolocation inputs for Stage-Discharge Rating Curves. Staff gauge and discharge transect geolocation data may contain multiple named locations (e.g., SITE.AOS.gauge.b, SITE.AOS.gauge.c). At Toolik Lake inflow/outflow locations, SITE will equal TOOK.inflow and TOOK.outflow, respectively.

Data Source	field	location
NEON geolocation database	location startDate	SITE.AOS.discharge
NEON geolocation database	location endDate	SITE.AOS.discharge
NEON geolocation database	location startDate	SITE.AOS.gauge
NEON geolocation database	location endDate	SITE.AOS.gauge
NEON geolocation database	location elevation	SITE.AOS.gauge
NEON geolocation database	location zOffset	SITE.AOS.gauge

over time some sampling locations may become impossible to sample, due to disturbance or other local changes. When this occurs, the location and its location ID are retired. A location may also shift to slightly different coordinates. Refer to the locations endpoint of the NEON API for details about locations that have been moved or retired: <https://data.neonscience.org/data-api/endpoints/locations/>

3.2 Temporal Sampling Design

A stage-discharge rating curve for a site or station is created following the conclusion of the water year (October 1st to September 30th).

3.3 Variables Reported

All data and geolocation variables used as inputs for the development of a stage-discharge rating curve are listed in Table 1 and Table 2. All variables reported in the published data (L4 data) are also provided separately in the file, NEON Data Variables for Stage-Discharge Rating Curves (DP4.00133.001) (AD[03]).

Field names have been standardized with Darwin Core terms (<http://rs.tdwg.org/dwc/>; accessed 16 February 2014), the Global Biodiversity Information Facility vocabularies (<http://rs.gbif.org/vocabulary/gbif/>; accessed 16 February 2014), the VegCore data dictionary (<https://projects.nceas.ucsb.edu/nceas/projects/bien/wiki/VegCore>; accessed 16 February 2014), where applicable. NEON AOS spatial data employs the World Geodetic System 1984 (WGS84) for its fundamental reference datum and Geoid12A geoid model for its vertical reference surface. Latitudes and longitudes are denoted in decimal notation



to six decimal places, with longitudes indicated as negative west of the Greenwich meridian.

Some variables described in this document may be for NEON internal use only and will not appear in downloaded data.

3.4 Spatial Resolution and Extent

The finest spatial resolution at which data are reported is a site, except at Toolik Lake where data is published from two stations.

3.5 Temporal Resolution and Extent

The finest temporal resolution at which data are reported is the interval of a rating curve not to exceed one water year (October 1st to September 30th). When there is a single stage-discharge rating curve for a water year, data will be published for September of said water year. When changes in channel morphology, hydrology, or geolocation data necessitate more than one stage-discharge rating curve for a water year, data will be published for multiple months of a water year. Users should download stage-discharge rating curve data from the NEON data portal for the time interval of October - September of a water year to ensure they are downloading the extent of the data available.

3.6 Associated Data Streams

The data from this L4 data product is derived from a L1 data product: Discharge field collection (DP1.20048.001). These data products can generally be linked by **siteID**, except at Toolik Lake where additional linking must be made (DP4.00133.001 records with **curveID** that contains 'TKIN' can be linked to DP1.20048.001 data that contains **namedLoction** 'TOOK.AOS.discharge.inflow'; DP4.00133.001 records with **curveID** that contains 'TKOT' can be linked to DP1.20048.001 data that contains **namedLoction** 'TOOK.AOS.discharge.outflow').

The data from this L4 data product is used to develop a level 4 (L4) data product: Continuous discharge (DP4.00130.001). These data products can be linked by **curveID**.

3.7 Product Instances

The NEON Observatory contains 24 wadeable streams, 3 large rivers, and 1 lake site containing measurable inflow and outflow.

Stage-discharge rating curves yields approximately 29 rating curves (1 per stream and river site, 2 at Toolik Lake) per water year comprised of approximately 702 stage and discharge pair records per year during stage-discharge relationship development and 324 stage and discharge records per year once a relationship has been developed.

3.8 Data Relationships

The algorithm used for this L4 data product produces as many records in `sdrc_gaugeDischargeMeas` as is used to develop a rating curve, which will include approximately as many records as in the past water year in the `dsc_fieldData` table in the Discharge field collection (DP1.20048.001) data product, and may



Title: NEON User Guide to Stage-Discharge Rating Curves (NEON.DP4.00133)	Date: 05/28/2025
Author: Kaelin M. Cawley	Revision: F

include records from previous water years if the measurements are relatable to the past water year. The values may differ in the two tables because, during rating curve development, the gauging records for each water year are evaluated and outliers in the stage/discharge gauging records are removed from rating curves if deemed appropriate (due to measurement errors or other apparent problems associated with the gauging). Gaugings from previous years that match the stage-discharge relationship observed in the current water year and have relatable staff gauge geolocations are included in the new rating curve. Stage values brought into the processing code (from `dsc_fieldData:streamStage`) are offset using information from the NEON geolocation database. Stage offset values correct staff gauge height data after having changed location. First, a total reference elevation is calculated for a staff gauge location as the sum of a staff gauge’s elevation above sea level (m) and `zOffset` (vertical correction needed in order for the staff gauge location to be relatable to previous staff gauge locations; m). Second, the total reference elevation for the initial location of a staff gauge is subtracted from each subsequent location to obtain the stage offset value for each subsequent location. Third, every stage measurement between the start date and end date of a staff gauge location will have the appropriate stage offset applied. One record is created for each hydraulic control at a site for the `sdr_c_posteriorParameters` table. One record is created for each rating curve (usually one per year) for the `sdr_c_stageDischargeCurveInfo` table. 500 records per hydraulic control at a site are created for the `sdr_c_sampledParameters`, which represent the Markov Chain Monte Carlo (MCMC) samples of the range of model parameters. One record per staff gauge/discharge measurement set used to develop the rating curve is created in the `sdr_c_resultsResiduals` table.

`sdr_c_gaugeDischargeMeas.csv` - > One record expected per staff gauge and discharge measurement used to develop the rating curve for the current water year

`sdr_c_posteriorParameters.csv` - > One record expected per hydraulic control at a site

`sdr_c_stageDischargeCurveInfo.csv` - > One record expected per rating curve developed for a site for the current water year

`sdr_c_sampledParameters.csv` - > 500 records expected per hydraulic control at a site

`sdr_c_resultsResiduals.csv` - > One record expected per staff gauge and discharge measurement used to develop the rating curve for the current water year

gaugeEventID can be used to link data in the `sdr_c_gaugeDischargeMeas` and `sdr_c_resultsResiduals` tables. There may be multiple entries for a given **gaugeEventID** in the `sdr_c_resultsResiduals` table if the staff gauge and discharge readings were used in more than one rating curve, which is common if the stream or river does not undergo major geomorphic change between water years.

allEventID in the `sdr_c_stageDischargeCurveInfo` table contains a concatenated string, which can be parsed using a “|” delimiter to determine which **gaugeEventIDs** were used for developing a specific rating curve. Parsing **allEventID** will enable linking the `sdr_c_stageDischargeCurveInfo` table with the `sdr_c_gaugeDischargeMeas` and `sdr_c_resultsResiduals` tables.

curveID can be used to link the `sdr_c_posteriorParameters`, `sdr_c_stageDischargeCurveInfo`, `sdr_c_sampledParameters`, and `sdr_c_resultsResiduals` tables.

The following data tables are processed as part of the Level 4 discharge input data (DP1.00133.001) data product, but are published with this data product.



Title: NEON User Guide to Stage-Discharge Rating Curves (NEON.DP4.00133)	Date: 05/28/2025
Author: Kaelin M. Cawley	Revision: F

sdr_c_controlInfo - > Three records expected per **controlNumber**. Data associated with the activation state of the hydraulic controls for a discharge cross section.

sdr_c_controlType - > One record expected per **controlNumber**. Data associated with the control type and geometry used for determining prior parameters for Bayesian modeling.

sdr_c_priorParameters - > One record expected per **controlNumber**. Data associated with the prior parameters used in the Bayesian model that produces a rating curve.

The sdr_c_controlInfo, sdr_c_controlType, and sdr_c_priorParameters tables can be linked by **siteID**, **endDate**, and **controlNumber**.

sdr_c_curvelidentification - > One record expected per **curveID** and **curveSegmentID**. Metadata needed to identify unique stage-discharge relationships for generating rating curves.

sdr_c_AISsiteSurveyResultsFile - > One record expected per **rawDataFileName**. Data that contains basic information about the Aquatic Instrumental System site survey and URLs to access cloud-storage data products used to delineate hydraulic controls.

Hydraulic control data used to generate the prior model (sdr_c_controlInfo, sdr_c_controlType, sdr_c_priorParameters) can be linked to data in sdr_c_posteriorParameters, sdr_c_stageDischargeCurveInfo, sdr_c_sampledParameters, and sdr_c_resultsResiduals through the sdr_c_curvelidentification table in the following manner:

The tables sdr_c_posteriorParameters, sdr_c_stageDischargeCurveInfo, sdr_c_sampledParameters, and sdr_c_resultsResiduals can each be linked to sdr_c_curvelidentification by **curveID**. Then, sdr_c_curvelidentification:**controlSurveyEndDateTime** can be linked to sdr_c_controlInfo:**endDate**, sdr_c_controlType:**endDate**, and sdr_c_priorParameters:**endDate**.

Hydraulic control data used to generate the prior model (sdr_c_controlInfo, sdr_c_controlType, sdr_c_priorParameters) can be linked to data in sdr_c_AISsiteSurveyResultsFile by **siteID** and **startDate**.

Data downloaded from the NEON Data Portal are provided in separate data files for each site and month requested. The neonUtilities package in R and the neonutilities package in Python contain functions to merge these files across sites and months into a single file for each table. The neonUtilities R package is available from the Comprehensive R Archive Network (CRAN; <https://cran.r-project.org/web/packages/neonUtilities/index.html>) and can be installed using the install.packages() function in R. The neonutilities package in Python is available on the Python Package Index (PyPi; <https://pypi.org/project/neonutilities/>) and can be installed using pip. For instructions on using the package in either language to merge NEON data files, see the Download and Explore NEON Data tutorial on the NEON website: <https://www.neonscience.org/download-explore-neon-data>.

4 DATA QUALITY

4.1 Data Entry Constraint and Validation

Many quality control measures are implemented at the point of data entry (i.e., the L1 data that is used as an input for this data product) within a mobile data entry application or web user interface (UI).



Title: NEON User Guide to Stage-Discharge Rating Curves (NEON.DP4.00133)	Date: 05/28/2025
Author: Kaelin M. Cawley	Revision: F

4.2 Data Revision

All data are provisional until a numbered version is released. Annually, NEON releases a static version of all or almost all data products, annotated with digital object identifiers (DOIs). The first data Release was made in 2021. During the provisional period, QA/QC is an active process, as opposed to a discrete activity performed once, and records are updated on a rolling basis as a result of scheduled tests or feedback from data users. The Issue Log section of the data product landing page contains a history of major known errors and revisions.

4.3 Uncertainty

One of the benefits of using BaM and MCMC sampling is that there are a large number of realizations from the posterior distribution, which can be used to quantify uncertainty associated with the maximum likelihood posterior parameters (BaRatin statistical model documentation and Le Coz et al., 2014). NEON publishes both the parametric and remnant (structural) error based off of 500 realizations from the posterior distribution.

4.4 Quality Flagging

There are currently no quality flags associated with this data product

5 REFERENCES

- Le Coz, J., B. Renard, L. Bonnifait, F. Branger, R. Le Boursicaud (2014) Combining hydraulic knowledge and uncertain gaugings in the estimation of hydrometric rating curves: A Bayesian approach. *Journal of Hydrology*, 509:573-587. DOI: 10.1016/j.hydrol.2013.11.2016
- Le Coz, J., C. Chaleon, L. Bonnifait, R. Le Boursicaud, B. Renard, F. Branger, J. Diribarne, M. Valente (2013) Bayesian analysis of rating curves and their uncertainties: the BaRatin method. *Houille Blanche-Revue Internationale De L Eau*, 6:31:41. DOI: 10.1051/lhb/2013048.