

# **Standard Operating Procedure: Discharge Analysis, Version 1.0**

## *Stream Communities and Ecosystems Monitoring Protocols Arctic Inventory and Monitoring Network*

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September 2018

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National Park Service  
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Fort Collins, Colorado

Please cite this Standard Operating Procedure as:

O'Donnell, J. A. 2018. Standard Operating Procedure: Discharge Analysis, Version 1.0. Stream Communities and Ecosystems Monitoring Protocols, Arctic Inventory and Monitoring Network. National Park Service, Fairbanks, Alaska. Available online at <https://irma.nps.gov/DataStore/Reference/Profile/2255976>

The main Narrative for the Protocol for monitoring Stream Communities and Ecosystems for the National Park Service's (NPS) Arctic Inventory and Monitoring Network (ARCN) is available from the NPS ARCN website (<http://science.nature.nps.gov/im/units/arcn>).

# SOP: Discharge Analysis, Version 1.0

Version 1.0 (September 2018)

| Version No. | Revision Date | Author | Changes Made | Reason for Change |
|-------------|---------------|--------|--------------|-------------------|
|             |               |        |              |                   |
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## Introduction

This standard operating procedure (SOP) describes methods for conducting statistical analyses on discharge data from the United States Geological Survey's (USGS) National Water Information System (NWIS; <https://waterdata.usgs.gov/nwis>) for sites draining or adjacent to Arctic Network parklands. This SOP is a component of the Stream Communities and Ecosystems Monitoring Protocol (O'Donnell and Miller, in prep). Tasks associated with this SOP include (1) downloading data from NWIS, (2) compiling data in Microsoft Excel, (3) importing data into R (R Stats; <https://www.r-project.org/>), and (4) conducting statistical analyses on long-term time-series datasets.

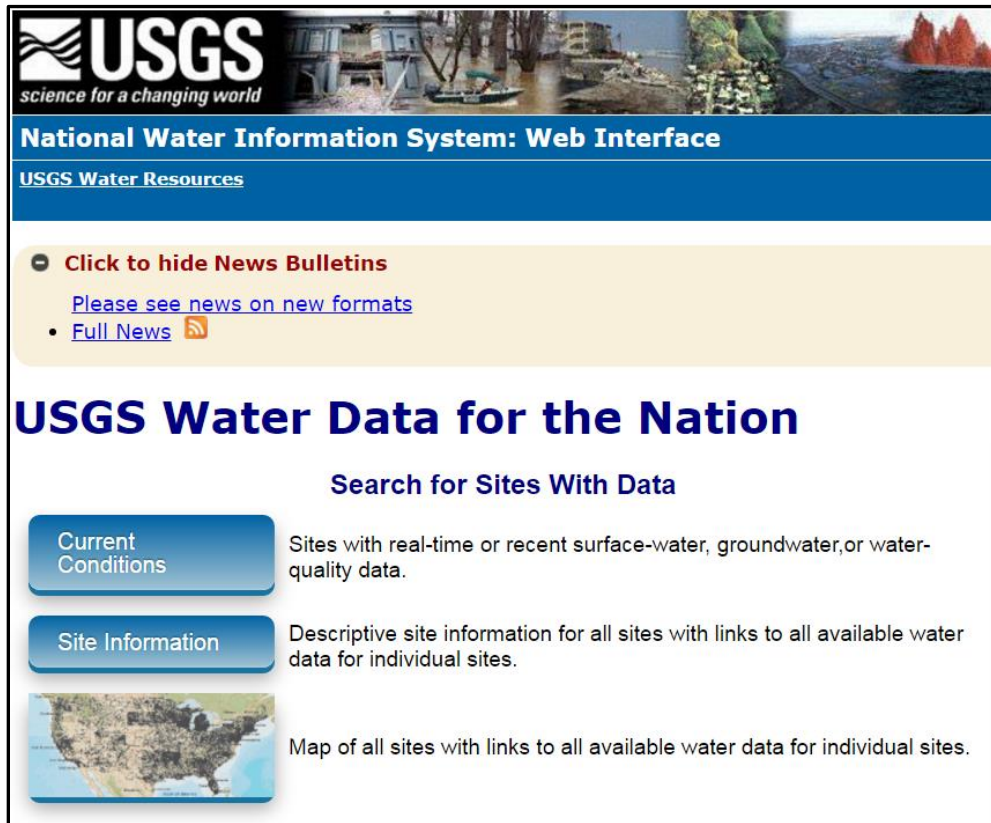
## Downloading Discharge Data from NWIS

- 1) Mean daily discharge data for streams or rivers that are in close proximity to ARCN park units through the United States Geological Survey (USGS) National Water Information System (NWIS) web interface (<http://waterdata.usgs.gov/nwis>). To download data, navigate to the NWIS website.
- 2) For discharge monitoring, I have identified 5 streams and rivers where USGS is actively monitoring discharge (Table 1).

Table 1. Discharge monitoring stations maintained by the USGS.

| Site Name                        | NWIS Site Number | Latitude (°N) | Longitude (°W) | Drainage Area (km <sup>2</sup> ) | Length of Record |
|----------------------------------|------------------|---------------|----------------|----------------------------------|------------------|
| Atigun R Tr Nr Pump Station 4 AK | 15904900         | 68.37361      | -149.31333     | 84                               | 1976 - Present   |
| Dahl C Nr Kobuk AK               | 15743850         | 66.94611      | -156.90888     | 28                               | 1986 - Present   |
| Kobuk R Nr Kiana AK              | 15744500         | 66.97361      | -160.13088     | 24552                            | 1976 - Present   |
| Slate C at Coldfoot AK           | 15564879         | 67.25479      | -150.17333     | 189                              | 1995 - Present   |
| Wulk R BI Tutak C Nr Kivalina AK | 15747000         | 67.87611      | -163.67444     | 1826                             | 1984 - Present   |

3) Click on the Site Information link:



**USGS**  
science for a changing world

**National Water Information System: Web Interface**

USGS Water Resources

Click to hide News Bulletins  
[Please see news on new formats](#)  
• [Full News](#)

## USGS Water Data for the Nation

### Search for Sites With Data

**Current Conditions**  
Sites with real-time or recent surface-water, groundwater, or water-quality data.

**Site Information**  
Descriptive site information for all sites with links to all available water data for individual sites.

  
Map of all sites with links to all available water data for individual sites.

4) Choose selection criteria to aid site-specific searches. Under “Site Identifier”, check the box next to “Site Number”. Then click the “Submit” button.

## Site Inventory for the Nation

### Choose Site Selection Criteria

Choose at least one of the following criteria to constrain the number of sites selected.

| Site<br>-- Location --                                     | Site<br>-- Identifier --                                       | Site<br>-- Attribute --                                             |
|------------------------------------------------------------|----------------------------------------------------------------|---------------------------------------------------------------------|
| <input type="checkbox"/> <a href="#">State/Territory</a>   | <input type="checkbox"/> <a href="#">Site Name</a>             | <input type="checkbox"/> <a href="#">Site type</a>                  |
| <input type="checkbox"/> <a href="#">Hydrologic Region</a> | <input type="checkbox"/> <a href="#">Site Number</a>           | <input type="checkbox"/> <a href="#">Altitude</a>                   |
| <input type="checkbox"/> <a href="#">Lat-Long box</a>      | <input type="checkbox"/> <a href="#">Multiple Site Numbers</a> | <input type="checkbox"/> <a href="#">Drainage area</a>              |
|                                                            | <input type="checkbox"/> <a href="#">Agency Code</a>           | <input type="checkbox"/> <a href="#">Data type</a>                  |
|                                                            | <input type="checkbox"/> <a href="#">File of Site Numbers</a>  | <input type="checkbox"/> <a href="#">Well depth</a>                 |
|                                                            |                                                                | <input type="checkbox"/> <a href="#">Hole depth</a>                 |
|                                                            |                                                                | <input type="checkbox"/> <a href="#">National aquifer (by code)</a> |
|                                                            |                                                                | <input type="checkbox"/> <a href="#">National aquifer (by name)</a> |
|                                                            |                                                                | <input type="checkbox"/> <a href="#">Local aquifer (by code)</a>    |
|                                                            |                                                                | <input type="checkbox"/> <a href="#">Local aquifer (by name)</a>    |

- 5) Next, enter one of the five NWIS site numbers (see Table 1) into the field under “Site Number” and select an output format. Then, click the “Submit” button.

### Select sites which meet all of the following criteria:

Define one or more values for each of the following site-selection criteria: --- or select [new criteria](#)

☒ **Site Number** -- enter a full or partial site ID (*optional*)
 

☒ exact match
 ☐ match from the start
 ☐ match any part

### Choose Output Format

Display Summary of Selected Sites

Choose one of the following options for displaying descriptions of the sites meeting the criteria above

☐ ☒ Show sites on a map NEW
☒ Table of sites grouped by ☐ Scroll list of sites -- allows selection of data for multiple sites
 ☐ Brief descriptions -- allows selection of data for multiple sites
 ☐ Site-description information displayed in 

table format

(Select fields to include in site-description output)
 

Agency
 Site identification number
 Site name
 Site type

☐ Save file of selected sites to local disk for future upload

- 6) Here is an example of the next page, displaying available data for the Atigun River monitoring site:

#### USGS 15904900 ATIGUN R TR NR PUMP STATION 4 AK

Available data for this site SUN

##### Stream Site

##### DESCRIPTION:

Latitude 68°22'25", Longitude 149°18'48" NAD27  
 North Slope Borough, Alaska, Hydrologic Unit 19060402  
 Drainage area: 32.4 square miles  
 Contributing drainage area: 32.6 square miles,  
 Datum of gage: 2,790 feet above NGVD29.

##### AVAILABLE DATA:

| Data Type                                       | Begin Date | End Date   | Count |
|-------------------------------------------------|------------|------------|-------|
| <a href="#">Daily Data</a>                      |            |            |       |
| Discharge, cubic feet per second                | 1976-10-01 | 2016-09-05 | 3868  |
| <a href="#">Daily Statistics</a>                |            |            |       |
| Discharge, cubic feet per second                | 1976-10-01 | 2016-09-05 | 3868  |
| <a href="#">Monthly Statistics</a>              |            |            |       |
| Discharge, cubic feet per second                | 1976-10    | 2016-09    |       |
| <a href="#">Annual Statistics</a>               |            |            |       |
| Discharge, cubic feet per second                | 1977       | 2016       |       |
| <a href="#">Peak streamflow</a>                 | 1976-07-29 | 2016-06-27 | 41    |
| <a href="#">Field measurements</a>              | 1976-06-29 | 2016-07-12 | 77    |
| <a href="#">Field/Lab water-quality samples</a> | 1976-09-19 | 1979-05-23 | 3     |
| <a href="#">Water-Year Summary</a>              | 2006       | 2016       | 10    |

- 7) On the next page, check the box next to “Discharge”, and select all data for the “Period of Record by entering dates into the “Begin date” and “End date” field. For Output format, select “Tab-separated” and then click on “Go”.

### USGS 15904900 ATIGUN R TR NR PUMP STATION 4 AK PROVISIONAL DATA SUBJECT TO REVISION

Available data for this site Time-series: Daily data GO

This station managed by the Fairbanks Field Office.

| Available Parameters                                                                                                           | Period of Record      | Output format                                                                                                                                                                                                                                 | Days (365)                                                     |
|--------------------------------------------------------------------------------------------------------------------------------|-----------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------|
| <input type="checkbox"/> All 1 Available Parameters for this site<br><input checked="" type="checkbox"/> 00060 Discharge(Mean) | 1976-10-01 2016-09-05 | <input checked="" type="radio"/> Graph<br><input type="radio"/> Graph w/ stats<br><input type="radio"/> Graph w/ meas<br><input type="radio"/> Graph w/ (up to 3) parms<br><input type="radio"/> Table<br><input type="radio"/> Tab-separated | -- or --<br>Begin date<br>2016-04-05<br>End date<br>2017-04-05 |

GO

- 8) After following these steps, the NWIS will then generate a text file with the discharge time series:

```
# ----- WARNING -----
# Some of the data that you have obtained from this U.S. Geological Survey database
# may not have received Director's approval. Any such data values are qualified
# as provisional and are subject to revision. Provisional data are released on the
# condition that neither the USGS nor the United States Government may be held liable
# for any damages resulting from its use.
#
# Additional info: https://help.waterdata.usgs.gov/policies/provisional-data-statement
#
# File-format description: https://help.waterdata.usgs.gov/faq/about-tab-delimited-output
# Automated-retrieval info: https://help.waterdata.usgs.gov/faq/automated-retrievals
#
# Contact: gs-w_support_nwisweb@usgs.gov
# retrieved: 2017-04-06 14:09:48 EDT (sdww01)
#
# Data for the following 1 site(s) are contained in this file
# USGS 15904900 ATIGUN R TR NR PUMP STATION 4 AK
# -----
#
# Data provided for site 15904900
# TS parameter statistic Description
# 1208 00060 00003 Discharge, cubic feet per second (Mean)
#
# Data-value qualification codes included in this output:
#
# A Approved for publication -- Processing and review completed.
#
# agency_cd site_no datetime 1208_00060_00003 1208_00060_00003_cd
# 5s 15s 20d 14n 10s
# USGS 15904900 1976-10-01 0.00 A
# USGS 15904900 1976-10-02 0.00 A
# USGS 15904900 1976-10-03 0.00 A
# USGS 15904900 1976-10-04 0.00 A
# USGS 15904900 1976-10-05 0.00 A
# USGS 15904900 1976-10-06 0.00 A
# USGS 15904900 1976-10-07 0.00 A
# USGS 15904900 1976-10-08 0.00 A
```

- 9) Download and update long-term discharge datasets at no more than 5-year intervals.

## Compiling Discharge Data in Microsoft Excel

1. Open the downloaded .txt file in Microsoft Excel. Select “Delimited” and then “Tab” to describe the input data format.
2. Organize spreadsheet in the following manner:

| Date       | Month | Day | Year | Discharge |
|------------|-------|-----|------|-----------|
| 10/1/1976  | 10    | 1   | 1976 | 0         |
| 10/2/1976  | 10    | 2   | 1976 | 0         |
| 10/3/1976  | 10    | 3   | 1976 | 0         |
| 10/4/1976  | 10    | 4   | 1976 | 0         |
| 10/5/1976  | 10    | 5   | 1976 | 0         |
| 10/6/1976  | 10    | 6   | 1976 | 0         |
| 10/7/1976  | 10    | 7   | 1976 | 0         |
| 10/8/1976  | 10    | 8   | 1976 | 0         |
| 10/9/1976  | 10    | 9   | 1976 | 0         |
| 10/10/1976 | 10    | 10  | 1976 | 0         |
| 10/11/1976 | 10    | 11  | 1976 | 0         |

3. To generate “month”, “day”, and “year” columns, use the Excel commands “=month()”, “=day()”, and “=year()”.

## Detecting Trends in Annual Discharge

1. In Excel, insert a pivot table to aid in generating summary statistics.
2. Calculate the number of observations for each year of record for each monitoring sites using the “Count” parameter in the PivotTable.
3. For any year where the number of observations is less than 365, omit that year from the trend analysis.
4. Compute annual discharge (in cubic feet per second, or cfs) by summing the mean daily discharge data for each year.
5. Plot annual discharge versus year. Use both linear regression and locally-weighted regression (LOESS) lines (Cleveland and Devlin 1988) to visually inspect trends.
6. To test for statistically significant trends, use the non-parametric Mann-Kendall test (Helsel and Hirsch 1992; Brabets and Walvoord 2009). Using this approach, significance can be assessed using two criteria.
  - A. First, if  $P > 0.10$ , it can be assumed that no trend exists.
  - B. Second, 95% confidence intervals should be computed for the slope of the trend line. If the confidence intervals include zero, it can be assumed that no trend exists.

## Trends in Timing of Peak Discharge during Snowmelt

1. To determine long-term changes in the timing of peak discharge during spring snowmelt, follow detailed methods described by Tape et al. (2016).
2. Open daily mean discharge time-series datasets for all monitoring sites.
3. Add column to spreadsheet to calculate the Julian day for each mean daily discharge value within the record.
4. Plot mean daily discharge vs. time (day) for each year in the record.
5. Identify the Julian day of peak discharge during the spring snowmelt period for each year of record. Peak discharge during snowmelt typically typically occurs in May or June in the Alaskan Arctic (Tape et al. 2016).
6. Plot peak discharge date (Julian day) vs. year, as in Figure 4 below from Tape et al. (2016):

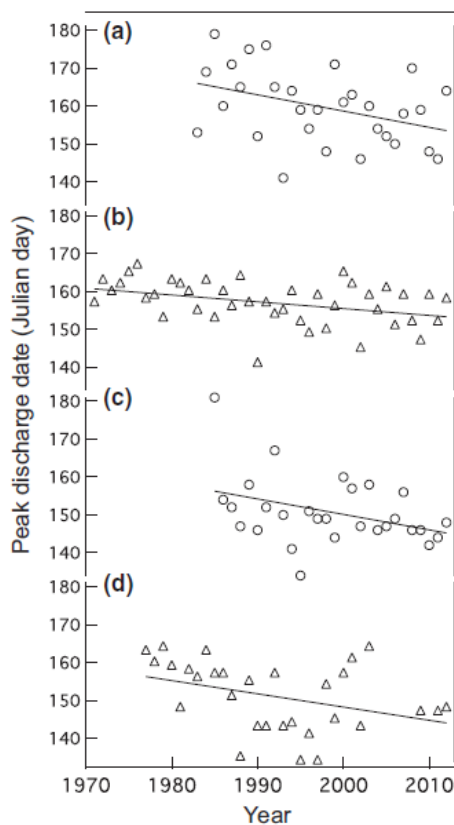


Fig. 4 Trends since the 1970s in the date of peak discharge (symbols) for four rivers in northern Alaska. Peak discharge dates during spring trended earlier on the Sagavanirktok (a:  $R^2 = 0.15$ ,  $P = 0.03$ ), Kugaruk (b:  $R^2 = 0.15$ ,  $P = 0.01$ ), Wulik (c:  $R^2 = 0.14$ ,  $P = 0.047$ ), and Kobuk Rivers (d:  $R^2 = 0.14$ ,  $P = 0.04$ ).

7. Use linear regression techniques to determine the significance of long-term trends in peak discharge during snowmelt.

## **Trends in Winter Flow**

1. Winter flow is defined as the average discharge during the period of January 1 through March 31, as defined by Walvoord and Striegl (2007) and O'Donnell et al. (2012). Due to cold, freezing conditions, surface runoff during winter is negligible in our study sites. Residual autumn flows can persist into December in some study sites. The winter flow period as defined here, assumes that any under-ice flow is derived from subsurface groundwater sources.
2. Open daily mean discharge time-series datasets for all monitoring sites.
3. Calculate average winter flow (during the period of January 1 to March 31) for each year of record for all monitoring sites.
4. Also, identify the annual minimum winter flow. This typically occurs right before spring snowmelt.
5. For each monitoring site, plot mean winter flow and annual minimum flow vs. year for the entire record.
6. To test for statistically significant trends, use the non-parametric Mann-Kendall test (Helsel and Hirsch 1992; Brabets and Walvoord 2009). Using this approach, significance can be assessed using two criteria.
  - a. First, if  $P > 0.10$ , it can be assumed that no trend exists.
  - b. Second, 95% confidence intervals should be computed for the slope of the trend line. If the confidence intervals include zero, it can be assumed that no trend exists.

## **Trends in Discharge during the Open-Water Season**

1. In the Arctic, the open-water season typically begins sometime in May and extends through September. Thus, to determine long-term trends in the discharge during the open-water season, we will calculate mean monthly flows for each month between May and September.
2. Open daily mean discharge time series datasets for all monitoring sites.
3. Calculate mean monthly flow for May, June, July, August, and September for each year of record.
4. For each monitoring site, plot mean monthly flow (e.g. June) vs. year.
5. Plot annual discharge versus year. Use both linear regression and (LOESS) lines (Cleveland and Devlin 1988) to visually inspect trends.

6. To test for statistically significant trends, use the non-parametric Mann-Kendall test (Helsel and Hirsch 1992; Brabets and Walvoord 2009). Using this approach, significance can be assessed using two criteria.
  - A. First, if  $P > 0.10$ , it can be assumed that no trend exists.
  - B. Second, 95% confidence intervals should be computed for the slope of the trend line. If the confidence intervals include zero, it can be assumed that no trend exists.

## **Trends in Timing of Autumn Freeze-Up**

1. River freeze-up during autumn is sensitivity to summer climate and watershed hydrologic conditions, which are both likely to change under a warming climate (Prowse et al. 2007). In the Arctic, river freeze-up typically occurs during September or October (Tape and O'Donnell, unpublished data).
2. Time-series discharge datasets from the USGS NWIS have an additional column that describes the quality of the data. When ice begins to form on the river during autumn, the USGS flags the mean daily discharge value with an “e” for “estimated” (*M. Schellekens, personal communication*). This is due to the fact that once ice forms, the stage-discharge rating curve is no longer valid and cannot be used directly to calculate discharge.
3. Thus, it follows that the timing of autumn freeze-up can be estimated by the day during autumn when an “e” first appears by the mean daily discharge value.
4. Open daily mean discharge time series datasets for all monitoring sites.
5. Identify the Julian day of freeze-up during the autumn freeze-up period (September-October) for each year of record. As noted above, this is done by identifying the first day of autumn when mean daily discharge is flagged with an “e” for “estimated” by USGS.
6. Plot Julian day of river freeze-up vs. year for all monitoring sites.
7. Use linear regression techniques to determine the significance of long-term trends in river freeze-up during autumn.

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