



Stream Channel Monitoring for Devils Tower NM

2022 Data Report

Natural Resource Data Series NPS/DETO/NRDS—2023/xxx



**ON THIS PAGE**

View of DETO SCM 001, facing downstream, June 2022.

Photograph courtesy of NGPN, National Park Service.

ON THE COVER

Cross-section at DETO SCM 001, with the Tower behind, August 2022.

Photograph courtesy of Northern Great Plains Network, National Park Service.

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Executive Summary

The Northern Great Plains Inventory and Monitoring Network (NGPN) began stream channel monitoring on the Belle Fourche River at Devils Tower NM in 2022. This data report summarizes the data collected during the 2022 season pertaining to watershed, reach, and physical habitat. After data are collected for at least four cycles, trends may be reported. This report covers three main areas: 1) Reporting on upland channel characteristics data that may affect habitat such as: land cover, drainage area, and total stream length; 2) Reporting of geomorphic dimensions such as: channel widths, bank angles, vegetative cover, reach slope, measures of bank stability; and 3) Determining physical habitat characteristics such as: size and distribution of bed sediment, large woody debris, and canopy cover.

Table ES-1 below shows the status of stream channel parameters for DETO for the collected data during 2022. Indices, benchmarks, and other studies are provided in the table for informational purposes to help put the Belle Fourche River's measurements in context but should not be considered as a reference condition. Upland characteristics of the watershed indicate majority range land use cover: cropland (1.1%), shrubland (34.6%) and grassland, including pasture (55.08%) with little development (1.58%) in the watershed area. Reach characteristics include bank cover, heights, bank stability index, and vegetative cover. Angles are steep, and there are some sandy banks that are unstable, however there is excellent access to the floodplain throughout the reach. When plots are revisited in three years, there will be greater understanding of the processes at play and the condition of the stream.

Physical characteristics include median particle size, percentage fine substrate, geomorphic units, and canopy cover. Cobble covers much of the stream and 'runs' are the dominant geomorphic channel unit. While there is an absence of large woody debris and canopy cover is low, many grassland rivers in good condition can have similar characteristics. More data are needed to fully assess those components and determine a suitable reference condition that can be used to later assess the status and trends of the Belle Fourche River at DETO. The reach data contained in this report are specific to a 220-m segment of the Belle Fouché River and cannot be extrapolated to conditions elsewhere on the river or to the park in general.

Table ES-1. Summary table for stream channel data in Devils Tower NM. Current values are based on data from 2022 alone.

Indicator	Measure	Status	Indices, Benchmarks, other Studies
Upland Land Use	Upland Land Cover Change	2019 NLCD cover Grassland= 50.9%, Forest= 5.7%, Shrubland =34.6%	2001 Land Cover: Grassland= 51.7%, Forest= 6.1%, Shrubland=34.6%
	Land Development Change	1.58 % of watershed developed in 2019	1.34 % of watershed developed in 2001
Reach Level	Mean Bank Angle	48.64° water to bankfull bank angle	Bank Stability Index (BSI): <30° is good, <60° fair, >60° poor according to BSI
	Erosion	18 out of 22 bank transects (81%) show erosion in 2 m bank segments. Additional quantification of erosion showed 59% of bank eroded.	TBD
	Mean. Bank Heights	1.19 m	BSI: <1 m bank is considered good
	Mean Bankfull width	11.69 m	TBD
	Bank Vegetation Cover %	71.82%	BSI: Vegetative cover>80% is "good", 50-80% fair, 20-49% poor, <20% very poor
	Bank Stability Index	10.70 on BSI index	<7.99 is considered stable, 8-10.99 at risk, 11-15.99 unstable, >16: very unstable
	Max Distance of Bank Migration	NA	TBD
	Cross-sectional Area	Mean bankfull area 9.43 m ² ; Mean channel full area 83.95 m ²	TBD
Physical Habitat	Median Particle Size of Representative Riffle	32mm, medium gravel	TBD
	Percentage fine substrate	Cobble dominant in 8 out of 11 transects. No transects were graded as smaller than gravel. Expanded analysis concurred with 60% of reach covered in fine sediment (sand or silt).	Median sand percentage was 100% in large NGPN rivers (Rust, 2006)
	Geomorphic units	Dominated by run, (61%), pool (10%), and riffle (29%) habitats	Reach has a good number and variety of habitats.
	Canopy cover	0% canopy cover from center of stream	0% cover was median for large NGPN rivers,(Rust 2006).

¹ National Land Cover Dataset

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Abbreviations and Acronyms

>:	greater than
≥:	greater than or equal to
<:	less than
≤:	less than or equal to
#:	number
303(d) list:	List of Impaired Waters , under the CWA
BSI:	Bank Stability Index
cfs:	cubic feet per second
CWA:	Clean Water Act
°C:	degrees Celsius
DEM:	digital elevation model
DEQ:	Department of Environmental Quality
DETO:	Devils Tower NM
DO:	dissolved oxygen
<i>E. coli</i> :	<i>Escherichia coli</i>
EMAP:	Environmental Monitoring and Assessment Program (USEPA)
EPA:	Environmental Protection Agency
HR:	High Resolution
HUC:	hydrologic unit code
I&M:	Inventory & Monitoring
IRMA:	Integrated Resource Management Applications
km ² :	square kilometers
mi ² :	square miles
mL:	milliliters

NAWQA:	National Water Quality Assessment (USGS)
NGPN:	Northern Great Plains Network
NHD:	National Hydrography Dataset
NHDPlus HR:	National Hydrography Dataset Plus High Resolution
NM:	National Monument
NPS:	National Park Service
NWIS:	National Water Information System (U.S. Geological Survey)
SECN:	Southeast Coast Network
SOP:	standard operating procedure
USACE:	U.S. Army Corps of Engineers
USEPA:	U.S. Environmental Protection Agency
USGS :	U.S. Geological Survey
WBD:	Watershed Boundary Dataset
WY:	Wyoming

Introduction

Devils Tower National Monument (DETO) was established in 1906 as the first National Monument in the United States, with a mission to preserve the Tower and the surrounding 1347 acres (545 ha) of ponderosa pine forests, mixed-grass prairies, and riparian corridor along the Belle Fourche River. Although there are several springs in the Monument, the Belle Fourche River is the major hydrologic feature of the park (NPS 1997). The Belle Fourche River is about 290 miles (470 km) long from the headwaters in northeastern Wyoming to its confluence with the Cheyenne River approximately 50 miles ENE of Rapid City, South Dakota (Figure 1). Northeastern Wyoming is a dry region; on average it receives 17 inches of precipitation annually, with two-thirds of that precipitation occurring as rain in the spring and summer.

Approximately 2 miles (3.6 km) of the Belle Fourche River runs through DETO as the river flows northeast toward South Dakota. In this area, river flow tends to peak between March and June, while annual low flows occur in November and December. River flow has been limited and altered since 1952 by the construction of the 168-foot tall Keyhole Dam and reservoir upstream of DETO (Linenberger 1996, USGS 2023b). The dam reduced the floods that cottonwood seedlings relied on for germination and establishment (Martin 1995). The river has become deeply incised, creating areas along the river where the water table is now 1.7–2.2 m deep and typical riparian vegetation, such as willows, are largely absent, having been replaced by grassland (Anderson 2013). Dams reduce water and sediment supply to downstream reaches and change the seasonality and magnitude of floods. The geomorphological response to dams may be slope changes, cross-sectional changes, planform, and bedform changes (Brandt 2000). Petts 1987 described additional effects from dams. First-order changes include direct changes to the water input to the downstream system such as sediment load, discharge, water quality, and plankton. Second order changes are changes to channel form, substrate, macroinvertebrate populations. Third order changes include biotic effects in fish and invertebrate populations. Channel narrowing and reductions in channel migration have been observed downstream of dams in the Great Plains (Friedman et al 1998). The Belle Fourche's hydrograph has been drastically altered by the dam operation and the Belle Fourche River's flow is affected by this major stressor (USGS 2023a, USGS 2020b) so we may expect to see channel-level changes as well. Peak flows have been shifted from spring flows to match irrigation demands later in the summer.

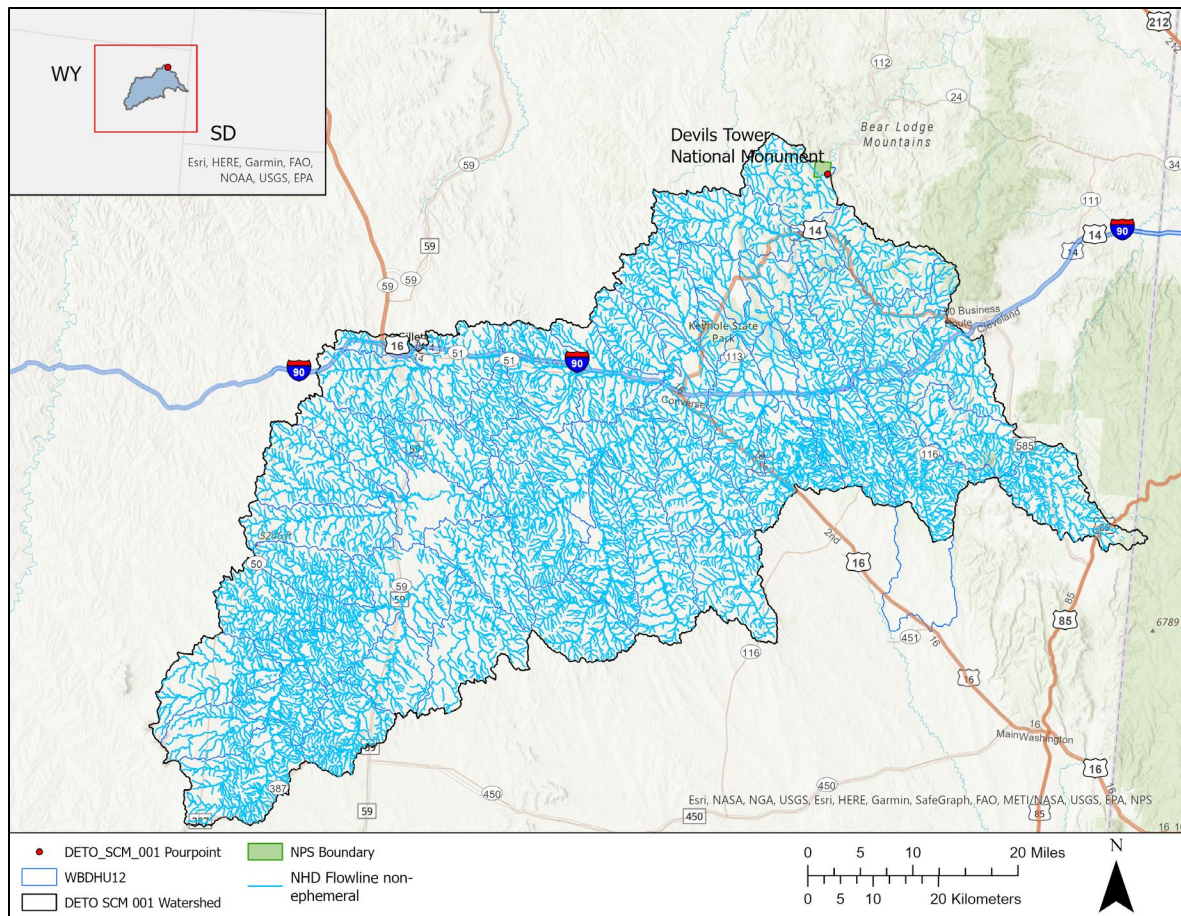


Figure 1. Map of DETO SCM 001 watershed.

Primary land uses in the region include livestock grazing, hay production, mineral extraction, and oil and gas production (WYDEQ 2020). The Belle Fourche River is designated as a Class 2AB warm water fishery, defined as a water known to support game fish populations or spawning and nursery areas at least seasonally and where a game fishery and drinking water use is attainable (WYDEQ 2018b). Several stretches of the river are listed as impaired waterways under section 303(d) of the Clean Water Act, including the 60.7-mile stretch running through DETO, from Arch Creek to Sourdough Creek, AUID= WYBF101202010904_00. This reach is impaired for fecal coliform bacteria (WYDEQ 2020). The Belle Fourche River reach running through Devils Tower is in the 17a Black Hills Foothills Level IV Ecoregion (Chapman et al 2004). It is best described as a ponderosa pine woodland and grassland savanna with 15–20 inches of precipitation annually. Livestock grazing, ranching, recreation, and wildlife habitat are described as the primary land uses with some gypsum and copper mining in the area (Chapman 2004).

The Northern Great Plains Inventory & Monitoring Program (NGPN) began monitoring stream channel characteristics at DETO in August 2022. The protocol is modeled after Southeast Coast Network’s (SECN) Wadeable Stream Habitat Condition Protocol (McDonald 2018). The protocol includes three different aspects of stream measurements:

- 1) Upstream **watershed characteristics** such as watershed area, catchment slope, and drainage density, as well as changes to land cover that may affect stream habitat.
- 2) **Geomorphic dimensions** (cross-sectional morphology) of selected wadeable stream reaches such as channel widths, bank characteristics (e.g., heights, angles, and vegetative cover), reach slope, and sinuosity.
- 3) **Physical** measures of benthic and riparian **habitat features** present in selected wadeable stream reaches such as the size, type, and distribution of bed sediment and large woody debris, the distribution of geomorphic channel units, canopy cover, and discharge.

NGPN conducted the first survey at DETO in August 2022. DETO SCM 001's 220-m reach was established between the concrete tetrahedron erosion structures and the campground.

Methods

The NGPN Stream Channel Monitoring Protocol (Thornburgh et al. 2019 [DataStore – Project – \(Code: 2259796\) \(nps.gov\)](#)) sets out the methods used for sampling stream channels. The protocol borrows heavily from the Southeast Coast Inventory and Monitoring Network [DataStore – Published Report – \(Code: 2254874\) \(nps.gov\)](#). Both protocols build on USGS's NAWQA (National Water Quality Assessment survey, Fitzpatrick 1998) as the foundation. The spatial hierarchy of basin, reach and segment from the NAWQA survey is followed here as well as many of the channel, bank, and riparian characteristics. For full descriptions of protocols please reference the above links, the general approach is briefly described below.

Site Selection

Stream channel monitoring in NGPN parks is targeted to be co-located with the water quality monitoring (WQM) station when the WQM station is on the stream segment of interest. Bank inaccessibility on high cut banks which are sandy and unstable, avoidance of hard stabilization projects, and park property boundaries are all reasons to shift the reach to a more suitable location. Of the eight NGPN WQM sites [DataStore – Water Quality Monitoring in Northern Great Plains Network \(nps.gov\)](#), one will not have stream channel measurements taken. The site at MNRR on the Niobrara River is not wadeable, so no stream channel measurements are performed there. Water quality monitoring and stream channel monitoring is done on a rotating basis at 9 parks. WICA was sampled in 2021 when it was the only site sampled. FOLA and MNRR-Bow Creek are scheduled to be included with it when next sampled in 2024. DETO, KNRI, and THRO were sampled near their WQM gages in 2022. AGFO and NIOB will be sampled near their WQM stations in 2023 along with MORU which does not have a WQM station.

At DETO, the site was placed upstream of the gage with a relatively accessible floodplain between the campground and the concrete erosion structures. A 150-m minimum reach length is used in USEPA Environmental Monitoring and Assessment Program (EMAP), National Aquatic Resource Survey (NARS), and National Water Quality Assessment (NAWQA) protocols. Reach length was based on initial wetted width, which was 11 meters. With a total reach length twenty times the initial mean stream width, the reach length is 220 meters. Permanent benchmarks indicating the starting and ending points of the three detailed transects were located with a high accuracy GNSS receiver. Rebar pounded flat to the ground with caps marked the benchmarks, which were located on the channel tops.

Data Collection

The Northern Great Plains Inventory and Monitoring Network (NGPN) began stream channel monitoring in Devils Tower NM in August 2022. Data collected during the 2022 season pertains to watershed, reach, and physical habitat. After data are collected for at least four cycles, trends may be reported. Data collection and reporting covers three main areas: 1) Status and trends of upland channel characteristics data that may affect habitat such as land cover, drainage area, and total stream length; 2) Status and trends of geomorphic dimensions such as channel widths, bank angles,

vegetative cover, reach slope, measures of bank stability; and 3) Status and trends of physical habitat characteristics such as size and distribution of bed sediment, large woody debris, and canopy cover.

Following the protocol, which is available here: [DataStore – Published Report – \(Code: 2260277\) \(nps.gov\)](#), the NGPN crew established a plot at DETO SCM 001 in August 2022 with rebar marking the GNSS occupation points. An Arrow Gold receiver was used to obtain high accuracy benchmark locations, summarized in Table 1 below.

Table 1. Benchmark locations at T1, T6, T11.

Point Name	Northing_m	Easting_m	Elevation in Ortho ht (m)	Datum	Lat WGS 84	Long WGS 84
DETO_SCM_001_LT1	453860.602	236688.677	1178.329	NAD83 (2011)	44.585077	-104.70466
DETO_SCM_001_LT6	453780.773	236610.035	1178.313	NAD83 (2011)	44.583507	-104.70636
DETO_SCM_001_LT11	453685.889	236554.689	1178.594	NAD83 (2011)	44.58436	-104.70566
DETO_SCM_001_RT1	453811.57	236733.346	1175.017	NAD83 (2011)	44.584629	-104.7041
DETO_SCM_001_RT6	453749.29	236662.649	1174.76	NAD83 (2011)	44.584073	-104.705
DETO_SCM_001_RT11	453666.536	236608.12	1174.197	NAD83 (2011)	44.583328	-104.70569

All locations are recorded in Wyoming State Plane East coordinate system (SPC 4901 WY E, WKID= 3702), though geographic coordinates in Web Mercator are also provided. The detailed transects are the lines along which a total station is utilized to collect distance and elevation data along the transect line relative to the GPS benchmarks. A Trimble SX 10 unit was rented, personnel were trained, and data collected in late August 2022.

The NGPN crew performed stream channel measurements in late August 2022 with a repeat in October 2022 for a QA visit. Discharge, photos, geomorphic channel units (pool, riffle, run, etc), representative pebble count at the riffle between transect 1-2, canopy cover, large woody debris, bank and bed sediment, channel- and bank-full heights and angles were taken. Vegetative bank cover and other cover measurements were taken in a one-meter strip up to bank full height. Figure 2 shows the layout of the reach. The longer yellow lines at T1, T6, and T11 show the permanent detailed transects where the total station was used.



Figure 2. Layout of sampled reach of DETO stream channel monitoring site DETO SCM 001. Transects number 1-11 running from down to upstream.

Watershed Characteristics

Watershed characteristics including total stream length, watershed size, and land use (among others) were calculated according to the Watershed and Segment Scale Assessment SOP [DataStore – Standard Operating Procedure – \(Code: 2259868\) \(nps.gov\)](#) by scientist-in-park GIS Assistant under

the supervision of NGPN Aquatic Ecologist during the winter of 2022-23. The Watershed and Segment Scale Analysis SOP [DataStore – Standard Operating Procedure – \(Code: 2259868\) \(nps.gov\)](#) is in the process of being updated. The first major change is that the workflow required is being updated to Arc Pro rather than ArcMap. Secondly, watershed parameters need to be redefined and clarified. Additionally, changes to the delineation procedure were made. Three methods used included the NHDPlus HR method, the 20- ha stream delineation method, and the StreamStats web application. Ultimately, the best delineation was based on the NHDPlus HR method. The NHD Plus HR method uses NHD flowlines to select the HUC 12s to include in the watershed delineation. NHD products and NED datasets are integrated to help define the watershed. The 20-ha method is the original procedure from the SOP. It uses a user-defined 20-ha threshold to delineate streams. However, this method failed in certain parks such as THRO and FOLA. The third method uses the StreamStats web application from USGS to delineate the watershed. Nebraska and Wyoming are undergoing some major changes in the application currently. Lastly, the requirement of using only of perennial streams was removed as perennial streams can be rare in areas especially in the northern Great Plains where intermittent streams dominant. Instead, ephemeral streams were removed from the flowlines considered as these seemed to cluster unevenly and only carry water a small portion of the year.

The following parameters were be calculated or extracted for each reach:

- **Watershed Drainage Area (km):** refers to the area within which precipitation, sediment, and dissolved constituents are funneled to a common outlet point (Dunne and Leopold 1978).
- **Total Stream Length (TSL km):** is the length of all streams that flow to a common outlet.
- **Drainage density (km/km²)** is the ratio of total stream length to drainage watershed area.
- **Watershed shape** is calculated by dividing watershed area by watershed length squared. Be careful to use consistent units.
- **Watershed length (km):** the distance as-the-crow-flies from the pour point to the drainage divide, uphill of the upper reach of the main path stream.
- **Watershed Relief** is the maximum amount of relief (maximum elevation minus minimum elevation) found within the watershed.
- **Watershed Relief Ratio** is calculated by dividing watershed relief by watershed length. Be careful to use consistent units.
- **Standard Deviation of Elevation (sdZ)** is the standard deviation of elevation within the watershed.
- **Watershed (CV):** coefficient of variation of slope for entire watershed. No units.

- **Slope** will be characterized by determining the average, standard deviation, and coefficient of variation of slope within the watershed.
- **Entire Stream Gradient** is calculated by determining the difference in elevation at 85% and 10% of the main stem stream length divided by the stream length between the two points.
- **Segment Gradient** is the difference in the upstream elevation of the stream segment minus the downstream elevation of the stream segment divided by the length of the stream segment.
- **Stream order** classifies streams based on the number and character of their tributaries (Strahler 1957). This SOP describes how to determine Strahler stream orders. NHDPlus HR provides a modified Strahler stream order in the Value-Added Attribute table included in the geodatabase.
- **Bifurcation ratio** is the ratio of the number of streams in a given Strahler order to the number of streams in the stream order above it (e.g., number of first order streams/number of second order streams). An average watershed bifurcation ratio can be determined by adding these individual ratios and dividing by the highest stream order minus one.
- **Land Use/Land Cover** will be calculated from the most recent NLCD dataset. This dataset classifies land cover using a modification of Anderson et al. 1976.

For more details regarding watershed and segment scale characterization and a complete definition of the above terms, refer to Fitzpatrick et al. 1998, the protocol and associated SOPs in [DataStore – Published Report – \(Code: 2260277\) \(nps.gov\)](#), and Monitoring Wadeable Stream Habitat Conditions in Southeast Coast Network Parks: Protocol Narrative (McDonald et al. 2018a).

NHD Plus-HR method of delineation

The basic workflow specific to DETO is described here: A 10-m digital elevation model (DEM), with corresponding NHDPlus HR geodatabase and NHDPlus HR rasters, was downloaded for the Watershed Boundary Dataset (WBD) HUC-8-level (hydrologic unit) area number 10120201. A large area was chosen so as not to mistakenly leave off distant headwaters. NHDPlus HR rasters were clipped to the outline of the DEM tile, then all rasters and the DEM were reprojected to the NAD83 (2011) Contiguous USA Albers coordinate system. NHDPlus HR Flowlines, Sinks, and WBD HUC-12 features were similarly reprojected. The site of DETO SCM 001 was used as the pour point. The Snap Pour Point tool was used to align it with the reprojected flowlines. The DEM was filled, then a flow direction raster was produced. The USGS has integrated elevation and hydrography GIS data with the National Hydrography Dataset Plus High Resolution (NHDPlus HR 2023), which includes the WBD (watershed boundary dataset). NHDPlus HR products include a hydro-conditioned “fdr” flow direction raster.

This “fdr” raster ran adequately in the Watershed tool. This initial “fdr”-derived watershed was useful for the shape of the watershed near the pour point. Polygons from the WBD HUC-12 level features were Selected by Location via intersection with the traced flowline results. The Erase tool was used on the selected HUC-12 polygons to remove the portion downstream of the boundary of the “fdr”-derived watershed. Extraneous edge slivers were manually edited out where the watershed and

HUC-12 polygons met to create a more precise overlay. The edited HUC-12 polygons were dissolved to create the final watershed shape.

The NHD-Plus HR flowlines in this region of Wyoming produced a disproportional number of stream segments (Figure 3). Those stream segments were reduced by excluding the ephemeral streams, selected out by using Fcode= 46007.

20-ha method of delineation

The NHDPlus HR-derived watershed was confirmed by running the stream production sequence of the old SOP 20-ha workflow [DataStore – Standard Operating Procedure – \(Code: 2259868\) \(nps.gov\)](#). A flow accumulation raster, a flow accumulation >2415 raster (cells which accumulate from at least a 20 ha catchment), then stream link and stream order rasters were created. The stream order raster was converted to lines via the Stream to Feature tool. The 20-ha stream layer very closely approximated the final watershed boundary used.

StreamStats method of delineation

The USGS StreamStats application [StreamStats \(usgs.gov\)](#) was used to generate a watershed area as an additional check on our procedures (USGS 2019). This application relies on a DEM and watershed tool like the one used in ArcGIS Pro. The procedure is very simple. One accesses the site, zooms in to an area of interest and clicks on the stream segment closest to the most downstream point of the watershed, approximating the same pourpoint as the previous methods. Annual exceedance probabilities for flow were constructed as well using associated regional regression equations (Williams-Sether 2015). The area generated by Streamstats was compared to the NHD watershed area and is discussed later in the report.

National Land Cover Database

Land cover classification rasters were downloaded, reprojected, clipped to the DETO SCM 001 watershed and summarized by land cover class. Data from 2001, 2006, 2013, 2016, and 2019 were downloaded and summarized.

Results

Watershed Characteristics

The watershed was delineated using the three methods: NHD_Plus HR, the 20-ha workflow, and the StreamStats methods. Total stream length was initially based on NHD-Plus HR stream segment lengths (13695.48 km) rather than the 20-ha derived stream network (12395.61 km, see Table 2). The NHD was further refined by eliminating ephemeral stream segments (FCode= 46007) to reduce the stream lengths down to 12533.81 km. Despite the high watershed slope, slopes in the immediate vicinity of the sampling site were less than .2%. Ultimately the best delineation was based on the NHDPlus HR dataset. The StreamStats web application is not fully available in Wyoming or Nebraska in 2023 and so cannot yet be used consistently across the network. The NHDPlus HR without ephemerals watershed and StreamStats watershed (6708.07 km²) yielded very similar results, about .11% difference from the NHDPlus- watershed (6700.55 km²), which is practically negligible. The Streamstats method may include some flow characteristics which are helpful to report. However, the Streamstats method also does not generate flowlines, only the watershed area.

Table 2. Stream lengths in DETO SCM 001 watershed.

Data source	Total stream length (km)
NHD-Plus High	13695.48
NHD- without ephemerals	12533.81
20-ha Derived Stream	12395.61

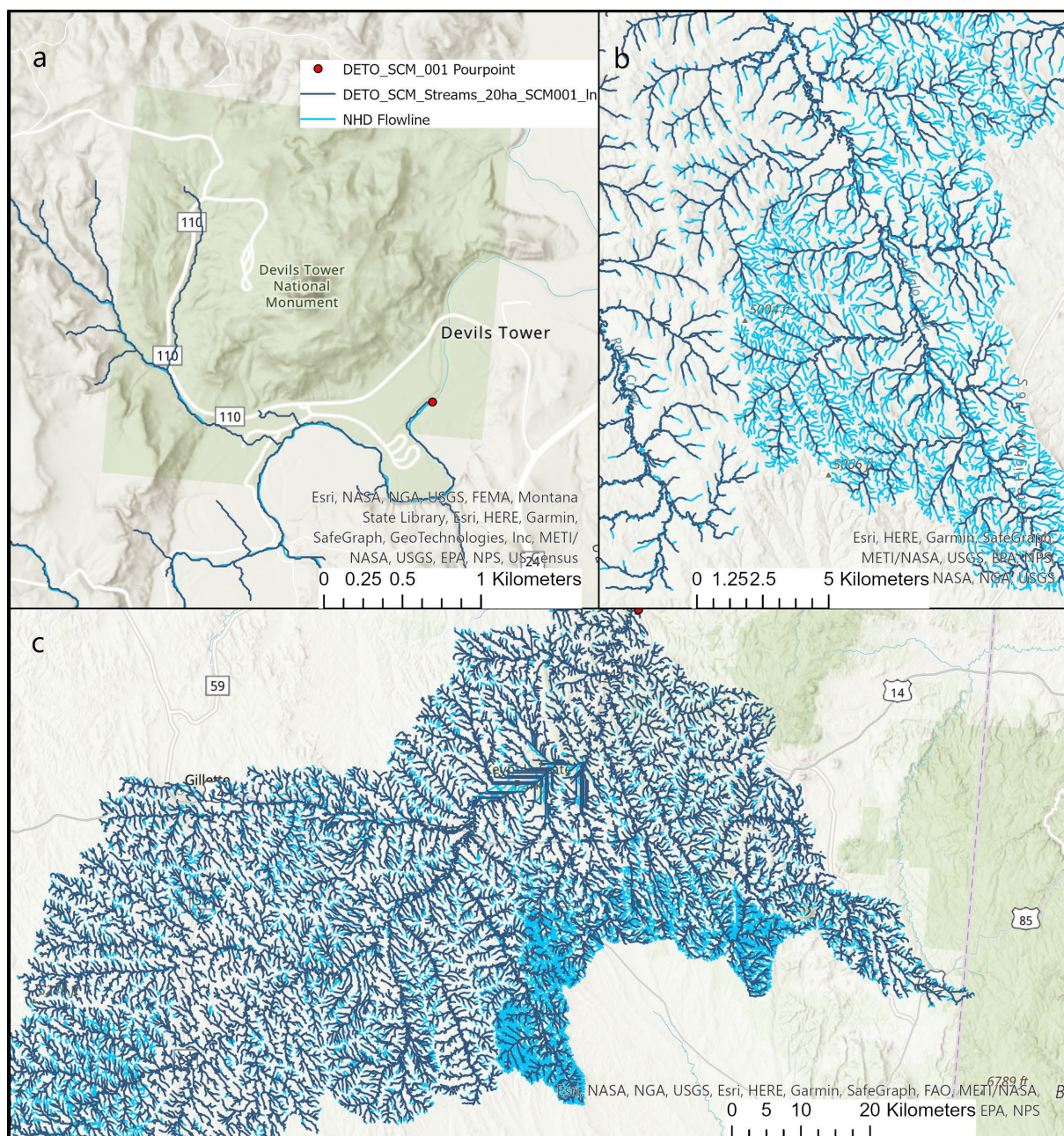


Figure 3. Flowlines associated with DETO stream channel monitoring site SCM 001. NHD flowlines are in light blue while 20-ha flowlines are in darker blue. There are many more NHD flowline segments than 20-ha segments. Panel 'a' shows the flowlines near to DETO SCM 001. Panel 'b' shows the prevalence of ephemeral flowlines while panel 'c' shows where those extra ephemeral flowlines are clustered in the watershed.

Table 3. Watershed Characteristics from elevation-derived delineated watershed using NHD-Plus stream length within HUC 12s upstream of DETO SCM 001.

Watershed Characteristic	DETO SCM 001
Watershed Drainage Area (km ²)	6700.55
Total Stream Length (km)	12533.81
Drainage Density (km/sq.km)	1.87
Watershed Shape	0.36
Watershed Slope- Average °	4.98
Watershed- Std. Dev °	5.17
Watershed- CV	1.04
Watershed Relief (m)	935.52
Elevation - Std. Dev (m)	109.01
Watershed Relief Ratio	0.01
Entire Stream Gradient (m)	1.0496
Strahler Order	8
Bifurcation Ratio	2.04
Stream Gradient (m)	1.3140
Flow Accumulation Threshold	NHDPlus HR, with ephemerals deleted

Table 3 shows the basin characteristics from the DETO SCM 001 watershed. The watershed was derived using the NHDPlus HR method outlines in the Method section. Results are above in Table 2 and recorded here with an explanation. Watershed drainage area was 6700.55 km². Some states are fully represented in the StreamStats application. StreamStats should improve in the future in Nebraska and Wyoming which are being revised and improved. Total stream length was the total kilometers of stream length within the watershed. NHD Flowlines, whose FCode= 46007, indicating ephemeral streams, were excluded due to the very high density of streams clustered in the southeast quadrant of the watershed (Figure 3). These streams were also excluded from the stream length calculation.

The NLCD was downloaded and applied to the DETO SCM 001 watershed. Upland characteristics of the watershed indicate high natural land use cover (forest, grassland and shrubland) with little development in the area. Grassland cover in 2019 was 55.08% including pasture, forest cover was 5.72%, shrubland cover was 34.64 %, and developed land cover was 1.58 %. Grassland cover in 2001 was 55.85 %, forest cover was 6.13 %, shrubland cover was 34.65%, and developed land cover was 1.34 % (Tables 4 and 5).

Table 4. National land cover dataset applied to elevation-derived delineated watershed.

NLCD Class	2001 Percent of Watershed	2006 Percent of Watershed	2011 Percent of Watershed	2016 Percent of Watershed	2019 Percent of Watershed
Open Water	0.55	0.28	0.62	0.57	0.66
Developed - Open ¹	0.69	0.71	0.72	0.72	0.72
Developed - Low ¹	0.36	0.38	0.40	0.42	0.42
Developed - Medium ¹	0.24	0.27	0.31	0.34	0.35
Developed - High ¹	0.05	0.06	0.07	0.08	0.08
Barren	0.42	0.57	0.78	0.86	0.86
Deciduous	0.03	0.03	0.03	0.03	0.03
Evergreen	6.10	5.89	5.89	5.61	5.69
Mixed Forest	0.00	0.00	0.00	0.00	0.00
Shrub	34.65	34.51	34.38	34.15	34.64
Grassland	51.74	52.09	51.60	51.66	50.89
Pasture	4.11	4.12	4.11	4.11	4.19
Cultivated	0.69	0.71	0.73	1.07	1.09
Woody Wetland	0.06	0.06	0.05	0.05	0.06
Herbaceous Wetland	0.31	0.33	0.30	0.32	0.31

¹ Developed subclasses: Open : <20% impervious surfaces; Low:20-49% impervious surfaces; Medium: 50-79% impervious surfaces, High: >80% impervious surfaces.

Table 5. 2019 National land cover dataset summarized categories applied to delineated Belle Fourche River watershed.

NLCD Class (2019)	DETO SCM 001
Developed Open & Low (%)	1.14
Developed Med. & High (%)	0.44
Forested (%)	5.72
Grassland (%)	55.08
Shrubland (%)	34.64
Wetland (%)	0.38

Watershed area can also be checked using the StreamStats application, [StreamStats | U.S. Geological Survey \(usgs.gov\)](https://streamstats.crk.usgs.gov/). Wyoming and Nebraska will be getting refined within the next few years which will make the site more functional. Table 6 shows the flow characteristics which are available from StreamStats. Not every parameter is available, and some are missing for our DETO SCM 001 watershed. We also included mean annual flow in this table, derived from USGS NWIS records.

Discharge is not calculated at the USGS Devils Tower station, 06427850. We use a downstream site at the WY-SD stateline, 06428500, to give an estimate for mean annual flow.

Table 6. Flow Characteristics derived from StreamStats.

Flow Characteristics	DETO SCM 001
Stream Stats Area (sq mi)	2590
Stream Stats Area (sq km)	6708.07
Mean Annual Flow (cfs)	61 ¹
2 year flood (50-percent AEP flood)	NA
50 year flood (2-percent AEP flood)	NA
100 year flood (1-percent AEP flood)	NA

¹ from NWIS, data from downstream at gage 06428500; 1954-2022, mean annual flow

Reach Characteristics

Detailed Transects

Reach characteristics include measurements from the detailed (total station) transects on three permanently marked transects and reach-level measurements on all transects. Active fluvial erosion is occurring within a relatively small area between the water and bank-full; the angle can be steep on cut banks and difficult to capture with the total station. Access to the floodplain is maintained throughout the reach.



Figure 4. DETO stream channel monitoring site SCM 001 at T11 (upstream) end. This transect had an “unstable” BSI score for bank stability (11.5).



Figure 5. DETO stream channel monitoring site SCM 001 at T11 (upstream) end from left channel top. The right bank is largely covered in vegetation with good access to the floodplain, yet it has some undercut and exposed banks.

Table 7 shows the cross-sectional area of each the three detailed transects with an average cross-sectional area calculated for the reach. The total station position and elevation measurements were used to calculate metrics such as area, perimeter, hydraulic radius (which is area divided by perimeter), width, depth, and width to depth ratio. The channel-full areas increase as the reach moves downstream. The channel generally widens and becomes more shallow as the reach moves downstream.

The R code associated with SECN’s 2.2.14 Wadeable Stream Processing and Analysis was updated slightly, but in general, our analysis follows their SOP. From the detailed (SX-10 derived measurements) transects, mean bank-full area was 9.43 m² and mean channel-full area was 83.95 m² (Table 6).

Table 7. Detailed transects derived from total station measurements.

Transect	Type	Area (m²)	Perimeter (m)	Hydraulic Radius (m)	Width (m)	Depth (m)	Width/Depth
T1	Bank-full	6.37	13.90	0.46	13.64	0.67	20.36
	Channel-full	114.17	58.56	1.95	57.43	3.35	17.15
	Ratio	17.93	4.21	4.26	4.21	5.00	0.84
T6	Bank-full	12.82	14.66	0.87	13.78	1.14	12.08
	Channel-full	83.67	52.30	1.60	50.86	3.00	16.98
	Ratio	6.53	3.57	1.83	3.69	2.63	1.41
T11	Bank-full	9.09	11.10	0.82	9.74	1.17	8.35
	Channel-full	54.01	50.98	1.06	49.20	2.69	18.28
	Ratio	5.94	4.59	1.29	5.05	2.31	2.19
Average	Bank-full	9.43	13.22	0.72	12.39	0.99	13.60
	Channel-full	83.95	53.95	1.54	52.50	3.01	17.47
	Ratio	10.13	4.12	2.46	4.32	3.31	1.48

The data were entered into R using SECN's R code with modifications. When plotting the transects on the same axis, the profiles were adjusted so left bank-full begins at the same position on the graph for all three transects. Figure 6 shows the cross sections below.

Additional measurements were taken with the total station at the water surface (ws) in the middle of each active channel area at the surface. Figure 7 shows the position of the ws at each transect and how the slope changes when moving downstream. Slope was -.2% from the top to the bottom of the reach.

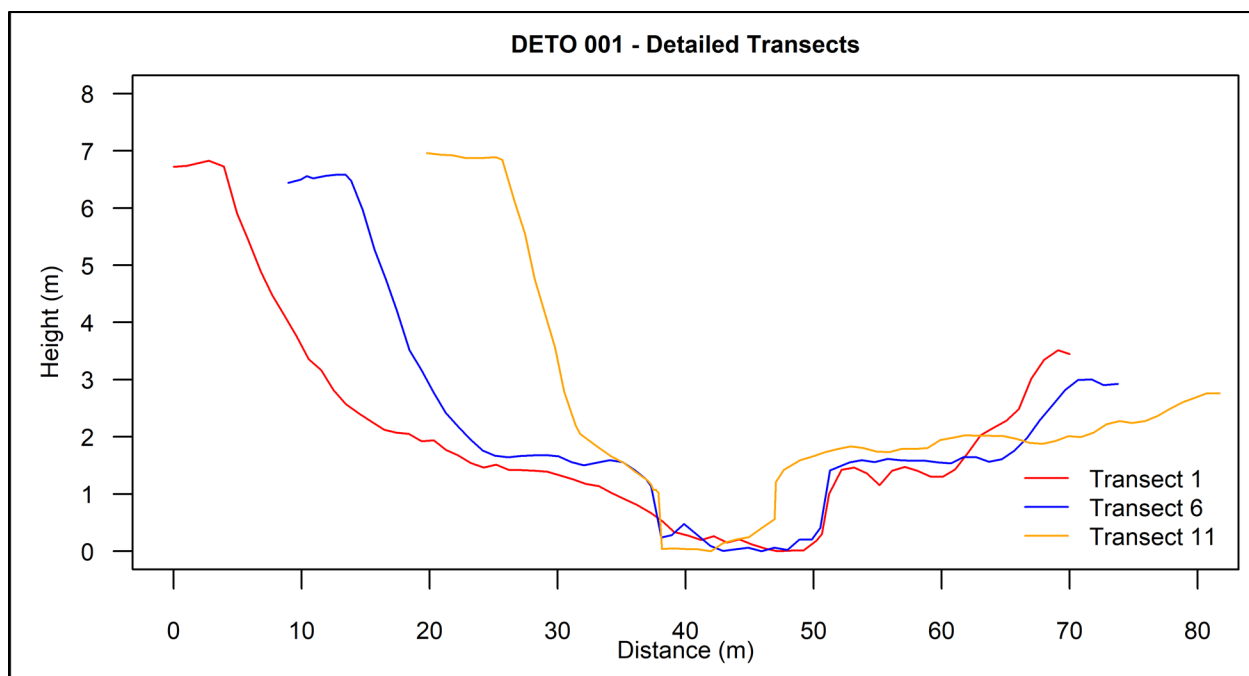


Figure 6. Detailed transects cross sections, plotting height above thalweg vs distance from the left benchmark (LBM). Axes were adjusted so that left bank-full begins at the same relative position for all three transects.

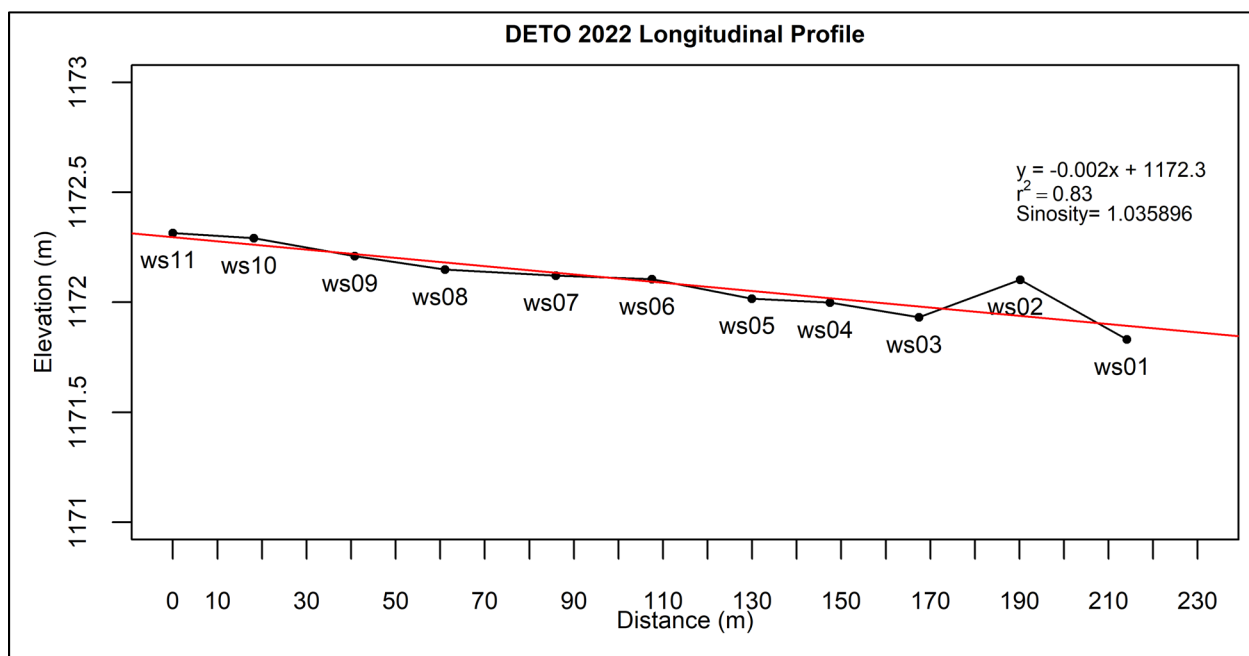


Figure 7. Elevational profile of DETO SCM 001. Slope is -.2%.

Reach-level Transects

Devils Tower was the QA SCM site for 2022. Some of the scouting pictures taken prior to July 20th show low water. Water began being released from the dam on July 20th. The detailed transect survey

was done in August of 2022 while water was still being released at roughly 60 cfs. The follow-up QA visit in October was taking at lower flows when water was not being released from the dam. Rather than combining measurements or going with the initial measurement, the values from the October visit are shown below. Whereas water depths in August had a mean thalweg of .66m, in October they dropped nearly a foot to .43m. The gage height August 23rd was 2.02 ft. The gage on October 3rd was at 1.18 ft [Belle Fourche River at Devils Tower, WY - USGS Water Data for the Nation](#). In future years, all effort will be made to avoid sampling during irrigation releases. Water depths remained relatively low throughout the reach with a mean thalweg (deepest spot of a stream along its cross-section) of 0.36 m. Table 8 shows the thalwegs or maximum water depth at each transect.

Table 8. Thalwegs at 11 transects at site DETO SCM 001 in October 2022.

Thalweg	n	Min	Max	Mean	Median	SD	CV
Depth (m)	11.00	0.21	0.68	0.43	0.38	0.18	0.43
Position ¹ (%)	11.00	5.00	80.00	33.18	20.00	23.16	0.70

¹ position is percent distance from left bank

Channel widths were wide throughout the site as shown in Table 9. Due to bars, wetted width was smaller than active channel width. Active channel refers to the unvegetated portion of the channel between the base of banks. Wetted width refers to the portion of the channel that was wet at the time of sampling. The terms ‘top of bank’ and bank-full and channel-full can cause confusion. In all cases at DETO SCM 001 ‘top of bank’ was synonymous with bank-full. Bank stability measurements are restricted then to the banks at bank-full. The portion of the bank continuing up to the channel-full top may be considered separately.

Table 9. Widths at transects at site DETO SCM 001 in October 2022.

Widths	n	Min (m)	Max (m)	Mean (m)	Median(m)	SD (m)	CV
Wetted	11	7.98	14.50	9.72	9.00	2.02	0.21
Active Channel	11	8.35	14.50	10.30	10.00	1.99	0.19
Bank-full	11	9.00	17.26	11.69	11.00	2.36	0.20
Channel-Full	11	48.81	65.83	58.77	58.85	4.92	0.08
Floodplain	11	4.02	35.79	16.33	14.92	7.16	0.44

Figure 8 shows channel diagnostic features from T1 looking upstream.



Figure 8. Bank and channel features from T1 looking upstream, taken earlier in the summer, July 2022 at low flow.

Bank stability index (BSI) is an important measure of the banks that incorporates bank angle, vegetative cover, bank height, and bank sediment. Tables 10a and 10b display the bank stability scoring and components. The left bank stability index was 10.5 and the right bank scored 10.91 for an average of 10.70 (Tables 10a and 10b). The difference is due to silty clay accumulated on the left bank, while the right bank contained more sand. BSI is extremely sensitive to substrate. A bank with “silt-clay” is scored 3.5 points lower than a bank scored as “sand”. A BSI score of 8-10.99 is in the “at-risk” category while 12-15.99 is in the “unstable” category (Table 10a). These scores are based on national metrics, (Fitzpatrick 1998) and what is appropriate for large Northern Great Plains rivers with sandy substrate remains to be seen. The bank stability index is confined to the bank full elevation. The bank stability index is used in SECN’s protocol [DataStore – Published Report – \(Code: 2254874\) \(nps.gov\)](#) but is ultimately derived from Fitzpatrick’s 1998 National Water Quality Assessment (NAWQA) protocol which is meant to be used nationwide, modified from Simon and Hupp 1992. Sandy banks or banks with sand and gravel are predisposed to instability. The Belle Fourche River cuts through alluvial layers which erode easily (GRI 2008).

Table 10a. Score range by Bank Stability Index scoring categories.

Category	Score Range
Stable	4 to 7.99
At-risk	8 to 10.99
Unstable	11 to 15.99
Very Unstable	16 to 22

Table 10b. Bank Stability Index scores by components range and type.

Component	Range or Type	Score
Angle (deg)	0-30	1
	31-60	2
	> 60	3
Vegetative Cover (%)	> 80	1
	50-80	2
	20-49	3
	<20	4
Height (m)	0-1	1
	1.1-2	2
	2.1-3	3
	3.1-4	4
	>4	5
Bank Sediment (type)	Bedrock, artificial	1
	Boulder, cobble	3
	Clay	4
	Silty clay	4.5
	Silt	5
	Sandy Silty Clay	5.5
	Silty Clay Sand	6.5
	Sand	8
	Gravel/sand	10

Tables 11 and 12 shows the reach-level bank stability index values.

Table 11. Reach-level bank characteristics for DETO SCM 001, Belle Fourche River.

Bank Characteristics	n (L)	n (R)	Min (L)	Min (R)	Max (L)	Max (R)	Mean (L)	Mean (R)	Median (L)	Median (R)
Bank Height ¹ (m)	11	11	0.61	0.64	1.64	2.02	1.10	1.27	1.10	1.34
Bankfull Height ^{2,3} (m)	11	11	0.61	0.64	1.64	2.02	1.10	1.27	1.10	1.34
Channel-full Height ^{2,3} (m)	11	11	6.48	1.76	7.98	4.25	7.05	3.15	6.98	3.16
Water Depth at Base ⁴ (m)	11	11	-0.16	-0.08	0.62	0.26	0.19	0.04	0.09	0.00
Bank Undercut (m)	11	11	0.00	0.00	0.22	0.22	0.07	0.07	0.02	0.00
Bank Angle ^(o)	11	11	5	15	90	55	60	38	65	40
Vegetation Cover (%)	11	11	30	30	100	95	73	70	80	75
Bank Stability ⁵	11	11	Stable	At-Risk	Unstable	Unstable	At-Risk	At-Risk	At-Risk	At-Risk

¹ Bank height is at bank-full throughout the DETO SCM 001 site.

² above thalweg

³ statistics are based on the transects where feature is present (# in parentheses)

⁴ a negative number indicates base of bank is above the water surface

⁵ See Table 8 for explanation of scores.

Table 12. Reach-scale bank characteristics.

Reach-scale	n	Min	Max	Mean	Median	SD	CV
Bank Height ¹ (m)	22.00	0.61	2.02	1.19	1.18	0.35	0.30
Bankfull Height ^{2,3} (m)	22.00	0.61	2.02	1.19	1.18	0.35	0.30
Channel-full Height ^{2,3} (m)	22.00	1.76	7.98	5.10	5.37	2.07	0.41
Water Depth at Base ⁴ (m)	22.00	-0.16	0.62	0.12	0.05	0.20	1.68
Bank Undercut ² (m)	22.00	0.00	0.22	0.07	0.01	0.08	1.23
Bank Angle ^(o)	22.00	5.00	90.00	48.64	45.00	22.42	0.46
Vegetation Cover (%)	22.00	30.00	100.00	71.82	75.00	19.24	0.27
Bank Stability ⁵	22.00	7.50	14.00	10.70	10.50	1.58	0.15

¹ Bank height is at bank-full throughout the DETO SCM 001 site.

² above thalweg

³ statistics are based on the transects where feature is present (# in parentheses)

⁴ a negative number indicates base of bank is above the water surface

⁵ See Table 8 for explanation of scores

Table 13. Transect-scale bank characteristics.

Transect-scale	Bank Height ¹ (m)	Bankfull Height ^{1,2} (m)	Channel-full Height ^{1,2} (m)	Water Depth at Base ³ (m)	Bank Undercut ² (m)	Bank Angle ^(o)	Vegetation Cover (%)	Left Bank Stability ⁴	Right Bank Stability ⁴
1	0.90	0.90	5.30	-0.08	0.04	22.50	95.00	7.50	9.50
2	0.63	0.63	4.82	0.09	0.06	42.50	75.00	10.50	8.50
3	1.50	1.50	6.12	0.31	0.03	32.50	87.50	8.50	10.50
4	1.42	1.42	5.20	0.09	0.01	52.50	70.00	11.50	10.50
5	1.16	1.16	4.91	0.06	0.07	57.50	77.50	11.50	10.50
6	1.26	1.26	5.07	0.04	0.00	60.00	75.00	11.50	11.50
7	1.83	1.83	5.66	0.18	0.07	65.00	72.50	11.50	11.50
8	1.04	1.04	4.25	0.12	0.10	45.00	70.00	9.50	14.00
9	0.85	0.85	4.74	0.00	0.00	42.50	87.50	10.50	8.50
10	1.25	1.25	4.83	0.19	0.21	47.50	50.00	10.50	12.50
11	1.25	1.25	5.22	0.32	0.17	67.50	30.00	12.50	12.50

¹ above thalweg

² statistics are based on the transects where feature is present (# in parentheses)

³ a negative number indicates base of bank is above the water surface

⁴ See Table 8 for explanation of scores

Transect 11 was the worst scoring transect overall for stability, while Transect 1 was the best. Pictures comparing transect 1 and 11 banks are below (Figure 9). High bank angles, higher bank heights, less cohesive substrate, and lack of vegetation contributed to the transects with higher bank instability.. Undercuts on some of the banks contributed to bank instability.



Figure 9. Transect 1 shows little erosion and has bank stability of score of 7.50 on the left bank (a) and 9.50 on the right bank (b). Transect 11 shows high areas of erosion and has bank stability of score of 12.5 on the left bank (c) and 12.5 on the right bank (d). While the right bank at T1 did have a .08 m by .07 undercut, undercutting was much more severe at T11 with a .22m x .42 m undercut on the left bank and a .12 x .1 m undercut on the right bank.

Bank erosion is measured in the original protocol in a qualitative manner by recording erosion and type (none, slump, or lateral) within a meter up and downstream of each transect. According to this method, 81% of bank transect measurements showed erosion. A high percentage of erosion was on the left bank, which showed 91% of the bank eroding while the right showed only 72% of the bank eroding. Rust 2006 methods which actually only directly measured erosion on smaller streams, not on large rivers like the Belle Fourche at DETO, but NGPN has modified the protocol to measure erosion on all wadeable streams. Therefore, additional measurements were taken by measuring the length of streambank eroded at each transect. A 10-m section was measured on each bank at each transect. Of 220 meters of bank length, 130 meters were recorded as eroded, representing 59.1 % of the streambank. 68.6% of the left bank was eroding, while 49.5 % of the right bank was eroding. This more quantitative measure of erosion was included in the 2022 revision of the Wadeable Stream Field Data Collection protocol [DataStore – Wadeable Stream Reach Scale Field Data Collection: Stream Channel Monitoring \(nps.gov\)](#).

This site will be revisited in 3 years to see if channel widening is occurring. Given the amount of undercut banks and the substantial widening of the channel and bank full areas moving downstream (Figure 10), we would expect erosion effects to get worse at T11. Channel change can be regarded as a redistribution of the imbalance between sediment and water (Schmidt and Wilcock 2008, Thorne and Lewin 2020). The revisits will allow us to better identify areas of sediment deposition and erosion and if these areas have changed from the 2022 visit.

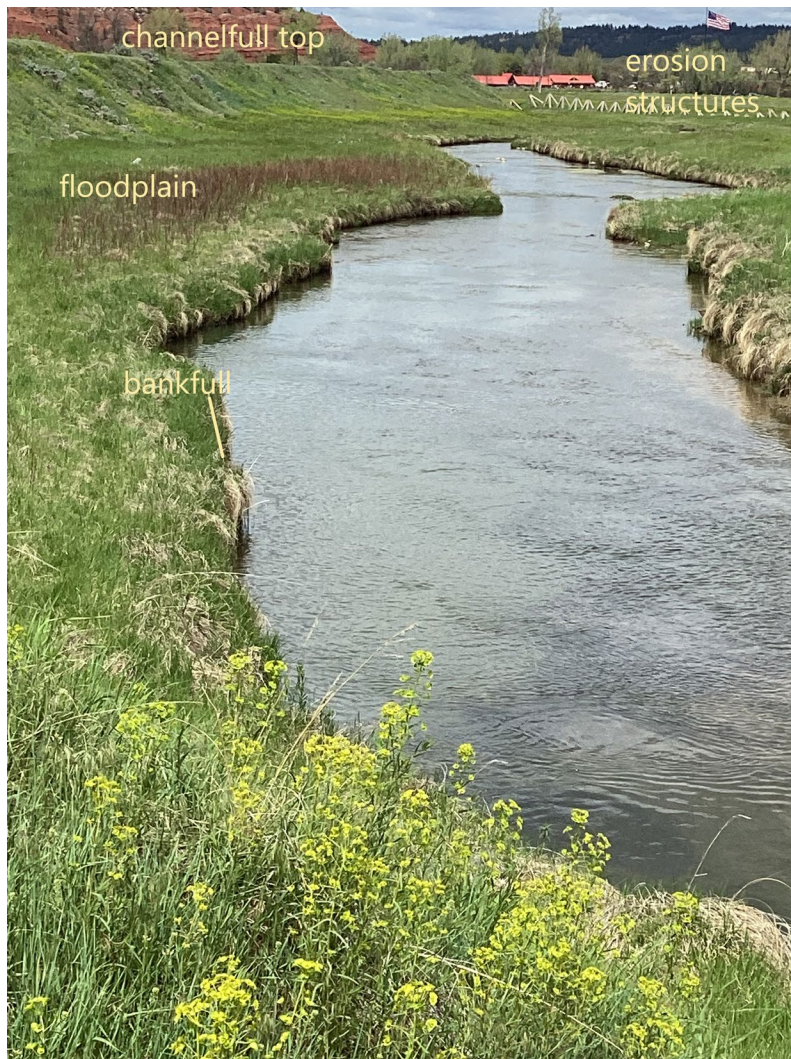


Figure 10. Site overview from right bank at T11 looking downstream.

Physical Characteristics

Physical characteristics include geomorphic units (Table 14a and 14b), median particle size in a representative riffle (measurements taken between transect 1-2, $d_{50}=32$ mm, Table 15), particle size and embeddedness (Table 16), percentage fine substrate (sand or silt/clay which was dominant in 0 out of 11 transects as well as percent of sediment particles sampled which were coded as “fines”, Table 17), and canopy cover (Table 18).

Table 14a. Transect-scale geomorphic channel units.

Transect	(%) Riffle	(%) Run	(%) Glide	(%) Pool	(%) Step
1 - 2	95	0	0	5	0
2 - 3	60	35	0	5	0
3 - 4	0	95	0	5	0
4 - 5	0	95	0	5	0
5 - 6	0	95	0	5	0
6 - 7	0	85	0	15	0
7 - 8	40	50	0	10	0
8 - 9	5	90	0	5	0
9 - 10	90	5	0	5	0
10 - 11	0	60	0	40	0

Table 14b. Calculated geomorphic channel metrics for all transects.

Metric	(%) Riffle	(%) Run	(%) Glide	(%) Pool	(%) Step
Frequency	5.0	9.0	0.0	10.0	0.0
Max (%)	95.0	95.0	0.0	40.0	0.0
Mean (%)	29.0	61.0	0.0	10.0	0.0
Median (%)	2.5	72.5	0.0	5.0	0.0
SD (%)	39.4	37.3	0.0	11.1	0.0

Table 15. Sediment diameters from a representative riffle- transect 1-2.

Statistic (n = 100)	Diameter (mm)
Min	0.062
D5	2
D16	5.6
D50	32
D84	128
D95	180
Max	512

Table 16. Particle size (mm) from channel cross-section.

Transect	Left	Left Center	Center	Right Center	Right
1	0.062	90	64	22.6	0.062
2	5.6	300	2	2	2
3	0.062	45	0.062	2	2
4	180	8	0.062	2	2
5	0.062	2	2	0.062	0.062
6	0.062	2.8	0.062	128	0.062
7	0.062	2	0.062	0.062	0.062
8	2	64	2	90	0.062
9	2.8	45	16	128	2
10	300	512	0.062	11	0.062
11	512	512	512	0.062	0.062

Table 17. Dominant particle size class and percent fines in reach.

Transect	Dominant Particle Class	Left	Left Center	Center	Center Right	Right	Percent Fines ¹
1	Cobble-small	0.062	90	64	22.6	0.062	40
2	Cobble-medium	5.6	300	2	2	2	60
3	Cobble-medium	0.062	45	0.062	2	2	80
4	Cobble-medium	180	8	0.062	2	2	60
5	Gravel- medium	0.062	2	2	0.062	0.062	100
6	Gravel- medium	0.062	2.8	0.062	128	0.062	60
7	Gravel-fine	0.062	2	0.062	0.062	0.062	100
8	Cobble-small	2	64	2	90	0.062	60
9	Cobble-small	2.8	45	16	128	2	20
10	Cobble -large	300	512	0.062	11	0.062	40
11	Cobble -large	512	512	512	0.062	0.062	40
Percent Fines for All Transects	0	—	—	—	—	—	60

¹ Particle size, Fines include sand (S), and silt clay (SiC), otherwise size is in mm.

Table 18. Canopy cover in reach.

Transect	Canopy Cover (%)
1	0
2	0
3	0
4	0
5	0
6	0
7	0
8	0
9	0
10	0
11	0
Min (%)	0
Max (%)	0
Mean (%)	0
Median (%)	0
SD (%)	0
CV	—

Substrate was a mix of cobbles and fine sediment (Tables 16 and 17). ‘Run’ habitat dominates but there are also riffles and pools (Tables 14a and 14b). While there is an absence of large woody debris (0% in active channel) and canopy cover is low (mean canopy cover was 0%; Table 18), many grassland and rivers streams in good condition can have similar characteristics (Rust 2006).

Sediment particles were measured following the protocol and using a gravelometer to record the size of the hole the particle can pass through. The segment between transect 1 and 2 was selected as the representative riffle. Diameters are summarized in Table 15, with the median particle size (D_{50}) corresponding to 32 mm, classified as medium gravel. Particle size decline over time can be evidence of siltation and increased embeddedness. Increases in particle size indicate armoring. Water supply can also have temporary effects on sediment size as fines build up on the stream bed until a flood event is big enough to wash them away. The pebble count is taken solely from the riffle and does not account for changes in depositional areas which may accumulate high sediment. Rust 2006 had recorded a lower percentage of fines and sand (13 % then vs 60% in 2022) and boulders or particles larger than 256 mm (6% then vs 11% in 2022) at that particular reach which included DETO SCM 001 but extended downstream to the bridge (Rust 2006).

Stream substrate is an important habitat feature. Dominant substrate can be difficult to determine visually when there is a mix of particle sizes. Additions were made to the SOP to better quantify the substrate with methods other than those in the protocol. Implementing the protocol depends on accurately identifying the dominant habitat type. Since the habitat is not uniform across the transect,

additional measurements were taken to support the dominant habitat data. Five sediment particles were selected at regularly spaced intervals across the wetted width of each transect and measured with a gravelometer (Tables 16 and 17). Those points were recorded. These additional survey points produced the same percentage of fine substrate as when estimating the dominant particle class as according to the protocol. The Field Data Collection SOP [680235 \(nps.gov\)](#) was updated to continue to measure five sediment particles across the transect to more accurately determine the percentage of fine sediment.

Canopy cover was low across the reach (Table 18) with mean value of 0%. Rust found that at NGPN large river sites, mean canopy cover was 11%, though it was 0% at DETO. In addition to canopy at the center of the reach, she measured canopy cover at the banks. In the future, we will include a bank canopy measurement on each bank in addition to the 4 center measurements and have incorporated this update into our new SOP and datasheet ([DataStore – Project – \(Code: 2259796\) \(nps.gov\)](#)).

The last component of physical characteristics was the discharge which was measured along the T11 transect in August. Discharge was measured with a Marsh-McBirney flow meter and was 48.07 cfs using the velocity-area method (Figure 11). The measured stage at the gage at that time was 2.02 feet. Cross section mean stream velocity at DETO SCM 001 was 0.67 ft/s (.20m/s). Keyhole Dam (17 miles upstream) was releasing 60.39 cfs on August 23rd [ARC040, Daily Data for Month \(usbr.gov\)](#). Keyhole provides water for downstream irrigators in Wyoming and South Dakota. Releases began July 20th and continued till September 1st in 2022 during the irrigation season. The maximum releases occurred on July 29th with 87.30 cfs. Releases have been even higher in past years. Daily releases topped 150 cfs in 2021, 300 cfs in 2020, and 1073 cfs in 2019. The past thirteen years of releases and release dates are shown below in Table 19. 2012 had no releases between May 17th and June 21st.

Table 19. Reservoir releases from Keyhole Dam 2010-2022.

Year	StartDate	EndDate	Max Q	Min Q	Average Q
2022	20-Jul	1-Sep	87.30	32.37	67.53
2021	6-Jul	28-Aug	158.20	30.55	109.16
2020	9-Mar	14-Sep	300.13	0.00	70.02
2019	24-Mar	28-Sep	1073.02	10.85	222.92
2018	1-Oct	2-Oct	220.08	95.11	157.59
2017	26-May	30-Sep	220.65	28.59	112.75
2016	20-Jun	7-Aug	119.70	23.94	85.74
2015	5-Jun	30-Sep	117.12	23.40	85.84
2014	—	—	—	—	—
2013	28-Aug	3-Sep	62.64	25.76	54.97
2012	14-Mar	11-Sep	149.94	1.55	85.29
2011	—	—	—	—	—
2010	—	—	—	—	—

The releases do not always occur at the same time each year and instead rely on the call for water downstream. In the future, taking velocity measurements at the detailed transects would be useful to better understand how stream velocity changes throughout the reach. We would expect stream velocity to be greater where the stream is narrow and straight.



Figure 11. Discharge was measured at the upstream end of the site, along the T11 detailed transect.

The hydrograph from 2022 shows the period where Keyhole was releasing water in Figure 12.

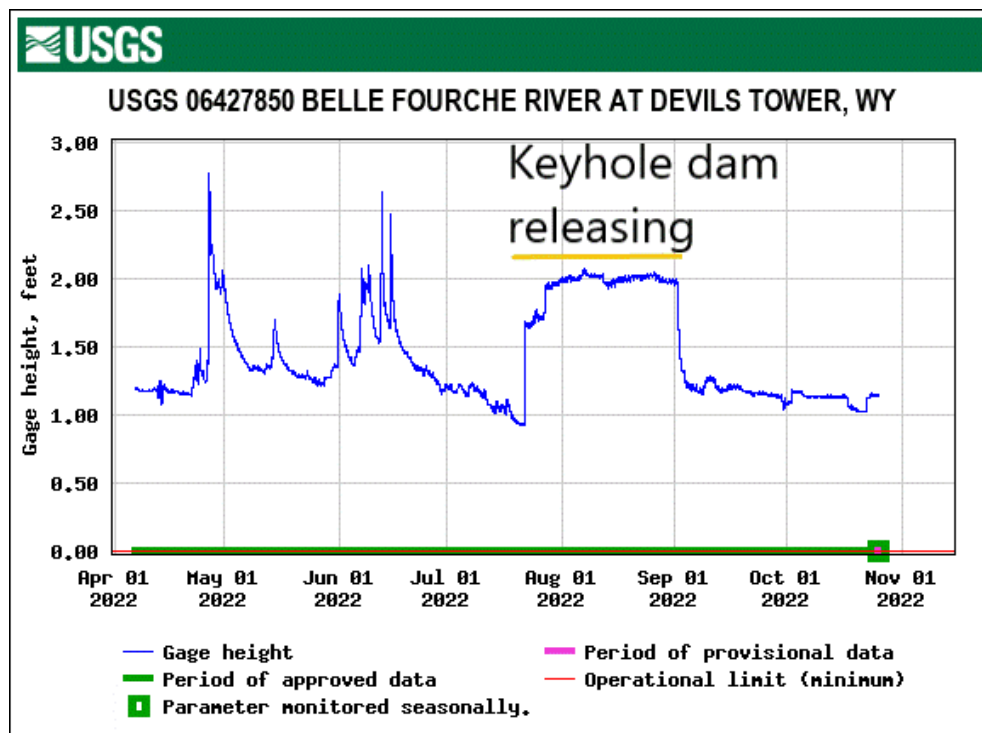


Figure 12. 2022 Hydrograph from USGS station 06427850 USGS 2023a.

The dam releases in late summer are a departure from the natural flow regime which typically peaked in the spring. The flow record at Devils Tower, Station 0647850, only began in 2013. Over fifty miles downstream at Station 06428500, the flow record goes back to 1947. Though the dam influence is attenuated there because it is further downstream, Figure 13 shows the hydrograph of the daily mean back to 1947 (a), and the regular near-yearly peak flows above 2000 cfs in pre-dam years (b), and some high flows but not nearly as regular in the last few years since 2017 (c). Daily flows in 1947 peaked in the spring (Figure 14a), while flows are much lower in 2022 and have a second spike in the summer coinciding with dam releases. It is not known yet how and to what extent extra water from the dam affects the channel and bank stability. We hope to explore those questions in future data reports.

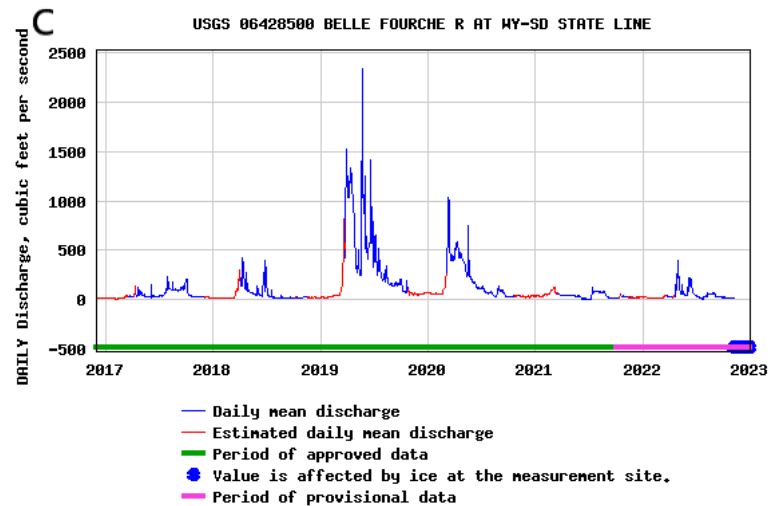
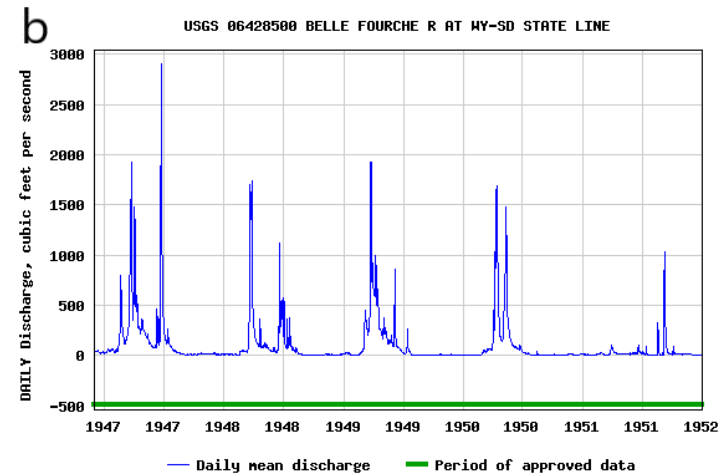
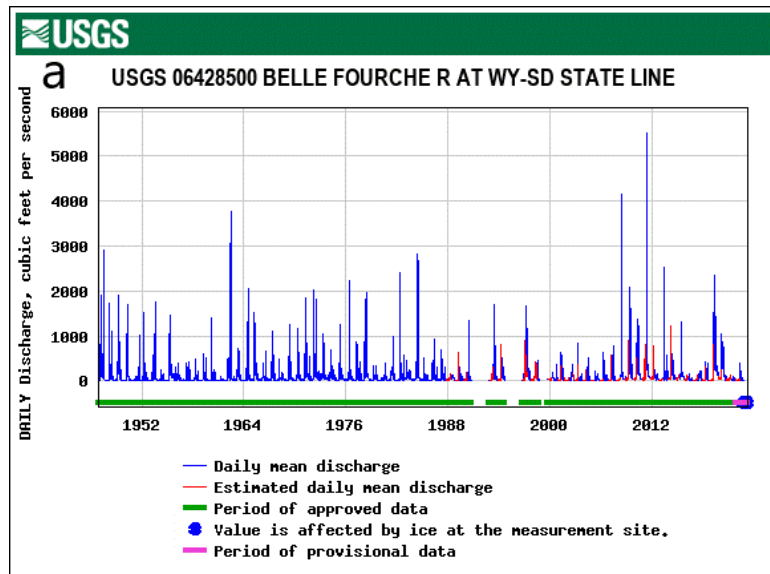


Figure 13. 2022 Hydrograph from USGS station 06427850, a station 50 miles downstream of Devils Tower. A. shows the hydrograph since 1947. The dam was finished in 1952. B. Shows some pre-dam hydrographs. C. shows the past 5 years of post-dam hydrographs.

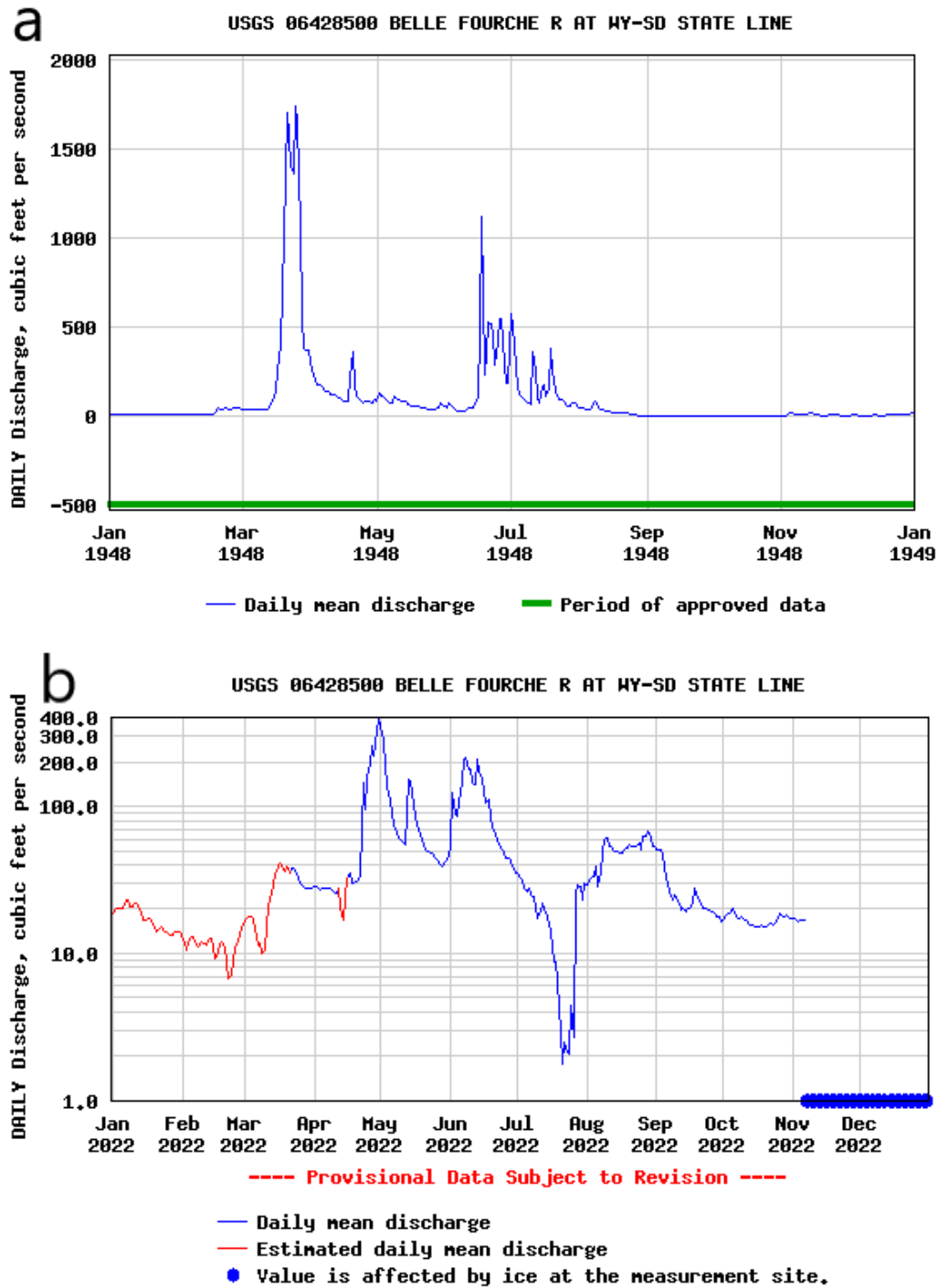


Figure 14. 2022 Hydrograph from USGS station 06427850, a station 50 miles downstream of Devils Tower. A. shows the hydrograph in 1948. The dam was finished in 1952. B. Shows the hydrograph for 2022, note the much lower peak and change in seasonality.

Further Analysis

This Data Report is intended to provide a basic review of the data collected during the 2022 stream channel monitoring in the Belle Fourche River at DETO. All data included in this report are available upon request from the Northern Great Plains Inventory and Monitoring Network. Data are also archived locally on the NGPN Server and will be re-named following Network standards. NGPN will store data on the NGPN Server in an NGPN Geodatabase. Certified data will also be uploaded to the Data Store annually, and to NPS Environmental Quality Information Systems (EQIIS) database /water quality portal. Reporting will consist of brief Natural Resource Data Series reports every year that the park is sampled which will summarize watershed characteristics, reach level geomorphic dimensions, and habitat features for selected wadeable stream reaches. After four sampling cycles (or twelve years), and every three sampling cycles thereafter, NGPN will publish trend reports for each park unit sampled.

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