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GENERAL INFORMATION

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1. Title of Dataset: 2025 Duluth Watersheds Geologic & Fluvial Geomorphic Information

2. Author Information

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3. Date published or finalized for release: May 2025

4. Date of data collection: 2023/011/01-2025/05/01

5. Geographic location of data collection: Duluth, Minnesota

6. Information about funding sources that supported the collection of the data: This project was funded by the National Science Foundation's Frontier Research in Earth Sciences (FRES) program.

7. Overview of the data (abstract): Uplift or base level fall in bedrock rivers can produce knickpoints (waterfalls) that propagate upstream to adjust the elevation of the longitudinal profile to reach a steady state. The migration rate of knickpoints is influenced by factors like local channel slope, drainage area (a proxy for discharge), and substrate erodibility. This dataset was used to investigate the geologic controls on bedrock landscape evolution following base level fall. Three map packages for three watersheds in the Duluth area (Amity Creek, Lester River, Mission Creek) are included in this dataset. A geologic map ("ExposureMap") for each watershed was created to determine what the substrate control was on fluvial erosion. Point files contain information relating to stream characteristics (channel elevation, upstream area, distance from mouth, channel slope, modeled Erosion Index ("Stream Power")), location of knickpoints (spikes in slope/stream power), and substrate erodibility in the channel (uniaxial compressive strength, fracture density, fracture intensity). Additional raster datasets include a Digital Elevation Model (DEM) of the watershed and a hillshade map.

SHARING/ACCESS INFORMATION

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2. Links to publications that cite or use the data: Not yet published

3. Data source(s):

Green, J.C.; Miller, James D., Jr.. (2008). M-182 Bedrock geology of the Duluth quadrangle, St. Louis County, Minnesota. Minnesota Geological Survey. Retrieved from the University of Minnesota Digital Conservancy, https://hdl.handle.net/11299/58225.

Minnesota Geological Survey, 2018. *Bedrock Geology of the Arrowhead Region* [online]. Available at: https://www.arcgis.com/home/item.html?id=4db2efe7cccd4c0b81f24087fbb579e2. [Accessed 1 Nov. 2023].

Minnesota Geological Survey, 2023. *Quaternary Geology - Western Lake Superior* [online]. Available at: https://services.arcgis.com/8df8p0NlLFEShl0r/arcgis/rest/services/D_01_Quaternary_Geology_WFL1/FeatureServer [Accessed 1 Nov. 2023].

Minnesota Department of Natural Resources. *DNR major and minor watersheds*. Minnesota Geospatial Commons. Available at: https://gisdata.mn.gov/dataset/geos-dnr-watersheds (Accessed: 1 Nov 2023).

Minnesota Geospatial Information Office, 2012. *LiDAR Elevation Data - Duluth 2012* [online]. Available at: https://gisdata.mn.gov/dataset/elev-lidar-duluth2012 [Accessed 1 Nov. 2023].

DATA & FILE OVERVIEW

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1. File List

A. Filename: AmityCreek.mpkx

Short description: This map package includes all field and geospatial data associated with the geologic and fluvial geomorphic properties of the Amity Creek watershed

B. Filename: LesterRiver.mpkx

Short description: This map package includes all field and geospatial data associated with the geologic and geomorphic properties of the Lester River watershed

C. Filename: MissionCreek.mpkx

Short description: This map package includes all field and geospatial data associated with the geologic and geomorphic properties of the Mission Creek watershed

2. Relationship between files: All map packages files have the same data within them, including:

-Watershed boundary

-Digital Elevation Model

-Hillshade map

-River line shapefile

-Geologic exposure map

-Channel characteristics (channel slope, stream power)

-Bedrock erodibility field surveys

Amity Creek and Lester River include the following file:

-Knickpoints

Lester River has the following file:

-TerraceSampleLocations

METHODOLOGICAL INFORMATION

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1. Description of methods used for collection/generation of data:

-Watershed boundary: Watershed boundaries were sourced from the Minnesota Department of Natural Resources Watershed Suite file: https://gisdata.mn.gov/dataset/geos-dnr-watersheds. The boundaries used are from the "Level 08_ all_catchments" shapefile.

-Digital Elevation Model: Sourced from: https://gisdata.mn.gov/dataset/elev-lidar-duluth2012. LiDAR was clipped to watershed boundaries.

-Geologic mapping: For bedrock geology: https://www.arcgis.com/home/item.html?id=4db2efe7cccd4c0b81f24087fbb579e2. For Quaternary geology: https://services.arcgis.com/8df8p0NlLFEShl0r/arcgis/rest/services/D_01_Quaternary_Geology_WFL1/FeatureServer

2. Methods for processing the data: <describe how the submitted data were generated from the raw or collected data>

-Hillshade map: Created using the clipped DEM of the watershed and running the tool "Hillshade" in ArcGIS Pro

-River line shapefile: Flow lines were created using the Fill, Flow Direction, and Flow Accumulation tools. A "greater than" value of 1.5 million was set to create perennial streams and not first order streams/colluvial valleys. Individual lines were selected moving from the mouth to the headwaters to show topography change through the entire watershed. These were merged to make a single line. The main stem feature was divided into equal 10-meter segments, then turned into points using "Feature to Point". These points that were created were used to sample the Flow Accumulation raster (A, for upstream area, each cell is 1x1m) and the DEM (for an elevation of a point along the long profile).

-Geologic exposure map: During field outings to the study watersheds, the substrate within the channel and at the surface was noted. Since bedrock and Quaternary geology maps are published separately, I created an ‘exposure map" to clearly address what the substrate control was on fluvial processes. These were created by using the “Clip” and “Erase” tools. Polygons represent the exposed substrate at the surface. Strath terraces (Qt) were identified geospatially using the hillshade map. Individual polygons were created to outline the flat “treads” of a terrace surface bounded by the steep sloping “risers”. These were also included in the exposure map.

-Terrace sampling: Four terraces were sampled for Optically Stimulated Luminescence Dating in Lester River in July 2024. This feature has GPS coordinates of where sampling occurred. Sampling was conducted by digging pits into the outcrop until reaching coarse channel deposits. Floodplain deposits were sampled by pounding an opaque aluminum tube horizontally into the outcrop to limit exposure to sunlight. The elevation of the surface, depth of the sampled sediment, and elevation above the active channel were noted to constrain a maximum depositional age to be used for interpreting the timing of incision for the individual terrace.

-Channel characteristics (channel slope, stream power, Slope_SP): Local slope (S) was calculated by taking the elevation change between 2 points upstream and 2 points downstream and dividing it by 50 meters. A stream power-based Erosion Index (“Stream Power”, proxy for incision rate) was calculated at each point by multiplying the upstream area of a point raised to the .5 by slope ($E=A^{0.5}S$).

-Knickpoints: Using the Slope_SP files, "spikes" in slope and stream power-based Erosion Index were used to map knickpoints since knickpoints have high stream power (shear stresses imposed vertically on the bed). Points were placed on near the highest slope value in a reach. This file is only found in Amity Creek and Lester River map packages.

-Bedrock erodibility field surveys: Each survey point in the shapefile is associated with a uniaxial compressive strength measurement, which was conducted using an “N” type Schmidt Hammer. Twenty-five Schmidt Hammer measurements were taken at each survey location on a flat surface, with each "hit" recording a rebound value. Outliers within each set of twenty-five measurements were filtered so an average rebound value could be used to calculate the average compressive strength of the surface. Many surveys, though not all, have data on fracture intensity (the mean total fracture length per unit area (m/m^2)) and the density of fractures (the mean number of fractures per unit area ($1/m^2$)) which was calculated by taking two dimensional photos of flat bedrock surfaces and annotating the fractures in Adobe Illustrator. Node files were uploaded to the MATLAB tool FracPaQ to extract desired metrics. Also included in the attributes tables of these surveys was the estimated bankfull width, which was recorded in the field using a laser rangefinder.

3. Instrument- or software-specific information needed to interpret the data: ArcGIS Pro Version 3.2

4. People involved with sample collection, processing, analysis and/or submission:

-Dr. Karen Gran, University of Minnesota Duluth

-Dr. Michael Braunagel, University of Minnesota Duluth

-Dr. Andrew Wickert, University of Minnesota Twin Cities

-Dr. Phillip Larson, Minnesota State University

-Leone Jacobson, Ungergraduate Research Assistant

-Elly Rectenwald, Undergraduate Research Assistant

DATA-SPECIFIC INFORMATION

-Geologic Exposure Maps:

1. Number of variables: 8

2. Variable List

-OBJID: Object ID for individual polygons

-Shape: Shape type (all polygons)

-Lithology: Lithology of substrate

-Alluvium

-Till

- -Poorly sorted river gravels and sands
- -Basalt
- -Diabase
- -Icelandite
- -Sandstone

-Map Unit: Map code for Minnesota State Geological Survey maps M-182 and M-183

- -Qal
- -Qb
- -Qc
- -Qt
- -Mnu
- -Mns
- -Mis
- -Mni
- -Mkf

-Formation: Name of formation:

- -Alluvium
- -Cromwell Formation
- -Barnum Formation
- -Terrace
- -Basalt flow
- -Northland Sheet
- -Miscellaneous Intrusion
- -Lester Park Icelandite
- -Fond du Lac Formation

-Flow Number: only for basalt flows (1-5)

-Shape length

-Shape area

-Stream characteristics (Slope_SP)

1. Number of variables: 11

2. Variable List

-OBJID: Object ID for individual points

-Shape: Shape type (all points)

-tenMChnlpt: number out of total count of 10 meter segments

-Distance Downstream: distance from top of line (headwaters) to bottom (mouth) in meters

-Distance from mouth: in meters

-X: in UTM

-Y: in UTM

-Stream elevation: elevation of point in stream (meters)

-Upstream area: sampled from a flow accumulation layer not included (in m^2)

-Slope: calculated by taking the elevation change between 2 points upstream and 2 points downstream and dividing it by 50 meters

-Stream power: Stream power-based Erosion Index, calculated using equation: $E=A^{0.5}S$

-Bedrock Surveys

1. Number of variables: 26

2. Variable List

-OBJID: Object ID for individual points

-Shape: Shape type (all points)

-Date: date of survey

-Pts# on GPS: descriptive location identifier (date+point#)

-Lat (Y) of survey

-Lat (X) of survey

-Elevation of GPS (m)

-Location: Area within watershed

-River: Amity, Lester, or Mission

-Bedrock lithology: rock descriptions from field and M-182/M-183

-Flow #: if basalt, the flow number (out of 5 stacked flows) was noted

-MapUnit: corresponds with nomenclature on exposure map

-LithologyCode: Lithology+MapUnit

-Rangefinder bankfull width:L estimated in the field with laser rangefinder (m)

-AvgRebound: Average of the 25 measurements taken with the Schmidt Hammer

-ReboundSTD: Standard deviation of the 5 measurements taken with the Schmidt Hammer

-Compressive Strength: calclauted using the average rebound value and the equation that is secific to the tool (in N/m^2)

-Distance from mouth: distance of survey point from mouth (m)

-Stream elevation: elevation of stream nearest to the survey location

-SlopePoint: slope of the river channel nearest to the survey location

-StreamPowerPoint: modeled Erosion Index in stream nearest to the survey location

-Fracture intensity: the mean total fracture length per unit area (m/m^2)

-Fracture density: the mean number of fractures per unit area ($1/m^2$)

-Scaling factor: value used to convert pictures in FracPaq from pixels to m^2

-Knickpoints

1. Number of variables: 2

2. Variable List

-Code: unique code for each point. See study publication for more information.

-Terrace Sample Locations:

1. Number of variables: 15

2. Variable list:

- Sample #

-SampleID: Date sampled + Sample #

-Lat (Y)

-Long (X)

-Elevation: elevation of ground surface on GPS (meters)

-Estimated terrace thickness: in meters

-Depth sampled: from the surface (in meters)

-Layer sampled: all from "Layer 2", which is overbank/floodplain sediment

-Top depth: depth of top of overbank (meters)

-Bottom depth: depth of bottom of overbank (meters)

-Thickness: distance between top and bottom of overbank in meters

-Color: color of sediment in overbank

-Structure: description of structure of sediment/soil in overbank

-Texture: texture of overbank sediment

-Sedimentology: sedimentary descriptions of overbank