CHyF Pilot Data Specification, v1.1

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This document is a refinement and extension of CHyF Pilot Data Specification, v1.0, dated 2018 March 6. It was prepared by Mark Sondheim, Marie-Eve Martin and Denis Boutin, (CCMEO, NRCan) with input from Chris Hodgson (Refractions).

This specification pertains to data used to generate graph theoretic constructs and other structures needed to support Version 1.1 of the CHyF hydrologic web application and services. The terms used herein generally follow CHyF terminology, but in several cases details have been added or altered. The specification is not appropriate for general distribution of CHyF compliant data; that will be the topic of a subsequent document.

Sections of this document are relevant to users of CHyF Data Processing Tools, specifically:

1. ChyfSEAProcessor, used to compute slope/elevation/aspect statistics, and
2. ChyfDistance2Water2DProcessor used to compute 2D distance to water statistics.

Those wishing to use these applications should read sections 5.2 and 5.3, and addendums 2 and 3.

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1 Projection

Data can be provided in any valid projection, but the projection information must be provided with the data. Areas and lengths must be precomputed and provided with the input data. The web application displays data in EPSG:3857, Web Mercator.

All data is reprojected to lat/long (EPSG: 4326) and reduced to a precision of 10^{14} for processing purposes.

2 Format

For Version 1.1, both shapefile and GeoPackage formats are supported. In the case of shapefiles a directory creating all the shapefiles must be created; for GeoPackage a single file is used.

3 Input Datasets

This section described the input datasets and their attributes required for the CHyF application.

3.1 Elementary Flowpath

Flowpaths must form a directed, acyclic network. In cases of double-line water features, skeletons connecting input flows to output flows should be included.

File/Layer Names

Format	File/Layer Name
Shapefile	Flowpath.shp
GeoPackage	Flowpath

Attributes

Attribute Name	Full Name	Required	Data Type
type	Type	Yes	String
rank	Rank	Yes	String
length	Length	Yes	Double
name	Name	No	String

nameid	Name ID	No	String

Type

Describes the type of flowpath. Valid values are:

- `Observed`
  If the elementary flowpath corresponds to a single line river segment mapped in the NHN as Observed.
- `Constructed`
  If the elementary flowpath corresponds to a single line river segment mapped in the NHN as Constructed.
- `Bank`
  If it corresponds to a section of a skeleton that connects to a bank catchment. Neither end of a bank type flowpath should connect to a pre-existing connection point. This has no equivalent in the NHN.
- `Inferred`
  If it corresponds to a section of a skeleton in a lake or double-line river that connects at both ends to other skeleton segments or to an observed flow. These are referred to as Inferred in the NHN.

Rank

Describes the importance of the flowpath. Valid values are:

- `Primary`
  If the flowpath is considered to contain the principal water flow. It is equivalent to LevelPriority=1 in the NHN.
- `Secondary`
  If the flowpath is considered a braid, a distributary or other flowpath encountered in a downstream direction that is of less importance than the primary flowpath. It is equivalent to LevelPriority=2 in the NHN.

Length

The planimetric length in metres (m) of the elementary flowpath.

Name

This is the primary name, which in the case of the pilot area will be in French.

Name ID

This is a UUID corresponding to the Primary Name described above. It is included in the pilot input data.

3.2 Elementary Catchment

The term elementary catchment refers to an areal feature with polygonal geometry that defines a fundamental drainage area.

File/Layer Names

Format	File/Layer Name
Shapefile	Catchment.shp
GeoPackage	ElementaryCatchment

Attributes

Attribute Name	Full Name	Required	Data Type
area	Area	Yes	Doube
d2wd2_mean	Mean Distance to Water 2D	No*	Double
d2w2d_max	Maximum Distance to Water 2D	No*	Double
elv_min	Minimum Elevation	No*	Double
elv_max	Maximum Elevation	No*	Double
elv_mean	Mean Elevation	No*	Double
slope_min	Minimum Slope	No*	Double
slope_max	Maximum Slope	No*	Double
slope_mean	Mean Slope	No*	Double
north_pct	Aspect Percent North	No*	Double
south_pct	Aspect Percent South	No*	Double
east_pct	Aspect Percent East	No*	Double
west_pct	Aspect Percent West	No*	Double
flat_pct	Aspect Percent Flat (slope < 3°)	No*	Double

*Additional software is provided to compute these values. See appendices.

Area

The planimetric area in meters of the elementary catchments provided in square metres (m^2).

Mean Distance To Water 2D

The average distance from a point within the catchment polygon to the nearest flowpath edge or waterbody bank edge in metres. Computation details can be found in the appendix.

Maximum Distance To Water 2D

The maximum distance from a point within the catchment polygon to the nearest flowpath edge or waterbody bank edge in metres. Computation details can be found in the appendix.

Minimum Elevation

The minimum elevation for the catchment in metres (m).

Maximum Elevation

The maximum elevation for the catchment in metres (m).

Mean Elevation

The average elevation for the catchment in metres (m).

Minimum Slope

The minimum slope for the catchment in degrees (º).

Maximum Slope

The maximum slope for the catchment in degrees (º).

Mean Slope

The average slope for the catchment in degrees (º).

Aspect Percent North

Percent facing North (>=315° & <45°) points with a slope >= 3°

Aspect Percent South

Percent facing South (>=135° & <225°) points with a slope >= 3°

Aspect Percent East

Percent facing East (>=45° & <135°) points with a slope >= 3°

Aspect Percent West

Percent facing West (>=225° & <315°) points with a slope >= 3°

Aspect Percent Flat

Percent with a slope < 3°

3.3 Waterbody

The waterbody file includes all waterbodies large enough to define with polygon geometry. The waterbody polygons are used to identify and classify water catchments. The waterbody polygon geometry should be identical to the polygon geometry of the corresponding water catchment.

File/Layer Names

Format	File/Layer Name
Shapefile	Waterbody.shp
GeoPackage	Waterbody

Attributes

Attribute Name	Full Name	Required	Data Type
area	Area	Yes	Double
definition	Definition	Yes	Integer

Area

For the pilot the planimetric area of the elementary catchments in provided in square metres (m^2). In the longer term all area measurement will be in hectares.

Definition

Classifies the waterbody into a subtype. Valid values are:

- 4
  Lake - The water catchment is part of a lake.
- 9
  Pond - The water catchment is part of a pond.
- 6
  River - The water catchment is part of a river.
- 1
  Canal - The water catchment is part of a canal

These values have been used in a pilot. They are consistent with Canada's National Hydro Network, but are not consistent with HY_Features or CHyF.

3.4 Working Limit

A layer containing a polygon representing the data limits. This layer is used to differentiate between true sinks (isolated flows) and sinks that occur because the boundary of the data is

reached (these sinks would connect to additional flows if more data was provided). For the pilot-data this layer was generated from the catchments polygons.

File/Layer Names

Format	File/Layer Name
Shapefile	Working_limit.shp
GeoPackage	Working_limit

Attributes

None

4 Input Dataset Topology Rules

4.1 Node and Vertex Topology

Where a flowpath meets another flowpath, the point of intersection is always either a start point or an end point for each flowpath. A flowpath never crosses another flowpath.

Where a flowpath meets an elementary catchment of any type, it must meet at a vertex on the polygon representing the boundary of the catchment. That vertex may be any of the vertices that compose the polygon. A flowpath never crosses a catchment boundary.

4.2 Detailed Rules

The input data is to conform to a series of rules as described below.

The following types of elementary flowpaths (F) exist:

1. Observed Flowpath (OF)
2. Constructed Flowpath (CF)
3. Inferred Flowpath (IF)
4. Bank Flowpath (BF)

The following types of elementary catchments (C) exist:

1. Reach Catchment (RC)
2. Water Catchment (WC)
3. Bank Catchment (BC)
4. Empty Catchment (EC)

The rules are based on their topological relationships and can be expressed using the Dimensionally Extended nine-Intersection Model (DE-9IM) model. The term *contained by* is introduced; if x *contains* y then y is *contained by* x.

1. Every F is contained by exactly one C, based on the type:
    a. Every OF is *contained by* an RC.
    b. Every CF is *contained by* an RC.
    c. Every IF is *contained by* one and only one WC.
    d. Every BF is *contained by* one and only one WC.
2. A C may contain 0, 1, or many Fs depending on the type:
    a. Every RC *contains* one or more F, which may be of type OF or CF. In the case where it contains more than 1 F, all F must form a single path (all internal nodes must be valence 2 node, with one inflow and one outflow).
    b. Every WC *contains* one or more IF.
    c. Every BC does not *contain* any F.
    d. Every EC does not *contain* any F.
3. The interaction between the geometries of Fs and Cs is limited in the following ways:
    a. For every RC, its boundary *intersects* the boundary of the contained F at either one or two points.
    b. The interior of every F is *disjoint* from all other F and from the boundary of all C.
    c. Every BC *touches* one and only one BF.
    d. Every BC *touches* one or more WC and the intersection of each such BC - WC pair is a line segment.
4. All F together form a directed, acyclic graph.
5. All C together form a continuous coverage with no gaps and no overlaps. (This is not expressed here using DE-9IM terminology, but it is closely related to these concepts.)

At any hydro end node with valence > 2, only one of the outflowing flowpaths can be primary. All other outflowing flowpath must be designated as secondary.

5 Output Features

This section described the output attributes for the various features types generated by the CHyF application.

5.1 Elementary Flowpath

Attributes

Attribute Name	Full Name	Data Type
ID	ID	Integer
name	Name	String
type	Type	String

rank	Rank	String
strahleror	Strahler Order	Integer
hortonor	Horton Order	Integer
hackor	Hack Order	Integer
length	Length	Double

ID
A system generated transient identifier, It is NOT immutable and should NOT be used to permanently reference data. It is provided to assist with software debugging and data assessment through its use as a temporary means of identifying features.

Name
This is the primary name, may be empty if not named.

Type
Describes the type of flowpath. Valid values are:

- `Observed`
  If the elementary flowpath corresponds to an observed single line river segment.
- `Constructed`
  If the elementary flowpath corresponds to a constructed single line river segment.
- `Bank`
  If it corresponds to a section of a skeleton that connects to a bank catchment.
- `Inferred`
  If it corresponds to a section of a skeleton in a lake or double-line river.

Rank
Describes the importance of the flowpath. Valid values are:

- `Primary`
  If the flowpath is considered to contain the principal water flow.
- `Secondary`
  If the flowpath is considered a braid, a distributary or other flowpath encountered in a downstream direction that is of less importance than the primary flowpath.

Strahler Order
Also referred to as stream order in the US. See Addendum 1 for a description of how it is calculated.

Horton Order
See Addendum 1 for a description of how it is calculated.

Hack Order

Also referred to as stream level in the US. See Addendum 1 for a description of how it is calculated.

Length (m)

The planimetric length in metres of the elementary flowpath.

5.2 Elementary Catchment

Attributes

Attribute Name	Full Name	Data Type
ID	ID	Integer
name	Name	String
type	Type	String
subtype	Sub Type	String*
rank	Rank	String
strahleror	Strahler Order	Integer
hortonor	Horton Order	Integer
hackor	Hack Order	Integer
area	Area	Double
d2wd2_mean	Mean Distance to Water 2D	Double
d2w2d_max	Maximum Distance to Water 2D	Double
elv_min	Minimum Elevation	Double
elv_max	Maximum Elevation	Double
elv_mean	Mean Elevation	Double
slope_min	Minimum Slope	Double
slope_max	Maximum Slope	Double
slope_mean	Mean Slope	Double
north_pct	Aspect Percent North	Double
south_pct	Aspect Percent South	Double
east_pct	Aspect Percent East	Double
west_pct	Aspect Percent Wes	Double
flat_pct	Aspect Percent Flat (slope < 3°)	Double

ID

A system generated transient identifier, NOT immutable and should not be used to reference data. It is provided as a debugging/sharing tool for the pilot project only.

Name

This is the primary name, which for the pilot is taken from the name of the contained flowpath.

Type

A description of the catchment. Valid values include:

- `Reach`
  If the catchment contains an observed or constructed flowpath.
- `Bank`
  If the catchment does not contain an elementary flowpath and is a neighbour of a water catchment.
- `Water`
  If the catchment is a lake, a portion of a lake, a double-line river or a portion of a double-line river.
- `Empty`
  A catchment containing no waterbodies and with no flow connections to other catchments. An empty catchment corresponds to a depression in a DEM, where water has not been mapped.

Sub Type

This is only provided for catchment polygons where “Type” is “Water”. Otherwise it is null.

- `Lake`
  The water catchment is part of a lake.
- `Pond`
  The water catchment is part of a pond.
- `River`
  The water catchment is part of a river.
- `Canal`
  The water catchment is part of a canal.

Rank

The value of this attribute is transferred from the corresponding flowpath. For water catchments, the rank is `Primary` if at least one contained flowpath has a rank of `Primary`. If no primary flowpath exists in the lake, but one or more secondary flowpaths do, then the water catchment has a rank of `Secondary`. Valid values are:

- `Primary`
  If the contained flowpath is considered to contain the principal water flow.

- `Secondary`
  If the contained flowpath is considered a braid, a distributary or other flowpath encountered in a downstream direction that is of less importance than the primary flowpath.

Strahler Order
The Strahler Order of the corresponding elementary flowpath. In the case of a lake catchment or river catchment, the value is that of the contained elementary flowpath with the largest Strahler Order value. If the catchment contains no flowpaths, then the value will be null.

Horton Order
The Horton Order of the corresponding elementary flowpath. In the case of a lake catchment or river catchment, the value is that of the contained elementary flowpath with the largest Horton Order value. If the catchment contains no flowpaths, then the value will be null.

Hack Order
The Hack Order of the corresponding elementary flowpath. In the case of a lake catchment or river catchment, the value is that of the contained elementary flowpath with the smallest Hack Order value. If the catchment contains no flowpaths, then the value will be null.

Area
The planimetric area of the elementary catchments provided in hectares (ha).

Mean Distance To Water 2D
The average distance from a point within the catchment polygon to the nearest flowpath edge or waterbody bank edge in metres (m). Computation details can be found in the appendix. Only available if it was provided in the input dataset.

Maximum Distance To Water 2D
The maximum distance from a point within the catchment polygon to the nearest flowpath edge or waterbody bank edge in metres (m). Computation details can be found in the appendix. Only available if it was provided in the input dataset.

Minimum Elevation
The minimum elevation for the catchment in metres (m). Only available if it was provided in the input dataset.

Maximum Elevation
The maximum elevation for the catchment in metres (m). Only available if it was provided in the input dataset.

Mean Elevation
The average elevation for the catchment in metres (m). Only available if it was provided in the input dataset.

Minimum Slope

The minimum slope for the catchment in degrees (º). Only available if it was provided in the input dataset.

Maximum Slope
The maximum slope for the catchment in degrees (º). Only available if it was provided in the input dataset.

Mean Slope
The average slope for the catchment in degrees (º). Only available if it was provided in the input dataset.

Aspect Percent North
Percent facing North (315° to 45°) points with a slope >= 3°. Only available if it was provided in the input dataset.

Aspect Percent South
Percent facing South (135° to 225°) points with a slope > =3°. Only available if it was provided in the input dataset.

Aspect Percent East
Percent facing East (45° to 135°) points with a slope >= 3°. Only available if it was provided in the input dataset.

Aspect Percent West
Percent facing West (225° to 315°) points with a slope >= 3°. Only available if it was provided in the input dataset.

Aspect Percent Flat
Percent with a slope < 3°. Only available if it was provided in the input dataset.

5.3 Drainage Areas

Drainage Areas are generated by combining elementary catchments to form a single larger drainage area. Pourpoint output catchments are drainage areas as are the results of the Catchment - Upstream of Point function.

Attributes

Attribute Name	Full Name	Data Type
area	Area	Double
d2wd2_mean	Mean Distance to Water 2D	Double
d2w2d_max	Maximum Distance to Water 2D	Double
elv_min	Minimum Elevation	Double

elv_max	Maximum Elevation	Double
elv_mean	Mean Elevation	Double
slope_min	Minimum Slope	Double
slope_max	Maximum Slope	Double
slope_mean	Mean Slope	Double
north_pct	Aspect Percent North	Double
south_pct	Aspect Percent South	Double
east_pct	Aspect Percent East	Double
west_pct	Aspect Percent West	Double
flat_pct	Aspect Percent Flat	Double

Area

The total planimetric area of all the elementary catchments that make up the drainage area provided in hectares (ha).

Mean Distance To Water 2D

The area weighted average of the mean distance to water value for all of the elementary catchments that make up the drainage area. Provided in metres (m). Only available if it was provided in the input dataset.

Maximum Distance To Water 2D

The maximum distance to water value for all of the elementary catchments that make up the drainage area. Provided in metres(m). Only available if it was provided in the input dataset.

Minimum Elevation

The minimum elevation in metres (m) of all the elementary catchments that make up the drainage area. Only available if it was provided in the input dataset.

Maximum Elevation

The maximum elevation in metres (m) of all the elementary catchments that make up the drainage area. Only available if it was provided in the input dataset.

Mean Elevation

The area weighted average of the mean elevation values for all the elementary catchments that make up the drainage area. Provided in metres (m). Only available if it was provided in the input dataset.

Minimum Slope

The minimum slope in degrees (°) of all the elementary catchments that make up the drainage area. Only available if it was provided in the input dataset.

Maximum Slope
The maximum slope in degrees (°) of all the elementary catchments that make up the drainage area. Only available if it was provided in the input dataset.

Mean Slope
The area weighted average of the slope values for all elementary catchments that make up the drainage area. Provided in degrees (°). Only available if it was provided in the input dataset.

Aspect Percent North
The area weighted average of all the aspect percent north values for all the elementary catchments that make up the drainage area. Only available if it was provided in the input dataset.

Aspect Percent South
The area weighted average of all the aspect percent south values for all the elementary catchments that make up the drainage area. Only available if it was provided in the input dataset.

Aspect Percent East
The area weighted average of all the aspect percent eastvalues for all the elementary catchments that make up the drainage area. Only available if it was provided in the input dataset.

Aspect Percent West
The area weighted average of all the aspect percent westvalues for all the elementary catchments that make up the drainage area. Only available if it was provided in the input dataset.

Aspect Percent Flat
The area weighted average of all the aspect percent flat values for all the elementary catchments that make up the drainage area. Only available if it was provided in the input dataset.

5.4 Hydro Node

Hydro nodes are generated by the CHyF system when loading data. In the CHyF pilot a hydro node is represented as point geometry where flowpaths meet other flowpaths, waterbody or catchment boundaries. (*In the software the term nexus is used, however that term has since been superseded with hydro node).*

Attributes

Attribute Name	Full Name	Data Type

ID	ID	Integer
type	Type	String

ID

A system generated transient identifier, NOT immutable and should not be used to reference data. It is provided as a debugging/sharing tool for the pilot project only.

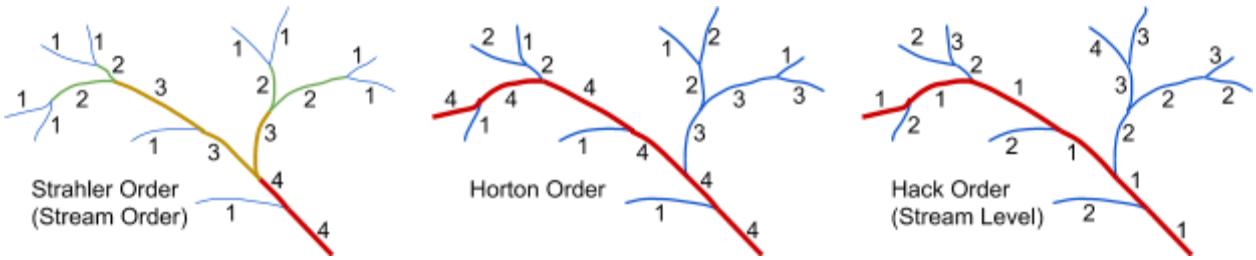
Type

A description of the hydro node. Valid values are:

- `Headwater`
  Headwater flowpath start point. The start of an elementary flowpath, for which the start point does not intersect other flowpaths, lake boundaries, or double-line river boundaries.
- `Terminal Isolated`
  Terminal flowpath endpoint. The endpoint of an elementary flowpath that is not connected to any other flowpath at the endpoint. These are true sinks or the endpoint of a flowpath across a terminal lake.
- `Terminal Boundary`
  Terminal flowpath endpoint. The endpoint of an elementary flowpath that is not connected to any other flowpath at the endpoint. These represent the limit of what was visible when the hydrography was compiled and would generally flow into other water if additional data was included.
- `Flowpath`
  Flowpath hydro node. The junction of a single-line river with another single-line river or with the boundary of a double-line river or lake. These are defined by the endpoints of observed flowpaths.
- `Water`
  Water hydro node. The junction of a double-line river or lake with another double-line river or lake, as represented by the intersection of the incoming and outgoing flowpaths at that location.
- `Bank`
  Bank hydro node. A type of hydro node that is arbitrarily placed on the boundary of adjacent catchments to show flow or potential flow from one to the other, where no observed flowpaths exist to convey that information, and where the upper catchment is land based and the lower is water based (lake or double-line river).
- `Inferred`
  Inferred junction. These are required for the purpose of connectivity only. They are not hydro nodes.

Addendum 1: Calculation of Stream Ordering Schemes

Three ordering schemes are defined here, Strahler Order, Horton Order, and Hack Order. They are depicted in the diagrams below.



These examples are very idealized. Details are provided below. However, in all three cases, the following two rules apply:

1. Only flowpaths with rank = 'Primary' are considered. All secondary flows are given the value *null* for all three orders.
2. Bank flowpaths are ignored and are also given the value *null* for all three orders.

Strahler Order

Strahler Order is determined by the geometry of the flowpaths with rank defined as primary.

1. Headwater stream segments (flowpaths with one endpoint coincident with a headwater hydro node) are assigned a value of 1.
2. Moving in a downstream direction, when two or more inflowing flowpaths meet at a hydro nodes and are of different orders, then the outflowing flowpath has a value equal to that of the inflowing flowpath with the largest order.
3. When two or more inflowing flowpaths meet with at least two of them of the same order and with that order higher than that of any other inflowing flowpaths, then the outflowing flowpath has a value equal to that order + 1.

Horton Order

Horton Order requires mainstems to be defined. CHyF defines mainstems using both names and flowpath lengths.

1. For each flowpath that ends at a terminal hydro node(including those at the boundary of the area in question), the horton order is assigned the same value as the strahler order.
2. Starting at this edge, an upstream mainstem path is calculated following these rules: Moving upstream:
    a. if there are any inflowing flowpaths at a hydro node with the same name as this outflowing flowpath, then the one with the longest flowpath to a headwater hydro node is selected as the mainstem

    b. otherwise, if there are any inflowing flowpaths with any name at all, the one with the longest flowpath to a headwater hydro node is selected as the mainstem
    c. otherwise, if there are any inflowing flowpaths at all, the one with the longest flowpath to a headwater hydro node is selected.
    d. otherwise, this is the top of this mainstem.

    Every edge along this created mainstem is given a horton order that matches the strahler order of the most downstream edge.
3. This process is repeated starting at each flowpath edge connecting to the newly defined mainstem (these edges are assigned a horton order equal to the strahler order of that flowpath, then a mainstem is defined starting at each of the edges). The process in steps two and three are followed iteratively until all flowpaths are assigned.

Hack Order

The logic behind the hack order is the same as that behind the horton order with two specific exceptions. In Step 1 above, the flowpaths that end at a terminal hydro node are assigned a hack order of 1. In Steps 2/3, the hack order of edges flowing into the mainstem are assigned a value of the hack order of the mainstem plus 1 (not the strahler order).

Another minor change that is useful analytically is as follows. For all flowpaths whose corresponding mainstem ends at a hydro node identified as terminal isolated, 1000 is added to the hack order. So for example the inferred flowpaths in isolated lakes have a hack order of 1001, however the flowpath at the mouth of the Richelieu keeps its calculated value of 1.

Addendum 2: Calculation of Slope, Elevation, and Aspect Data

The CHyF pilot project provides a datatools package to compute slope, aspect, and elevation statistics for catchments. This processing is not done automatically, and must be done by a user before providing the catchments to the web application.

Input Data Requirements

DEM

DEM provided in TIF format in a valid equal area projection for the area of interest. The projection should also preserve aspect for the resulting aspect values to be accurate. All elevation data should be provided in meters.

For performance reasons this TIF image should be tiled with 1024x1024 tiles. This can be achieved using gdal_translate with the options `-co "TILED=YES" -co "BLOCKXSIZE=1024" -co "BLOCKYSIZE=1024"`. The TIF file provided should include tiling as described; however, the application will still run without it.

Elementary Catchments

The elementary catchments provided as a shapefile (Catchment.shp) or geopackage (ElementaryCatchment layer) in any projection. Catchments are reprojected to the same projection as the DEM for processing. Each polygon in this file will have slope, aspect and elevation statistics computed for it.

Output Data

A copy of the elementary catchments input will be created with the following attributes added to each catchment.

Attribute Name	Name	Type	Description
elv_min	Minimum Elevation	Double	The minimum elevation for the catchment in metres.
elv_max	Maximum Elevation	Double	The maximum elevation for the catchment in metres.
elv_mean	Mean Elevation	Double	The average elevation for the catchment in metres.
slope_min	Minimum Slope	Double	The minimum slope for the catchment in degrees.
slope_max	Maximum Slope	Double	The maximum slope for the catchment in degrees.
slope_mean	Mean Slope	Double	The average slope for the catchment in degrees.
north_pct	Aspect Percent North	Double	Percent facing North (>=315° & <45°) with a slope >= 3°
south_pct	Aspect Percent South	Double	Percent facing South (>=135° & <225°) with a slope >= 3°

east_pct	Aspect Percent East	Double	Percent facing East (>=45° & <135°) with a slope >= 3°
west_pct	Aspect Percent West	Double	Percent facing West (>=225° & <315°) with a slope >= 3°
flat_pct	Aspect Percent Flat	Double	Percent of points with a slope < 3°

Software Usage

Requirements

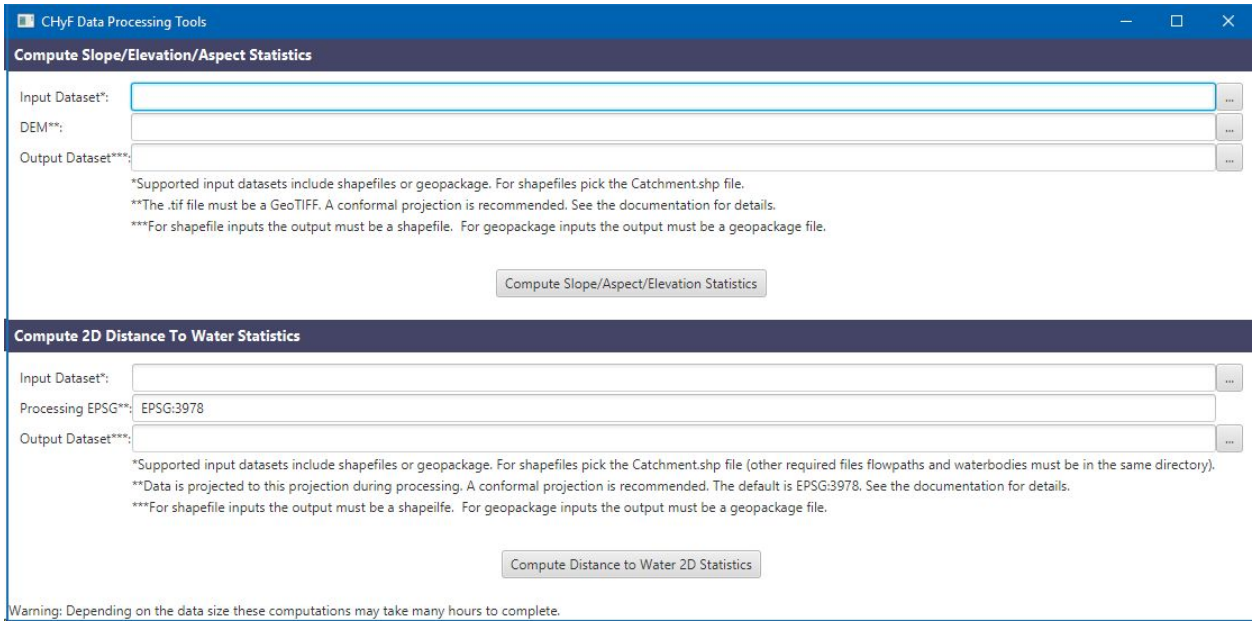
Java version 8 or 9 must be installed and placed on the classpath. This can be verified by running "`java -version`" from a command line.

Note: depending on your java version this may appear as `1.<VERSION> (1.8)` or just `<VERSION> (8.x)`.

This tools makes use of JavaFx. For Java Version 8 & 9 JavaFx is included in the Oracle Java release. Other Java distributions may not contain JavaFx.

User Interface

To run the software, unpackage the zip file and run the included .bat (windows) or .sh (linux) file. This will launch the CHyF Data Processing Tool user interface, as shown below.



The first section of this user interface is used for computing slope, aspect, and elevation statistics. Users must select the Input Dataset, DEM, and Output Dataset, then click the 'Compute Slope/Aspect/Elevation Statistics' button. For large datasets processing may take many hours. A progress bar will appear, and a dialog will be displayed when processing is completed.

Both Shapefile and Geopackage input/output formats are supported. The output format must match the input format (input shapefiles require output shapefile).

Command Line

The application can also be run from the command line.

```
Java -cp ./lib/* net.refractions.chyf.datatools.ChyfSEAProcessor [input] [dem] [output]
[input] - the input dataset (must be either Catchment.shp OR a geopackage file)
[dem] - the tiled DEM in geotiff format.  Must be in a projection that maintains area and aspect
[output] - the output location (either a shapefile or a geopackage file)
```

Example

```
> java -cp ./lib/* net.refractions.chyf.datatools.ChyfSEAProcessor
./testdata/slopeaspectelevation/Catchment.shp ./testdata/slopeaspectelevation/test_elevations.tif
./testdata/slopeaspectelevation/Catchment.out.shp
```

Computing Slope Aspect Elevation

Slope

Slope is computed using the Horn algorithm for slope outlined in this document:
http://people.csail.mit.edu/bkph/papers/Hill-Shading.pdf

ESRI provides a description of the algorithm here:
http://desktop.arcgis.com/en/arcmap/10.3/tools/spatial-analyst-toolbox/how-slope-works.htm

No slope is computed for DEM cells where any one of the 8 surrounding cells is a NODATA cell.

Aspect

A description of how to compute aspect can be found here:

http://desktop.arcgis.com/en/arcmap/10.3/tools/spatial-analyst-toolbox/how-aspect-works.htm

Elementary Catchment Assignment

Slope, aspect and elevation are assigned to a catchment based on the center point of the DEM cell. The catchment which overlaps the center points gets the slope/aspect/elevation values computed for that DEM cell.

For each catchment all slope/aspect/elevation values are summarized as follows:

- Minimum Elevation - minimum elevation value

- Maximum Elevation - maximum elevation value
- Mean Elevation - average of all elevation values
- Minimum Slope - minimum slope value
- Maximum Slope - maximum slope value
- Mean Slope - average of all slope values
- North Percent - percentage of points with a North aspect (315° to 45°) and slope >= 3°
- South Percent - percentage of points with a South aspect (135° to 225°) and slope >= 3°
- East Percent - percentage of points with an East aspect (45° to 135°) and slope >= 3°
- West Percent - percentage of points with a West aspect (225° to 315°) and slope >= 3°
- Flat Percent - percentage of points with a slope < 3°

Elementary catchments that do not intersect any DEM center points, are assigned the same values as their neighbour catchment with the longest shared edge. These elementary catchments are generally very small.

Addendum 3: Calculation of 2D Distance to Water

The CHyF pilot project provides a datatools package to compute 2D distance to water statistics for every catchment in a collection of catchments. This processing must be done by a user or central agency before providing the catchments to the web application.

Input Data Requirements

Both shapefile and geopackage formats are supported. In the case of shapefiles all files must be in the same directory.

Elementary Catchments

The elementary catchments provided as a shapefile (Catchment.shp) or geopackage (ElementaryCatchment layer) in any projection. As part of the processing, the user must specify what projection to process the data in.

Waterbodies

The polygonal waterbodies provided as a shapefile (Waterbody.shp) or in the geopackage (Waterbody layer) in any projection. No attributes are required.

Elementary Flowpaths

The elementary flowpaths provided as a shapefile (Flowpath.shp) or in the geopackage (Flowpath layer) in any projection. No attributes are required.

Output Data

A copy of the elementary catchments input will be created with the following attributes added to each catchment.

Attribute Name	Name	Type	Description
d2w2d_mean	Mean Distance To Water 2D	Double	The average distance from a point within the catchment polygon to the nearest flowpath edge or waterbody bank edge in metres.
d2w2d_max	Maximum Distance To Water 2D	Double	The maximum distance from a point within the catchment polygon to the nearest flowpath edge or waterbody bank edge in meters.

Software Usage

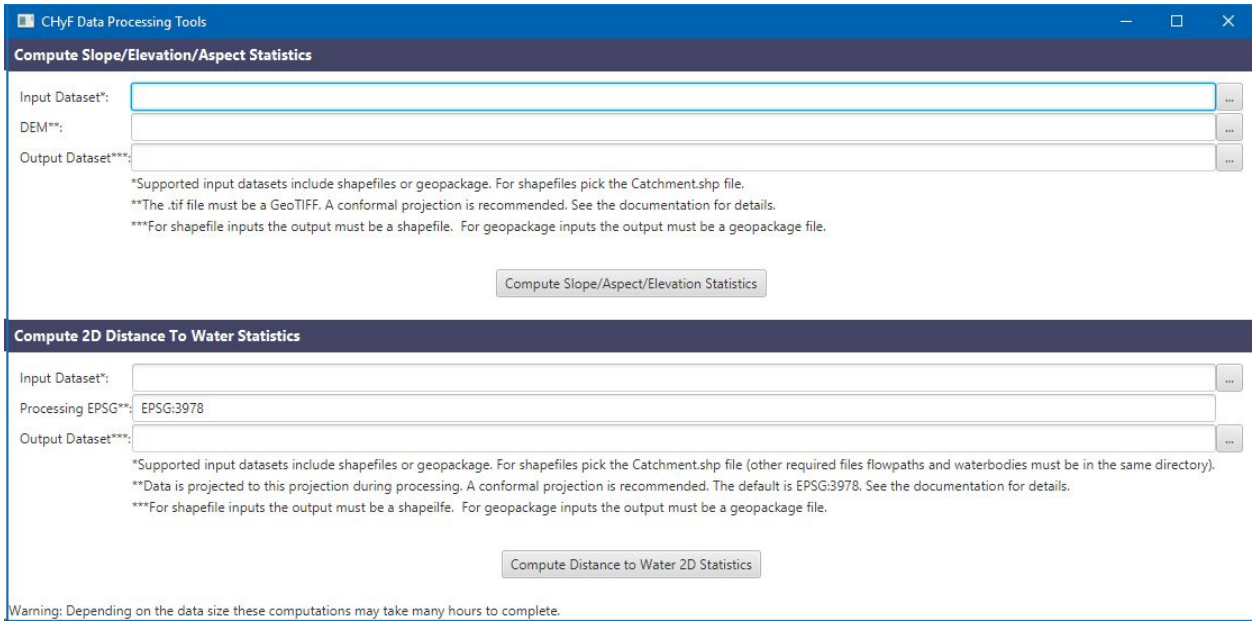
Java Requirements

Java version 8 or 9 must be installed and placed on the classpath. This can be verified by running "`java -version`" from a command line.
Note: depending on your java version this may appear as `1.<VERSION> (1.8)` or just `<VERSION> (8.x)`.

This tools makes use of JavaFx. For Java Version 8 & 9 JavaFx is included in the Oracle Java release. Other Java distributions may not contain JavaFx.

User Interface

To run the software, unpackage the zip file and run the included .bat (windows) or .sh (linux) file. This will launch the CHyF Data Processing Tool user interface, as shown below.



The second section of this user interface is used for 2D distance to water statistics. Users must select the Input Dataset, Processing EPSG code, Output Dataset, then click the 'Compute Distance to Water 2D Statistics' button. For large datasets processing may take many hours. A progress bar will appear, and a dialog will be displayed when processing is completed.

Both Shapefile and Geopackage input/output formats are supported. The output format must match the input format (input shapefiles required output shapefile).

Command Line

The application can also be run from the command line.

```
Java -cp ./lib/* net.refractions.chyf.datatools.ChyfDistance2Water2DProcessor [srid] [input] [output]
[srid] - [srid] - the equal area projection valid for the input dataset to compute distances in (eg EPSG:3978)
[input] - the input dataset (must be either the Catchment.shp file OR a geopackage file).  If providing Catchment.shp file, the Waterbody.shp and Flowpath.shp files must exist in the same directory.
[output] - the output location (either a shapefile or a geopackage file)
```

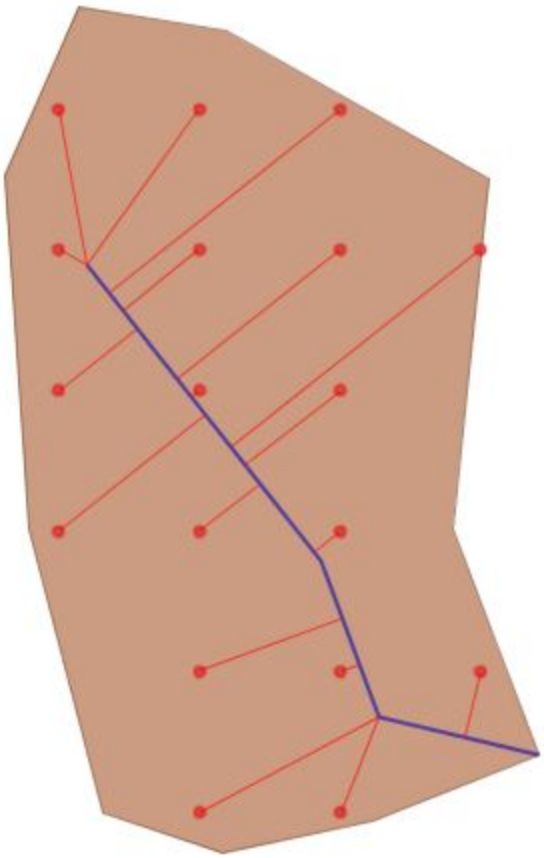
Example

```
> C:\data\CHyF\chyf-datatools-1.1.0-201902211656>java -cp ./lib/*
net.refractions.chyf.datatools.ChyfDistance2Water2DProcessor EPSG:3978
./testdata/distance2water2d/Catchment.shp ./testdata/distance2water2d/Catchment.out.shp
```

Computing Distance to Water

2D distance to water values are computed for each catchment, by generating a 1m grid (of points within the catchment) and computing the shortest distance to a water for each cell. “Water” can either be an elementary flowpath (of any type) or a waterbody. The maximum of these values is assigned to the d2wd2_max attribute, and the average of these values to the d2wd2_mean.

Consider the following figure:



In this simple example the element catchment appears in brown, and the flowpath in blue. The red dots represent a subset of the 1m grid cells that fall within this polygon, and the red lines the shortest distance from each grid cell to the flowpath. The maximum 2d distance to water is computed as the longest of these red lines for all grid cells, and the mean 2d distance to water value is computed as the average length of these red lines.