HydroATLAS-Zambia

A compendium of hydro-environmental sub-basin and river reach characteristics at 15 arc-second resolution for Zambia

Technical Documentation Version 1.0

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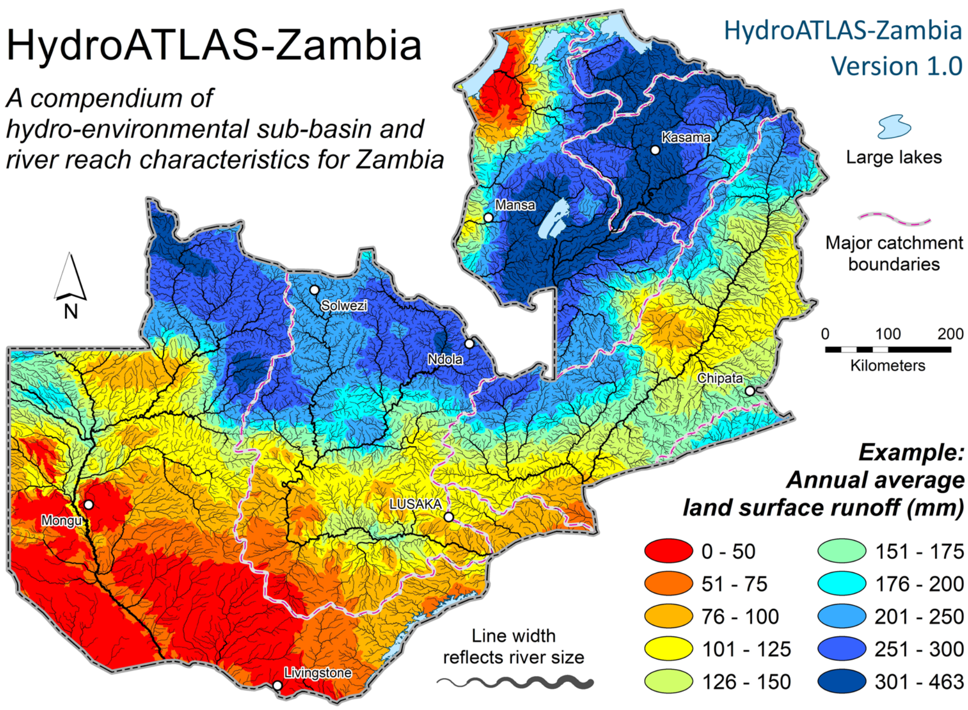

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1. Background and introduction

The goal of HydroATLAS-Zambia is to provide a broad user community with a standardized compendium of hydro-environmental attribute information for all catchments and rivers of Zambia at high spatial resolution. HydroATLAS-Zambia is a regionally customized and extended version of the global HydroATLAS database (Linke et al. 2019). Version 1.0 of HydroATLAS-Zambia offers data for 51 variables, partitioned into 259 individual attributes and organized in seven categories: hydrology; physiography; climate; land cover & use; soils & geology; anthropogenic influences; and Zambia-specific ecological information (Table 1 and Appendix 1).

HydroATLAS-Zambia derives the hydro-environmental attributes by reformatting original data from well-established global digital maps and/or national and regional repositories. The attributes were then linked to the sub-basin polygons (level 10) and river reach lines of the global HydroSHEDS database at 15 arc-second (~500 m) resolution. The sub-basin and river reach information is offered in two companion datasets: **(1) BasinATLAS-Zambia and (2) RiverATLAS-Zambia**. The standardized format of HydroATLAS-Zambia ensures easy applicability while the inherent topological information supports basic network functionality such as identifying up- and downstream connections. HydroATLAS-Zambia is fully compatible with other products of the overarching global HydroSHEDS project enabling versatile hydro-ecological assessments.

The documentation of HydroATLAS-Zambia is organized in two parts: Part 1 (this document) provides general explanations of the HydroATLAS-Zambia database. Part 2 is provided in two alternative files: 'BasinATLAS_Zambia_Catalog' or 'RiverATLAS_Zambia_Catalog'. Each catalog file first offers a summary table listing all hydro-environmental variables and their basic characteristics. This is followed by detailed information on each variable, including source data descriptions, units, conversion methodology, and citations. Each variable is presented on one standardized sheet which includes a map of Zambia indicating the spatial distribution of values of the respective variable. Note that the summary table and information sheets are hyperlinked within each catalog.

The development of the global HydroATLAS database is fully described in Linke et al. (2019). For data citations and acknowledgements see section 4.4 below. General citations of HydroATLAS-Zambia should refer to:

WWF-Zambia and Lehner, B. (2020). HydroATLAS-Zambia. Technical Documentation Version 1.0. Available at: https://www.hydrosheds.org/hydroatlas-zambia.

Table1. Categories of hydro-environmental variables offered in the HydroATLAS-Zambia database.

Identifier	Category	Description
H	Hydrology & hydrography	Hydrological and hydrographic characteristics related to quantity, quality, location and extent of terrestrial water *Examples: natural runoff and discharge, groundwater table depth*
P	Physiography	Topographic characteristics related to terrain, relief or landscape position *Examples: elevation, slope, stream gradient*
C	Climate	Climatic characteristics *Examples: mean temperature, precipitation, climate moisture index*
L	Land cover & land use	Land cover and land use characteristics including biogeographic regions *Examples: land cover classes, cropland extent, freshwater ecoregions*
S	Soils & geology	Soil and geology characteristics including substrate types and soil conditions *Examples: percentage clay in soil, soil water stress, soil erosion*
A	Anthropogenic influences	Anthropogenic characteristics including demographic and socioeconomic aspects *Examples: population density, urban extent, human footprint*
Z	Zambian information	Zambia-specific information on ecologically relevant variables and aquatic species distributions *Examples: number of dams and waterfalls, distribution of aquatic species by class and by individual species*

2. Methods and data characteristics

HydroATLAS-Zambia is based on the global version of HydroATLAS from which sub-basins and river reaches were extracted for the extent of Zambia and the larger Zambezi and upper Congo (Luapula and Tanganyika) regions. Additional information specific for Zambia was added from national or regional data repositories.

The methods used to create the global version of HydroATLAS are fully described in Linke et al. (2019). All spatial units of HydroATLAS, i.e. either sub-basin polygons or river reach lines, were extracted from World Wildlife Fund's HydroSHEDS database (Lehner et al. 2008; Lehner and Grill 2013) at a grid resolution of 15 arc-seconds (approx. 500 m at the equator). For more information on HydroSHEDS please refer to its Technical Documentation at https://www.hydrosheds.org.

HydroATLAS consists of two complementary parts: BasinATLAS and RiverATLAS. BasinATLAS provides hydro-environmental attributes for sub-basins (polygons); ***note that the expression 'sub-basin' is synonymous with 'sub-catchment'***. RiverATLAS provides hydro-environmental attributes for stream and river reaches (line segments).

2.1 Creation and characteristics of sub-basins (BasinATLAS-Zambia)

Catchment boundaries provide important geospatial units for many hydro-environmental applications. At a global scale, the HydroSHEDS database provides hydrographic data layers that allow for the derivation of catchment boundaries for any given location based on the high-resolution (90 m) SRTM digital elevation model. Using this hydrographic information, catchments were delineated in a consistent manner at different scales, and a hierarchical sub-catchment breakdown (in HydroSHEDS called 'sub-basins') was created following the topological concept of the Pfafstetter coding system. The resulting polygon layers are termed HydroBASINS and represent a subset of the HydroSHEDS database.

BasinATLAS-Zambia uses the sub-basin delineation of HydroBASINS (for more information on HydroBASINS see https://www.hydrosheds.org/page/hydrobasins).

An important characteristic of any sub-basin delineation is the sub-basin breakdown, i.e. the decision of when and how to subdivide a larger basin into multiple tributary basins. Standard GIS tools offer the possibility to break out sub-catchments at any confluence where the inflowing branches (i.e., a tributary and its main stem) exceed a certain size threshold, typically measured as the number of upstream pixels or the upstream catchment area. HydroBASINS follows the same concept and divides a basin into two sub-basins at every location where two river branches meet which each have an individual upstream area of at least 100 km^2. It should be noted that this concept still allows for smaller sub-basins to occur, namely the inter-basins between the tributaries (which can have any smaller size). Also, sub-basins can grow to sizes much larger than the 100 km^2 threshold if there is no tributary joining the main stem for a long distance. This inconsistency due to "oversized" sub-basins has been addressed and reduced in HydroBASINS by forcing additional subdivisions for every sub-basin larger than 250 km^2: these polygons are split into appropriately sized sub-basins by introducing break points along their main stem rivers.

A second critical feature of sub-basin delineations is the way the sub-basins are grouped or coded to allow for the breakout of nested sub-basins at different scales, or to navigate within the sub-basin network from up- to downstream. One of the easiest methods for navigation is to provide the ID of the next downstream object, which allows for moving from object to object in order to traverse the network. As for nesting and topological concepts, the 'Pfafstetter' coding system is frequently used due to its relative simplicity and ease of application (see Figure 1). The basic principle of the Pfafstetter coding is that a larger basin is sequentially subdivided into 9 smaller units (the 4 largest tributaries, coded with even numbers, and the 5 inter-basins, coded with odd numbers). Thus, the next finer resolution of a sub-basin delineation is achieved at the next Pfafstetter level by adding one digit to the code of the previous level.

The global HydroBASINS and HydroATLAS products follow the Pfafstetter concept (with some modifications) and provide nested sub-basins at levels 1 to 12.

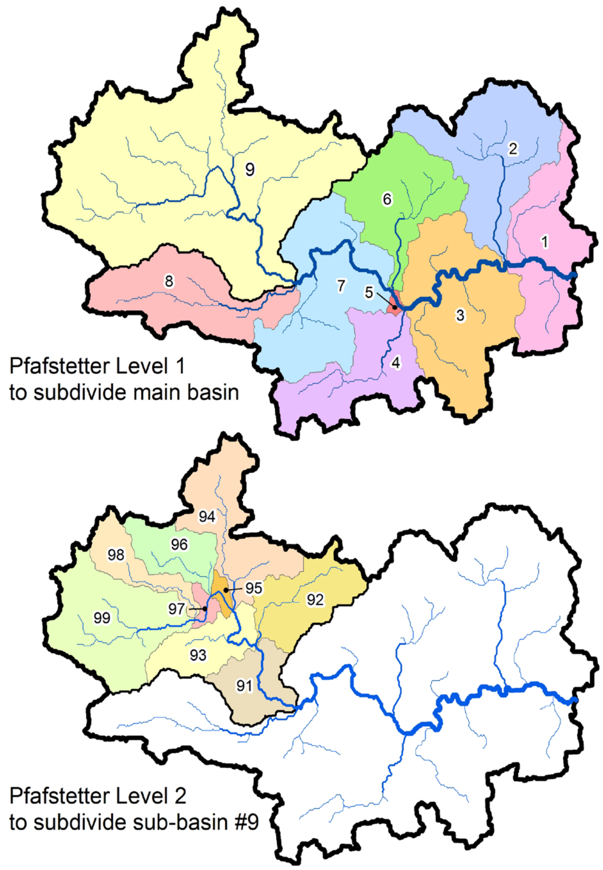

Figure 1: Overview of Pfafstetter sub-basin coding scheme. Sub-basins are nested within hierarchical levels.

2.2 Creation and characteristics of river reaches (RiverATLAS-Zambia)

As an alternative to catchments, river reaches can be used as geospatial units for many hydrologic applications, in particular for those which require in-stream information such as discharge amounts. In general, river reaches are spatially more explicit than the units of sub-basins which are more lumped (i.e., one sub-basin can include multiple river reaches). A global river network delineation has been extracted from the HydroSHEDS database and is available as a stand-alone product termed HydroRIVERS. The extraction process used the flow direction grid of HydroSHEDS at 15 arc-second resolution, as well as an auxiliary grid of upstream catchment areas and a grid of long-term average discharge estimates (see below for more details).

RiverATLAS-Zambia uses the river reach delineation of HydroRIVERS (for more information on HydroRIVERS see https://www.hydrosheds.org/page/hydrorivers).

In HydroRIVERS, streams have been defined to start at all pixels where the accumulated upstream catchment area exceeds 10 km^2, or where the long-term average natural discharge exceeds 0.1 cubic meters per second, or both. Streams smaller than these thresholds were not extracted as they are increasingly unreliable in their spatial representation due to the inherent uncertainties in the underpinning global elevation and hydrologic data. All identified stream pixels at 15 arc-second resolution were then converted into vector format to produce a line network consisting of individual

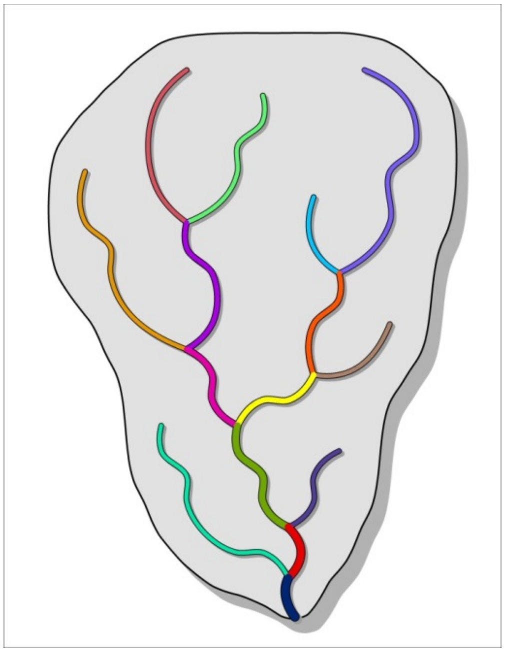

Figure 2: Overview of river reach concept. Every river reach, depicted by a line segment in a different color, is defined as a stretch of river between two tributaries, or between the start/end of the network and a tributary.

segments, i.e. river reaches (Figure 2). Note that each river reach is also geospatially linked to its contributing catchment area (i.e. the local catchment that drains directly into the reach).

For the delineation of the river network presented in HydroRIVERS, a discharge threshold was used to define the initiation points of all headwater streams. For this purpose, estimates of long-term (1971-2000) average discharge were derived through a geospatial downscaling procedure (Lehner and Grill 2013) from the 0.5 degree resolution runoff and discharge layers of the global WaterGAP model (Döll et al. 2003; version 2.2 as of 2014), a well-documented and validated integrated water balance model. A validation of the downscaled discharge estimates against observations at 3,003 global gauging stations, provided by the Global Runoff Data Center, Koblenz, Germany, representing river sizes from 0.004 to 180,000 m^3/s, confirmed good overall correlations for long-term average discharges ($R^2 = 0.99$ with 0.2% positive bias and a symmetric mean absolute percentage error sMAPE of 35%, improving to 13% for rivers ≥100 m^3/s). Despite these overall good correlations, significant uncertainties were observed in certain regions, in particular areas that are dominated by large wetland complexes or arid and semi-arid conditions.

While each river reach of HydroRIVERS resides in exactly one sub-basin of HydroBASINS (one-to-one relationship), each sub-basin can contain none, one, or multiple river reaches (one-to-many relationship). Each river reach can be joined or linked to its corresponding sub-basin in which it resides via the HydroBASINS ID that is provided as part of the attribute table (see section 3 below).

2.3 Extraction and enhancement of HydroATLAS-Zambia

The global version of HydroATLAS is available at https://www.hydrosheds.org/page/hydroatlas. HydroATLAS-Zambia has been extracted from the global version and was then customized and extended to better fit the requirements of Zambia.

a) Extraction of HydroATLAS data for Zambezi and upper Congo region (HydroATLAS-Zambezi)

As a first step, the full HydroATLAS v1.0 information, including RiverATLAS and all 12 BasinATLAS levels, were extracted for the region of the entire Zambezi Basin and the upper Congo Basin (i.e., relevant parts of Luapula and Tanganyika catchments; see Figure 3 for extent). The purpose of this extracted dataset is to provide all HydroATLAS data that are of potential interest for Zambia, including hydrologically connected up- and downstream parts. This regional version also offers the possibility to change scales within the 12 nested sub-basin levels.

The extracted data layers are available as a stand alone product termed **'HydroATLAS-Zambezi'** at https://www.hydrosheds.org/hydroatlas-zambia (including copies of the global HydroATLAS Technical Documentation and Catalog files).

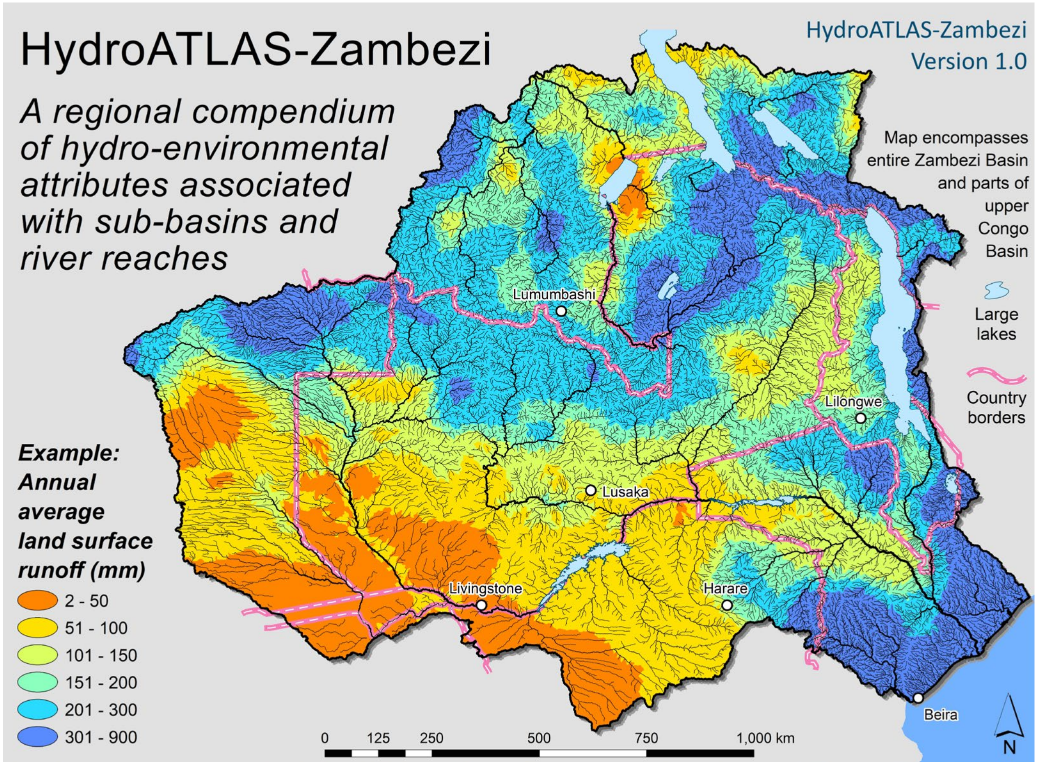

Figure 3: Spatial extent of HydroATLAS-Zambezi.

b) <u>Creation of HydroATLAS-Zambia</u>

From the regional copy of HydroATLAS-Zambezi, two layers were extracted: the sub-basin polygons at level 10 and all river reach lines. These two layers form the basis for HydroATLAS-Zambia. The following specifications or modifications were then applied:

- The spatial extent of the region (i.e., including the entire Zambezi Basin and portions of the upper Congo; Figure 3) was maintained. This ensures that hydrological connections to up- and downstream parts of catchments remain intact and can be used in analyses that require these connections. Each sub-basin and river reach was flagged to be within or outside Zambia.
- Some attributes from the global HydroATLAS database were removed. These include attributes that are not relevant in Zambia (e.g., permafrost or glacier extents) as well as attributes that are not considered of enough spatial precision to be useful at the national scale of Zambia (e.g., the course resolutions of potential vegetation or lithological zones).
- Additional attributes that exist at the national extent of Zambia were added to HydroATLAS-Zambia. These attributes mostly include freshwater ecological information, including species distribution ranges. These additional attributes are provided in the category of 'Z – Zambian information'. Note that all additional information is only provided within the national extent of Zambia. For more details see section 3 below.

Within Zambia, BasinATLAS-Zambia provides 5,539 individual sub-basin polygons (level 10 only) with an average area of 141.7 km^2 (std. dev. 77.7 km^2) covering a total area of 785,057 km^2 (Figure 4). RiverATLAS-Zambia encompasses a total of 36,099 individual river reaches with an average length of 4.8 km (std. dev. 4.0 km), totaling 172,871 km of river network within Zambia (Figure 5).

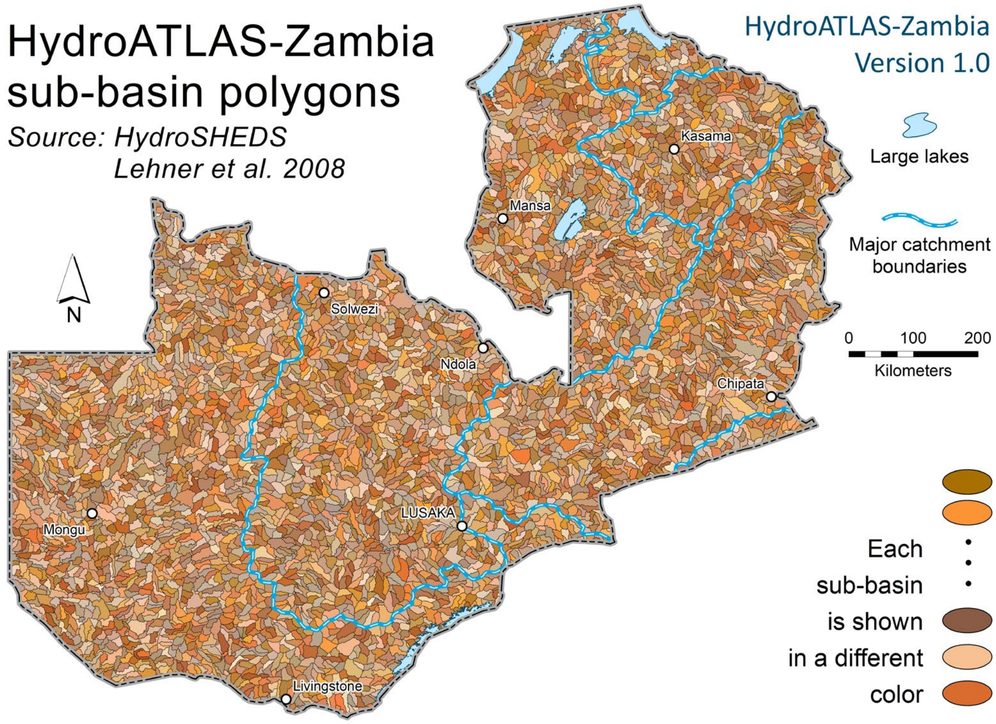

Figure 4: Sub-basin delineation of HydroATLAS-Zambia (level 10 only).

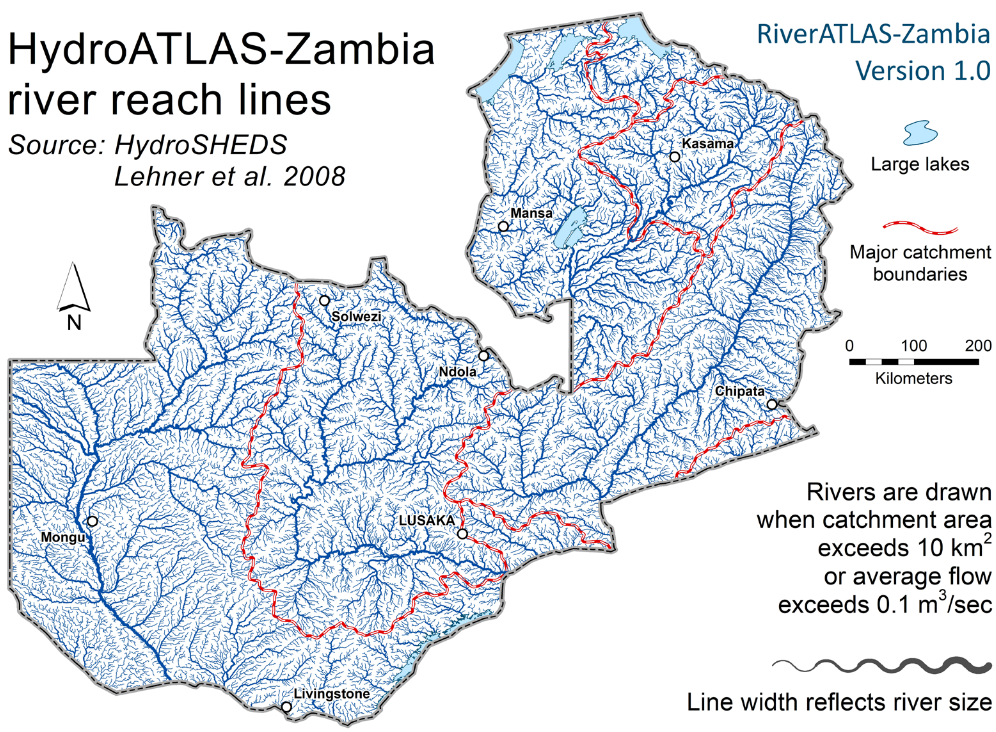

Figure 5: River reach delineation of HydroATLAS-Zambia.

3. Data format and distribution

a) *Data format and projection*

The HydroATLAS-Zambia data layers are offered in two spatial formats: per sub-basin and per river reach:

- ***BasinATLAS_Zambia_v10*** contains the sub-basin polygons (at Pfafstetter level 10)
- ***RiverATLAS_Zambia_v10*** contains the river reach lines

Each of the two datasets is provided in both ESRI© Geodatabase and Shapefile formats; i.e., each is available either as a feature layer in a Geodatabase called 'HydroATLAS_Zambia_v10.gdb' or as a Shapefile in a folder called 'HydroATLAS_Zambia_v10_shp'.

HydroATLAS-Zambia data are available electronically in compressed zip file format. To use the data files, the zip files must first be decompressed. Each zip file includes a copy of the HydroATLAS-Zambia Technical Documentation. The data are projected in a Geographic Coordinate System using the World Geodetic System 1984 (GCS_WGS_1984). The attribute tables can also be accessed as stand-alone files in dBASE format which are included in the Shapefile format.

b) *Available columns and column name syntax*

The attribute tables of HydroATLAS-Zambia contain the pre-existing columns of HydroBASINS and HydroRIVERS, respectively (see Tables 2 and 3 below). The hydro-environmental attributes are then appended in a series of additional columns using a specific column name syntax (explained below and in Tables 4 to 6). All existing hydro-environmental attributes and their associated column names are summarized in Appendix 1 and at the beginning of the BasinATLAS-Zambia and RiverATLAS-Zambia catalogs.

Each hydro-environmental attribute column name has 10 digits (for example '*dis_m3_syr*') and its syntax is as follows:

<Layer name key>_<Unit key>_<Spatial key>< Dimension key>

Layer name key:

Three digits that describe the name of the attribute. The layer name key is unique to the attribute it represents. *Example: 'dis' for discharge.*

Unit key:

Two digits that describe the units of the attribute value. See Table 4 for possible keys.

Spatial extent key:

One digit that describes the spatial extent of the attribute. See Table 5 for possible keys.

Dimension key:

Two digits that describe the dimension of the attribute in terms of its aggregation level or other type of spatiotemporal association. The dimension key can refer to a temporal dimension, a statistical aggregation, or a class or year association. See Table 6 for possible keys.

Table 2: The BasinATLAS-Zambia polygon layer contains an attribute table which first provides a set of 14 core attributes (including IDs and geometric information) followed by the 259 hydro-environmental attributes. This table describes the information contained in the core attribute columns. Note that the columns and descriptions are slightly modified from the original dataset of HydroBASINS (for full documentation on HydroBASINS see https://www.hydrosheds.org/page/hydrobasins).

Column	***Description***
HYBAS_ID	Unique basin identifier. The code consists of 10 digits. The first 1 digit represents the region: 1 = Africa. The next 2 digits define the Pfafstetter level (10 for BasinATLAS-Zambia). The next 6 digits represent a unique identifier within the HydroSHEDS network, and the last 1 digit is set to 0 for BasinATLAS-Zambia. *For more information please refer to the full documentation of HydroBASINS.*
NEXT_DOWN	HYBAS_ID of the next downstream polygon. This field can be used for navigation (up- and downstream) within the river network. The value '0' indicates a polygon with no downstream connection (i.e., the last polygon draining into the ocean or into an inland sink).
MAIN_BAS	HYBAS_ID of the most downstream polygon in the river basin, i.e. its outlet. This field can be used to identify the entire river basin that a polygon belongs to (by querying all records that show the same ID in the MAIN_BAS field).
DIST_MAIN	Distance along the river network from polygon outlet to the most downstream sink, i.e. to the outlet of the main river basin, in kilometers. The most downstream sink or outlet is that of the main basin, i.e. either the outlet at the ocean, or the final sink of a large endorheic catchment which forms its own basin.
SUB_AREA	Area of the individual polygon (i.e. sub-basin), in square kilometers.
UP_AREA	Total upstream area, in square kilometers, calculated from the headwaters to the polygon location (including the polygon).
PFAF_ID	The Pfafstetter code (at level 10 for BasinATLAS-Zambia). *For more information please refer to the full documentation of HydroBASINS.*
ENDO	Indicator for endorheic (inland) basins without surface flow connection to the ocean: 0 = not part of an endorheic basin; 1 = part of an endorheic basin; 2 = sink (i.e. most downstream polygon) of an endorheic basin.
COAST	Indicator for lumped coastal basins: 0 = no; 1 = yes. Coastal basins represent conglomerates of small coastal catchments that drain into the ocean between larger river basins.
ORDER	Indicator of river order (classical ordering system): order 1 represents the main stem river from sink to source; order 2 represents all tributaries that flow into a 1st order river; order 3 represents all tributaries that flow into a 2nd order river; etc.; order 0 is used for conglomerates of small coastal catchments.
SORT	Indicator showing the record number (sequence) in which the original polygons are stored in the database (i.e. counting upwards from 1 in the original global database). The original polygons are sorted from downstream to upstream. This field can be used to sort the polygons back to their original sequence or to perform topological searches.

LINK_BAS	Internal ID used in the creation of HydroBASINS to assign hydro-environmental attribute values from original grids. This information may be useful for users who want to produce their own HydroATLAS attributes and append them to the attribute table. *Please contact B. Lehner for more information.*
ZAMBIA_YN	Binary indicator showing values of 1 or 0 (yes/no) where 1 identifies all polygons that are part of Zambia (i.e., polygons that are fully or partially within Zambia). This field can be used to query and/or extract those polygons that are needed for analyzing data at a Zambian extent.
ZAM_CATCH	Unique identifier used to assign each polygon to one of the six major catchments as defined by WARMA: 1 = Zambezi; 2 = Kafue; 3 = Luangwa; 4 = Luapula; 5 = Chambeshi; 6 = Lake Tanganyika. The value '0' is used for all other polygons. Note that values are also assigned to polygons outside the national boundary of Zambia if they form part of the respective basin (e.g., all polygons of the Zambezi Basin).

Table 3: The RiverATLAS-Zambia line layer contains an attribute table which first provides a set of 17 core attributes (including IDs and geometric information) followed by the 259 hydro-environmental attributes. This table describes the information contained in the core attribute columns. Note that the columns and descriptions are slightly modified from the original dataset of HydroRIVERS (for full documentation on HydroRIVERS see https://www.hydrosheds.org/page/hydrorivers).

Column	*Description*
HYRIV_ID	Unique identifier for each river reach. The code consists of 8 digits. The first digit represents the region: 1 = Africa. The other 7 digits represent a unique identifier within the river network.
NEXT_DOWN	HYRIV_ID of the next downstream line segment. This field can be used for navigation (up- and downstream) within the river network. The value '0' indicates a line with no downstream connection (i.e., the last river reach draining into the ocean or into an inland sink).
MAIN_RIV	HYRIV_ID of the most downstream reach in the river basin, i.e. its outlet. This field can be used to identify the entire river network that belongs to this basin (by querying all records with the same ID in the MAIN_RIV field).
LENGTH_KM	Length of the river reach segment, in kilometers.
DIST_DN_KM	Distance from the reach outlet, i.e., the most downstream pixel of the reach, to the final downstream location along the river network, in kilometers. The final downstream location is either the pour point into the ocean or an endorheic sink.
DIST_UP_KM	Distance from the reach outlet, i.e., the most downstream pixel of the reach, to the most upstream location along the river network, in kilometers. The most upstream location is the furthest upstream point from this reach on the watershed divide.

CATCH_SKM	Area of the catchment that contributes directly to the individual reach, in square kilometers. The catchment only relates to the reach itself, while the contributing area of all upstream reaches is not included (see next column).
UPLAND_SKM	Total upstream area, in square kilometers, calculated from the headwaters to the pour point (i.e., the most downstream pixel) of the reach.
ENDORHEIC	Indicator for endorheic (inland) basins without surface flow connection to the ocean: 0 = not part of an endorheic basin; 1 = part of an endorheic basin.
DIS_AV_CMS	Average long-term discharge estimate for the river reach, in cubic meters per second. See section 2.2 for more information.
ORD_STRA	Indicator of river order following the Strahler ordering system: order 1 represents headwater streams; when two 1st order streams meet, they form a 2nd order river; when two 2nd order rivers meet, they form a 3rd order river; etc.
ORD_CLAS	Indicator of river order following the classical ordering system (also called 'Hack's stream orders'): order 1 represents the main stem river from sink to source; order 2 represents all tributaries that flow into a 1st order river; order 3 represents all tributaries that flow into a 2nd order river; etc. This ordering system can be used to identify 'backbone' rivers, i.e., the main stem of a river from source to sink.
ORD_FLOW	Indicator of river order using river flow to distinguish logarithmic size classes: order 1 represents river reaches with a long-term average discharge ≥ 100,000 m^3/s; order 2 represents river reaches with a long-term average discharge ≥ 10,000 m^3/s and < 100,000 m^3/s; … order 9 represents river reaches with a long-term average discharge ≥ 0.001 m^3/s and < 0.01 m^3/s; and order 10 represents river reaches with a long-term average discharge < 0.001 m^3/s (i.e., 0 in the provided data due to rounding to 3 digits).
HYBAS_L10	HYBAS_ID of the corresponding BasinATLAS-Zambia sub-basin in which the river reach resides (at Pfafstetter level 10).
LINK_RIV	Internal ID used in the creation of HydroRIVERS to assign hydro-environmental attribute values from original grids. This information may be useful for users who want to produce their own HydroATLAS attributes and append them to the attribute table. *Please contact B. Lehner for more information.*
ZAMBIA_YN	Binary indicator showing values of 1 or 0 (yes/no) where 1 identifies all river reaches that are part of Zambia (i.e., line segments that are fully or partially within Zambia). This field can be used to query and/or extract those river reaches that are needed for analyzing data at a Zambian extent.
ZAM_CATCH	Unique identifier used to assign each river reach to one of the six major catchments as defined by WARMA: 1 = Zambezi; 2 = Kafue; 3 = Luangwa; 4 = Luapula; 5 = Chambeshi; 6 = Lake Tanganyika. The value '0' is used for all other line segments. Note that values are also assigned to river reaches outside the national boundary of Zambia if they form part of the respective basin (e.g., all river reaches of the Zambezi Basin).

Table 4: Unit keys. Note that some values are stored in factors of the given units (to efficiently store them as integers without losing precision), e.g. temperature is stored in tenths of degrees; these factors are listed in the respective data sheet of each variable in the BasinATLAS-Zambia or RiverATLAS-Zambia catalogs.

Key	Unit of values
bi	Binary (1/0, yes/no)
cl	Classes
cm	Centimeters
ct	Count (e.g. number of people)
dc	Degrees Celsius (°C)
dg	Degrees
dk	Decimeters per kilometer
ha	Hectares
id	ID number
ix	Index value
kh	Kilogram per hectare (kg/ha) per year
m3	Cubic meters per second (m^3/s)
mc	Million cubic meters (mcm)
mk	Meters per square kilometer (m/km^2)
mm	Millimeters
mt	Meters *or* Meters above sea level (m.a.s.l.)
pc	Percent *or* Percent cover
pk	Per square kilometer (e.g. people per square kilometer)
tc	Thousand cubic meters
th	Tonnes per hectare
ud	US dollars

Table 5: Spatial extent keys. Note that all attributes represent average values within the spatial unit unless stated otherwise in the attribute's catalog sheet.

Key	Spatial representation
c	In reach catchment (i.e. the local catchment that drains directly into the reach)
p	At sub-basin pour point *or* At reach pour point
r	Along reach segment
s	In sub-basin
u	In total basin area upstream of sub-basin pour point *or* In total basin area upstream of reach pour point *or*

Table 6: Dimension keys.

Key	Temporal or statistical aggregation or other association
01-12	Calendar month (January to December) for monthly data
00-99	Other numbers may be used and explained as needed (e.g. to refer to individual land cover classes, aquatic species, or specific years)
av	Average
g1-g9	Class groupings (individual groups are defined in HydroATLAS catalogs)
lt	Long-term maximum
mj	Spatial majority (dominant value)
mn	Minimum *or* Annual minimum
mx	Maximum *or* Annual maximum
se	Spatial extent (%)
su	Sum
va	Value
yr	Annual average

4. License, disclaimer and acknowledgement

4.1 License agreement

4.2 Disclaimer of warranty

The HydroATLAS database and any related materials contained therein are provided “as is” without warranty of any kind, either express or implied, including, but not limited to, the implied warranties of merchantability, fitness for a particular purpose, noninterference, system integration, or noninfringement. The entire risk of use of the data shall be with the user. The user expressly acknowledges that the data may contain some nonconformities, defects, or errors. The authors do not warrant that the data will meet the user's needs or expectations, that the use of the data will be uninterrupted, or that all nonconformities, defects, or errors can or will be corrected. The authors are not inviting reliance on these data, and the user should always verify actual data.

4.3 Limitation of liability

In no event shall the authors be liable for costs of procurement of substitute goods or services, lost profits, lost sales or business expenditures, investments, or commitments in connection with any business, loss of any goodwill, or for any direct, indirect, special, incidental, exemplary, or consequential damages arising out of the use of the HydroATLAS database and any related materials, however caused, on any theory of liability, and whether or not the authors have been advised of the possibility of such damage. These limitations shall apply notwithstanding any failure of essential purpose of any exclusive remedy.

4.4 Data citations and acknowledgements

When using an attribute contained in HydroATLAS-Zambia, citations and acknowledgements should be made to both the original data source and the HydroATLAS-Zambia compendium. For example, the following template illustrates a reference to precipitation data sourced from HydroATLAS-Zambia:

> "*Precipitation data from the WorldClim v1.4 database (Hijmans et al. 2005) have been used in the spatial format as provided by HydroATLAS-Zambia v1.0 (WWF-Zambia & Lehner 2020).*"

Information regarding the reference(s) for each hydro-environmental attribute is provided on the individual attribute sheets in the BasinATLAS-Zambia and RiverATLAS-Zambia catalogs. In addition, every data source may have individual requests for acknowledgements, and users of HydroATLAS-Zambia are asked to honor those requests when using the respective attributes.

Citations and acknowledgements of HydroATLAS-Zambia should be made as follows:

> *WWF-Zambia and Lehner, B. (2020). HydroATLAS-Zambia. Technical Documentation Version 1.0. Available at: https://www.hydrosheds.org/hydroatlas-zambia*.

General citations and acknowledgements of the global version of HydroATLAS should be made as follows:

> *Linke, S., Lehner, B., Ouellet Dallaire, C., Ariwi, J., Grill, G., Anand, M., Beames, P., Burchard-Levine, V., Maxwell, S., Moidu, H., Tan, F., Thieme, M. (2019). Global hydro-environmental sub-basin and river reach characteristics at high spatial resolution. Scientific Data 6: 283. DOI: 10.1038/s41597-019-0300-6.*

We kindly ask users to cite both source data and HydroATLAS-Zambia in any published material produced using the data. If possible, online links to the HydroATLAS-Zambia website should be provided (https://www.hydrosheds.org/hydroatlas-zambia).

5. References

Lehner, B., Grill G. (2013). Global river hydrography and network routing: baseline data and new approaches to study the world's large river systems. Hydrological Processes 27(15): 2171-2186. *DOI: https://doi.org/10.1002/hyp.9740*.

Lehner, B., Verdin, K., Jarvis, A. (2008). New global hydrography derived from spaceborne elevation data. Eos, Transactions, AGU 89(10): 93-94. *DOI: https://doi.org/10.1029/2008EO100001*.

Linke, S., Lehner, B., Ouellet Dallaire, C., Ariwi, J., Grill, G., Anand, M., Beames, P., Burchard-Levine, V., Maxwell, S., Moidu, H., Tan, F., Thieme, M. (2019). Global hydro-environmental sub-basin and river reach characteristics at high spatial resolution. Scientific Data 6: 283. *DOI: 10.1038/s41597-019-0300-6*.

WWF-Zambia and Lehner B. (2020). HydroATLAS-Zambia. Technical Documentation Version 1.0. Available at: https://www.hydrosheds.org/hydroatlas-zambia.

Appendix 1: Attributes included in version 1.0 of HydroATLAS-Zambia (for more details see BasinATLAS-Zambia and RiverATLAS-Zambia catalog files)

HydroATLAS-Zambia Attributes (version 1.0)

ID	Category	Attribute	Source Data	Citation	Column(s)	Count
H01	Hydrology	Natural Discharge	WaterGAP v2.2	Döll et al. 2003	dis_m3_---	x15
H02	Hydrology	Land Surface Runoff	WaterGAP v2.2	Döll et al. 2003	run_mm_---	x13
H03	Hydrology	Inundation Extent	GIEMS-D15	Fluet-Chouinard et al. 2015	inu_pc_---	x6
H04	Hydrology	Limnicity (Percent Lake Area)	HydroLAKES	Messager et al. 2016	lka_pc_---	x2
H09	Hydrology	River Volume	HydroSHEDS & WaterGAP	Lehner & Grill 2013	riv_tc_---	x2
H10	Hydrology	Groundwater Table Depth	Global Groundwater Map	Fan et al. 2013	gwt_cm_---	x1
P01	Physiography	Elevation	EarthEnv-DEM90	Robinson et al. 2014	ele_mt_---	x4
P02	Physiography	Terrain Slope	EarthEnv-DEM90	Robinson et al. 2014	slp_dg_---	x2
P03	Physiography	Stream Gradient	EarthEnv-DEM90	Robinson et al. 2014	sgr_dk_---	x1
C01	Climate	Climate Zones	GEnS	Metzger et al. 2013	clz_cl_---	x1
C02	Climate	Climate Strata	GEnS	Metzger et al. 2013	cls_cl_---	x1
C03	Climate	Air Temperature	WorldClim v1.4	Hijmans et al. 2005	tmp_dc_---	x16
C04	Climate	Precipitation	WorldClim v1.4	Hijmans et al. 2005	pre_mm_---	x14
C05	Climate	Potential Evapotranspiration	Global-PET	Zomer et al. 2008	pet_mm_---	x14
C06	Climate	Actual Evapotranspiration	Global Soil-Water Balance	Trabucco & Zomer 2010	aet_mm_---	x14
C07	Climate	Global Aridity Index	Global Aridity Index	Zomer et al. 2008	ari_ix_---	x2
C08	Climate	Climate Moisture Index	WorldClim & Global-PET	Hijmans et al. 2005	cmi_ix_---	x14
L01	Landcover	Land Cover Classes	GLC2000	Bartholomé & Belward 2005	glc_cl_---	x1
L02	Landcover	Land Cover Extent	GLC2000	Bartholomé & Belward 2005	glc_pc_---	x44
L07	Landcover	Forest Cover Extent	GLC2000	Bartholomé & Belward 2005	for_pc_---	x2
L08	Landcover	Cropland Extent	EarthStat	Ramankutty et al. 2008	crp_pc_---	x2
L09	Landcover	Pasture Extent	EarthStat	Ramankutty et al. 2008	pst_pc_---	x2
L10	Landcover	Irrigated Area Extent (Equipped)	HID v1.0	Siebert et al. 2015	ire_pc_---	x2
L13	Landcover	Protected Area Extent	WDPA	IUCN & UNEP-WCMC 2014	pac_pc_---	x2
L14	Landcover	Terrestrial Biomes	TEOW	Dinerstein et al. 2017	tbi_cl_---	x1
L15	Landcover	Terrestrial Ecoregions	TEOW	Dinerstein et al. 2017	tec_cl_---	x1
L16	Landcover	Freshwater Major Habitat Types	FEOW	Abell et al. 2008	fmh_cl_---	x1
L17	Landcover	Freshwater Ecoregions	FEOW	Abell et al. 2008	fec_cl_---	x1
S01	Soils & Geology	Clay Fraction in Soil	SoilGrids1km	Hengl et al. 2014	cly_pc_---	x2
S02	Soils & Geology	Silt Fraction in Soil	SoilGrids1km	Hengl et al. 2014	slt_pc_---	x2
S03	Soils & Geology	Sand Fraction in Soil	SoilGrids1km	Hengl et al. 2014	snd_pc_---	x2
S04	Soils & Geology	Organic Carbon Content in Soil	SoilGrids1km	Hengl et al. 2014	soc_th_---	x2
S05	Soils & Geology	Soil Water Content	Global Soil-Water Balance	Trabucco & Zomer 2010	swc_pc_---	x14
S07	Soils & Geology	Karst Area Extent	Rock Outcrops v3.0	Williams & Ford 2006	kar_pc_---	x2
S08	Soils & Geology	Soil Erosion	GloSEM v1.2	Borrelli et al. 2017	ero_kh_---	x2
A01	Anthropogenic	Population Count	GPW v4	CIESIN 2016	pop_ct_---	x2
A02	Anthropogenic	Population Density	GPW v4	CIESIN 2016	ppd_pk_---	x2
A03	Anthropogenic	Urban Extent	GHS S-MOD v1.0 (2016)	Pesaresi & Freire 2016	urb_pc_---	x2
A04	Anthropogenic	Nighttime Lights	Nighttime Lights v4	Doll 2008	nli_ix_---	x2
A06	Anthropogenic	Human Footprint	Human Footprint v2	Venter et al. 2016	hft_ix_---	x4
Z01	Zambia	Major Catchments	WRPA Assessment	WWF-Zambia et al. 2019	cat_id_---	x1
Z02	Zambia	Dam Count	WRPA Assessment	WWF-Zambia et al. 2019	dam_ct_---	x1
Z03	Zambia	Waterfall Count	WRPA Assessment	WWF-Zambia et al. 2019	wfa_ct_---	x1
Z04	Zambia	Hotspring Presence	WRPA Assessment	WWF-Zambia et al. 2019	hsp_bi_---	x1
Z05	Zambia	Important Bird Areas	IBA Assessment	Leonard 2005	iba_pc_---	x1
Z06	Zambia	High Amphibian Richness	IUCN Species Data	Darwall et al. 2011	amp_bi_---	x1
Z07	Zambia	High Crab Richness	IUCN Species Data	Darwall et al. 2011	crb_bi_---	x1
Z08	Zambia	High Fish Richness	IUCN Species Data	Darwall et al. 2011	fsh_bi_---	x1
Z09	Zambia	High Mollusc Richness	IUCN Species Data	Darwall et al. 2011	mol_bi_---	x1
Z10	Zambia	High Odonatan Richness	IUCN Species Data	Darwall et al. 2011	odo_bi_---	x1
Z11	Zambia	Aquatic Species Extent	IUCN Red List	IUCN 2018	spc_pc_---	x42
	Total	**Variables: 51**			**Attributes:**	**259**