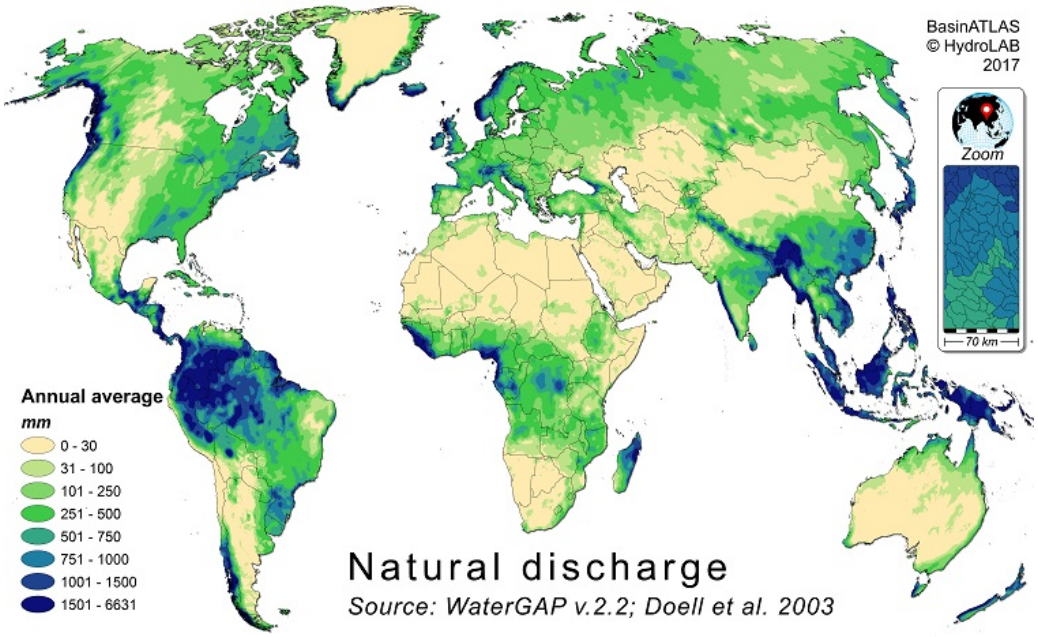
HydroATLAS

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

Technical Documentation Version 0.1

prepared by Bernhard Lehner
(bernhard.lehner@mcgill.ca)

March, 2018



1. Background and introduction

The goal of HydroATLAS is to provide a broad user community with a standardized compendium of hydro-environmental attribute information for all watersheds and rivers of the world at high spatial resolution. Version 0.1 of HydroATLAS offers a set of 70 attributes organized in seven categories: hydrology; physiography; climate; land cover; geology; soils; and demographics (Table 1 and Appendix 1). HydroATLAS derives the hydro-environmental attributes by reformatting original data from well-established global digital maps. The attributes are then linked to hierarchically

nested sub-basins at multiple scales, as well as to individual river reaches, both extracted from the global HydroSHEDS database at 15 arc-second (~500 m) resolution. The sub-basin and river reach information is offered in two companion datasets: BasinATLAS and StreamATLAS. The standardized format of HydroATLAS ensures easy applicability while the inherent topological information supports basic network functionality such as identifying up- and downstream connections. HydroATLAS is fully compatible with other products of the overarching HydroSHEDS project enabling versatile hydro-ecological assessments. Updates of HydroATLAS are envisioned as new data become available.

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

The development of HydroATLAS is fully described in Linke et al. (2018). General citations of HydroATLAS should refer to:

Linke, S., Lehner, B., Ouellet Dallaire, C., Ariwi, J., Grill, G., Beames, P., Thieme, M. (2018): HydroATLAS: A global compendium of hydro-environmental sub-basin and river reach characteristics. Under review. Data available at http://www.hydrosheds.org.

Table1. Categories of hydro-environmental attributes presented in the HydroATLAS database

Identifier	Category	Description
H	Hydrology	Hydrological and hydrographic characteristics related to quantity, quality, location and extent of terrestrial water *Examples: natural runoff and discharge, groundwater table depth, lake cover*
P	Physiography	Topographic characteristics related to terrain, relief or landscape position *Examples: elevation, slope*
C	Climate	Climatic characteristics *Examples: mean temperature, climate moisture index, global aridity*
L	Land Cover	Land cover and land use characteristics including biogeographic regions *Examples: land cover classes, permafrost extent, freshwater ecoregions*
G	Geology	Geological characteristics *Examples: lithography, karst*
S	Soils	Soil-related characteristics including substrate types and soil conditions *Examples: percentage clay in soil, organic carbon content in soil, soil water stress*
D	Demographics	Demographic characteristics including anthropogenic and socioeconomic aspects *Examples: population density, human footprint, GDP per capita*

2. Methods and data characteristics

The methods used to create HydroATLAS are fully described in Linke et al. (2018). 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 please refer to the Technical Documentations of HydroSHEDS at http://www.hydrosheds.org.

HydroATLAS consists of two complementary parts: BasinATLAS and StreamATLAS. BasinATLAS provides hydro-environmental attributes for sub-basins (polygons). StreamATLAS provides hydro-environmental attributes for stream reaches (line segments).

Basin and sub-basin delineations have been pre-processed as a customized derivative of HydroSHEDS at 15 arc-second resolution and are available as a stand-alone product termed HydroBASINS (Lehner and Grill 2013). HydroBASINS offer a suite of 12 layers, each containing nested sub-basins that were subdivided and coded using the topological concept of the Pfafstetter system, which provides a methodology for the breakdown of sub-basins at different scales in a hierarchical and systematic manner (Figure 1a).

A global stream network delineation has been extracted from HydroSHEDS at 15 arc-second resolution and is available as a stand-alone product termed HydroSTREAMS (available at http://www.hydrosheds.org). For this network, streams have been defined to start at all pixels where the accumulated upstream catchment area exceeds 50 km², or where the long-term average natural discharge exceeds 0.1 cubic meters per second, resulting in a line network consisting of individual stream and river reaches (Figure 1b).

It should be noted that the quality of HydroSHEDS data is significantly inferior for regions above 60 degrees northern latitude as there is no underlying SRTM elevation data available and thus a coarser scale DEM has been inserted (HYDRO1k provided by USGS).

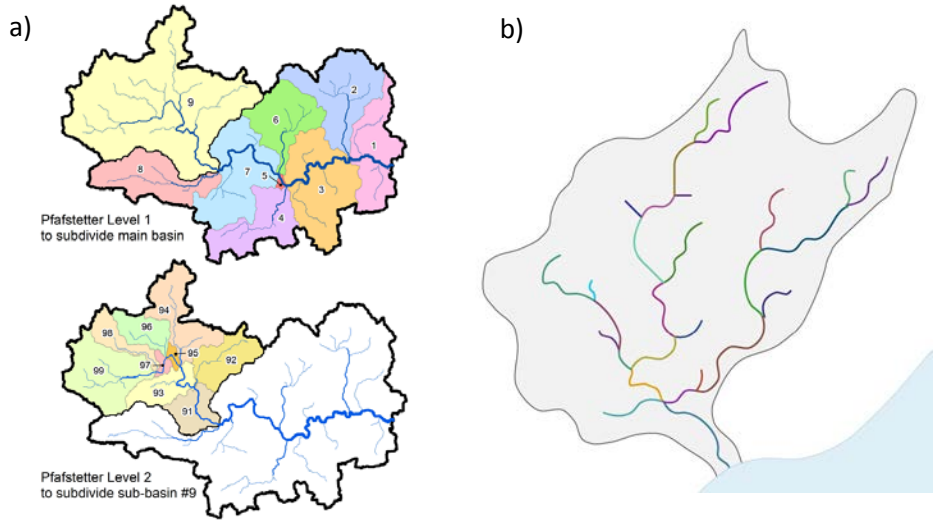


Figure 1: Overview of Pfafstetter sub-basin coding scheme used in BasinATLAS (a); and stream reach concept used in StreamATLAS (b). Sub-basins are nested within 12 hierarchical levels. A stream reach is defined as a stretch between two tributaries, or between the start/end of the network and a tributary.

3. Data format and distribution

a) Data format and projection

HydroATLAS is publicly available for download at http://www.hydrosheds.org. All map data layers, including attribute tables, are provided in ESRI© Geodatabase and Shapefile formats. The data is projected in a Geographic Coordinate System using the World Geodetic System 1984 (GCS_WGS_1984). The attribute table can also be accessed as a stand-alone file in dBASE format which is included in the Shapefile format.

HydroATLAS data is 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 Technical Documentation.

b) Available columns and column name syntax

The attribute tables of HydroATLAS contain the pre-existing columns of HydroBASINS and HydroSTREAMS, respectively. The hydro-environmental attributes are then appended in a series of additional columns. This section provides information on the column name syntax used for the identification of each sub-basin or stream reach attribute provided in the HydroATLAS database. All existing attributes and their associated column names are summarized in Appendix 1 and at the beginning of the individual documents BasinATLAS_Catalog or StreamATLAS_Catalog.

Each hydro-environmental attribute column name has 10 digits (for example '*dis_m3_s01*') and its syntax is as follows:

<Layer name key>_<Unit key>_<Spatial key>< Aggregation 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 value units of the attribute. See Table 2 for possible keys.

Spatial key:
One digit that describes the spatial extent of the attribute. See Table 3 for possible keys.

Aggregation key:
Two digits that describe the type or dimension of aggregation of the attribute. The aggregation key can refer to a temporal dimension, spatial dimension, or statistical dimension. See Table 4 for possible keys.

Table 2: Unit keys

Key	Unit of values
cl	Classes
dc	Degrees Celsius (°C)
dg	Degrees
ha	Hectares
id	ID number
ix	Index value
km	Kilometers
m3	Cubic meters per second (m^3/s)
mc	Million cubic meters (mcm)
mm	Millimeters
mt	Meters *or* Meters above sea level (m.a.s.l.)
pc	Percent *or* Percent cover
pd	Population density (people per km^2)
pp	People count
sk	Square kilometers
th	Tonnes per hectare
ud	US dollars

Table 3: Spatial keys

Key	Spatial representation
c	In reach catchment *or* Mean of reach catchment
p	At sub-basin pour point *or* At reach pour point
r	Along reach segment
s	In sub-basin *or* Mean of sub-basin
u	In total watershed upstream of sub-basin pour point *or* Mean of total watershed upstream of sub-basin pour point *or* In total watershed upstream of reach pour point *or* Mean of total watershed upstream of reach pour point

Table 4: Aggregation keys

Key	Temporal, Spatial, or Statistical Dimension
01-12	Monthly average (number represents calendar month January to December)
01-99	Spatial extent (%) by class
av	Average
g1-g9	Spatial extent (%) by class grouping
lt	Long-term maximum
mj	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 and citations

a) License agreement

The geometric information of HydroATLAS is covered by the same License Agreement as the HydroSHEDS database, which is available at http://www.hydrosheds.org. For all regulations regarding license grants, copyright, redistribution restrictions, required attributions, disclaimer of warranty, indemnification, liability, waiver of damages, and a precise definition of licensed materials, please refer to the HydroSHEDS License Agreement. By downloading and using the data the user agrees to the terms and conditions of the License Agreement.

In addition, every data source used in the creation of hydro-environmental attribute columns contained in HydroATLAS is governed by its own individual license agreement, and users of HydroATLAS are obliged to honor those licenses when using the respective attributes (more details regarding individual licenses are provided on the individual attribute sheets in BasinATLAS_Catalog and StreamATLAS_Catalog).

b) Acknowledgement and citations

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

> "*Precipitation data from the WorldClim database (Hijmans et al. 2005) has been used in the spatial format as provided by HydroATLAS (Linke et al. 2018).*"

Information regarding the reference(s) for each hydro-environmental attribute is provided on the individual attribute sheets in BasinATLAS_Catalog and StreamATLAS_Catalog. Citations and acknowledgements of HydroATLAS should be made as follows:

> *Linke, S., Lehner, B., Ouellet Dallaire, C., Ariwi, J., Grill, G., Beames, P., Thieme, M. (2018): HydroATLAS: A global compendium of hydro-environmental sub-basin and river reach charcteristics. Under review. Data available at http://www.hydrosheds.org.*

We kindly ask users to cite HydroATLAS in any published material produced using the data. If possible, online links to the HydroSHEDS website (http://www.hydrosheds.org) should be provided.

If users rely on HydroATLAS as the main data source for their studies, or if their findings depend on the HydroATLAS database in a fundamental way, it is requested that for scientific publications an offer of co-authorship is extended to the creators of HydroATLAS.

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.

Lehner, B., Verdin, K., Jarvis, A. (2008): New global hydrography derived from spaceborne elevation data. Eos, Transactions, AGU, 89(10): 93-94.

Linke, S., Lehner, B., Ouellet Dallaire, C., Ariwi, J., Grill, G., Beames, P., Thieme, M. (2018): HydroATLAS: A global compendium of hydro-environmental sub-basin and river reach characteristics. Under review. Data available at http://www.hydrosheds.org.

Appendix 1: Attributes included in current version 0.1 of HydroATLAS

HydroATLAS Attributes (Version 0.1)

ID	Category	Attribute	Source Data	Citation	Column(s)	#s
H01	Hydrology	Natural Discharge	WaterGAP v.2.2	Döll et al. 2003	dis_m3_---	x1
H02	Hydrology	Land Surface Runoff	WaterGAP v.2.2	Döll et al. 2003	run_mm_---	x1
H03	Hydrology	Inundation Extent	GIEMS-D15	Fluet-Chouinard et al. 2015	inu_pc_---	x2
H04	Hydrology	River Reach Volume	HydroSHEDS & WaterGAP	Lehner & Grill 2013	riv_mc_---	x1
H05	Hydrology	River Length Upstream	HydroSHEDS	Lehner et al. 2008	rlu_km_---	x1
H06	Hydrology	River Length Downstream	HydroSHEDS	Lehner et al. 2008	rld_km_---	x1
H07	Hydrology	Groundwater Table Depth	Global Groundwater Map	Fan et al. 2013	gwt_mt_---	x1
P01	Physiography	Elevation	EarthEnv-DEM90	Robinson et al. 2014	ele_mt_---	x1
P02	Physiography	Terrain Slope	EarthEnv-DEM90	Robinson et al. 2014	slp_dg_---	x2
C01	Climate	Climate Zones	GEnS	Metzger et al. 2013	clz_cl_---	x1
C02	Climate	Air Temperature	WorldClim	Hijmans et al. 2005	tmp_dc_---	x1
C03	Climate	Precipitation	WorldClim	Hijmans et al. 2005	pre_mm_---	x2
C04	Climate	Potential Evapotranspiration	Global-PET	Zomer et al. 2007 & 2008	pet_mm_---	x2
C05	Climate	Actual Evapotranspiration	Global Soil-Water Balance	Zomer et al. 2007 & 2008	aet_mm_---	x2
C06	Climate	Global Aridity Index	Global Aridity Index	Zomer et al. 2007 & 2008	ari_ix_---	x2
C07	Climate	Climate Moisture Index	WorldClim & Global-PET	Willmott & Feddema 1992	cmi_ix_---	x1
C08	Climate	Snow Cover Extent	MODIS/Aqua	Hall et al. 2007	snw_pc_---	x3
L01	Landcover	Land Cover Classes	GLC2000	Bartholomé & Belward 2005	glc_cl_---	x1
L02	Landcover	Land Cover Extent	GLC2000	Bartholomé & Belward 2005	glc_pc_---	x2
L03	Landcover	Potential Natural Vegetation Classes	EarthStat	Ramankutty & Foley 1999	pnv_cl_---	x1
L04	Landcover	Wetland Classes	GLWD	Lehner & Döll 2004	wet_cl_---	x1
L05	Landcover	Wetland Extent	GLWD	Lehner & Döll 2004	wet_pc_---	x4
L06	Landcover	Cropland Extent	EarthStat	Ramankutty et al. 2008	crp_pc_---	x2
L07	Landcover	Pasture Extent	EarthStat	Ramankutty et al. 2008	pst_pc_---	x2
L08	Landcover	Irrigated Area Extent	GMIA	Siebert et al. 2013	ire_pc_---	x1
L09	Landcover	Glacier Extent	GLIMS	GLIMS & NSIDC 2012	gla_pc_---	x2
L10	Landcover	Permafrost Extent	PZI	Gruber 2012	prm_pc_---	x2
L11	Landcover	Protected Area Extent	WDPA	UNEP & IUCN 2014	pac_pc_---	x2
L12	Landcover	Terrestrial Biomes	TEOW	Olson et al. 2001	tbi_cl_---	x1
L13	Landcover	Terrestrial Ecoregions	TEOW	Olson et al. 2001	tec_cl_---	x1
L14	Landcover	Freshwater Major Habitat Types	FEOW	Abell et al. 2008	fmh_cl_---	x1
L15	Landcover	Freshwater Ecoregions	FEOW	Abell et al. 2008	fec_cl_---	x1
G01	Geology	Lithological Classes	GLiM	Hartmann & Moosdorf 2012	lit_cl_---	x1
G02	Geology	Karst Area Extent	Rock Outcrops v.3.0	Ford & Williams 2007	krs_pc_---	x2
S01	Soils	Clay Fraction in Soil	SoilGrids1km	Hengl et al. 2014	cly_pc_---	x1
S02	Soils	Sand Fraction in Soil	SoilGrids1km	Hengl et al. 2014	snd_pc_---	x1
S03	Soils	Silt Fraction in Soil	SoilGrids1km	Hengl et al. 2014	slt_pc_---	x1
S04	Soils	Organic Carbon Content in Soil	SoilGrids1km	Hengl et al. 2014	soc_th_---	x1
S05	Soils	Soil Water Content	Global Soil-Water Balance	Trabucco & Zomer 2010	swc_pc_---	x2
D01	Demography	Population Count	GPW v.4	CIESIN 2016	gpw_pp_---	x1
D02	Demography	Population Density	GPW v.4	CIESIN 2016	gpw_pd_---	x1
D03	Demography	Urban Extent	GRUMP v.1	CIESIN 2011	ubx_pc_---	x2
D04	Demography	Nighttime Lights	Nighttime Lights v.4	Doll 2008	nli_ix_---	x2
D05	Demography	Road Density	gROADS v.1	CIESIN 2013	rdd_pc_---	x1
D06	Demography	Human Footprint	Human Footprint v.2	WCS & CIESIN 2005	hft_ix_---	x2
D07	Demography	Global Administrative Boundaries	GADM	University of Berkley 2012	gam_id_---	x1
D08	Demography	GDP per Capita	World Bank	World Bank 2017	gdp_ud_---	x1
D09	Demography	GINI Index	World Bank	World Bank 2017	gni_ix_---	x1