WORLD RESOURCES INSTITUTE

Working Paper

AQUEDUCT METADATA DOCUMENT

YELLOW RIVER BASIN STUDY

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EXECUTIVE SUMMARY

Prior to the creation of the global Aqueduct Water Risk Atlas indicators (Table 1) were developed and tested in a number of river basins worldwide. The results of these Basin Studies helped inform and shape the global Aqueduct Water Risk Framework. Complete guidelines and processes for indicator selection, data collection, calculations, and mapping techniques are described in the Aqueduct Water Risk Framework.[1] This study focuses on the specific characteristics of the indicator data and calculation in the Yellow River Basin (YRB).

Table 1 | **Aqueduct Indicators**

Baseline water stress	Drought severity	Upstream protected land
Inter-annual variability	Upstream storage	Media coverage
Seasonal variability	Return flow ratio	Access to water
Flood occurrence	Water quality (3 indicators)	Threatened amphibians

The data selection and validation process for the Yellow River Basin Study involved three steps: (1) a literature review, (2) identification of data sources in the public domain, and (3) the compilation and expert review of the selected data sources. Calculation of 6 of the 14 indicators required the creation of original datasets to estimate water availability and use at a sub-basin scale. The hydrological catchments used in the exercise were extracted from the Global Drainage Basin Database (GDBD) developed by Masutomi et al.[2] Computation of the original datasets was completed by ISciences, L.L.C.

CONTENTS

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Two measures of water use were used in the study: *total withdrawal*, the total amount of water abstracted from freshwater sources for human use, and consumptive use, the portion of withdrawn water consumed through evaporation or incorporation into a product thus no longer available for downstream use. Annual total water withdrawal by sector and province is reported in the 2009 *Yellow River Water Resources Bulletin*. Consumptive water use is derived from the provincial consumptive use ratio from the 2009 *Yellow River Water Resources Bulletin*. Both the withdrawals and consumptive use are coded at the hydrological catchment scale.

Two metrics of water supply are computed: *total blue water* and *available blue water*. Total blue water approximates natural river discharge and does not attempt to account for withdrawals or consumptive use. Available blue water is an estimate of surface water availability minus upstream consumptive use. Modeled estimates of water supply are calculated using a catchment-to-catchment flow accumulation approach developed by ISciences, L.L.C., which aggregates water by catchment and transports it to the next downstream catchment. Water supply is computed from runoff (R), which is the water available to flow across the landscape from a particular location and is calculated as the remainder of precipitation (P) after evapotranspiration (ET) and change in soil moisture storage (ΔS) are accounted for (i.e., $R = P - ET - \Delta S$). The runoff data is courtesy of National Oceanic and Atmospheric Administration (NOAA) and obtained from their Climate Forecast System Reanalysis (CFSR)[3] for generating runoff values by GDBD for the years from 1979 to 2009.

The remainder of this document contains the definitions, formulas, and data sources for the Yellow River Basin Study.

TOTAL WITHDRAWAL

Description: *Total withdrawal* is the total amount of water removed from freshwater sources for human use.

Calculation: Water withdrawal data by sector and province are spatially disaggregated by sector based on regressions with spatial datasets selected to maximize the correlation with the reported withdrawals (irrigated areas for agricultural, nighttime lights for industrial, population for domestic withdrawals, and gridded domestic and industrial water use data).

Data Sources

VARIABLE	PROVINCIAL BOUNDARIES
Author	National Geospatial Intelligence Agency
Title	VMAP0 (rev. 5)
URL	http://earth-info.nga.mil/publications/vmap0.html
Resolution	Province

VARIABLE	BASIN DELINEATIONS
Authors	Yuji Masutomi, Yusuke Inui, Kiyoshi Takahashi, and Yuzuru Matsuoka
Title	Development of Highly Accurate Global Polygonal Drainage Basin Data
Year of publication	2009
URL	http://www.cger.nies.go.jp/db/gdbd/gdbd_index_e.html
Resolution	1 sq.km.
Comments	The Yangtze River Basin hydrological catchments are extracted from the Global Drainage Basin Database.

VARIABLE	GRIDDED POPULATION
Authors	Center for International Earth Science Information Network (CIESIN), Columbia University, and Centro Internacional de Agricultura Tropical (CIAT)
Title	Gridded Population of the World, Version 3 (GPWv3): Population Density Grid, Future Estimates, v3 (2005,2010,2015)
Year of publication	2005
Time covered in analysis	2005
URL	http://sedac.ciesin.columbia.edu/data/set/gpw-v3-population-density-future-estimates
Resolution	2.5 arc minute raster

VARIABLE	NIGHTTIME LIGHTS
Author	NOAA National Geophysical Data Center (NGDC)
Title	Version 4 DMSP-OLS Nighttime Lights Time Series
Year of publication	2010
Time covered in analysis	2000
URL	http://www.ngdc.noaa.gov/dmsp/downloadV4composites.html
Resolution	30 arc second raster

VARIABLE	GLOBAL IRRIGATION AREAS
Authors	S. Siebert, P. Döll, S. Feick, J. Hoogeveen, and K. Frenken
Title	Global Map of Irrigation Areas Version 4.0.1
Year of publication	2007
Time covered in analysis	2000
URL	http://www.fao.org/nr/water/aquastat/irrigationmap/index60.stm
Resolution	5 arc minute raster

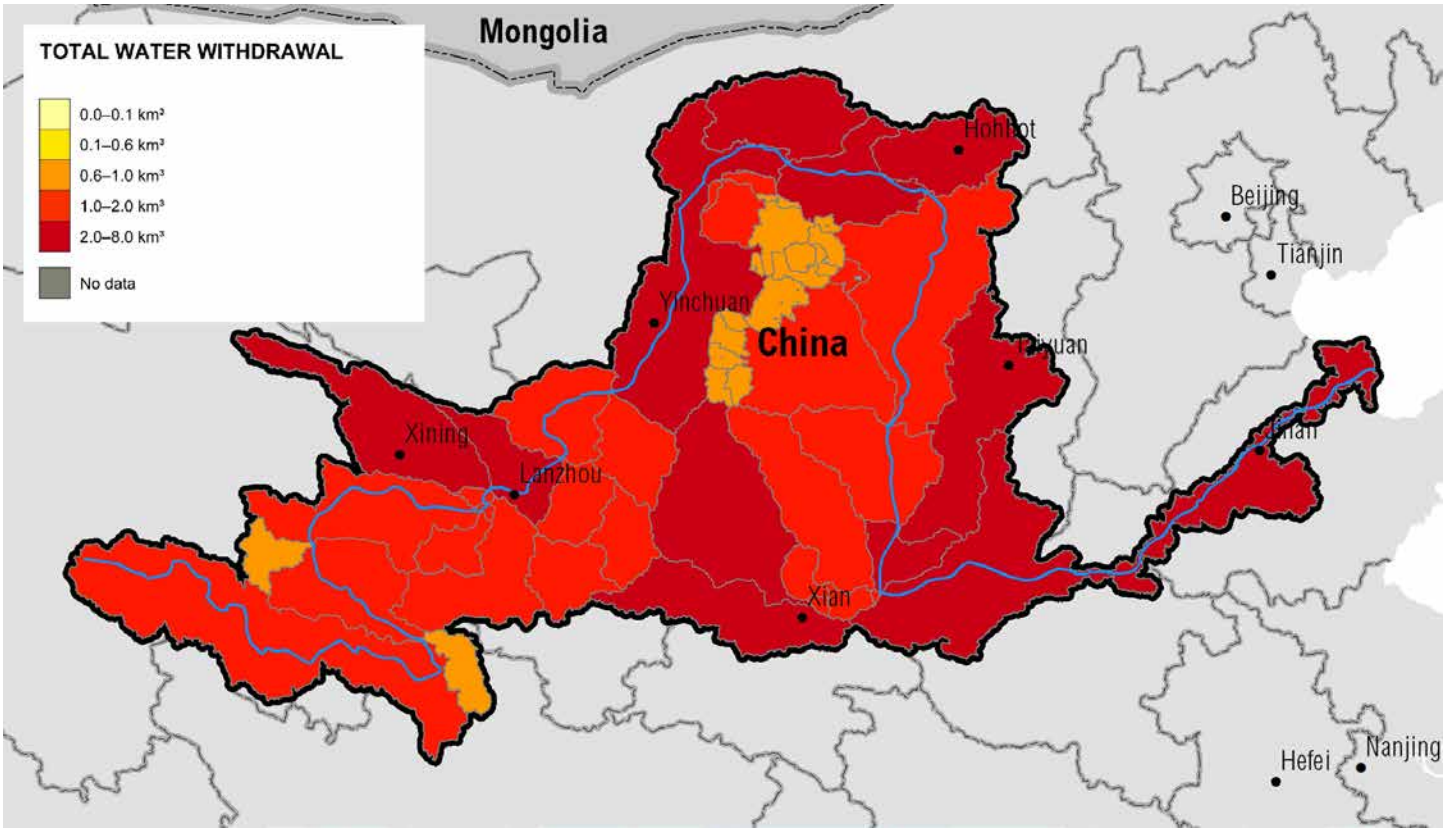
VARIABLE	WITHDRAWALS BY SECTOR AND PROVINCE
Author	Yellow River Conservancy Commission of Ministry of Water Resources of China
Title	Yellow River Water Resources Bulletin 2009
Year of publication	2010
Time covered in analysis	2009
URL	http://www.yellowriver.gov.cn/other/hhgb/2009/2009.html
Resolution	Province and sub-basin

TOTAL WITHDRAWAL, CONTINUED

Data Sources

VARIABLE	WATER WITHDRAWALS
Author	Chinese Academy of Sciences
Title	National Gridded Water Resources Dataset
Year of publication	2000
Time covered in analysis	2000
Resolution	1 km raster

Total Withdrawal



CONSUMPTIVE AND NON-CONSUMPTIVE USE

Description: *Consumptive use* is the portion of all water withdrawn that is consumed through evaporation or incorporation into a product, thus is no longer available for reuse. *Non-consumptive use* is the remainder of withdrawals that are not consumed and return to ground or surface water bodies.

Calculation: Consumptive use by sector is estimated from total withdrawal using consumptive use ratios reported in the *Yellow River Water Resources Bulletin 2009*.

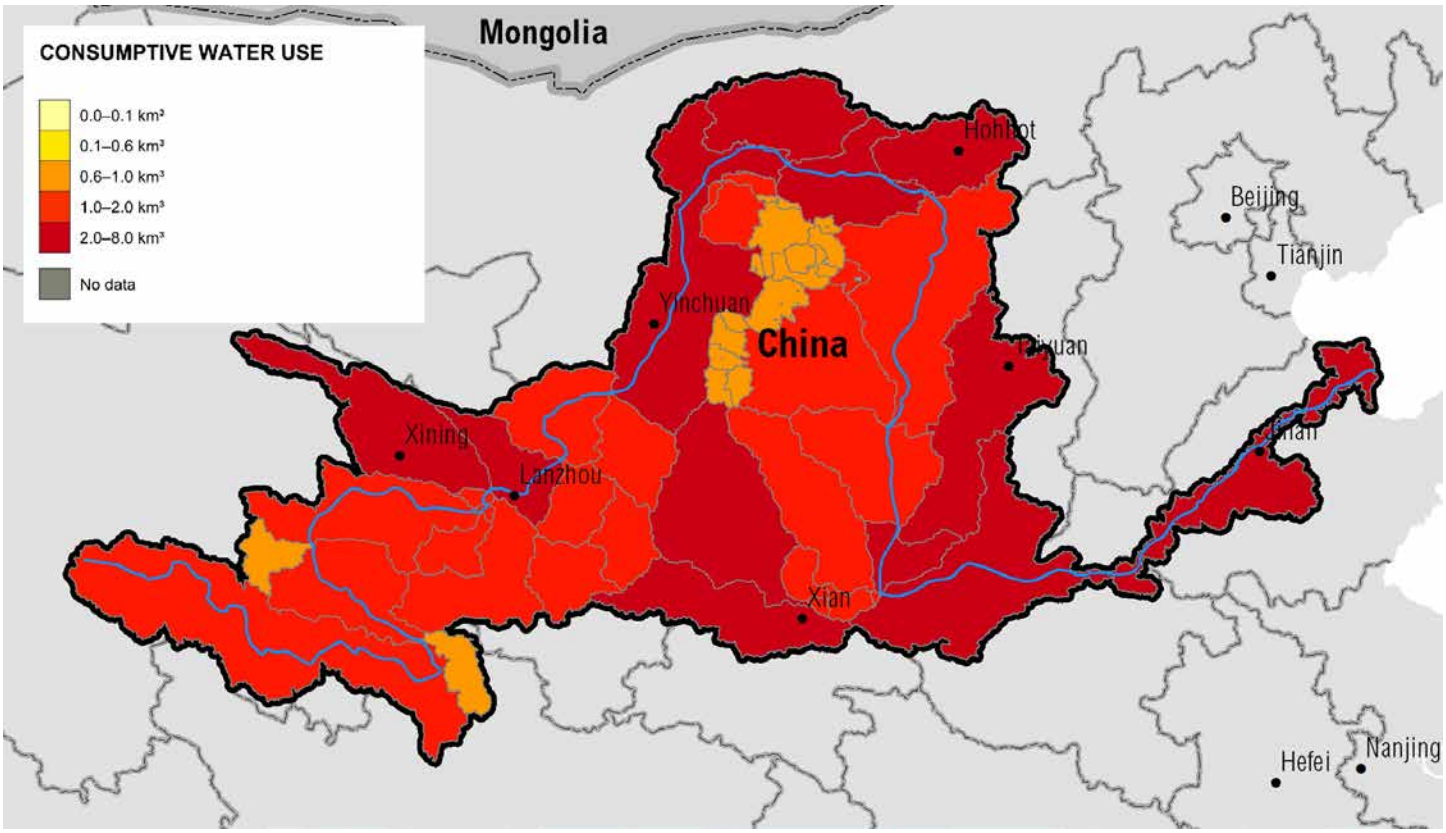
Data Sources

VARIABLE	WITHDRAWALS
Comments	See Total Withdrawal

Data Sources

VARIABLE	CONSUMPTIVE USE RATIOS
Author	Yellow River Conservancy Commission of Ministry of Water Resources of China
Title	Yellow River Water Resources Bulletin 2009
Year of publication	2010
Time covered in analysis	2009
URL	http://www.yellowriver.gov.cn/other/hhgb/2009/2009.html
Resolution	Province and sub-basin

Consumptive and Non-Consumptive Use



TOTAL BLUE WATER (Bt)

Description: *Total blue water (Bt)* for each catchment is the accumulated runoff upstream of the catchment plus the runoff in the catchment.

Calculation: $Bt(i) = R_{up}(i) + R(i)$ where $R_{up}(i) = \sum Bt(i_{up})$, *iup* is the set of catchments immediately upstream of catchment *i* that flow into catchment *i*, and $R_{up}(i)$ is the summed runoff in all upstream catchments. For first-order catchments (those without upstream catchments, e.g., headwater catchments), $R_{up}(i)$ is zero, and total blue water is simply the volume of runoff in the catchment.

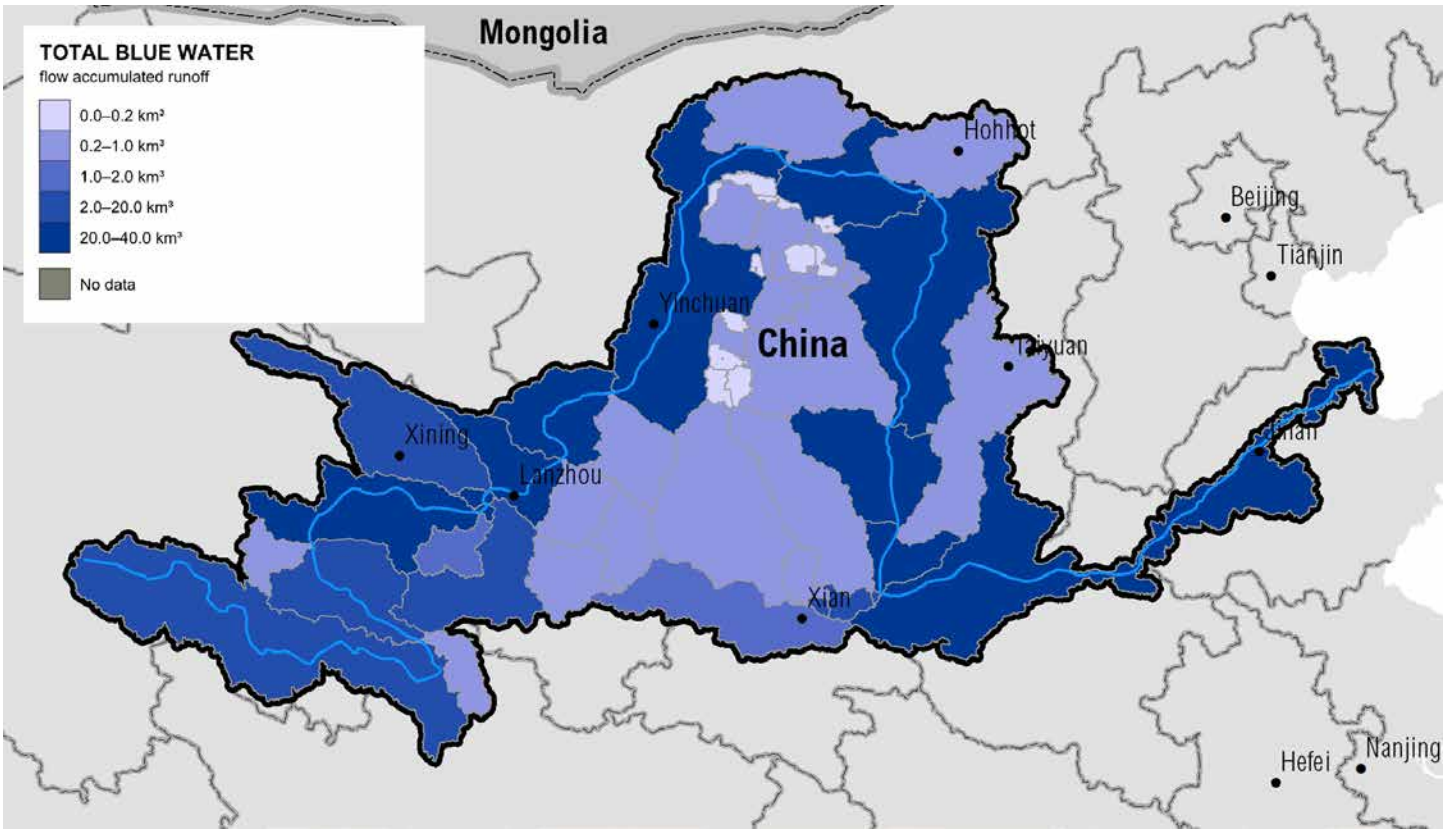
Data Sources

VARIABLE	BASIN DELINEATIONS
Comments	See Total Withdrawal

Data Sources

VARIABLE	RUNOFF
Author	National Centers for Environmental Prediction (NCEP)
Title	The NCEP Climate Forecast System Reanalysis
Year of publication	2010
Time covered in analysis	1979–2009
URL	http://cfs.ncep.noaa.gov/cfsr/
Resolution	38km

Total Blue Water



AVAILABLE BLUE WATER (Ba)

Description: *Available blue water (Ba)* is the total amount of water available to a catchment before any uses are satisfied. It is calculated as all water flowing into the catchment from upstream catchments minus upstream consumptive use plus runoff in the catchment.

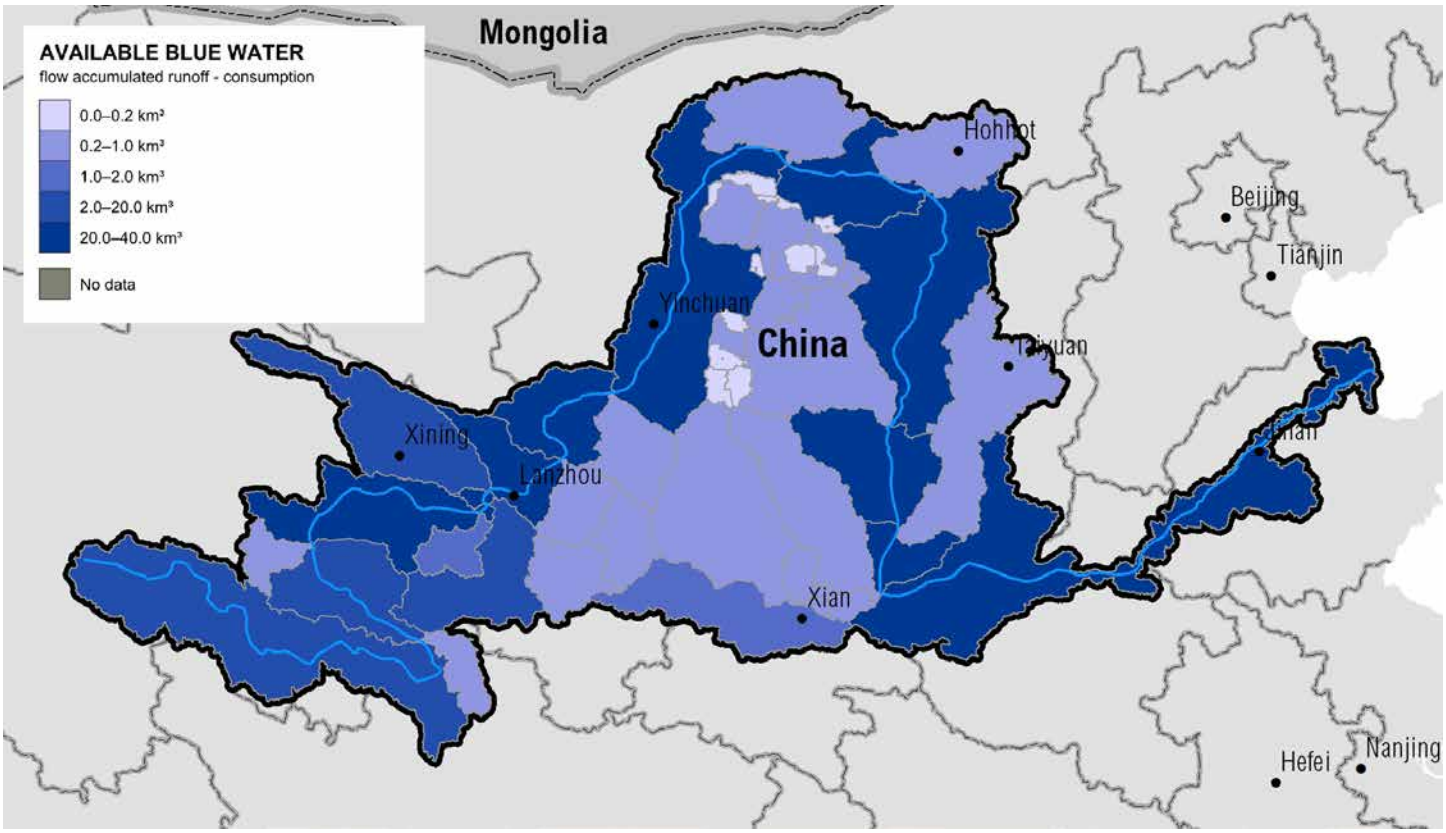
Calculation: $Ba(i) = R(i) + \sum Q_{out}(i_{up})$ where Q_{out} is defined as the volume of water exiting a catchment to its downstream neighbor: $Q_{out}(i) = \max(o, Ba(i) - Uc(i))$, $Uc(i)$ are the consumptive uses in from catchment i. Negative values of Q_{out} are set to zero. In first-order catchments $\sum Q_{out}(j)$ is zero, so available blue water is runoff plus imports.

Data Sources

VARIABLE	RUNOFF
Comments	See Total Blue Water

VARIABLE	CONSUMPTIVE USE
Comments	See Consumptive and Non-consumptive Use

Available Blue Water



BASELINE WATER STRESS

Description: *Baseline water stress* measures total annual water withdrawals (municipal, industrial, and agricultural) expressed as a percentage of the total annual available blue water. Higher values indicate more competition among users.

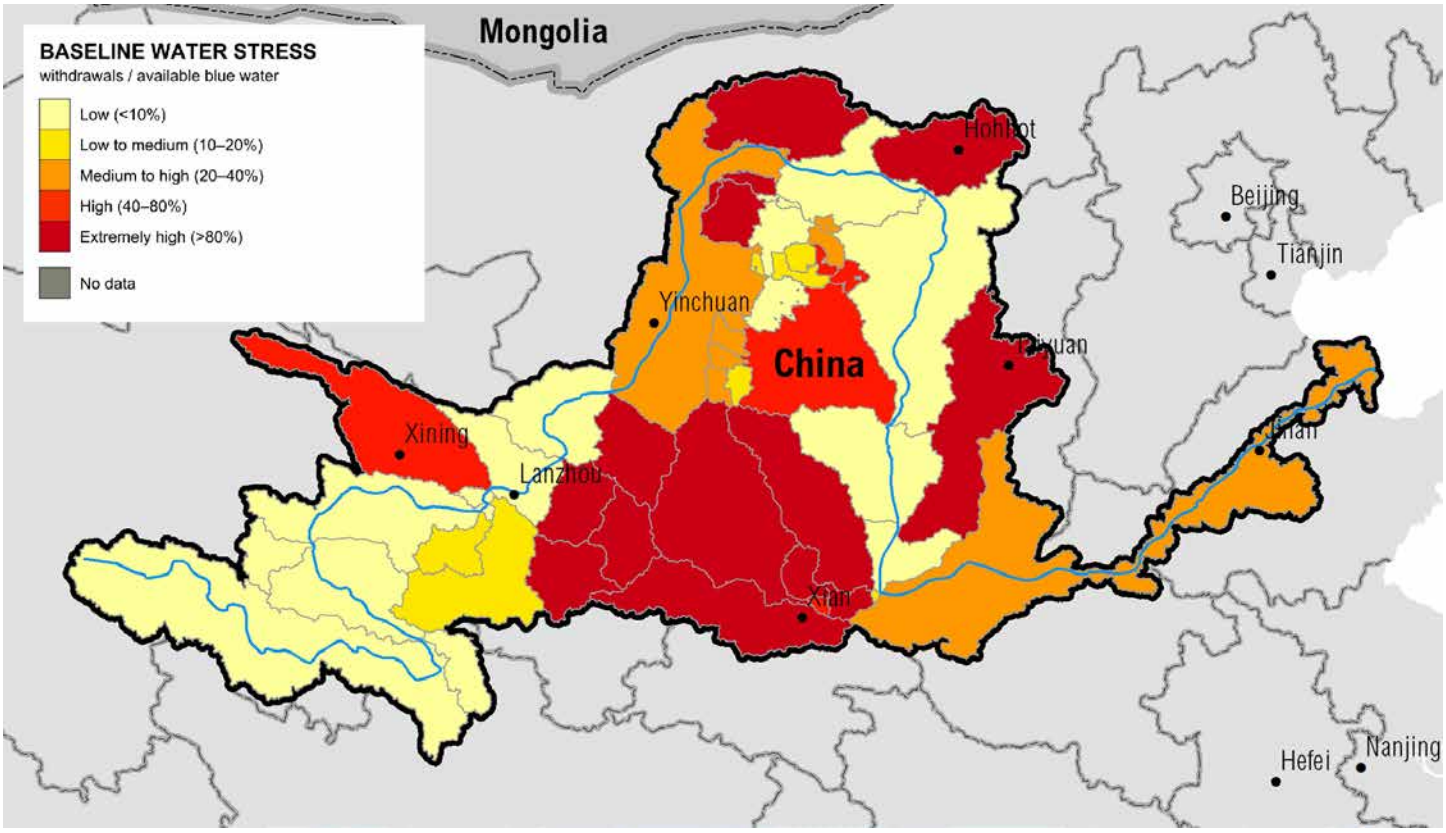
Calculation: Annual water withdrawals (2009) divided by the mean of available blue water (1979–2009). Areas with available blue water and water withdrawal equal to zero are coded as missing data.

Data Sources

VARIABLE	WITHDRAWALS
Comments	See Total Withdrawal

VARIABLE	AVAILABLE BLUE WATER
Comments	See Available Blue Water

Baseline Water Stress



INTER-ANNUAL VARIABILITY

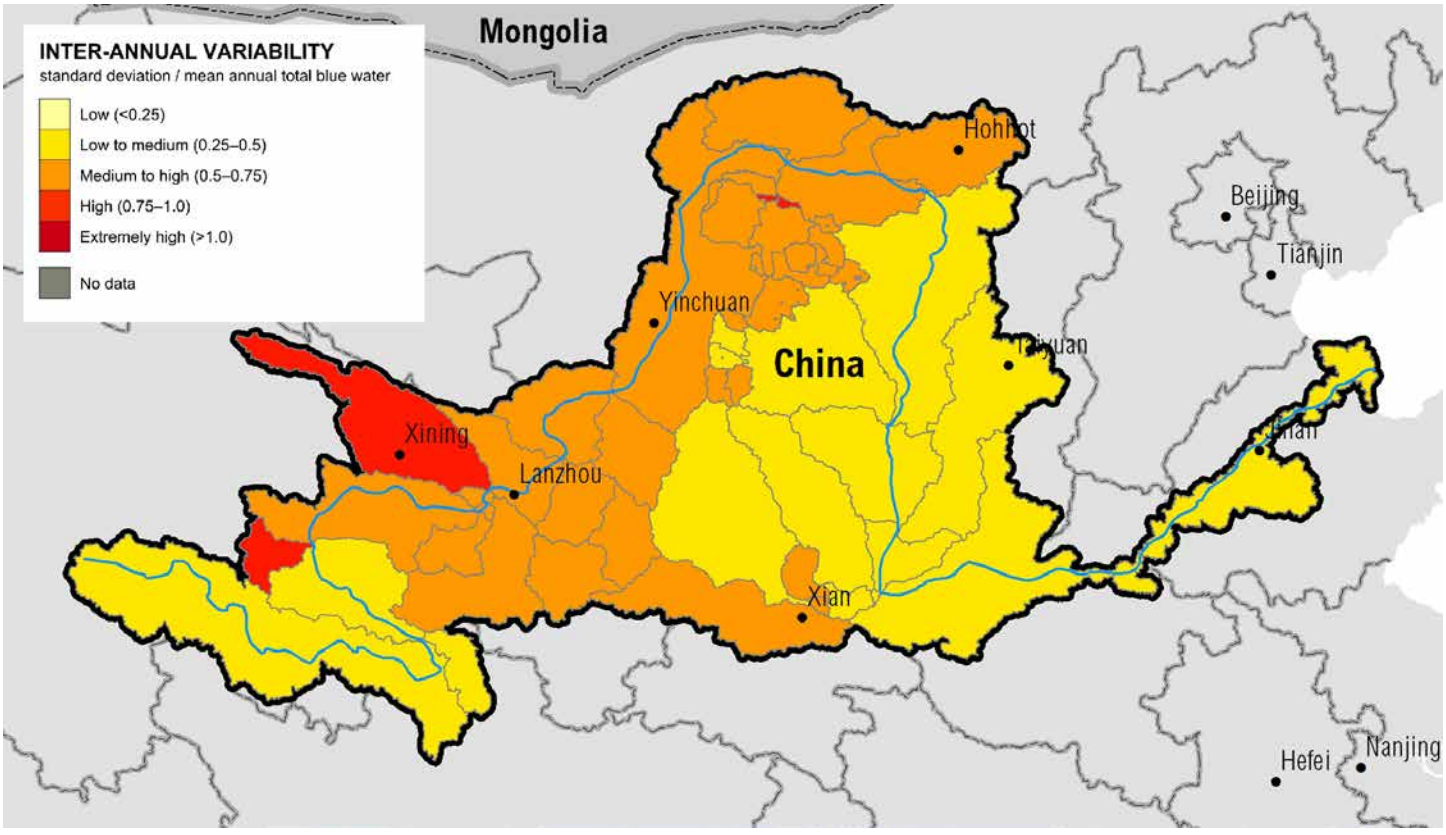
Description: *Inter-annual variability* measures the variation in water supply between years.

Calculation: Standard deviation divided by the mean of annual total blue water (1979-2009).

Data Sources

VARIABLE	TOTAL BLUE WATER
Comments	See Total Blue Water

Inter-annual Variability



SEASONAL VARIABILITY

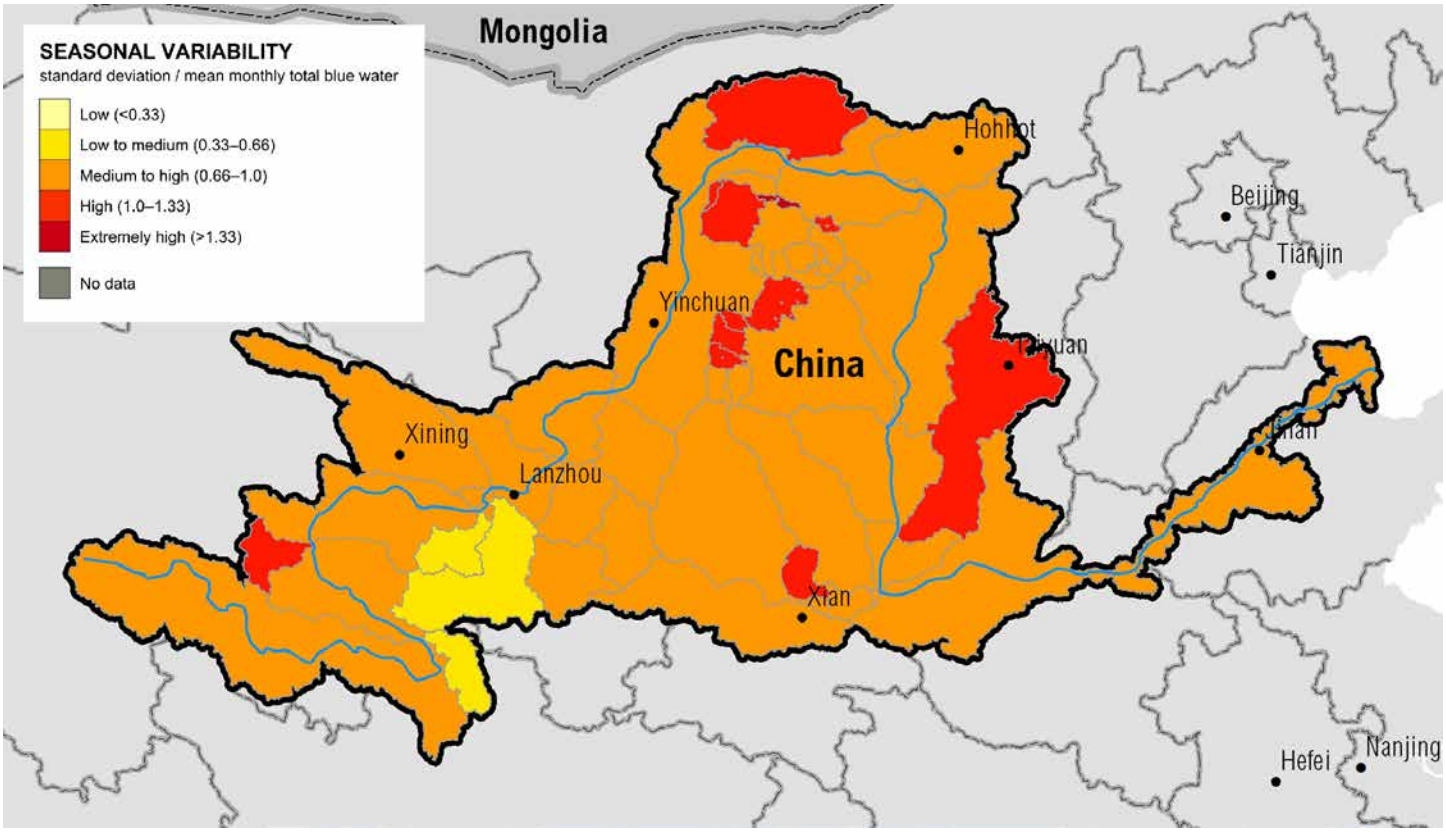
Description: *Seasonal variability* measures variation in water supply between months of the year.

Calculation: Standard deviation divided by the mean of monthly total blue water (1979-2009). Mean monthly total blue water for each of the 12 months is first calculated, then the variance is estimated between the mean monthly values.

Data Sources

VARIABLE	TOTAL BLUE WATER
Comments	See Total Blue Water

Seasonal Variability



FLOOD OCCURRENCE

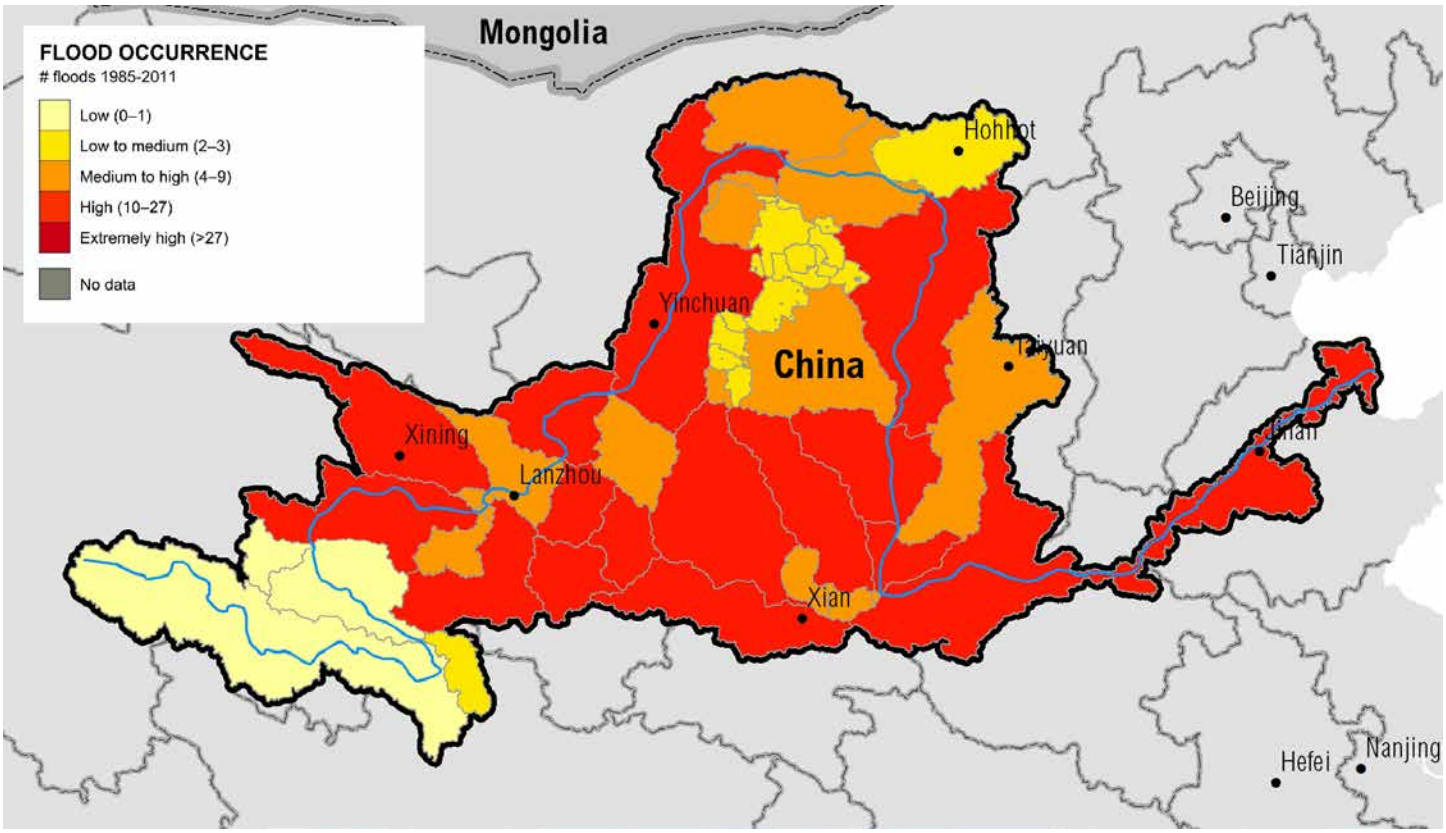
Description: *Flood occurrence* is the number of floods recorded from 1985 to 2011.

Calculation: Number of flood occurrences (1985-2011). Flood counts were calculated by intersecting hydrological units with estimated flood extent polygons. Only floods whose extent polygons' centroids lie within the Yellow River Basin are counted.

Data Sources

VARIABLE	FLOOD EVENTS
Authors	G.R. Brakenridge, Dartmouth Flood Observatory, University of Colorado
Title	Global Active Archive of Large Flood Events
Time covered in analysis	1985 – October 2011
URL	http://floodobservatory.colorado.edu/Archives/index.html
Date accessed	October 15, 2011
Resolution	Flood extent polygons (multiple scales)
Comments	The Global Active Archive of Major Flood Events aggregates flood events from news, governmental, instrumental, and remote sensing sources and estimates the extent of flooding based on reports of affected regions.

Flood Occurrence



DROUGHT SEVERITY

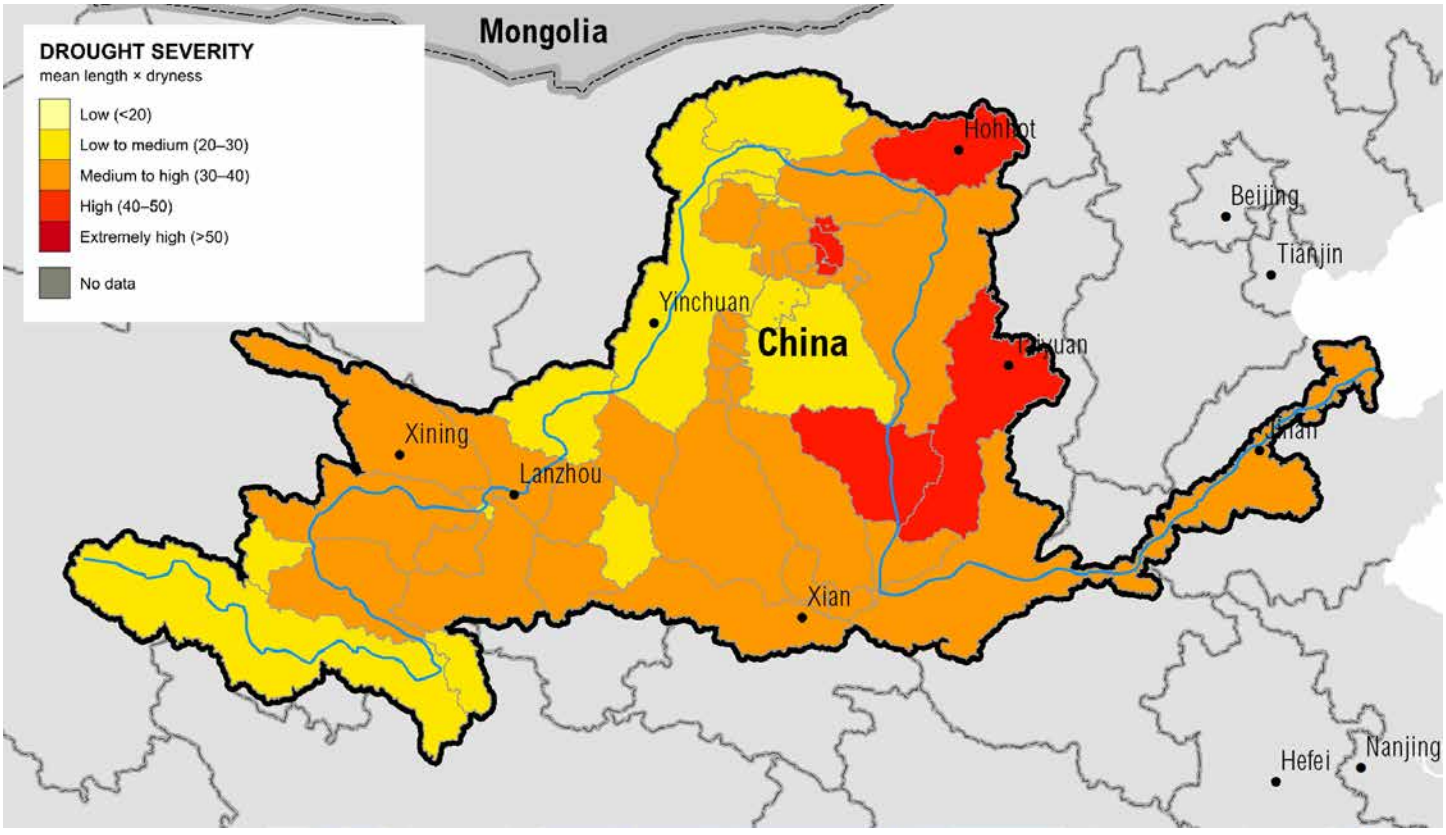
Description: *Drought severity* measures the average length of droughts times the dryness of the droughts from 1901 to 2008.

Calculation: Drought severity is the mean of the lengths of droughts times the dryness of droughts occurring in an area. Drought is defined as a contiguous period in which soil moisture remains below the 20th percentile. Drought length is measured in months and dryness is the average number of percentage points by which soil moisture drops below the 20th percentile. Drought data is resampled from original raster form into hydrological catchments.

Data Sources

VARIABLE	DROUGHT SEVERITY
Authors	J. Sheffield and E.F. Wood
Title	Projected Changes in Drought Occurrence under Future Global Warming from Multi-Model, Multi-Scenario, IPCC AR4 Simulations
Year of publication	2007
Time covered in analysis	1901–2008
URL	http://ruby.fgcu.edu/courses/twimberley/EnviroPhilo/Drought.pdf
Resolution	1 degree raster
Comments	Sheffield and Wood's drought dataset combines a suite of global observation-based datasets with the National Centers for Environmental Prediction–National Center for Atmospheric Research (NCEP-NCAR) reanalysis, and creates a global drought event occurrence dataset with a spatial resolution of 1 degree.

Drought Severity



UPSTREAM STORAGE

Description: *Upstream storage* measures the water-storage capacity available upstream of a location relative to the total water supply at that location. Higher values indicate areas more capable of buffering variations in water supply (i.e. droughts and floods) because they have more water storage capacity upstream.

Calculation: Upstream storage capacity (2012) divided by the mean of total blue water (1979-2009). Multiple dam datasets were combined for more complete coverage.

Data Sources

VARIABLE	TOTAL BLUE WATER
Comments	See Total Blue Water

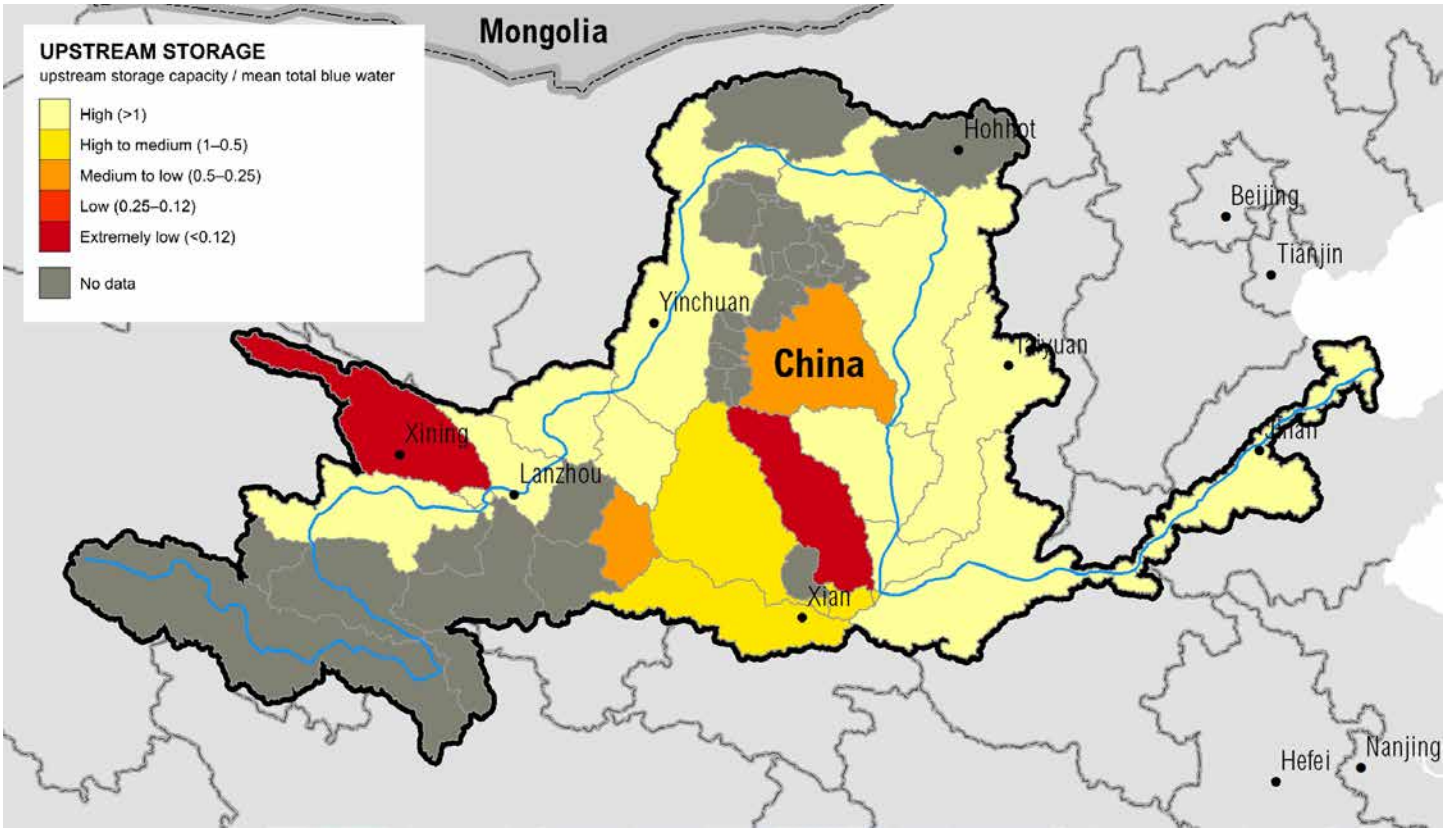
VARIABLE	MAJOR DAMS AND RESERVOIRS
Authors	B. Lehner, C. R-Liermann, C. Revenga, C. Vörösmarty, B. Fekete, P. Crouzet, P. Döll, et al.
Title	Global Reservoir and Dam (GRanD) Database Version 1.1
Year of publication	2011
Time covered in analysis	2010
URL	http://atlas.gwsp.org/index.php?option=com_content&task=view&id=207&Itemid=68
Resolution	Dams (point)
Comments	GRanD database includes reservoirs with a storage capacity of more than 0.1 cubic km although many smaller reservoirs were included.

Data Sources

VARIABLE	MAJOR DAMS AND RESERVOIRS
Author	The International Commission on Large Dams
Title	The International Commission on Large Dams Database
Year of publication	2012
Time covered in analysis	2012
URL	http://www.icold-cigb.net/
Resolution	Dams (point)
Comments	Dams with a storage capacity of more than 0.1 cubic km were selected from ICOLD database, and located on Google Earth to identify geolocation information.

UPSTREAM STORAGE, CONTINUED

Upstream Storage



RETURN FLOW RATIO

Description: *Return flow ratio* measures the percent of available water previously used and discharged upstream as wastewater. Higher values indicate higher dependency on treatment plants and potentially lower water quality in areas that lack sufficient treatment infrastructure and policies.

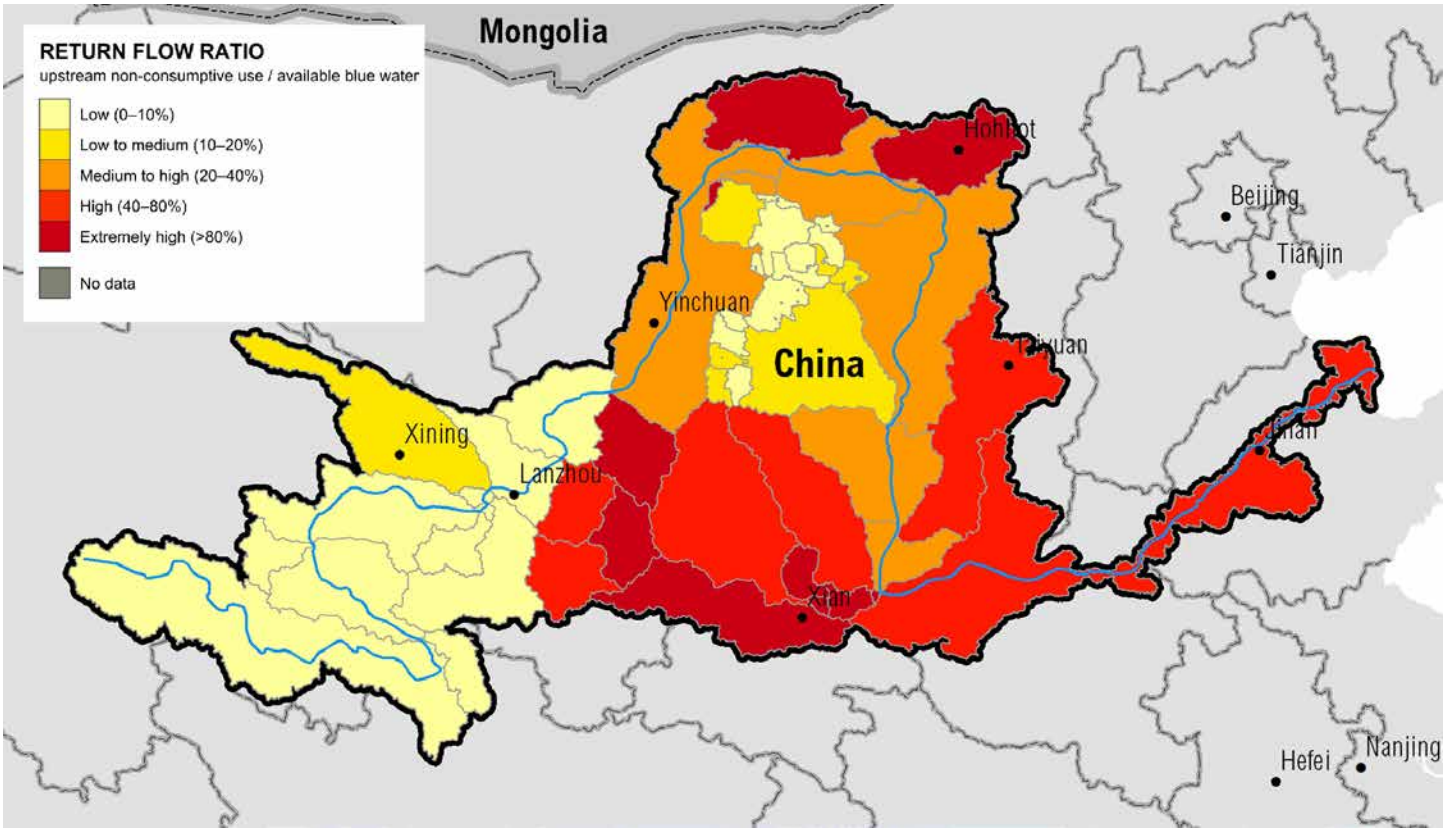
Calculation: Upstream non-consumptive use (2009) divided by the mean of available blue water (1979–2009).

Data Sources

VARIABLE	NON-CONSUMPTIVE USE
Comments	See Consumptive and Non-consumptive Use

VARIABLE	AVAILABLE BLUE WATER
Comments	See Available Blue Water

Return Flow Ratio



WATER QUALITY—DISSOLVED OXYGEN (DO)

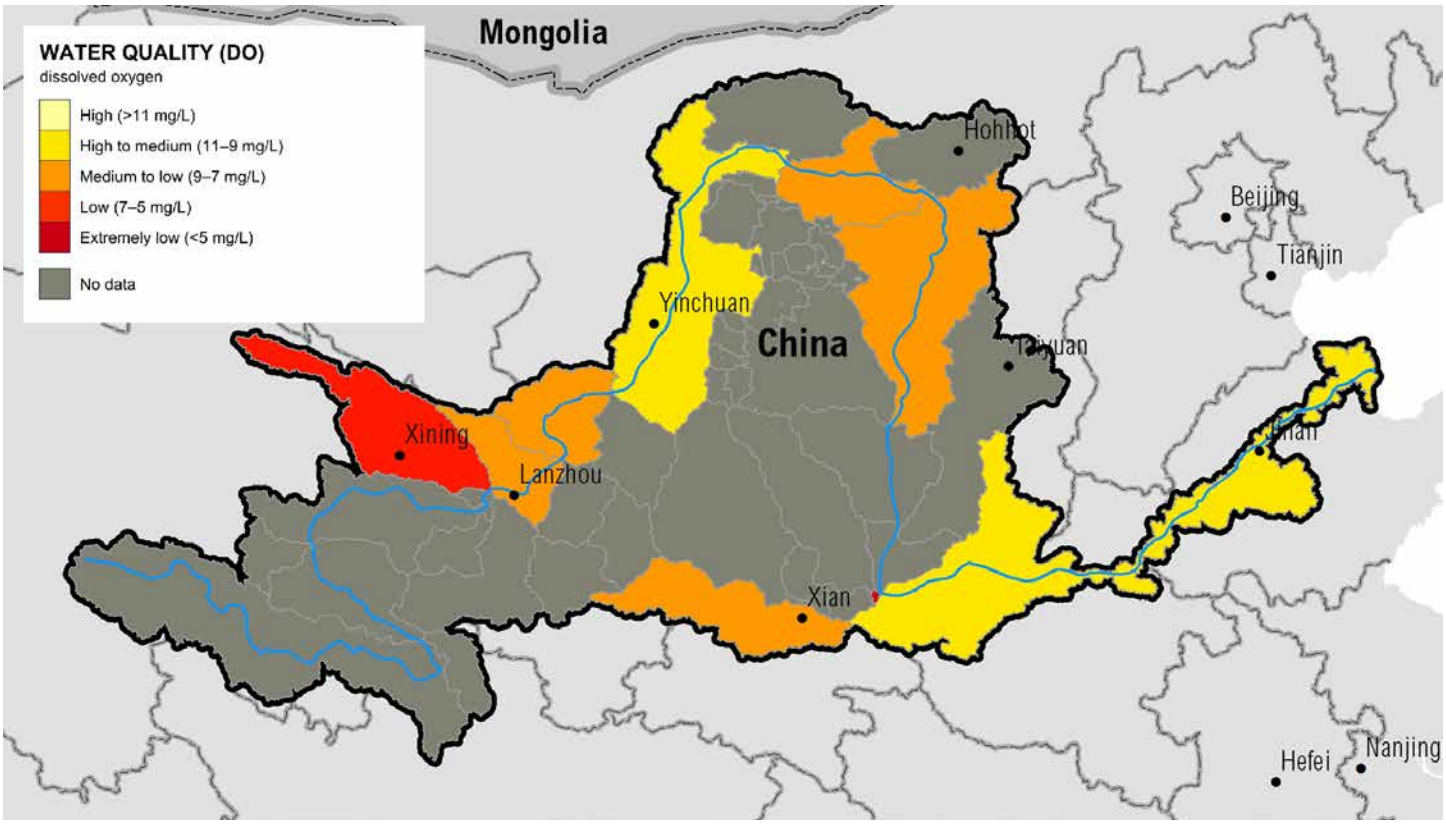
Description: *Dissolved oxygen (DO)* measures the availability of oxygen in water. In general, lower values reflect poorer water quality.

Calculation: DO is reported using empirical sample data and averaged over the year. Catchments are assigned values equal to the average of all water-quality sample data within the polygon. Catchments that do not include sample data for which a given parameter is measured are coded as missing data.

Data Sources

VARIABLE	DISSOLVED OXYGEN (DO)
Author	Ministry of Environmental Protection of the People's Republic of China
Title	National Main Basin's Major Cross Section Water Quality Annual Report
Year of publication	2012
Time covered in analysis	2005–2012
URL	http://datacenter.mep.gov.cn/report/getCountGraph.do?type=runQianWater
Date accessed	August 9, 2012
Resolution	Sample data (point)
Comments	Hydrologic units were assigned equal to the average of all water quality sample data within the polygon. Hydrologic units that do not include sample data for which a given parameter is measured are coded as missing.

Water Quality – Dissolved Oxygen



WATER QUALITY—CHEMICAL OXYGEN DEMAND (COD)

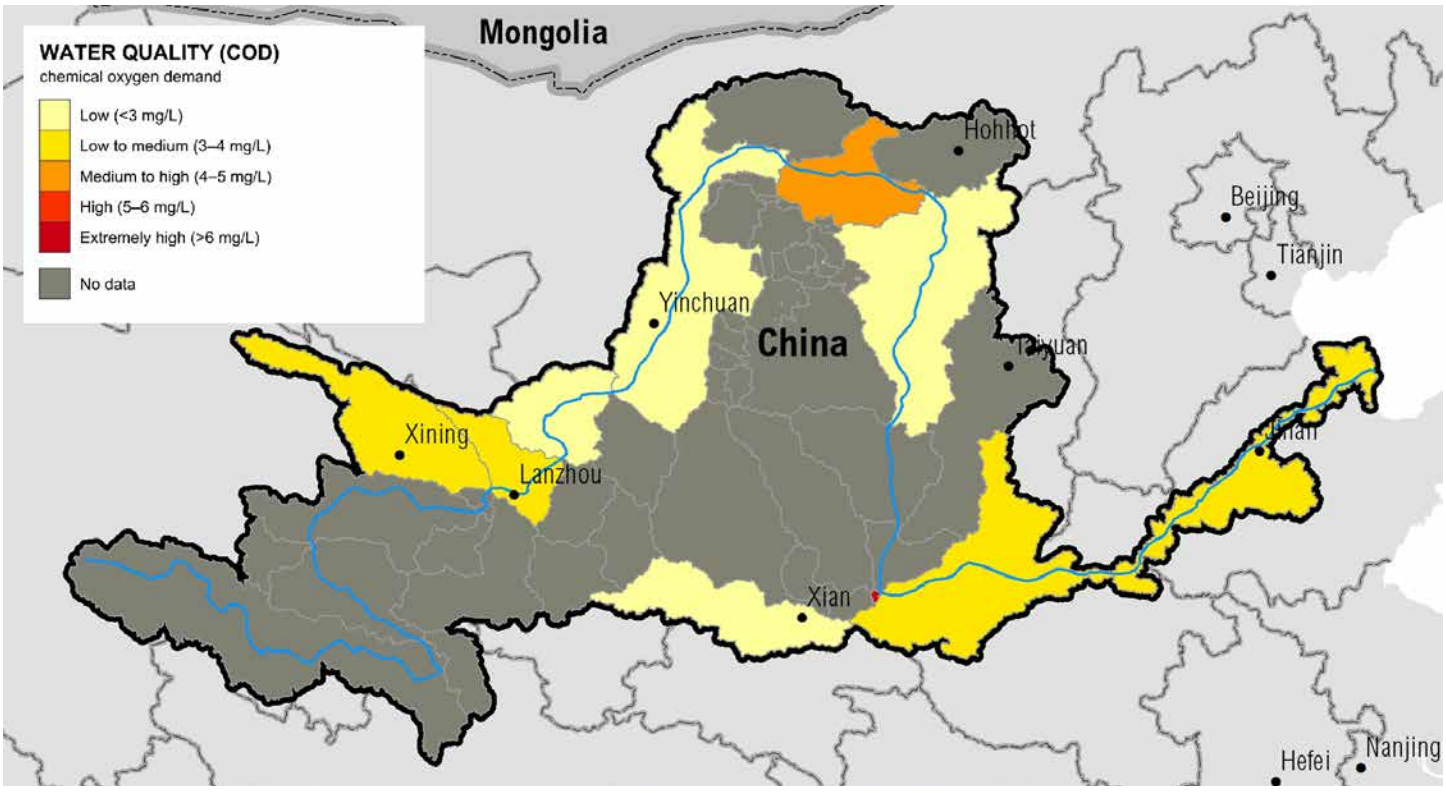
Description: *Chemical oxygen demand (COD)* measures the amount of organic compounds in water. In general, higher values reflect poorer water quality.

Calculation: COD is reported using empirical sample data and averaged over the year. Catchments are assigned values equal to the average of all water-quality sample data within the polygon. Catchments that do not include sample data for which a given parameter is measured are coded as missing data.

Data Sources

VARIABLE	CHEMICAL OXYGEN DEMAND (COD)
Author	Ministry of Environmental Protection of the People's Republic of China
Title	National Main Basin's Major Cross Section Water Quality Annual Report
Year of publication	2012
Time covered in analysis	2005–2012
URL	http://datacenter.mep.gov.cn/report/getCountGraph.do?type=runQianWater
Date accessed	August 9, 2012
Resolution	Sample data (point)
Comments	Hydrologic units were assigned equal to the average of all water quality sample data within the polygon. Hydrologic units that do not include sample data for which a given parameter is measured are coded as missing.

Water Quality – Chemical Oxygen Demand



WATER QUALITY—AMMONIA NITROGEN (NH_3-N)

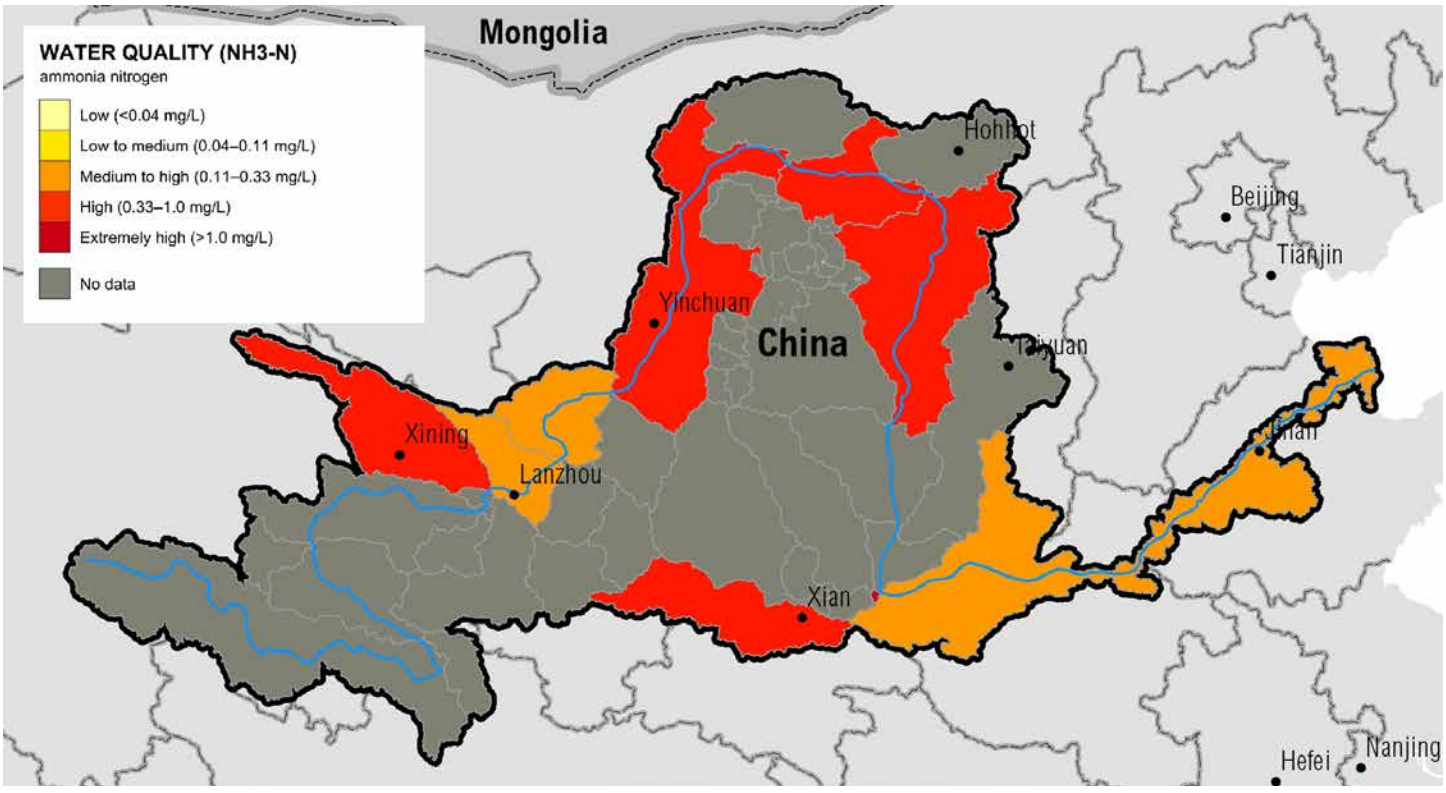
Description: *Ammonia nitrogen (NH3-N)* is the measure of the levels of nitrogen. Higher values, often driven by fertilizer use as well as domestic and industrial discharges, may have a detrimental effect on water quality.

Calculation: NH3-N is reported using empirical sample data and averaged over the year. Catchments are assigned values equal to the average of all water-quality sample data within the polygon. Catchments that do not include sample data for which a given parameter is measured are coded as missing data.

Data Sources

VARIABLE	AMMONIA NITROGEN (NH_3-N)
Author	Ministry of Environmental Protection of the People's Republic of China
Title	National Main Basin's Major Cross Section Water Quality Annual Report
Year of publication	2012
Time covered in analysis	2005–2012
URL	http://datacenter.mep.gov.cn/report/getCountGraph.do?type=runQianWater
Date accessed	August 9, 2012
Resolution	Sample data (point)
Comments	Hydrologic units were assigned equal to the average of all water quality sample data within the polygon. Hydrologic units that do not include sample data for which a given parameter is measured are coded as missing.

Water Quality – Ammonia Nitrogen



UPSTREAM PROTECTED LAND

Description: *Upstream protected land* measures the percentage of total water supply that originates from protected ecosystems. Modified land use can affect the health of freshwater ecosystems and have severe downstream impacts on both water quality and quantity.

Calculation: Percentage of total blue water that originates in protected areas. IUCN category V protected lands, as well as a large number of unclassified proposed lands, breeding centers, municipal parks, cultural and historic sites, and exclusively marine areas are excluded.

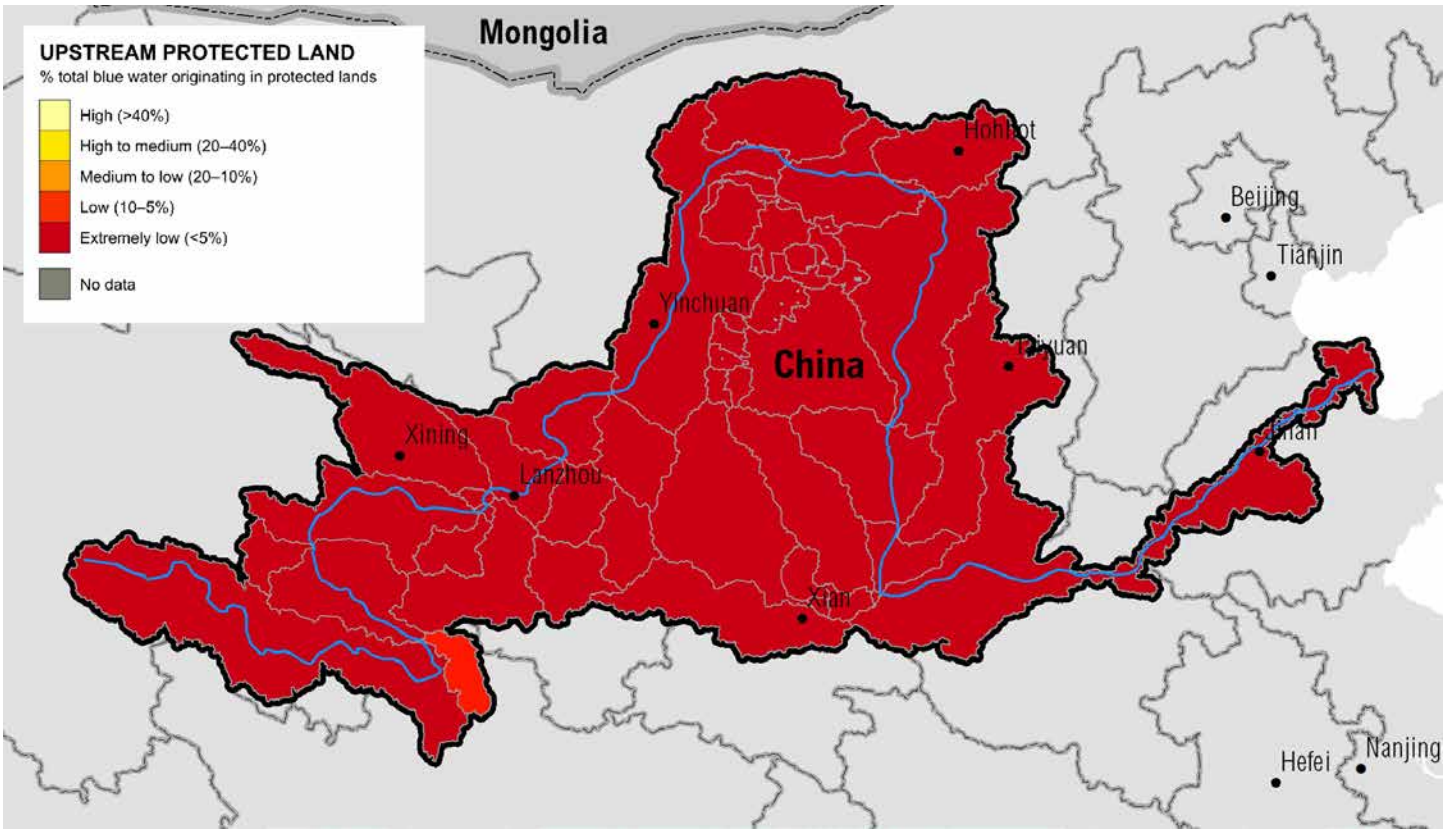
Data Sources

VARIABLE	TOTAL BLUE WATER
Comments	See Total Blue Water

Data Sources

VARIABLE	PROTECTED AREAS
Authors	International Union for Conservation of Nature (IUCN) and United Nations Environment Programme World Conservation Monitoring Centre (UNEP–WCMC)
Title	The World Database on Protected Areas
URL	http://protectedplanet.net/
Date accessed	June 14, 2012
Resolution	Protected areas (multiple scales)

Upstream Protected Land



MEDIA COVERAGE

Description: *Media coverage* measures the percentage of media articles in a geographic area about water-related issues. Higher values indicate areas with higher public awareness of water issues, and consequently, higher reputational risks to those not sustainably managing water.

Calculation: Percentage of all media articles that are on water scarcity and/or pollution. Google Archives is used to search a string of keywords including river name, "water shortage" or "water pollution," and administrative unit, e.g. "Yellow River + water shortage + Shanxi." The time frame was limited to the past 10 years from January 1, 2002 to December 31, 2011. For each province, the number of articles for both water shortage and water pollution was summed and divided by the total number of articles on any topic found in a search of the administrative unit.

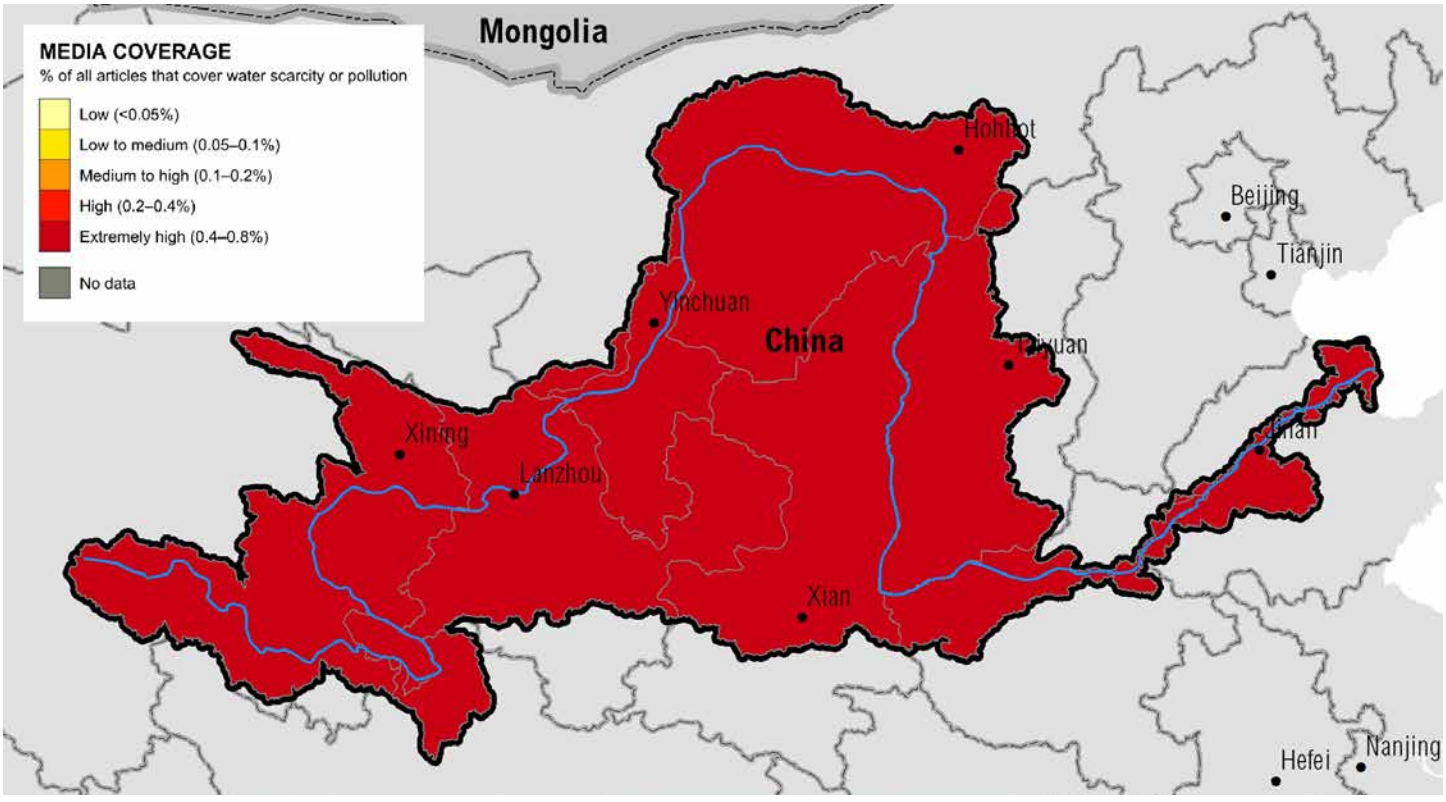
Data Sources

VARIABLE	PROVINCIAL BOUNDARIES
Comments	See Total Withdrawal

Data Sources

VARIABLE	MEDIA COVERAGE
Author	Google
Title	Google News
Time covered in analysis	2002–2011
URL	http://news.google.com/news/advanced_news_search?as_drrb=a
Date accessed	September 26, 2012
Resolution	Province

Media Coverage



ACCESS TO WATER

Description: *Access to water* measures the percentage of population without access to municipal water supply sources. Higher values indicate areas where people have less access to safe drinking water supplies, and consequently high reputational risks to those not using water in an equitable way.

Calculation: Percentage of population that have no access to tap water sources.

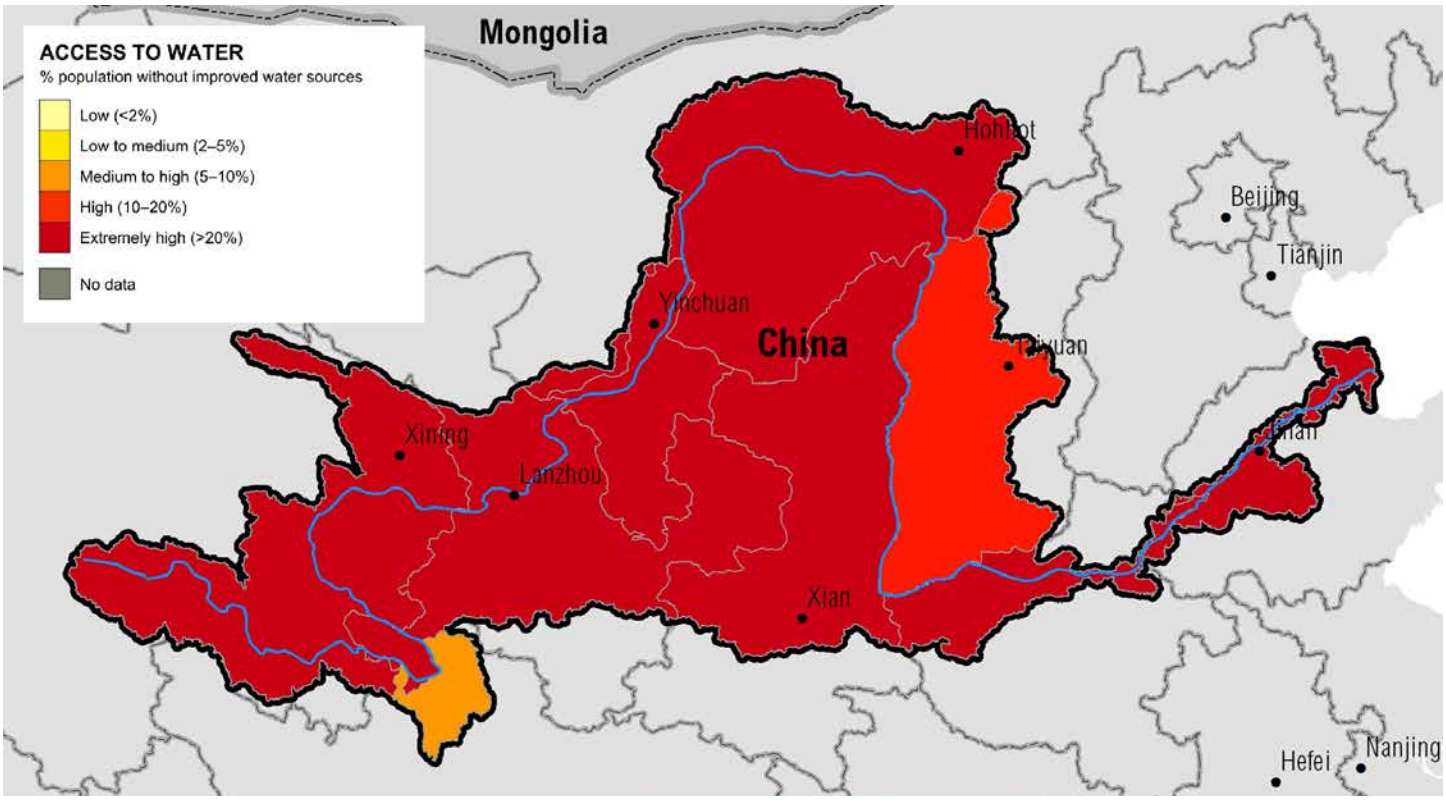
Data Sources

VARIABLE	PROVINCIAL BOUNDARIES
Comments	See Total Withdrawal

Data Sources

VARIABLE	ACCESS TO WATER
Author	National Bureau of Statistics of China
Title	China Annual Provincial Macro-Economy Statistics
Year of publication	2010
Time covered in analysis	2010
URL	http://www.stats.gov.cn/tjsj/
Resolution	Province

Access to Water



THREATENED AMPHIBIANS

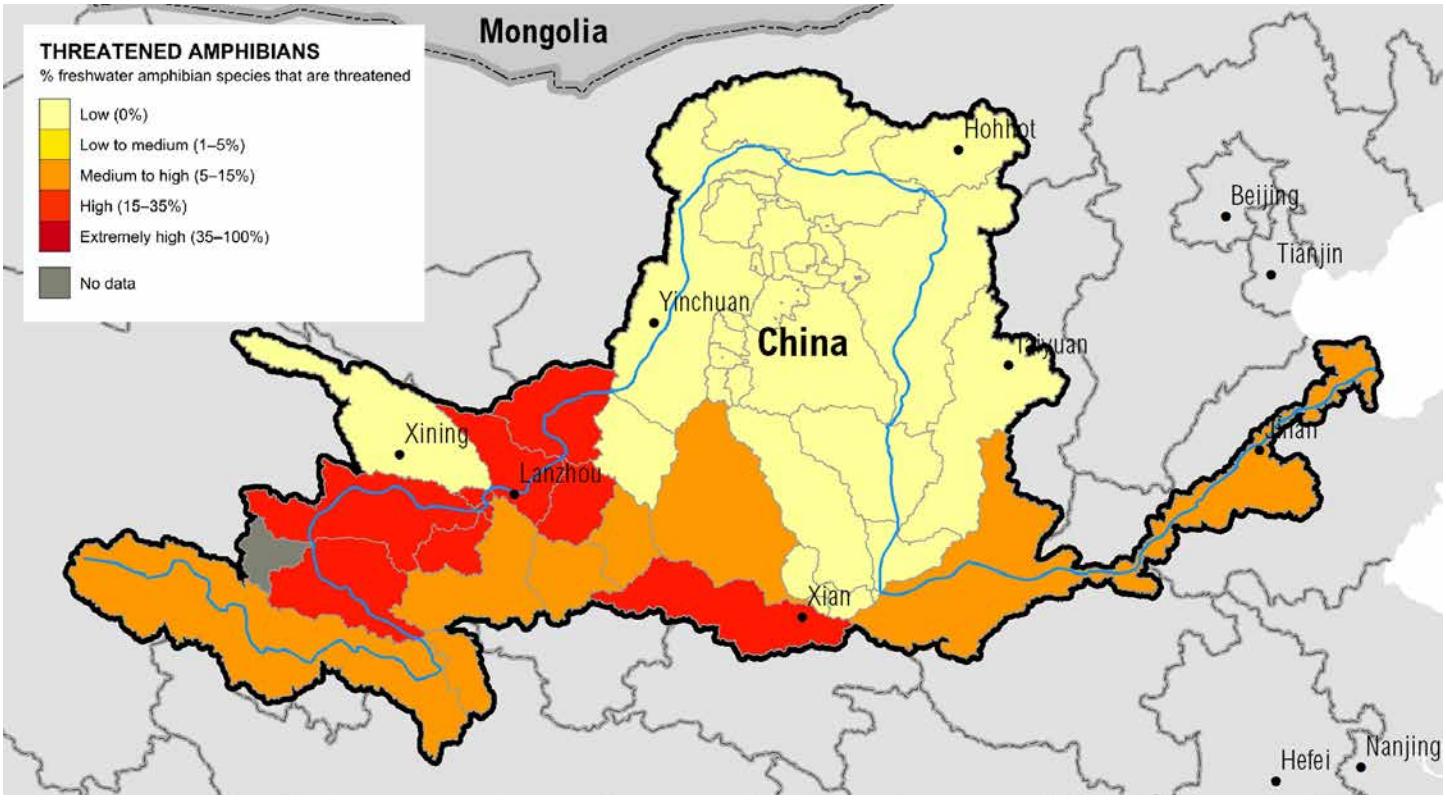
Description: *Threatened amphibians* measures the percentage of freshwater amphibian species that are classified by IUCN as threatened. Higher values indicate more fragile freshwater ecosystems and thus areas more likely to be subject to water withdrawal and discharge regulations.

Calculation: The percentage of amphibian species that are classified by IUCN as threatened in a particular area. For each catchment, the total number of threatened freshwater amphibian species is counted and divided by the total number of species whose ranges overlap the catchment. Catchments with fewer than two amphibian species are excluded.

Data Sources

VARIABLE	THREATENED AMPHIBIANS
Author	International Union for Conservation of Nature (IUCN)
Title	The IUCN Red List of Threatened Species
Year of publication	October 2010
URL	http://www.iucnredlist.org/technical-documents/spatial-data#amphibians
Resolution	Ranges (multiple scales)
Comments	Amphibian species status database is joined to the known species range spatial data. Several name corrections were made in joining the data.

Threatened Amphibians



ENDNOTES

1. Reig, P., T. Shiao, and F. Gassert. 2013. "Aqueduct Water Risk Framework." Working Paper. Washington, DC: World Resources Institute. Available online at http://www.wri.org/publication/aqueduct-water-risk-framework.

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