academicJournals

Vol. 12(1), pp. 21-68, January 2018
DOI: 10.5897/AJEST2017.2347
Article Number: 0A56E5E67009
ISSN 1996-0786

http://www.academicjournals.org/AJEST

African Journal of Environmental Science and Technology

Full Length Research Paper

The Uttarakhand 2013 and Jammu-Kashmir 2014 disasters: Upstream effects of water piracy

Miah Muhammad Adel

Professor of Physics, Astronomy, and Water and Environmental Sciences, University of Arkansas, Pine Bluff, AR 71601, USA.

Received 3 May, 2017; Accepted 29 September, 2017

Countries lack the infrastructure to deal with the drainage following flashfloods from localized downpours which may originate from localized evaporation or its combination with that from surroundings or from hurricanes. The natural distribution of water is the best and optimum for the globe. Among the world's riparian countries, India makes her territory both the sources and the sinks of river discharges by constructions of dams, reservoirs, barrages, weirs, etc. on international rivers and diversion of their courses within herself. Water confinement constructions make rivers silted heavily reducing their discharge capacities all through but more so in the downstream. The two catastrophic incidences – 2013 Uttarakhand and 2014 Jammu-Kashmir - presented in this article vouch for the curses of water confinement. Theoretical treatments have been provided for studying the impacts on the climatic variables for pre- and post-dam periods. Against the backdrop of these incidences, India has threatened her western neighbor of cutting off water supply which she has already done to the eastern neighbor. She, however, opens the gates of all dams and barrages built upstream of the river-silted eastern neighbor Bangladesh and floods that country causing irreparable losses of lives and properties, and adding misery to millions of people when India fails to accommodate excess water. On top of this confinement of river discharges within India, she has been working on the master plan of river networking. It is imperative for judges of international arbitration court, donors, World Bank, policy makers, etc. etc. to take lessons out of this study.

Key words: Dams, reservoirs, evaporation, macrostate, microstate, extreme event, powerhouse, river basin, Ganges, Indus, Teesta, tributary, distributary, water piracy, upstream, downstream.

INTRODUCTION

Water has the highest potential, on any account, to cause climate change. Nature has set up weather pattern over eons based on the distribution of the water resources. The established pattern can withstand up to certain amount of perturbation introduced via exploitation of water resources by anthropogenic activities. Beyond this

E-mail: adelm@uapb.edu. Tel: (870) 575-8788.

a b c d

Figure 1. (a) Rising floodwaters spread through the low-lying suburb of Depot Hill in Rockhampton, eastern Queensland (https://www.theguardian.com/world/gallery/2011/jan/03/australia-floods-queensland, Photograph: MECHIELSEN LYNDON/AFP/Getty Images); (b) Rockhampton, having a population of 75,000 people would be supplied with food and medicine by military helicopters and by barge Photograph: KELLY WATT/EPA (https://www.theguardian.com/world/gallery/2011/jan/03/australia-floods-queensland); (c) Cattle crowd on to the highest spot they could find near Rockhampton Photograph: Lyndon Mechielsen/Newspix/Rex Features (https://www.theguardian.com/world/gallery/2011/jan/03/australia-floods-queensland); (d) Ants swarm on a post just above the floodwaters in Rockhampton Photograph: Lyndon Mechielsen/Newspix/Rex Features (https://www.theguardian.com/world/gallery/2011/jan/03/australia-floods-queensland).

point, on a microscale compared to continental or global one, harshness and irregularities in weather phenomena can occur.

Infrastructures are made to withstand average effects but not the extreme ones which happen rarely. Rainfalls beyond the usual amount lead to difficult drainage. On top of these, rivers lose drainage capacities through obstructions to discharge and water-holding capacities through silt deposition in the wake of constructions of dams and barrages.

In the gas dynamics of weather phenomena, the mixture of two masses of gas a very large number of molecules of a certain mass, occupying a certain volume and a total energy occurs; it results in finite probabilities of multiple macrostates defined as a set of microstates that refers to the state of each element of the system. In the equilibrium condition of the system, only a tiny fraction of the macrostate has a reasonable probability of occurring. If any exchange of volume through expansion of one gas and contraction of the other occurs on top of exchange of energy (which is common in the weather phenomena), the multiplicity function of a component gas will have a sharp peak of width equal to the ratio of the combined total volume and the square root of the total number of molecules. It is very likely that some macrostate multiplicity may satisfy the critical conditions for production of extreme events.

Recently, localized extreme events of flooding occurred in several countries, viz. in Australia, USA, European, Asian, and African countries (https://en.wikipedia.org/wiki/List_of_floods). Just to give a few examples for the current decade, Queensland City in Australia was cut off in 2011 as floodwater hit an area the size of France and Germany (Figure 1a to d), affecting 200,000 people in more than 20 towns and cities (Australia News, 2011; https://www.theguardian.com/world/gallery/2011/jan/03/australia-floods-queensland; https://www.google.com/search?q=KELLY+WATT/EPA+in+Rockhampton+flood+image&tbm=isch&tbo=u&source=univ&sa=X&ved=0ahUKEwjb6PHh5ejVAhVBzlQKHUc-CpcQsAQIJQ&biw=1467&bih=719#imgrc=6AYeEdCocpBVLM).

The city of Carbondale in Southern Illinois in the USA was hit by flood in 2012 (Figure 2a and b). There were reports of very high water near railroad tracks into Carbondale. Highway 13 was closed (http://www.disaster-report.com/2012/09/carbondale-is-flooding-updated.html).

In 2013, the Danube River, the Elbe River and their distributaries were flooded (Figure 3a and b) after several days of rain in late May and early June in the year 2013, one of the wettest including 1962 and 1965 in the last 156 years. The affected countries were German, Czech Republic, Austria, Switzerland, Slovakia, Belarus, Poland, Hungary, and Serbia (Vojvodina) (https://en.wikipedia.org/wiki/2013_European_floods) and the references therein.

a b

Figure 2. (a) JimCantore Carbondale, Illinois this evening! This is downtown. pic.twitter.com/iCk7wTNz (http://www.disaster-report.com/2012/09/carbondale-is-flooding-updated.html); (b) jamfan4033# A ton of flooding. yfrog.com/h47lmfwj (http://www.disaster-report.com/2012/09/carbondale-is-flooding-updated.html).

a b

Figure 3. (a) Flooding in Passau, Bavaria where the Danube, Inn and Ilz rivers converge (Penninger, 2013); (b) Flooding in Budapest, Hungary on 5 June 2013 (Norden, 1990, 2013).

A cold polar air mass from Central Europe entered into the Mediterranean Basin causing a mixture with the humid subtropical air forming a very low pressure cyclone termed Tamara and Yvette. It caused a rainfall breaking 120 years of records (Figure 4a to d). The devastating cyclone took place during May 13 and 18, 2014 (https://en.wikipedia.org/wiki/2014_Southeast_Europe_flood: Herold, 2014).

More news, images and videos of the worst floods occurring every year somewhere on the globe are available in multiple sites (https://news.search.yahoo.com/search;_ylt=A0LEVzdjtJhZGMYAJjxXNyoA;_ylu=X3oDMTEyNzVrY2ZyBGNvbG8DYmYxBHBvcwMxBHZ0aWQDQjQ0ODNfMQRzZWMDc2M-?p=worst+floods+in+2015&fr=tightropetb&fr2=cosmos; https://search.yahoo.com/search?ei=utf8&fr=tightropetb&p=worsts+floods+in+2016&type=75989_080317).

In the current year 2017, New Orleans streets in the state of Louisiana in the USA fell under waist-high water (Figure 5a) in the wake of the day-long deluge on Saturday, August 5, 2017 (Lartey, 2017). Weekend storm and heavy rainfall flooded and caused closure of hundreds of roads in Missouri, Arkansas, and Illinois (Figure 5b to d). A major waterway was shutdown (Sounds, 2017).

As of 31 July, 2017 10:32 EDT, 231 died in Gujarat, India (Figure 6a and b), but the figure was rising with receding water. Nearly 130,000 people were relocated. More than 150 factories were shut down, about 50,000 cotton farms got water logged, and more than 4,000 animals were killed. Nearly 700 people died across

Figure 4. (a) The Yvette storm in Southeast Europe and Balkans, 15 May 2014 (NASA Worldview, 2014); (b) 2014 floods in Gunja, Croatia, may 2014 (Platenik, 2014); (c) 2014 flood in Zenica, Bosnia and Herzegovina (BiH, 2014); (d) Flooding in the city of Doboj, Bosnia and Herzegovina, 16 May 2014 (Getty Images).

India in the monsoon season (Safi, 2017).

During the time July 1 and August 13, Sierra Leone's Freetown received more than 27 inches of rain which is more than double the average of 11.8 inches, according to the US National Weather Service's Climate Prediction Center. As of August 15, the death toll rose to 245. The number was expected to grow. People were desperately hunting for 600 people missing ones. The number of displaced people lay between 2,000 and 3,000 (The Associated Press, 2013; CNN, 2017). Figure 7a to f shows some of the tragic scenes.

In Bangladesh, the *Daily Star* newspaper reported a dangerous flood in the country (Daily Star, 2017a) echoed by the joint report of the UNO resident coordinator and the European Union's Joint Research Center in Bangladesh (Figure 8a). In the developing news, the daily continued reporting 12 drowned (Figure 8b) in the northern part of Bangladesh (Daily Star, 2017b). Also, the English *Daily Star* reported 8 deaths and 5 missing (Figure 8c) on August 13, 2017 in the newly worsening flood situation in Bangladesh (UNB, 2017). The Daily Star last reported 20 deaths and about 6 million marooned in water (Daily Star, 2017c; http://amar-desh24.com/bangla/index.php/details/nationalnews/13736#). India opens the gates of all dams and barrages built upstream of the river-silted Bangladesh (Figure 9); it floods the country causing irreparable losses of lives and property and adding misery to millions of people when India fails to accommodate excess water. Bangladesh falls into double trouble if she suffers from flood caused by onsite rainfalls and flooding. This is as a result of Indian release of floodwater. In some years, India drowned Bangladesh twice by flood in the same season.

As the anthropogenic activities of changing the virgin

Figure 5. (a) The Circle Food Store engulfed in floodwaters in New Orleans on Saturday. Photograph: Brett Duke/AP (https://www.theguardian.com/us-news/2017/aug/10/new-orleans-vulnerable-louisiana-floods); (b) Arkansas flooding (http://strangesounds.org/2017/05/historic-floodings-missouri-arkansas-illinois-loods-video-pitures-map.html); (c) Missouri flooding (http://strangesounds.org/2017/05/historic-floodings-missouri-arkansas-illinois-loods-video-pitures-map.html); (b) Illinois flooding (http://strangesounds.org/2017/05/historic-floodings-missouri-arkansas-illinois-loods-video-pitures-map.html).

Figure 6. (a) Flood victims, including a patient needing kidney dialysis, await an airlift from a rooftop in Abiyana village, Gujarat after monsoon floods hit. Photograph: AFP/Getty Images (https://www.theguardian.com/world/2017/jul/31/india-monsoon-floods-gujarat-death-toll-over-200); (b) Soldiers rescue stranded flood victims in Khariya village, Gujarat, India. Photograph: Sam Panthaky/AFP/Getty Images.

Figure 7. (a) Severe flooding engulfs Sierra Leon's Freetown (courtesy of https://www.youtube.com/watch?v=1G2MvdIC1FI); (b). Four storey building swept by ferocious mudslide in Sierra Leone (Courtesy of https://www.youtube.com/watch?v=OgNFPcV1lac, Africa Cable Network); (c). Sierra Leon's mudslides and flooding; (d) Volunteers search for bodies from the scene of heavy flooding and mudslides in Regent, just outside of Sierra Leone's capital Freetown on Aug. 15, 2017 (Photo:Kamara, 2017; AP); (e) Victims' relatives at the Freetown Morgue, 16 August, 2017 (Courtesy of */ AFP PHOTO / SAIDU BAH)*; (f) Volunteers waiting to receive coffins of the victims for mass graving at the Waterloo Cemetary (Courtesy of SEYLLOU / AFP/GETTY IMAGES) for the coffins of mudslide victims on August 17, 2017 at Waterloo cemetery near Freetown, Sierra Leone (Nigeria News Today, 2017).

Figure 8. (a) Residences under water (http://amar-desh24.com/bangla/index.php/details/nationalnews/13412); (b) Risky way of ferrying people (http://amar-desh24.com/bangla/index.php/details/nationalnews/13413); (c) People wading in more than knee-deep water and a truck is driven in flood water (http://www.thedailystar.net/country/8-killed-overall-bangladesh-flood-situation-worsens-1448041); (d) Water, water everywhere, not a single drop of water to drink: 93 died, 6 million affected http://www.thedailystar.net/frontpage/bangladesh-flood-situation-2017-hits-20-districts-1448749).

environment have increased in coverage, so the feedback effect from nature has increased spatially and temporally. The frequency of natural disasters like tornadoes, tsunamis, floods, etc., has increased in space and time. Tornadoes are followed by heavy rainfalls that cause flashfloods.

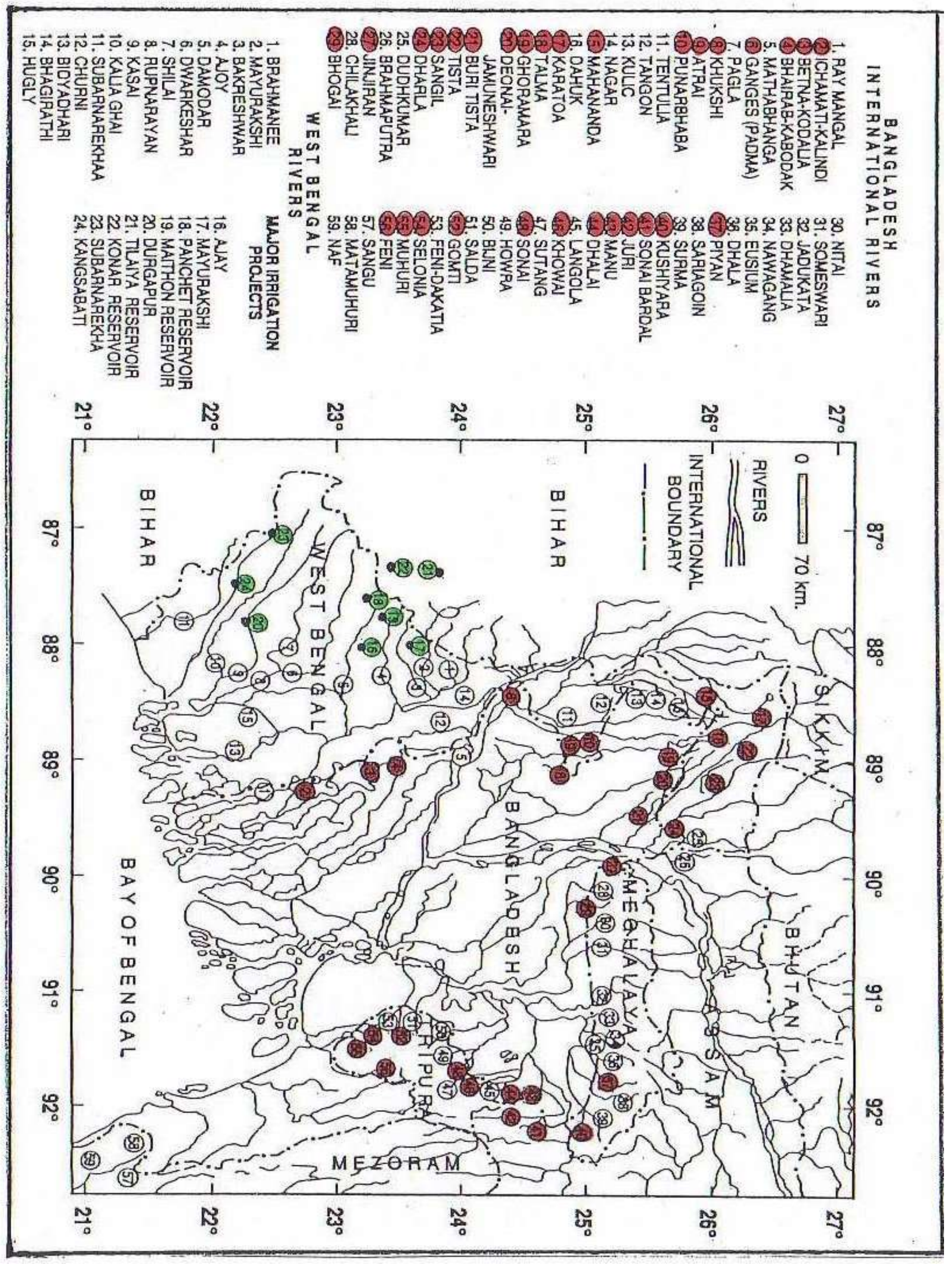


Figure 9. The Great Ring of Dams and Barrages constructed by India upstream of Bangladesh (Adel, 2001).

By far the most important factor of flooding treated in this article as obtained from the general causes of flood (Asumadu-Sarkodie et al., 2015a; Scottish Government, 2008) is the poor drainage capacity of dammed rivers and stream channels rendered by anthropogenic activities of tampering with water resources.

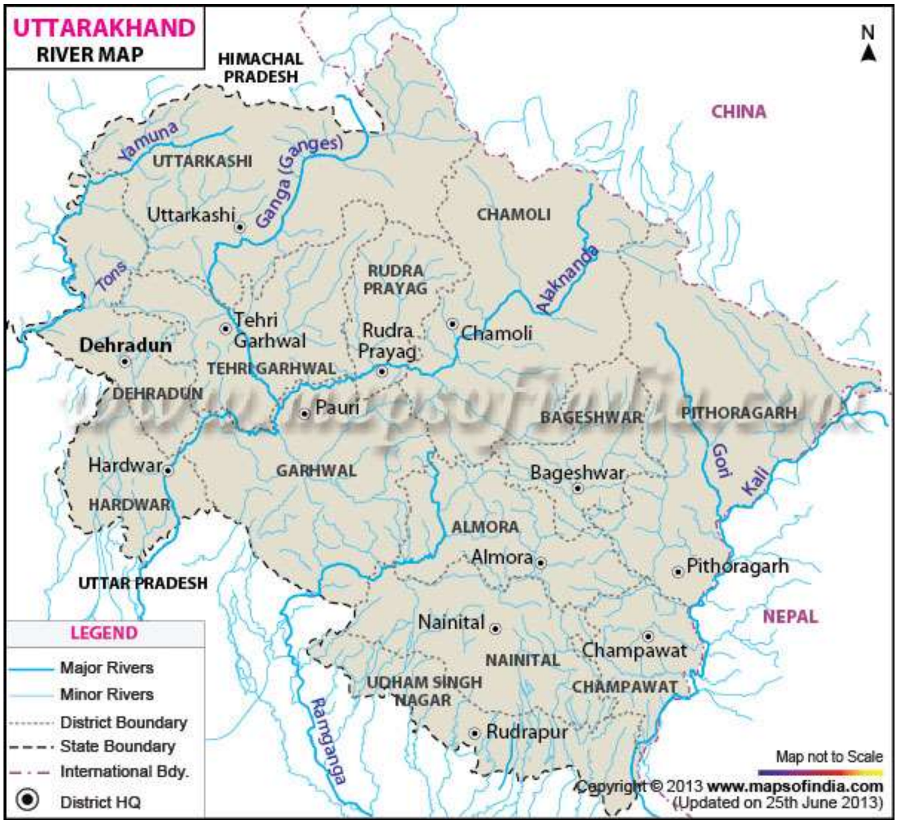


Figure 10. Uttarakhand Rivers (http://www.mapsofindia.com/maps/uttaranchal/rivers/).

Pujari and Dandekar (2013) analyzed Uttarakhand rainfalls for 1901 through 2013 to find maximum rainfalls which were heavier in 1922 (685.6 mm in August) than in 2013 (510.4 mm in June-July 3). The most devastating flood occurred in 2013, clearly indicating the impact of anthropogenic activities in causing the disastrous event.

This article focuses on the backdrop of the anthropogenic activities that brought the climax event mentioned in the title.

Project site

The event under study occurred in the hilly state of Uttarakhand (Figure 10) in Northern India (Figure 11) and in Kashmir (Figure 45). Uttarakhand land area is about 53,484 km^2. It was founded on 8 November 2000. According to 2012 Census, its population is 10.08 million. The rivers that include the Ganges and its tributaries in Uttarakhand are the Alakanda River, the Bhagirathi River, the Bhilaganga River, the Dhauliganga River-Garhwal, the Dhauliganga River-Kumaon, the Ganga River, the Gaula River, the Gori Ganga River, the Kali River, the Kosi River, the Mandakini River, the Nandakini River, the Naya River-Easter, the Naya River-Western, the Pindar River, the Ramganga-Western, the Ramganga -Eastern, the Saryu River, the Tons River, and the Yamuna River (Adel, 2013, 2015a, b, c, d, e). All these are prominent rivers of India.

In Uttaranchal, the cultivable land is 784,117 hectares that support 90% of its population's livelihood of cultivation. Irrigation is done on about 12% of the land and feeding from natural springs is done in 64% of the land. More than 61% of the land is forested. The net sown area is roughly 14%. The gross irrigated area is less than 50% of the net sown areas. Soil is mostly sandy that fails to retain water. Rice, barley, wheat, and corn are major crops (http://efreshglobal.com/efresh/Content/Country.aspx?u=utk; http://agropedia.iitk.ac.in/content/present-scenario-agriculture-uttarakhand).

Hydropower projects in Uttarakhand (SANDRP, 2013) are shown in Table 1.

Hydropower projects require deforestation, building of dams, diversion structure, desilting mechanism, 5- to 30-km long tunnels wide enough to carry three trains side by side, and also roads, townships, mining, among other components, massive proportion blasting, etc. Further, the activities of constructions of dams, reservoirs, barrages, weirs, etc., which in a cluster can form a mini

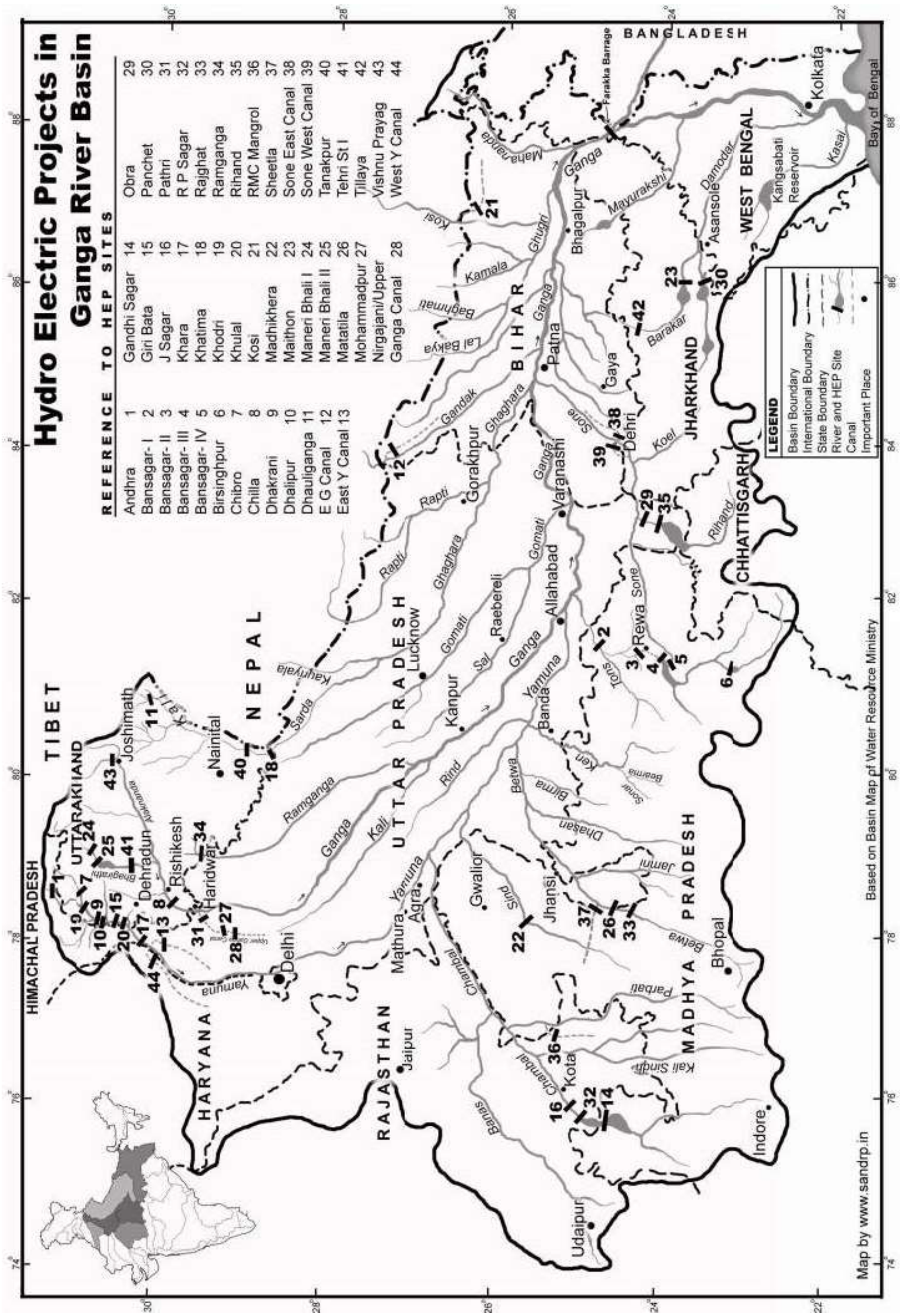


Figure 11. Hydroelectric projects in the Ganga basin (http://sandrp.in/basin_maps/Hydropower_Projects_in_Ganga_Basin.pdf).

Table 1. Hydroelectric projects in Uttarakhand

Basin	Number of existing projects and capacity (MW)	Number of under-construction projects and capacity (MW)	Number of proposed projects and capacity (MW)	Total number and capacity (MW)
Alakanda	32 and 456.97	16 and 1291.1	74 and 5199.25	122 and 6947.32
Bhagirathi	13 and 1851.5	13 and 1084.75	22 and 801.9	48 and 3737.75
Ganges sub-basin	4 and 173.8	2 and 1.75	-	6 and 185.55
Ramganga	12 and 210.8	-	20 and 408.5	32 and 619.35
Sharda	28 and 427.75	8 and 0.375	48 and 12022.28	84 and 12450.405
Yamuna	9 and 478.195	2 and 0.14	33 and 2780.85	44 and 3259.185
Total	98 and 3598.665	41 and 2378.115	197 and 21212.78	336 and 27189.56

land-locked ocean introduce the perturbation factor in the weather system. Concentration of these structures over a locality or irrigation over wide spread areas contributes to additional vapors favoring rainfalls. All of these basically affect the land use and land cover (LULC) changes and thence the climate.

METHODOLOGY

A survey of the tributaries of the world's 8th largest River Ganges that originates in Uttarakhand has been made. Facts and figures of each of the main basins have been presented with the existing, under-construction, and proposed dams which reflect the extent of the land use and land cover (LULC) changes. A graphic description of the devastation referred to by the title has been presented briefly as the impact of LULC changes which have the biggest potential to change climatic variables. Theoretical treatments of the changes of climatic variables have been presented at length. LULC changes have effect upon temperature, evapotranspiration, relative humidity, and thence rainfall. Since in rainfalls, mixtures of gases occur, it has been proposed that mixtures result in finite probabilities of multiple macrostates. In the equilibrium condition of the system, only a tiny fraction of the macrostate has a reasonable probability of occurrence. It is very likely that some macrostate multiplicity may satisfy the critical conditions for production of extreme events. The presentation has provided rooms for determining the impacts upon them (climatic variables) as a result of LULC changes. The likelihood of extreme events as a result of the interactions of two huge masses of gases has been referred to ascertain the occurrences of extreme events. India's hegemony upon the eastern and the western neighbors with the international water issue has been discussed. India's mega project of LULC through the Grand River networking plan along with the potential threat has been mentioned too.

Facts and figures: LULC changes in Uttarakhand

Tributaries of the ganges

The Ganges, the world's 8th largest river, with its tributaries and distributaries is spread out over the Indian Subcontinent. The tributaries that make up the Ganges are shown in Table 2. Most of these tributaries are dammed.

Constructions of dams and barrages extend from the main river to its remotest tributaries (Adel, 2015a, b, c).

Projects in the Ganges Basin

Figures 12 to 22 present the numbers and locations of the hydroelectric projects in the main tributary basins cited in Table 2. Each of the figures mentions the proposed, underconstruction, and operational projects. The numbers presented in Table 1 are the most likely to have changed because of being on-going.

Hydroelectric projects and the widespread commercial irrigation lose a lot of water in the form of vapor. This is due to the turning localized sources of water to distributed ones making huge water surfaces available for evaporation. SEBAL method may be used to estimate the evapotranspiration rate from irrigated lands and reservoirs (Bastiaanssen et al., 1998; Mkhwanazi et al., 2015). This is a perpurbation upon the established hydroelectric cycle and the local weather pattern.

The 2013 Uttarakhand event

Torrential rains lasting about 24 h on June 15 and 16, 2013 poured more than one-third meter that damaged infrastructure, lives and properties in Uttarakhand. The monstrous flood wiped out at least six villages and buried dozens in mud. It wrecked over 1,000 km of highways. Some of the scenes are as shown in Figure 23a to c. More than 5,000 buildings were damaged and dumped into the floodwater. Government estimates at least 5,000 people lost their lives (http://timesofindia.indiatimes.com/india/Uttarakhand-5000-feared-killed-19000-still-stranded/articleshow/20731541.cms). The non-government estimate was likely to be more than this figure.

RESULTS OF THE UTTARAKHAND 2013 DISASTER

The unfolding of the tragedy including rotten corpses flowing down the Ganga in Uttarakhand was reported by Soma Basu on September 11, 2016 (https://fakirchand.wordpress.com/tag/tragedy/). Some of Bosu's pictures appear in Figure 24. Table 3 provides an estimated loss, converting the numbers of Basu in millions and showing the equivalence of rupees with US dollars, incurred by the hydroelectric projects.

To mention a few of the damaged hydroelectric

Table 2. Tributaries of the Ganges.

Primary tributary	Secondary tributary	Tertiary tributary	Quaternary tributary	Quinary tributary	Senary tributary
Jodhganga	-	-	-	-	-
Bhilaganga	-	-	-	-	-
Alakanda	Mandakini	-	-	-	-
-	Kali/Sarda	Goriganga	-	-	-
-	-	Sarju	Ramganga E	-	-
	Rqmganga W	-	-	-	-
-	Pindar	-	-	-	-
Yamuna	Chambal	Kalisindh	Parwan Uja	-	-
-	-	-	-	Newaj	-
-	-	-	-	Ghar	-
-	-	-	-	Chappi	-
-	-	-	-	Ghorapachhar	-
-	-	Mej	-	-	-
-	-	Chakan	-	-	-
-	-	Parvati	-	-	-
-	-	Kuno/Kunu	-	-	-
-	-	Sip	-	-	-
-	-	Khan	-	-	-
-	-	Sipra	-	-	-
-	-	Alinia	-	-	-
-	-	Banas	Bearch	-	-
-	-	-	Gambhiri	-	-
-	Tons	-	-	-	-
-	Betwa	Dhasan	-	-	-
-		Kaliasote	-	-	-
-		Halali	-	-	-
-		Bah	-	-	-
-		Sagar	-	-	-
-		Budhna	-	-	-
-		Jamini	-	-	-
-		Bina	-	-	-
-		Virma	-	-	-
-	Giri	-	-	-	-
-	Assan	-	-	-	-
Sind	Pahuj	-	-	-	-
-	-	-	Karai	-	-
-	-	-	Mahaur	-	-
-	-	-	Parwati	Lasi	-
Berni	-	-	-	-	-
Bethli	-	-	-	-	-
Andheri	-	-	-	-	-
Retri	-	-	-	-	-
Dubraj	-	-	-	-	-
Bilas	-	-	-	-	-
Kunu	-	-	-	-	-
-	-	-	Banas	Menali	-
-	-	-	-	Mashi	Bandi
-	-	-	-		Sohadora

Table 2. Cont.

-	-	-	-	Kothari	
-	-	-	-	Khari	Mansi
-	-	-	-		Nekhadi
-	-	-	-	Dai	
-	-	-	-	Dheel	Guida
-	-	-	-	Murel	Dhund
-	-	-	-	-	Kankrauli
-	-	-	-	-	Kalisil
Berach	Ayar	-	-	-	-
Wagli Wagon	-	-	-	-	-
Gambhiri	-	-	-	-	-
Orai	-	-	-	-	-
-	-	-	Kalisind	Parwan	-
-	-	-	Khan	-	-
-	-	-	Sipra	-	-
-	-	Ken	-	-	-
-	-	Hindon	-	-	-
-	-	Bata	-	-	-
-	Sone	Kanhar Theme	-	-	-
-	-	-	Lanva	-	-
-	-	-	Pandu	-	-
-	-	-	Goita	-	-
-	-	-	Hathinala	-	-
-	-	-	Suria	-	-
-	-	-	Chana	-	-
-	-	-	Sendur	-	-
-	-	-	Kursa	-	-
-	-	-	Galphulla	-	-
-	-	-	Semarkhar	-	-
-	-	-	Riger	-	-
-	-	-	Cherna Nalla	-	-
-	-	Rihand	-	-	-
-	-	Johilla	-	-	-
-	-	Mahanadi	-	-	-
-	-	Gopad	-	-	-
-	-	Rehar	-	-	-
-	-	Banas	-	-	-
-	Karnali	-	-	-	-
Ghagra Seti	-	-	-	-	-
-	Bheri	-	-	-	-
Sarda/Kali	-	-	-	-	-
Mahakali	-	-	-	-	-
Surya	-	-	-	-	-
Rapti	-	-	-	-	-
-	Karmanasha	-	-	-	-
-	Gandaki	-	-	-	-
-	Ramganga	-	-	-	-
-	Kosi	-	-	-	-
-	Bhahmaputra	Teesta	-	-	-
-	Meghna		-	-	-

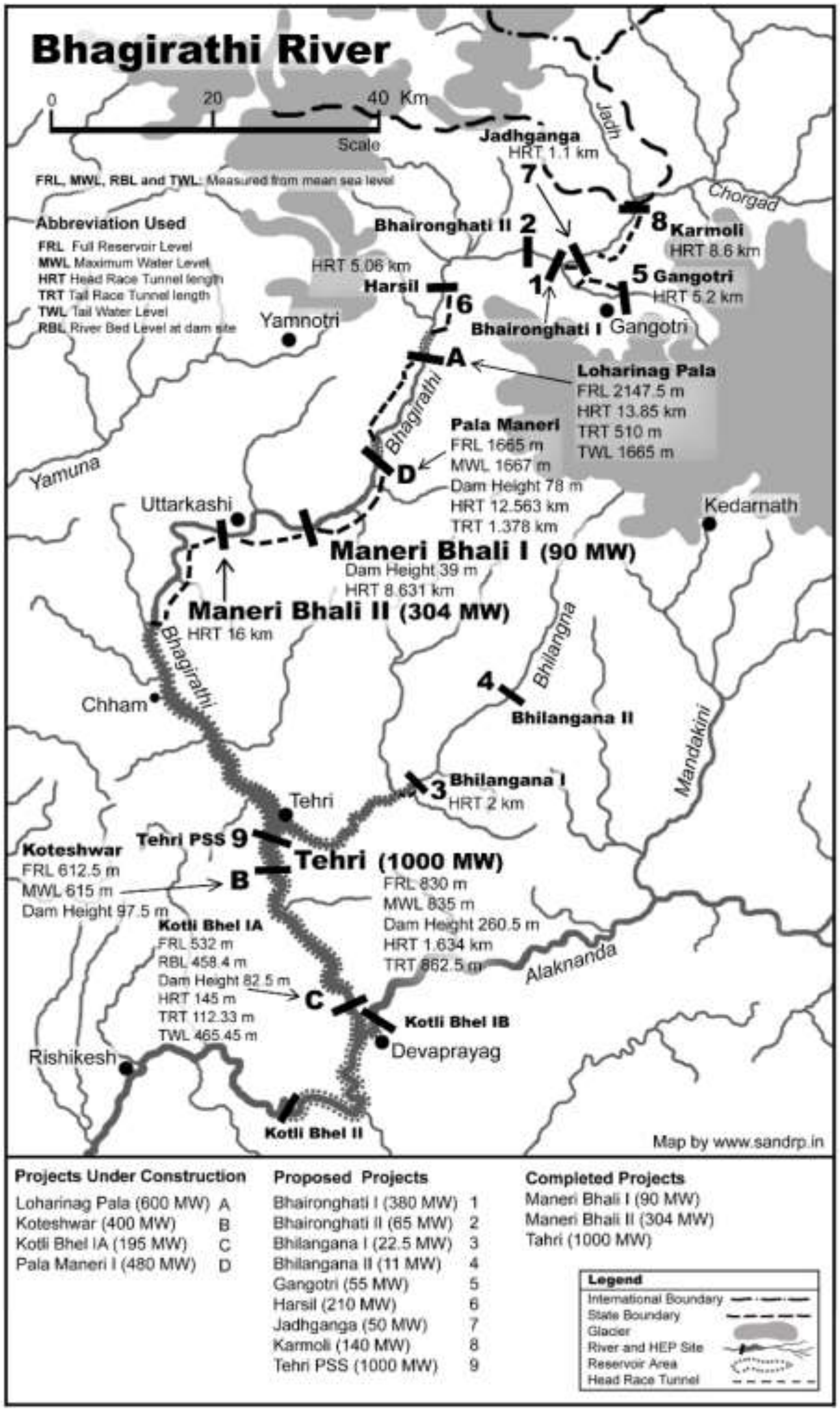


Figure 12. The Bhagirthi basin (http://sandrp.in/basin_maps/Bhagirathi%20150411.jpg).

projects, the flood seriously damaged 10 large projects that included operational and underconstructional ones in that state. It destoyed 19 small size (<25 MW) operational projects.

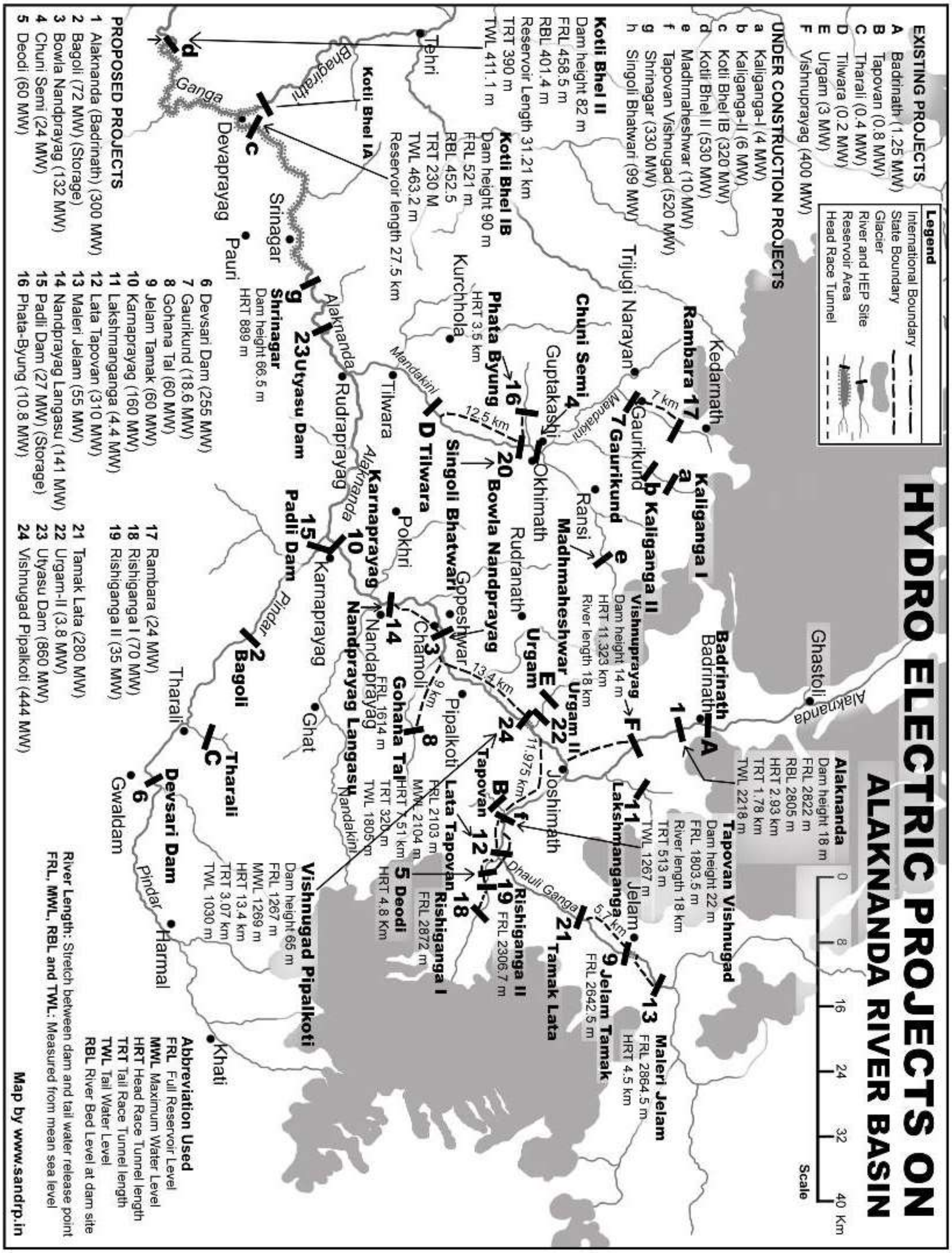


Figure 13. The Alaknanda basin (http://sandrp.in/basin_maps/Alaknanda%20150411.jpg).

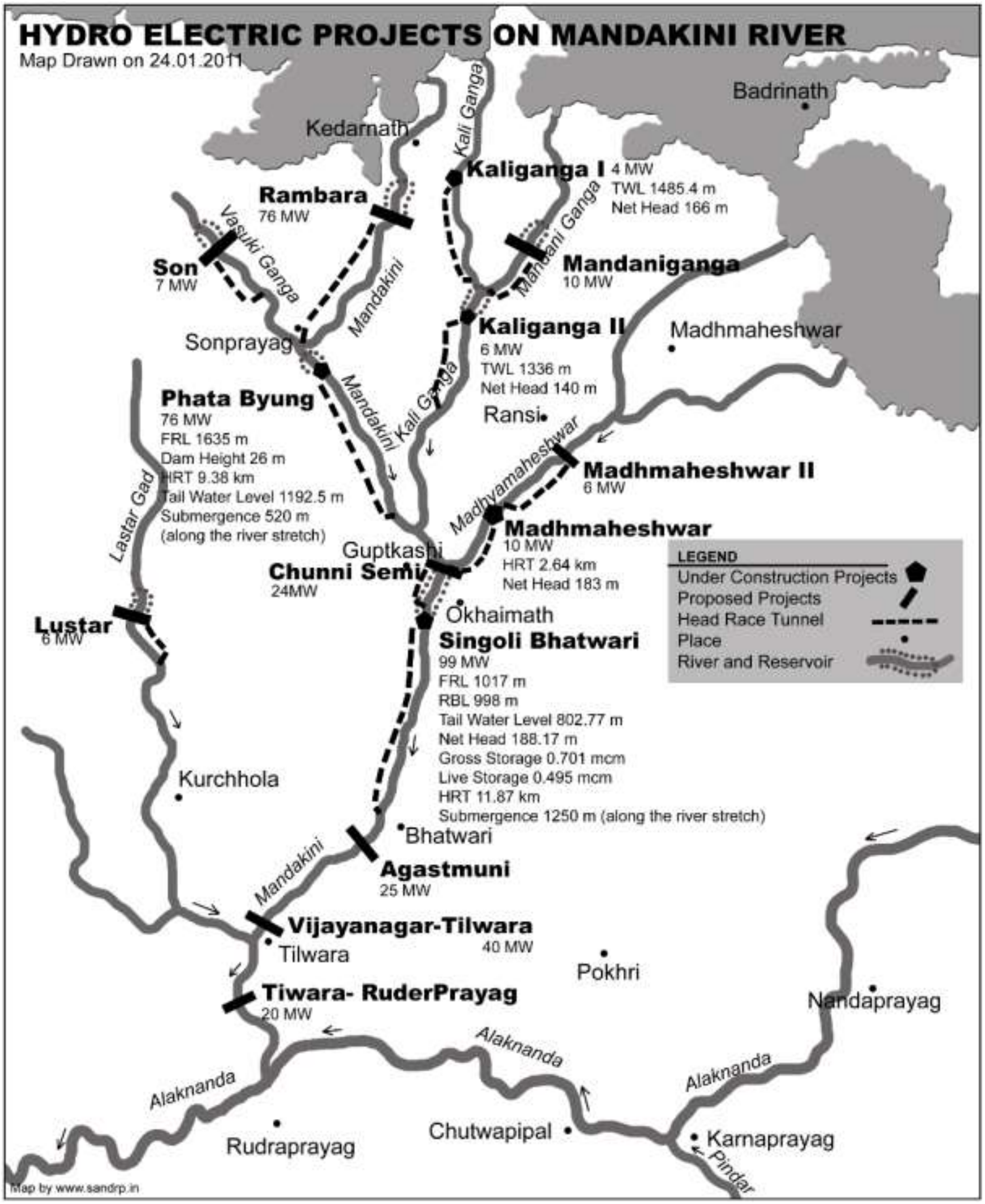


Figure 14. The Mandakini basin (http://sandrp.in/basin_maps/Mandakini150411.jpg).

Floodwater surged over the 16.76-m high dam of the Vishnuprayag Hydroelectric Project on the Alakanda River and boulders buried it under 18.3-m thick rubbles. Figure 25 (reproduced with permission from SANDRP) shows some of the destructions. Boulders brought by the swelling river current battered the Vishnuprayag

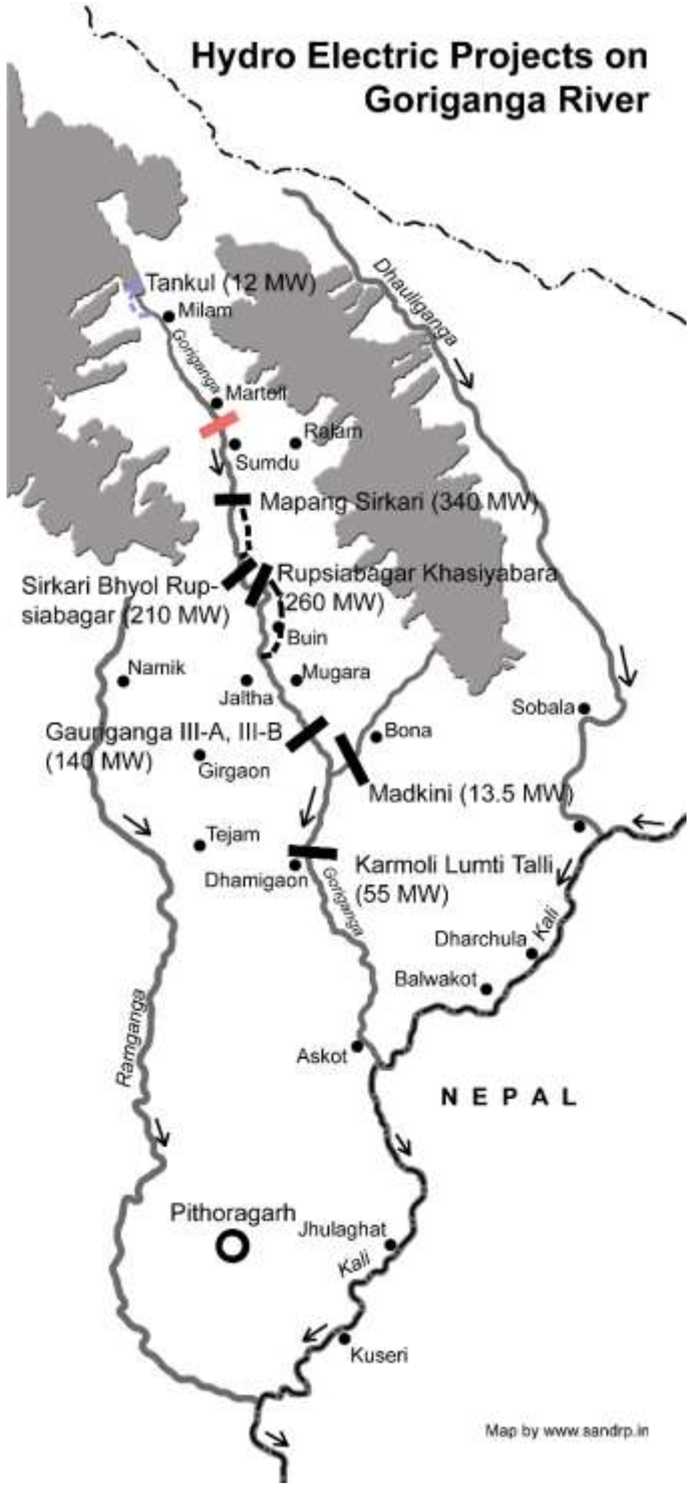


Figure 15. The Goriganga basin (http://sandrp.in/basin_maps/Goriganga150411.jpg).

Hydroelectric Project on the Alakanda River. Mud and silt piled up on the damtop. The concrete cracked and ruptured, and the steel reenforcing bars were exposed. Its capacity was 400 MW. It took five months to remove

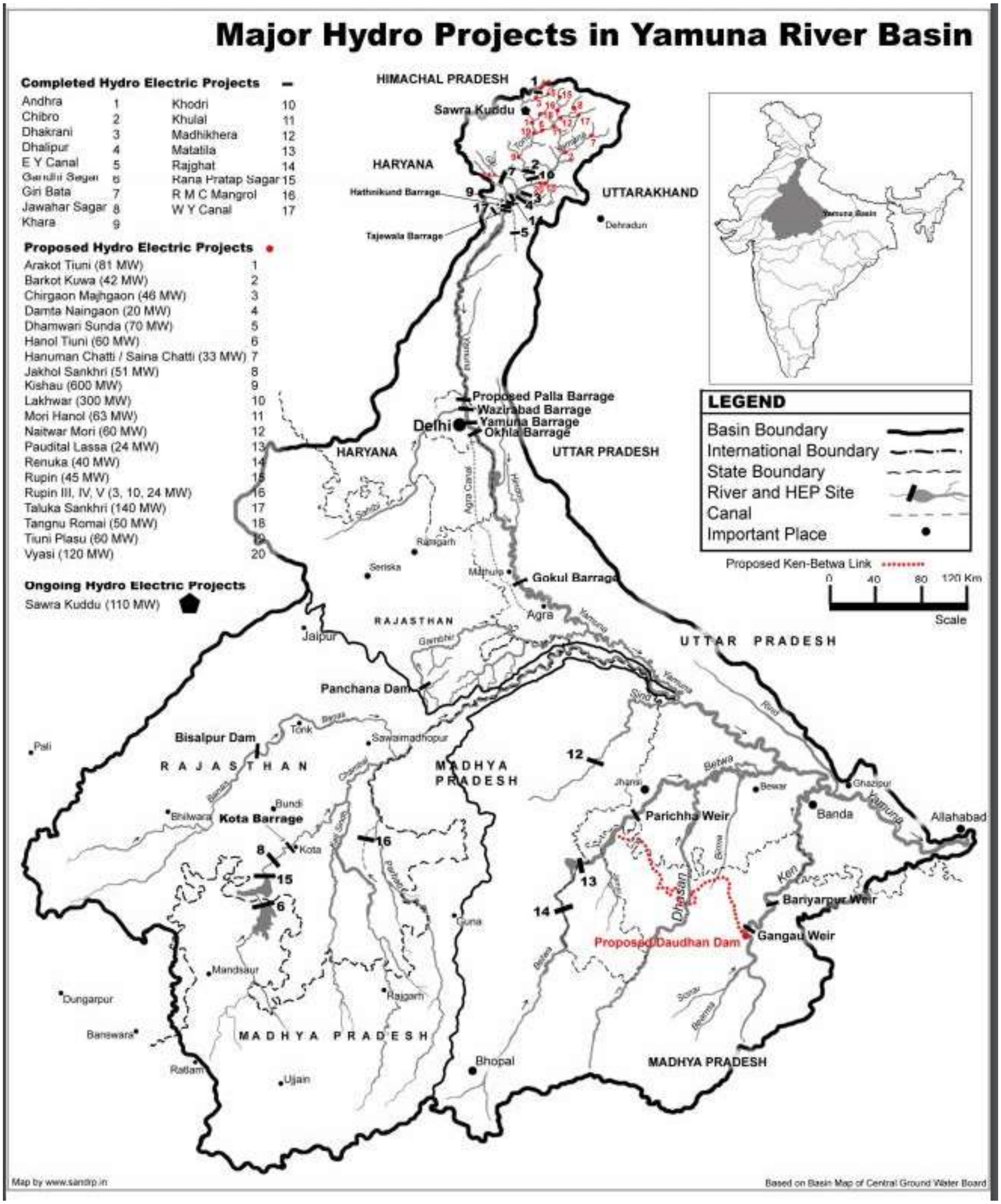


Figure 16. The Yamuna basin (http://sandrp.in/basin_maps/Major_Hydro_Projects_in_Yamuna_Basin.pdf).

much of the piles of boulders on the dam. The project was buried under 20 m of rubbles, its reservoir got filled with rubbles, and the penstock was likely wrecked.

Further, the severe consequences included back-flowing of the river to the reservoir behind the dam, filling it with rubbles, opening of a new channel around its eastern side, and washing away of the operating offices and a national highway

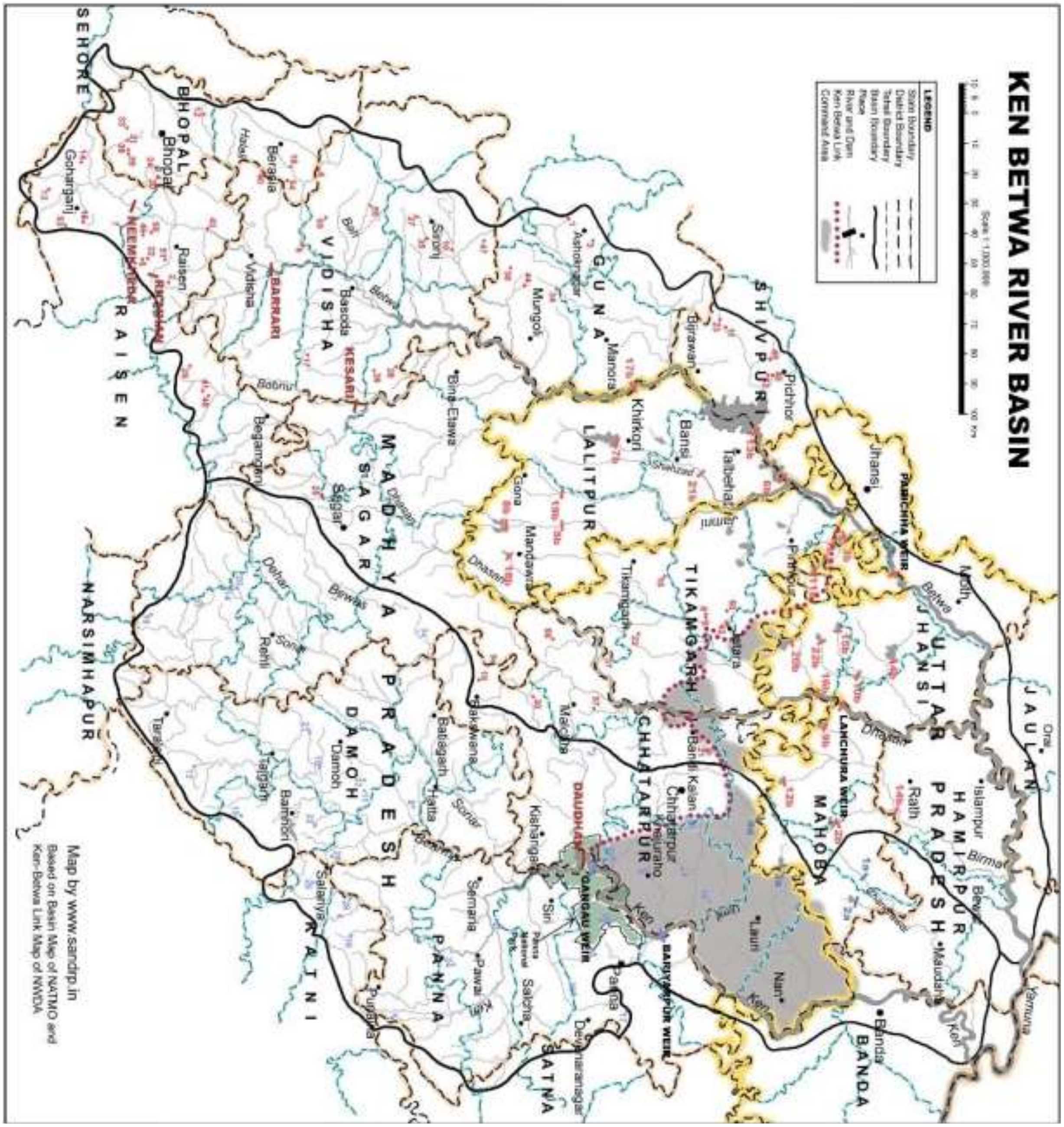


Figure 17. The Ken Betwa basin (http://sandrp.in/basin_maps/Ken%20betwa%20All%20Projects150411.jpg).

(http://www.circleofblue.org/2014/world/uttarakhand-flood-disaster-made-worse-existing-hydropower-projects-expert-commission-says/).

The walls of both the dams of the 25-year old and 99-MW generating Maneri Bhali-I and the five-year-old 304-MW generating Maneri Bhali-II (Figure 25c) on the Bhagirathi River collapsed. Also, it affected the Banbasa Project on the Sarda River near Nepal.

The Singoli-Bhatwari Hydroelectric Project (Figure 26a) was constructed on the Mandakini River, a headstream of the Alaknanda River. The 99-MW capacity project was so destructively attacked by the gushing water that large concrete chunks were gouged out of its foundation bending and deforming the exposed steel reinforcing rods. The 330-MW Hydroelectric Project on the Alaknanda River is shown in its new condition in Figure 26b and in its demolished condition in Figure 27a. The disaster destroyed more than 1,000 km of the state's

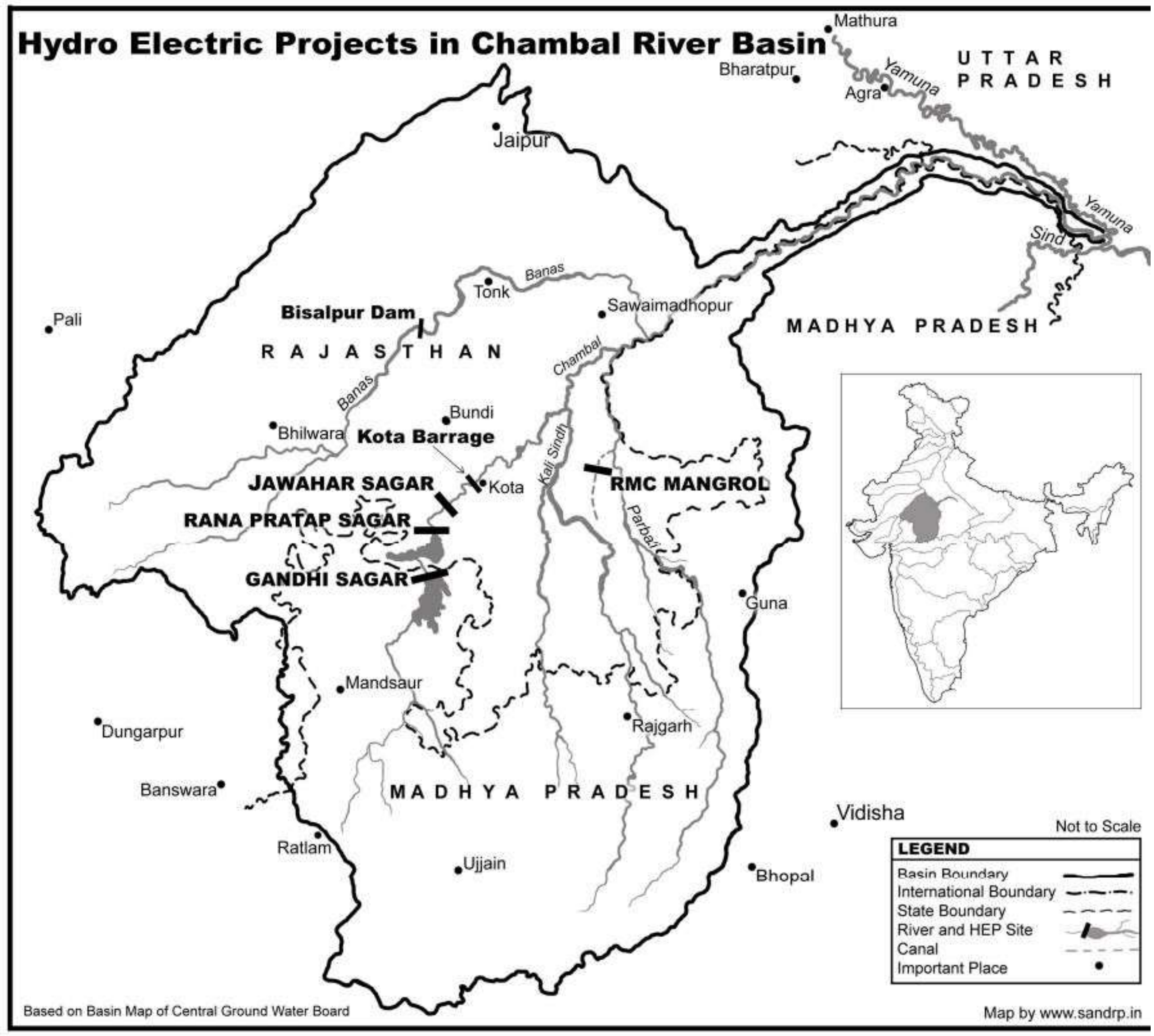


Figure 18. The Chambal basin (http://sandrp.in/basin_maps/Hydropower_Projects_in_Chambal_Basin.pdf).

one-way-in, one-way-out highway (Figure 26c).

Another severely damaged huge project was the 330-MW Alaknanda Hydro Power Project in Srinagar (Figure 27a). The floodwater inundated the power station. The turbine got stuck with the deposition of mud and grit. The project's opening was delayed from October 2013 to March 2014. Included among the under-construction dams that were damaged are the 520-MW Tapovan Vishnugad Dam (Figure 27b) on a tributary of the Alaknanda River that lost the tunnel carrying water to the power house, and the 171-MW Lata Tapovan Project got its concrete work damaged. Also, a landslide blocked the discharge tunnel end at the 280-MW Dhauliganga Power Project (Figure 27c). The closure caused the backup water submerged the entire turbine room that was set deep inside the hill by the dam. It was a damage of at least \$50 million (Schneider, 2014).

Piana Gad is a small hydroelectric project. Its demolished condition is shown in Figure 28a. The under-construction Assi Ganga-II project had a reservoir depth of 3 m and the full reservoir level was 1,372.95 m high. Its catchment area was 167 km^2. Its design discharge was 8.56 cumecs. The total length of the water conductor system was 2.162 km, and the river was diverted over a distance of 2 km. Its damaged condition is as shown in Figure 28b and c.

The damaged condition of Kali Ganga I HEP of 4 MW and Kaliganga II HEP of 6 MW in Rudraprayag District in the Mandakini River basin are shown in Figure 29.

The post-disaster condition of the Madhy Maheshwar Project in Rudra Prayag District appears in Figure 30a. Figure 30b shows the image of the Phata Byung HEP of

Figure 19. The Banas basin (http://sandrp.in/basin_maps/Bisalpur%20dam.jpg).

76 MW on the Mandakini River in Rudra Prayag District. The upstream of the dam site shows 10 to 15 m eroded material deposited in the Mandakini River bed. Figure 30c shows the condition of the Singoli Bhatwari HEP of 99 MW on the Mandakini River in Rudra Prayag District.

The damaged Bhyunder Ganga HEP of 15 MW on the Alaknanda River in Chamoli District is shown in Figure 31a and the Banala Mini HEP 15 MW in Chamoli District in Figure 31b. The Lata Taopan HEP of 171 MW in Chamoli District appears in Figure 31c.

The establishment of too many structures of water resources exploitation at a place leads to loses of the local natural balance. The virgin state may be altered within certain limits, but not limitlessly. It establishes the local climate which is a long-time average effect. Having fulfilled the upstream demand, the water fluid should be left to flow in response to its properties. The flood of 2013 was a reminder to the Indians of this lesson. Had there been not so many dams/reservoirs and barrages, the swelling rivers could quickly discharge their water, and the incessant rain might not even occur because of the lack of the support from the locally produced water vapor. The huge loss of lives and properties could be saved.

Facts and Figures: Projects in the Indus Basin

The Indus River

The Indus River (Figure 32, 33 and 34) has length of 3,200 km and a discharge of 6,600 cumecs. Its basin is spread over Pakistan (47%), India (39%), China (8%), and Afghanistan (6%) and these countries have 65, 14, 1, and 11% of their land, respectively, in the Indus Basin (http://www.fao.org/nr/water/aquastat/basins/indus/index.stm). The origins of the rivers of Pakistan being in India

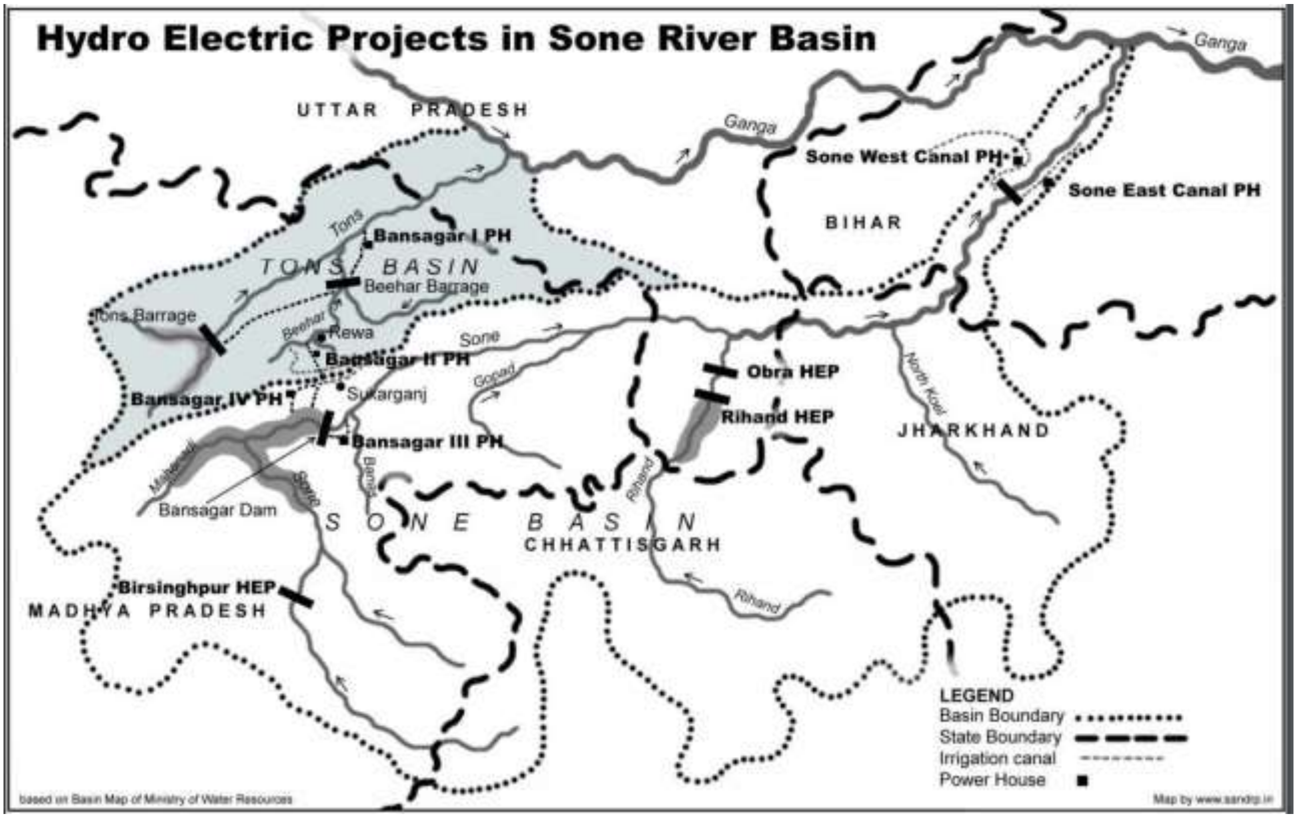


Figure 20. The Sone basin (http://sandrp.in/basin_maps/Hydropower_Projects_in_Sone_Basin.pdf).

(Figure 33), Pakistan feared that India could close the supply of water to Pakistan at times of tensions or wars between the two countries. The World Bank mediated the water sharing treaty between the two countries and it was signed by the Indian Premier and the Pakistani President on 19 September 1960. Although these two countries fought wars, they did not fight for water rights since treaty was signed. It is said to be one of the most successful treaties.

According to the treaty, Pakistan got exclusive rights over the Chenub, the Jhelum, and the Indus called the Western River, and India got exclusive rights over the water of the Ravi, the Beas (Figures 32 and 46), and the Sutlej called the eastern rivers (Figure 33). All these rivers join the Indus on its east side.

LULC in the Indus Basin

The followings are the dams in the Indus Basin covering up to India-Pakistan International Border in the state of Jammu and Kashmir of 222,229 km^2 serving a population of 12.55 million as of 2011 (http://www.india-wris.nrsc.gov.in/wrpinfo/index.php?title=Dams_in_Jammu_and_Kashmir):

(1) 143-m high and 364.362 m long Baglihar Dam on the Chenab near Ramban City in Ramban District in the Indus Basin up to International Border;
(2) 65-m high 186-m long Dulhasti Dam on the Chenab near Kishtwar City in Kistwar District in the Indus Basin up to International Border;
(3) 37-m high, 189-m long Kishenganga Dam on the Kishenganga in Bandipur;
(4) 57-m high, 247-m long Nimoo Bazgo Dam on the Indus near Leh City in Leh (Ladakh) District;
(5) 227-m long Niu Karewa Storage Yusmarg Dam near Chadura City;
(6) 167-m high, 305-m long Pakal Dul Dam on Marusudar in Kishtwar District;
(7) 113-m high, 487-m long Salal (Rockfill And Concrete) Damon the Chenab near Gool Gulab Garh City in Reasi District;
(8) 53-m high, 114-m long Sewa St II Dam on Sewa near Bashohli City in Kathua District;
(9) 176-m long Uri-II Dam on the Jhelum near Uri City in Baramula District.

The rivers of Pakistan that have origins in India are as shown in Figure 33. The hydroelectric projects in the

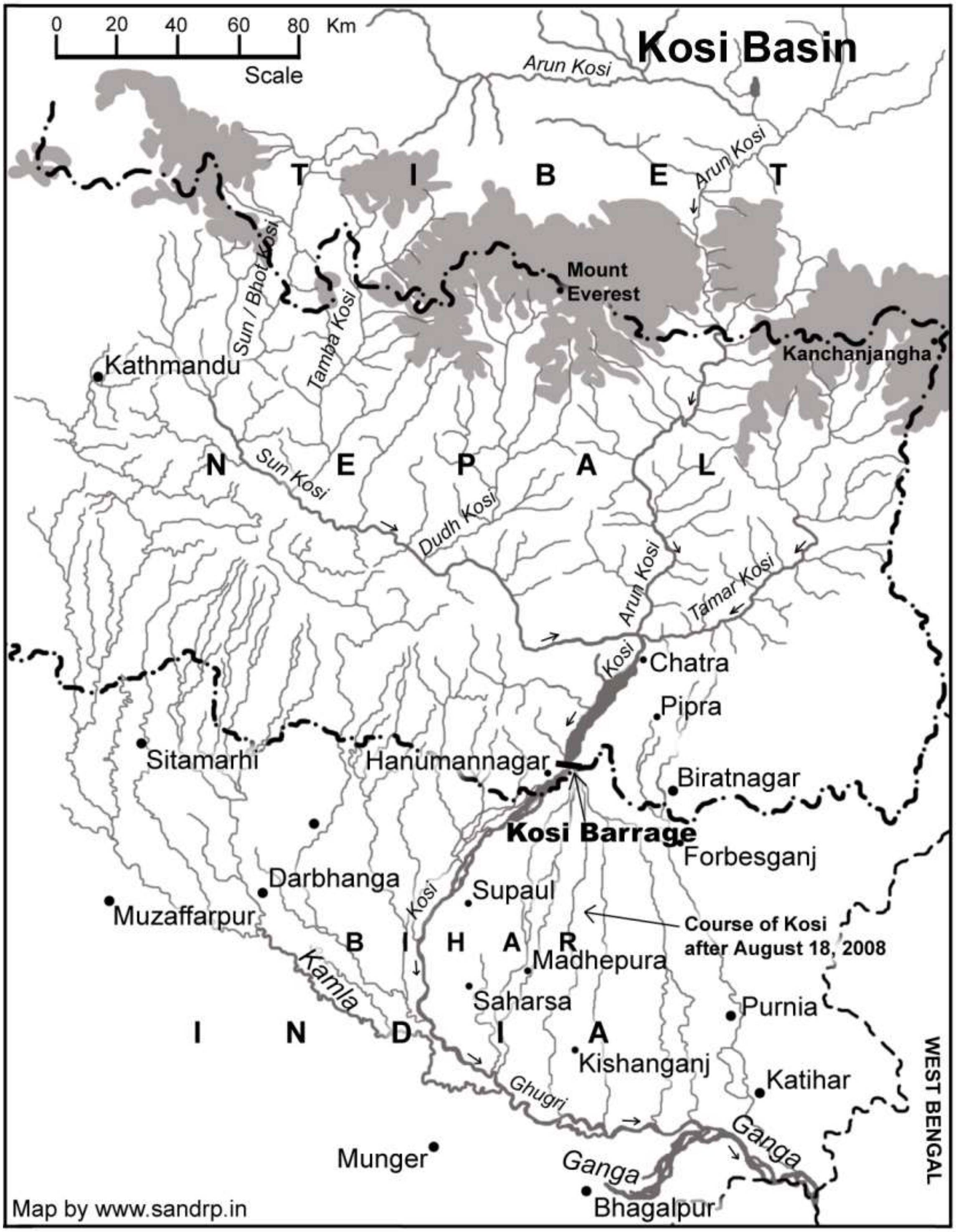


Figure 21. The Kosi basin (http://sandrp.in/basin_maps/Kosi%20Basin150411.jpg).

Indus Basin, on the Indus River, on the Jhelum River, in the Chenab River basin, in the Ravi River Basin, in the Beas River Basin, and in the Sutlej River Basin are as shown in Figures 35, 36, 37, 38, 39, 40, and 41, respectively. Figure 42 shows the existing projects in the Sutlej River basin.

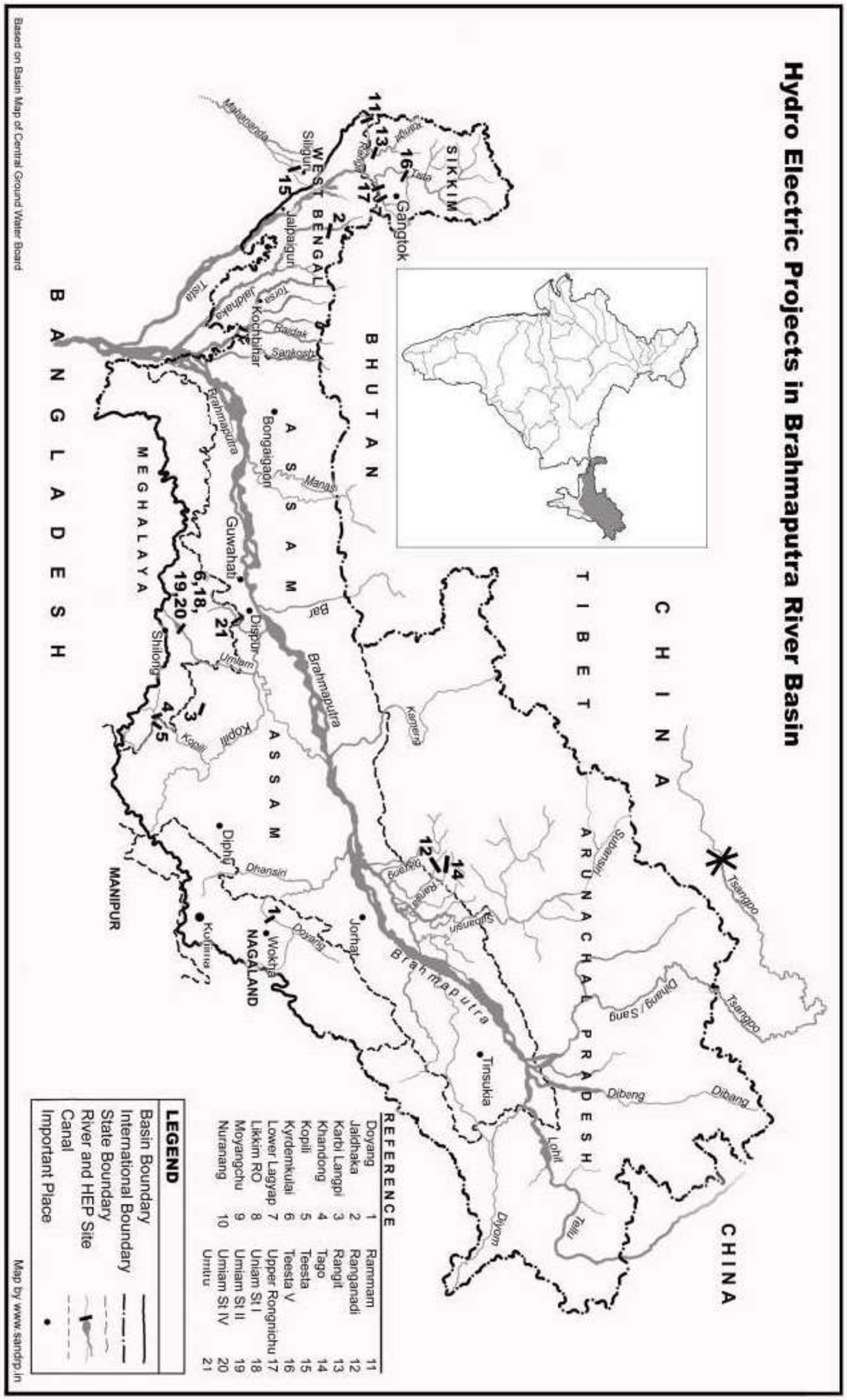


Figure 22. The Brahmaputra basin (http://sandrp.in/basin_maps/Hydropower_Projects_in_Brahmaputra_Basin.pdf).

Figure 23. (a) The cloud in Uttarakhand sky that made the downpour (NASA, MODIS, 2013); b. Uttarakhand Alakand River flood (Uttarakhand News, https://www.youtube.com/watch?v=scUKQ5IRZCY); c. Uttarakhand Alakand River flood 2013: cars, bus float like toys (Uttarakhand News https://www.youtube.com/watch?v=scUKQ5IRZCY).

The Indus Basin 2014 Jammu-Kashmir disaster

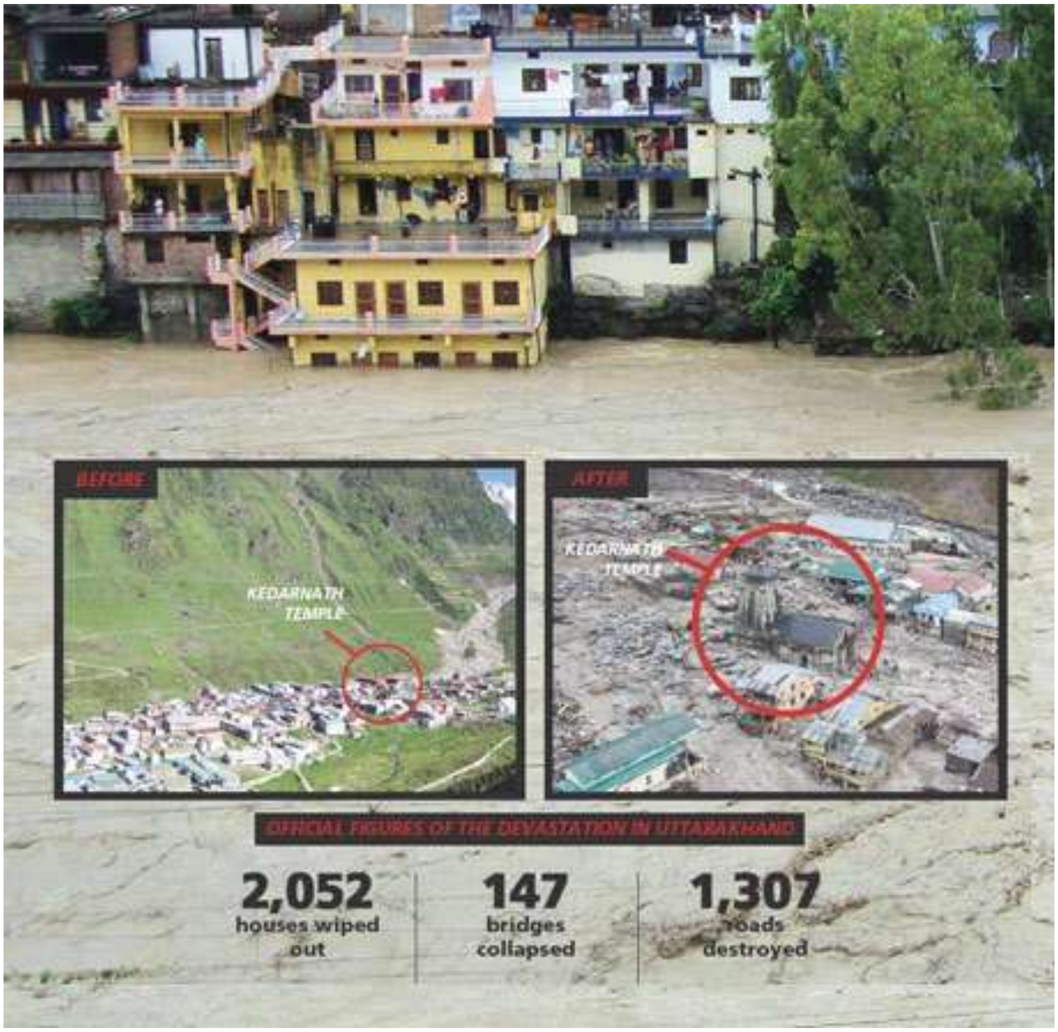
The 2014 India-Pakistan flood may be attributed to the same reason that causes anthropogenic activities.

Above this dam-abundant area in the sky, NASA noticed the cloud imaged in Figure 43. This reenforces the idea of locally generated abundant moisture in the air that formed the cloud. The downpour started from September 2, 2014.

The state of Jammu and Kashmir had incessant rainfall from September 2, 2014 onward that caused Srinagar's Jhelum River discharge 70000 cumecs against the normal discharge of 25000 cumecs. The catastrophic rainfall submerged 390 villages in Kashmir, partially affected 1225 villages and affected 1000 villages in Jammu Division. Adjoining areas of Pakistan were also affected (Greater Kashmir newspaper official website. Retrieved on 7 September 2014. http://www.greaterkashmir.com/news/2014/Sep/5/kashmir-floods-throw-life-out-of-gear-6.asp*; "Flood Situation Grim in Jammu and Kashmir, Army Called for Rescue Efforts"*. New Indian Express. 5 September 2014*. Retrieved 7 September 2014*; *"India and Pakistan Strain as Flooding Kills Hundreds". New York Times. 8 September 2014. Retrieved 9 September 2014*).

The record-break amounts of rainfall from the spell during September 4 to 5 in different cities/places are stated in Table 4.

Even on 8 September, Srinagar's many surrounding parts were under about 4-m deep water. As of 10



a

b

Figure 24. (a) The impact of the disastrous flood (https://fakirchand.wordpress.com/tag/tragedy/); (b) A corpse stuck in debris in a residence in Kedarnath (https://fakirchand.wordpress.com/tag/tragedy/).

Table 3. Estimated losses from damage to hydropower projects (HEPs) on the Ganga.

Project	Location	Capacity (MW)	Estimated Loss (Rs. 60.00 ≈ US$1.00)
Dhauli Ganga	Pithoragarh	280	Rs 3,000 million (project completely submerged)
Kaliganga I	Rudraprayag	4	Rs 18,000 -19,000 million (power house and 4 houses washed away)
Kaliganga II	Rudraprayag	6	Rs 16,000 million (power house and 4 houses washed away)
Sobla	Pithoragarh	8	Rs 14,000 million (completely washed away)
Kanchauti	Pithoragarh	2	Rs 12,000 million (totally washed away)
Chirkila	Pithoragarh	1.5	Rs 20,000 million (part of the project washed away)
Maneri Bhali I&II	Uttarkashi	304+90	Rs 200 million + Rs 500 million (walls collapsed, silt in barrages)

Courtesy of Soma Basu (http://www.downtoearth.org.in/news/hydropower-projects-suffer-severe-damage-41442 (https://fakirchand.wordpress.com/tag/tragedy/).

a b c

Figure 25. (a) Flood-destroyed SSB Academy in Srinagar, Uttarakhand (Photo by Upadhyay, 2013); (b). The disaster-demolished 400-MW VishnuPrayag hydroelectric project on the Alakanda River (http://www.circleofblue.org/2014/world/uttarakhand-flood-disaster-made-worse-existing-hydropower-projects-expert-commission-says/); (c) Phase II of the Maneri Bhali project on the Bhagirathi near Uttarkashi (http://www.tribuneindia.com/2009/20090224/dplus.htm).

a b c

Figure 26. (a) The damaged Singoli-Bhatwari Hydroelectric Project on the Mandakini River (left inset); (b) The newly constructed 330-MW Hydroelectric Project on the Alaknanda River (Reproduced with permission from SANDRP); (c) The demolished Uttarakhand's highway on a steep Himalayan slope (http://www.circleofblue.org/2014/world/uttarakhand-flood-disaster-made-worse-existing-hydropower-projects-expert-commission-says/).

September, more than 190 lives were lost in the Kashmir Valley. Southern Kashmir districts were mostly affected (https://en.wikipedia.org/wiki/2014_India%E2%80%93Pakistan_floods).

India's Hegemony

Recently, India is diverting water to build a 330-MW hydroelectric project on the Kishenganga River (Figures 34, 44 and 45), a tributary of the Jhelum River, one of the rivers that Pakistan has exclusive rights on. This river is at an elevation of 750 m, length 245 km, and an average discharge of 465 cumecs. Pakistan approached the international court protesting that India would be diverting the water that would affect its 969-MW Neelum-Jhelum hydroelectric project. She would divert the Kishenganga water through a 24-km long tunnel dug through the

a b c

Figure 27. (a) Srinagar Hydroelectric Project on Alaknanda river, UK, India Srinagar HEP - Source: http://www.circleofblue.org/waternews/2014/world/uttarakhands-furious-himalayan-flood-bury-indias-hydropower-program/ (left inset); (b) Land slide near the dam of Tapovan Vishnugad HEP (https://sandrp.wordpress.com/2014/06/16/uttarakhand-flood-disaster-of-june-2013-lest-we-forget-the-experience-and-its-lessons/) (middle inset); (c) The Dhauliganga hydropower dam aftet being flushed off of bed-load sediment following 2013 Flood (http://sandrp.wordpress.com/2013/09/27/uttarakhand-floods-of-june-2013-curtain-raiser-on-the-events-at-nhpcs-280-mw-dhauliganga-hep/).

a b c

Figure 28. (a) A 2013 flood destruction of a small-size 5 MW hydroelectric project on the Piana Gad (http://sandrp.files.wordpress.com/2013/07/e_theophilus_img_28782_lbld_rsz5mwmotighatheppithorgarh.jpg, with permission) (Picture on June 23, 2013 by E. Theophilus/Himal Prakriti); (b) The damaged Assi Ganga –II HEP power house; (c) The damaged intake side (https://sandrp.wordpress.com/2014/06/16/uttarakhand-flood-disaster-of-june-2013-lest-we-forget-the-experience-and-its-lessons/).

a b c

Figure 29. (a) Kali Ganga I HEP (4 MW, Rudraprayag District) (https://sandrp.wordpress.com/2014/06/16/uttarakhand-flood-disaster-of-june-2013-lest-we-forget-the-experience-and-its-lessons/); (b) Kaliganga II HEP (6 MW, Rudraprayag district, Mandakini Basin), muck-deposited 3-4 m that damaged the building of HEP (https://sandrp.wordpress.com/2014/06/16/uttarakhand-flood-disaster-of-june-2013-lest-we-forget-the-experience-and-its-lessons/); (c) The damaged structures of Kaliganga II HEP.

a b c

Figure 30. (a) The condition of the Madhy Maheshwar Project (https://sandrp.wordpress.com/2014/06/16/uttarakhand-flood-disaster-of-june-2013-lest-we-forget-the-experience-and-its-lessons/); (b) Phata Byung HEP (76 MW, Mandakini river, Rudra Prayag district) (https://sandrp.wordpress.com/2014/06/16/uttarakhand-flood-disaster-of-june-2013-lest-we-forget-the-experience-and-its-lessons/); (c) Singoli Bhatwari HEP (99 MW, Mandakini river, Rudra Prayag district) (https://sandrp.wordpress.com/2014/06/16/uttarakhand-flood-disaster-of-june-2013-lest-we-forget-the-experience-and-its-lessons/).

a b c

Figure 31. (a) Bhyunder Ganga HEP (15 MW, Alaknanda river, Chamoli Disrict) (https://sandrp.wordpress.com/2014/06/16/uttarakhand-flood-disaster-of-june-2013-lest-we-forget-the-experience-and-its-lessons/) (left inset); (b) Banala Mini HEP (15 MW, Chamoli Dist) (https://sandrp.wordpress.com/2014/06/16/uttarakhand-flood-disaster-of-june-2013-lest-we-forget-the-experience-and-its-lessons/) (middle inset); (c) Lata Taopan HEP (171 MW, Chamoli district) (https://sandrp.wordpress.com/2014/06/16/uttarakhand-flood-disaster-of-june-2013-lest-we-forget-the-experience-and-its-lessons/) (right inset).

mountains (Figure 44) to Bandipur to meet the Wular Lake and the Jheelum River. In 2013, the court gave the verdict in favor of India.

Valuable pieces of information are availabe from case studies on upstream water piracy. Tributaries are the sources of discharge in the main river. Blocking a tributary discharge can cause very adverse effects in the main river basin. The decades-long study results of this author are mentioned in the references. These give valuable insights for the parties, the judges and others concerned in resolving disputes over international water bodies. The verdict was not certainly a wise one in respect of many interconnected potentially harmfull direct and feedback effects for the downriver ecosystem. Certainly, the judges were not aware of the causes of losing the founding and sustaining water resources for a riparian ecosystem.

DISCUSSION

Surface features change leading to new radiation balance: Temperature variation effect

Other than degrading the river, the upstream basin suffers from deforestration in the process of construction of dams and barrages on the rivers. It causes erosion which is carried downstream creating heavy siltation on river beds. The siltation favors clogging the heads of the distributaries consequent upon which inland surface water bodies are deprived of water. The aquatic world faces the risk of endangerment and extinction. Apart from

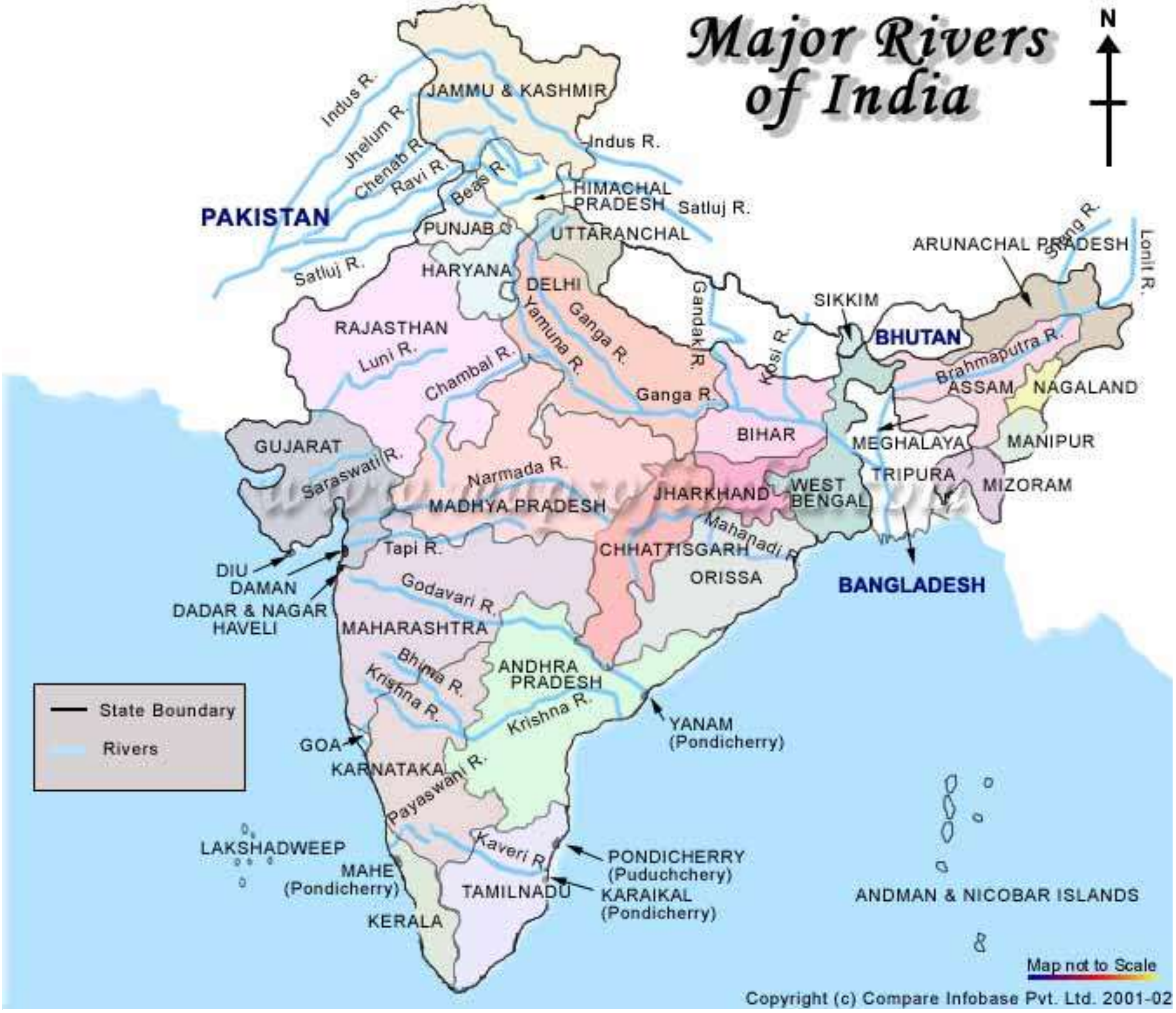


Figure 32. River map of India (http://barra.tk/india-river-maps/).

those effects, landslides can occur in the upstream hilly regions.

Temperature change

The temperate effect may be understood from the radiation balance equation. On the surface of the earth, the energy balance equation is:

$$M^{*}_{R} = M_G + M_{LH} + M_{SH} + \Delta M_s + \Delta M_{adv} \quad (8)$$

where M^{*}_{R} (W m^{-2}) is the net radiant flux density, that is, the difference between incoming and outgoing radiation; M_G (W m^{-2}) is the soil heat flux density, a term that includes the thermal diffusivity k, the soil volumetric heat capacity C_V, and the downward temperature gradient $\delta T/\delta z$; M_{LH} (W m^{-2}) is the latent heat flux density, a term that includes the latent heat of vaporization L, the air density ρ, the aerodynamic transfer coefficient for humidity C_{DE}, the mean wind speed U_r at the reference height r, and the difference between the specific humidity of the surface q_s and at the reference height q_a in the air, $q_s - q_a$:

$$M_{LH} = LE \qquad \text{(Arya, 1998)} \quad (9)$$

$$M_{LH} = \alpha s M_R/(s + \gamma) \quad \text{(Henry and Heinke, 1996)} \quad (10)$$

where α is a proportionality constant whose value lies between unity, for a wide range of surface features that are not under very dry conditions, and 1.26 for fully moist surfaces; s is the slope of the saturation vapour pressure versus temperature curve, and $\gamma = 0.64$ hPa K^{-1}. M_{SH} (W m^{-2}) is the sensible heat flux density, a term that includes the specific heat of air at constant pressure C_p, the air

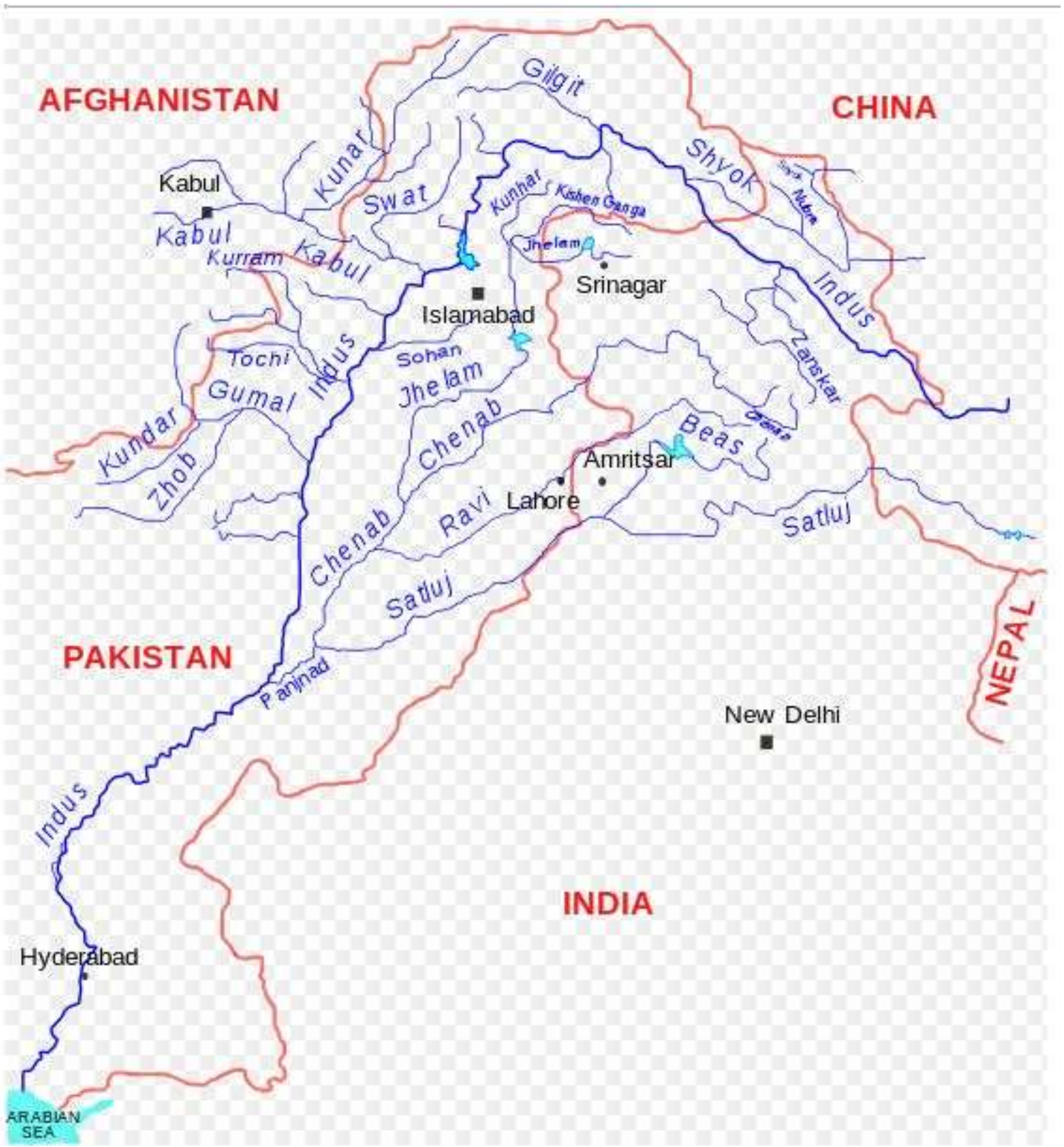


Figure 33. Rivers of Pakistan (Kmhkmh, 2009).

density ρ, the aerodynamic transfer coefficient for temperature C_{DH}, the mean wind speed U_r at the reference height r, and the difference between the temperature of the surface T_s and at the reference height T_a in the air, $T_s - T_a$ (Hartmann, 1994).

$$\Delta Ms = 1/A \int \partial/\partial t\, (\rho_{water} cT)\, dV \qquad (11)$$

where A is the area and V the control volume of the project site, ρ_{water} is the density of water, which has the highest specific heat of all materials, c is the specific heat of water, and T is the absolute temperature of water. ΔM_{adv} is the heat contribution from the incoming and outgoing air and water in the project site. The right-hand side of Equation 8 shows the distribution of the net radiation, which is made up of

$$M^*_R = (1 - \rho)M^-_{SW} + M^-_{LW} - M^+_{LW} \qquad (12)$$

where the superscript plus sign means upward outgoing and the superscript minus sign means downward incoming

$$M^*_R = (1 - \rho)M^-_{SW} + 5.31 \times 10^{-12} T^6_{air} - \varepsilon_s \sigma T^4_s \qquad (13)$$

Figure 34. Left inset:Indus River in Gilgit, Beluchistan, Pakistan (Kogo, 2004); right inset: The Kishenganga River known as the Nilam River in Pakistan (Samoon, 2009).

where ρ is the albedo, that is, the ratio of wavelength-averaged solar radiation reflected by the surface to that incident, M^{-}_{SW} is the major part of the daytime radiation received by the Earth and is obtained by integration of the radiance (W m^{-2} Sr^{-1}) measured over a solid angle of 2π steradians; σ is the Stefan-Boltzmann constant (5.67 × 10^{-8} W m^{-2} K^{-4}); ε_s (K^{-3} s^{-1} m^{-2}) is the soil surface emissivity; T_s (K) is the surface temperature; T_{air} (K) is the air temperature; M^{-}_{LW} is the thermal sky incoming radiation or longwave irradiance (W m^{-2}) and is an integral over azimuth, zenith angle, and wavelength:

$$M^{-}_{LW} = 5.31 \times 10^{-12} T^{6}_{air} \text{ (Swinbank, 1963)} \quad (14)$$

M^{+}_{LW} (W m^{-2}) is the surface longwave upwelling radiation:

$$M^{+}_{LW} = \varepsilon_s \sigma T^{4}_{s} \quad (15)$$

Taking differentials of the terms in Equation 13 to fit in the changes due to land-cover changes yields:

$$0 = -\delta\rho M^{-}_{SW} + 3.2 \times 10^{-11} T^{5}_{air} \delta T_{air} - 4\varepsilon_s \sigma T^{3}_{s} \delta T_s \quad (16)$$

The changes are referring to differences between the pre- and post-dammed average values of the quantities over a certain time interval. While applying Equation 16 for Uttarakhand, the relative weights of the terms in the equation have to be calculated in the perspective of the land use patterns for the pre- and post-dam eras (Adel, 2001). The required data are beyond the author's reach.

Daily evapotranspiration

The calculation of daily evapotranspiration needs some physical data which are innate to Uttarakhand environment and are beyond the author's reach. Dey et al. (2013) give daily evapotranspiration rate for a vegetative field as:

$$ET_{24} = 8.64 \times 10^{7} \Lambda_{ins} M^{*}_{R} / \lambda\rho_w \quad (17)$$

where M^{*}_{R} is W/m^2, λ=2.47×10^6 J/kg, and ρ_w = 1000 kg/m^3.

The calculation according to FAO Penman-Monteith (http://www.fao.org/docrep/X0490E/x0490e06.htm ,1998) method is given by:

$$ETo = [0.408\Delta (M^{*}_{R} - M_G) + \gamma\, 900\, u_2 (e_s - e_a) / (T + 273)]/[\Delta + \gamma(1 + 0.34u_2)] \quad (18)$$

where ETo = reference evapotranspiration in mm/day, M^{*}_{R}= net radiation at the crop surface in MJ/m_2.day, M_G = soil heat flux density in MJ/m^2.day, T = daily average temperature (°C) at 2-m height, u_2= wind speed at 2-m height in m/s, e_s= saturation vapor pressure in kPa, e_a= actual vapor pressure in kPa, Δ= slope of vapor pressure curve in kPa/°C, and γ= psychrometric constant in kPa/°C.

Relative humidity change

The variation of the humidity can be explained by the evapotranspiration taking place from distributed water sources. Rind (1995) reported finding a 30% increase in atmospheric moisture following a 4°C rise in temperature. Adel (2001) find from a decade-long study of microlevel climate change an increase of summertime relative humidity of 2.3% for a 1°C rise in temperature.

Humidity is dependent on the distribution of water source which has increased in the dammed period. With distributed water resources, at least, near-saturation or saturation is reached more quickly than a few point

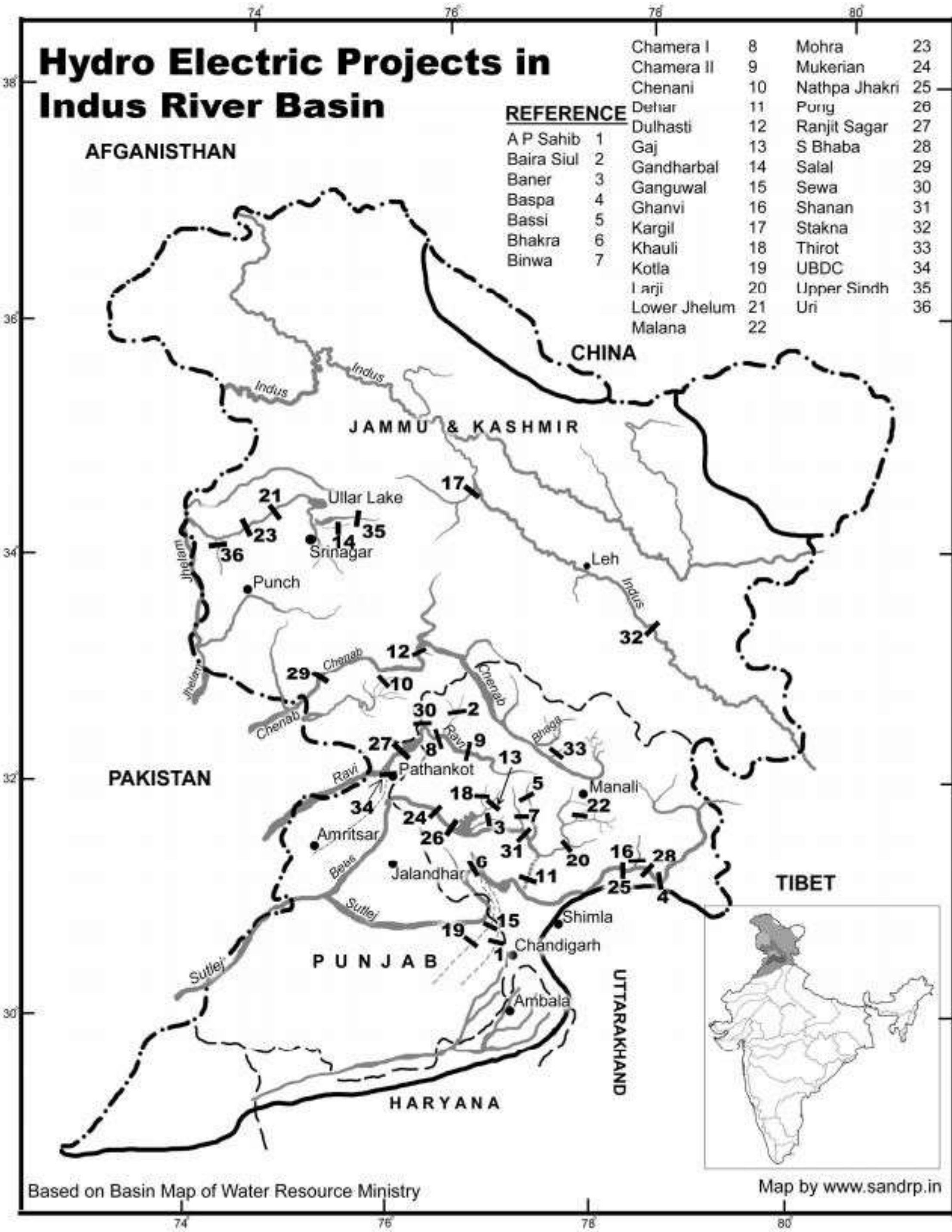


Figure 35. The Indus basin (http://sandrp.in/basin_maps/Hydropower_Projects_in_Copmposite_Indus_Basin.pdf).

sources.

The variations in the relative humidity may be understood if we can relate them quantitatively with the variations in temperature. The relative humidity U is the ratio of the actual vapor pressure e to the saturation vapor pressure e_s:

$$U = e/e_s \tag{19}$$

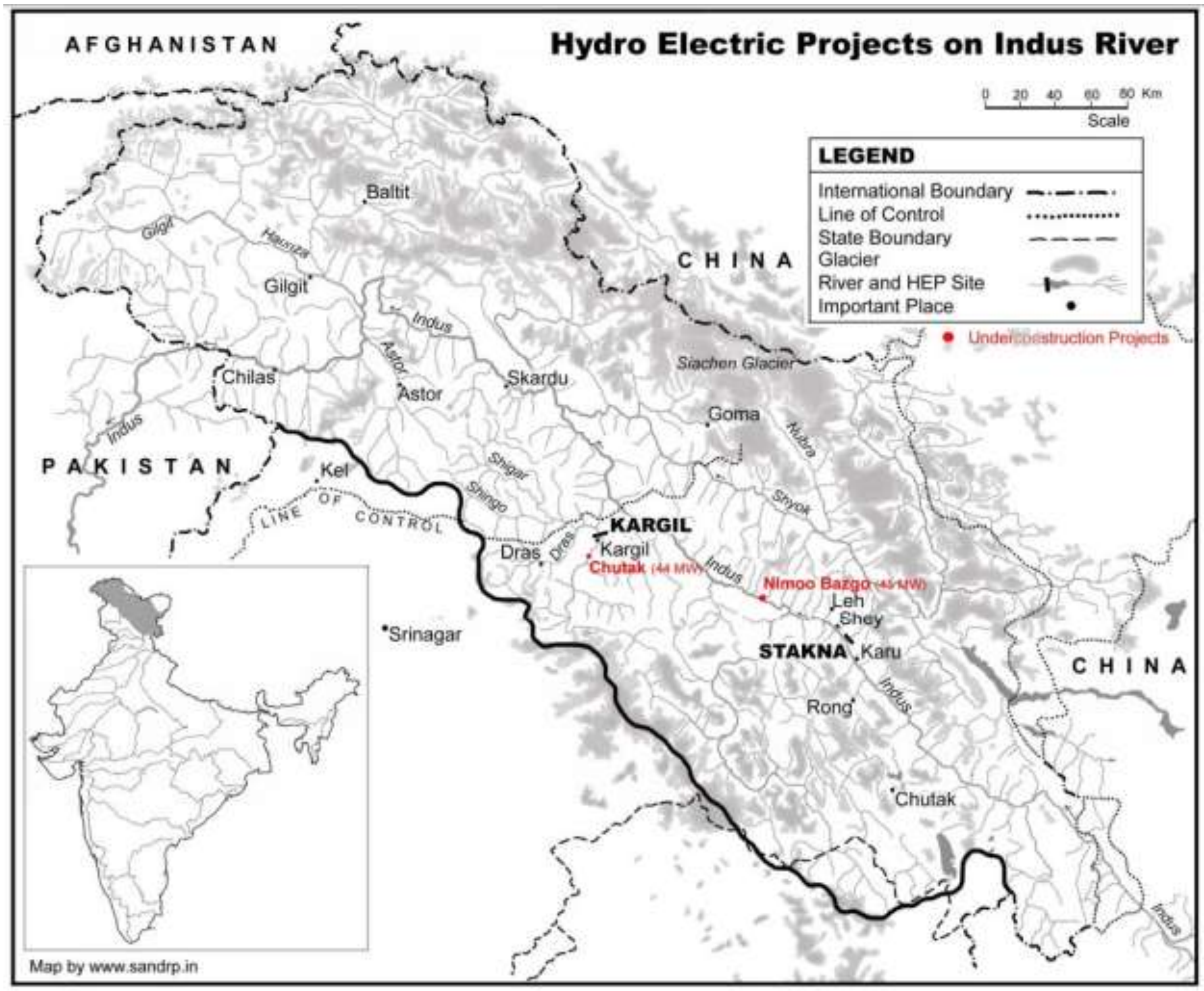


Figure 36. Hydroelectric projects in the Indus basin (http://sandrp.in/basin_maps/Hydropower_Projects_in_Indus_Basin.pdf).

The Clausius-Clapeyron relation (Wallace and Hobbs, 1977) may be manipulated to understand the increase of U with increase in temperature. The relation is:

$$de_s/dT = L/T\ (a_v - a_l) \quad (20)$$

where L is the latent heat of vaporization, T is temperature, a_v is the specific volume in the vapor phase, and a_l is the specific volume in the liquid phase. The ideal gas equation for water vapor is:

$$ea_v = R_vT \quad (21)$$

where R_v is the gas constant for water vapor (Wallace and Hobbs, 1977). Since $a_v >> a_l$,

$$de_s/dT = L/T\ a_v \quad (22)$$

Substituting for a in Equation 21:

$$de_s/dT = Le_s/R_vT^2 \quad (23)$$

Expressing fractional changes in saturation vapor to the fractional changes in temperature:

$$\delta e_s/e_s = (L/R_vT)(\delta T/T) = r\ \delta T/T \quad (24)$$

For $r \approx 20$ at $T \approx 260$ K (Hartmann, 1994), r may be approximately found at the maximum temperature in post-dammed years.

From Equation 19:

$$\delta U = (\delta e - \delta e_s/e_s)/e_s \quad (25)$$

The fractional change in relative humidity is related to the

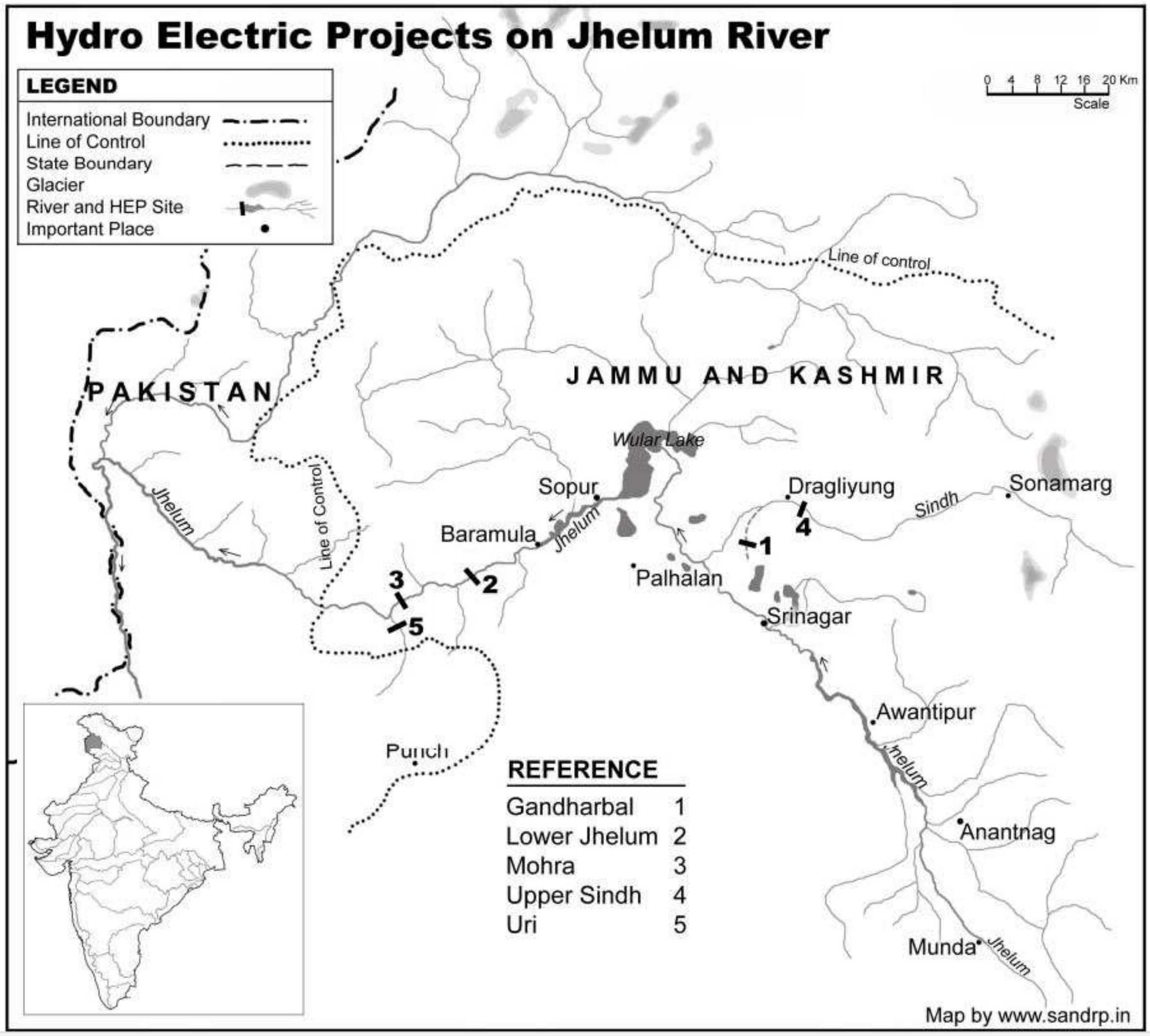


Figure 37. Hydroelectric projects in the Jhelum basin (http://sandrp.in/basin_maps/Hydro_Electric_Projects_on_Jhelum_River_Basin.pdf).

actual vapor pressure and temperature by:

$$\delta U/U = \delta e/e - (r/e)(\delta T / T) \quad (26)$$

which is obtained with a little manipulation of Equations 19 and 24. The vapor pressure e (hPaHg) can be related to temperature by the equation:

$$e = \exp(A) \exp[-B/(C + T)] \quad (27)$$

where T (K) is a temperature in the range 284-441 K, A = 18.3036, a constant, B = 3816.44, a second constant, and C = −46.13, a third constant.
From Equation 27:

$$\delta e/e = B\delta T /(C + T)^2 \quad (28)$$

Equation 26 can be written as:

$$\delta U/U = B\delta T / (C + T)^2 - r / \exp[A - B/(C + T)](\delta T / T)$$
$$= \delta T \{[B / (C + T)^2] - r / T \exp[A - B/(C + T)]\} \quad (29)$$

This shows that the fractional change in relative humidity is related to the change in temperature. Again site-specific values of these quantities may be introduced to find the fractional changes in relative humidity.

Rainfall pattern change

The basic steps necessary for precipitation are the developments of Equation 1, a saturation condition, almost, exclusively by cooling off an updraft movement of

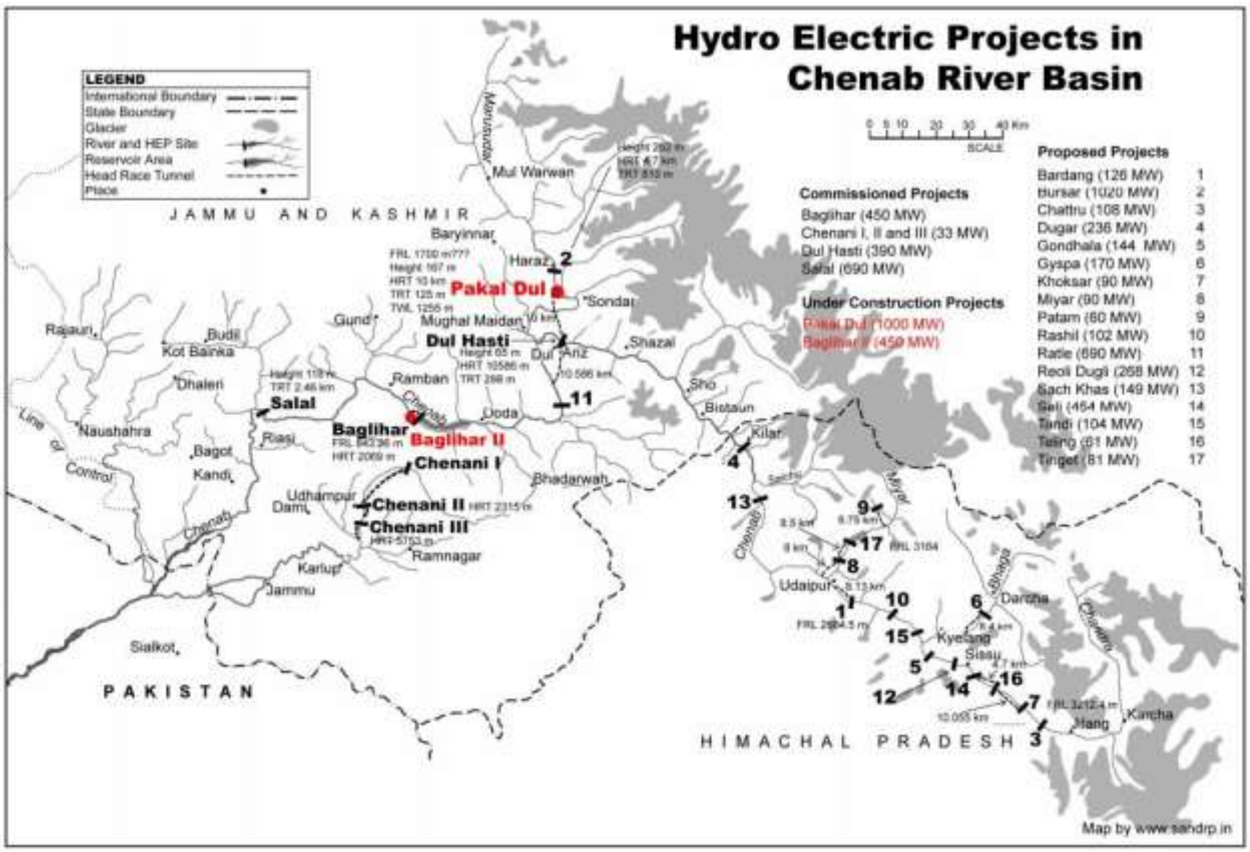


Figure 38. Hydroelectric Projects in the Chenum basin (http://sandrp.in/basin_maps/Hydro_%20Electric_Projects_in_Chenab_River_Basin.pdf).

moist air, (2) a phase change from the vapor state to liquid and/or the solid state, and (3) small water droplets to precipitation size.

The cooling effect may be of cyclonic, orographic, or convective origins. Cyclonic cooling of both non-frontal and frontal types of tropical origin can cause moderate rainfall, often for a long duration and resulting in over 300 mm of rainfall. In orographic cooling, lifting of moist wind up a slope results in expansion and cooling of the air at high altitude, favoring cloud formation followed by precipitation if the dew point is reached. In convective cooling, surface heating generates vertical instability of moist air, resulting in a convection current. Precipitation in this latitude range occurs predominantly from rising air.

Surface heating can produce vertical instability of moist air, resulting in a convection current. Convective precipitation occurs for a short duration but with a high intensity. In about an hour of precipitation, about 100 mm rainfall can occur.

Further, for the change of phase from vapor to liquid to occur and remain in equilibrium, the liquid must be in equilibrium with a saturated vapor with a pressure intensity. The free energy to form a droplet of radius r is given by Eagleson (1970):

$$\Delta G = -4/3\pi\, r^3\, \eta kT \ln(e/e_s) + 4\pi\, r^2\, \sigma \qquad (30)$$

where η = number of molecules per unit volume, k is Boltzmann's constant, e/e_s is the saturation ratio, σ is the interfacial free energy per unit area, that is, the surface tension, e is the vapour pressure, and T is the temperature.

For unsaturated vapor ($e<e_s$), there is a critical radius r_* beyond which a droplet can decrease the free energy by growing. This free energy is obtained by differentiating the aforementioned relation:

$$\Delta G_* = 16\pi\sigma^3 /3[\eta kT \ln(e/e_s)]^2 \qquad (31)$$

Applying the Boltzmann's distribution to the number n(r) of water droplets of radius r, we can write

$$n(r) = n(I)\, e^{-\Delta G/kT} \text{ (when } n(r) << n(I)) \qquad (32)$$

where n(I) is the number of unassociated water molecules in the same vapor volume. The critical nucleation rate is the rate at which a water droplet of

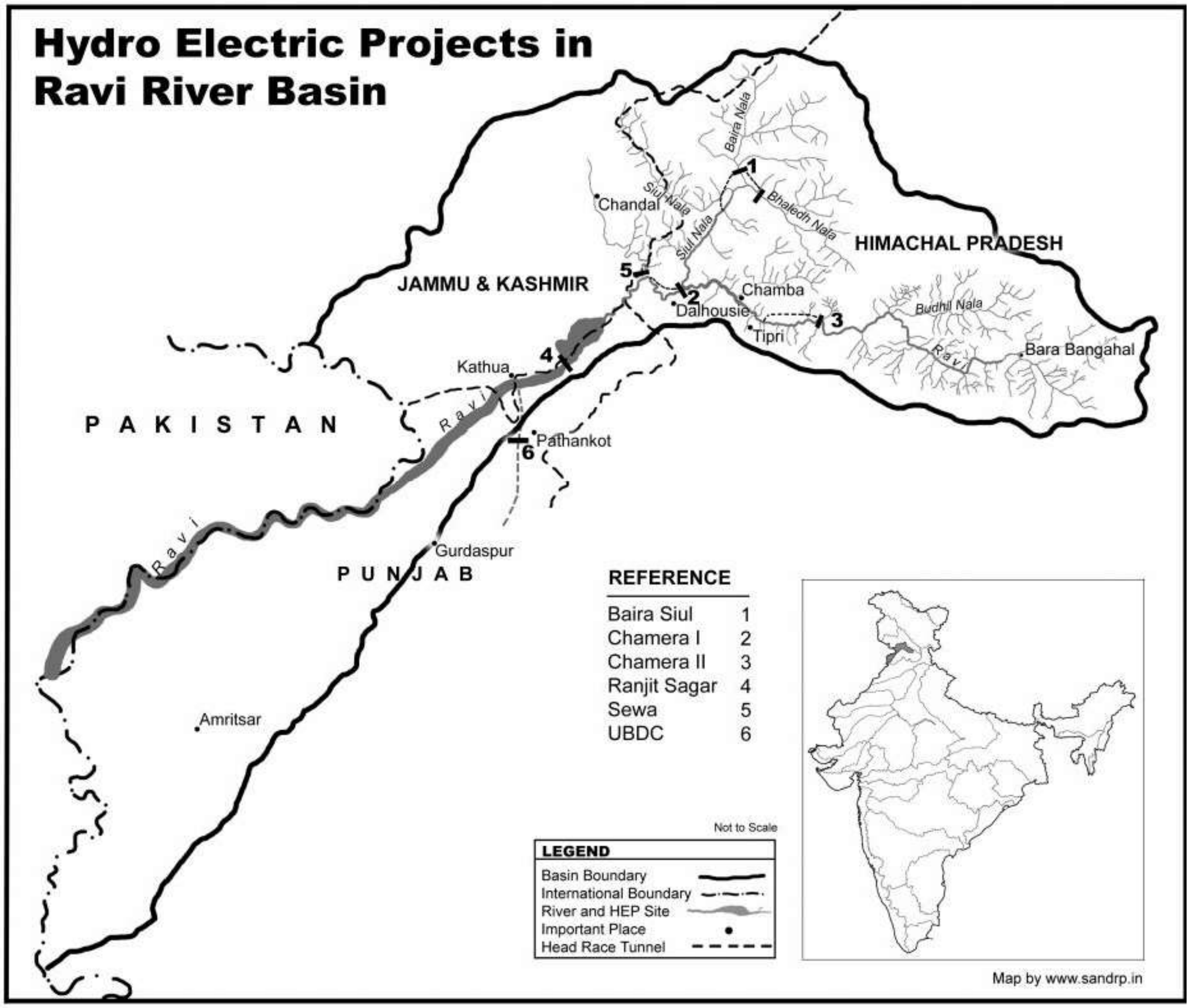


Figure 39. Hydroelectric projects in the Ravi River basin (http://sandrp.in/basin_maps/, reproduced with permission from SANDRP).

radius r_* can attach to another water molecule through diffusion/collision from the surrounding vapor molecules.

The rate of formation of stable-sized droplets is given by:

$$J = Bn(I)\, e^{-\Delta G_*/kT} \quad (33)$$

where $Bn(I) \approx 10^{25}\ cm^{-3}\ s^{-1}$ is the kinetic coefficient for spherical droplets (Fletcher, 1962).

Equations 31 and 33 together establish a relation between relative humidity and the critical nucleation rate. The relation predicts negligible nucleation rate if the saturation ratio $e/e_s < 4$. The rate increases as the saturation ratio approaches 4. In the light of the dammed scenario of the state, it can be said that the local moist air or this in conjunction with the incoming moist air from the adjoining areas has added to the humidity of the observation site that did not exist during pre-dammed years.

Also, rainfall depends on the growth of water droplets to acquire fall velocities against the updrafts of convective clouds typically of about 1 m/s. The processes of coalescence and diffusion add to the radius of a large droplet in a cloud of smaller droplets.

To escape updrafts, drops of average size of 20 µm have to grow about ten times bigger. Vigorously rising deeper clouds make the droplets to grow quicker (Bowen, 1950).

Likelihood of extreme events

Two large interacting systems evolve toward the

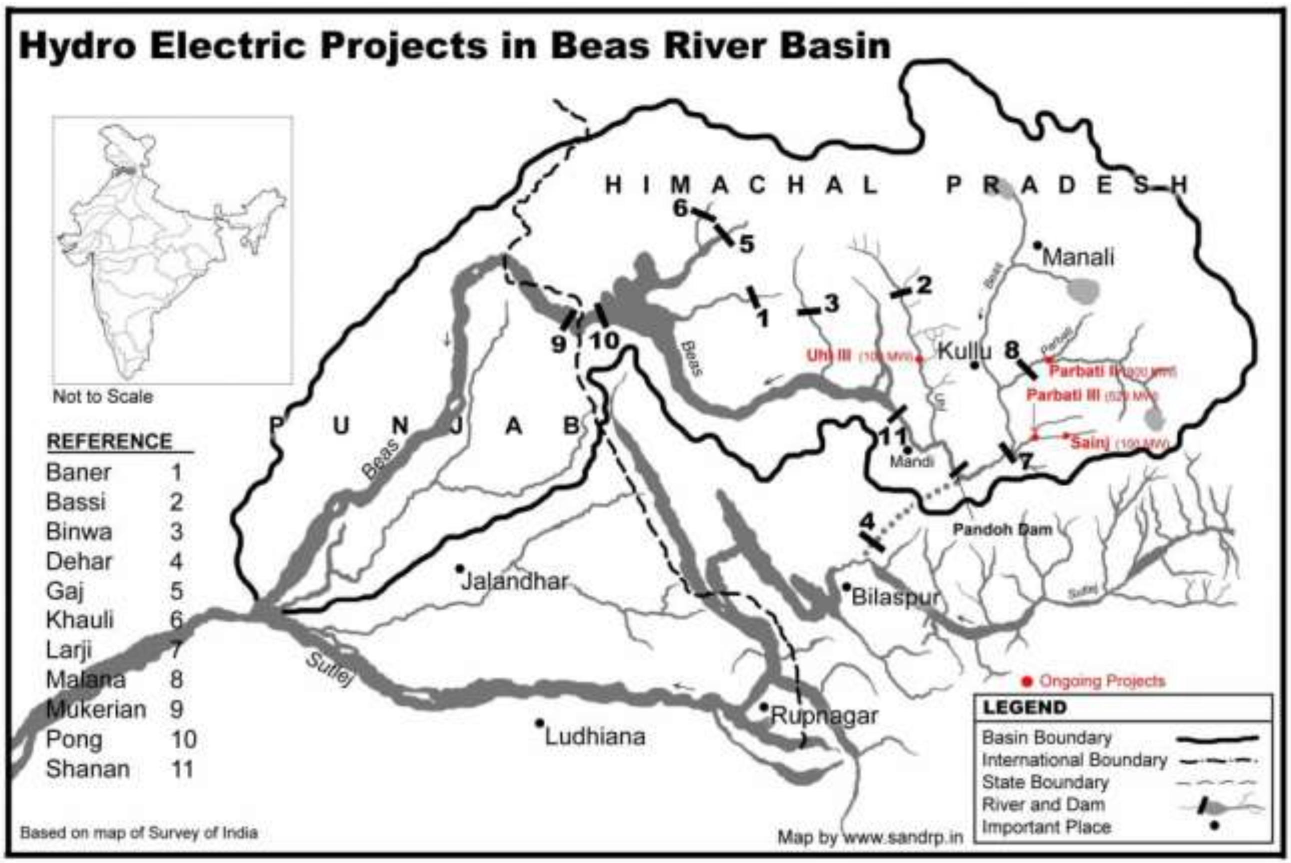


Figure 40. Hydroelectric projects in the Beas River basin (http://sandrp.in/basin_maps/Hydropower_Projects_in_Beas_Basin.pdf, reproduced withpermission from Sandrp).

macrostate of the highest possible entropy. In gas dynamics of mixture of gases, there are finite probabilities of multiple macrostates defined as a set of microstates that refers to the state of each element of a system. The multiplicities of a macrostate depend on the volume, energy, and the number of molecules assumed very large. Monatomic and diatomic molecules differ in their degrees of freedom and so in their energies. At room temperature, the thermal energy is:

$$U_{thermal} = N.\ f.\ ½\ kT \qquad (34)$$

where N is the number of molecules, f is the degrees of freedom, k is Boltzmann's constant, and T is the Kelvin temperature. At room temperature, air molecules have f = 5. At higher temperatures, vibrational modes contribute, and we may take $f_{air} = 7$. Treating as an ideal gas, the multiplicity function of N indistinguishable molecules of mass m occupying a volume V and total energy U turns out to be:

$$\Omega_N \approx (1/N!)(\ V^N/h^{3N})(\pi^{3N/2})/(3N/2)!(\sqrt{2mU})^{3N} \qquad (35)$$

The multiplicity dependence on U and V is given by

$$\Omega(UVN)\ = f(N))(V^N)(U)^{3N/2} \qquad (36)$$

For two gases A and B each having the same N molecules, volumes V_A and V_B and energies U_A and U_B, the multiplicity of the system will be

$$\Omega_{Total} = [f(N)]^2 V_A V_B)^N (U_A U_B)^{3N/2} \qquad (37)$$

The multiplicity function as a function of U_A will have a sharp peak

$$\text{Width of the peak} = U_{Total}/\sqrt{(3N/2)} \qquad (38)$$

Assuming N is very large, in the equilibrium condition of the system, only a tiny fraction of the macrostate has a reasonable probability of occurring. If any exchange of volume through expansion of one gas and contraction of the other occurs on top of exchange of energy, the multiplicity plotted as a function of V_A will have a sharp peak of width.

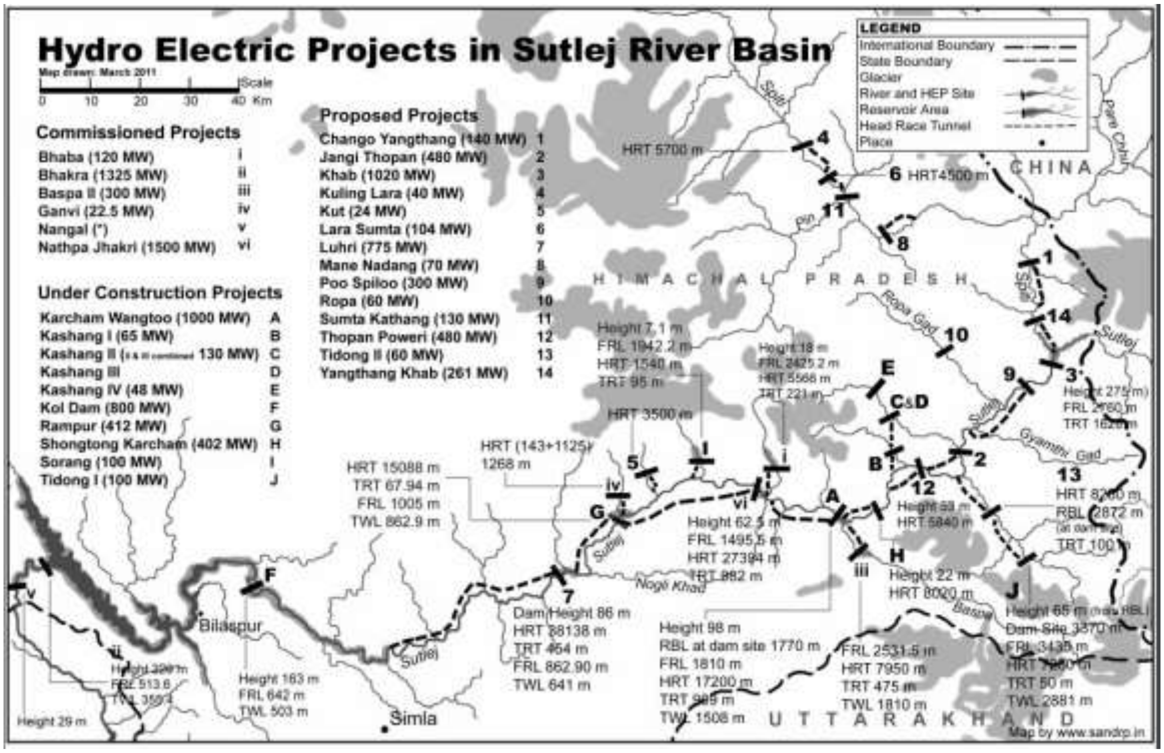


Figure 41. Hydroelectric projects in the Sutlej River basin (http://sandrp.in/basin_maps/, reproduced with permission from SANDRP).

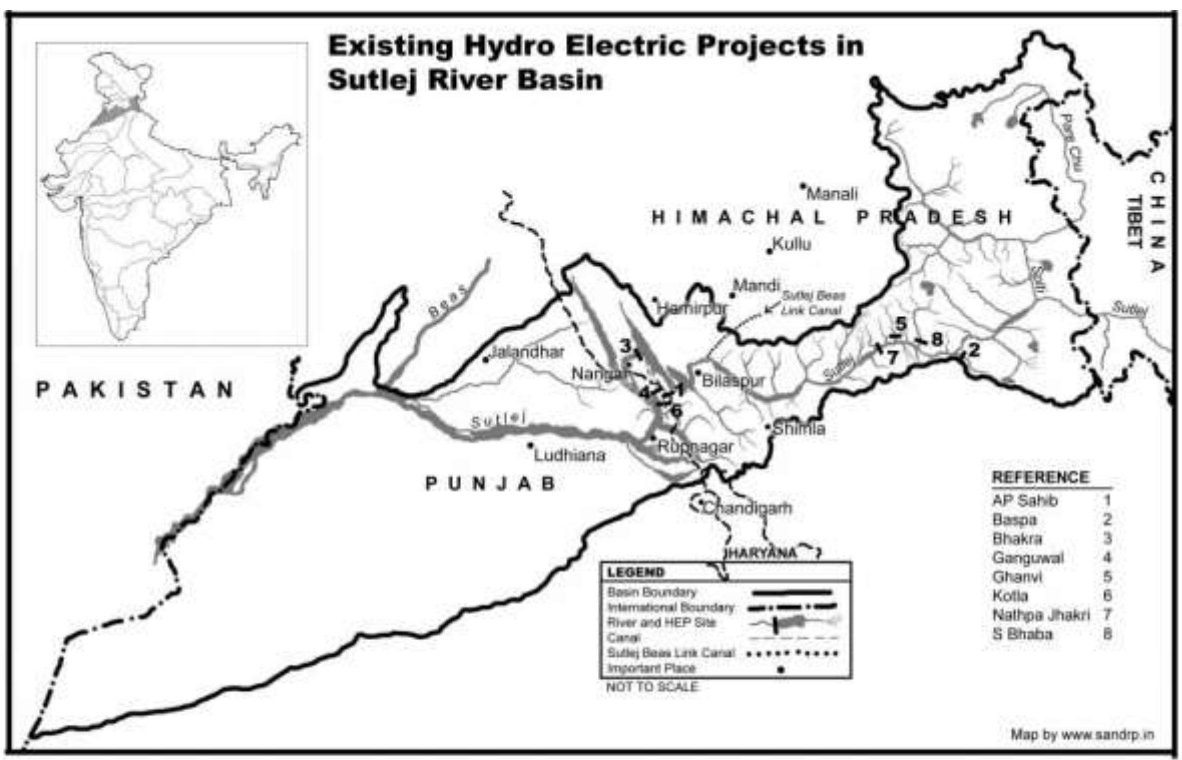


Figure 42. Existing hydroelectric in the Sutlej basin (http://sandrp.in/basin_maps/Hydropower_Projects_in_%20Sutlej_River_Basin.pdf).

Figure 43. This image of the northern Indian subcontinent captured by NASA shows the monsoon clouds over the of en:Jammu and Kashmir, en:Azad Kashmir, en:Gilgit-Baltistan & Pakistani Punjab.(NASA, 4 September 2014).

Width of the peak = $V_{total}/\sqrt{N}$ (39)

Figure 48 shows Ω_{Total} is plotted as a function of U_A and V_A. If there is exchange of molecule, for finding the equilibrium macrostate, the nature of Ω_{Total} has to be studied as a function of N_A and U_A. It would turn out to be a complicated analysis. In weather phenomena, the mixture of N, V, and U occurs. It is thought that some macrostate multiplicity may have satisfied the critical conditions for the production of extreme events.

Remediation

Dammed rivers become degraded. When the naturalstrength of the current is reduced, many unwanted stuffs accumulate on the water bodies. Figure 48 illustrates this scenario. Figure 48a shows the condition of the Ganges when the Maneri Valley-I was not constructed. The middle one, Figure 48b shows when the dam was operational. The right side one, Figure 48c shows the dam across the Ganges. The reporter took the pictures at the same place and at the same time. The middle, Figure 48b shows the extent of the damage (http://www.slideshare.net/ManushiIndia/ganga-held-captive).

Jhunjhunwala (2009) analyzed the costs and benefits of a typical river dam holistically. He hardly found that benefits outweigh costs. He states that the costs he shows are ignored by the supporters of hydropower.

Rivers need to be dredged regularly in its upper and lower courses. The silted river beds, if dredged, can hold

Table 4. The record-break amount of rainfall from the spell during September 4-5 in different cities/places.

Cities	Rainfall (mm)
Palandari, Rawalakot, Azad Kashmir	981
Lahore: Airport	498
Sahi Qila	466
Misri Shah	453
Shahdra	452
Upper Mall	389
Jail Road	379
Sialkot:Cantt	471
Sialkot: Airport	346
Rawalakot Azad Kashmir	464
Kotli, Azad Kashmir	410
Rawalpindi: Airport	336
Shamasabad	311
Bokra	208
Gujranwala	286
Kasur	280
Islamabad (Zero Point)	274
Saidpur	268
Golara Sharif	209
Okara	257
Gujrat	231
Muree	204
Jhelam	202

several times more water than in the silted condition. Also, there has to be an infrastructure built-in place to facilitate drainage in case of heavy downpours. Cities get water-logged quickly because of poor drainage facility and poor water infiltration underground because of concrete structures. These two hindrances have to be overcome in urban areas. River dredging and river dyke construction can offset the flooding in the rural areas.

NASA has plans to protect the planet from stray asteroid hits by diverting their courses of motion (http://whnt.com/2017/07/01/nasa-announces-plan-to-re-direct-asteroid-coming-near-earth/). NASA can work on such a plan to diminish rainfalls when there is the possibility of having a heavy downpour.

Jhunjhunwala (2009) suggested ROR (run of the river) dams to have the minimum impact on the rivers. Figure 48b, d, and shows the deplorable conditions of rivers having ROR dams. Although it is said that ROR does not require a reservoir or a little reservoir, in practice it is different. In the Himalayan Region, the large ROR dams fragment the river forcing water through tunnels to hydel plants before reuniting them into the river. Riverways between the dams and the power plant that are bypassed are quite long, and up to 90% of the wintertime river discharges are forced to follow the bypass paths. In the 510-MW Teesta V project in Sikkim (Figure 48f), the" head race tunnel" is 18.5 km long and the river bypassesa stretch of 23 km. Contrary to ROR-advocates' arguments, the daily fluctuation in river discharges risks the riverine ecology. Also, a series of dams in river virtually makes the river flow through tunnels. Further, the wider the surface of a watercourse the more the evaporation, aiding to climate change (Adel et al., 2014). From the basin discharge expression (Asumadu-Sarkodie et al., 2015b).

$$Q_p = 0.278 \times C_s \times C \times i \times A \quad (40)$$

with Q_p= run-off rate (m^3 /s), C=run-off co-efficient (0.7 - 0.95 for urban areas), C_s= storage coefficient, i= rainfall intensity (mm/h) and A= area of drainage (km^2), and the observation of the dilapidated conditions of dammed channels after the rainfall in the basin, it is obvious that all of C_s, C, i, and A are drastically changed impacting Q_p. In this hilly river-origins and river-abundant state with sloping river valleys, it is the anthropogenic activities of dams and barrage constructions that is the prime artificial

Figure 44. Tunneling at the 330-MW Kishenganga hydroelectric project in the Gurej area of Jammu and Kashmir (Photo credit: Panaromia.com, reproduced with permission from SANDRP, https://sandrp.wordpress.com/page/23/).

fator of flooding, given that the causes of rainfalls are beyond human control although their creation of reserviors in the basin favors rainfalls.

Facts and figures: India's water encroachment in the Teesta Basin

The Teesta Basin is illustrated in Figure 49. The Teesta water piracy is shown in Table 5.

Facts and figures: River networking

India has taken a grand plan to interconnect her rivers (Figure 50). The project has three components: the Himalayan component in the north, the Peninsular component in the south, and an intrastate component (Adel, 2013).

Contrary to Indian government's preaching, India plans to keep all the river waters within herself. She already changed the course of the world's 8th largest river the Ganges that flowed through neighboring Bangladesh under the pretext of a so-called Ganges Treaty that Bangladesh government was forced to sign following a marathon number of meetings between the two parties and intermittent deprival of water to Bangladesh. The current Indian Government threatened Pakistan not to have Indian water flow in that neighboring country (Dawn.com, 2016), a sheer breach of the Indus Water Treaty brokered by the World Bank. In the light of the aforementioned discussion, it is expected that there will be more climatic changes and severe climate-related effects in India.

Potential threats

Confining all water within the Indian land can trigger macrostate multiplicities. It is not known out of the numerous states that would be generated, which one can have disastrous effects and how often that can happen. Indian government should think twice following the two disasters and the 2017 flood to arrest all waters within India and not let any water flow to the arch enemy Pakistan and the bosom friend Bangladesh camouflaged

Figure 45. The Kishenganga Dam site (http://bestcurrentaffairs.com/w/international-court-of-arbitration-upholds-indias-right-on-kishanganga-project/, reproduced with permission).

with sweet words.

Conclusion

Water is fluid. Arresting it to confinements is against its nature. Excess water beyond one's use should be released. Following the Indian leader Mr. Gandhi, it can be said that enough resources are around to meet everybody's need but not to anyone's greed. Had there been no constructions of dams and reservoirs beyond India's needs, this kind of mega-disaster could be averted. Thousands of people would not lose their lives and properties would remain intact. People's sufferings were brought to satisfy Indian greed. India's future plan is likely pushing her to face further loss of lives and properties. International arbitration court judges should be aware of the potential aftermaths following their

Figure 46. The Beas River basin (https://sandrp.wordpress.com/2013/06/22/hydropower-generation-performance-in-beas-river-basin/).

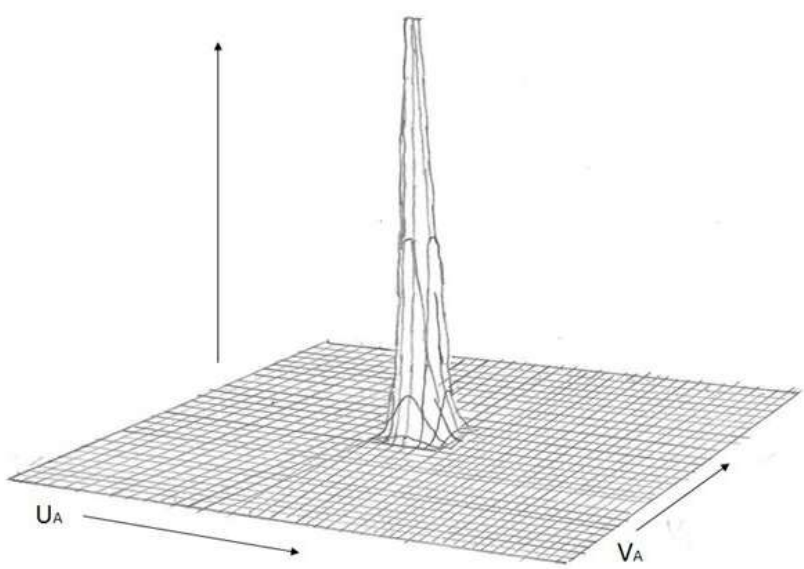


Figure 47. Multiplicity of a system of two ideal gases plotted as a function of energy and volume, the total energy and total volume being held fixed. Source: Schroeder (2000).

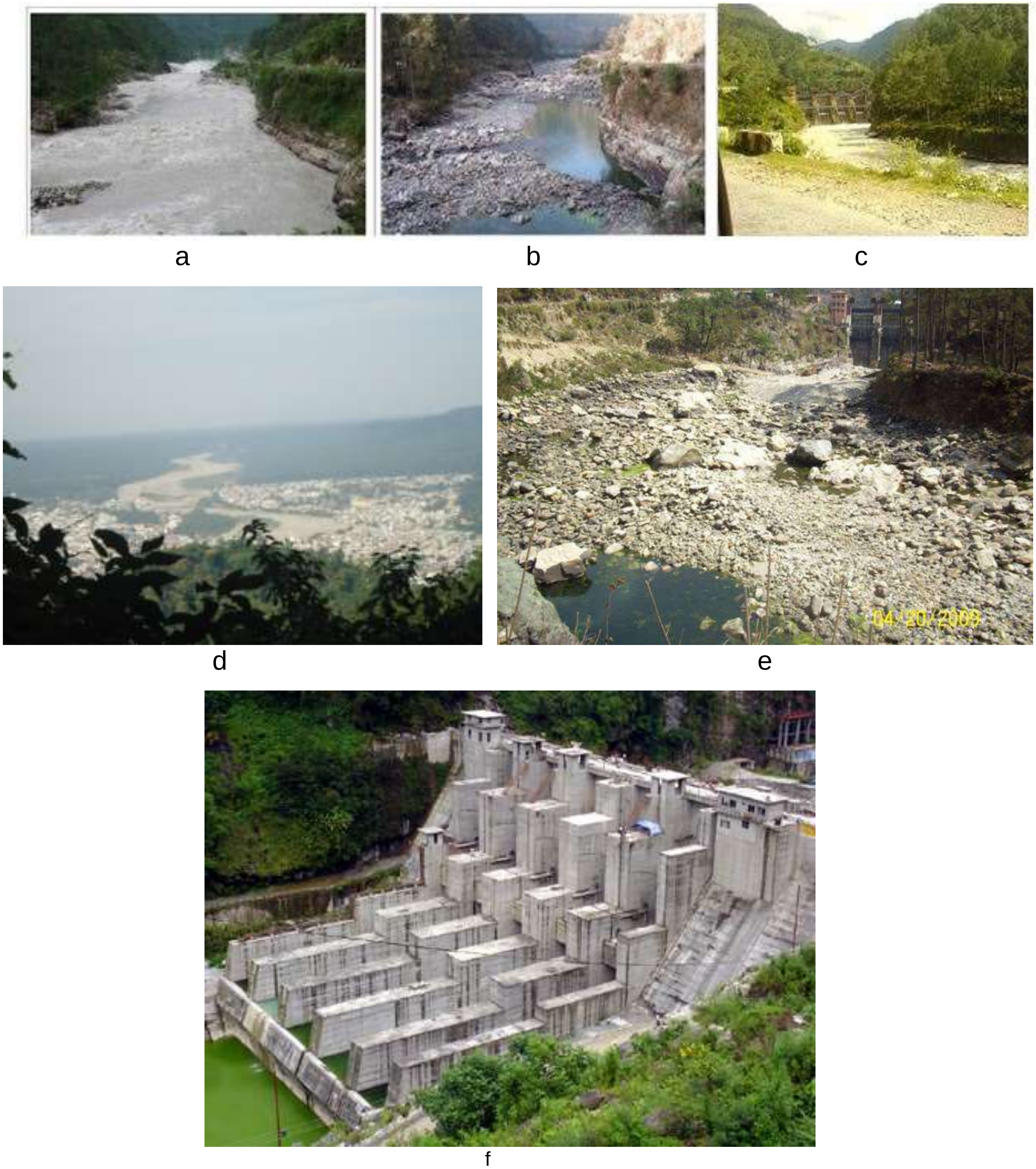


Figure 48. The Ganges River in her full and natural flow before the dam Maneri Bhali I was operational and before any water was diverted from her: (a) This is the picture of the same spot as the one beside it (right inset) before the construction of Maneri Bhali I; (b) The Ganges River after the Maneri Bhali I was operational and and almost all the water was diverted from her into the tunnels. This is the picture of the same spot as the one beside it (left inset); (c) The dam is seen on the Ganges. (Reproduced with permission from Ganga Ahvaan available from http://www.slideshare.net/ManushiIndia/ganga-held-captive); (d) The Ganga River after the river is diverted for Chilla HEP (http://sandrp.wordpress.com/2013/05/22/upper-ganga-report-with-pro-hydro-bias-does-not-do-justice-to-its-terms-or-to-ganga-people-or-environment/, reproduced with permission); (e) Debris-covered dry Bhagirathi downstream Maneri bhali HEP (http://sandrp.wordpress.com/2013/05/22/upper-ganga-report-with-pro-hydro-bias-does-not-do-justice-to-its-terms-or-to-ganga-people-or-environment/, reproduced with permission); (f) The Teesta V Hydroelectric Project in Sikkim. Soucre: Reproduced with permission (http://www.oversy.org/en/Home/ProjectPage?projId=9).

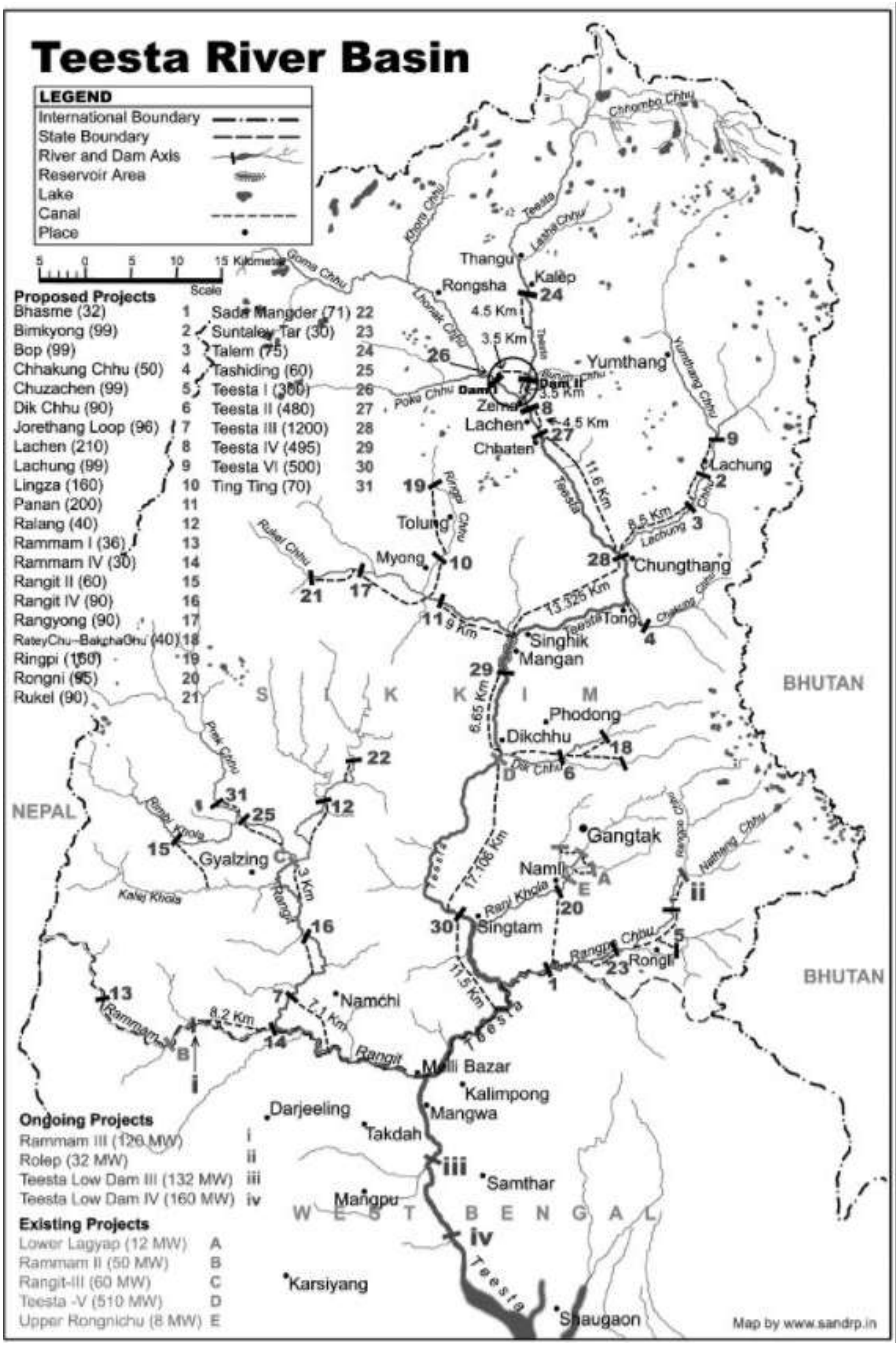


Figure 49. The Teesta basin (http://sandrp.in/basin_maps/Teesta%20150411.jpg).

Table 5. Teesta water piracy.

Year	Highest discharge (cumecs)	Lowest discharge (cumecs)
1980	84,900	4,494
1990	158,096	4,732
2000	174,702	529
2005	3,892	8
2014	-	42.45 (January)
-	-	11.57 (March)

Source: Hydrology Department, Rangpur, Bangladesh (http://archive.thedailystar.net/2006/11/03/d611031803114.htm).

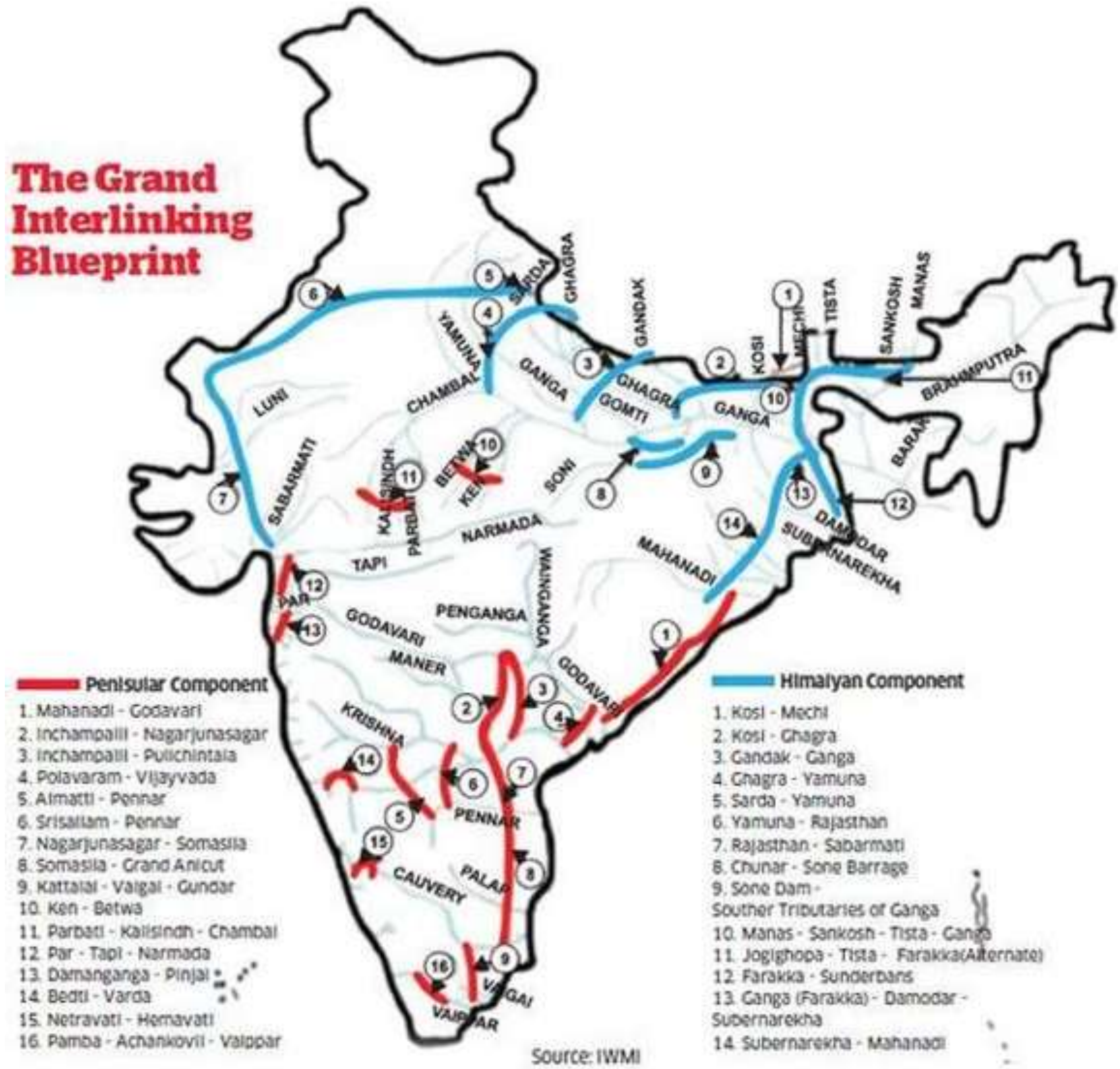


Figure 50. Indian river networking plan (IWMI, 2015).

verdicts. Let the middle course be followed in every conflict resolution. Countries prone to these disasters should have some infrastructure in place to minimize the effects of extreme events like unprecedented floods.

NASA may device some way of diffusing such storms the same way the agency is trying to divert an on-coming asteroid to protect the planet. The UN can fund NASA for such projects. Some closed experimental setups may be pursued to detect the proper conditions for the generation of extreme events with measured N, m, V, and E.

CONFLICT OF INTERESTS

The author(s) did not declare any conflict of interest.

ACKNOWLEDGEMENTS

The author is sincerely thankful to those individuals and agencies that contributed the essential facts and figures to prepare the article in the service of global humanity.

REFERENCES

Adel MM (2001). Effects on Water Resources from Upstream Water Diversion in the Ganges Basin. J. Environ. Qual. 30:336-368.

Adel MM (2013). *Jaladasyupana*, Dibyaprakash, 38/2ka Banglabazar, Dhaka 1100, Bangladesh

Adel MM (2015a). *The Dam-Deluged Gasping Ganges Vol 1.* Published by Lap Lambert, Germany and the references therein.

Adel MM (2015b). The Dam-Deluged Gasping Ganges Vol 2. Published by Lap Lambert, Germany and the references therein.

Adel MM (2015c). The Dam-Deluged Gasping Ganges Vol 2. Published by Lap Lambert, Germany and the references therein.

Adel MM (2015d). Farakka Barrage Vol. 1. Published by Lap Lambert, Germany and the references therein.

Adel MM (2015e). Farakka Barrage Vol. 2. Published by Lap Lambert, Germany and the references therein.

Arya SP (1998). *Introduction to Micrometeorology*. Academic Press: San Diego; 11.

The Associated Press (2013). Hundreds missing in Sierra Leone mudslides likely dead, minister says, Sat., Aug. 19, 2017. Available from https://www.thestar.com/news/world/2017/08/19/hundreds-missing-in-sierra-leone-mudslides-likely-dead-minister-says.html.

Asumadu-Sarkodie S, Owusu PA, Rufangura P (2015a). Impact analysis of flood in Accra, Ghana. Adv. Appl. Sci. Res. 6(9):53-78.

Asumadu-Sarkodie S, Owusu PA, Jayaweera HMPC (2015b). Flood risk management in Ghana: A case study in Accra, Adv. Appl. Sci. Res. 6(4):196-201

Australia News (2011). Rockhampton floods expected to peak today, Updated 5 Apr 2017, 9:07pm. Available from http://www.abc.net.au/news/2017-04-06/rockhampton-flooded-fitzroy-to-reach-peak-around-midday/8418340

Bastiaanssen WGM, Menenti M, Feddes RA, Holtslag AAM (1998). A remote sensing surface energy balance algorithm for land (SEBAL). 1. Formulation. J. Hydrol. 212:198-212.

Bowen EG (1950). The formation of rain by coalescence. Aust. J. Sci. Ser. A 3:193-213.

CNN (2017). Sierra Leone mudslide: Desperate hunt for 600 people still missing, Updated 1:38 PM ET, Tue August 15, 2017. Available from http://www.cnn.com/2017/08/15/africa/sierra-leone-mudslide/index.html

Daily Star (2017a). Heavy rains raise fresh flood alarm. Available from http://www.thedailystar.net/frontpage/heavy-rains-raise-fresh-flood-alarm-1447759.

Daily Star (2017b). Rivers show signs of major flood,Available from http://www.thedailystar.net/frontpage/rivers-show-signs-major-flood-1448233

Daily Star (2017c). 8 killed as flood situation worsens in Bangladesh. Available from http://www.the dailystar.net/country/8-killed-overall-bangladesh-flood-situation-worsens-1448041

Daily Star (2017d). Flood hits 20 districts, August 20, 2017. Available from http://www.thedailystar.net/frontpage/bangladesh-flood-situation-2017-hits-20-districts-1448749

Dandekar P (2011). We are not doing a true cost-benefit analysis of hydropower dams in India – Interview with Dr. Bharat Jhunjhunwala, 28 January, 2011. Available at http://www.indiawaterportal.org/articles/we-are-not-doing-true-cost-benefit-analysis-hydropower-dams-india-interview-dr-bharat

Dawn.com (2016). Water belonging to India cannot go to Pakistan,' says Modi, The Dawn, November 25, 2016, https://www.dawn.com/news/1298575

Dey NC, Bala KS, Islam AKMS, Rashis MA (2013). Sustainability of groundwater use for irrigation in Northwestern Bangladesh, BRAC University Report, Dhaka Bangladesh.

Eagleson PS (1970). Dynamic Hydrology. McGraw-Hill: New York.

Fletcher NH (1962). The Physics of Rainclouds. Cambridge University Press: New York.

Hartmann DL (1994). Global Physical Climatology. Academic Press: 350.

Henry JG, Heinke GW (1996). Environmental Science and Engineering, 2nd edn. Prentice Hall: Upper Saddle River, NJ. pp. 241-242.

IWMI (2015). File: File:River interlink in India.jpg, 4 October 2015. Available from https://commons.wikimedia.org/wiki/File:River_interlink_in_India.jpg. Source: https://commons.wikimedia.org/wiki/File:River_interlink_in_India.jpg

Jhunjhunwala B (2009). Economics of Hydropower, Google Books

Lartey J (2017). New Orleans at risk of further floods after fire cuts power to pumps, Thursday, 10 August 2017. Available from https://www.theguardian.com/world/natural-disasters

Mkhwanazi M, Chávez JL, Andales AA (2015). SEBAL-A: A Remote Sensing ET Algorithm that Accounts for Advection with Limited Data. Part I: Development and Validation, *Remote Sens*. 7, 15046-15067; doi:10.3390/rs71115046, ISSN 2072-4292 www.mdpi.com/journal/remotesensing

Nigeria News Today (2017). Mass burials for Sierra Leone flood victims, Thursday, August 17, 2017. Available from https://www.newsheadlines.com.ng/guardian-news/2017/08/17/mass-burials-for-sierra-leone-flood-victims/

Norden (2013). European floods (Budapest, 2013-06-05), 5 June 2013, 23:36:17. Available from https://commons.wikimedia.org/wiki/File:Budapest_%C3%A1rv%C3%ADz_2013-06-05.jpg

Penninger S (2013). Hochwasser in der Passauer Altstadt, im Vordergrund das Wurm & Köck-Schiff Sissi. Juni 2013, 3 June 2013, 12:39. Available from https://commons.wikimedia.org/wiki/File:Hochwasser_Passau_2013-06-03.jpg

Platenik D (2014) not cited. Floods in Gunja, Croatia, May 2014, 24 May 2014. Available from https://commons.wikimedia.org/wiki/File:Floods_in_Croatia_Gunja_2.jpg

Pujari D, Dandekar P (2013). Uttarakhand Rainfall: Since 1901 and in light of the 2013 disaster, Sept. 25, 2013, available from (https://sandrp.wordpress.com/2013/09/25/uttarakhand-rainfall-since-1901-and-in-the-light-of-2013-disaster/)

Rind D (1995). Drying out. New Scientist May 6: Pp. 36-40.

Safi M (2017). India floods: 213 killed in Gujarat as receding waters reveal more victims, Monday 31 July 2017 10.32 EDT.

SANDRP (2013). Hydroelectric projects in Uttarakhand.

Schneider K (2014). Uttara hand's Furious Himalayan Flood Could Bury India's Hydropower Program, Available from April 2, 2014. Available from http://www.circleofblue.org/waternews/2014/world/uttarakhands-furious-himalayan-flood-bury-indias-hydropower-program/

Scottish Government (2008). The future of flood risk management in Scotland: a consultation document. Sounds S, Historic floodings far from over across the Midwest and South: Nine deaths blamed on flooding in several states, May 4, 2017. Available from http://www.gov.scot/publications/2008/02/13095729/9

Scroeder DV (2000). An Introduction to Thermal Physics, P. 72, Addision Wesley Longman, New York.

Swinbank WC (1963). Longwave radiation from clear skies. Quart. J. Royal Meteorol. Soc. 89:339.

UNB (2017). 8 killed as flood situation worsens in Bangladesh, 09:37 PM, August 13, 2017 / LAST MODIFIED: 09:50 PM, August 13, 2017. Available from http://www.thedailystar.net/country/8-killed-overall-bangladesh-flood-situation-worsens-1448041

Upadhyay K (2013). Residents blame it on Sreenagar dam, June 24, 2013, 01:49 IST, The Hindu. Available from http://www.thehindu.com/news/national/residents-blame-it-on-srinagar-dam/article4843800.ece

Wallace JM, Hobbs PV (1977). Atmospheric Science: An Introductory Survey. Academic Press: New York; 467p.