"Correlating urban system and hydrological system in context of physical planning"

Sheetal Sharma

Abstract: Urbanization result in rapid development of landscape and housing leading to physical modification of habitats, which often results with degradation of the ability of ecosystems to maintain their structures and properties, thus providing ecosystem imbalances. An area when developed for housing or other urban purposes, the immediate hydrologic effect is to increase the area of low or zero infiltration capacity and to increase the efficiency or speed of water transmission in channels or conduits ((D. &. Leopold 1978).

Perhaps the most obvious landscape-level change to accompany urbanization is the extent to which previously natural surfaces are covered by engineered, impervious ones. Once vegetation and soil is replaced with buildings and paved surfaces, the infiltration potential for precipitation is greatly reduced, resulting in increased runoff, decreased lag time and increased peak discharge in streams. Urbanization has steadily replaced open spaces and forced dramatic changes to watersheds in the process. Natural drainages have been replaced by human structures, or reengineered for human purposes.

The central theme of hydrology is that water moves throughout the Earth through different pathways and at different rates. (L. B. Leopold 1968)The most vivid image of this is in the evaporation of water from the ocean, which forms clouds. These clouds drift over the land and produce rain. Thus hydrology consist water in form of precipitation, water table, soil moisture, surface flow, ground water table, evaporation and evapotranspiration.

Hence when both these systems come together, a variation in pattern of working is observed basically in the hydrological system due to modification and effects of urbanization on some of important parameters of Hydrology.

The paper is an attempt to correlate both systems with certain literature review and case studies done worldwide and by self in Bhopal City, Madhya Pradesh state, India.

Key words: Urban System, Hydrological System, Correlation, Runoff, Recharge.

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1.0 Introduction:

Urbanization can be termed as social phenomenon and a physical transformation of landscapes by the people for the people. Most of the changes in natural systems like floods, droughts, climate changes and global warming, due to urban development are irreversible and gives a very strong reflection of impact of anthropogenic activities on it.

As per present world facts and conclusions from various summits, conferences, researches and programs, it has been observed that there is dramatic change in urbanization as well as in Natural systems all over the world. The facts of increasing urbanization and variations in natural systems are identified by different organizations, scientists and various departments like IPCC, (IPCC 2007)UNEP, USGS, Rio Summit, and MDG etc. The panelists at World Water day 2011 (Worldwater 2007) identified rapid urbanization, poor planning, inadequate investments and overdependence on external resources as the main challenges facing water management in cities. Thus urbanization has become one the main reason for the overdependence as well as over exploitation of resources and also poor planning cannot be ruled as result of unplanned developments in many places around world.

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Hence it is necessary to know about urbanization and how it affects the vital parameters of these natural systems. The relation between these is to learn first to tackle future possibilities of both affecting each other. To start with a short description of urbanization, its meaning in different ways, facts about its rapid increase are discussed. Following this a short description of Hydrology (water cycle) is discussed with its main components and facts for present variations of it are illustrated. Then a relation between these two is identified with different scenarios like within undeveloped (natural) state, urbanized state and with climate change.

Urbanization is the process by which large numbers of people become permanently concentrated in relatively small areas, forming cities. A country is considered to urbanize when over 50 per cent of its population live in the urban areas. Historically, human populations have led rural lifestyles as hunters, gatherers, and farmers. However, since the industrial revolution, human societies have been transitioning from a rural lifestyle, to a more urban one, at an exponential rate. From 1800 to 1900 the number of people that lived in urban areas increased from less than 5%, to 14% of the total population. Between 1900 and 1950, rates of urbanization more than doubled up to 30% and by the year 2000, 47% of the human population, or

2.8billion people, lived in urban areas. By 2030, demographers estimate that approximately 65% of humans will live in urban areas. (umich.edu 2008)

2.0 Study of systems:

2.1 Urban systems:

There are numerous subsystems and corresponding resources in urban Systems:

- natural,
- financial,
- human and man-made- within an urban development such as
- Urban Lands
- Land use-Land Covers.
- water,
- energy,
- transport,
- waste,
- economic and
- social systems.

Source: Figure 2. Framework for AUSTIME interrelated subsystem models

Integrated urban system modeling was studied in detail using multi-agent systems by various researchers like 1Daniell, K.A., 2H.C. Somerville, 3B.A. Foley, 3H.R. Maier, 3D.J. Malovka and 4A.B. Kingsborough 1Cemagref/ENGREF, UMR G-EAU, Montpellier, France / Centre for Resource and Environmental Studies (CRES), Australian National University, 2Sinclair Knight Merz (SKM), Melbourne, 3Centre for Applied Modeling in Water Engineering (CAMWE), School of Civil and Environmental Engineering and The University of Adelaide, 4Kellogg, Brown and Root (KBR), Adelaide which concluded that urban systems are combination of different systems altogether and have an impact on the naturally existing systems and cycles through their changing scenarios and thus tend to alter Macro as well as micro cycles of the Earth system.

2.2 The hydrological system:

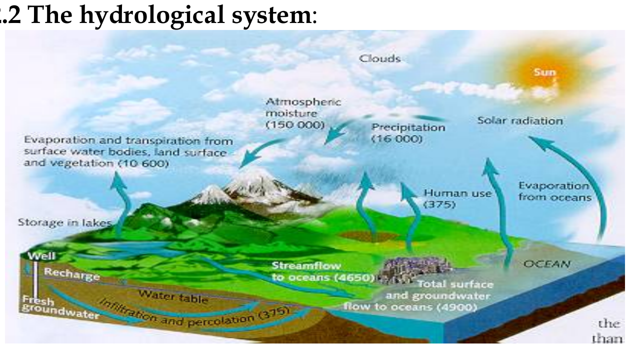

Figure 1 Water in Hydrological Cycle

Source: Section 2: CHANGING NATURAL SYSTEMS (UNESCO, United Nations Educational, Scientific and Cultural Organization) WMO, (World Meteorological Organization), IAEA (International Atomic Energy Agency)

2.2.1 Hydrological Cycle.

The water cycle, also known as the hydrological cycle, is the continuous exchange of water between land, water bodies, and the atmosphere. When precipitation falls over the land, it follows various routes. Some of it evaporates, returning to the atmosphere, some seeps into the ground, and the remainder becomes surface water, traveling to oceans and lakes by way of rivers and streams.

The principal natural component processes of the hydrological cycle are:

- precipitation,
- infiltration,
- runoff,
- evaporation and
- Transpiration.

(GLEICK 2008-2009)

These systems have their specific role in the cycle and above components affect the working of this cycle. Subsequently the other interrelated components and cycles also get affected by the changes in one or other components thus disturbing the equilibrium of the cycles and consequently natural hazards or disasters are observed. Many a times the behavioral changes are seen in specific areas and conditions such as in cities, in watersheds, in river flows, along coastal plains etc. these behavioral changes are due to alterations in cycles in the conditions or components of the cycle . To get an idea of what has contributed in the changes or alterations we need to observe some alterations in behavior in different scenarios. Some of the behavioral changes observed and quoted by researches and institutes are described below to describe the behavior of the same system in different conditions.

3.0 Changes in urban systems:

As people are increasingly living in cities, and as cities act as both human ecosystem habitats and drivers of ecosystem change, it has become increasingly important to foster urban systems that contribute to human well-being and reduce ecosystem service burdens at all scales.

New data collection from CIESIN's Global Rural Urban Mapping project (GRUMP 2005) shows that as much as three percent of the earth’s land area has already been urbanized, which is double previous estimates. While the world’s urban population grew very rapidly (from 220 million to 2.8 billion) over the 20th century, the next few decades will see an unprecedented scale of urban growth in the developing world. By 2030, the towns and cities of the developing world will make up 81 per cent of urban humanity. (UNFPAChapters 2007)

As per report a worldwide observed increase in urban land area of 58,000 km2 from 1970 to 2000. India, China, and Africa have experienced the highest rates of urban land expansion, and the largest change in total urban extent has occurred in North America. Across all regions and for all three decades, urban land expansion rates are higher than

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or equal to urban population growth rates, suggesting that urban growth is becoming more expansive than compact. This new data collection, known as the Global Rural Urban Mapping Project, or GRUMP, has provided the basis for a number of important insights not previously known. This project is led by the Center for International Earth Science Information Network (CIESIN), part of the Earth Institute.

4.0 Changes in hydrological systems:

Several international documents IPCC fourth assessment report of the international Panel on climate in 2007 , conventions like "Dialogue on water and climate change , National Water Commission of Mexico, Feb 2010," and documents like "White Paper- water and climate change session-Draft White Paper on needs – 25August 2009" have focused on the emerging issues regarding impacts of urbanization on water related issues stating that observational evidence from all continents and most oceans shows that many natural systems , upon which the hydrological cycle and thus water availability , water quality and water services depend are being affected by anthropogenic climate change. Also water is predicted to be the primary medium through which early climate change impacts will be felt by people, ecosystems and economies. Both observational records and climate projections provide strong evidence that freshwater resources are vulnerable, and have the potential to be strongly impacted. [Source: The State of resource: Chapter-4, By UNESCO, WMO, IAEA]

In addition to this recent reports from [IPCC 2007] have reported that:

- Annual global freshwater withdrawal has grown from 3 790 km3 in 1995, to 4 430 km3 in 2000 [Shiklomanov, 1999].

- In 2000, about 57% of the world's freshwater withdrawal, and 70% of its consumption, took place in Asia, where the world's major irrigated lands are located (UNESCO, 1999).

- In the future, annual global water withdrawal is expected to grow by about 10-12% every 10 years, reaching approximately 5 240 km3 (or an increase of 1.38 times since 1995) by 2025. Water consumption is expected to grow at a slower rate of 1.33 times (UNESCO, 1999).

- In the coming decades, the most intensive growth of water withdrawal is expected to occur in Africa and South America (increasing by 1.5-1.6 times), while the smallest growth will take place in Europe and North America (1.2 times) (Harrison and Pearce, 2001; Shiklomanov, 1999; UNESCO, 1999). Source: The State of resource : Chapter-4, By UNESCO, WMO, IAEA)

Table 1 Comparison of developed v/s undeveloped runoff condition:

Storm freq	Est Runoff %	Ia /p	Qu	Est peak Discharge %		Storm freq	Est Runoff %	Ia /p	Qu	Est peak Discharge
2	0.14	0.59	230	1.0		2	0.60	0.31	620	11.6
10	0.53	0.41	340	5.6		10	1.33	0.22	660	27.4
100	1.40	0.28	450	19.7		200	2.64	0.15	710	58.6

Undeveloped condition (Woods) Developed condition (Half acre residential)

5.0 Behavioral changes in systems:

5.1 Hydrological behavior in undeveloped catchments:

When an area is undeveloped and is in its natural state with local vegetation and land cover, there is generally no runoff from small rainfall events. The rainwater is either infiltrated (i.e. soaks into the ground), evaporated or transpired (by vegetation).

"Runoff from moderate-large events generally follows natural drainage paths to receiving water bodies. When rain falls on undeveloped land most of the water will soak into the topsoil and slowly make its way to the nearest receiving water body (via subsurface flow). A small portion of rainfall in undeveloped catchments, generally 10-20%, will become direct surface runoff and most of this will be generated by only a few intense rainfall events a year (The Parliament of the Commonwealth of Australia 2002; Argue 2004; Department of Environment 2004). (Austrailia 2003)"

The features of undeveloped catchments that result in the above processes are:

- the large proportion of pervious surfaces (e.g. sand, loam, leaf litter), which allow for on-site infiltration;
- the native vegetation cover, which increases water capture and use (evapotranspiration);
- the occurrence of natural water conveyance and storage areas (e.g. creeks, wetlands, low points in the landscape such as interdunal swales, and floodplains); and
- The existence of natural water movement processes (e.g. intermittent flooding in floodplains and meandering watercourses – water does not flow in a straight line, but flows in a wave form (Pen 1999).

5.2 Hydrological behavior in a specific climate system:

Climate change could increase annual precipitation and make more fresh water available in some places. Rising temperatures, however, could increase the rate of evaporation from surface waters and rising temperatures, however, could increase the rate of evaporation from surface waters and reservoirs and lead to the loss of freshwater held in glaciers. Furthermore, increased rainfall might come in the form of storms that lead to flooding and damage thereby doing more harm than good. Climate change poses a series of risks to water availability and water management systems, although much uncertainty remains. (IUCN 2008)

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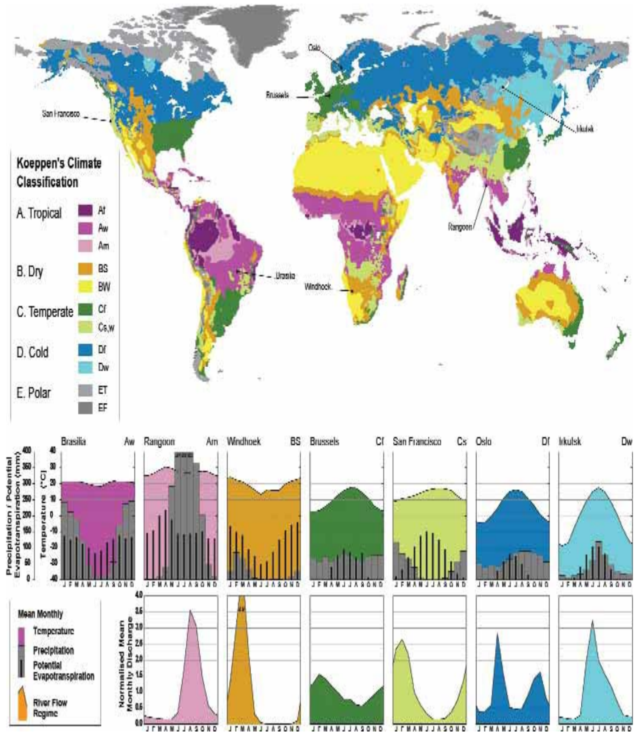

Figure 2 Typical hydrographs in accordance with climatic settings(E.B 2004)

Note:

• For tropical climates close to the equator (Af), perennial rivers flow all year.

• Towards the north and south the tropical climates have a distinct rainy season and a dry season (Am and Aw).

• In dry climates (B) rivers are often ephemeral and only flow periodically after a storm.

• In the temperate Cf climate, there is no distinct dry or wet season, whereas the 'Mediterranean climate' (Cs) has a pronounced seasonal water deficit in the summer and a rainy winter reflected in the hydrograph.

• The cold climates (D) have a distinct snowmelt runoff peak and the Df climate has an additional peak in the autumn caused by rain.

5.3 Hydrological behavior in developed catchments:

Figure 4.2: Schematic of the hydrologic cycle components in present-day setting

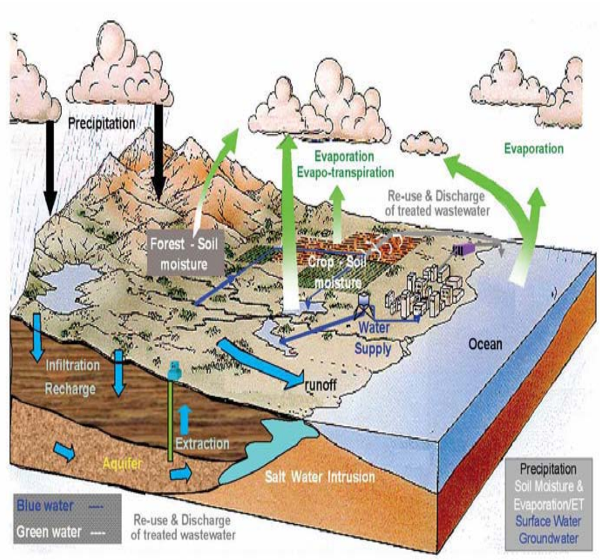

Figure 3 Urban Water Cycle Source: (White 2006)

Some case studies were done from literature review for the present condition on hydrological and urban systems around the world and the findings were observed to draw inferences about the relation between the two and the effects of parameters on the components leading to imbalance in the systems.

The following literature review and study was carried out from numerous papers and publication, conference proceedings and technical reports of various institutes and organizations.

6.0 Case studies: Source: Literature Review

Table 2 some case studies

sn	Case study	Method	Conclusion	Thoughts contributed in research area.
1	Role of satellite remote sensing for monitoring of surface water resources in an arid environment, jodhpur (Hydrological Sciences - Journal - des Sciences Hydrologiques, 34,5, 10/1989)(K. D. SHARMA, SURENDRA SINGH, NEPALSINGH & A. K. KALLA, Central Arid Zone Research Institute, Jodhpur 342003, India)	Land stat TM Data	Due to the interaction of man, land and water desertic environmental conditions have deteriorated resulting in the desertification of a large acreage of adjoining agricultural Lands.	Desertic environmental conditions are deteriorating in India.
2	Effects of urbanization on changes in groundwater quantity and quality in Delhi State, India, S. M. TRIVEDI, B. R. YADAV, N. GUPTA*,H. CHANDRASEKHARAN	ARC-INFO and ARCVIEW GIS	The results of this analysis indicate that the groundwater in the urbanized areas in the west and northwest of Delhi are toxic.	The approximate net quantity of groundwater, i.e. the withdrawal in excess of recharge, has been evaluated at some urbanized locations near Delhi.
3	Geomorphological Studies for exploration of ground water in Rajasthan Desert. Proc. Indian .Sci.Acad, 46, A, No.5, 1980, pp 509-518., by P.C Chatterjee and Surendra Singh, central arid zone research Institute, Jodhpur.	Ground water potential zones identified with study of Shallow and deep Aquifers.	The Dominant Geomorphic factors which have favored the development of the potential aquifers under the geomorphological settings are-type and extent of drainage pattern, thickness of alluvial and Aeolian materials, presence and extent of structurally weak zone, and presence or absence of concealed structure.	The study of local geomorphology and soil characteristics help to demarcate water potential zones, which if considered in planning can help water sustainability.
4	Natural and human influence on the hydrological cycle in South India, Y. Janardan Rao, B. E. Vijayam and J. S. V. L. Narasimham	Observations of rivers in study area and crops grown were assessed with respect to geology, Physiography and rainfall.	The effects of human activities such as agriculture, drainage, reservoir construction, and urbanization, on the erosion patterns and on surface and groundwater resources	Human activity has interfered with every part of the hydrological cycle; runoff is stored in the large reservoirs behind dams, transpiration losses are reduced by Deforestation, groundwater is recharged by water spreading and pumping.

5	Analysis of Land Use Change and Urbanization in the Kucukcekmece Water Basin (Istanbul, Turkey) with Temporal Satellite Data using Remote Sensing and GIS, H. Gonca Coskun *, Ugur Alganci and Gokce Usta, ISSN 1424-8220, Kucukcekmece Watershed (Metropolitan Istanbul, Turkey) from 1992 to 2006.	multitemporal satellite imagery with change detection techniques, using RS and GIS techniques, changing satellite data into coordinate system. Supervised and unsupervised classification.	LULC changes in the Kucukcekmece Water Basin for the years 1992, 1993, 2000 and 2006 shows that, remotely sensed data combined with ground truth data makes it possible to explore the LULC management problems associated with the future rapid growth of the Kucukcekmece population	Land use plans should be prepared in accordance with a protection strategy. Local governments, Relevant administrations, municipalities, planning and environmental protection agencies must protect the catchments area for protection of this precious reserve of good drinking water. They must cooperate with universities and scientific organizations; work in harmony under good co-ordination, rather than attempting isolated solutions on an individual basis.
6	The hydrological cycle and human impact on it, Lev S. Kuchment Water Problems Institute, Russian Academy of Sciences, Moscow,Russia, WATER RESOURCES MANAGEMENT - The Hydrological Cycle and Human Impact on it - Lev S. Kuchment	Literature on Hydrological Cycle, Water Resources, Precipitation, Evaporation, Evapotranspiration etc	The global hydrological cycle is produced by water exchange between the atmosphere, the land, and the oceans, and its main components are precipitation on the land and the oceans, evaporation from the land and the oceans, and runoff from the land to the oceans.	The terrestrial hydrological cycle is of special interest as the mechanism of formation of water resources on a given area of the land. Components- precipitation, interception, storage in land surface depressions infiltration of water into soil and vertical transfer of soil moisture; evapotranspiration; recharge of groundwater and ground flow; river runoff generation; and movement of water in river channel systems.
7	Climate change urban flooding and rights of the urban ppooor in Africa., Key findings from six African cities, Nairobi, Kenya, Kampala, Uganda, Lagos, Nigeria, Accra, Ghana, Free Town, Sierra Leone, Maputo, Mozambique	participatory vulnerability analysis (PVA) and Policy analysis	Heavy thunderstorm rains appear to have increased in frequency. Urban areas may help to increase thunderstorm activity because their built-up surfaces attain higher temperatures than surrounding areas and create a local air circulation that produces an 'urban heat island'.	Climate change is making weather less predictable, rains more uncertain and heavy storm rainfalls more likely. Urban areas may help to increase thunderstorm activity because their built-up surfaces attain higher temperatures than surrounding areas and create a local air circulation that produces an 'urban heat island'.

8.	Analyzing Land Use Change In Urban Environments	Features are interpreted from diverse data Sources including historical topographic maps, satellite images, census statistics, and aerial photographs.	Planners use Urban Dynamics data to evaluate environmental impacts, to delineate urban growth boundaries or service areas, to develop land use zoning plans, and to gauge future infrastructure requirements.	Results from modeling urban growth and land use change can be used by the public, land use planners, and policy makers to anticipate and plan for the future. Land use change models can also generate alternative landscape predictions on the basis of different land use policies and environmental constraints.
9.	Alterations to Natural Catchments due to Urbanization, a Morphologic Approach, urbanized catchment located in the city of Raleigh, North Carolina, USA	Rodriguez et al., Digital Elevation Model, geomorphologic instantaneous unit hydrograph (GIUH),	Alterations to the morphology of drainage systems, need to be taken into account to better understand the hydrologic response of anthropogenic basins, and to improve the modeling, planning and design of sub-urban and urban areas	A "functional landscape" should conserve the ecological processes and, from a hydrologic point of view, emulate the predevelopment temporary storage (detention) and infiltration (retention) functions of the site. This functional landscape is designed to mimic the predevelopment hydrologic conditions through runoff volume control, peak runoff rate control, flow frequency/duration control, and water quality control

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7.1 Facts for changes in urban systems

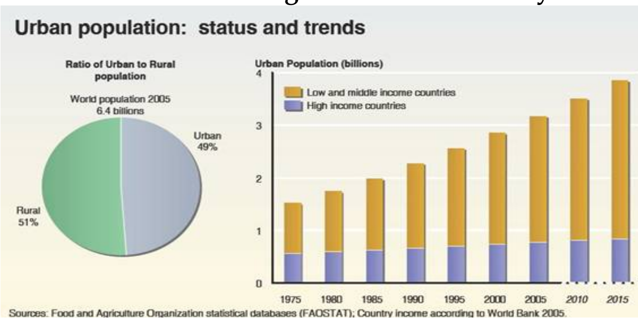

Figure 4 Urbanization over time by income

The reasons for rapid growth of urban populations include overall high population growth rates, and 'pull factors' such as opportunities for employment, education, and improved access to health care which attract people from urban areas. The United Nations projected that half of the world's population would live in urban areas at the end of 2008. By 2050 it is predicted that 64.1% and 85.9% of the developing and developed world respectively will be urbanized.

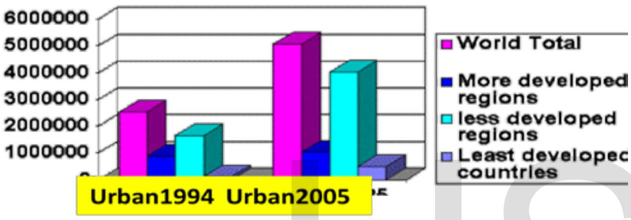

Figure 5 shows the projected growth of the urban and rural populations in developed and less developed countries.

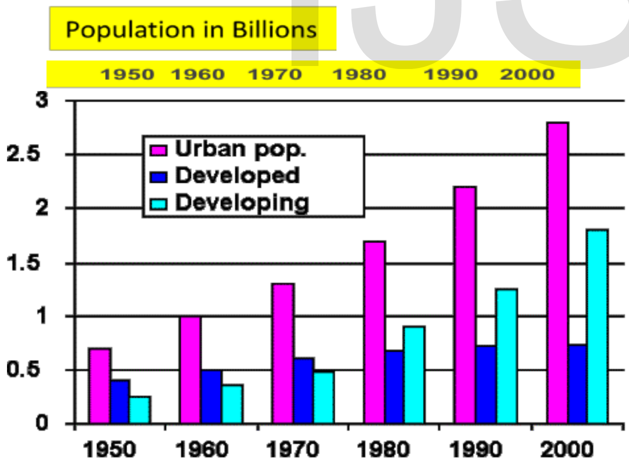

Figure 6 shows the urban population growth between 1950 and the year 2000. In 1950, less than 30% of the world's population lived in cities.

This number grew to 47% in the year 2000 (2.8 billion people), and it is expected to grow to 60% by the year 2025.

Table 3 -Percentage Urban increase from 1950 to 2050

Year	Urban Percentage
1950	29.1
1955	30.9
1960	32.9
1965	34.7
1970	36.0
1975	37.3
1980	39.1
1985	40.9
1990	43.0
1995	44.7
2000	46.6
2005	48.6
2010	40.6
2015	52.7
2020	54.9
2025	57.2
2030	59.7
2035	62.2
2040	64.7
2045	67.2
2050	69.6

Source: (UN2013 2013)

Report of Earth Science and remote sensing unit NASA-Johnson Space Center- "The Gateway to Astronaut Photography of earth has observed the increase in urban percentage from 1950 to 2050

7.2 Changes in urban lands and land covers:

Urbanization mostly leads to imperviousness of the natural land. Impervious surfaces associated with urbanization include roads, sidewalks, parking lots, and buildings- any artificial, hardened surface termed as built up. (Arnold and Gibbons 1996)

7.3 Changes in built up during urbanization:

Table 4 Urban % and built up

Year	Urban %	Built up %
1973	8%	5%
1996	30-40	40-60%
2000	50-60	75-80%

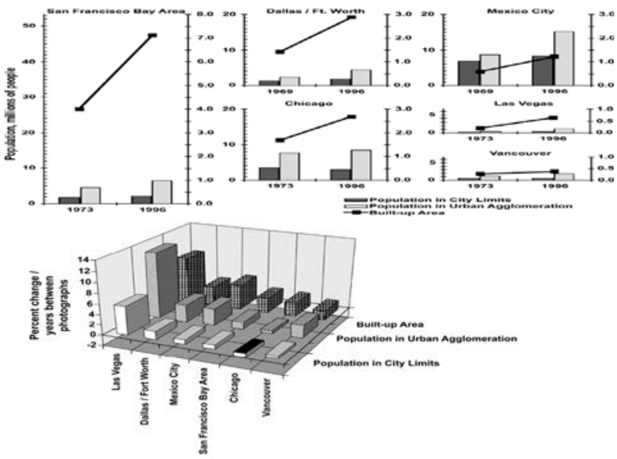

Figure 7 changes in population and built up area in urban areas. (Julie A. Robinson 2000)

Percentage change in built-up area and in human population (population data compiled from UN figures described in Table 3.1). The total percentage change has been annualized by dividing by the number of years between photographs.

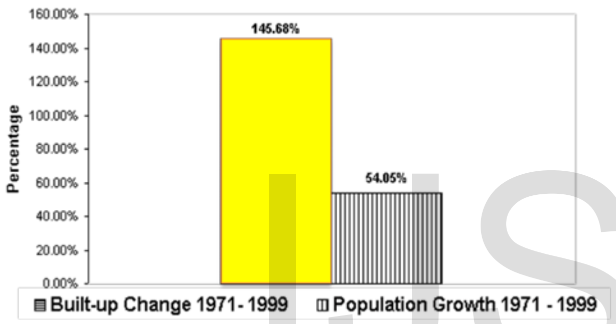

Figure 8 changes in built up and population (Un)

8.0 Inferences of facts for urbanization:

Urbanization result in rapid development of landscape and housing leading to physical modification of habitats, which often results with degradation of the ability of ecosystems to maintain their structures and properties, thus providing ecosystem imbalances. An area when developed for housing or other urban purposes, the immediate hydrologic effect is to increase the area of low or zero infiltration capacity and to increase the efficiency or speed of water transmission in channels or conduits (Dunne and Leopold 1978).

Perhaps the most obvious landscape-level change to accompany urbanization is the extent to which previously natural surfaces are covered by engineered, impervious ones (May 1997). Once vegetation and soil is replaced with buildings and paved surfaces, the infiltration potential for precipitation is greatly reduced, resulting in increased runoff, decreased lag time and increased peak discharge in streams. Urbanization has steadily replaced open spaces and forced dramatic changes to watersheds in the process. Natural drainages have been replaced Changes in Hydrological components:

Changes in many subsystems and components of hydrological systems are observed world wide as per IPCC 2007 and world water day report of 2007,2011. Table 1- shows the simulated changes of the global values of groundwater recharge, total runoff from land and total cell runoff (which includes evaporation from lakes and wetlands as well as evaporation of the water that is withdrawn for human water use).

While both runoff values increase by approximately 9% between 1961-1990 and the 2050s (in the case of the ECHAM4 A2 scenario, with an increase of continental precipitation of 4%), groundwater recharge increases by only 2%.

The effect of neglecting increased future climate variability on groundwater recharge as computed by WGHM cannot be estimated without actual computations of groundwater recharge under the impact of changed climate variability, as the effect is expected to be both cell-specific and depending on the precise change of climate variability.

9.0 Variations in global recharge:

Table 4 Global Recharge variation with time

Year	1961-90 average	2000	2050
Recharge	45to50%	10to30%	-10 to-30

9.1 Evapotranspiration:

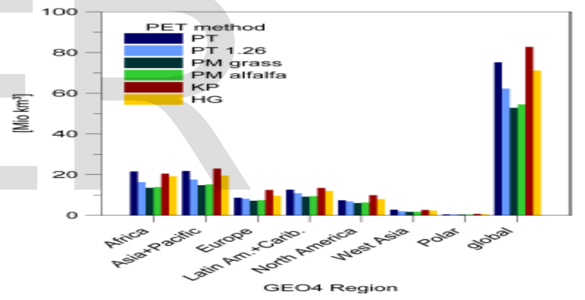

Fig. 9. Global and regional potential evapotranspiration (PET) sums based on various methods for the GEO4 regions.

Figure 9 Evapotranspiration changes

9.2 Variations in Ground water Abstraction %

World Water Council: Third world water Forum, Global Water Partnership, The world International Union, for the conservation of Nature (IUCN) International Water Association, Netherlands, water Partnerships, Intergovernmental Panel on Climate Change (IPCC), Food and Agriculture, Organization, UNESCO, The World Bank, United Nations Development Programme.

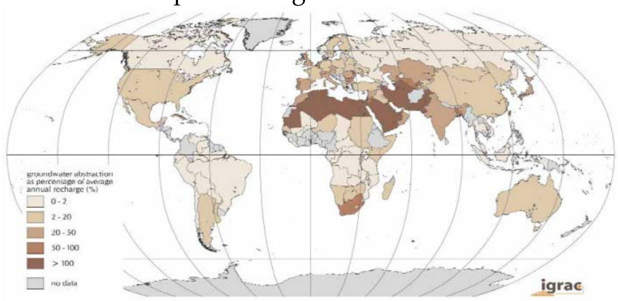

Figure 10 Ground water Abstraction as percentage of average annual recharge

(%)Groundwater abstraction rate as a percentage of mean recharge, Source: IGRAC, 2004., Global Hydrology and Water, Chapter 4, The State of Resource by Unesco.

9.3 Variations in Ground water withdrawal and consumption:

Similarly Water cycle parameters were observed for the variations at Global Level. As per the State of resource Chapter 4, UNESCO, it was observed that the major variations in hydrological parameters were observed in Asia North and South America. The Global water withdrawal also is highest in Asia which is a threatening to the natural resources of this area. Since America is a developed country, Asia was selected as suitable for Study area because it is a fast developing continent at present.

Table 5 changes in hydrological components in continents

Region	Precipitation km3	Runoff%	Evaporation%
North America	18300	45	55
South America	28400	43	57
Europe	8290	35	65
Africa	22300	20	80
Asia	32200	45	55
Australia and Oceania	7080	35	65

Source (Peter.H Gleick, water in crisis, New York, Oxford University Press,1993) (Gleick 2008-09)

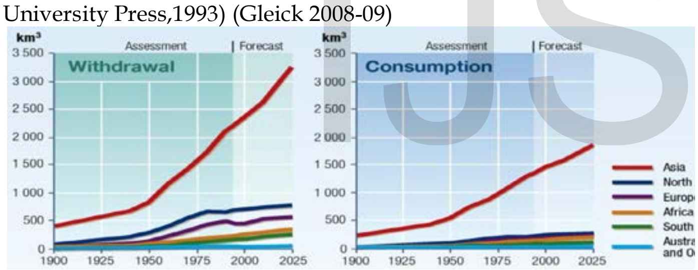

Figure 11 World water withdrawal and consumption

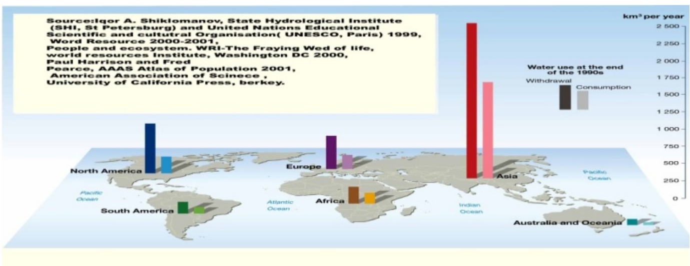

Figure 12 water uses in various regions.

Source: (E.B, Thestate of Resource, Chapter 4 2004) Global Withdrawal and Consumption (1999) http://www.unep.org/dewa/vitalwater/jpg/0210-withdrawcons-cont-EN.jpg
(UNEP 2008)

10.0 Observations:

The above charts clearly show the most critical changes are observed in Asia regarding to water cycle and urbanization. Considering India as a part of Asia and the most developing nation of today, a short look on the major Indian Urban centre's as well as Indian Meteorological status was also observed for changes in water availability and crisis.

10.1 Variations in % Floods:

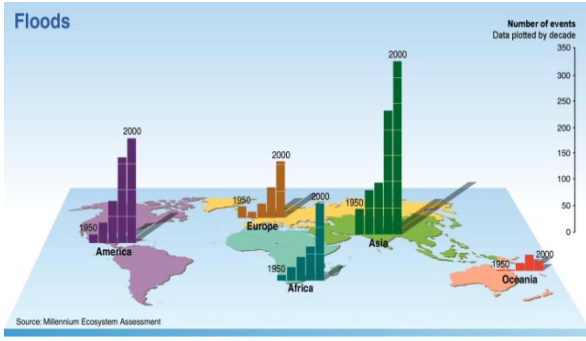

Figure 13 Floods in last 5 decades (UNEP 2008)

Above statistics and figures and Several water related problems identified by American Journal of Applied Sciences , Lut Block, Iran, Ebrahim Moghimi , Iran,, 1st National Hydropolis Conference 2006, Burswood Convention Centre, Perth, Western Australia, Emma Monk1 and Lisa Chalmers2, Environmental Research Laboratory Office of Research and Development U.S. Environmental Protection Agency, ATHENS, GA 30613 , have identified variations in almost all natural systems like modification of microclimate, changed environmental conditions for water cycle, reduced capacity for water retention and thus increased peak discharges that lead to vulnerability of extreme events (e.g., long-lasting droughts and extreme floods) and deteriorated quality of water resources, which become burning issues and challenges in the new global urbanized world.

10.2 Variations in Urban runoff

Table 6 Evaluation of Variations in urban runoff.

Example Effects of increased Urbanization on runoff volumes (USDA SCS-1986)	
Development Scenario	Predicted Runoff
100 percent open space	2.81 inches (Baseline)
70 percent of the total area divided into ½ acre lots, each lot is 25 % impervious; 30 percent of the total area is open space.	3.28 inches (24 percent increase)
70percent of the total area is divided into ½ acre lots; each lot is 35 percent impervious;30 percent of the total area is open space.	3.48 inches(24percent increase)
30 percent of the total area is divided into ½ acre lots-each lot is 25 percent impervious and contiguous; 40 percent is divided into ½ acre lot, each lot is 50 percent impervious and disconnected;30 percent of the total area is open space.	3.19 inches(14percent increase)

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(EPA 1993) (USEPA 1986) (USEPA, A Standardized system for Evaluating Ground water Pollution Potential using Hydrologica Settings. 1987b)

10.3 Similar Case Studies

The management of surface water flooding is hindered by the characteristics of urban Drainage. The presence or large sealed surfaces in urban area (such as Buildings Roads, car parks) raises the volume of surface water runoff and lowers the underground water percolation from paved coverings.

Similarly open and green vegetated spaces reduce direct runoffs and facilitate the water infiltration in ground and through the evapotranspiration back into the air.

Several studies carried out (gill and Ripl 1995) have modeled surface water runoff from different types of land uses and found that runoff increases with proportion of built up areas. Some readings from these studies are as follows

Table7 case Studies similar to Study area

Case studies	% vegetated	% infiltration	% run off	evapotranspiration
Natural condition	natural	50	10	10
Modified	modified	6	50	
Northwest England	66	1	32	1
	20	4	74	2
California, thompson creek	natural	50 (25 shallow + 25 Deep)	10	40
	80-90	42(21+21)	20	38
	50-65	35(20+15)	30	35
	0-50	15(10+5)	55	30
Harzliya , Israel	30-40(residential		45	
	60-75(Industrial)		90	

Therefore it is apparent that land use, land cover and the evapotranspiring surfaces have a significant influence on behavior of water in urban water cycle and related urban flooding. Similarly Induction of Built up areas around natural water routes make these readings more focused on placement of Land use –land cover as per accordance to the natural landscaping behavior.

Table 8 vegetated land cover and runoff relation

cover	Vegetated Land cover	Runoff
Vegetated cover in low density residential areas	66%	32%
Very less vegetated Town centers	20 %	74%

10.5 Indian Scenario:

The Annual Replenishable Ground Water Resource for the entire country has been assessed as 431 billion cubic meter (bcm) of which 57% is contributed by monsoon rainfall alone. The overall contribution of rainfall to country's Annual Replenishable Ground Water Resource is 68%. The ground water level in the country general varies between 5 and 40 m below ground level (bgl). Shallow water levels less than 5 m bgl are observed in pockets in eastern part of the country, canal command areas, river banks etc. (Dr. S.C. Dhiman 2010)

A comparison of depth to water level during Pre-Monsoon (May 2009) (November 2009) (January 2010) with decadal mean (1999-2008) (Plate IV)reveals that in general, there is decline in the water level throughout the country. Fall in water level more than 2 meters on long term basis has also been observed in various parts of the states such as Madhya Pradesh, Uttar Pradesh, Gujarat, Rajasthan, Haryana, Punjab and Maharashtra. The stage of ground water development for the country as a whole is 58%. (CGWB, Ground Water Scenario of India 2009-2010)

10.4 World largest urban centers and their water availability scenario

A study of major urban centers in India for the water demand, water supply, total land area available for recharge, population, declining water levels was performed to see variations. The observations are as under. Study of some Indian Major Urban Centre's for alterations in Components of Hydrological Cycle with respect to impervious areas reveal that built up areas and water withdrawal has resulted in declining of water levels in areas. (S.Sharma 2013)

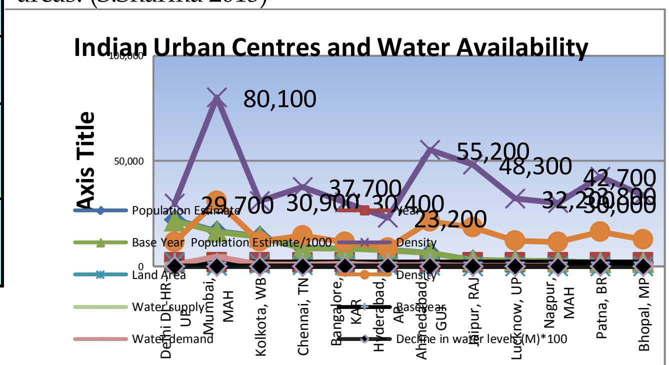

Figure 14 Chart showing Indian urban centers and their water availability. Source: Demographia World Urban Areas: 8th Annual Edition: Version 2 (2012.07)

10.4.1Case Study –BHOPAL CITY (Personal Findings) - Built up Area Calculation- Chronological Method using GIS Imageries for Subsequent years and calculating the urban sprawl by grid cover. (S.Sharma 2013)

Table 9 Comparative analysis of recharge and built up for wards in Bhopal City. .

S.N	WARD	Recharge (year)						Drop in Recharge % Average	Increase in Built up %
		1991	1994	1996	2001	2004	2009		
1	25(Tulsi nagar)	12.56 9.49	17.83 11.56	17.07 9.80	10.64 3.20	9.65 4.23	12.76 3.21	Decrease 75% to 25%	44.7 to 70.43%
2	26 (Panchsheel)	8.65 8.26	12.28 10.35	11.76 9.71	7.33 4.56	6.65 1.07	8.79 0.97	Decrease 95% to 11%	2.64% to 88.96%
3	27 (MANIT)	135.19 134.29	191.98 134.29	183.82 188.60	114.55 179.61	103.87 107.00	137.32 95.39	Decrease 99% to 69%	0.31 % to 11.71%
4	28(Chuna Bhatti)	666.59 643.62	946.63 821.73	906.41 761.14	564.83 457.16	512.13 338.32	677.14 398.52	Decrease 96.55 % to 58.85%	2.22% to 41.14%
5	45(Ravishankar Nagar)	208.41 159.64	295.97 229.98	283.39 220.78	176.601 137.70	160.13 125.42	211.70 175.32	Decrease 76.59 %to	76.6 % to 85.86%
6	48(Arera Colony)	136.72 90.03	194.16 60.69	185.91 46.19	115.85 16.42	105.05 13.50	138.88 7.08	Decrease 65.84 %to 6.73%	0.16 to 94.9%
7	52 (Shapura)	25.22 24.10	35.82 33.18	34.29 31.13	21.37 11.80	19.38 10.20	25.62 13.25	Decrease 95.55% to 51.71%	1.11 to 48.27%
8.	34 Jawahar nehru	10.97 3.53	15.57 4.47	14.91 2.41	9.29 1.20	8.43 0.62	11.14 0.80	Decrease 32.17% to 7.18%	58.52 % to 92.79%
Villages in Nagar Palika									
1	Akbarpur	10.43 9.87	14.82 13.92	14.19 13.14	8.84 5.86	8.02 4.76	10.60 3.90	Decrease 94.63 to 36.79%	2.81 % to 63.23%
2	Nayapura	29.93 28.22	42.51 39.78	40.70 37.47	25.36 22.34	23.00 19.07	30.41 23.88	Decrease 94.28 to 78.52%	3.88 to 21.46%
3.	Bairagarh Chichli	53.41 52.85	75.84 73.96	72.62 70.29	45.25 43.73	41.04 39.60	54.25 52.33	Decrease 98.95 % to 96.46%	0.86 to 3.55%
4.	Neel bad	26.24 25.10	37.2735.53	35.68 34.03	22.24 20.82	20.16 18.72	26.66 24.22	Decrease 95.65 % to 90.84%	1.01 % to 9.15%

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10.4.6: Factors responsible for behavioral changes:

The main changes of the physical pathways of the water cycles due to urbanization include:(UNESCO.lodz 2002)

- removal of natural vegetation drainage patterns;
- loss of natural depressions which temporarily store surface water;
- loss of rainfall absorbing capacity of soil;
- creation of impervious areas (e.g., rooftops, roads, parking lots, sidewalks, driveways)
- Provision of man-made drainage systems (e.g., storm sewers, channels, detention ponds).

Therefore, although the hydrological cycle consists of the same elements, their proportions in urban area are significantly different due to following reasons:

- interception of rainfall is reduced due to removal of trees;
- precipitation is usually higher than in rural areas;
- evapotranspiration is much lower;
- surface run-off is much larger;
- ground-water run-off, infiltration and recharge is small;
- water storage is much lower;
- runoff volumes and peak flows in rivers are higher;
- Frequency of surface runoff is increased.

Urban development significantly increases the amount of storm water and the frequency of extreme hydrological events experienced by the City's catchments. The increased runoff causes more intense local flooding, while droughts during dry weather are deeper and longer. (Figure1 & 2)

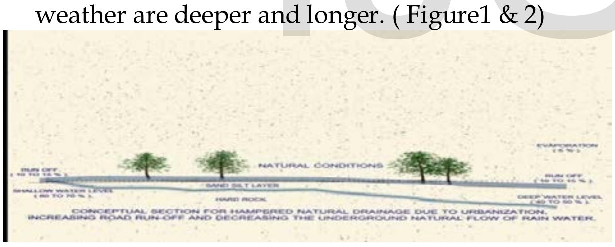

Figure 16 Pre & Post development variations

Figure 17 Hydrological system affected by urbanization

Human activities (settlements, industry, and agricultural developments) can disturb the components of the natural cycle through land use diversions and the use, reuse and discharge of wastes into the natural surface water and groundwater pathways.

The processes of evaporation and transpiration (evapotranspiration) are closely linked to the water found in soil moisture; these processes act as driving forces on water transferred in the hydrological cycle. Movement through soil and vegetation is large and accounts for 62 percent of annual globally renewable freshwater. Evapotranspiration rates depend on many locally specific parameters and variables that are difficult to measure and require demanding analyses in order to calculate an acceptable level of accuracy. Evaporation from surface water bodies such as lakes, rivers, wetlands and reservoirs is also an important component of the hydrological cycle and integral to basin development and regional water management.

Near-surface soil moisture content strongly influences whether precipitation and irrigation waters either run off to surface water bodies or infiltrate into the soil column. Regionally, mapping soil moisture deficit is becoming a widely used technique to link climatological and hydrological information in agriculture (e.g. Illinois, US) and to reflect drought conditions (US Drought Mitigation Center, 2004). Soil moisture distribution is now identified as a prerequisite for effective river-flow forecasting, irrigation system maintenance, and soil conservation. Its distribution in time and place are now viewed as essential to hydrological, ecological and climatic models – both at the regional and global level (US NRC, 2000).

10.5 Changes observed:

According to Studied Four interested but separate effects of Land use changes on the Hydrology of an area were Observed.

1. Changes in Peak flow Characteristics.
2. Changes in Total Runoff.
3. Changes in Quality of Water.
4. Changes in Hydrologic amenities or Appearance of River Channels.

10.6 Main Reasons:

- Runoff that spam's the entire region of flow-
- Measured by number and Characteristics.
- 2 principal factors governing flow regimen.
- Percentage of area made impervious.
- Rate at which water is transmitted across the land to stream channels.
- Percentage of area impervious- is governed by the type of land use.
- Rate water is transmitted is- governed by the density; size and characteristics of tributary channels and storm sewerage.
- Volume of Runoff α % of area covered by roofs, streets and other impervious surfaces.
- Because Volume of runoff is governed by infiltration characteristics and is related to land slope and soil type as well as to the type of vegetative cover.

10.6.1Two Principles factors governing flow regime-

1. The percentage of area made impervious.
2. The rate at which water is transmitted across the land to stream channels.

11.0 Conclusion of literature review:

Urban development significantly changes the hydrological cycle...

The main changes of the physical pathways of the water cycles due to urbanization include:

- removal of natural vegetation drainage patterns;
- loss of natural depressions which temporarily store surface water;
- loss of rainfall absorbing capacity of soil;
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Bibliography

Aleksandra Kaźmierczak, Gina Cavan. Surface water flooding risk to urban communities: Analysis of vulnerability, hazard and exposure. Volume 103, Issue 2, 30 November 2011, Pages 185–197, Manchester, U.K: Landscape and Urban Planning, Elseivier, 2011.
Austrailia, Parliament of. "www.aph.gov.au." aph.gov. 2003. http://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/Browse_by_Topic/ClimateChange/whyClimate/factors (accessed 2011).
Booth, Derek. "Urbanization and the natural drainage System:Impacts,solutions and Prognosis." The Northwest Environmental Journal 7, no. 1 (1991): 93-118.
CGWB. Ground Water Scenario of India. Ground water year book., Faridabad: Central Ground Water Board, Ministry of Water Resources, Government of India, 2009-2010.
CGWB. Ground Water Scenario of India 2009-2010. Government Report, Faridabad: Centre ground waer board, Ministry of water resources., 2010.
Dr. S.C. Dhiman, S. Kunar,Rana Chatterjee,Prahlad Ram. Assessing ground water resources and their sustainability. Research report, New Delhi: 5th Asian Regional Conference of INCID, 2010.
E.B, White. "Thestate of Resource, Chapter 4." unesco.org. 2004. www.unesco.org/bpi/wwap/press/pdf/wwdr2_chapter_4.pdfaccessed)
.(2011 ,11 Sept
—. "unesco.org/bpi/wwap/press/pdf/wwdr2_chapter_4.pdf ".
.2004 .org.unesco
pdf.4_chapter_2wwdr/pdf/press/wwap/bpi/org.unesco.www
(accessed Sept 11, 2011).
EPA. Management measures for urban areas. Washington: EPA, 1993.
Gleick, Meena Palaniappan and Peter H. "Chapter 1. Peak water World water." www.world water .org. 2008-09. http://www.worldwater.org/data20082009/ch01.pdf (accessed July 12, 2013).
GRUMP. "Global Rural-Urban Mapping Project (GRUMP)." columbia.edu. 1997. http://sedac.ciesin.columbia.edu/data/collection/grump-v1 (accessed 07 12, 2013).
—. "www.earth.columbia.edu." The earth Institute Columbia University. 05 03, 2005. http://www.earth.columbia.edu/news/2005/story03-07-05.html (accessed jul 12, 2013).
Heidi M. Peterson, John L. Nieber, Roman Kanivetsky. "Hydrologic regionalization to assess anthropogenic changes." Journal of Hydrology Volumne 408, no. Issue 3-4 (October 2011): 212-225.
IPCC. Climate Change 2007. The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment , Cambridge: Cambridge University, 2007.
IPCC. Linking climate change and water resources. Technical Paper, www.ipcc.ch/pdf/technical-papers/ccw/chapter3.pdf, 2007.
IUCN. "www.ScienceDaily.com." october 27, 2008. http://www.sciencedaily.com/releases/2008/10/081013143031.htm (accessed November 17, 2011).
Julie A. Robinson, Brett McRay, and Kamlesh P. Lulla. "Twenty-Eight Years of Urban Growth in North America Quantified by Analysis of Photographs from Apollo, Skylab, and Shuttle-Mir." In "The Gateway to Astronaut Photography of Earth.", by JUlie. A Robinson, 25-41,262,269-270. New York: NASA Johnson Space Centre, 2000.
Kundzewicz.Z.W, L.J Mata, N.W. Arnell,P.Doll, P.Kabat, B.Jimenez, K.A Miller, I.A Shiklomanoy. Feshwater resources and their management, Climate CHange 2007. Assessment report of the Intergovermental Panel on Climate Change., Cambridge: IPCC, 2007.
Leopold, Dunne &. Water in Environment Planning. W. H. Freeman, 1978.
Leopold, Luna B. Hydrology of urban land planning-A guidebook on the Hydrologic Effects of Land use.
S.Sharma, A.Bharat, V.M Das, V.K Bhatt. "Indian Urban centres in need of water sensitive Urban Planning." India Water Week. Delhi: Ministry of water resources , Govt. of India, 2013. 143.
umich.edu. "Urbanization and unequality." globalchange.umich.edu. 2008. http://www.globalchange.umich.edu/gctext/Inquiries/Inquiries_by_Unit/Exploring_G_Change/Urbanization.htm (accessed June 12, 2014).
UN2013. "World Urbanization Prospects, the 2011 Revision." www.un.org. 2013. http://esa.un.org/unup/p2k0data.asp (accessed June 12, 2010).
UNEP. Water withdrawal and consumption: the big gap. Research by International French language newspaper "Le Monde diplomatique", Norway: UNEP/GRID-Arendal , 2008.
UNESCO.lodz. "Water Cycle in Urban Areas." lodz.pl. 2002. http://www.aquatic.unesco.lodz.pl/index.php?p=water_cycle (accessed july 28, 2011).
University, Carnegie Mellon. "http://telstar.ote.cmu.edu/environ/m2/s2/#ftnref1." cmu.edu. 2003. http://telstar.ote.cmu.edu/environ/m2/s2/#ftnref1 (accessed Sept 11, 2011).
USEPA. A Standardized system for Evaluating Ground water Pollution Potential using Hydrologica Settings. DC. EPA/530-SW-89-006(Technical), Washington: U.S Environmental Protection Agency, 1987b.
USEPA. Septic systems and groundwater Protection-A prgram Managers Guide and reference book. Technical report-Guide, Washington: U.S Environmental Protection Agency.Office of Water, 1986.
White, E.B WWDR2. Chapter 4-The state of Resource. 2nd UNITED NATIONS WORLD WATER DEVELOPMENT REPORT, WWDR2, UNESCO,WMO, IAEA, Mexico: 2nd UNITED NATIONS WORLD WATER DEVELOPMENT REPORT: WATER, A SHARED RESPONSIBILITY, 2006, 120-156.
Worldwater. Coping with Water Scarcity, CHallenges of the twenty first Century. World Water Report., NewYork: www.world water 2007.org, 2007