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TREND AND CHALLENGES OF DAM CONSTRUCTION – A STRATEGIC IMPACT ASSESSMENT

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ABSTRACT

River engineering is now important tool for so call development in our technocratic civilization. The World Commission on Dam (WCD) was born from the debate of the impacts of dam on local people and environment. The United Nation's World Water Development report (2003) shows 60% of the world's 227 largest rivers are severely fragmented by dams. The major objective of this paper is to review the development effectiveness of large dams and to assess alternatives for water resources and energy development. The report (London &Sterling 2000) has given stress on the decommissioning of large dams for river restoration.

Key Words: Sedimentation, Aquatic Ecosystems, Seismic Activity, decommissioning dams, Groundwater recharge, Dam disaster. Waterborne diseases

Introduction

River is not a part of civilization but a indispensible part of nature. Rivers basins are renowned at the cradles of civilization and cultural heritage. Ancient and modern communities alike have dependent on rivers for livelihood, commerce, habitat and the sustaining ecological functions they provide. Throughout history alternation to rivers- natural or human generated- have affected riverine communities in one way or another. River engineering is the ruins of irrigation canals over eight thousand years old in Mesopotamia. Remains of water storage dams found in Jordan, Egypt and other parts of the Middle East date back to at least 3000 BC. The Dujiang irrigation project, which supplied 800 000 hectares in China, is 2200 years old. The great poet **Rabindranath Tagore felt pains** about river and have expressed his view in his poem .

In Bengali- “ Keno More gelo Nadī /

Āmi bāndhi tāre, chai dhoribāre //

Pāibāre nirabadhi/

Tāi more gelo nadī //”

It means

Why did the river die.

I came once and again to tie her with me, I wanted to catch her

For having her forever

Even then it died

(By Rabindranath Tagore’s Poem **‘Durākāṁksā’** from the collection ***Chitra***)

Large Dams:

From the starting time the area and the height of the dams was very small but with the passage of time the characteristics of dam in respect of height and area is being changed and started to adverse effect on rivers. According to the definition of International Commission on Large Dams (ICOLD)-A large dam as one with a maximum height of more than 15 meters from its deepest foundation to the crest and the capacity of the reservoir formed by the dam is not less than one million cubic meters or the maximum flood discharge dealt with by the dam is not less than 2000 cubic meters per second. From 1940 to 1990 the height of new dams was between 30-34 meters but after 1990 the height reached to 45 meters. From 1945 to 1960 the average area of dam was 50 sq. km. but remarkably the area of dam is being reduced to 17mt. on 1980 and after 1990 it reduced to 23sq km. (**W.C.D. Analysis of ICOLD, 1998**).

Trend of Dam construction in the World:

The last century saw a rapid increase in large dam building. In between 1930 to 1970 dam construction was a parameter of development. In the year 1970 average two or three dam was constructed every day. By 1949 about 5 000 large dams had been constructed worldwide, three-quarters of them in industrialized countries. Over the past two decade there is decline trend of dam construction in Europe and North America. By the end of the 20th century, there were over 45 000 large dams in over 140 countries. Approximately two thirds of the world's existing large dams are in developing countries. The top five dam-building countries account for nearly 80% of all large dams worldwide (**The Report of the World Commission on Dams, Nov-2000**).

Table-1 (Leading Countries of Dam Construction):

Countries	China	U.S.A	India	Spain	Japan
Number of Dams	22000	6390	4000	1000	1200

Source: ICOLD, 1997, International Journal of Hydropower and Dams,2000

Table-2 (Dams under Construction):

Countries	India	China	Turkey	South Korea	Iran
Number of Dams	695-960	280	209	132	48(>60 mt)

, Source: WCD India Case Study, 2000

An estimated 1700 large dams have been under construction in other parts of the world in the last few years. Of this total, 40% are reportedly being built in India. India ranks third in the world after China and U.S.A in terms of number of dams. In every year about 160-320 dams is being constructed in every day.

Trends of Dam Construction in India

From the Table 1 it is clear that at independence, in 1947, there were fewer than 300 large dams in India. By the year 2000 the number had grown to

over 4000, more than half of them built between 1971 and 1989. India ranks third in the world in dam building, after US and China. As per the latest information compiled, there are about 4711 completed large dams and another 390 are under construction.

In India (Table-3) Maharashtra secured first position (1821), Madhyapradesh Second position (906) and Gujrat secured third position (666). From the statistics (table 3) it is clear that most of the dams have constructed between1950-2000. But the rate is quiet slow in between 2000-2009.

Table-3 (State - Wise Distribution of Large Dams):

Sl. No.	Name State	1900	1901 - 1950	1951-200	After 2001	Total Constructed Dams	Dams Under Construction	Total Dams
1	Andaman & Nicobar Islands			01	01	2	-	2
2	Andhra Pradesh	7	35	112	112	129	283	334
3	Arunachal Pradesh				1	1	-	2
4	Assam				2	2	2	4
5	Bihar	1		21	2	24	4	28
6	Chhattisgarh		11	202	30	243	16	259
7	Goa			5	-	5	-	5
8	Gujarat	6	59	504	29	598	68	666
9	Haryana					-	-	0
10	Himachal Pradesh			6	07	13	6	19
11	Jammu & Kashmir			5	5	10	3	13
12	Jharkhand			46	3	49	28	77
13	Karnataka	6	26	171	26	229	7	236
14	Kerala		1	50	2	53	1	54
15	Madhya Pradesh	3	86	716	94	899	7	906
16	Maharashtra	20	40	1501	115	1676	145	1821
17	Manipur			02		2	3	5
18	Meghalaya			04	1	5	2	7
19	Mizoram					0		
20	Nagaland					0		
21	Orissa	1	1	153	2	187		157
22	Punjab			11	3	14	1	15
23	Rajasthan	15	7	141	17	180	23	203
24	Sikkim			01	1	2		2
25	Tamil Nadu	1	10	86	10	107	1	108
26	Tripura			01		1		1
27	Uttar Pradesh	4	25	84	2	115	16	131
28	Uttrakhand			11	2	13	6	19
29	West Bengal			24	4	28		28
TOTAL		**64**	**301**	**3853**	**286**	**4711**	**390**	**5101**

Source: National Register of Large Dams-2009

Dam Safety Organisation (DSO) was established under the Central Water Commission (CWC) in May, 1979. Subsequently, CWC helped in setting up independent Dam Safety Organisations in most of the States in the country. A National Committee on Dam Safety (NCDS) was set up on 1987 taking with membership of all the States and organization under the Chairmanship of Chairman, CWC with CE (DSO).The main purpose of all those organization was monitoring the activity and oversee the safety factors of dam construction in our country.

Uses of Dam

Primary purpose of Dam is Economic. Among the total dams 50% are used for irrigation 18% for hydropower, 12% of water supply and 10% for flood control and the rest for other functions.

I. Irrigation Purpose

A majority of the dams built in the world are multipurpose in nature, but irrigation is the largest user of the waters withdrawn. One fifth of the Earth's surface is irrigated land. After Green Revolution volume of irrigated land is being increased. The vast quantities of water in reservoirs allow them to act as effective and steady sources of water for irrigation with minimal seasonal fluctuations. 30 to 40 percent of the 271 million hectares that are irrigated worldwide rely on irrigation dams **(WWF – Dam facts and figures, 2013, November 23)**. Four countries- China, India, U.S.A and Pakistan account for more than 50% of the world's total irrigated area. Dams supply the water for almost 100% of irrigation production in Egypt.

II. Water Supply for Industrial Use

The water in the reservoirs can be sent to treatment plants to make it suitable for drinking. Globally, urban water consumption accounts for 7% of total fresh water withdraws from rivers and 22% from lakes. Many reservoirs were built to provide a reliable supply of water to meet rapidly growing urban and industrial needs. Globally 12% of the largest dams are designated as water supply dams. About 60% of these dams are in North America and Europe.

III. Hydroelectric Power

Dams can harvest gravitational potential energy to provide electrical power at low rates. Nineteen percent of world's electricity supply comes from hydroelectric dams. First hydroelectricity production from reservoir's water started from 1890.At present hydropower supply 19% of the world's total required electricity. About 150 countries depend on hydropower for their electricity. Among these countries about in 24 countries 96% electricity comes from hydropower and 63 countries get their 50% electricity from hydropower **(Michigan Government, Department of Natural Resources, 2013, December 2)**. At the global scale, current levels of hydropower generation offset 4.4 million barrels of oil – equivalent a day, roughly 6% of the world's oil production.

IV. Flood Control

About 13% of all large dams in the world in more than 75 countries – have a flood management function. Reservoirs can act to prevent floods downstream by holding and regulating the flow during major flood events. Reservoirs can also be used to balance flow during different weather conditions, such as decreasing the flow by holding water back during heavy rainfall and releasing more water during droughts. Such as Aswan dam over the Nile river can store 1.5 times more water which is being flow in a year.

Dams have been constructed to a lesser extent to improve river transportation and also used for recreation, tourism and aquaculture.

Problems Related with Large Dams

A. Environmental Effects

I. Physical Transformation of Rivers:

The World Dams are the most common forms of direct infrastructure on rivers. Commission on Dams stated that large dams have fragmented and transformed the world's rivers. The World Resource Institute (WRI) found that at least one large dam modifies 46% of the world's primary watersheds. Due to the construction of dam local base level created which caused hydrological break of slope and interrupt the normal flow pattern of river. Following figure (fig 1) proves this fact that in Dwarka river due to the construction of Deucha dam local base level created.

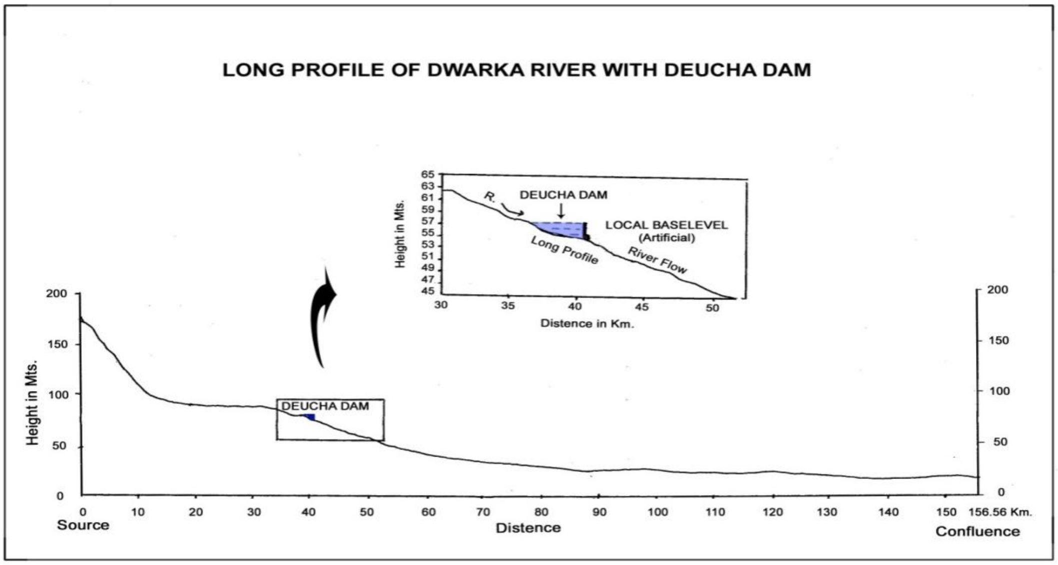

Fig. 1

Due to the construction of Dam in the river path river loses its actual way and stagnant in one place.This is also felt by Great poet Rabindranath Tagore who wrote in his another one poem that

"Je nodī hārāye srot cholite nā pāre/

Sahasra saibāldām bāndhe āsi tāre"//

It means-

The river loses its path and has no way to move on/

Gets tied with the strings of mosses//

(By Rabindranath Tagore's Poem **'Moho'** from the collection ***Kshanika***)

II. Acclerate the Rate of Flood Devastation

Due to the sedimentation and siltation and sudden flush of sediments from reservoirs causes riverbed degradation which caused the flood propensity high and also increased the flood frequency. To proves this fact I have cited one example from my research study area that Deucha dam accelerated the growth of flood frequency in Dwarka river.

Example: How Far Deucha Dam is Responsible for Flood Frequency Acceleration in Dwarka River Basin?

Out of total 37 very meso to macro level floods in response to spatial extent and flood height since 1900, 28 floods happened after the construction of Massanjore dam (1954) across Mayurakshi River and Deucha Dam across Dwarka River and only 9 were occurred before mentioned time. So, anybody could have doubt about the role of dams and barrages for the proliferation of flood frequency. So, when huge volume of discharges are releasing from Massanjore or Tilpara barrage, a large portion of it is received by Dwarka river trough the said canal and distributary. Dam and barrages accelerated flood frequency in Dwarka river basin.

Table 4: Flood Frequency Before and After Deucha dam since 1900 to 2008.

	Flood year	**Non flood year**	**Total**
Before Deucha dam	9	46	55
After Deucha dam	28	26	54
Total	37	72	109

Source: Local people's experience and Ankur Patrika, Annual Journal of Purandarpur.

Sudden releases can be disastrous for people living downstream, for their crops and for entire ecosystems. Reportedly, such releases occurred twice from the famous Bhakra dam, in the late 1970s and again in 1988. Another case was that of the Rihand dam. In 1997, huge amounts of water were suddenly released and flooded 175 villages in Rewa district of Madhya Pradesh as well as Rewa town, killing 14 people and causing an estimated damage of Rs. 200 crores.

III. Sedimentation

An estimated 0.5% -1% of the total fresh water storage capacity of existing dams is lost each year to sedimentation in both large and small reservoirs worldwide. This means that 25% of the world's existing fresh water storage capacity may be lost in the next 25 to 50 years due to sedimentation. After construction of dams, silt, which is brought by the rivers, gathers in the reservoirs and siltation causes riverbed degradation. Siltation reduces the life of reservoirs, and once reservoirs are filled up with sediment, they cannot be of much use further. The life span of reservoirs has frequently proven much shorter than planned. The life expectancy of the Bhakara dam initially estimated to be 88 years is now expected to be 47 years and Hirakud dam from 110 years to 35 years, because of the high rate of siltation.

IV. Changing Aquatic Ecosystems

Building a dam in a river causes great changes within the river and leads to great changes in the river systems, leading to habitat loss. The temperature and chemical composition of water in the reservoir is also different from that of the flowing river. The reduced water flowing downstream causes the water downstream to be more saline, making it less suitable for certain fish nurseries and also enables predators to reach them. The water running off from the catchment areas upstream carry with them sediments and nutrients. Human activity upstream can increase the nutrient level in the reservoir with may lead to eutrophication, which eventually leads to the loss of most species in the reservoir. (T**imofti, D., Doltu, C., & Trofin, M. , 2013, November 23).**For example, river dolphins of the Yangtze were lead to extinction after the three Gorges Dam was built; the variety of fishes dolphins in the Mekong region are also at risk or extinction. The Glines Canyon Dams in the Elwha River in Washington, USA, has been responsible for almost wiping out the entire steelhead trout and salmon population. This loss of fish populations can also lead to loss of economy from fisheries.

Ecosystem transformation does not only occur in the upper, lower and mid reaches of watersheds, they also impact on river estuaries, which are frequently complex ecosystems. Closing the months of major rivers, salt intrusion, and destruction of mangroves and loss of wetlands are among the many issues at stake (**World Commission on Dams, 2000**)

V. Greenhouse Gas Emission

The condition at the base of the reservoir is anaerobic, meaning that vegetation under the reservoir are decomposed by anaerobic bacteria that give out greenhouse gases such as methane and carbon dioxide (**Lindström, Andreas; Granit, Jakob ,Aug 2012)**. According to the WDC, if the area being flooded during the reservoir filling is not cleared out, the amount of greenhouse gases produced could be higher for the same amount of energy produced by a coal powered station (**Wikipedia, 7 Nov 2013)**. However, power generation from the dams does not cause emission of gases such as sulfur dioxide, nitric oxide and carbon monoxide which are responsible for acid rain and blood poisoning, making them more eco-friendly in this sense than fossil fuels such as coal, which does produce these gases when burned.

The emission of greenhouse gases (GHG) from reservoirs due to rotting vegetation and carbon inflows from the catchment is a recently identified ecosystem impact of storage dams. an estimate suggests that the gross emissions from reservoirs may account for between 1% and 28% of the global warming potential of GHG emissions**(World Commission on Dams ,2000)**.

VI. Seismic Activity

It has been known that the filling of reservoirs of large dams has triggered seismic activity because of the physical change incurred in the area where the reservoir was filled, and the activity of the dam **[Houqun, Chen; Zeping, Xu; Ming, Li (8 Feb 2010)]**. Scientists have traced the cause of over 100 earthquakes worldwide to dams. In May 2008, the 7.9-magnitude earthquake in Sichuan killed 80,000 people has been linked to the construction of the Zipingpu Dam, and is possibly the most serious earthquake caused by a dam (**International Rivers Organization, 2013, Nov 23).** In India on 1962 an earth quake was happened surroundings the Koiana dam at Maharashtra due to the reservoir's stored water pressure.

Earthquakes and volcanic activity can be induced by the weight of the reservoir on nearby fault lines, and lubrication of faults by excess water. There are many recorded cases of this effect, including 5 strong earthquakes on the Indian peninsula in the 1980´s and 4 earthquakes over 6 Richter since the 1960´s. (**Gupta, 1992**). Even small earthquakes (common under dams) can lead to dam cracking and reservoir overtopping, as in the Vaiont dam disaster in Italy which killed 2,600 people when landslides caused the dam to overflow. **(McCully, 2001).**

B. Social Effects

I. Displacement of People

An area to be flooded for use as a reservoir has to be cleared of human population. It is estimated that 40 to 80 million people have been displaced by dam construction worldwide. Many of them have not been resettled or received adequate compensation between 1986 and 1993, an estimated 4 million people were displaced annually by an average of 300 large dams starting construction each year. The world's two most populous countries China and India, have built around 57% of the world's large dams and account for the largest number of people displaced. In the late 1980s China officially recognized some 10.2 million people as 'reservoir resettlers'. In India, estimates of the total number of people displaced due to large dams vary form 16 to 38 million people. Large dams and reservoirs already built in the Yangtz basin alone have led to the relocation of at least 10 million people. (World Commission on Dams (2000). Dams and development: A new framework for decision-making).

II. Health Hazards:

The large lake created by the dam's reservoir provides a habitat in which water borne diseases and parasites thrive. In tropical areas, reservoirs provide a perfect breeding ground for parasitic organisms, especially as mosquitoes. Large dams have serious health hazards to human beings. There is a steep increase in diseases like schistosomiasis (a debilitating intestinal and urinary disease caused by the larvae of a blood fluke), cerebral and spinal meningitis, pneumonia, measles, and malaria. These diseases emerge because of continuous standing water in the command area of the dam region.

In the case of the Aswan dam in Egypt, schistosomiasis is prevalent among a large population. According to a study conducted between the Aswan dam and Cairo city, schistosomiasis has increased from five per cent in 1930 to 35 per cent in 1972. The Kano river project in Nigeria was supposed to improve health through provision of clinics. But in reality, very limited clinics were provided and that too at inconvenient locations. On the contrary, there has been a dramatic increase in several waterborne diseases. While building dams, this aspect remains totally neglected and safety and precautions are not taken into account.

Voice against Dams

Conflicts over water and dams are probably as ancient as dam building. In medieval England, boat owner opposed millers blocking rivers to create millponds to turn their wheels. On 17 th century Scotish fisherman trying to destroy a newly completed weir. Intentionally many times or due to isolated location people's resistance to dams often went unnoticed and in many cases govt. also suppress the movement against dam.

Eight people died and over 30 were injured when colonial government forces on Tonga people resisting removal to make way for the Kabira dam resevoir. At the same time in Mexico, the Papaloapan River Commission set fire to the houses of indigenous Mazatecs who refused tom move for the Miguel Aleman dam. In 1978 police killed four people when they fired at an anti-resettlement rally at Chandil dam in the state of Bihar in India.In Nigeria in April 1980, police fired at people blocking roads in protest against the Bakolori dam. And in 1985, 376 Maya Achi

Indians, most of them women and children, were murdered in the course of clearing the area to be submerged by the Chixoy dam in Guatemala. When the number of dams increased then the voice against dam increased. Protestors were able to stop the 175 mt high Echo dam Park on a tributary of the Colorado River in the 1950s.

World Bank is a largest financer for large dams. On 1993 World Bank started an appeal mechanism for citizens who were adversely affected by bank funded dam's project .In 1973-77, the resistance of indigenous peoples to four dams along the Chico River in the Philippines led the World Bank to withdraw from project and resulted in the government postponing it indefinitely. Other important milestones include the World bank's withdrawl from the Sardar Sarovar project in india in 1993, and then from Arun iii in Nepal **(The Report of the World Commission on Dams, Nov-2000).**

Dam Removals

Dams are a symbol of human ingenuity and engineering prowess—controlling the flow of a wild rushing river is no small feat. In recent years, many communities and dam owners have begun to remove dams, particularly those that have deteriorated. While dams serve many beneficial purposes, they also can cause negative impacts to rivers, wildlife, and local communities. Some dams no longer provide any of their intended benefits and continue to harm the river. Others have significant negative impacts that outweigh the aggregate benefits. Others still are simply so old and/or unsafe that maintenance costs are prohibitive and not worth the effort. For these cases, dam removal has proved to be a reasonable option to eliminate negative impacts and safety concerns (**American Rivers, Friends of the Earth, & Trout Unlimited, 1999**). The publication Dam Removal Success Stories states that over 465 dams have been removed in the United States since 1912. A clear history of many dam removals is difficult to find due to the lack of documentation available from the various agencies that have been involved with them. Many removals of smaller dams (i.e. less than six feet high) often are not documented at all (**American Rivers, Friends of the Earth, & Trout Unlimited, 1999**). Since 1998, the decommissioning rate of large dams has overtaken the rate of construction in the U.S.A.

The decommissioning dams have enabled the restoration of riverine ecological processes. But dam's removal should be executed with proper knowledge of those dams. After decommissioning the large dams there may be happened negative impact in downstream aquatic life due to sudden flush of sediments accumulated in the reservoir. Where there has been industrial and mining activity upstream, these sediments may be contaminated with toxic substances.

Recommendations

1. **Disassemble Old, Outdated Dams**:

Constructed dams no longer serve the economic output profitable because the maintenance cost exceeds the profit. Many dams silted cannot able to produce hydroelectricity and also destroy the river ecosystem. So it should be removed and the costs of removing a dam could be up to 3 to 5 times less than the costs of maintaining it .Funding for larger projects could possibly be obtained from the World Bank since these projects deal with restoring the environmental health of a country. The WCD recommends dam owners to set aside funds for future dam decommissioning (**International Rivers Organization, 2013, December 3**).

2. **Increase the Efficiency of Existing Dam**

In the technocratic world the number of dams is huge, so there is no required to construct a new dam, rather it will be fruitful if we increased the efficiency of exist dams such as Hydropower dams can be made more efficient by replacing its turbines, Large gates should be built into the base of dams and opened when the flow rate is high etc.

3. **Alternative Solutions**

I. Instead of hydroelectricity alternative sources of energy may be used which will reduce the demand dams.
II. Improving the surface irrigation systems
III. Enhancing local water storage in ponds or lakes through small structures, connecting channels, and measures to encourage groundwater recharge.
IV. Adopting water harvesting techniques.

4. Some Consideration during Construction of New Dams

a. Minimize the environmental and social effects of dams; Dams should be situated at a site. which has the least environmental impacts
b. Dams should minimize surface area and maximize depth so as to reduce evaporation and the rate of siltation. Thus it is preferable to situate dams in deep gorges that will require little or no flooding of forests, to prevent decay and hence, carbon dioxide and methane production and eutrophication **(http://siteresources.worldbank.org, 2013)**
c. Efforts should be done for integrated land use planning with floodplain management below dams.
d. The project of dam's construction only approved if it is predicted that the affected individuals will be able to tackle the effect of the dam.
e. Flood insurance should be provided within a dam failure inundation zone.

Conclusion

To protect the environment, Mission 2017 proposes to reduce the numbers of dams in the rivers and allow rivers to flow naturally to preserve the environment and biodiversity. At present, it is not possible to eliminate all dams. Still, there must be efforts to take down old, outdated dams and to return as many rivers to their natural state as possible. Construction of dams as flood control measure or for immediate profit would be like mortgaging the future generations to derive some temporary benefits for the present generation.

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