A study of Environmental and Ecological impacts due to Construction and Operation of Tehri-Polavaram Dam

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Abstract. Any water resources project has both a positive and a negative impact on the environment. Sometimes these environmental losses are unavoidable, so it is most important to minimize the environmental losses and their social-ecological and geopolitical impact. Environmental impact assessment plays an important role in identifying, predicting, and mitigating the various impacts on the environment. This paper presents the details of the construction of Tehri and Polavaram dam projects and their various impacts on the environment and ecological aspects. Any water resource expansion that fulfills minimum needs without endangering future generations' ability to fulfill their own will be considered sustainable. There are a number of factors to consider when it comes to the long-term effects of dams on the surrounding environment, including redevelopment and relocation of people and businesses, socioeconomic influence on the surrounding area, and environmental concerns such as sedimentation, among others. Sustainable development also means that, in addition to minimizing the dam's negative effects on the environment, making sure that the benefits of the dam outweigh the negative ones. As a result, it is recognized that water resource projects must be intended, implemented, and managed to meet future population demands while reducing disturbance to the existing eco-system and incorporating effective control measures at various phases to ameliorate any adverse effects.

Keywords: Tehri and Polavaram Dam, environmental impact, ecological aspects, future scenario

1. Introduction
Dams play a critical role in the efficient use of water. Many years have passed since they were built before the current state of knowledge about hydraulics and hydromechanics could be gleaned. There is nothing typical about these structures. When it comes to managing stream flows and satisfying water needs, dams have played a significant role in the evolution of civilization. Since ancient times, dams have been built to keep rivers dry, provide fresh water for irrigation, generate electricity, and all of the above. Additionally, dams have a wide range of good and bad impacts on the environment, such as regulating stream regimes, preventing floods, getting water from the dam's reservoir, and producing energy. In addition to their benefits, including providing society's fundamental needs and raising living standards, dams contain the potential for significant harm to living organisms [1]. Up to the 1950s, over 700 dams were constructed every ten years. After the 1950s, this number climbed significantly. As the dams were being constructed, it became apparent that something was missing, and this was damaging. Despite the fact that water has a profound impact on human life and civilization, it is claimed that the economic benefits anticipated from projects designed to utilize water resources will not be realized, and that necessary precautions to reduce environmental, economic, and social losses will not be taken. Some international institutions are conducting studies aimed at thwarting these water supply schemes in developing countries. In light of these findings, water management, considering economic, social, and cultural development, as well as environmental implications, has become increasingly important in the sustainable water management [12]. Because of this, water resource studies must have a legal foundation to assure long-term growth and sustainability. Water resources planning studies often conflict with laws concerning the responsibilities and powers of government entities and establishments. These relate directly to environmental issues.
Tehri Dam is the world's tallest dam. Initially, in 1994, the government approved this proposal for implementation. The Tehri Hydro Development Authority, a joint venture between the Indian and Uttar Pradesh governments, took over in 1998. On the Bhagirathi River, the Tehri dam is located, which is approximately 200 miles north-east of Delhi. It is the fifth-tallest dam in the world. With a total height of 840 ft (256 m), the dam can generate 244 million kilowatt-hours of electricity and provide water for an extent of 270,000 hectares. After a lot of thought, the Tehri dam was thought up in 1949. The location was chosen in 1961, the Planning Commission approved it in 1972, and work began on the dam in 1978 under a lot of security. For the Tehri Development Project, a preliminary investigation was completed in 1961, and after completion of the design of the dam it was approved in 1972. Construction of this dam started in 1978, and Cofferdam was finished in 1996. The last two tunnels were closed in December 2002, and the project is expected to be completed in August 2003. Whereas, Polavaram Project is one of the major projects in India approved by the central government. The proposed project is a multipurpose project mainly for irrigation, public water supply, and hydropower generation. The site is in Andhra Pradesh state in Polavaram village. Site selected for construction is in Godavari River in the east and west Godavari districts of Andhra Pradesh, which is under construction. The Godavari River is a perennial river in India which is the second largest in the country. The Polavaram project was initially planned in 1941. In 1870, Lt-Col. Haig, Superintending Engineer, Superintending Engineer, after observation, prepared a plan and sent a report to construct a reservoir across the Sokileru River, which is a tributary of the Sabri River, for irrigation purposes of about 7,300 hectares. In the year 1896, Mr. Walch wrote in his book, “The Engineering Works of the Godavari Delta,” that storage could be achieved at a cost that was not prohibitive, although a dam across the main Godavari River was not considered. The Polavaram reservoir was first proposed in 1941 by Diwan Bahadur. Diwan Bahadur L. Venkata Krishna Iyer, head engineer of the Presidency's irrigation department, after a detailed investigation, the project was finalized and named Rampada Sagar. The project name was given, keeping the mythic in view, as the back waters of the reservoir would touch the Lord Rama temple at Bhadrachalam. For this project, the total cost was estimated at 129 crores. But at the dam site, due to the absence of hard rock strata at a shallow depth, the proposed dam project was postponed. Therefore, due to the deeper depth of excavation for the foundation and construction difficulties, the project was not found to be economical.

Due to a flood in the Godavari River in 1953, the Visakhapatnam Steel Plant saw the need for a barrage on the Godavari River. Different agreements have been put up by the neighboring states to share the water of the Godavari River and for the completion of the project. After a long period of inactivity, detailed investigations had to be carried out in 1976, and the project was presented in 1978. Once again, after detailed investigations and on the basis of comments by the Central Water Commission in the 1978 and 1982 projects, that report was finalized for the Polavaram project. As per the rates in 1985-1986, the project cost is estimated at 2665 crores. Once again, due to political issues, project work could not be executed. The project was taken on by YSR Reddy, the chief minister of Andhra Pradesh, in 2004 to complete, but work on the project was halted to obtain clearance from the Ministry of Forests and Environment.

2. Study area
The Polavaram Project is an irrigation project on the Godavari River in Andhra Pradesh's West Godavari and East Godavari districts. The Indian government has designated the project as a national initiative. Its backwater goes up to Dummugudem Anicut, which is about 150 km downstream from the Polavaram Dam, and 115 km downstream on the Sabari River. It also goes into Chhattisgarh and Odisha. The reservoir covers the popular Papikonda National Park, boosting tourism in the Godavari Districts. On the left bank of the river are the Polavaram HEP and National Waterway 4. It is 40 kilometers upstream of the Sir Arthur Cotton Barrage and 25 km from Rajahmundry Airport. Whereas, Tehri Dam is India's tallest dam. It is a multi-purpose rock and earth-fill embankment dam on the Bhagirathi River in Uttarakhand. It is the main dam of the Tehri hydropower complex. Phase 1 ended in 2006. The Tehri Dam contains a reservoir that is used for agricultural, municipal water supply, and hydroelectric power generation. The dam's 1,000 MW variable-speed pumped-storage project is anticipated to be completed in 2025. ‘Figure 1’
shows the study area map which contains Polavaram dam and Tehri dam, respectively. Apart from that table 1 represents the silent features of the same.

![Study area map](image)

**Figure 1.** Study area map.

**Table 1.** Silent features of study area.

| Technical details                      | Polavaram Dam                      | Tehri Dam                  |
|----------------------------------------|------------------------------------|----------------------------|
| Type of dam                            | Rock fill type                     | Rock and earth fill type   |
| River Impoundment                      | Godavari river                     | Bhagirathi river           |
| Maximum height above ground level      | 48.32 m                            | 260.5 m                    |
| Project completion period              | 1941-2018                          | 1978-2003                  |
| Catchment Area                         | 306643 sq. km                      | 7293 sq km                 |
| Design flood discharge                 | 1.02 lakh cumecs                    | 15540 cumecs               |
| District                               | Tehri Garhwal                      | East Godavari              |
| Length of dam                          | 2454 m                             | 575 m                      |
| Annual rainfall                        | 1082.95 mm                         | 1000 mm                    |
| Power generation                       | 960 MW                             | 1000 MW                    |
| Land area under submergence            | 47403 Hectare                      | 5200 Hectare               |
| Number of villages under               | 239                                | 80                         |
| Rehabilitated population               | 1,88,370                           | 24,000                     |
| Location                               | 81° 39' 46" E to 17° 16' 53" N     | 78° 28' 46.074 E to 30° 22' 38.7984 N |
| Capacity of spillway                   | 3600000 cusecs                     | 15540 cusecs               |
| Spillway types                         | Chute                              | Combination of Shaft and Chute spillway |
| Type of Gates                          | Radial                             | Controlled                 |
| Type of Turbine                        | Kaplan                             | Francis                    |
| Number of gates                        | 42                                 | 2                          |
3. Positive and Negative impacts of dam

3.1 Positive impacts of dam

3.1.1 Irrigation
The majority of people in Andhra Pradesh rely on agriculture, and agriculture accounts for 51.58% of total income. The Godavari River is the primary source of water for high areas in West Godavari and Krishna districts, including the region being cultivated by the Nagarjuna Sagar left bank canal. In the case of inadequate rainfall, there may be a possibility of a shortage of water for irrigation. In that case, the Polavaram dam can meet all of the needs and remove backwardness from these areas.

3.1.2 Water supply
The dam can supply 270 million gallons of water per day to Uttaranchal, Uttar Pradesh, and Delhi. Vishakhapatnam is a port city in Hyderabad and there are so many industries, steel plants, and proposed to be setup nearby, such as the harbor, naval complex, shipyard, refinery, etc., which require an adequate and continuous supply of water. People in Visakhapatnam, West Godavari, Krishna, and East Godavari also want drinking water during the summer.

3.1.3 Power generation
‘Figure 2’ shows the overview of hydroelectric power plant. In the Polavaram Project, power 12×80 MV capacity must be installed, which means that in so many areas, electricity can reach about 3,100 million units annually. Whereas, the Tehri dam can generate 244 million kilowatt-hours (MKWH) of electricity.

3.1.4 Flood control
As we know, in 1953, 1959, and 1986, when floods came into the Godavari River, it damaged and flashed away some agricultural crops, which was the reason for the huge loss in property and livestock across the plains. The Godavari River flood can be controlled via the Polavaram project. However, a total of 80 villages would be entirely or partially flooded due to the construction of Tehri dam.

3.1.5 Navigations
Due to the lack of water in the river (insufficient depth), navigation is not possible. In the Polavaram Project, there is a target for the formation of a foreshore lake, and the left canal of this dam is specially designed for navigation. Once the Polavaram project is completed, it will be helpful for cheap and quick transportation of products produced by forest and food grains in the market industry and for the supply of different coals and ores in the industries. However, the Tehri dam cannot be used for navigational purposes.

3.2 Negative impacts of dam

3.2.1 Displacement and Rehabilitation
The Polavaram Irrigation Project is slated to uproot 276 communities and 44,574 people, primarily in the state of Andhra Pradesh, where archaeological sites, coal deposits, a wildlife sanctuary, and many hectares of arable land will be submerged. After investigation, it is understood that 56% of agriculture, 15% of villages, 13% of vegetation, 9% of barren land and 8% of forest land are coming under the submergence area of the dam due to the construction of the same on the upstream of the river. Therefore, the results cause severe disturbance of natural, wildlife, and other species. However, in the case of the Tehri Dam,
approximately 1,000,000 individuals were affected by the disaster, but there was no plan to relocate them: some received compensation, others were given houses, and still others received nothing. Even though a reported sum of Rs. 1117.15 million was spent on rehabilitation, the results were dismal. Land acquisition started in the year 1979 without preparing any master plan or giving any compensation to affected people. As per the 2002 Status Report by the Public Works Department of Tehri, many people lost their land, but it was not officially recognized as project affected [13]. Furthermore, ‘Figure 3’ shows the rally against Polavaram and Tehri dam, respectively.

![Figure 3](https://www.sandrp.in/).

**3.2.2 Earth crust**

Even though it is claimed that the dam reservoirs have some seismic effects, it must be stated that this has not been proven scientifically [15].

**3.2.3 Aquatic entity**

The dam prevents animals from swimming from one mouth of the river to the other. Dams harm fish that reside in the springtime or in high-bodied dams' sluice gates, rotors, and pumps. This dam will disrupt the life cycle of these organisms and cause mass deaths. Bypass flow is designed for this purpose [7].

**3.2.4 Disappearance and wane of historical places**

After a reservoir is built, archaeological and historically esteemed sites, as well as geological and topographical wonders, are buried beneath it.

**3.2.5 Scouring of river**

Water flowing from reservoirs, even those with turbines, typically contains very little suspended sediments, which can result in river bed scouring and river bank erosion [3], [9].

**3.2.6 Generation of new species**

The temperature, salt content, and oxygen distribution of the water may alter vertically as a result of reservoir development. As a result, new living species may evolve, and the old environment may become extinct. (According to the International commission of large dam) [2], [8], [10], [11].

**3.2.7 Human heath**

According to ‘Figure 4’ it is possible that the dam's accumulation of wood and waste will lead to a rise in water-borne illnesses like fever, dysentery, and cholera that impair human health in the immediate vicinity of the dam and reservoir [5].
Figure 4. Accumulation of wood and garbage because of dam (Source: https://www.sandrp.in/).

3.3 Environmental and ecological impacts on dam

The Polavaram Project includes a large area consisting of agricultural, forest, and barren land. This area is becoming a submergence area due to dam construction. Natural, wildlife, and other species will suffer badly due to submergence of forest land area. Sloth bears and tigers are being degraded due to habitat loss and over-hunting of wild creatures such as tigers and gaurs. Therefore, the loss of wildlife will disturb the diversity of the region, and the famous tourist spot ‘Papikondalu’ is completely getting submerged due to its construction. The Polavaram dam is affecting the state of Andhra Pradesh but also has minor effects on the adjacent states of Orissa and Chhattisgarh. In the proposed area, there are so many agricultural areas from which various types of crops and food grains are generated. But after the dam is constructed, there may be a shortage of food security for people. Thousands of crores of rupees are expended to obtain the clearance for this project and the re-habitation of people. This project has gotten clearance after certain modifications by the government, and its design procedure is outdated. So, it’s design procedure cannot be taken into fully consideration. It needs to consider the present status, otherwise it may cause damage to the ecology and people. According to the NCAER study, some of the submergence areas contain deposits of minerals, e.g., iron ore, chromite, graphite, etc. So, it is essential to collect information about this and make an assessment of the various impacts of submergence on this area. A coal field is coming under submergence area that contains a large amount of coal, which is part of the Sigaroni coal fields, one of the important coal fields in the south of India. Because these detailed investigations are not being conducted, it is impossible to predict what the true impact of these submerged areas will be. However, in the case of the Tehri dam, the protests have been led by environmentalists and residents of the area. Environmentalist Sunder Lal Bahuguna was the driving force behind the anti-Tehri Dam campaign from the 1980s and extending up to 2004. The anti-displacement movement sparked the demonstration, as did the environmental consequences of a degraded ecosystem, which sparked the anti-displacement movement. It has also sparked questions about how a dam of this size and scope will affect the delicate ecosystem of the Himalayan foothills, and Concerns have also been raised regarding the dam's geological durability and viability. A large fault zone and the Tehri dam are located near the Central Himalayan Seismic Gap. At the time of the earthquake, the dam was located 53 kilometers (33 miles) away from the epicenter. For this project, which will be in the Himalayas, the dam's proponents contend that the design is intricate enough to endure an earthquake with a magnitude of 8.4 on the Richter scale. Some seismologists believe that if an earthquake of magnitude 8.5 or greater occurs in the immediate area, a dam break might affect half a million people. Lalitpur and Jhansi Districts have been adversely affected by compensatory afforestation to the extent of 4586.07 hectares. To prevent soil erosion and protect 52.204 hectares of land drains were built to decrease water logging and salinity. The creation of a "greenbelt" (14.28 hectares) for the conservation of key plant species, a fish hatchery, and a fishery for Mahseer Siltation along the reservoir perimeter has resulted in the creation of an area known as a "greenbelt." Urban areas have a higher standard of living due to the availability of more services and the potential for future growth [4]. It is also important for rural areas to have a sufficient water supply and road network system, as well as improved infrastructure. Treatment and land reclamation work at the THDC were preferentially given to those who had been affected by the project schemes for earning money through training facilities for the khadi industry by the UP-state department of horticulture and food preservation.
4. Present scenario of the projects

The present Polavaram Project is also known as the Rampada Sagar Project, and it is getting late to complete the project due to political issues and some other reasons. Also, due to the modification of the project, the project cost has increased. The project has gotten all the necessary approvals and the government of India has designated the Polavaram Project as a National Project (section 90 of the AP Reorganization Act 2014). The project is expected to be completed by the end of March 2018 (excluding the installation of dam gates). The anticipated cost of this project is Rs. 16010.45 crores after the Planning Commission have given its final approval (price level based on 2010-11 rate). However, in the case of Tehri dam, a benefit-cost study by the Indian National Trust for Art and Culture Heritage (INTACH) found that the project costs would be at least twice the anticipated benefits, and more than US $2.5 billion was spent on the first phase in July 2006, compared to an estimated US $12 million in July 2006.

5. Conclusions

Water has always been a vital plus critical resource for the survival of civilizations around the planet. In some regions around the world, an imbalance between demand and accessible water, food, and energy threatens life's survival. Dams and reservoirs can and should cohabit with the social and natural environment of the region. The next challenge will be to employ dams and reservoirs to prudently manage the world's water supplies as part of each nation's social and economic development goals. The dam's negative environmental consequences can be reduced or eliminated with thorough planning and design that includes public participation and input early in the process. When relevant mitigation measures are discovered early in the dam and reservoir planning and design phase, they can be included effectively and efficiently into the project design, construction, and operation.

These projects have undeniably substantial and significant benefits. With increased electrical generation, irrigation canals and food production have improved. Dams protect downstream residents from floods. Dams can be decided after weighing the costs and benefits for a long time, and the benefits of dams may outweigh the drawbacks in the future. But these massive engineering feats should warn us that we cannot modify the entire environment. Because ecology connects entire chains A single broken chain link or cog piece will destroy the entire system. So, when planning, the environment should be thoroughly evaluated. Precautions should be taken to avoid major risks caused by minor sensitive responses. Aside from their significant social and environmental benefits, dams must be minimized in order to achieve sustainable development. The environmental impact assessment concept takes into account the above impacts and solutions. In addition, the overall summary, the environmental changes caused by dams vary in magnitude and impact. Hence, it is impossible to predict the positive and negative impacts of these interactions in advance. Each dam and reservoir should be estimated separately. However, it is incorrect to interpret the consequences negatively.

References

[1] Chen, S., Chen, B. and Su, M 2011 The cumulative effects of dam project on river ecosystem based on multi-scale ecological network analysis. Procedia Environmental Sciences, 5, pp.12-17
[2] Altinbilek, D 2002 The role of dams in development. Water Science and Technology, 45(8), pp.169-80
[3] Jeon, J., Lee, J., Shin, D. and Park, H 2009 Development of dam safety management system. Advances in Engineering Software, 40(8), pp.554-63
[4] Bohlen, C. and Lewis, L.Y 2009 Examining the economic impacts of hydropower dams on property values using GIS. Journal of Environmental Management, 90, pp.S258-S69
[5] Tetteh, I.K., Frempong, E. and Awuah, E 2004 An analysis of the environmental health impact of the Barekese Dam in Kumasi, Ghana. Journal of environmental management, 72(3), pp.189-94
[6] Graf, W.L 2006 Downstream hydrologic and geomorphic effects of large dams on American rivers. Geomorphology, 79(3-4), pp.336-60
[7] Adams, W.M. and Hughes, F.M 1986 The environmental effects of dam construction in tropical Africa: impacts and planning procedures. Geoforum, 17(3-4), pp.403-10
[8] Schilt, C.R 2007 Developing fish passage and protection at hydropower dams. Applied Animal Behaviour Science, 104(3-4), pp.295-25
[9] Giers, A., Freistühler, E. and Schultz, G.A 1998 Methodology for assessment of ecohydrological effects of dam construction in a headwater region. IAHS Publications-Series of Proceedings and Reports-Intern Assoc Hydrological Sciences, 248, pp.509-14
[10] Sayadi, A. and Partani, S 2009 Environmental Impact Assessment of Gotv and Hydro-Electric Dam on the Karoon River Using ICOLD Technique. International Journal of Environmental and Ecological Engineering, 3(6), pp.118-25

[11] Walker, K 2008 Environmental impact statement for Traveston Crossing dam (Mary River, Queensland): a review with regard for species of concern under the EPBC Act 1999. Environmental Defenders Office, Canberra, ACT, Australia

[12] Küçükarslan, S. and Coşkun, S.B 2003 Fifth National Conf. on Earthquake Engineering Dam-reservoir interaction including the reservoir bottom effects under earthquake ground motion. İ.T.U., İstanbul, Turkey pp 26-30

[13] Duvail, S. and Hamerlynck, O 2003 Mitigation of negative ecological and socio-economic impacts of the Diama dam on the Senegal River Delta wetland (Mauritania), using a model-based decision support system. Hydrology and Earth System Sciences, 7(1), pp.133-46

[14] Pytharouli, S. and Stiros, S 2008 Proc. on 13th FIG symposium on deformation measurement and analysis and 4th IAG symposium on Geodesy for Geotechnical and Structural Engineering Dam crest settlement, reservoir level fluctuations and rainfall: evidence for a causative relationship for the kremasta dam greece. LNEC Lisbon Portugal pp. 12-15