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Review Paper on Surface Water-Quality Assessment of Chitravati River after the Establishment of Check-Dam in Puttaparthi, Andhra Pradesh

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Abstract

Puttaparthi is a birthplace of Bhagawan Sri Sathya Sai Baba and is a small town situated in the district of Anantapur, in Andhra Pradesh. Chitravathi River is the main water-body in Puttaparthi. The river remained dry for many years. Only in the recent years, rainfall events fed water to the river. Last year in 2019 a check-dam was also constructed in Puttaparthi due to which the river water has been stagnant. This review paper aims to assess the surface water quality of the Chitravati River in Puttaparthi after the establishment of the check-dam. In this regard, literature reviews were performed and the paragraphs in the literature reviews were arranged as per three major themes, which are: 1. check-dams, 2. water-quality assessment and monitoring, and 3. non-perennial river systems. By examining these three themes through the literature reviews, key inferences were made. For instance, it can be understood that the check-dam in Puttaparthi is an important water-storage structure, which is likely to have both positive and negative impacts upon the nearby region. Secondly, in order to examine water-bodies like the Chitravati River in Puttaparthi, we have to perform water quality assessment and monitoring. To perform water quality assessment and monitoring for the Chitravati River in Puttaparthi; we have to use important tools like the Water Quality Index (WQI), Water Pollution Index (WPI), and Water Poverty Index (WPI). Thirdly, non-perennial river systems such as intermittent rivers, ephemeral rivers and their key features have been stressed upon by several readings. These are river systems where a river ceases to flow for some months or for several years. The Chitravati River in Puttaparthi can be appropriately classified as a non-perennial river system and as an intermittent river. Finally, this review paper concludes through a personal reflection, which stresses upon studying the Chitravati River in Puttaparthi and how the literature reviews will help in this regard.

Keywords: Check-Dams, Ephemeral Rivers, Intermittent Rivers, Non-Perennial Rivers, Perennial Rivers, Physicochemical Parameters, Water Pollution Index, Water Poverty Index, Water Quality Index

1. Introduction

Puttaparthi is a small town and a well-known pilgrimage in India as it is the birthplace of Bhagawan Sri Sathya Sai Baba. Puttaparthi is situated in Andhra Pradesh and is located in the district of Anantapur. The climate in Puttaparthi is mostly dry and warm year-round with rainfall during the months of June and July. Major water-body in Puttaparthi is the Chitravati River, which has total length of 205 km. Chitravati River, a non-perennial river

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originating from Chikkaballapur district of Karnataka is a long inter-state river. The Basin of Chitravati River covers over 5900 km^2 area and the river is a tributary of the Pennar River in Karnataka. Chitravati River in Puttaparthi remained dry for many years. Rainfall events during the recent two to three years in Puttaparthi fed water to the Chitravati River. However, in the case of non-perennial rivers like the Chitravati, the river water always pose a threat of becoming stagnant and can become a source of disease due to mosquito breeding and a sink for anthropogenic pollutants generated from agriculture, domestic waste and industrial discharges.

There are numerous human settlements from village area; living nearby the Chitravati River in Puttaparthi. Chitravati River also serves as an important part of the livelihood of many rural households. The Chitravati River is of key importance in sustaining the aesthetic well-being of the Puttaparthi town and its surrounding villages. A check-dam has been constructed last year in Chitravati River, which circumvents the pilgrim town of Puttaparthi. The check-dam construction has resulted in recharging of the groundwater aquifer and has resulted in availability of groundwater through bore-well even during the peak summer months, which have observed dry bore-well during the earlier years. However, the Chitravati River water has been stagnant since the construction of check-dam. Monitoring the stagnant water bodies of the Chitravati River to mitigate the unchecked discharge of anthropogenic waste becomes an essential environmental remediation step for a safe and sustained habitation. In this regard, the surface-water quality of the Chitravati River needs a stringent monitoring for healthy and hygienic environment, which is critical for the maintenance of good health of local population, which otherwise can fall victim for air and water borne disease.

As a precursor to understand the surface water quality of Chitravati River near Puttaparthi, literature review was done on check-dams, surface water-quality assessment and monitoring techniques and non-perennial river systems. These three themes have been presented in the literature review in the order: 1. Check-dams, 2. water-quality assessment and monitoring, and 3. non-perennial river systems. Finally, the concluding paragraph summarizes the key findings of the research paper based on the literature reviews performed and integrates these findings with the Chitravati River in Puttaparthi.

2. Literature Review

2.1. Check Dams

In order to understand the role of the check-dam at the Chitravati River in Puttaparthi, it is imperative to have basic knowledge of: 1. Check-dams, 2. Different types of Check dams, and 3. the positive and negative impacts of check-dams especially on the surrounding region. Check dams are "widespread and effective soil and water conservation structures throughout the world. They are built across water channels to reduce the rate of intensive flow, monitor and trap sediments, increase channel downward permeability, increase vegetation, reduce flood peak discharge, retain runoff and induce sedimentation, flood-control and water-storage dam" (Abbasi, *et al.*, 2019)[1]. Check dams are often constructed throughout a drainage network such that they make up a system of erosion control structures that can affect large land areas" (Nichols, *et al.*, 2016)[30]. Check dams are of greater importance as it addresses water conservation as well as soil erosion. In general, check dams are usually suggested for lower-order streams (up to third order), and the slope of the terrain should be between flat and gentle slope in order to retain a maximum possible quantity of water which comes under the L-section" (Meshram, *et al.*, 2019)[26]. Furthermore, check dams not only reduces peak flows but also impacts surface-water availability in the treated watershed (Norman, *et al.*, 2015)[31]. Emphasizing upon check dams, it has been indicated that "Among all civil engineering structures, check dams are probably the most emblematic of torrent control works" (Pitonm, *et al.*, 2016)[35]. Author further describes check dams as transversal structures built across stream beds and gullies in torrential watersheds. They can be made of logs, gabions, dry stones, masonry or/and reinforced concrete. In the absence of effective local groundwater demand management, government, non-government organizations and farmers since the 1960s have established check dams in ephemeral streams along with other watershed management improvements to augment groundwater recharge, buffer against storage decline and increase resilience of their livelihoods (Dashora, *et al.*, 2017)[7]. The author further state about check dams by saying "the check dam is designed where slope is more predominant. The check dam work like a storage reservoir" (Joodi & Satyanarayana, 2015)[17]. It has been mentioned about check dams that "It is a certain fact that these structures trap an important amount of sediment around the world that is not delivered into watercourses" (Diez, *et al.,* 2017)[9]. Check dams are also described as small barriers built across the direction of water flow on water ways, small streams and rivers for the purpose of water harvesting" (Oke, *et al.,* 2015)[33].

Check dams are of different types. One major type of check dam is the rock check dam as highlighted by Nichols, *et al.,* (2016)[30]. Rock check dams are typically constructed from either local or purchased rocks that are placed perpendicular to the flow direction (Nichols, *et al.,* 2016). Torrent check dams are another major check dam type. Check dams are typical torrential structure to lower the channel longitudinal slope, stabilise steep channels and diminish energy of torrential processes (Sodnik, *et al.,* 2015)[46]. Another check dam type is the prototype micro check dam. To indicate about the prototype micro check dam, it has been argued that it is basically micro check dam which utilizes the capacity of small streams and rivers whether ephemeral or perennial to provide water for agricultural activities beyond the period of high discharge (Oke, *et al.,* 2015)[33]. Similarly, straw bale check dams are another key type of check dams. Straw bale check dams are relatively quick and easy treatment to install in burned catchments. They are installed perpendicular to flow in the channel bed by keying in and tightly abutting straw bales together end to end (Robichaud, *et al.,* 2019)[37]. Open-type check dams or slit check dams are also major type of check dams. Slit check dams (open-type check dams) intend to control the transport and deposition processes of the sediments carried downstream by debris flows, and it is nowadays widely applied all over the world as a short-term mitigation measure. Whenever properly designed and built, slit check dams are normally assumed to allow for finer (harmless) sediments to pass through, while trapping larger blocks. They are preferable over other retention structures (e.g. closed type check dams, retention basins) for their effectiveness during debris flow events and also for better preserving the natural environment and the landscape of mountain torrents, reducing the long-term downstream effects on morphological evolution (Silva, *et al.,* 2016)[44]. Open type check dams are constructed with suitable openings in the body of the structure, thus part of the sediment is allowed to pass through (Zou & Chen, 2015)[50]. Similarly, closed-type check dams are also significant. In this regard, Zou and Chen (2015), describe closed-type check dams as dams that are overflowed by the water discharge and intercepted by all but the fine particles of the solid material. Hence they are rapidly filled up by the sediment transport. Finally, another check dam type is the slot-check dam. Slot check dam is described as an open-type check dam with slot shaped openings which has been shown to be efficient in reducing debris flow run-out (Zou & Chen, 2015).

To acquire better understanding about the check dam in the Puttaparthi region, it is necessary to learn about the positive impacts of check dams upon the surrounding region. Check dams have significant impacts on the region where it is constructed. With respect to check-dams, rock check dams have significant impacts upon the surrounding environment. Rock check dams are commonly constructed in low-order water bodies and upper reaches of channel networks where small structures can be effective for grade stabilization and erosion control without the threat of causing damage through catastrophic failure (Nichols, *et al.,* 2016). The restoration of riparian corridors using rock check dams, when streams have been altered by cattle grazing and other disturbances, is found to promote a cascade of beneficial processes to the larger watershed and ecosystem (Norman, *et al.,* 2015)[31]. Check dams are expected to have site-specific recharge effectiveness depending on runoff and the proportion that is captured, morphology, sedimentation, hydraulic conductivity of alluvium, the nature of the connection between the pooled water and the aquifer, the hydraulic characteristics and storage capacity of the aquifer and ambient groundwater quality (Dashora, *et al.,* 2017)[7]. Check dams also have significant impacts upon the livelihoods of the local communities. For instance, it has been indicated that construction of check dams in some parts of India has improved the livelihood by increasing the income from agricultural activities because of the availability of water (Parimalarenganayaki & Elango, 2016)[34]. They further state about the impacts of check dams upon local communities by mentioning the construction of check dam in Raigad district in Maharashtra, India which has resulted in reduction of the time spent by the women in fetching water from distance source, thus they could concentrate on other income-generating household activities. Construction of check dams are prominent in Gulf countries like Oman where check dams are considered to be beneficial for the local communities and nearby regions. In this regard, it has been stressed that it contributes for economic development of rural Oman. The stored water at the check dam will be used to augment Falaj Daris canal or to supply nearby villages water for irrigation (Joodi & Satyanarayana, 2015)[17]. Check dams also impact the surrounding environment by trapping large amounts of sediments. To elaborate upon the trapping of sediments by check dams it has been indicated "For example, the 100,000 check dams built in the Loess Plateau in China trapped 21 million m^3 in 50 years. In Spain, more than 6.58 million m^3 had been trapped up until 1999. In the River Segura basin (Spain), 425 check dams trapped a mean value of 1,998 t, while in the River Corneja basin, 123 gabion check dams trapped 7,418.96 t. In Malaysia, three check dams alone trapped 6,162 m^3 of sediment in the Yellow River (China)" (Diez *et al.,* 2017)[9].

Check dams might adversely impact the surrounding environment as well. Adverse impact of check dam as stated by Diez, *et al.,* (2017) is the negative effects downstream due to bed scouring. The erosion problems could sometimes exist downstream under heavy rainfall conditions. As an outcome some changes in diversity of riparian vegetation have been detected (Diez, *et al.,* 2017). Similarly, failure of check dams can be disastrous for the surrounding region. To elaborate upon possible check dam failures, it has been stated they can impose hazard to environment and infrastructure – when they fail. Especially large sediment-retention dams, even more if they are built in a cascade (a chain of check dams), can impose hazard (hyper-concentrated sediment flow, debris flow), if they fail during torrential flash floods or when destroyed by overtopping by a debris flow initiated on slopes or in natural torrent channels (Sodnik, *et al.,* 2015)[46]. Failure of check dams can result due to ineffective construction standards followed to construct check dams. With respect to ineffective check dam construction standards, it has been stated that approximately 30,000 check dams have been constructed in South Tyrol, Italy, since 1900, and 16% of them were judged not to satisfy the required reliability and, consequently, technical efficiency requirements" (Mazzorana, *et al.,* 2017)[25]. Another major concern of check dams are associated with the straw bale check dams. It has been mentioned by (Robichaud, *et al.,* 2019)[37] about the studies to evaluate post-fire channel sediment yields with the use of straw bale check dams, which produced mixed findings and recommendations. Here, it has been suggested that straw bale check dams are unsuccessful in primary watersheds or small catchments if fine sediments and ashes wash past the structures and are released into higher order channels (Robichaud, *et al.,* 2019). In order to elaborate upon the failures of straw bale check dams, it has been argued by (Robichaud, *et al.,* 2019) that following the 1991 Oakland Hills Fire, straw bale check dams had a 50% failure rate just three months after installation. Primary failure mechanisms associated with straw bale check dams were undercutting, flow routing around structures, structure displacement, and erosion of previously deposited sediments (Robichaud, *et al.,* 2019). Finally, those check-dams, which have been constructed several years ago, might generate potential concerns. In this regard, it has been argued that due to their age, wear and tear, and the intensity of the phenomenon that they must resist, different kinds of pathologies may appear affecting their performance level" (Nour, *et al.,* 2019)[32].

2.2. Water-Quality Assessment and Monitoring

To perform an in-depth assessment of the Chitravati River surface water-quality in the Puttaparthi region, it is crucial to acquire a general knowledge about: 1. the concept of water-quality assessment and monitoring, 2. different techniques available for performing water quality assessment and monitoring, and 3. physico-chemical parameters associated with water quality assessment.

Water quality assessment is key for improving the human health and wellbeing of a region as it assists in "pollution control and protection of surface and ground water" (Sharma & Walia, 2016)[43]. At present, there is an increasing need to perform water quality assessment and monitoring of surface water bodies. In this regard, it has been explained that with an increased understanding about the importance of drinking water quality to public health and raw water quality to aquatic life, there is a great need to examine surface water quality (Sener, *et al.,* 2017)[41]. Elaborating upon the necessity of undertaking water quality assessment and monitoring it has been argued that assessing water quality is essential to determine the water quality status and to improve the environmental conditions and the related public health (Troyer, *et al.,* 2016)[48]. To indicate about water quality assessment, it is further indicated that "A good water quality assessment method should not only provide the water quality rank, but also accurately reflect the spatial and temporal variations of water quality condition" (Li, *et al.,* 2016)[22]. Similarly, water quality assessment is urgently needed especially when water pollution occurs due to industrial accident in a particular water body (Effendi, 2016)[11]. With respect to the significance of water quality assessment and monitoring, it has been mentioned. "Therefore, it is important that monitoring is undertaken to ensure that water resources and their quality remains within acceptable limits for sustainable end use" (Misaghi, *et al.,* 2017)[27].

One major technique to perform water quality assessment and monitoring is through the WQI. The term WQI is described as "Water quality index allows for a general analysis of water quality on many levels that affect a stream's ability to host life and whether the overall quality of water bodies poses a potential threat to various uses of water" (Magadum, *et al.,* 2017)[23]. In another instance, Magadum, *et al.,* (2017), describes the Water Quality Index as one of the major indices used to assess the pollution and one of the effective ways to create awareness among the public. To reflect upon the WQI, it has been depicted as "a concise numerical representation of overall quality of water, which is easy to express and convenient to interpret. WQI is essentially a function of the concentrations of the WQP" (Roy & Majumder, 2017)[39]. The WQI is further mentioned as "a very useful tool for communicating the information on the overall quality of water. The Bureau of Indian Standard and ICMR Standards have been considered for calculation of WQI" (Yadav, *et al.,* 2014)[49]. Elaborating upon the water quality index it is argued "An important and widely used WQI was developed by the National Sanitation Foundation (NSF) of the United States in 1970, based on a survey that determined the nine most important parameters driving overall water quality" (Effendi, 2016). The NSF Water Quality Index or NSFWQI is a major type of water quality index. NSFWQI is mentioned as "Of the indexes developed, the NSFWQI is one of the most common comprehensive indices for surface water quality classifications worldwide. The NSFWQI is used to compare the water quality of different water bodies and is therefore generic in nature. The NSFWQI is determined based on nine water quality parameters including temperature, pH, turbidity, PO_4^{2-}, NO_3^-, TDS, DO, BOD and faecal coliform concentrations" (Misaghi, *et al.,* 2017). In order to emphasize upon the water quality index it is also stated that WQI is useful in assessing the suitability of river waters for a variety of uses such as agriculture, aquaculture, and domestic use. WQI is applied to relate a group of parameters to a common scale and combining them into a single number. WQI is thus one of the most effective tools to provide feedback on the quality of water to the policy makers and environmentalists (Naubi, *et al.,* 2016)[29].

Another technique to perform water quality assessment and monitoring is through the WPI. The significance of water pollution index has been highlighted in different readings. For instance, it has been described as an approach which minimizes the data volume to a great extent and simplifies the expression of water quality status (Effendi, 2016). To reflect upon the water pollution index and its significance it has also been mentioned that "Nemerow and Sumitomo's WPI is one of the methods to evaluate water quality in an ecosystem, which was originally developed in the United States in the 1970's" (Jubaedah, *et al.,* 2015)[18]. Similarly, it is important to know that Water Pollution Index was initially formulated from the Nutrient Pollution Index (NPI). The NPI was also a critical tool for performing water quality assessment and monitoring. To describe about the NPI, it has been stated "One of the indices used in the assessment of nutrient pollution was the concept of NPI. It was primarily suggested by Bach, and modified by Trivedi *et al.,* to use as a measure for water quality assessment. Dodds, *et al.,* in U.S.A. and Lee & An in South Korea successfully applied it to assess nutrient and organic pollution" (Atique & An, 2018)[6]. Author also mentioned about the nutrient pollution index that "It can categorize water bodies as oligotrophic, mesotrophic, or eutrophic depending upon the level of organic and nutrient pollutants in ambient water". Atique and An (2018) also elaborated upon the core reason for replacing the NPI with the WPI. In this regard, it has been argued "Since the metrics used in NPI cannot be categorized as pollutants, nor all as nutrients, a modification of the name for the model from NPI to WPI was inevitable" (Atique & An, 2018). Finally, the Water Pollution Index can be applied for determining the level of pollution relative to the allowed water quality parameters (Riyadi, *et al.,* 2018)[36].

Another key technique to perform water quality assessment and monitoring is through the WPI. WPI, has been described as a "simple, open and transparent tool, one that can appeal the politicians and decision makers, and at the same time empower poor people to better participate in water sector interventions and budgets development in general" (Thakur, *et al.,* 2017)[47]. The WPI has been depicted by Garriga and Foguet (2015)[12] as an interdisciplinary tool that takes into account the key issues relating to water resources, combining physical, social, and economic information. The core theoretical framework of Water Poverty Index encompasses water resources availability, people's ability to get and sustain access to water and to use this resource for productive purposes, and the environmental factors which impact on the ecology which water sustains (Garriga & Foguet, 2015). Author stresses about the core advantage of the Water Poverty Index, which is that it encapsulates more than one measure of influencing factors in a single number, and single line representation of the whole picture. As such, WPI reflects the status of water resources of the basin and thus, aids in the effective water management in the needy water stress zones. With respect to the significance of the WPI, it has been argued by Thakur, *et al.,* (2017) that "WPI can enable progress towards developmental targets to be monitored, and water projects to be better targeted to meet the needs of current generation, while securing water availability for the needs of future generations, as recommended in the Brundtland Report". Similarly, the significance of the Water Poverty Index has also been reflected upon as "The WPI has found great relevance in policy-making as an effective water management tool, particularly in resources allocation and prioritization processes" (Shalamzari & Zhang, 2018)[42]. Finally, the Water Poverty Index is evaluated based on five major components, which are "water resources, access, capacity, usage and environment. These components enable establishing connections between poverty, social marginalization, environmental integrity, water availability and health" (Alvarez, *et al.,* 2015)[5].

In the reading by Shalamzari and Zhang (2018), the advantage of the Water Poverty Index has been stated as "The WPI is mainly developed for water scarcity assessments at the scale of local communities, but the ability to adapt this index for different scales is one of its advantages". However, one major drawback is associated with the Water Poverty Index, which is mentioned as "However, the index fails to efficiently tackle the problem of temporal scale" (Garriga & Foguet, 2015)[12].

Finally, the water quality of a given river or water-body is assessed by determining the physico-chemical parameters. To elaborate upon physico-chemical parameters, it has been defined as "Quality of water is assessed in terms of the physico-chemical parameters, which are the physical, chemical, and biological parameters" (Magadum, *et al.,* 2017)[23]. Physico-chemical parameters have also been described as "the physical, chemical, and biological characteristics of water" (Ali Khan, *et al.,* 2015)[2]. Most importantly, Ali Khan, *et al.,* (2015) indicates that by studying and analyzing the physico-chemical parameters, we can detect whether the physico-chemical parameters are within the pollution limits for a particular water-body. Physico-chemical parameters in-turn determines the WQI of a given water-body. In this regard, Magadum, *et al.,* (2017) suggests total of 10 parameters (pH, Conductivity, TDS, TSS, DO, BOD, Hardness, Nitrate, Fluoride and Sulphate), which were selected for calculating the WQI. Ali Khan *et al.,* (2016)[3] states about the significance of physico-chemical parameters in determining surface-water quality, which has been stated as "Observing the river water quality by considering the biological and physicochemical characteristics can assist to reduce the ramification in explanation of water quality due to spatial variations".

Some of the major physico-chemical parameters include pH, Conductivity, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Hardness, Nitrate, Fluoride and Sulphate (Magadum, *et al.,* 2017). Similarly, the reading by Hassan, *et al.,* (2017)[15] determined the following physico-chemical parameters like water temperature, pH, Electrical Conductivity (EC), TDS, DO, Total Alkalinity (TA), BOD, Chemical Oxygen Demand (COD), phosphate (PO_4^{3-}) and nitrate (NO_3^-). Ali Khan, *et al.,* (2015), examined different physico-chemical parameters like pH, turbidity, electrical conductivity, Hardness was determined through the presence of calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions, chloride (Cl^-), sulphate, biochemical oxygen demand, chemical oxygen demand, nitrate, fluoride and phosphate. Finally, the paper by Mishra, *et al.,* (2015) includes physico-chemical parameters like pH, total dissolved solids, chemical oxygen demand, biochemical oxygen demand, DO, turbidity, conductivity, total hardness, sulphate, chloride, total phosphate and four heavy metals like iron (Fe^{2+}), copper (Cu^+), zinc (Zn^{2+}), and chromium (Cr^{3+}).

2.3. Non-Perennial River Systems

To become familiar about the Chitravati River in Puttaparthi, we need to have a proper understanding about: 1. non-perennial river systems, 2. impacts of non-perennial river systems upon nearby regions, and 3. factors affecting the water availability and water-quality of non-perennial river systems.

The Chitravati River in Puttaparthi is a typical example of a non-perennial river system. Non-perennial river systems have been defined as "Many rivers cease to flow from time to time and some even dry up completely for a few days, a few months, or a few years at a stretch. All of these can be said to be Non-Perennial Rivers (N-PRs), in that they do not behave like 'normal' rivers that flow all the time" (Day, *et al.,* 2019). Non-perennial river systems can be distinguished from perennial river systems as "Perennial Rivers and Streams (herein PRS) flow throughout the year, whereas temporary systems (herein non-perennial rivers and streams, NPRS) cease to flow at the surface for some time of the year" (Skoulikidis, *et al.,* 2017). Non-perennial river systems are further mentioned as "Non-perennial streams are defined by flow cessation, often experience partial, or complete surface drying and are characterised by high temporal and spatial variability" (Mathers, *et al.,* 2019). Skoulikidis, *et al.,* (2017), describes the features of non-perennial river systems as "Depending on the specific flow regime, NPRS can be classified, according to the most common perceptions, as intermittent, ephemeral or episodic. Intermittent rivers cease to flow seasonally or occasionally (usually for weeks to months); Ephemeral streams flow only in response to precipitation or snowmelt events (days to weeks); Episodic streams carry surface water only during very short periods (hours to days), primarily after heavy rainfall events".

Intermittent rivers can be best described as "Intermittent rivers (fluvial landforms that cease to flow at some point in space or time) are globally widespread and occur in all climates and terrestrial biomes" (Allen, *et al.,* 2019). Furthermore, intermittent rivers has been depicted as "Intermittent (or temporary) rivers are among the most dynamic freshwater ecosystems" (Karaouzas, *et al.,* 2018). Intermittent rivers have also been defined as "Intermittent rivers and streams are lotic ecosystems that seasonally exhibit partial or total flow cessation. These fluctuating aquatic ecosystems, with extreme high and low flow periods, are dominant in arid and semi-arid regions" (Glarou, *et al.,* 2019). Finally, to elaborate upon non-perennial river systems especially Intermittent Rivers and Ephemeral Streams (IRES), it has been defined as "waterways that cease to flow at some point in space and time along with their course" (Kaletova, *et al.,* 2019)[19].

In order to understand about the impacts of non-perennial river systems upon the nearby regions, Robinson (2019)[38], stresses about the vital role played by non-perennial river systems in the nearby regions by storing nutrients and organic materials. In this regard, it has been stated by Robinson (2019) that dry river channels function as storage areas for nutrients and organic material that may become available to downstream water bodies when flow resumes". Elaborating further upon the impacts of non-perennial river systems, it has been argued that Non-perennial stretches of rivers are common features in headwater systems, but they can also be found throughout river networks and play key ecological roles in a watershed context during dry and wetted phases" (Robinson, 2019). Day, *et al.,* (2019), suggests about another significant impact generated by non-perennial river systems especially in dry arid regions. For instance in arid areas, non-perennial river systems support vegetation and associated animals and represent scarce resources in a dry terrestrial landscape (Day, *et al.,* 2019). Similarly, the impacts of non-perennial river systems upon the surrounding region have been depicted as "These streams supply water, sediment, nutrients, and biota to mainstream rivers. In addition, they are a primary source of recharge to alluvial aquifers and regional groundwater aquifers" (Goodrich, *et al.,* 2018)[14]. Non-perennial river systems like intermittent rivers positively impact the surrounding region by providing habitats to diverse group of flora and fauna. These river systems support unique taxa with adaptations for withstanding drought and provide habitat for many threatened and endangered species" (Hwan & Carlson, 2015)[16]. Kaletova, *et al.,* (2019), argues that overall, non-perennial river systems such as IRES in the landscape tend to have more positive than negative effects with the main positive impact occurring during its flowing phase. Similarly, Kaletova, *et al.,* (2019), also emphasizes about some of the ecosystem services to the surrounding environment provided by non-perennial river systems like IRES. These ecosystem services include "water supplying, fish production, recreational space or aesthetics". Glarou, *et al.,* (2019)[13] also highlights about the ecosystem services and other benefits provided by intermittent rivers to the nearby regions. Here, it is mentioned "they are increasingly recognized as unique environments that provide important ecosystem services. Furthermore, they support a high biodiversity with many range-restricted endemic and threatened species" (Glarou, *et al.,* 2019). Finally, to indicate the impacts, which non-perennial river systems like intermittent rivers (IRs) have on the surrounding regions, it has been argued that IRs help maintain biodiversity in the landscape and perform fundamental ecosystem services such as nutrient cycling and groundwater renewal (Leigh, *et al.,* 2015)[21].

There are some key factors, which affects the water availability and water-quality of non-perennial river systems. Amongst them, precipitation and evapotranspiration are two key driving factors. In this regard, it has been emphasized that low annual amounts and high variable precipitation where potential evapotranspiration exceeds precipitation; has a profound effect on stream flow characteristics (Goodrich, *et al.,* 2018). Water-level in non-perennial river systems in-turn affects the water-quality of these river systems. In this regard, it has been argued that the amount of water present determines the hydrological state of the river – whether it is in a state of flood, a small trickle, a longitudinal system of isolated pools, or dry river bed (with or without) hyporheic (under-bed) flow. The amount of water is likely to influence, amongst other factors, the concentrations of solutes (salts, toxins), nutrients and water temperature (Day, *et al.,* 2019). Anthropogenic activities are another factor, which hinders the water quality of non-perennial river systems especially on Intermittent Rivers (IR). To elaborate upon this, it has been mentioned "scientists raised concerns that the hydrological variability of IRs was threatened by flow regulation for irrigation and other human activities, especially in dryland regions" (Leigh, *et al.,* 2015). Leigh, *et al.,* (2015) also highlights degradation of IRs as another core factor, which hinders the water-quality and water availability of non-perennial river systems. For instance, many IRs have suffered degradation from their use as rubbish disposal sites and drains for wastewater and sewage effluent, or from impacts of catchment vegetation clearing, urbanisation, mineral extraction and flow modification. Stressing upon the water-availability in non-perennial river systems, it has been reflected that duration of flow in seasonal streams is a function of precipitation and groundwater inputs, and may be strongly controlled by geology, storage, and losses to deep groundwater, evapotranspiration, and human water withdrawals (Ebersole, *et al.,* 2015)[10]. The water-availability in non-perennial river systems can also be lowered due to increased drought events. In this regard, it has been argued that increases in drought severity might separately influence drying patterns by reducing the availability of groundwater inputs or increasing evapotranspiration throughout the watershed (Allen, *et al.,* 2019). Similarly, Karaouzas, *et al.,* (2018)[20], also determines extreme climatic conditions as a dominant factor responsible for affecting the water-quality and water availability in non-perennial river systems. Here, it is indicated that extreme climatic conditions of water scarcity and prolonged droughts influence both the physicochemical and the ecological status of water bodies (Karaouzas, *et al.,* 2018). The flow variation is another core factor, which in-turn affects the water-availability in non-perennial river systems like intermittent rivers. To elaborate upon this, Glarou, *et al.,* (2019), suggests that flow variation is the defining critical component of all intermittent streams affecting a multitude of biogeochemical and ecological processes, thus successively affecting abiotic parameters and river biota. Kaletova, *et al.,* (2019), suggests that increasing air temperatures in arid-regions can affect the water availability within both perennial and non-perennial river systems. Here, it is further suggested that increasing air temperatures in arid-regions can thereby assist in the formation of non-perennial river systems like Intermittent Rivers and Ephemeral Streams (IRES). In this respect, it has been mentioned that the increase of air temperature will influence the hydrologic balance of currently flowing perennial rivers in arid and semi-arid areas that can result in the rise of IRES in the landscape (Kaletova, *et al.,* 2019).

Reflecting upon the deterioration of water-quality and reduced water availability in non-perennial river systems like IRES, it has been mentioned "IRES are ecologically diverse, but are at risk of deterioration as climate change and local anthropogenic activity, such as impoundment, abstraction, effluents and augmented flow are changing the natural variability in their hydrological behaviour and the ecosystem services they provide" (Sefton, *et al.,* 2019)[40]. Finally, Karaouzas, *et al.,* (2018), emphasizes the factors responsible for the deterioration of water-quality and decreased water availability in non-perennial river systems like intermittent rivers. For instance, intermittent (or temporary) rivers are among the most dynamic freshwater ecosystems but concurrently among the most vulnerable ones, because they are located in water scarce areas, where water resources are often over-exploited, accentuating natural inter-annual and intra-annual flow variability (Karaouzas, *et al.,* 2018).

3. Conclusion

In order to obtain an in-depth understanding about the surface water-quality of the Chitravati River in Puttaparthi, literature reviews were performed. Literature reviews were performed based on three major themes, which include:

1. check-dams, 2. water-quality assessment and monitoring, and 3. non-perennial river systems. Accordingly, different scholarly articles focusing on topics related to check-dams, water-quality assessment and monitoring, and Non-perennial River systems; were selected.

The literature reviews for theme 1, check-dams provided some major insights, which will help to enhance our understanding about the Chitravati River surface water-quality in Puttaparthi. Based on the literature reviews on check-dams some key findings were also determined about the check-dam in Puttaparthi. For instance, the check-dam in Puttaparthi is a man-made structure, which was constructed in 2019. The check-dam is situated at the end of the Chitravati River's 1 km stretch in the Puttaparthi town. The major purpose of the Chitravati River check-dam is to harvest and store river water especially during the monsoon season when some rainfall events occur in the Puttaparthi town. The check-dam in Puttaparthi has been constructed by using mostly cement and dry-rocks. Similarly, the check-dam in Puttaparthi has no opening gates or closing gates, thereby preventing river water and sediments to pass through. As Puttaparthi's check-dam does not have any opening gates or closing gates, it might have contributed to the lack of flow for the river and made the river-water stagnant. Similar to other check-dams in India and around the world, there are numerous positive and negative impacts upon the surrounding region associated with the check-dam in Puttaparthi. One major positive impact of the check-dam in Puttaparthi, is upon the aquifer recharge. The check-dam will enhance the percolation of river-water within the sub-surface water-table, which in-turn will help in the recharge of aquifers. Furthermore, the check-dam in Puttaparthi is more likely to benefit the local people by making the river-water available for domestic activities like clothes washing, which will provide the local people with some income to sustain their livelihoods. Similarly, during rainfall events the check-dam will help to store some amount of the rain-water in the river. This will ensure that some portion of river-water remains available even if the Chitravati River completely dries out in the near-future. Finally, some-portions of the river-water stored by the check-dam can be supplied for agricultural activities and for irrigation purposes, which will help sustain the livelihoods of the local people in Puttaparthi. In contrast, Puttaparthi's check-dam might negatively impact the nearby regions. As the Chitravati River has been completely stagnant since the check-dam construction, the river-water might be a favourable habitat for the breeding of mosquitoes thus increasing possible risks from malaria. Another adverse impact of the check-dam in Puttaparthi might be prominent as the check-dam gets older. In this regard, Nour, et al., (2019)[32], and other literatures have also stressed upon the ageing of check-dams. In a similar manner, as Puttaparthi's check-dam ages and gets older, it will lead to more wear-and-tear. More wear-and-tear will prohibit the check-dam's effectiveness to store river-water. Puttaparthi's check-dam might adversely affect the Chitravati River's fish population by restricting their movements from upstream to downstream. As the fish population is affected, some of the local fishermen along with the nearby fauna might be adversely affected. Similarly, as the check-dam in Puttaparthi does not have any opening gates or closing gates, any human-generated wastes or animal wastes, which are disposed of to the Chitravati River will be stagnant within the river-water thus adversely affecting the river-water quality. Finally, the check-dam in Puttaparthi will increase the rate of erosion downstream especially when heavy rainfall events occur. As the check-dam in Puttaparthi has been recently constructed, the impacts of the check-dam upon the nearby region have been mixed having both positive and negative impacts. Therefore, the check-dam will be of prime relevance to policy makers and planners especially in the formulation of well-honed water-storage and conservation efforts in the Puttaparthi region.

To understand about the surface water-quality of the Chitravati River in Puttaparthi, literature reviews were performed for theme 2, water-quality assessment and monitoring. Through the literature reviews different readings have emphasized how water-quality assessment can assist in determining the level of cleanliness and the amount of contaminants present within a particular water-body. Similarly, in order to determine the level of cleanliness and the amount of contaminants present; water-quality assessment will be necessary for the Chitravati River in Puttaparthi. To perform water-quality assessment different tools like Water Quality Index (WQI), Water Pollution Index (WPI), and Water Poverty Index (WPI) were emphasized by the selected readings. These tools can be applied to detect the surface water-quality of the Chitravati River in Puttaparthi. In the literature reviews, the selected readings considered major physicochemical parameters like pH, temperature, Electrical Conductivity

(EC), total alkalinity, heavy metals (i.e. iron, copper, zinc and chromium), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Dissolved Oxygen (DO), turbidity, Total Dissolved Solids (TDS), hardness, sodium, potassium, fluoride, chloride, nitrate, phosphate, and sulphate. Similarly to determine the water-quality index of the Chitravati River in Puttaparthi, major physicochemical parameters like pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), turbidity, hardness, fluoride, sodium and potassium; needs to be analyzed for. By determining the respective concentrations of these physicochemical parameters, it will help in assessing the level of cleanliness and the extent of contaminants within the Chitravati River in Puttaparthi. Assessing the given physicochemical parameters will also be critical at present especially for obtaining data related to the current water-quality assessment and monitoring status for the Chitravati River in Puttaparthi.

Finally, to understand about the surface water-quality of the Chitravati River in Puttaparthi, literature reviews were performed for theme 3, non-perennial river systems. The selected readings for the literature review stressed about flow cessation as a major characteristic of non-perennial river systems like intermittent rivers. In a similar manner, it is appropriate to classify the Chitravati River in Puttaparthi as a non-perennial river system and as an intermittent river as the river was dry for many years in the past thus resulting in flow cessation of the river. In addition, the impacts of non-perennial river systems upon the nearby region have been highlighted by several readings. These impacts are in terms of supporting vegetation growth, storing nutrients and organic materials, providing water supply, serving as habitats for diverse flora and fauna, and increasing the recharge of nearby aquifers. In this respect, the Chitravati River in Puttaparthi might also impact the nearby regions by supporting vegetation growth, storing nutrients and organic materials, providing water supply to nearby regions, serving as habitats for diverse flora and fauna, and increasing the recharge of nearby aquifers. Furthermore, different readings have indicated about different factors, which affect the water-availability and water-quality of non-perennial river systems. The outlined factors include precipitation and evapotranspiration, water-level and water-flow variations, anthropogenic activities, extreme climatic conditions like droughts, and increasing air temperature in arid regions. Similarly, these factors are likely to affect the water availability and water-quality of non-perennial rivers like the Chitravati River in Puttaparthi. Finally, from the selected readings it is evident that there is a degree of uncertainty associated with future river-flow trajectories for non-perennial river systems. For instance, for non-perennial river systems, it is currently difficult to predict whether the river-flow will last for several years or whether the river will dry out as before. Therefore, it will be critical for policymakers to currently preserve the Chitravati River in Puttaparthi especially if the river-flow ceases in the near-future.

4. Personal Views

The literature reviews performed in this review paper will be significant in terms of studying the Chitravati River in Puttaparthi in the long-run. For instance, the literature reviews provided different case studies for studying water bodies in India and around the world, which can also be followed in the context of the Chitravati River in Puttaparthi. The literature reviews helped formulate my personal views about the Chitravati River in Puttaparthi, which are the following. Firstly, the check-dam in Puttaparthi is an important structure for storing Chitravati river-water. In this regard, the check-dam needs to be well-maintained in order to effectively conserve river-water. In addition, opening and closing gates, which the check-dam currently lacks, need to be installed for allowing the river-water to pass through. Allowing the river-water to pass through the gates will ensure the river-water is not stagnant. As an outcome, the risks from malaria will decrease thereby improving the surface-water quality. Secondly, regular water-quality assessment and monitoring of the Chitravati River in Puttaparthi will be an imperative at present for ensuring the cleanliness and for minimising the extent of harmful contaminants within the river. In order to address about water-quality assessment and monitoring for the Chitravati River in Puttaparthi; regular stakeholder meetings between local people, government agencies, NGO's, and respective authorities should be arranged. Here, arranging stakeholder meetings on a regular basis will further assist in formulating effective water-quality assessment and monitoring measures for the Chitravati River. Finally, preserving the Chitravati River in Puttaparthi will be vital especially if the river-flow ceases in the near-future. This will require the facilitation of storage facilities where the river-water can be properly preserved and stored. In this regard, joint steps should be taken by the government, local people and respective authorities for developing facilities where the river-water can be properly preserved and stored in the long-run.

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