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ASSESSING HITI SYSTEM AS A NATURE BASED SOLUTION IN ADDRESSING WATER SECURITY IN KATHMANDU VALLEY

by

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A THESIS

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CERTIFICATE OF THESIS APPROVAL

This is to certify they have read, and recommended to the Institute of Engineering for the acceptance, a thesis report titled "**Assessing Hiti System as a Nature Based Solution in addressing Water Security in Kathmandu Valley**" submitted by **Mr. Sarik Awale (078-MSUrP-015)** in the partial fulfillment of the requirements for the degree of **Masters of Science in Urban Planning.**

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DECLARATION

I hereby declare that the thesis entitled "**Assessing Hiti System as a Nature Based Solution in addressing Water Security in Kathmandu Valley**", submitted to the Department of Architecture in partial fulfillment of the requirement for the degree of Masers of Science in Urban Planning, is a record of an original work done under the guidance of Dr. Sanjaya Uprety, Institute of Engineering, Pulchowk Campus. This thesis contains only work completed by me except for the consulted material which has been duly referenced and acknowledged.

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Abstract:

Water security is a global concern, with Kathmandu Valley, the largest urban agglomeration in Nepal, facing its own set of water issues such as water stress, water affordability, water resilience, declining ground water levels and urban pluvial flooding. Research from various regions has underscored that solely relying on built infrastructure is insufficient for resolving long-term water security issues. Consequently, a comprehensive approach that combines built infrastructure solutions with nature-based solutions is essential. Drawing inspiration from "sponge cities", which is based on the ancient water management wisdom of China, and is a leading example of Nature Based solutions, this research explores the potential of Hiti System which is the indigenous water management system of Kathmandu Valley and is deeply rooted within the community, as the Nepalese version of Nature based solution for addressing water security. The study aims to showcase this by highlighting how the system acts to in conservation of ecosystem, promotes local resource utilization and community engagement, through the two successful case studies of Alko Hiti and Pimbahal Pond of Patan. The research being mostly qualitative and having parts of descriptive results, the study has been carried out through field observations, key informant interviews, semi structured interviews with the community and literature review. The research then channelizes these findings to present how water security is being addressed through these efforts. Further the study attempts to view Hiti System as a sustainable means to address water security, and advocates that it should not be limited to the perspective of cultural preservation. Lastly, the study also points out the shortcomings of the system owing to present realities, and works to propose a solution to it.

Keywords: Hiti System, Nature Based Solutions, Water Security, Sponge Cities.

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I am also indebted to my family and friends who supported and ecouraged me through out this journey.

List of Acronyms

UN: United Nations

KII: Key Informant Interview

UNEP: United Nations Environment Program

LID: Low Impact Development

SDG: Sustainable Development Goals

WSUD: Water Sensitive Urban Design

KVWSMB: Kathmandu Valley Water Supply Management Board

IPCC: Intergovernmental Panel on Climate Change

GHG: Green House Gases

ADB: Asian Development Bank

Nbs: Nature Based Solutions

GoN: Government of Nepal

UN-Habitat: United Nations Humans Settlement Program

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CHAPTER ONE: INTRODUCTION

1.1 Background

Water security is a pressing global issue for major cities around the world. Around two billion people worldwide don't have access to safe drinking water today (Sachs et al., 2022), and about half of the world's population is experiencing severe water scarcity for at least part of the year (Pachauri et al., 2015). From 2001 to 2018, water related disasters accounted for 73.9% of all-natural disasters (Lee et al., 2020). Water-related ecosystems across the planet – such as lakes, rivers, reservoirs and wetlands – are changing rapidly, with over 85% of the world's wetlands degraded in the last 300 years (Sachs et al., 2022).

The Kathmandu Valley, which is the largest urban agglomeration of Nepal, is experiencing, its own set of water security challenges, which range from increased pluvial urban flooding (Salikhe & Pokhrel, 2019), drastically decreasing ground water levels (Shrestha, 2009) to heightened water stress (Udmale, 2016). To combat these challenges, built infrastructure such as piped storm water drainage lines, dams etc. alone are seemingly unlikely to provide reliable solutions in the future (Ozment et al., 2015). Studies on leading examples across the globe suggest that a combination of built and nature based solutions will be needed for efficient and effective management of water resources (Smith, 2013). Simply put, Nature Based Solutions are actions to protect and enhance ecosystems for human as well as environment wellbeing. Nature based solutions are being increasingly used in different parts of the world, for e.g. Low Impact Developments (LID) approach in the United States, Sustainable Urban Drainage Systems (SuDs) and the Blue-Green Cities (BGCs) approach in the United Kingdom, Water Sensitive Urban Design (WSUD) in Australia, and most notably in China through the concept of "sponge cities". The sponge city concept is based upon the ancient farming and water management wisdom of China, and it uses the landscape to retain water at its source, slow down water flow and clean it throughout the process, to tackle the urban flooding. Similarly, in context to Nepal, particularly Kathmandu Valley, the Hiti system is the traditional knowledge base of sustainable usage of water and its management. The Hiti system is a system of canals, ponds, stone spouts, conduits and various such structures, which was not only utilized to bring water for drinking and domestic purpose to city, but also for irrigation, checking landslides and pluvial flooding & improving ground water recharge, (Joshi,2021), with consideration to the ecology of the Valley. These services of the Hiti system are very relevant to the challenges faced by Kathmandu Valley in present scenario.

Furthermore, the state of Hiti system is in a declining phase. The past management methods of ensuring continuity of Hiti system is fading, and in need for newer mechanisms for its continuation, and the Nature Based Solution approach may be one such mechanism.

1.2 Need of research

According to the world urbanization report (2014), the world population living in cities is 54% in 2014, which is expected to grow to 66% in 2050. The Kathmandu Valley is the largest urban agglomeration of Nepal having a population of slightly more than 3 million(census, 2021).This urbanization has come with serious issues of water security. The ground water extractions is six times larger than recharging rate (Shrestha, 2009). According to the study done by Salikhe and Pokhrel(2017), in Kathmandu Metropolitan City, the largest metropolitan area of Kathmandu Valley, the flooding is expected to increase by 40% for a 25 year return period, and the water per capita consumption is well below the national targets(Nagarik, 2017). To address these issues, the need of hybrid usage of built infrastructures and Nature based solutions is being realized globally. The global assessment report on Biodiversity and ecosystem services (2019), stated that Nature-based solutions are estimated to provide 37 per cent of climate change mitigation until 2030. As such, the system of Hiti based on the traditional knowledge of water management may also be a nature based solution which can address the issues of water security in the Valley. This study shall assess the salient features of Hiti system in respect to the Nbs concept and how it can work in increasing water security.

1.3 Importance of Research

As stated, the Hiti system may be a viable Nature based solution to address the concerns for water security in Kathmandu Valley. Besides this, the Hiti system defines the water culture of the valley (UN Habitat 2008), which is in a declining rate. The attempts to save this heritage has been seen mostly from a cultural conservation point of view. However, this study strives to present Hiti system as a solution to address water security, so that it can be used in the present city planning context and enable the development of further financial mechanisms to support the Hiti system. This may further work to conserve and enhance the system. Also, this research has attempted to underline the present management related shortcomings of the system, and also proposed solutions towards it. This may be useful for government agencies and other related organizations in carrying about further works relating to the system.

1.4 Problem Statement

The introduction of Melamchi Water Supply Line in the Valley in 2021, has been only able to partially address the issues of water security in the valley. There still exist challenges to distribution network, frequent maintenance and dependence on a different watershed which has its own set of problems(Joshi,2021). The urban drainage management infrastructure designed based on current climate conditions will not be able to cope under future climate conditions (Salikhe & Pokhrel, 2017). The overdependence of deep aquifer ground water resource, which is not a renewable source of water, through deep boring is also concerning. Owing to this Cress et. al(2001) estimated that the deep aquifer ground water resource would be depleted below present extraction levels in 100 years. So, clearly, the way in which water security is being addressed is insufficient and incoherent. Learning from the global best practices, a hybrid of built and natural structure solutions are required to combat the modern challenges of water security.

Also, Hiti system which is an indigenous system of Kathmandu valley, defines the “Water Culture” of the Valley. But it is experiencing fast paced destruction. According to KVWSMB(2019), there are a total of 573 Hitis in Kathmandu Valley, of which only a few remain functioning. They are being looked solely from a conservation perspective, but owing to recent times, newer meanings and mechanism much also be put in place.

1.5 Research Objectives:

Main Objective

1. To assess the role of Hiti system as a nature based solution in addressing water security in Kathmandu Valley.

The objective has been sub divided into the following:

1. To study the planning of Hiti system.
2. To examine the salient features of Hiti system as a nature based solution.
3. To assess the role of Hiti system in addressing water security through case studies.

1.6 Limitations:

The limitations of the study are,

1. Though water security is integrated with all water systems, this study does not include the study of waste water systems.
2. The study of state canals(rajkulo) is also not included in this study.
3. Water Stress is limited to domestic water stress and water security is analyzed in a localized manner.
4. The research is limited to qualitative indicators of water security.

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CHAPTER TWO: RESEARCH DESIGN

2.1 Paradigm Discussion

The Hiti system has a socio-cultural, physical and ecological dimension. Similarly, the water security faced by the residents also has a subjective and an objective reality. Thus the ontology of the study is based upon multiple realities. The ontological claim of the study is that Hiti system can work as a nature based solution to address the issues of water security, in the Valley. Epistemology deals with what can be considered as a valid knowledge to claim the ontological assumption. The basis is the understanding of Hiti system in its natural setting, qualitatively and quantitatively, can secure the needed resources to validate its role in addressing water security as Nature Based Solutions. Thomas Kuhn (1970) introduced the term paradigm which was used to discuss the shared generalizations, beliefs, and values of a community of specialists regarding the nature of reality and knowledge. Owing to this subjective as well as objective reality, the pragmatic paradigm is adopted. As a research paradigm, pragmatism is based on the proposition that researchers should use the philosophical and/or methodological approach that works best for the particular research problem that is being investigated (Tashakkori and Teddlie 1998). It is often associated with mixed-methods or multiple-methods. Pragmatism as a research paradigm refuses to get involved in the contentious metaphysical concepts such as truth and reality. Instead, it accepts that there can be single or multiple realities that are open to empirical inquiry (Creswell and Plano Clark 2011). For the purpose of this research, a pragmatic paradigm is adopted, with a case study approach, which accounts for mixed method research.

2.2 Methodology

It deals with the how and what procedures can be used to acquire the knowledge. As the research is mostly qualitative, with aspects of quantitative, in nature, a variety of methods have been used to frame the research. Firstly, thorough literature review was conducted on Hiti system, and water security context of Kathmandu Valley. Consultations and field observations were then carried out to identify the problem statement. Based upon these, case studies were selected, and further literature were reviewed. This introduced the scene of Nature Based Solutions in the research. With this, the relationship between the three key concept of the research the Hiti system, Nature Based Solutions and Water Security, were studied through secondary sources. Subsequently, Key informant interviews were conducted with experts and

conservationists in the field of Hiti conservation, and community representatives in relation to the case study. Then a series of field observations and measurements were performed and, the process was aided with semi structured interviews with 20 user respondents in the case study. As mentioned, the research being mostly qualitative, having a descriptive quantitative aspect, so the study has been presented in a narrative review. A narrative review is a review method in which the researchers summarize different primary studies from which conclusions may be drawn in a systematic way and from a holistic point of view, contributed by researchers' own experience and existing theories.

2.3 Methods

Several methods including literature review, interviews along with case study were applied to accomplish the objectives for this research.

Literature Review: This includes the existing body of knowledge available on the subject matter. Literature Review was extensively done from problem identification to the final stages of the research. Journal Articles and books published on Hiti system were studied for conducting this research. Government reports were referred for the contextualization of water security. Similarly, global reports and journals were also reviewed, to base the concept of Nature Based Solutions and the global scenario. Further, relevant articles, journals and research papers were reviewed.

Key Informant Interview: KII was performed to understand mostly the socio-cultural aspect of the study. For this, key personnel's, who were involved in the Hiti conservation and revival process of the case study, community leaders of the case study and subject matter experts were interviewed. Through the key informant interviews, this research aims to provide a holistic narrative of the subject matter.

Semi Structured Interview: This method was used in the case study area of Alko Hiti, where a total of 20 households out of the total 185 user households were interviewed. A semi structured approach was undertaken, to understand the experience of the users, and also because, literature surrounding the structured interview was limited to modern supply lines, which did not take into account the indigenous water supply system.

Case Study: The case study area was chosen to be two locations namely Alko Hiti and Pimbahal pond of Patan. The Valley has three major systems of Hiti viz. The Kathmandu System, the Bhaktapur system and the Patan system. Out of all these systems Patan has comparatively better maintained Hiti system. Additionally, the cultural linkages to the system is still relatively strong till present (UN Habitat 2008). As the study entails assessing the features of Hiti system, which can be better assessed on a well-functioning Hiti system, the two cases of Patan were chosen. A mixture of qualitative methods which were KII and semi structured interview, and quantitative methods which were field observations and measurements were performed.

Sample Survey: Convenience and Purposive sampling were used. Those who were available during the time of survey were interviewed, and people who were directly involved in managing water for their households were purposively selected for the interviewed. Out of 185 households, a total of 20 households were interviewed.

Field Observation: Field measurements relating to discharge of water in Hiti, depth of water in ponds, dimensions, and observations regarding water storage facilities, present scenario of the case area etc. were taken.

The flowchart for the method adopted is shown below in fig 1.

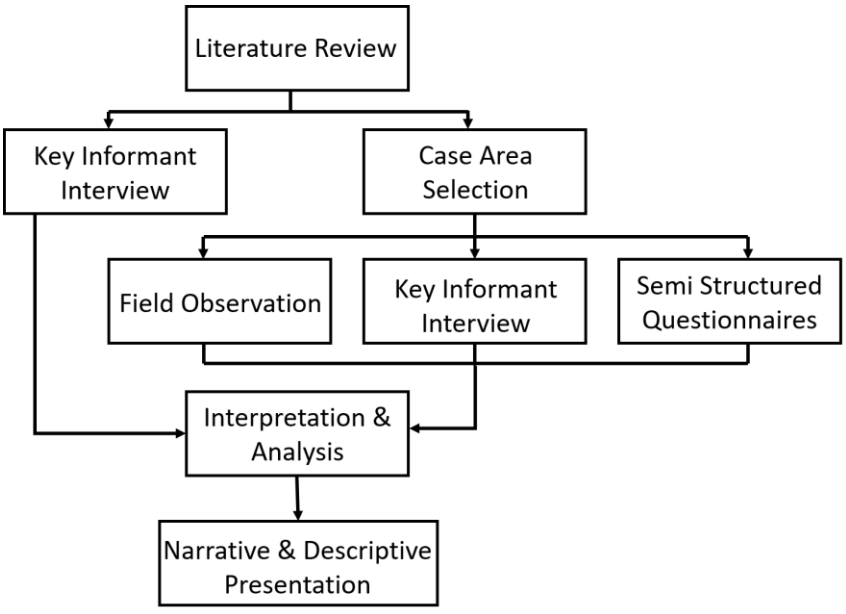


Figure 1: Method Flowchart

CHAPTER THREE: LITERATURE REVIEW

3.1 Core Concepts

3.1.1 Nature Based Solution

The concept of 'Nature-based solutions' (NbS) was introduced towards 2009 by the World Bank and IUCN. Nbs was then put forward by IUCN in context to climate change negotiations in Paris "as a way to mitigate and adapt to climate change, secure water, food and energy supplies, reduce poverty and drive economic growth." (IUCN 2014). The European Commission then adopted NbS as "actions which are inspired by, supported by or copied from nature" (EC, 2015). According to the World bank(2019), "Nature-based solutions are actions to protect, sustainably manage, or restore natural ecosystems, that address societal challenges such as climate change, human health, food and water security, and disaster risk reduction effectively and adaptively, simultaneously providing human well-being and biodiversity benefits" (p.1).Similarly, IUCN (2016), "Nature-based Solutions address societal challenges through the protection, sustainable management and restoration of both natural and modified ecosystems, benefiting both biodiversity and human well-being. They target major challenges like climate change, disaster risk reduction, food and water security, biodiversity loss and human health, and are critical to sustainable economic development." Simply put, Nature Based Solutions are actions to protect and enhance ecosystems for human as well as environment wellbeing.

According to the Seddon et al. (2021), the guidelines for Nature Based Solutions(NbS) are,

- They are not a substitute for the rapid phase-out of fossil fuels and must not delay urgent action to decarbonize our economies,
- They involve the protection, restoration and/or management of a wide range of natural and semi-natural ecosystems,
- They are designed, implemented, managed and monitored by or in partnership with indigenous peoples and local communities through a process that fully respects and champions local rights and knowledge, and generates local benefits,
- They support or enhance biodiversity.

These guidelines are used to ascertain the characteristics of Nature Based Solutions for the purpose of this study. The notion of Nature Based solution has been readily accepted in the Paris Agreement and SDG's (SDG 17).

3.1.2 Water Security

UN-Water (2013), the United Nations' inter-agency coordination mechanism for all water-related issues, defines water security as: "The capacity of a population to safeguard sustainable access to adequate quantities and acceptable quality of water for sustaining livelihoods, human wellbeing, and socio-economic development, for ensuring protection against waterborne pollution and water related disasters, and for preserving ecosystems in a climate of peace and political stability" (p.1). A sustainable and safe water source is essential for human well-being, economic development, ecosystem preservation, and the prevention of water-related hazards. Under this framework there are four key components to water security, which are Drinking Water and Human Well Being, Ecosystem, Water Related Hazards and Climate Change, and Economic Activities and Development. Further, Aboelnga et al., 2019, under the framework of water security assessment, has sub divided these key components. But, these components have been designed for a modern piped supply system of water. Owing to the differences, out of the listed components, for the purpose of this study, water stress, water affordability, water resilience, ground water recharge, and urban pluvial flooding control have been studied. The study of the components has been carried out under the following working definitions.

1. **Water Stress** is understood as the ratio between water use (i.e., abstraction or consumption) to the environmentally available water resources (Vanham et al., 2021). This definition is also used in the Sustainable Development Goals indicator 6.4.2 on water stress. For the purpose of this study water stress is studied in terms of domestic water needs of the pople.
2. **Water Affordability** is the ability of the most vulnerable populations to pay for essential water services.
3. **Water Resilience** is defined as "the capacity of urban water infrastructure to cope in the short term, and adapt and develop in the long term in the face of unforeseen changes such as major system failures, acute water infrastructure degradation, inadequate drinking water and wastewater infrastructure, and/or natural disasters" (Singh & Pandey, 2019).

4. **Urban Pluvial Flooding** is defined as the "flooding which results from rainfall generated overland flow, before the runoff enters any watercourse or sewer or when it cannot enter because the drainage system is already full to capacity" (Salikhe and Pokhrel, 2017).

3.2 Review of Research Findings

Roughly two billion people worldwide do not have access to safe drinking water today (SDG Report 2022), and about half of the world's population is experiencing severe water scarcity for at least part of the year (IPCC, 2014). These numbers are projected to increase, fueled by population growth and climate change. Asia-Pacific regions face an imminent water crisis with 60% of the households in the region live without a safe piped water supply or improved sanitation, and South Asia is faring the worst (ADB, 2013). Seventy percent of all fatalities resulting from natural disasters are due to water-related disasters, which have topped the list of disasters over the previous 50 years (World Bank, 2019). Flood-related disasters have increased 134% since 2000 compared to the two decades before and Asia was home to the majority of flood-related fatalities and financial damages (WMO, 2022). Over 85% of the world's wetlands were lost over the past 300 years, primarily due to drainage and land conversion, and many of the remaining wetland regions have been degraded. Also, other water-related ecosystems like lakes, rivers, and reservoirs are also undergoing rapid change (SDG, 2022).

In this context, studies show that built infrastructure solutions alone are increasingly unlikely to provide future water security against predicted climate change impacts (Ozment et al., 2015). Using NbS by harnessing the water-related services of 'natural infrastructure', such as forests, wetlands and floodplains, can help combat the risk of water crisis, particularly in the face of future climate stresses (Ozment et al., 2015). Though, nature alone might not be able guarantee water security for people in every situation, adopting a combination of both built and natural infrastructure can work to efficiently and effectively manage water resources (Smith, 2013). The concept of Nbs in context to water security has been summed up well by WWF (2021), as "Urban development replaces forests and wetlands with buildings and nonporous infrastructure. When it rains heavily, storm water that doesn't get absorbed can cause severe flooding. That runoff then washes into streams, lakes, or rivers, where it can increase sediments, pollute

drinking water, or harm wildlife. Nature-based solutions such as green roofs, rain gardens, or constructed wetlands can minimize damaging runoff by absorbing storm water, reducing flood risks and safeguarding freshwater ecosystems. In addition, nature-based solutions keep cities cooler during the summer, support birds and other pollinators, and promote people's mental and physical health."

The global assessment report on Biodiversity and Ecosystem Service (2019), suggests that up to 37% of climate change mitigation until 2030 can be possible through Nature Based Solutions. This way solutions for water security that incorporate natural infrastructure can work to enhance efficiency, effectiveness and equity in water management. The framework of NbS was endorsed at the 2019 United Nations Climate Summit and highlighted in the IPCC's Special Report "Global Warming of 1.5°C" and the IPCC Climate Change and Land Report (IPCC, 2019), as having the potential to address major global societal and ecological challenges.

3.3 International Case Area: - Nature Based Solution: Sponge City, China

The urban areas of China are prone to severe flooding and waterlogging. After decades of rapid urbanization, China now faces with water shortages and flooding – which are exuberated by the effects of climate change. Also, pollution is degrading the water quality, meaning much of the water available is unusable. In Zhengzhou, the capital city of Henan province with a population of more than 10 million, an extreme rainfall event on July 20 2021, caused severe pluvial flooding which reportedly resulted in over 290 deaths and direct economic losses of more than US$10 billion (World Bank, 2021).

To combat this situation, realizing that conventional urban flood management approaches alone might no longer be sufficient to provide the level of climate resilience and services required to address the heightened threats, the Chinese government announced the sponge city program in 2014.

Sponge city is a Nature Based Solution which that takes full advantage of the rainwater, which is absorbed, stored, and slowly released by the city facilities, such as waterways, sunken rain garden, green spaces, permeable pavement and floor tiles, and green roof buildings to control storm water runoff and to accumulate, infiltrate, and purify naturally (Liu et al., 2017)

The core design concepts of a sponge city include the following:

1. Similar to how a sponge's pores soak up water, sponge cities incorporate numerous retention ponds and lakes to gather and store water.
2. In the manner that water meanders through a sponge, sponge cities redirect the flow of water, avoiding straight-line paths.
3. Rather than constructing large buildings along waterfronts, sponge cities transform coastlines into natural reservoirs where water can naturally drain into the ocean

This approach integrates green and blue systems like wetlands into conventional “gray” infrastructure, such as concrete embankments, contributing to the 2030 UN Sustainable Development Goal (SDG) 11 to “make cities and human settlements inclusive, safe, resilient and sustainable”. By 2030, China aims to turn 80 percent of its urban areas into ‘sponge-like’; addressing surface-water flooding, lowering peak run-off, improving purification of urban runoff, and enhancing water conservation while improving environmental quality(World Bank,2021). The Chinese government has chosen 16 pilot cities and allocated to each of them between 400 and 600 million yuan (around €55 million) for the implementation of innovative water management strategies. Amogst them, the city of Shenzen has been highlighted in this study because the 2019 National Sponge City Project Evaluation organized jointly by the Ministry of Finance, Ministry of Housing and Urban-Rural Development, and Ministry of Water Resources of the Chinese government ranked Shenzen first among 14 sponge city initiatives

3.3.1 The city of Shenzen

Shenzhen is a mega-city in southern China, as shown in figure 2, with a population of over 17 million in 2020. It is a major high-tech and financial with a vibrant and booming economy. During the decades of China's opening up and urbanization, the city has undergone from a small village into a modern metropolis.

Figure 2:- Shenzen, China

However, the municipal planning of Shenzhen is not in par with the rapid growth of the city, and is consequently facing issues of frequent waterlogging. Wang et. al,(2021) states that, "Shenzhen's water management is not well coordinated with the river basins. The insufficient connection between urban development and the construction of drainage facilities have led to the overflow of sewage into the rainwater system. Drainage management of municipal construction projects such as rail transit is not in place, and the original drainage system has been destroyed, resulting in a large number of new waterlogging points. In addition, the rain and sewage mixed flow are common in Shenzhen. The sewage treatment system is designed and constructed according to pure sewage, which makes it less effective during the rainy seasons." However, even with these setbacks in the drainage facilities, the city of Shenzen has stood out in the sponge city movement.

Upto 2021, 38 sponge cities supporting policies and standards have been issued in Shenzen. One of them is the construction of Futian Mangrove Ecological Park as shown in figure 3,

where the control rate of total annual runoff has reached 92%; which means that 92% of the total annual rainfall has been infiltrated into the green space and the remaining 8% is only discharged outside the park.

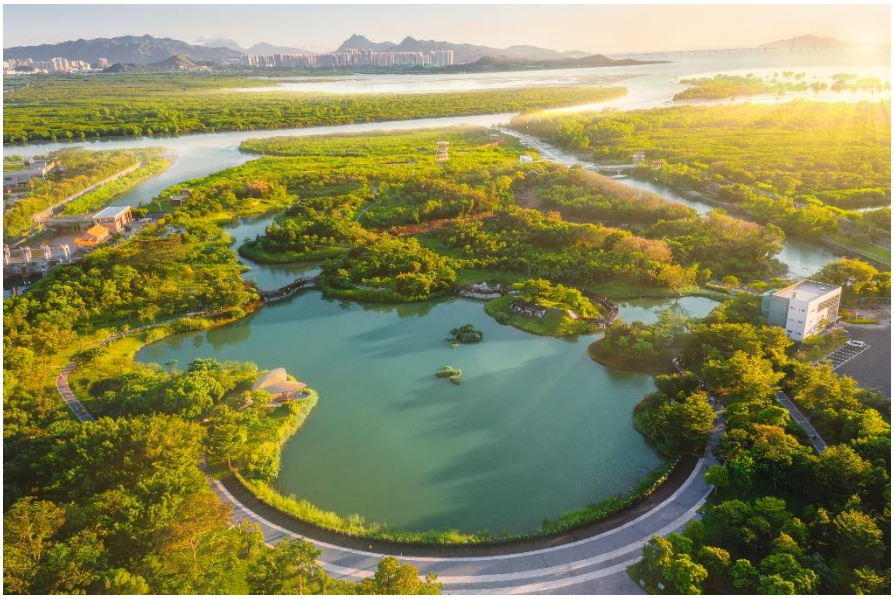


Figure 3: Mangrove Ecological Park

Figure 4: Shenzen Bay Park

Another example is Shenzen Bay Park as shown in figure 4, which is made up of permeable bikeways and floodable greenways that serve as a natural barrier between Shenzhen's crowded downtown areas and the sea while allowing thousands of people daily to take in the views along the city's 13 km of coastline. It functions as a cross between a bike path and a floodway. These

projects provide successful experiences for the transformation and construction in Shenzhen's sponge city. (Wang et. al, 2021)

Overall, 1,361 projects have been completed in Shenzhen, and the newly built-up sponge city area is 276 km^2, accounting for 28.3% of the urban area, exceeding the national target of 20% for sponge city while eliminating 220 historical waterlogging points (Liu et al., 2020).

In this way the NbS concept provides an integrated approach that can help nations meet crucial international agreements and targets, such as the United Nations Sustainable Development Goals (SDGs), the Paris Agreement, and the Sendai Framework for Disaster Risk Reduction.

3.4 Historical Urban Development of Kathmandu Valley

The earlier urban development of Kathmandu Valley can be traced back to Kirat period (ca. 500 BC to 78 A.D.). The Kirata settlements, named pringaa, would be centered around a built space protector god, which came to be known as Dyochhen. The Dyochhen, literally meaning the house of god, had a counterpart natural spot outside the town called Pith. Several religo-cultural (rituals) and socio-cultural (festivals) practices were developed to continuously remind the city dwellers of the limits of the protection of town was dependent on the protection of Nature and its place specific micro-ecology(Tiwari, 2016). The pith would be located in an ecologically important site, such a clump of trees, rock spur, spring source of water, hillock etc. found within the agricultural hinterland of individual settlements. Such a group of similarly conceived settlements in the valley region, each with their own rituals and festivals aimed at sustaining local micro ecology, ensured that urban expansion did not hamper with nature (Tiwari, 2016).

With the Lichchhavi development(78A.D to ca. 880A.D), settlements started growing with rising commerce and pringgas might have expanded out to the farms, a problem that seems to have taken several centuries for a solution under a wider religo-cultural framework for assuring adherence to town boundaries were developed (Tiwari, 2016). Another issue was that of insufficient supply, the spring sources, ponds and the likes protected as pith outside the settlement, were not being able to meet water supply needs of expanding towns. So, water was brought through canals that stretched from the foothills of the valley to towns to feed ponds, which in turn recharged supply to recessed pit conduits, a technology that is working to this day in Kathmandu (Tiwari, 2016), which is known as the Hiti system.

The settlements were made on higher raised areas, while the lower fertile land was kept for agriculture. This acted to protect the agricultural lands, and also protect the settlement against flooding. In this context, it is through the Hiti system, water could be transported to areas farther from the river, for the settlement. So, in a way Hiti system guided the locational attributes of the Newar settlements.

With the expansion of town, the activities sphere extended beyond local micro-ecology to reach spots that were of macro-ecological significance to the valley. So, festivals and rituals were framed to guide public behavior for protection of distant sources and water sheds from as early as the written history starts showing (Tiwari, 2001). To ensure ecological behavior, instead of legal mediation which relied on the power of the state, they used ritual mediation, which was framed on prevailing religious faiths and thus relied on ethics, individual faithfulness and inner discipline.

In the Malla era(1200 A.D. to 1768 A.D.), larger towns developed and wider ritual mediation was used.. The effectiveness of a single dyochhen or in-town protector in commanding faithful behavior got challenged with increasing mix and complexity of religious faiths among the people reduced efficacy of ritual mediation through a single religious faith (Tiwari, Kathmandu Valley Urban Capital Region and Historical Urbanism, 2016). In parallel, the increasing population living in one built up area, the influence area and the agricultural hinterland expanded beyond the ability of one nature protector or pith. This induced the need for larger water supply and irrigation systems which were put in place that relied on more than one source and had to be shared with other settlements, and thus expanding Hiti systems.

3.5 Hiti System

Hiti system is a water supply and management system, which is indigenous to the Kathmandu Valley. According to Joshi (2021), the construction of Hiti in Kathmandu Valley can be attributed to the amalgam of knowledge base from Kirat and Lichavi time. Kirats had the knowledge of ponds & springs in the hill slopes and tar lands. While, lichhavis had the knowledge of ground water and knew the usage of pond and wells. This knowledge was linked to form the Hiti system, which was later extended in the Malla period. Hiti system, worked to not only provide drinking water, but also acted for irrigation purpose, controlling landslides & pluvial flooding, promoting ground water recharge, which worked to enhance the overall water security and resilience of the community. Some famous old hities are Tyagā Hiti , Nugā Hiti, Chyasal Hiti, Konti Hiti, and many more.

The system intertwined with socio-cultural belief system, which acted for its enhancement and protection. Hiti system is interesting not only from an engineering point of view, but it is also an architectural masterpiece. The details of the Hiti complex are well carved with statues of water gods and beings, and properly placed based on their functions and religious inclinations(UN Habitat 2008). In his well-researched and well-documented work, Becker Ritterspach (1994) claims that the traditional below-ground structures for the collection and distribution of water are architectural monuments in their own right that compete with the best above-ground ones, are part and parcel with them, and are a vital and integral part of the architectural ensemble of the Valley. An inscription, in situ in the impressive sunken fountain still in use in the royal square in Patan, neighbor to Kathmandu, dates its foundation to 570 A.D. (UN Habitat, 2008) as shown in fig 5. Therefore, from a functional view the system is the lifeline to the Valley, and from a cultural view it is the jewel to the historic cities of the Valley(Tiwari, S. R. 2002). Even in recent times, in Lalitpur, around 20 per cent of the population access water from spouts while around 10 per cent of the Valley population rely on spouts as their primary water source (Molden et al., 2016).

Figure 5:- Tusa Hiti, Mangalbazar, Patan

3.5.1 Physical Dimension

Water is transported from rivers to state canals or rajkulos, into different strategic ponds. The ponds are then interconnected through canals. These canals are primarily used for irrigation purposes, and later drain into the rivers. The ponds work to recharge aquifers. The aquifer areas are areas where water is stored in natural formation. The intake of Hiti is kept in these aquifers, and through different filtration and transportation structure, the water is brought to the Hiti complex, which is used for drinking and domestic purpose. The outlet of this Hiti, may be connected to ponds, or fields or maybe drained into rivers.

The simplified representation of Hiti system is as shown in fig 6,

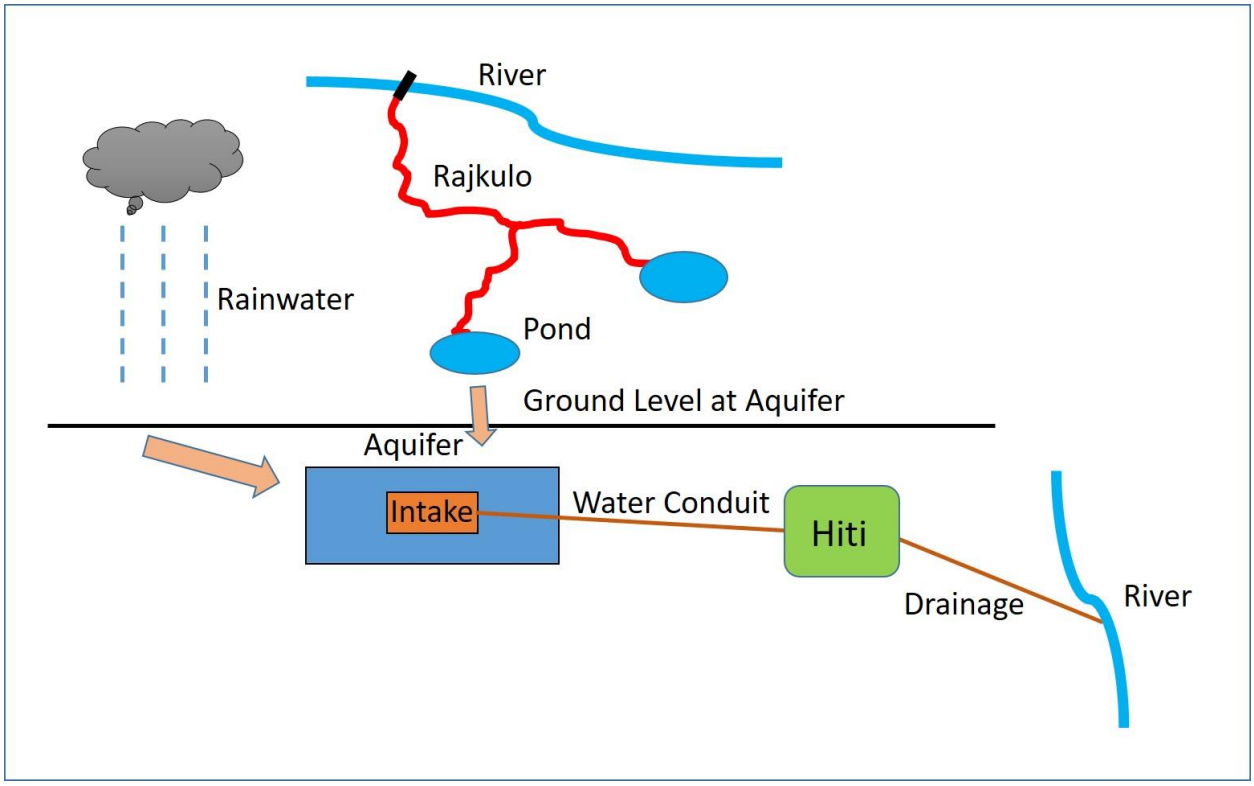


Figure 6:- Simplified Representation of Hiti System

The traditional water network of Hiti System has nine major components:

1. Rajkulo(Water Canal)
2. water storing cum recharging body – the Pukhus;
3. Aquifers
4. Intake
5. The conveyance system – surface or sub-surface flow channels;
6. Filter
7. Hiti Complex
8. Stone Spouts (Hiti Manga)
9. the drainage system.

3.5.1.1 Rajkulo(Water Canals)

The rajkulo or the state canals are water canals tapped from the river source, which is then supplied to the settlement and fields, for multiple purposes such as irrigation, domestic purposes and filling ponds to recharge the groundwater system. It can be suggested that the system was built through the times of several kings in Lichchhavi time and later extended in Malla period(Tiwari, S. R. 2002). The three major water works of Kathmandu Valley are the waterworks from Budhanilkantha to Kathnandu, the Bageswori canal to Bhaktapur, and the Tikabhairav canal to the ponds of Patan(Tiwari, S. R. 2002).

3.5.1.2 Water storing and recharging body – the Pukhus(Ponds)

According to UN-Habitat(2008), Pukuhus are manmade ponds constructed through indigenous methods. The ancient system is still in continuation is many cities and villages within the Valley. Ponds served multiple functions in the Hiti planning According to Joshi(2021), there are three types of ponds in the valley. They are,

1. **Ponds above the settlement**: - As the Newar settlement is mostly situated on Hill tars. There are possibilities of landslides and urban flooding. To control this peak flood, the ponds above the settlement, work to store the water, which decreases peak flow. These ponds also work to recharge the ground water aquifer. To add to this, these ponds work

to aid irrigation. Ikha Pukhu in Kathmandu, Na: Pukhu in Bhaktapur and Paleswan Pukhu in Patan are the few examples of ponds above settlements in the valley.

2. **Ponds inside the settlement**: These ponds are used of domestic purposes. It also helps in controlling urban flooding and also works to recharge aquifers. Further, these ponds also aid irrigation. An example of this is the pond of Pimbahal, which is our case study.
3. **Ponds below the settlement**: These ponds are used to control the flooded water from directly discharging into plain areas, which might cause soil instability. It also works as water source for livestock.

These ponds can be found to be connected to rajkulo(irrigation channel), and they work as sedimentation and storage reservoirs also. Retention of the water in pond is the main task for pond construction. The bottom of ponds was layered with special type of black cotton soil called *Gathucha* to avoid leakage of water.

3.5.1.3 Aquifers:

Aquifers are natural formations which allow for the storage of water underground The source of water in Hities and wells are charged through shallow aquifers. They are mostly recharged in the monsoon and are also partly recharged through pukhus. Examples of aquifers found in Patan are Naricha:, Nyakhyo: , Khwyebahi etc. s(Joshi, P. R. 1993).

3.5.1.4 Water conduits:

The hities from the aquifer, water is channeled through burnt clay or wooden channel (or hitidun in Newari) up to stone spouts as shown in fig 7. The water conduit is connected to the intake and it is sloped downwards towards the Hiti complex. The water flow is open channel flow, which is based upon gravity. Generally, the water conduit is placed 3m to 3.5m below the surface. A delicate balance of slope has to maintained in the water conduit, so that the particles in the water do not settle in the pipe, while also it should not be large to create scouring in the pipes. This is what is known in modern times as non-silting and non-scouring velocity

Figure 7:- Hitidun of Alko Hiti

3.5.1.5 Filtration

Filtration mechanisms are placed at different points on the water conveyance system depending upon the length and quality of water. Different types of filtration systems were found such as use of sand, grading of gravel & charcoal (Joshi, 1993 and Becher-Ritterspach, R 1994). It is said that *Lapsi* was also used in Kathmandu for water treatment in the Lichhavi Era(Tiwari, 2002).

3.5.1.6 Drainage

Drainage of the Hiti complex is an important aspect of the water system. The drain outlets are kept in hiti complex, which discharge the water to agricultural fields or ponds or rivers and they are typically called as *Dhon*. Depending upon the terrain the drainage water is utilized for functions like irrigating agricultural land, washing agricultural products, duck farming etc. However, drainage outlet is being seen as a problem in Hiti management. As hiti complex(gaa hities) are constructed in depressions, a good number of them are being rendered dysfunctional because of the damaged or clogged drainage.

3.5.1.7 Hiti Complex

The visible portion of the Hiti system is called the Hiti complex as shown in fig 8. It is an extraordinary work of art, architecture, and culture. The Hiti Complex may be close to the surface or further beneath it, depending on the topography. The intake, distance, slope, and placement all affect the complex's depth. The input water level and the outlet water level are taken into account when building the Hiti Complex. The Hiti complex will include a centrally

situated stone spout and side walls which work to bring slope stability. The complex space is also used for sun bathing and drying clothes. One can picture a hiti complex, of not being only an engineered water conduit, but also a immensely designed religious master piece of art & architecture.

Figure 8:- Mangaa: Hiti Complex

3.5.1.8 Hitimanga(Stone Spouts)

The Hiti complex will have centrally located stone spout as shown in fig 9, on one or mode side walls hanging about a meter from the base such that water can be fetched easily in the water vessel, traditionally called *ghā* and also take baths conveniently. Based on the availability of water resource and no. of users, there can be one or more spouts in a Hiti complex. There are various depictions in Hitimangaa:. One most common depiction is that of a crocodile, which is the vehicle of goddess Ganga, the goddess of water.

Figure 9: Hiti mangaa: of Patan Durban Square

3.5.1.9 Intake

The intake is the structure of Hiti which collects water from the aquifer and allows it to flow through the water conveyance system. The size and design of the intake depends on the amount of water that needs to be conveyed. A guiding principle in intake construction is that, even during the dry periods intake are so constructed that they lie below the ground water level, enabling them to function year round.

3.5.2 Socio-Cultural Dimensions of Hiti System

Management of Hiti consists of two important pillars of Guthi System and the process of ritualization, which works to bring about ownership from the level of individual to the community and the state with the system. This system is deeply intertwined with the religious and cultural beliefs of the society.

3.5.2.1 Guthi System

Newari guthis are deeply ingrained in the fabric of Kathmandu Valley society, playing a vital role in preserving cultural heritage. They are institutions responsible for organizing and overseeing various social, religious, and cultural aspects of Newari life (Toffin, 2007). These guthis are widespread throughout the Kathmandu Valley, with many Newari individuals belonging to different guthis. These organizations exhibit a wide range of characteristics; they can be mono-caste or multi-caste, mandatory or voluntary, inherited or chosen. Guthis are intricately tied to kinship, caste, and locality, shaping a Newari man's responsibilities and connections within his various communities.

In Newari culture, donating land to a Guthi is considered a highly virtuous act with religious significance. Historically, kings, influential figures, and ordinary people alike would contribute land to a Guthi, believing it would bring spiritual salvation for seven generations. Such contributions also held a prominent status symbol in society. Additionally, land endowments helped safeguard the property from potential state intervention, as confiscating Guthi land was deemed a grave offense. These factors contributed to the accumulation of land within Guthis, forming a foundation for generating regular income to fulfill their designated functions.

Individuals belonging to a Guthi are referred to as "guthiyars." Examples of guthis include Si: Guthi, primarily responsible for coordinating and conducting funeral rites for its members (Toffin, 2007), and Barahi Da Guthi, tasked with woodworking duties during the Machhindranath Jatra, among others. Guthis served purposes related to deities, the living, and the deceased, with members actively engaged in activities associated with these three themes. The management of the Hiti system also derives its structure and functioning from the Guthi System.

3.5.2.2 Ritualization:

The process of ritualization has been used as a way to bring about socially and environmentally productive behavior from the community through rituals that are set up from the sound basis of religion and cultural. There are different mechanisms to do this, such as celebrating festivals, sports, encouraging productive competition between toles etc. Examples of festivals which directly relate to the Hiti system are, Machhindranath Jatra, Sithi Nakha, Matya: etc. They have been briefly explained.

Machhindranath Jatra

The Jatra is important for this study as it relates to the water heritage of the valley. Among the many jatras happening throughout Kathmandu Valley each year, the Rato Machhindranath Jatra stands out for being the biggest and longest jatra of Patan(Yala), and featuring the highest and the biggest chariot as shown in fig 10. The deity is known as Machhindtanath, Matsyendranath, Aryalokitesvara, Lokeshwor, Karunamaya, Loknath, Padma-pani and Bunga Dyah.

Figure 10: Machhindranath Jatra

History:

Gorakhnath had come to the valley to ask for alms. The valley's residents were pre occupied with their work as it was planting season, none of them attended to Gorakhnath. Enraged by this, he meditated and trapped all the nagas in the valley. This caused drought in the valley. The then king with a renowned tantric, devised a plan to bring the guru of guru Gorakhnath, so that Gorakhnath would get up and release all the nagas. The then king, with the tantric and a porter went to get Karunamaya Lokeshwor, the guru of Gorakhnath. They were successful in bringing Karunamaya Lokeshwor, and established an idol of the guru, and took it on a chariot procession. Seeing his guru, Gorakhnath immediately got up and released all the nagas, thus bringing rain in the valley(CIUD, 2020)

Ritualization through Rato Machhindranath Jatra

The Jatra is embedded to the process of maintenance of Hiti system through the process of different rituals. The rituals are,

1. Before starting the chariot procession, all the major ponds of Lalitpur must be full with water. The procession takes place in the dry months, so the water must be filled through the state canals. This means that the maintenance work of state canals must have been completed before the monsoon.
2. The route of the procession symbolizes the connection with the water structures. The procession starts from the strategic pond(pukhu) Kamalpokhari of Pulchowk and firstly, rests at Purnachandi pukhu of gabahal. The chariot is then rested at Nuga Hiti(Sundhara), Langa pukhu(Lagankhel), and continues thereafter to end near jawlakhel Hiti and pukhu. Water from Sundhara is used in the daily ritual of Lord

Machhindra Nath during its stopover in Sundhara Tole. Water from Tanagh Hiti, Lagan Hiti and Jawalakhyo Hiti is also used in a similar manner(Joshi, 1993).

3. Even after regular annual maintenance, there is a need for larger maintainance after longer period of time. This is embedded in the chariot festival, where large water works are carried out in every 12 years, and resembling this the chariot is made anew and pulled all the way from Bungamati to Lalitpur.

Guthi System of Rato Machhindranath Jatra

The Barahi Da Guthi is responsible for making the chariot structure, which encompass the woodworks. The Chitrakars caste paints the eyes of Bhairava on the wheels of the chariot and a skilled subgroup of Chitrakar painters known as the Nyekhu paint the statue of Rato Matsyendranath every year before the night of the jatra. The Yamwa use ropes, leaves, and other natural materials to stabilize the chariot, which rises over 20 meters. (Toffin, 2007). The Ghahkhu are the brakes men who are responsible for stopping the wheels of the chariot when needed. At present, the management of the Rato Machhindranath Jatra is overseen by the Guthi Sansthan.

Matya:

Matya is an annual procession in Patan, where the participants walk from early morning up to late evening, covering various religious pilgrimages in Patan and paying respect to them. It is also done to pay home to homage to one's deceased ones. During this procession, the important structures of Hiti are also covered. The way this has been done is by installing important religious temples and idols in the structures such as Hiti complex, aquifer area etc, motivating the people to pay homage to them as shown in fig 11. This works to directly, establish a connection between the people and the Hiti.

Figure 11: Matya Procession

Sithi Nakha :

This festival is also an example of how culture has been engrained to meet societal good. It is one of the important festivals in Newar community which is celebrated annually on the sixth day of bright fortnight of Jestha which marks the beginning of monsoon(Joshi, 2021). On this day, people clean the water resources in their community such as hiti, ponds, wells etc.

3.5.3 Importance of Patan in the Hiti system of Kathmandu Valley

The ancient water systems found in Patan were not unique to that city but were widespread in many Newar settlements both within and beyond the valley. While urbanization has nearly wiped out the traditional water system in Kathmandu and posed a threat to Bhaktapur and other smaller settlements, Patan stands out. Despite being the second-largest city in the valley and facing challenges, Patan still relies partially on water from stone spouts and wells. Although the cultural ties to traditional water management are slowly fading, recent efforts in Lalitpur to preserve stone spouts and ponds are a positive development(UN Habitat, 2008). Therefore, for the purpose of this study, we concentrate on Patan in Kathmandu, as it provides a more effective illustration of the Hiti system's role as a nature-based solution and its significance in addressing water security.

3.5.3.1 Hiti System of Patan

Patan is located on the northern slopes of Phulchwoki and the southern hills of the Kathmandu Valley, with the Bagmati River to the north. The historical water system of Patan includes a canal called rajkulo, connected to ponds (pukhu) and water conduits (Tiwari, 2002). This multipurpose canal, originating 16 km south of Lagankhel, channels water from Lele and Naldu rivers. It irrigates fields, serves settlements, and reaches cascades of ponds at Lagankhel. Overflow from Lagankhel's Pukhus, including Paleswan Pukhu and neighboring ponds like Pode Pukhu, flows to Jagmadu Pukhu. A sub-channel links to Purnachandi Pukhu. Once Jagmadu Pukhu is full, excess water is drained through Nhyandha canal, passing Ashok Party Palace, and finally into the Bagmati River. Another canal from Lagankhel Pukhu goes to Prayag Pukhu, then to Bhandarkhal Pukhu through an open drain. After Bhandarkhal Pukhu, the drain becomes underground, flowing to Chyasal and eventually into the Bagmati. The open drain, known as Hakha Khusi, is remembered by the older generation (UN Habitat, 2008). Patan had various canals providing water for washing and cleaning. A similar system exists in Sankhu, and it is believed that Chapagaon had a similar system until recently.

3.5.4 Destruction of Hiti

The Hiti system originated as a fusion of knowledge from the Kirat and Lichhavi periods, and it saw significant expansion during the Malla period. A key factor behind its continuous development was the willingness of successive rulers during that era to embrace and contribute to its growth. However, a different scenario unfolded during the Shah and Rana rule, where the rulers seemed largely unaware of the valuable knowledge associated with the Hiti system (Joshi, 2007). During this period, there was a failure to fully appreciate the importance of the Hiti System, leading to an excessive reliance on the Municipal Water Supply System and a disregard for the Hiti system. Unfortunately, the Municipal Water Supply System proved inadequate to meet the valley's water needs (Joshi, 2021). The introduction of municipal water supply was seen as a convenient replacement for the traditional Hiti system, and the lure of having water taps individually in homes led the community to one by one abandon the traditional Hiti system (Joshi, 2007). As a result, people gradually shifted from traditional sources to municipal supply, leaving the spouts neglected and ill managed, which became a major cause of their deterioration. Nevertheless, the elderly continued to visit the Hiti to collect "nilah," i.e. the pure water, for their daily religious ceremonies and rituals. Due to the unreliability of municipal water, some still used Hiti for washing clothes and bathing, particularly among the urban poor, for whom the Hiti system remained a dependable source of

water. The state ignorance or some level of interference to Guthi and Guthi land, which was the pioneer institution for the management of various culture and rituals, created a lack of ownership to the rich heritage of valley. The people who were mainly based on subsistence economy, were also not much aware of these happenings. The knowledge of land use in general and urban land use in particular is the weakest aspect of current city management. The administrators were unaware of the ecological surroundings and environmental services that land provides. The inability to comprehend land and its uses, by the state and the population in the later time, eclipsed the profound knowledge of land use developed by the Kirats, which was extended during the Lichchhavi time and further devleloped by the Mallas (UNESCO, 2008).

3.6 Methodological Review

The usage of Nature Based Solutions in addressing Water security is being studied with advanced monitoring systems in developed cities. Organization and institutions such as IUCN, World Bank, UNEP, governments etc. are working by establishing real time data monitoring systems. This data is being used by researchers such as Ozment et al., (2015), Vigerstol et. al., (2023) and alike, to establish the urgency, usage and method of Nature Based Solutions in water security. However, in context to the study area, such extensive data are not available. Prominent researchers in this field such as Creswell(2001), Thapa et. al (2018), have estimated the scenario of water security in Kathmandu Valley through indirect means such as reports, simulation and sample study. Further, the research in Hiti system has been mostly limited to qualitative in nature. The recent works of Joshi(2021), a prominent researcher in this field, is also limited to the qualitative understanding of the Hiti system.

3.7 Legal Framework

In the Constitution, the federal and province governments are granted concurrent responsibilities for water supply and sanitation (Schedule-7), and “basic health and sanitation” is assigned to local governments (Schedule8). As such, the Constitution clearly recognizes the fundamental rights of citizens to “access to clean drinking water and sanitation” as laid out in Article 35. The Article 30 recognizes that “every person shall have the right to live in a healthy and clean environment,”. In an international level Nepal is a signatory of the 2010 United Nations Resolution on the Human Right to Water and Sanitation (UNGA 2010). .

In line with these framework, the National Urban Water Supply and Sanitation Policy, 2014 has been adopted which aims to provide 100 lpcd for domestic purpose in areas of high service.

As Kathmandu Valley is the highest urban conglomerate of the nation, high level service is expected. According to WHO guidelines, 135 lpcd of water is needed for domestic purposes.

The Water resource act 2049, and its subsequent rules, the Water resource rules 2050, are the major legislative framework on water resources. It has been in place for the rational utilization, conservation, management and development of the water resources that are available in the Nepal in the form of surface water, underground water or in whatsoever form. However, the implementation phase has not been much satisfactory. For e.g. the Water resource strategy was placed in 2002. The strategy had different output objectives, of which a few are, by 2027, quality of watersheds will be increased by 80% in all regions, and by 2012, 100% coverage of water supply. It is evident that both these outcomes have not yet been fulfilled.

Later, National Water Plan was enacted, which introduced the principles of integrated water resource management. The integrated water resources management (IWRM) principle professes that water must be viewed from a holistic perspective, both in its natural state and in balancing the competing demands on it, e.g. domestic, agriculture, hydropower, industrial, cultural and environmental.

However, this was also not much successful, which was professed in the National Water Resource Policy (2077). The most recent policy, the National Water Resource Policy(2077) was enacted with the aim to conserve and promote water resources while pursuing multipurpose development and sustainable usage of water, in order for economic growth and societal change. This policy calls for the co-ordination of Federal, Provincial and Local government to conserve and develop water resources. In accordance to this policy, the strategy 3 and 10 of this policy is relevance to the present need of conservation of Hiti. The Strategy 3 states that there will be provisions for the conservation, development, management and institutional arrangement for water resource area. The Strategy 10 states that the impact to social, cultural and environmental dimensions will be maintained to a minimum during the usage and management of water resources. Further sub clause 10 of this strategy states that the framework will be placed to stop the over extraction of ground water resources. The rational usage of Hiti can be envisioned through the clauses of this policy.

3.8 Institutional Framework for water management in Kathmandu Valley

The Water Supply Management Board Act of 2063 created the Kathmandu Valley Water Supply Management Board (KVWSMB or Board), an independent government agency. The Ministry of Water Supply and Sanitation is the reporting line ministry. All assets connected

to the water supply and sewage system in the Kathmandu Valley are owned by KVWSMB. It is accountable for creating and enforcing service policies, licensing service providers to operate and manage the water supply and sanitation service system in the Kathmandu Valley, and monitoring those operations to guarantee that enough potable water is supplied to consumers at a reasonable cost with an acceptable residual pressure head.

Under a License and Lease Agreement with the Kathmandu Valley Water Supply Management Board (KVWSMB) for 30 years, Kathmandu UPatyaka Khanepani Limited manages the water supply and wastewater services in the Valley. The government established Kathmandu Upatyaka Khanepani Limited (KUKL), a public corporation registered under the Nepal Government's corporation Act 2063 and operating under the Public Private Partnership (PPP) model, to provide water delivery in the Kathmandu Valley.But, with the enactment of federal structure from 2015 and the enactment of Local Government Operation Act(2017), the role of municipalities and rural municipalities are being more and more crucial in water management in the local context, and central level agencies such as KUKL are mostly focused on larger water projects.

CHAPTER FOUR: STUDY CONTEXT

The research is based on the study of water security issues of Kathmandu valley. Then the two case areas of Alko Hiti and Pimbahal pond, which are two successful examples of restoration of Hiti system within the Kathmandu Valley is studied, with the aim of assessing its features and drawing out results which may aid regenerating Hiti system in addressing water security of the Valley.

4.1 Kathmandu Valley

The Kathmandu Valley is the largest urban agglomeration in Nepal, located between 27.537° and 27.819° N latitude and 85.1919° and 85.5272° E longitude as shown in fig 12, and is surrounded by hills in the periphery. The Valley is elliptical in shape with a diameter of 25 km N-S and 30 km E-W. The average altitude of the Valley is 1350 meter above sea level (masl), however, surrounding hills can reach as high as 2800 msl in elevation. The Valley is in a semi-tropical zone, has a warm and temperate climate, and receives more than 80% of its total annual rainfall during the monsoon between June through September. The average annual rainfall was 1340 mm and 1500 mm in 2017 and 2018, respectively (DHM 2019).

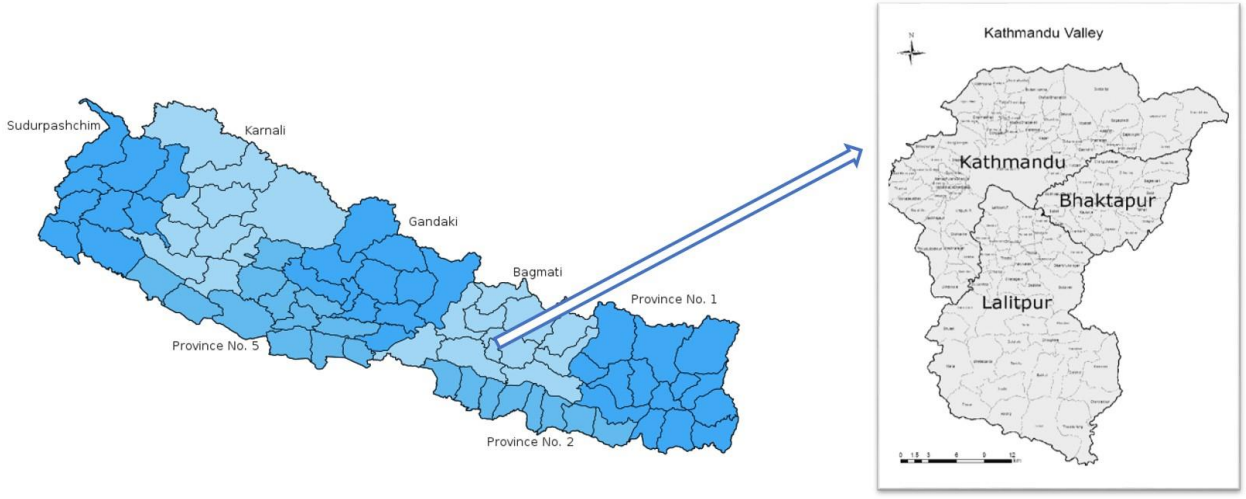


Figure 12: Location Map of Kathmandu Valley

4.1.1 Geological Formation

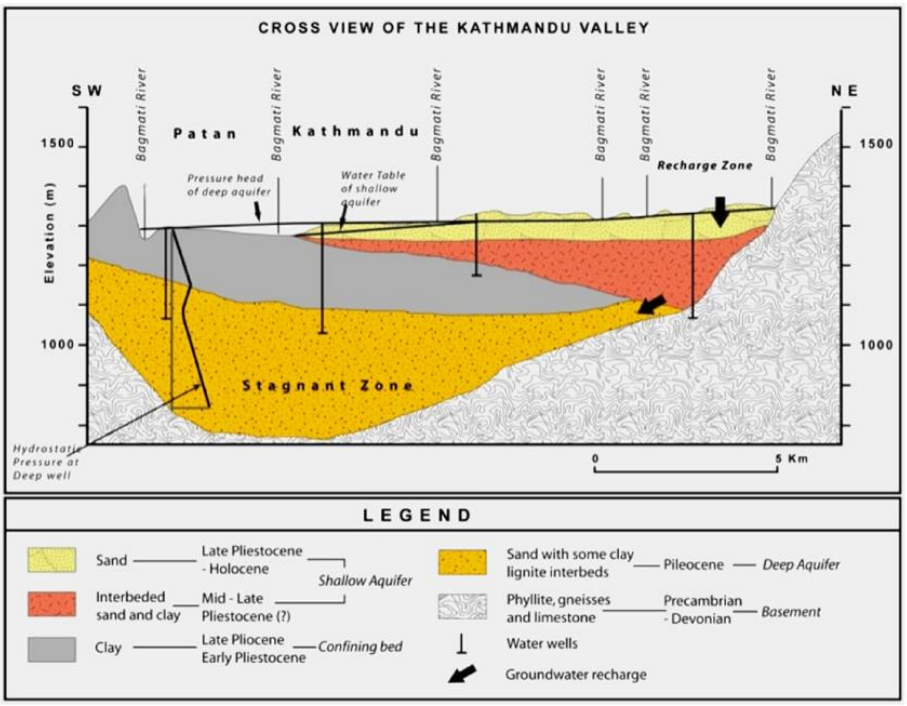


Figure 13: Geological Formation Kathmandu Valley

An upper, unconfined aquifer consists of discontinuous, Late Quaternary sand, silt and clay lenses and is up to 20m thick in places. This overlies on an aquitard of black clay containing peat and lignite bands. Benath the aquitard is a sequence of Pliocene sand and gravel beds, intercalated with clay, peat, and lignite. These sand and gravel beds collectively comprise the deep, confined aquifer(Cresswell et. al, 2001). In this way there are three layers to the Kathmandu Valley ground water system compromising of, Shallow or Unconfined Aquifer, Aquitard (Clay Layer) and Unconfined Auifer as shown in fig 13.

4.2 Water Security Context of Kathmandu Valley

The Water security context of Kathmandu Valley can be broadly divided into Water Stress and affordability, Groundwater Depletion and Urban Pluvial Flooding.

4.2.1 Water Stress and affordability

According to the 2079 annual report by Kathmandu Upatyaka Khanepani Limited, which is the responsible organization for the operation and management of water and wastewater services in the valley, out of the total demanded 472 Million Litres per day, KUKL has an average production of 126.55 MLD. Factoring a loss of 20%, an average supply of 101.24 MLD is

obtained from KUKL piped supply (KUKL, 2021). This ushers a deficit of 345.45 MLD, owing to the water stress in the valley. Even with the introduction of Melamchi Water Supply project in 2021, which introduced 170 MLD (excluding losses) to the valley, the supply has not been reliable enough and the distribution has not been accessible to all. The project has been facing serious issues in the monsoon due to landslides, most notably in the Melamchi Floods of 2021. According to KUKL the project is still in testing phase and, metering and billing of the project has not yet commenced. However, in best case scenario, if we are to add the whole of Melamchi Water Supply Project including losses and present KUKL supplies, there would still be a defecit of 234.76 MLD in the present context, which is expected to grow steadily. Best case scenario of KUKL Water Supply (Considering 20% Loss)

KUKL Existing Water Supply	101.24 MLD
Melamchi Water Supply	136.00 MLD
Deficit	234.76 MLD

Figure 14:- Present Water Supply Condition

To cover this gap, the population of the valley have been relying on different sources such as wells, tube wells, stone spouts, jar, tanker etc. According to census 2021, only 45.7%, 44.3%, 50.2% of the households in Kathmandu, Lalitpur and Bhaktapur respectively, identify taped water within their compound as their main source of drinking water. From the same report, it can be inferred that there is a high dependence upon jar water in the Valley. This scenario underlies the water stress of the valley, and its implications in socio-economic disparity.

According to the annual report of KUKL 2021, there were 22694 trips of water tankers of which 2072 trips were by government and 20622 trips were by private tankers in the fiscal year of 2078/2079. Considering the standard size of tankers of 7000 liters and 10% losses, this accounts to an average of 4 MLD. Up to ten thousand liters, KUKL charges a fee of Rs150 (Rs 100 for water and Rs 50 for sewage), while private water supply companies charge a fair of Rs 2000 to 2500 (based on quotation from 3 private water supply companies) for 7000 liters of water, which is 21 times that of KUKL water supply. Also, The Department of Commerce, Supplies and Consumer Protection (DoCSCP) fixed the price of 20l jar of drinking water to be Rs 47 in 2022, which is around 155 times more than that of KUKL water supply. In this context, where KUKL has limited distribution and private tankers and jars are expensive, water affordability has become a major issue. In instances, hitis are still the only source of water for many; especially for the urban poor(Joshi, 2015).

4.2.2 Groundwater Depletion

In line with this water stress, the population of the valley have been relying heavily on ground water. Out of the average production of 126.55 MLD of KUKL, an average of 40MLD is supplied through ground water source (KUKL 2021). Udmale(2016), suggests that nearly half of the valley's total water supply during the wet season, and 60%–70% during the dry season, comes from groundwater sources supplied by KUKL. In early 1990's, JICA(1990), warned about the ground water depletion of Kathmandu Valley, and that the then rate of extraction was twice as that of the available capacity. As stated before, KUKL is not able to cater to the whole of valley, so private entities and households take it to themselves to extract and use ground water sources. In lieu of this, there have been over extraction of water to meet the increasing water demand. In year 1991 and year 2001, the ground water recharge rate was 9.6 MCM/year while the rate of extraction was as high as 40 MLD (or 14.6 MCM/year) and 59.06 MLD (or 21.56 MCM/year) respectively (Pandey et al., 2010). Many different studies (Dixit and Upadhya, 2005; Pandey et al., 2010), show the heavy rate of groundwater extraction as compared to the recharge. Overexploitation of groundwater has lowered the groundwater level by 1.38–7.5 m during 2000–2008 (Pandey et al., 2010). Others research show that the overall rate of groundwater extraction exceeds the rate of natural recharge capacity by 6 times, thus causing the decline in the groundwater table by approximately 2.5 metres per year (Shrestha et al., 2009). Shrestha et al. (2020) further expands that groundwater in most of the core urban areas of the KV are more vulnerable in comparison with the peri-urban areas due to rapidity of urbanization.

As mentioned in section 4.1.1, the Kathmandu Valley consists of a shallow aquifer and confined aquifer system. Though shallow aquifers can be replenished and thus there is space for its recovery, but confined aquifers cannot be replenished. Our heavy reliance on confined aquifer is thus a serious threat. In confined aquifers, Cresswell 2001, estimates that at least 20 times the amount of recharge is being pumped from deep aquifer. This trend has only increased with the growing population. Cresswell,2001 further estimates that, the resource will be depleted below present extraction levels within 100 years & this confined aquifer source is not a renewable source as the maximum age for the deepest waters, furthest from the recharge zone is 400,000 years, while the minimum age is more than 200,000 years for the deepest waters from the study. An estimate of confined aquifer usage can be made through the data of KUKL annual report 2021, which states that KUKL owns more than 107 deep tube wells (DTWs), 19 dug wells, and 32 pumping stations (KUKL, 2021). This shows that most of the supply of

KUKL through ground water is through deep tube wells. This coupled with the trend of private entities and businesses to construct private boring facilities has led to serious depletion of ground water in confined aquifers.

4.2.3 Urban Pluvial Flooding

By using satellite images, Devkota et. al 2021, have identified that Kathmandu valley has witnessed a maximum increase in built-up areas with 206.88 km^2 (368.06%) increase during the period of the last thirty years (1990 to 2020). The built-up areas occupied 8.05% (56.21 km^2) in 1990, 12.2% (85.12 km^2) in 2000, 22.76% (158.86 km^2) in 2010 and 37.7% (263.09 km^2) in 2020. This transformation limits water infiltration and increases the speed and the amount of water run-off on the ground (Salikhe, 2017). The water run-off on the ground has resulted in increased urban pluvial flooding. Urban pluvial flooding, a product of inadequate management of the urban drainage system and strongly correlated with built-up areas and climate change, has become more evident in urban areas of Nepal, especially Kathmandu Valley. The urban services of the area, such as roads, roofs, parking lots, etc., replace the permeable soil with impermeable surfaces that store little water. This in turn decreases the ability of the land to absorb rainfall-runoff, reduces infiltration of water into the ground, and accelerates runoff to ditches and drainage systems, overwhelming the drainage system and resulting in urban flooding. (Salikhe & Pokhrel, 2016). According to a study done by Salikhe & Pokhrel(2017), based on the urbanization and climate change conditions for the case of Kathmandu Metropolitan City, there will be a 40 percentage increase in the flooding amount considering the current and future climate for a 25 year return period.

So, with increasing water stress and unaffordability, decreasing ground water levels and increased risk of urban flooding, the water security of Kathmandu Valley is under serious pressure

4.3 Case Area Selection

In this research the water security context of Kathmandu Valley is analyzed and the measures to address this through the Hiti system is addressed. For this, two cases namely Alko Hiti and Pimbahal pond of Patan, were taken as two cases of the Hiti system, so as to research **the common characteristic** of Hiti system through the two case studies, which can then be used to address the water security of Kathmandu as a whole.

Also, both the Alko Hiti and Pimbahal pond lie in Patan. The Valley has three major systems of Hiti viz. The Kathmandu System, the Bhaktapur system and the Patan system. Out of all these systems Patan has comparatively better maintained Hiti system. Moreover, the cultural linkages to Hiti system still remains strong, though it is losing ground slowly (UN Habitat 2008). As the study entails assessing the features of Hiti system, which can be better assessed on a well-functioning Hiti system these two cases of Patan were choosen.

4.4 Case Area: Alko Hiti

4.4.1 History

Alko Hiti Complex is situated in Ikhachhen tole, which is a historic Newar tole in Patan, presently lying in Ward 11 of Lalitpur Metropolitan City as shown in fig 15, of Kathmandu Valley. The existing city gate right next to the hiti shows that this tole was the north-western end of old settlement of Patan(UN Habitat, 2007). The inscription in the Hiti complex states that the Hiti was established in 535 Nepal Sambat or 1415 AD by the forefathers of Bajracharya family living nearby the Hiti complex as shown in fig 46(Annex C), during the reign of the Mallas in the Valley. The Hiti is considered to be one of the highest discharging Hities of Patan . Legend has it that once the wife of Nagdevata was unwell. Nagdevata then approached the then famous tantric Tumhadev Bajracharya, who eventually cured her. In return, Nagdevata asked Tumadev to ask for anything. As the settlement had problems with water, Tumadev asked for water. This is how Alko Hiti came was made.

Figure 15:- Alko HIti

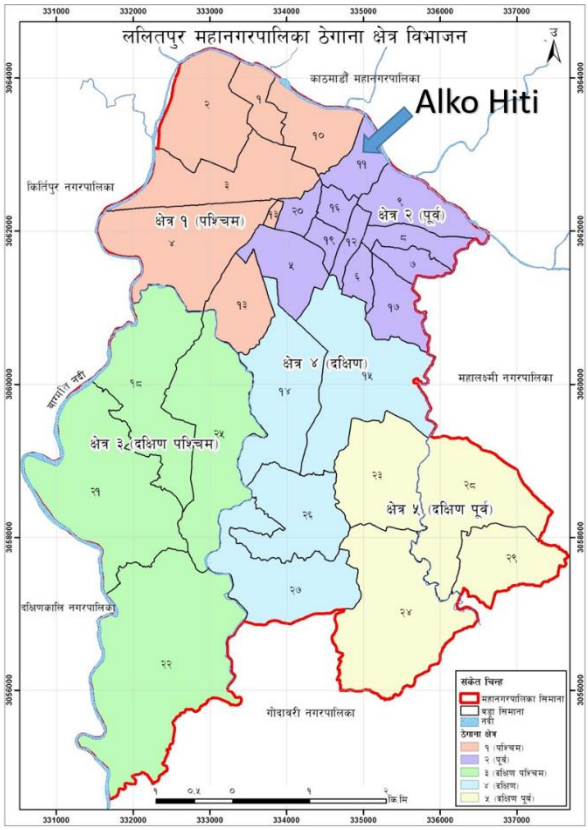


Figure 16: Location Map of Alko Hiti in Lalitpur Metropolitan City

4.4.2 Geology of Alko HIti

The slope of Patan tends downwards from South to North. Lagankhel which is south boundary of Patan, is at a level of 1331.90 from sea level, and this tends downwards North to Alko Hiti(Ikkhachen Tole) at 1294m from the sea level, which is the northern boundary of Patan, and then the slope tends further north to Bagmati River(Joshi, 2021). The Alko Hiti region has a gravel formation which could be found as near as 18 inch from the ground level. This gravel formation is part of the Tikabhairav Formation underlain by clay soil. According to the KII with Mr. Padma Sunder Joshi, he suggested that the region also has a clay layer which blocks further passage of water in the region. These conditions make formation of a strong aquifer system possible.

The ground water flowing from South to North, owing to the geography is trapped by the aquitard i.e. black clay. And as gravel layer is available within the aquifer, easy extraction is possible.

4.4.3 Features of Alko Hiti

There are five Hitimangaa(stone spouts) in the Hiti Complex which collectively discharge water in the range of 3 lakh litres in dry seasons to 6 lakh litres in the wet season. The complex also has numerous shrines such as the Ganesh Mandir, Shiva linga, Budha etc. as shown in fig. 47(Annex C). The Hiti is charged through three sources as shown in fig 16.

Figure 17:- Source of Hiti

The Hiti complex has three different sources and distributes water from 5 stone spouts.

1. The source of Narayan Hiti is believed to be inside the Ganesh Temple lying North East to the Hiti.
2. The source of the other two Hities on the North are believed to lie in the ground, which is east of the Hiti complex.
3. The source of these two Hities is believed to lie in the ground south of the Hiti complex.

Hiti Structures

The intake structure for source 2 is shown in fig. 17. Water is trapped from the aquifer through this intake and channeled through a pipe which is either made up of wood or terracotta called the Hiti dun as shown in fig 18, then with the help of other substructures such as athal, tepa etc. as shown in fig 19, the water is channeled to the Hiti complex.

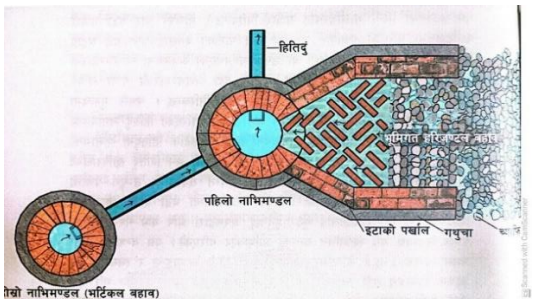


Figure 18: Intake Structure of Alko Hiti, Source:- Hiti Pranali

Figure 19:- Hiti Dun

Figure 20:- Hiti Substructure (Tepa)

4.4.4 Alko Hiti Water Management System

An interesting incident happened some 20 years back, when the locals were faced with severe water scarcity, and they united to form Aalok Hiti Conservation and Water Supply Users Committee in 2003. This committee was tasked to create a water collection system by harvesting water from the Hiti and distributing it via pipes to individual households and within a few moths they were able to complete the project and it is running efficiently till date, which has vastly added to the water security of not only Ikhachhen tole, but also that of nearby toles.

Water is collected from the Hiti through a pipe leading to a collection drum as shown in fig 20. The collection is done mostly after 12:30 noon and depending upon the necessity it may be carried on till 8 to 9 p.m. Also, during the time of this case study which was in the month of Asar, water was available in high discharge in Hiti, so only two Hiti spouts were tapped. Depending upon the necessity, all three spouts can be tapped. But, the remaining two spouts are left for consumption, even in the time of pumping. This water is then pumped upwards as shown in fig 21 to an overhead tank reservoir as shown in fig 22, of ten thousand litres through a pipe having 1-inch diameter.

Figure 21:- Water Collection from Hiti

Figure 22: Pump

Figure 23:- Overhead tank

The water is then distributed to individual houses through underground pipe lines. The underground pipelines extend upto households within the periphery of 400 to 500m The main pipe from the overhead tank in laid into different junctions(Chowks). In these junctions, a joint box is installed, through which pipe of diameter 0.5 inch is connected to individual households. At present there are two saffs working for the project which is managed by the Tole Sudhar Samiti and there are 180 registered housholds paying 250 monthly.

4.5 Case Area: Pimbahal Pond(Pokhari) or Jagmadu Pukhu

4.5.1 Introduction

Pimbahal Pond or in local term “Jagmadu Pukhu” lies in Ward no. 19 of Lalitpur Metropolitan City of Kathmandu Valley as shown in fig 24. It was built around 14th century. Legend has it that once a lakhe, who was in love with a woman, would transform into a human to meet her. One day she could not meet him in their usual place, as she had to go to fetch water from a far source. So, the lakhey made a pond which came to be known as Jagmadu pond in one single night, so that she wouldn’t have to go far to fetch water and they could meet again. With reference to the types of pond in the literature review section 3.6.1, the type of this pond is ponds within the settlement, which was used for domestic as well as irrigation purposes. The state canal connected to Pimbahal Pukhu and then to present day Ashok party palace and would discharge to the Bagmati river after irrigating the fields(UN Habitat, 2008). A picture of the old Pukhu is shown in fig 48 (Annex C).

Figure 24: Pimbahal Pokhari

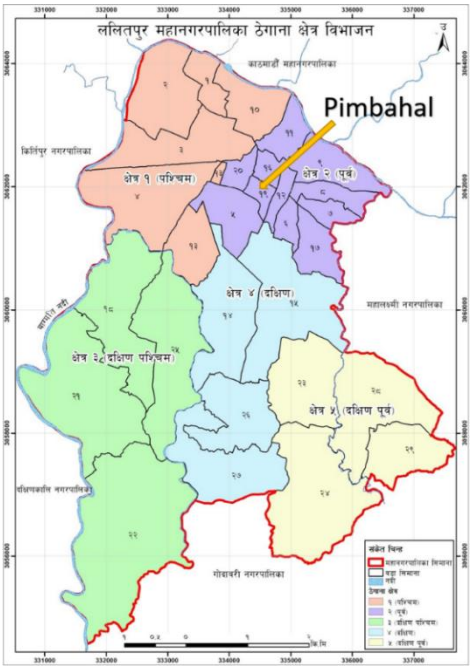


Figure 25:- Location Map in Lalitpur Metropolitan City

4.5.2 Destruction of the pond

However, during and after the Panchayat era the Pukhu underwent through a series of deformation. Even Before 2017 A.D, the situation of the pond was quite poor. The water level went so low that bushes grew upon it and people could walk around it. People also threw their household garbage in the pond. All sorts of pipes carrying the dirt drained into it as a result of this situation was that people there suffered from mosquito infestation. So there were proposals coming in to convert the pond into a shopping center, park and only a small portion to a pond.

4.5.3 Revival of the Pond

However, with the active efforts of the community led by Mr. Shailendra Shrestha, and financial aid from World Bank PURPP, (Pro-Poor Urban Regeneration Pilot Project) in 2017, things took a different turn for the good. The restored pond is one of the most successful Urban regeneration project of World Bank in Nepal. The main theme of this project by world bank was to conserve tangible and intangible heritage while also fuel economic regeneration. The place is now a famous tourist attraction with hotels and restaurants steadily propping up.

During the regeneration of the pond, the bed of the pond is still untouched, with loose brick layer added and the retaining walls of the pond have rebuilt. The surrounding areas have been paved. Mr. Shrestha says that, "*Local Participation and instilling a feeling of self ownership was the main reason for this success*." He further attributes that, removing the compound walls and making the pond visible also attracted people towards the place. Presently, with the introduction of boating and fish farming and collection of minimal fare from the surrounding houses, the pond has been self-sustaining. But of all, the outstanding feature of this pond is the construction of its Rain Water Harvesting System.

4.5.4 Rainwater Harvesting System

The project has a well-functioning system of inlet and outlet. The inlet consists of a Rainwater harvesting system providing for year round availability of water to the and the outlet system drains to the municipal drain which is used minimally.

The system consists of a surface drain laid from about 167m from Chabahal Gate upto the pond as shown in figure 25. The two drain lines from Chahabal Gate are as shown in the fig. The rain water is allowed to flow in these drains with adequate slope and enters the main drains 1 & 2(fig 26). This water is then sent to the collection chamber (fig 27), and discharged to the pond after primary sedimentation. Rain water also enters from sedimentary

drains laid around the pond. There are in total 9 secondary drains as shown in fig 28. The drain inlet system is as shown in the fig 27. Also, there is an outlet drain located in the North East corner as shown in the fig 30, which is connected to the municipal drain. This eliminated the need for municipal drain for storm water for the route lying from Chahabahal Gate to the pond and the service road of the pond.

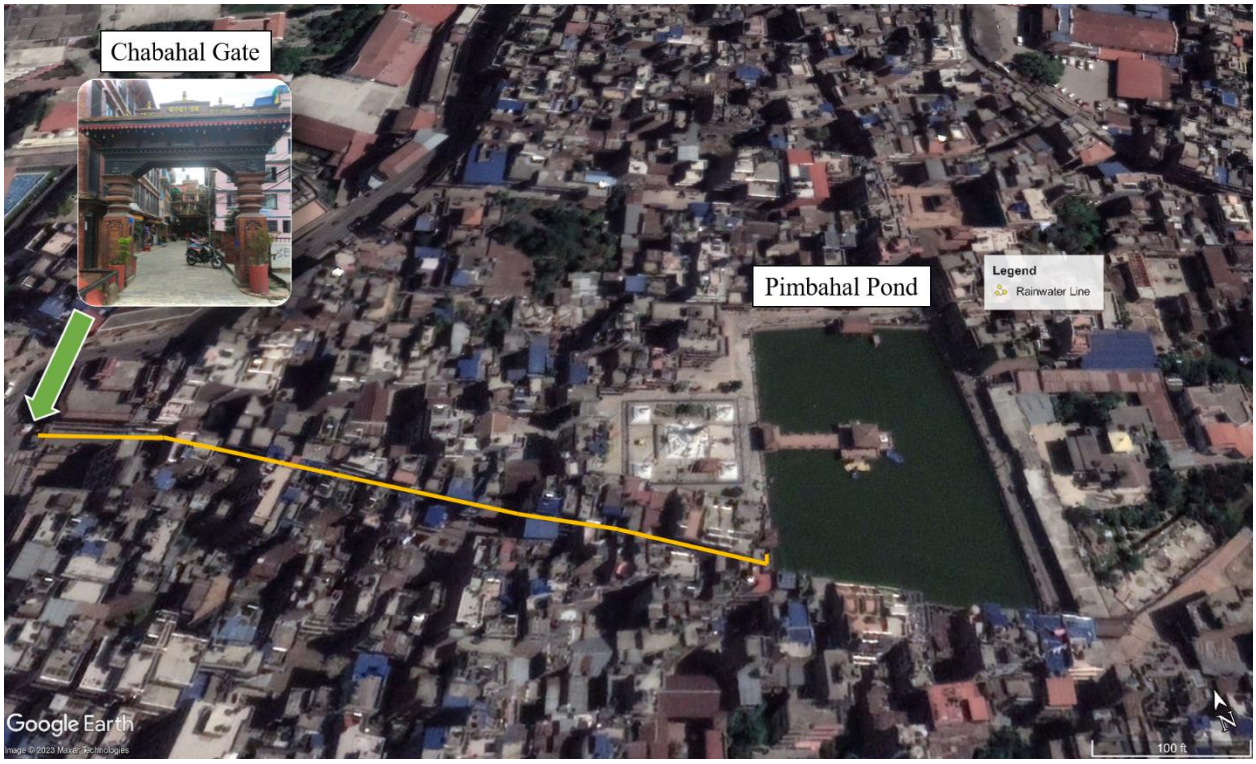


Figure 26:- Rainwater Collection Line of Pimbahal Pukhu

Figure 27:- Drain Lines and Drain

Figure 28:- Collection Chamber

Figure 29:- Inlet and Outlet Points

Figure 30:- Inlet Drain

Figure 31:- Outlet Drain

CHAPTER FIVE: FINDINGS AND ANALYSIS:

The findings and analysis of both the case areas of Alko Hiti and Pimbahal Pond have been presented.

5.1 Findings and Analysis of Case Area: Alko Hiti

The findings are based upon field observations, semi structured interviews, key informant interviews and document study.

5.1.1 Protection of Sources(Aquifer)

The sources have been mapped in figure 16. This section the protection initiatives taken to protect these sources.

5.1.1.1 Source: - 1

The Ganesh Mandir as shown in fig. 31, which is the source of Narayan Hiti is protected by building a temple, so that no one would be able to do any harm to the source of Hiti as shown un figure. Ritual Mediation has been adopted as the means for this source protection.

Figure 32: Source 1

5.1.1.2 Source 2:

The playground to the east of Hiti is also well protected as a community space as shown in fig. 33. Previously it was subjected to attempts of physical infrastructure development, but due to stern community resistance it now lies protected within the boundaries of the complex as shown in figure.

Figure 33:- Source 2

Figure 34:- Present State of the source

Both the playground and Ganesh Mandir lie within the wall boundary of the Hiti complex, thus maintaining it as a public space.

5.1.1.3 Source: 3

However, the source to the south of Hiti is a privately owned land. The source 3 of Hiti is said to lie in the land as shown in fig. In addition to this, the 4 ropanies(around) of land of this area is also said to be the aquifer of the Alko Hiti which was owned by the guthi of the Alko Hiti, according to senior locals. Its urgency for protection arose due to a bone mill incident in 2000 A.D. A bone mill was being run on the aquifer area of Alko Hiti in that time. In time the blood from the bones seepaged into the aquifer, which caused around 12 people to be sick and few of them had to be rushed to the hospital. This incident enraged the community and they tried to remove the mill by taking assistance from the local bodies and government. But, the government did not show much interest in it and later the people resorted to protests which was supported by people from other neighboring toles as well, and this time they were successful in removing the mill. This incident led them to be more careful towards aquifer protection. When this movement was gaining momentum, there were attempts to sell the land having the source 3, but this too did not succeed, as this time around the local people were much more aware. Presently, a board has been kept near the periphery of the land as shown in fig.35, warning people not to make any physical infrastructures on this land as show in fig. The current condition of the source 3 has been shown in fig. 51 (Annex C)

Figure 35:- Board placed by the community

It was through these community efforts the ecologically sensitive areas of the Hiti were protected, enabling Alko Hiti to flow prosperously. Further, a pond has been developed and the area north to Hiti has been developed as a children's park as shown in fig. 49 and 50(Annex C) respectively, further adding to the protection of the aquifer region.

After the success from the bone mill incident, and the evident water scarcity, the local activists had understood that without easy access to water, the local participation in the functioning of Hiti would not be possible in the long run. So they looked into the earlier proposed plan of water collection from Hiti proposed in 1985 by NWSC and UDLE in 1993. Motivated by this, the youths of Ikhachhen formed a committee with the leadership of Mr. Sushil Shrestha on October 2003, having their main task to harvest water from the Hiti and distribute it to households doorsteps.

After, failing to gain any momentum on multiple attempts of outside funding, the committee decided to start the project locally. Their first project was to build a building for the overhead tank for which the locals worked enthusiastically and voluntarily. The youths went as far as carrying sand from the Bagmati basin to build the building. The building was built within 3 months and at a cost of 3 lakh rupees(the cost of similar buildings was 10 lakhs then). Further overhead tank of 10 thousand litres was installed in the tower and as local enthusiasm grew, so did the support for the project.Pipes were laid onto each household and in March 28,2004, water distribution commenced and has been serving for the past twenty years. There are 185 households presently benifitting from the project.

This project enabled a community in a then water stricken Patan, Kathmandu Valley to be independent of municipal water system i.e. Kathmandu Upatyaka Khanepani Limited(KUKL). Infact, the community did not join KUKL lines up until now, for the laying out of Melamchi Project.

However, the Melamchi Water supply line has been inconsistent to the people. When this study was being performed the locals said that the water line had been halted from last week. However, the people of Ikhhachen did not have to face issues of water security as their community based system was up and running.

5.1.2 Field Data and Analysis: -

1. Reserve Tank Capacity: - 22000 liters

Analysis:

This method of ponding the Hiti water also helps to solve the critical issue of drainage of Hiti system, which most Hiti's suffer. During, the fast paced urbanization of the last three decades, the traditional drainage mechanisms have been damaged to a large extent. This causes water log in the Hiti, which increases the possibility of abandoning the Hiti entirely.

Through this management scheme, however, the altitude of the Hiti water is raised, and thus enabling easy drainage. Also, this scheme, enables the use of water which would otherwise have gone to waste.

2. Discharge: The discharge of the Hiti was approximately measured in the site and it was found to be,

Hiti Designation	**Discharge(l/s)**
A	2.85
B	1.5
C	0.5
D	1
E	0.5

Total Discharge = 6.35 litres/ second

So the total discharge was found to be 5,48,640 litres per day.

Analysis:

The data from secondary source which stated that discharge of Hiti is measured to be 3,00,000 litres per day in dry months and 6,00,000 litres per day in wet months, was verified.

3. Water is supplied at an average of more than 200l per day.
    a. Water per capita of Kathmandu Valley = 34l (Nagarik, 2017)
    b. Considering an average family size of 4 members,
        i. Water Supplied by Alko Hiti Scheme = 200/4 = 50lpcd

Analysis:

The data shows that water per capita of Alko Hiti management scheme is higher than that of average of Kathmandu Valley. Also, the Hiti has been supplying water continuously from 2021 (when Melamchi was introduced) throughout the year, in a time when KUKL water supply has been facing issues with regards to continuity. This asserts the role of Alko Hiti Management Scheme in aiding to the water security of Ikkhachhen and nearby toles.

4. Water Quality measurements have been done and have been found within drinking water standards.

Analysis:

The management committee claimed that water quality testing is being done periodically by government agencies and that the water was safe for drinking.

5.1.3 Demographic data of Interviewees

There were a total of 185 households connected to the Alko Hiti Distribution Network. Amongst them, 20 households were interviewed. There demographic data, pertaining to them are,

1. Gender:

   Somewhat higher percentage of female were involved as compared to males.

Gender	Number	Percentage
Female	12	60
Male	8	40

2. Age:

   People above 40 were found to be more engaged in the household water management.

Age Group	Number	Percentage
50 Plus	5	25
40 to 50	7	35
30 to 40	5	25
20 to 30	3	15
Total	20	100

3. Caste: As the society is a Newar society, most of the people interviewed were Newars. The Bhramin family had been staying in the community for more than 30 years, and have been integrated in the community.

Caste/ Locals	Number	Percentage
Shrestha	6	30
Shakya	6	30
Tandukar	3	15
Bajracharya	2	10
Bhramin	1	5
Maharjan	2	10
Total	20	100

5.1.4 Findings from Semi Structured Interviews

No. of Households interviewed = 20 households

1. The number of people who had used external water source (for e.g. water tanker) in the last year was zero, while the percentage of respondents using external water source was 50% in the last five years.

   Analysis:

   The external water source was used during the dry months of Poush-Magh, when the discharge from Hiti was very low. Respondents unanimously agree that this is due to boring hole projects nearby such as the one in Konti, which is within 200m radius of Alko Hiti. They say that when the boring projects are operated there is a visible effect on the discharge of the water of Hiti. But, this year due to the introduction of Melamchi water project, there has been less strain on boring projects and so this year the Hiti did not dry up, so there was no need for external water sources. Though the old KUKL lines were not connected to the tole, they decided to connect the Melamchi Water Supply Project line last year, which also has been supplying water on an irregular basis. At the time of this study, the Melamchi project did not supply water to the households, however, this was not an issue as they had the security of Alko Hiti.

2. When the respondents were asked to rate their satisfaction on a five-point scale of the project,
   a. Highly Unsatisfied
   b. Unsatisfied
   c. Neutral
   d. Satisfied
   e. Highly Satisfied

   75% responded with highly satisfied and the remaining with satisfied.

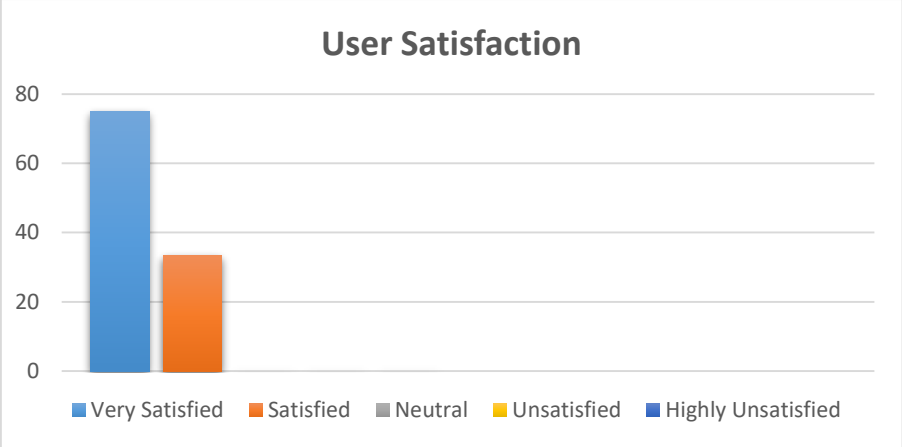


Figure 36: User Satisfaction

Analysis:

Even though the provided water by the project is below the per capita water supply requirements of 135 lpcd, people still responded with satisfaction. This can be attributed to the relative water security with other toles in Patan. Also this can also be attributed to water culture from place to place. One respondent when inquired that they are getting less water than the per capita requirement, they simply said *"There will never be enough of water. It depends upon how you use it."* A point that was frequently raised when answering this question was the consistency of the Hiti supply sytem. For e.g. in the KUKL system when there are problems in the pipe line the maintenance cost is high and time consuming, but in the Hiti system there are rarely such maintenance issues in the pipeline, and even if there are, it can be appropriated locally.

3. The households used the distributed piped water from the project for various domestic purposes such as drinking, cleaning, washing, sanitation etc., however even with piped supply, all of them also used water fetched directly from Hiti on a regular basis.

   Analysis:

   The water fetched directly from Hiti is believed to be "pure water". For other domestic activities such as cooking, washing etc. people use the piped supply water, but for the purpose of drinking, most people revere to Hiti water collected in traditional vessels as being better for the body.

Though there are people who are reverting to other sources such as jar water, for drinking but the linkages to religious activities remain even stronger. For the purpose of religious offering, pure water is required, which is believed to be flowing water from the Hiti. This water is called as “Nhi La:” and people come to the Hiti to fetch it for daily religious activities or during puja in festivals or important events. An example of this can be seen in “Napichandra Bouddha Pariyat Kendra” as shown in fig.37, which is a Newar styled Buddhist monastery called Bahi, lying 70m south west of Alko Hiti. For performing religious activities in the monastery, the water from Hiti is taken as “Nhi La:”.

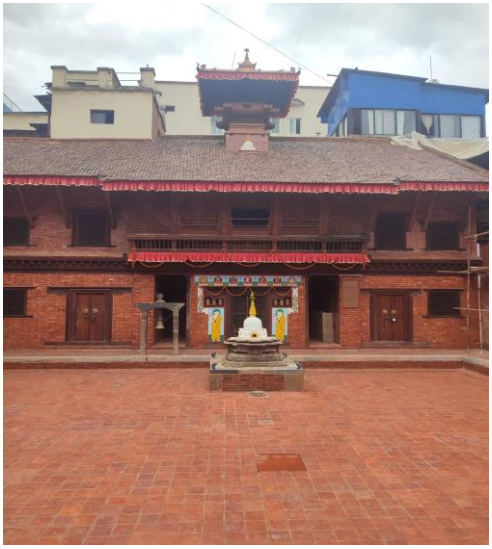


Figure 37: Napichandra Bouddha Pariyat Kendra

Further, Mr. Prayag Joshi, Hiti Expert, states that, “Aluko Hiti on its part has a different value. Water from this Hiti is used in all the rituals that have to be performed in each and every household (if a child is born or if a person dies) in the area.”

4. When asked on a five-point scale if the water supplied from the Hiti suffices the water needs on a scale of,
    a. Fully Sufficient
    b. Mostly Sufficient
    c. Sometimes sufficient and sometimes not
    d. Mostly Insufficient
    e. Never Sufficient

The respondents answered with 10% of them saying fully sufficient, 65% of them saying mostly sufficient and 25% of them saying sometimes sufficient and sometimes not.

Analysis:

This shows that Alko Hiti water supply project has catered to the water needs of majority of the respondents. None of the respondents responded in the negative spectrum. The people who answered sometimes sufficient and sometimes not, were generally found to be people having higher number of family members (joint family in general), and when asked what are the areas where the scarcity is felt, the respondents in general mentioned for washing clothes.

5.1.5 Hiti Usage Data and analysis:

The data of usage of Hiti was collected in the peak hours of morning and evening for three days on July 14,16 & 18 and an average of the data is presented below. The timing for the monitoring of peak hour in morning and evening was taken based on the information provided by the management community. The identification of people from inside the tole and outside the tole was done through the aid of a local resident.

Table 1: Morning Data of Hiti Usage

Morning (6 a.m. To 7 a.m.)				
	Native		Non-Native	
Time	Male	Female	Male	Female
6 to 6:20	10	24	0	13
6:20 to 6:40	7	14	4	3
6:40 to 7	4	3	8	3
Sum	21	41	12	19
Total(Male+Female)	62		31	

Table 2: Evening Data of Hiti Usage

Evening(5:30 p.m. to 6:30 p.m.)			
Native		Non-Native	
Male	Female	Male	Female
7	5	15	10

Analysis:

The data shows that the Hiti water is used predominantly by the local community in the morning, while it is used predominantly by the non-native community in the evening. The usage characteristic is also somewhat different. The local community perform their morning religious rituals in the Hiti and also take water for drinking purpose, while the non-native

people take water for domestic purposes. The local people, offer the Hiti water to the idols of different gods and goddesses, kept in the Hiti complex and make a round to the Ganesh Temple in the complex. The way in which the local people use the Hiti shows homage to the gods and goddesses, as well as the Hiti itself.

Morning data

In case of the local community, two thirds of the ones arriving in the Hiti were women. This time is also seen as being distinctly utilized by women for social bonding. So it serves a threefold purpose of religious rituals, social bonding and water usage. Also, the data shows a high number of locals using the Hiti is from 6:00 to 6:40 a.m., after which the non-native users start to increase. This is again attributed to the purpose of usage of Hiti, which is dominantly religious for the locals, while it is for water consumption for the non-native users.

Evening Data

The local community can be seen to be using the Hiti for washing their hands and filling a 1 to 2l water bottles for dinner. The non-native community can be seen using the Hiti water to fill up mostly 15l to 20l jars for domestic purposes. Of the total nonnative community users, 60% were found to be male. This might be attributed to the male student renters living in nearby communities.

5.1.6 Biodiversity of Hiti

The Hiti complex has an interesting depiction of different beings. The importance of the need for co-existence of species is essential in Hiti system. The rules placed in Alko Hiti forbids anyone from killing serpents or doing any harm to them as shown in fig. 45(Annex C). People fondly remember there used to be serpents in the Hiti, some 20 years back. But after the usage of soaps and shampoos, the no. of serpents decreased and at present, there are no serpents in Alko Hiti. There have been initiatives to tackle this by prohibiting the use of shampoo and soaps in the Hiti, and also introducing fishes in the nearby pond. These efforts have led to a gradual increase in the number of frogs, but still serpents are yet to be seen. This importance of biodiversity can also be seen carved in the Hiti complex and stone spouts, which is carved with crocodile, snake, mongoose to tribute the reptiles and insects for unclogging the groundwater. (Avni, 2021). In Thapa Hiti, a Hiti near to Alko Hiti, metal pipe was used instead of terracotta pipe. Once this was used, old people in the area say that fishes, frogs and other animals are not found in the Hiti anymore. (Joshi, 2007).

5.2 Findings of Study Area: - Jagmadu Pukhu(Pimbahal Pond)

5.2.1 Rain Water Collection

The pond has a well-functioning rainwater harvesting system..

- Depth of Pond :- 5.5 ft (approx.)
- Surface Area of the pond :- 3235 sq. metres (Source: Google Earth Pro)

The Jagmadu Pukhu Area Development Committee, which steered the redevelopment of the pond was interviewed during this study, and the committee members stated that they had constructed the pond to a level of 5.5 ft, and a minimum level of 3 ft is maintained in all seasons. This means that a level of 1.5ft(0.46m) is filled during the monsoon, which amounts to,

Tentative volume of water stored in monsoon = Depth increase in monsoon * Surface Area of pond

= 0.46m * 3235 m2

= 1488 cubic metres

The outlet is rarely used, and during the time of this study i.e. in monsoon, the outlet still did not have to be used. This helps to dampen the urban flooding.

Also, upon asking the committee member of Jagmadu Pukhu Area Development Committee, he said, *"Our system is self-reliant unlike other project*s". The committee member is referring to Rani Pokhari in Kathmandu, where water had to be poured to refill it.

To add to the utility of the pond, Mr. Shailendra Shrestha of Pimbahal also acknowledged the disaster risk reduction aspect of the pond. He said, "The pond water has also been used to fight multiple instances of firefighting purpose"

5.2.2 Well Recharge

Further, the pond may have aided in the recharge of the surrounding wells. The ponds in Kathmandu Valley, which are mostly manmade are constructed through the use of specific technology, using a soil called "*gathucha*". This construction technique allows for the recharge of nearby sources. For, the purpose of this study, unstructured interviews were also carried out with the users of the will, and KII with the management committee of the pond. A representative statement by Mr. Shailendra Shrestha, is stated as, "During the reconstruction of the pond in 2017, the water had to be drained out. When this happened, the people from the nearby toles asked the committee to fill the water in the pond as water levels in their wells had gone down." The works of Joshi(2021) and Tiwari(2002), also point out that the pukhus in Newar community is constructed such that it works as ground water recharge bodies. For this the water level of a well lying 56m North from the pond was measured as shown in fig. 38. The water level was found to be,

Water Level = 1.9m from the ground meter.

Figure 38:- Measurement of water level of well

This indicated a high ground water level. However, the time of measurement was in the time of monsoon, where the ground water level is also naturally higher. So, further research needs to be done to assess the contribution of pukhu in ground water recharge.

5.2.3 Salient Features:

Based upon the findings, the salient features of the pond can be listed as,

1. The Jagmadu Pukhu development model uses rainwater harvesting as a means to sustainably store rain water. This does not require any artificial refilling of the pond, which is the reason for many recent pond development failures.
2. Also, this model has eliminated the need for storm water drainage works in the service area.
3. It has been used for firefighting purpose.
4. It stores a tentative amount of 1488 cubic meters in the monsoon, which aids to dampen the pluvial urban flooding.
5. To add to it, the pond might have aided in increased level of water levels in the surrounding wells.

5.3 Findings and analysis from Key Informant Interview:

The physical aspect was noted through field observations and literature review. So, the key informant interviews were mostly focused on the socio-cultural aspect of the study. The interviewees unanimously agreed that Hiti system can be a solution to our water security issues, but the essence of its sustainability lies in its "Community Based Management Approach". As stated by Mr. Shailendra Shrestha, who led Jagmadu Pukhu Development Area project,

"The reason why Hiti system survived more than 1500 years, is because of its integration with the community through Guthi System and the process of Ritualization, creating a sense of ownership. So, if we are to go forward with engaging Hiti system as a Nature Based Solution, the mechanism for community engagment of Hiti system must be a crucial component."

Mr. Shrestha further highlighted on the importance of Guthi saying,

"Even for playing Dhyame(a local instrument), and carrying out a small procession there used to be Guthi. Though, local youths are interested in this nowadays, but can interest solely be backed upon for its continuation? What if they don't feel like doing it one day? Certainly not, and economic linkages have to be established."

Figure 39: Youths playing Dhyame

On the importance of ritualization or ritual mediation Mr. Padma Sunder Joshi, author of Hiti Pranali, said,

"The Machhindranath Jatra is an excellent example of ritualization. The jatra happens during the dry period, and all the strategic ponds have to filled before the commencement of the jatra. This is possible only when the state canals(rajkulo) are well maintained. So, before the starting

of jatra, the state canals are maintained every year, establishing a ritual, and to carry out the jatra different ethnic groups have their management institutions in the form of different guthi, which delegates roles and responsibilities needed for the functioning of Machhindranath Jatra. Also, different guthi's such as Barahi Guthi, are involved in the construction and operation of the chariot festival."

This institutional setup of Guthi and the socio-cultural linkages established through ritual mediation has developed a unique "Water Heritage" of the valley which has been continuing for more than 1500 years, and an important factor for this continuity is that the mechanism is not limited solely to volunteerism. Most Guthi systems have land endowments vested in them which act as financial mechanism. As Mr. Joshi puts it,

"In Newar culture, for e.g. simply building a temple is not enough. It is the custom that the donor also make a Guthi where collective decisions are made, and sufficient land rights are vested in the Guthi for its functioning in the long run."

However, there are newer realities confirming to the present scenario. They are,

1. There has been massive decline of the guthi land,
2. The state owned, guthi sansthan is not being able to cater to localized customs and traditions.
3. The economy has moved from an agricultural economy. So, basing agricultural production on the Guthi land as a stable source of income might not be feasible.

In the case area of Alko Hiti, the surrounding 9.25 ropanies was said to be Guthi Land, and owned by the Bajracharya family living nearby. The land is believed to have been entrusted for the operation and management, and rituals of the Hiti. However, now the public land is limited to the Hiti complex, so much so that one of the source of the Hiti lies in a private land. This disrupted the economic linkages to the Hiti, and might be one of reasons the Hiti was left unattended before the water scarcity in early 2000's. It was only through tough struggle that even the remaining public land had been saved, and the source protected. Presently, the Bajracharya family guthi have established an endowment fund, which is limited to performing puja in the Hiti. Mr. Sushil Srestha, who led the Alko Hiti restoration said,

"There was a Guthi of Alko Hiti, which also had 9 ropanies of the nearby land, belonging to the Bajracharya family, but we don't know what they did with the land. It is unknown. The Bajracharya family does conduct puja 2 to 3 times a year, but are not involved in its

maintenance. Now, the responsibility of Hiti is with the tole committee, and we will work for its betterment."

In case of another case area, Jagmadu Pukhu, if it weren't for local involvement, the pukhu might have been transformed into a shopping mall. Mr. Shailendra Shrestha who led the regeneration of the pond said,

"The local authorities did not care much about the pond, and were waiting for the world bank project of urban regeneration to finish. If it weren't for our intervention they would have given the project away, but we persisted, and the construction of the project was completed in 6 months. We situated that maximum local participation happened, by forming smaller committees for construction, and engaging as many people as possible."

There also exists a guthi in Pimbahal pond, however, the guthi is engaged in religious works, and does not look after the management.

One thing, which is common to these cases, is that the sustained revival of Hiti system, has to come from the community level and mechanisms have to be identified to finance these systems in newer context.

With the declining state of guthi system, in both the study context, "Tole Sudhar Samiti", which is an elected body of representatives from the community, backed by a degree of local government, are working to fill the institutional gap in the Hiti system. This was also confirmed with Mr. Prayagraj Joshi, Hiti expert. He said,

"Most of the management of Hiti is now taken by Tole Sudhar Samiti. However, the local government needs to do more in this matter."

An important feature for their success is that in both the case studies, the restoration projects have also been financially feasible. In Alko Hiti financing has been through monthly user's fee of Rs. 250, while in Pimbahal it has been through fish farming which ears 2 to 3 lakh per year, boating which earns 10 to 15 thousand per month and users fee.

Both these cases provide a similar framework for approach for future actions focusing on two aspects,

1. Community Engagement through Tole Sudhar Samiti
2. Financing Mechanisms

These aspects have been undertaken and an institutional mechanism which considers present conditions has been proposed in the **Recommendation(Section-8).**

CHAPTER SIX: DISCUSSION

The main research objective of the study was to assess the role of Hiti system as a nature based solution in addressing water security of Kathmandu Valley and this objective was further sub divided into understanding the planning of Hiti system, assessing the salient features of Hiti system as a nature based solution, and how it works to aid water security.

6.1 Hiti System as a Nature Based Solution

In accordance to the first sub objective, the planning of Hiti system has been studied in this research through literature reviews, key informant interviews and case study approach, and the salient features of the system have been identified. These salient features have then been identified with concept of Nature Based Solution, to fulfill the second sub objective. This can be summarized as below.

6.1.1 Protection, management and enhancement of Natural Ecosystem

The conservation of Hiti system, consequently amounts to conservation of ecologically water sensitive areas. These areas are generally the underground shallow aquifers, which are essential in maintaining the underground water storage and flow. These sources are renewable sources of water, which get replenished every monsoon, and its judicial use can bring about sustainable usage of water. Through the case area of Alko Hiti, this study has underlined how the usage of Hiti system works to protect the shallow aquifers which in turn favors the community by attending to its water stress issues. The thorough study of Hiti system, underlies the ecologically sensitive areas and the need to protect them. Further through the case of Pimbahal, the importance of rain water harvesting has been underlined. This in turn works to aid in groundwater recharge and check urban flooding. Also, the system of Hiti is based upon allowance of percolation of rainwater, and co-existence within all species, which is crucial for functioning of the natural ecosystem.

6.1.2 Localized Solution

Hiti system is the system of understanding and using the local geology of Kathmandu Valley. It uses the local aquifers as its main source which are generally not located more than 3km. The aquifers are recharged every monsoon through rainwater in the Kathmandu Valley watershed. The state canals(Rajkulo), which run into the ponds of Hiti system, which then work to recharge the ground water, also have their source within the watershed itself. The case of Alko Hiti has been presented which utilizes the local geology to store and provide water to the community.

This is essential with respect to Environmental Justice. According to the key informant interview with Mr. Padma Sunder Joshi, author of Hiti Pranali,

"The first right of the watershed is by the local people. While we are wasting our waters down the drains, it is incorrect from the view of environmental justice that we use Melamchi water. We should first prioritize to conserve and better use our local resources."

The use of local water sources minimizes impacts to the environment and the cost of maintaining local water systems is usually low, and therefore, community people and householders generally assume most of the operation and maintenance costs of these systems. Widespread use of local water systems can enhance local participation in environmental conservation. Large scale water transfer to the city can also cause many problems in rural Melamchi.

Reports suggest that most of the water needs of Kathmandu could be met with only 6% of the rainwater if harvested properly. (Domènech et. al, 2013). Also, it has been earlier stressed that Melamchi Water Supply has not been reliable yet and is prone to disasters in monsoon. So, in order to build water resilience, we should be working on better utilizing our local resources.
In the case of Alko Hiti, at the time of this research there were problems with Melamchi Water Supply Project, but the community did not face any issues relating to water. Before 2021, when most areas of Patan were troubled by water, but the community of Ikkachen, owing to its usage of local resource, was resilient to water availability issues.

6.1.3 Community Based Water Management

The Hiti system is based upon the community and its beliefs. Its management engulfs community involvement and ownership. It carries a history of socio-cultural linkages with the community. Traditionally, these aspects along with the financial mechanisms were catered through the guthi system, but our interventions have weakened the system. Owing to these changing realities, the research has also sought to propose institutional mechanisms to regenerate Hiti system, where the ties with the community have weakened. If the socio-cultural ties with the community remain strong and appropriate financing mechanisms are established these systems can once again run in perpetuity. This is the case with both Alko Hiti and Pimbahal bond, where the newer mechanism of financing and community ownership have been established.

6.2 Hiti system in solving water security

The research has gone to fulfill the third sub objective of assessing the role of Hiti system in addressing water security through case studies and practical examples. This can be summarized as follows,

6.2.1 Water Stress

As mentioned in 4.2, piped water supply caters to only a portion of the people of Kathmandu even with the introduction of Melamchi water. The case of Alko Hiti shows that how the community managed Hiti system can relieve water stress by providing an average water of 50lpcd. Further, the Newar toles such as Ikkachhen of our case study has a high number of rental population which have poor living standards and are vulnerable. Hiti system has been an important source of water for them, relieving them of their water stress issues relating to domestic use such as cleaning, washing, and bathing.

6.2.2 Water affordability

Most Hiti systems have been delivering water free of cost, if not minimally. As mentioned in section 4.2.1, jar water and water tankers are 155 times and 21 the cost of piped water supply, and piped supply is only catering to 25% of the demand, the affordability aspect of the system has been crucial, especially to the urban poor. Further, it is based on gravity flow which does not require pumping, the filtration process is based on natural filtration methods, and sophisticated devices are not required, thus the cost of operation of the system is low.

6.2.3 Water Resilience

Locals are often seen complaining of the maintenance issues in piped supply as in the case with Alko Hiti, and its maintenance is mostly not possible to be done by the community. But in case of Hiti system, the community can move forward to fix its own problems and in itself is a low maintenance system. It has been functioning properly for the last 1500 years with little maintenance In case of Alko Hiti, there have been very few issues regarding maintenance, thus ensuring reliability, and whenever there are issues of maintenance it is within the reach of the community, and thus can be solved quickly. In case of disaster related events, for e.g. in earthquake 2072, piped supply faced numerous issues, while Hiti system served as an important source during that time. The system has also been helping to combat disasters, through the protection of open spaces, and water for firefighting purpose.

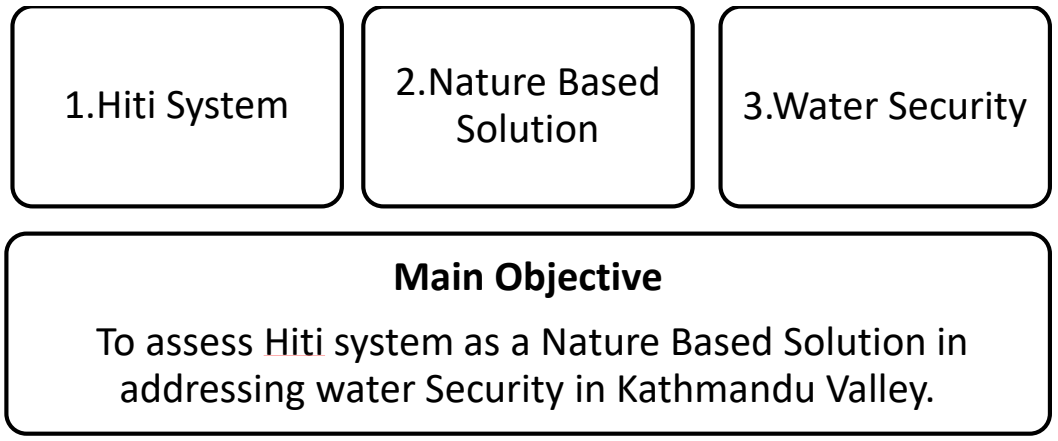
6.2.4 Urban Pluvial Flooding

As mentioned in section 4.2.3, rapid unmanaged urbanization has caused increased urban pluvial flooding. The previously permeable surface, has been converted into built up areas at a staggering rate of increase by 368.06% in the last thirty years in the Kathmandu Valley. In response to this mismanagement of rainwater, the case study of Pimbahal shows that, storm water drainage can be eliminated through the process of rainwater harvesting. As stated, Ponds served multiple functions in the Hiti planning and one major function is the control of urban pluvial flooding, which was calculated to be 1488 cubic meters in a season in case of Pimbahal. This offsets the peak in flooding time, and also has the simultaneous benefit of aiding in water recharge.

6.2.5 Sustainable Usage of Water

The system is based upon usage of replenish able source of water i.e. shallow aquifers. It uses rainwater harvesting in the form of ponds, wetlands, and aquifer storage. The principle of the system bases upon allowing percolation of rainwater and protecting ecologically sensitive areas. All this is done by motivating the people to look after their own ecosystem through the delicate act of religion and social ties.

In this way the research has been positioned to fulfill the three sub objectives which add up to fill the main objective of the research.



CHAPTER SEVEN: CONCLUSION

As with major cities around the world, the Kathmandu Valley is facing serious issues of water security. The learnings from studies around across the globe is that built infrastructures alone is not being able to solve water security in the long run and that is why to combat this a combination of anthropogenic as well as Nature based solutions must be in place. These Nature Based Solutions have been observed to be based on traditional knowledge of water management, and as Hiti system is an indigeneous system of water management in the Valley, which is deeply connected to the community, this research has strived to showcase Hiti system as the Nepalese version to Nature Based Solutions .In this research the salient features of Hiti system as a Nature Based Solution has been assessed which encompasses protection of ecosystem, local watershed usage and community engagement. This works to reducing water stress and increasing water affordability, water resilience, checking urban flooding and enhancing sustainable usage of water, all adding to the water security of the Valley. In this way, the sub objectives of the research, to understand the Hiti system, assess its salient features as a Nature Based solution and investigate how it adresseses water security have been studied, with the intention of fulfilling the larger objectective of assesing Hiti system as a Nature Based Solution in addressing water security in the Kathmandu Valley.

This research engages in firstly understanding the planning of Hiti system through literature review, in line with the first sub objective of the reasearch. This is then followed by the study of Hiti system as a Nature Based Solution through the case studies, as required by the second objective of the research. Then the reasearch follows to seek how the Hiti system is addressing the issue of water security in the local level and what are the common characteristics which can be implicated in a larger level in the Kathmandu Valley, which is underlined as the third sub-objective of the research. So, by understanding and asseing the intterrelationship between the Hiti System, Nature Based Solutions and Water Security, this research attempts to fulfill its main objective.

CHAPTER EIGHT: RECOMMENDATION

The recommendations are given as,

1. The research advocates that, the protection and enhancement of Hiti system be not limited to the notion of cultural preservation. It should be seen as providing essential service of addressing water security through the notion of Nature Based Solution. This view makes Hiti system an important mechanism to achieve sustainability, and thus can be viewed within the frame of Sustainable Development Goals and Climate Change Mitigation. This opens oppurtunities for various related agencies to work in the sector of Hiti system, and access climate related financing. Climate Financing is a steadily increasing source of internatinal financing for sustainability. In-line agencies and the government can propose the Hiti system owing to its environment benefits and social interconnectedness to various such climate related financing instruments such as Green Climate Fund(GCF), Global Environment Facility(GEF), Green Loans, Adaptation Fund etc.

2. Learning from the commitmment shown in preserving and promoting traditional water management systems through Sponge Cities in China, the Government of Nepal should enact a strong commitment to conserve and advance the Hiti System with the motive of achieving sustainability and cultural preservation. It should be specifically reflected upon the budget of three tier government. This can help to realize the importance of Hiti system as an urban planning tool for the present and the future.

3. The research also proposes an institutional model as shown in fig 40, for the Hiti system having dysfunctional management systems, which can cater to the changed realities of the present. Most Guthi's relating to Hiti have become dysfunctional, mainly due to their inaccessibility with land rights. Also, the population dynamics and societal structure is changing, which urges the need for greater participation from youths and the diversifying community. As, in both cases of Pimbahal and Alko Hiti, empowering "Tole Sudhar Samiti" with co-ordination from local government can be a viable way of moving forward with the management of Hiti system. It can ensure participation from youths and all castes and as it is an elected body of the people who live in the same area, the institution can be held the most accountable for the preservation of Hiti. The

Tole Sudhar Samiti can finance the operation through internal revenue, governmental budgets, and climate financing (Recommendation-1).

In doing so, the role of local government in facilitating the local community, in terms of resources and expert guidance becomes crucial. In this way functional integration of the system can be made and is proposed in fig. 40. However, even in dysfunctional Guthi's, act of performing religious rituals still remain in some, and in those where it is has been disregarded, efforts should be made to promote them to perform such rituals, so as to keep the religious and cultural integration intact. In this way, by inspiring both cultural and functional aspects, the sense of community ownership can be revived to the Hiti system, which in turn adds to the water security. This way of protecting the ecosystem by engagigng the community can be Nepal's own version of Nature Based Solution.

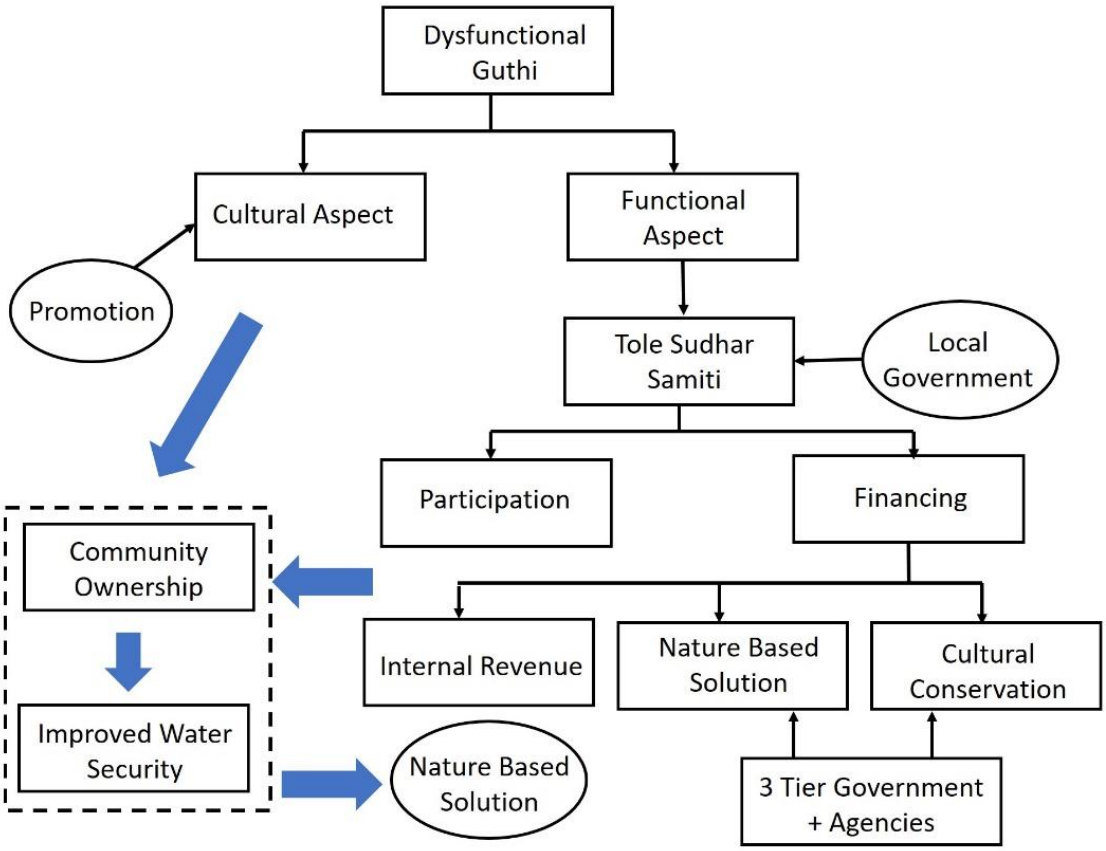


Figure 40: Proposed Institutional Setup for Dysfunctional Hiti Guthi

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ANNEXURES

10.1 Annex A: Key Informant Interview

1. Mr. Sushil Shrestha, President of Ancient Stone Spouts and Source Conservation Organization
2. Ikkachhen Tole Sudhar Samiti committee members
3. Mr. Shailendra Shrestha, Past President of Jagamadu Pond Area Development Committee
4. Jagmadu Pond Area Development Committee
5. Mr. Prayagraj Joshi, Hiti system expert
6. Mr. Padma Sunder Joshi, Author of “Hiti Pranali”
7. Mr. Anil Chitrakar, Conservationist

Figure 41: Key Informant Interview with Mr. Shailendra Shrestha

Figure 42: Key Informant Interview with Mr. Prayagraj Josh

10.2 ANNEX B: Semi Structured Interviews

The semi structured questionnaire was conducted to users of Alko Hiti water management scheme.

1. What is your experience of using water from the Hiti System and how has it evolved over the years?
2. On a scale of five, how satisfied are you with the present water management system of Alko Hiti?
    a. Highly dissatisfied
    b. Not satisfied
    c. Neutral
    d. Satisfactory
    e. Highly Satisfactory
3. Did you have to use any other sources of water other than the Alko Hiti water supply in the past year and how frequently?
    a. Water Tanker
    b. Jar Water
    c. Well
    d. Others
4. Did you have to use any other sources of water other than the Alko Hiti water supply in the past 5 years and how frequently?
    a. Water Tanker
    b. Jar Water
    c. Well
    d. Others
5. Do you use the water supplied through the pipes of Alko Hiti water supply for drinking purpose?
6. Do you use the water of Alko Hiti for religious rituals such as morning prayers, festivals or important events?
7. Does the water supplied from Alko Hiti suffice for your water needs? If not, what are the areas where you felt the scarcity of water?

Figure 43: Semi Structured Interview with personnel from Buddhist monastery

Figure 44: Semi Structured Interview with Local Community

10.3 ANNEX C: Field Observation Photos

Figure 45: Rules in ALko Hiti

Figure 46: Inscription at Alko Hiti

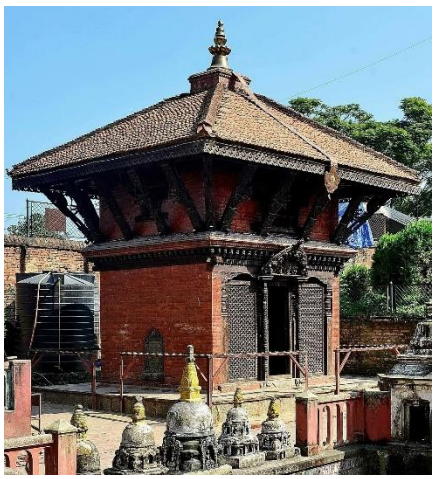

Figure 47: Shrines and Idols at Alko Hiti

Figure 48: Pimbahal Pokhari Sketch in 1854 A.D. by Oldfield, Henry Ambrose

Figure 49: Alko Hiti Pond

Figure 50: Children's park in Alko Hiti

Figure 51: Present State of Source III

10.4 ANNEX D: IOE Graduate Conference

त्रिभुवन विश्वविद्यालय
Tribhuvan University
इन्जिनियरिङ अध्ययन संस्थान
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फोन- ५५२१५३१, फ्याक्स- ५५२५८३०

Date: November 26, 2023

To Whom It May Concern:

This is to certify that the paper titled "***Assessing Hiti System as a Nature Based Solution in addressing Water Security in Kathmandu Valley***" (Submission# **286**) submitted by **Sarik Awale** as the first author has been accepted after the peer-review process for presentation in the 14th IOE Graduate Conference being held during Nov 29 to Dec 1, 2023. Kindly note that the publication of the conference proceedings is still underway and hence inclusion of the accepted manuscript in the conference proceedings is contingent upon the author's presence for presentation during the conference and timely response to further edits during the publication process.

Bhim Kumar Dahal, PhD
Convener,
14th IOE Graduate Conference

IOE Graduate Conference
[Placeholder for Publication Information]

Assessing Hiti System as a Nature Based Solution in addressing Water Security in Kathmandu Valley

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Abstract
Water security is a global concern, with Kathmandu Valley, the largest urban agglomeration in Nepal, facing its own set of water issues such as water stress, water affordability, water resilience, declining ground water levels and urban pluvial flooding. Research from various regions has underscored that solely relying on built infrastructure is insufficient for resolving long-term water security issues. Consequently, a comprehensive approach that combines built infrastructure solutions with nature-based solutions is essential. Drawing inspiration from "sponge cities", which is based on the ancient water management wisdom of China, and is a leading example of Nature Based solutions, this research explores the potential of Hiti System which is the indigenous water management system of Kathmandu Valley and is deeply rooted within the community, as the Nepalese version of Nature based solution for addressing water security. The study aims to showcase this by highlighting how the system acts to conserve the ecosystem, promotes local resource utilization and community engagement, through the two successful case studies of Alko Hiti and Pimbahal Pond of Patan. The research being mostly qualitative and having parts of descriptive results, the study has been carried out through field observations, key informant interviews, semi structured interviews with the community and literature review. The research then channelizes these findings to present how water security is being addressed through these efforts. Further the study attempts to view Hiti System as a sustainable means to address water security, and advocates that it should not be limited to the perspective of cultural preservation only. Lastly, the study also points out the shortcomings of the system owing to present realities, and works to propose a solution to it.

Keywords
Hiti System, Water Security, Sponge City, Nature Based Solution

1. Introduction

Water security is a pressing global issue for major cities around the world. About two billion people worldwide don't have access to safe drinking water today [1], and roughly half of the world's population is experiencing severe water scarcity for at least part of the year [2]. From 2001 to 2018, water related disasters accounted for 73.9% of all-natural disasters. [3]. The Kathmandu Valley, which is the largest urban agglomeration of Nepal, is experiencing, its own set of water security challenges, which range from increased pluvial urban flooding [4], drastically decreasing ground water levels to heightened water stress [5]. To combat these challenges, built infrastructure alone is increasingly unlikely to provide reliable solutions in the future [6]. A combination of built and nature based solutions will be needed for efficient and effective management of water resources [7]. Nature based solutions are being increasingly used in different parts of the world, for e.g. Low Impact Developments (LID) approach in the United States, Water Sensitive Urban Design (WSUD) in Australia, and most notably in China through the concept of "sponge cities". The sponge city concept based on the ancient farming and water management wisdom of China, uses the landscape to retain water at its source, slow down water flow and clean it throughout the process, to tackle the urban flooding in the cities in China. Similarly, in context to Nepal, particularly Kathmandu Valley, the Hiti system is the traditional knowledge base of sustainable usage of water. The Hiti system is a system of canals, ponds, stone spouts, conduits and various such structures, which was not only utilized to bring water for drinking and domestic purpose to city, but also for irrigation, checking landslides and pluvial flooding and improving ground water recharge[8], with consideration to the ecology, in the traditional planning of the Valley. These services of the Hiti system are more so relevant to the challenges faced by Kathmandu Valley in the present scenario. In context to this, the research aims to assess the role of Hiti System as a Nature Based Solution in addressing water security in Kathmandu Valley. Further, the state of Hiti system is in a declining phase. The attempts to conserve Hiti system through cultural significance has only been partially successful. Inherent to the changing realities, newer meanings need to be attached to the system, and this research proposes the concept of Nature Based Solution as one such approach.

2. Literature Review

2.1 Nature Based Solution

Nature based solutions are defined as the actions to protect, sustainably manage, or restore natural ecosystems, which address societal challenges such as climate change, human health, food and water security, and disaster risk reduction effectively, providing human well-being and biodiversity benefits[9].The guidelines for Nature Based Solutions(NbS) are that NbS should not be though as a substitute for decarbonizing our economy and, Nbs works to protect and manage ecosystems

while fostering local involvement and enhancing biodiversity[10].

2.2 Water Security

Water Security is defined as "the capacity of a population to safeguard sustainable access to adequate quantities and acceptable quality of water for sustaining livelihoods, human well being, and socio-economic development, for ensuring protection against waterborne pollution and water related disasters, and for preserving ecosystems in a climate of peace and political stability"[11].Accordingly, four key components to it are, Drinking Water and Human Well Being, Ecosystem, Water Related Hazards and Climate Change, and Economic Activities and Development. Further, under the framework of water security assessment[12], these key components have been sub divided. Amongst them, for the purpose of this study, water stress, water accessibility, water resilience, ground water recharge, water affordability and urban flooding control have been studied.

2.3 Relationship between water security and Nature Based Solution

About two billion people worldwide don not have access to safe drinking water today [1], and roughly half of the world's population is experiencing severe water scarcity for at least part of the year [2]. Asia-Pacific regions face an ever growing water crisis. Water-related disasters have been dominating the list of disasters over the past 50 years and accounting for 70 per cent of all deaths related to natural disasters [9]. In this context of water security, built infrastructure on its own is unlikely to provide future water security and resilience against predicted climate change impacts [6]. New demands on solutions for water security are emerging in a global context. Usage of NbS by harnessing the water-related services of 'natural infrastructure', such as forests, wetlands and floodplains, can help combat the risk of water crisis, particularly in the face of future climate stresses[6]. However, nature alone cannot guarantee water security for people in every situation. Both built and natural infrastructure are needed for efficient and effective management of water resources [7]. The global assessment report on Biodiversity and Ecosystem Service estimates that Nature-based solutions can provide up to 37 per cent of climate change mitigation until 2030 [13].

2.4 International Case Area for Nature Based Solution: Sponge City, China

The urban areas of China are prone to severe flooding and waterlogging. After decades of rapid urbanization, China now faces with water shortages and flooding - only exuberated by the effects of climate change. In Zhengzhou, the capital city of Henan province having a population of more than 10 million, an extreme rainfall event on July 20 2021, caused severe pluvial flooding which reportedly resulted in over 290 deaths and economic losses of more than CNY 65.5 billion (equivalent to US 10 billion) [6]. To combat this situation, realizing that conventional urban flood management approaches alone might no longer be sufficient to provide the level of climate resilience and services required to address the heightened threats, the Chinese government announced the sponge city program in 2014. A "sponge city" is a nature based solution that draws on the landscape to hold onto water at its source, slow down water flow, and clean it as it moves through. It is motivated by historic farming and water management knowledge. This method that takes advantage of the rainwater, which is absorbed, stored, and slowly released by the city facilities, such as waterways, sunken rain garden, green spaces, permeable pavement and floor tiles, and green roof buildings to control storm water runoff and to accumulate, infiltrate, and purify naturally [14]. In the city of Shenzhen, a mega-city in southern China with a population of over 17 million(2020), 28.3% of the total area has been converted into sponge area [14]. Initiatives such as Futian Mangrove Ecological Park Restoration is contributing to 92% control rate of run off towards the park, Dadingling Forest Park development worked to eliminate flooding in six flood prone areas and Shenzen Bay Park which is a hybrid of floodway and cycling route, are some excellent examples of the Sponge City Program in Shenzen.

2.5 Historical Development of Kathmandu Valley

The earlier urban development of Kathmandu Valley can be traced back to Kirat period(ca. 500 BC to 78 A.D.). The Kirata settlements, named pringaa, would be centered around a built space protector god, which came to be known as Dyochhen. Several religo-cultural (rituals) and socio-cultural (festivals) practices were developed to continuously remind the city dwellers of the limits of the protection of town was dependent on the protection of Nature and its place specific micro-ecology [15]. With the Lichchhavi development(78A.D to ca. 880A.D), settlements started growing causing insufficient water supply. The spring sources, ponds and the likes protected as pith, were not being able to meet water supply needs of expanding towns. So, water was brought through canals that stretched from the foothills of the valley to towns to feed ponds, which in turn recharged supply to recessed pit conduits, a technology that is working to this day in Kathmandu [15], which is known as the Hiti system. In the Malla Era (1200 to 1768 A.D.), larger towns developed which led to the gradual expansion of the Hiti system.

2.6 Hiti System

Hiti system is a water supply and management system, which is indigenous to the Kathmandu Valley, with its functioning deeply tied to the community. Hiti system, worked to not only provide drinking water, but also acted for irrigation purpose, controlling landslides and pluvial flooding, promoting ground water recharge, which worked to enhance the overall water security and resilience of the community [8]. Adding to this, is the architectural beauty of the system. The below-ground level traditional structures i.e, the Hiti's are architectural monuments in their own right which compete with the best above-ground ones [15]. The system consists of Rajkulo(State Canals) which transport water from river sources, into well connected ponds. The ponds work to recharge the ground aquifers and are also connected via canals to act as irrigation channels. Water is tapped from the aquifer source and through conveyance system, brought to the Hiti Complex, which is then ultimately drained to fields or rivers or pond.

Socio-Cultural Dimensions of Hiti System Newar Society has a particular feature of translating social values into culture, and bringing about a sense of ownership, [8]. This is the case in

Hiti system too. Through the process of ritualization or religious mediation and institutional backing of "guthi system", the Hiti system has been interwoven in such a way that it makes up the "water heritage" of Kathmandu Valley. An excellent example of this is the festival of Rato Machhindranath Jatra in Patan, which a chariot procession with the highest fanfare. For the Jatra to commence, all the strategic ponds in the in Lalitpur must be full with water. The procession takes place in the dry months, so the water must be filled through the state canals. This means that the maintenance work of state canals must have been completed before the monsoon [8]. To mobilize this procession various ethnic groups have their management institution as guthi, which delegates responsibilities and tasks of the procession.

Destruction of Hiti System The system of Hiti was pioneered with the mixture of knowledge from Kirat and Lichhavi period, which was extensively developed in the Malla period. With every new ruler, they embraced the technology and further contributed in its growth. However, during Shah and Rana rule, the rulers were rather ignorant to the richness of knowledge of Hiti [8].This led to gradual introduction of Municipal Water Supply System. But, the municipal water could never meet the demand of water. The pride and convenience of having water tap at home made the community easily swift from the traditional water supply system [8]. This left the spouts unattended and poorly managed. However, due to the uncertainty of municipal water, Hiti was still used of washing clothes and taking bath, more so for the urban poor.

3. Research Design

As the research is consisting of both qualitative and quantitative in nature, with the qualitative aspect being dominant, a mixed method approach is used. Owing to this, the research has been conducted in pragmatic paradigm, employing case study research method. The case study area was chosen to be two locations namely Alko Hiti and Pimbahal pond of Patan. The Valley has three major systems of Hiti viz. The Kathmandu System, the Bhaktapur system and the Patan system. Out of all these systems Patan has a comparatively better maintained Hiti system. As the study entails assessing the features of Hiti system, which can be better assessed on a well-functioning Hiti system these two cases of Patan namely, Alko Hiti and Pimbahal pond were chosen. A mixture of field observations, key informant interview and semi structured interview was used in data collection. For the case of Alko Hiti, field observation relating to physical aspects, key informant interviews with the management committee, and semi structured questionnaire survey with the users group was conducted. For the semi structured questionnaire survey, 20 samples were collected based on convenient sampling, considering the availability of the people. For the case of Pimbahal pond, field observations were carried about to assess the physical attributes, while key informant survey with the management committee was conducted to assess the socio-cultural aspects. As mentioned, the research being mostly qualitative, having a descriptive quantitative aspect, so the study has been presented in a narrative review. The flowchart for this is referred to in fig 1.

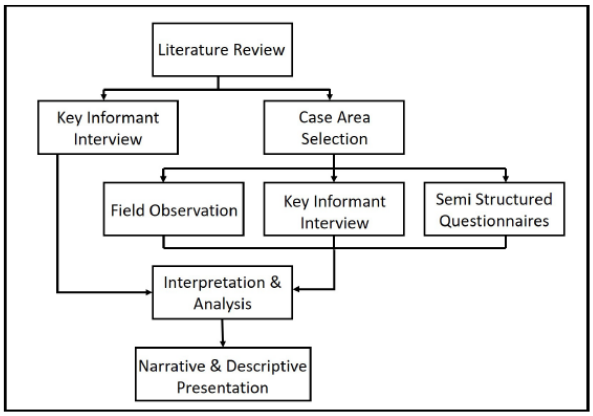

Figure 1: Methodology

4. Study Context

The research is based on the study of water security issues of Kathmandu valley, which is the largest urban agglomeration of Nepal. Then the two case areas of Alko Hiti and Pimbahal pond, which are two successful examples of restoration of Hiti system within the Kathmandu Valley is studied, with the aim of assessing its features and drawing out results which may aid regenerating Hiti system in addressing water security of the Valley.

4.1 Kathmandu Valley

The water security context of Kathmandu Valley can be classified as,

Water Stress and affordability As per the annual report(2079) of Kathmandu Upatyaka Khanepani Limited(KUKL), which is the responsible organization for the operation and management of water and wastewater services in the valley, out of the total demand of 472 Million Litres per day, KUKL has an average production of only 101.24 MLD (including losses)[16]. Even with the introduction of Melamchi Water Supply project in 2021, which introduced 170 MLD (excluding losses) to the valley, the supply has not been reliable enough and the distribution has not been accessible to all. However, if we are to add Melamchi Water Supply Project including losses and present KUKL supplies, there would still be a defecit of 234.76 MLD in the present context, which is expected to grow steadily. To cover this gap, the population of the valley have been relying on different sources such as wells, tube wells, stone spouts, jar, tanker etc. According to census (2021), only 45.7%, 44.3%, 50.2% of the households in Kathmandu, Lalitpur and Bhaktapur respectively, identify taped water within their compound as their main source of drinking water. From the same report, it can be inferred that there is a high dependence upon water tankers and jar water in the Valley, which is 21 and 155 times more expensive than KUKL water respectively. In instances, hitis are still the only source of water for many; especially for the urban poor.

Groundwater Depletion According to KUKL(2021) report, out of the average production of 126.55 MLD of KUKL, an average of 40MLD is supplied through ground water source. Reports, suggests that nearly half of the valley's total water

supply during the wet season, and 60%–70% during the dry season, comes from groundwater sources supplied by KUKL [17]. The Kathmandu Valley consists of a shallow aquifer which is easily replenished and confined aquifer system which is not a renewable source of water. In confined aquifers [18],atleast 20 times the amount of recharge is being pumped and the groundwater will be depleted below present extraction levels in 100 years. The KUKL(2021) is mostly dependent upon deep tube wells for its ground water and this coupled with the trend of private entities and businesses to construct private boring facilities has led to serious depletion of ground water.

Urban Pluvial Flooding Through satellite images, it has been observed that in the last thirty years(1990 to 2020), the Kathmandu valley has witnessed an alarming increase of 206.88 km2(368.06%) in built up area[19]. This transformation limits water infiltration and increases the speed and the amount of water run-off on the ground [4]. Causing urban pluvial flooding. Urban pluvial flooding, a product of inadequate management of the urban drainage system and strongly correlated with built-up areas and climate change, has become more evident in urban areas of Nepal, especially Kathmandu Valley. According to a study done by [4], based on the urbanization and climate change conditions for the case of Kathmandu Metropolitan City, there will be a 40% increase in the flooding amount considering the current and future climate for a 25 year return period. So, with increasing water stress and unaffordability, decreasing ground water levels and increased risk of urban flooding, the water security of Kathmandu Valley is under serious pressure

4.2 Case Area: Alko Hiti

Alko Hiti Complex is situated in Ikhachhen tole, which is a historic Newar tole in Patan, presently lying in Ward 11 of Lalitpur Metropolitan City of Kathmandu Valley. The inscription in the Hiti complex states that the Hiti was established in in 535 Nepal Sambat (1415 AD) by the forefathers of Bajracharya family living nearby the Hiti complex.

Figure 2: Alko Hiti

Alko Hiti Water Management System About 20 years back, the locals were faced with severe water scarcity, and they united to form Aalok Hiti Conservation and Water Supply Users' Committee in 2003. This committee created a water collection system by harvesting water from the Hiti and distributing it via pipes to individual households. Water is collected from the Hiti through a pipe leading to a collection drum. This water is then pumped upwards to an overhead tank reservoir of ten thousand litres and then distributed to individual houses through underground pipe lines to 180 households at present.

4.3 Case Area: Pimbahal Pokhari

Pimbahal Pond or Jagmadu Pukhu in local language was built around 14th century nad lies in Ward no. 19 of Lalitpur Metropolitan City of Kathmandu Valley. Before 2017 A.D, the situation of the pond was quite poor. All sorts of pipes carrying the dirt drained into it as a result of this situation was that people there suffered from mosquito infestation. So there were proposals coming in to convert the pond into a shopping center, park and only a small portion to a pond. However, with the active efforts of the community led by Mr. Shailendra Shrestha, and financial aid from World Bank PURPP, (Pro-Poor Urban Regeneration Pilot Project) in 2017, things took a different turn for the good. The restored pond is one of the most successful Urban regeraration project of World Bank in Nepal.

Figure 3: Pimbahal Pond

5. Results and Discussion

5.1 Alko Hiti

The findings from field observations, semi structured interviews and key informant interview from Alko Hiti are listed as,

5.1.1 Semi Structured Interview

There were a total of 185 households connected to the Alko Hiti Distribution Network. Amongst them, semi structured interview was conducted in 20 households.The study included 60% females and 40% males. Likewise, 15% of the people surveyed were aged more than 50, 35 % were aged between 40 to 50, 25% were aged 30 to 40 and 25% were aged 20 to 30. Also, efforts were made to include all the ethnic groups present such as Shakya, Maharjan, Shrestha, Tandukar, Bajracharya and Bhramin. The results are,

1. The households used the distributed piped water from the project for various domestic purposes such as drinking, cleaning,

washing, sanitation etc., however even with piped supply, all of them also used water fetched directly from Hiti on a regular basis.

Analysis: The water fetched directly from Hiti is believed to be "pure water". For other domestic activities such as cooking, washing etc. people use the piped supply water, but for the purpose of drinking, most people revere to Hiti water collected in traditional vessels as being better for the body. Though there are people who are reverting to other sources such as jar water, for drinking but the linkages to religious activities remain even stronger. For the purpose of religious offering, pure water is required, which is believed to be flowing water from the Hiti. This water is called as "Nhi La:" and people come to the Hiti to fetch it for daily religious activities or during puja in festivals or important events.

2. When the respondents were asked to rate their satisfaction on a five-point scale of the project, ranging from highly unsatisfied to highly satisfied, 75% responded with highly satisfied and the remaining with satisfied.

Analysis: Even though the provided water by the project is below the per capita water supply requirements of 135 lpcd, people still responded with satisfaction. This can be attributed to the relative water security with other toles in Patan and the water culture from place to place. One respondent when inquired that they are getting less water than the per capita requirement, they simply said "There will never be enough of water. It depends upon how you use it." A point that was frequently raised when answering this question was the consistency of the Hiti supply sytem. For e.g. in the KUKL system there might be problems in the pipe line in the locality and maintenance cost might be high, but in the Hiti system there are no such maintenance issues in the pipeline.

5.1.2 Hiti Usage Data

The data of usage of Hiti was collected in the peak hours of morning(6 a.m. to 7 a.m.) and evening(5:30 p.m. to 6:30 p.m.) for three days on July 14,16 and 18, 2023 and an average of the data is shown in Figure 4.

	Native		Non Native	
Time	Male	Female	Male	Female
Morning	21	41	12	19
Evening	7	5	15	10

Figure 4: Hiti Usage Data

Analysis: The data shows that the Hiti water is used predominantly by the local community in the morning, while it is used predominantly by the non-native community in the evening. The usage characteristic is also somewhat different. The local community perform their morning religious rituals in the Hiti and also take water for drinking purpose, while the non-native people take water for drinking and other domestic purposes. In case of the local community, two thirds of the ones arriving in the Hiti were women. This time is also seen as being distinctly utilized by women for social bonding. So it serves a threefold purpose of religious rituals, social bonding and water usage. The non-native community can be seen using the Hiti water to fill up mostly 15l to 20l jars for domestic purposes. Of the total nonnative community users, 60% were found to be male. This might be attributed to the male student renters living in nearby communities.

5.2 Jagmadu Pukhu or Pimbahal Pond

The findings from field observations and key informant interviews with Jagmadu Pukhu Chhetra Bikas Samiti are as follows.

5.2.1 Rainwater Harvesting

The project has a well-functioning system of inlet providing for year round availability of water to the pond and the outlet system to the municipal drain which is used minimally. For this, surface drain is laid from about 167m from the pond. The rain water is allowed to flow in these drains with adequate slope and enters the main drains, and then sent to the collection chamber, and discharged to the pond after primary sedimentation. Rain water also enters from secondary drains laid around the pond. There are in total 9 secondary drains and an outlet drain located in the North East corner.

5.2.2 Water collection

The depth of the pond is approximated to 5.5 ft and the surface area is 3235 sq. metres (Source: Google Earth Pro). The Jagmadu Pukhu Area Development Committee steered the redevelopment of the ponds, and the committee members stated that they had constructed the pond to a level of 5.5 ft, and a minimum level of 3 ft is maintained in all seasons which means that a level of 1.5ft(0.46m) is filled during the monsoon, which amounts to 1488 cubic meters.

5.2.3 Well Recharge

Further, the pond may have aided in the recharge of the surrounding wells. The ponds in Kathmandu Valley, which are mostly man made are constructed through the use of specific technology, using a soil called "gathucha". This construction technique allows for the recharge of nearby sources. A representative statement by Mr. Shailendra Shrestha, is stated as, "During the reconstruction of the pond in 2017, the water had to be drained out. When this happened, the people from the nearby toles asked the committee to fill the water in the pond as water levels in their wells had gone down". Also, previous researches too point that the pukhu in fact worked as a water recharging body [8]. To compliment this notion, the water level of a well lying 56m North from the pond was measured. The water level was found to be 1.9m from the ground level.

5.2.4 Analysis

The Jagmadu Pukhu development model uses rainwater harvesting as a means to sustainably store rain water. This does

not require any artificial refilling of the pond. The system of dedicated inlets and outlets, charged through rainwater of this model, are the shortcomings for many recent pond development failures. Besides this, the pond water has also been used for firefighting purposes. Also, this model has eliminated the need for storm water drainage works in the service area. It stores a tentative amount of 1488 cubic metres in the monsoon, which aids to dampen the pluvial urban flooding. To add to it, the pond might have aided in increased level of water levels in the surrounding wells.

5.3 Findings and Analysis from Key Informant Interview

The key informant interviews were mostly focused on the socio-cultural aspect of the study.The interviewees unanimously agreed that Hiti system can be a solution to our water security issues, but the essence of its sustainability lies in its "Community Based Management Approach". As stated by Mr. Shailendra Shrestha, who led Jagmadu Pukhu Development Area project,

"The reason why Hiti system survived more than 1500 years, is because of its integration with the community through Guthi System and the process of Ritualization, creating a sense of ownership. So, if we are to go forward with engaging Hiti system as a Nature Based Solution, the mechanism for community engagment of Hiti system must be a crucial component."

An example of this has been given by Hiti expert, Mr. Padma Sunder Joshi as,

"The Machhindranath Jatra is an excellent example of ritualization. The jatra happens during the dry period, and all the strategic ponds have to filled before the commencement of the jatra. This is possible only when the state canals(rajkulo) are well maintained. So, before the starting of jatra, the state canals are maintained every year, establishing a ritual, and to carry out the jatra different ethnic groups have their management institutions in the form of different guthi, which delegates roles and responsibilities needed for the functioning of Machhindranath Jatra."

But, this sense of ownership is not limited solely to volunteerism. Most Guthi systems have land endowments vested in them which act as financial mechanism. This institutional backing which has socio-cultural linkages through ritual mediation has been effective in bringing about the sense of community ownership, and also establishing financial resource for generations.However, at present there has been massive decline in guthi land, the state owned guthi sansthan is not being able to cater to localized customs and traditions and the economy has moved on from an agricultural economy. In the case area of Alko Hiti, the surrounding 9.25 ropanies was said to be Guthi Land, and owned by the Bajracharya family living nearby. The land is believed to be entrusted for the operation and management, and rituals of the Hiti. However, the land rights do not lie with the Guthi now. Mr. Sushil Srestha, who led the Alko Hiti restoration said,

"There was a Guthi of Alko Hiti, which also had 9 ropanies of the nearby land, belonging to the Bajracharya family, but we don't know what they did with the land. The Bajracharya family does conduct puja 2 to 3 times a year, but are not involved in its maintenance. Now, the responsibility of Hiti is with the tole committee, and we will work for its betterment."

Incase of another case area, Jagmadu Pukhu, if it weren't for local involvement, the pukhu might have been transformed into a shopping mall. Mr. Shailendra Shrestha says that,

"The local authorities did not care much about the pond, and were waiting for the world bank project of urban regeneration to finish. If it weren't for our intervention they would have given the project away, but we persisted, and the construction of the project was completed in 6 months. We situated that maximum local participation happened, by forming smaller commit for construction, and engaging as many people as possible."

One thing, which is common to these cases, is that the sustained revival of Hiti system, has to come from the community level and mechanisms have to be identified to integrate financial resources to it. With the declining state of guthi system, in both the study context, "Tole Sudhar Samiti", which is an elected body of representatives from the community, backed by a degree of local government, are working to fill the institutional gap in the Hiti system as evident in the two successful case study of Hiti system. An important feature for their success is that in both the case studies, the restoration projects have also been financially feasible. In Alko Hiti financing has been through monthly user's fee, while in Pimbahal it has been through fish farming, boating and users fee.

These cases can provide a framework for approach for future actions. Most Guthi's relating to Hiti have become dysfunctional, mainly due to their inaccessibility with land rights. Also, the population dynamics and societal structure is changing, which urges the need for greater participation from youths and the diversifying community. As, in both cases, empowering "Tole Sudhar Samiti" with co-ordination from local government can be a viable way of moving forward with the management of Hiti system. It can ensure participation from youths and all castes and as it is an elected body of the people who live in the same area, the institution can be held the most accountable for the preservation of Hiti. The Tole Sudhar Samiti can finance the operation through internal revenue, and from the budgets of the 3 tier government and agencies. For this, if we can add the notion of Nature Based Soutions to the notion of cultural preservation to Hiti system, then this can work to create newer possibilities of financing. In this way functional integration of the system can be made as shown in fig. 5.

However, even in dysfunctional Guthi's, the act of performing religious rituals still remain, and in those where it is has been disregarded, efforts should be made to promote them to perform such rituals. In this way, by inspiring both cultural and functional aspects, the sense of community ownership can be revived to the Hiti system, which in turn adds to the water security. This way of protecting the ecosystem, by engagigng the community, can be Nepal's own version of Nature Based Solution.

6. Discussion

6.1 Hiti as a Nature Based Solution

In accordance to the first sub objective, the planning of Hiti system has been studied in this research through literature reviews, key informant interviews and case study approach, and the salient features of the system have been identified. These

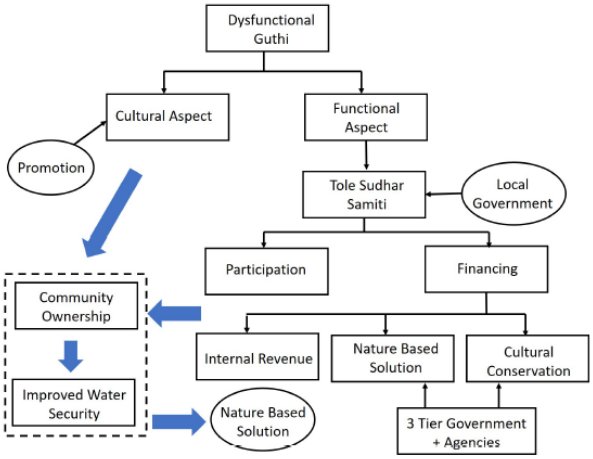

Figure 5: Proposed Institutional Structure

salient features have then been identified with concept of Nature Based Solution, to fulfill the second sub objective. This can be summarized as below.

Protection, management and enhancement of Natural Ecosystem The conservation of Hiti system, naturally amounts to conservation of ecologically water sensitive areas. These areas are generally the underground shallow aquifers and wetlands, which are essential in maintaining the underground water storage. These sources are renewable sources of water, which get replenished every monsoon, and its judicial use can bring about sustainable usage of water which is evident through the case area of Alko Hiti.

Localized Solution Hiti system is a local solution which is coherent with the principles of Environmental Justice. It is not right that Kathmandu Valley wastes its water, and then uses a different watershed for filling its need. This has been causing issues for the Melamchi watershed. Most of the water needs of Kathmandu could be met with only 6% of the rainwater (Domènech et. al, 2013).Also, it has been earlier stressed that Melamchi Water Supply has not been reliable yet and is prone to disasters in monsoon. So, in order to build water resilience, we should be working on better utilizing our local resources.

Community Based Management The Hiti system is based upon the community and its beliefs. Its management engulfs community involvement and ownership. It carries a history of socio-cultural linkages with the community. Traditionally, these aspects along with the financial mechanisms were catered through the guthi system, but our interventions have weakened the system. However, the socio-cultural ties with the community still remain strong and if appropriate financing mechanisms are established these systems can once again run in perpetuity. This is the case with both Alko Hiti and Pimbahal bond, where the community ownership remains and financial mechanisms have been established.

6.2 Hiti system in solving water security

The research has gone to fulfill the third sub objective of assessing the role of Hiti system in addressing water security through case studies and practical examples. This can be summarized as follows,

Water Stress The case of Alko Hiti shows that how the combination of Hiti and piped system can relieve water stress. It has been observed that only Melamchi will not be enough, so a localized mechanism of water supply should also be sought.

Water affordability Most Hiti systems have been delivering water free of cost, if not minimally. Considering the case when, jar water is 155 times the cost of piped water supply, and piped supply is only catering to 25% of the population, the affordability aspect of the system has been useful, especially to the urban poor. Further, it is based on gravity flow, which does not require pumping costs, and the filtration process is based on natural filtration methods.

Water Resilience Locals are often seen complaining of the maintenance issues in piped supply, and its fixation might not be done by the community alone, but in case of Hiti system, the community can move forward to fix its own problems. Hiti system is a low maintenance system. It has been functioning properly for the last 1500 years with little maintenance In case of Alko Hiti, there have been very few issues regarding maintenance, thus ensuring reliability.In case of disaster related events, for e.g. in earthquake 2072, piped supply faced numerous issues, while Hiti system served as an important source during that time. The system has also been helping to combat disasters, through the protection of open spaces, and water for firefighting purpose.

Urban Pluvial Flooding The case study of Pimbahal shows that, an alternative storm water drainage through the process of rainwater harvesting can prove to be beneficial. Ponds served multiple functions in the Hiti planning and a major function is the control of urban pluvial flooding, which was calculated to be 1488 cubic metres in a season in case of Pimbahal. This offsets the peak in flooding time, and also has the simultaneous benefit of aiding in water recharge. This principle has also been duly implemented in the sponge cities of China. For e.g. Mangrove Ecological Park in the city of Shenzen, China.

Sustainable Usage of Water The system is based upon usage of replenishable source of water i.e. shallow aquifers. It uses rainwater harvesting in the form of ponds, wetlands, and aquifer storage. The principle of the system bases upon allowing percolation of rainwater and protecting ecologically sensitive areas. All this is done by motivating the people to look after their own ecosystem through the delicate act of religion and social ties. Protection and groundwater Recharge

In this way the reasearch has been positioned to fulfill the three sub objectives which add up to fill the main objective of the research.

7. Conclusion and Recommendation

As with major cities around the world, the Kathmandu Valley is facing serious issues of water security. The learnings from studies around across the globe is that built infrastructures alone is not being able to solve water seucirity in the long run and that is why to combat this a combination of anthropogenic as well as Nature based solutions must be in place. These Nature Based Solutions have been observed to be based on traditional knowledge of water management, and as Hiti system is an indigeneous system of water management in the Valley, which is deeply connected to the community, this research has strived to showcase Hiti system as the Nepalese version to Nature Based Solutions .In this research the salient features of Hiti system as a Nature Based Solitop has been assessed which encompasses protection of ecosystem, local watershed usage and community engagement. This works to reducing water stress and increasing water affordability, water resilience, checking urban flooding and enhancing sustainable usage of water, all adding to the water security of the Valley. In this way, the sub objectives of the research, to understand the Hiti system, assess its salient features as a Nature Based solution and investigate how it adresseses water security have been studied, with the intention of fulfilling the larger objectective of assesing Hiti system as a Nature Based Solution in addressing water security in the Kathmandu Valley.

The research advocates that, the protection and enhancement of Hiti system be not limited to the notion of cultural preservation only. It should be seen as providing essential service of addressing water security. This view makes Hiti system an important mechanism to achieve sustainability. Consequently, the system can be viewed through the lens of SDG's and Climate Change Mitigation, which opens up newer possibilities for related agencies and the government to work to invest and conserve the Hiti System. With this shift in perspective the importance of Hiti system as an urban planning tool for the present and the future can be realized.

Further, the system of Hiti, is a community based system. The research also proposes an institutional model as shown in fig. 5, for the Hiti system having dysfunctional management systems, so as to reinvigorate the community relationship, which is essential to the functioning of the system.

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10.5 ANNEX E: Originality Report

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