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**Study on Identification and Development of
Hot Water Spring Sources in Nepal**

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FINAL REPORT

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Executive Summary

Introduction

Nepal is globally renowned for its natural beauty, encompassing the majestic Himalayas, diverse topography, and rich cultural heritage. Among its natural assets are numerous hot water springs, which are manifestations of geothermal activity beneath the Earth's surface. These springs emerge along tectonic belts like the Main Central Thrust (MCT), Main Boundary Thrust (MBT), and Ramgarh Thrust (RT), making them significant from geological, cultural, and economic perspectives.

Hot water springs in Nepal serve diverse purposes, including tourism, wellness, and potential renewable energy sources. However, limited scientific exploration and unstructured development have restricted their utility and potential contributions to sustainable development. This study, commissioned by the Water and Energy Commission Secretariat (WECS), aims to identify, evaluate, and propose development strategies for these natural resources.

Objective and Scope of Work

The primary objective of this study is to identify hot water spring resources in Nepal and develop a comprehensive plan for their promotion as tourism destinations. The scope of the work includes identifying hot water springs, conducting site visits to collect data, and assessing various parameters such as accessibility, historical significance, and geological conditions. The study will also evaluate the tourism potential and vulnerability of these resources while preparing a detailed development plan, including cost estimation and economic analysis of selected four sources.

The Study Area

The study area encompasses all major hot water spring sources in Nepal, aiming to prepare a comprehensive inventory of hot water springs that meet the specified threshold values (i.e., discharge, $Q \geq 1$ L/s, and temperature, $T >$ ambient temperature).

Methodology

The consultant used a systematic approach to identify and develop plans for promoting tourism at potential hot springs in Nepal. They first reviewed existing reports and consulted with local bodies to compile a list of springs with a discharge rate of at least 1 liter per second and temperatures above ambient. Field teams then conducted reconnaissance surveys to verify locations, measure flow rates and temperatures, assess accessibility and geological conditions, and gather data on historical, religious significance, and tourism potential. The verified springs were ranked, with top selections undergoing further field studies and topographic surveys using drones. For these, the consultant developed master plans outlining conservation measures, tourism infrastructure like ponds, cost estimates, revenue potential, and recommendations for implementation and investment structures.

Data Collection

Identification of potential hot spring sources across Nepal was begun by reviewing existing reports, browsing the internet, and contacting local government bodies through phone calls and emails. Combining this data, a list of 162 prospective hot spring locations was created and plotted on a map of Nepal. To verify which springs met the criteria of at least 1 liter/second discharge and temperatures above ambient, field teams led by hydrogeologists visited each location. During these reconnaissance

visits, experts collected data on flow rate, temperature, accessibility, geological conditions, and historical/cultural significance from residents. This initial survey narrowed the list down to 66 identified springs, with 41 passing the threshold for further detailed study.

Qualitative Parameters of Hot Waters

The quality of hot water springs is determined by various physical and chemical properties. Physically, the temperature plays a key role - mildly warm springs around 32-38°C can provide relaxation and therapeutic benefits, while hotter temperatures up to 45°C may aid pain relief but require caution. Other physical aspects like color, odor (e.g. sulfurous), turbidity, and pH value are also important indicators. Chemically, hot springs can contain dissolved minerals like iron, calcium, chloride, sulfur, silica, and bicarbonates which impact water hardness. While some minerals like sulfur have therapeutic value, others like nitrates, manganese, and arsenic pose health risks at high levels. By analyzing these qualitative parameters through field testing and lab analysis, the suitability of a hot water spring can be assessed for different uses like bathing, soaking, drinking water, or geothermal energy, as well as any need for treatment before utilization. Maintaining the right balance of properties is key to safely harnessing the potential benefits of these natural hot springs.

Findings

After an extensive process of reviewing existing literature, consulting with local bodies, and conducting field surveys across Nepal, the study team identified a total of 66 natural hot water spring sources. Out of these, 41 locations were found to meet the threshold criteria of having a discharge rate of at least 1 liter per second and temperatures above the ambient level. Detailed information like GPS coordinates, flow rates, temperatures, geological conditions, and qualitative parameters were collected for each of these 41 hot springs during reconnaissance surveys by trained field teams. The hot springs were assigned unique identification codes for easy tracking. Laboratory testing of water samples revealed that while most springs had acceptable levels of dissolved minerals for bathing/recreational use, around 13 sources had highly corrosive water requiring treatment before utilization. With this comprehensive data compiled, the team has shortlisted the most promising hot spring sources that can be developed further for promoting geo-tourism activities, and selected four sources for preparing site-specific master plan.

Site-Specific Master Plans

Site-specific master plans were prepared for four priority sites, integrating tourism, ecological conservation, and community engagement. These plans were developed based on extensive field visits conducted by a multidisciplinary team of experts, including geologists, urban planners, topographic surveyors, and hydrologists. Hydrological analyses were conducted using long-term data from rivers associated with each hot water spring source, while detailed topographic surveys were carried out using appropriate methods and advanced technology.

Paudwar and Bhurung Tatopani (Myagdi)

The master plan integrates sustainable development with modern amenities.

Paudwar Tatopani

- Entrance facilities and enhance accessibility considering new suspension bridge.

- Structures include ticket counters, administrative buildings, wellness centers, communal hot spring pools, and eco-friendly accommodations.
- Universal design principles ensure inclusivity, while renewable energy and waste management promote sustainability.

Bhurung Tatopani

- Facilities include retail shops, a canteen for 35 visitors, changing rooms, and two large gender-segregated pools.
- Accessibility features (ramps, wide paths) are incorporated, and ecological integrity is preserved by protecting the hot spring source.

The total project cost, including VAT and contingencies, is estimated at NPR 128,376,778.15. Revenue projections suggest annual gross revenue of NPR 29.37 million, ensuring sustainability and economic viability.

Tapta Kunda (Dang)

The Tapta Kunda master plan emphasizes leveraging existing structures while introducing immersive architectural features to enhance visitor experiences.

Key proposed facilities include:

- Parking areas (main and secondary).
- Toilets, changing rooms, and open showers.
- Hot spring and Surya Kunda bathing facilities.
- Cafeteria, food court, and landscaped garden.
- Pathways to the Shiva Mandir for spiritual and recreational purposes.
- River retaining walls and provisions for future expansions.

The design integrates sustainability by preserving natural vegetation and planning for adaptability while enhancing the site's cultural, recreational, and natural appeal.

The total project cost for the Tapta Kunda development is estimated at NPR 46,759,321.86, including VAT and contingencies. The inclusion of an entry fee of NPR 100 per person in the revenue model further ensures economic sustainability. Annual net revenue of NPR 4,653,000 after accounting for operational expenses.

Jarami Tatopani (Jumla)

The Jarami Tatopani master plan prioritizes inclusivity, sustainability, and enhanced visitor experiences. Key proposed features include:

- **Essential Facilities:** Office, ticket counters, toilets, changing rooms, and storage tanks.
- **Recreational Features:** Male and female ponds, sunbathing areas, and Dhunge Dhara (traditional stone taps).
- **Accessibility Improvements:** Differently-abled access paths and main road connections.
- **Environmental Measures:** Retaining walls, covered drains, and water management systems to minimize ecological impact.

The site's design reflects a holistic approach, integrating natural and cultural elements while ensuring long-term sustainability.

The total estimated project cost, including VAT and contingencies, is NPR 43,524,551.39. Revenue projections assume an entry fee of NPR 100 per visitor, with enhanced facilities like jacuzzis expected to increase both visitor numbers and revenue, making the project even more economically attractive.

Sunikot Tatopani (Bajhang)

The Sunikot Tatopani master plan emphasizes functionality, sustainability, and user experience. Key components of the master plan include:

- **Access and Parking:** Main entry and parking areas to facilitate visitor flow.
- **Facilities:** Cafeteria, hot water spring, outdoor showers, changing rooms, toilets, and office spaces.
- **Sustainability Features:** Solar panels for renewable energy, retaining walls, and water management systems to minimize ecological impact.
- **Future Expansion:** A reserved area for future growth while maintaining the site's natural beauty.

The site layout has been carefully designed for optimal accessibility, comfort, and environmental consciousness, while future-proofing the site for potential expansion.

The total project cost for the Sunikot Tatopani development, including VAT and contingencies, is estimated at NPR 42,743,531.66. A viability gap funding (VGF) of NPR 1.4 crore in the first year and NPR 2 crore in the second year of construction would make the project feasible. This funding would enhance the project's social benefits for the Bajhang district, making it economically viable.

The development plan integrates modern amenities with ecological sensitivity, promising a sustainable, accessible, and culturally enriched destination for visitors.

Conclusions

The study identified 162 prospective hot water spring sources through desk research, communication with local authorities, and field verification. Of these, 66 springs were confirmed, and 41 met the required threshold parameters for further analysis. After chemical testing and environmental studies, four sites—Paudwar and Bhurung Tatopani (Myagdi), Tapta Kunda (Dang), Jarami Tatopani (Jumla), and Sunikot Tatopani (Bajhang)—were recommended for further study and master planning.

The study confirms that geological structures, particularly thrusts, are the primary cause of the springs' hot water, with other factors contributing. Geothermal energy from these springs has great potential as a clean energy source, but the cost of geothermal electricity is higher compared to hydropower projects.

The development plans outlined include essential facilities such as offices, ticket counters, ponds, showers, and changing rooms. Special consideration was given to inclusivity and environmental sustainability, ensuring accessibility and minimizing ecological impact. The integrated design promotes a relaxing, community-engaging environment, highlighting the power of architecture to improve lives.

Recommendations

1. The details of the hot water springs identified should be shared with local governments for further tourism development activities.
2. Regular monitoring of the springs' flow, physical, and chemical parameters should be conducted before proceeding with any implementation or further development.

3. A comprehensive study on the causes of the hot water springs should be undertaken to ensure their preservation and a deeper understanding.

Organization of Report

This Final Report is presented in three volumes, Volume-1: Main Report, Volume-2: Annexes and Volume-3: Master Plans.

Volume 1: Main Report

- 1 Introduction
- 2 Methodology
- 3 Data Collection
- 4 Qualitative Parameters of Hot Water
- 5 Findings
- 6 Geothermal Energy
- 7 Ranking of Hot Water Spring from Tourism Aspect
- 8 Selection of Hot Water Spring for Preparation of Master Plan
- 9 Preparation of Master Plan
- 10 Conclusions

Volume 2: Annexes

- Annex-1: Response Letter from All Local levels
- Annex-2: Comparison of 162 Hot Water Springs
- Annex-3: Location map of 66 hot water springs
- Annex-4: Description of all Hot Water Springs
- Annex-5: All 66 Hot Water Springs table
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- Annex-9: Lab report test analysis summary
- Annex-10: Lab Reports
- Annex-11: D-Card of Hot Water Spring Sources
- Annex-12: Correspondences with stakeholders for Master Plan
- Annex-13: Comments response sheet

Volume 3: Master Plans

- 3A: Master Plan of Paudwar and Bhurung Tatopani, Myagdi
- 3B: Master Plan of Tapta Kunda, Dang
- 3C: Master Plan of Jarami Tatopani, Jumla
- 3D: Master Plan of Sunikot Tapoban, Bajhang

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Abbreviations

BCR	Benefit Cost Ratio
BM	Benchmarks
C	Celsius
CAD	Computer Aided Design
CBS	Central Bureau of Statistics
DEM	Digital Elevation Model
DNA	Deoxyribonucleic Acid
DSM	Digital Surface Model
EIRR	Economic Internal Rate of Return
FAO	Food and Agriculture Organization
FY	Fiscal Year
GDWQ	Guidelines for Drinking-water Quality
GIS	Geographic Information System
GoN	Government of Nepal
GPS	Global Positioning System
HDI	Human Development Index
HS/HWS	Hot Water Spring
JECFA	Joint Expert Committee on Food Additives
JV	Joint Venture
lps	Litre Per Second
MBT	Main Boundary Thrust
MCT	Main Central Thrust
MNRs	Million Nepalese Rupees
MUTM	Modified Universal Transverse Mercator
NCBI	National Centre for Biotechnology Information
NDWQS	National Drinking Water Quality Standards
NPV	Net Present Value
NRs	Nepalese Rupees
PMTDI	Provisional Maximum Tolerable Daily Intake
PNet	Professional Network for Engineering Services Pvt. Ltd.
REA	Rapid Environmental Assessment

RT	Ramgarh Thrust
Q	Discharge
SRTM	Shuttle Radar Topography Mission
T	Temperature
TDS	Total Dissolved Solid
ToR	Terms of Reference
UAV	Unmanned Aerial Vehicle
UNDP	United Nations Development Programme
US\$/	United States Dollar
VAT	Value Added Tax
WECS	Water and Energy Commission Secretariat
WHO	World Health Organization
Wtg.	Weightage

1 INTRODUCTION

Water and Energy Commission Secretariat (WECS) intends to study on Identification and Development of Hot Water Spring Sources in Nepal. For conducting consultant services of the same, WECS has nominated Global – PNet – Azad JV as per the governing laws.

This Final Report has been prepared in accordance with the Term of Reference (ToR) prepared by the Water and Energy Commission Secretariat (WECS), Singha Durbar, Kathmandu for the consulting services of the study on the Identification and Development of Hot Water Spring Sources in Nepal.

1.1 Background

Nepal, known for its majestic mountains and cultural heritage, is also home to numerous Hot Water Springs scattered across the country. These Hot Water Springs are not only natural wonders, but they also hold cultural and spiritual significance for many Nepalese people. The geothermal activity beneath the Earth's surface in Nepal has given rise to many Hot Water Springs, with temperatures ranging from lukewarm to scorching hot. These natural Hot Water Springs are believed to have therapeutic and healing properties, and people from all over the country and beyond visit them for their health benefits. These Hot Water Springs not only offer relaxation and healing benefits but also provide a unique opportunity to experience the beauty of Nepal's natural landscape.

In this scenario, the identification of hot water spring sources in Nepal emerges as a pivotal endeavour at the governmental level. As one of its core objectives of offering suggestions, recommendations, and guidance concerning the development of multipurpose projects in the water resources and energy sectors, the Water and Energy Commission Secretariat (WECS) is committed to undertaking a comprehensive study focusing on the promotion, development, and environmental safeguarding of such projects in Nepal. Consequently, WECS aims to study on Identification and Development of Hot Water Spring Sources in Nepal.

Hot Water Spring is a natural source of hot water that gets heated by the geothermal gradient beneath the earth and ultimately rises to the earth's surface through the fissures or fractures of the rocks. A Hot Water Spring, hydrothermal spring, or geothermal spring is a spring produced by the emergence of geothermally heated groundwater onto the surface of the Earth. The groundwater is heated either by willow bodies of magma or by circulation through faults to hot rock deep in the Earth's crust. In non-volcanic areas, the temperature of rocks within the Earth also increases with depth - this temperature increase is known as the Geothermal Gradient. If water percolates deeply enough into the crust, it comes into contact with hot rocks and can circulate to the surface through the fissures or fractures of the rocks to form Hot Water Springs. In Nepal, Hot Water Springs are mostly originated in the area of geologically active tectonic belts (major faults): the Main Central Thrust (MCT), the Ramgarh Thrust (RT) and the Main Boundary Thrust (MBT). Location map of Hot Water Springs in Nepal was modified from (Ranjit, 1994) and updated by Rai et al. (2020) is presented in Figure 1.1.

The study of hot water springs sources in Nepal is important for several reasons:

Tourism: Nepal is a popular tourist destination, and many tourists visit the country to see its natural beauty and experience its unique culture. Hot water springs are a natural attraction for tourists, and studying these sources can help promote tourism in the region.

Health benefits: Hot water springs are known for their therapeutic properties and have been used for centuries to treat various health conditions. Studying these sources can help identify the medicinal properties of the water and provide insights into how it can be used for health purposes.

Geothermal energy: Hot water springs are a potential source of geothermal energy, which can be used for electricity generation, heating, and cooling. Studying these sources can help identify the potential for geothermal energy production in the region and contribute to the development of renewable energy sources.

Environmental concerns: Hot water springs are often located in environmentally sensitive areas and can be affected by human activities. Studying these sources can help identify the environmental impacts of human activities on the hot water springs and provide recommendations for sustainable use and conservation.

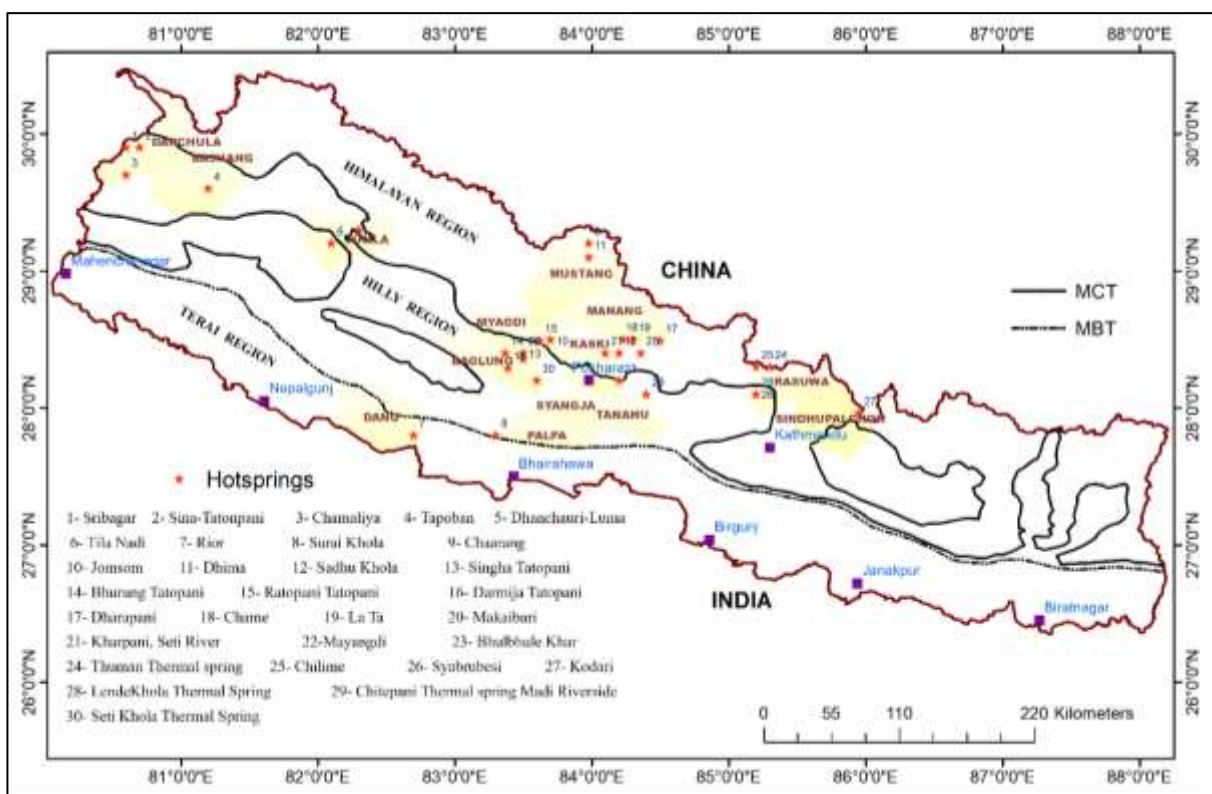


Figure 1.1: Hot Water Springs in Nepal (Rai et al., 2020)

Overall, the study of hot water springs sources in Nepal can provide important insights into the natural, cultural, and economic resources of the region and contribute to its sustainable development.

1.2 Objective of the Study

The prime objective of this study is to identify the hot water spring resources of Nepal and develop a detailed plan for most potential Hot Water Spring sources for tourism promotion.

1.3 Scope of the Work

The general scope of the work can be grouped into two areas which are as follows:

1.3.1 Task 1: Identification of Hot Water Spring Sources in Nepal

The detailed scopes of works for Task 1 are presented below:

1. Identification of Hot Water Spring sources
2. Site visit for verification and field data collection
3. The consultant shall assess the following parameters during the site visit:
 - GPS Co-ordinate of hot water springs
 - Accessibility condition
 - Status of hot water spring
 - Current use of resources
 - Historical importance
 - Topographic Condition
 - Geological Condition
 - A D-Card of each Hot Water Spring (with all information gathered)
4. Specific Properties of each hot water spring using suitable technology
5. Vulnerability Assessment
 - Depletion of resources
 - Needs for protection/conservation
 - Usage of hot water spring
6. Tourism Study
7. Preliminary Cost Estimation
8. Selection for further development

The following aspects shall be evaluated while selecting the Hot Water Spring sources for further development:

- Undeveloped area
- Good Accessibility
- Good Discharge
- Tourism potentiality

After the selection of the most potential spring sources, the consultant shall work on task 2.

1.3.2 Task 2: Prepare development plan for Geo-tourism promotion of potential Hot Water Spring sources

The detailed scopes of works of Task 2 are presented below:

1. Topographic Survey
2. Preparation of Master Plan
3. Cost Estimation
4. Economic Analysis
5. Recommendation on Implementation Structure

1.4 The Study Area

The study area will cover all the major hot water spring sources in Nepal for preparing a complete inventory of Hot Water Springs above-specified threshold values (i.e., $Q \geq 1$ lps and $T >$ ambient temperature).

2 METHODOLOGY

ToR provided by Water and Energy Commission Secretariat (WECS) contains a detailed coverage of the nature and extent of work required for the proposed study. The ToR also clearly defines the type and nature of output desired from the study.

To complete the consulting services desired by WECS, the Consultant developed a detailed methodology and work plan for the study on the Identification and Development of Hot Water Spring Sources in Nepal. Details of the methodology followed so far and to complete the remaining tasks are presented in this chapter.

2.1 Phases of Study

The present study has major two tasks as mentioned in the objective and scope of work.

Task 1: Identification of Hot Water Spring sources in Nepal

Task 2: Prepare a development plan for Geo-tourism promotion of potential Hot Water Spring sources

The methodology that the consultant followed in each of these phases after being appraised by WECS during Inception Study is described in the subsequent sections and the flowchart of overall activities for completion of the study is shown in Figure 2.1.

2.2 Task 1: Identification of Hot Water Spring Sources in Nepal

At the start, the consultant reviewed journals, reports, and maps relevant to the study on the Identification and Development of Hot Water Spring Sources in Nepal. The consultant has completed the shortlisting of Hot Water Spring Sources within Nepal. The following sub-tasks are completed for the outcome listing of Hot Water Spring Sources.

2.2.1 Inception Study

During the Inception Study, the consultant collected available literatures and feasibility/detail reports of previous studies (if any) related to the study and reviewed all these documents thoroughly. Parallely, the consultant reviewed the profile of local levels and also used telephonic conversation with the officials of local levels to collect additional sources and information. The consultant extracted the prospective location of Hot Water Spring Sources in Nepal from both literatures and telephonic conversation. The extracted locations were merged to the extent as possible and a map with the national boundary of Nepal was prepared. After the presentation of these data, the consultant further approached to all 753 local levels by means of electronic mail sent via WECS.

After collecting all the data and processing further, lists of prospective locations, 162 locations, was prepared. During this stage, the consultant has prepared the formats that will be used for data collection for different attributes of the hot water spring sources.

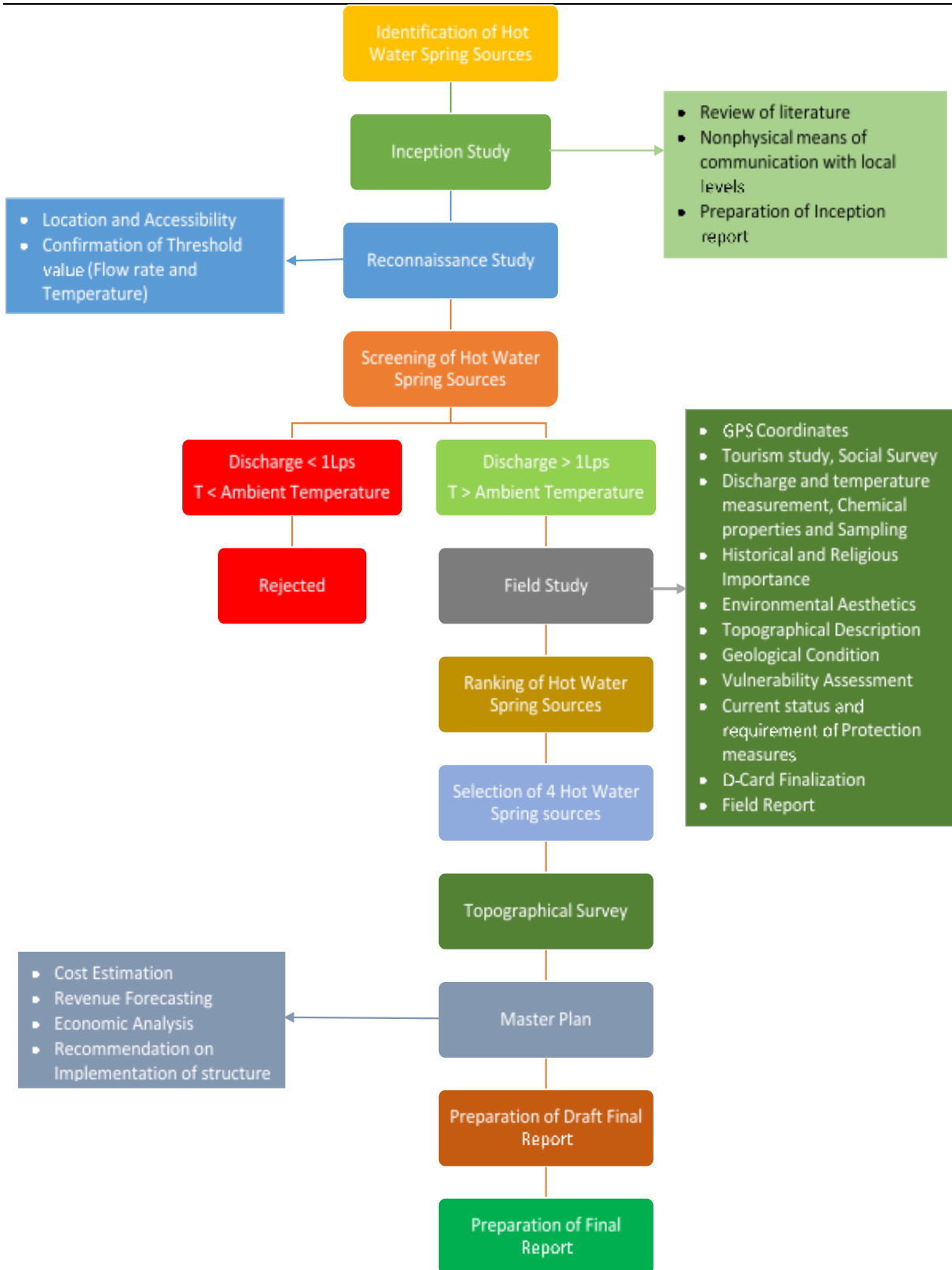


Figure 2.1: Flowchart of the activities to complete the study

2.2.2 Reconnaissance Survey

During this phase of study, consultant had split the list of prospective sources in five groups. To confirm the threshold parameters and location of Hot Water Spring Sources, 5 groups of 12 persons led each

group by a Hydrogeologist are prepared and provided a training session by expert team including Team Leader for measuring and collecting field data in anticipated formats to complete reconnaissance survey. Following parameters were considered and followed during reconnaissance survey.

Hot Water Spring quality assessment

The consultant has estimated the discharge of each hot water spring. Similarly, some important Physical properties e.g. in-situ temperature, temperature variation in 24 hours, color, turbidity, odor, pH value etc. are recorded during field survey and samples were collected from the Hot Water Spring Source with threshold parameters to perform tests in laboratory for major chemical content like Content of Sulphate, Potassium, Sodium, Magnesium, Total Dissolved Solid, Mono Carbonate, Bi Carbonate.

Hot Water Spring yield measurement

Hot Water Spring flow was measured to assess how much water is available. Where water is flowing through single source, the measurement was easy and where source is seepage type, digging for water collection was needed. The methods are described below:

Point source measurement: If the source is distinct and flowing single point through pipe, the following method can be used:

- A bucket of capacity of 5 to 15 litres will be taken. If the source is at remote area, small capacity bucket will be used.
- A measuring cylinder of capacity 1 to 2 litres will be taken. If the source is remote area and if the topography is rugged, we will take 500 ml measuring cylinder. The glass cylinder is heavy and breakable; thus, plastic measuring cylinder will be taken.
- A digital stop watch will be taken with insurance about the battery backup.
- Water will be collected directly from source and take out the bucket before it gets filled. Also, time of collection will be noted. To note the time of collection, start stop watch when we plunge the bucket in spring source for collection and stop the watch when we take out our bucket.
- A measuring cylinder will be taken and water will be poured from bucket to know the exact volume (V) of water that has been collected. The water should not be dropped or overflow from cylinder while pouring water.
- The yield (Y) will be calculated by dividing total water collected by time (T).
$$Y = V/T$$

In some condition, the source lies on cliff and within the water body and/or pond of hot water. For these type of sources, appropriate alternative methods were applied. For some sources, it couldn't conduct and data from the literature, if available, were used.

Measurement of Temperature

To measure the temperature of hot water spring, a digital laboratory thermometer was used. In general, most digital laboratory thermometers provide a temperature reading within a few seconds of being dipped in the liquid. To ensure accuracy, consultant had left the thermometer in the water for more than 60 seconds before recording the temperature reading.

Historical and Religious Importance Assessment

Assessment of historical and religious importance of the hot water spring source, of the place and/or any other landmarks nearby of the hot water spring source were gathered by communicating with local people of the area and officials of local levels in approved format.

Environmental Aesthetics Assessment (Scenic Beauty)

Environmental aesthetics explores how individuals and societies create and experience beauty in nature and the built environment, and how this beauty affects our well-being and relationship with the environment. This field survey was also considered the ethical implications of aesthetic experiences and how they inform our attitudes and actions towards the environment.

Environmental aesthetics encompasses a broad range of topics, including environmental art, landscape design, and the aesthetic value of nature. These parameters were noted with experience and photographic expression.

Geological Study

Geological study was a vital part of the identification of hot water spring sources. To complete geological study of each location of hot water spring sources, whole to the part and part to the whole methods were used. For this, gross regional geological setting was considered during inception study and planning for the field study. Later on, the geological data set were collected from field. These data again compared with the regional geological maps available. After completion of back and front processes, geological setting of each location described in detailed.

Stakeholder Consultation on Planning

Based on the experience of other Hot Water Spring works in Nepal and the proposed development concept of Water and Energy Commission Secretariat, planning for the present study was prepared and discussed with the Stakeholders. During the field survey, discussion with local level stake holders were conducted and information were collected.

For this survey, five teams, each team led by hydrogeologist were equipped to collect flow measurement, temperature, the coordinates of the location, other field tests, sampling of hot water and formats to collect physical, biological and social information within and surrounding of Hot Water Spring Sources. These teams were mobilized on 19th May, 2023 and all the teams were returned till 20th June, 2023.

After completion of field verification, a comparative list of all prospective locations was prepared.

These data were used to screen the hot water spring sources which meet the threshold condition i.e. flow rate > 1 liter/sec and temperature higher than ambient temperature. Ambient temperature was taken as the average annual temperature mentioned locally or nationally published documents like Profile of Local levels and/or other appropriate means.

2.2.3 Field Study

Preliminary ranking of the screened hot water spring sources was performed on the basis of parameters from the field and lists of Hot Water Spring Sources was prepared.

On the basis of preliminary ranking of the hot water spring sources, further field verification of the important and critical sites was conducted from 29th September, 2023 to 18th December, 2023. Further, laboratory tests of all the hot water spring with threshold parameters were performed.

The field study team was incorporated of team leader, geologist, hydrologist and representative from WECS with required equipment and accessories. The consultant updated status of the existing projects, their functionality and adequacy of water for the existing system. The consultant indicated GPS coordinates of each hot water spring source in digital map. The consultant had measured the water discharge at source and made notes on existing protection and recreational structures, if any. The consultant prepared detailed inventory on the basis of observation and available data in study area.

After observation and collection of all the information, further analysis was conducted and following parameters for each location were accessed.

2.2.3.1 Vulnerability and Sustainability Assessment

Exploring geothermal environments is not always completely safe, as there are a number of problems that can occur, some of them rather unexpectedly. Apart from the risk of thermal burns from extreme Hot Water Springs such as erupting geysers, active steam vents can release extremely hot gas or vapor, which can lead to severe burns. That might be burning the surrounding vegetation and covering nearby roads with mud and debris, causing their short-term closure for traffic. However, extremely hot gas is not reported in the context of Nepal till the date.

Other geothermal hazards include gas emissions such as Hydrogen Sulfide (H₂S) which can pose a serious threat, as this gas is potentially lethal within moments at higher concentrations. H₂S is known to occur near some Hot Water Springs and has been the cause of fatal accidents.

Along with the assessment of vulnerability by the hot water spring to the surrounding environment and visitors, the consultant will discuss with concerned authorities and locals to assess the vulnerability of the proposed hot water spring by the surrounding environment and people. The discussion will be held for comparison between current and past status of hot water spring in terms of:

- Change in flow rate and temperature
- If hot water spring source is in depletion, need for protection/conservation and possible types
- Present status for usage of hot water spring and possibility of conflict after development as a tourism destination
- Slope stability condition and impact on hot water spring, which will be observed by respective expert
- Assessing source of hot water supply by means of visual observation and regional geological interpretation (based on available geological maps) and evaluating threats to the source in future

Based on this discussion and observation, depletion rate, need for protection and conservation and measures for protection, use of hot water in different prospective were documented and further recommendations are made.

For assessment of vulnerability, rapid environmental assessment (REA) was conducted for each of the hot water spring sources with threshold parameters. During this assessment, negative impact of the hot water spring sources was also incorporated.

2.2.3.2 Tourism Study

The consultant studied the tourism importance of hot water spring sources which meet threshold criteria, current tourist flow in these locations, linkages with other tourist areas, and potential for increment in tourism activities in the future after conservation and development.

Explore the status of tourism potentiality within the identified hot water spring systems

Assessment of trail audits, a trail audit is a systematic evaluation of a trail's physical and ecological conditions, user safety, and sustainability, was done using the resources available in tourism industry. This information was used to identify route to hot water spring source and relation to already established tourism spot.

Geothermal resources such as Hot Water Springs and geothermal features as visual attractions play a significant role in several tourism sectors. Recreational activities as well as health and wellness spas are other aspects of natural hot water spring. Hot Water Springs for human use such as treatment for health conditions depend on factors like access, temperature, mineral content and a sustainable quality of the water. Hot Water Springs are commonly known for their curative powers and their therapeutic benefits and worldwide occurrence. Some mineral in hot water springs are with curative powers and they can be taken internally as well. Natural mineral and geothermal waters are used in balneology, balneotherapy, hydrotherapy and crenotherapy, which can be combined under the umbrella of thermalism.

The Consultant put its utmost efforts to gather information for tourism attraction for each point. Regular interactions with the Client was done to get suggestions and feedback. Tourism structures are so designed that they allow for flexibility in operation.

The Consultant considered tourism infrastructure that includes:

- Tourism and related structures; and
- Augmentation infrastructures, if found technically and financially viable.
- The planning concept will follow the intermittent tourism approach or rotational tourism to be introduced in accordance with Trail Audit.

Defining all the attributes collected and are useful for future use, a GIS Database was prepared and presented in map. The shapefile of the same are submitted to WECS for future use.

2.2.3.3 Preliminary Cost Estimation

The consultant assessed the current status of hot water spring sources and identify the possibility for developing as tourism spot along with conservation and protection measures required to preserve the sources. These parameters were used for a preliminary costing and revenue forecasting which was based on the experience and practices that consultant already had and obtained from present practice of already developed hot water spring sources. This preliminary cost was a parameter for the selection of hot water spring source for further development.

2.2.4 Selection for Further Development

Selection for further development plan for Geo-tourism promotion of the hot water spring source among the various sources is not a defined work and it needs multiple parameters for consideration. However, selection of potential hot water spring was done by ranking of sources with evaluation of potential factors to define sustainability of development.

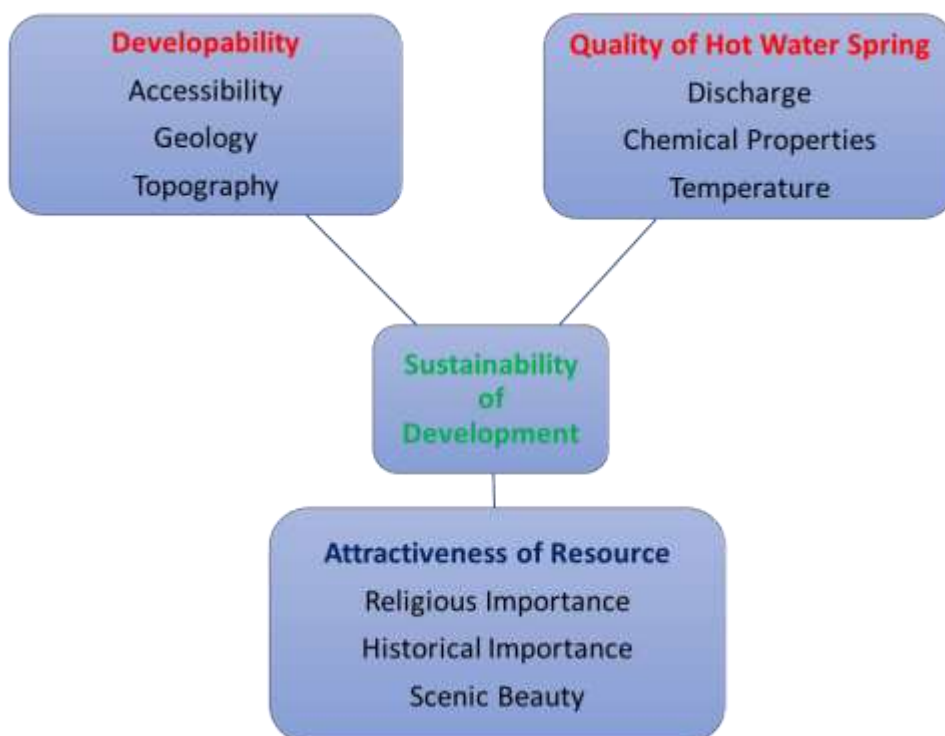


Figure 2.2: Potential factors for sustainability of development of hot water spring source

Among these factors, quality of hot water spring source and developability are potential cost factors and attractiveness of resource are potential revenue factors. These factors further used for ranking. Weightage of these factors for selection for further development was achieved as shown in Table 2.1.

Table 2.1: Weightage of factors for selection of further development of hot water spring source

Quality		Developability		Attractiveness of Resource	
Attribute	Wtg.	Attribute	Wtg.	Attribute	Wtg.
Discharge	40%	Accessibility	40%	Religious Importance	20%
Chemical Properties	30%	Geology	20%	Historical Importance	20%
Temperature	30%	Topography	20%	Scenic Beauty	20%
		Stage of development	10%	Economic Factor	40%
		HDI of Province	10%		
Potential Cost Factors				Potential Revenue Factors	
Weightage: 20%		Weightage: 30%		Weightage: 50%	

All of these attributes further ranked and ranked values were used to get overall ranking of the hot water spring source for further development.

Table 2.2: Ranking definition of attributes of selection parameters of potential hot water spring

SN	Parameters	Ranking	Remarks
Discharge			
1	1-2 lps	1	HWS with less than <1 lps is not considered for further study
2	2-3 lps	2	
3	3-4 lps	3	
4	>4 Lps	4	
Chemical properties/Therapeutic value			
1	Hazardous chemical	Reject	
2	Neutral or Low Significant	1	
3	Moderate Significant	2	
4	Significant	3	
5	Highly Significant	4	
Temperature			
1	> ambient temperature and/or <30°C	1	HWS with temperature less than ambient is not considered for further study
2	30°-38°	2	
3	>45°	3	
4	38°-45°	4	
Accessibility			
1	Very remote	1	2 or more days walk from road head and/or 3 days or more days travel time to reach the site from major city
2	Remote	2	Less than 2 days walk from road head and/or less than 3 days travel time to reach the site from major city
3	Accessible	3	Only hours walk to reach site and less than 2 days travel with mostly gravel and earthen road from major city
4	Easy Access	4	Only few hours walk to reach site and less than 2 days travel with mostly blacktopped road from major city
Geology (Geology, Geomorphology and Stability)			
1	Unstable and will be stable with support	1	Parameters and ranking will be obtained from Expert's observation, field measurements of discontinuities and experience
2	Unstable and will be stable with minimum support	2	
3	Generally stable	3	
4	Stable	4	
Topography			
1	Congested with very little space	1	
2	Fairly spacious	2	
3	Spacious	3	
4	Well spacious	4	
Stage of development			

1	Considerably developed	1	
2	Moderately developed	2	
3	Slightly developed	3	
4	Not developed (in its natural condition)	4	
Human Development Index of Provinces			
1	HDI >0.65	1	Less developed area will be prioritized by this factor
2	HDI 0.6 - 0.65	2	
3	HDI 0.55 - 0.6	3	
4	HDI <0.55	4	
Religious Importance			
1	Secondary Low	1	Secondary - Other Religious places nearby
2	Secondary High	2	
3	Primary Low	3	Primary - Hot Water Spring's religious value
4	Primary High	4	
Historical Importance			
1	Secondary Low	1	Secondary - Other Historical places nearby
2	Secondary High	2	
3	Primary Low	3	Primary - Hot Water Spring's historical value
4	Primary High	4	
Scenic Beauty			
1	Non-significant	1	
2	Low Significant	2	
2	Significant	3	
3	High significant	4	
Economic Factor			
1	Marginally beneficial	1	The non-beneficial sites will score 0 for this factor
2	Low Significant	2	
3	Significant	3	
4	Highly significant	4	

For preparing ranking of Hot Water Spring Sources for further development as tourism destination, Nepal Tourism Statistics 2021 and 2022 were thoroughly reviewed and considered the parameters defined by it. Furthermore, Nepal Government recently announced the next decade (2023-2033) as the tourism decade which was also considered.

After completion of all the information and analysis Field Report-2 was prepared and submitted. Ranking of the Hot Water Spring Sources are thoroughly discussed with WECS and concerned authorities.

After selection of the most potential spring sources and taking consent from WECS, the consultant proceeded for Task 2.

2.3 Task 2: Prepare development plan for Geo-tourism promotion of potential Hot Water Spring sources

The Consultant performed a field survey required for planning and design of development plan for Geo-tourism promotion of potential Hot Water Spring sources. The Consultant started these activities

after obtaining consent from WECS for selecting four locations of potential Hot Water Spring sources. The consultant performed following field surveys and study to prepare development plan for Geo-tourism promotion of potential Hot Water Spring sources.

2.3.1 Topographic Survey

The consultant used an unmanned aerial vehicle (UAV) and/or total station to conduct topographic survey of the selected potential Hot Water Spring sources. UAV based measurements are contactless which allows for highly visual representations of natural or manmade environment. They can be used to get information from places which cannot be easily (or safely) accessed, such as highways, rocky cliffs, remote locations, etc. As taking measurements does not interfere with traffic of work processes, low altitude photogrammetry can offer elegant control over cultivation, drainage, cliffs, landslides etc.

UAV method employed a general workflow for mapping which is similar to the one based on aerial mapping. The workflow consists of: (i) preparation; (ii) flight planning; (iii) automated flight; (iv) data processing. The first phase is preparation which includes area definition and hardware setup. The second phase is flight planning using Mission Planner software. This step will be done in the field to make the best plan based on real terrain and weather condition. We will define the time lapse interval of camera shutting in this phase. Below are flight and data acquisition parameters:

Altitude: 30 - 140 m

Ground speed: 10 m/second

Shutting intervals: 3.9 seconds

Side overlap: 75%

Forward overlap: 60%

Flights will be done automatically using waypoints defined in the flight planning phase. The flight controller recorded all of the flight parameters into a log file which will be used to determine data acquisition parameters such as camera viewing angle, position, and orientation of sensors.

Data collected with UAV from the previous phase was then processed using Pix4D Mapper software to stitch images and get georeferenced-orthophoto. The software will then generate a Digital Surface Model (DSM) and 3D Textured Mesh from the orthophoto. Once the DSM and 3D Textured Mesh have been generated, the data can be exported in various formats, including a point cloud, a contour map, or a 3D model. After generating the contour map of the desired interval, it can be exported as a 2D vector file or as a georeferenced image.

Data collected with total station, the X, Y, and Z coordinates of every detail have been recorded and saved in the Total Stations and downloaded to the computer later. The further processing of all topographic data was done on the computer and the plot of the file in AutoCAD format was prepared.

The contour map and/or 3D model will be used to prepare a master plan for the development of potential Hot Water Spring sources.

2.3.2 Rapid Environmental Assessment

During site visit for detail observation for the selected four potential hot water spring, rapid environmental assessment (REA) was conducted.

2.3.3 Preparation of Master Plan

The development plan for Geo-tourism promotion of potential Hot Water Spring sources will be prepared with the general concept to be used in CAD. This concept will be presented to the Project and Stakeholders. Comments and suggestions will be discussed and adequately incorporated and the plan will be finalized.

The master plan for the development of potential Hot Water Spring sources has two major aspects.

1. Long term conservation of Hot Water Spring Source
2. Development of a Hot Water Spring Source to promote tourism activities

Development of a Hot Water Spring Source to promote tourism activities

The selection of the potential Hot Water Spring sources, to be developed for promoting tourism activities, will already have sufficient screening works up to this stage. The preparation of the development plan will consider the following parameters.

1. Location and accessibility
2. Topographic and geological condition
3. Current use of resources
4. Water supply rights and land use
5. Medical and therapeutic properties of hot water spring
6. Historical and religious importance
7. Scenic Beauty (natural aesthetics) and Beautification

With the confirmation of land use, water supply rights and available area for development, different recreational features like swimming pond, bathing pond, bathing showers etc. will be incorporated on the master plan. During this stage, area will be allocated for additional features like hotels, restaurants.

The architectural sketch of the development concept will be discussed with stakeholders and final master plan will be prepared.

Preparation of Maps and Drawings

After the completion of study, identification and design work, the Consultant will prepare maps and drawings of the master plan. Map preparation will be done using remote sensing data and GIS tools. The Consultant will produce the drawings in GIS and AutoCAD clearly showing the plans and required section to present the concept and details of structures. The drawings will clearly indicate all the dimensions. The details of the drawings will be sufficient to estimate the cost of the project. Typical drawing details will include:

- Location Map of Hot Water Spring Source
- General arrangements of Trail Audits
- Architectural design and master plan
- Interfaces with other structures

- Structural drawing and details of structures
- Member size and arrangement
- Design and drawing of other structures as required

So far as practicable, the drawings will be prepared and presented in A-3 size paper.

2.3.4 Cost Estimation

The Consultant estimated cost for development of the selected hot water spring sources based on the proposed design and drawings. The cost is obtained using district rates of respective hot water spring sources. The basic cost for Tourism Management Works are considered, which incorporates trail audit management to connect previously defined places of historical and religious importance and other touristic values in the vicinity of the hot water spring source.

2.3.5 Economic Analysis

A geo-tourism project based on a hot water spring can have economic benefits for a region, but it is important to conduct an economic analysis to determine the potential costs and benefits of such a project.

Firstly, the costs associated with a geo-tourism project of hot water spring would include the initial investment in developing the infrastructure such as building swimming ponds, bathing ponds, bathing showers, parking lots, changing rooms, walkways and other recreational features. Ongoing maintenance costs for the hot water spring, such as protection of source, cleaning, water quality testing, and repairs to infrastructure, would also need to be factored in. Additionally, staff salaries, marketing expenses, and insurance costs would also contribute to the overall cost of the project.

On the other hand, the benefits of a geo-tourism project of hot water spring can be significant. The project can generate revenue for the region by attracting visitors and generating sales of local goods and services. Local businesses such as restaurants, hotels, and souvenir shops can benefit from increased tourism in the area. In addition, employment opportunities can be created for local residents, which can lead to increased income and economic growth.

Furthermore, a geo-tourism promotion project of hot water spring can have environmental benefits, as it can raise awareness about the importance of preserving natural resources. It can also lead to the preservation of local ecosystems and the promotion of sustainable tourism practices.

To determine the overall economic viability of a geo-tourism project of hot water spring, a cost-benefit analysis should be conducted. This analysis should consider all costs associated with the project, as well as the potential economic benefits. It should also factor in any environmental and social benefits, as well as any negative impacts that the project may have on the local community or the environment.

Overall, a geo-tourism project of hot water spring has the potential to provide significant economic benefits to a region, but careful analysis should be undertaken to ensure that the project is economically, socially, and environmentally sustainable.

The consultant performed a revenue forecasting with the various sources of revenues along with tourism benefits obtained due to development of the hot water spring as per aforementioned discussion. Cost benefit analysis was performed based on project cost and revenue to assess the feasibility of developing the hot water spring project.

Economic analysis is carried out to assess economic viability of the project. Various indicative parameter including Economic Rate of Return (EIRR), Net Present Value (NPV), Benefit cost ration (BCR) and payback period has been evaluated considering the project cost and direct benefit resulted from tangible income as revenue generated from hot water spring.

2.3.6 Recommendation on Implementation Structure

The implementation structure of a geo-tourism promotion project of hot water spring will depend on a number of factors, including the size and scope of the project, the resources available, and the specific goals of the project. The consultant has assessed the current organizational structure for operation and maintenance of the proposed hot water spring sources and recommend the suitable mechanism for construction, operation and maintenance of the project. The consultant has also proposed investment and revenue sharing modality to ensure that the project can be implemented effectively and efficiently.

2.3.7 Web-based Application

The consultant presented Web-based application for the output of this study in conceptual form in the report and provided a recommendation of study with benefits and uses of the application.

3 DATA COLLECTION

To identify the location of Hot Water Spring Sources in Nepal, two methods are used: Desk Study and Phone and Correspondence Study. Briefs of these methods are presented in following subheadings.

3.1 Desk Study

During the desk study phase of the project, the team thoroughly reviewed several relevant research papers and reports before moving on the fieldwork. For gathering information web-based browsing was also conducted. This comprehensive literature review aimed to gather as much information as possible about the hot water springs (also known as thermal springs) in Nepal, including their locations, origins, and significance. Data collected from different sources were tabulated for the location of the hot water springs. Some major sources are listed below.

1. **"Hot Water Springs (Thermal Springs) in Nepal: A Review on Their Location, Origin, and Importance" (2020) by Rai et al.**

This article provided a valuable overview of Nepal's hot water springs, mentioning a total of 35 such springs across the country. The article was extremely useful in identifying potential sites for further investigation during the fieldwork stage.

2. **"Hot Springs in Nepal: Health Benefits and Geothermal Applications (2021)" by Ranjit, M.**

Another important source was this article, which listed 83 hot water springs in Nepal. However, during the actual field visits, the team encountered several inconsistencies. Many of the identified locations had temperatures lower than ambient, and some springs were found to be dried up, washed away by floods, or damaged by earthquakes or repeated in list with different names. Additionally, the team found that the locations of some hot water springs were questionable, and when they contacted local authorities, they were informed that hot water springs did not exist in those areas.

3. **United Nations Economic and Social Commission for Asia and the Pacific, in cooperation with Nepal's Department of Mines and Geology (ESCAP Vol.9)**

This 1993 journal provided a concise overview of Nepal's hot water springs, focusing on 14 specific locations. While it did not cover all the springs in the country, it served as a valuable reference point for the researchers, helping them understand the general distribution and characteristics of these thermal springs.

4. **YouTube Sources**

In addition to academic publications, the team also scanned YouTube for relevant information. Many vloggers had visited hot water springs in Nepal and shared their experiences through videos. The team carefully reviewed these videos and compiled a list of the identified hot water spring locations, which is included in annex 5 in the second volume of this report.

5. **Web Browsing**

Web browsing was conducted extensively for seeking any of the material related with hot water springs of Nepal.

3.2 Phone and Correspondence Study

Along with the review of literatures, telecommunication to each local level throughout the country was attempted. Most of the local level bodies responded and list of the springs are prepared. Further, communication to local was continued through Electronic-mails. E-mails were sent to each local level for confirmation of hot water spring sources in their locality via WECS. This process helped us identify

an additional 25 hot water springs, which are not mentioned in the reviewed papers and reports. Letters sent to local level and obtained from there are presented in Volume-2, Annex-1.

Further, all the data collected from different sources are plotted in administrative map of Nepal and filtered duplicates. A list of 162 prospective location of hot water springs were prepared for the screening to obtain 60 nos. of springs which meets threshold criteria i.e. discharge > 1 lps and temperature > ambient temperature.

3.3 Verification and Field Data Collection

For the verification of the hot water spring sources, a field visit was planned as screening of hot water spring sources with threshold values for the maximum of 60 locations couldn't be confirmed from the desk study.

3.3.1 Identification (First Stage Survey)

These prospective locations were planned to be visited by at least one trained technician. Further, it was conducted by the team led by a hydrogeologist taken consent from WECS. During these visits, physical properties, chemical properties like pH value, topographical and geological description, sociological and environmental information, route and road heads along with road condition, and samples for laboratory tests were collected.

An inventory of prospective hot water spring source locations with respect to threshold criteria and confirmation of location is prepared (Volume-2, Annex-2).

3.3.2 Field Data Collection (Second Stage) and Verification

From the preliminary data collected from the field, a draft ranking of hot water spring sources for further development as touristic spot will be done. This ranking will be verified in the second stage of field visit and additional information will be gathered for the important and critical hot water springs shortlisted from the preliminary study.

4 QUALITATIVE PARAMETERS OF HOT WATER

Physical and chemical properties of the water from hot spring are qualitative parameters which defines the suitability of water utilization for bathing, drinking and other uses. The guiding properties and their ranges along with consequent effect are discussed below:

4.1 Physical Properties

Hot water springs, also known as thermal springs or geothermal springs, are natural features where water emerges from the ground at a temperature significantly higher than the surrounding air or ground. The physical properties of hot water springs can vary based on factors such as the geological and hydrological conditions of the area. Here are some common physical properties associated with hot water springs:

4.1.1 Temperature

Bathing in hot water springs can have various health effects, and the temperature of the water plays a significant role in these outcomes. Here are some characteristics and health effects associated with different temperatures for bathing in hot water springs:

4.1.1.1 Mildly Warm to Moderately Hot (32°C to 38°C)

This temperature range is generally considered comfortable for most people. It promotes relaxation and can help soothe muscles and joints. Mildly warm water is often suitable for extended soaking.

Health Effects

Improved circulation: Warm water can enhance blood circulation, which may benefit cardiovascular health.

Muscle relaxation: Soaking in mildly warm water helps relax muscles, reducing tension and promoting a sense of well-being.

"Human Biological Adaptability: Adapting to Climate Extremes" - Palomar College

URL: https://www.palomar.edu/anthro/adapt/adapt_2.htm

"The temperature of emotions"-PMC - NCBI

URL: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8174739/>

ncbi.nlm

Source: "The temperature of emotions" - PMC - NCBI

URL: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8174739/>

Thermohuman: "Thermography and emotions" - Thermohuman

URL: <https://thermohuman.com/2024/02/28/thermography-and-emotions/>

ResearchGate: "The mental and subjective skin: Emotion, empathy, feelings and thermography"

URL: https://www.researchgate.net/publication/275887295_The_mental_and_subjective_skin_Emotion_empathy_feelings_and_thermography

PubMed Central: "Thermal Infrared Imaging to Evaluate Emotional Competences in Nursing"

URL: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7248891/>

ResearchGate: "Infrared Thermography as a Measure of Emotion Response"

URL: https://www.researchgate.net/publication/271704323_Infrared_Thermography_as_a_Measure_of_Emotion_Response

4.1.1.2 Hot (38°C to 40°C)

Hot water in this range may induce a slight sweating effect. It can feel invigorating but might be too hot for prolonged exposure for some individuals.

Health Effects

Stress relief: Hot water induces a relaxation response, potentially reducing stress and anxiety.

Detoxification: Sweating can assist in the elimination of toxins from the body.

4.1.1.3 Very Hot (40°C and 45°C)

Water temperatures in this range can be intense and may require acclimatization. It's essential to be cautious and not stay in extremely hot water for extended periods.

Health Effects

Increased circulation: Very hot water may further enhance blood flow and oxygen delivery to tissues.

Pain relief: Intense heat can alleviate certain types of pain, but caution is needed to prevent burns or overheating.

Extremely hot water with temperature greater than 45°C are not recommended to use directly. These sources shall be treated to make within limitation of temperature.

4.1.1.4 Variable Temperature (Alternating Hot and Cold)

Some hot springs feature alternating hot and cold pools or have natural variations in temperature. This type of bathing is known as contrast bathing.

Health Effects

Improved circulation: Alternating between hot and cold water can stimulate blood vessels and improve circulation.

Muscle recovery: Contrast bathing may be beneficial for athletes, aiding in muscle recovery and reducing inflammation.

4.1.1.5 Thermal Pools with Varying Temperatures

Characteristics: Some hot spring facilities have pools with different temperatures, allowing visitors to move between them.

Health Effects

Customized experience: Users can choose the pool temperature that suits their comfort and therapeutic preferences.

Relaxation and rejuvenation: The variety of temperatures may enhance the overall spa experience.

It's crucial to note that individual tolerance to hot water varies, and certain health conditions may affect one's ability to tolerate specific temperatures. Individuals with cardiovascular issues, pregnant women, and those with certain medical conditions should consult with a healthcare professional before using hot springs. Additionally, staying hydrated is important when bathing in hot water to prevent dehydration.

4.1.2 Discharge

The discharge of hot water springs plays a crucial role in both tourism development and health-related aspects. Here's an exploration of these aspects:

Hot water springs are natural attractions, drawing visitors due to their unique features and the therapeutic value associated with the mineral-rich water.

Hot water springs often provide opportunities for recreational activities such as bathing, soaking, and swimming. Facilities built around these springs, including pools, spas, and resorts, enhance the overall tourism experience.

Hot springs are sometimes associated with cultural and historical significance. They may have been used for rituals, ceremonies, or as places of healing in indigenous cultures. Educational programs and interpretive centres can be developed to inform visitors about the geological and ecological aspects of hot springs.

Tourism around hot water springs can contribute significantly to the local economy by generating revenue through entrance fees, accommodation, dining, and the sale of local products. Job creation in the hospitality, tourism, and service sectors is often a direct result of increased tourist activity.

Some hot spring areas may also be sources of geothermal energy, contributing to sustainable development. Discharge of the hot water spring has directly related with this type of use.

Aesthetics and recreational activities are also influenced by the discharge of the hot water spring. The more the discharge, the more the flexibility of management will be achieved for different purpose of utilization.

4.1.3 Colour

The colour of the water in hot springs can vary due to the presence of dissolved minerals. For example, some springs may have a milky appearance due to suspended particles, while others may exhibit vibrant colours due to specific mineral concentrations. The colour may add the aesthetics of the hot water spring.

4.1.4 Odour

Hot water springs can exhibit variations in odour due to the presence of different gases and minerals dissolved in the water. The types of odours and their meanings can provide valuable information about the composition of the spring, but it's important to note that not all hot springs have a distinct odour. Here are some common odour types associated with hot water springs and their potential meanings:

4.1.4.1 Odour Description

1. Sulphur/Orotund Odour

A distinct rotten egg or sewage-like smell.

Possible Meaning:

Presence of hydrogen sulfide gas (H_2S) in the water, which is released during microbial breakdown of organic matter in the Earth's crust.

Sulphur compounds contribute to the therapeutic properties of some hot springs.

2. Mineral/Earthy Odour

A subtle earthy or mineral-like scent.

Possible Meaning:

Dissolved minerals such as Sulphur, iron, and other trace elements in the water.

Common in geothermal areas where the water interacts with rocks and minerals.

3. Vegetation/Algae Odour

A green or organic smell resembling vegetation.

Possible Meaning:

Presence of algae, bacteria, or other microorganisms in the spring.

The decomposition of organic matter in the water.

4. Hydrogen Peroxide/Ozone Odour:

A faint, bleach-like scent.

Possible Meaning:

Presence of ozone (O_3) or hydrogen peroxide (H_2O_2) resulting from geothermal activity.

Ozone is known for its oxidizing properties.

4.1.4.2 Health Issues Associated with Hot Springs Odours

While the odours themselves are not necessarily harmful, certain health issues may arise from exposure to specific substances in hot springs:

Hydrogen Sulfide (H_2S)

Inhalation of high concentrations of hydrogen sulfide can cause respiratory irritation, headaches, and dizziness.

Prolonged exposure to elevated levels of H_2S may have more severe health effects.

Sulphur Compounds

Some Sulphur compounds, in moderation, are believed to have therapeutic benefits for the skin and respiratory system.

Caution

Individuals with respiratory conditions may need to be cautious due to potential irritation.

Other Mineral Content

The minerals in hot springs may have skin-soothing and muscle-relaxing properties.

Caution

Some people may be sensitive to specific minerals, and excessive exposure may lead to skin irritation.

Microbial Presence

Certain microorganisms may contribute to the overall health of hot springs.

Caution

Contaminated hot springs may pose health risks, so it's crucial to ensure water quality and adhere to safety guidelines.

4.1.5 Turbidity

- Turbidity is the measure of the relative clarity of a liquid.
- Anything that makes the water cloudy will increase turbidity.
- The limit of turbidity in water is 5(15)

NTU Reasons

- a. Caused by the slit, mud, or chemicals precipitated in water.
- b. Caused by the presence of excess chloride in water.

Health Effects

Turbidity alone has no health effects. But it can interfere with disinfection, allow harmful microbes to grow, and may indicate the presence of harmful microbes, including bacteria, viruses, and parasites.

4.1.6 pH

- pH of water is a measure of acid-base equilibrium.
- pH value is a good indicator of whether water is hard or soft.
- pH of drinking water lies within the range of 6.5-8.5 (WHO).
- A higher value of pH represents that there is high chloride, bicarbonate, and carbonate in water which means water is alkaline.

Reasons

- a. Landfills sites
- b. Mining sites
- c. Large animal farms
- d. Rock formation
- e. Chemical runoff and other pollutants.

Health Effects of pH

- a. May cause kidney diseases, diarrhoea, vomiting, liver and stomach cramps.
- b. Greater tendency to leach metals from pipes.

- c. Acidic water often contains high amounts of heavy metals like arsenic, copper, lead, cadmium, chromium and zinc. Thus, inhalation may cause heavy metal poisoning.

How to neutralize the pH?

Use of neutralizing filter containing calcite or ground limestone (Calcium Carbonate) on a definite proportion.

4.2 Chemical Properties

4.2.1 Arsenic

Arsenic is a natural component of the earth's crust and is widely distributed throughout the environment in the air, water and land.

Sources of arsenic

Arsenic can enter groundwater through natural processes, such as the weathering and dissolution of arsenic-bearing minerals in rocks and sediments. It can also be introduced through human activities, including mining, industrial discharges, and the use of arsenic-containing pesticides and fertilizers. However, natural geological sources are the primary contributors to arsenic contamination in groundwater.

Health risks

It is highly toxic in its inorganic form. Arsenic is a known carcinogen and can have effects on human health, even at low concentrations. Prolonged exposure to elevated levels of arsenic in drinking water has been linked to various health problems, including skin lesions, cardiovascular disease, respiratory issues, and an increased risk of certain cancers, such as skin, bladder, lung, and kidney cancers. In utero and early childhood exposure has been linked to negative impacts on cognitive development and increased deaths in young adults.

In 2010, the Joint FAO/WHO Expert Committee on Food Additives (JECFA) re-evaluated the effects of arsenic on human health, taking new data into account. JECFA concluded that for certain regions of the world where concentrations of inorganic arsenic in drinking-water exceed 50–100 µg/L, there is some evidence of adverse effects. In other areas, where arsenic concentrations in water are elevated (10–50 µg/L), JECFA concluded that while there is a possibility of adverse effects. These would be at a low incidence that would be difficult to detect in epidemiological studies.

Prevention and control of High Arsenic Concentration

Firstly, it is required to identify the precise concentrations of arsenic from different springs. Water of higher concentration must be avoided for drinking and other recreational use.

Secondly, the higher concentration of arsenic could be diluted using with low arsenic containing water to maintain the guideline value or less.

Thirdly, Arsenic Removal System could be installed to get rid of the higher concentration of arsenic. Some recently developed technologies could be adopted for arsenic removal include oxidation, coagulation-precipitation, absorption, ion exchange and membrane techniques.

Various treatment methods can be employed to reduce arsenic levels in groundwater:

- Coagulation and filtration: Chemical coagulants can be added to water to form larger particles that can be removed through filtration. This method is effective for removing arsenic that is present in particulate form.
- Ion exchange: Ion exchange resins can selectively remove arsenic ions from water by exchanging them with other ions, such as chloride.

4.2.2 Chloride

In natural hot spring chloride could be present as in compound form or as an anion. Chlorides are widely distributed in nature as salts of sodium (NaCl), potassium (KCl), and calcium (CaCl₂). Chlorides are leached from various rocks into soil and water by weathering.

Health Effects

A normal adult human body contains approximately 81.7 g chloride. On the basis of a total obligatory loss of chloride of approximately 530 mg/day, a dietary intake for adults of 9 mg of chloride per kg of body weight has been recommended (equivalent to slightly more than 1 g of table salt per person per day). For children up to 18 years of age, a daily dietary intake of 45 mg of chloride should be sufficient. A dose of 1 g of sodium chloride per kg of body weight was reported to have been lethal in a 9-week-old child.

Chloride toxicity has not been observed in humans except in the special case of impaired sodium chloride metabolism, e.g. in congestive heart failure. Healthy individuals can tolerate the intake of large quantities of chloride provided that there is a concomitant intake of fresh water. Chloride concentrations in excess of about 250 mg/litre can give rise to detectable taste in water, but the threshold depends upon the associated cations. Consumers can, however, become accustomed to concentrations in excess of 250 mg/litre. No health-based guideline value is proposed for chloride in drinking-water.

Prevention and control of High Chloride Concentration

However, increased levels of chloride relate to increased levels of TDS which then require treatment to prevent the negative effects and reduce the overall amounts. Some negative effects of chloride include contamination and health risks. To reduce the Chloride content of the spring various ways could be adopted on the basis of Chloride concentration and our requirement. Some of the ways that could be adopted are

Ion Exchange Filter

Ion exchange filters consist of resin beads that are chemically charged to exchange ions with salts containing chloride. This solution particularly removes chloride by the process of absorption onto the resin beads. The removal of chloride from water can easily be delivered and used for the application of industrial wastewater or irrigation. A benefit to this system is that it does not require frequent backwashing cycles.

Reverse Osmosis System

Reverse Osmosis is the one process that can reduce the most amounts of dissolved solids (TDS) and salts including augmenting chloride removal from water. The process of Reverse Osmosis Systems

consists of pressurizing water through a semipermeable membrane for high quality water. As high pressure is applied on the feed water, the finely pored filter captures all major contaminants and only allowing water molecules to pass through. The permeate water from this water treatment system contains about 90-95% less TDS and salt particles; making it one of the cleanest and highest quality forms of water. This procedure could not be executed on larger scale.

4.2.3 Iron

Iron exists in two forms ferrous and ferric ions. Ferrous ion is soluble and dissolved in water while ferric is insoluble in water and forms solid particles that can cause a visible discoloration.

Effects on water quality

Anaerobic groundwater may contain ferrous iron at concentrations up to several milligrams per litre without discoloration or turbidity in the water when directly pumped from a well. When the water is exposed to air or oxidizing agents, ferrous iron can be oxidized to ferric iron, causing the formation of reddish-brown precipitates or stains. These particles can settle and accumulate in water pipes, fixtures, and appliances, leading to clogging or staining. Iron can also affect the taste and odour of the water, giving it a metallic or rusty flavour.

Health effects

No health-based guideline value is proposed for iron. Iron is an essential mineral for the body, and small amounts of dietary iron are necessary. Estimates of the minimum daily requirement for iron depend on age, sex, physiological status and iron bioavailability and range from about 10 to 50 mg per day. However, consuming water with extremely high iron levels may have adverse effects on health, such as gastrointestinal issues and potential interference with nutrient absorption.

As a precaution against storage in the body of excessive iron, in 1983, JECFA established a PMTDI of 0.8 mg/kg body weight, which applies to iron from all sources except for iron oxides used as colouring agents and iron supplements taken during pregnancy and lactation or for specific clinical requirements. An allocation of 10% of this PMTDI to drinking-water gives a value of about 2 mg/l, which does not present hazard to health. The taste and appearance of drinking-water will usually be affected below this level (Guidelines for drinking-water quality Fourth edition incorporating the first and second addenda, 2022).

Prevention and control of High Iron Concentration

Iron is a chemical element that is abundant on earth's crust, including water from natural spring. Iron can be suspended in water with organic substances or inorganic solids in the form of ferrous cations (Fe^{2+}) and ferric (Fe^{3+}). The presence of iron that exceeds the threshold can cause various health hazards. The iron content in hot springs can be reduced so that it can be used as water that is fit for recreational use by reducing the direct and indirect health problems. Some of the process to reduce the iron content from the spring are as follows:

Filtration

Filtration is the process of purifying or filtering water through the media, whereas long as the water flows through the media there will be a quality improvement. This is due to the separation of suspended and colloid particles, reduction of other bacterial organisms, and the exchange of chemical

constituents present in water. The filtering process aims to remove suspended solids and reduce iron levels through porous media.

Aeration

Aeration is a process of adding air or oxygen in water by bringing water and air into close contact, by spraying water into the air, or by giving air fine bubbles and letting it rise through the water. This process is an effort to increase the oxygen concentration contained in water so that the oxidation (aeration) process of biology by microbes will run well. The aeration process usually consists of an aerator, settling tank, and filter or filter. An aerator is a tool for touching oxygen from the air with water so that the iron in the raw water reacts with oxygen to form ferric compounds that are relatively insoluble in water.

Adsorption

Adsorption is the process of collecting substances dissolved in solution by the surface of the absorbent substance. Both of them often appear simultaneously with a process, so that there is something called sorption. In adsorption, there are what are called adsorbents and adsorbates. Adsorbents are absorbent substances, while adsorbates are substances that are absorbed. Adsorption is the process of binding a molecule from the gas or liquid phase into an adsorbent from an adsorbate. The most potential adsorbent is activated carbon. Activated carbon is a porous solid containing 85-95% carbon.

Coagulation

Coagulation is defined as the process of destabilizing colloid loads of suspended solids including bacteria and viruses with a coagulant, thus forming flocks, with the influence of gravity being sedimented [13]. Commonly used coagulant materials are alum ($Al_2(SO_4)_3$), ferrous sulphate ($FeSO_4$), ferric sulphate ($Fe_2(SO_4)_3$), poly aluminium chloride (PAC), ferrous chloride ($FeCl_2$), ferric chloride ($FeCl_3$), and natural coagulants of moringa seeds.

Electrocoagulation

Electrocoagulation is a process of coagulation or clotting with electric power through an electrolysis process to reduce or decrease metal ions and particles in the water. The basic principle of electrocoagulation is the reaction of reduction and oxidation (redox). In an electrocoagulation cell, the oxidation event occurs at the positive (+) electrode, namely the anode, while reduction occurs at the negative (-) electrode, namely the cathode. The electrocoagulation (electrochemical) method is used to reduce the concentration of pollutants such as iron in groundwater using a certain voltage to precipitate pollutants in the form of iron oxide.

<https://ejournal.uin-malang.ac.id/index.php/jip/article/download/12078/8730>

These are the some of the methods that are used to reduce the iron content from the natural spring water. As per site condition, space availability and cost factor these methodologies could be adopted for healthy spring water.

4.2.4 Calcium

Calcium is a naturally occurring mineral commonly found in water sources.

Sources of calcium

Calcium enters the water through various sources, including the dissolution of minerals in rocks and soil, particularly limestone and gypsum. Water sources in areas with high calcium-containing geological formations are more likely to have elevated calcium levels.

Adequate intake of calcium is important for proper skeletal growth, preventing osteoporosis, and maintaining dental health. Drinking water with moderate levels of calcium can contribute to the overall dietary intake of this essential nutrient.

Most calcium in surface water comes from streams flowing over limestone, CaCO_3 , gypsum, CaSO_4 , $2\text{H}_2\text{O}$ and other calcium-containing rocks and Minerals. Calcium carbonate is relatively insoluble in water, but dissolves more readily in water containing significant levels of dissolved carbon dioxide.

Effect on water quality

High calcium levels can contribute to the formation of cloudy or milky water, particularly when combined with high levels of bicarbonate ions (resulting in temporary hardness). These particles can settle or form a coating on surfaces.

Health Benefits

Maintained ingestion of calcium helps the individual to overcome the diseases directly and indirectly. Calcium is a major element of human body metabolism. Consumption of calcium can help the human body in following diseases:

- Osteoporosis
- Kidney Stones
- Hyper tension and Stroke
- Insulin Resistance

Health Effects

Calcium in water is generally considered safe for consumption and does not pose any health risks. In fact, calcium is an essential nutrient that the body requires. However, it's worth noting that excessive calcium intake from all sources (including water and food) may lead to health issues for certain individuals, such as those with certain kidney conditions or a predisposition to kidney stones.

When absorbed calcium is in excess of need, the excess is excreted by the kidney in most healthy people. Concern for excess calcium intake is directed primarily to those who are prone to milk alkali syndrome (the simultaneous presence of hypercalcaemia, metabolic alkalosis and renal insufficiency) and hypercalcaemia. Although calcium can interact with iron, zinc, magnesium and phosphorus within the intestine, thereby reducing the absorption of these minerals, available data do not suggest that these minerals are depleted when humans consume diets containing calcium above the recommended levels. For example, even though high intakes of calcium can exert acute effects on iron absorption, there is no evidence of reduced iron status or iron stores with long-term calcium supplementation.

Prevention and control of High Calcium Concentration

Excessive amount of Calcium could be altered by following processes:

Filtration

Water filtration systems, such as reverse osmosis or distillation, can help remove minerals like calcium from water. These systems use a physical barrier or a chemical process to filter out impurities.

Ion Exchange

Water softeners use ion exchange resins to replace calcium and magnesium ions with sodium ions, reducing the hardness of the water. This is a common method used to soften water in the system.

Chemical Treatment

The use of water softeners minimizes the concentration of high levels of calcium in water. Adding chemicals like lime or alum to the water can help precipitate out calcium carbonate. However, this method may not be suitable for drinking water without proper expertise.

Electrolysis

Some advanced water treatment systems use electrolysis to remove calcium ions from water. This method involves passing an electric current through the water to separate out ions.

4.2.5 Bicarbonates

Bicarbonates get into water when it passes through a calcium carbonate or magnesium carbonate (limestone or dolomite) rock formation. The stone dissolves into calcium and/or magnesium ions and bicarbonate ions. Sodium bicarbonate mixed in water can be used as an antacid to treat acid indigestion and heartburn. Its reaction with stomach acid produces salt, water, and carbon dioxide.

Hardness is due to the higher value of calcium and magnesium.

Effect

- Bicarbonate produce temporary hardness.

Total Hardness

- Caused by Ca and Mg ions present in water

Health considerations

Hardness in water does not possess any direct health effects. However, a high level of hardness may cause some health effects.

Prevention and control of High Carbonates Concentration

The bicarbonate ion may combine with calcium and magnesium and precipitate as calcium carbonate and magnesium carbonate.

Electrocoagulation is also adopted to control the concentration of Carbonates.

Solutions

- Use of water softeners.
- Boiling water before its use.

4.2.6 Magnesium

Magnesium is the fourth most abundant cation in the body and the second most abundant cation in intracellular fluid. It is a cofactor for some 350 cellular enzymes, many of which are involved in energy metabolism. It is also involved in protein and nucleic acid synthesis and is needed for normal vascular tone and insulin sensitivity. Low magnesium levels are associated with endothelial dysfunction, increased vascular reactions, elevated circulating levels of reactive protein and decreased insulin sensitivity. Low magnesium status has been implicated in hypertension, coronary heart disease, type 2 diabetes mellitus and metabolic syndrome. Magnesium acts as prime resistive element on following health problems.

- Hypertension
- Cardiac arrhythmias
- Pre-eclampsia
- Atherosclerosis
- Coronary Heart Diseases
- Diabetes Mellitus
- Magnesium Depletion Status
- Hypermagnesemia
- Gastrointestinal function

Prevention and control of High Magnesium Concentration

Magnesium compounds are usually removed from water, because of the role magnesium plays in water hardness. This is achieved by means of water softening.

Magnesium hydroxide is applied as a flocculant in water purification.

<https://www.lenntech.com/periodic/water/magnesium/magnesium-and-water.htm#ixzz8fTu2iNQU>

4.2.7 Sodium

Sodium is an essential nutrient necessary for maintenance of plasma volume, acid-base balance, transmission of nerve impulses and normal cell function. Sodium deficiency is extremely unlikely in healthy individuals. Excess sodium is linked to adverse health outcomes, including increased blood pressure. The taste threshold concentration of sodium in water depends on the associated anion and the temperature of the solution. At room temperature, the average taste threshold for sodium is about 200 mg/l. No health-based guideline value has been derived, as the contribution from drinking-water to daily intake is small. Sodium is an essential nutrient and is needed by the body in relatively small amounts (provided that substantial sweating does not occur) to maintain a balance of body fluids and keep muscles and nerves running smoothly. Sodium attracts water, and a high-sodium diet draws water into the bloodstream, which can increase the volume of blood and subsequently your blood pressure. High blood pressure (also known as hypertension) is a condition in which blood pressure remains elevated over time. Hypertension makes the heart work too hard, and the high force of the blood flow can harm arteries and organs (such as the heart, kidneys, brain, and eyes).

Prevention and control of High Sodium Concentration

water treatment may be a practical way to remove sodium and other minerals, whether natural or added by softening. Reverse osmosis or distillation are the treatment options.

4.2.8 Potassium

Potassium is an essential element in humans and is seldom, if ever, found in drinking water at levels that could be a concern for healthy humans. The recommended daily requirement is greater than 3000 mg. Potassium occurs widely in the environment, including all-natural waters. It can also occur in drinking-water as a consequence of the use of potassium permanganate as an oxidant in water treatment. In some countries, potassium chloride is being used in ion exchange for household water softening in place of, or mixed with, sodium chloride, so potassium ions would exchange with calcium and magnesium ions. Possible replacement or partial replacement of sodium salts with potassium salts for conditioning desalinated water has been suggested. Potassium has many important functions on human body:

- It allows the nerves to respond to stimulation and muscles to contract (tighten), including those in the heart.
- It reduces the effect of sodium (present in table salt) on blood pressure.
- It helps move nutrients into cells, and waste products out of cells.

The maintained potassium quantity on human body helps to:

- control blood pressure
- protect against strokes and cardiovascular diseases
- protect against osteoporosis
- prevent kidney stones

Prevention and control of High potassium Concentration

A high potassium (hyperkalaemia) is a serious and potentially life-threatening condition. So, to take the health benefit of potassium, it is essential to control the concentration of Potassium in the waterbody. Potassium may be removed from water by means of reverse osmosis.

Potassium is applied in water purification. For example, potassium permanganate is applicable for oxidation of waterborne compounds, such as for iron or manganese removal, and disinfection. This is however not generally recommended. Potassium permanganate application makes it possible to determine the oxidative capacity of organic matter in water.

(<https://www.lenntech.com/periodic/water/potassium/potassium-and-water.htm#ixzz8fTfEkPFv>)

4.2.9 Silica

Silica is commonly found mineral on lithosphere. Silica naturally occurs in mineral water and is believed to improve heart health in the human body by reducing cholesterol levels that cause plaque and fatty acids to build up in the arteries and blood vessels. Silica in water benefits to support toned skin, lustrous hair and strong nails by increasing collagen production, which decreases during the ageing process and helps to strengthen connective tissues. It also helps to detoxify the body and support the immune system.

Prevention and control of High Silica Concentration

Excessive Silica of the Water Source could be reduced by following Methods:

- Filtration
- Chemical Precipitation

- Reverse Osmosis
- Strong Base and Ion Exchange

Conventional precipitation technologies are messy and time consuming. When complete silica removal is required, various combinations of Reverse Osmosis and ion exchange processes are used. RO systems are currently unable to remove as much silica as ion exchange can but is far better at removing various forms of non-reactive silica and will remove many additional contaminants not addressed by ion exchange.

4.2.10 Sulphur

Sulphur- naturally occurring - a result of decay and chemical reactions with soil and rocks. The water in hot water springs may contain dissolved minerals, including Sulphur compounds, derived from the surrounding rocks. Sulphur can be present in various mineral forms, such as sulphides and sulphates, which may dissolve in the hot water of these springs.

Sulphur is an abundant mineral in the human body. It occurs naturally and has many functions. Proteins, vitamins, and other elements in the body contain sulphur, which plays a vital role in several processes that are essential to life.

Some people believe that taking sulphur supplements (capsules or powders) offers various benefits, such as relief from allergies, osteoarthritis (a common form of arthritis that wears away the protective cartilage at the ends of bones), and muscle soreness. In addition, topical sulphur products are touted as treatments for various skin conditions.

Health Benefits

Sulphur is an essential mineral that plays a vital role in various bodily functions. Here are some of the key health benefits of sulphur:

- Sulphur is known for its potential benefits for the skin. It may help in the treatment of certain skin conditions like acne, psoriasis, and eczema. Sulphur helps maintain the integrity of connective tissues like skin, tendons, and ligaments.
- Sulphur helps produce glutathione, one of the body's main antioxidants. Glutathione protects cells from damage caused by oxidative stress and inflammation.
- Sulphur is necessary for the synthesis and repair of DNA. It helps maintain the integrity of genetic material.
- Sulphur is involved in the metabolism of food and the production of energy within cells.
- The warm water itself from hot springs may improve blood circulation, promoting overall skin health.
- Soaking in Sulphur-rich hot water may provide relief to individuals with joint and muscle pain. It is believed to have anti-inflammatory properties.
- Inhalation of steam from Sulphur-containing hot springs may be beneficial for respiratory conditions like asthma or sinus congestion.
- Sulphur supports immune function and helps fight infections and diseases.

Caution

While hot water springs with Sulphur content are often associated with potential health benefits, caution should be exercised, especially for individuals with allergies or certain health conditions. Consulting with a healthcare professional and being aware of one's own health status is essential

before seeking therapeutic benefits from hot water springs. Additionally, taking precautions to avoid overexposure and burns is important for a safe and enjoyable experience.

Health Effects of High Sulphur Intake

- While sulphur is essential, consuming too much from certain sources can have negative health effects:
- Drinking water with high sulphur levels may cause loose stools, diarrhoea, and digestive discomfort.
- Breathing in high concentrations of sulphur dioxide gas can irritate the respiratory tract and exacerbate conditions like asthma. Factors like exercise and breathing dry or cold air can worsen these effects.
- Some people may be sensitive to sulphites, sulphur-derived preservatives used in certain foods and beverages. This can trigger allergic reactions in sensitive individuals.

Prevention and Control

Prevention and control of negative health effects of high sulphur concentration:

- Avoid drinking water with high sulphur content
- Limit consumption of foods and beverages with added sulphites
- Use caution when working with sulphur-containing chemicals and gases
- Seek medical attention for severe respiratory distress or allergic reactions

Sulphur Treatment

Aeration

Aeration is one of the most effective methods for removing hydrogen sulphide (H₂S) from water. Exposing the water to air causes the dissolved H₂S gas to be released, which can then be vented away. Aeration systems that bubble air through the water or expose it to a large surface area are commonly used.

Oxidation

Oxidizing agents like chlorine, hydrogen peroxide, or potassium permanganate can be used to convert dissolved sulphur compounds into insoluble forms that can be filtered out. This process involves injecting the oxidant into the water and providing sufficient contact time before filtration.

Filtration

After oxidation, the insoluble sulphur particles can be removed through mechanical filtration. Filters containing materials like sand, greensand, or activated carbon are effective at trapping the sulphur solids.

Ion Exchange

For sulphate removal, ion exchange systems that use resin beads to adsorb the sulphate ions can be employed. The resin must be periodically regenerated by flushing with a brine solution.

Reverse Osmosis

Reverse osmosis membranes can effectively remove both sulphate and hydrogen sulphide from water by rejecting the dissolved sulphur compounds.

Distillation

Distillation systems boil the water, causing the sulphur compounds to be left behind in the boiling chamber while the purified steam is collected. The most appropriate sulphur removal method depends on factors like the specific sulphur compounds present, their concentrations, and the overall water chemistry.

<https://www.verywellhealth.com/sulfur-what-should-i-know-about-it-89517>

<https://draxe.com/nutrition/foods-high-in-sulfur/>

<https://www.webmd.com/vitamins/ai/ingredientmono-1527/sulfur>

<https://www.rxlist.com/supplements/sulfur.htm>

<https://www.healthline.com/nutrition/foods-with-sulfur>

<https://www.ncbi.nlm.nih.gov/books/NBK596165/>

4.2.11 Hydrogen Sulphide

Hydrogen sulphide is a colourless, flammable gas with a characteristic odour of rotten eggs. It is produced naturally and as a result of human activity. Natural sources include non-specific and anaerobic bacterial reduction of sulphates and sulphur containing organic compounds. Hydrogen sulphide is found naturally in crude petroleum, natural gas, volcanic gases, and hot springs. It is also found in groundwater. It is released from stagnant or polluted waters and manure or coal pits. Hydrogen sulphide may be produced by a variety of commercial methods. The principal source of hydrogen sulphide is recovery as a by-product in the purification of natural and refinery gases. It is also a by-product of Kraft pulp and paper manufacturing and carbon disulphide production. It is used as an intermediate in the manufacture of sulfuric acid and inorganic sulphides and as an agricultural disinfectant. Hydrogen sulphide is also produced as a decomposition product of xanthates (used in the mining industry) when they come into contact with water.

The concentration of hydrogen sulphide in air in unpolluted areas is very low, between 0.03 and 0.1 µg/m³. Humans may be exposed to hydrogen sulphide from endogenous production and from exogenous sources. Most endogenous production results from the metabolism of sulfhydryl-containing amino acids (e.g., cysteine) by bacteria present in both the intestinal tract and the mouth. Hydrogen sulphide is also produced in the brain and several smooth muscles (e.g., thoracic aorta, ileum, and portal vein) by enzymes found in these tissues. In the rat, the endogenous level of hydrogen sulphide is 50–160 µmol/litre in the brain and 1 mmol/litre in the ileum.

Hydrogen sulphide (H₂S) exhibits both physiological and toxicological roles in the biological systems. Acute exposure to high levels of H₂S is life threatening while long-term exposure to ambient levels of H₂S elicits human health effects.

Health Benefits of Hydrogen Sulphide

Hydrogen sulphide (H₂S) is a naturally occurring gas that has been found to have several important health benefits when present in the body at appropriate levels:

- H₂S acts as an antioxidant, helping to neutralize reactive oxygen and nitrogen species that can cause oxidative damage to cells. It also has cytoprotective properties, helping to protect cells from apoptosis and degeneration.
- H₂S plays a role in regulating blood pressure and vascular tone. It can help relax blood vessels and improve blood flow.
- H₂S has been shown to have neuroprotective effects, helping to protect neurons from damage and degeneration in the central nervous system.
- H₂S can help reduce inflammation by modulating the immune response and signalling pathways.

Health Effects of High Hydrogen Sulphide Exposure

While H₂S is important in the body, exposure to high concentrations can have severe negative health effects:

Breathing in high levels of H₂S can irritate the respiratory tract, causing coughing, difficulty breathing, and fluid build-up in the lungs. Exposure to very high concentrations can lead to respiratory failure and death.

H₂S is a neurotoxin that can impair the central nervous system. High exposure can cause headaches, dizziness, confusion, unconsciousness, and seizures.

Acute exposure to H₂S can lead to low blood pressure, abnormal heart rhythms, and cardiovascular collapse.

H₂S can irritate the eyes, causing redness, pain, and even blindness with severe exposures.

Prevention and Control of high hydrogen sulphide

To prevent and control the negative health effects of high hydrogen sulphide exposure:

- Identify and eliminate sources of H₂S in the work or living environment
- Use proper ventilation and engineering controls to reduce H₂S levels
- Wear appropriate personal protective equipment like respirators when working with H₂S
- Monitor H₂S levels in the air and take immediate action if concentrations become dangerously high
- Seek immediate medical attention if experiencing symptoms of H₂S poisoning

Treatment

Chlorination and Filtration

One of the most common and effective methods is to use chlorination followed by filtration:

- Add chlorine (approximately 2 mg/L chlorine per 1 mg/L H₂S) to oxidize the H₂S into insoluble sulphide particles
- Allow sufficient contact time (20-30 minutes) for the reaction to complete
- Filter the water to remove the insoluble sulphide particles using an activated carbon filter
- The carbon filter also removes any residual chlorine

Aeration

Aeration can also be used to remove H₂S by stripping the gas from the water. However, this process may not always reduce H₂S to unnoticeable levels, so combining it with a carbon filter is recommended.

Manganese Greensand Filtration

Using a filter containing manganese greensand is another option. The manganese dioxide in the greensand oxidizes the H₂S, and the oxidized particles are then filtered out. Shock Chlorination If the H₂S is caused by sulfur bacteria, shock chlorination of the entire water system can kill the bacteria and eliminate the source of the problem. The choice of treatment method depends on the concentration of H₂S and other water quality factors. Consulting a water treatment professional can help determine the most appropriate solution for a given situation.

<https://www.news-medical.net/news/20230731/Tiny-amounts-of-hydrogen-sulfide-could-help-people-live-healthier-for-longer.aspx>

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6977057/>

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6221678/>

<https://wwwn.cdc.gov/TSP/MMG/MMGDetails.aspx?mmgid=385&toxid=67>

<https://www.gdscorp.com/blog/hydrogen-sulfide/harmful-health-effects-of-hydrogen-sulfide-h2s/>

4.2.12 Sulphate

Sulphates occur naturally in numerous minerals, including barite (BaSO₄), epsomite (MgSO₄·7H₂O) and gypsum (CaSO₄·2H₂O) (Greenwood & Earnshaw, 1984). These dissolved minerals contribute to the mineral content of many drinking-waters and water bodies of recreational use. Reported taste threshold concentrations in drinking-water are 250–500 mg/litre (median 350 mg/litre) for sodium sulphate, 250–1000 mg/litre (median 525 mg/litre) for calcium sulphate and 400–600 mg/litre (median 525 mg/litre) for magnesium sulphate (NAS, 1977). In a survey of 10–20 people, the median concentrations that could be detected by taste were 237, 370 and 419 mg/litre for the sodium, calcium and magnesium salts, respectively (Whipple, 1907). Concentrations of sulphates at which 50% of panel members considered the water to have an “offensive taste” were approximately 1000 and 850 mg/litre for calcium and magnesium sulphate, respectively (Zoeteman, 1980).

The presence of sulphate in drinking-water can cause noticeable taste, and very high levels might cause a laxative effect in unaccustomed consumers. Taste impairment varies with the nature of the associated cation; taste thresholds have been found to range from 250 mg/l for sodium sulphate to 1000 mg/l for calcium sulphate. It is generally considered that taste impairment is minimal at levels below 250 mg/l. No health-based guideline value has been derived for sulphate. (Guidelines for drinking-water quality Fourth edition incorporating the first and second addenda, 2022).

Chloride sulphate waters stimulate intestinal motility and are administered against chronic constipation and other digestive and hepatic biliary disorders.

Sulphate bicarbonate-calcium-magnesian mineral waters, administered as hydropinotherapy, are useful against disorders of the biliary tract; these waters are particularly efficacious thanks to anions

that exert choleresis and cholagogue actions, thus helping in removing gallbladder hypomotility and correcting the tendency to gallstones.

Prevention and control of High Sulphate Concentration

High sulphate concentration could be controlled by following processes:

Reverse osmosis/nanofiltration

Water is forced under pressure through a porous membrane designed to remove ions from the water.

Ion exchange

Inorganics are removed by passing water over cation and anion exchangers, replacing cations and anions with H⁺ or Cl⁻ or OH⁻

Electrodialysis

Direct current is applied across a body of water separated into vertical layers alternatively permeable to cations and anions.

4.3 Health Effect of Chemical Components

Chemical hazards can enter surface water or be deposited on water bodies from anthropogenic sources or natural sources. Contamination may be from point sources, such as industrial outfalls, or non-point (diffuse) sources, such as runoff. However, this is less possible phenomena for hot water springs as they come from deep ground. The frequency, extent and likelihood of exposure are important inputs into assessing the risks from chemicals in recreational waters. The form and frequency of recreational activity (7–8 swimming events per year in temperate climates and up to 150 swimming events per year in warmer climates; Schets, Schijven & de Roda Husman, 2011; NHMRC, 2019) will therefore play a significant role.

Routes of exposure can include contact with the skin (dermal), eyes and mucous membranes; inhalation; and ingestion.

4.3.1 Dermal Exposure

Skin and eye irritation result from exposure to some chemicals, including cyanobacterial toxins such as lyngbyatoxin-a, and alkaline and acidic substances with extreme pH (<4 or >11). Generally, irritation will be transient and resolved by washing in clean water. Exposure may be exacerbated by broken or damaged skin.

4.3.2 Ingestion

Limited data are available on volumes of water ingested during recreational activities. Estimates of volumes ingested per swimming event (95th percentiles) are 170–179 mL in children and 87–210 mL in adults in fresh waters, and 140–250 mL in children and 124–170 mL in adults in marine waters (Schets, Schijven & de Roda Husman, 2011; DeFlorio-Barker et al., 2017).

4.3.3 Inhalation

Inhalation can be important where there is a significant amount of spray, such as during water-skiing or white-water canoeing. Inhalation can be of greater significance in swimming pools and related environments where chemical disinfection is practiced (WHO, 2006).

4.3.4 Chemical Hazards

Potential sources of chemical hazards include:

- onshore and offshore industrial discharges and spills
- wastewater discharges
- discharges from contaminated sites
- local use of motorized crafts
- petroleum receiving stations
- pesticides
- mining wastes
- naturally occurring chemicals, including algal toxins

Information on past industry in the recreational water catchment area will give an indication of whether contaminated sediments are likely to be present and the identity of possible contaminants.

4.3.5 Guideline Values

Targeted chemical analyses should be undertaken to support quantitative risk assessments when contamination is known or suspected (e.g. from industrial discharges, historical contaminated sites or mineral rich strata, if identified by sanitary surveys).

No specific rules can easily be applied to calculate guideline values for chemical contaminants in recreational waters that take account of the various degrees and frequencies of contact (e.g. passive, incidental, whole body) and types of exposure (e.g. dermal, ingestion, inhalation). However, provided that care is taken in their application, the GDWQ (WHO, 2017) provide a starting point for deriving values that can be used in a screening level risk assessment, together with estimates of exposure associated with recreational activities.

As discussed, ingestion of water when swimming ranges from 1.7 L to 2 L per year in temperate waters and 32 L to 38 L per year in warmer waters. This represents less than 0.3% and 5%, respectively, of the volume of drinking-water ingested per year. A simple screening approach is therefore to investigate a substance occurring in recreational water at a concentration 20 times higher than the guideline value in the GDWQ as shown in Table 4.1 on reference with the Guideline on Recreational Water Quality Vol 1, WHO 2021 and National Drinking Water Quality Standard, 2005 Government of Nepal.

Exceedances do not necessarily indicate that a problem exists. Rather, they suggest the need for a specific evaluation of the chemical, taking into consideration local circumstances and conditions of the recreational water area. These could include the types and frequencies of recreational water activities, and the effects of winds, currents and tides on chemical concentrations.

Table 4.1: Screening value for indicative chemicals in Recreational water bodies

SN	Chemical Component	Drinking water guideline value (mg/L)	Remarks
1	Arsenic	0.05	NDWQS
2	Chloride	250	NDWQS
3	Iron	0.3	NDWQS
4	Sulphate	250	NDWQS
5	Sodium	N/A	GDWQ
6	Potassium	N/A	GDWQ
7	Calcium	200	NDWQS
8	Hydrogen Sulphide	N/A	GDWQ

The natural hot spring may be contaminated with different Chemical components from the source or during the shifting of the hot water. Pollution events should be managed, and timely and effective communication should be provided about recreational water environments affected by chemical hazards. If changes are detected in water quality as a result of pollution events, multifaceted approaches will generally be needed to provide public health advisories, including:

- presenting Information of physical and chemical parameter of the water
- communication with community or residents' groups
- installation of signage and its maintenance (e.g. in the event of vandalism)

Information should be provided on:

- the cause and nature of contamination
- the basis for assessing risks, including the source of guideline values applied
- activities to be avoided
- potential health risks
- remedial action

Where waters have been assessed as being permanently unsuitable for recreational use, it is essential that the public is informed and regularly reminded of the risks associated with water contact. If fencing is installed to prevent access, it needs to be regularly checked and maintained; signage also needs to be maintained.

Management of pollution events will be influenced by the type and form of contamination. For example, spills can entail shorter-term responses, with a focus on clean-up and remediation. Management may be driven by the need to mitigate environmental impacts rather than public health impacts and will be directed by environmental protection agencies. Detection of potentially persistent events, such as pollutants being carried from sites separated from water bodies, will require much

longer remediation strategies, even after the polluting activity ceases. These are also likely to be directed by environmental protection agencies (Guideline on Recreational Water Quality Vol 1, WHO 2021). In general, it is recommended that up to 20 times of the threshold parameters for drinking purpose can be adopted for recreational purposes.

4.4 Hot Water Spring as Health Benefit

On recent study Hot springs are exhumated naturally on the surface. Geothermal heat is considered as the main sources of heat, whereas many other factors may be playing the vital role. During the heating and exhumation process, the quantitative mass of water is going through different natural contaminations. Natural Hot water springs are rich in different minerals that can treat and heal the various health disorders.

From Prehistoric time Natural Hot springs are adopted to heal from the various Health disorders. So, the water that comes out from the hot springs or mineral springs from different parts of the world is unique in form, size, temperature, and mineral content. It is used through dermal exposure, ingestion and inhalation to treat the individuals sometimes combined as well. The heat content of the water itself has a unique power to treat our body, let alone the effect of minerals it contains. Just by dipping in hot water for a short time, the temperature of the body gradually increases, thus killing harmful germs and viruses. It also increases blood circulation as compared to saunas and steam baths. The increasing blood flow also helps dissolve and eliminate toxins (poisons produced by bacteria) from the body. It also increases the flow of oxygen-rich blood throughout the body, bringing improved nourishment to vital organs (such as kidney, heart, lungs, liver) and tissues. It also helps to stimulate the secretions of the intestinal tract and the liver, aiding digestion.

Repeated hot spring bathing (especially over a 3- or 4-week period) can help normalize the functions of the endocrine glands as well as the functioning of the body's autonomic nervous system. This system regulates a variety of body processes such as heartbeat, blood flow, breathing, and digestion that takes place without conscious effort. Besides the effect of temperature, the presence of specific minerals and gasses in the water helps to figure out the medicinal qualities of a spring. Trace amounts of carbon dioxide, sulphur, calcium, magnesium, and lithium are absorbed by the body and provide healing effects to various body organs and systems. These healing effects can include stimulation of the immune system, leading to enhanced immunity, physical and mental relaxation. Mineral springs contain high amounts of negative ions, which can help promote feelings of physical and psychological well-being.

Das et al. (2012) have carried out a research on the use of hot spring linking it with the society and medical importance in Sikkim, India. The study indicated that 36.98% of people with arthritis, 30.14% with joint pain, 19.18% with gastric/metabolic disorder, 5.59% with skin diseases such as scabies, and 9.59% of the people with paralysis (4.11%) have utilized the hot spring to help them cure. Hamzah et al. (2013) carried out a research on the hot spring water of State of Selangor, Malaysia and found the chemical constituents of Na⁺, K⁺, Ca²⁺, S, SO₄²⁻ and Cl⁻ anion present in the water are good for balneotherapy. Vaidya & Nakarmi (2020) have carried out a research on the belief and perception of patients towards the natural hot spring bath and its medicinal properties for musculoskeletal problems in Myagdi, Nepal. They found that 31% of the patients had inflammatory arthritis, degenerative disorders (29.4%) and followed by soft-tissue rheumatism in 12.7% (Rai et al. 2020).

Most of the people have felt some sort of cure after hot spring treatments, and some even fully recovered. However, we still do not have enough researches to link the specific properties of hot spring water which is contributing to cure diseases. Are there any relations between chemical and mineralogical compositions of the hot spring water with the chemistry of the human body (patient)? If such a research is carried out, it would be interesting to see the interaction between the chemical properties of the hot water and the body chemistry of the patient. Such study will certainly help to highlight the importance of the hot spring in curing certain specific type of disease.

With hot spring treatments, the majority of patients had some kind of healing; some even made a full recovery. The exact qualities of hot spring water that are linked to the treatment of diseases, however, remain the subject of insufficient investigation. Exist any connections between the chemistry of the patient's body and the chemical and mineralogical abundance on the hot spring water? The interplay between the patient's body chemistry and the chemical characteristics of the hot water would be intriguing to observe if such study is conducted. The significance of hot springs in treating a particular kind of sickness will undoubtedly be highlighted by this kind of research. On escalation of such research it undoubtedly increases the number of visitors to heal from the Hot spring directly and indirectly.

5 FINDINGS

The field survey was started with the list of 162 locations found from literature reviews, telephonic communications, and electronic-mail correspondences, 169 locations were assessed with the appropriate method of verification (Volume-2, Annex-2), and 66 locations are listed as Hot Water Spring Sources and shown in map (Volume-2, Annex-3). Out of 66 locations, 41 locations were found to meet threshold criteria.

Information collected from the field is presented in briefs for the locations which meet threshold criteria and listing of some hot water springs that do not meet threshold criteria and developed to an extent and may need further protection.

5.1 Nomenclature of Hot Water Spring Sources

For defining a Hot Water Spring Source, a tag name for permanent identification code is proposed and used with suggestion and consent from WECS. A sample for nomenclature of Hot Water Spring Source is shown below:

HS/PD DLL WW-NN

Definition,

HS = Hot Water Spring

P = One number to represent province as per the geographical code of district in sequential manner (Central Bureau of Statistics)

DD = Two numbers to represent district within a province as per the geographical code of district in sequential manner (Central Bureau of Statistics)

LL = Two numbers to represent local level within a district as per the geographical code of local level in sequential manner (Central Bureau of Statistics)

WW = Two numbers to represent Ward number within a local level in sequential manner

NN = sequential number assigned for hot water spring source within the country, first recorded hot water spring will be 01, 02 and so on. If any of new discovery in future can be adopted in similar way in the same sequence.

Province will be represented by following manner

Koshi Province = 1

Madhesh Province = 2

Bagmati Province = 3

Gandaki Province = 4

Lumbini Province = 5

Karnali Province = 6

Sudur Pashchim Province = 7

The code for the Local Level, District and Province will be as following (geographical code of district, CBS as of FY 2079/80).

Example:

Hot Water Spring recorded in 57th number (in sequence) in Sudurpashchim Province and lies in Ward no. 3 of Saipal Gaunpalika, Bajhang will be **HS/7020103-57**.

Hot Water Spring recorded in 2nd number (in sequence) in Bagmati Province and lies in ward no. 2 of Bhotekoshi Gaunpalika, Sindhupalchok will be **HS/3020102-02**.

If any other hot water spring source found in future, the code can be obtained as mentioned above with following the last sequential number of this study.

5.2 Identified Hot Water Spring Sources of Nepal

Identification of hot water spring sources of Nepal was conducted following the procedure mentioned in Heading 3. At the initial phase of the desk study, all local levels were contacted through electronic mails and telephonic communication and collected the information about the hot water spring. After the confirmation of the prospective location of hot water spring sources, trained technicians and/or hydrogeologists were mobilized towards the site. These trained technicians measured discharge, temperature and other geological, environmental and social parameters in each of the locations. After desk study, telephonic communication and field confirmation, 66 numbers of hot water spring sources are identified all over the Nepal (Table 5.1, Figure 5.1 and Figure 5.2). Location map, detail description of all HWS and detailed list are presented in Volume-2, Annex 3, Annex 4 and Annex 5 respectively.

Table 5.1: List of identified Hot Water Spring Sources of Nepal

HWS Code	Name of HWS	Northing	Easting	Local Level/Local Name
HS/11020104-01	Hatiya Tatopani	27°44'25.49"N	87°20'10.59"E	Bhotkhola Gaunpalika-3, Hatiya
HS/3020102-02	Tatopani	27°56'49.08"N	85°57'5.19"E	Bhotekoshi Gaunpalika-2, Tatopani
HS/3030205-03	Purano Tatopani, Pargang	28°14'27.16"N	85°21'31.07"E	Aamachhodingmo RM-05, Pargang
HS/3030101-04	Naya Tatopani, Chilime	28°12'6.47"N	85°17'23.59"E	Aamachhodingmo RM-05, Brapche, Chilime
HS/3030101-05	Timure Tatopani	28°14'27.16"N	85°21'31.07"E	Gosaikunda Gaunpalika Ward no-1, Timure
HS/3030105-06	Syabrubesi Tatopani	28°9'46.14"N	85°20'16.49"E	Gosaikunda Gaunpalika Ward no-5, Syabrubesi
HS/3040104-07	Hindung Tatopani	28°12'10.40"N	85°4'9.28"E	Rubi Valley Gaunpalika Ward no -4, Hindung
HS/3040202-08	Jharlang Tatopani	28°5'41.54"N	85°0'38.31"E	Khaniyabash Gaunpalika Ward no -2, Dundure
HS/4010403-09	Dharche Tatopani	28°16'30.89"N	84°53'55.87"E	Dharche Gaunpalika-03, Tatopani
HS/4010402-10	Machhi Khola Tatopani	28°13'50.96"N	84°52'33.35"E	Dharche Gaunpalika-2, Machhikhola
HS/4010801-11	Bhulbhule Khar	28°1'2.78"N	84°32'58.24"E	Paluntar Municipality-01, Bulbulekhar
HS/4020102-12	Tatopani	28°39'47.26"N	84°13'45.55"E	Narpha Bhumi Gaunpalika Ward no -2
HS/4020305-13	Mencheu	28°33'8.77"N	84°14'35.69"E	Chame Gaunpalika-05, Mencheu

HWS Code	Name of HWS	Northing	Easting	Local Level/Local Name
HS/4020403-14	Maiche Tatopani	28°31'50.95"N	84°21'1.62"E	Nason Gaunpalika Ward no -3, Dharapani
HS/4060204-15	Jagat Taopani Kunda	28°24'45.16"N	84°24'45.16"E	Marsyangdi Gaupalika-4, Jagat
HS/4060206-16	Bahundanda Tatopani Kunda	28°20'21.70"N	84°23'52.45"E	Marsyangdi Gaupalika-6, Bahundanda
HS/4050101-17	Hugu Tatopani	28°23'19.71"N	84°7'4.71"E	Madi Gaunpalika Ward no -1, Hugu
HS/4050201-18	Poje Tatopani	28°25'18.18"N	83°59'30.11"E	Machhapuchchhre Gaunpalika, Ward no -1
HS/4050201-19	Kharpani Tatopani, Mirsa Tatopani	28°21'39.41"N	83°57'36.54"E	Machhapuchchhre Gaunpalika Ward no -1, Kharpani
HS/4050311-20	Tauji Baraha Tatopani	28°24'56.27"N	83°49'43.13"E	Annapurna Gaunpalika Ward no -11, Jhinu Dada, Ghandruk
HS/4030101-21	Chharang	29° 5'27.60"N	83°56'13.20"E	Lo-Ghekar Damodarkunda Gaupalika-01, Chharang
HS/4040105-22	Paudwar Tatopani Kunda	28°30'00.68"N	83°39'20.47"E	Annapurna Gaunpalika Ward no -5 Paudwar Kunda
HS/4040102-23	Bhurung Tatopani	28°29'46.53"N	83°39'15.40"E	Annapurna Gaunpalika Ward no -2, Tatopani Kuda, Bhurung
HS/4040106-24	Ratopani Tatopani	28°28'41.79"N	83°38'28.66"E	Annapurna Gaunpalika Ward no -6 Ratopanikunda
HS/4040101-25	Serkaku Tatopani	28°27'28.29"N	83°37'34.12"E	Annapurna Gaunpalika Ward no -1, Sekarku Tatopani
HS/4040204-26	Darmija Tatopani	28°27'11.36"N	83°30'51.08"E	Raghuganga Gaupalika-04, Darmija
HS/4040604-27	Singha Tatopani	28°22'03.93"N	83°30'09.00"E	Beni Municipality-04, Singha
HS/4040406-28	Chhyarchhyare Tatopani	28°24'43.88"N	83°23'36.27"E	Malika RM-6, Chhyarchhyare Tatopani
HS/4040304-29	Bagara Tatopani	28°34'56.39"N	83°23'19.50"E	Dhaulagiri Gaupalika-04, Bagara
HS/5010102-30	Pelma Tatopani	28°40'09.55"N	82°57'12.18"E	Putha Uttarganga Gaunpalika -2, Pelma Tatopani
HS/5010102-31	Bhalun Pelma Tatopani	28°40'11.61"N	82°57'9.57"E	Putha Uttarganga Gaunpalika -2, Bhalun
HS/5010103-32	Ranma	28°42'29.24"N	82°50'46.91"E	Putha Uttarganga Gaunpalika -3
HS/5010106-33	Jharna tatopani	28°40'07.98"N	82°48'34.07"E	Putha Uttarganga Gaunpalika -6, Dimurgaira
HS/5010113-34	Tamphe Tatopani	28°38'33.4"N	82°46'24.45"E	Putha Uttarganga Gaupalika-13, Tamphe
HS/5010204-35	Panga Pokhara	28°37'46.98"N	82°35'29.44"E	Sisne Gaunpalika, Panga Pokhara
HS/5010204-36	Sisne tatopani	28°37'44.50"N	82°35'27.02"E	Sisne Gaunpalika -4, Tatopani, Panga Pokhara
HS/5090301-37	Surai Bridge Tatopani	27°46'07.05"N	82°50'15.29"E	Shivaraj Municipality -01, Surai Bridge

HWS Code	Name of HWS	Northing	Easting	Local Level/Local Name
HS/5100709-38	Tapta Kunda	27°54'30.83"N	82°20'12.43"E	Lamihi Municipality -09, Rihar
HS/6010802-39	Dolpa	28°59'22.90"N	83°21'10.79"E	Chharka Tangsong Gaupalika-2
HS/6070702-40	Kayakhet Tatopani	28°48'36.45"N	82°22'05.85"E	Nalgad Municipality-08, Kayakhet
HS/6040602-41	Jarami Tatopani	29°14'10.45"N	82°03'49.75"E	Tatopani Gaunpalika Ward no -2, Jarami
HS/6020213-42	Ruga Tatopani	29°34'02.70"N	82°08'51.12"E	Chhayanath Rara Gaupalika -13, Ruga
HS/6020306-43	Soru-Kulaha	29°36'27.06"N	81°58'41.75"E	Soru Gaupalika -06, Kulaha
HS/6030603-44	Jair	29°40'9.74"N	81°53'42.62"E	Adanchuli Gaupalika-03, Jair
HS/6030603-45	Unapani	29°47'21.04"N	81°53'40.40"E	Sarkegad Gaupalika -03, Unapani
HS/6030205-46	Kharpunath Mandir	29°56'27.36"N	81°51'21.45"E	Kharpunath Gaunpalika Ward no -5, Kharpunath Mandir
HS/6030205-47	Kharpu	29°56'33.52"N	81°51'25.57"E	Kharpunath Gaupalika -05, Kharpu
HS/6030403-48	Khayala	30°02'08.25"N	81°44'38.63"E	Namkha Gaunpalika -3 Khayalagaun, Humla
HS/6030402-49	Kermi	30°03'21.74"N	81°42'09.88"E	Namkha Gaunpalika -2 Kermi
HS/6030406-50	Takchhe	30°16'00.44"N	81°39'50.91"E	Namkha Gaupalika -6 Limi, Takchhe
HS/6030406-51	Chhamjo- Chhirku	30°15'56.75"N	81°39'53.26"E	Namkha Gaupalika -6 Limi, Chhamjo Chhirku
HS/6030406-52	Jhang Tatopani	30°14'32.99"N	81°37'06.47"E	Namkha Gaupalika -6 Limi, Jhang
HS/6030403-53	Paucha	30°01'32.38"N	81°45'10.50"E	Namkha Gaunpalika Ward no -3, Paucha
HS/6030104-54	Humla	29°44'57.24"N	81°02'12.64"E	Chankheli Gaupalika -04, Salisalla
HS/6030104-55	Tapunu	29°45'02.84"N	82°02'48.02"E	Chankheli Gaupalika -04, Tapunu
HS/6100610-56	Bulbule Taal	28°35'00.26"N	81°37'11.12"E	Birendranagar Municipality-10, Naulapur
HS/7020102-57	Jima Tapoban	29°43'52.03"N	81°21'58.23"E	Saipal Gaupalika-02, Jima Tapoban
HS/7020103-58	Kaya Tapoban	29°44'6.00"N	81°18'22.32"E	Saipal Gaupalika-03, Kaya Tapoban
HS/7020401-59	Talkot Tapoban	29°35'37.34"N	81°14'31.49"E	Talkot Gaupalika-01, Talkot
HS/7020504-60	Bajhang Tapoban	29°35'32.86"N	81°14'28.93"E	Masta Gaupalika-04, Tapoban
HS/7020302-61	Seldegadi	29°35'49.99"N	81°9'7.12"E	Surma Gaupalika-02, Seldegadi
HS/7020301-62	Tapoban	29°46'35.43"N	81°7'22.73"E	Surma Gaupalika-01, Tapowan
HS/7030501-63	Chmida Tapoban	29°50'42.2"N	80°53'32.04"E	Apihimal Gaunpalika Ward No-1, Chmida Nadi (Tapoban)
HS/7030601-64	Chameliya	29°44'50.60"N	80°47'19.36"E	Marma Gaupalika-04, Rela
HS/7030101-65	Sina Tatopani	29°55'4.95"N	80°40'19.10"E	Byas Gaupalika-03, Sina
HS/7030201-66	Sribagad Tatopani	29°51'56.42"N	80°33'42.90"E	Duhun Gaupalika-04, Sribagad

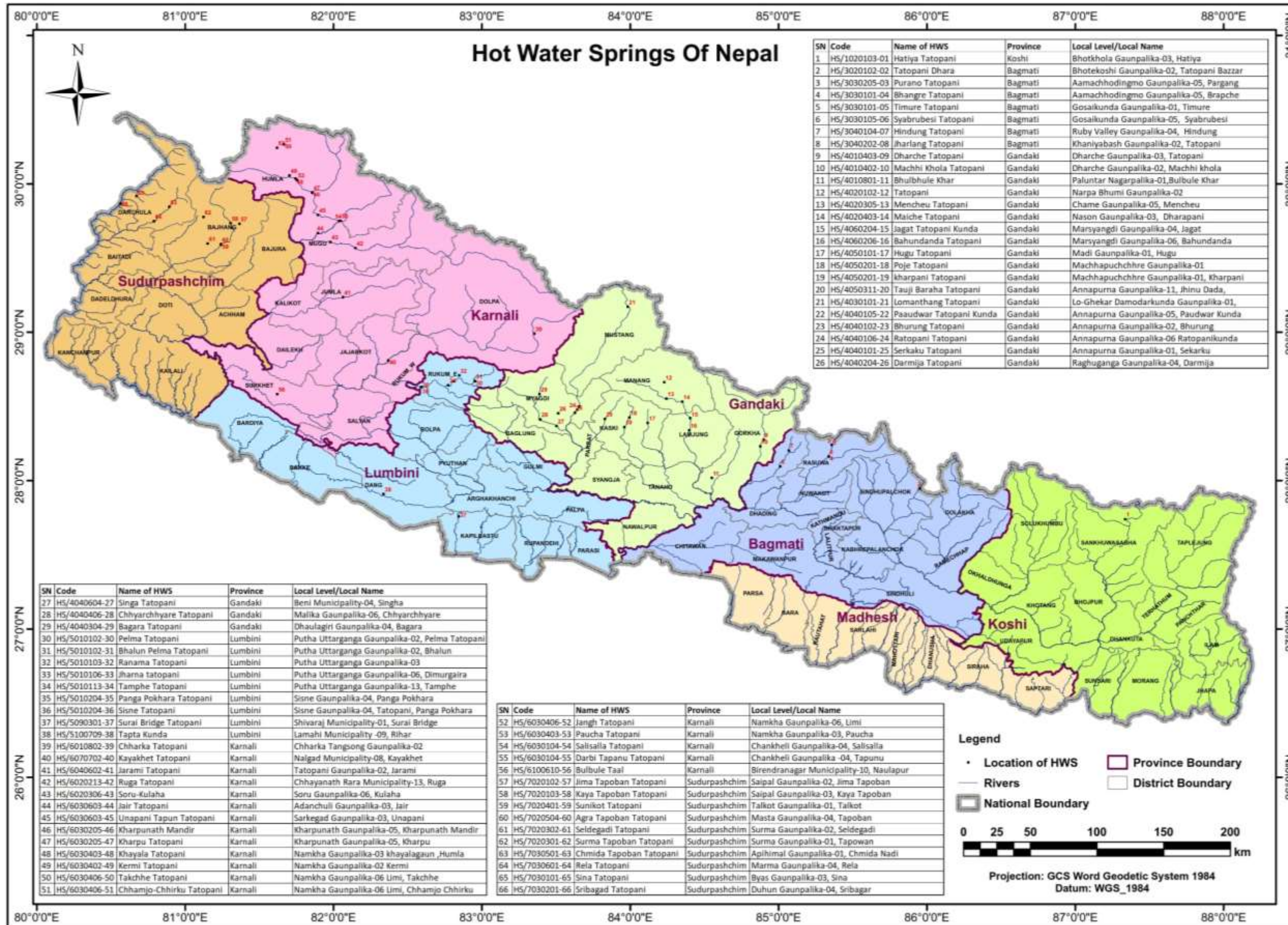


Figure 5.1: Location of Identified Hot Water Spring Sources of Nepal with administrative boundaries

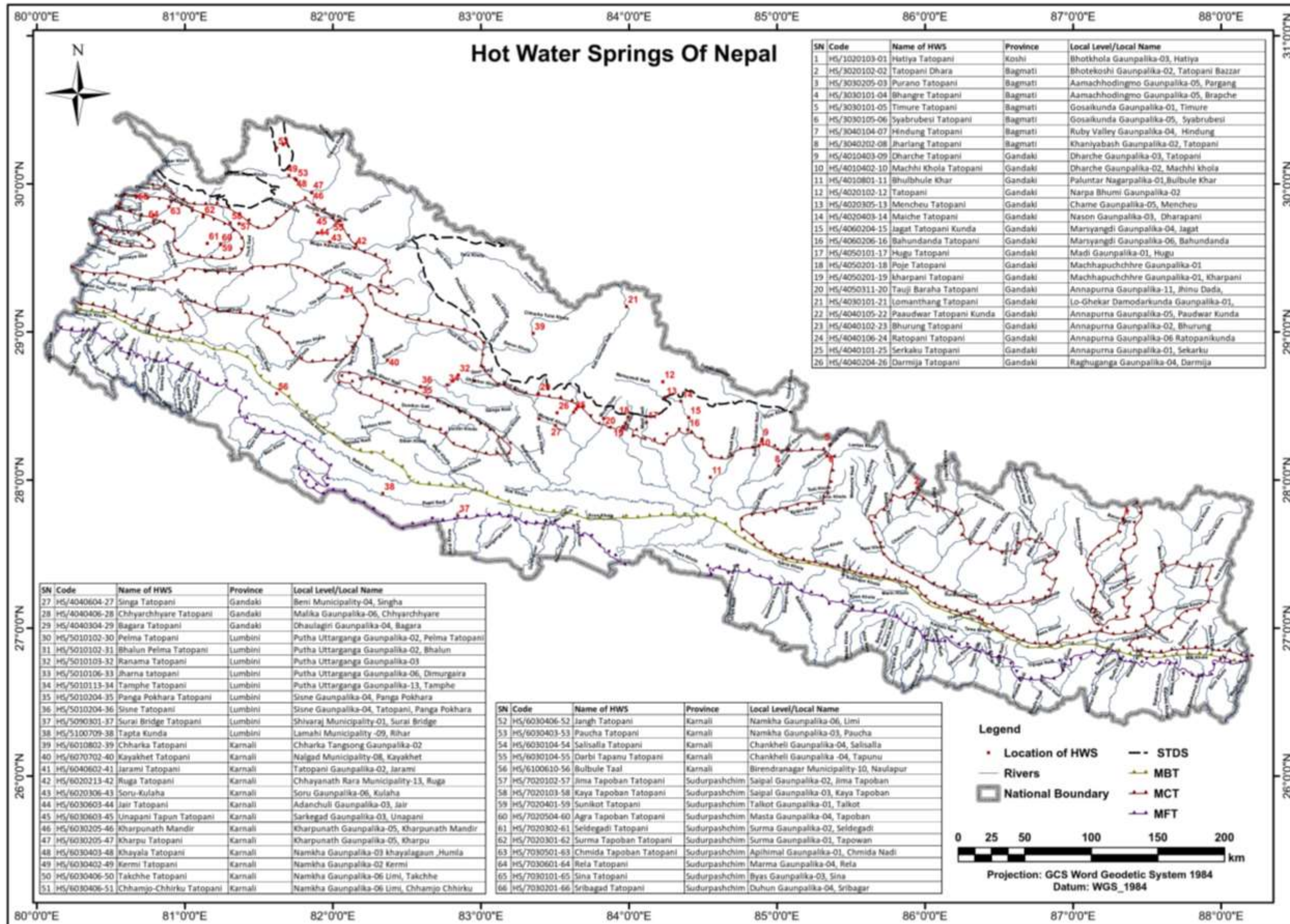


Figure 5.2: Location of Identified Hot Water Spring Sources of Nepal with geological structures

5.3 Hot Water Springs with over threshold parameters

Among the identified 66 numbers of hot water spring sources, only 41 hot water spring sources found to meet the criteria defined according in ToR for the study. These sources and their locations, discharges and temperatures are presented in Table 5.2 and brief description is presented in following sub-headings. Detail descriptions of all of the hot water spring sources is provided in Volume-2, Annex-4. Locations of all hot water spring sources is presented in Volume-2, Annex-5.

Table 5.2: List of Hot Water Spring Sources with threshold parameters

New code	Name of HWS	Northing	Easting	Discharge (l/s)	Temp. (°C)	Local Level/Local Name
HS/3020102-02	Tatopani Dhara	27°56'49.08"N	85°57'5.19"E	3.4	49.8	Bhotekoshi Gaunpalika -2, Bhotekoshi
HS/3030101-04	Bhangre Tatopani	28°12'6.47"N	85°17'23.59"E	1.7	41.95	Aamachhodingmo Gaunpalika-05, Brapche
HS/3040104-07	Hindhug Tatopani	28°12'10.40"N	85°4'9.28"E	1.09	46.6	Rubi Valley Gaunpalika -4, Hindung
HS/4010403-09	Dharche Tatopani	28°16'30.89"N	84°53'55.87"E	1.01	46.65	Dharche Gaunpalika-03, Tatopani
HS/4010402-10	Machhi Khola	28°13'50.96"N	84°52'33.35"E	1.028	60.7	Dharche Gaunpalika-2, Machhi khola
HS/4010801-11	Bhulbhule Khar	28°1'2.78"N	84°32'58.24"E	2.03	34.8	Paluntar Nagarpalika-01, Bulbule Khar
HS/4020305-13	Mencheu Tatopani	28°33'8.77"N	84°14'35.69"E	1	47	Chame Gaunpalika-05, Mencheu
HS/4020403-14	Maiche Tatopani	28°31'50.95"N	84°21'1.62"E	1.05	31.9	Nashong Gaunpalika-3, Dharapani
HS/4060204-15	Jagat Tatopani	28°24'45.16"N	84°24'45.16"E	2.44	54.64	Marsyangdi Gaunpalika-4, Jagat
HS/4050201-18	Poje	28°25'18.18"N	83°59'30.11"E	1.77	49.665	Machhapuchchhre Gaunpalika -1
HS/4050311-20	Tauji Baraha	28°24'56.27"N	83°49'43.13"E	2.36	57.86	Annapurna Gaunpalika -11, Jhinu Dada, Ghandruk
HS/4040105-22	Paaudwar	28°30'00.68"N	83°39'20.47"E	2.55	65.3	Annapurna Gaunpalika-5 Paudwar Kunda
HS/4040102-23	Bhurung	28°29'46.53"N	83°39'15.40"E	2.86	58.23	Annapurna Gaunpalika-2,

New code	Name of HWS	Northing	Easting	Discharge (l/s)	Temp. (°C)	Local Level/Local Name
						Bhurung
HS/4040106-24	Ratopani	28°28'41.79"N	83°38'28.66"E	4.75	45.6	Annapurna Gaunpalika-6 Ratopanikunda
HS/4040204-26	Darmija	28°27'11.36"N	83°30'51.08"E	1.57	45.75	Raghuganga Gaupalika-04, Darmija
HS/4040604-27	Singha	28°22'03.93"N	83°30'09.00"E	3.54	51.1	Beni Nagarpalika- 04, Singha
HS/4040304-29	Bagara	28°34'56.39"N	83°23'19.50"E	1.13	44.23	Dhaulagiri Gaunpalika-04, Bagara
HS/5010102-30	Pelma	28°40'09.55"N	82°57'12.18"E	2.15	51.9	Putha Uttarganga Gaunpalika-2, Pelma Tatopani
HS/5010102-31	Bhalun Pelma	28°40'11.61"N	82°57'9.57"E	1.5	68	Putha Uttarganga Gaunpalika-2, Bhalun
HS/5010106-33	Jharna	28°40'07.98"N	82°48'34.07"E	1.24	51	Putha Uttarganga Gaunpalika-6, Dimurgaira
HS/5010113-34	Tamphe	28°38'33.4"N	82°46'24.45"E	1	52.34	Putha Uttarganga Gaupalika-13, Tamphe
HS/5010204-35	Panga Pokhara	28°37'46.98"N	82°35'29.44"E	1	56	Sisne Gaunpalika-4, Panga Pokhara
HS/5010204-36	Sisne	28°37'44.50"N	82°35'27.02"E	3	45.15	Sisne Gaunpalika-4, Tatopani, Panga Pokhara
HS/5090301-37	Surai Khola	27°46'07.05"N	82°50'15.29"E	1.11	34.26	Shivaraj Nagarpalika-01, Surai Bridge
HS/5100709-38	Tapta Kunda	27°54'30.83"N	82°20'12.43"E	1.82	41.8	Lamihi Nagarpalika-09, Rihar
HS/6040602-41	Jarami	29°14'10.45"N	82°03'49.75"E	4.17	40.31	Tatopani Gaunpalika-2, Jarami
HS/6020213-42	Ruga	29°34'02.70"N	82°08'51.12"E	2.31	32	Chhayanath Rara Gaupalika-13, Ruga
HS/6030603-45	Unapani	29°47'21.04"N	81°53'40.40"E	18.6	47	Unapani Gaupalika-03, Sarkegad
HS/6030205-47	Kharpu	29°56'33.52"N	81°51'25.57"E	2	59.6	Kharpunath Gaupalika-05, Kharpu

New code	Name of HWS	Northing	Easting	Discharge (l/s)	Temp. (°C)	Local Level/Local Name
HS/6030402-49	Kermi	30°03'21.74"N	81°42'09.88"E	1.51	47	Namkha Gaupalika-2 Kermi
HS/6030406-50	Takchhe	30°16'00.44"N	81°39'50.91"E	1.16	53	Namkha Gaupalika-6 Limi, Takchhe
HS/6030406-51	Chhamjo-Chhirku	30°15'56.75"N	81°39'53.26"E	1.825	61	Namkha Gaupalika-6 Limi, Chhamjo Chhirku
HS/6030104-55	Darbi Tatopani	29°45'02.84"N	82°02'48.02"E	4.72	65	Chankheli Gaupalika-04, Tapunu
HS/6100610-56	Bulbule Taal	28°35'00.26"N	81°37'11.12"E	17.51	25	Birendranagar Nagarpalika-10, Naulapur
HS/7020102-57	Jima Tapowan	29°43'52.03"N	81°21'58.23"E	1.39	65.5	Saipal Gaupalika-02, Jima Tapowan
HS/7020103-58	Kaya Tapowan	29°44'6.00"N	81°18'22.32"E	1.11	51.5	Saipal Gaupalika-03, Kaya Tapowan
HS/7020401-59	Sunikot Tapowan	29°35'37.34"N	81°14'31.49"E	19.25	44.55	Talkot Gaupalika-01, Talkot
HS/7020504-60	Agra Tapowan	29°35'32.86"N	81°14'28.93"E	8	56.5	Masta Gaupalika-04, Tapoban
HS/7020301-62	Surma	29°46'35.43"N	81°7'22.73"E	2.5	42	Surma Gaupalika-01, Tapowan
HS/7030601-64	Rela	29°44'50.60"N	80°47'19.36"E	1.87	35	Marma Gaupalika-04, Rela
HS/7030201-66	Sribagad	29°51'56.42"N	80°33'42.90"E	1.25	55	Duhun Gaupalika-04, Sribagad

Table 5.3: Table showing chemical parameters and their value.

Code of location	Parameters														
	pH	Turbidity	Temperature	Arsenic	Chloride	Iron	Sulphate	Sodium	Potassium	Calcium	Magnesium	Silica	Bicarbonates	Hydrogen Sulphide	Sulphur
Permissible value	6.5-8.5	5	-	0.05	250	0.3 (3)	250	-	-	200	-	-	-	-	-
HS/3020102-02	7.2	23.47	49.8	<0.005	41.98	0.07	111.4	13	2.7	36	14.42	64.13	400	<0.05	<0.5
HS/3030205-04	7.8	<0.1	41.95	<0.00	14.99	<0.01	139.7	1.99	1.96	90	36.07	72.58	278	<0.05	<0.5

Code of location	Parameters														
	pH	Turbidity	Temperature	Arsenic	Chloride	Iron	Sulphate	Sodium	Potassium	Calcium	Magnesium	Silica	Bicarbonates	Hydrogen Sulphide	Sulphur
HS/3040104-07	7.4	<0.1	46.6	<0.005	59.98	<0.01	257.6	30	6.4	<1	<1	69.61	1000	<0.05	<0.5
HS/4010403-09	8.1	<0.1	46.65	<0.005	40.98	<0.01	5.91	33	4.4	17.64	45.19	55.33	788	<0.05	<0.5
HS/4010402-10	7.5	0.43	60.7	<0.005	66.98	<0.01	79.33	13.9	4.9	22.44	164.27	77.71	640	<0.05	<0.5
HS/4010801-11	7.3	<0.1	34.8	<0.005	61.98	<0.01	3.97	24.5	1.31	<1	<1	18.47	<10	<0.05	<0.5
HS/4020305-13	7.6	3.01	47	<0.005	830.74	<0.01	26.4	29	3.2	44.89	33.05	55.31	192	<0.05	<0.5
HS/4020403-14	7.1	1.02	31.9	<0.005	1485	<0.01	15.13	60	14.2	166.7	25.76	135.6	354	<0.05	<0.5
HS/4060204-15	7.7	<0.1	54.64	<0.005	1691.4	<0.01	22.48	137.5	21.2	319.04	14.58	101.2	88	<0.05	<0.5
HS/4050201-18	7.7	<0.1	49.66	<0.005	2473.2	<0.01	60.37	32	0.48	17.64	1.94	214.7	88	<0.05	<0.5
HS/4050311-20	7.6	<0.1	57.86	<0.005	14.99	<0.01	31.95	4.9	<1	14.43	42.77	42.65	364	<0.05	<0.5
HS/4040105-22	7.2	<0.1	65.3	<0.005	435.24	<0.01	284.1	173	15.9	30	12.02	174.2	626	<0.05	<0.5
HS/4040102-23	7.2	<0.1	58.23	<0.005	481.85	<0.01	96.24	28	6.7	44	17.64	89.42	90	<0.05	<0.5
HS/4040106-24	8	<0.1	45.6	<0.005	18.99	<0.01	37.04	2.8	0.5	38	15.23	57.87	104	<0.05	<0.5
HS/4040101-25	7.3	<0.1	38.48	<0.005	41.98	<0.01	43.94	4.9	<1	54	21.64	74.48	706	<0.05	<0.5
HS/4040204-26	8.3	<0.1	45.75	<0.005	11.99	<0.01	13.22	0.91	<1	40	16.03	45.15	72	<0.05	<0.5
HS/4040604-27	7.5	<0.1	51.1	0.005	61.88	<0.01	86.86	41	4.4	<1	<1	82.79	490	<0.05	<0.5

Code of location	Parameters														
	pH	Turbidity	Temperature	Arsenic	Chloride	Iron	Sulphate	Sodium	Potassium	Calcium	Magnesium	Silica	Bicarbonates	Hydrogen Sulphide	Sulphur
HS/4040406-28	7.8	<0.1	23.9	<0.005	97.8	<0.01	104.2	24	7.5	60	24.05	88.59	298	<0.05	<0.5
HS/4040304-29	8	<0.1	44.23	<0.005	46.36	<0.01	284.7	123	24.7	26	10.42	165.7	688	<0.05	<0.5
HS/5010102-30	7.7	<0.1	51.9	<0.005	24.99	<0.01	10.12	3.8	0.77	20.84	7.78	36.58	86	<0.05	<0.5
HS/5010102-31	8	13.79	68	<0.00	24.99	<0.01	13.97	5.5	0.53	20.84	10.69	36.54	118	<0.05	<0.5
HS/5010106-33	7.9	<0.1	51	<0.005	90.97	<0.01	15.37	9.5	2.1	36.87	9.23	21.34	198	<0.05	<0.5
HS/5010113-34	8.5	0.04	52.34	<0.005	28.99	<0.01	9.94	9.2	0.43	<1	<1	46.32	158	<0.05	<0.5
HS/5010204-35	8.2	<0.1	56	<0.005	331.89	<0.01	17.67	48	2.2	8.02	13.61	85.69	614	<0.05	<0.5
HS/5010204-36	8	5.81	45.15	<0.00	238.9	<0.01	12.95	7.4	2.9	20.84	18.47	40.56	480	<0.05	<0.5
HS/5090301-37	8.1	<0.1	34.26	<0.005	13.99	<0.01	34.66	12.3	<1	38	15.23	56.47	476	<0.05	<0.5
HS/5100709-38	8.4	24.39	41.8	<0.005	19.99	<0.01	16.49	6.2	2	8.02	5.83	43.9	584	<0.05	<0.5
HS/6070702-40	7.5	<0.1	41.59	<0.005	482.84	<0.01	22.22	8.4	4.7	16.03	60.75	41.9	386	<0.05	<0.5
HS/6040602-41	8.1	<0.1	40.31	0.005	66.97	<0.01	39.61	10.4	<1	14.43	0.49	49.78	312	<0.05	<0.5
HS/6020213-42	7.3	19.9	32	<0.005	431.86	<0.01	44.95	29	6.8	36.87	127.33	89.52	318	<0.05	<0.5
HS/6030603-45	6.5	<0.1	47	<0.005	51.98	<0.01	2.2	2.8	0.7	14.43	35.96	66.74	610	<0.05	<0.5
HS/6030403-48	7.2	26.84	45	0.005	27.96	<0.01	5.87	21	2.7	9.61	41.8	63.42	414	<0.05	<0.5

Code of location	Parameters														
	pH	Turbidity	Temperature	Arsenic	Chloride	Iron	Sulphate	Sodium	Potassium	Calcium	Magnesium	Silica	Bicarbonates	Hydrogen Sulphide	Sulphur
HS/6030402-49	7.4	<0.1	47	<0.005	48.98	<0.01	9.87	13.5	0.63	24.05	3.89	36.25	300	<0.05	<0.5
HS/6030406-50	7.3	<0.1	53	<0.005	53.98	<0.01	19.8	30	2.9	8.02	30.13	55.61	108	<0.05	<0.5
HS/6030406-51	7.5	<0.1	61	<0.005	56.98	<0.01	17.36	24	2.9	8.02	24.3	52.14	416	<0.05	<0.5
HS/6030406-52	7.1	<0.1	41	<0.005	55.98	<0.01	19.82	43	1.62	11.22	27.22	54.62	334	<0.05	<0.5
HS/6030403-53	7.9	<0.1	42.73	0.005	5.99	<0.01	7.3	24	0.79	11.22	26.24	45.22	444	<0.05	<0.5
HS/6030104-54	7.7	<0.1	39.33	<0.005	27.99	<0.01	7.7	11.6	0.49	8.02	14.58	65.24	228	<0.05	<0.5
HS/6030104-55	7.5	<0.1	65	<0.005	218.93	<0.01	37.26	13.9	5.8	41.68	61.24	90.12	56	<0.05	<0.5
HS/6100610-56	7.7	0.33	25	<0.005	18.99	<0.01	3.74	1.08	1.16	44.89	22.36	59.3	100	<0.05	<0.5
HS/7020102-57	7.6	<0.1	65.5	<0.005	27.99	<0.01	10.02	1.09	1.53	12.82	21.38	60.85	16	<0.05	<0.5
HS/7020103-58	7.5	<0.1	51.5	<0.005	56.98	<0.01	16.37	4.1	1.24	23.25	28.19	68.24	42	<0.05	<0.5
HS/7020401-59	6.4	3.23	46.16	<0.005	53.98	<0.01	10.24	6.1	2	26.45	54.43	65.74	144	<0.05	<0.5
HS/7020504-60	7.4	<0.1	55	<0.005	337.89	<0.01	9.62	6	6	22.44	46.65	73.6	200	<0.05	<0.5
HS/7020302-61	7.4	<0.1	34	<0.005	57.98	<0.01	8.48	6.7	3.6	22.44	44.71	70.36	134	<0.05	<0.5
HS/7020301-62	7.7	<0.1	42	<0.005	30.99	<0.01	2.65	0.09	0.11	2.4	20.41	97.1	<10	<0.05	<0.5
HS/7030601-64	7.8	<0.1	35	<0.005	102.97	<0.01	14.73	12.1	2.3	21.64	63.66	78.41	176	<0.05	<0.5

Code of location	Parameters														
	pH	Turbidity	Temperature	Arsenic	Chloride	Iron	Sulphate	Sodium	Potassium	Calcium	Magnesium	Silica	Bicarbonates	Hydrogen Sulphide	Sulphur
HS/7030201-66	7.7	2.45	55	<0.005	62.98	<0.01	2.38	11.8	1.75	11.22	61.24	80.46	214	<0.05	<0.5

Chemical parameters are tested for 47 hot water springs. Comparing with drinking water parameters 3 hot water springs are found to be perfectly safe, 31 hot water springs needs few treatments and water of 13 sources found to be highly corrosive considering chloride, sulphate and bicarbonate content. Summarized table is presented in Annex-8 and laboratory test sheets are presented in Annex-9. However, the threshold of these parameters for soaking, swimming and bathing is not clearly mentioned in any literature which are reviewed. Chloride and sulphates are considered as therapeutic chemical and the ranges are not very far from drinking water parameters along with the feedback of the users, it is considered as safe for soaking, swimming and bathing which are the main recreational features of tourism aspects of hot water spring sources.

5.3.1 HS/3020102-02

Tatopani Dhara, Sindhupalchok

Tatopani Bazar's hot spring, situated in Nepal's Sindhupalchok district, is at 85°57'5.19"E longitude and 27°56'49.08"N latitude. The area is hilly, with the hot spring on the Bhotekoshi River's right bank. It discharges 3.45 litres/sec at 49.8°C. The exposed bedrock consists of garnet-bearing schist and gneiss, indicating fair rock condition. The region faces flood and landslide risks. The community, mainly Janjati ethnic groups, practices rituals at the hot spring, believed to have healing properties.



Photograph 5.1: Bathtub constructed at the Tatopani Dhara

Land use involves forests (70%), agriculture (10%), and grazing (20%). The economy relies on tourism, with around 3,000 monthly visitors, peaking in winter. Despite its therapeutic value, the hot spring

has minimal ecological impact, maintaining water quality. Seasonal dynamics affect discharge, but temperature remains constant. Local reports emphasize the need for resource management to prevent pollution. Overall, Tatopani Bazar's hot spring serves as a cultural, economic, and therapeutic hub, drawing visitors without significant environmental harm.



Photograph 5.2: Discharge measurement at the Tatopani Dhara

Geologically, the area where hot water spring originates is situated within the Main Central Thrust (MCT) zone, a factor that could contribute to the formation of hot springs. However, it's important to note that not every MCT zone necessarily gives rise to hot springs. Typically, the source of the hot water is the bedrock and the presence of joints in the rock formations facilitates the percolation of water. This water, heated by the geothermal energy of the earth's interior, eventually finds its way to the surface, often emerging in areas with more permeable material, such as the sediment-rich banks of rivers. The loose sediments in these river banks provide an easier path for the hot water to travel, leading to the emergence of hot springs in these locations.

Regarding Sulphur found in the region is that Sulphur is a chemical element and may be present in Sulphurated waters as a free or combined ion. It may comprise various combinations of Sulphur ions, water, and other ions. Initially, Sulphur and sulphate ions are produced from hydrogen sulphide (H_2SO_4) in underground hot springs water. Meanwhile, sulphide (S^{2-}) will be oxidized when the water rises to the surface. The Sulphate ion (SO_4^{2-}) may have originated from the weathering of pyrite or the leaching of other sulphide (S^{2-}) by hypothermal waters of deep origin. The sulphide (S^{2-}) in the form of pyrites (FeS^2) that consist in the hot springs water can react chemically with water to produce H_2S and heat. The H_2S rises with the heated groundwater, giving it strong odours like rotten eggs.

Also, Sulphur is a naturally occurring element that can dissolve in water. The hot water rises to the surface in the form of a hot spring, where it loses some of this heat to its cooler surroundings. The dissolved H_2S molecules becomes less soluble, releasing the gas around the hot spring as the water cools.

The water from hot spring contains a variety of minerals and elements in concentrations that offer therapeutic benefits, particularly for skin and muscular conditions, without posing significant health hazards at the reported levels. It's important to consider individual sensitivities and health conditions, as reactions can vary.

5.3.2 HS/3030205-04

Bhangre Tatopani, Rasuwa

The Bhangre Tatopani hot spring is located in the Amachodingmo Rural Municipality of Rasuwa district, Nepal, on the Chilime River's bank. It's a natural hot water source with an average temperature of 42 degrees Celsius. The area is hilly with steep slopes and has rock formations like gneiss and schist. The hot spring is at an elevation of 1394 metre and is prone to flooding and landslides due to its topography.



Photograph 5.3: Bathing pond constructed at the Bhangre Tatopani

Only about 50-55 people live nearby, mainly from the Tamang, Newar, and Ghale ethnic groups, however people from the region use the hot spring for religious and healing rituals, believing in its therapeutic properties for skin and joint problems. The area is mostly forested and has a trekking route, making it attractive for tourists. Local hotels benefit economically from the visitors to the hot spring, which sees about 90 to 150 visitors monthly, especially in winter.

The hot spring is environmentally friendly; it doesn't release harmful gases or liquids and doesn't negatively affect the local wildlife or water quality. Seasonal changes affect the water discharge but not its temperature. While currently, there's little pollution, there's a risk of increased pollution if the area is developed without proper management.



Photograph 5.4: The Chillime River and local person taking bath at the Bhangre tatopani

In summary, the water from 'Bhangre Tatopani' hot springs contains several minerals and elements beneficial for health, particularly for skin and muscle relaxation. The levels of most components are within safe and therapeutic ranges, though the temperature and arsenic content require cautious monitoring. Regular testing is crucial to ensure the continued safety and efficacy of the springs for therapeutic uses.

5.3.3 HS/3040104-07

Hindung Tatopani, Dhading

In Dhading district, Nepal, "Hindung Tatopani" in the Rubi Valley which is located by a river. The spring is at coordinates 85°4'9.28"E, 28°12'10.40"N. The area's hilly, with steep slopes and a deep valley. There are two hot water sources 8-10 metre apart, flowing at different rates, combining to 1.098 litres per second, at 46.6°C. The ground has quartzite rocks and is prone to flooding, needing protective walls.

A small community of about 20-25 Tamang household lives nearby. They hold the hot spring sacred, believing it heals ailments. There are festivals and a religious site (Gumba) close by. The area's mostly forest, with some farmland and grazing land. Hotels are the main income source, attracting tourists for the spring.

The spring doesn't emit harmful gases and is believed to have health benefits. It hasn't harmed the local environment or wildlife. The water quality is good, and there's no risk of waterborne diseases or conflicts over water rights. Despite being a tourist spot, it hasn't led to pollution or affected the local ecosystem significantly. The spring's flow and temperature stay stable throughout the year, although long-term data shows some variation.



Photograph 5.5: Taps constructed at the Hindung tatopani



Photograph 5.6: The area around the Hindung Tatopani

Overall, this hot spring is important for the local community, both culturally and economically, and is a unique natural feature with minimal environmental impact.

Overall, the 'Hindung Tatopani' exhibit characteristics beneficial for therapeutic use, particularly for skin health and relaxation. The mineral content is largely within safe and beneficial ranges. However,

caution should be exercised with the high-water temperature and the presence of arsenic, albeit at a low concentration. Regular monitoring is essential to ensure the continued safety and therapeutic quality of the spring water.

5.3.4 HS/4010403-09

Dharche Tatopani, Gorkha

The Dharche Rural Municipality in Gorkha district, Nepal, is home to a notable hot spring, "Dharche Tatopani," situated near the bank of Budhi Gandaki River. This area is mountainous, with steep hills and a deep valley formed by the river. The hot spring has two sources, with temperatures around 45°C and 48°C. It's a clear, salty-smelling spring used for bathing, and its water eventually flows into the river.



Photograph 5.7: Measurement of discharge of the hot water at the Dharche tatopani

Geologically, the area consists of pale yellow to grey quartzite, a type of rock, with some joint sets. Land around the spring is mainly forests, roads, and a few settlements, with a warm climate. The spring is at an altitude of 953 metres and has measures in place to protect it from flooding.

Local Gurung community members, about 20-25 households in total, live nearby. They use the spring for religious ceremonies and believe it has health benefits. There's a temple and a festival each year, attracting many visitors. The area is mostly forest, with some grazing land, and local hotels benefit economically from tourists visiting the spring.



Photograph 5.8: The surrounding area and the pond constructed at the Dharche tatopani

Environmentally, the spring doesn't harm wildlife or water quality. Seasonally, the spring's water flow changes, but temperature stays consistent. Post-earthquake and road construction have affected its natural discharge. Although pollution is currently low, there's a risk of it increasing with development.

Overall, the hot water spring has properties that are potentially beneficial for therapeutic use, especially for skin health and relaxation. The mineral content is within safe ranges, offering various health benefits. However, caution is advised with the high-water temperature, and regular water quality monitoring is essential to maintain safety and therapeutic value.

5.3.5 HS/4010402-10

Machhi Khola Tatopani, Gorkha

The Machhi Khola hot spring is located in Dharche Rural Municipality, Gorkha district, Nepal. Situated on the left bank of the Budhi Gandaki River, the spring is surrounded by hilly terrain with steep slopes. The hot spring water, which has a temperature of about 60.7°C, flows into a natural pond before reaching the river. The area's geology features quartzite rock with several joint sets.



Photograph 5.9: Surrounding area of the Machhi Khola Tatopani



Photograph 5.10: Iron leaching in the Machhi khola Tatopani

The local community, mainly comprising Janjati and Dalit groups, values the spring for its perceived health benefits, especially during the "Ghatu Naach" festival. The spring is accessible from the Benighat Larkhe Bhanjyang road and is near forests covering most of the land. Agriculture and hotel businesses drive the local economy, with tourism boosted by the hot spring.

Environmentally, the hot spring has minimal impact on local wildlife, vegetation, and water quality. It's known for its medicinal properties, particularly for skin and joint ailments. Seasonal changes don't significantly affect the spring's discharge and temperature. However, potential risks include flooding and landslides due to the region's topography and lack of protective measures. There are no major concerns regarding water rights or pollution, but careful management is needed to prevent future environmental issues.

Overall, the hot water springs present a water profile that could be beneficial for therapeutic use, particularly for skin health and relaxation. The mineral content, including the notably high magnesium level, offers various health benefits. However, the high temperature of the water necessitates caution to avoid burns. Regular monitoring of water quality, especially for parameters like arsenic, is important to ensure safety and therapeutic value.

5.3.6 HS/4010801-11

Bhulbhule Khar, Gorkha

The Bhulbhulekhar hot spring is located in Gorkha district, Nepal, at the junction of Foudhe Khola and Chadi Khola. It has two main sources with taps filling pools for bathing. The spring discharges about 2 litres per second at an average temperature of 34.8°C. The water is clear and smells like black salt. The area is flat, surrounded by hills and terrace deposits, and the spring sits on alluvial deposits. The rock quality in the area is fair, with various joint sets identified.



Photograph 5.11: Measurement of discharge at the Bhulbhule Khar Tatopani

About 2,500 people live nearby, belonging to different ethnic groups. The hot spring, important for religious rituals and believed to have medicinal benefits, is near temples and a memorial. The region is mostly agricultural, with some forest and grazing land. The spring attracts tourists, boosting the local economy through hotels and agriculture.



Photograph 5.12: The surrounding area and the pond of the Bhulbhule Khar Tatopani

Environmentally, the hot spring has minimal impact. It doesn't emit harmful gases or significantly affect humidity, biodiversity, or water quality. The water has medicinal properties, and its use doesn't lead to water-borne diseases or conflicts. Seasonal changes affect the spring's discharge and temperature, but the overall environmental impact remains low.

Overall, the 'Bhulbhulekhar Tatopani' have a composition that is generally safe and potentially beneficial for therapeutic uses, particularly for relaxation and skin health. The water is clear with a balanced pH, and most of the minerals are present in safe concentrations. The temperature is warm but not overly hot, making it suitable for comfortable and safe bathing experiences. Regular monitoring, especially for parameters like arsenic, remains important to ensure ongoing safety and quality.

5.3.7 HS/4020305-13

Mencheuu Tatopani, Manang

The hot spring, known as Mencheuu Tatopani, is located in Chame, Manang district, Nepal, near the Marsyangdi River. It's at about 2700 metre elevation, in a hilly, steep area with a cold climate. The spring flows at about 1 litre per second with water at 47.1°C. The surrounding rocks are mainly gneiss, indicating stable geological conditions.



Photograph 5.13: People taking bath and the Marsyangdi River at the Mencheu Tatopani

This area is home to around 43 households, mainly Tamang, Gurung, and Lama ethnic groups. Locals have strong cultural ties to the spring, using it for health and religious rituals, including "Kulpuja" for ancestor worship. There's also a 300-year-old monastery nearby.

Most of the land is forested, with some agriculture and grazing. The hot spring, with its beautiful setting near hills and the Manaslu mountain range, attracts tourists for bathing and worship, boosting the local economy which relies on hotels and tourism. Around 1000-1500 people visit monthly, especially in winter.

The spring doesn't seem to harm the environment; it doesn't emit harmful gases or affect local wildlife or vegetation noticeably. The water's high temperature and slight smell don't alter local humidity or cause waterborne diseases. However, there's a moderate risk of pollution if the area isn't well-managed. Seasonally, the spring's flow changes, but the temperature stays fairly consistent.

Overall, the Mencheu hot water spring have a composition that is generally safe for therapeutic uses, particularly for relaxation and skin health. The water is slightly turbid, which should be investigated for potential contamination. The high temperature makes it suitable for short, relaxing soaks. The chloride level is notably high, which could be a concern for individuals with certain health conditions. Regular monitoring, especially for parameters like arsenic and turbidity, remains important to ensure ongoing safety and quality.

5.3.8 HS/4020403-14

Dharapani Tatopani, Manang

In Dharapani, Manang District, Nepal, a hot spring called "Maichhe Tatopani" is located on the Marsyangdi River's bank. The hot spring has two sources with temperatures around 31 degrees Celsius. It's in a hilly, steep area, and the rocks around it are mostly quartzite and schist. The area is prone to landslides and flooding, but no safety measures are in place.



Photograph 5.14: Source area of the hot water spring of the Dharapani Tatopani

About 300-350 people live nearby in 43 households, belonging to ethnic groups like Tamang, Gurung, and Lama. They use the hot spring for religious rituals and believe it helps with health issues like skin allergies and joint pain. The area is mostly forest, with some farmland and grazing land, and offers beautiful views of nature and the Manaslu mountain range.

The hot spring is important for local tourism, with hotels being a key part of the economy. There aren't many environmental problems from the spring. It doesn't harm the wildlife or plants, and the water quality downstream is good. The hot spring's discharge and temperature stay pretty stable throughout the year, not changing much with the seasons.



Photograph 5.15: The surrounding area of the Dharapani Tatopani, Manang

In summary, the 'Maichhe or Dharapani Tatopani' has a composition generally safe for bathing and therapeutic uses, particularly for relaxation and skin health. The temperature is comfortably warm, and the pH is close to neutral. However, the high chloride content is unusual and could be a concern for certain health conditions. The turbidity is slightly elevated, suggesting a need for monitoring water clarity. The rest of the elements are present in concentrations that are generally considered safe and potentially beneficial for health, with regular monitoring advisable to ensure ongoing safety.

5.3.9 HS/4060204-15

Jagat Tatopani, Lamjung

The hot spring source is situated uphill of the Marsyangdi River in Jagat, which falls within Ward No. 1 of the Machhapuchre Rural Municipality in the Kaski district. The hot spring's coordinates are approximately 84°24'45.16"E longitude and 28°24'45.16"N latitude, at an elevation of 1174 metre above sea level. The region has hilly, steep terrain with a warm, humid climate. There are two main hot water sources here, with temperatures around 55 degrees Celsius and a total discharge rate of 2.47 litres per second.

The area is mostly forested, with some agriculture and grazing land. The local community of about 255 people, mainly Gurung and Tamang ethnic groups, values the hot spring for its medicinal properties, especially for skin and joint problems. They also hold religious events and New Year celebrations here.

Tourism is vital to the local economy, with many visitors coming to enjoy the hot spring, especially in winter. The spring's popularity doesn't seem to harm the environment; it doesn't affect local wildlife or water quality negatively.



Photograph 5.16: Top view of the Jagat Tatopani



Photograph 5.17: Surrounding area at the Jagat Tatopani, Lamjung

While the hot spring's discharge and temperature vary with the seasons, it maintains its role as a significant cultural and economic resource for the local community, without causing major environmental or social issues.

In summary, the water from 'JagatTatopani Kunda' is generally safe for bathing and therapeutic uses, with a few elements to monitor. The temperature is on the higher side, so caution with exposure time is advised. The high chloride content is unusual and could be a concern, especially for individuals with certain health conditions. Sodium is also moderately high, which may be a concern for those with sodium-sensitive hypertension. The rest of the elements, including calcium, magnesium, and silica, are present in concentrations that are generally considered safe and potentially beneficial for health. Regular monitoring is advisable to ensure ongoing safety.

5.3.10 HS/4050201-18

Poje Tatopani, Kaski

The Poje hot spring, situated near the Seti River in Nepal's Kaski district, are notable for their therapeutic properties and cultural significance. Located in a hilly, forest-covered area at 1745 metre elevation, these springs are marked by two main sources with temperatures around 49.66°C and 66.06°C. The region, home to a small population of 11 people across three households, is part of a diverse ecosystem and is mainly used for forestry, agriculture, and grazing.



Photograph 5.18: Pond constructed for bathing purpose at Poje tatopani

Local communities, comprising ethnic groups like Tamang, Magar, Bahun, and Chhetri, hold the springs in high regard for religious and health-related practices. The area is also near a temple, enhancing its cultural importance. While the hot springs were once more frequently visited, a lack of proper infrastructure has led to reduced tourism.

Geologically, the springs are located in a valley with steep hills and are fed by water emerging from gneiss and schist bedrocks. The water, clear with a Sulphuric smell, does not significantly impact the local environment or wildlife. Seasonal changes affect the springs' discharge and temperature.

Although there's potential for pollution due to human settlement, no major environmental impacts have been observed. However, there's a need for proper management to prevent future pollution. The springs also play a role in the local economy, primarily driven by agriculture, with tourism as a potential secondary source of income.



Photograph 5.19: Source area of the hot water at the Poje tatopani

Overall, the hot springs water is generally safe and potentially therapeutic for bathing, with a few notable elements to monitor. The very high chloride content is unusual and could be a concern for individuals with hypertension or other health conditions sensitive to high chloride levels. The temperature is moderately high, so some caution is advised. The rest of the elements, including calcium, magnesium, and silica, are present in concentrations that are generally considered safe and potentially beneficial for health. Regular monitoring is advisable to ensure ongoing safety.

5.3.11 HS/4050311-20

Tauji Baraha Tatopani, Kaski

The Jhinu Danda hot spring, known locally as "Tauji Baraha Tatopani," is located in Nepal's Annapurna Rural Municipality, Kaski district, along the Modi Khola riverbank. This area is hilly with steep slopes and deep valleys. There are two hot water sources close to each other, with temperatures around 35°C and 39°C, and varying water discharge.



Photograph 5.20: Pond constructed and the surrounding area of the Tauji Baraha Tatopani

Geologically, the region features gneiss and schist rocks and lacks exposed bedrock due to alluvial deposits. Seasonal changes affect the area, with potential flooding during monsoons. The local government has built structures like retaining walls to protect the springs from flooding.

The local community, comprising 9 households with about 45 people from ethnic groups like Gurung, Bahun, and Kami, values these springs for religious and health-related reasons. The springs are near a temple and are a part of the Annapurna Base Camp trekking route, attracting many trekkers and tourists. The area's economy relies heavily on tourism, with hotels being a primary source of income, alongside agriculture and animal husbandry.

Environmentally, the hot springs don't significantly affect local biodiversity or water quality. There's no notable toxic gas emission or impact on the local climate. However, there is a concern about pollution from nearby settlements and the potential increase in pollution with tourism development.

The springs experience seasonal variations in water temperature and discharge, with higher discharge and lower temperatures during the rainy season, and vice versa in winter.

In summary, the Tauji Baraha hot springs water appears to be safe and potentially therapeutic for bathing. The temperatures are on the higher side, so caution with exposure time is advised. The mineral content, including calcium, magnesium, and silica, are present in concentrations that are considered safe and beneficial for health. The chloride and sodium levels are low, reducing concerns related to hypertension or other sodium-sensitive conditions. Regular monitoring would be advisable to ensure the ongoing safety of the water.



Photograph 5.21: People taking bath at the Tauji Baraha Tatopani

5.3.12 HS/4040105-22

Paudwaar Tatopani, Myagdi

The Paudwar Tatopani Kunda is located in the Annapurna Rural Municipality of Myagdi district, Nepal. It's near the Kaligandaki River, at an elevation of about 1230 metre. The area is mountainous and has a cold climate. The spring flows at about 1 liter per second and has an average temperature of around 60 degrees Celsius. It's a significant part of the local culture and economy, with about 3000 people living nearby, mostly from Janjati and Dalit communities. People visit the spring for health benefits and religious practices, especially during festivals like Khair puja. The region also has a temple and other natural attractions.

Most of the land around the hot spring is forest, with some agriculture and grazing land. This area is rich in biodiversity, with various plant and animal species. The local economy benefits from tourism, with many visitors coming to the hot spring, especially in winter. The spring is ecologically safe, not harming the environment or wildlife. It doesn't affect the water quality downstream or pose health risks. However, there could be future pollution risks if not managed properly. The spring's discharge varies with the seasons, but its temperature remains stable.



Photograph 5.22: Pond constructed and the area around Paudwaar Tatopani



Photograph 5.23: Source area of the hot water spring at Paudwaar Tatopani

In summary, water of the 'Paudwaar Tatopani Kunda' seems safe and potentially therapeutic for bathing and soaking. The temperature is quite high, so caution with exposure time is advised. The mineral content, including a higher level of silica, may be beneficial for the skin and overall health. The chloride and sodium levels are moderate, which might require caution for individuals with sodium-sensitive conditions. Regular monitoring, especially of the sulphate level, is advisable to ensure ongoing safety.

5.3.13 HS/4040102-23

Bhurung Tatopani, Myagdi

The Bhurung Tatopani, located in the Annapurna Rural Municipality in Nepal, is a natural thermal spring on the Kaligandaki River's bank. It's known for its 60.49°C warm, clear water, which flows at about 1 litre per second. The spring is in a hilly area with steep slopes and a deep valley, surrounded by quartzite rock formations. It's at 1225 metre above sea level and is prone to floods and landslides.



Photograph 5.24: Top view of the Bhurung Tatopani

The hot spring is close to the Korola Highway (Kaligandaki Corridor) and is a significant cultural site for the nearby Thakali community of about 200 people. They hold religious ceremonies here and believe in the spring's healing properties. The region celebrates various festivals, adding to its cultural richness.

Most of the land is forested, contributing to the area's beauty and biodiversity. The rest is used for agriculture and grazing. The local economy depends on tourism, with hotels being the primary income source. The hot spring attracts many visitors, especially during the rainy season.



Photograph 5.25: Dimension measurement of the reserve tank at Bhurung Tatopani

The hot spring is environmentally friendly, with no harmful effects on the local ecology. It's a popular health and wellness destination, believed to help with various physical ailments. The spring doesn't affect local wildlife or water quality significantly. However, managing tourism and preventing pollution is essential to protect this natural resource. Seasonal changes affect the water flow but not its temperature.

Overall, the hot spring water appears to be safe and potentially beneficial for therapeutic uses such as bathing. The high temperature warrants caution to avoid burns. The mineral content, particularly

silica, sulphate, and bicarbonates, may offer health benefits for the skin and muscles. The chloride level is moderately high but should not pose a significant risk for external use. Regular monitoring is recommended to ensure ongoing safety and to check for any changes in these parameters.

5.3.14 HS/4040106-24

Ratopani Tatopani, Myagdi

The Annapurna Rural Municipality in Myagdi district, Nepal, is home to a hot spring called "Ratopani Tatopani." Located on the Kaligandaki River's right bank, the spring's water is around 48.53 degrees Celsius. The area is hilly with steep slopes and has a rich geological makeup, including quartzite rock. It's near a small community of about 100 people, mainly from the Chhetri and Janjati ethnic groups. This hot spring is important for their religious and cultural practices, including various festivals and healing beliefs.



Photograph 5.26: Top view of the Ratopani tatopani

Most of the land in vicinity of the spring is forest, with some used for agriculture and grazing, however hot water spring lies on the flood plain of Kaligandaki River. The spring attracts tourists, benefiting local hotels and providing income to the community. Some people also work in agriculture or outside the area. The spring is popular, especially in winter, drawing many visitors for its therapeutic properties.

Environmentally, the hot spring coexists well with nature. It doesn't harm the local ecosystem, wildlife, or water quality. There's no significant pollution, but careful management is needed to maintain this. Seasonal changes don't greatly affect the spring's discharge or temperature, showing its stability. Overall, the spring is a vital part of the local community, both culturally and economically, while also being environmentally harmonious.



Photograph 5.27: Source area of the Ratopani Tatopani

Overall, the hot spring water appears to be suitable for therapeutic uses such as bathing. The slightly alkaline pH and moderate mineral content, especially silica, can be beneficial for skin health. The temperature is comfortably warm for relaxation but should be approached with caution to avoid overheating or burns. The low levels of potentially harmful elements like arsenic and sulphur are well within safe limits, making the water safe for external use. Regular monitoring is advised to ensure the continued safety and quality of the water.

5.3.15 HS/4040204-26

Darmija Tatopani, Myagdi

The Darmija Tatopani hot spring, located in Myagdi district, Nepal, is on the Raghuganga River's banks, known for their therapeutic properties. The area is hilly and steep with two main hot water sources, discharging about 1.57 litres per second. The water is clear and odourless, with temperatures around 40-43 degrees Celsius. The geology includes quartzite bedrock and is prone to landslides.

The local community, comprising diverse ethnic groups, values the springs for religious and health reasons. The springs are near a road and other temples, drawing visitors for worship and healing. The region, mostly forested, supports agriculture and has diverse flora and fauna. Tourism to the hot springs may boost the local economy.

Environmentally, the springs don't emit harmful gases and haven't negatively impacted local wildlife or vegetation. They remain stable in temperature despite seasonal changes in water discharge. Pollution levels are low, but there is a potential risk of corrosion without proper management. Overall, these springs are a vital natural and cultural asset, offering therapeutic and religious significance to the local community and visitors.

Overall, water from the 'Darmija Tatopani' appears to be very well suited for therapeutic uses. The slightly alkaline pH and moderate mineral content, especially calcium, magnesium, and silica, can be beneficial for skin and muscle health. The temperature is warm and can offer relaxation benefits, but caution should be exercised for sensitive individuals or prolonged exposure. The trace levels of potentially harmful elements like arsenic and sulphur are well within safe limits, ensuring the water's suitability for external use. Regular monitoring is recommended to maintain its quality and safety.

5.3.16 HS/4040604-27

Singa Tatopani, Myagdi

The Singa Tatopani hot spring is located near the Myagdi Khola in Nepal. It's a man-made pond with water at about 51.1 degrees Celsius. The area is hilly with a valley, forests, and agriculture. The bedrock is mainly quartzite. The hot spring, important for the local community of about 5000 people, is near the Beni-Darbang highway. People use it for health benefits, especially for skin and joint issues. The community, diverse in ethnicity, celebrates various festivals and holds religious practices at the spring.



Photograph 5.28: People taking bath at the Singa tatopani

About half of the land is forest, and 40% is used for agriculture. The hot spring is a tourist attraction, bringing in about 1000 visitors monthly, especially in summer and winter. It boosts the local economy, including through hotels and businesses.



Photograph 5.29: The Myagdi Khola and the area of Singa Tatopani

Environmentally, the hot spring has a moderate impact. It doesn't significantly affect wildlife or water quality downstream. The area doesn't face major pollution yet, but tourism development could

increase pollution if not managed well. The hot spring's discharge and temperature are consistent throughout the year with very small variation. Overall, it's a culturally and economically important site with a manageable environmental impact.

Overall, the 'Singa Tatopani' seems suitable for therapeutic uses. The water is characterized by its neutral pH, clear appearance, and moderately high temperature, making it potentially relaxing and beneficial for muscles and skin. The mineral content, particularly the high bicarbonate and moderate silica levels, can also offer health benefits. However, the presence of arsenic at the maximum allowable concentration for drinking water requires careful consideration and regular monitoring, especially if the water is to be used frequently or for extended periods. The unusually low levels of calcium and magnesium are notable and diverge from the typical mineral profile of natural hot springs.

5.3.17 HS/4040304-29

Bagara Tatopani, Myagdi

The Bagara Hot Spring, located in the Dhaulagiri Rural Municipality of Myagdi district, is a natural hot water source on the left bank of a river. It consists of two sources, with temperatures around 44 degrees Celsius. The area is hilly with steep slopes and is geologically characterized by slate rock formations. There are risks of landslides and flooding, but no protective measures are in place.



Photograph 5.30: The pond constructed for bathing at the Bagara Tatopani

The hot spring is important to the local community of about 200 people from diverse ethnic backgrounds. It's used for health purposes and religious activities, especially during local festivals. The

region is mostly forested, with some agricultural land and grazing areas. The local economy depends on agriculture, tourism to the hot spring, and other small businesses.

The hot spring attracts many visitors, especially in winter, who believe in its medicinal benefits. Environmentally, the hot springs have a minimal impact, not affecting wildlife or water quality significantly. There's no major pollution issue, but future management is crucial to prevent problems.

Seasonal changes don't significantly affect the spring's discharge or temperature, which remains relatively constant throughout the year. This consistency is important both for the local community and the visitors who come to enjoy the hot springs.



Photograph 5.31: River and the hot water spring at the Bagara Tatopani

In summary, the 'Bagara Tatopani' is characterized by its slightly alkaline pH, clear appearance, and warm temperature, which make it potentially beneficial for relaxation and soothing muscular discomfort. The water's mineral content, especially its high bicarbonate and silica levels, along with moderate sulphate, sodium, and potassium levels, may offer therapeutic benefits for the skin. The presence of arsenic is well below levels of concern for external use. This water profile indicates suitability for therapeutic bathing, with the potential for muscle relaxation and skin benefits.

5.3.18 HS/5010102-30

Pelma Tatopani, Rukum East

In Ward No. 2 of Putha Uttarganga in Rukum East, Nepal, there's a special hot spring near the Kaari River. It's at 2413 metre above sea level, with a temperature of 51.9°C, and flows at 2.15 litres per

second. The area is hilly, with steep slopes and river terraces. There are risks of floods and landslides, but the spring is still important to the local community of about 1050 people from various ethnic groups. This hot spring, called "Pelma Tatopani," is a place for healing rituals and is near other cultural sites and diverse religious places.



Photograph 5.32: Interaction program organized at the Pelma Tatopani



Photograph 5.33: Surrounding area around the Pelma tatopani

The region is mostly forested, with rare species, and is home to a small amount of agriculture. The hot spring attracts many tourists, especially in winter, boosting the local economy. People believe the spring can treat health problems like joint pain and skin issues. The spring doesn't harm the environment much. It doesn't affect wildlife or water quality, and no significant pollution has been

noted. However, as tourism grows, there's a need to manage this to avoid environmental damage. The spring's water flow changes with the seasons, but its temperature stays the same. Overall, this hot spring is an important cultural, economic, and natural site in the region.

In summary, the 'Pelma Tatopani' is characterized by its near-neutral pH, clear appearance, and warm temperature. The water's mineral content, including moderate levels of calcium and silica, along with low levels of sodium, potassium, and sulphate, suggests potential health benefits for the skin. The presence of arsenic and other elements is well below levels of concern for external use. This water profile indicates suitability for therapeutic bathing, particularly for skin health and relaxation.

5.3.19 HS/5010102-31

Bhalun Tatopani, Rukum East

The hot spring, known as Bhalun Tatopani, is located in Putha Rural Municipality, Rukum East district, Nepal. It's on the left bank of the Putha River, with coordinates of 82°57'9.57"E longitude and 28°40'11.61"N latitude. The area is hilly with steep slopes and is mainly covered in forests. The spring's water is hot, averaging 68°C, and flows at 1.5 litres per second.



Photograph 5.34: Conductivity and pH measurement at the Bhalun Tatopani

The region is geologically characterized by quartzite rock formations. The hot spring lies in an area prone to flooding and landslides due to its steep terrain and river proximity. The local population of about 1050 people, mainly Janjati, Chhetri, and Dalit, values the spring for religious and healing purposes. The economy is mostly based on agriculture and tourism, with the hot spring attracting many visitors for its therapeutic benefits.



Photograph 5.35: Surrounding area around the Bhalun Tatopani

Environmentally, the hot spring doesn't emit harmful gases and has minimal impact on local wildlife and water quality. It's seen as medically beneficial for treating various ailments. Pollution levels are currently low, but there's a risk of increase with development.

Seasonally, the spring's discharge and temperature remain relatively stable, showing little variation throughout the year. Overall, this hot spring is an important natural, cultural, and economic resource for the local community, attracting visitors while maintaining its environmental integrity.

In summary, the 'Bhalun Tatopani' is characterized by its slightly alkaline pH and moderately high turbidity. The water's temperature is very high and should be cooled before use. The mineral content, including moderate levels of calcium, magnesium, and silica, along with low levels of sodium and potassium, suggests potential health benefits for the skin. The presence of arsenic and other elements is well below levels of concern for external use. This water profile indicates suitability for therapeutic bathing, particularly for skin health and relaxation, provided the temperature is adequately managed.

5.3.20 HS/5010106-33

Jharna Tatopani, Rukum East

The Jharna Tatopani hot spring is located in Dimmurgaira, Rukum East, Nepal, near the Sanibheri River. It's at an altitude of 1620 metre and is important for the local community, who believe in its healing properties. The area is hilly and the hot spring, with its two main sources, has an average temperature between 49.9 and 55.3 degrees Celsius. The region is known for its steep slopes, forests, and diverse wildlife.



Photograph 5.36: Taps and pond constructed at the Jharna Tatopani

About 350 people live nearby, from various ethnic backgrounds. They use the hot spring for religious rituals, especially during the Maghe Sankranti festival. There are also nearby historical sites. The land is mostly forested, with some agriculture and grazing areas. The hot spring is a popular tourist spot, with around 20-30 daily visitors, increasing during peak seasons.



Photograph 5.37: Close view of the Jharna Tatopani

The hot spring doesn't significantly impact the environment or local wildlife. It doesn't affect the water quality downstream or pose a risk of waterborne diseases. However, with growing tourism, there's a need for careful management to prevent pollution.

Seasonal changes affect the hot spring's water discharge but not significant in its temperature. The local economy relies on agriculture, tourism, and some business activities. The hot spring is a key part of the area's socio-economic and cultural life.

In summary, the 'Jharna Tatopani' features a nearly neutral pH and very low turbidity, indicating clear water. The temperature is quite high, necessitating cooling for safe bathing. The mineral content, including moderate levels of chloride, calcium, and bicarbonates, along with low levels of sodium, potassium, and magnesium, suggests potential benefits for skin health. The presence of arsenic and other harmful elements is negligible, making this water suitable for therapeutic use, particularly for relaxation and skin health, once appropriately cooled.

5.3.21 HS/5010113-34

Tamphe Taopani, Rukum East

Tamphe Hot Spring is located in Rukum East district, Nepal, by the Sanibheri River. It's in a hilly area with steep slopes and a river valley. The hot spring has two sources with temperatures around 44.46°C and 60.23°C, emerging from slate bedrock. This area, at 1484 metre elevation, is prone to landslides and flooding but lacks protective measures.



Photograph 5.38: Pond constructed for bathing and the Sanibheri River at Tamphe Tatopani

Around 300 households live nearby, including Dalits and Janjati. The hot spring is important for local culture and health, used for religious ceremonies and to treat ailments like skin allergies and joint pain. The area celebrates various festivals and is covered by forests, agricultural land, and grazing areas.



Photograph 5.39: The source area and the Sanibheri River at the Tamphe Tatopani

The local economy relies on agriculture, tourism to the hot spring, animal husbandry, and business. The spring draws about 10-15 visitors daily, increasing to 20 in peak season. It's believed to have medical benefits, like relieving joint pain and skin issues, without harming the environment or wildlife. The water quality remains good, and there's no significant pollution yet.

Seasonal changes affect the spring's water flow but not its temperature. Overall, Tamphe Hot Spring is a culturally and ecologically important site with potential for tourism, needing careful management to prevent environmental damage.

Overall, the 'Tamphe Tatopani' is characterized by its moderately alkaline pH, very low turbidity, and relatively high temperature. The mineral content is generally low, with notable amounts of silica and bicarbonates. The presence of harmful elements like arsenic is negligible. This water profile suggests suitability for therapeutic use in skin health and relaxation, once appropriately cooled for safety.

5.3.22 HS/5010204-35

Sisne Tatopani, Rukum East

Sisne Tatopani, a hot spring in Nepal, is located near the Sanibheri River in Rukum East district. Surrounded by hilly terrain, it has two main hot water sources with an average temperature around 56 degrees Celsius. These springs are culturally important to the local community of about 12,000 people, who use them for health benefits and religious practices, especially during the Maghe Sankranti festival.



Photograph 5.40: Protection work done to safeguard the hot water spring at the Sisne Tatopani

The area is diverse in flora and fauna, with forests and agriculture being the main land uses. Around 20-30 people visit the hot spring daily, increasing to about 5,000 during peak seasons. The local economy thrives on agriculture, tourism from the hot spring, and other businesses.

The hot spring has a slight impact on the environment, emitting a mild alum-like smell and affecting local humidity, but it doesn't harm the local wildlife or water quality. Pollution is currently low, but there's a risk of it increasing without proper management. Seasonal changes don't significantly affect the spring's discharge or temperature.



Photograph 5.41: Source area of the hot water spring at the Sisne Tatopani

In summary, Sisne Tatopani is a vital natural and cultural site in Nepal, providing health benefits and supporting the local economy, with minimal environmental impact.

Overall, the 'Sisne Tatopani' is characterized by its moderately alkaline pH, very low turbidity, and relatively high temperature. The mineral content is generally moderate, with notably high levels of silica and bicarbonates. The presence of harmful elements like arsenic is negligible. This water profile suggests suitability for therapeutic use in skin health and relaxation, once appropriately cooled for safety as it is burning hot.

5.3.23 HS/5010204-36

Panga Pokhara, Rukum East

Panga Pokhara is a hot spring located in Rukum East, Nepal, near the Sanibheri River. It's important to the local community of about 10,000 people, who use it for health and religious rituals. The area, which is hilly and forested, has two main hot water sources with temperatures around 45°C and 46°C. These springs are in a valley with steep hills and are at risk of landslides and flooding.



Photograph 5.42: Source area of the Panga Pokhara Tatopani

The local people, belonging to various ethnic groups, gather at the hot spring for an annual festival and for traditional healing practices. The area around the spring is mostly forest and farmland, and its home to diverse plants and animals. About 20-30 people visit daily, and during peak times, like winter, this can rise to 5,000 per day. This tourism helps the local economy, which mainly depends on agriculture and animal husbandry.

The hot springs don't seem to harm the environment much. They don't affect the local wildlife or water quality significantly, and they aren't a source of pollution yet. Seasonal changes don't affect the spring's water flow or temperature. Overall, Panga Pokhara is a culturally and economically important spot for the local community, with minimal environmental impact.



Photograph 5.43: The Sanibheri River and the pond at the Panga Pokhara Tatopani

Overall, the 'Panga Pokhara Tatopani' has a moderately alkaline pH, a slightly higher turbidity indicating some suspended matter, and a moderately warm temperature. The mineral content is generally moderate, with a notably high level of bicarbonates. The presence of harmful elements like arsenic is negligible. This water profile suggests suitability for therapeutic use in skin health and relaxation, with some caution advised due to turbidity.

5.3.24 HS/5090301-37

Surai Bridge Tatopani, Kapilvastu

The Surai Bridge Tatopani is located in the Shivaraj Municipality, Kapilvastu district, Nepal. It's in a hilly area of Chure, near the Suarai Khola River, with a water discharge of about 1.11 litres per second and a temperature of around 34.26°C. The area has steep hills and a river valley, with the land mainly covered by forests and agricultural fields. The rocks around the spring are slightly weathered and have several joints.

Around 1,500 people live in this area, however there is no residents in the immediate vicinity of hot spring, including various ethnic groups like Brahmins, Chhetris, Tharus, Magars, and Dalits. They use the hot spring for religious rituals and believe it helps with health issues like skin allergies and joint pain. The area is also known for its natural beauty, wildlife, and religious sites like the Shivagadi and Dhan Khola temples.



Photograph 5.44: Discharge measurement at the Surai Bridge Tatopani

The local economy relies on tourism, especially the hot spring, which attracts many visitors. Hotels are a significant source of income here. However, the hot spring lacks good management and facilities.

The hot spring is environmentally friendly and does not harm the local biodiversity or water quality. There's no conflict over water use, and pollution levels are low, although this could change without proper management. The spring's water discharge and temperature are generally stable throughout the year.



Photograph 5.45: Field verification at the Surai Bridge Tatopani

Overall, the 'Surai Bridge Tatopani' is characterized by a moderately alkaline pH, very low turbidity, and a comfortably warm temperature. The mineral content is generally moderate, with notable levels of silica and bicarbonates. This water profile suggests it may be beneficial for skin health and relaxation, with no significant health hazards noted from the analysis.

5.3.25 HS/5100709-38

Tapta Kunda, Dang

The "Tapta Kunda" is located in Lamahi Municipality, Dang district, near Rihar Dham. It's on flat land in the Churia range and next to a river, with hot water flowing at about 41.8°C. The spring is well-maintained and protected from floods. Around 2,500 people live in this area, which is ethnically diverse and rich in culture and traditions. The community values the hot spring for its health benefits and religious significance. There are several temples nearby, and festivals like Maghi and Teej are celebrated with enthusiasm.



Photograph 5.46: Dimension measurement of the pond at the Tapta Kunda

The region is 50% forest, 40% agricultural land, and 10% grazing land. Wildlife, including tigers and crocodiles, live here. The local economy depends on tourism to the hot spring, with hotels being a major income source. The spring draws around 800 visitors monthly, peaking in winter and on special occasions.



Photograph 5.47: Another view of the pond at the Tapta Kunda

Environmentally, the hot spring is safe, without harmful gases or liquids, and it doesn't harm the surrounding ecosystem. While it's a tourist attraction, it hasn't significantly affected local wildlife or water quality. Seasonal changes slightly affect the spring's discharge and temperature, but overall, it remains stable. The area's development could increase pollution, so careful management is needed to preserve this natural wonder.

Overall, the Tapta Kunda is characterized by a moderately alkaline pH, warm temperature, and notable bicarbonate content. The higher turbidity level suggests more suspended particles, which could affect the clarity and purity of the water. This profile indicates potential benefits for skin health and relaxation, with no major health hazards noted from the analysis.

5.3.26 HS/6040602-41

Jarami Tatopani, Jumla

The Jarami Tatopani, also known as Jumla Tatopani and Tila Nadi Tatopani, is located in the Tatopani Rural Municipality of Jumla district, Nepal, near the Tila Nadi. It's found in a hilly area at 2236 metre elevation, with steep slopes and a valley formed by the river. The spring has two main sources, producing a total of 7.17 litres per second of hot water, with temperatures around 41.5 to 42.1 degrees Celsius. The water, clear with a Sulphuric odour, flows from bedrock formations of banded gneiss.



Photograph 5.48: People taking a bath at the Jarami Tatopani

This region is mostly forested and used for agriculture and grazing. It is home to around 1800 people from diverse ethnic groups, living in 495 households. The hot spring, an important cultural and

religious site for locals, attracts 50-70 visitors daily, boosting the local economy through tourism and agriculture.



Photograph 5.49: The Tila Nadi and the hot water spring area at the Jarami Tatopani

The hot spring's warm water slightly alters the local humidity and has a distinctive smell, but it doesn't significantly impact the environment or local wildlife. Pollution is currently low, but there's a risk of increased pollution if the area isn't managed properly. Seasonal changes affect the water discharge rate, but the temperature remains fairly constant.

In summary, Jarami Tatopani is a culturally significant hot spring in a remote Nepalese community, attracting tourists and supporting local livelihoods while coexisting harmoniously with the environment.

Overall, 'Jarami Tatopani' has a profile that suggests it could be beneficial for skin health and relaxation. The pH is mildly alkaline, the temperature is comfortably warm, and it contains moderate levels of silica, sulphates, and bicarbonates. The arsenic level, while at the upper safety limit, requires monitoring. The overall quality indicates a potential for therapeutic use with no significant health hazards from the analysed components.

5.3.27 HS/6020213-42

Ruga Tatopani, Mugu

The Ruga Hot Spring, located in Chhayanath Rural Municipality in Nepal's Mugu district, is a natural hot water source on the Mugu Karnali River's right bank. At about 1720 metre elevation, it comprises two sources on the left bank, together discharging 2.31 litres per second of hot water into a man-made pond. The area is characterized by steep hills and metamorphic terrain, with schist and quartzite

bedrock. The region is prone to landslides and flooding, though gabion walls have been constructed for protection.



Photograph 5.50: Source area of the hot water spring at the Ruga Tatopani

This hot spring, known as Ruga Tatopani, is vital for the local community of about 200 people, consisting mainly of Chhetri and Dalit ethnic groups. It's used for religious activities and is believed to have health benefits, like treating skin allergies and joint pain. The area, rich in forests and agriculture, hosts diverse flora and fauna, with the local economy relying on agriculture, tourism, and animal husbandry.

The hot spring attracts many visitors, especially in winter, for its therapeutic benefits and religious significance. Environmentally, the hot spring has minimal negative impacts, with no significant harm to wildlife, vegetation, or water quality. Seasonal changes affect its discharge and temperature but don't cause long-term changes. Effective management is necessary to prevent pollution and maintain its ecological balance.

Overall, the 'Ruga Tatopani' appears to have a beneficial composition for therapeutic use, especially for skin health, due to the presence of minerals like silica, magnesium, and sulphates. The high chloride content is notable but not typically a concern for external use. The pH is close to neutral, making it gentle for most skin types. The arsenic level is within safe limits, but continuous monitoring is advisable. The turbidity is relatively high, which might affect the aesthetic appeal but doesn't necessarily indicate a health hazard.



Photograph 5.51: Pond constructed for bathing at the Ruga Tatopani

5.3.28 HS/6030603-45

Unapani Tatopani, Humla



Photograph 5.52: Conductivity and pH measurement at the Unapani Tatopani

The Unapani Tatopani is located in Humla district, Nepal, near a river and surrounded by hills. It has two main sources with water temperatures around 47°C and a combined discharge of about 18.6 liters

per second. The area is geologically characterized by marble and granitic gneiss rocks. The hot spring, at 1869 metre elevation, is in a region prone to flooding and lacks soil conservation measures.

Around 1900 people from various ethnic groups live nearby, using the spring for health and religious reasons. The area is 2 kilo metres from the nearest highway and involves a journey through Nepalgunj-Surkhet-Manma-Unapani Khola. Locally, the land is mostly foresting and agricultural, with the community relying on farming, animal husbandry, and tourism for income. The hot spring attracts around 50-60 daily visitors, increasing to 2500 per day in peak season.



Photograph 5.53: Interaction program with the local people at the Unapani Tatopani

The environmental impacts of the hot spring are moderate. The warm water slightly changes the local microclimate but doesn't significantly affect wildlife or water quality downstream. No major social or political conflicts over water rights have been noted. Seasonal changes affect the spring's discharge and temperature. Long-term effects on the environment or biodiversity are not fully understood, but increased tourism could lead to potential pollution if not managed properly.

Overall, the 'Unapani Tatopani' has a slightly acidic pH, which could be beneficial for certain skin conditions. The presence of minerals like silica, magnesium, and bicarbonates suggests potential skin health benefits. The mineral content is generally moderate to high, except for low sulphates. The water is clear with very low turbidity. Arsenic levels are within safe limits, but continuous monitoring is advisable. The temperature is comfortably warm, making it suitable for relaxation and muscle relief.

5.3.29 HS/6030205-47

Kharpunath Tatopani, Humla

In Humla, Nepal, there's a special hot spring called Kharpunath Tatopani, near the Karnali River. It has two water sources with different temperatures, and people believe it has healing powers. The area around it is hilly and has unique rocks and steep slopes. Despite being prone to floods, there's no protection for the spring.



Photograph 5.54: Hot water spring in the background and the Karnali River

About 600 people live nearby, mostly Chhetri, Bhramin, and Dalit. They use the spring for health and religious rituals, especially for skin and joint problems. The region is mostly forests and farms, and the hot spring is a beautiful place with lots of plants and animals. The local economy depends on farming, but the spring also attracts tourists.

The hot spring doesn't harm the environment much. It's not toxic, and it doesn't affect the local wildlife or plants. It even helps with health issues like joint pain and skin problems. The temperature of the spring can change with the seasons, but it doesn't affect the water flow or the environment. It's important to manage the spring well to avoid pollution as more people visit.

5.3.30 HS/6030402-49

Kermi Tatopani, Humla

Kermi Hot Spring, located in Humla, Nepal, sits on the left bank of Tatopani Khola. It has 12 hot water sources combined into two main ones, with temperatures around 46°C and 59°C. The area is hilly with steep slopes and the terrain features granitic gneiss rock. The hot spring, at 2994 metre elevation, is surrounded by forests, rivers, and agricultural land but lacks flood and soil conservation measures.

The local community, comprising about 500 people from Dalit and Janjati ethnic groups, values the spring for health and religious purposes. Festivals like Dashain and Loshar are celebrated here. The region's economy relies on agriculture, tourism, and business activities, with the hot spring attracting many visitors, especially in winter.

The spring's warm water, believed to have medicinal benefits, does not release toxic elements but does affect local humidity slightly. Its development has led to some vegetation reduction but hasn't significantly impacted wildlife or water quality downstream. Seasonal changes affect the spring's water discharge but not its temperature. Managing potential pollution and ensuring sustainable use are important for preserving this natural resource and its benefits for the local community.



Photograph 5.55: Top view of the Kermi Tatopani



Photograph 5.56: Discharge measurement at the Kermi Tatopani

Overall, the 'Kermi Tatopani' has a neutral pH and contains a variety of minerals in moderate concentrations, which can be beneficial for skin health. The temperature is warm enough for a relaxing and therapeutic experience, while the low turbidity indicates clear water. Arsenic and other potentially harmful elements are present in trace amounts, well within safe limits. The water appears to be suitable for bathing, offering potential health benefits, especially for the skin and muscles.

5.3.31 HS/6030406-50

Takchhe Tatopani, Humla

The Takchhe Tatopani are located in the Humla district of Nepal, near the Chirku River. This area is characterized by gentle slopes and hills and is predominantly covered by forests. The hot springs are at an elevation of about 4177 metre and have two main sources with temperatures of 43.4°C and 56.96°C, respectively. The area is home to a community of 500 people from diverse ethnic backgrounds, who use the springs for health and religious rituals.



Photograph 5.57: Temperature measurement and the pond at the Takchhe Tatopani

The hot springs are about 100 metre from the Limi Lapcha road and are accessible via a specific route. The region's land is mainly used for forests, agriculture, and grazing. The hot springs, surrounded by rich biodiversity, attract about 10-15 visitors daily, increasing to 200 per day in peak seasons. Visitors come for the therapeutic benefits of the springs, believed to help with joint pain and skin conditions.

The springs emit a Sulphur odour and slightly affect the local microclimate but don't significantly impact the area's biodiversity or water quality. However, there's a potential risk of pollution if the springs are not managed properly. The springs experience seasonal changes in water discharge but maintain a consistent temperature throughout the year.



Photograph 5.58: Discharge measurement at the Takchhe Tatopani

Overall, the 'Takchhe Tatopani' hot springs water has a near-neutral pH and contains a variety of minerals at safe levels. The temperature is on the higher side, which can be beneficial but also requires caution for sensitive individuals. Trace elements like arsenic are present below harmful levels. The water is suitable for bathing and may offer health benefits, particularly for skin and muscles, but it's important to limit exposure time due to the high temperature.

5.3.32 HS/6030406-51

Chhamjo Chirkhu Tatopani, Humla

Chhamjo Chirkhu Tatopani, a hot spring in Namkha Rural Municipality, Humla district, is located on the left bank of the Chirku River. It consists of two distinct sources, with temperatures around 61.7°C and 63.6°C, and a combined discharge rate of 2.15 liters per second. The region, characterized by flat terrain, gentle slopes, and a deep river valley, is mostly forested and experiences a cold climate.

Home to 150 households with around 500 people, the community near the hot spring practices traditional worship at the site for health benefits. The area is ethnically diverse, with Janjati and Dalit groups. Locals celebrate festivals like Dashain and Tihar, and the land is used for forests, agriculture, and grazing.

The hot spring, known for its therapeutic benefits, attracts 10-15 visitors daily and up to 200 during peak season. It does not significantly impact local biodiversity or water quality, and there's no evidence of increased pollution or conflicts over water rights. The springs experience seasonal discharge changes but maintain a consistent temperature.



Photograph 5.59: Chhamjo Chirku Tatopani and the pond constructed



Photograph 5.60: Close view of the hot water spring and the pond at the Chhamjo Chirkhu Tatopani

The area holds potential for tourism development, but careful management is needed to avoid environmental impacts. The local economy, primarily based on agriculture, benefits from the influx of tourists to the hot spring.

Overall, the 'Chhamjo Chirku Tatopani' appears to be of good quality for bathing, with a near-neutral pH and an array of minerals present in safe concentrations. The temperature is notably high, which can offer therapeutic benefits but also poses a risk of overheating or burns. Users should be cautious with exposure time. The trace elements like arsenic are below harmful levels, making the water generally safe for external use.

5.3.33 HS/6030104-55

Darbi Tatopani, Humla

In Chankheli Rural Municipality of Humla, there's a hot spring known as "Darbi Tatopani or Chankheli Tatopani" near the Salisalla-Mugu road. Located on the right bank of the Karnali River at about 1570 metre above sea level, it is part of a hilly and forested region with steep terrain. The hot spring water, with an average temperature of 65°C, is clear but smells like rotten eggs due to its mineral content. Geologically, the area features white marble bedrock and is prone to flooding in the rainy season.



Photograph 5.61: Interaction program with the local people at the Darbi Tatopani

This hot spring is central to the local community of about 350 people, mainly Chhetri and Dalit ethnic groups. They use the spring for religious rituals and believe it has healing properties for ailments like skin allergies and joint pain. The area is mostly covered in forests (90%), with some land used for agriculture and livestock grazing. Tourism in the hot spring, especially during winter and fall, is a significant source of income for the locals.

Environmentally, the hot spring doesn't significantly impact the surroundings. It doesn't pose a threat to wildlife or the quality of downstream water. Seasonal changes affect the spring's water discharge but not its temperature. While currently there are no major pollution issues, poor management could lead to environmental concerns in the future.



Photograph 5.62: Conductivity and pH measurement at the Darbi Tatopani

Overall, the 'Darbi Tatopani' appears to be of good quality for external use, with a balanced pH and a range of minerals present in safe concentrations. The high temperature offers therapeutic benefits but requires caution to avoid burns or overheating. The trace elements such as arsenic are below harmful levels, making the water generally safe for external use. The presence of silica at a higher concentration can be particularly beneficial for skin health.

5.3.34 HS/6100610-56

Bulbule Taal, Surkhet

Bulbule Taal is a hot spring located in Birendranagar Municipality, Surkhet District, Nepal. The water, which has no odour and is clear, comes from a single source and flows through pipes into a man-made pond. The area around the spring is mostly flat, with alluvial deposits from the river, and is surrounded by hills with gentle slopes. This region is covered by forests, farmland, and settlements, and has a hot and humid climate.

About 1100 people live in the nearby community, belonging to various ethnic groups, however Birendranagar lies in the close vicinity with rapidly growing population. The hot spring is culturally and religiously significant and used for healing and religious rituals. The area also has a temple and hosts major festivals. Most of the land is used for agriculture, which is the main livelihood, along with tourism from the hot spring.

The hot spring is believed to help with health issues like joint pain and skin problems. It's environmentally friendly, without harming local wildlife or vegetation. It attracts many visitors, especially in winter, boosting the local economy. There's no significant pollution or negative impact on the environment from the hot springs. Its water flow and temperature remain consistent throughout the year.



Photograph 5.63: Taps constructed at the Bulbule Taal



Photograph 5.64: Pond constructed at the Bulbule Taal

Overall, the water from the 'Bulbule Taal' appears suitable for bathing purposes, with most parameters within acceptable limits and offering potential health benefits for drinking purpose as well as the skin on bathing. However, the temperature of the spring is lowering compared to the record obtained from the literatures.

5.3.35 HS/7020102-57

Jima Tatopani, Bajhang

The Jima Tatopani is located in Jima Village, Saipal Rural Municipality, Bajhang district, Nepal. Positioned on the right bank of the Seti River, the spring is surrounded by steep, hilly terrain and quartzite bedrock. The hot spring water, which flows into the Seti River, has an average temperature of 65.5°C and a distinct salty smell. The area is prone to landslides and flooding due to its topography and geological features.

Home to around 200 people, mostly from the Chhetri and Dalit ethnic groups, the local community uses the hot spring for religious rituals and to treat health issues like skin allergies and joint pain. The hot spring, about 30 kilo metres from the nearest road, is dominated by forests, agricultural land, and grazing areas. The local economy relies on agriculture, with tourism to the hot spring providing additional income, especially during winter.



Photograph 5.65: Source area at the Jima Tatopani

The hot spring has moderate levels of toxic gases and liquids, but it's still considered medicinal. It doesn't significantly affect local wildlife or water quality, and the risk of water-borne diseases is low. Seasonal changes have little impact on the spring's discharge and temperature. However, increased tourism could potentially lead to pollution, so careful management is needed to protect this natural resource.

Overall, the 'Jima Tatopani' appears to be of good quality for external use, with a slightly alkaline pH and a range of minerals present in safe concentrations. The high temperature, though potentially therapeutic, requires caution. The trace elements such as arsenic are below harmful levels, and the presence of silica at a higher concentration is particularly beneficial for skin health.



Photograph 5.66: Discharge measurement at the Jima Tatopani

5.3.36 HS/7020103-58

Kaya Tatopani, Bajhang

The Kaya Tatopani is located on the Seti River's bank in Nepal's Bajhang district. It has two main sources with a total flow of 1.11 litres per second and a temperature of 51.5°C. The water is light yellow and smells like black alum. This region, at 1954 metre above sea level, is hilly with steep slopes and prone to landslides and floods.



Photograph 5.67: Close view of the Kaya Tatopani

About 200 people live in this area, mostly Brahmin and Chhetri. The hot spring is important for religious rituals, believed to heal skin and joint problems. There's a temple nearby, and the community celebrates festivals like Dashain and Tihar. The area, rich in forests and wildlife, also supports agriculture and grazing.



Photograph 5.68: The surrounding area around the Kaya Tatopani

The hot spring is popular with tourists, especially in winter, with up to 300 visitors daily. This boosts the local economy, which relies on farming, animal husbandry, and business.

The hot water has some toxic elements but is believed to have health benefits. It hasn't significantly affected the local environment, wildlife, or water quality downstream. Seasonal changes don't greatly affect its flow or temperature. However, future development could increase pollution if not managed well.

Overall, the water from the 'Kaya Tatopani' exhibits good quality for external use. The water's slightly alkaline pH, combined with a range of beneficial minerals like calcium, magnesium, and silica at moderate to high concentrations, makes it potentially therapeutic for skin health. The temperature is within a range that can provide relaxation benefits but should be approached with caution to avoid overheating. The low levels of potentially harmful elements like arsenic and iron further indicate its suitability for external use including recreational activities.

5.3.37 HS/7020401-59

Sunikot Tatopani, Bajhang

In the Talkot Rural Municipality of Bajhang district, there's a hot spring near the Seti River, known as Sunikot Tatopani. It is also known as Talkot Tapowan and Tapowan Jalkunda. It is located in a hilly, forested area with steep slopes and is home to a community of about 700 people, mainly from the Chhetri and Dalit groups. The spring, with an average temperature of 45.1°C, is important for local religious practices and is believed to have healing properties.



Photograph 5.69: The Sunikot Totopani and the source area of the hot water spring

The area's geology features white quartzite bedrock with good stability. Seasonal changes don't much affect the spring's flow or temperature. The land around is mostly forest and farmland, with some used for grazing. Locals depend on agriculture, but the spring also attracts tourists, boosting the economy.



Photograph 5.70: The pond constructed at the Sunikot Totopani

The spring, being a natural resource, has environmental impacts. However, it hasn't caused major ecological damage or affected water quality downstream. No serious pollution issues are noted, and wildlife remains largely unaffected.

Overall, this hot spring is not just a natural feature but also a cultural and economic cornerstone for the local community, blending environmental significance with social and spiritual importance.

Overall, the 'Sunikot Tatopani' appears to be suitable for external therapeutic use. The slightly acidic pH may offer benefits for certain skin types, while the moderate turbidity indicates natural mineral content. The temperature is ideal for relaxation and therapeutic purposes, but care should be taken to avoid overheating or burns. The mineral content, including calcium, magnesium, and silica, is present in beneficial concentrations for skin health. Low levels of sodium and potassium, along with very low levels of potentially harmful elements like arsenic and iron, indicate a low risk for all type uses. The presence of bicarbonates contributes to the overall soothing effect of the water. The trace amounts of hydrogen sulphide and sulphur, known for their therapeutic properties in skin, add to the potential health benefits of these hot springs.

5.3.38 HS/7020504-60

Agra Tatopani, Bajhang

The Agra Tatopani hot spring is located in Masta Rural Municipality of Bajhang district, Nepal, near the Seti River. It's in a hilly area with steep slopes and is known for its 56.5°C water, which flows at 8 liters per second. The area, at 1338 metre above sea level, is geologically characterized by quartzite rock formations and is prone to landslides and flooding.



Photograph 5.71: Interaction program at the Agra Tatopani

Around 700 people, mainly Dalit and Chhetri, live near the hot spring. They use it for religious ceremonies and believe in its healing powers for skin and joint issues. The region, which includes the Seti Highway, temples, and scenic spots like Khaptad National Park, relies on agriculture and is increasingly attracting tourists to the hot spring, boosting the local economy.

Environmentally, the hot spring has moderate effects, like altering local humidity and emitting a black salt odour. It hasn't significantly impacted wildlife or water quality. With tourism growth, there's a risk

of increased pollution, but currently, it's minimal. The hot spring's water flow and temperature stay consistent throughout the year, unaffected by seasonal changes.



Photograph 5.72: Hot water spring and the protection work done at the Agra Tatopani

Overall, the 'Agra Tatopani' appears to be well-suited for therapeutic use. The pH level is balanced, and the turbidity is exceptionally low, indicating clear water. The temperature is high, suitable for therapeutic bathing but requires caution. The mineral content, including moderate levels of chloride, calcium, magnesium, and high silica, is beneficial for health, particularly for skin and muscle relaxation. Low levels of sodium, potassium, and trace amounts of potentially harmful elements like arsenic and iron indicate a low risk for external use. The presence of bicarbonates adds to the soothing effect, and the minimal levels of hydrogen sulphide and sulphur are typical for hot springs, adding to the potential therapeutic benefits.

5.3.39 HS/7020301-62

Surma Tapowan Kunda, Bajhang

The Surma Tapowan Kunda is located in the Surma Rural Municipality, Bajhang district, by the Tapowan River. It's at an elevation of about 3920 metre in a hilly area with steep slopes and is known for its hot water, which flows into the river. The water is 42 degrees Celsius and has a salty smell.

This hot spring is important to the local community of about 5000 people, with Dalits and Chhetris being the main ethnic groups. They use it for health benefits and religious activities, especially during local festivals. The area is mostly grazing fields and is rich in wildlife and plants, which adds to its ecological value. Tourism, mainly from Baisakh to Bhadra, significantly helps the local economy.

The hot spring has some environmental impacts. It releases gases and liquids, but these haven't been shown to harm local wildlife or vegetation. There's no major water pollution or conflict over water rights. Seasonal changes don't affect the spring's water flow or temperature.



Photograph 5.73: Hot water spring and the surrounding area at the Surma Tapowan Kunda

Overall, the 'Surma Tatopani' appears to be suitable for therapeutic use. The pH is slightly alkaline, and the water is very clear with low turbidity. The temperature is warm but not excessively hot, making it suitable for comfortable soaking. The mineral content is characterized by very high silica, which is beneficial for the skin, and moderate magnesium levels, which can aid in relaxation. Other minerals like sodium, potassium, calcium, and bicarbonates are present in very low quantities, reducing their potential health benefits but also minimizing health risks. The trace levels of potentially harmful elements like arsenic and iron are well below hazardous levels, ensuring safety for external use. Although, the parameters of hot water spring are in range for good use, it is difficult to develop as touristic purpose due to located in high altitude.

5.3.40 HS/7030601-64

Rela Tatopani, Darchula

Rela Tapowan Tatopani is a hot spring located in the Darchula district, Nepal, near the Chamaliya River. It has two hot water sources on the right riverbank, with the upper source flowing at 1.85 litres per second and the lower at 0.66 litres per second. The upper source is 35°C and the lower is 41°C. The area, at an elevation of 1082 metre, features hilly and steep terrain with black to light grey slate bedrock.

About 300 households live nearby, with a mix of Janjati and Dalit communities. The hot spring, 440 metre from the Simar highway, is important for local rituals and health treatments, especially for skin and joint problems. There's a temple nearby, and the spring is a site for various ceremonies and festivals.

The land around is mostly forests and agricultural, contributing to a rich ecosystem and biodiversity. The hot spring is a popular tourist spot, especially in winter, attracting around 3600 visitors monthly. It boosts the local economy, which mainly relies on agriculture and animal husbandry.



Photograph 5.74: Discharge measurement at the Rela Tatopani



Photograph 5.75: The source area of the hot water spring at the Real Tatopani

The spring has no significant negative environmental impact. It doesn't harm the local wildlife or vegetation and doesn't affect the water quality downstream. Seasonal changes influence the water flow but not its temperature. Proper management is needed to prevent pollution as tourism develops.

Overall, the 'Rela Tatopani' is characterized by a slightly alkaline pH, clear water with low turbidity, and a comfortably warm temperature. The mineral content is rich in magnesium and silica, beneficial for muscle relaxation and skin health, respectively. Moderate levels of chloride and bicarbonates also contribute to the therapeutic properties of the water. Trace elements like arsenic and iron are present in safe quantities, ensuring the water is suitable for therapeutic external use.

5.3.41 HS/7030201-66

Sribagad Tatopani, Darchula

The Sribagad hot spring, located on the Mahakali River's left bank in Darchula district, Nepal, is a natural wonder with over 25 hot water sources. These springs, lying in hilly terrain at about 930 metre elevation, have water temperatures around 55-56 degrees Celsius. The region's bedrock is mainly coarse-grained sandstone, prone to weathering and with a low Rock Quality Designation, suggesting it's not very strong.



Photograph 5.76: The River and the hot water spring source at the Sribagad Tatopani

This hot spring is crucial for the local community of about 400 people from diverse ethnic backgrounds. They use the hot spring for health and religious reasons. The region's economy relies on agriculture, with additional income from tourism due to the hot spring's popularity, especially during winter.

Environmentally, the hot spring has a moderate impact. While it's valued for its medicinal properties, there's a slight reduction in vegetation and water quality issues downstream. However, there's no major threat to local wildlife or waterborne diseases. The hot spring doesn't affect the area's biodiversity or water supply significantly.

In conclusion, the hot spring is an important cultural and natural site, with potential environmental impacts that need careful management as tourism develops. Its consistent temperature and discharge rate throughout the year make it a unique and steady attraction.

Overall, the 'Sribagad Tatopani' shows a slightly alkaline pH, elevated turbidity, and a warm temperature suitable for therapeutic baths. The mineral content is rich in magnesium, beneficial for muscle relaxation, and high in silica, which is good for skin health. Trace elements like arsenic and iron are present in safe quantities, ensuring the water is suitable for external use. The higher bicarbonate level indicates good potential for skin soothing and pH stabilization.



Photograph 5.77: The surrounding area of the Sribagad Tatopani

5.4 Hot Water Spring Formations in Nepal

The formation of the hot water spring in the Nepal Himalayas is a complex process and many scientific studies have been done but have been done in limited areas only. These studies have led to appropriate findings and many researchers have concluded that the formations of Hot water springs are geothermal. Among these findings, some have concluded that the formation of hot water springs is from the decay of radioactive elements like Radon-222 and CO₂ discharge. The review based on the formation of the hot water springs in the Nepal Himalayan is discussed below.

Evans et.al (Evans, M. J., L. A. Derry, and C. France-Lanord (2008), Degassing of metamorphic carbon dioxide from the Nepal Himalaya, *Geochem. Geophys. Geosyst.* 9, Q04021.)

Based on the information provided in the article "Degassing of metamorphic carbon dioxide from the Nepal Himalaya" by Evans et al., the formation of hot water springs in the Nepal Himalaya can be attributed to the entrainment of a small amount of metamorphic fluid into the meteoric circulation system. This inference is supported by the enriched d13C values observed in the hot spring fluids, which are among the highest reported for geothermal waters globally.

The study suggests that no known sources of CO₂ exist in the study area with sufficiently high d13C values to explain the enriched d13C DIC (dissolved inorganic carbon) values in the hot springs. Additionally, the presence of a carbonate unit in the Lesser Himalayan of Central Nepal with d13C values ranging from -3.5 to -0.1‰ indicates that the source of the high CO₂ in the sampled fluids is likely from metamorphic fluid entrainment rather than from local carbon sources.

Therefore, the formation of hot water springs in the Nepal Himalayas is primarily driven by the incorporation of metamorphic fluids into the hydrological system, leading to the release of CO₂ and the enrichment of d13C values in the hot spring fluids.

Frédéric Girault and Frédéric Perrier (Girault 2014) The Syabru-Bensi hydrothermal system in central Nepal: 2. Modeling and significance of the radon signature, J. Geophys. Res. Solid Earth, 119, 4056–4089.

The primary reason for the formation of hot water springs in the Syabru-Bensi region of central Nepal is the presence of hydrothermal activity. The hot water springs in this area are associated with significant degassing of almost pure CO₂ (>90%) marked with radon, indicating a strong connection to subsurface geothermal processes. The production of CO₂ through metamorphic reactions in the region, as supported by geochemical studies, contributes to the hydrothermal transport system in the Nepal Himalayas. This geothermal activity, along with fault zone architecture and permeability structures, likely plays a crucial role in the formation of the hot water springs in the Syabru-Bensi area.

Therefore, the combination of metamorphic reactions, fault structures, and geothermal processes in the region contributes to the formation of hot water springs with unique characteristics, such as high temperatures and significant CO₂ degassing, making the Syabru-Bensi hydrothermal system a fascinating area for further study and understanding of geothermal processes in the Himalayan region.

Evans, M. J., L. A. Derry, and C. France-Lanord (2004), Geothermal fluxes of alkalinity in the Narayani river system of central Nepal, Geochim. Geophys. Geosyst. 5, Q08011

The formation of hot water springs in the central Nepal Himalayan front region is the interaction of hydrothermal fluids with local lithologies through high-temperature silicate alteration processes. The article mentions that numerous hot springs in the area have total dissolved solids (TDS) up to 7000 mg/L, with Na⁺ and K⁺ typically comprising more than 50% of the cationic charge. This composition indicates that high-temperature silicate alteration is the dominant source of hot spring alkalinity. Additionally, the Sr isotope ratios from the hydrothermal fluids are similar to those found in the host rocks, suggesting significant fluid-rock interaction with local lithologies.

The presence of fault/fracture zones intersecting with topographic lows in the region also plays a role in the formation of hot springs. Hot springs tend to flow where these fracture zones intersect with topographic lows, indicating a strong regional topographic control over spring locations.

Therefore, the combination of high-temperature silicate alteration processes and the interaction of hydrothermal fluids with local lithologies, particularly in areas where fault/fracture zones intersect with topographic lows, provides a compelling explanation for the formation of hot water springs in the central Nepal Himalayan front region.

Dharmendra K. Gupta (Journal of Environmental Radioactivity 112 (2012) 171–174)

One of the significant reasons for the formation of hot water springs in the Himalayan region, particularly in Nepal, is the geothermal activity associated with tectonic processes. The Himalayas are a seismically active region due to the collision of the Indian Plate with the Eurasian Plate, leading to intense tectonic movements and the development of geothermal reservoirs beneath the surface.

The tectonic processes in the Himalayan region result in the accumulation of heat deep within the Earth's crust. This heat can be transferred to groundwater through fractures and faults in the rocks, causing the water to become heated. As the heated water rises towards the surface, it can emerge as hot water springs.

Additionally, the presence of faults and fractures in the geological formations of the Himalayas provides pathways for groundwater to circulate deep underground. When this groundwater comes into contact with the heated rocks at depth, it absorbs heat and ascends back to the surface, resulting in the formation of hot water springs.

Furthermore, the unique geological setting of the Himalayan region, with its complex tectonic history and diverse rock formations, contributes to the variability in temperature and mineral content of the hot water springs. The interaction between the circulating groundwater and the geologically active environment plays a crucial role in the formation and sustenance of hot water springs in the Himalayas.

In conclusion, the formation of hot water springs in the Himalayan region, including Nepal, is primarily attributed to geothermal activity driven by tectonic processes, the presence of faults and fractures facilitating groundwater circulation, and the unique geological characteristics of the region.

Perrier 2011 (F. Girault and F. Perrier: Heterogeneous temperature sensitivity of effective radium)

Based on the information provided in "Perrier 2011," the formation of hot water springs in the region can be attributed to the geological characteristics of the area, particularly the presence of a geothermal system. The study conducted in Nepal, specifically near the Syabru-Bensi geothermal system, indicates that the distribution of hot geological fluids can impact the effective radium concentration in rock and soil samples.

Hot water springs are often associated with geothermal activity, where underground heat from the Earth's mantle is transferred to the surface through various geological processes. In the case of the Syabru-Bensi region in Nepal, the presence of a geothermal system likely contributes to the formation of hot water springs. The interaction of geological structures, such as faults and fractures, with subsurface fluids, can lead to the heating of groundwater and the emergence of hot springs in the area.

Furthermore, the study mentions that the spatial and temporal variations of radon discharge near the Syabru-Bensi hot springs are associated with carbon dioxide degassing, indicating a complex interplay between geological processes and gas emanation. This suggests that the presence of hot geological fluids, possibly related to the geothermal system, plays a significant role in the formation and maintenance of hot water springs in the region.

Therefore, the geological setting of the Syabru-Bensi area, characterized by a geothermal system and associated fluid circulation, is likely a key factor contributing to the formation of hot water springs in the region.

Frédéric Girault, Bharat Prasad Koirala, Frédéric Perrier, Patrick Richon, Sudhir Rajaure (F. Girault et al. / Journal of Environmental Radioactivity 100 (2009) 955–964)

The study on the persistence of radon-222 flux during monsoon at the Syabru-Bensi geothermal zone in Nepal, the formation of hot water springs in this region can be linked to the following points:

Geothermal System

The Syabru-Bensi area is characterized by high radon-222 and CO₂ discharge, indicating the presence of a geothermal system. Geothermal activity in the region contributes to the heating of groundwater, leading to the formation of hot water springs.

Gas Discharge Zones

The study identified multiple gas discharge zones, including Gas Zones 1, 2, and 3, which are associated with high gas fluxes. These zones are indicative of subsurface processes such as geothermal activity and fluid circulation that contribute to the formation of hot water springs.

Radon-222 and CO₂ Fluxes

The study observed exceptionally high radon-222 and CO₂ fluxes in the reference transect near the hot springs. The correlation between radon-222 and CO₂ fluxes suggests a relationship between these gases, possibly related to the geothermal system and the formation of hot water springs.

Seasonal Variations

Despite the monsoon season with heavy precipitation, radon-222 and CO₂ fluxes remained persistent in the region. The study found that radon and its carrier gas fluxes were similar during both the wet and dry seasons, indicating the continuous release of gases from the geothermal system and hot water springs.

Importance of Further Research

The study highlights the need for additional research to better understand the geochemical and geophysical processes driving the formation of hot water springs in the Syabru-Bensi geothermal zone. Investigating the persistence of radon-222 fluxes and their correlation with other gases can provide valuable insights into the dynamics of the geothermal system and the factors influencing hot water spring formation.

In conclusion, the presence of high radon-222 fluxes, coupled with CO₂ discharge, in the Syabru-Bensi geothermal zone indicates active geothermal processes that contribute to the formation of hot water springs. The persistence of radon-222 fluxes during different seasons underscores the significance of ongoing research to unravel the complex interactions between geothermal activity, gas emissions, and the formation of hot water springs in this region.

5.4.1 Summary of Literature Review

There is limited research regarding the formation of hot water springs. The researchers in general consider the source formation by geothermal temperature and associated with thrusts. Still, some research at places reveals radioactive decay and CO₂ flow in hot water from the springs. The formation of these hot water spring sources may vary from place to place. The scope of the present study does not cover these all investigations. Hence, further research will be required to define the hot water spring formation throughout the Nation.

5.4.2 Hot Water Spring and Geological Structures

Locations of the hot water spring is shown in Figure 5.2. The major faults presented in the map are sourced from Dhital, 2015. The map shows that the source of thermal spring shall be directly related with thrust and faults in general. Even, almost all of the hot water spring seems to be associated with Main Central Thrust and related structures. Two hot springs, Tapta Kunda and Surai Bridge Tatopani, are in the vicinity of Main Frontal Thrust (MFT) which also known as Himalayan Frontal Thrust (HFT).

Bulbule Taal at Surkhet lies in the vicinity of Main Boundary Thrust (MBT). Some of the hot water spring in Rukum East, Mustang, Dolpa and Humla are located quite far from major structures.

From present study, it seems more confirmative that the major cause for hot water springs shall be the geological structures especially thrusts and other aforementioned parameters might be additional reason for hotness of these springs.

6 GEOTHERMAL ENERGY

Geothermal energy from hot water springs has immense potential as a clean and reliable power source. By tapping into the Earth's warmth from these springs, we can generate electricity in a unique way. The process involves adding cold water to the hot spring, creating a temperature difference that is converted into power. This method, known as binary cycle technology, efficiently harnesses the thermal energy present in the hot water.

The advantage of this approach is its consistent nature as hot water springs provide a constant heat source, ensuring a steady supply of electricity. Unlike some other renewables, geothermal energy from hot water springs doesn't depend on weather conditions. Additionally, this method has a low environmental impact, as it doesn't produce harmful emissions.

By utilizing the change in heat from hot water springs, we not only unlock a reliable energy source but also contribute to a cleaner and more sustainable energy future. It's a unique method, providing power while respecting the environment.

To calculate the amount of electrical energy that can be generated from a 70 degrees Celsius hot water spring with a flow rate of 1 liter per second (1 lps), we can use the concept of the available thermal energy and the efficiency of a power generation process.

The basic idea is to use the temperature difference between the hot water source (70°C) and a cooler reservoir (usually ambient temperature) to generate power using a heat engine, like a Rankine cycle or an Organic Rankine Cycle (ORC). The efficiency of the process will determine how much of the available thermal energy can be converted into useful electrical energy.

Let's assume an ideal scenario where the efficiency is 100%. The formula to calculate the electrical power output (P) can be given as:

$$P = m * c * \Delta T$$

Where:

P is the power output in watts (W)

m is the mass flow rate of water in kg/s (which can be approximated as 1 kg/s for 1 lps of water)

c is the specific heat capacity of water in J/ (kg°C)

ΔT is the temperature difference in °C (70°C - ambient temperature)

The specific heat capacity of water is approximately 4.186 J/ (g°C) or 4186 J/ (kg°C).

Let's use this information to calculate the power output. Assuming an ambient temperature of around 25°C:

$$\Delta T = 70^\circ\text{C} - 25^\circ\text{C} = 45^\circ\text{C}$$

$$m = 1 \text{ kg/s}$$

$$c = 4186 \text{ J/ (kg}^\circ\text{C)}$$

Plugging in the values:

$$P = 1 \text{ kg/s} * 4186 \text{ J/ (kg}^\circ\text{C)} * 45^\circ\text{C} = 188,370 \text{ W}$$

So, in an ideal scenario with 100% efficiency, you could generate approximately 188,370 watts or 188.37 kilowatts of electrical power from a 70°C hot water spring with a flow rate of 1 lps.

However, in practical applications, the efficiency of the power generation process is unlikely to be 100%. Real-world efficiencies are typically lower due to various factors such as heat losses, mechanical inefficiencies, and the limitations of the chosen power generation technology. To get a more accurate estimation of the actual electrical energy that can be generated, the efficiency of the specific power generation system is to be considered. The adopted efficiency of steam turbine is 50%.

Table 6.1: Potential calculation for geothermal electricity generation

Hot Spring Code	Place Name	Discharge, Lps	Water Temperature	Power potential in kilowatts	Power Generation considering efficiency of steam turbine, Kw	Estimated cost of investment (MNRs)
HS/3020102-02	Tatopani Bazar	2.5	51.6	376	188	86
HS/3030101-04	Chilime	1.7	41.95	185	92.5	42
HS/3040104-07	Tatopani	1.09	46.6	143	71.5	33
HS/4010403-09	Tatopani	1.01	46.65	117	58.5	27
HS/4010402-10	Machi Khola	1.02	60.7	174	87	40
HS/4010801-11	Kharpani	2.03	34.8	109	54.5	25
HS/4020305-13	Chame	1	47	165	82.5	38
HS/4020403-14	Dharapani	1.05	31.9	86	43	20
HS/4060204-15	Jagat	2.44	54.64	380	190	86
HS/4050201-18	Poje	1.77	49.665	266	133	61
HS/4050311-20	Jhinu Danda	2.36	57.86	422	211	96
HS/4040106-24	Ratopani	2.5	48.53	324	162	74
HS/4040102-23	Tatopani	1	60.49	181	90.5	41
HS/4040105-22	Paaudwar	1	60.75	183	91.5	42
HS/4040204-26	Darmija	1.57	45.75	194	97	44
HS/4040604-27	Singha	3.54	49.94	450	225	102
HS/4040304-29	Bagara	1.13	44.23	149	74.5	34
HS/5010102-30	Pelma	2.15	51	375	187.5	85
HS/5010102-31	Pelma	1.5	68	368	184	84
HS/5010106-33	Dimmurgaira	1.24	51	189	94.5	43
HS/5010113-34	Pipaltung	1	52.34	154	77	35
HS/5010204-35	Panga Pokhara	1	56	159	79.5	36
HS/5010204-36	Panga Pokhara	3	45.15	341	170.5	78
HS/5090301-37	Surai Bridge	1.11	34.26	51	25.5	12
HS/5100709-38	Rihar	4.95	36.63	270	135	61
HS/6040602-41	Tatopani	4.17	40.31	520	260	118
HS/6020213-42	Ruga	2.31	32	175	87.5	40
HS/6030603-45	Saskegad	3.72	43	469	234.5	107
HS/6030205-47	Kharpu	2	59.6	401	200.5	91
HS/6030402-49	Kermi	1.51	47	262	131	60
HS/6030406-50	Limi	1.16	53	267	133.5	61
HS/6030406-51	Limi	1.82	61	481	240.5	109

Hot Spring Code	Place Name	Discharge, Lps	Water Temperature	Power potential in kilowatts	Power Generation considering efficiency of steam turbine, Kw	Estimated cost of investment (MNRs)
HS/6030104-55	Darbi	3.15	60	596	298	136
HS/6100610-56	Naulapur	17.51	25	309	154.5	70
HS/7020102-57	Tapowan	1.39	65.5	315	157.5	72
HS/7020103-58	Tapowan	1.11	51.5	182	91	41
HS/7020401-59	Sunikot	1.34	46.16	167	83.5	38
HS/7020504-60	Tapowan	2.1	55	340	170	77
HS/7020301-62	Tapowan	2.5	42	443	221.5	101
HS/7030601-64	Rela	1.87	35	133	66.5	30
HS/7030201-66	Tapowan	1.25	55	188	94	43

The cost of installation of an electricity plant from thermal springs is taken from the international practice and taken in US\$ and further converted in NRs. with an exchange rate of 1\$ = 130 NRs. From this, the cost of geothermal electricity seems far more expensive in comparison with the cost of electricity generation by hydropower project from the above-mentioned table.

7 RANKING OF HOT WATER SPRINGS FROM TOURISM ASPECT

After completion of desk study, communication with local levels via. Electronic mail and telephone, field verification by trained technicians and hydrogeologists in the field and a visit by experts from a consultant along with a representative from WECS were organized. After completion of all data acquisition including laboratory test of water from the hot spring and field confirmation, ranking of the hot water spring sources with over threshold values is done as per the method given in Heading 2.2.4.

The main objective of ranking hot water spring sources is based on the possibility of development of the area for tourism promotion keeping the hot water spring in the centre. As the scope of this study is limited to the preparation of a Master Plan of four hot water spring sources, it is important to make proper procedure for the selection of four hot water spring sources among 41 sources that meet the threshold criteria of the study. This procedure, presented in the aforementioned heading, was prepared after a discussion with WECS and its concerned departments.

For preparing the ranking of Hot Water Spring Sources for further development as a tourism destination, Nepal Tourism Statistics 2021 and 2022 are thoroughly reviewed and considered the parameters defined by it. Furthermore, the Nepal Government recently announced the next decade (2023-2033) as the tourism decade. The outline of the strategic action plan prepared by the working group formed by the Ministry of Culture, Tourism, and Civil Aviation was announced in a program organized on Friday.

According to the report, the government will focus on the following theme each year

YEAR	THEME
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2023	Planning
2024	Cultural Heritage Campaign in Bagmati Province
2025	Remote area tourism promotion in Gandaki Province
2026	Adventurous and spiritual tourism
2027	Buddhist tourism promotion in Lumbini Province
2028	Ramayan-based tourism campaign in the Madhesh Province
2029	Natural and spiritual tourism promotion in Sudarpaschim Province
2030	Biodiversity Promotion in Koshi Province
2031	Virgin Karnali Province campaign
2032	Festive Nepal campaign

Based on the concept of tourism for all, the tourism decade aims to create an environment where 3.5 million tourists will visit the country annually within the next 10 years. According to the action plan, the goal has been taken to develop multi-faceted infrastructure across the country, revive the tourism sector, and bring tourism arrival to the previous state of 2019 by 2024.

7.1 Description of Weightage Factor

The weightage factor is divided into three categories i.e. quality, developability, and attractiveness of resources. Quality is further divided into three subheadings they are discharge, chemical properties, and temperature. Similarly, developability is divided into five, and attractiveness of resource is divided into four subheadings. The reason for dividing these weightage factors is to obtain weightage ratings and the weighted average afterward used in the ranking of each hot water spring. Furthermore, the ranking is used for the sustainability of the development of each hot water spring as a tourism development.

7.1.1 Quality

Quality is assessed through discharge, chemical properties, and temperature of hot water springs, with higher discharge rates, neutral or low significant chemical properties, and optimal temperatures receiving superior rankings.

7.1.1.1 Discharge

The ranking of hot water springs is based on their discharge, with those having higher discharge rates receiving higher ratings. For example, a spring with a discharge of >4 lps will have the highest rating of 4 while, a discharge between 1 lps to 2 lps will get a rating of 1.

7.1.1.2 Chemical Properties

The therapeutic value of hot water springs is evaluated based on their chemical properties. Hot springs with neutral or low significant chemical properties receive the highest ranking, while those with hazardous chemicals are rejected.

7.1.1.3 Temperature

The temperature of hot water springs plays a crucial role. Springs with temperatures above ambient or between 38°-45°C get a higher rating of 4 as they can directly be used and in the therapeutic range, while those less than ambient temperature are not considered for further study.

7.1.2 Developability

Developability is evaluated based on accessibility, geology, topography, and stage of development, favoring easily accessible, stable, and well-spacious sites with considerable development.

7.1.2.1 Accessibility

The ease of reaching hot water springs is assessed, with very remote locations ranked lower and easily accessible ones receiving higher rankings. For instance, a site with easy access, only a few hour's walk or drive from a major city, will have the highest rating of 4.

7.1.2.2 Geology

The stability of the site's geology, including factors like instability and the need for support, determines its ranking. More stable sites receive higher ratings.

7.1.2.3 Topography

The available space and layout of the hot water spring area influence the rating. Well-spacious areas receive a higher rating compared to congested ones.

7.1.2.4 Stage of Development

The current level of development at the hot water spring site determines its rating. More developed sites receive lower ratings and those not developed or in their natural state will obtain the highest rating of 4. This parameter is used to prioritize fewer development areas for further development as most of the stakeholders suggested focusing on underdevelopment sites.

7.1.2.5 HDI of Province

The Human Development Index (HDI) of the province where the hot water spring is located is also used as a stage of development. Less developed areas with lower HDI receive higher ratings. The referenced HDI is taken from the Nepal Human Development Report, 2020 published by the National Planning Commission, Government of Nepal in collaboration with UNDP.

7.1.3 Attractiveness of Resource

The attractiveness of resources considers factors like religious and historical importance, scenic beauty, and economic factors.

7.1.3.1 Religious Importance

The religious significance of the hot water spring is assessed, with primary religious importance is indicated by the importance of the hot water spring and/or the specific location associated with hot water spring, while secondary importance is taken as other religious place in the vicinity of the hot water spring and/or the specific location associated with hot water spring. If the importance of hot water spring, the spring obtained the highest rating of 4, and if low importance of secondary religious or no specific importance in the contest will get the lowest rating of 1.

7.1.3.2 Historical Importance

Similar to religious importance, the historical significance of the hot water spring is assessed, with primary historical importance indicated by the importance of the hot water spring and/or the specific location associated with hot water spring, while secondary importance is taken as other historical place in the vicinity of the hot water spring and/or the specific location associated with hot water spring. If the importance is high for the hot water spring, the spring obtained the highest rating of 4, and if the low importance of secondary historical places or no specific importance in the contest will get the lowest rating of 1.

7.1.3.3 Scenic Beauty

The aesthetic appeal of the hot water spring site influences its rating, with higher significance and beauty receiving higher ratings. The openness of the area, natural features, and viewing ranges of the landscape will guide the highest rating.

7.1.3.4 Economic Factor

The economic viability of the hot water spring site is estimated based on accessibility and condition of access, with highly significant economic factors receiving a higher rating. For instance, a site with highly significant economic benefits would get a rating of 4. A more accurate estimation of economic factors will be obtained only after a detailed study. With the limited scope of the study, economic factors could not be concluded. As a result, the lowest rating of 1 is provided for all of the hot water spring sources, and well-earning hot water springs at present have provided the highest rating of 4.

7.2 Calculation of Rank Values

For the ranking of the hot water spring sources, the aforementioned parameters and weightage. The calculation as an example is presented below for Tatopani Dhara, Sindhupalchok.

For the Quality parameter first ratings are provided and the weighted rating and weighted average for quality are obtained as

$$W_Q = R_1 \times W_1 + R_2 \times W_2 + R_3 \times W_3$$

Parameters	Description	Rating	Weightage	Weighted Rating
Discharge	3.47 lps	R1=3	W1=40%	3 X 40% = 1.2
Chemical	Low Significant	R2=2	W2=30%	2 X 30% = 0.6
Temperature	51.6°C	R3=3	W3=30%	3 X 30% = 0.9
Weighted Average, R _Q				2.7

Similarly, these values are obtained for Developability as

$$W_D = R_4 \times W_4 + R_5 \times W_5 + R_6 \times W_6 + R_7 \times W_7 + R_8 \times W_8$$

Parameters	Description	Rating	Weightage	Weighted Rating
Accessibility	50-60 m from the road and less than 2 days travel with mostly blacktopped road from Kathmandu	R4=4	W4=40%	4 X 40% = 1.6
Geology	Located at the bank and in the proximity of the river, generally stable	R5=3	W5=20%	3 X 20% = 0.6
Topography	Spacious area around the hot water spring	R6=2	W6=20%	2 X 20% = 0.4
Stage of development	Moderately developed	R7=2	W7=10%	2 X 10% = 0.2
HDI of Province	HDI of Bagmati is 0.669	R8=1	W8=10%	1 X 10% = 0.1
Weighted Average, R _D				2.9

The same procedure is followed for the Attractiveness of Resources as

$$W_A = R_9 \times W_9 + R_{10} \times W_{10} + R_{11} \times W_{11} + R_{12} \times W_{12}$$

Parameters	Description	Rating	Weightage	Weighted Rating
Religious Importance	Shiva Temple, Listti Mai Temple, Guru Rinpoche (Primary Low)	R9=3	W9=20%	3 X 20% = 0.6
Historical Importance	Primary low	R10=3	W10=20%	3 X 20% = 0.6
Scenic Beauty	Kodari Waterfall, Liping Waterfall	R11=3	W11=20%	2 X 20% = 0.6

Economic Factor	Highly Significant as it generates good revenue.	R ₁₂ =4	W ₁₂ =40%	4 X 40% = 1.6
Weighted Average, R _A				3.4

After obtaining the Weighted Average of rating for all three categories, further calculation is carried out according to Table 2.1 as

$$\text{Final Rating Value } R_F = R_Q \times W_Q + R_D \times W_D + R_A \times W_A$$

Categories	Rating	Weightage	Weighted Rating
Quality	R _Q = 2.7	W _Q = 20%	2.7 X 20% = 0.54
Developability	R _D = 2.9	W _D = 30%	2.9 X 30% = 0.87
Attractiveness of Resource	R _A = 3.4	W _A = 50%	3.4 X 50% = 1.70
Final Rating Value, R _F			3.11

The ranking of the hot water spring sources from the tourism aspect is presented in Table 7.1. Details of Ranking and Ranking parameters are presented in Annex-6 and Annex-7.

Table 7.1: Ranking of the hot water spring sources from the tourism aspect

SN	Hot Water Spring Code	Local Name	Local Level	District	Province	Final Rating
1	HS/4040105-22	Paaudwaar Tatopani Kunda	Annapurna Gaunpalika-05	Myagdi	Gandaki	3.33
2	HS/5100709-38	Tapta Kunda	Lamahi Municipality -09	Dang	Lumbini	3.15
3	HS/3020102-02	Tatopani Dhara	Bhotekoshi Gaunpalika-02	Sindhupalchok	Bagmati	3.11
4	HS/4040102-23	Bhurung Tatopani	Annapurna Gaunpalika-02	Myagdi	Gandaki	3.02
5	HS/6040602-41	Jarami Tatopani	Tatopani Gaunpalika-02	Jumla	Karnali	2.99
6	HS/4040604-27	Singa Tatopani	Beni Municipality-04	Myagdi	Gandaki	2.97
7	HS/7020401-59	Sunikot Tatopani	Talkot Gaunpalika-01	Bajhang	Sudurpashchim	2.79
8	HS/7020504-60	Agra Tatopani	Masta Gaunpalika-04	Bajhang	Sudurpashchim	2.73
9	HS/6030104-55	Chankheli Tatopani	Chankheli Gaunpalika-04	Humla	Karnali	2.63
10	HS/4050311-20	Tauji Baraha Tatopani	Annapurna Gaunpalika-11	Kaski	Gandaki	2.53
11	HS/6100610-56	Bulbule Taal	Birendranagar Municipality-10	Surkhet	Karnali	2.49
12	HS/4010801-11	Bhulbhule Khar	Paluntar Municipality-01	Gorkha	Gandaki	2.48
13	HS/5010204-36	Sisne Tatopani	Sisne Gaunpalika-04	Rukum East	Lumbini	2.38
14	HS/4060204-15	Jagat Tatopani Kunda	Marsyangdi Gaunpalika-04	Lamjung	Gandaki	2.34
15	HS/4050201-18	Poje Tatopani	Machhapuchchhre Gaunpalika-01	Kaski	Gandaki	2.33
16	HS4040204-26	Darmija Tatopani	Raghuganga Gaunpalika-04	Myagdi	Gandaki	2.27
17	HS/4020305-13	Chame Tatopani	Chame Gaunpalika-05	Manang	Gandaki	2.26

18	HS/6030205-47	Kharpunath Tatopani	Kharpunath Gaunpalika-05	Humla	Karnali	2.24
19	HS/5010204-35	Panga Pokhara	Sisne Gaunpalika-04	Rukum East	Lumbini	2.21
20	HS/4040106-24	Ratopani Tatopani	Annapurna Gaunpalika-06	Myagdi	Gandaki	2.20
21	HS/7020301-62	Surma Tapowan	Surma Gaunpalika-01	Bajhang	Sudurpashchim	2.20
22	HS/5010106-33	Jharna Tatopani	Putha Uttarganga Gaunpalika-06	Rukum East	Lumbini	2.09
23	HS/6030406-50	Chhamjo Chhirku Tatopani	Namkha Gaunpalika-06	Humla	Karnali	2.08
24	HS/6030406-51	Chhamjo Chhirku Tatopani	Namkha Gaunpalika-06	Humla	Karnali	2.02
25	HS/6030402-49	Kermi Tatopani	Namkha Gaunpalika-02	Humla	Karnali	2.00
26	HS/5010102-30	Pelma Tatopani	Putha Uttarganga Gaunpalika-02	Rukum East	Lumbini	1.99
27	HS/4010403-09	Dharche Tatopani	Dharche Gaunpalika-03	Gorkha	Gandaki	1.94
28	HS/5010102-31	Pelma Tatopani	Putha Uttarganga Gaunpalika-02	Rukum East	Lumbini	1.91
29	HS/7030601-64	Rela Tatopani	Marma Gaunpalika-04	Darchula	Sudurpashchim	1.90
30	HS/4040304-29	Bagara Tatopani	Dhaulagiri Gaunpalika-04	Myagdi	Gandaki	1.89
31	HS/3040104-07	Ruby Valley Tatopani	Rubi Valley Gaunpalika-04	Dhading	Bagmati	1.86
32	HS/5090301-37	Surai Bridge Tatopani	Shivaraj Municipality -01	Kapilvastu	Lumbini	1.83
33	HS/6030603-45	Unapani Tatopani	Sarkegad Gaunpalika-03	Humla	Karnali	1.80
34	HS/4010402-10	Machhi Khola Tatopani	Dharche Gaunpalika-02	Gorkha	Gandaki	1.76
35	HS/7020102-57	Tapowan	Saipal Gaunpalika-02	Bajhang	Sudurpashchim	1.74
36	HS/7020103-58	Kaya Tapowan	Saipal Gaunpalika-03	Bajhang	Sudurpashchim	1.74
37	HS/7030201-66	Duhun (Sribagad) Tatopani	Duhun Gaunpalika-04	Darchula	Sudurpashchim	1.70
38	HS/6020213-42	Ruga Tatopani	Chhayanath Rara Gaunpalika-13	Mugu	Karnali	1.68
39	HS/4020403-14	Maiche Tatopani	Nason Gaunpalika-03	Manang	Gandaki	1.64
40	HS/5010113-34	Tamphe Tatopani	Putha Uttarganga Gaunpalika-13	Rukum East	Lumbini	1.61
41	HS/3030205-04	Bhangre Tatopani	Aamachhodingmo Gaunpalika-05	Rasuwa	Bagmati	1.57

8 SELECTION OF HOT WATER SPRING FOR PREPARATION OF MASTER PLAN

After the completion of the ranking of hot water spring sources with over threshold values (Table 7.1), the consultant discussed with WECS on 21st December 2023 (Photograph 8.1).



Photograph 8.1: Discussion for ranking and selection of Hot Water Spring Sources

With the conclusions of the discussion, Draft Field Report-2 was submitted to WECS and the presentation of the report and discussion with stakeholders was organized on 23rd January 2024 (Photograph 8.2 and Photograph 8.3).



Photograph 8.2: Presentation held on 23rd January 2024 and discussion with stakeholders (viewing to Dash)



Photograph 8.3: Presentation held on 23rd January 2024 and discussion with stakeholders (viewing to screen)

From the ranking obtained and completion of the discussion, four hot water spring sources are recommended for further study i.e. preparation of a Master Plan. Out of these four hot water spring sources, water from Paudwar Tatopani Kunda is highly corrosive considering chloride, sulphate, and bicarbonates compared with drinking water parameters. However, these parameters are only showing effects on continuous use as drinking water. Chloride and sulphate are major therapeutic components of hot water springs, it is still recommended for bathing, soaking, and swimming purposes as recreational features for tourism promotion.

As further studies and construction had already started, the Tatopani Dhara was removed from the list of preparing master plans with the approval of WECS. Although the Singa Tatopani of Myagdi was on the following list, it was also not included for Masterplan preparation to avoid two sites in the same district as suggested by the stakeholders including WECS, so that regional balance could be maintained. As a result, the Sunikot Tatopani (Tapowan Jalkunda) of Bhajang following the list was taken for further study with the approval of the Client. The list of Selected Hot Water Spring Sources for the preparation of the Master Plan is presented in Table 8.1.

Table 8.1: Selected Hot Water Spring Sources for preparation of Master Plan

SN	HWS Code	Local Name	Local Level	District	Province	Remarks
1	HS/4040105-22	Paaudwar Tatopani Kunda	Annapurna Gaunpalika-05	Myagdi	Gandaki	Recommended for joint development
	HS/4040102-23	Bhurung Tatopani	Annapurna Gaunpalika-02	Myagdi	Gandaki	
2	HS/5100709-38	Tapta Kunda	Lamahi Municipality -09	Dang	Lumbini	
3	HS/6040602-41	Jarami Tatopani	Tatopani Gaunpalika-02	Jumla	Karnali	
4	HS/7020401-59	Sunikot Tatopani	Talkot Gaunpalika-01	Bajhang	Sudurpashchim	

The master plan for the top four selected sites was selected according to the ranking obtained. The team of experts visited the sites for the master planning and also studied the details of the five sites.

9 PREPARATION OF MASTER PLANS

Nestled in the tranquil beauty of Nepal's landscape, hot springs have great potential to grow as a tourism destination. Travelers seeking physical rejuvenation and cultural immersion have taken notice of Nepal's major hot springs, among which the consultant team along with the coordination with WECS have identified and shortlisted 5 hot springs, out of which two hot water springs are recommended to develop in combination. A thorough evaluation that considered a number of variables, including accessibility, geological significance, cultural legacy, and the potential for sustainable development, led to their selection for the master plan.

Historically, hot springs have held a special place in Nepal's cultural fabric, revered for their therapeutic properties and spiritual significance. Despite their cultural and natural importance, many of these hot springs have faced neglect in terms of infrastructure and management. This neglect has not only hindered their ability to attract visitors but has also posed threats to their ecological integrity.

The initiation of the master plan marks a crucial step towards addressing these challenges. It aims to revitalize the existing infrastructure of the hot springs, including bathing facilities, accommodation options, and recreational amenities. Additionally, the plan proposes the development of new structures and services tailored to enhance the overall visitor experience, thereby unlocking the full tourism potential of these natural assets.

Moreover, the master plan is underpinned by a strong commitment to environmental conservation and sustainable practices. Efforts will be made to minimize the ecological footprint of tourism activities, with initiatives focusing on waste management, biodiversity conservation, and the promotion of eco-friendly practices among visitors and local stakeholders.

The master plan recognizes the importance of community engagement and empowerment in ensuring the long-term success of tourism initiatives. Local communities will be actively involved in the planning and implementation process, with opportunities for capacity building, entrepreneurship, and cultural preservation initiatives. By fostering a sense of ownership and stewardship among local residents, the master plan seeks to create a tourism ecosystem that is not only economically viable but also socially and environmentally sustainable.

In essence, the development of the master plan represents a holistic approach to hot springs tourism in Nepal, one that seeks to balance the economic benefits of tourism with the imperative of environmental conservation and cultural preservation. Through strategic interventions and collaborative efforts, it aims to transform these hot springs into thriving destinations that offer enriching experiences for visitors while safeguarding Nepal's natural and cultural heritage for generations to come.

9.1 Necessity of Redevelopment

Nepal's hot springs need to be developed again for a number of reasons that will help the local population as well as the tourism industry. The hot springs, a natural attraction, have a lot of promise for tourism as they entice people looking for rest and healing properties. However, the attractiveness of the current amenities may be limited if they don't live up to the expectations of tourists. The location can draw more people and create economic opportunities for the community by improving the amenities, bathing spaces, and changing rooms. Additionally, by addressing environmental issues

like waste management and water quality, rehabilitation projects can guarantee the site's sustainability for coming generations. Better security protocols and hygienic amenities can also improve the general guest experience while fostering health and wellbeing. In the end, redevelopment offers a chance to several issues currently plague the site of in Nepal, impacting both the local community and visitors. These problems hinder the area's potential for tourism and economic development. Here's an overview of the key challenges:

- Underdeveloped tourism infrastructure, including accommodation options, restaurants, and recreational activities.
- Insufficient facilities such as changing rooms, toilets, and bathing areas.
- Limited road access and poor transportation infrastructure.
- Seasonal fluctuation of visitors.
- Lack of sustainable management of water resources.
- Lack of Management.
- Inadequate sanitation facilities and safety measures

9.2 Concept and Design Development

Redevelopment of hot springs offers an opportunity to transform the site into a sustainable and attractive destination that celebrates its natural beauty, cultural heritage, and offers enriching experiences for visitors. The main concept for the redevelopment is to create a premier eco-tourism destination that harmonizes with nature, celebrates local culture, promotes wellness, and fosters economic opportunities for the community while preserving the environment for future generations.

9.2.1 Key Concept of Redevelopment

9.2.1.1 *Natural Hot Springs Enhancement*

Restore and enhance the natural hot springs while preserving their ecological integrity. Develop bathing/soaking pools and relaxation areas with eco-friendly infrastructure. Integrate natural landscaping to create a tranquil and immersive experience.

9.2.1.2 *Sustainable Infrastructure*

Implement sustainable design practices in all infrastructure development, focusing on energy-efficient buildings, water conservation measures, and waste management systems. Design pedestrian-friendly pathways to minimize environmental impact and promote active transportation. Introduce renewable energy sources, such as solar power, for lighting and heating.

9.2.1.3 *Wellness and Eco-Tourism Offerings*

Develop eco-lodges and sustainable accommodations that blend with the natural surroundings. Offer wellness retreats, yoga sessions, and holistic healing experiences centered around the hot springs. Provide opportunities for eco-friendly adventure activities such as hiking, birdwatching, and nature walks.

9.2.1.4 *Universal Design*

Universal design principles are crucial to ensuring inclusion and accessibility for all people in the redevelopment plan. Ramps facilitate easy access to pathways, entrances, and common areas by being

smoothly incorporated into the infrastructure. In order to safely and pleasantly accommodate those with mobility issues, these ramps have non-slip surfaces, large widths, and moderate slopes. Wider entrances and accessible fixtures are examples of accessibility features that prioritize the comfort of visitors with impairments in the design of accommodations and restrooms. Ramps are also thoughtfully positioned to accommodate a variety of ground levels and open areas, according to the natural curves and facilitating smooth transitions between them. The town creates a friendly atmosphere for both locals and guests by ensuring clear navigation and accessibility throughout with inclusive signage and wayfinding.

9.2.1.5 Community Engagement and Empowerment:

Involve the local community in the planning, development, and management of the site. Create opportunities for community-owned enterprises, including homestays, guided tours, and handicraft sales. Invest in training and capacity building programs to enhance the skills and entrepreneurship of local residents.

9.2.1.6 Sustainable/Green features

These features help sustain the hot spring leaving behind less carbon footprint. By prioritizing sustainability, the natural environment is preserved for future generations.

9.2.1.7 Renewable resources

Maximizing the use of daylight can reduce energy consumption by incorporating PV cells for electricity production. This approach includes utilizing direct, indirect, and isolated gain, along with proper planning of windows and sun shading devices.

9.2.1.8 Water Pollution

The hot spring should not put pressure on the nearby water body and shouldn't pollute the existing river. The activities related to hot spring should have minimal effects on the water body used for placing the remains.

9.2.1.9 Solid Waste Management

Segregation of waste should be done before disposal such that maximum organic materials are composted and recyclable materials are sent for recycling. Following the 5R principles for disposal of waste can help minimize the overall waste.

By embracing this concept for the redevelopment of hot springs, the site can emerge as a model for sustainable tourism, offering memorable experiences that enrich the lives of visitors, support the livelihoods of the local community, and safeguard the natural and cultural heritage of the region for generations to come.

Prior to prepare master plan, a visit of expert to the site with representatives from WECS was conducted. Following the site visit, topographic survey with Total station was conducted. Using the outcome of survey and other relevant information, hydrological study was performed and flood on the Kaligandaki River was calculated as both of the hot springs lie on the bank of the river. Utilizing all

the information, aforementioned considerations and suggestions from stakeholders, masterplan of hot water spring sources was done.

9.3 Paudwar and Bhurung Tatopani Kunda, Myagdi

Descriptions of major works performed and outcomes of master plan are described in following sub-headings.

9.3.1 Topographic Survey

Topographic survey and mapping are an essential task in the study of any project. The survey of the project area will allow the project designer to set out project components in appropriate locations and prepare and quantity estimation. In addition, the topographical mapping will be useful for geological mapping, and social studies.

The topographical survey of Paudwar and Bhurung Tatopani Myagdi has been carried out using Total Station. The Total Station approach of the survey has been chosen for horizontal and vertical control surveys. The detailed topographical survey of different components has been carried out using high-precision Topcon & Sokkia Total Station.

The base control points namely BM-9 & BM-10 have been used for the whole project survey works. These points have been situated at the proposed headwork area of the Mistri-2 Hydropower Project. The project is upstream of the Paudwar Hot Spring. By using the Total station approach, sufficient numbers of benchmarks or control points have been established in the project area in terms of accuracy.

The coordinates and their elevations are tabulated below.

Table 9.1: List of Permanent Benchmarks

Station	Northing	Easting	Elevation	Remarks
BM-9	3153097.948	466411.894	1224.633	
BM-10	3152940.988	466423.896	1222.017	
BM-3	3152804.742	466210.684	1299.511	

The topographical mapping was to be done of the proposed project area in 1 in 1000 scales with 1-metre contour intervals. Keeping this in view, sufficient survey control points were fixed during the stage of horizontal controlling.

For a detailed topographic survey, the tachometric method of survey has been introduced. The X, Y, and Z coordinates of every detail were recorded by the Total Stations instrument on the site. The procedure for detail surveying is as follows.

After setting the instrument over a known survey station, the back sight was fixed on the prism reflector placed over a known point and then started taking details on the ground. The details include roads, footpaths, and houses, with physical and man-made features, also with hydrographic features such as rivers, streams, etc. Some special landslide signs such as cracks, scarp areas, etc. have been surveyed. All information mentioned in the scope has been depicted from the ground.

The X, Y, and Z coordinates of every detail have been recorded and saved in the Total Stations and downloaded to the computer later. The further processing of all topographic data was done on the computer and the plot of the file in AutoCAD format was prepared. The detail of the topographic survey is presented in Volume 3A.

9.3.2 Hydrological Study

The preparation of the master plan includes the conservation plan and the tourism development plan. The development plan includes tourism development infrastructure such as recreational areas, swimming ponds, bath showers, sliding decks, etc. The main objective of a hydrological study is to determine the hydrological parameters of the river for the design of infrastructure, ensuring that the design flood would pass without endangering the structures.

The river basin characteristics are determined based on satellite data. SRTM 30m DEM is used for analysis of basin characteristics and river morphometry. Kaligandaki River originates from the Tibetan plateau and has a perennial flow. The highest and lowest elevations in the catchment are 8167.0 masl and 1238.9 masl respectively. The gradient of Kaligandaki River at the hot water spring stretch is 2.54%. The watershed area of the river at hot water spring is 3919.01 km² which is shown in Figure 9.1.



Figure 9.1: Watershed Map of the Kaligandaki River at hot water spring on Google Earth Base map

Maximum design discharge is the peak river discharge that corresponds to a certain return period, which usually taken as 100 years for the design of the infrastructure. The Gumbel distribution was employed to compute the peak discharge using the maximum instantaneous discharges at station 410. The obtained data was used to compute the peak flood using the catchment area correlation method. The 100-year flood computed for the Kaligandaki River at the hot water spring is 2835.42 m³/s.

The high flood level computed at the Paudwar hot water spring (HS/4040105-22) is 1234.07 m with an average velocity of 7.57 m/s and flow depth of 7.26 m. The velocity distribution across the cross-section and high flood level at the Paudwar hot water spring is presented in Figure 9.2.

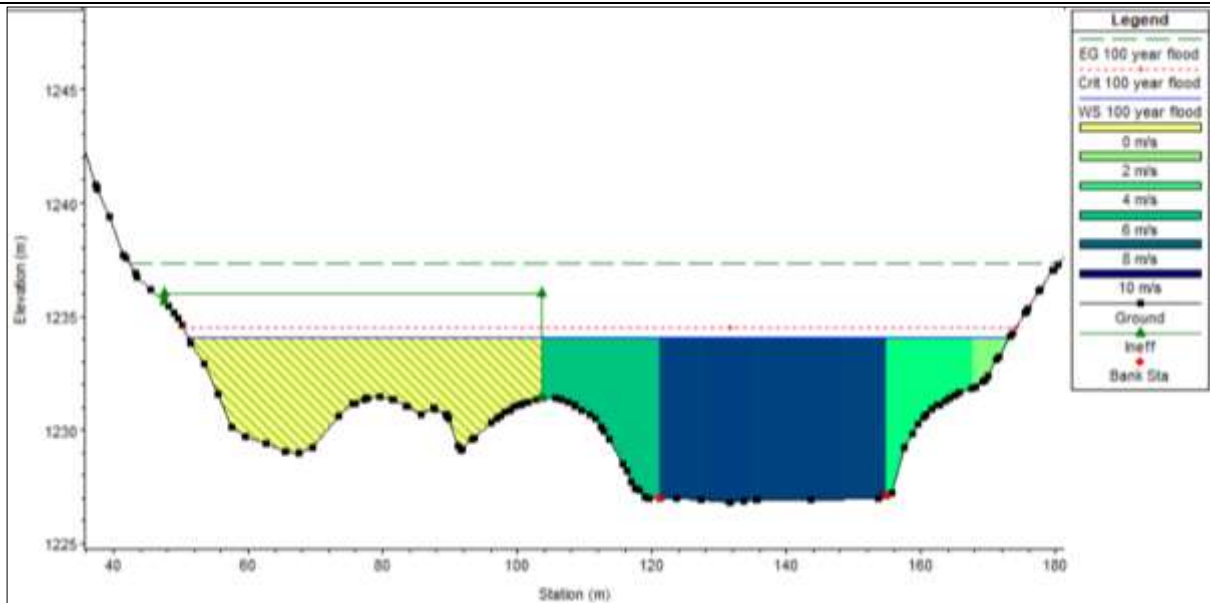


Figure 9.2: Velocity distribution and high flood level during 100 years flood at the Paudwar Tatopani (HS/4040105-22)

The rating curve for elevation versus discharge at the Paudwar Tatopani (HS/4040105-22) is presented in Figure 9.3.

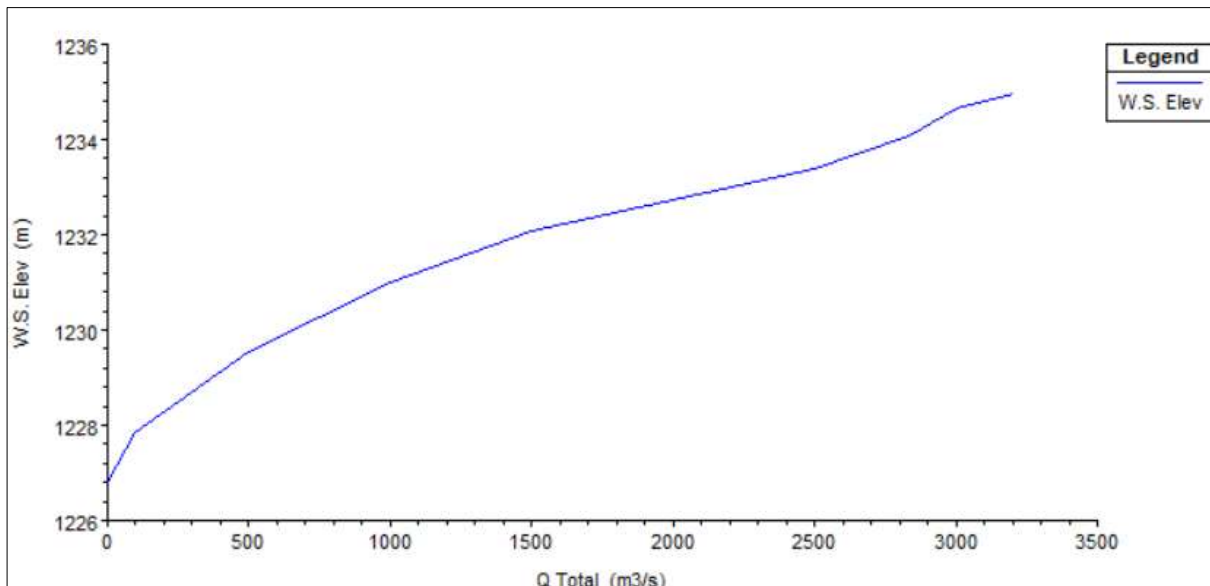


Figure 9.3: Rating Curve at the Paudwar hot water spring (HS/4040105-22)

The high flood level computed at the Bhurung hot water spring (HS/4040105-23) is 1222.88 m with an average velocity of 8.3 m/s and flow depth of 8.89 m. The velocity distribution across the cross-section and high flood level at the Bhurung hot water spring (HS/4040105-23) is presented in Figure 9.4.

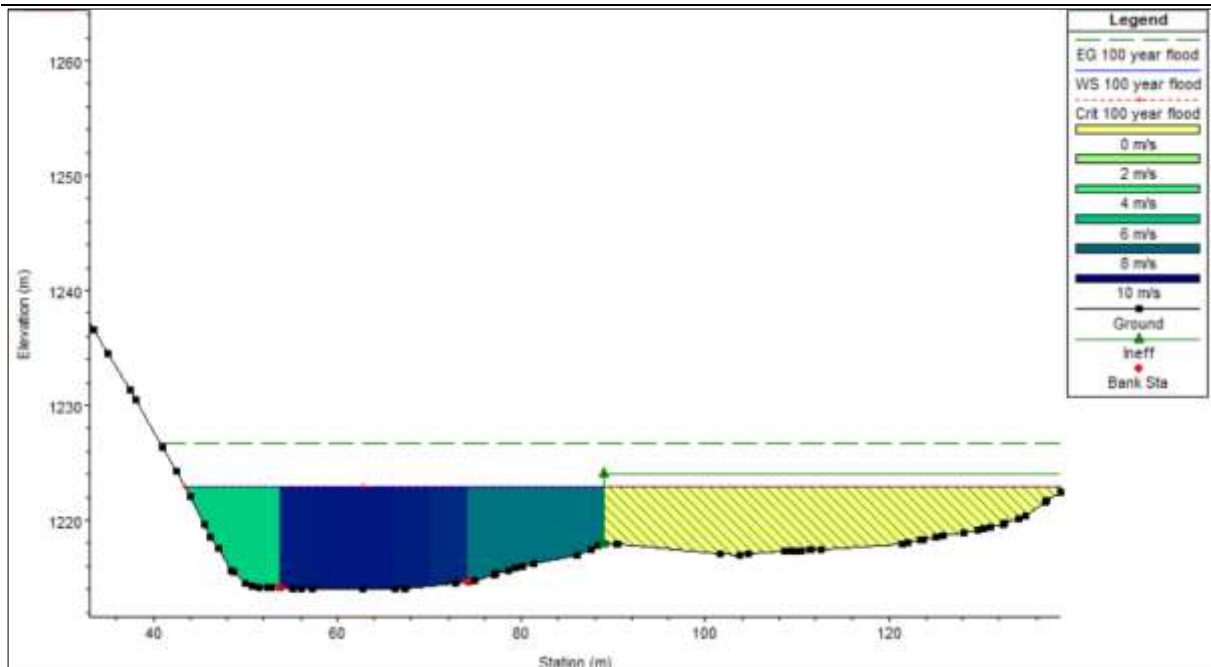


Figure 9.4: Velocity distribution and high flood level during 100 years flood at Bhurung hot water spring (HS/4040105-23)

The rating curve for elevation versus discharge at the Bhurung hot water spring is presented in Figure 9.5.

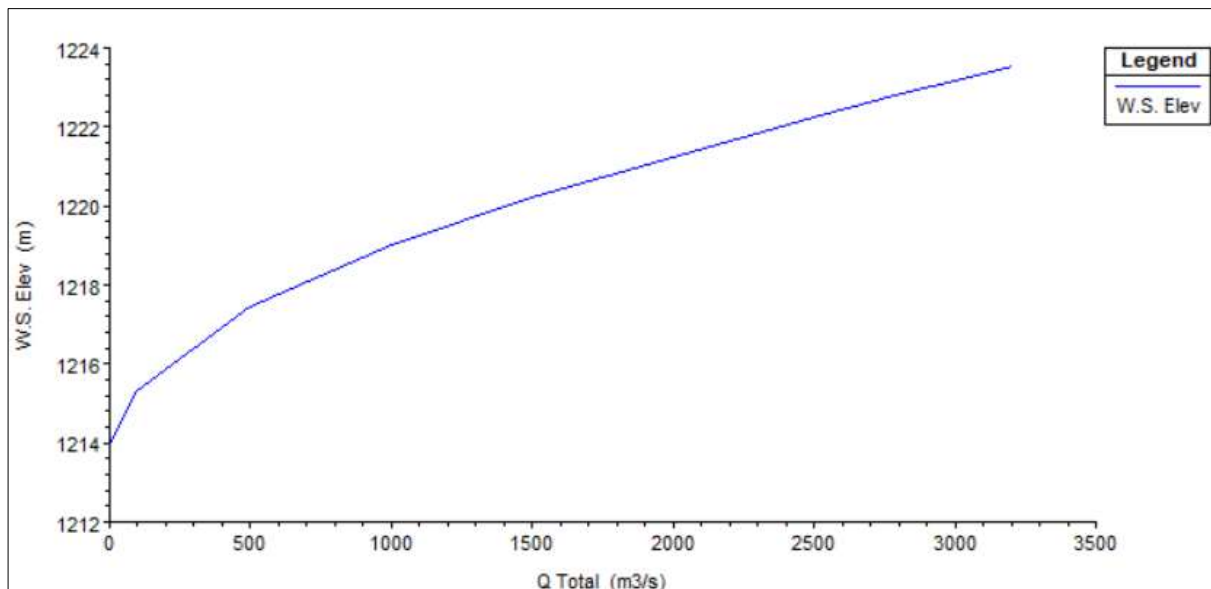


Figure 9.5: Rating Curve at the Bhurung hot water spring (HS/4040105-23)

9.3.3 Master Plan

The masterplan for the redesign of Paudwar seamlessly integrates modern amenities with sustainable practices, ensuring that the site remains a harmonious blend of natural beauty, cultural heritage, and functional spaces. The entrance design respects the existing pathways and enhances accessibility through a new bridge over the Kaligandaki River, maintaining a connection to the Baglung Highway. The ticket counter, constructed with locally sourced materials like stone, timber, and bamboo,

provides a functional and aesthetically pleasing gateway that blends with the environment while offering efficient visitor services.



Figure 9.6: An illustrative plan with a conceptual view of the Paudwaar Tatopani Kunda

The administrative building, strategically located near the entrance, combines office space, a restaurant, retail shop, and accommodations, creating a multifunctional hub that prioritizes accessibility and visitor comfort. Its design incorporates natural light and a large lawn area, fostering a seamless connection between indoor spaces and the surrounding landscape. Complementing this, well-designed sanitation facilities, including accessible toilets and changing rooms, enhance visitor convenience, while hot bathtubs and dedicated shower areas provide immersive, nature-integrated experiences.

The redesign of the hot springs into communal, private, and cooling kundas enriches Paudwaar's appeal, offering diverse bathing options that cater to varying visitor preferences and promote wellness tourism. Universal design principles are embedded throughout the site, ensuring accessibility for all visitors through ramps, wide entrances, and thoughtful spatial planning. Sustainable features, such as the use of renewable energy, effective waste management, and measures to protect the nearby water body, highlight the project's commitment to environmental stewardship.

Finally, the plan emphasizes community development by supporting local crafts, sustainable agriculture, and vocational training, thereby enhancing the local economy and fostering community engagement in the planning process. Overall, the masterplan for Paudwar Tatopani exemplifies a holistic approach to development, balancing modern functionality with ecological sensitivity and cultural respect, ultimately revitalizing the area as a sustainable, inclusive, and welcoming destination for all.



Figure 9.7: An illustrative plan with a conceptual view of the Bhurung Tatopani

The masterplan for Bhurung thoughtfully integrates functional facilities with sustainable design principles to enhance visitor experiences while preserving the site's natural and cultural heritage. The

entrance gate, strategically placed near the parking area, accommodates 6-7 cars and 25-30 bikes, providing a clear and organized entry point for visitors. Adjacent hoarding boards supply essential information, ensuring that visitors are well-informed from the moment they arrive.

Central to the plan is the new block, which houses retail shops, a canteen, toilets, and changing rooms, catering to the diverse needs of visitors. The retail shops offer local crafts and essentials, while the canteen provides a range of food and beverage options in a space that can serve up to 35 people, enhancing both convenience and the local economy. The thoughtfully designed toilet and changing room facilities, which include separate amenities for male and female visitors as well as accessible options for differently-abled individuals, ensure comfort and privacy, contributing to a welcoming atmosphere for all guests.

The outdoor shower area, with separate facilities for men and women, offers privacy and convenience, incorporating spaces for washing garments amidst the natural surroundings. This design provides a refreshing prelude or conclusion to the hot springs experience, enhancing overall visitor satisfaction. The hot springs themselves, featuring two large pools segregated for male and female visitors and surrounded by stone walkways, offer a serene and spacious environment for relaxation. A central platform serves as a communal area, fostering social interaction and enjoyment of the natural setting.

Universal design principles are embedded throughout the site, ensuring accessibility with smooth pathways, ramps, and inclusive fixtures, allowing all visitors, regardless of mobility, to comfortably enjoy the facilities. The protection of the hot spring source by metal rails, located near the tranquil Kaligandaki River, allows safe visitor access and appreciation while preserving its natural integrity. Overall, the Bhurung masterplan effectively balances modern functionality with ecological sensitivity, creating a sustainable, inclusive, and enriching destination for all visitors.

9.3.4 Cost Estimate and Economic Analysis

Preliminary quantity estimates are based on the measurements of the structures and the section in the drawings. The architectural drawing of main civil works was created and quantity were derived. The cost for other works is estimated on lump sum basis. Rate for items were derived from GoN norms.

The project cost estimate is carried out in parallel with the quantities of various items taken from the feasibility level of drawings and quantities derived from empirical relations. Total cost summing up for master plan of both the hot water spring is NRs. 128,376,778.15 inclusive of VAT. However, this cost only covers the cost required with in the proposed boundary of Hot Water Spring and include other facilities, recreational structures and river protection works.

Table 9.2: Cost Estimate for Paudwar and Bhurung Tatopani

S. N.	Particulars	Amount (NRs.)	Remarks
A	Civil works		
1	All building, landscaping, protection	83,227,140.23	
	Total of Civil works	83,227,140.23	
B	Electrical and Allied Installations		
1	Indoor and outdoor	6,226,000.00	

	Total of Electrical and Allied Installations	6,226,000.00	
C	Sanitary, Plumbing & Water Supply Works		
1	Indoor and outdoor	5,220,000.00	
	Total of Sanitary, Plumbing & Water Supply Works	5,220,000.00	
D	Total Cost of Building (A+B+C):	94,673,140.23	
E	Physical Contingency @ 10% of Sub-Total D	9,467,314.02	
F	Price Contingency @ 10% of Sub-Total D	9,467,314.02	
G	Subtotal (D+E+F)	113,607,768.28	
H	VAT @ 13% of Sub-Total G	14,769,009.88	
I	Total Cost with VAT and Contingency (G+H)	128,376,778.15	

Economic analysis is carried out to assess economic viability of the project. Various indicative parameter including Economic Rate of Return (EIRR), Net Present Value (NPV), Benefit cost ration (BCR) and payback period has been evaluated considering the project cost and direct benefit resulted from tangible income as revenue generated from hot water spring.

The economic parameters including BCR, NPV and payback period were estimated based on following parameters.

Table 9.3: Adopted parameters for financial analysis

Parameter	Value	Remarks
Total Project cost	NRs. 128,376,778.15	
Annual O&M	5.0%	
Escalation rate	5.0%	
Discount rate	10.0%	
Annual Gross revenue	29,372,200.00	
Annual Net Revenue	23,497,760.00	
Annual benefit increment	2.0%	
Operation duration	20 years	
Construction duration	2 years	(40% cashflow on first and 60 % on second year)

From the economic analysis following output is obtained

Table 9.4: Output of financial analysis

Parameter	Value	
IRR	22.41%	
NPV	NRs. 390,417,400.71	
Payback period	7	years
BCR	> 2.74	

The analysis carried out in terms of economic rate of return shows the development of hot water spring source seems to be feasible.

The details of works performed, analysis, and outcome for the Paudwaar and Bhurung Tatopani, Myagdi are presented in Volume-3A.

9.4 Tapta Kunda, Dang

A topographic survey was conducted using UAV technology and a hydrological study was conducted and flood on the Rihar Khola was calculated as the hot spring lies on the bank of the river. Descriptions of major works performed and outcomes of master plan are described in following sub-headings.

9.4.1 Topographic Survey

A topographical survey was conducted survey method with the help of an unmanned aerial vehicle (UAV). Unmanned aerial vehicles, however, present us with the possibility of measuring large areas just as accurately as and far more elegantly than in the case of classical land surveying methods. The standard results of a photogrammetric survey consist of point clouds, digital terrain models, and digital orthophotos.



Figure 9.8: Photograph of Tapta Kunda using UAV technology

The following hard copy topographical base maps and GIS database of the same maps have been collected together with the coordinate's data from the Survey Department, GoN. The survey control points are 3rd ordered geodetic points which are supposed to be precise trig. Points in terms of accuracy.

- (i) Topographical base maps and GIS database of Map Sheet no 2782-02A have been purchased from the Survey Department, GoN
- (ii) The GIS database of the above topographical maps has been purchased from the Survey Department, GoN.
- (iii) The collected coordinates and elevations data of Trig. points 132 and 133 have been tabulate below in the next pages:

Table 9.5: Coordinates and Elevations data collected from the Survey Department

S.N.	Point Name	Easting (m.)	Northing (m.)	Height (m.)	Remarks
01	Trig. 132	631309.536	3088327.699	232.5	
02	Trig. 133	631629.546	3087520.464		

9.4.2 Hydrological Study

The preparation of the master plan includes the conservation plan and the tourism development plan. The development plan includes tourism development infrastructure such as recreational areas, swimming ponds, bath showers, sliding decks, etc. The main objective of a hydrological study is to determine the hydrological parameters of the river for the design of infrastructure, ensuring that the design flood would pass without endangering the structures.



Figure 9.9: Watershed Map of Rihar Khola at hot water spring on Google Earth base map

The river basin characteristics are determined based on satellite data. SRTM 30m DEM is used for analysis of basin characteristics and river morphometry. The Rihar khola originates from the Siwalik range and has an ephemeral flow. The highest and lowest elevations in the catchment are 945.0 masl and 237.0 masl respectively. The gradient of the Rihar Khola at the hot water spring stretch is 0.98%. The watershed area of the Rihar khola at hot water spring is 26.3 km² which is shown in Figure 9.9.

Maximum design discharge is the peak river discharge that corresponds to a certain return period, which usually taken as 100 years for the design of the infrastructure. The Rihar Khola is an ungauged river and does not have discharge data. Hence, a different Empirical method was employed to compute the peak discharge. The maximum discharge was given by the WECS DHM approach. Thus, the adopted 100-year flood for the Rihar Khola at the hot water spring is 165.83 m³/s.

The high flood level computed at the Tapta Kunda (HS/5100709-38) is 234.0 m with an average velocity of 3.48 m/s and flow depth of 1.52 m. The velocity distribution across the cross-section and high flood level at the Tapta Kunda is presented in Figure 9.10.

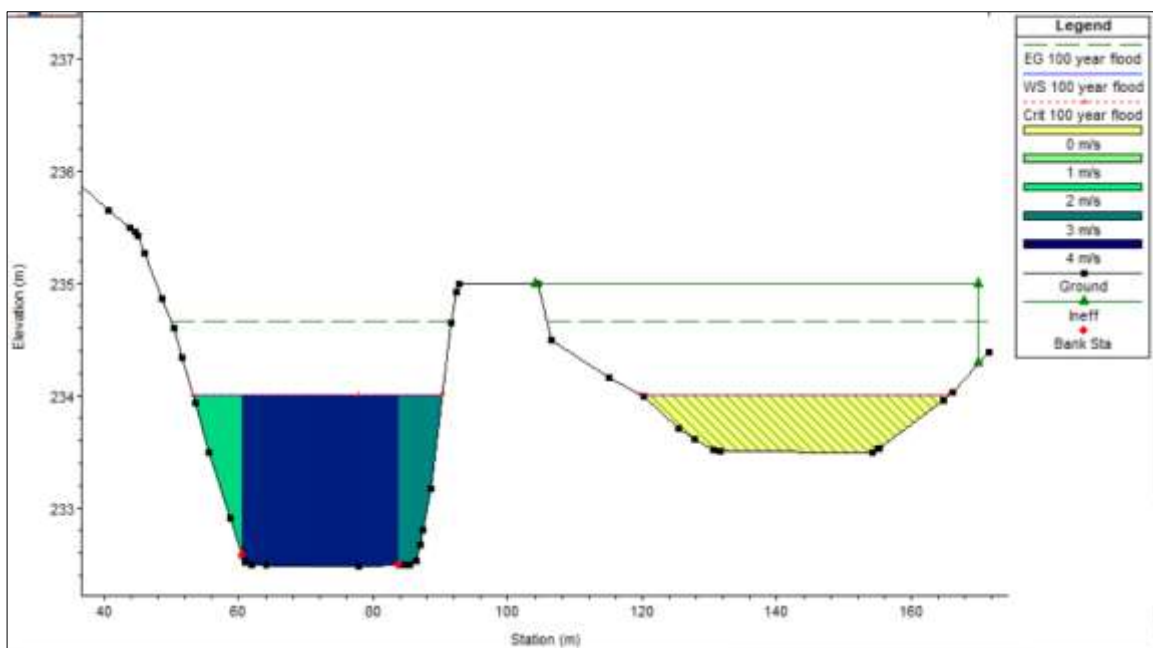


Figure 9.10: Velocity distribution and high flood level during 100 years flood at the Tapta Kunda (HS/5100709-38)

The rating curve for elevation versus discharge at the Tapta Kunda (HS/5100709-38) is presented in Figure 9.11.

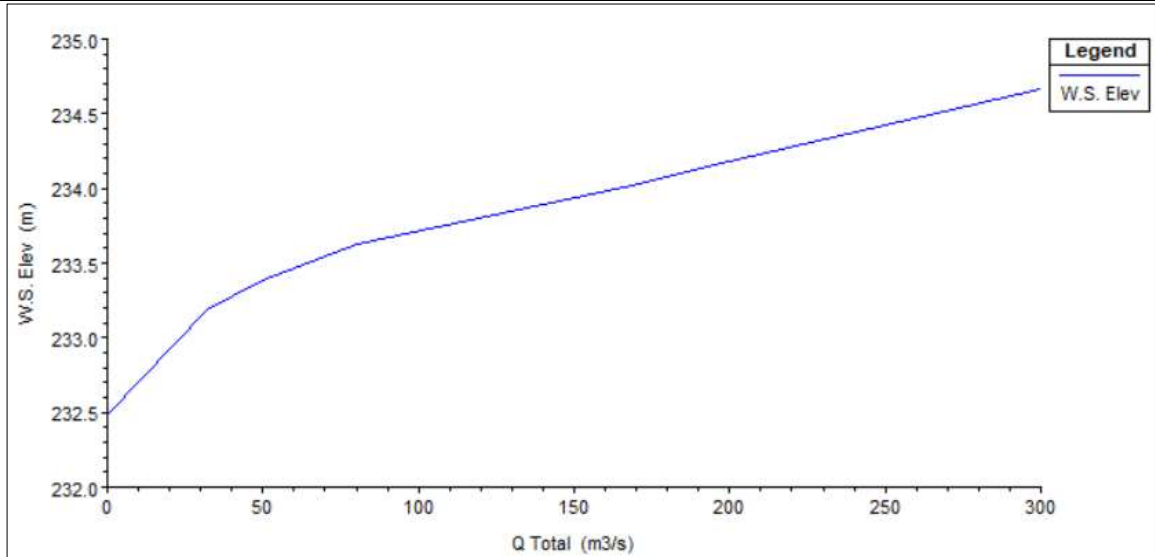


Figure 9.11: Rating Curve at Tapta Kunda hot water spring (HS/5100709-38)

9.4.3 Master Plan

The master plan is based on the idea of making maximum use of existing structures while creating an immersive architectural experience.

The list of programs is presented below:

- 1) Parking.
- 2) Toilet.
- 3) Help Post.
- 4) Office.
- 5) Existing Building.
- 6) Landscape.
- 7) Existing Temple.
- 8) Shiva Mandir.
- 9) Open Shower.
- 10) Hot Spring.
- 11) Surya Kunda.
- 12) Toilet and Changing Room.
- 13) Cafeteria.
- 14) Food Court.
- 15) Future Expansion.
- 16) Secondary entry and Parking.
- 17) Boulevard and Garden.
- 18) River Retaining Wall.

An illustrative plan with conceptual view profiles is give below:



Figure 9.12: An illustrative plan with a conceptual view of the Tapta Kunda

In conclusion, the architectural design presented for the Tatopani site embodies a thoughtful and comprehensive approach to meeting the programmatic requirements outlined. From the main entry parking area accommodating both cars and motorbikes to the strategically placed secondary entry

and parking facility catering to visitors and café patrons, every aspect of the design has been meticulously planned to optimize functionality and enhance user experience.

The inclusion of features such as the open food court, hot spring facility, and Surya Kunda reflects a deep understanding of the site's cultural and natural context, providing visitors with opportunities for relaxation, rejuvenation, and spiritual reflection. Additionally, the provision for future expansion and the preservation of natural vegetation demonstrates a commitment to sustainability and adaptability, ensuring that the Tatopani site can evolve and thrive in the years to come.

Overall, the architectural design not only fulfills the programmatic requirements but also elevates the Tatopani site into a harmonious blend of cultural, natural, and recreational elements, inviting visitors to immerse themselves in its serene ambiance and enriching experiences.

9.4.4 Cost Estimate and Economic Analysis

Preliminary quantity estimates are based on the measurements of the structures and the section in the drawings. The architectural drawing of main civil works was created and quantity were derived. The cost for other works is estimated on lump sum basis. Rate for items were derived from GoN norms.

The project cost estimate is carried out in parallel with the quantities of various items taken from the feasibility level of drawings and quantities derived from empirical relations. Total cost summing up for master plan of Tapta Kunda is NRs. 46,759,321.86 inclusive of VAT. However, this cost only covers the cost required with in the proposed boundary of Hot Water Spring and include other facilities, recreational structures and river protection works.

Table 9.6: Cost Estimate for Tapta Kunda

S. No.	Particulars	Amount (NRs.)	Remarks
A	Civil & Architectural Works - Building		
1	Civil works	33,198,087.00	
	Total of Civil & Architectural Works - Building	33,198,087.00	
B	Electrical and Allied Installations		
1	Electrical works	2,709,000.00	
	Total of Electrical and Allied Installations	65,188.71	
C	Sanitary, Plumbing & Water Supply Works		
1	All sanitary, plumbing and water supply	1,220,000.00	
	Total of Sanitary, Plumbing & Water Supply Works	1,220,000.00	
D	Total Cost of Building (A+B+C):	34,483,275.71	
E	Physical Contingency @ 10% of Sub-Total D	3,448,327.57	
F	Price Contingency @ 10% of Sub-Total D	3,448,327.57	
G	Subtotal (D+E+F)	41,379,930.85	
H	VAT @ 13% of Sub-Total G	5,379,391.01	
I	Total Cost with VAT and Contingency (G+H)	46,759,321.86	

Economic analysis is carried out to assess economic viability of the project. Various indicative parameter including Economic Rate of Return (EIRR), Net Present Value (NPV), Benefit cost ration (BCR) and payback period has been evaluated considering the project cost and direct benefit resulted from tangible income as revenue generated from hot water spring.

The economic parameters including BCR, NPV and payback period were estimated based on following parameters.

Table 9.7: Adopted parameters for financial analysis

Parameter	Value	Remarks
Total Project cost	46,759,321.86	
annual O&M	5.0%	
Escalation rate	5.0%	
Discount rate	10.0%	
Annual Gross revenue	5,816,250.00	
Annual Net Revenue	4,653,000.00	Considering 20% expense
Annual benefit increment	2.0%	
Operation duration	20 years	
Construction duration	2 years	(40% cashflow on first and 60 % on second year)

From the economic analysis following output is obtained

Table 9.8: Output of financial analysis

Parameter	Value
IRR	16.35
NPV	19,117,379.20
Payback period	10
BCR	>1.1

At present the use of Tapta Kunda is free. As the Kunda attracts many tourist years around there is possibility to introduce entry fees. The entry fee considered in analysis is NRs. 100 per person for the visitors throughout the year with special discounted fee of NRs.50 per person for the visitors during Maghe Sangranti Mela. With the entry fee of NRs. 100 on base year the project is feasible economically.

The details of works performed, analysis, and outcome for the Tapta Kunda, Dang are presented in Volume-3B.

9.5 Jarami Tatopani, Jumla

A topographic survey was conducted with Total station and hydrological study was conducted and flood on the Tila Nadi was calculated as the hot spring lies on the right bank of the river. Descriptions of major works performed and outcomes of master plan are described in following sub-headings.

9.5.1 Topographic Survey

A topographical survey was conducted survey method with the help of an unmanned aerial vehicle (UAV). Unmanned aerial vehicles, however, present us with the possibility of measuring large areas just as accurately and far more elegantly than in the case of classical land surveying methods. The standard results of a photogrammetric survey consist of point clouds, digital terrain models, and digital orthophotos.

The following hard copy topographical base maps and GIS database of the same maps have been collected together with the coordinates data from the Survey Department, GoN. The survey control points are 3rd ordered geodetic points which are supposed to be precise trig. Points in terms of accuracy.

- (iv) Topographical base maps and GIS database of Map Sheet no 2982-13 have been purchased from the Survey Department, GoN
- (v) A GIS database of the above topographical maps have been purchased from Survey Department, GoN.
- (vi) The collected coordinates and elevations data of Trig. points 187, 137, and 138 have been tabulating below in the next pages:

Table 9.9: Coordinates and Elevations data collected from the Survey Department

Trig/BM Gravity No.	Easting	Northing	Latitude	Longitude	Elevation
187	597866.542	3230388.583	29.191209°	82.004209°	
137	604300.85	3240617.573	29.28352	82.074002	3705
138	605802.014	3232330.342	29.208874°	82.086486°	

9.5.2 Hydrological Study

The preparation of the master plan includes the conservation plan and the tourism development plan. The development plan includes tourism development infrastructure such as recreational areas, swimming ponds, bath showers, sliding decks, etc. The main objective of a hydrological study is to determine the hydrological parameters of the river for the design of infrastructure, ensuring that the design flood would pass without endangering the structures.

The river basin characteristics are determined based on satellite data. SRTM 30m DEM is used for analysis of basin characteristics and river morphometry. The Tila River originates from Patarasi Peak and has a perennial flow. The highest and lowest elevations in the catchment is 6293.0 masl and 2206.5 masl respectively. The gradient of the Tila River at the hot water spring stretch is 0.515%. The watershed area of the river at hot water spring is 1300.95 km² which is shown in Figure 9.9.

Maximum design discharge is the peak river discharge that corresponds to a certain return period, which is usually taken as 100 years for the design of the infrastructure. The Gumbel distribution was employed to compute the peak discharge using the maximum instantaneous discharges at station 220. The obtained data was used to compute the peak flood using the catchment area correlation method. The 100-year flood computed for the Tila Nadi at the hot water spring is 436.16 m³/s.



Figure 9.13 Watershed Map of the Tila Nadi at the hot water spring on Google Earth Base map

The high flood level computed at the Jarami hot water spring (HS/6040602-41) is 2207.46 m with an average velocity of 4.34 m/s and flow depth of 2.48 m. The velocity distribution across the cross-section and high flood level at the Jarami hot water spring is presented in Figure 9.10.

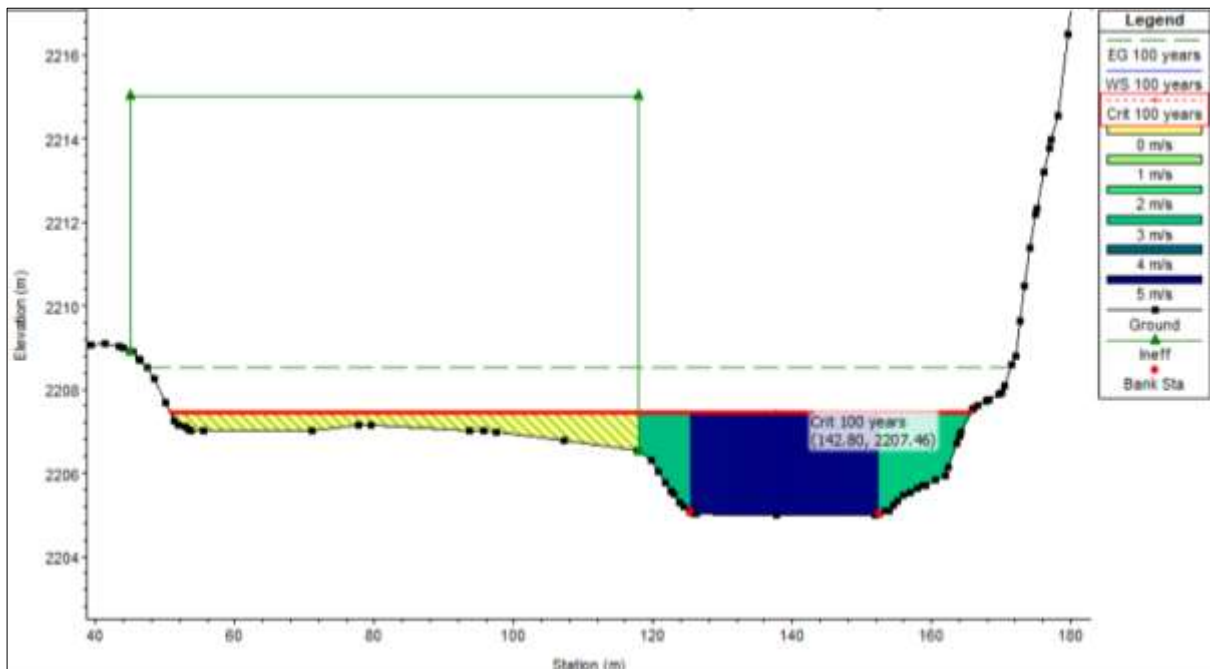


Figure 9.14: Velocity distribution and high flood level during 100 years flood at the Jarami Tatopani (HS/6040602-41)

The rating curve for elevation versus discharge at Jarami hot water spring (HS/6040602-41) is presented in Figure 9.11.

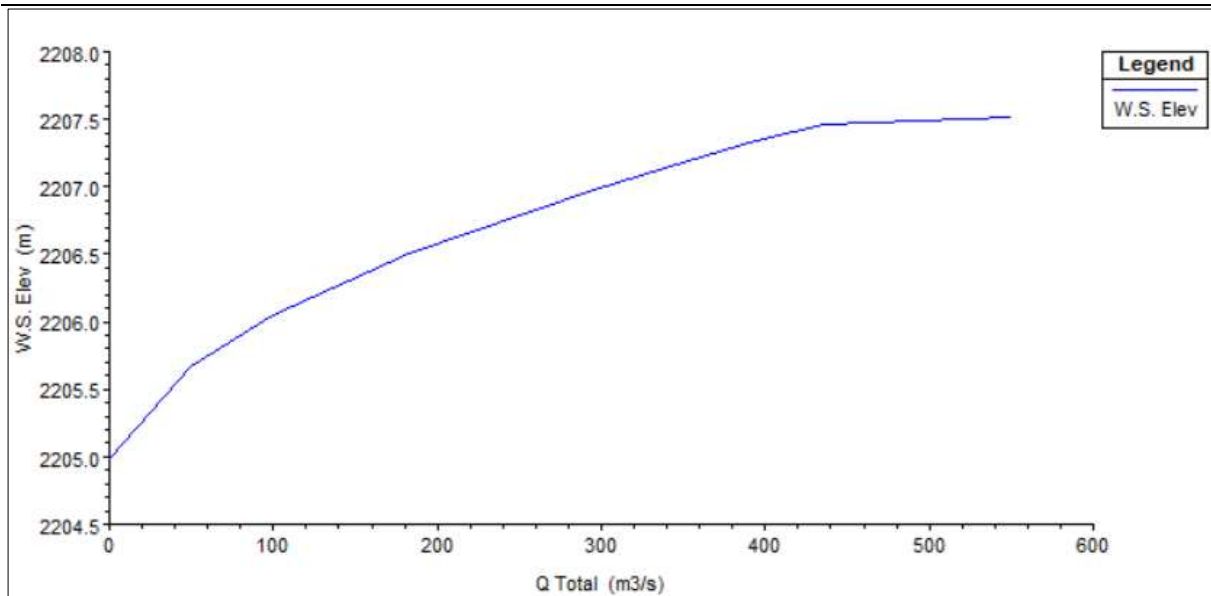


Figure 9.15 Rating Curve at the Jarami hot water spring (HS/6040602-41)

The river protection structure is proposed based on site condition, hydrological analysis and river hydraulics condition.

Jarami Tatopani lies at right bank of Tila River with source location at hill slope at backside of current shower area. The source is safe from floods at Tila river. The current development has been carried out by construction of flood wall at Tila River and a flat deck is constructed for activities. The top level of deck is safe from the flood. The Tatopani area lies at straight reach of river with minimal chance of river morphological deviation. The upstream end of current protection structure shall be extended to minimize the chance of hitting by river in development area. The protection works will also allow to develop the road access up to the development area making the access easier. The adopted top level of river protection works is 2208 m and which should be the minimum plinth level for construction of structure as planned in masterplan.

9.5.3 Master Plan

The master plan is based on the idea of making maximum use of existing structures while creating an immersive architectural experience. The list of programs is presented below:

- 1) Entry
- 2) Office and Ticket Counter.
- 3) Dhunge Dhara
- 4) Sitting Space
- 5) Storage Tank
- 6) Shower Area
- 7) Pond (Female)
- 8) Pond (Male)
- 9) Toilet (Male)
- 10) Universal Toilet
- 11) Changing Room (Male)
- 12) Drain
- 13) Sunbathing Area
- 14) Changing Room (Female)

- 15) Existing Toilet (Female)
- 16) Area to be acquired
- 17) Differently able access
- 18) River Retaining Wall
- 19) Access to Main Road

An illustrative plan with conceptual view profiles is given below:



Figure 9.16: An illustrative plan with a conceptual view of Jarami Tatopani

The diverse programs outlined in this report present a holistic approach to site development, catering to a wide range of needs and preferences. From the establishment of essential facilities like offices and ticket counters to the provision of recreational spaces such as parks and sunbathing areas, each program is meticulously crafted to enhance the overall experience for visitors.

Key highlights include the thoughtful design of amenities such as ponds, showers, and changing rooms, which prioritize functionality, comfort, and privacy. Additionally, special consideration is given to inclusivity through features like differently abled access paths and universal design principles, ensuring that the site is accessible and welcoming to all individuals.

Moreover, environmental sustainability is a central theme, with initiatives such as water management systems, covered drains, and strategic positioning of facilities to minimize ecological impact. By incorporating these measures, the site not only promotes responsible stewardship of natural resources but also creates a serene and harmonious environment for visitors to enjoy.

In conclusion, the integration of these diverse programs reflects a commitment to creating a vibrant and inclusive space that fosters relaxation, recreation, and community engagement. Through careful

planning and thoughtful execution, the site stands as a testament to the power of architecture to enrich lives and uplift communities.

9.5.4 Cost Estimate and Economic Analysis

Preliminary quantity estimates are based on the measurements of the structures and the section in the drawings. The architectural drawing of main civil works was created and quantity were derived. The cost for other works is estimated on lump sum basis. Rate for items were derived from GoN norms.

The project cost estimate is carried out in parallel with the quantities of various items taken from the feasibility level of drawings and quantities derived from empirical relations. Total cost summing up for master plan of Jarami Tatopani is NRs. 43,524,551.39 inclusive of VAT. However, this cost only covers the cost required with in the proposed boundary of Hot Water Spring and include other facilities, recreational structures and river protection works.

Table 9.10: Cost Estimate for Jarami Tatopani

S. No.	Particulars	Amount (NPR)	Remarks
A	Civil & Architectural Works - Building		
1	Civil works	30,214,163.05	
	Total of Civil & Architectural Works - Building	30,214,163.05	
B	Electrical and Allied Installations		
1	Electrical and lights	970,000.00	
	Total of Electrical and Allied Installations	65,188.71	
C	Sanitary, Plumbing & Water Supply Works		
1	All sanitary and plumbing	1,818,400.00	
	Total of Sanitary, Plumbing & Water Supply Works	1,818,400.00	
D	Total Cost of Building (A+B+C):	32,097,751.76	
E	Physical Contingency @ 10% of Sub-Total D	3,209,775.18	
F	Price Contingency @ 10% of Sub-Total D	3,209,775.18	
G	Subtotal (D+E+F)	38,517,302.11	
H	VAT @ 13% of Sub-Total G	5,007,249.27	
I	Total Cost with VAT and Contingency (G+H)	43,524,551.39	

Economic analysis is carried out to assess economic viability of the project. Various indicative parameter including Economic Rate of Return (EIRR), Net Present Value (NPV), Benefit cost ratio (BCR) and payback period has been evaluated considering the project cost and direct benefit resulted from tangible income as revenue generated from hot water spring.

The economic parameters including BCR, NPV and payback period were estimated based on following parameters.

Table 9.11: Adopted parameters for financial analysis

Parameter	Value	Remarks
Total Project cost	43,524,551.39	
annual O&M	5.0%	
Escalation rate	5.0%	
Discount rate	10.0%	
Annual Gross revenue	5,972,312.50	
Annual Net Revenue	4,777,850.00	Considering 20% expense
Annual benefit increment	2.0%	
Operation duration	20 years	
Construction duration	2 years	(40% cashflow on first and 60 % on second year)

From the economic analysis following output is obtained

Table 9.12: Output of financial analysis

Parameter	Value	
IRR	18.58	
NPV	70,008,886.59	
Payback period	9	years
BCR	>1.6	

The economic analysis shows the development of hot water spring is seem to be feasible from direct perspective of economics. The current average ticket rate per visitor is NRs 50 which has to be increased to NRs 100 be increased. Addition of new facilities including jacuzzi will enhance the both number of visitor and revenue and make the project more attractive from economics perspective.

The details of works performed, analysis, and outcome for the Jarami Tatopani, Jumla are presented in Volume-3C.

9.6 Sunikot Tatopani, Bajhang

A topographic survey was conducted with Total station and a hydrological study was conducted and flood on the Seti River was calculated as the hot spring lies on the bank of the river. Descriptions of major works performed and outcomes of master plan are described in following sub-headings.

9.6.1 Topographic Survey

Topographical surveys and mapping are an essential task in the study of any project. The survey of the project area will allow the project designer to determine the gross head, set out project components in appropriate locations, and prepare and prepare quantity estimation. In addition, topographical mapping will be useful for geological mapping, geophysical investigation, and social studies.

These are references to this control point required numbers of lower orders of control points were estimated and are monumented.

9.6.1.1 Traversing Control Point from National Grid

The coordinate of the two control points was calculated by using the National Control point. The calculated coordinate is according to MUTM projection. Other control points were calculated by measurement of angle and distance by using a total station. The coordinates of the control points listed are as follows.

9.6.1.2 Benchmarks

SN	Easting	Northing	Elevation	Point code
1	523532.236	3274452.980	1349.228	National Grid 016-114
2	523536.011	3274436.473	1345.352	BM 1
3	523561.908	3274453.566	1341.938	BM-2

The topographical mapping was to be done of the proposed project area in 1 in 1000 scales with 1-metre contour intervals. Keeping this in view, sufficient survey control points were fixed during the stage of horizontal controlling.

For a detailed topographic survey, the tachometric method of survey has been introduced. The X, Y, and Z coordinates of every detail were recorded by the Total Stations instrument on the site. The procedure for detail surveying is as follows.

After setting the instrument over a known survey station, the back sight was fixed on the prism reflector placed over a known point and then started taking details on the ground. The details include roads, footpaths, houses, physical and man-made features, and hydrographic features such as rivers, streams, etc. Some special landslide signs such as cracks, scarp areas, etc. have been surveyed. All information mentioned in the scope has been depicted from the ground.

The X, Y, and Z coordinates of every detail have been recorded and saved in the Total Stations and downloaded to the computer later. The further processing of all topographic data was done in the computer and they prepared the plot file in AutoCAD format. The detail of the topographic survey is presented in Volume 3D.

9.6.2 Hydrological Study

The preparation of the master plan includes the conservation plan and the tourism development plan. The development plan includes tourism development infrastructure such as recreational areas, swimming ponds, bath showers, sliding decks, etc. The main objective of a hydrological study is to determine the hydrological parameters of the river for the design of infrastructure, ensuring that the design flood would pass without endangering the structures.

The river basin characteristics are determined based on satellite data. SRTM 30m DEM is used for analysis of basin characteristics and river morphometry. The Seti River originates from Jethi Bahurani peak and has a perennial flow. The highest and lowest elevations in the catchment are 6568.0 masl and 1322.5 masl respectively. The gradient of the Seti River at the hot water spring stretch is 1.61 %. The watershed area of the Seti River at hot water spring is 1724.4 km² which is shown in Figure 9.9.

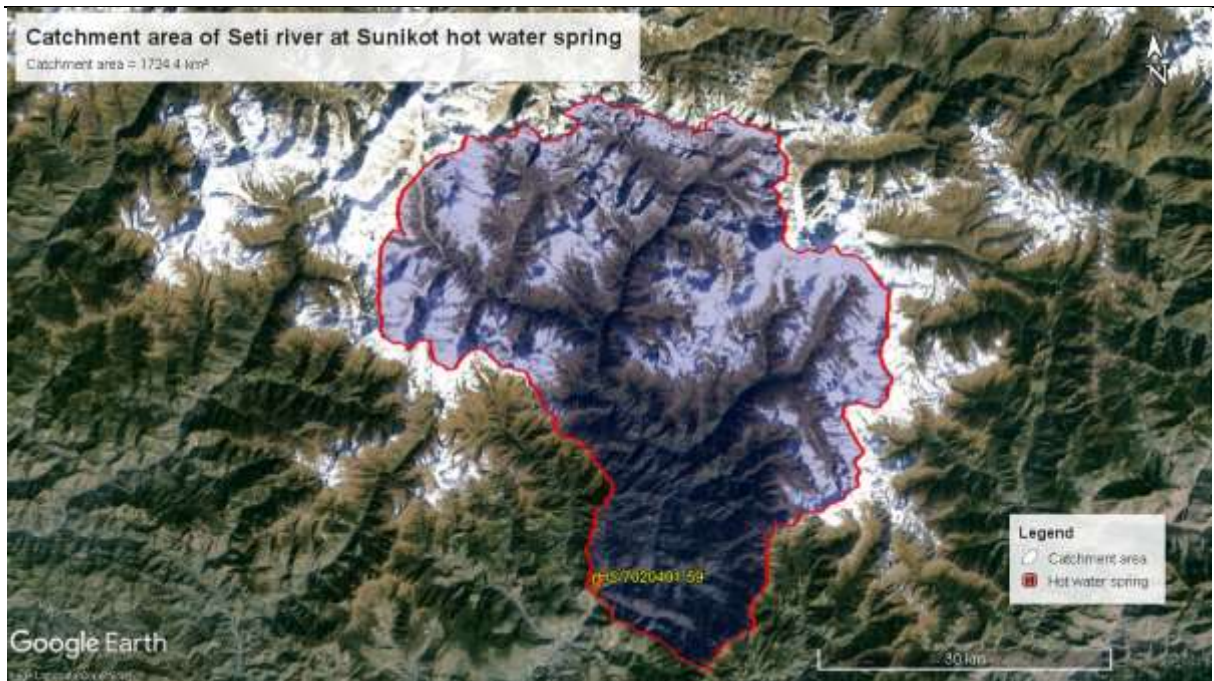


Figure 9.17: Watershed Map of the Seti River at hot water spring on Google Earth Basemap

Maximum design discharge is the peak river discharge that corresponds to a certain return period, which usually taken as 100 years for the design of the infrastructure. The Gumbel distribution was employed to compute the peak discharge using the maximum instantaneous discharges at station 259.2. The obtained data was used to compute the peak flood using the catchment area correlation method. The 100-year flood computed for the Seti River at the Sunikot hot water spring is 1970.75 m³/s.

The high flood level computed at the Sunikot hot water spring (HS/7020401-59) is 1327.15 m with an average velocity of 8.21 m/s and flow depth of 4.65 m. The velocity distribution across the cross-section and high flood level at the Sunikot hot water spring is presented in Figure 9.10.

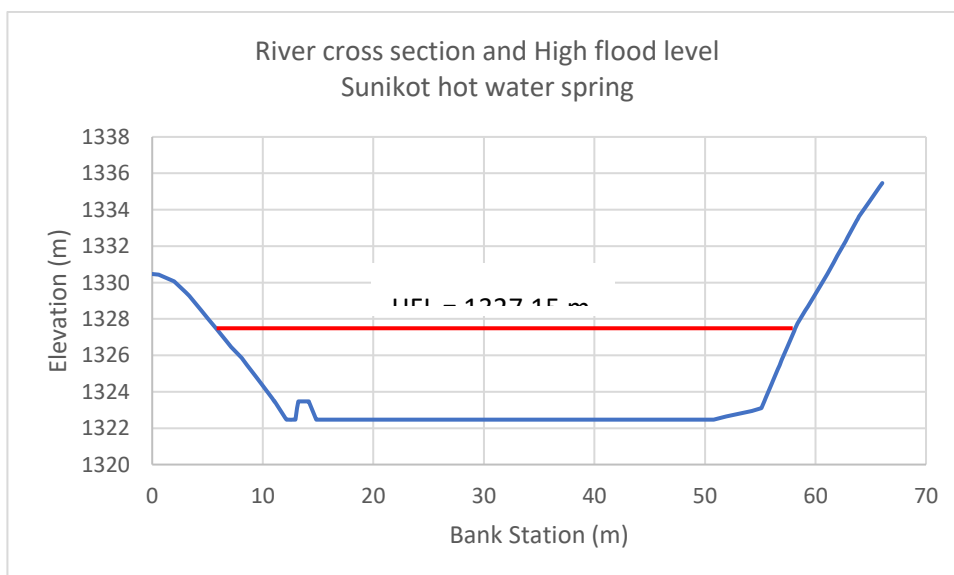


Figure 9.18: Velocity distribution and high flood level during 100 years flood at the Sunikot Tatopani (HS/7020401-59)

The rating curve for elevation versus discharge at the Sunikot hot water spring (HS/7020401-59) is presented in Figure 9.11.

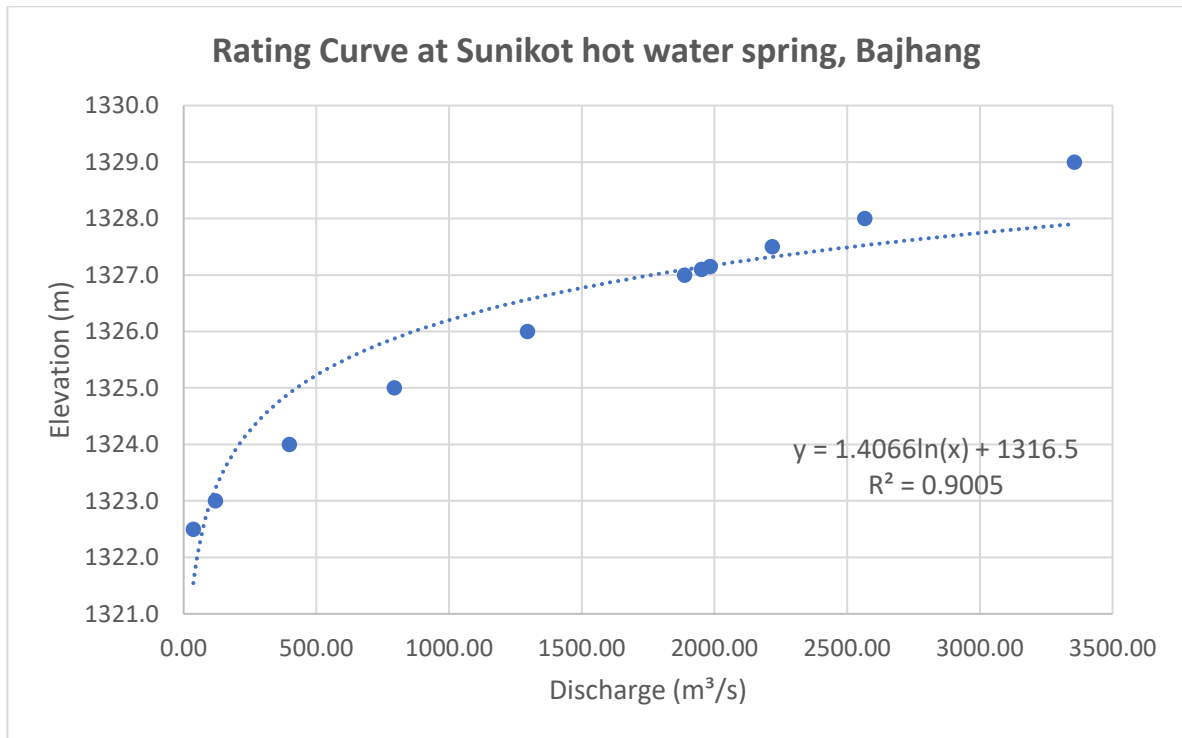


Figure 9.19: Rating Curve at the Sunikot Tatopani (HS/7020401-59)

9.6.3 Master Plan

The master plan is based on the idea of making maximum use of existing structures while creating an immersive architectural experience. The list of programs is presented below:

- 1) Main Entry and Parking
- 2) Parking
- 3) Future Expansion
- 4) Cafeteria
- 5) Hot Water Spring
- 6) Outdoor Shower
- 7) Changing and Toilet
- 8) Pedestrian and Entry
- 9) Office
- 10) Solar Panels
- 11) Source
- 12) Overhead Tank
- 13) Retaining Wall

An illustrative plan with conceptual view profiles is given below:



Figure 9.20: An illustrative plan with a conceptual view of the Sunikot Tatopani

The architectural design of the hot spring site exemplifies a thoughtful and comprehensive approach that prioritizes functionality, sustainability, and user experience. Each component of the site has been meticulously planned and positioned to ensure convenience, comfort, and environmental consciousness.

The layout of the site has been strategically organized to optimize accessibility and usability. Facilities such as the parking area, cafeteria, hot water spring, outdoor shower, toilet, and office are positioned for easy access, enhancing the overall visitor experience. Thoughtful placement of amenities like the cafeteria ensures financial sustainability without disrupting the tranquillity of the hot spring area.

Environmental sustainability is a core principle underlying the design. Natural vegetation is integrated into the parking area and around the hot water spring, providing shade, aesthetic value, and environmental benefits. Effluent management from the hot spring facility ensures water sustainability by directing water into the neighbouring Seti River. Additionally, the incorporation of solar panels reflects a commitment to renewable energy, reducing the site's carbon footprint and promoting energy efficiency.

The design also considers future expansion and flexibility. The reserved northern section of the site allows for potential growth opportunities while preserving the natural beauty of the surroundings. This forward-thinking approach ensures adaptability to future demands and enhances the site's appeal for visitors.

User experience and privacy are paramount in architectural design. Facilities such as the outdoor shower and toilet/changing rooms are designed to offer comfort and privacy, blending seamlessly with the natural landscape. Lush landscaping elements provide privacy barriers, enhancing the ambiance and relaxation for visitors.

Operational efficiency is achieved through multifunctional spaces such as the office, which serves as a ticketing area, staff operations hub, and meeting space. The pedestrian entry, strategically located

near the office, streamlines daily operations and enhances usability, promoting a user-friendly environment.

Aesthetic integration is evident throughout the site, where architectural elements harmonize with the natural surroundings. Attention to detail, such as directional signage and distinct line markings, enhances the visual appeal and functionality of the site, contributing to a memorable and enjoyable experience for visitors.

In conclusion, the architectural design of the hot spring site embodies a holistic approach that balances human needs with environmental stewardship. It creates a sustainable, welcoming, and aesthetically pleasing environment that enriches the visitor experience while preserving the natural beauty of the area.

9.6.4 Cost Estimate and Economic Analysis

Preliminary quantity estimates are based on the measurements of the structures and the section in the drawings. The architectural drawing of main civil works was created and quantity were derived. The cost for other works is estimated on lump sum basis. Rate for items were derived from GoN norms.

The project cost estimate is carried out in parallel with the quantities of various items taken from the feasibility level of drawings and quantities derived from empirical relations. Total cost summing up for master plan of Sunikot Tatopani is NRs. 42,743,531.66 inclusive of VAT. However, this cost only covers the cost required with in the proposed boundary of Hot Water Spring and include other facilities, recreational structures and river protection works.

Table 9.13: Cost Estimate for Sunikot Tatopani

S. No.	Particulars	Amount (NRs.)	Remarks
A	Civil Works		
1	Civil cost	28,961,878.51	
	Total of Civil Works	28,961,878.51	
B	Electrical and Allied Installations		
1	Electrical	1,775,000.00	
	Total of Electrical and Allied Installations	1,775,000.00	
C	Sanitary, Plumbing & Water Supply Works		
1	Sanitary works	784,900.00	
	Total of Sanitary, Plumbing & Water Supply Works	784,900.00	
D	Total Cost of Building (A+B+C):	31,521,778.51	
E	Physical Contingency @ 10% of Sub-Total D	3,152,177.85	
F	Price Contingency @ 10% of Sub-Total D	3,152,177.85	
G	Subtotal (D+E+F)	37,826,134.21	
H	VAT @ 13% of Sub-Total G	4,917,397.45	
I	Total Cost with VAT and Contingency (G+H)	42,743,531.66	

Economic analysis is carried out to assess economic viability of the project. Various indicative parameter including Economic Rate of Return (EIRR), Net Present Value (NPV), Benefit cost ration (BCR) and payback period has been evaluated considering the project cost and direct benefit resulted from tangible income from agriculture on reclaimed land after project completion.

The economic parameters including BCR, NPV and payback period were estimated based on following parameters.

Table 9.14: Adopted parameters for financial analysis

Parameter	Value	Remarks
Total Project cost	42,743,531.66	
Annual O&M	2.5%	
Escalation rate	5.0%	
Discount rate	10.0%	
Annual Gross revenue	1,505,625.00	
Annual Net Revenue	1,204,500.00	Considering 20% expense
Annual benefit increment	2.0%	
Operation duration	20 years	
Construction duration	2 years	(40% cashflow on first and 60 % on second year)

The economic analysis shows that the project is not feasible economically on above criteria. However, from above social analysis the project is beneficial for the community in surrounding. Hence the viability gap funding from different level of government will make the project feasible. During the construction period a viability gap fund of NRs. 1.4 crore is required in first year and NRs. 2 crore is required in second year of construction. With application of gap funding the project will be economically feasible and yields following returns:

Table 9.15: Output of financial analysis

Parameter	Value	
IRR	16.38 %	
NPV	2,436,037.29	
Payback period	10	
BCR	>1.1	

The economic analysis shows the development of hot water spring is seem to be feasible from social benefit for overall development of Bajhang district and hence the gap funding shall be introduced to make project economically feasible.

The details of works performed, analysis, and outcome for the Sunikot Tatopani, Bajhang are presented in Volume-3D.

10 CONCLUSIONS AND RECOMMENDATIONS

10.1 Conclusions

From desk study, electronic mail, and telephonic communication with local levels, 162 prospective hot water spring sources. During the first stage of verification, only 66 numbers of hot water springs are confirmed. Out of these 66, only 41 numbers of hot water springs are found to meet the threshold parameters as per ToR. Second-stage verification and chemical testing of these 41 hot water spring sources is conducted. From the outcomes of physical, chemical, social, and environmental studies of hot water springs and the formulation defined during the inception study, the ranking of these hot water springs as prospective tourism promotion locations is completed. Four hot water spring sources namely Paudwar and Bhurung Tatopani of Myagdi, Tapta Kunda of Dang, Jarami Tatopani of Jumla, and Sunikot Tatopani of Bajhang are recommended for further study and prepared Master Plan of these sites.

From present study, it seems more confirmative that the major cause for hot water springs shall be the geological structures especially thrusts and other parameters might be additional reason for hotness of these springs.

Geothermal energy from hot water springs has immense potential as a clean and reliable power source. By tapping into the Earth's warmth from these springs, we can generate electricity in a unique way. The process involves adding cold water to the hot spring, creating a temperature difference that is converted into power. This method, known as binary cycle technology, efficiently harnesses the thermal energy present in the hot water. For evaluating geothermal energy applicability, the cost of installation of an electricity plant from thermal springs is taken from the international practice. From this, the cost of geothermal electricity seems far more expensive in comparison with the cost of electricity generation by hydropower project.

The diverse programs outlined in this report present a holistic approach to site development, catering to a wide range of needs and preferences. From the establishment of essential facilities like offices and ticket counters to the provision of recreational spaces such as parks and sunbathing areas, each program is meticulously crafted to enhance the overall experience for visitors.

Key highlights include the thoughtful design of amenities such as ponds, showers, and changing rooms, which prioritize functionality, comfort, and privacy. Additionally, special consideration is given to inclusivity through features like differently abled access paths and universal design principles, ensuring that the site is accessible and welcoming to all individuals.

Moreover, environmental sustainability is a central theme, with initiatives such as water management systems, covered drains, and strategic positioning of facilities to minimize ecological impact. By incorporating these measures, the site not only promotes responsible stewardship of natural resources but also creates a serene and harmonious environment for visitors to enjoy.

In conclusion, the integration of these diverse programs reflects a commitment to creating a vibrant and inclusive space that fosters relaxation, recreation, and community engagement. Through careful planning and thoughtful execution, the site stands as a testament to the power of architecture to enrich lives and uplift communities.

10.2 Recommendations

Following recommendations are made on the study conducted:

- The details of hot water spring presented in this study shall be made available to local government such that local government can seek further activities for tourism development.
- The regular monitoring (Flow, physical and chemical parameters) of the resources shall be carried out before proceeding to implementation and further development activities.
- Causes of hot water springs are not studied specifically, a thorough study shall be done for understanding and preserving these springs.

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