TRIBHUVAN UNIVERSITY

INSTITUTE OF ENGINEERING

PULCHOWK CAMPUS

THESIS NO: M-409-MSREE-2020-2026

Comparative Analysis of Bieri Vertical and Conventional Sediment Flushing in Hydropower Projects of Gandaki Basin

by

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A THESIS

SUBMITTED TO THE DEPARTMENT OF MECHANICAL & AEROSPACE ENGINEERING

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE IN RENEWABLE ENERGY ENGINEERING

DEPARTMENT OF MECHANICAL AND AEROSPACE ENGINEERING

LALITPUR, NEPAL

JANUARY, 2026

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In order to partially fulfill the requirements for the Master of Science in Renewable Energy Engineering degree, Janak Neupane submitted a thesis titled "**Comparative Analysis of Bieri Vertical and Conventional Sediment Flushing in Hydropower Projects of Gandaki Basin.**" The undersigned certifies that they have read the thesis and recommended its acceptance to the Institute of Engineering.

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ABSTRACT

In The efficiency, dependability, and longevity of hydropower plants are seriously threatened by high silt loads in Himalayan Rivers, which result in severe turbine abrasion and frequent operational shutdowns. The Bieri Vertical Sand Flushing System (BVFS) at the Middle Marsyangdi Hydropower Project (MMHPP) and Conventional Sediment Flushing Systems (CSFS) at the Upper Trishuli 3A Hydropower Project (UT3A) are compared in this study.

The primary objective was to test the performance of the two systems on cost, sediment removal, and the functioning of the system under the conditions within the Gandaki Basin of Nepal. The quantitative case study design was applied in the study where three years of operating data, site visit, and primary data was used to trace the downtime, energy loss and maintenance cost. The outcomes are clear that BVFS is more effective in its operation. It suffered zero forced outages in the flushing process but the CSFS experienced approximately 273.69 hours of unavailability in the same period. The water consumed by BVFS was also approximately half as much and its energy loss was almost 85 percent less than that of the routine horizontal flushing technique. With a higher initial cost of about the NPR 400 million, BVFS proved to be financially sustainable, with payback of 18.21 years the main reason being in savings on energy and maintenance annually. Generally, the results indicate that BVFS is a good alternative in the control of sediment in high-head projects in heavy sediment zones. It enables power production to be maintained even on peak months of monsoon. According to this, BVFS should be given priority during new projects having high sediment loads and old plants experiencing frequent silt related shutdowns should seriously consider retrofit.

ACKNOWLEDGEMENTS

First of all, I'd like to express my heartfelt appreciation to Prof. Dr. Rajendra Shrestha, Ph.D., Department of Mechanical and Aerospace Engineering, Pulchowk Campus, the supervisor of my thesis, for consistently helping me throughout the course of my thesis work. He has been incredibly helpful to me at every stage, and his optimistic view of the research process has transformed my perspective on it into something that should be done with enthusiasm but at a leisurely pace.

Additionally, I would like to express my sincere gratitude to Associate Professor Dr. Hari Bahadur Darlami of the Department of Mechanical and Aerospace Engineering, Pulchowk Campus, MSREE Program Coordinator, for providing the platform and for his unwavering support and direction during this research.

I also want to express my gratitude to my informants. Their names cannot be released, but I want to acknowledge and appreciate their support and transparency during my investigation. I was able to finish this thesis because to their information.

Furthermore, I'd want to send my heartfelt appreciation to Mr. Kapil Pudasaini, Senior Mechanical Engineer, Units Engineering Consultancy Private Limited and Mr. Mahendra Bikram Shahi, Mechanical Engineer, Nepal Electricity Authority for their cooperation and support during the data analysis and report writing.

Lastly and most importantly, I'd want to show my thanks to my father Kabiraj Upadhyay, mother Kaushila Upadhyay, Brother Keshav Neupane, and Sister Bhagawati Neupane for their consistent encouragements and supports during this period.

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ρ	Density of Water
g	Acceleration Due to Gravity
Q	Design Flow Rate
H	Net Water Head
P	Installed Capacity of Hydropower Project
µm	Micrometer (unit for sediment particle size)
Mohs	Mohs scale of mineral hardness
h_{max}	Maximum water height
v_e	Ejection velocity from Bieri Plates
v	Flushing canal flow velocity
C_s	Sediment concentration in flushed mixture
A_{full}	Flushing canal cross-section area
V_{mix}	Total Volume of Water & Sediment Mixture
V_s	Sediment volume flushed
V_w	Total Water Volume Loss during Flushing
Q_{avg}	Average Flushing Discharge
Q_d	System-indicated (direct) measurement of water loss (BVFS)
Q_i	Predicted water loss using an indirect measuring technique (BVFS)
W_d	System-indicated (direct) measurement of energy loss (CSFS)
W_i	Predicted energy loss using an indirect measuring technique (CSFS)

LIST OF ABBREVIATIONS

BVFS	Bieri Vertical Sand Flushing System
CSFS	Conventional Sediment Flushing System
MMHPP / MMHPS	Middle Marsyangdi Hydropower Project / Plants
UT3AHPP/UT3AHPS	Upper Trishuli 3A Hydropower Project / Plants
RoR	Run-of-River (hydropower plant type)
PRoR	Peaking Run-of-River
O&M	Operation and Maintenance
SSC	Suspended Sediment Concentration
PPM	Parts Per Million (sediment concentration unit)
EM	Electromechanical (equipment/components)
HPP	Hydropower Plant
HPS	Hydropower Station
masl	Meters Above Sea Level
GWh	Gigawatt-hour
MWh	Megawatt-hour
KWh	Kilowatt-hour
MW	Megawatt
kV	Kilovolt
m	Meter
m^3/s	Cubic meters per second
mm	Millimeter
µm	Micrometer
NEA	Nepal Electricity Authority
DoED	Department of Electricity Development (Nepal)
ICIMOD	International Centre for Integrated Mountain Development
ICOLD	International Commission on Large Dams
IHA	International Hydropower Association
SCADA	Supervisory Control And Data Acquisition
NPR	Nepalese Rupees (currency)

CHAPTER 1: INTRODUCTION

1.1 Background

Hydropower is the backbone of Nepal’s energy system, producing more than 90% of the nation’s electrical generation. The Himalayan area, where steep topography, delicate geology, and heavy monsoon rainfall result in exceptionally large sediment loads, is home to the majority of Nepal's hydropower plants. The Rivers Marsyangdi, Kali Gandaki, Trishuli, and Sunkoshi contain some of the world’s highest concentrations of sand and sediment. This directly impacts the efficiency and performance of hydro-power plants.

Functional challenges associated with sedimentation include erosion of turbine parts, reduction in hydraulic efficiency, wear and tear of electromechanical equipment, blocking of waterways, and periodic plant shut-down for maintenance. To counter these issues, different sediment management schemes in the form of settling basins, flushing tunnels, silt excluders, or advanced flushing technologies are used by the companies involved in the development of hydropower.

Of these, the Bieri Vertical Sand Flushing System, which has been installed at Middle Marsyangdi Hydropower Project, is considered to be a reasonably modern and efficient method in which the silt is evacuated vertically prior to its entry into the turbine intakes. The Conventional Sediment Flushing Systems installed at Upper Trishuli 3A, on the other hand, mainly involve the evacuation of sediments horizontally with the aid of desilting basins and flushing gates.

This comparison between BVFS and CSFS is both relevant and necessary, especially in the context of Nepal’s rivers being laden with sediment and being prone to extreme weather and floods.

1.2 Sedimentation Problems in Himalayan Hydropower Plants

One of the largest challenges that affect the functioning of hydropower plants in the Himalayan regions is sedimentation. For example, since the mountains in Nepal are young and weak, the process of erosion is also rapid, and the amount of sediment in the rivers is massive since the soil in the mountains is composed of fine particles that can easily settle at the bottom of the river, especially during the monsoon season when the water levels rise considerably.

Sediment has the following effects on hydropower:

- Severe turbine abrasion, especially of runner blades, guiding vanes, and nozzle tips
- Reduction in efficiency, leading to loss of annual energy generation
- Regular shutdowns brought on by mechanical problems caused by silt
- Damage to waterways, such as penstocks, desilting chambers, and flushing tunnels
- Higher expenses for operation and maintenance (O&M)
- Lower economic return and a decreased plant factor
- Shortened lifespan of electromechanical components

At Middle Marsyangdi, the concentration of sediments is often close to 21267.61 ppm during the peak monsoon time, triggering the BVFS. At Upper Trishuli 3 A, in the monsoon, sediment concentration nears 20186.12 ppm. In cases of high sediment input, the sediment flushing process becomes hampered at the site, leading to wear and shut down of the turbines. It underscores the importance of developing better frameworks for performance assessment and better sediment management practices.

1.3 Research Gap/Problem Statement

Hydropower stations on the Nepalese rivers always encounter issues with high levels of silt. Although most of the stations employ conventional sediment flushing systems, there is still wear and tear on the turbines, station shutdowns, or low power production. The Bieri Vertical Sand Flushing System, which has been used in the Middle Marsyangdi Hydropower Project, provides a different option which apparently has better sediment removal efficiency. However, there are only a few studies available which compare it with conventional systems in relation to its performance and daily operation in the same river conditions.

This lack of comparison data often leaves the decision-maker with uncertainty when comparing sedimentation methods for new construction or the reconstruction of an existing facility. As a result of this information void, the plant could be subject to increased maintenance costs, its productive life reduced, and poor investment choices being made.

1.4 Objectives

1.4.1 Main Objective:

To compare and contrast the performance and effectiveness of the Bieri Vertical Sand Flushing System used in the Middle Marsyangdi Hydropower Project to that of the conventional sediment flushing system used in Upper Trishuli 3A.

1.4.2 Specific Objectives:

- To compare the flushing efficiency of both BVFS and CSFS under similar hydrological conditions.
- To assess each system's impacts on the frequency of maintenance and down time of the plant.
- To analyze and compare each flushing system’s effect on annual energy generation.
- To compare the total revenue loss due to flushing in BVFS and CSFS.

1.5 Scope and Limitation of Work

The assumption and limitations of this research are:

- The research will only focus on hydroelectric power stations in the Gandaki Basin, and this means it cannot be generalized to other basin regions to a large extent.
- Variations in plant capacity, turbine type, and operating plans may impact the results despite best efforts to account for them.
- The study will concentrate on short- to medium-term performance metrics; it might not adequately account for long-term effects like structural deterioration over decades.

CHAPTER 2: LITERATURE REVIEW

2.1 Sedimentation Challenges in Himalayan Run-of-River Hydropower Plants

For Himalayan hydropower plants, particularly run-of-river (RoR) projects that lack sizable regulating reservoirs, sedimentation continues to be one of the most significant operational issues. Rivers coming from the high Himalayas have unusually high sediment concentrations due to steep topographic gradients, fragile geological structures, and rapid monsoon-driven erosion (Shrestha et al., 2013). Quartz, feldspar, and mica minerals with high hardness levels (Mohs 6–7) that are quite abrasive to electromechanical components make up the majority of the sediment in these rivers.

Major Sources of Sediment Load

- Melt water streams move vast quantities of fine suspended sediments year-round. According to studies, some of the biggest unit sediment production in the world are produced by rivers like Marsyangdi and Trishuli.
- Over 70% of yearly sediment load occurs during 3–4 months during monsoon, typically with rapid sediment spikes >50,000 ppm.
- The Lesser Himalaya's weak geology frequently causes landslides, which directly dump enormous amounts of fine and coarse material into river courses.

Operational Impacts

Hydropower systems are impacted by sediment in several important ways:

- Turbine erosion reduces turbine efficiency and hydraulic performance by causing runner blade deformation, wicket gate erosion, and greater clearances.
- During peak flows, fines (less than 0.063 mm) evade traditional settling basins and proceed to turbines.
- To avoid catastrophic damage, plants must reduce electricity generation during severe sediment spikes.
- Post-monsoon rehabilitation at plants like Kali Gandaki A, Middle Marsyangdi, and Upper Trishuli 3A costs tens of millions of rupees every year.

In Nepal's hydroelectric system, sedimentation is therefore a direct economic danger that affects generation, plant availability, and asset lifetime in addition to being a hydraulic or environmental issue.

2.2 Conventional Sediment Flushing Systems (CSFS)

Conventional Sediment Flushing Systems are the most extensively employed sediment management approach in Nepalese hydropower projects. CSFS uses low-level flushing outlets or bottom under-sluices to periodically remove settled sediments from settling basins.

Principles of Design

- Used in weir or intake structures to start scouring at low water levels.
- Release sediment-laden water from the bottom of the settling basin.
- Usually performed during high flow periods when water supply is abundant.

Strengths

- Simple operational and structural design.
- Coarse silt (>0.2 mm) can be effectively removed.
- Widely used and well-understood in engineering practice.

Limitations Identified in Himalayan Context

- Poor removal of fine sediment (<0.063 mm):
    - Due to sluggish settling velocity, these particles remain suspended and travel into turbines.
- High flushing discharge requirements:
    - Requires high water loss, decreasing electricity generation.
- Inefficiency during continuous high sediment inflow:
    - Settling basin input often surpasses flushing capacity during high monsoon.
- Frequent operational interruptions:
    - Frequent flushing lowers plant factor and interferes with generation.

Relevant Nepalese Case Studies

Marsyangdi:

Even with regular flushing, there is still a significant amount of fine sediment escape, which exacerbates turbine erosion.

Upper Trishuli 3A:

Desanders exhibit typical CSFS behavior; during the monsoon, flushing cycles intensify and frequently necessitate plant shutdowns.

These limitations justify the seeking of alternative systems such as BVFS for improved sediment control.

2.3 Bieri Vertical Sand Flushing System (BVFS)

The Bieri Vertical Sand Flushing System (BVFS) was created to address the limitations of Conventional Sediment Flushing Systems (CSFS) by providing continuous or semi-continuous evacuation of fine and medium particles. As of right now, Madhya Marsyangdi HPP is the only reference plant in Nepal where it is installed.

Principle of Operation

Vertically arranged flushing shafts embedded in the settling basin's floor make up BVFS. High-velocity vertical jets produced by these shafts take in sediment that has been deposited close to the basin floor and move it downstream via flushing channels.

Important Operational Features:

- Continuous elimination of particles (0.063–0.2 mm) Enhances protection against turbine abrasion.
- Lower water requirement compared to full-basin flushing.
- Localized sediment evacuation, decreasing the requirement for basin emptying.

Advantages:

- Short-term amortization of the installation as a result of few production halts,
- 50% less water is used for flushing than with a horizontal flushing desander.
- It is not necessary to use flushing water continuously.
- Increased economic efficiency of the turbine system,
- Selective flushing only when the basin's individual desanding sections' sand heights have reached the specified level,
- Robust local flushing flow as a result of the sluices' construction (they open every 0.5 meters),
- Even stubborn silt can be effectively flushed thanks to vertical flushing, which guarantees a strong water flow over the many sluice holes.
- The ability to modify the system to accommodate local constraints
- The sliding mechanism is not obstructed.
- Self-cleaning desanding
- Decrease in the turbines' repair cycles.

Limitations

- Increased initial building expenses.
- Requires expert operation and maintenance.

- Limited field data under Himalayan circumstances.

For instance, Madhya Marsyangdi HPP in Nepal

- According to reports, the concentration of fine silt that reaches turbines can be reduced by up to 50–60%.
- However, problems including backflow during flood peaks, mechanical wear, and clogging have been noted.
- Lack of long-term comparison datasets remains a challenge.

For sediment-rich Himalayan Rivers, this system is among the most promising sediment management solutions.

CHAPTER 3: RESEARCH METHODOLOGY

This study adopts a comparative case study approach focusing on hydropower plants within the Gandaki Basin of Nepal. Madhya Marsyangdi Hydropower Project (MMHPP), equipped with the Bieri Vertical Sand Flushing System (BVFS), will be compared with Upper Trishuli 3 A Hydropower Project (UT3AHPP) plants that use Conventional Sediment Flushing Systems (CSFS).

Both quantitative analysis of data, observation, and a review of the related literature will be adopted.

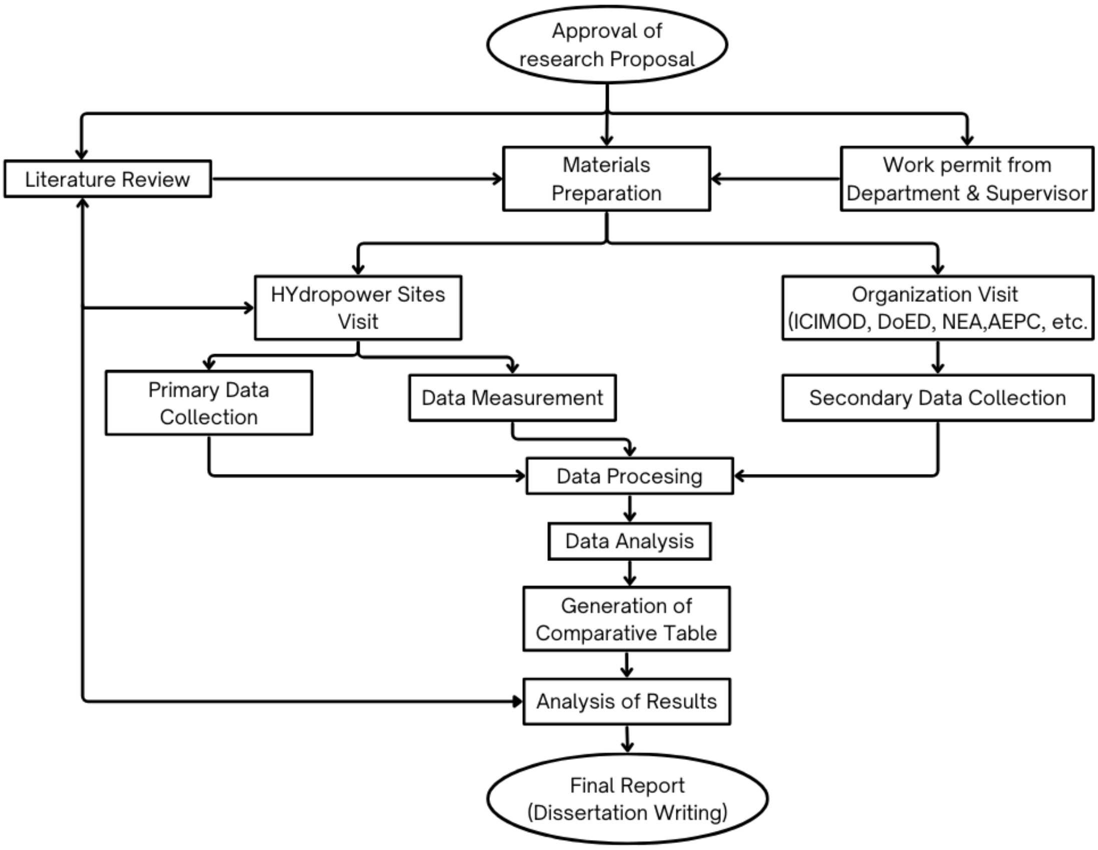

Figure 1 Methodology Work Flow Chart for Research

The following methods and steps were adopted to carry out the proposed research.

1) Approval of Research Proposal
    a) The study begins with the formal approval of the thesis proposal by the Department of Mechanical Engineering at Pulchowk Campus.
    b) This means that aims & scope of the research are realistic and valid for academic purposes.

2) Literature Review

    a) A comprehensive examination of the international and Nepal-related literatures pertaining to sediment management, erosion of turbines, and flushing systems.

    b) The base this establishes is good for spotting gaps in literature and for giving a reason for the comparison study between BVFS (Madhya Marsyangdi) and CSFS (Upper Trishuli 3 A Hydropower Project (UT3AHPP)).

3) Work Permit from Department & Supervisor

    a) Formal permissions are obtained from NEA, project sites, and supervisors for access to operational data, sediment information, and hydropower plant visits.

    b) Access to the site is important because the plants in the Gandaki Basin have delicate infrastructure.

4) Materials Preparation

    a) Historical sediment concentrations data (ppm, particle size distribution).

    b) Records regarding energy production (plant factor and monsoon outages).

    c) Hydrological data (River discharge, flood information)

5) Data Collection

    a) Primary and secondary data obtained from selected hydropower projects

    b) Field visits, engineer interviews, and collection of operational reports.

    c) The collection include flushing frequency, sediment trapping efficiency, downtime hours and O&M cost data.

6) Data Processing

    a) Cleaning, digitizing and standardizing data of various plants.

    b) Handling repair logs and generation records of turbines and converting them to similar measures of sediment flushing efficiency.

    c) Normalization of various plant sizes (e.g. 70 MW vs 60 MW plants) will be done using statistical tools.

7) Data Comparison

   - a) Comparison of the performance of BVFS vs CSFS compared in terms of same indicators
   - b) Comparisons make sure that the insights are made with the same hydrological and geological environment of Gandaki Basin.

8) Generation of Charts and Calculation.
   - a) The use of charts will aid in vivid representation of the differences between BVFS and CSFS
9) Validation of Results
   - a) The results are cross-verified with the plant operation logs and the opinions of experts
   - b) Validation: comparison between calculated sediment flushing parameters and values given by NEA.
10) Analysis of Results
    - a) Intensive analysis of results:
      - i) Which system is more effective in reducing the turbine erosion?
      - ii) Does BVFS really reduce costs of operation even though it costs more to establish?
      - iii) What are the most favorable conditions in each system under flooding or a sediment spike of river?
    - b) The discussion will relate engineering performance with the economic & sustainability perspectives.
11) Final Report (Dissertation Writing)
    - a) Documentation of findings in structured thesis format:
    - b) Final submission to the Department of Mechanical Engineering, Pulchowk Campus.

3.2 Sampling Techniques

Purposive Sampling will be applied, as the selection of projects is based on unique sediment flushing methods.

Sample Plants:

- BVFS: Madhya Marsyangdi HPP (70 MW).
- CSFS: Upper Trishuli 3A (60 MW).

Criteria for selection:

- Location within the Gandaki Basin.
- Similar sediment load environments (glacial and monsoon-fed rivers).
- Data availability for at least 2–3 years.

3.3 Data Collection

3.3.1 Primary Data

- Field Visits to MMHPP and selected UT3A PP plant.
- Interviews/Questionnaires with plant engineers/operators to gather operational experiences on sediment flushing efficiency, turbine wear and downtime.
- On-site Observations of flushing events, maintenance events and normal operation.
- Measurement of some data like sediment concentration, velocity and flow of flushed particles in discharge channel, total volume of water loss during flushing, different linear measurements, etc.

3.3.2 Secondary Data

- Plant Operation Records (generation logs, flushing schedules, downtime, and maintenance logs).
- Hydrological Data (sediment concentration, particle size distribution, flow discharge).
- Design Documents (Engineering Drawing & layout of flushing system, sediment exclusion structures).
- Scientific Literature & Reports (DoED, NEA, international journals).

3.4 Data Analysis

Comparative Performance Analysis

- Total Water Loss due to Flushing
- Annual Energy Loss due to Sedimentation

3.5 Validation of the Forecasting Relationship

- Cross-validation with historical operation data from NEA and Department of Electricity Development (DoED).
- Triangulation by comparing field observations, interviews, and recorded plant data.
- Benchmarking against international sediment management guidelines (ICOLD, IHA, IITR Guidelines).

3.6 Ethical Considerations

- Prior consent will be obtained from plant operators and authorities for data usage.
- Sensitive operational data will be anonymized where required.
- Research findings will be shared with stakeholders to enhance knowledge transfer.

3.7 Expected Challenges

- Limited access to complete operation data from NEA plants.
- Seasonal restrictions for field visits during monsoon.
- Variability in record-keeping standards among hydropower stations.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Energy Loss Due to Flushing

4.1.1 Energy Loss and Revenue Loss Due to Flushing in Conventional Flushing System (UT3A)

The operational effects of UT3A's horizontal sediment evacuation technique are shown in this table. In order to remove sediment, the traditional technique uses low-level exits or under-sluices, which frequently necessitates lowering high water levels or stopping operations.

- The most important finding from Table 1 is that complete plant outages are necessary for the CSFS to carry out flushing. The plant experienced a total of 273.69 hours of unavailability throughout the documented 3-year period.
- The monsoon months of Shrawan, Ashar, and Bhadra saw the greatest losses. For example, the plant lost 1,433,910 KWh of energy and 8,603,460 NPR in revenue during 47.8 hours of interruptions in Shrawan 2081.
- The conventional system produced a total energy loss of 8,210,650 KWh throughout the course of the three-year analysis period, which translated into a cash loss of 49,263,900 NPR. When water is otherwise plentiful, these frequent shutdowns reduce the plant factor and interfere with generation during times of high flow.

Table 1 Energy Loss Due to Flushing in Conventional Flushing System (UT3A)

Year & Month	Total Outage in hour during Flushing (CSFS)	Total Energy Loss in KWh (CSFS)	Total Loss in Rs. (CSFS)
2079 Ashar	17.63	528,900	3,173,400
2079 Shrawan	47.68	1,430,400	8,582,400
2079 Bhadra	4.45	133,500	801,000
2079 Ashoj	5.12	153,500	921,000
2080 Jestha	16.65	499,500	2,997,000
2080 Ashar	23.3	699,000	4,194,000
2080 Shrawan	6.88	206,500	1,239,000
2080 Bhadra	22.65	679,400	4,076,400
2080 Ashoj	2.52	75,500	453,000
2081 Ashar	23.78	713,400	4,280,400
2081 Shrawan	47.8	1,433,910	8,603,460
2081 Bhadra	27.701	831,030	4,986,180
2081 Ashoj	27.53	826,110	4,956,660

(Source: UT3A Flushing Report)

4.1.2 Energy Loss and Revenue Loss Due to Flushing in Bieri Vertical Flushing System (MMHPP)

The performance of the BVFS, which uses vertically positioned flushing shafts in the basin bottom to remove sediment using high-velocity jets, is seen in this table.

- Table 2 demonstrates that BVFS produces zero forced outage hours, in contrast to the typical system. Even during the flushing process, the technology enables continuous power output.
- The amount of water diverted for flushing rather than being fed through the turbines is what causes the "Energy Loss" shown in this table, not plant downtime. "Volume of water loss (m³) per minute," as seen in the table, averages about 32 m³/min.
- Despite the high flushing duration (3,630 minutes) during peak sediment months like Shrawan 2081, the overall income loss was just 1,290,540 NPR. Compared to the 8.6 million NPR lost by the traditional system in the same month, this is much less.
- Over the course of the three years, BVFS lost 1,231,630 KWh of energy, which is around 85% less than what the CSFS lost.

Table 2 Energy Loss Due to Flushing in Bieri Vertical Flushing System (MMHPP)

Year & Month	Flushing Duration in minutes in respective month (BVFS)	Volume of water (m³) loss per minute during Flushing (BVFS)	Total Volume of water loss (m³) during Flushing (BVFS)	Total Energy Loss in KWh (BVFS)	Total Revenue Loss in NPR Rs. (BVFS)
2079 Ashar	1,336.5	32.03	42,800	79,340	476,040
2079 Shrawan	3,615.0	32.01	115,700	214,560	1,287,360
2079 Bhadra	337.5	32.00	10,800	20,030	120,180
2079 Ashoj	390.0	31.79	12,400	23,030	138,180
2080 Jestha	1,260.0	32.06	40,400	74,930	449,580
2080 Ashar	1,770.0	31.92	56,500	104,850	629,100
2080 Shrawan	525.0	31.81	16,700	30,980	185,880
2080 Bhadra	1,725.0	31.88	55,000	101,910	611,460
2080 Ashoj	195.0	31.28	6,100	11,330	67,980
2081 Ashar	1,800.0	32.06	57,700	107,010	642,060
2081 Shrawan	3,630.0	31.96	116,000	215,090	1,290,540
2081 Bhadra	2,100.0	32.00	67,200	124,650	747,900
2081 Ashoj	2,085.0	32.04	66,800	123,920	743,520

(Source: MMHPP Flushing Report)

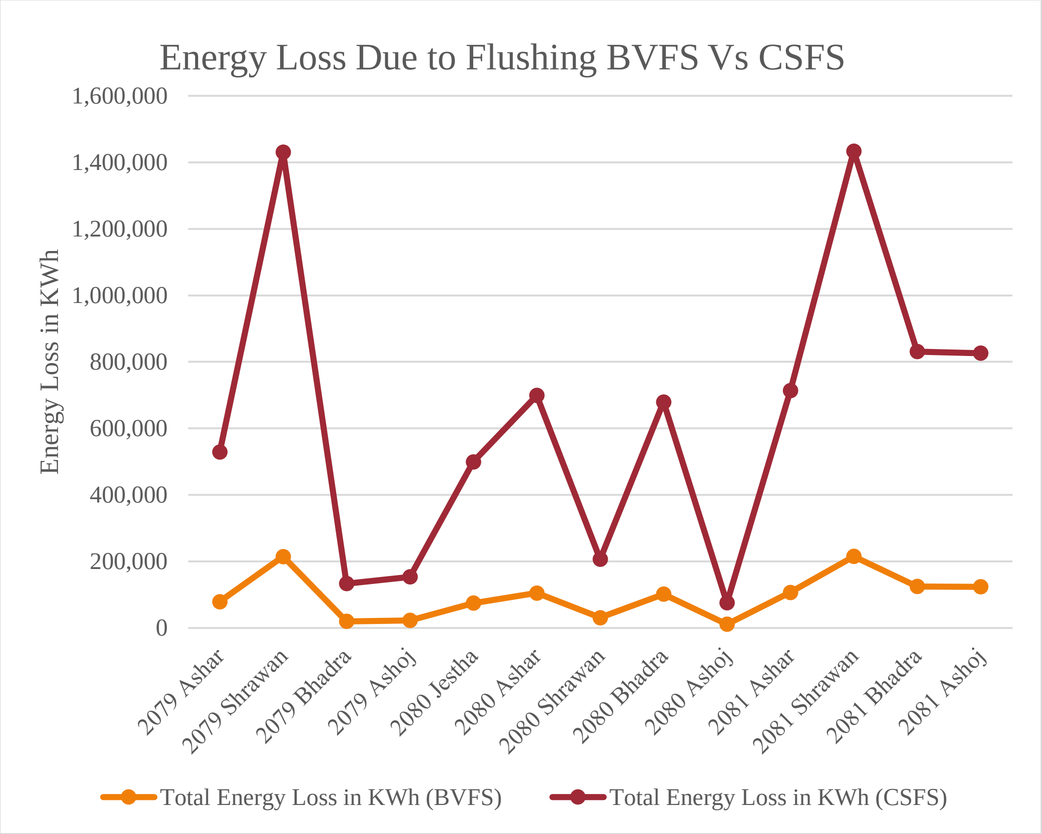

Figure 2 Line Graph of Energy Loss Comparison Due To Flushing

A clear comparison of the monthly energy loss from flushing for the two projects over the research period is shown in Figure 2. Large and erratic energy losses are indicated by the CSFS (UT3A) line's extremely high peaks and significant month-to-month changes, particularly during the monsoon season. The energy loss increases dramatically to about 1.43 million KWh in months like Shrawan 2079 and Shrawan 2081 since the conventional system necessitates whole plant shutdowns during flushing, which results in the losing of all potential generation. The BVFS (MMHPP) line, on the other hand, stays significantly lower and very consistent over the course of the three years. Even while there are minor increases during the months when sedimentation is at its worst, as Shrawan 2081 with a loss of roughly 215,090 KWh, these losses happen without the plant being shut down and are mostly caused by the tiny quantity of water that is diverted for cleansing jets. Overall, the graph shows an approximately 85% decrease in overall energy loss, with CSFS losing 8,210,650 KWh while BVFS lost just 1,231,630 KWh during the same period. It also illustrates the far improved operational stability of BVFS.

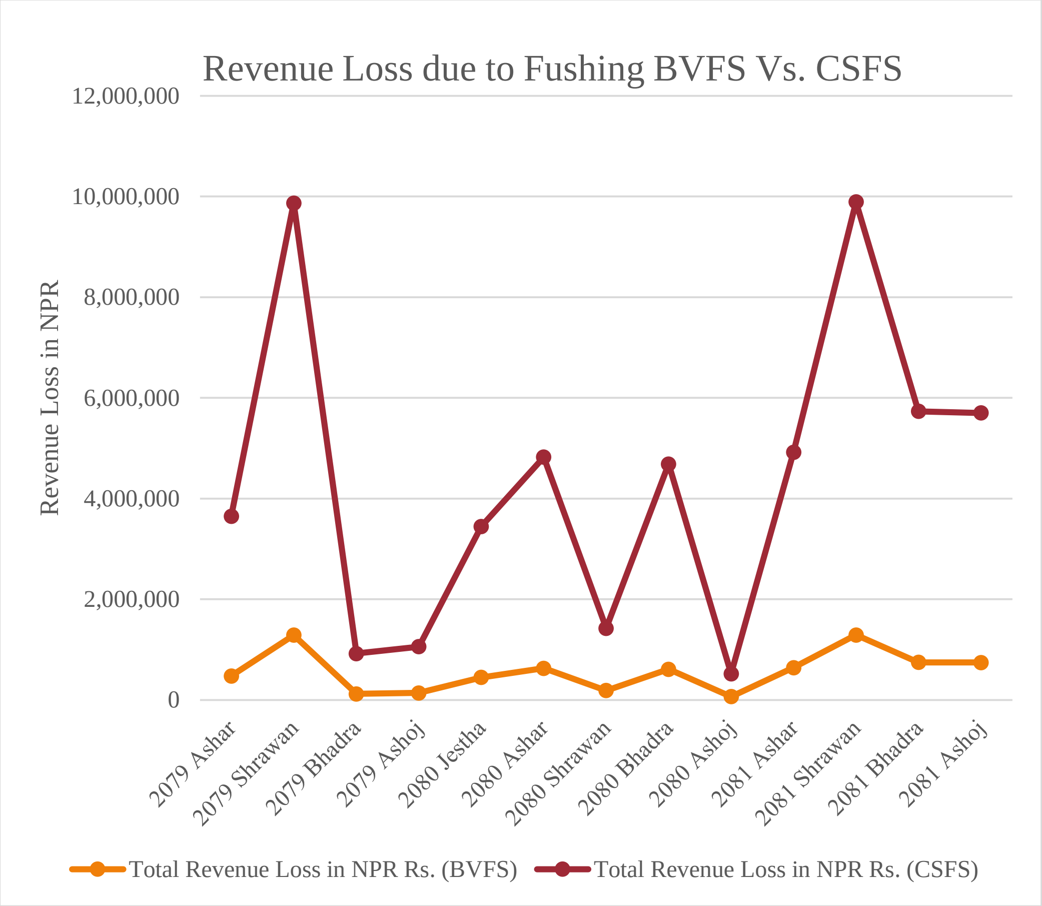

Figure 3 Line Graph of Revenue Loss Comparison due to Flushing

Figure 3 illustrates the economic impact of flushing by converting the energy losses depicted in Figure 2 into revenue losses using a generating cost of 6 NPR per unit. The significant financial impact of frequent and protracted shutdowns during the monsoon season, when sediment concentration is extremely high, is reflected in the CSFS line, which once again displays extreme peaks during heavy sediment months with monthly revenue losses exceeding 8.6 million NPR. In contrast, because the system keeps producing electricity while flushing, the BVFS line continually stays lower, even during crucial months like Shrawan 2081, when the maximum loss is restricted to roughly 1.29 million NPR. The long-term economic benefit of BVFS is amply demonstrated by the large and continuous difference between the two lines during the monsoon months. CSFS lost 49,263,900 NPR in total revenue over the course of the three years, but BVFS only lost 7,389,780 NPR. When taken as a whole, these figures highlight how BVFS successfully removes forced interruptions caused by sediment management, attaining zero outage hours as opposed to 273.69 hours for CSFS. As a result, it provides a more favorable life-cycle cost-benefit performance with a straightforward payback period of roughly 18.2 years.

4.2 Data Validation of Water Volume loss in MMHPP

a) Measured Data:

Ejection velocity from holes: 12.9 m/s

Canal flow velocity: 7.75 m/s

17,000 ppm by weight of sediment were present in the flushed mixture.

b) Interpretation of the water-level data via measurement

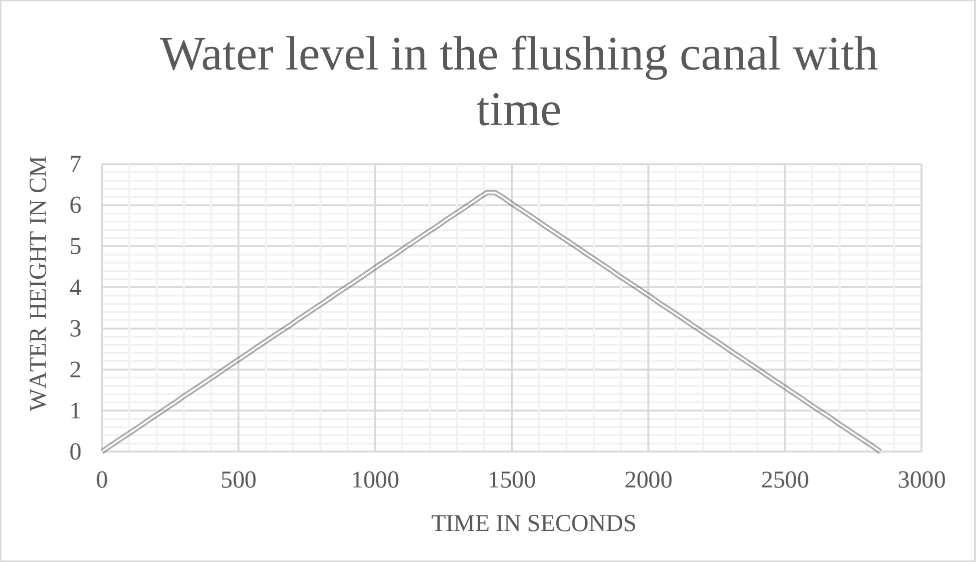

Figure 4 the water level in the flushing canal Vs Time during Fluhing

From the beginning of the sediment movement to the end of the flushing process, the water level in the flushing canal was measured every 30 seconds. According to the collected data, the water depth increased gradually and almost linearly from 0 cm at the beginning of flushing to a maximum depth of roughly 6.31 cm, which was attained between 1410 and 1440 seconds. This rise is consistent with the flushing discharge gradually becoming more intense when sediment-laden flow reached the canal.

With the reduction in sediment supply and the subsequent reduction in flushing flow, the water level decreased symmetrically after briefly being constant at its peak value, indicating a stable stage in the flushing process. The flushing process finally stopped at 2850 seconds, at which time the water level had attained its zero value. The water-level variation depicts an increase, stable, and then a decrease, which symbolizes the stable and smooth functioning of the Bieri Vertical Flushing System.

c) Calculations of Total Water Volume Loss per Minute in MMHPP:

Field data gathered during a particular flushing event that lasted 47 minutes and 30 seconds in order to calculate the total water volume loss per minute at the Middle Marsyangdi Hydropower Project (MMHPP) were examined. Fixed physical parameters, such as a measured flow velocity of 7.75 meters per second and a flushing canal width of 1.8 meters, were first identified.

Establishing the instantaneous discharge, or the volume of the mixture passing through the canal at any given second, was the first step in the computation. This was accomplished by multiplying the water velocity by the breadth of the canal and the current water depth. Measurements of the water depth were made at specific intervals of 30 seconds since the water level varied during the flushing process, rising as sediment-laden flow arrived and lowering as the supply was depleted.

Mathematical method called the trapezoidal rule for numerical integration to determine the total volume of the mixture of water and silt was used. The different discharge rates that were noted during the flush was able to add up. The mixture's total volume 1,268 cubic meters by using the entire dataset of depth measurements was determined.

Isolating the actual water loss from the solid material was the next step. The exact volume occupied by the flushed material using a measured sediment concentration of 17,000 parts per million by weight was determined. The entire water volume loss was calculated by deducting this sediment volume from the whole combination volume, and it came out to be roughly 1,246 cubic meters.

Ultimately, the rate of 26.231 cubic meters per minute was determined by dividing the total water loss by the flush time in minutes. Furthermore, by dividing the total volume of the combination by the total time in seconds, an average flushing discharge for the entire mixture was determined. The sources state that in order to find possible mistakes brought on by things like turbulence, unpredictable flow conditions, and manual measurement uncertainties, this computed value was subsequently compared to direct system measurements.

Maximum water height (h_{max}) = 6.31cm = 0.0631m

Ejection velocity from Bieri Plates (v_e) = 12.9 m/s

Flushing canal flow velocity (v) = 7.75 m/s

Sediment concentration in flushed mixture (C_s) = 17,000 ppm = 0.017(by weight)

Width of Flushing Canal (b) =1.8m, Height of Flushing Canal (h) = 2.4m, Flushing canal cross-section area (A_{full}) = $b \times h$ = 1.8×2.4 = 3.672 m^2

Total flushing duration (T) = 47 Minutes and 30 seconds (2850s)

Measured water depth variation in canal h(t) at every 30 seconds (converted from cm to m).

The flushing canal's effective flow area at any given time t, $A(t) = b\,,h(t)$

Instantaneous discharge $Q(t) = v\,,A(t)$

$$Q(t) = v\,,b\,,h(t)$$

Substituting known values:

$$Q(t) = 7.75 \times 1.8 \times h(t)$$

$$Q(t) = 13.95\, h(t) \text{ (m}^3\text{/s)}$$

Total flushed volume is obtained by integrating discharge over the flushing duration:

Total Volume of Water & Sediment Mixture (V_{mix}) = $\int_0^T Q(t), dt$

The trapezoidal rule is used for numerical integration because h(t) is measured discretely at equal time intervals (Δt=30s):

$$V_{mix} = \sum_{i=1}^{n-1} \frac{Q_i + Q_{i+1}}{2} \Delta t$$

$$V_{mix} = \sum_{i=1}^{n-1} \frac{13.95(h_i + h_{i+1})}{2} \times 30 \quad \textit{(Substituting Q =13.95h)}$$

$$V_{mix} = 209.25 \sum_{i=1}^{n-1} \frac{(h_i + h_{i+1})}{2}$$

Using the full measured dataset (0–2850 s), Volume of Water & Sediment Mixture (V_{mix}) becomes 1268 m^3. Detail table is in Annex D

Sediment concentration by weight (C_s) = 0.017

Sediment volume flushed (V_s) = $C_s \times V_{mix}$

$$V_s = 0.017 \times 1268$$

$$V_s = 21.556 \approx 21.6 \text{ m}^3$$

Total Water Volume Loss during Flushing (V_w) = $V_{mix} - V_s$

$$V_w = 1268 - 21.6$$

$$V_w = 1246.4 \approx 1246 \text{ m}^3$$

Total Water Volume Loss per Minute = $\frac{\text{Total Water Volume Loss during Flushing}}{Total\ Time\ Taken\ for\ one\ FLush}$

$$= \frac{1246}{47.5\ (2850\ Sec.)} = 26.231 \text{ m}^3$$

Average Flushing Discharge (Q_{avg}) = $\frac{V_{mix}}{T}$

$$Q_{avg} = \frac{1268}{2850}$$

$$Q_{avg} = 0.445 \text{ m}^3/\text{s}$$

d) Error Calculation:

The system-indicated (direct) measurement of water loss during the Bieri Valve Flushing System (BVFS) operation on Bhadra 18, 2081, was reported as follows: $Q_d = 32\text{m}^3/\text{min}$

Nevertheless, the predicted water loss using an indirect measuring technique (based on field observations and computed discharge characteristics) was: $Q_i = 26\text{m}^3/\text{min}$

Relative Error = $\frac{|Q_d - Q_i|}{Q_d} = \frac{|32-26|}{26} = 0.1875 = 18.75\%$

The main causes of the observed difference between the indirectly calculated discharge (26 m^3/min) and the system-indicated flushing discharge (32 m^3/min) are:

- The flow conditions created by BVFS operation are extremely erratic and fleeting.
- Underestimation results from the assumption of continuous or quasi-steady flow in indirect measurement.
- Despite having a significant proportion of silt, flushing water was calculated as clear water.
- The presence of sediment lowers effective velocity estimation and increases energy loss.
- During flushing, there is significant turbulence and jet contraction at the bottom valve.
- There was insufficient accounting for local head losses at the valve, bends, and exit.

- Near-peak or short-interval averaged values are represented by system-indicated discharge.
- Time-averaged flow over a longer period of time is represented by indirect measurement.
- Uncertainty in head measurement results from the water level fluctuating quickly during flushing.
- Significant discharge reduction occurs when the head is slightly underread.
- Without field calibration, a standard or assumed valve discharge coefficient was employed.
- The real discharge coefficient is changed by sediment abrasion and valve wear.
- System-indicated values may be slightly inflated by instrument response lag or overshoot.
- Small human error may introduced by manual timing and observation.
- Cumulative underestimate is the outcome of multiple systematic errors acting in the same direction.

4.3 Data Validation of Water Volume loss in UT3AHPP

The Upper Trishuli 3A Hydropower Project (UT3AHPP) had 28.33 outage hours in Bhadra 2081, which were mostly caused by desander and reservoir washing operations. These maintenance tasks were divided between two units: Unit-2 recorded 14 hours and 25 minutes of downtime, while Unit-1 recorded 13 hours and 55 minutes.

These interruptions had the following effects:

- Total Energy Loss: 843,690 KWh was lost overall.
- Financial Loss: At a generation cost of Rs. 6 per unit, there was a total revenue loss of Rs. 5,062,140.

Table 3 Direct Measured Data of Total Stoppage Hour & Total Energy Loss

Month: Bhadra
Unit-1

Date	**Stop**	**Start**	**Outage Hr**	**Remarks**
Bhadra/4/2081	11:24	13:45	2:21	Desander+reservoir flushing
Bhadra /11/2081	11:34	13:29	1:55	Desander+reservoir flushing
Bhadra /14/2081	16:05	18:18	2:13	Flushing
Bhadra /20/2081	13:23	17:45	4:22	Desander+reservoir flushing and load spill
Bhadra /29/2081	12:45	15:49	3:04	flushing
Total Outage Hr			13:55	
Total Energy Loss MWh			414.39	
Total Units KWh			414390	
Generation Cost (considering Rs 6/unit)				2486340

Unit-2

Date	**Stop**	**Start**	**Outage Hr**	**Remarks**
Bhadra /3/2081	14:47	17:49	3:02	Desander Flushing
Bhadra /4/2081	11:24	13:41	2:17	Desander+reservoir flushing
Bhadra /11/2081	11:37	13:26	1:49	Desander+reservoir flushing
Bhadra /14/2081	16:02	17:11	1:09	Desander+reservoir flushing
Bhadra /20/2081	13:23	17:09	3:46	Desander+reservoir flushing
Bhadra /29/2081	13:18	15:40	2:22	flushing
Total Outage Hr			14:25	
Total Energy Loss MWh			429.3	
Total Units KWh			429300	
Generation Cost (considering Rs 6/unit)				2575800

Total Outage Hour of UT3AHPP in Bhadra: 28hr 20min =28.33 hrs

Total Energy Loss KWh of UT3AHPP in Bhadra: 843690 KWh

Total Revenue Loss due to flushing of UT3AHPP in Bhadra : Rs.50,621,40

a) Error Calculation:

The system-indicated (direct) measurement of Energy Loss KWh during the Conventional Sediment Flushing System (CSFS) operation on Bhadra Month of 2081, was reported as: W_d = 831,030 KWh

Nevertheless, the predicted water loss using an indirect measuring technique (based on field observations and computed discharge characteristics) was: W_i = 843,690 KWh

Relative Error = $\frac{|W_d - W_i|}{W_d} = \frac{|831030 - 843690|}{831030}$ = 0.015 = 1.5%

This compared various methods of measuring the energy loss during the operation of the Conventional Sediment Flushing System (CSFS) in order to guarantee data accuracy. The indirect method based on field observations anticipated 843,690 KWh, whereas the system-indicated direct measurement was 831,030 KWh. This led to a low relative error of 1.5%, indicating that the project's monitoring techniques were very reliable.

4.4 Data Summary (3-Year Analysis Period)

Table 4 Data Summary (3-Year Analysis Period)

System	Total Plant Outage Hours	Total Energy Loss (KWh)	Total Financial Loss (NPR)
CSFS (UT3A)	273.691 hours	8,210,650 KWh	49,263,900 NPR
BVFS (MMHPP)	0 hours	1,231,630 KWh	7,389,780 NPR

BVFS demonstrates an 85% decrease in energy waste, which translates into an 85% decrease in financial loss.

4.5 Payback Period Calculation

Capital Cost Differential:

- BVFS installation: NPR 650,000,000
- CSFS installation: NPR 250,000,000
- Additional investment for BVFS: NPR 400,000,000

Annual Savings from BVFS:

- Direct savings on energy loss: NPR 13,958,040/year
- Additional O&M savings: NPR 8,000,000/year (30-40% lower maintenance)
- Total annual savings: NPR 21,958,040/year

Simple Payback Period:

Payback Period = $\frac{Additional\ Investment}{Annual\ Savings} = \frac{400,000,000}{21,958,040}$ = 18.21 years

4.6 Sensitivity Analysis

Table 5 Sensitivity Analysis Table

Scenario	Annual Savings Variation	Payback Period
Base Case	NPR 21.96 million	18.2 years
Conservative (10% less savings)	NPR 19.76 million	20.2 years
Optimistic (20% more savings)	NPR 26.35 million	15.2 years
High Sediment Year	NPR 30.0 million	13.3 years

4.7 Comparison Table

Table 6 Comparison Table among BVFS & CSFS

Feature / Performance Metric	**Bieri Vertical Sand Flushing System (BVFS)**	**Conventional Sediment Flushing System (CSFS)**
Reference Plant	Middle Marsyangdi (MMHPP)	Upper Trishuli 3A (UT3A)
Operating Principle	Silt is collected by vertical evacuation through basin floor shafts before it reaches turbines.	Horizontal evacuation using low-level flushing valves and settling basins.
Total Plant Outage Hours (3-Year Period) During Flushing	0 hours.	273.691 hours.
Total Energy Loss (3-Year Period)	1,231,630 KWh	8,210,650 KWh
Total Financial Loss (3-Year Period)	7,389,780 NPR	49,263,900 NPR
Flushing Efficiency	95% for particles ≥ 0.2 mm.	85% for particles of 0.13 mm fall diameter.
Water Consumption	Compared to horizontal systems, about 50% less flushing water is used.	Increased water loss is necessary for horizontal scouring to be successful.
Estimated Capital Cost	NPR 650,000,000.	NPR 250,000,000.
Annual O&M Savings	NPR 8,000,000 (30–40% lower maintenance costs).	Increased expenses as a result of regular turbine maintenance and deterioration.
Operational Impact	Permits constant power production while flushing.	Plant shutdowns are frequently required during periods of heavy sediment influx.

4.8 Discussion

The findings show that the Bieri Vertical Flushing System (BVFS) at the Middle Marsyangdi Hydropower Project (MMHPP) and the Conventional Sediment Flushing System (CSFS) at the Upper Trishuli 3A (UT3A) differ significantly in terms of technical performance, economic impact, and operational efficiency. The debate that follows assesses the ramifications of these two systems in light of these discoveries.

Operational Continuity and Energy Production

Forced operational outages are the most significant difference between the two systems. In order to lower water levels and remove sediment through horizontal under-sluices, the CSFS necessitates total plant shutdowns, which results in 273.691 hours of unavailability over a three-year period. On the other hand, because the BVFS's design permits continuous power generation even throughout the flushing operation, it achieves zero forced outage hours.

During the monsoon months (Ashar, Shrawan, and Bhadra), when water is most abundant but sediment concentration is at its highest, this operational stability is very important. The BVFS continues to generate power, experiencing only tiny energy losses from the water diverted to the flushing jets rather than turbine downtime, whereas the CSFS must cease operations precisely when generation potential is maximum.

Economic Impact and Revenue Stability

A significant disparity in revenue loss is highlighted by the financial statistics. Over the course of three years, shutdowns cost the CSFS a total of 49,263,900 NPR. In contrast, the BVFS had an 85% decrease in financial loss, losing only 7,389,780 NPR.

From a long-term investment standpoint, the BVFS offers significant annual savings while requiring a much larger initial capital expenditure (650 million NPR as opposed to 250 million NPR for CSFS). The system offers a base case payback period of 18.2 years, with approximately 21.96 million NPR in yearly savings derived from both recovered energy and 30–40% lower maintenance expenses. According to sensitivity research, this payback period may shorten to as little as 13 years during high-sediment years.

Technical Efficiency and Water Conservation

Technically speaking, the BVFS exhibits excellent water conservation and sediment control. For particles larger than 0.2 mm, it reaches a 95% efficiency rate, while the CSFS only reaches 85% for smaller particles. Additionally, compared to the horizontal scouring needed by traditional systems, the BVFS consumes around 50% less flushing water. Water-level data further supports the stability of the BVFS by demonstrating a symmetrical increase and reduction in canal depth, which suggests a controlled and seamless flushing procedure.

Data Reliability and Limitations

The reliability of the data is supported by validation measures:

- CSFS Validation: The traditional system's relative error between direct and indirect measures was only 1.5%, indicating very dependable monitoring.
- BVFS Validation: A greater relative inaccuracy of 18.75% was displayed by the BVFS. Turbulence, unpredictable and transient flow conditions, and manual measurement errors during the vertical flushing process are all blamed for this disparity,

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

- BVFS shows significantly higher flushing efficiency than CSFS, achieving about 95% sediment removal for particles >0.2 mm and maintaining stable performance even during monsoon conditions.
- BVFS completely eliminates forced outages, whereas CSFS experienced about 273.691 hours of downtime, indicating much lower maintenance frequency and higher operational reliability.
- Energy loss during flushing is reduced by about 85% with BVFS (1.23 GWh compared to 8.2 GWh over three years), resulting in substantially higher annual energy generation.
- BVFS leads to significantly lower revenue loss, with annual savings exceeding NPR 21.96 million (NPR 2.196 crore) and a payback period of approximately 18.21 years.

BVFS is a technically, economically, and operationally superior sediment management system compared to CSFS, particularly suitable for sediment-laden Himalayan rivers.

5.2 Recommendations

5.2.1 For Hydropower Developers & Investors

New Project Development:

- Give BVFS top priority for projects in rivers with silt concentrations more than 5000 parts per million.
- Rather than solely focusing on capital costs, it would be better to use lifespan cost analysis.
- Allocate a sufficient fund for advanced sediment management practices (3-5% of the project cost).

Project-Specific Considerations:

- High Head Francis turbines (>100m head): Due to vulnerability to sediment abrasion, BVFS is strongly recommended.
- Peaking plants: As BVFS retains less generation during the flushing process, it is highly preferred.

- Remote Locations: Although the initial transport costs would be higher, it is important to consider the reduced O&M costs of BVFS itself.

5.2.2 For Plant Operators & NEA

Operational Optimization:

- Use sediment concentration monitoring to inform predictive flushing.
- Create maintenance procedures tailored to BVFS parts (servomotors, aperture plates).
- Train the operators on complex SCADA controls.

Performance Monitoring:

- Establish standardized methods of evaluating sedimentation management systems.
- Establish a common database of maintenance and down times related to sediment.
- All flushing systems should undergo periodic efficiency tests every two to three years.

5.2.3 For Policy Makers & Regulatory Bodies

Standards & Guidelines:

- Add sophisticated technologies like BVFS to sediment management recommendations.
- Incorporate energy loss measurements into evaluations of operational and environmental compliance.
- Create systems to encourage the use of effective sediment control techniques.

Research & Development:

- Find Comparative studies that compare other river basins (Koshi, Karnali).
- Encourage the adaptation of technology to different sediment properties
- Encourage hydropower operators to exchange knowledge.

5.2.4 For Existing CSFS Plants

Retrofit Considerations:

- Explore the retrofit ability of BVFS in plants that are experiencing:

    - High rates of turbine abrasion (>2 mm/year erosion)
    - Regular monsoon shutdowns (more than 50 hours annually)
    - Reduced plant factor as a result of silt problems
- Give strategic plants with a capacity of more than 50 MW priority for retrofitting.
- The majority of units impacted by sediment should be implemented first.

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ANNEXURE A: MIDDLE MARSYANGDI HYDROPOWER PROJECT PLANT DETAILS

Middle Marsyangdi Hydropower Station (MMHPS) is a 70 MW peaking run-of-river (PRoR) project located in Siudibar, Lamjung District, Gandaki Province. The project diverts water from the Marsyangdi River, whose headwaters originate from Tilicho Lake in Manang. The plant is capable of providing up to five hours of daily peaking operation, even during low-flow periods.

The project was inaugurated on 14 December 2008 and entered commercial operation one month later. Its design annual energy generation is 398 GWh, and it has generated a cumulative 7091.1 GWh as of FY 2081/82. The generation for FY 2081/82 reached 427.9 GWh, which is 107.6% of the design target but 3% lower than the previous fiscal year.

A. General Project Information

Project Name	Middle Marsyangdi Hydropower Project
Location	Siudibar, Lamjung, Gandaki Province
Commissioning Date	14 December 2008
Installed Capacity	70 MW (2 × 35 MW)
Plant Type	Peaking Run-of-River (PRoR)
Peaking Duration	5 hours (minimum discharge)
Design Annual Generation	398 GWh
Cumulative Generation (Up to FY 2081/82)	7091.1 GWh
Generation in FY 2081/82	427.9 GWh

B. Hydrology and Headworks Data

Catchment Area	2,729 km²
Average Annual Flow	99.5 m³/s
Maximum Gross Head	110 m
Maximum Net Head	98 m
Live Storage Volume	1.65 million m³
Diversion Length	95 m
Spillway Capacity	4,270 m³/s
Spillway Gates	12 × 19.54 m

Surge Tank Size	20 × 45 m
Orifice Diameter	2.9 m

Water Levels

Maximum Operating Level	626 masl
Minimum Operating Level	621 masl
Highest Tailwater Level	530 masl
Minimum Tailwater Level	516 masl
Turbine Center Elevation	EL. 389.50 m

C. Water Conveyance System

Waterway Length	5940 m
Penstock Length	212–218 m
Penstock Diameter	4.60 m
Intake Type	Submerged tunnel intakes with trash racks and gates

D. Electromechanical System

Type	Francis Turbine, Vertical Shaft
Number of Units	2
Rated Output	35 MW/unit
Rated Discharge	42.4 m³/s per unit
Design Net Head	96.5 m
Maximum Gross Head	105 m
Rated Speed	333.33 rpm
Runaway Speed	810 rpm
Direction of Rotation	Clockwise
Runner Inlet Diameter	1786.9 mm
Runner Outlet Diameter	2103.0 mm
Runner Height	1210.5 mm
Number of Blades	13

Generator & Transformer Data

Generator Rated Capacity	39 MVA
Transformers	6 + 1 spare, single-phase

Transformer Capacity	14.5 MVA each, 11/132 kV, ±2 × 2.5% tap changer

E. Desander and Flushing System (BVFS)

Desander Type	Bottom Valve Flushing System (BVFS)
Flushing efficiency	95% for suspended sediment particles of 0.2 mm or larger
Desander Size	130 m × 15 m × 27 m
Designed Flushing Discharge	80 m^3/s
Number of Flushing Outlets	3
Minimum Reservoir Level During Flush	621 masl

F. Energy Generation, Losses, and Costs

Gross Annual Generation	397,590 MWh
Environmental Compliance Cost	NPR 27.6 Arab/year

ANNEXURE B: UPPER TRISHULI 3A HYDROPOWER PROJECT PLANT DETAILS

Upper Trishuli 3A Hydropower Station (UT3A HPS) is a 60 MW run-of-river (RoR) hydropower project located at the border of Rasuwa and Nuwakot districts, Bagmati Province, Nepal. The plant comprises two vertical Francis turbines, each rated at 30 MW, operating under a gross head of 144.5 m and a design discharge of 51 m^3/s (25.15 m^3/s per unit).

Commercial operation began in May 2019 (Unit 1) and August 2019 (Unit 2).

General Plant Characteristics

UT3A is NEA’s second-largest hydropower station in terms of annual design energy generation. Its annual design generation is 489.76 GWh, while the cumulative generation till FY 2081/82 reached 2391.5 GWh. In FY 2081/82 alone, the plant generated 356 GWh, which is 17% lower than the previous fiscal year and represents 78% of the annual target and 73% of the design generation.

Salient Features of UT3A HPS

Project Name	Upper Trishuli 3 A Hydropower Project
Type	Run-of-River Hydropower Project
Location	Rasuwa & Nuwakot, Bagmati Province
Installed Capacity	60 MW (2 × 30 MW)
Annual Design Energy	489.76 GWh
Gross Head	144.5 m
Design Discharge	51 m^3/s
Catchment Area	4542 km^2
Design Flood	2424 m^3/s (1:1000 year)
Intake Type	Side Intake
Desander	Twin Type (95 × 30 × 9.2 m)
Desander Flushing Efficiency	85% of particles with a fall diameter of 0.13 mm.
Headrace Tunnel	4095 m, circular, 5.4–5.9 m dia.
Surge Shaft	17 m dia., 37.7 m height
Pressure Tunnel	86.6 m, 4.0–2.0 m dia.
Powerhouse	Underground Cavern

Transmission Line	48 km, 220 kV D/C (charged at 132 kV)
Interconnection	Matatirtha Substation
Total Project Cost	USD 125.78 million
B/C Ratio	2.18
EIRR	21.60%

Yearly Energy Generation Summary

Cumulative Generation (from first run to FY 2080/81)

Total generation: 1,827.836 GWh

Fiscal Year	Annual Generation (MWh)
2075/76	16,185
2076/77	405,406
2077/78	314,770.5
2078/79	432,636
2079/80	437,116
2080/81 (till Poush)	221,722.5

Monthly generation data (Shrawan–Ashar) confirms seasonal variation with maximum output during monsoon months and minimal generation during winter.

ANNEXURE C: FIGURES

Figure 5 Desander(CSFS) of UT3A HPP

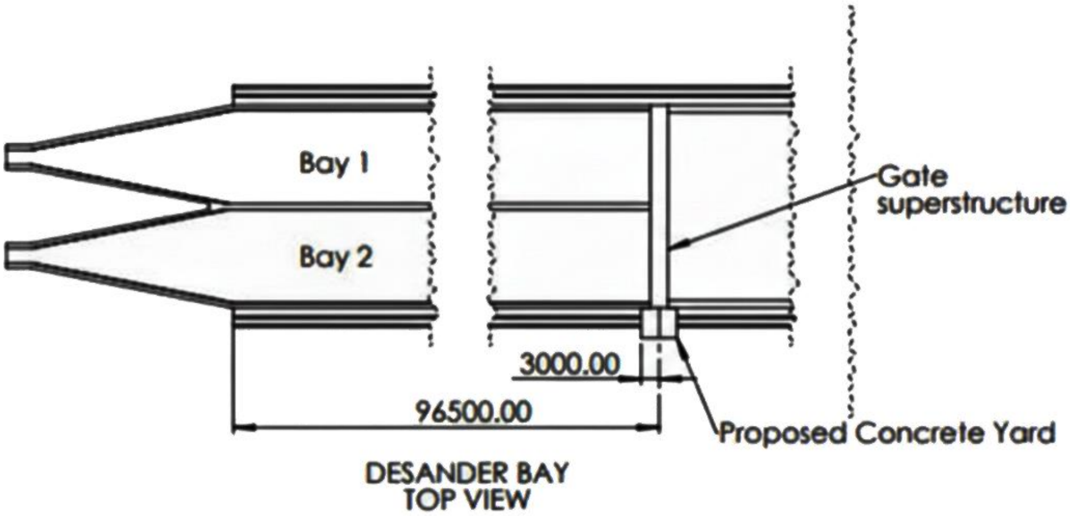


Figure 6 Engineering Drawing of Conventional Desander of Uper Trishuli 3A HPP

Figure 7 Sand Deposition at Desander of Upper Trishuli 3A HPP

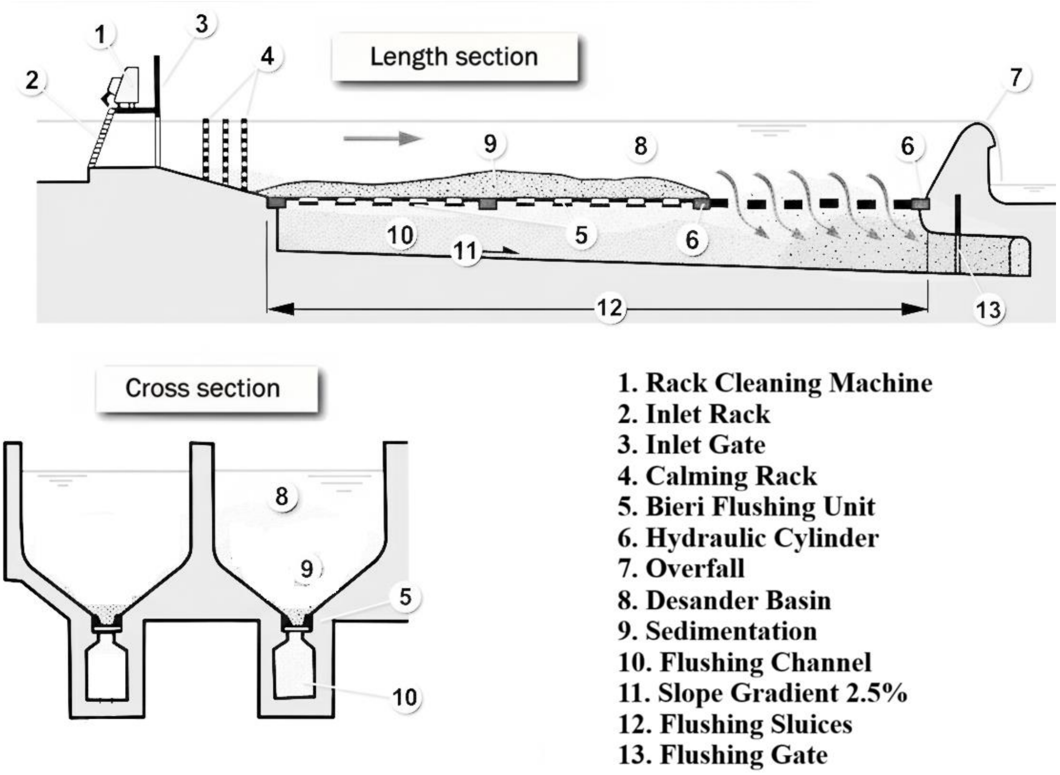


Figure 8 Bieri Desander System Layout

Figure 9 Bieri Vertical Sand Flushing System of MMHPP

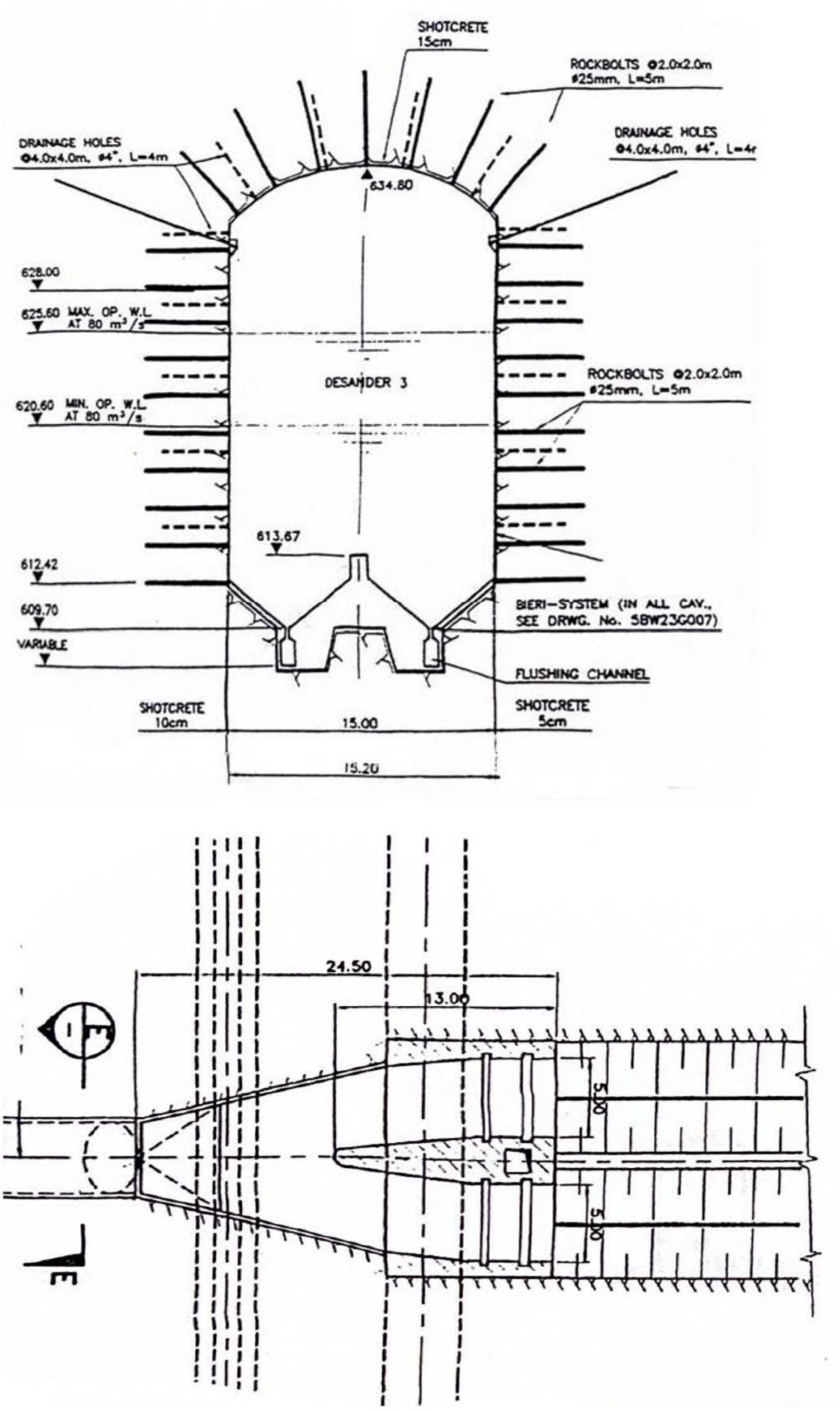


Figure 10 Engineering Drawing (Plan & Section View) of BVFS in MMHPP

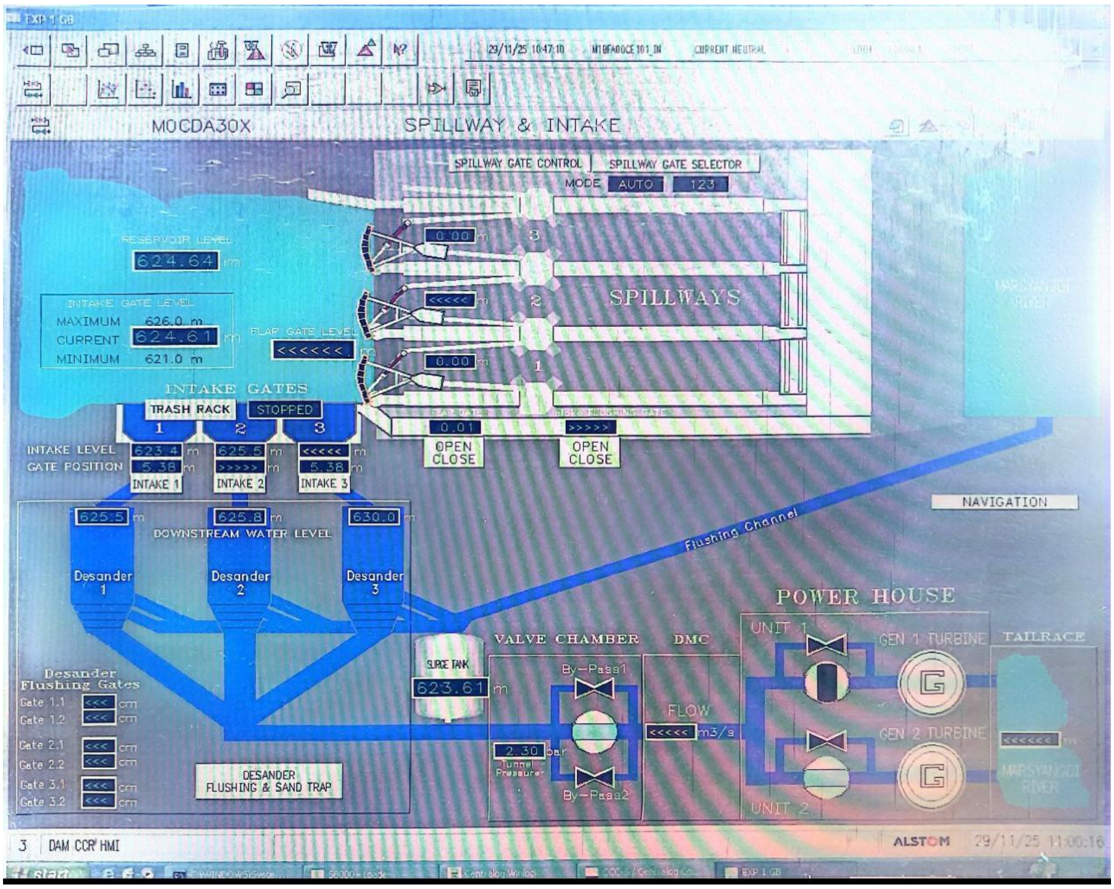


Figure 11 SCADA Layout of MMHPP showing 3 units of BVFS

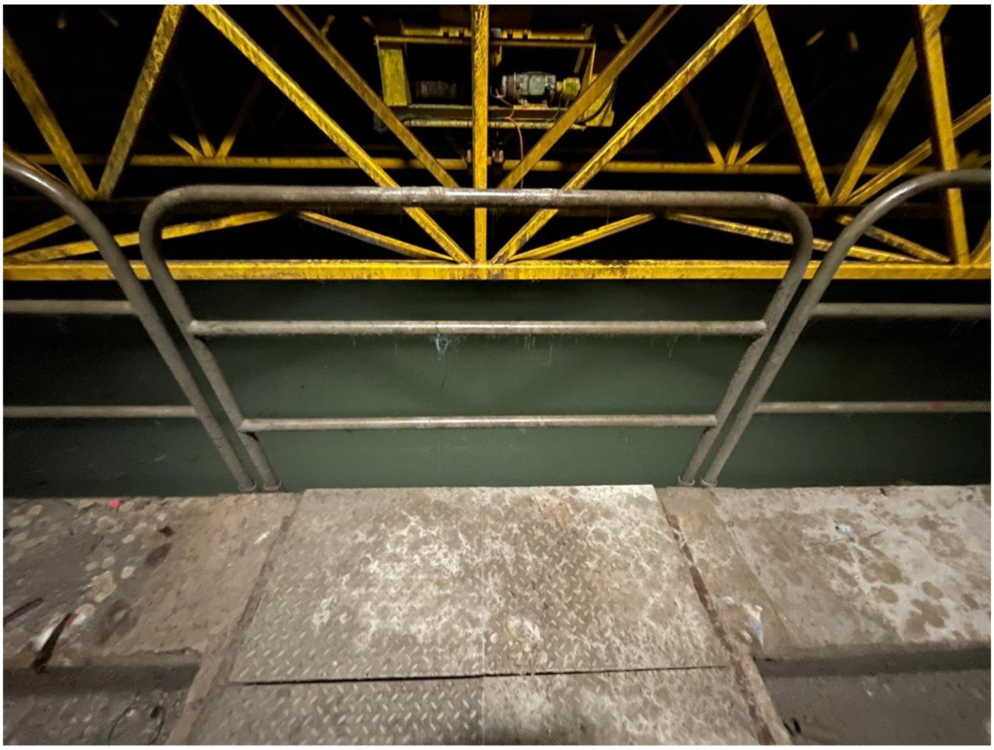
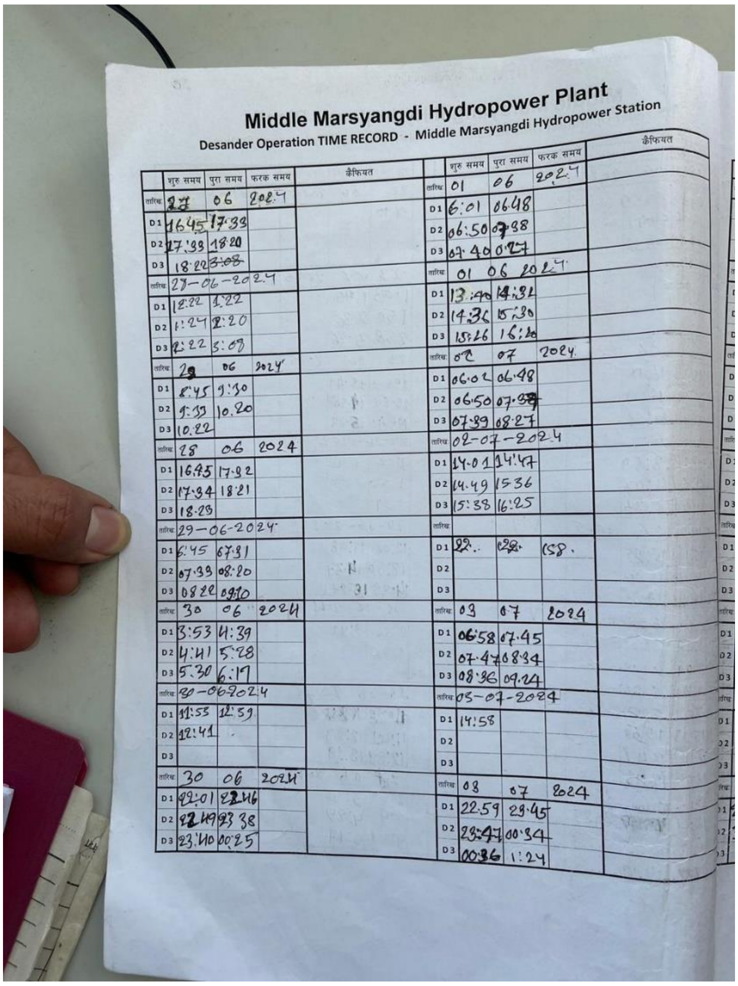


Figure 12 Desander Unit-3 of MMHPP

Figure 13 Flushing Gate of Desander in MMHPP



Middle Marsyangdi Hydropower Plant

Desander Operation TIME RECORD - Middle Marsyangdi Hydropower Station

	शुरु समय	पुरा समय	फरक समय	कैफियत
तारिख	27	06	2024	
D1	16:45	17.33		
D2	17.33	18.20		
D3	18.22	~~3:08~~		
तारिख	28-06-2024			
D1	12:22	1:22		
D2	1:24	2:20		
D3	2:22	3:08		
तारिख	29	06	2024	
D1	8:45	9:30		
D2	9:33	10.20		
D3	10.22			
तारिख	28	06	2024	
D1	16.45	17.32		
D2	17.34	18.21		
D3	18.23			
तारिख	29-06-2024			
D1	6:45	07.31		
D2	07.33	08:20		
D3	08.22	09.10		
तारिख	30	06	2024	
D1	3:53	4:39		
D2	4:41	5:28		
D3	5.30	6:17		
तारिख	30-06-2024			
D1	11:53	12:39		
D2	12:41			
D3				
तारिख	30	06	2024	
D1	22:01	22.46		
D2	22.49	23.38		
D3	23:40	00.25		

	शुरु समय	पुरा समय	फरक समय	कैफियत
तारिख	01	06	2024	
D1	6:01	06.48		
D2	06:50	07.38		
D3	07.40	0.27		
तारिख	01	06	2024	
D1	13:40	14:32		
D2	14:36	15:30		
D3	15:26	16:20		
तारिख	02	07	2024	
D1	06.02	06.48		
D2	06.50	07.38		
D3	07.39	08.27		
तारिख	02-07-2024			
D1	14.01	14:47		
D2	14.49	15.36		
D3	15:38	16:25		
तारिख				
D1	22..	22.	158.	
D2				
D3				
तारिख	03	07	2024	
D1	06:58	07.45		
D2	07.47	08.34		
D3	08.36	09.24		
तारिख	03-07-2024			
D1	14:58			
D2				
D3				
तारिख	03	07	2024	
D1	22.59	23.45		
D2	23:47	00.34		
D3	00.36	1:24		

Figure 14 Desander Operation Time Record of MMHPP

MOCDA60X DESANDER

Desander 1

CONTROL MODE AUTO
READY FOR OPERATION READY
ELECTRICAL SYSTEM NORMAL
HYDRAULIC SYSTEM NORMAL
SAND TRAP FLUSHING OFF

MO LNE30-A3020 <<< cm 1.1 CLOSE
MO LNE31-A3020 1.2 CLOSE <<< cm
Unit 1.4 OFF
Unit 1.8 OFF
Unit 1.3 OFF
Unit 1.7 OFF
Unit 1.2 OFF
Unit 1.6 OFF
Unit 1.1 OFF
Unit 1.5 OFF

Desander 2

CONTROL MODE AUTO
READY FOR OPERATION READY
ELECTRICAL SYSTEM NORMAL
HYDRAULIC SYSTEM NORMAL
SAND TRAP FLUSHING OFF

MO LNE40-A3020 <<< cm 2.1 CLOSE
MO LNE41-A3020 2.2 CLOSE <<< cm
Unit 2.4 OFF
Unit 2.8 OFF
Unit 2.3 OFF
Unit 2.7 OFF
Unit 2.2 OFF
Unit 2.6 OFF
Unit 2.1 OFF
Unit 2.5 OFF

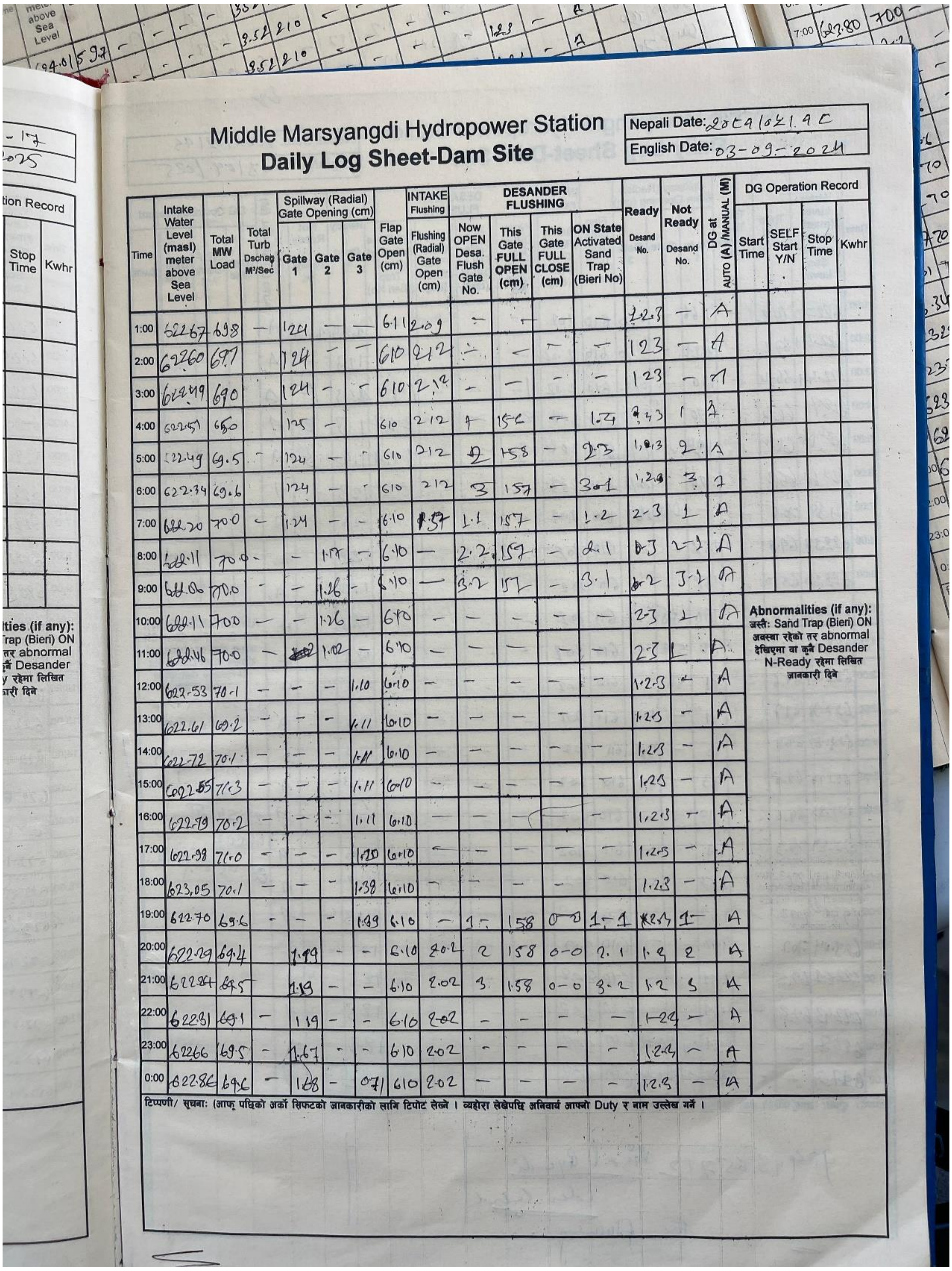
Desander 3

CONTROL MODE AUTO
READY FOR OPERATION READY
ELECTRICAL SYSTEM NORMAL
HYDRAULIC SYSTEM NORMAL
SAND TRAP FLUSHING OFF

MO LNE50-A3020 <<< cm 3.1 CLOSE
MO LNE51-A3020 3.2 CLOSE <<< cm
Unit 3.4 OFF
Unit 3.8 OFF
Unit 3.3 OFF
Unit 3.7 OFF
Unit 3.2 OFF
Unit 3.6 OFF
Unit 3.1 OFF
Unit 3.5 OFF

Figure 15 SCADA Layout of three Desander Units of MMHPP

Figure 16 Two Desander units of UT3A HPP



Middle Marsyangdi Hydropower Station

Daily Log Sheet-Dam Site

Nepali Date: 2081/05/18

English Date: 03-09-2024

Time	Intake Water Level (masl) meter above Sea Level	Total MW Load	Total Turb Dschag M³/Sec	Spillway (Radial) Gate Opening (cm) Gate 1	Gate 2	Gate 3	Flap Gate Open (cm)	INTAKE Flushing: Flushing (Radial) Gate Open (cm)	DESANDER FLUSHING: Now OPEN Desa. Flush Gate No.	This Gate FULL OPEN (cm)	This Gate FULL CLOSE (cm)	ON State Activated Sand Trap (Bieri No)	Ready Desand No.	Not Ready Desand No.	DG at AUTO (A) /MANUAL (M)	DG Operation Record: Start Time	SELF Start Y/N	Stop Time	Kwhr
1:00	62267	69.8	–	124	–	–	6.11	2.09	–	–	–	–	1.2.3	–	A				
2:00	62260	69.7		124	–	–	610	212	–	–	–	–	123	–	A				
3:00	622.49	690		124	–	–	610	2.12	–	–	–	–	123	–	A				
4:00	622.51	68.0		125	–		610	212	1	156	–	1.4	2,3	1	A				
5:00	622.49	69.5	–	124	–	–	610	212	2	158	–	2.3	1,3	2	A				
6:00	622.34	69.6		124	–	–	610	212	3	157	–	3.1	1,2	3	A				
7:00	622.20	70.0	–	1.24	–	–	6.10	1.57	1.1	157	–	1.2	2-3	1	A				
8:00	622.11	70.0	–	–	1.17	–	6.10	–	2.2	157	–	2.1	1-3	2-1	A				
9:00	622.06	70.0	–	–	1.26	–	6.10	–	3.2	157	–	3.1	1-2	3-1	A				
10:00	622.11	70.0	–	–	1.26	–	6.10	–	–	–	–	–	2-3	1	A				
11:00	622.46	70.0	–	[illegible]	1.02	–	6.10	–	–	–	–	–	2.3	1	A				
12:00	622.53	70.1	–	–	–	1.10	6.10	–	–	–	–	–	1.2.3	–	A				
13:00	622.61	69.2	–	–	–	1.11	6.10	–	–	–	–	–	1.2.3	–	A				
14:00	622.72	70.1	–	–	–	1.11	6.10	–	–	–	–	–	1.2.3	–	A				
15:00	622.55	71.3	–	–	–	1.11	6.10	–	–	–	–	–	1.2.3	–	A				
16:00	622.79	70.2	–	–	–	1.11	6.10	–	–	–	–	–	1.2.3	–	A				
17:00	622.98	71.0	–	–	–	1.20	6.10	–	–	–	–	–	1.2.3	–	A				
18:00	623.05	70.1	–	–	–	1.38	6.10	–	–	–	–	–	1.2.3	–	A				
19:00	622.70	69.6	–	–	–	1.39	6.10	–	1	158	0-0	1-1	*2.3	1	A				
20:00	622.29	69.4		1.99	–	–	6.10	2.02	2	158	0-0	2.1	1.3	2	A				
21:00	622.84	69.5		1.19	–	–	6.10	2.02	3	1.58	0-0	3.2	1.2	3	A				
22:00	622.31	69.1	–	1.19	–	–	6.10	2.02	–	–	–	–	1.2.3	–	A				
23:00	622.66	69.5	–	1.67	–	–	6.10	2.02	–	–	–	–	1.2.3	–	A				
0:00	622.86	69.6	–	1.68	–	0.71	610	2.02	–	–	–	–	1.2.3	–	A				

Abnormalities (if any):
जस्तै: Sand Trap (Bieri) ON अवस्था रहेको तर abnormal देखिएमा वा कुनै Desander N-Ready रहेमा लिखित जानकारी दिने

टिप्पणी/ सूचना: (आफू पछिको अर्को सिफटको जानकारीको लागि टिपोट लेख्ने । व्यहोरा लेखेपछि अनिवार्य आफ्नो Duty र नाम उल्लेख गर्ने ।

Figure 17 Daily Log Sheet-Dam Site of MMHPP

Figure 18 Sediment Concentration Measurement using Sieve shaker machine

Figure 19 Measuring various Dimensions of Desander of MMHPP

ANNEXURE D: TRAPEZOIDAL INTEGRATION TABLE

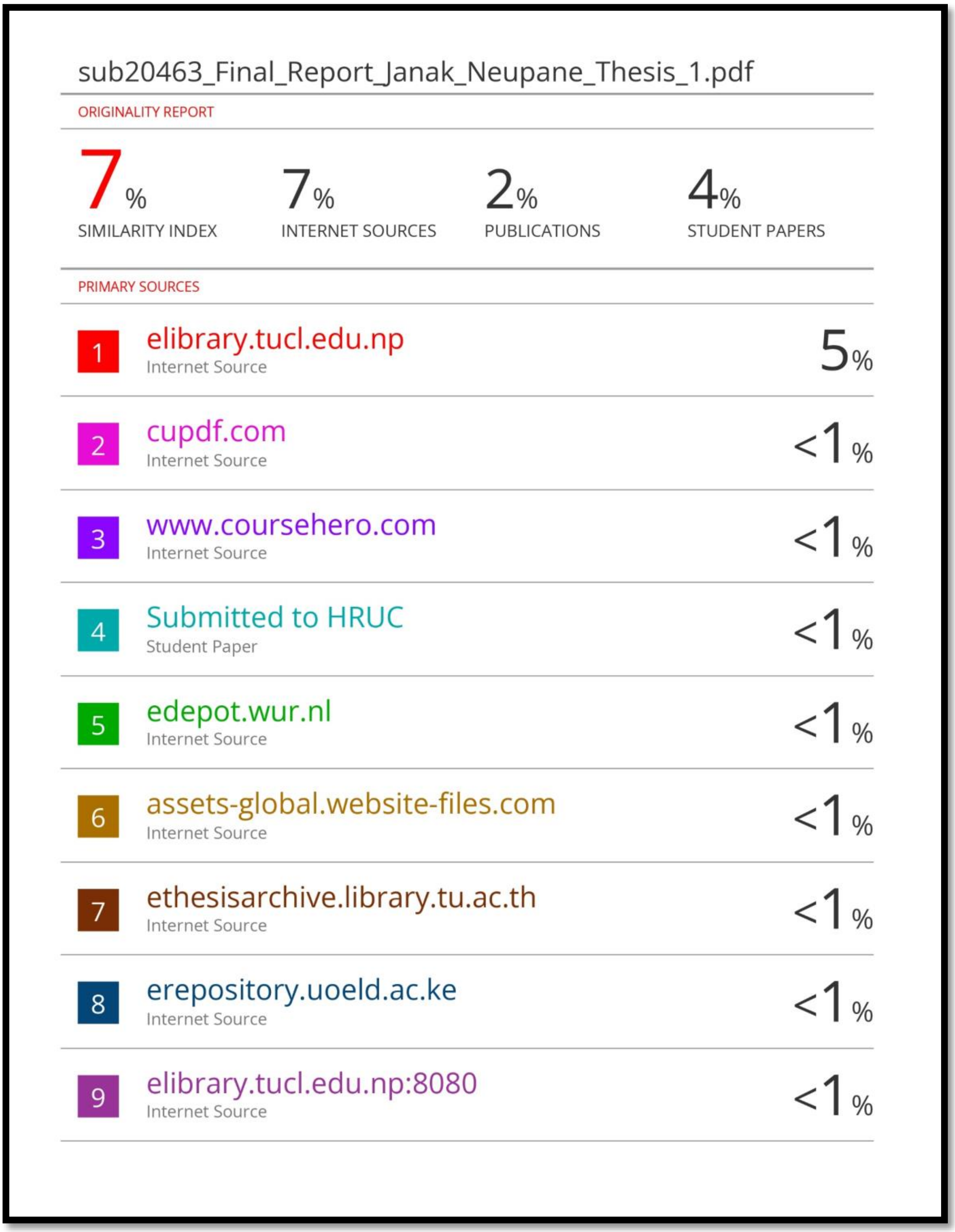
Table 7 Measurement of Water Level during all time intervals

Interval	Time interval (s)	depth of water in cm (h_i)	h_{i+1} in cm	Average Depth in m	Volume (Vi) in m^3
1	0–30	0.00	0.13	0.0007	0.14
2	30–60	0.13	0.27	0.0020	0.42
3	60–90	0.27	0.40	0.0034	0.70
4	90–120	0.40	0.54	0.0047	0.98
5	120–150	0.54	0.67	0.0060	1.26
6	150–180	0.67	0.81	0.0074	1.55
7	180–210	0.81	0.94	0.0087	1.83
8	210–240	0.94	1.07	0.0101	2.11
9	240–270	1.07	1.21	0.0114	2.39
10	270–300	1.21	1.34	0.0128	2.67
11	300–330	1.34	1.48	0.0141	2.95
12	330–360	1.48	1.61	0.0154	3.23
13	360–390	1.61	1.75	0.0168	3.51
14	390–420	1.75	1.88	0.0181	3.79
15	420–450	1.88	2.02	0.0195	4.07
16	450–480	2.02	2.15	0.0208	4.35
17	480–510	2.15	2.28	0.0222	4.64
18	510–540	2.28	2.42	0.0235	4.92
19	540–570	2.42	2.55	0.0249	5.20
20	570–600	2.55	2.69	0.0262	5.48
21	600–630	2.69	2.82	0.0275	5.76
22	630–660	2.82	2.96	0.0289	6.04
23	660–690	2.96	3.09	0.0302	6.33
24	690–720	3.09	3.22	0.0316	6.61
25	720–750	3.22	3.36	0.0329	6.89
26	750–780	3.36	3.49	0.0343	7.17
27	780–810	3.49	3.63	0.0356	7.45
28	810–840	3.63	3.76	0.0369	7.73
29	840–870	3.76	3.90	0.0383	8.01
30	870–900	3.90	4.03	0.0396	8.29
31	900–930	4.03	4.16	0.0405	8.48
32	930–960	4.16	4.30	0.0415	8.69
33	960–990	4.30	4.43	0.0437	9.13
34	990–1020	4.43	4.57	0.0450	9.40
35	1020–1050	4.57	4.70	0.0464	9.73
36	1050–1080	4.70	4.84	0.0483	10.09
37	1080–1110	4.84	4.97	0.0485	10.15
38	1110–1140	4.97	5.11	0.0504	10.54
39	1140–1170	5.11	5.24	0.0517	10.82
40	1170–1200	5.24	5.37	0.0529	11.03
41	1200–1230	5.37	5.51	0.0544	11.38
42	1230–1260	5.51	5.64	0.0558	11.66

43	1260–1290	5.64	5.78	0.0571	11.95
44	1290–1320	5.78	5.91	0.0583	12.21
45	1320–1350	5.91	6.05	0.0598	12.51
46	1350–1380	6.05	6.18	0.0611	12.79
47	1380–1410	6.18	6.31	0.0624	13.07
48	1410–1440	6.31	6.31	0.0631	13.20
49	1440–1470	6.31	6.18	0.0624	13.07
50	1470–1500	6.18	6.05	0.0612	12.81
51	1500–1530	6.05	5.91	0.0598	12.51
52	1530–1560	5.91	5.78	0.0578	12.09
53	1560–1590	5.78	5.64	0.0571	11.93
54	1590–1620	5.64	5.51	0.0558	11.66
55	1620–1650	5.51	5.37	0.0544	11.38
56	1650–1680	5.37	5.24	0.0529	11.03
57	1680–1710	5.24	5.11	0.0517	10.82
58	1710–1740	5.11	4.97	0.0499	10.42
59	1740–1770	4.97	4.84	0.0495	10.36
60	1770–1800	4.84	4.70	0.0487	10.18
61	1800–1830	4.70	4.57	0.0473	9.91
62	1830–1860	4.57	4.43	0.0460	9.62
63	1860–1890	4.43	4.30	0.0448	9.37
64	1890–1920	4.30	4.16	0.0423	8.84
65	1920–1950	4.16	4.03	0.0430	8.98
66	1950–1980	4.03	3.90	0.0413	8.63
67	1980–2010	3.90	3.76	0.0383	7.99
68	2010–2040	3.76	3.63	0.0370	7.76
69	2040–2070	3.63	3.49	0.0346	7.24
70	2070–2100	3.49	3.36	0.0333	6.95
71	2100–2130	3.36	3.22	0.0329	6.88
72	2130–2160	3.22	3.09	0.0316	6.61
73	2160–2190	3.09	2.96	0.0302	6.32
74	2190–2220	2.96	2.82	0.0289	6.04
75	2220–2250	2.82	2.69	0.0275	5.76
76	2250–2280	2.69	2.55	0.0262	5.48
77	2280–2310	2.55	2.42	0.0249	5.20
78	2310–2340	2.42	2.28	0.0235	4.91
79	2340–2370	2.28	2.15	0.0222	4.63
80	2370–2400	2.15	2.02	0.0208	4.35
81	2400–2430	2.02	1.88	0.0195	4.07
82	2430–2460	1.88	1.75	0.0181	3.79
83	2460–2490	1.75	1.61	0.0168	3.51
84	2490–2520	1.61	1.48	0.0155	3.23
85	2520–2550	1.48	1.34	0.0141	2.95
86	2550–2580	1.34	1.21	0.0128	2.67
87	2580–2610	1.21	1.07	0.0114	2.38
88	2610–2640	1.07	0.94	0.0101	2.11
89	2640–2670	0.94	0.81	0.0087	1.83

90	2670–2700	0.81	0.67	0.0074	1.55
91	2700–2730	0.67	0.54	0.0060	1.26
92	2730–2760	0.54	0.40	0.0047	0.98
93	2760–2790	0.40	0.27	0.0034	0.70
94	2790–2820	0.27	0.13	0.0020	0.42
95	2820–2850	0.13	0.00	0.0007	0.14
Rectangular (Riemann sum) volume estimate					**634**
Numerically integrated total flushing volume					**1268**

ANNEXURE E: PLAGIARISM TEST REPORT



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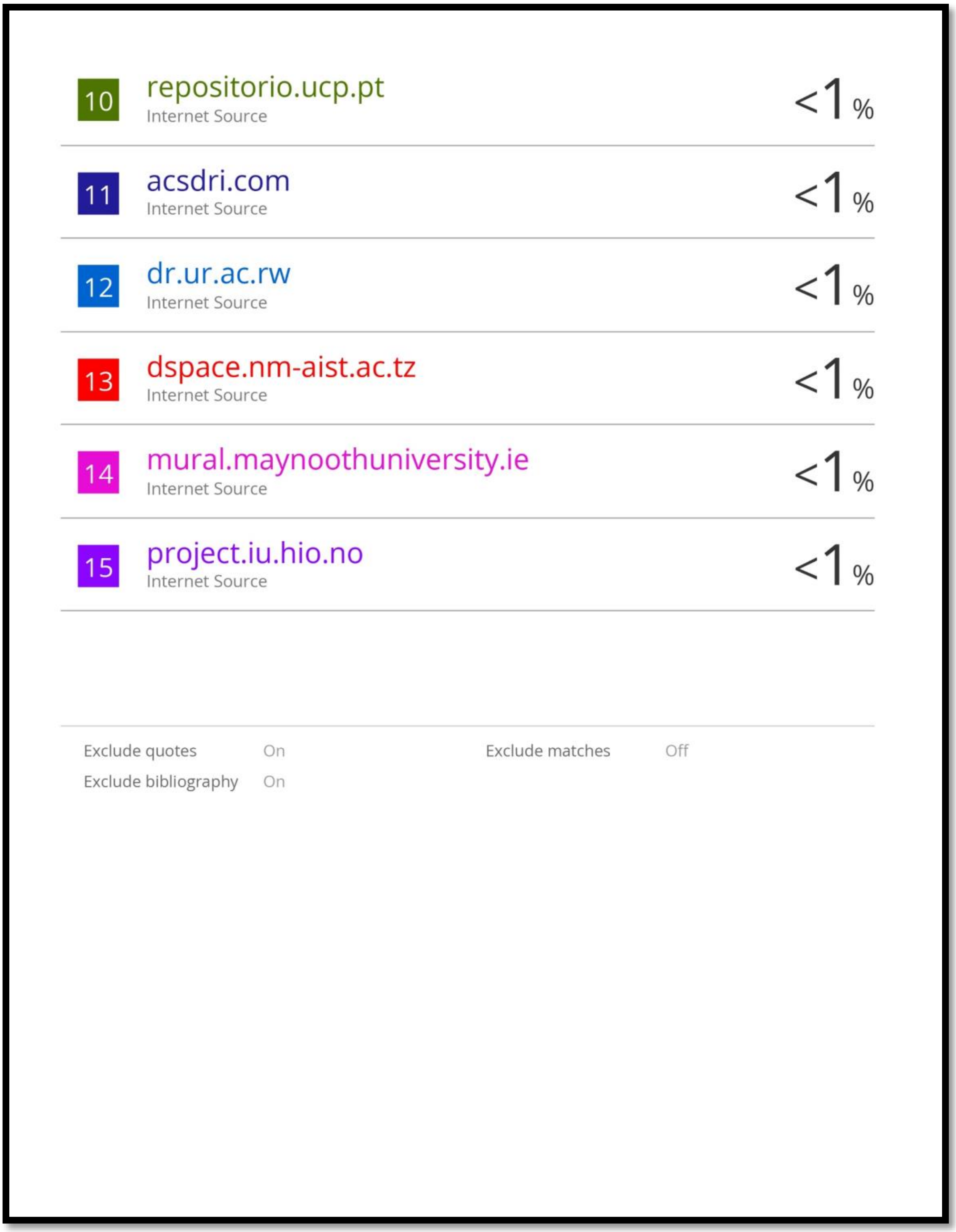

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