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Operation Optimization Based Upon Discharge and Power Requirement of Middle Marsyangdi Hydropower Station

by

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A THESIS

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The undersigned certify that they have read, and recommended to the Institute of Engineering for acceptance, a thesis entitled **"Operation Optimization Based Upon Discharge and Power Requirement of Middle Marsyangdi Hydropower Station"** submitted by Mr. Sajan Shrestha in partial fulfillment of the requirements for the degree of Master in Renewable Energy Engineering.

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ABSTRACT

This research studied the condition of units of Middle Marsyangdi Hydropower Station. The study was focused to determine state of each unit. Amongst the two units, Unit 2 was found to have 0.28m lower head loss than Unit 1. But, Unit 1 was found to have 3.68% higher efficiency than Unit 2.

Optimal power generation that could be achieved with any given total discharge and any value of gross head was determined. Similarly, the minimum discharge required to meet any particular power demand at any value of gross head was also determined.

Based on the study of state of individual unit and optimization solution, comparison of optimal operation for each second of a day with operation from historical data of the power plant was done for eight days. The comparison of actual operation and the optimal operation shows that generation gain of 1.66-7.20% from same discharge and discharge saving of 1.58-4.96% for same generation is possible through optimal operation.

ACKNOWLEDGEMENTS

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LIST OF ABBREVIATIONS

cumec	cubic meter per second
DCS	Distributed Control System
el.	elevation
Eq.	Equation
GDP	Gross Domestic Product
GRG	Generalized Reduced Gradient
IEA	International Energy Agency
INPS	Integrated Nepal Power System
IPP	Independent Power Producer
IGHEM	International Group for Hydropower Efficiency Measurement
PPP	Purchasing Power Parity
LDC	Load Dispatch Center
masl	meter above sea level
MMHPS	Middle Marsyangdi Hydropower Station
NEA	Nepal Electricity Authority
PROR	Peaking Run-Off-River
ROR	Run-Off-River
SQQ	Sequential Quadratic Programming
USBR	United States Bureau of Reclamation
WECS	Water and Energy Commission Secretariat

CHAPTER ONE: INTRODUCTION

1.1. Background

Energy resources are the backbone of development for any country. Especially in developing countries as Nepal with the average GDP (PPP) per capita income around US$ 409 (IEA 2015), it is of primary importance. Nepal relies heavily on traditional energy resources. The average per capita energy consumption of Nepal is around 15.49 GJ per year (IEA 2015), which is one of the lowest in the world. Total energy consumption in Nepal for year 2008/2009 was 400.51 million GJ (WECS 2010). Energy mix of Nepal is composed of 87% Biomass (77.7% is met by firewood alone), 8.2% Petroleum, 2% Electricity and renewable less than 1% (WECS 2010). Total energy consumption in the country has increased by about 2.4% per annum only but electricity consumption is growing with an annual rate of about 10% between the years 2000/01 and 2008/09 (WECS 2010).

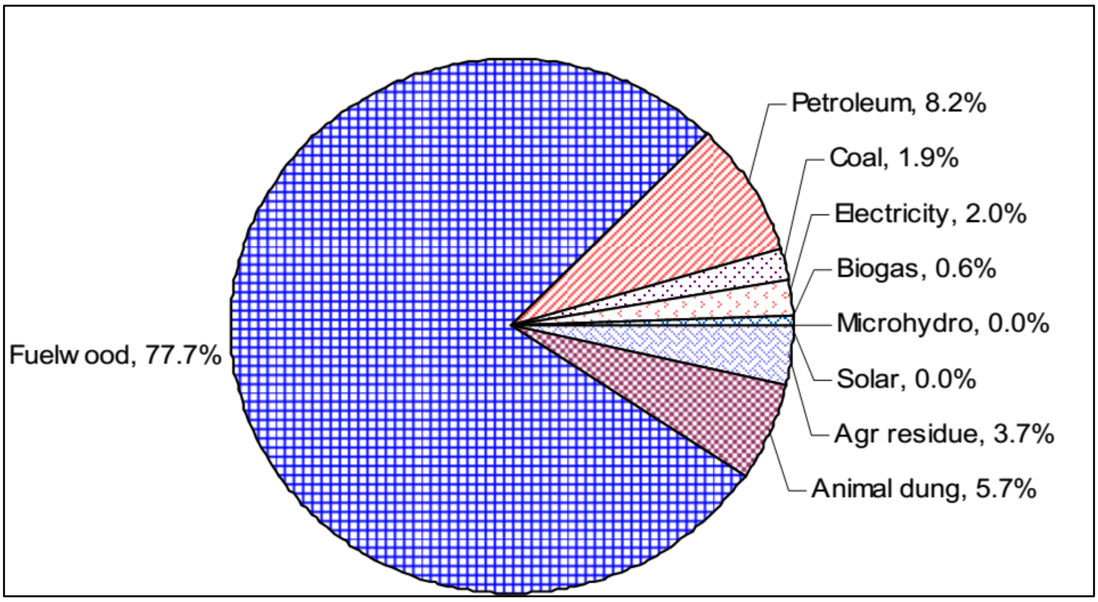

Figure 1.1: Total Energy Consumption by Fuel type (WECS 2010)

With the increasing growth rate of customers availing electricity services of NEA, the power and energy demand is also increasing accordingly. In 2015/16, the numbers of customers grew by 4.82% as compared to that of previous year (NEA 2016). Accordingly the peak power demand and energy demand also grew by 7.30% and 8.25%, respectively in that year (NEA 2016). This growth is more significant in residential and industrial sector and a little less in other development sectors.

1.2. Problem Statement

Even though the peak power demand and energy demand has continuously increased, increase in electricity generation is not in par with demand. Total installed capacity of INPS grid (NEA-grid and IPP combined) is 851.25MW only as compared to peak power demand of 1385.3MW (NEA 2016). This results in deficit of 534.05MW even in wet seasons. This difference is further exacerbated in dry months of year.

It is of utmost importance that new hydropower plants are timely constructed and are connected to INPS so that growing electricity demand is met. But due to long gestation period needed for development of hydropower plants, other avenues for meeting electricity demand have to be looked into. Demand side management could reduce peak power demand and energy demand itself. Optimal utilization of existing hydropower plants can generate additional energy as well as help in meeting portion of peak power demand especially during dry season. This research focuses on optimizing generation from a particular hydropower plant.

1.3. Research Objectives

1.3.1. Main Objective

To optimize daily energy generation of Middle Marsyangdi Hydropower Station by discharge commitment for different units based upon performance of individual units during period of limited discharge availability in Marsyangdi River

1.3.2. Specific Objectives

i. To determine head loss of individual units and compare them with designed value

ii. To determine current performance of individual units for various head and discharge condition, based upon recent data available from Middle Marsyangdi Hydropower Station log

iii. To optimize total power generated for each instant for maximizing daily energy generation of the plant

iv. To optimize flow to meet a particular value of power demand for each instant to minimize total daily volume of water used

1.4. Limitations

- Plant operators cannot continuously make adjustments to stick to the optimal operation conditions.
- The calculations have to be updated frequently to remain relevant to changing conditions of plant equipment. It is only possible if a system of retrieving data and making necessary calculations are integrated in the SCADA system.
- No useful data are available for a unit after its overhauling. The plant may not be operated in optimal condition during the duration of collection of sufficient data for operation of that unit after overhauling.
- Faulty instrumentation can lead to inoperable conditions. Redundancy of sensors and instruments may be required for a reliable operation.

CHAPTER TWO: LITERATURE REVIEW

2.1. Bernoulli's Principle

Bernoulli's equation states that, for steady flow of a frictionless fluid along a streamline, the total energy per unit weight remains constant from point to point although its division between the three forms of energy may vary. The three terms of Bernoulli's equation are the pressure energy per unit weight, the kinetic energy per unit weight and the potential energy per unit weight; the constant is the total energy per unit weight.

Pressure energy per unit weight + Kinetic energy per unit weight
+ Potential energy per unit weight = Total energy per unit weight
(constant)

$$\frac{P}{\rho * g} + \frac{v^2}{2 * g} + z = H \qquad \text{Eq. (2.1)}$$

where, P is fluid pressure

v is fluid velocity

z is elevation

ρ is fluid density

g is acceleration due to gravity

Between any two points, 1 and 2, Eq. (2.1) becomes,

$$\frac{P_1}{\rho * g} + \frac{v_1^2}{2 * g} + z_1 = \frac{P_2}{\rho * g} + \frac{v_2^2}{2 * g} + z_2 \qquad \text{Eq. (2.2)}$$

In Eq. (2.2), it has been assumed that energy has not been supplied to or taken from the fluid between the two points. Energy could be supplied to the fluid by device like pump, or could be lost by friction, or extracted by doing work in machine like turbine. The Bernoulli's equation is modified to include these conditions as follows,

$$\frac{P_1}{\rho * g} + \frac{v_1^2}{2 * g} + z_1 = \frac{P_2}{\rho * g} + \frac{v_2^2}{2 * g} + z_2 + h_l + w - e \qquad \text{Eq. (2.3)}$$

where, h_l is energy lost per unit weight due to friction, w is work done per weight by the fluid, and

e is energy supplied per unit weight to the fluid

2.2. Head loss

For bounded flow, such as in a pipe, the velocity of the fluid is zero at the boundary and increases to a maximum at the center of the pipe. There is a velocity gradient and, thus, shear stresses in the fluid. In order to maintain flow, additional forces must do work on the fluid. In other words, there must be a continuous supply of energy for the flow to exist. This energy, supplied solely to maintain flow in a bounded system, is usually expressed per unit weight of the fluid flowing. This head (or energy) is considered as lost because it cannot be used for any other purpose than to maintain flow and hence it is called head loss.

2.2.1. Frictional head loss

Frictional head loss is conveniently expressed for all types of fully developed internal flows by Darcy-Weisbach equation.

$$h_f = \frac{f * l * \left(v_{avg}\right)^2}{2 * g * d} \qquad \text{Eq. (2.4)}$$

where, h_f is frictional head loss

f is friction factor,

l is length of the closed conduit,

v_{avg} is average flow velocity, and

d is diameter of the closed conduit.

The friction factor, f, is given by empirical formulae which is also represented in the form of Moody's chart.

2.2.2. Separation losses

Drop in pressure is observed whenever a uniform cross section of a pipeline is interrupted by pipe fitting or flow measurement device. The flow separates from the pipe walls as it passes through the obstruction, resulting in eddies in the flow, with consequent pressure loss. The values of separation losses, which are sometimes misleadingly referred to as 'minor losses', have to be included in a pipeline's total resistance if errors in flow calculations are to be avoided.

- Separation losses in sudden expansion and contraction

$$h_s = \left(\frac{A_2}{A_1} - 1\right)^2 * \frac{\overline{u_2}^2}{2 * g} \qquad \text{Eq. (2.5)}$$

where, h_s is separation head loss due to sudden expansion,

A_1 is cross sectional area before expansion,

A_2 is cross sectional area after expansion,

$\overline{u_2}$ is average flow velocity after expansion

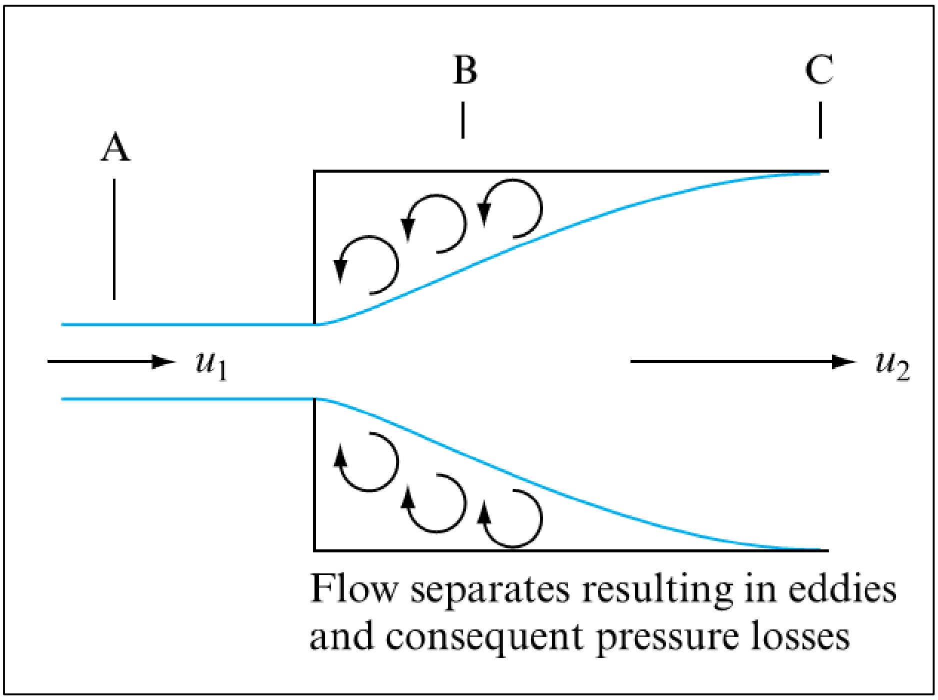

Figure 2.1: Separation loss in sudden expansion (Douglas, et al. 2006)

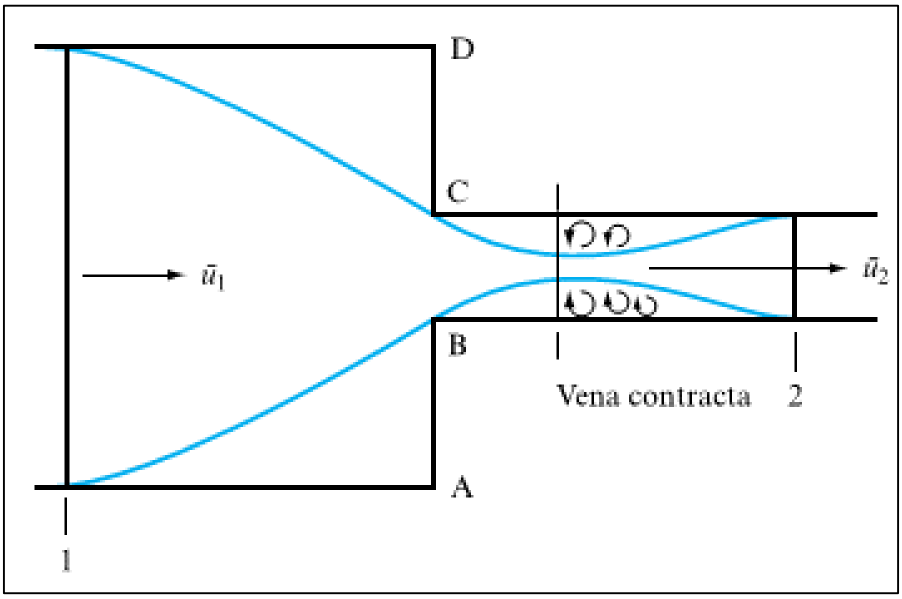

Figure 2.2: Separation loss in sudden contraction (Douglas, et al. 2006)

$$h_s = K * \frac{\overline{u_2}^2}{2 * g} \qquad \text{Eq. (2.6)}$$

where, h_s is separation head loss due to sudden contraction, and

K is loss coefficient.

Table 2.1: Loss coefficients for sudden contraction (Douglas, et al. 2006)

A_2/A_1	0.1	0.3	0.5	0.7	1.0
K	0.41	0.34	0.24	0.14	0

- Separation losses in pipe fittings, bends and at pipe entry

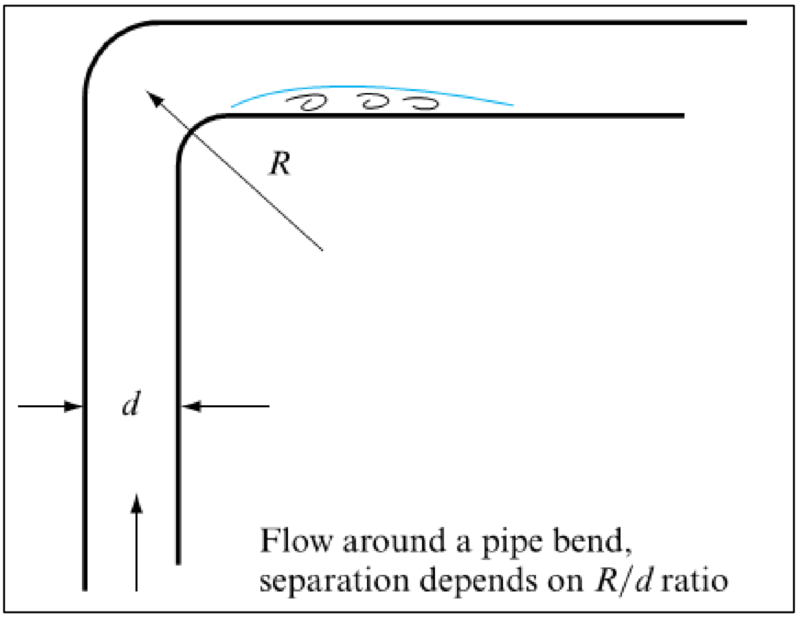

Figure 2.3: Separation loss in bends (Douglas, et al. 2006)

Separation losses in pipe fittings, bends and at pipe entrance are expressed in the form as Eq. (2.6).

Table 2.2: Head loss coefficients for a range of pipe fittings (Douglas, et al. 2006)

Fitting	**Loss coefficient K**
Gate valve (open to 75 per cent shut)	0.25 →25
Globe valve	10
Spherical plug valve (fully open)	0.1
Pump foot valve	1.5
Return bend	2.2
90° elbow	0.9
45° elbow	0.4
Large-radius 90° bend	0.6
Tee junction	1.8
Sharp pipe entry	0.5
Radius pipe entry	→0.0
Sharp pipe exit	0.5

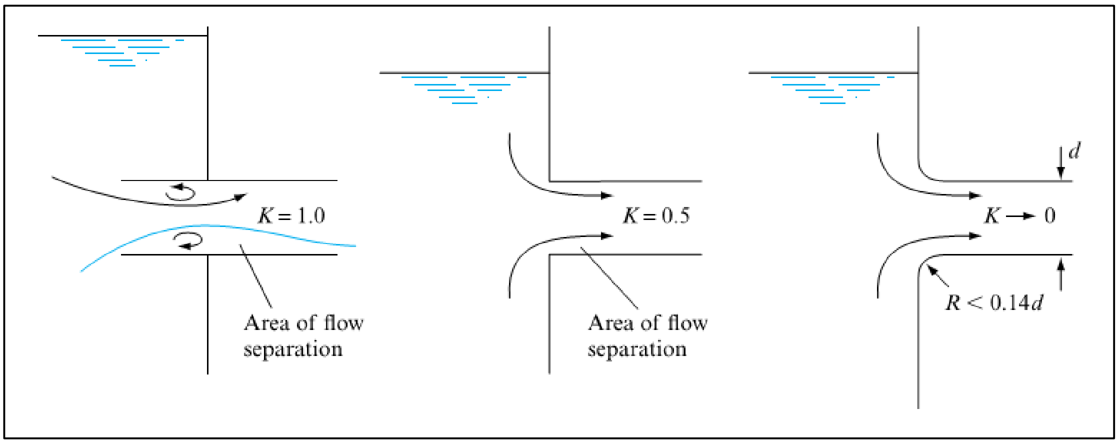

Figure 2.4: Separation loss coefficients for pipe entry (Douglas, et al. 2006)

2.3. Theory of Optimization

The objective of mathematical optimization is to minimize or maximize a specified mathematical expression. This expression is known as an objective function.

As shown in Figure 2.5 below, optimization approaches can be divided into traditional (calculus based) optimization algorithms and heuristic algorithms. The latter class of optimization methods may also be described as meta-heuristics or heuristic optimizers, depending on the author and the source.

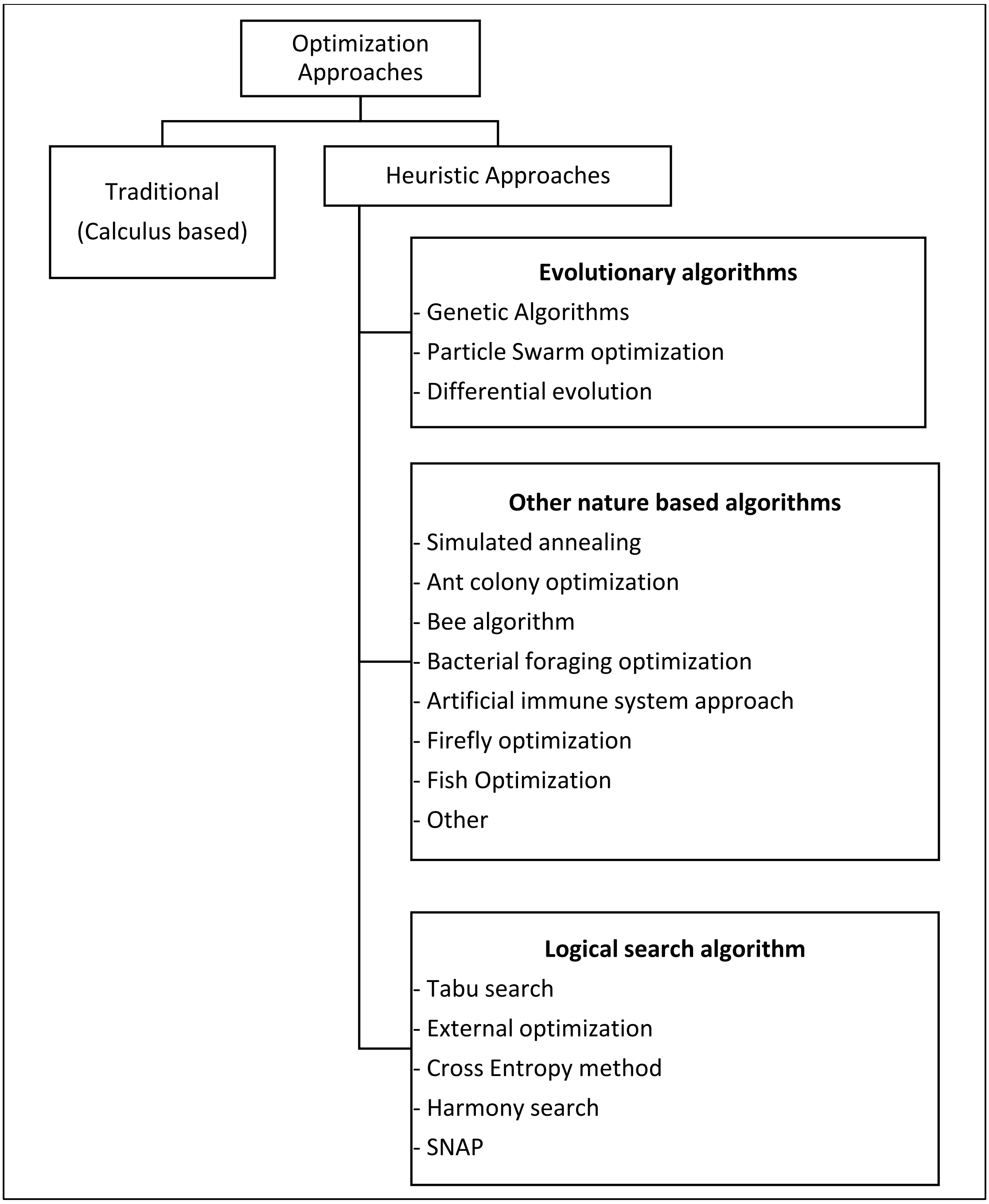

Figure 2.5: Taxonomy of Optimization Process (USBR 2012)

2.3.1. Traditional Method

Optimization problems have traditionally been addressed with a variety of traditional calculus based methods commonly referred to as "traditional" or calculus based approaches. Calculus based optimization approaches are routinely taught to all engineers and economists.

Since the time of Sir Isaac Newton, mathematicians, economists and engineers have collectively devoted vast amounts of effort to the study of optimization, with a particular focus on convex optimization problems with constraints. Numerical solution of convex optimization problems is typified by the Newton Raphson approach and its many variants. This approach has been taught to engineers and economists since the early 1950's.

Newton-Raphson approach has been largely supplanted by some of its recent and more advanced variants. At the present time, two approaches are in the forefront of current calculus based optimization technology. These are the sequential quadratic programming (SQQ) method and the generalized reduced gradient (GRG) method. The SQQ method is often used in high-end commercially available optimization platforms. The GRG method has found its niche as the optimization solver incorporated in all currently shipping versions of Microsoft Excel. As such, it may well be the world's most frequently used optimization algorithm (USBR 2012).

2.3.2. Heuristic Methods

Heuristic optimization approaches are based on the application of rules and logic which reduce the search space and allow for solution of difficult optimization problems. Generalizing rather broadly, we can classify these methods into the three categories shown; evolutionary algorithms, other nature based algorithms and logical algorithms.

Evolutionary algorithms are based on the concept of biological evolution. These approaches are based on the improvement of an artificial population of individuals over a series of generations or iterations. Each individual carries a solution to the optimization problem. At each generation, the most-fit individuals in the population reproduce and their offspring survive into the next generation, the less fit individuals die and their inferior genes are lost. The fitness of the population and the quality of the solutions found, improve over time. Genetic algorithms, differential evolution and particle swarm optimization fall into this category of algorithms.

There are an amazing variety of optimization heuristics related to living organisms, their behavior or some other natural physical phenomenon. Among these are ant colony optimization, bee optimization, firefly optimization and a host of others. As might be surmised, some of these algorithms are predicated on the collective food location strategies typified by the species.

2.4. Optimization of Hydropower Plant

Optimization problem of energy generation from an ROR type hydropower plant is that of discharge commitment to different available units based upon difference in performance characteristics of different units. This preferential treatment is able to produce higher energy generation in comparison to equal distribution of discharge to all units because of the fact that performance of all units are not same due to several factors such as difference in length of waterways, alignment, manufacturing tolerances, wear of turbine parts, etc. for different units.

Optimization problem of a PROR hydropower plant is slightly complicated than that of an ROR hydropower plant due to addition of reservoir live capacity. Optimization problem of a ROR plant is to optimally distribute available discharge to different units in order to maximize energy generation from plant. An additional factor- time horizon is added to optimization problem of PROR plant. Optimization problem of PROR plant actually is that of when to distribute volume of water available in reservoir to different units such that energy generation from the plant for the time horizon is maximized. Additional constraints such as maximum and minimum allowable reservoir levels have to be added to optimization problem for PROR hydropower plant. Optimization problem of a PROR plant is as shown in Figure 2.6.

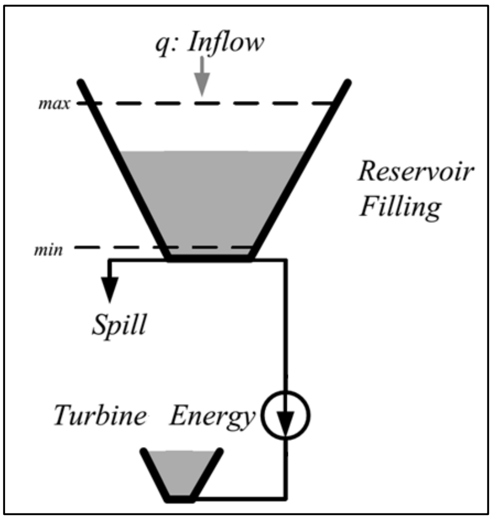

Figure 2.6: Schematic model for optimization problem of a PROR plant

PROR plant may be subjected to another type of optimization problem. The plant may be required to generate power as per requirement from LDC. In this case, the optimization problem is not for maximizing generation but of meeting the power requirement with minimum total discharge of water. Since water is a limited resource in dry season, minimizing total discharge will result in availability of water for later use.

2.5. Optimization Platform

The optimization problem of a hydropower plant deals with optimizing a non-linear but continuous function over a constrained domain. For this type of optimization problem, simplex method is not suitable since it only deals with linear optimization function.

Generalized Reduced Gradient method has been proven to be capable of converging to an optimal value as other optimization algorithms (Lee, Chen and Kang 2004). For optimization problems with few variables and non-complex functions, the number of iterations and the duration required for convergence is actually lower than that required by evolutionary algorithms (Lee, Chen and Kang 2004).

There are several software programming platforms that can solve the non-linear continuous optimization problem but most common platform is Microsoft Excel addin called Solver developed by Frontline Systems Inc. (USBR 2012).

The Excel solver addin has three solving methods, viz. Simplex Method, GRG Non-linear Method and Evolutionary Method. Both GRG Non-linear Method and Evolutionary Method can solve the hydropower optimization problem, but evolutionary method is more suitable for non-linear discontinuous optimization problems. Additionally, the evolutionary method needs more iterations to converge to a solution. Drawback of any evolutionary algorithm is that a solution is better only in comparison to other presently known solutions; such an algorithm actually has no concept of an optimal solution or any way to test whether a solution is optimal. For this reason, evolutionary algorithms are best employed on problems where it is difficult or impossible to test for optimality. This also means that an evolutionary algorithm never knows for certain when to stop, aside from the length of time, or the number of iterations or candidate solutions, that it is allowed to explore.

GRG non-linear algorithm is the fastest method amongst the available two algorithms but the solution obtained with this algorithm is highly dependent on the initial conditions and may not be the global optimum solution as shown in Figure 2.7 below. The solver will most likely stop at the local optimum value nearest to the initial conditions, giving a solution that may or may not be optimized globally.

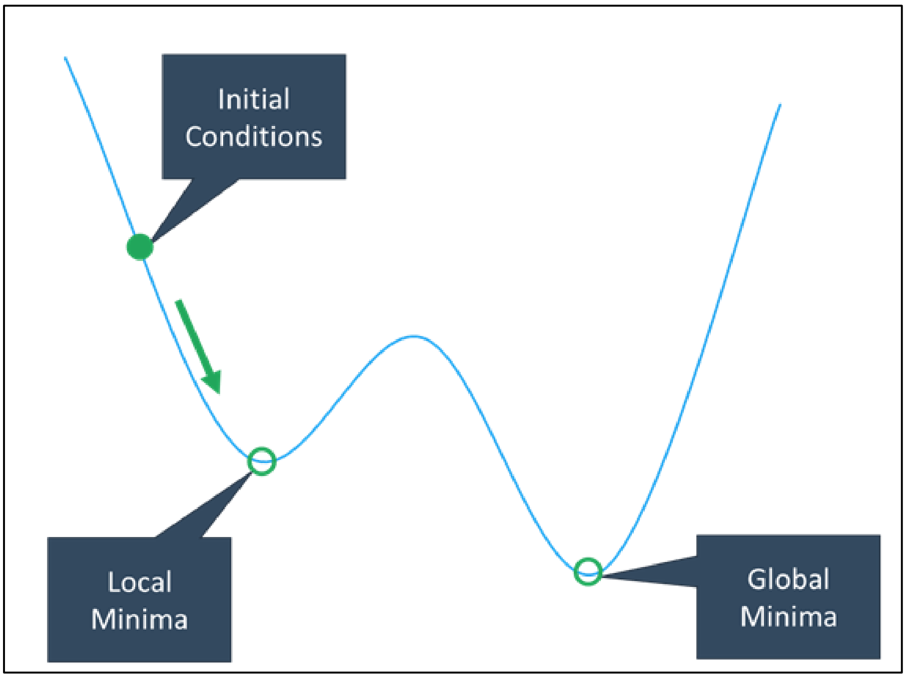

Figure 2.7: GRG Algorithm Problem (Charlie 2017)

This downside of GRG algorithm can be greatly reduced by using GRG Multistart algorithm in Excel solver. This algorithm creates a randomly distributed population of initial values that are each evaluated independently using the traditional GRG Nonlinear algorithm. By starting multiple times from different initial conditions, change of obtaining global optimum solution is very high (Charlie 2017).

2.6. SCADA

Supervisory control and data acquisition (SCADA) is a control system architecture that uses computers, networked data communications and graphical user interfaces for high-level process supervisory management, but uses other peripheral devices such as programmable logic controllers and discrete controllers to interface to the process plant or machinery. The operator interfaces which enable monitoring and the issuing of process commands, such as controller set point changes, are handled through the SCADA supervisory computer system. However, the real-time control logic or controller calculations are performed by networked modules which connect to the field sensors and actuators (Wikipedia Foundation Inc. 2017).

The SCADA concept was developed as a universal means of remote access to a variety of local control modules, which could be from different manufacturers allowing access through standard automation protocols. In practice, large SCADA systems have grown to become very similar to distributed control systems in function, but using multiple means of interfacing with the plant. They can control large-scale processes that can include multiple sites, and work over large distances. It is one of the most commonly-used types of industrial control systems, however there are concerns about SCADA systems being vulnerable to cyberwarfare/cyberterrorism attacks (Wikipedia Foundation Inc. 2017).

2.7. Middle Marsyangdi Hydropower Station

Middle Marsyangdi Hydropower Station was commissioned in 2008. It is currently the second largest power plant of Nepal in terms of installed capacity and third largest in terms of annual generation.

Table 2.3: Salient Features of Middle Marsyangdi Hydropower Station

General	
Type of project	Run of river with daily pondage for 5 hours peaking
Location	Phaliasanghu/ Siundibar (Headworks/ Powerhouse), Lamjung
Maximum gross head/net head (80m^{3}s)	110/98m
Total length of the waterways	5940m
Power and Energy	
Installed capacity	70 MW
Annual average energy	398GWh
Hydrology	
Catchments area	2,729km^2
Average annual flow	99.5m^3/s
Reservoir	
Minimum/ Maximum operating levels	621.0masl/ 626.0masl
Live storage volume	1.65 million m^3
Surface area at maximum operating level	427,000m^2

Dam	
Type of dam	Combined concrete gravity and rockfill dam
Crest el. of dam	629.00/ 630.00masl
Crest length of dam (in total)	95m
Height above foundation	34.50m
Spillway capacity	4,270m^3/s(Design flood,10,000 years return period) at headwater level of 626.00 masl
Spillway gates	3 Radial gates, W*H =12.00*19.54m
Energy dissipation	Roller bucket
Intake Structures	
Type	Submerged tunnel intakes with trash racks and gates.
Sill/Platform levels	616.00 masl/ 629.00 masl
Length	25m (intake structure) 70-75m connecting tunnels to Desanding basins)
Desanding basins	
Type	Underground desander in caverns
Length/ width/ height per cavern	130m/15m-27m
Number of basins	6 accommodated in 3caverms,i. e. 2 in each
Length/ width/ height per basins	100.75/ 7.50m/ 25.10m
Efficiency	95% of particle size 0.2 mm, maximum sediment concentration 20,000 ppm
Flushing operation	Vertical flushing; BIERI system.
Operating levels (80m^3/s)	Max. el. 626.0masl
Power Tunnel and Surge Tank	
No. of adits	5
Diameter	5.4m
Length (1,2,3, Valve chamber, Surge Tank	390m, 390m, 670m, 175m, 230m
Power Tunnel (low pressure line)	
Length	5,230m (between desander outlet and surge tank)
Excavated tunnel diameter	6.20m (branch tunnels=4.90m)
Lined tunnel diameter	5.40m (branch tunnels=4.30m)
Lining	Concrete, partly reinforced
Surge tank	
Type	Vertical, circular surge tank, underground, concrete lined with throttle
Net diameter	20m, orifice Ø 2.90m
Height	45m
Max. up-/ down surge	el.640.93/ el.606.71 masl
Power tunnel (high pressure line)	
Length	225m (between surge tank and discharge measurement chamber)
Excavated tunnel diameter	5.80m
Lined tunnel diameter	4.60m
Lining	Steel

Penstock	
Number, Type	1, concrete cased steel pipe (cut and cover)
Diameter penstock/bifurcation-manifold	Ø 4.60m / Ø3.00m to Ø2.60m
Length	212-218m (between discharge measurement chamber and turbine inlet valve)
Powerhouse and Service Building	
Type	Concrete structure below the ground constructed in an open excavation pit, 27m deep. Service building on top, above ground with bridge crane
Bridge Crane capacity	130/10 tons
Tailrace length	42.2m
Switchyard at MMHPS	
Type	Open - air switchyard at el. 540.00 masl
Dimensions (L×W)	43×50m
Turbines	
Number and Type	2 Francis, vertical shaft
Rated discharge	40 m^3/s
Gross head	110m
Rated output	35.9MW
Rated speed	333.33rpm
Axis of scroll case	515masl
Tailrace level	517masl
Generators	
Number and Type	Two,3-phase synchronous
Rated output	39 MVA
Rated voltage	11kv±7.5%
Rated frequency	50Hz
Power factor	0.85-0.90
Rated speed	333.33rpm (18 poles)
Fly wheel effect(GD2)	600 tm^2
Transmission line	
Route	Middle Marsyangdi HPS-Lower Marsyangdi HPS
Nominal voltage/Length	132 kv,38.2 km

(NEA, Generation Operation and Maintenance Group 2013)

Intake level is measured at reservoir through a level sensor. Water is taken through headrace intake. Desilting occurs at three underground desanders. Water travels through a single headrace tunnel to the valve chamber. A penstock valve (butterfly valve) is located at valve chamber. Headrace tunnel pressure is measured just before the penstock valve. Water then flows through a single steel lined inclined penstock to

Discharge Measurement Chamber (DMC). Flow in penstock is measured at DMC. Penstock bifurcates just downstream of DMC into two penstock of equal diameter. Discharge is divided as per opening of guide vanes of individual units. Pressure is measured just before Main Inlet Valve (MIV). Both MIVs are also of butterfly valve type. Pressure is also measured at spiral case. Discharge then passes through Francis runner. Outlet pressure is measured at draft tube. Then the water is discharged back into Marsyangdi river (tailrace level). Figure 2.8 below is the schematic diagram of waterways of MMHPS.

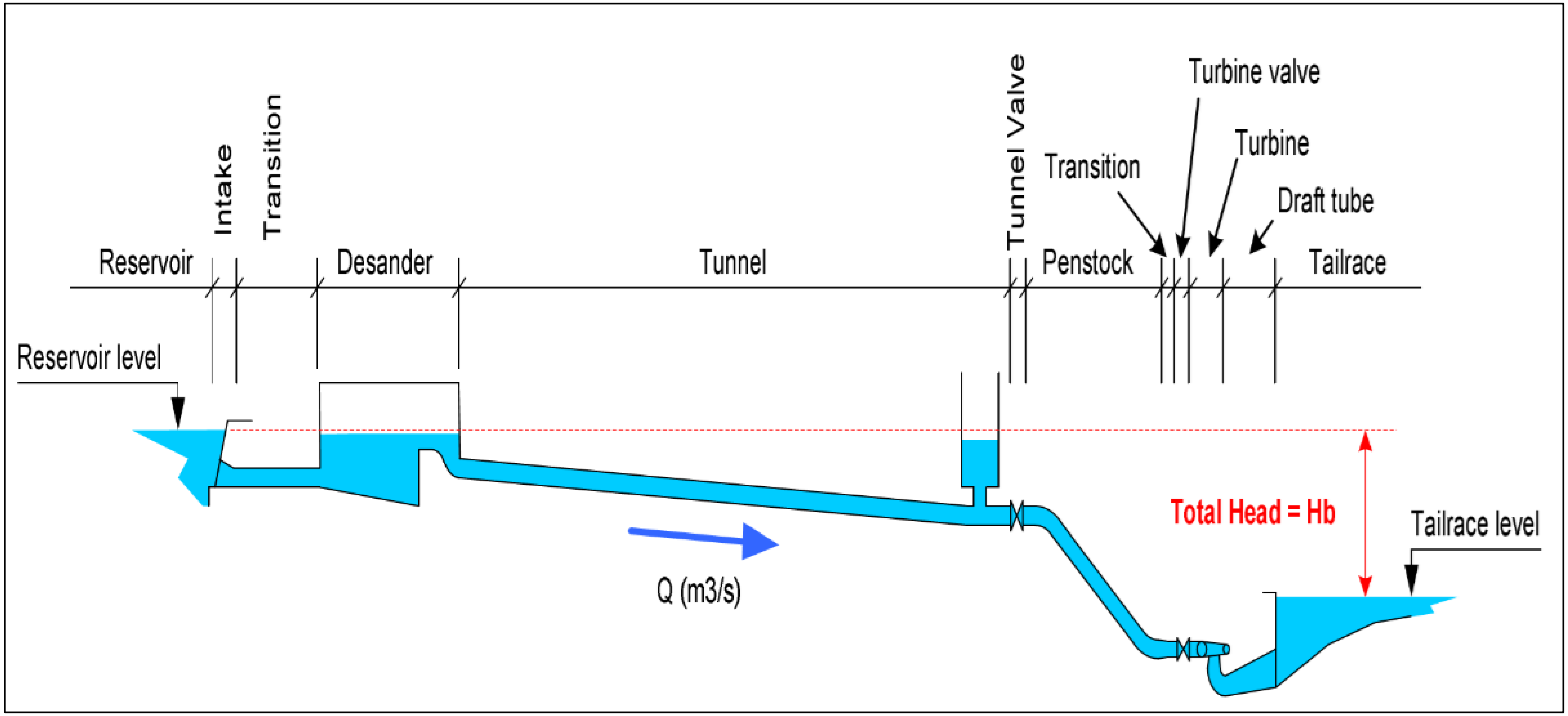

Figure 2.8: Schematic of Waterway of MMHPS

CHAPTER THREE: RESEARCH METHODOLOGY

3.1. Methodology

Methodology as shown in Figure 3.1 below was implemented during the research:

Problem Formulation

- Problem Identification
- Development of Problem Statement

Objectives

- Determination of Main Objective
- Determination of Specific Objectives

Literature Review

- International Journals
- Internet
- Earlier Research and Thesis Report

Optimization Model Development

- Definition of Objective Function and Determination of Constraints
- Development of Governing Equations
- Determinition of Required Parameters for Calculation

Data Collection

- Determinition of Period for Data Analysis
- Extraction of Primary Data from HDSR of MMHPS's SCADA in *.csv Format
- Import of *.csv Files into Excel *.xlsb Files Using Visual Basic Applications Code
- Combining of Several *.xlsb Files into a Common Set of *.xlsb Files Using Visual Basic Applications Code

Calculation

- Calculation of Head Loss Before Bifurcation and in Unit 1 Penstock When Unit 1 is Running and Unit 2 is Shutdown
- Calculation of Head Loss Before Bifurcation and in Unit 2 Penstock When Unit 2 is Running and Unit 1 is Shutdown
- Calculation of Head Loss Before Bifurcation for All Possible Values of Total Discharge
- Calculation of Unit Draft Tube Head Losses and Net Head for All Possible Values of Discharge
- Calculation of Unit Efficiencies for All Possible Values of Net Head and Discharge

Optimization

- Optimization of Total Power for All Possible Values of Gross Head and Total Discharge
- Determination of Optimal Distribution of Discharge Amongst The Two Units for Maximum Power Generation
- Optimization of Required Total Discharge for All Possible Values of Power Required and Gross Head

Comparison

- Comparison of Actual Unit Head Losses With Designed Value
- Calculation of Optimal Power Generated for 8 Number of Days from Historical Data Log
- Calculation of Optimal Discharge Requirement for Same 8 Days from Historical Data Log
- Comparison Between Optimal and Actual Historical Generation

Report Writing and Presentation

- Draft Report Writing as per Department's Guidelines
- Report Presentation
- Final Report Preparation Including Comments Made During Presentation
- Final Report Presentation

Figure 3.1 Research Methodology

3.2. Data Collection

3.2.1. SCADA System at MMHPS

MMHPS incorporates SCADA system developed by Alstom Power. The platform of the SCADA system is called as ALSPA P320 Centralog 10. It has three workstations and a single report writer station. The workstations are monitored continuously by operators for any alarm conditions, supervision and necessary adjustments.

Headrace level is measured by three programmable submerged pressure transducers, each located at each pier of concrete dam at reservoir. The 4-20mA signal transmitted by these transmitters are treated by DCS.

Total discharge is measured in common penstock inside Discharge Measurement chamber, located upstream of penstock bifurcation, by sixteen transducers, with eight paths, ultrasonic system that has 0.5% accuracy.

Penstock pressure is measured by pressure transducer connected to pressure tapping just upstream of Main Inlet valve and tailrace pressure is measured by six pressure transducers near the tailrace outlet for each unit as shown in Figure 3.5 below.

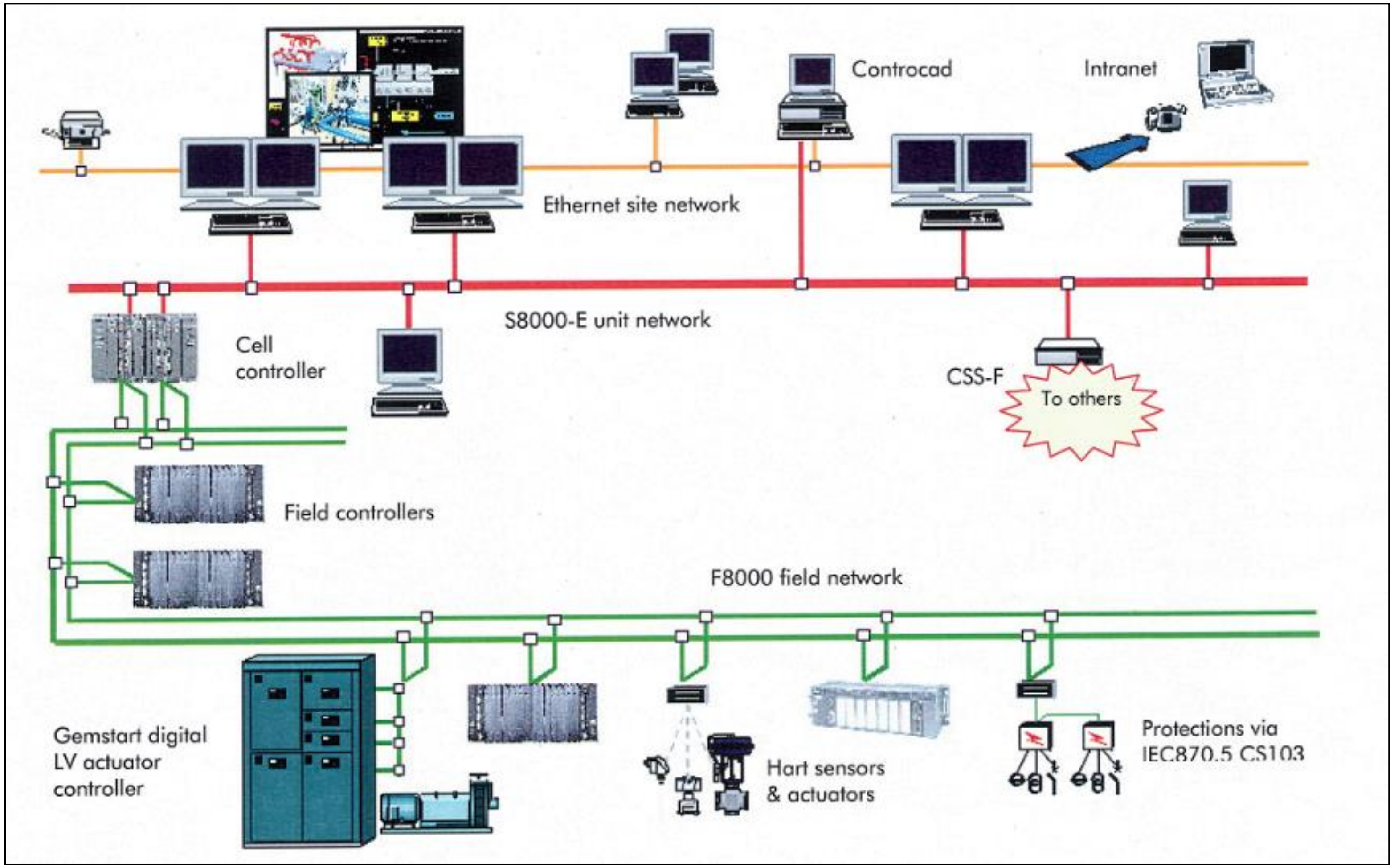

Figure 3.2: ALSPA P320 Architecture (ALSTOM Power Generation AG 2005)

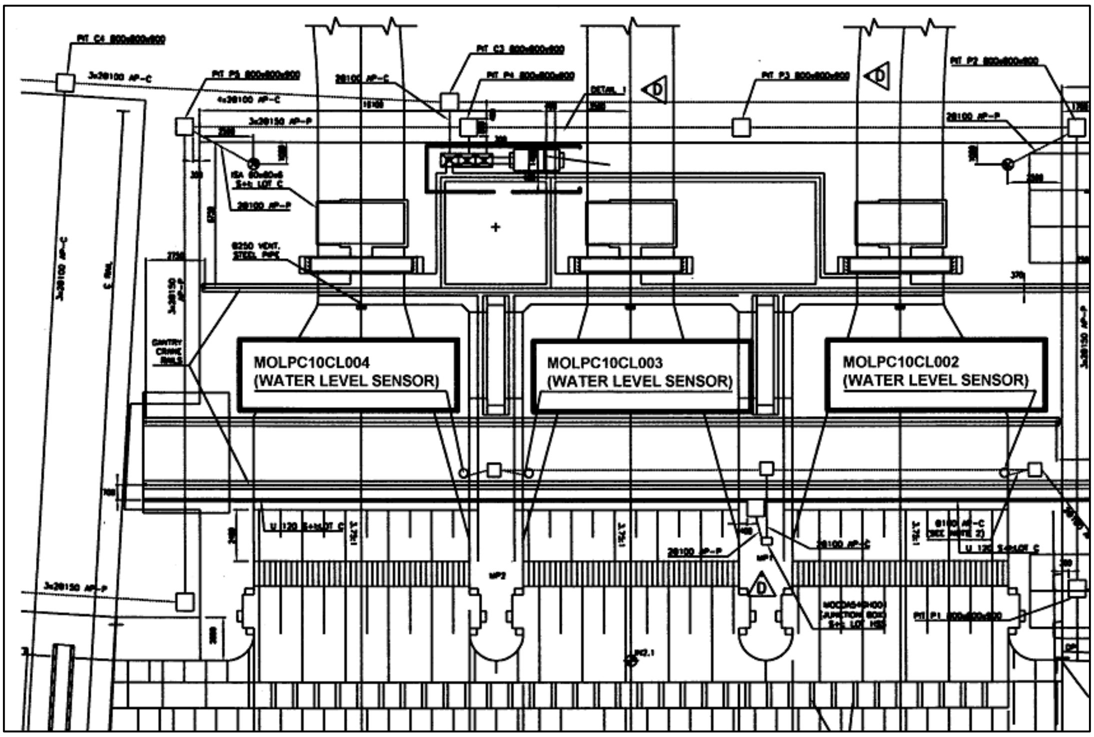

Figure 3.3: Position of Headrace Level Sensor (ALSTOM Power Generation AG 2005)

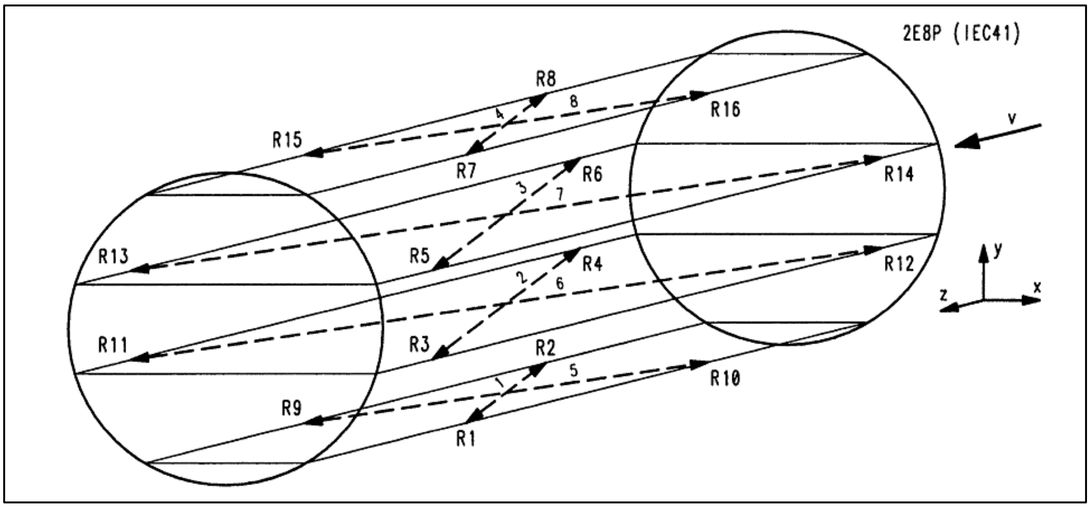

Figure 3.4: Schematic diagram of position and paths of ultrasonic flow measurement system (ALSTOM Power Generation AG 2005)

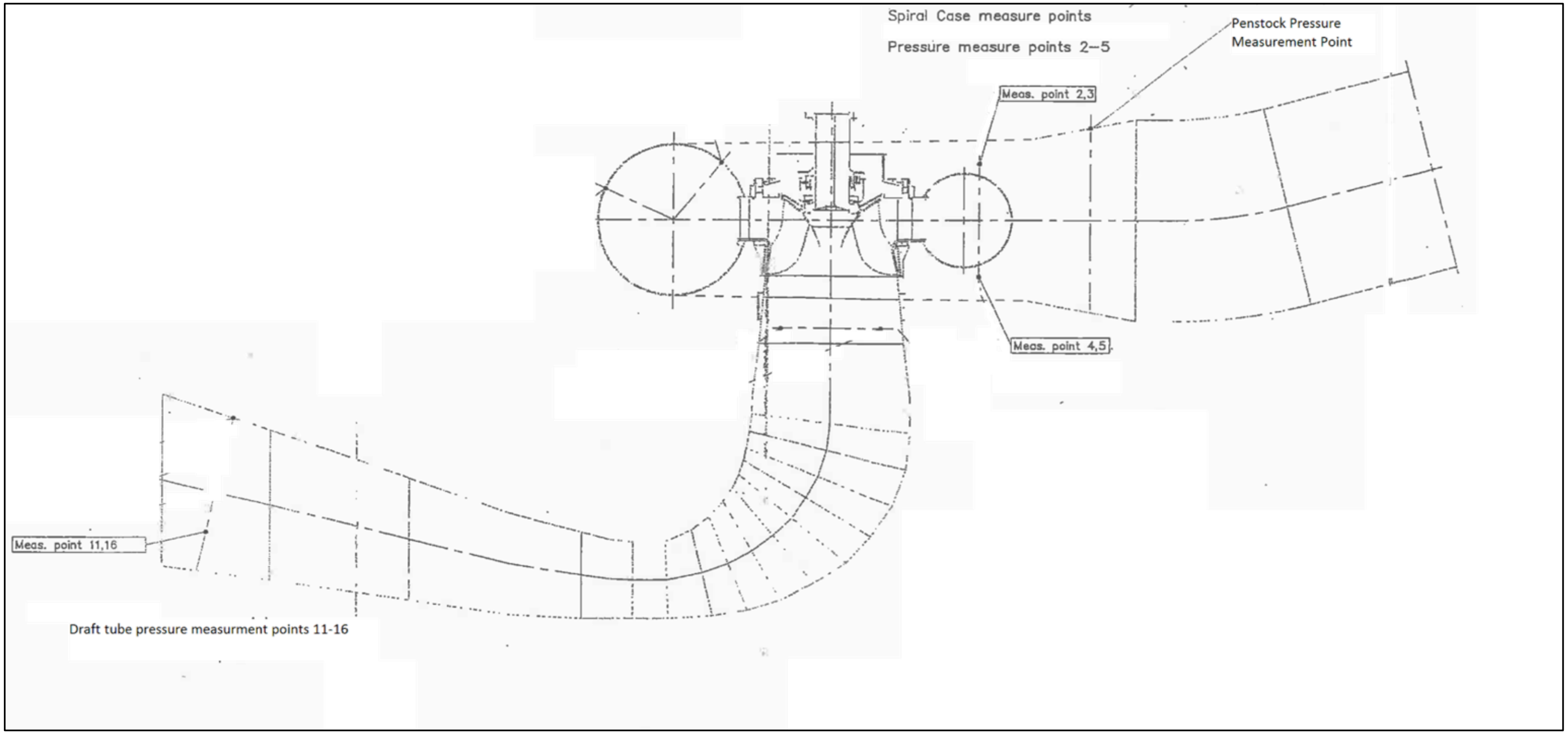

Figure 3.5: Schematic of Position of Penstock Pressure measurement point and draft tube pressure measurement point (Voith Siemens Hydro GmbH 2008)

3.2.1. Primary Data Acquisition

ALSPA P320 system has an HDSR (Historic Data Storage and Retrieval) function which enables process data to be recored for immediate analysis and for storage in optical disk. These data are archived every twenty-four hours. These archived files can be retrieved from any workstation in future.

HDSR system can export only four parameters at a time over a time horizon of six hours. Since, ten parameters are required for calculation, a total of twelve files are required for each day. All of these files are data files in text document (*.txt) format; thus, not readily readable by data processing Software-Excel. Macro-based programs were developed to import, combine and sort the data contained in the text documents and convert them into calculable form. Necessary data from October, 2016 to January, 2017 were extracted from HDSR. Since the number of data sets is too large, only a sample of data sets have been included in Appendix 1: .

CHAPTER FOUR: OPTIMIZATION

4.1. Assumptions

Following are the assumptions made for the research analysis:

- Variation in the performance of each unit is small for the period of analysis considered. This is logical since the period of analysis considered is dry months, when the sediment concentration in water is almost negligible. Thus, the variation in performance is negligible, even if present.
- The tailrace level for both units is same. The draft tube outlet of both units are constructed alongside. Thus, the difference in tailrace level is negligible, even if present.
- There is no influence on tailrace level by discharge of water.

4.2. Optimization Model

The main goal of the optimization model is to maximize daily energy generation of MMHPS. This can be done by operating the available units under optimal condition by economic dispatch of the available water flow at every instant of the day. Total daily generation is

$$TDE = \sum_{t=0}^{86400} \frac{(U_1 * P_1 + U_2 * P_2)}{3600} \qquad \text{Eq. (4.1)}$$

where, U_1 is status of unit 1 at instant t (1 for operational and 0 for non-operational)

U_2 is status of unit 2 at instant t (1 for operational and 0 for non-operational)

P_1 is power generated by unit 1 at instant t

P_2 is power generated by unit 2 at instant t

Unit power is a function of

$$P = f(\eta, H, Q) \quad \text{Eq. (4.2)}$$

where, η is unit efficiency

H is unit net head

Q is unit discharge

But, unit net head is a function of

$$H = f(InL, TrL, \Delta h) \quad \text{Eq. (4.3)}$$

where, InL is intake level at reservoir, masl

TrL is tailrace level of river, masl

Δh is headloss in waterways between reservoir and tailrace

So the objective function is

$$Maximize\ TDE = \sum_{t=0}^{86400} Max. \frac{(U_1 * P_1 + U_2 * P_2)}{3600} \quad \text{Eq. (4.4)}$$

subjected to constraints

$$P_1 \leq 39.90MW \quad \text{Eq. (4.5)}$$

$$P_2 \leq 39.90MW \quad \text{Eq. (4.6)}$$

The limit set by maximum capacity of unit generators.

$$U_1 = 0\ or\ 1 \quad \text{Eq. (4.7)}$$

$$U_2 = 0\ or\ 1 \quad \text{Eq. (4.8)}$$

Binary limit of unit status represent the non-operational or operational state of each unit.

$$Q_1 \leq 50m^3/s \quad \text{Eq. (4.9)}$$

$$Q_2 \leq 50m^3/s \quad \text{Eq. (4.10)}$$

The limit on unit discharge is set by maximum allowable discharge through wicket gates of each unit.

$$Q_{total} = Q_1 + Q_2 \leq Q_{available} \quad \text{Eq. (4.11)}$$

where, $Q_{available}$ is the available discharge

The total discharge used by both units cannot physically exceed the available discharge.

$$Q_1 = 0 \ or > 15m^3/s \quad \text{Eq. (4.12)}$$

$$Q_2 = 0 \ or > 15m^3/s \quad \text{Eq. (4.13)}$$

Unit discharge between 0-15m^3/s is avoided because this region is rough generation for the unit during which vortices are induced in draft tube which lead to increase in cavitation. During operation, unit is ramped as fast as possible in this range.

$$P_1 \geq 0, P_2 \geq 0 \quad \text{Eq. (4.14)}$$

The non-negativity restrictions represent the generators will never operate in motor mode.

The dual optimization problem for primal problem model of Eq. (4.4) is

$$Minimize\ Q_{total} = \sum_{t=0}^{86400} minimum\ (Q_1 + Q_2) \quad \text{Eq. (4.15)}$$

subjected to constraints

$$P_1 \leq 39.90MW \quad \text{Eq. (4.16)}$$

$$P_2 \leq 39.90MW \quad \text{Eq. (4.17)}$$

$$P_{total} = P_1 + P_2 \geq P_{required}$$ Eq. (4.18)

where, $P_{required}$ is the power demand in the grid.

$$U_1 = 0\ or\ 1$$ Eq. (4.19)

$$U_2 = 0\ or\ 1$$ Eq. (4.20)

$$Q_1 \leq 50m^3/s$$ Eq. (4.21)

$$Q_2 \leq 50m^3/s$$ Eq. (4.22)

$$Q_1 = 0\ or > 15m^3/s$$ Eq. (4.23)

$$Q_2 = 0\ or > 15m^3/s$$ Eq. (4.24)

$$P_1 \geq 0, P_2 \geq 0$$ Eq. (4.25)

The optimization problem presented by both models are continuous non-linear optimization problems whose solutions will be sought by non-linear generalized-reduced-gradient (GRG) method.

4.3. Governing Equations

Elevation of valve chamber pressure taps	594.0masl
Elevation of unit penstock pressure taps	516.3masl
Elevation of unit Spiral case pressure taps	515.0masl
Elevation of draft tube pressure taps	512.015 masl
Tailrace level	518.0 masl
Cross-sectional area of headrace tunnel	31.9m^2
Diameter of penstock before bifurcation	4.6m
Diameter of penstock after bifurcation	2.6m
Diameter of draft tube at pressure taps	2.63m

Cross-sectional area of inclined penstock before bifurcation is given by

$$Penstock\ cross\ sectional\ area\ before\ bifurcation\ (A_{bb}), m^2 = \pi * \frac{(d_{bb})^2}{4}$$

$$= \pi * \frac{4.6^2}{4} = 16.619m^2$$

where, d_{bb} is diameter of penstock before bifurcation, m

Cross-sectional area of inclined unit penstocks is given as

$$Unit\#1\ penstock\ cross\ sectional\ area\ (A_1), m^2$$

$$=\ Unit\#2\ penstock\ cross\ sectional\ area (A_2), m^2 =\ \pi * \frac{(\mathrm{d})^2}{4}$$

$$= \pi * \frac{2.6^2}{4} = 5.309 m^2$$

where, d is diameter of penstock after bifurcation, m

Cross-sectional area of draft tube at point of pressure tapping is given by,

$$Unit\#1\ draft\ tube\ cross\ sectional\ area (A_{d1}), m^2$$

$$=\ Unit\#2\ draft\ tubecross\ sectional\ area (A_{d2}), m^2 =\ \pi * \frac{(d_d)^2}{4}$$

$$= \pi * \frac{2.63^2}{4} = 5.433 m^2$$

where, d_d is diameter of draft tube at point of pressure tapping, m

Gross head is defined as,

$$Gross\ head\ (GH), m = InL - TrL = InL - 518 \qquad \text{Eq. (4.26)}$$

where, InL is intake level at reservoir, masl

TrL is tailrace level of river, masl

The head loss from intake up to penstock bifurcation depends only upon total discharge flowing through the power tunnel system. Thus,

$$Headloss\ from\ intake\ up\ to\ penstock\ bifurcation\ (\Delta h_{bb})$$

$$= InL - \left[\frac{P_{bb} * 10^5}{\rho * g} + \frac{1}{2g} * \left(\frac{Q}{A_{bb}}\right)^2 + z_{bb}\right] \qquad \text{Eq. (4.27)}$$

where, P_{bb} is pressure at penstock bifurcation, bar

ρ is density of water= 1000kg/m^3

g is acceleration due to gravity= 9.81m/s^2

Q is total discharge through power tunnel system, m^3/s

z_{bb} is elevation of penstock bifurcation, masl

Headloss from intake up to penstock bifurcation includes head losses in trash rack, intake tunnels, desanders, headrace tunnel and penstock up to bifurcation. But, its direct measurement is not possible since there are no pressure measurement instruments at bifurcation.

After bifurcation, head loss in each unit penstock is dependent upon water discharge in each unit penstock.

We know,

$$Unit\ 1\ penstock\ head\ loss\ (\Delta h_1), m = InL - \left[\frac{P_1 * 10^5}{\rho * g} + \frac{1}{2g} * \left(\frac{Q_1}{A_1}\right)^2 + z_1\right] - \Delta h_{bb} \quad \text{Eq. (4.28)}$$

where, P_1 is pressure at end of unit 1 penstock, bar

Q_1 is discharge through unit 1 penstock, m^3/s

z_1 is elevation of pressure tap of unit 1 penstock, masl

Similarly,

$$Unit\ 2\ penstock\ head\ loss\ (\Delta h_2), m = InL - \left[\frac{P_2 * 10^5}{\rho * g} + \frac{1}{2g} * \left(\frac{Q_2}{A_2}\right)^2 + z_2\right] - \Delta h_{bb} \quad \text{Eq. (4.29)}$$

where, P_2 is pressure at end of unit 2 penstock, bar

Q_2 is discharge through unit 2 penstock, m^3/s

z_2 is elevation of pressure tap of unit 2 penstock, masl

When unit 2 is shut down and only unit 1 is running, then $Q_2 = 0$, $Q = Q_1$ and $\Delta h_2 = 0$.

$$\left[\frac{P_{bb} * 10^5}{\rho * g} + \frac{1}{2g} * \left(\frac{Q}{A_{bb}}\right)^2 + z_{bb}\right] = \left[\frac{P_2 * 10^5}{\rho * g} + z_2\right] \quad \text{Eq. (4.30)}$$

And Eq. (4.27) and Eq. (4.28) respectively become

$$\Delta h_{bb}, m = InL - \left[\frac{P_2 * 10^5}{\rho * g} + z_2\right] \quad \text{Eq. (4.31)}$$

$$\Delta h_1, m = \left[\frac{P_2 * 10^5}{\rho * g}\right] - \left[\frac{P_1 * 10^5}{\rho * g} + \frac{1}{2g} * \left(\frac{Q_1}{A_1}\right)^2\right] \quad \text{Eq. (4.32)}$$

$(And,\ z_1 = z_2)$

Similarly, when unit 1 is shut down and only unit 2 is running, then Q_1 =0, Q=Q_2 and Δh_1=0.

$$\left[\frac{P_{bb} * 10^5}{\rho * g} + \frac{1}{2g} * \left(\frac{Q}{A_{bb}}\right)^2 + z_{bb}\right] = \left[\frac{P_1 * 10^5}{\rho * g} + z_1\right] \quad \text{Eq. (4.33)}$$

And Eq. (4.27) and Eq. (4.29) respectively become

$$\Delta h_{bb}, m = InL - \left[\frac{P_1 * 10^5}{\rho * g} + z_1\right] \quad \text{Eq. (4.34)}$$

$$\Delta h_2, m = \left[\frac{P_1 * 10^5}{\rho * g}\right] - \left[\frac{P_2 * 10^5}{\rho * g} + \frac{1}{2g} * \left(\frac{Q_2}{A_2}\right)^2\right] \quad \text{Eq. (4.35)}$$

Head loss also occurs during flow of water in draft tube. Head loss in draft tube of each unit is dependent upon discharge of water in each unit. They are calculated from formulae below.

$$Unit\#1\ draft\ tube\ head\ loss\ (\Delta h_{d1}), m$$
$$= \left[\frac{P_{d1} * 10^5}{(\rho * g)} + \frac{1}{2g}\left(\frac{Q_1}{A_{d1}}\right)^2 + z_{d1}\right] - TrL \quad \text{Eq. (4.1)}$$
$$= \left[\frac{P_{d1} * 10^5}{(\rho * g)} + \frac{1}{2g}\left(\frac{Q_1}{A_{d1}}\right)^2 + z_{d1}\right] - 518.0$$

where, P_{d1} is pressure draft tube pressure tap, bar

z_{d1} is elevation of draft tube pressure tap, masl

Similarly,

$$Unit\#2\ draft\ tube\ head\ loss\ (\Delta h_{d2}), m = \left[\frac{P_{d2} * 10^5}{(\rho * g)} + \frac{1}{2g}\left(\frac{Q_2}{A_{d2}}\right)^2 + z_{d2}\right] - TrL = \left[\frac{P_{d2} * 10^5}{(\rho * g)} + \frac{1}{2g}\left(\frac{Q_2}{A_{d2}}\right)^2 + z_{d2}\right] - 518.0 \quad \text{Eq. (4.36)}$$

where, P_{d2} is pressure draft tube pressure tap, bar

z_{d2} is elevation of draft tube pressure tap, masl

So,

$$Unit\#1\ total\ head\ loss\ (\Delta h_{total1}) = \Delta h_{bb} + \Delta h_1 + \Delta h_{d1} \quad \text{Eq. (4.37)}$$

$$Unit\#2\ total\ head\ loss\ (\Delta h_{total2}) = \Delta h_{bb} + \Delta h_2 + \Delta h_{d2} \quad \text{Eq. (4.38)}$$

Finally,

$$Unit\#1\ net\ head\ (H_1), m = GH - \Delta h_{total1} \quad \text{Eq. (4.39)}$$

$$Unit\#2\ net\ head\ (H_2), m = GH - \Delta h_{total2} \quad \text{Eq. (4.40)}$$

$$Unit\#1\ efficiency\ (\eta_1) = \frac{P_1 \times 10^6}{\rho \times g \times H_1 \times Q_1} * 100\% \quad \text{Eq. (4.41)}$$

$$Unit\#2\ efficiency\ (\eta_2) = \frac{P_2 \times 10^6}{\rho \times g \times H_2 \times Q_2} * 100\% \qquad \text{Eq. (4.42)}$$

Since electrical output power is used instead of mechanical power, unit efficiencies represent efficiencies of the unit; not just mechanical efficiencies.

4.4. Requirements

From equations in 4.3 above, following parameters are required for calculation:

- Headrace level, masl
- Total Discharge, m^3/s
- Unit#1 penstock pressure, bar
- Unit#1 discharge, m^3/s
- Unit#2 penstock pressure, bar
- Unit#2 discharge, m^3/s
- Unit#1 Power, MW
- Unit#2 Power, MW
- Unit#1 draft tube pressure, bar
- Unit#2 draft tube pressure, bar

CHAPTER FIVE: RESULTS AND DISCUSSION

5.1. Head Losses and Unit Efficiencies

5.1.1. Head Loss Before Bifurcation

Headloss from intake up to bifurcation when Unit 2 was shut down and only Unit 1 was operating was calculated as per Eq. (4.31). Similarly, headloss from intake up to bifurcation when Unit 1 was shut down and only Unit 2 was operating was calculated as per Eq. (4.34). The calculated headloss before bifurcation was then tabulated using Pivot table into Table 5.1 below.

Table 5.1: Head loss in Power Tunnel System up to Penstock Bifurcation

Total Discharge, m^3/s	**Headloss before bifurcation, m**	**Total Discharge, m^3/s**	**Headloss before bifurcation, m**
0	0.000000	21	1.933286
1	0.108060	22	1.994382
2	0.216836	23	2.044612
3	0.325874	24	2.108351
4	0.435074	25	2.213300
5	0.544391	26	2.297846
6	0.653797	27	2.385366
7	0.763278	28	2.419780
8	0.872831	29	2.449358
9	0.982492	30	2.495367
10	1.092653	31	2.575651
11	1.229001	32	2.793605
12	1.344883	33	3.006904
13	1.471746	34	3.144664
14	1.474593	35	3.234292
15	1.471239	36	3.354850
16	1.522677	37	3.497045
17	1.645599	38	3.612469
18	1.766628	39	3.743756
19	1.854113	40	3.972931
20	1.863924		

Head loss before bifurcation is graphically represented in Figure 5.1 below.

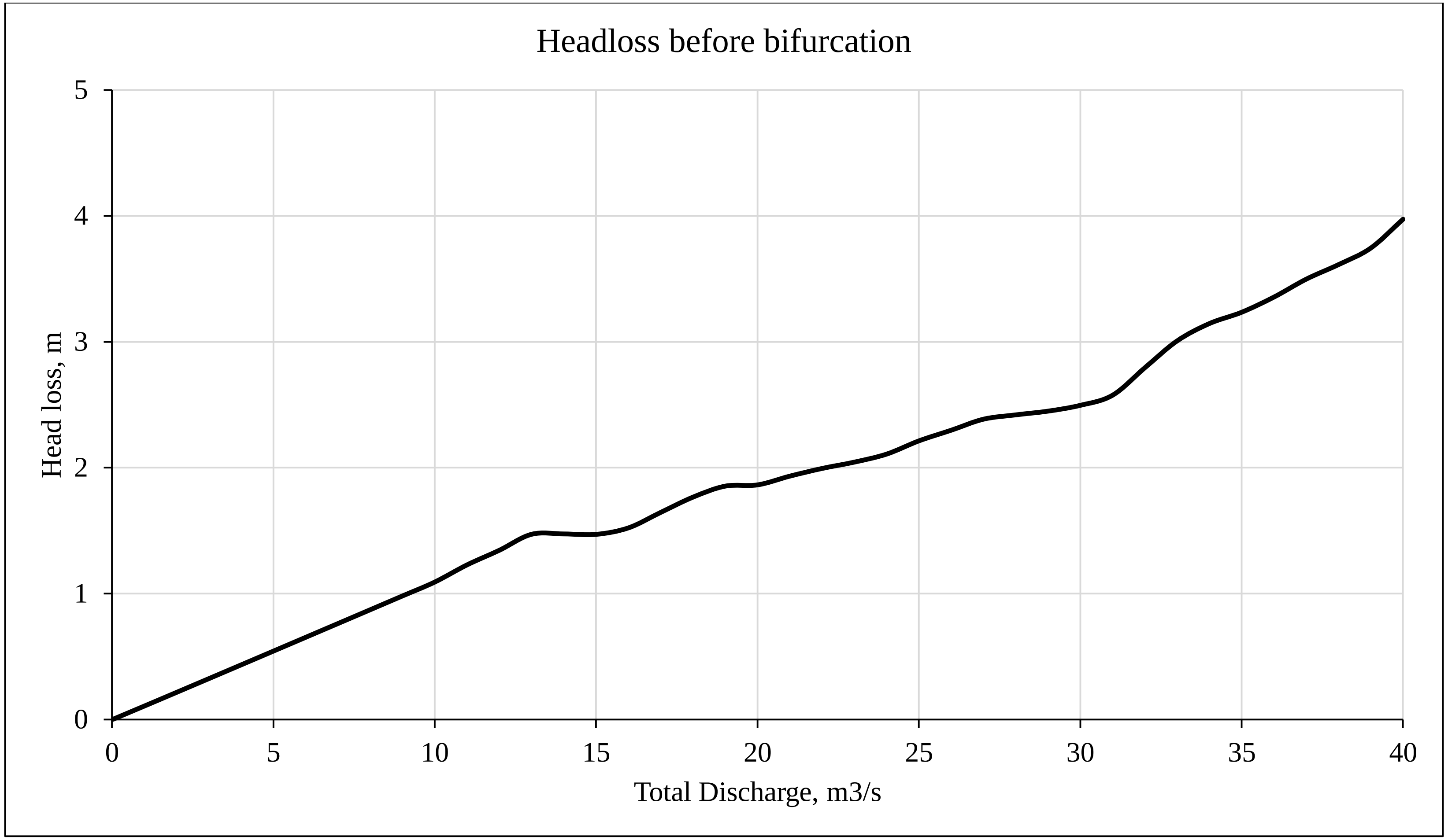

Figure 5.1: Head loss between Intake and Penstock Bifurcation

5.1.2. Unit 1 Head Loss and Efficiency

For calculation of head loss in penstock of Unit 1, the data sets that represent shut down of Unit 2 and operation of Unit 1 were sorted out. A sample of the sorted out data has been included in Appendix 2: .

Head losses in Unit 1 Penstock, Unit 1 draft tube and Unit 1 total head loss were calculated as per Eq. (4.31), Eq. (4.32), Eq. (4.1) and Eq. (4.37), respectively. Also, net head for Unit 1 and Unit 1 efficiency were calculated as per Eq. (4.39) and Eq. (4.41), respectively. A sample of calculated table for few data sets is presented in Appendix 3: .

The calculated head losses in Unit 1 Penstock, Unit 1 draft tube and Unit 1 total head loss were tabulated using Pivot table into Table 5.2 below.

Table 5.2: Head losses of Unit 1

Unit#1 Discharge	**Unit 1 Penstock head loss**	**Unit 1 Draft tube head loss**	**Unit#1 total Head loss**
	Eq. (4.32)	Eq. (4.1)	Eq. (4.37)
0	0.000000	0.000000	0.000000
1	0.025696	0.003178	0.148543
2	0.051564	0.006396	0.298082
3	0.077497	0.009648	0.447993
4	0.103472	0.012932	0.598142
5	0.129481	0.016251	0.748465
6	0.155517	0.019609	0.898923
7	0.181580	0.023010	1.049488
8	0.207673	0.026460	1.200141
9	0.233808	0.029966	1.350869
10	0.260022	0.033542	1.501675
11	0.286613	0.037208	1.652822
12	0.405114	0.042585	1.912582
13	0.407318	0.044243	1.923307
14	0.442210	0.062157	1.908961
15	0.455062	0.111795	2.038096
16	0.470707	0.161037	2.054421
17	0.484717	0.219233	2.349549

Unit#1 Discharge	Unit 1 Penstock head loss	Unit 1 Draft tube head loss	Unit#1 total Head loss
	Eq. (4.32)	Eq. (4.1)	Eq. (4.37)
18	0.478006	0.282452	2.527086
19	0.514017	0.333693	2.701823
20	0.529304	0.429206	2.822434
21	0.542055	0.520830	2.996171
22	0.579407	0.654188	3.227977
23	0.644650	0.774268	3.463531
24	0.698732	0.887506	3.694588
25	0.712571	1.003141	3.929011
26	0.711558	1.104155	4.113558
27	0.708940	1.156087	4.250393
28	0.808351	1.189961	4.418092
29	0.814257	1.262996	4.694118
30	0.817645	1.367081	4.949669
31	0.826458	1.522898	5.086790
32	0.818091	1.663704	5.335400
33	0.717651	1.812309	5.536865
34	0.671665	1.954731	5.771060
35	0.667691	2.123136	6.025119
36	0.676859	2.291689	6.323398
37	0.689070	2.488216	6.674331
38	0.693960	2.703765	7.010193
39	0.703463	2.829059	7.276278
40	0.706130	2.901031	7.580092

The Table 5.2 above is represented by Figure 5.2 below. Unit efficiency is dependent upon both net head and unit discharge. Unit 1 efficiency for various net head and discharge condition is tabulated in Appendix 4: and is represented graphically in Figure 5.3 below. Unit 1 efficiency for various discharge and two particular value of net head is represented in Figure 5.4 below.

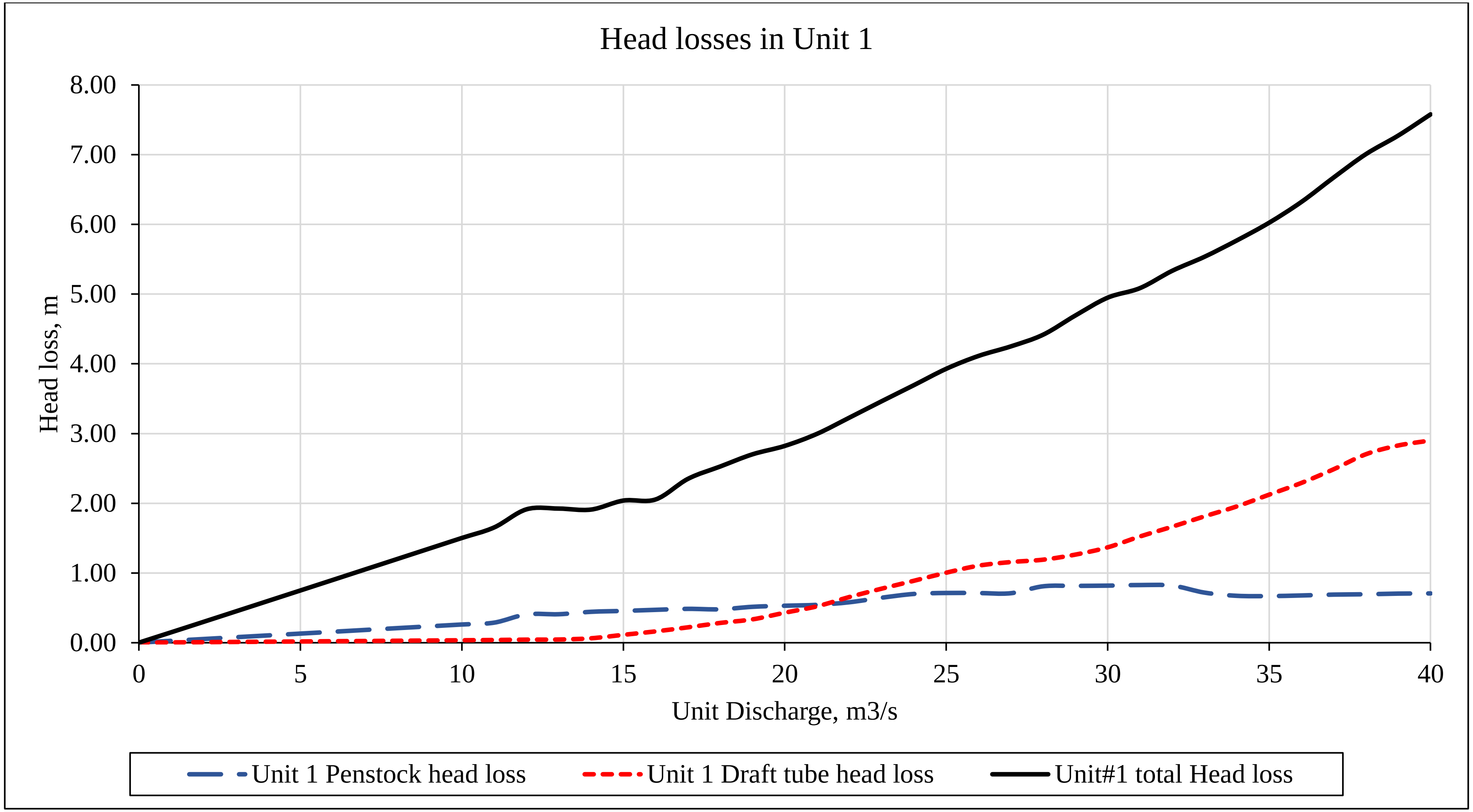

Figure 5.2: Head losses in Unit 1

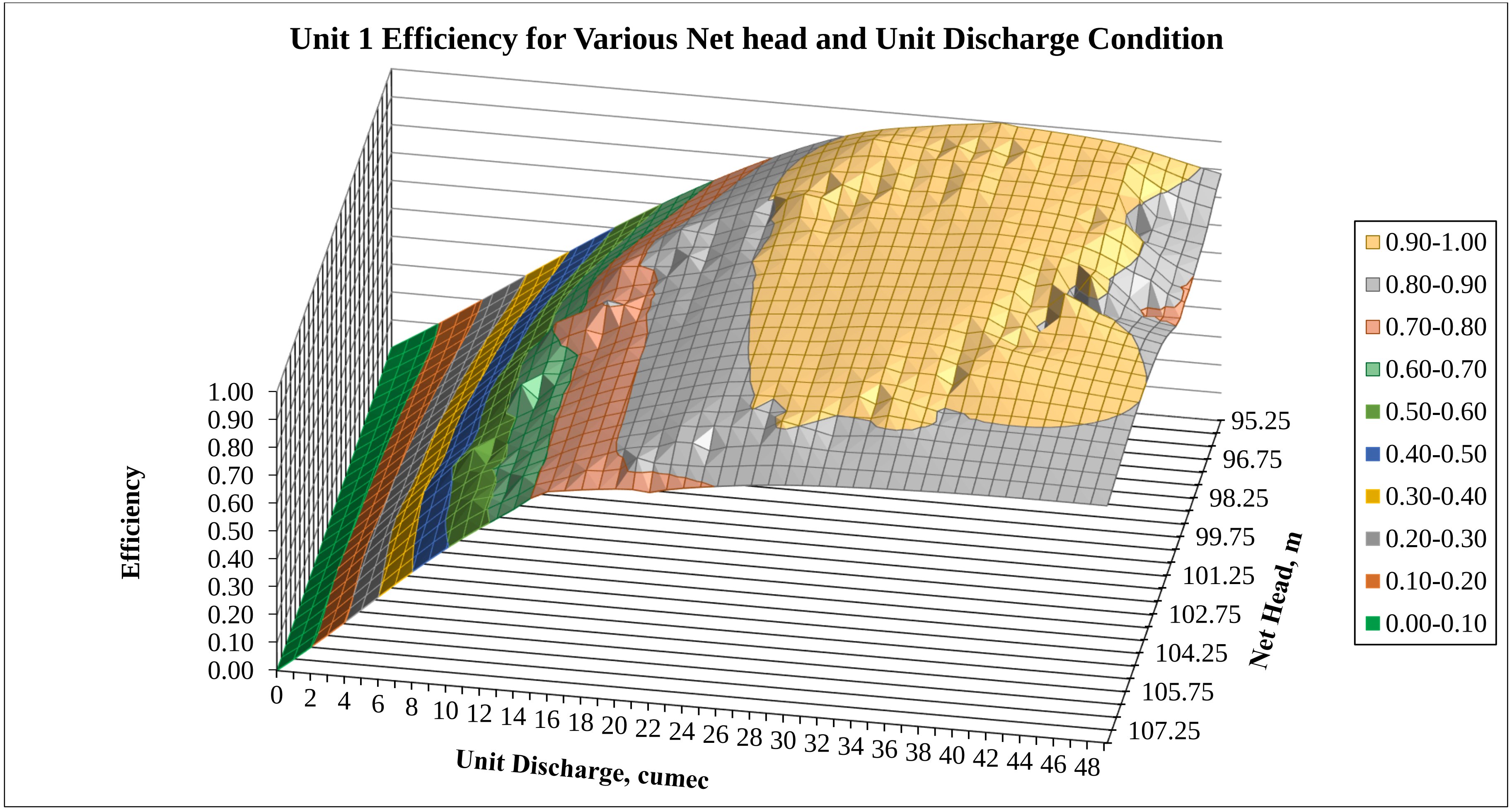

Figure 5.3: Unit 1 Efficiency for Various Net head and Unit Discharge Condition

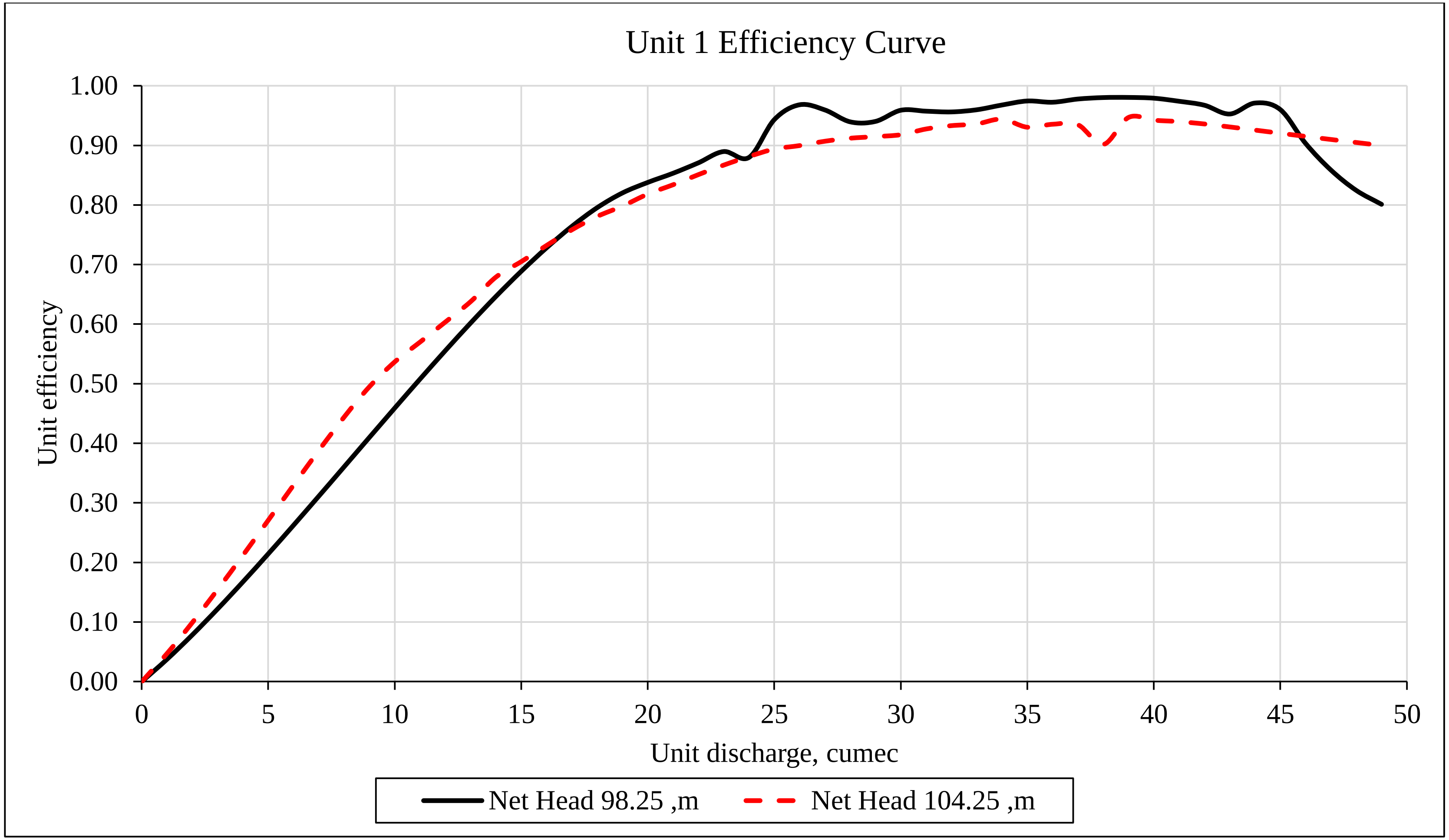

Figure 5.4: Unit 1 Efficiency for Two Different Net Head

From above graph, it is observed that the unit efficiency for lower value of net head is higher than that for higher value of net head for the designed operating range (20-40m^3/s). The reason for this is that the turbine installed at the plant is manufactured for net head of 96.5m and the lower value of the net head is actually closer to the designed value.

5.1.3. Unit 2 Head Loss and Efficiency

Similarly, for calculation of head loss in penstock of Unit 2, the data sets that represent shut down of Unit 1 and operation of Unit 2 were sorted out. A sample of the sorted out data has been included in Appendix 5: .

Head losses in Unit 2 Penstock, Unit 2 draft tube and Unit 2 total head loss were calculated as per Eq. (4.35), Eq. (4.36) and Eq. (4.38), respectively. A sample of calculated table for few data sets is presented in Appendix 6: .

The calculated head losses in Unit 2 Penstock, Unit 2 draft tube and Unit 2 total head loss were tabulated using Pivot table into Table 5.3 below.

Table 5.3: Head losses of Unit 2

Unit#2 Discharge	**Unit#2 Penstock head loss**	**Unit#2 Draft tube head loss**	**Unit#2 Total Head loss**
	Eq. (10)	Eq. (12)	Eq. (14)
0	0.000000	0.000000	0.000000
1	0.006728	0.017624	0.121308
2	0.013502	0.035379	0.243437
3	0.020294	0.053196	0.365882
4	0.027099	0.071059	0.488535
5	0.033913	0.088963	0.611344
6	0.040736	0.106906	0.734282
7	0.047566	0.124888	0.857328
8	0.054403	0.142908	0.980471
9	0.061248	0.160970	1.103701
10	0.068101	0.179075	1.227015
11	0.074962	0.197228	1.350408

Unit#2 Discharge	Unit#2 Penstock head loss	Unit#2 Draft tube head loss	Unit#2 Total Head loss
	Eq. (10)	Eq. (12)	Eq. (14)
12	0.081832	0.215434	1.473880
13	0.088714	0.233701	1.597432
14	0.095610	0.252039	1.721070
15	0.102526	0.270464	1.844802
16	0.109470	0.289001	1.968645
17	0.116462	0.307693	2.092632
18	0.123586	0.326652	2.216866
19	0.148380	0.354207	2.356700
20	0.200324	0.467842	2.532090
21	0.209663	0.589076	2.732025
22	0.219559	0.690084	2.904026
23	0.298688	0.782140	3.125440
24	0.300526	0.892801	3.301678
25	0.319290	0.973885	3.506474
26	0.388932	1.156791	3.843568
27	0.429785	1.180165	3.995316
28	0.418717	1.311908	4.150405
29	0.470362	1.365339	4.215059
30	0.401141	1.493502	4.240010
31	0.414135	1.646499	4.636285
32	0.410975	1.778415	4.982995
33	0.344420	1.887484	5.238808
34	0.321834	2.023171	5.489669
35	0.316326	2.182124	5.732742
36	0.287575	2.400683	6.043109
37	0.294767	2.628437	6.420249
38	0.299626	2.780376	6.692470
39	0.300245	2.907088	6.951090
40	0.307241	3.020717	7.300890

The Table 5.3 above is graphically represented in Figure 5.5 below. Unit 2 efficiency for various net head and discharge condition is tabulated in Appendix 7: and is represented graphically in Figure 5.6 below. Unit 2 efficiency for various discharge and two particular value of net head is represented in Figure 5.7 below.

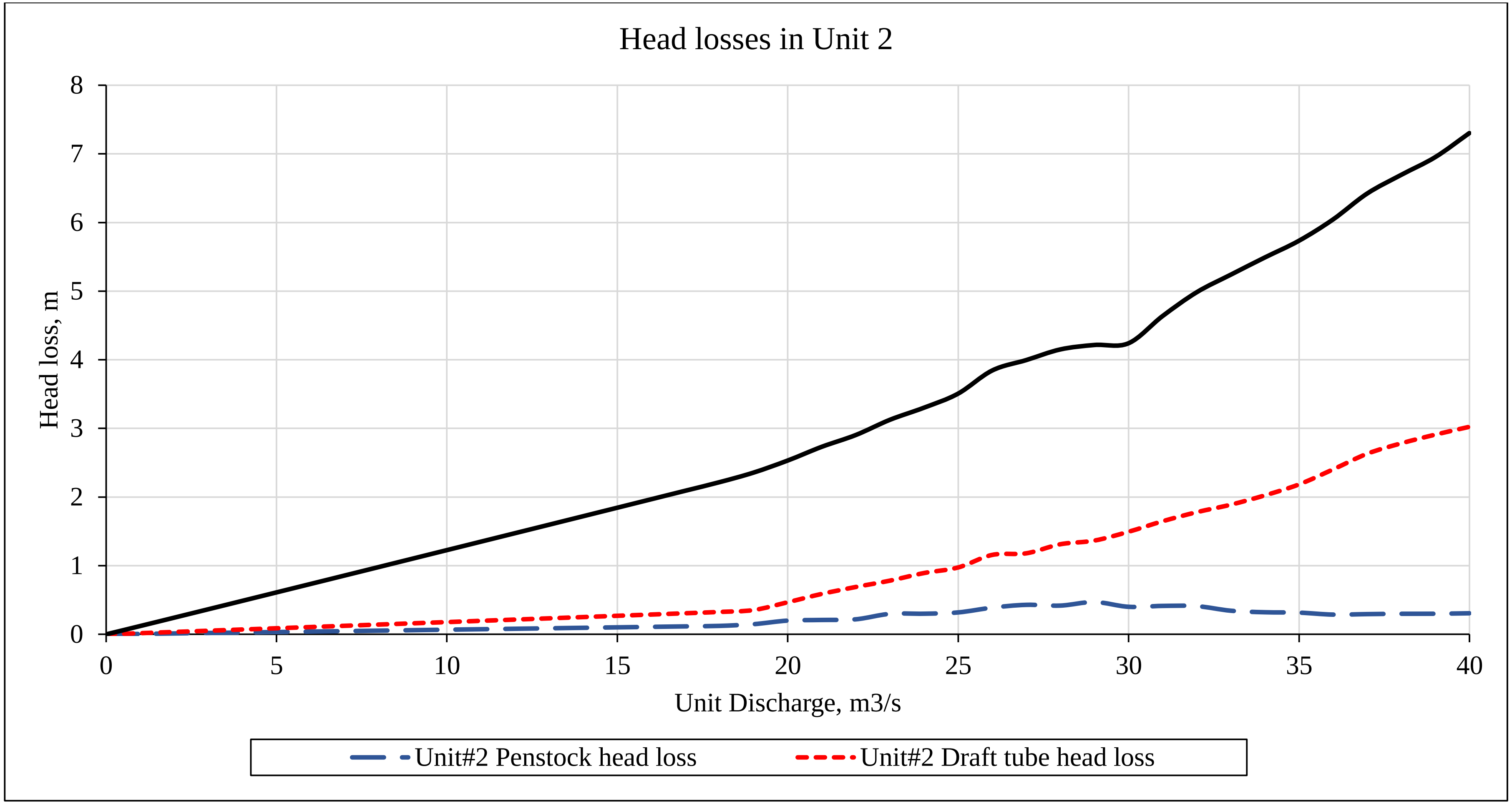

Figure 5.5: Head loss in Unit 2

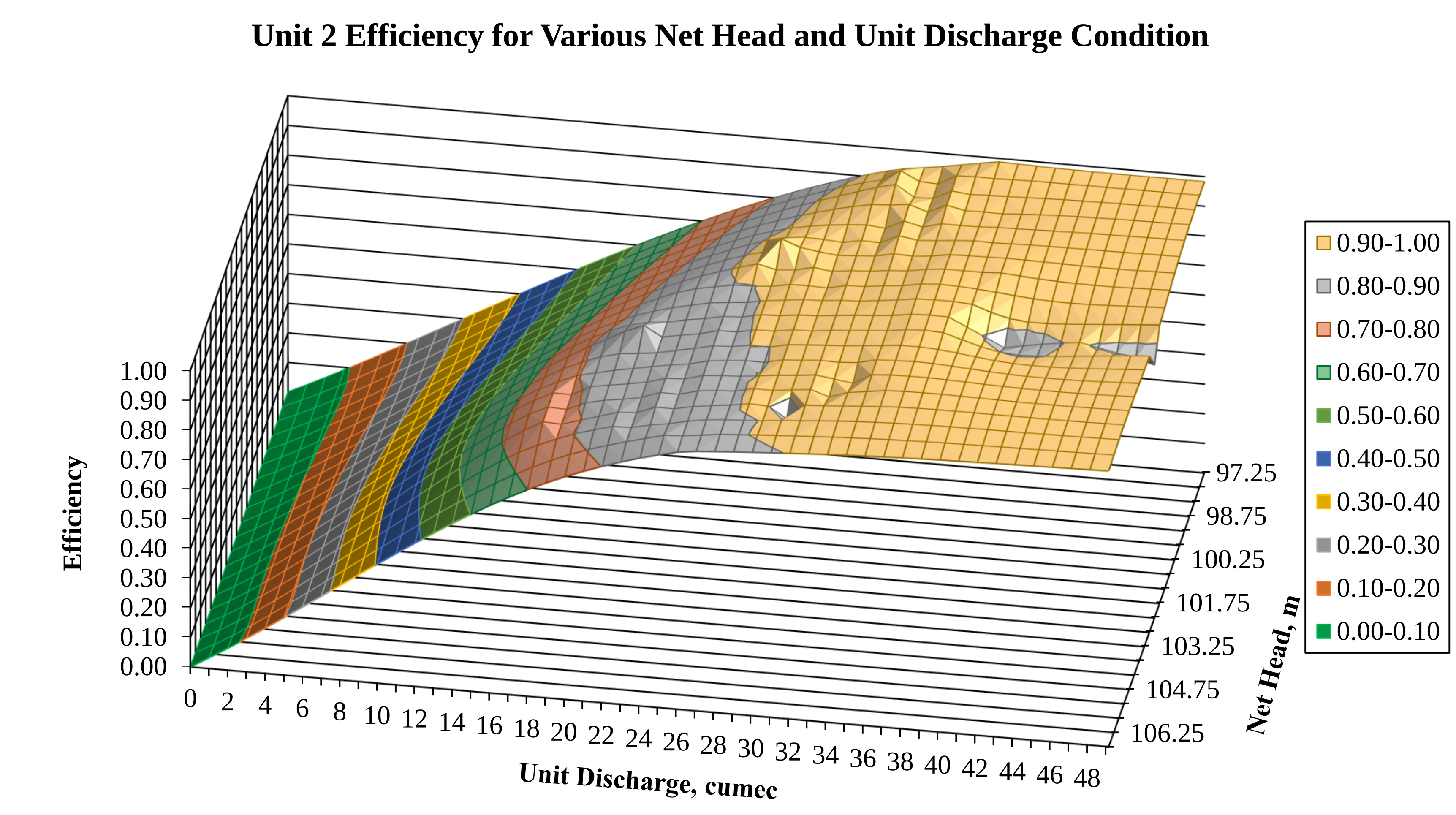

Figure 5.6: Unit 2 Efficiency for Various Net Head and Unit Discharge Condition

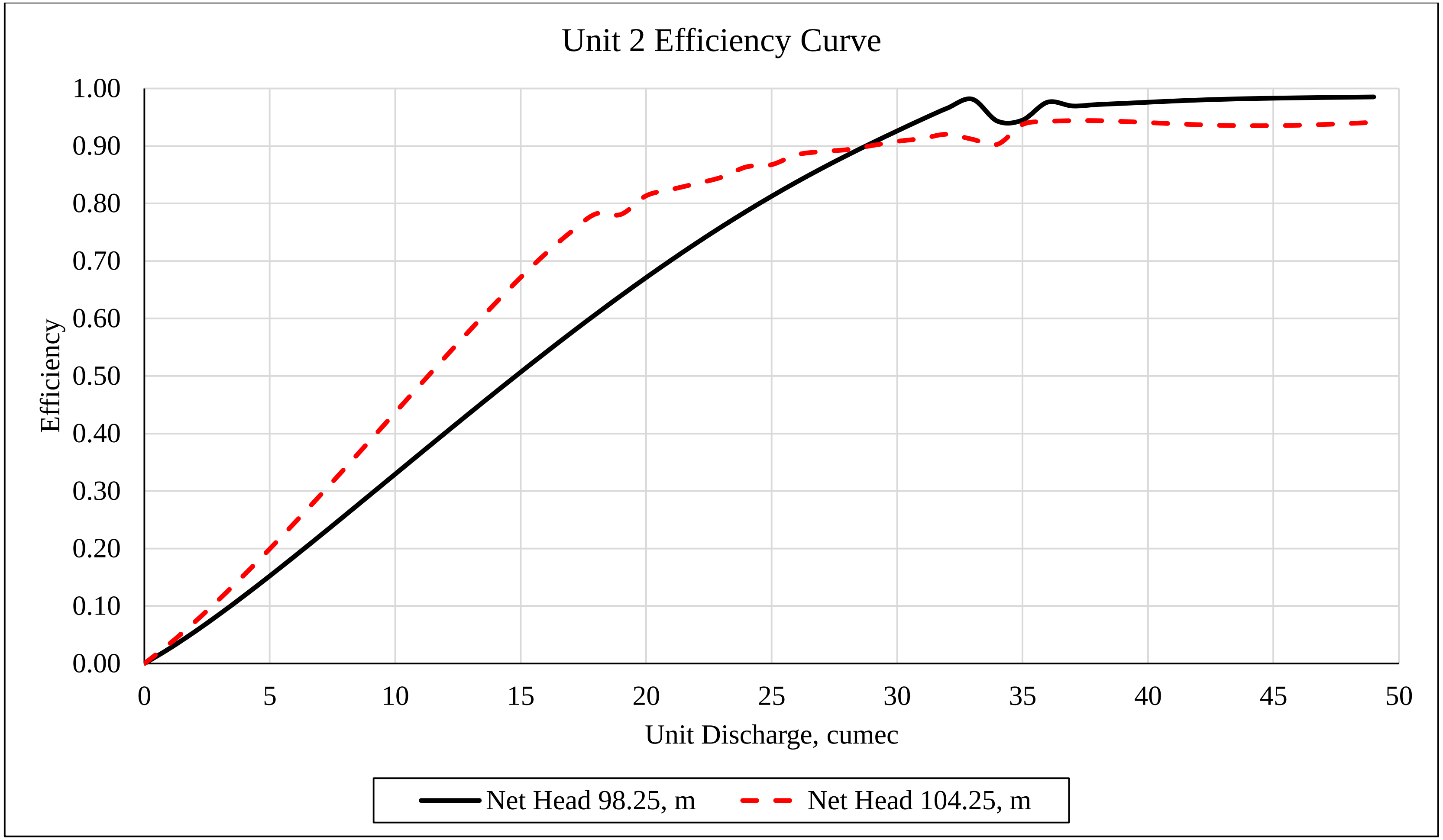

Figure 5.7: Unit 2 Efficiency for Two Different Net Head

5.1.4. Head Loss Comparison

The primary basis for this research is that the performance of both units vary due to difference in waterway for both units and condition of the runner.

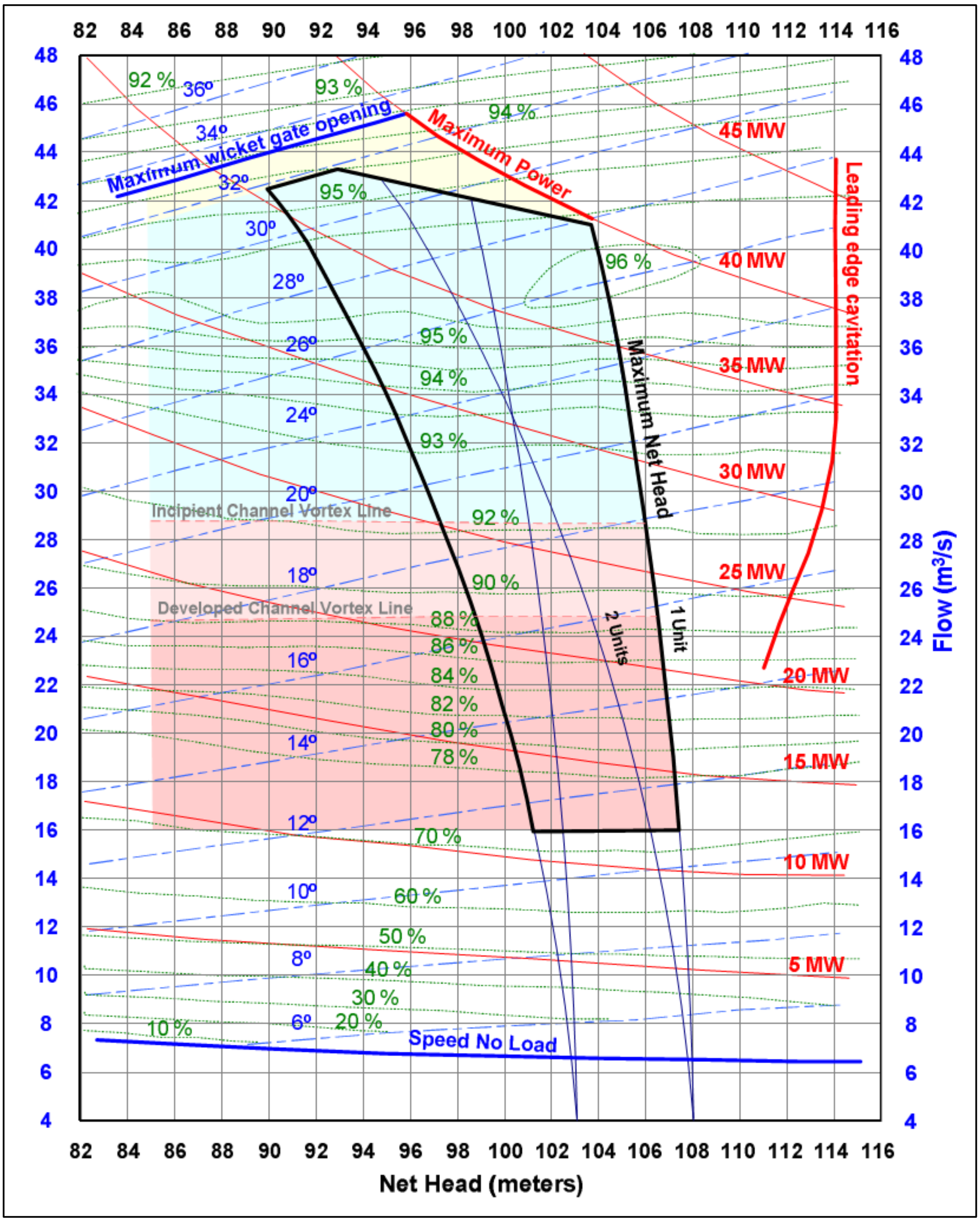

Figure 5.8: Turbine Hill Diagram of MMHPS (Lopez 2012)

The Figure 5.8 above represents turbine hill diagram for MMHPS. This is the initial designed condition. The major flaw in this chart is that it assumes both unit to have same performance.

The designed head loss when single unit is operational is calculated by digitizing net head curve of 1 unit from Figure 5.8 above. The designed head loss is compared graphically with total head loss of Unit 1 and Unit 2; under single unit operation condition.

From Figure 5.9 below, it is clearly observed that the total unit head loss of both units are higher than the original designed condition. Moreover, the difference between the actual unit head loss and original designed head loss increases as unit discharge increases. At rated discharge of $40m^3/s$, designed head loss is only 4.054076m but head loss of Unit 1 is 7.580092m and head loss of Unit 2 is 7.300890m.

The length of Unit 1 penstock after bifurcation is 212m whereas the length of Unit 2 penstock after bifurcation is 218m. But from Figure 5.9 below, it is observed that the Unit 1 head loss is higher than Unit 2 head loss despite being shorter in length. The reason behind such apparent anomaly can be explained from Figure 5.10 below. Even though the hydraulic path of Unit 2 is longer than that of Unit 1, it is far straighter than the hydraulic path of Unit 1. Presence of a bend in Unit 1 penstock is the cause for unit 1 penstock having higher head loss.

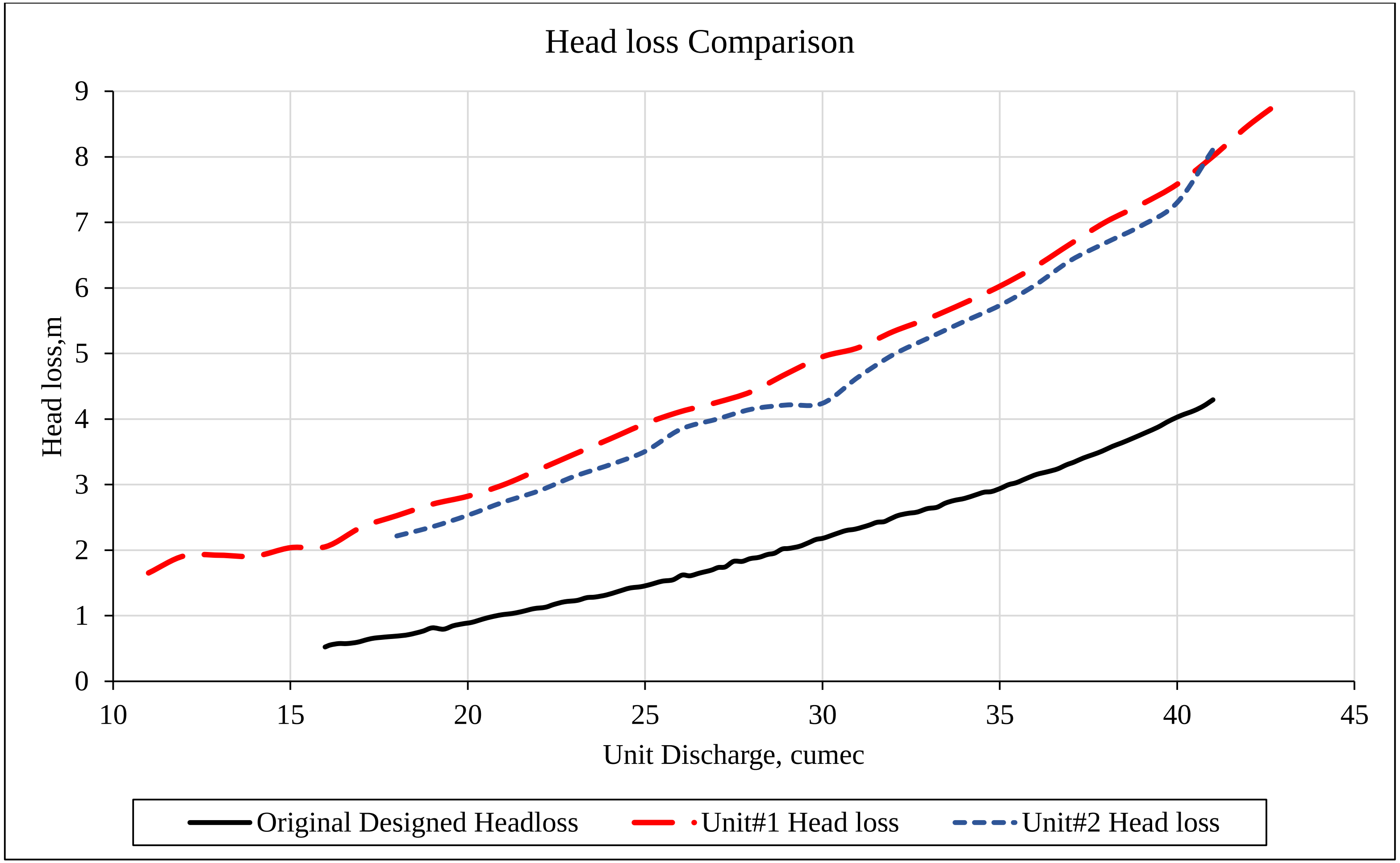

Figure 5.9: Comparison of Total Unit Head loss

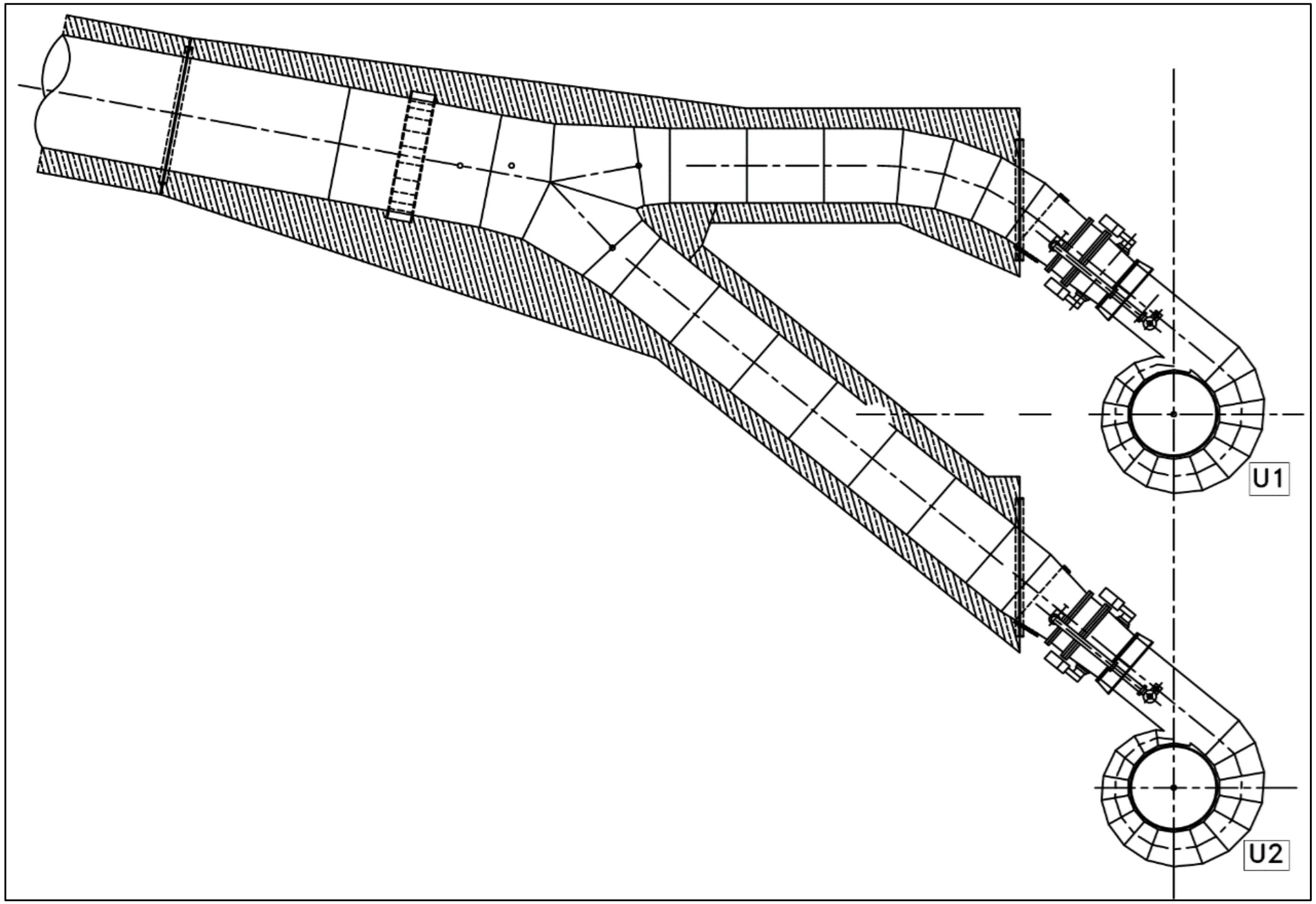

Figure 5.10: Plan View of Penstock bifurcation and Unit Penstocks

5.1.5. Unit Efficiency Comparison

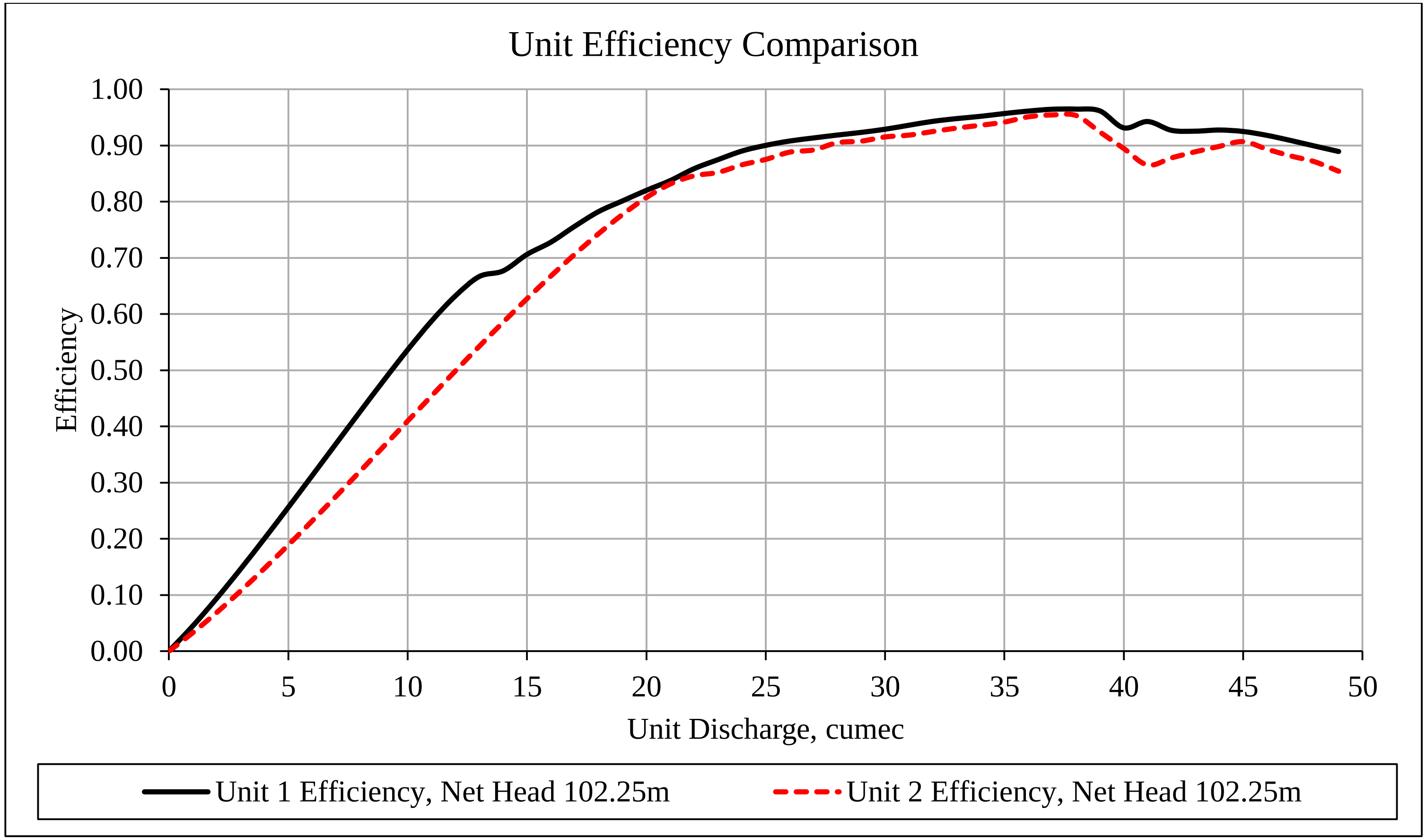

Figure 5.11: Comparison of Unit Efficiencies for a Particular Net Head

The Figure 5.11 above compares Unit 1 and Unit 2 efficiency for various discharge and particular value of net head, 102.25m. From the chart above, performance of Unit 1 is better than that Unit 2 for unit discharge for whole operating range. At net head of 102.25m and rated discharge of 40m^3/s, unit 1 has efficiency of 93.15% and unit 2 has efficiency of 89.47%. The difference in performance of Unit 1 and Unit 2 can be explained by reviewing the maintenance history log of both units of MMHPS as shown in Table 5.4 below.

Table 5.4: Maintenance History Log of Both Units of MMHPS

	S. No.	**Date**	**Energy Meter Reading (MWh)**	**Running Hour**	**Duration since last overhauling (hour)**	**Generation during that duration (MWh)**	**Type of maintenance**
Unit 1	1	9/3/2010	307,645.10	11,517.50	11,517.50	307,645.10	Maintenance
	2	11/18/2010	350,753.90	13167.7	13,167.70	350,753.90	Maintenance
	3	1/27/2012	612,191.25	22,005.90	22,005.90	612,191.25	**Overhauling**
	4	8/30/2013	961,300.31	33,569.60	11,563.70	349,109.06	Maintenance
	5	2/28/2014	1,056,364.00	37,238.80	15,232.90	444,172.75	Maintenance
	6	3/19/2015	1,311,017.75	45,007.60	23,001.70	698,826.50	**Overhauling**
	7	1/31/2017	1,773,347.75	59,633.40	**14,625.80**	**462,330.00**	
Unit 2	1	11/27/2010	366,557.80	14,180.20	14,180.20	366,557.80	Maintenance
	2	1/29/2012	576,288.25	20,330.50	20,330.50	576,288.25	Maintenance
	3	8/9/2012	677,453.88	23,664.50	23,664.50	677,453.88	Maintenance
	4	1/30/2013	773,901.56	26,687.40	26,687.40	773,901.56	**Overhauling**
	5	1/23/2015	1,198,487.75	40,988.10	14,300.70	424,586.19	Maintenance
	6	1/31/2017	1,616,804.00	54,108.25	**27,420.85**	**842,902.44**	

This research has considered data sets from October 2016 to January 2017. Unit 1 went through a major overhauling on 03/19/2015, during when major electromechanical parts including runner, wicket gates, wicket gate bushes and facing plates were replaced and other electromechanical parts were repaired. Since then, it had been in operation for 14,625.80 hours during which it generated 462,330.00MWh of energy. In contrast, Unit 2 had undergone a major overhauling on 01/30/2013. After that, it had undergone through a maintenance on 01/23/2015, during which minor repairs were conducted on electromechanical parts. Unit 2 had been in operation for 27,420.85hours during which it had generated 842,902.44MWh of energy, since its last overhauling. During this period, the electromechanical parts of Unit 2 must have eroded considerably to result in lower performance in comparison to Unit 1.

5.2. Optimization

5.2.1. Primal Optimization

After establishing performance of each unit, optimum combination of flow through each unit for maximum total power was determined for all possible gross head and flow condition. The table of solution is in Appendix 8: .

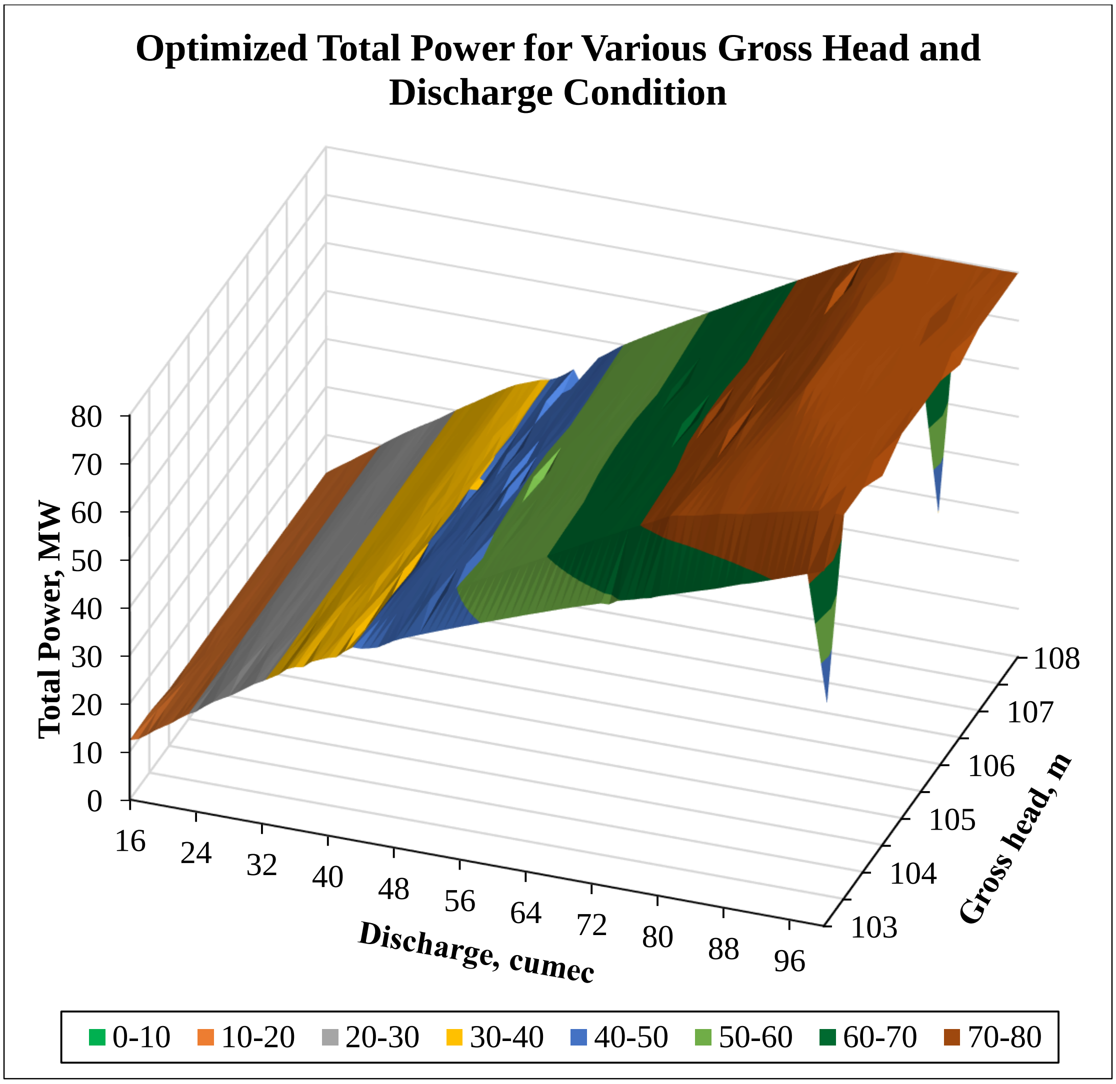

Figure 5.12: Optimized Total Power for Various Gross Head and Discharge Conditions

Gross head, m	Discharge, cumec																																										
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58
103.0	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆
103.5	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆
104.0	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆
104.5	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆
105.0	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆
105.5	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆
106.0	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆
106.5	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆
107.0	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆
107.5	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆
108.0	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	△	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆

Gross head, m	Discharge, cumec																																									
	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
103.0	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆
103.5	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆
104.0	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆
104.5	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆
105.0	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆
105.5	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆
106.0	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆
106.5	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆
107.0	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆
107.5	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆
108.0	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆

Legend

△ Unit 1 running, Unit 2 Shut down ◆ Both Units running

Figure 5.13: Unit Status Grid Matrix

Figure 5.12 above graphically shows optimal total power generation for all possible conditions of gross head and total discharge.

Figure 5.13 above shows a unit status grid matrix, which would be useful for a plant operator to determine the conditions of gross head and total available discharge for startup and shut down of individual units.

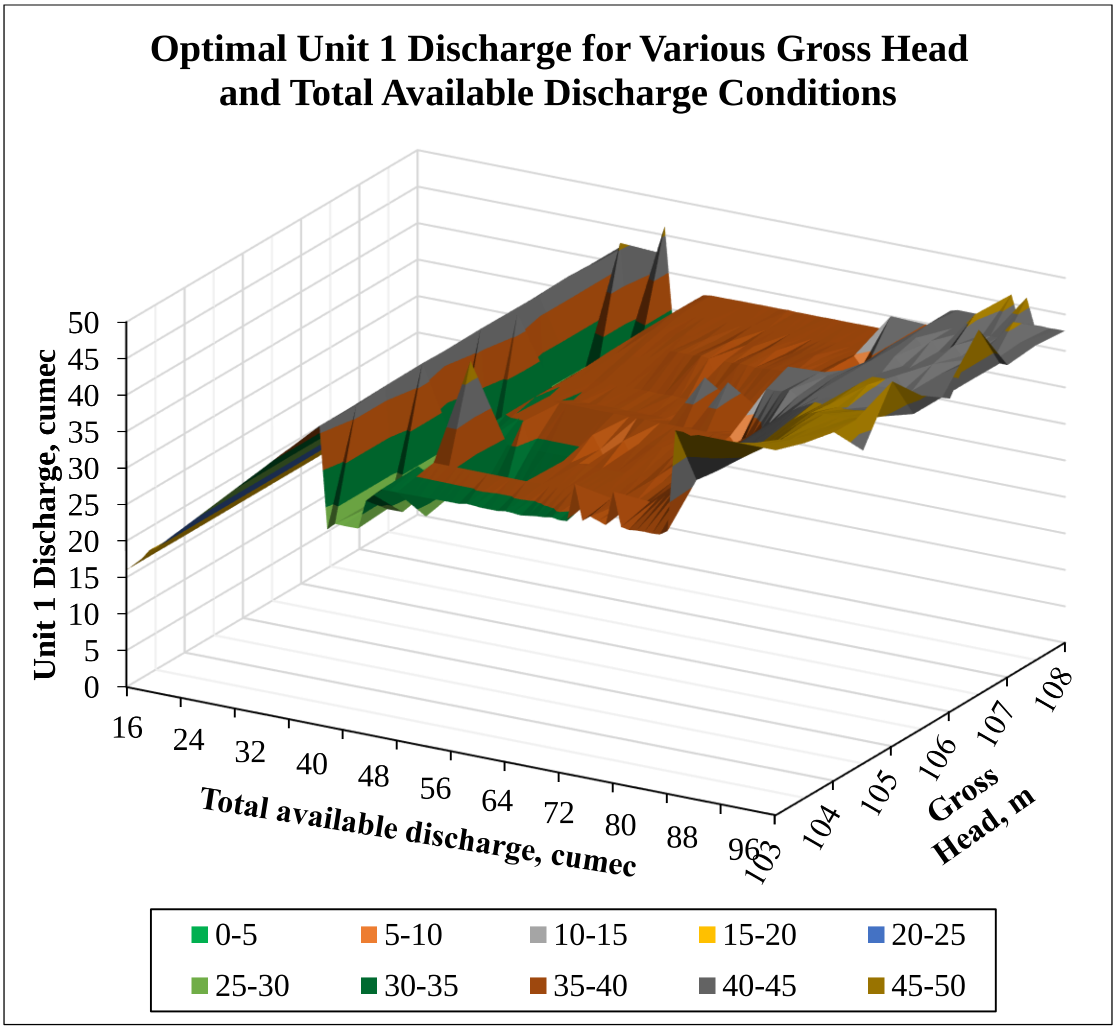

Figure 5.14: Unit 1 Discharge Distribution for Various Gross Head and Discharge Conditions

Figure 5.14 above and Figure 5.15 below represent the share of unit 1 and unit 2 discharge for maximum total power generation, respectively, for all possible conditions of gross head and total discharge. From Figure 5.15 below, it is clear that unit 2 is operated only when full capacity of Unit 1 is reached.

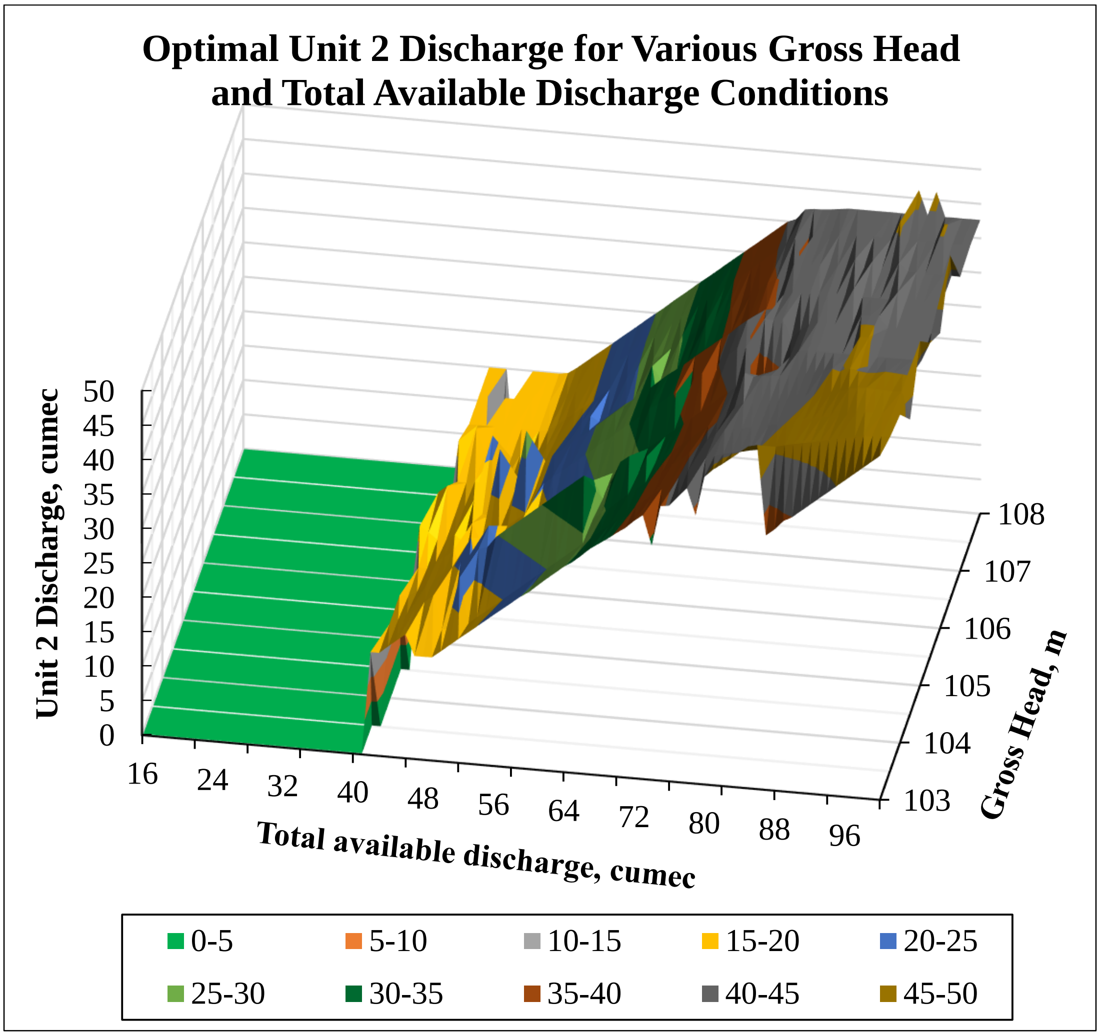

Figure 5.15: Unit 2 Discharge Distribution for Various Gross Head and Discharge Conditions

5.2.2. Dual Optimization

Similarly, the minimum total discharge required for all possible conditions of power requirement and gross head was determined. Figure 5.16 below graphically represents optimal discharge for various gross head and power requirement conditions.

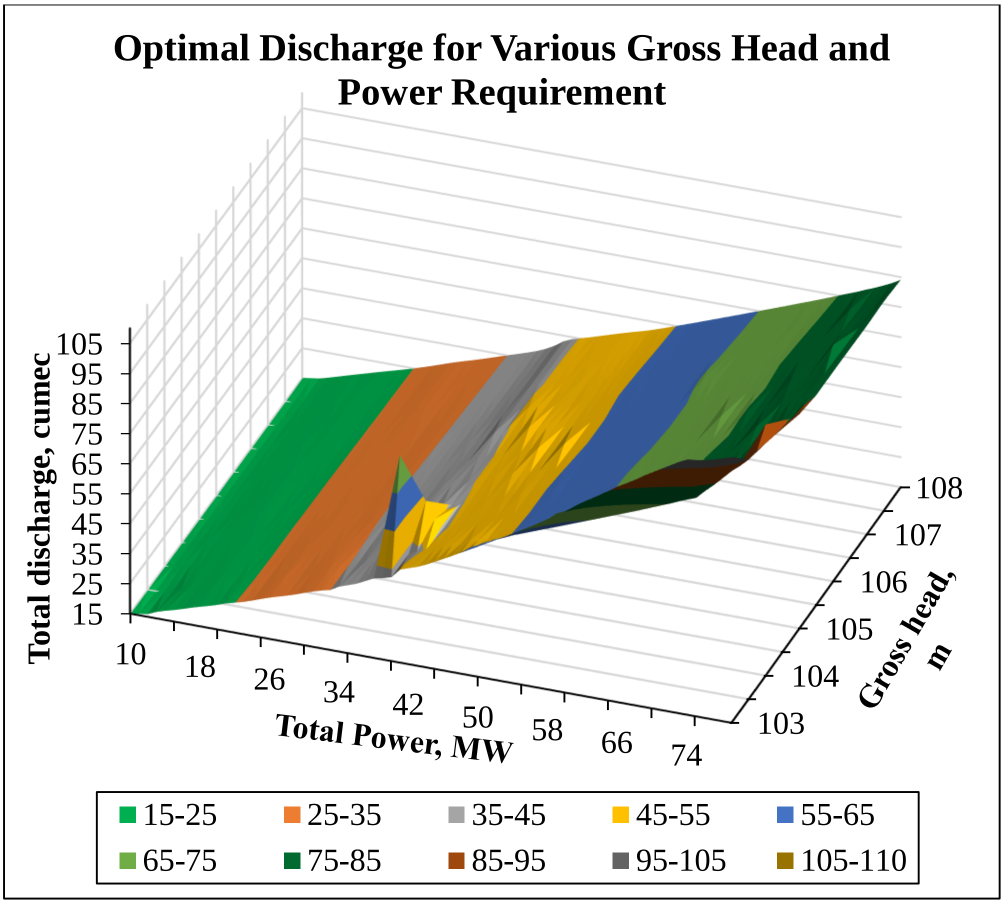

Figure 5.16: Optimal Discharge for Various Gross Head and Power Requirement

5.2.3. Comparison of Historical Operation Data with Optimal Operation

Primal optimization of maximizing total generation under same discharge and dual optimization of minimizing discharge consumption to meet the same total power generation as of actual historical data of few random dates, viz. November 14, 2016, November 15, 2016, November 24, 2016, December 01, 2016, December 17, 2016, December 30, 2016, January 01, 2017 and January 29, 2017 were done for every second of the day and summarized hourly. Hourly summary of the optimization is presented in Table A9.1, Table A9.2, Table A9.3, Table A9.4, Table A9.5, Table A9.6, Table A9.7 and Table A9.8 for November 14, 2016, November 15, 2016, November 24, 2016 December 01, 2016, December 17, 2016, December 30, 2016, January 01, 2017 and January 29, 2017, respectively and are graphically represented as Figure 5.17, Figure 5.18, Figure 5.19, Figure 5.20, Figure 5.21 Figure 5.22, Figure 5.23 and Figure 5.24, respectively.

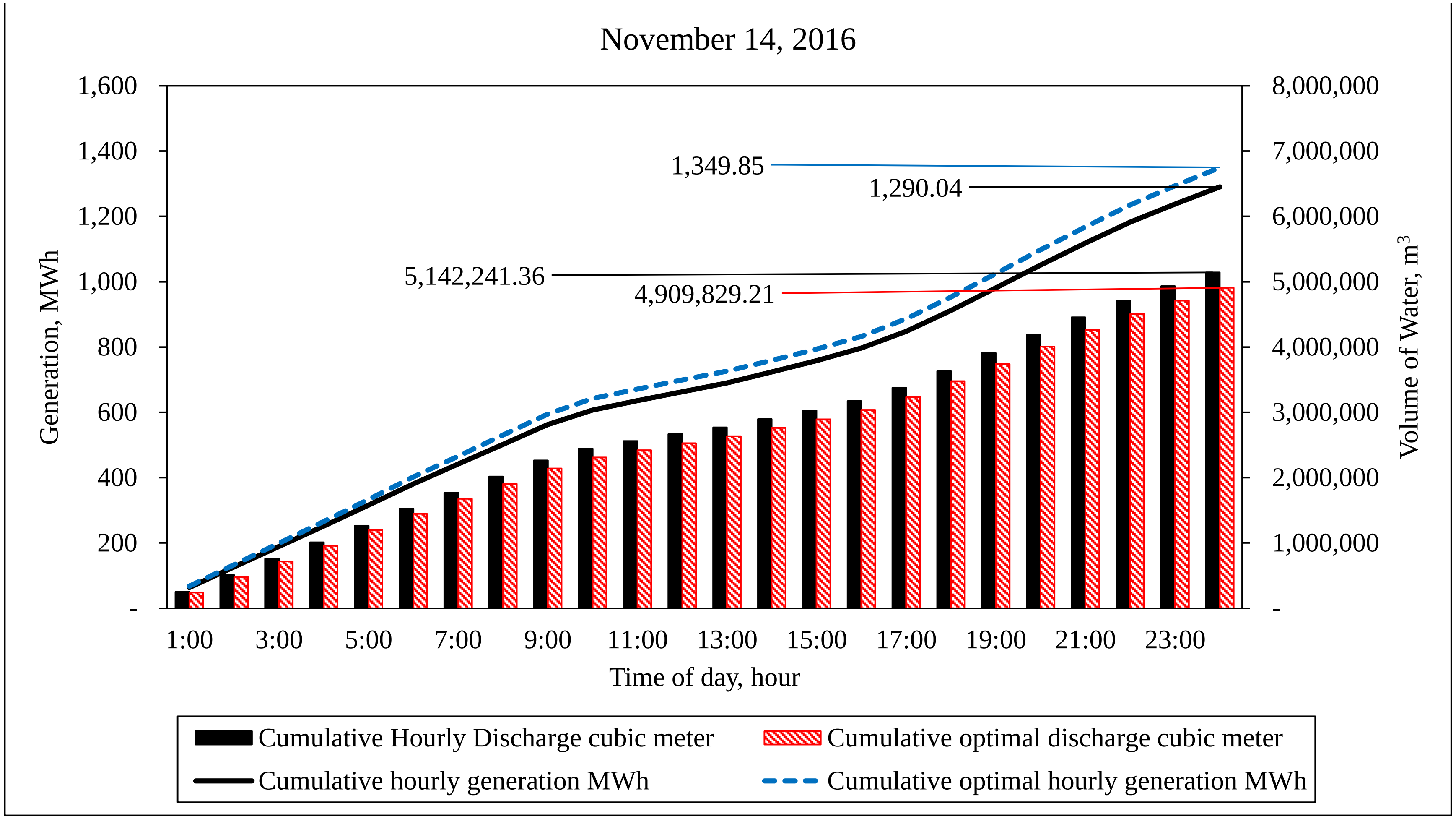

Figure 5.17: Comparison of actual and optimal operation for November 14, 2016

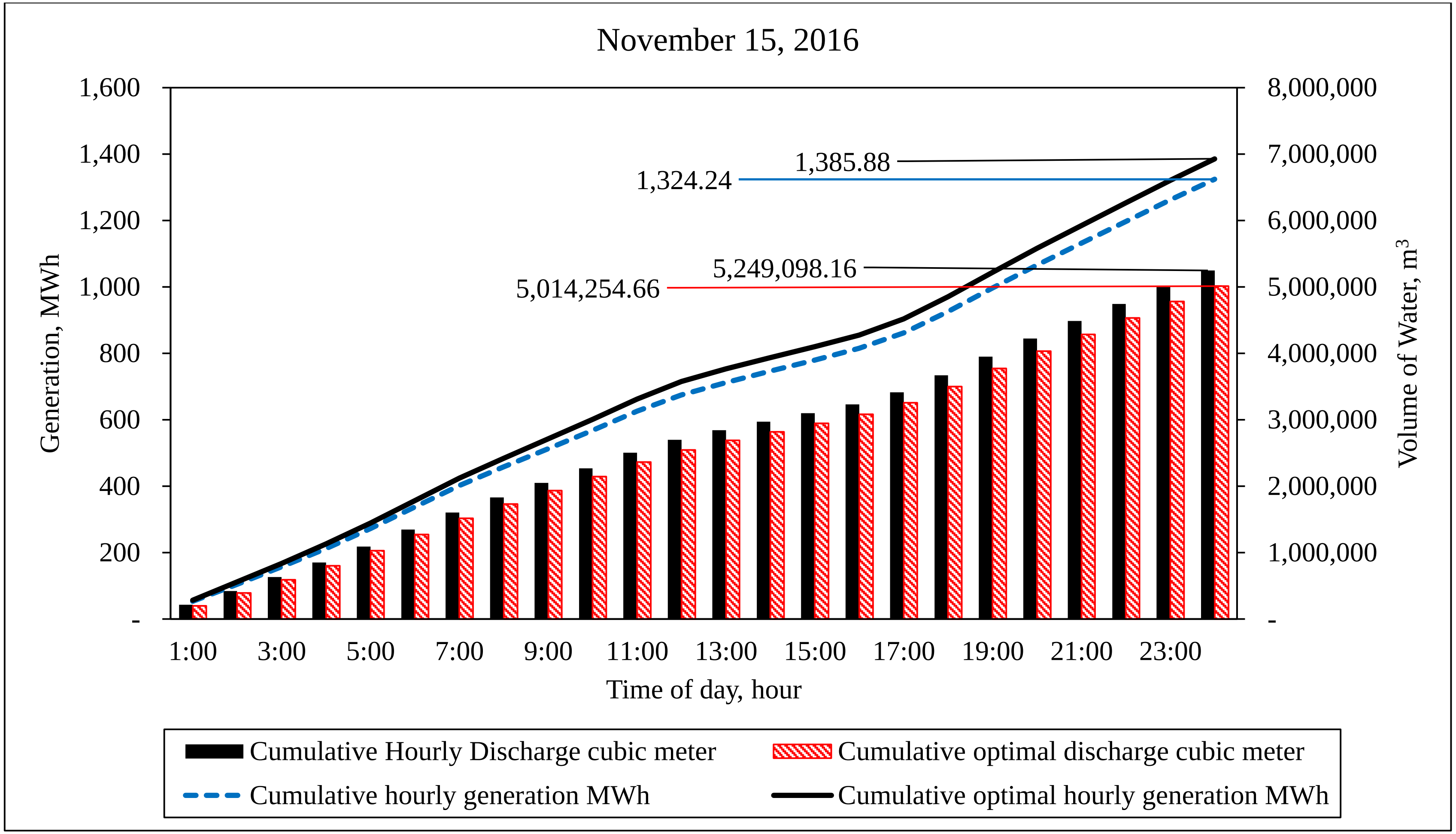

Figure 5.18: Comparison of actual and optimal operation for November 15, 2016

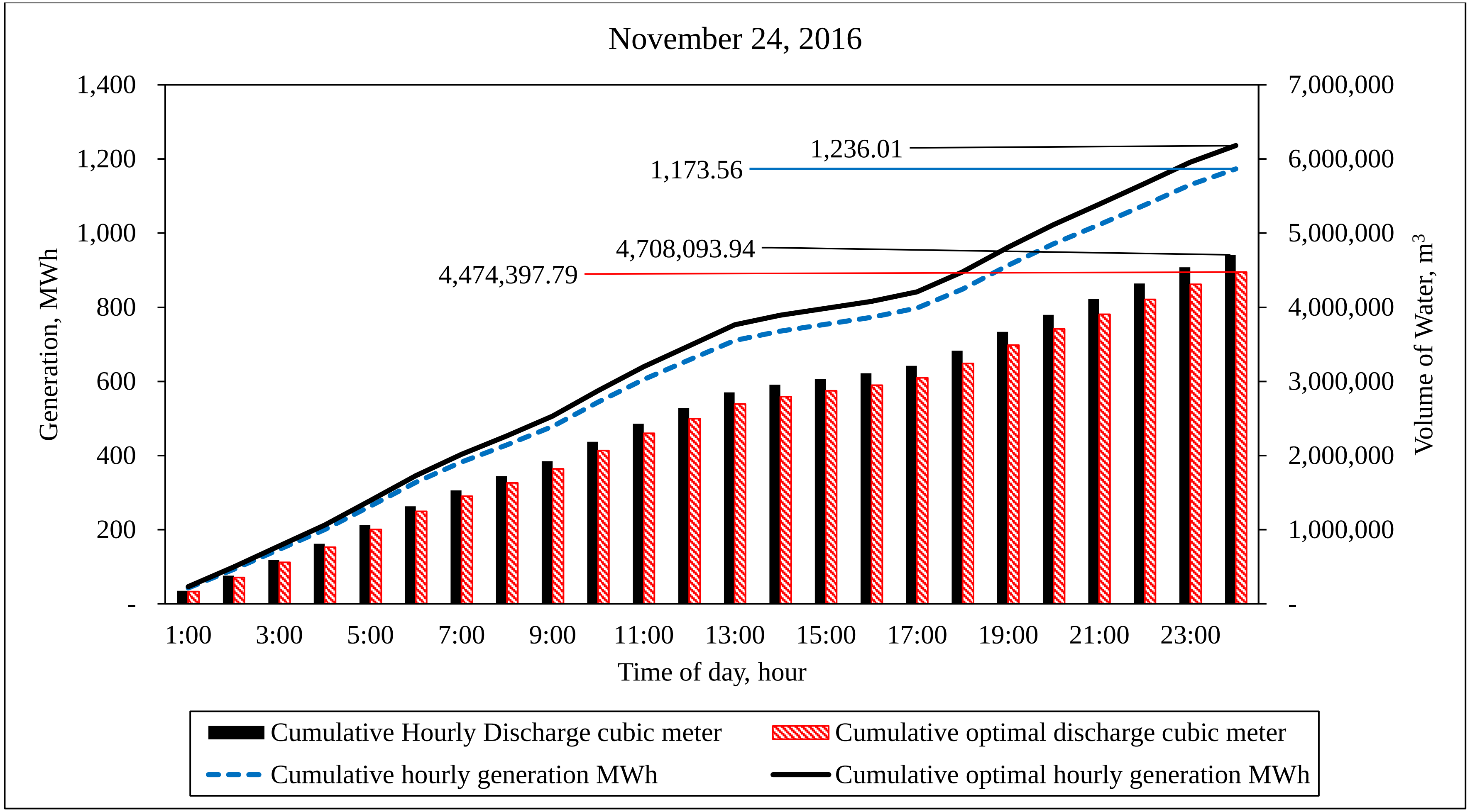

Figure 5.19: Comparison of actual and optimal operation for November 24, 2016

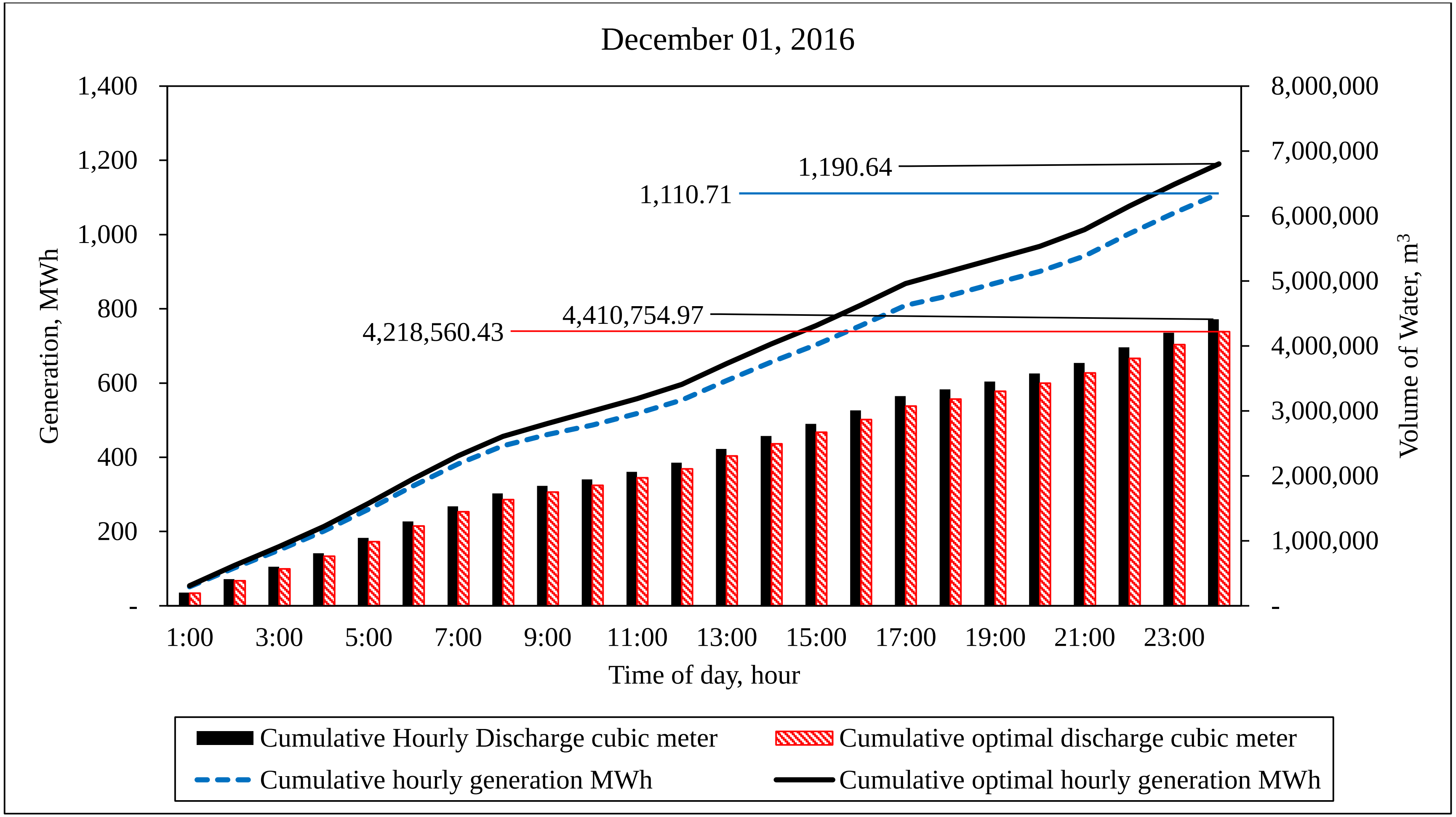

Figure 5.20: Comparison of actual and optimal operation for December 01, 2016

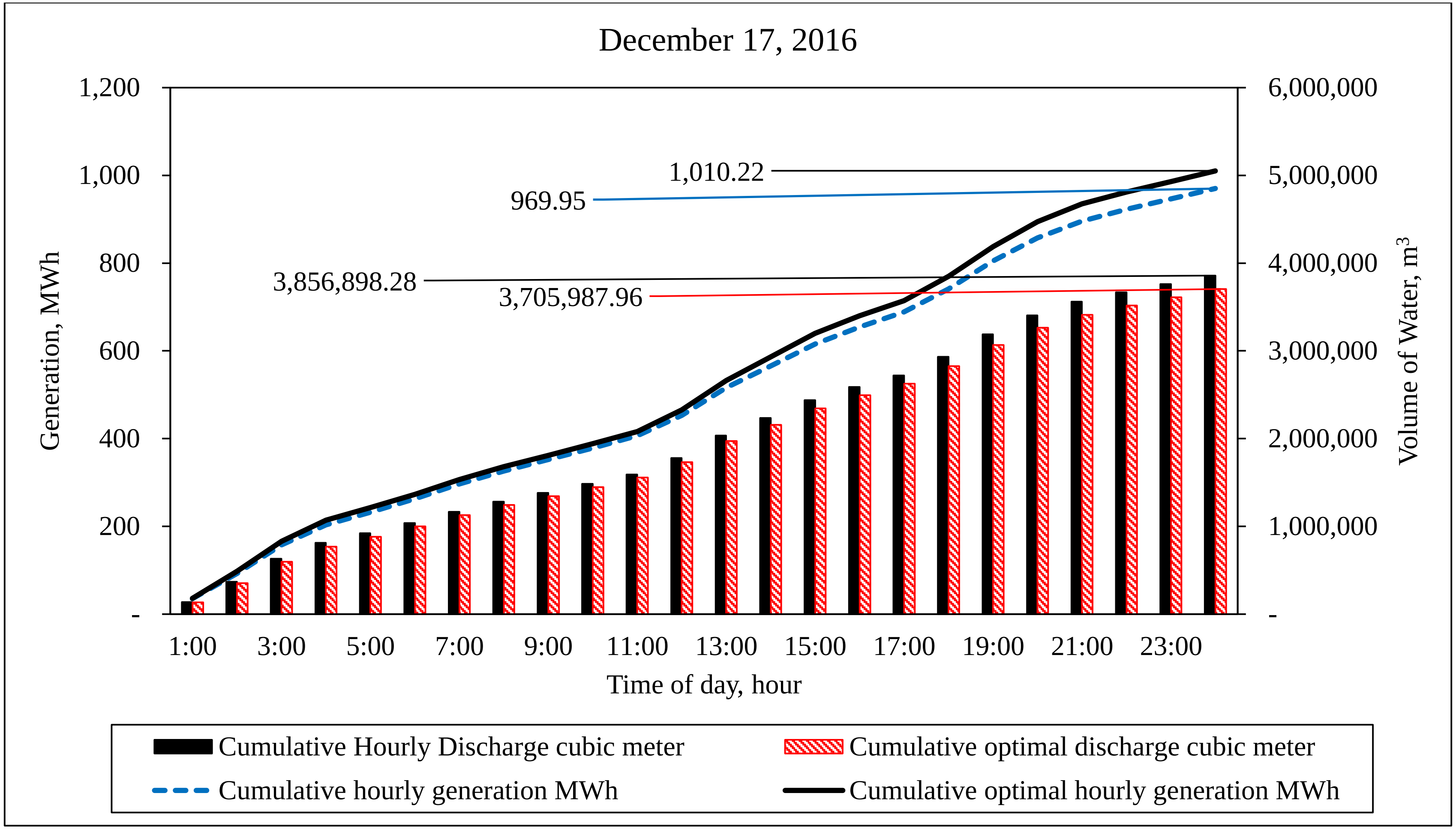

Figure 5.21: Comparison of actual and optimal operation for December 17, 2016

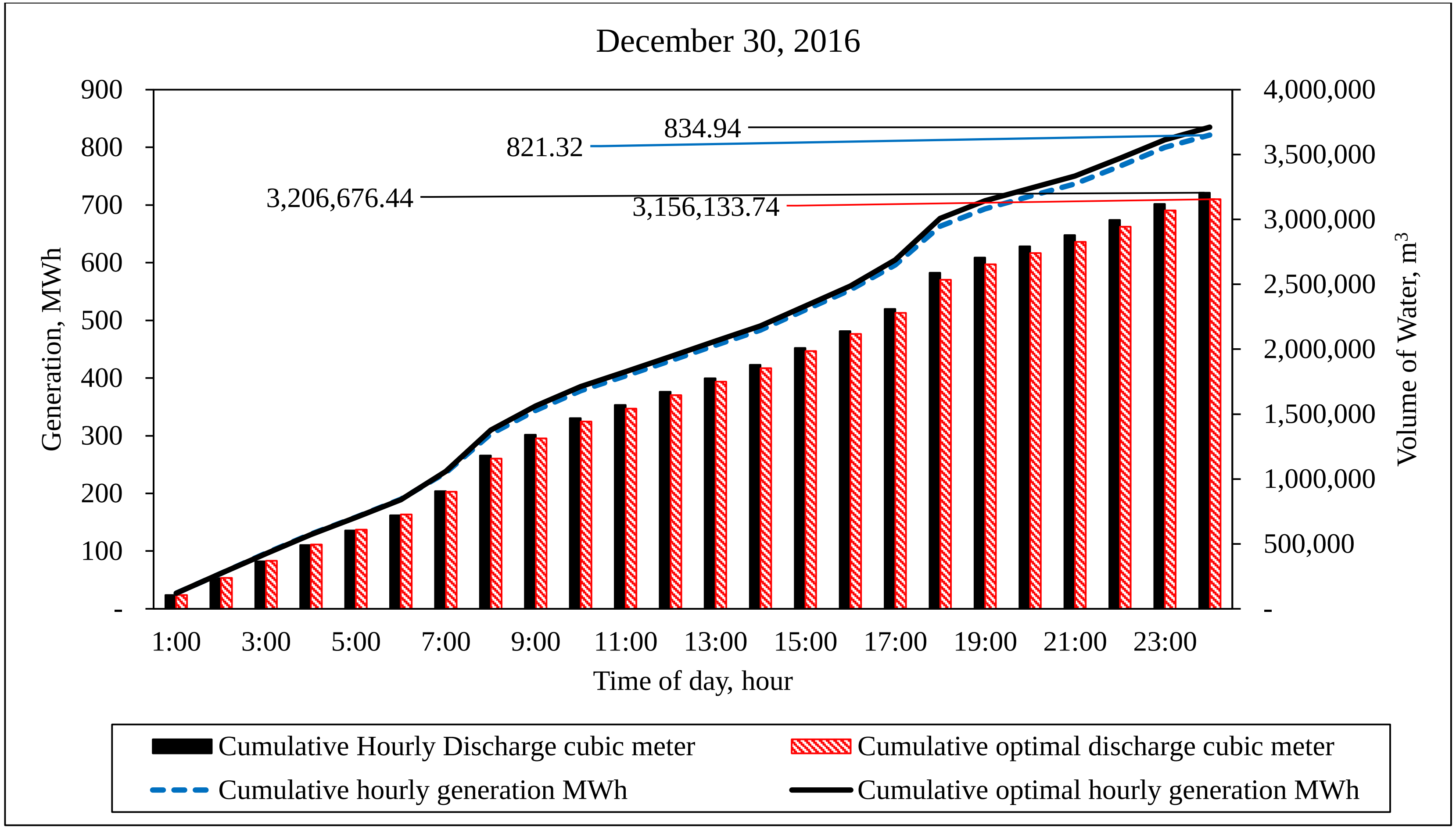

Figure 5.22: Comparison of actual and optimal operation for December 30, 2016

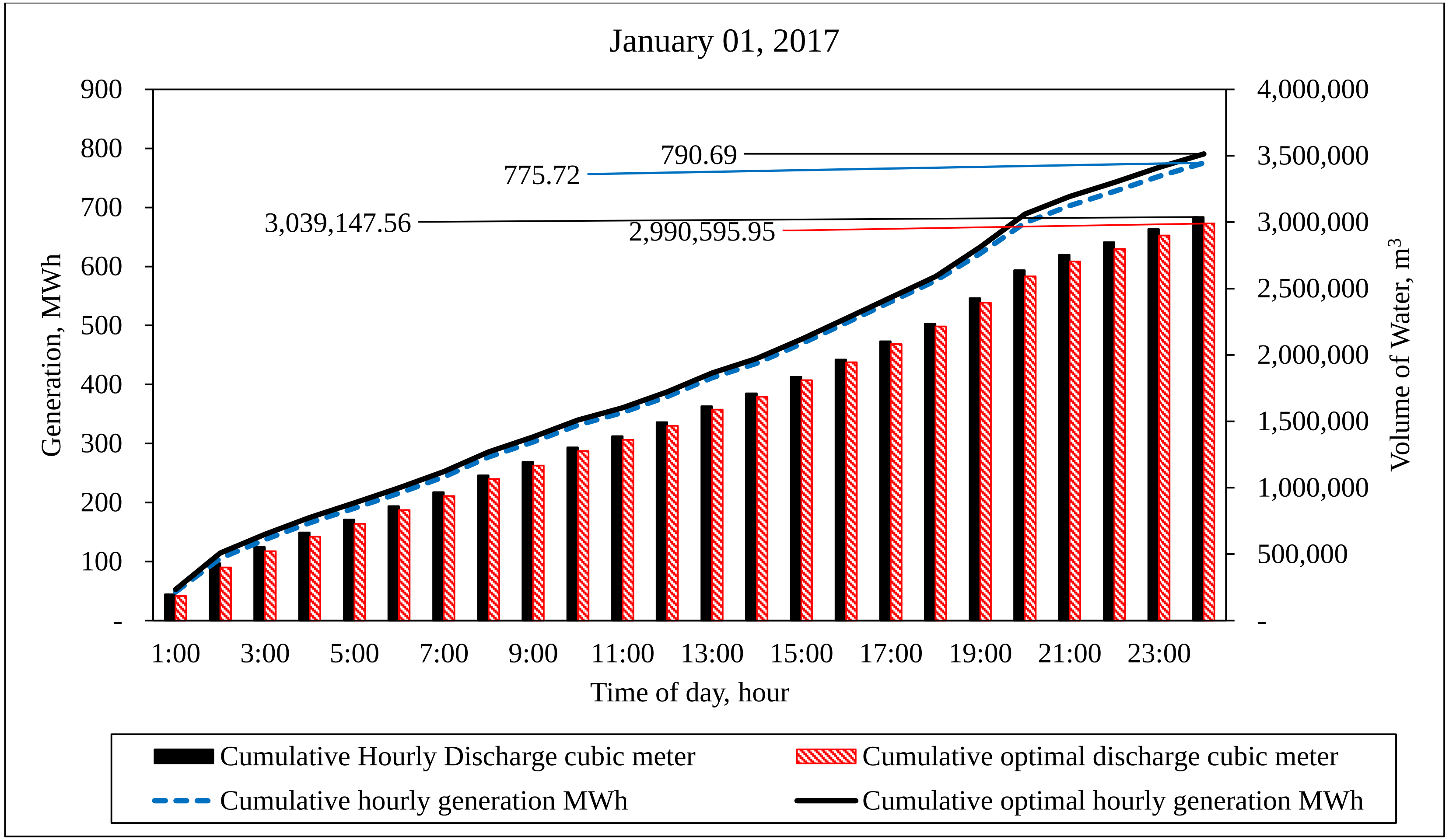

Figure 5.23: Comparison of actual and optimal operation for January 01, 2017

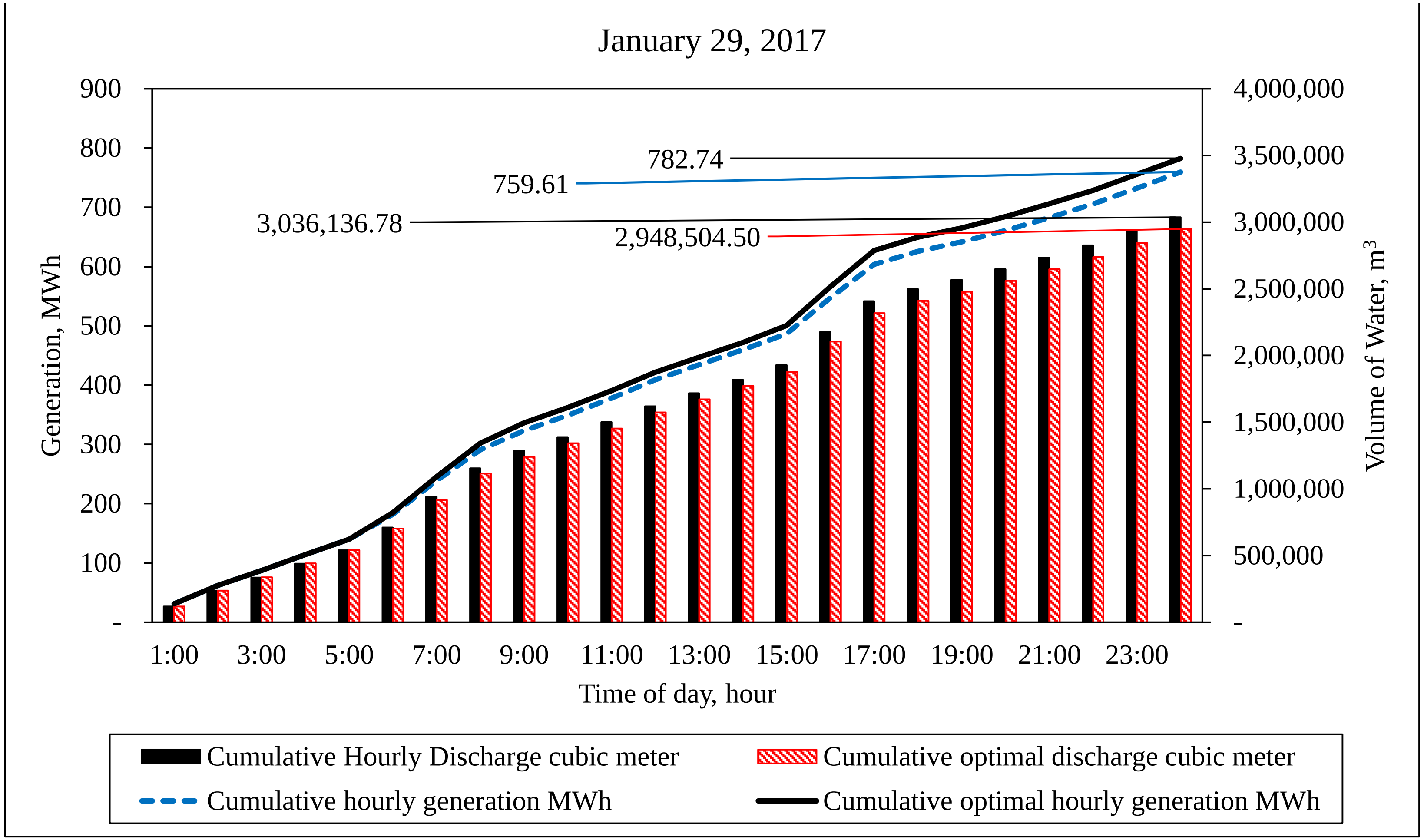

Figure 5.24: Comparison of actual and optimal operation for January 29, 2017

Table 5.5: Generation Gain and Discharge Saving of Real Historical Data

Date	Actual Generation MWh	Actual Discharge m^3	Optimal Generation MWh	Generation Gain MWh, %	Minimal Discharge m^3	Discharge Saving m^3, %
14 Nov., 2016	1,290.04	5,142,241.36	1,349.85	59.82, 4.64%	4,909,829.21	232,412.15, 4.52%
15 Nov., 2016	1,324.24	5,249,098.16	1,385.88	61.63, 4.65%	5,014,254.66	234,843.50, 4.47%
24 Nov., 2016	1,173.56	4,708,093.94	1,236.01	62.46, 5.32%	4,474,397.79	233,696.14, 4.96%
01 Dec., 2016	1,110.71	4,410,754.97	1,190.64	79.93, 7.20%	4,218,560.43	192,194.53, 4.36%
17 Dec., 2016	969.95	3,856,898.28	1,010.22	40.27 , 4.15%	3,705,987.96	150,910.32, 3.91%
30 Dec., 2016	821.32	3,206,676.44	834.94	13.62, 1.66%	3,156,133.74	50,542.70 , 1.58%
01 Jan., 2017	775.72	3,039,147.56	790.69	14.97, 1.93%	2,990,595.95	48,551.61, 1.60%
29 Jan., 2017	759.61	3,036,136.78	782.74	23.13, 3.04%	2,948,504.50	87,632.29, 2.89%
Generation Gain/ Discharge Saving				**1.66-7.20%**		**1.58-4.96%**

Table 5.5 above summarizes the generation gain and discharge saving from Table A9.1, Table A9.2, Table A9.3, Table A9.4, Table A9.5, Table A9.6, Table A9.7 and Table A9.8. It is determined that 1.66%-7.20%% additional energy could have been generated if optimal unit commitment and economic load dispatch had been done. Similarly, 1.58%-4.96% discharge saving could have been achieved to meet the same load demand, if the optimal load allocation had been done.

5.3. Validation

Study of optimal utilization of discharge through unit commitment conducted at Devighat Hydropower Plant has shown that additional gain in energy generation up to 6% is achievable for a ROR plant (Dahal 2013). Study of reservoir operation of Hoa Binh River in Vietnam has shown that additional 3% gain in energy production can be achieved through optimization of reservoir operation (Madsen, et al. 2009). A study conducted in Lower Colorado River system consisting of three power plants using dynamic programming determined that 1.8% increase in basin wide efficiency value can be obtained by optimal unit commitment (Yi, Labadie and Stitt 2003). A decision support system that addresses optimal unit dispatch and load allocation in a multi-unit Pensacola power plant of total installed capacity 90MW was able to obtain 1.9% improvement in annual energy generation (Cook and Walsh 2008).

Short term hydropower generation scheduling done on Xiluodu (12,600MW) and Xiangjiaba (6,000MW) cascaded hydropower stations located in Jisha River of China using binary coded bee colony optimization algorithm has shown that water saving of 1.36% of actual total water consumption can be achieved under same load conditions and river inflow (Lu, et al. 2015). Real-time operation optimization done on Itá Hydropower Plant (1450MW), located in southern Brazil, has shown a 0.28% lower outflow is required for same power requirement set by independent system operator (Cordova, et al. 2014).

CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion

- Head loss for both units are higher than the designed value. Amongst the units, Unit 1 was found to have 0.28m higher head loss than Unit 2 due to the difference in hydraulic path. So, even if discharge to both units are same, Unit 2 will be subjected to more hydraulic power than Unit 1.
- From efficiency comparison, it was found that Unit 1 has better performance than Unit 2 for all possible head and discharge conditions. At rated conditions, efficiency of Unit 1 exceeds that of Unit 2 by 3.68%. Unit 2 has been in operation for more hours since its last overhauling than Unit 1 and the erosion and cavitation associated with operational hours is the root cause of Unit 2 having poorer efficiency than Unit 1.
- Unit 2 has higher value of net head due to its hydraulic path but has lower value of efficiency due to higher operational hours. These two factors are counter-acting each other and from result of the optimization, it is observed that the effects of efficiency are greater than the effects of head loss.
- From unit status grid matrix and unit discharge distribution of each individual unit, it is observed that Unit 1 is to be operated for all conditions of gross head and total discharge; Unit 2 is to be started up as guided by unit status grid matrix.
- Primal and dual optimization solution provides operational guide for operators. The optimization of historical data based on solution of primal and dual optimization shows that generation gain can be achieved with same use of discharge. The generation gain is 1.66-7.20%. Similarly, for same generation discharge saving of 1.58-4.96% could have been achieved.

6.2. Recommendations

- It is advisable to provide runner with better performance to Unit 2 than to Unit 1 since Unit 2 is subjected to higher hydraulic power due to lesser head loss.

- It is advisable to develop a Decision support system which is integrated to existing SCADA system to have optimum output and to provide ease of operation to plant operators.
- Sand deposition in intake and choking of trash rack should be avoided as much as possible to reduce head loss.

REFERENCES

ALSTOM Power Generation AG. 2005. "ALSPA Centralog- User's Manual." Salzgitter.

ALSTOM Power Generation AG. 2005. "Instrumentation and Control Manual." Salzgitter.

Charlie, Young. 2017. *Excel Solver: Which Solving Method Should I Choose?* Accessed 2017. http://www.engineerexcel.com/excel-solver-solving-method-choose/.

Cook, Jim, and Jim Walsh. 2008. "Optimization of Hydro-Power Plants for Generation." *IGHEM Conference 2008.* Milano. 10.

Cordova, M.M., E.C. Finardi, F.A.C. Ribas, V.L. de Matos, and M.R. Scuzziato. 2014. "Performance evaluation and energy production optimization in the real-time operation of hydropower plants." *Electric Power Systems Research* 201-207.

Dahal, Suraj. 2013. "Operation Optimization and Performance Evaluation of Devighat Hydropower Plant." Lalitpur, Nepal.

Douglas, John F., Janusz M. Gasiorek, John A. Swaffield, and Lynne B. Jack. 2006. *Fluid Mechanics.* Pearson Prentice Hall.

Frontline Systems Inc. 2017. *Frontline Solvers.* Accessed 2017. http://www.solver.com.

Harmon, Mark. 2011. "Step-by-Step Optimization with Excel Solver." *Excel Master Series.* http://www.excelmasterseries.com/New_manuals.php.

IEA. 2015. "Key World Energy Statistics 2015."

Lee, Hong-Tau, Sheu-Hua Chen, and He-Yau Kang. 2004. "A Study of Generalized Reduced Gradient Method with Different Search Directions." *Journal of Metrology Management* 25-38.

Lopez, Balbino. 2012. *Essential Concepts on Mechanics of Fluids Applied to Power Plants.* Lamjung.

Lu, Peng, Jianzhong Zhou, Chao Wang, Qi Qiao, and Li Mo. 2015. "Short-term hydro generation scheduling of Xiluodu and Xiangjiaba cascade hydropower stations using improved binary-real coded bee colony optimization algorithm." *Energy Conversion and Management* 19-31.

Madsen, Henrik, Bertrand Richaud, Claus B. Pedersen, and Carter Borden. 2009. "A Real-Time Inflow Forecasting and Reservoir Optimization System for Optimizing Hydropower Production." *Waterpower XVI* . PennWell Corporation.

NEA. 2016. "A Year in Review- Fiscal Year 2015/16." Kathmandu.

NEA, Generation Operation and Maintenance Group. 2013. "Generation." Kathmandu.

USBR. 2012. "Advanced Algorithms for Hydropower Optimization." Denver, Colorado.

Voith Siemens Hydro GmbH. 2008. "Operation and Maintenance Manual." Heidenheim.

WECS. 2010. *Energy Sector Synopsis Report.* Kathmandu, Nepal: Kamala Media Pvt. Ltd Kathmandu.

Wikipedia Foundation Inc. 2017. *Wikipedia.* April 01. Accessed April 11, 2017. https://en.wikipedia.org/wiki/SCADA.

Yi, Jaeeung, John W. Labadie, and Steven Stitt. 2003. "Dynamic Optimal Unit Commitment and Loading in Hydropower Systems." *Journal of Water Resources Planning and Management* 388-398.

APPENDIX

APPENDIX 1: SAMPLE DATA SET

A sample of thirty-seven (37) data sets of thirty-seven (37) seconds of plant operation is tabulated below.

Time	Water Flow	Intake Level	U1 Penstock Pressure	U1 Spiral Case Pressure	U1 Draft Tube Pressure	U2 Penstock Pressure	U2 Spiral Case Pressure	U2 Draft Tube Pressure	U1 Active Power	U2 Active Power
3:09:00	76.402340	621.793800	9.171875	9.101562	1.318125	9.304688	9.093750	1.614375	35.710000	30.610000
3:09:01	76.402340	621.793800	9.171875	9.101562	1.318125	9.304688	9.093750	1.614375	35.710000	30.610000
3:09:02	76.031250	621.793800	9.171875	9.078125	1.314375	9.265625	9.101562	1.605000	35.590000	30.270000
3:09:03	76.031250	621.793800	9.171875	9.078125	1.314375	9.265625	9.101562	1.605000	35.590000	30.270000
3:09:04	75.625000	621.793800	9.179688	9.101562	1.318125	9.257812	9.101562	1.614375	35.520000	29.950000
3:09:05	75.187500	621.793800	9.148438	9.085938	1.318125	9.257812	9.101562	1.616250	35.460000	29.870000
3:09:06	75.000000	621.793800	9.164062	9.093750	1.314375	9.296875	9.109375	1.606875	35.470000	29.820000
3:09:07	75.000000	621.793800	9.164062	9.093750	1.314375	9.296875	9.109375	1.606875	35.470000	29.820000
3:09:08	75.062500	621.793800	9.164062	9.078125	1.310625	9.242188	9.117188	1.616250	35.460000	29.700000
3:09:09	75.062500	621.793800	9.164062	9.078125	1.310625	9.242188	9.117188	1.616250	35.460000	29.700000
3:09:10	75.062500	621.793800	9.164062	9.085938	1.310625	9.273438	9.125000	1.605000	35.380000	29.680000
3:09:11	75.062500	621.768700	9.164062	9.085938	1.310625	9.273438	9.125000	1.605000	35.380000	29.680000
3:09:12	75.156250	621.768700	9.164062	9.085938	1.314375	9.265625	9.125000	1.608750	35.310000	29.640000
3:09:13	75.156250	621.768700	9.164062	9.085938	1.314375	9.265625	9.125000	1.608750	35.310000	29.640000
3:09:14	75.250000	621.768700	9.179688	9.117188	1.306875	9.289062	9.132812	1.614375	35.390000	29.660000
3:09:15	75.375000	621.768700	9.171875	9.093750	1.316250	9.281250	9.132812	1.608750	35.450000	29.680000
3:09:16	75.500000	621.768700	9.179688	9.117188	1.305000	9.281250	9.132812	1.620000	35.410000	29.680000

Time	Water Flow	Intake Level	U1 Penstock Pressure	U1 Spiral Case Pressure	U1 Draft Tube Pressure	U2 Penstock Pressure	U2 Spiral Case Pressure	U2 Draft Tube Pressure	U1 Active Power	U2 Active Power
3:09:17	75.500000	621.768700	9.179688	9.117188	1.305000	9.281250	9.132812	1.620000	35.410000	29.680000
3:09:18	75.437500	621.768700	9.179688	9.109375	1.314375	9.312500	9.148438	1.605000	35.410000	29.700000
3:09:19	75.437500	621.768700	9.179688	9.109375	1.314375	9.312500	9.148438	1.605000	35.410000	29.700000
3:09:20	75.343750	621.787500	9.187500	9.125000	1.306875	9.335938	9.164062	1.614375	35.340000	29.710000
3:09:21	75.343750	621.787500	9.187500	9.125000	1.306875	9.335938	9.164062	1.614375	35.340000	29.710000
3:09:22	75.312500	621.787500	9.203125	9.132812	1.303125	9.328125	9.164062	1.627500	35.390000	29.640000
3:09:23	75.312500	621.787500	9.203125	9.132812	1.303125	9.328125	9.164062	1.627500	35.390000	29.640000
3:09:24	75.250000	621.787500	9.203125	9.171875	1.310625	9.335938	9.164062	1.605000	35.370000	29.630000
3:09:25	75.125000	621.787500	9.234375	9.164062	1.312500	9.335938	9.164062	1.605000	35.390000	29.630000
3:09:26	75.031250	621.787500	9.218750	9.164062	1.314375	9.335938	9.171875	1.616250	35.440000	29.550000
3:09:27	75.031250	621.787500	9.218750	9.164062	1.314375	9.335938	9.171875	1.616250	35.440000	29.550000
3:09:28	74.628910	621.787500	9.210938	9.164062	1.314375	9.351562	9.171875	1.616250	35.560000	29.510000
3:09:29	74.628910	621.787500	9.210938	9.164062	1.314375	9.351562	9.171875	1.616250	35.560000	29.510000
3:09:30	74.535160	621.793800	9.210938	9.140625	1.314375	9.335938	9.171875	1.606875	35.490000	29.380000
3:09:31	74.535160	621.793800	9.210938	9.140625	1.314375	9.335938	9.171875	1.606875	35.490000	29.380000
3:09:32	74.472660	621.793800	9.210938	9.171875	1.314375	9.320312	9.187500	1.625625	35.490000	29.350000
3:09:33	74.472660	621.793800	9.210938	9.171875	1.314375	9.320312	9.187500	1.625625	35.490000	29.350000
3:09:34	74.160160	621.793800	9.218750	9.140625	1.321875	9.343750	9.187500	1.621875	35.490000	29.340000
3:09:35	74.066410	621.793800	9.218750	9.156250	1.310625	9.351562	9.187500	1.606875	35.470000	29.340000
3:09:36	74.035160	621.793800	9.203125	9.132812	1.314375	9.343750	9.195312	1.608750	35.440000	29.320000

APPENDIX 2: SAMPLE DATA SET OF UNIT 1 OPERATION

A sample of data sets representing shutdown of Unit 2 and operation of Unit 1 only is tabulated below.

Water Flow	Intake Level	U1 Penstock Pressure	U1 Spiral Case Pressure	U1 Draft Tube Pressure	U2 Penstock Pressure	U2 Spiral Case Pressure	U2 Draft Tube Pressure	U1 Active Power	U2 Active Power
37.937500	624.600000	9.945312	9.875000	1.471875	10.289060	0.039063	1.453125	36.540000	-
37.937500	624.600000	9.945312	9.875000	1.471875	10.289060	0.039063	1.453125	36.540000	-
37.968750	624.600000	9.953125	9.890625	1.470000	10.289060	0.039063	1.453125	36.540000	-
37.968750	624.600000	9.953125	9.890625	1.470000	10.289060	0.039063	1.453125	36.540000	-
38.062500	624.600000	9.953125	9.890625	1.471875	10.265620	0.039063	1.453125	36.570000	-
38.062500	624.600000	9.953125	9.882812	1.470000	10.242190	0.039063	1.455000	36.600000	-
38.093750	624.600000	9.945312	9.890625	1.468125	10.265620	0.039063	1.455000	36.590000	-
38.093750	624.600000	9.945312	9.890625	1.468125	10.265620	0.039063	1.455000	36.590000	-
37.968750	624.600000	9.976562	9.898438	1.471875	10.242190	0.039063	1.451250	36.630000	-
37.968750	624.600000	9.976562	9.898438	1.471875	10.242190	0.039063	1.451250	36.630000	-
37.812500	624.600000	9.945312	9.882812	1.471875	10.265620	0.039063	1.455000	36.590000	-
37.812500	624.600000	9.945312	9.882812	1.471875	10.265620	0.039063	1.455000	36.590000	-
37.875000	624.600000	9.937500	9.890625	1.473750	10.281250	0.039063	1.455000	36.610000	-
37.875000	624.600000	9.937500	9.890625	1.473750	10.281250	0.039063	1.455000	36.610000	-
37.812500	624.600000	9.968750	9.898438	1.471875	10.265620	0.039063	1.455000	36.580000	-
37.781250	624.600000	9.945312	9.882812	1.471875	10.273440	0.039063	1.453125	36.580000	-
37.781250	624.600000	9.953125	9.898438	1.471875	10.281250	0.039063	1.453125	36.570000	-
37.781250	624.600000	9.953125	9.898438	1.471875	10.281250	0.039063	1.453125	36.570000	-
37.937500	624.600000	9.953125	9.882812	1.471875	10.281250	0.039063	1.453125	36.570000	-

Water Flow	Intake Level	U1 Penstock Pressure	U1 Spiral Case Pressure	U1 Draft Tube Pressure	U2 Penstock Pressure	U2 Spiral Case Pressure	U2 Draft Tube Pressure	U1 Active Power	U2 Active Power
37.937500	624.600000	9.953125	9.882812	1.471875	10.281250	0.039063	1.453125	36.570000	-
38.031250	624.600000	9.937500	9.882812	1.471875	10.281250	0.039063	1.455000	36.610000	-
38.031250	624.600000	9.937500	9.882812	1.471875	10.281250	0.039063	1.455000	36.610000	-
37.937500	624.600000	9.945312	9.890625	1.471875	10.273440	0.039063	1.455000	36.600000	-
37.937500	624.600000	9.945312	9.890625	1.471875	10.273440	0.039063	1.455000	36.600000	-
37.843750	624.600000	9.960938	9.890625	1.471875	10.265620	0.039063	1.455000	36.580000	-
37.843750	624.600000	9.945312	9.882812	1.470000	10.281250	0.039063	1.455000	36.580000	-
37.875000	624.600000	9.945312	9.890625	1.471875	10.273440	0.039063	1.455000	36.590000	-
37.875000	624.600000	9.945312	9.890625	1.471875	10.273440	0.039063	1.455000	36.590000	-
37.781250	624.600000	9.945312	9.898438	1.471875	10.257810	0.039063	1.455000	36.590000	-
37.781250	624.600000	9.945312	9.898438	1.471875	10.257810	0.039063	1.455000	36.590000	-
37.781250	624.600000	9.960938	9.890625	1.473750	10.257810	0.039063	1.455000	36.560000	-
37.781250	624.600000	9.960938	9.890625	1.473750	10.257810	0.039063	1.455000	36.560000	-
37.937500	624.600000	9.953125	9.898438	1.471875	10.281250	0.039063	1.455000	36.570000	-
37.937500	624.600000	9.953125	9.898438	1.471875	10.281250	0.039063	1.455000	36.570000	-
38.031250	624.600000	9.945312	9.890625	1.471875	10.257810	0.039063	1.455000	36.550000	-
38.062500	624.600000	9.937500	9.882812	1.479375	10.281250	0.039063	1.453125	36.530000	-
38.187500	624.600000	9.945312	9.882812	1.471875	10.281250	0.039063	1.453125	36.540000	-
38.187500	624.600000	9.945312	9.882812	1.471875	10.281250	0.039063	1.453125	36.540000	-
38.093750	624.600000	9.968750	9.890625	1.471875	10.289060	0.039063	1.453125	36.560000	-
38.093750	624.600000	9.968750	9.890625	1.471875	10.289060	0.039063	1.453125	36.560000	-
37.812500	624.600000	9.984375	9.890625	1.471875	10.281250	0.039063	1.451250	36.530000	-
37.812500	624.600000	9.984375	9.890625	1.471875	10.281250	0.039063	1.451250	36.530000	-

APPENDIX 3: SAMPLE CALCULATION OF UNIT 1 HEAD LOSS

A sample of calculation of few data sets for head loss in Unit 1 is tabulated below.

Water Flow	Headloss Before Bifurcation	Unit#1 Penstock Head Loss	Unit#1 Draft Tube Head Loss	Unit#1 Net Head	Unit#1 Efficiency
14.125000	2.505601121	0.594971118	0.000470659	103.667657	0.666210066
16.312500	2.920980836	0.235527633	0.000760197	103.548931	0.741680276
16.312500	2.927280836	0.235527633	0.000760197	103.548931	0.741680276
16.312500	0.294635576	0.71330541	0.000760197	105.778799	0.726045302
16.312500	0.294635576	0.71330541	0.000760197	105.778799	0.726045302
16.312500	1.572018349	0.315242209	0.000760197	105.061979	0.743489608
16.312500	1.578218349	0.315242209	0.000760197	105.061979	0.743489608
12.906250	1.785810703	0.495115901	0.000924508	104.324449	0.633680405
12.906250	1.785810703	0.495115901	0.000924508	104.324449	0.633680405
16.656250	2.761755556	0.533586413	0.001215963	103.409642	0.734453845
14.531250	3.245833333	0.414592147	0.00145928	103.050615	0.692987191
14.531250	3.245833333	0.414592147	0.00145928	103.050615	0.692987191
14.531250	0.607435984	0.573817427	0.00145928	104.085987	0.683398006
13.750000	0.011995719	0.45444457	0.001534203	106.275826	0.663398254
13.750000	0.011995719	0.45444457	0.001534203	106.275826	0.663398254
14.156250	3.222420693	0.195003932	0.001996714	103.349279	0.682115646
14.156250	3.222420693	0.195003932	0.001996714	103.349279	0.682115646
14.156250	0.209270846	0.672883647	0.001996714	104.384549	0.680869223
14.156250	0.209270846	0.672883647	0.001996714	104.384549	0.680869223
14.156250	0.607435984	1.309988641	0.001996714	103.349279	0.680722151

Water Flow	Headloss Before Bifurcation	Unit#1 Penstock Head Loss	Unit#1 Draft Tube Head Loss	Unit#1 Net Head	Unit#1 Efficiency
12.500000	2.644640979	0.354554825	0.002215696	103.667389	0.623809535
12.500000	2.644640979	0.354554825	0.002215696	103.667389	0.623809535
12.500000	2.326088481	0.434167465	0.002215696	103.906328	0.626299222
12.500000	2.326088481	0.434167465	0.002215696	103.906328	0.626299222
12.500000	2.326088481	0.593494683	0.002215696	103.747001	0.620972716
16.343750	1.094240571	0.552234724	0.002522327	105.301002	0.738606678
15.656250	1.350191131	0.11424001	0.002760816	105.420308	0.718288112
15.656250	1.350191131	0.11424001	0.002760816	105.420308	0.718288112
15.656250	3.839238328	0.034525433	0.002760816	102.792275	0.720183604
15.656250	3.839238328	0.034525433	0.002760816	102.792275	0.720183604
15.656250	3.239533333	0.19385265	0.002760816	103.270053	0.708655489
14.937500	1.170578491	0.472556146	0.003017853	105.141348	0.686048032
14.562500	2.124650561	0.333233481	0.003029178	104.245287	0.682232389
14.562500	1.795183486	0.492560698	0.003029178	104.484227	0.69742105
14.562500	1.795183486	0.492560698	0.003029178	104.484227	0.69742105
13.375000	1.350045566	0.154286089	0.003083386	105.061285	0.6485329
13.375000	1.350045566	0.154286089	0.003083386	105.061285	0.6485329
14.187500	2.266763201	0.511954723	0.003526142	103.986456	0.67160606
14.187500	2.266763201	0.511954723	0.003526142	103.986456	0.67160606
14.187500	2.983480836	0.51205666	0.003526142	103.269636	0.680442333
14.187500	1.709270846	0.910221798	0.003526142	104.145681	0.676788328

APPENDIX 4: UNIT 1 EFFICIENCY

Following table represent Unit 1 efficiency for various net head and unit discharge conditions.

	Net Head, m																									
Unit 1 Discharge, m^3/s	**95.25**	**95.75**	**96.25**	**96.75**	**97.25**	**97.75**	**98.25**	**98.75**	**99.25**	**99.75**	**100.25**	**100.75**	**101.25**	**101.75**	**102.25**	**102.75**	**103.25**	**103.75**	**104.25**	**104.75**	**105.25**	**105.75**	**106.25**	**106.75**	**107.25**	**107.75**
0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1	0.0351	0.0319	0.0326	0.0338	0.0351	0.0364	0.0376	0.0388	0.0399	0.0409	0.0419	0.0428	0.0437	0.0444	0.0450	0.0455	0.0460	0.0467	0.0473	0.0476	0.0473	0.0465	0.0453	0.0439	0.0427	0.0464
2	0.0715	0.0676	0.0685	0.0707	0.0733	0.0759	0.0786	0.0810	0.0833	0.0855	0.0875	0.0895	0.0913	0.0928	0.0941	0.0951	0.0963	0.0978	0.0993	0.1001	0.0996	0.0980	0.0956	0.0930	0.0912	0.0950
3	0.1089	0.1057	0.1069	0.1101	0.1139	0.1180	0.1221	0.1259	0.1295	0.1328	0.1360	0.1391	0.1419	0.1443	0.1462	0.1478	0.1496	0.1521	0.1547	0.1561	0.1554	0.1529	0.1494	0.1456	0.1430	0.1450
4	0.1471	0.1451	0.1471	0.1513	0.1564	0.1620	0.1675	0.1728	0.1776	0.1821	0.1864	0.1907	0.1947	0.1980	0.2004	0.2024	0.2048	0.2083	0.2122	0.2145	0.2136	0.2101	0.2055	0.2005	0.1965	0.1960
5	0.1857	0.1853	0.1884	0.1938	0.2004	0.2074	0.2145	0.2212	0.2273	0.2329	0.2383	0.2438	0.2490	0.2532	0.2561	0.2582	0.2608	0.2653	0.2709	0.2744	0.2731	0.2685	0.2627	0.2566	0.2509	0.2473
6	0.2247	0.2261	0.2306	0.2373	0.2453	0.2539	0.2626	0.2707	0.2780	0.2846	0.2910	0.2977	0.3042	0.3094	0.3125	0.3144	0.3169	0.3222	0.3299	0.3351	0.3331	0.3270	0.3203	0.3132	0.3055	0.2986
7	0.2638	0.2671	0.2731	0.2813	0.2909	0.3011	0.3114	0.3210	0.3295	0.3369	0.3441	0.3520	0.3600	0.3661	0.3693	0.3705	0.3721	0.3779	0.3882	0.3958	0.3922	0.3846	0.3771	0.3693	0.3596	0.3494
8	0.3029	0.3081	0.3158	0.3256	0.3368	0.3487	0.3606	0.3717	0.3813	0.3893	0.3970	0.4061	0.4159	0.4230	0.4260	0.4260	0.4256	0.4312	0.4442	0.4561	0.4489	0.4397	0.4322	0.4246	0.4128	0.3991
9	0.3419	0.3490	0.3584	0.3698	0.3827	0.3963	0.4100	0.4226	0.4333	0.4416	0.4491	0.4594	0.4716	0.4796	0.4820	0.4807	0.4768	0.4809	0.4951	0.5153	0.4997	0.4913	0.4841	0.4783	0.4643	0.4473
10	0.3807	0.3896	0.4007	0.4138	0.4283	0.4437	0.4592	0.4734	0.4852	0.4934	0.5000	0.5111	0.5270	0.5355	0.5365	0.5348	0.5252	0.5269	0.5367	0.5728	0.5394	0.5389	0.5303	0.5300	0.5127	0.4934
11	0.4190	0.4298	0.4425	0.4572	0.4733	0.4905	0.5078	0.5239	0.5368	0.5448	0.5491	0.5603	0.5825	0.5899	0.5876	0.5881	0.5710	0.5692	0.5700	0.5510	0.5668	0.5842	0.5672	0.5798	0.5560	0.5369
12	0.4568	0.4693	0.4836	0.4998	0.5175	0.5364	0.5555	0.5735	0.5880	0.5958	0.5964	0.6047	0.6397	0.6414	0.6323	0.6353	0.6734	0.6013	0.6036	0.5999	0.5912	0.6083	0.5937	0.5948	0.5943	0.5779
13	0.4940	0.5081	0.5239	0.5414	0.5605	0.5810	0.6019	0.6217	0.6383	0.6465	0.6433	0.6393	0.7150	0.6860	0.6669	0.6713	0.6252	0.6351	0.6378	0.6401	0.6357	0.6292	0.6384	0.6168	0.6273	0.6171
14	0.5304	0.5460	0.5630	0.5817	0.6021	0.6239	0.6465	0.6680	0.6868	0.6967	0.6896	0.6977	0.7452	0.7201	0.6769	0.6750	0.6795	0.6826	0.6790	0.6734	0.6661	0.6742	0.6711	0.6812	0.6600	0.6561
15	0.5660	0.5829	0.6011	0.6207	0.6419	0.6648	0.6887	0.7112	0.7315	0.7460	0.7304	0.7388	0.7743	0.7456	0.7062	0.7067	0.7026	0.7062	0.7049	0.7089	0.7060	0.7013	0.6981	0.7018	0.7007	0.7007
16	0.6007	0.6187	0.6378	0.6580	0.6797	0.7031	0.7280	0.7506	0.7687	0.7937	0.7598	0.7622	0.8101	0.7352	0.7280	0.7337	0.7360	0.7336	0.7321	0.7330	0.7300	0.7270	0.7271	0.7235	0.7205	0.7296
17	0.6344	0.6535	0.6732	0.6936	0.7152	0.7385	0.7640	0.7863	0.7959	0.7989	0.7766	0.7688	0.7999	0.7658	0.7563	0.7638	0.7623	0.7603	0.7583	0.7573	0.7560	0.7549	0.7542	0.7507	0.7404	0.7379
18	0.6671	0.6870	0.7071	0.7274	0.7483	0.7704	0.7953	0.8188	0.8153	0.8037	0.7870	0.7917	0.7877	0.7910	0.7825	0.7883	0.7834	0.7814	0.7808	0.7801	0.7778	0.7750	0.7738	0.7684	0.7692	0.7464
19	0.6987	0.7194	0.7397	0.7595	0.7789	0.7987	0.8201	0.8495	0.8294	0.8084	0.8183	0.8071	0.8110	0.8067	0.8015	0.7998	0.8002	0.7991	0.7982	0.7966	0.7955	0.7948	0.7947	0.7886	0.7723	0.7537
20	0.7292	0.7505	0.7709	0.7898	0.8074	0.8237	0.8377	0.8446	0.8378	0.8532	0.8316	0.8273	0.8293	0.8240	0.8203	0.8184	0.8187	0.8191	0.8183	0.8162	0.8150	0.8139	0.8117	0.8115	0.7845	0.7603
21	0.7585	0.7805	0.8007	0.8185	0.8338	0.8463	0.8531	0.8398	0.8425	0.8369	0.8436	0.8393	0.8392	0.8362	0.8376	0.8361	0.8364	0.8354	0.8340	0.8323	0.8314	0.8276	0.8245	0.8231	0.8304	0.7636
22	0.7867	0.8092	0.8293	0.8459	0.8585	0.8673	0.8706	0.8617	0.8646	0.8674	0.8584	0.8623	0.8602	0.8606	0.8589	0.8568	0.8546	0.8530	0.8509	0.8482	0.8462	0.8459	0.8434	0.8296	0.8174	0.7583
23	0.8135	0.8368	0.8567	0.8719	0.8817	0.8867	0.8895	0.8836	0.8877	0.8874	0.8834	0.8798	0.8781	0.8764	0.8749	0.8734	0.8711	0.8691	0.8669	0.8653	0.8630	0.8633	0.8629	0.8520	0.8169	0.7733
24	0.8390	0.8631	0.8830	0.8966	0.9035	0.9050	0.8796	0.8862	0.8855	0.8941	0.8999	0.8930	0.8939	0.8915	0.8902	0.8884	0.8856	0.8831	0.8814	0.8795	0.8779	0.8737	0.8644	0.8528	0.8183	0.7843
25	0.8629	0.8880	0.9080	0.9201	0.9237	0.9237	0.9430	0.9130	0.9129	0.9148	0.9083	0.9072	0.9040	0.9024	0.9003	0.8986	0.8967	0.8954	0.8939	0.8915	0.8881	0.8759	0.8732	0.8299	0.8204	0.7934
26	0.8849	0.9113	0.9317	0.9417	0.9426	0.9341	0.9680	0.9310	0.9236	0.9240	0.9192	0.9151	0.9115	0.9095	0.9080	0.9063	0.9042	0.9021	0.8996	0.8978	0.8935	0.8823	0.8754	0.8492	0.8258	0.8016
27	0.9047	0.9325	0.9540	0.9600	0.9618	0.9292	0.9593	0.9294	0.9340	0.9276	0.9227	0.9184	0.9166	0.9147	0.9135	0.9122	0.9100	0.9087	0.9070	0.9048	0.9012	0.9015	0.8768	0.8572	0.8331	0.8093
28	0.9218	0.9505	0.9749	0.9733	0.9631	0.9648	0.9393	0.9253	0.9290	0.9304	0.9275	0.9247	0.9223	0.9204	0.9187	0.9170	0.9144	0.9132	0.9120	0.9099	0.9020	0.8889	0.8783	0.8653	0.8401	0.8163
29	0.9358	0.9633	0.9948	0.9809	0.9686	0.9453	0.9401	0.9398	0.9372	0.9336	0.9324	0.9313	0.9290	0.9265	0.9234	0.9209	0.9182	0.9165	0.9147	0.9137	0.9116	0.8999	0.9125	0.8723	0.8456	0.8223
30	0.9469	0.9695	0.9895	0.9831	0.9583	0.9408	0.9588	0.9506	0.9407	0.9393	0.9369	0.9355	0.9331	0.9312	0.9291	0.9265	0.9234	0.9208	0.9179	0.9153	0.9128	0.9061	0.9005	0.8739	0.8494	0.8274
31	0.9559	0.9709	0.9842	0.9835	0.9744	0.9698	0.9572	0.9519	0.9491	0.9462	0.9436	0.9421	0.9401	0.9381	0.9361	0.9348	0.9327	0.9307	0.9275	0.9217	0.9179	0.9118	0.8880	0.8712	0.8516	0.8315
32	0.9647	0.9702	0.9795	0.9801	0.9641	0.9625	0.9560	0.9563	0.9532	0.9506	0.9491	0.9479	0.9463	0.9447	0.9431	0.9414	0.9385	0.9359	0.9331	0.9255	0.9192	0.8989	0.8741	0.8685	0.8531	0.8350
33	0.9746	0.9772	0.9700	0.9892	0.9763	0.9674	0.9596	0.9598	0.9562	0.9537	0.9529	0.9516	0.9503	0.9494	0.9480	0.9461	0.9432	0.9396	0.9360	0.9364	0.9296	0.9008	0.8798	0.8685	0.8546	0.8380
34	0.9817	0.9841	0.9967	0.9896	0.9734	0.9657	0.9676	0.9615	0.9598	0.9576	0.9569	0.9559	0.9550	0.9536	0.9520	0.9504	0.9472	0.9453	0.9441	0.9355	0.9053	0.9026	0.8857	0.8707	0.8565	0.8407
35	0.9895	0.9890	0.9753	0.9914	0.9935	0.9910	0.9743	0.9688	0.9640	0.9624	0.9621	0.9609	0.9597	0.9586	0.9570	0.9535	0.9465	0.9406	0.9305	0.9313	0.9335	0.9173	0.8904	0.8732	0.8585	0.8432
36	0.9978	0.9918	0.9919	0.9905	0.9941	0.9888	0.9723	0.9714	0.9705	0.9692	0.9678	0.9665	0.9658	0.9643	0.9614	0.9559	0.9482	0.9419	0.9355	0.9189	0.9214	0.9113	0.8920	0.8752	0.8604	0.8455
37	0.9889	0.9931	0.9731	0.9819	0.9818	0.9790	0.9776	0.9767	0.9761	0.9750	0.9738	0.9725	0.9711	0.9688	0.9646	0.9585	0.9436	0.9466	0.9346	0.9149	0.9080	0.9037	0.8910	0.8762	0.8619	0.8475
38	0.9858	0.9915	0.9985	0.9810	0.9836	0.9802	0.9801	0.9806	0.9795	0.9787	0.9779	0.9762	0.9739	0.9722	0.9649	0.9489	0.9316	0.9305	0.9015	0.9123	0.8951	0.8976	0.8891	0.8765	0.8631	0.8493
39	0.9824	0.9889	0.9845	0.9802	0.9850	0.9808	0.9803	0.9751	0.9775	0.9787	0.9783	0.9767	0.9747	0.9711	0.9616	0.9618	0.9463	0.9504	0.9469	0.9157	0.8992	0.8949	0.8876	0.8765	0.8640	0.8507
40	0.9785	0.9857	0.9828	0.9741	0.9802	0.9783	0.9790	0.9748	0.9755	0.9727	0.9735	0.9716	0.9691	0.9516	0.9315	0.9426	0.9629	0.9526	0.9423	0.9198	0.9029	0.8946	0.8867	0.8764	0.8646	0.8520
41	0.9741	0.9830	0.9811	0.9735	0.9777	0.9783	0.9738	0.9730	0.9722	0.9671	0.9592	0.9486	0.9217	0.9427	0.9428	0.9181	0.9498	0.9528	0.9399	0.9213	0.9053	0.8951	0.8863	0.8763	0.8651	0.8530
42	0.9686	0.9801	0.9854	0.9793	0.9765	0.9720	0.9672	0.9663	0.9677	0.9645	0.9696	0.9624	0.9266	0.8707	0.9271	0.9237	0.9402	0.9453	0.9359	0.9207	0.9064	0.8955	0.8861	0.8762	0.8655	0.8539
43	0.9613	0.9751	0.9854	0.9774	0.9743	0.9719	0.9525	0.9655	0.9620	0.9462	0.8745	0.7357	0.9797	0.9429	0.9256	0.9253	0.9338	0.9376	0.9310	0.9188	0.9062	0.8954	0.8859	0.8761	0.8657	0.8546
44	0.9516	0.9645	0.9853	0.9725	0.9706	0.9656	0.9709	0.9678	0.9424	0.9274	0.9567	0.8197	0.9531	0.9456	0.9276	0.9245	0.9285	0.9306	0.9257	0.9160	0.9050	0.8949	0.8854	0.8758	0.8658	0.8551
45	0.9393	0.9469	0.9464	0.9122	0.8248	0.8499	0.9599	0.9400	0.9152	0.8932	0.9000	0.8569	0.9188	0.9345	0.9250	0.9217	0.9234	0.9242	0.9204	0.9125	0.9032	0.8938	0.8847	0.8754	0.8657	0.8554
46	0.9253	0.9257	0.9100	0.8520	0.8527	0.8538	0.9031	0.9014	0.8850	0.8419	0.8570	0.8607	0.8983	0.9187	0.9181	0.9169	0.9179	0.9182	0.9151	0.9088	0.9008	0.8923	0.8837	0.8748	0.8654	0.8556
47	0.9110	0.9054	0.8836	0.8443	0.8358	0.8389	0.8585	0.8555	0.8637	0.7782	0.8257	0.8512	0.8823	0.9032	0.9089	0.9105	0.9120	0.9123	0.9099	0.9049	0.8981	0.8905	0.8824	0.8740	0.8650	0.8556
48	0.8973	0.8881	0.8662	0.8374	0.8248	0.8231	0.8244	0.8062	0.8194	0.7840	0.8086	0.8397	0.8687	0.8894	0.8991	0.9033	0.9058	0.9065	0.9049	0.9008	0.8951	0.8883	0.8809	0.8730	0.8645	0.8555
49	0.8849	0.8739	0.8539	0.8309	0.8167	0.8098	0.8009	0.7934	0.7955	0.7844	0.8012	0.8301	0.8572	0.8776	0.8894	0.8958	0.8994	0.9008	0.8999	0.8968	0.8920	0.8860	0.8792	0.8718	0.8638	0.8552

APPENDIX 5: SAMPLE DATA SET OF UNIT 2 OPERATION

A sample of data sets representing shutdown of Unit 1 and operation of Unit 2 only is tabulated below.

Water Flow	Intake Level	U1 Penstock Pressure	U1 Spiral Case Pressure	U1 Draft Tube Pressure	U2 Penstock Pressure	U2 Spiral Case Pressure	U2 Draft Tube Pressure	U1 Active Power	U2 Active Power
40.843750	623.787500	10.484380	10.500000	1.395000	10.195310	10.109380	1.466250	-	35.470000
40.843750	623.787500	10.484380	10.500000	1.395000	10.195310	10.109380	1.466250	-	35.470000
37.156250	623.787500	10.359380	10.375000	1.430625	10.164060	10.062500	1.443750	-	34.100000
37.156250	623.787500	10.359380	10.375000	1.430625	10.164060	10.062500	1.443750	-	34.100000
35.781250	623.787500	10.359380	10.382810	1.441875	10.148440	10.062500	1.462500	-	33.680000
35.781250	623.787500	10.359380	10.382810	1.441875	10.148440	10.062500	1.462500	-	33.680000
35.656250	623.787500	10.375000	10.398440	1.428750	10.164060	10.062500	1.462500	-	33.550000
35.562500	623.787500	10.382810	10.406250	1.434375	10.164060	10.039060	1.460625	-	33.530000
35.687500	623.787500	10.382810	10.398440	1.441875	10.164060	10.054690	1.455000	-	33.530000
35.687500	623.787500	10.382810	10.398440	1.441875	10.164060	10.054690	1.455000	-	33.530000
35.812500	623.787500	10.375000	10.398440	1.453125	10.164060	10.062500	1.445625	-	33.610000
35.812500	623.787500	10.375000	10.398440	1.453125	10.164060	10.062500	1.445625	-	33.610000
35.718750	623.787500	10.359380	10.375000	1.441875	10.179690	10.062500	1.466250	-	33.680000
35.718750	623.787500	10.359380	10.375000	1.441875	10.179690	10.062500	1.466250	-	33.680000
35.718750	623.787500	10.421880	10.437500	1.441875	10.179690	10.078120	1.471875	-	33.660000
35.718750	623.787500	10.421880	10.437500	1.441875	10.179690	10.078120	1.471875	-	33.660000
35.625000	623.787500	10.390620	10.421880	1.447500	10.187500	10.085940	1.456875	-	33.600000
35.562500	623.787500	10.398440	10.437500	1.451250	10.179690	10.085940	1.460625	-	33.610000
35.562500	623.787500	10.398440	10.429690	1.451250	10.187500	10.093750	1.468125	-	33.570000

Water Flow	Intake Level	U1 Penstock Pressure	U1 Spiral Case Pressure	U1 Draft Tube Pressure	U2 Penstock Pressure	U2 Spiral Case Pressure	U2 Draft Tube Pressure	U1 Active Power	U2 Active Power
35.562500	623.787500	10.398440	10.429690	1.451250	10.187500	10.093750	1.468125	-	33.570000
35.562500	623.787500	10.398440	10.429690	1.441875	10.187500	10.078120	1.466250	-	33.630000
35.562500	623.787500	10.398440	10.429690	1.441875	10.187500	10.078120	1.466250	-	33.630000
35.562500	623.787500	10.437500	10.460940	1.445625	10.187500	10.101560	1.464375	-	33.640000
35.562500	623.793800	10.437500	10.460940	1.445625	10.187500	10.101560	1.464375	-	33.640000
35.562500	623.793800	10.414060	10.437500	1.451250	10.187500	10.101560	1.470000	-	33.660000
35.562500	623.793800	10.414060	10.437500	1.451250	10.187500	10.101560	1.470000	-	33.660000
35.718750	623.793800	10.414060	10.437500	1.441875	10.210940	10.101560	1.445625	-	33.750000
35.781250	623.793800	10.414060	10.437500	1.441875	10.179690	10.085940	1.455000	-	33.770000
35.781250	623.793800	10.406250	10.437500	1.441875	10.234380	10.140620	1.456875	-	33.810000
35.781250	623.793800	10.406250	10.437500	1.441875	10.234380	10.140620	1.456875	-	33.810000
35.687500	623.793800	10.453120	10.484380	1.451250	10.226560	10.125000	1.466250	-	33.750000
35.687500	623.793800	10.453120	10.484380	1.451250	10.226560	10.125000	1.466250	-	33.750000
35.593750	623.793800	10.406250	10.421880	1.449375	10.210940	10.140620	1.462500	-	33.840000
35.593750	623.793800	10.406250	10.421880	1.449375	10.210940	10.140620	1.462500	-	33.840000
35.687500	623.793800	10.429690	10.453120	1.445625	10.226560	10.132810	1.455000	-	33.920000
35.687500	623.793800	10.429690	10.453120	1.445625	10.226560	10.132810	1.455000	-	33.920000
35.937500	623.793800	10.437500	10.460940	1.445625	10.234380	10.125000	1.464375	-	34.040000
35.968750	623.793800	10.437500	10.460940	1.449375	10.234380	10.125000	1.464375	-	34.050000
35.937500	623.793800	10.453120	10.476560	1.451250	10.226560	10.125000	1.470000	-	34.050000

APPENDIX 6: SAMPLE CALCULATION OF UNIT 2 HEAD LOSS

A sample of calculation of few data sets for head loss in Unit 2 is tabulated below.

Water Flow	Headloss Before Bifurcation	Unit#2 Penstock Head Loss	Unit#2 Draft Tube Head Loss	Unit#2 Net Head	Unit#2 Efficiency
40.843750	0.613086137	0.267070124	3.606832366	102.300511	0.865343961
40.843750	0.613086137	0.267070124	3.606832366	102.300511	0.865343961
35.781250	1.887296126	0.09373686	2.420958862	102.385508	0.93714993
35.781250	1.887296126	0.09373686	2.420958862	102.385508	0.93714993
35.656250	1.728070846	0.108080447	2.539331853	102.412017	0.936562861
35.562500	1.648458206	0.198417836	2.451350371	102.489274	0.937764628
35.687500	1.648458206	0.184111896	2.332936911	102.621993	0.93327144
35.687500	1.648458206	0.184111896	2.332936911	102.621993	0.93327144
35.812500	1.728070846	0.090143121	2.13812481	102.831161	0.930336641
35.812500	1.728070846	0.090143121	2.13812481	102.831161	0.930336641
35.718750	1.250191131	0.419467426	2.508808338	102.609033	0.936188403
35.718750	1.250191131	0.419467426	2.508808338	102.609033	0.936188403
35.625000	1.568845566	0.031943923	2.287014572	102.899696	0.934332177
35.562500	1.489130989	0.198417836	2.279332023	102.820619	0.93697285
35.562500	1.489130989	0.118805195	2.355784622	102.823779	0.935828976
35.562500	1.489130989	0.118805195	2.355784622	102.823779	0.935828976
35.562500	1.489130989	0.118805195	2.432237221	102.747327	0.938199172
35.562500	1.489130989	0.118805195	2.432237221	102.747327	0.938199172
35.562500	1.090965851	0.516970333	2.374897772	102.804666	0.937954712
35.562500	1.097265851	0.516970333	2.374897772	102.804666	0.937954712

Water Flow	Headloss Before Bifurcation	Unit#2 Penstock Head Loss	Unit#2 Draft Tube Head Loss	Unit#2 Net Head	Unit#2 Efficiency
35.562500	1.336205708	0.278030476	2.374897772	102.804666	0.938512354
35.562500	1.336205708	0.278030476	2.374897772	102.804666	0.938512354
35.718750	1.336205708	0.021200351	2.24122424	103.195170	0.933359921
35.781250	1.336205708	0.332574781	2.344506263	102.780513	0.93604292
35.687500	0.938040571	0.263724537	2.35205006	103.239985	0.93377171
35.687500	0.938040571	0.263724537	2.35205006	103.239985	0.93377171
35.687500	1.176878491	0.024886616	2.294710611	103.297324	0.937954213
35.687500	1.176878491	0.024886616	2.294710611	103.297324	0.937954213
35.937500	0.938040571	0.234962069	2.421195416	103.199602	0.935884436
35.937500	0.938040571	0.234962069	2.421195416	103.199602	0.935884436
35.937500	0.938040571	0.234962069	2.382969117	103.237828	0.932515606
35.937500	0.938040571	0.234962069	2.382969117	103.237828	0.932515606
36.125000	1.097265851	0.054033173	2.368073754	103.274427	0.929259423
36.125000	1.097265851	0.054033173	2.368073754	103.274427	0.929259423
35.968750	0.699100714	0.4702925	2.272170276	103.352237	0.933141957
35.812500	1.017653211	0.010428544	2.367482609	103.398236	0.934869318
35.812500	1.017653211	0.010428544	2.367482609	103.398236	0.934869318
36.062500	0.778713354	0.300118181	2.302943836	103.412025	0.93291142
36.062500	0.778713354	0.300118181	2.302943836	103.412025	0.93291142
35.937500	0.778713354	0.314574709	2.363855967	103.336656	0.934368693
35.875000	0.938040571	0.003231652	2.356105968	103.496422	0.93510072

APPENDIX 7: UNIT 2 EFFICIENCY

Following table represent Unit 1 efficiency for various net head and unit discharge conditions.

	Net Head, m																			
Unit 2 Discharge, m^3/s	**97.25**	**97.75**	**98.25**	**98.75**	**99.25**	**99.75**	**100.25**	**100.75**	**101.25**	**101.75**	**102.25**	**102.75**	**103.25**	**103.75**	**104.25**	**104.75**	**105.25**	**105.75**	**106.25**	**106.75**
0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1	0.0294	0.0259	0.0262	0.0270	0.0278	0.0287	0.0296	0.0305	0.0314	0.0322	0.0329	0.0335	0.0340	0.0343	0.0343	0.0340	0.0335	0.0329	0.0325	0.0368
2	0.0597	0.0550	0.0551	0.0564	0.0581	0.0599	0.0618	0.0636	0.0655	0.0672	0.0688	0.0702	0.0712	0.0719	0.0720	0.0716	0.0707	0.0696	0.0695	0.0751
3	0.0909	0.0861	0.0861	0.0879	0.0903	0.0931	0.0960	0.0989	0.1018	0.1046	0.1071	0.1093	0.1111	0.1121	0.1124	0.1119	0.1107	0.1094	0.1093	0.1147
4	0.1227	0.1185	0.1187	0.1209	0.1241	0.1278	0.1318	0.1358	0.1399	0.1437	0.1473	0.1504	0.1529	0.1545	0.1551	0.1545	0.1530	0.1513	0.1510	0.1552
5	0.1551	0.1518	0.1524	0.1552	0.1592	0.1639	0.1690	0.1741	0.1793	0.1843	0.1890	0.1931	0.1964	0.1986	0.1995	0.1989	0.1971	0.1949	0.1939	0.1963
6	0.1878	0.1857	0.1870	0.1905	0.1954	0.2010	0.2072	0.2135	0.2199	0.2261	0.2319	0.2370	0.2412	0.2440	0.2452	0.2447	0.2426	0.2396	0.2375	0.2380
7	0.2208	0.2200	0.2222	0.2265	0.2323	0.2390	0.2462	0.2537	0.2613	0.2687	0.2756	0.2818	0.2869	0.2905	0.2921	0.2916	0.2890	0.2852	0.2816	0.2799
8	0.2540	0.2546	0.2578	0.2630	0.2697	0.2775	0.2858	0.2945	0.3032	0.3119	0.3200	0.3273	0.3334	0.3377	0.3398	0.3393	0.3362	0.3313	0.3260	0.3219
9	0.2873	0.2893	0.2936	0.2999	0.3076	0.3163	0.3258	0.3356	0.3456	0.3554	0.3647	0.3732	0.3802	0.3854	0.3881	0.3876	0.3838	0.3776	0.3704	0.3639
10	0.3207	0.3240	0.3295	0.3369	0.3456	0.3554	0.3660	0.3770	0.3881	0.3991	0.4096	0.4192	0.4273	0.4333	0.4366	0.4361	0.4317	0.4240	0.4147	0.4055
11	0.3540	0.3587	0.3654	0.3739	0.3837	0.3945	0.4062	0.4183	0.4306	0.4427	0.4544	0.4650	0.4741	0.4811	0.4851	0.4848	0.4796	0.4702	0.4585	0.4466
12	0.3871	0.3933	0.4012	0.4108	0.4216	0.4335	0.4462	0.4593	0.4727	0.4860	0.4988	0.5104	0.5205	0.5285	0.5332	0.5332	0.5272	0.5159	0.5017	0.4871
13	0.4201	0.4276	0.4368	0.4474	0.4593	0.4722	0.4858	0.5000	0.5144	0.5288	0.5426	0.5552	0.5661	0.5750	0.5807	0.5810	0.5742	0.5609	0.5440	0.5266
14	0.4528	0.4616	0.4720	0.4837	0.4966	0.5104	0.5250	0.5401	0.5554	0.5708	0.5855	0.5989	0.6104	0.6202	0.6270	0.6278	0.6204	0.6047	0.5849	0.5648
15	0.4851	0.4953	0.5068	0.5195	0.5334	0.5481	0.5635	0.5793	0.5954	0.6117	0.6273	0.6412	0.6529	0.6633	0.6714	0.6730	0.6651	0.6467	0.6242	0.6016
16	0.5170	0.5284	0.5410	0.5548	0.5695	0.5850	0.6011	0.6176	0.6343	0.6512	0.6677	0.6820	0.6932	0.7036	0.7130	0.7153	0.7077	0.6863	0.6612	0.6366
17	0.5484	0.5610	0.5747	0.5893	0.6048	0.6211	0.6378	0.6547	0.6718	0.6891	0.7065	0.7208	0.7306	0.7398	0.7504	0.7528	0.7471	0.7221	0.6957	0.6697
18	0.5793	0.5930	0.6076	0.6231	0.6393	0.6562	0.6733	0.6905	0.7075	0.7249	0.7431	0.7577	0.7643	0.7707	0.7820	0.7827	0.7822	0.7525	0.7272	0.7006
19	0.6096	0.6243	0.6398	0.6560	0.6728	0.6901	0.7076	0.7248	0.7413	0.7580	0.7772	0.7925	0.7933	0.7967	0.7811	0.7802	0.7795	0.7783	0.7557	0.7292
20	0.6392	0.6549	0.6712	0.6879	0.7052	0.7228	0.7404	0.7575	0.7729	0.7877	0.8074	0.8257	0.8167	0.8111	0.8134	0.8082	0.7984	0.8027	0.7812	0.7555
21	0.6681	0.6847	0.7016	0.7188	0.7363	0.7541	0.7716	0.7883	0.8023	0.8133	0.8315	0.8584	0.8326	0.8256	0.8244	0.8223	0.8172	0.8201	0.8035	0.7797
22	0.6963	0.7136	0.7310	0.7484	0.7661	0.7838	0.8011	0.8171	0.8296	0.8346	0.8462	0.8851	0.8386	0.8373	0.8346	0.8309	0.8361	0.8375	0.8229	0.8018
23	0.7236	0.7416	0.7593	0.7768	0.7944	0.8119	0.8286	0.8433	0.8551	0.8518	0.8522	0.8506	0.8466	0.8492	0.8456	0.8436	0.8403	0.8396	0.8406	0.8222
24	0.7501	0.7687	0.7865	0.8038	0.8210	0.8382	0.8540	0.8667	0.8730	0.8658	0.8657	0.8626	0.8601	0.8602	0.8637	0.8653	0.8645	0.8530	0.8570	0.8407
25	0.7756	0.7947	0.8126	0.8292	0.8458	0.8627	0.8771	0.8876	0.8850	0.8797	0.8753	0.8733	0.8728	0.8693	0.8675	0.8651	0.8648	0.8635	0.8734	0.8571
26	0.8002	0.8198	0.8374	0.8529	0.8683	0.8855	0.8976	0.9069	0.8970	0.8864	0.8883	0.8895	0.8872	0.8848	0.8847	0.8815	0.8778	0.8775	0.8770	0.8717
27	0.8238	0.8438	0.8610	0.8748	0.8880	0.9061	0.9152	0.9249	0.8992	0.8921	0.8922	0.8903	0.8905	0.8919	0.8904	0.8885	0.8868	0.8876	0.8847	0.8798
28	0.8463	0.8667	0.8836	0.8948	0.9042	0.9213	0.9660	0.9097	0.9032	0.9037	0.9051	0.9029	0.9003	0.8972	0.8936	0.8923	0.8939	0.8935	0.8930	0.8846
29	0.8676	0.8884	0.9051	0.9131	0.9165	0.9271	0.9424	0.9152	0.9153	0.9108	0.9078	0.9043	0.8998	0.8969	0.9007	0.9062	0.9043	0.8972	0.8977	0.8892
30	0.8875	0.9086	0.9260	0.9297	0.9255	0.9256	0.9333	0.9291	0.9162	0.9187	0.9153	0.9141	0.9130	0.9108	0.9080	0.9054	0.9021	0.9009	0.9021	0.8935
31	0.9062	0.9268	0.9463	0.9447	0.9323	0.9211	0.9265	0.9209	0.9144	0.9206	0.9186	0.9159	0.9181	0.9152	0.9130	0.9131	0.8645	0.9080	0.9063	0.8975
32	0.9233	0.9417	0.9657	0.9575	0.9373	0.9329	0.9311	0.9292	0.9286	0.9273	0.9250	0.9235	0.9222	0.9204	0.9204	0.9200	0.9158	0.9120	0.9103	0.9014
33	0.9369	0.9792	0.9814	0.9614	0.9313	0.9313	0.9358	0.9328	0.9306	0.9297	0.9311	0.9289	0.9264	0.9194	0.9117	0.9003	0.9198	0.9179	0.9140	0.9050
34	0.9460	0.9481	0.9432	0.9687	0.9611	0.9603	0.9483	0.9412	0.9387	0.9376	0.9361	0.9343	0.9322	0.9242	0.9029	0.9210	0.9243	0.9227	0.9175	0.9084
35	0.9551	0.9453	0.9450	0.9479	0.9466	0.9508	0.9465	0.9451	0.9444	0.9451	0.9418	0.9387	0.9381	0.9391	0.9374	0.9298	0.9294	0.9265	0.9206	0.9115
36	0.9665	0.9787	0.9761	0.9769	0.9630	0.9550	0.9524	0.9562	0.9557	0.9546	0.9511	0.9484	0.9445	0.9417	0.9425	0.9386	0.9339	0.9297	0.9234	0.9144
37	0.9778	0.9808	0.9696	0.9638	0.9632	0.9612	0.9625	0.9626	0.9603	0.9569	0.9545	0.9523	0.9450	0.9447	0.9441	0.9415	0.9371	0.9322	0.9258	0.9169
38	0.9880	0.9799	0.9721	0.9651	0.9645	0.9657	0.9645	0.9625	0.9593	0.9566	0.9534	0.9495	0.9414	0.9430	0.9440	0.9426	0.9390	0.9342	0.9278	0.9193
39	0.9859	0.9822	0.9740	0.9643	0.9674	0.9646	0.9657	0.9626	0.9549	0.9527	0.9241	0.9310	0.9353	0.9398	0.9427	0.9426	0.9400	0.9356	0.9295	0.9214
40	0.9843	0.9832	0.9761	0.9689	0.9686	0.9668	0.9667	0.9666	0.9504	0.9312	0.8947	0.9128	0.9275	0.9360	0.9408	0.9420	0.9404	0.9367	0.9310	0.9233
41	0.9833	0.9835	0.9781	0.9725	0.9704	0.9684	0.9665	0.9616	0.9443	0.9160	0.8653	0.9001	0.9207	0.9323	0.9387	0.9412	0.9406	0.9375	0.9322	0.9250
42	0.9825	0.9837	0.9799	0.9752	0.9722	0.9693	0.9656	0.9575	0.9392	0.9097	0.8781	0.8958	0.9164	0.9294	0.9370	0.9404	0.9406	0.9381	0.9333	0.9266
43	0.9821	0.9838	0.9812	0.9773	0.9738	0.9700	0.9645	0.9545	0.9363	0.9101	0.8890	0.8978	0.9150	0.9278	0.9358	0.9398	0.9406	0.9386	0.9344	0.9281
44	0.9819	0.9840	0.9823	0.9789	0.9750	0.9704	0.9638	0.9529	0.9356	0.9138	0.8985	0.9027	0.9158	0.9274	0.9353	0.9395	0.9407	0.9391	0.9353	0.9295
45	0.9818	0.9842	0.9831	0.9801	0.9761	0.9709	0.9636	0.9524	0.9367	0.9188	0.9070	0.9086	0.9182	0.9281	0.9354	0.9396	0.9410	0.9398	0.9363	0.9309
46	0.9819	0.9844	0.9837	0.9811	0.9770	0.9715	0.9638	0.9530	0.9389	0.9241	0.9146	0.9148	0.9216	0.9297	0.9361	0.9401	0.9415	0.9405	0.9373	0.9322
47	0.9820	0.9846	0.9843	0.9819	0.9779	0.9723	0.9645	0.9543	0.9418	0.9295	0.9216	0.9208	0.9255	0.9319	0.9374	0.9410	0.9423	0.9414	0.9384	0.9336
48	0.9823	0.9848	0.9848	0.9826	0.9787	0.9732	0.9657	0.9561	0.9451	0.9347	0.9279	0.9266	0.9297	0.9346	0.9391	0.9422	0.9433	0.9424	0.9396	0.9351
49	0.9826	0.9852	0.9853	0.9833	0.9796	0.9742	0.9671	0.9583	0.9486	0.9397	0.9337	0.9321	0.9340	0.9376	0.9412	0.9437	0.9445	0.9436	0.9409	0.9365

APPENDIX 8: OPTIMAL ECONOMIC DISPATCH

Optimal economic dispatch for all possible gross head and available discharge condition is tabulated below.

Gross Head	Available Discharge	Unit#1 Status	Unit#2 Status	Unit#1 Discharge	Unit#2 Discharge	Discharge Used	Unit 1 Power	Unit 2 Power	Total Power
m	m^3/s			m^3/s	m^3/s	m^3/s	MW	MW	MW
103	0.00	0	0	0.00	0.00	0.00	0.00	0.00	0.00
103	16.00	1	0	16.03	0.00	16.03	12378.25	0.00	12378.25
103	17.00	1	0	17.01	0.00	17.01	12888.63	0.00	12888.63
103	18.00	1	0	18.00	0.00	18.00	13977.63	0.00	13977.63
103	19.00	1	0	19.39	0.00	19.00	15270.68	0.00	15270.68
103	20.00	1	0	20.00	0.00	20.00	16373.78	0.00	16373.78
103	21.00	1	0	21.00	0.00	21.00	17404.31	0.00	17404.31
103	22.00	1	0	22.02	0.00	22.02	18703.03	0.00	18703.03
103	23.00	1	0	23.00	0.00	23.00	19881.78	0.00	19881.78
103	24.00	1	0	24.00	0.00	24.00	20760.68	0.00	20760.68
103	25.00	1	0	25.00	0.00	25.00	22090.53	0.00	22090.53
103	26.00	1	0	26.00	0.00	26.00	23346.69	0.00	23346.69
103	27.00	1	0	27.00	0.00	27.00	24310.08	0.00	24310.08
103	28.00	1	0	28.00	0.00	28.00	25241.51	0.00	25241.51
103	29.00	1	0	29.00	0.00	29.00	26298.15	0.00	26298.15
103	30.00	1	0	30.00	0.00	30.00	27472.42	0.00	27472.42
103	31.00	1	0	31.00	0.00	31.00	28666.58	0.00	28666.58
103	32.00	1	0	32.00	0.00	32.00	29567.69	0.00	29567.69

Gross Head	Available Discharge	Unit#1 Status	Unit#2 Status	Unit#1 Discharge	Unit#2 Discharge	Discharge Used	Unit 1 Power	Unit 2 Power	Total Power
m	m^3/s			m^3/s	m^3/s	m^3/s	MW	MW	MW
103	33.00	1	0	33.00	0.00	33.00	30581.01	0.00	30581.01
103	34.00	1	0	34.00	0.00	34.00	31594.28	0.00	31594.28
103	35.00	1	0	35.02	0.00	35.02	33046.01	0.00	33046.01
103	36.00	1	0	36.04	0.00	36.04	33787.10	0.00	33787.10
103	37.00	1	0	37.00	0.00	37.00	34130.43	0.00	34130.43
103	38.00	1	0	38.00	0.00	38.00	35531.10	0.00	35531.10
103	39.00	1	0	39.00	0.00	39.00	36285.44	0.00	36285.44
103	40.00	1	0	40.00	0.00	40.00	36968.70	0.00	36968.70
103	41.00	1	0	41.00	0.00	41.00	37422.40	0.00	37422.40
103	42.00	1	1	27.02	15.00	42.03	24882.16	14034.54	38916.70
103	43.00	1	1	28.00	15.00	43.00	25949.04	14146.71	40095.75
103	44.00	1	1	27.97	16.03	44.00	25352.03	14778.80	40130.83
103	45.00	1	1	27.97	17.05	45.02	25016.04	15507.63	40523.68
103	46.00	1	1	27.99	18.01	46.00	24799.84	16213.41	41013.24
103	47.00	1	1	32.00	15.00	47.00	28392.69	13623.91	42016.60
103	48.00	1	1	33.00	15.00	48.00	29378.05	13668.50	43046.55
103	49.00	1	1	33.97	15.03	49.00	30169.92	13673.04	43842.96
103	50.00	1	1	34.00	16.00	50.00	30038.78	14475.54	44514.33
103	51.00	1	1	33.98	17.02	51.00	29872.18	15311.33	45183.51
103	52.00	1	1	33.99	18.01	52.00	29731.81	16118.58	45850.39
103	53.00	1	1	34.01	18.99	53.00	29607.96	16907.10	46515.06
103	54.00	1	1	34.04	19.96	54.00	29493.30	17663.36	47156.66

Gross Head	Available Discharge	Unit#1 Status	Unit#2 Status	Unit#1 Discharge	Unit#2 Discharge	Discharge Used	Unit 1 Power	Unit 2 Power	Total Power
m	m^3/s			m^3/s	m^3/s	m^3/s	MW	MW	MW
103	55.00	1	1	34.04	20.96	55.00	29360.90	18439.11	47800.01
103	56.00	1	1	34.06	21.95	56.02	29250.31	19202.79	48453.10
103	57.00	1	1	34.08	22.92	57.00	29144.10	19926.77	49070.87
103	58.00	1	1	34.09	23.91	58.00	29030.45	20674.08	49704.54
103	59.00	1	1	34.09	24.91	59.00	28908.74	21430.42	50339.16
103	60.00	1	1	34.30	25.70	60.00	28956.69	21979.83	50936.52
103	61.00	1	1	34.24	26.78	61.02	28796.06	22775.33	51571.38
103	62.00	1	1	34.15	27.85	62.00	28615.41	23565.92	52181.33
103	63.00	1	1	34.16	28.84	63.01	28513.27	24285.84	52799.11
103	64.00	1	1	34.16	29.86	64.02	28400.94	25027.46	53428.40
103	65.00	1	1	34.34	30.66	65.00	28437.55	25577.79	54015.34
103	66.00	1	1	34.28	31.72	66.00	28291.45	26316.08	54607.53
103	67.00	1	1	34.18	32.82	67.00	28105.41	27115.64	55221.05
103	68.00	1	1	34.33	33.67	68.00	28127.47	27692.69	55820.16
103	69.00	1	1	34.49	34.51	69.00	28147.66	28254.02	56401.68
103	70.00	1	1	34.56	35.44	70.00	28104.69	28865.20	56969.89
103	71.00	1	1	34.75	36.28	71.02	28147.89	29386.75	57534.64
103	72.00	1	1	34.58	37.43	72.01	27930.34	30139.49	58069.83
103	73.00	1	1	34.65	38.35	73.00	27889.78	30739.78	58629.57
103	74.00	1	1	39.95	34.05	74.00	31502.56	27210.98	58713.55
103	75.00	1	1	35.10	39.90	75.00	28044.75	31707.27	59752.02
103	76.00	1	1	35.91	40.08	75.99	28538.41	31706.13	60244.54

Gross Head	Available Discharge	Unit#1 Status	Unit#2 Status	Unit#1 Discharge	Unit#2 Discharge	Discharge Used	Unit 1 Power	Unit 2 Power	Total Power
m	m^3/s			m^3/s	m^3/s	m^3/s	MW	MW	MW
103	77.00	1	1	35.54	41.46	77.00	28185.44	32487.68	60673.12
103	78.00	1	1	35.16	42.84	78.00	27823.56	33384.41	61207.97
103	79.00	1	1	39.97	39.03	79.00	31095.33	30492.34	61587.67
103	80.00	1	1	35.32	44.70	80.02	27771.28	34527.87	62299.15
103	81.00	1	1	35.12	45.88	81.00	27542.94	35291.57	62834.51
103	82.00	1	1	35.25	46.75	82.00	27556.53	35821.53	63378.07
103	83.00	1	1	35.29	47.71	83.00	27506.85	36413.78	63920.63
103	84.00	1	1	35.25	48.75	84.00	27400.53	37061.33	64461.86
103	85.00	1	1	35.33	49.69	85.01	27376.32	37633.21	65009.53
103	86.00	1	1	36.00	50.00	86.00	27777.98	37745.16	65523.14
103	87.00	1	1	50.00	37.00	87.00	37690.11	28378.47	66068.57
103	88.00	1	1	50.00	38.00	88.00	37632.23	29051.07	66683.30
103	89.00	1	1	49.69	39.31	89.00	37347.12	29958.71	67305.83
103	90.00	1	1	50.00	40.00	90.00	37517.73	30404.65	67922.38
103	91.00	1	1	50.00	41.00	91.00	37461.10	30931.09	68392.19
103	92.00	1	1	50.00	42.00	92.00	37404.87	31556.85	68961.71
103	93.00	1	1	50.00	43.00	93.00	37349.03	32204.44	69553.46
103	94.00	1	1	50.00	43.99	93.99	37294.08	32851.39	70145.47
103	95.00	1	1	50.00	45.00	95.00	37238.50	33512.29	70750.79
103	96.00	1	1	50.00	46.00	96.00	37183.80	34167.55	71351.35
103	97.00	1	1	50.00	47.00	97.00	37129.47	34822.42	71951.89
103	98.00	1	1	50.00	48.00	98.00	37075.49	35476.44	72551.94

Gross Head	Available Discharge	Unit#1 Status	Unit#2 Status	Unit#1 Discharge	Unit#2 Discharge	Discharge Used	Unit 1 Power	Unit 2 Power	Total Power
m	m^3/s			m^3/s	m^3/s	m^3/s	MW	MW	MW
103	99.00	1	1	50.00	49.00	99.00	37021.87	36129.31	73151.18
103	100.00	1	1	50.00	50.00	100.00	36968.60	36780.83	73749.43
103.5	0.00	0	0	0.00	0.00	0.00	0.00	0.00	0.00
103.5	16.00	1	0	16.02	0.00	16.02	12564.80	0.00	12564.80
103.5	17.00	1	0	17.00	0.00	17.00	13458.87	0.00	13458.87
103.5	18.00	1	0	18.00	0.00	18.00	14132.45	0.00	14132.45
103.5	19.00	1	0	19.00	0.00	19.00	15168.07	0.00	15168.07
103.5	20.00	1	0	20.01	0.00	20.01	16345.39	0.00	16345.39
103.5	21.00	1	0	21.00	0.00	21.00	17437.22	0.00	17437.22
103.5	22.00	1	0	22.00	0.00	22.00	18580.32	0.00	18580.32
103.5	23.00	1	0	23.00	0.00	23.00	19951.84	0.00	19951.84
103.5	24.00	1	0	24.00	0.00	24.00	21038.41	0.00	21038.41
103.5	25.00	1	0	25.01	0.00	25.01	22303.49	0.00	22303.49
103.5	26.00	1	0	26.00	0.00	26.00	23440.64	0.00	23440.64
103.5	27.00	1	0	27.01	0.00	27.01	24565.82	0.00	24565.82
103.5	28.00	1	0	28.00	0.00	28.00	25285.45	0.00	25285.45
103.5	29.00	1	0	29.00	0.00	29.00	26393.90	0.00	26393.90
103.5	30.00	1	0	30.00	0.00	30.00	27618.88	0.00	27618.88
103.5	31.00	1	0	31.00	0.00	31.00	28620.82	0.00	28620.82
103.5	32.00	1	0	32.00	0.00	32.00	29504.61	0.00	29504.61
103.5	33.00	1	0	33.00	0.00	33.00	30549.28	0.00	30549.28
103.5	34.00	1	0	34.00	0.00	34.00	31500.25	0.00	31500.25

Gross Head	Available Discharge	Unit#1 Status	Unit#2 Status	Unit#1 Discharge	Unit#2 Discharge	Discharge Used	Unit 1 Power	Unit 2 Power	Total Power
m	m^3/s			m^3/s	m^3/s	m^3/s	MW	MW	MW
103.5	35.00	1	0	35.00	0.00	35.00	33117.21	0.00	33117.21
103.5	36.00	1	0	36.00	0.00	36.00	34097.43	0.00	34097.43
103.5	37.00	1	0	37.00	0.00	37.00	34537.92	0.00	34537.92
103.5	38.00	1	0	38.00	0.00	38.00	35466.79	0.00	35466.79
103.5	39.00	1	0	39.00	0.00	39.00	36272.31	0.00	36272.31
103.5	40.00	1	0	40.02	0.00	40.02	37188.93	0.00	37188.93
103.5	41.00	1	0	41.00	0.00	41.00	37618.49	0.00	37618.49
103.5	42.00	1	0	41.71	0.00	41.71	37695.76	0.00	37695.76
103.5	43.00	1	1	28.00	15.00	43.00	25874.96	14095.37	39970.33
103.5	44.00	1	1	28.32	15.72	44.04	26064.56	14724.85	40789.41
103.5	45.00	1	1	28.30	16.70	45.00	26042.05	15629.48	41671.54
103.5	46.00	1	1	28.30	17.70	46.00	26031.59	16562.46	42594.05
103.5	47.00	1	1	28.30	18.70	47.00	26027.65	17486.69	43514.34
103.5	48.00	1	1	28.31	19.69	48.01	26035.66	18387.21	44422.87
103.5	49.00	1	1	33.99	15.01	49.00	31367.58	14177.17	45544.75
103.5	50.00	1	1	35.00	15.00	50.00	32462.69	14267.33	46730.02
103.5	51.00	1	1	28.31	22.69	51.00	26026.25	21087.42	47113.67
103.5	52.00	1	1	35.90	16.10	52.00	33426.62	15394.84	48821.46
103.5	53.00	1	1	35.89	17.13	53.03	33420.26	16374.20	49794.45
103.5	54.00	1	1	35.89	18.11	54.00	33415.38	17302.45	50717.83
103.5	55.00	1	1	35.89	19.11	55.00	33413.88	18248.66	51662.54
103.5	56.00	1	1	35.89	20.11	56.00	33408.48	19169.89	52578.37

Gross Head	Available Discharge	Unit#1 Status	Unit#2 Status	Unit#1 Discharge	Unit#2 Discharge	Discharge Used	Unit 1 Power	Unit 2 Power	Total Power
m	m^3/s			m^3/s	m^3/s	m^3/s	MW	MW	MW
103.5	57.00	1	1	35.88	21.12	57.00	33405.17	20097.09	53502.26
103.5	58.00	1	1	35.89	22.11	58.00	33403.84	21022.08	54425.92
103.5	59.00	1	1	35.88	23.12	59.00	33395.88	21940.84	55336.73
103.5	60.00	1	1	35.88	24.12	60.00	33393.28	22863.72	56257.00
103.5	61.00	1	1	35.88	25.12	61.00	33397.71	23775.61	57173.31
103.5	62.00	1	1	35.87	26.14	62.02	33385.85	24688.07	58073.92
103.5	63.00	1	1	35.87	27.13	63.00	33384.94	25596.90	58981.84
103.5	64.00	1	1	35.86	28.14	64.00	33376.53	26513.83	59890.36
103.5	65.00	1	1	35.86	29.14	65.00	33375.48	27426.87	60802.35
103.5	66.00	1	1	35.87	30.13	66.00	33378.99	28340.95	61719.95
103.5	67.00	1	1	35.87	31.13	67.00	33374.35	29234.90	62609.25
103.5	68.00	1	1	35.86	32.14	68.00	33365.71	30143.64	63509.35
103.5	69.00	1	1	35.86	33.14	69.00	33366.70	31061.40	64428.10
103.5	70.00	1	1	35.86	34.14	70.00	33368.86	31954.79	65323.66
103.5	71.00	1	1	35.86	35.14	71.00	33368.67	32834.55	66203.22
103.5	72.00	1	1	35.87	36.13	72.00	33370.22	33696.20	67066.42
103.5	73.00	1	1	35.86	37.14	73.00	33362.80	34552.61	67915.42
103.5	74.00	1	1	35.85	38.15	74.00	33353.83	35432.91	68786.74
103.5	75.00	1	1	35.86	39.15	75.00	33356.62	36311.59	69668.21
103.5	76.00	1	1	35.89	40.11	76.00	33382.89	37139.36	70522.25
103.5	77.00	1	1	35.86	41.16	77.01	33357.32	37909.90	71267.22
103.5	78.00	1	1	35.84	42.16	78.00	33341.06	38831.32	72172.37

Gross Head	Available Discharge	Unit#1 Status	Unit#2 Status	Unit#1 Discharge	Unit#2 Discharge	Discharge Used	Unit 1 Power	Unit 2 Power	Total Power
m	m^3/s			m^3/s	m^3/s	m^3/s	MW	MW	MW
103.5	79.00	1	1	35.84	43.16	79.00	33338.56	39751.75	73090.31
103.5	80.00	1	1	36.41	43.59	80.00	33615.12	39900.23	73515.35
103.5	81.00	1	1	37.05	43.95	81.00	33896.75	39906.39	73803.14
103.5	82.00	1	1	37.73	44.27	82.00	34199.56	39900.06	74099.61
103.5	83.00	1	1	38.44	44.56	83.00	34572.54	39900.02	74472.56
103.5	84.00	1	1	39.17	44.83	84.00	35002.39	39912.39	74914.78
103.5	85.00	1	1	39.96	45.04	85.00	35505.98	39900.65	75406.64
103.5	86.00	1	1	40.64	45.36	86.00	35820.87	39900.00	75720.88
103.5	87.00	1	1	41.30	45.70	87.00	36096.46	39916.94	76013.41
103.5	88.00	1	1	41.97	46.03	88.00	36361.81	39899.99	76261.80
103.5	89.00	1	1	42.69	46.31	89.00	36743.14	39900.22	76643.37
103.5	90.00	1	1	43.44	46.56	90.00	37178.56	39900.25	77078.81
103.5	91.00	1	1	44.20	46.80	91.00	37632.37	39900.10	77532.47
103.5	92.00	1	1	44.94	47.06	92.00	38053.38	39900.00	77953.38
103.5	93.00	1	1	45.67	47.33	93.00	38446.54	39901.02	78347.56
103.5	94.00	1	1	46.38	47.62	94.00	38816.52	39905.71	78722.24
103.5	95.00	1	1	47.10	47.90	95.00	39174.65	39900.82	79075.47
103.5	96.00	1	1	47.81	48.19	96.00	39521.18	39897.87	79419.05
103.5	97.00	1	1	48.51	48.49	97.00	39859.82	39900.09	79759.91
103.5	98.00	1	0	48.60	0.00	48.60	39934.33	0.00	39934.33
103.5	99.00	1	1	48.62	48.55	97.17	39911.97	39913.19	79825.16
103.5	100.00	1	1	48.63	48.56	97.20	39918.78	39919.30	79838.08

Gross Head	Available Discharge	Unit#1 Status	Unit#2 Status	Unit#1 Discharge	Unit#2 Discharge	Discharge Used	Unit 1 Power	Unit 2 Power	Total Power
m	m^3/s			m^3/s	m^3/s	m^3/s	MW	MW	MW
104	0.00	0	0	0.00	0.00	0.00	0.00	0.00	0.00
104	16.00	1	0	16.00	0.00	16.00	11759.93	0.00	11759.93
104	17.00	1	0	17.03	0.00	17.03	13136.42	0.00	13136.42
104	18.00	1	0	18.00	0.00	18.00	14217.47	0.00	14217.47
104	19.00	1	0	19.00	0.00	19.00	15305.45	0.00	15305.45
104	20.00	1	0	20.02	0.00	20.02	16463.64	0.00	16463.64
104	21.00	1	0	21.01	0.00	21.01	17518.72	0.00	17518.72
104	22.00	1	0	22.01	0.00	22.01	18761.90	0.00	18761.90
104	23.00	1	0	23.00	0.00	23.00	19969.61	0.00	19969.61
104	24.00	1	0	24.01	0.00	24.01	21243.86	0.00	21243.86
104	25.00	1	0	25.00	0.00	25.00	22351.97	0.00	22351.97
104	26.00	1	0	26.02	0.00	26.02	23519.61	0.00	23519.61
104	27.00	1	0	27.03	0.00	27.03	24532.91	0.00	24532.91
104	28.00	1	0	28.00	0.00	28.00	25474.49	0.00	25474.49
104	29.00	1	0	29.00	0.00	29.00	26459.89	0.00	26459.89
104	30.00	1	0	30.02	0.00	30.02	27548.12	0.00	27548.12
104	31.00	1	0	31.00	0.00	31.00	28609.55	0.00	28609.55
104	32.00	1	0	32.00	0.00	32.00	29622.68	0.00	29622.68
104	33.00	1	0	33.00	0.00	33.00	30592.48	0.00	30592.48
104	34.00	1	0	34.03	0.00	34.03	31745.44	0.00	31745.44
104	35.00	1	0	35.00	0.00	35.00	32963.68	0.00	32963.68
104	36.00	1	0	36.00	0.00	36.00	34123.80	0.00	34123.80

Gross Head	Available Discharge	Unit#1 Status	Unit#2 Status	Unit#1 Discharge	Unit#2 Discharge	Discharge Used	Unit 1 Power	Unit 2 Power	Total Power
m	m^3/s			m^3/s	m^3/s	m^3/s	MW	MW	MW
104	37.00	1	0	37.00	0.00	37.00	34734.66	0.00	34734.66
104	38.00	1	0	38.02	0.00	38.02	35525.57	0.00	35525.57
104	39.00	1	0	39.00	0.00	39.00	36273.99	0.00	36273.99
104	40.00	1	0	40.00	0.00	40.00	37082.67	0.00	37082.67
104	41.00	1	0	41.00	0.00	41.00	37990.03	0.00	37990.03
104	42.00	1	0	42.00	0.00	42.00	38393.33	0.00	38393.33
104	43.00	1	1	28.00	15.00	43.00	25787.13	14047.82	39834.95
104	44.00	1	1	29.01	15.00	44.01	27182.64	14338.96	41521.60
104	45.00	1	1	29.26	15.74	45.00	27465.54	15079.25	42544.79
104	46.00	1	1	29.24	16.79	46.03	27445.85	16078.42	43524.26
104	47.00	1	1	29.25	17.75	47.00	27456.64	16996.72	44453.36
104	48.00	1	1	29.25	18.75	48.00	27454.32	17948.77	45403.08
104	49.00	1	1	29.25	19.76	49.01	27457.57	18887.51	46345.08
104	50.00	1	1	29.25	20.75	50.00	27453.92	19808.16	47262.07
104	51.00	1	1	29.24	21.76	51.00	27448.91	20743.36	48192.28
104	52.00	1	1	29.24	22.76	52.00	27450.60	21660.52	49111.12
104	53.00	1	0	47.70	0.00	47.70	39924.16	0.00	39924.16
104	54.00	1	1	29.25	24.75	54.00	27455.78	23503.73	50959.51
104	55.00	1	1	29.25	25.80	55.05	27457.44	24444.37	51901.81
104	56.00	1	1	29.23	26.77	56.00	27443.54	25330.88	52774.41
104	57.00	1	1	29.24	27.76	57.00	27450.24	26241.49	53691.73
104	58.00	1	1	29.23	28.77	58.00	27440.93	27165.96	54606.89

Gross Head	Available Discharge	Unit#1 Status	Unit#2 Status	Unit#1 Discharge	Unit#2 Discharge	Discharge Used	Unit 1 Power	Unit 2 Power	Total Power
m	m^3/s			m^3/s	m^3/s	m^3/s	MW	MW	MW
104	59.00	1	1	29.23	29.77	59.00	27437.83	28093.37	55531.20
104	60.00	1	1	29.23	30.77	60.00	27442.27	28990.24	56432.50
104	61.00	1	1	29.23	31.80	61.03	27438.77	29918.76	57357.54
104	62.00	1	1	29.22	32.78	62.00	27433.17	30820.34	58253.51
104	63.00	1	1	29.22	33.78	63.00	27434.06	31727.83	59161.89
104	64.00	1	1	29.23	34.77	64.00	27436.31	32616.08	60052.39
104	65.00	1	1	36.50	28.50	65.00	34027.25	26925.04	60952.29
104	66.00	1	1	36.48	29.52	66.00	34007.08	27866.35	61873.42
104	67.00	1	1	36.53	30.47	67.00	34054.14	28729.98	62784.13
104	68.00	1	1	36.52	31.48	68.00	34044.20	29637.06	63681.27
104	69.00	1	1	36.48	32.52	69.00	34009.44	30585.93	64595.37
104	70.00	1	1	36.52	33.48	70.00	34042.17	31468.33	65510.50
104	71.00	1	1	36.54	34.46	71.00	34060.20	32345.61	66405.81
104	72.00	1	1	36.56	35.44	72.00	34078.19	33207.36	67285.55
104	73.00	1	1	36.58	36.42	73.00	34098.30	34049.75	68148.05
104	74.00	1	1	36.55	37.45	74.00	34070.80	34941.52	69012.32
104	75.00	1	1	36.54	38.46	75.00	34061.45	35826.86	69888.31
104	76.00	1	1	36.53	39.47	76.00	34051.61	36720.40	70772.02
104	77.00	1	1	36.75	40.25	77.00	34233.50	37363.04	71596.54
104	78.00	1	1	36.49	41.51	78.00	34016.26	38368.45	72384.71
104	79.00	1	1	36.49	42.54	79.03	34014.57	39316.34	73330.91
104	80.00	1	1	36.81	43.19	80.00	34278.79	39909.09	74187.88

Gross Head	Available Discharge	Unit#1 Status	Unit#2 Status	Unit#1 Discharge	Unit#2 Discharge	Discharge Used	Unit 1 Power	Unit 2 Power	Total Power
m	m^3/s			m^3/s	m^3/s	m^3/s	MW	MW	MW
104	81.00	1	1	37.61	43.39	81.00	34797.47	39900.00	74697.47
104	82.00	1	1	38.38	43.62	82.00	35267.38	39901.38	75168.76
104	83.00	1	1	39.16	43.84	83.00	35760.19	39900.00	75660.19
104	84.00	1	1	39.94	44.06	84.00	36282.83	39902.37	76185.20
104	85.00	1	1	40.65	44.35	85.00	36641.30	39900.53	76541.83
104	86.00	1	1	41.31	44.69	86.00	36932.70	39927.75	76860.45
104	87.00	1	1	41.99	45.01	87.00	37201.61	39900.00	77101.61
104	88.00	1	1	42.69	45.31	88.00	37553.39	39909.62	77463.01
104	89.00	1	1	43.41	45.59	89.00	37939.91	39900.05	77839.96
104	90.00	1	1	44.12	45.88	90.00	38321.04	39913.13	78234.17
104	91.00	1	1	44.82	46.19	91.01	38671.79	39909.80	78581.59
104	92.00	1	1	45.48	46.52	92.00	38979.76	39921.77	78901.53
104	93.00	1	1	46.17	46.83	93.00	39276.73	39900.00	79176.73
104	94.00	1	1	46.81	47.19	94.00	39540.69	39926.39	79467.07
104	95.00	1	1	47.48	47.52	95.00	39811.48	39900.02	79711.50
104	96.00	1	1	47.73	47.66	95.39	39908.87	39910.19	79819.06
104	97.00	1	1	47.71	47.64	95.34	39900.08	39900.00	79800.08
104	98.00	1	1	47.71	47.64	95.35	39903.39	39900.36	79803.75
104	99.00	1	1	47.75	47.67	95.43	39918.01	39911.84	79829.85
104	100.00	1	1	47.75	47.66	95.40	39915.76	39900.00	79815.76
104.5	0.00	0	0	0.00	0.00	0.00	0.00	0.00	0.00
104.5	16.00	1	0	16.00	0.00	16.00	11743.97	0.00	11743.97

Gross Head	Available Discharge	Unit#1 Status	Unit#2 Status	Unit#1 Discharge	Unit#2 Discharge	Discharge Used	Unit 1 Power	Unit 2 Power	Total Power
m	m^3/s			m^3/s	m^3/s	m^3/s	MW	MW	MW
104.5	17.00	1	0	17.01	0.00	17.01	12894.95	0.00	12894.95
104.5	18.00	1	0	18.00	0.00	18.00	14123.15	0.00	14123.15
104.5	19.00	1	0	19.00	0.00	19.00	15303.65	0.00	15303.65
104.5	20.00	1	0	20.01	0.00	20.01	16447.29	0.00	16447.29
104.5	21.00	1	0	21.02	0.00	21.02	17595.74	0.00	17595.74
104.5	22.00	1	0	22.00	0.00	22.00	18802.79	0.00	18802.79
104.5	23.00	1	0	23.02	0.00	23.02	20048.07	0.00	20048.07
104.5	24.00	1	0	24.00	0.00	24.00	21197.34	0.00	21197.34
104.5	25.00	1	0	25.00	0.00	25.00	22384.11	0.00	22384.11
104.5	26.00	1	0	26.02	0.00	26.02	23501.11	0.00	23501.11
104.5	27.00	1	0	27.00	0.00	27.00	24502.87	0.00	24502.87
104.5	28.00	1	0	28.02	0.00	28.02	25544.04	0.00	25544.04
104.5	29.00	1	0	29.00	0.00	29.00	26508.41	0.00	26508.41
104.5	30.00	1	0	30.00	0.00	30.00	27551.17	0.00	27551.17
104.5	31.00	1	0	31.00	0.00	31.00	28648.11	0.00	28648.11
104.5	32.00	1	0	32.00	0.00	32.00	29688.14	0.00	29688.14
104.5	33.00	1	0	33.02	0.00	33.02	30714.60	0.00	30714.60
104.5	34.00	1	0	34.00	0.00	34.00	31673.49	0.00	31673.49
104.5	35.00	1	0	35.02	0.00	35.02	32817.71	0.00	32817.71
104.5	36.00	1	0	36.00	0.00	36.00	33800.46	0.00	33800.46
104.5	37.00	1	0	37.00	0.00	37.00	34782.67	0.00	34782.67
104.5	38.00	1	0	38.00	0.00	38.00	35699.29	0.00	35699.29

Gross Head	Available Discharge	Unit#1 Status	Unit#2 Status	Unit#1 Discharge	Unit#2 Discharge	Discharge Used	Unit 1 Power	Unit 2 Power	Total Power
m	m^3/s			m^3/s	m^3/s	m^3/s	MW	MW	MW
104.5	39.00	1	0	39.00	0.00	39.00	36621.83	0.00	36621.83
104.5	40.00	1	0	40.00	0.00	40.00	37140.65	0.00	37140.65
104.5	41.00	1	0	41.00	0.00	41.00	37987.13	0.00	37987.13
104.5	42.00	1	1	25.99	15.74	41.73	24223.57	14882.45	39106.02
104.5	43.00	1	0	42.93	0.00	42.93	39190.82	0.00	39190.82
104.5	44.00	1	1	29.00	15.00	44.00	26920.88	14205.37	41126.25
104.5	45.00	1	1	30.00	15.00	45.00	28058.10	14353.90	42412.00
104.5	46.00	1	1	30.00	16.04	46.04	28059.88	15344.13	43404.01
104.5	47.00	1	1	30.00	17.02	47.02	28060.77	16277.94	44338.70
104.5	48.00	1	1	30.00	18.00	48.00	28061.48	17212.37	45273.86
104.5	49.00	1	1	33.99	15.02	49.01	31856.53	14405.64	46262.17
104.5	50.00	1	1	30.00	20.00	50.00	28062.74	19083.47	47146.21
104.5	51.00	1	1	33.83	17.18	51.01	31700.09	16462.12	48162.21
104.5	52.00	1	1	30.00	22.00	52.00	28064.08	20940.74	49004.82
104.5	53.00	1	1	34.01	19.03	53.04	31871.44	18220.45	50091.90
104.5	54.00	1	1	34.02	19.98	54.00	31878.48	19101.58	50980.06
104.5	55.00	1	1	34.03	20.97	55.00	31883.15	20025.28	51908.43
104.5	56.00	1	1	37.66	18.36	56.02	35116.46	17627.06	52743.51
104.5	57.00	1	1	34.05	22.95	57.00	31905.23	21848.47	53753.70
104.5	58.00	1	1	34.01	23.99	58.00	31862.86	22815.39	54678.25
104.5	59.00	1	1	34.05	24.95	59.00	31901.06	23702.98	55604.04
104.5	60.00	1	1	34.04	25.96	60.00	31894.26	24596.98	56491.24

Gross Head	Available Discharge	Unit#1 Status	Unit#2 Status	Unit#1 Discharge	Unit#2 Discharge	Discharge Used	Unit 1 Power	Unit 2 Power	Total Power
m	m³/s			m³/s	m³/s	m³/s	MW	MW	MW
104.5	61.00	1	1	34.04	26.96	61.01	31895.30	25531.38	57426.68
104.5	62.00	1	1	34.06	27.94	62.00	31910.58	26422.74	58333.31
104.5	63.00	1	1	34.04	28.96	63.00	31887.39	27361.04	59248.43
104.5	64.00	1	1	34.04	29.96	64.00	31892.22	28282.55	60174.77
104.5	65.00	1	1	37.70	27.34	65.04	35152.90	25936.04	61088.94
104.5	66.00	1	1	35.93	30.06	65.99	33579.30	28402.11	61981.41
104.5	67.00	1	1	34.06	32.94	67.00	31908.52	30988.20	62896.71
104.5	68.00	1	1	34.09	33.90	67.99	31934.08	31855.14	63789.22
104.5	69.00	1	1	37.73	31.33	69.06	35175.42	29582.55	64757.97
104.5	70.00	1	1	35.93	34.07	70.00	33571.08	32036.98	65608.07
104.5	71.00	1	1	37.74	33.31	71.05	35184.95	31399.07	66584.02
104.5	72.00	1	1	37.74	34.26	72.00	35184.93	32258.56	67443.49
104.5	73.00	1	1	37.82	35.18	73.00	35255.98	33071.62	68327.60
104.5	74.00	1	1	37.81	36.19	74.00	35246.12	33951.94	69198.06
104.5	75.00	1	1	37.76	37.26	75.02	35197.81	34875.67	70073.48
104.5	76.00	1	1	37.74	38.26	76.00	35184.62	35753.06	70937.69
104.5	77.00	1	1	37.74	39.26	77.00	35184.15	36639.92	71824.08
104.5	78.00	1	1	38.00	40.00	78.00	35395.87	37290.46	72686.33
104.5	79.00	1	1	38.11	40.89	79.00	35487.70	37914.60	73402.30
104.5	80.00	1	1	37.70	42.30	80.00	35144.80	39215.26	74360.06
104.5	81.00	1	1	37.95	43.05	81.00	35359.37	39900.00	75259.37
104.5	82.00	1	1	38.83	43.17	82.00	36031.83	39900.00	75931.83

Gross Head	Available Discharge	Unit#1 Status	Unit#2 Status	Unit#1 Discharge	Unit#2 Discharge	Discharge Used	Unit 1 Power	Unit 2 Power	Total Power
m	m^3/s			m^3/s	m^3/s	m^3/s	MW	MW	MW
104.5	83.00	1	1	39.68	43.32	83.00	36658.33	39901.93	76560.27
104.5	84.00	1	1	40.48	43.52	84.00	37194.13	39909.59	77103.71
104.5	85.00	1	1	41.22	43.78	85.00	37607.58	39915.36	77522.94
104.5	86.00	1	1	41.92	44.07	85.99	37935.06	39892.67	77827.73
104.5	87.00	1	1	42.63	44.37	87.00	38288.97	39901.36	78190.33
104.5	88.00	1	1	43.32	44.68	88.00	38634.20	39905.28	78539.49
104.5	89.00	1	1	44.00	45.00	89.00	38963.45	39912.12	78875.57
104.5	90.00	1	1	44.66	45.34	90.00	39237.53	39900.27	79137.80
104.5	91.00	1	1	45.28	45.72	91.00	39460.23	39899.80	79360.03
104.5	92.00	1	1	45.89	46.11	92.00	39649.66	39900.00	79549.66
104.5	93.00	1	1	46.49	46.51	93.00	39819.19	39900.00	79719.19
104.5	94.00	1	1	46.83	46.75	93.58	39912.90	39902.56	79815.46
104.5	95.00	1	1	46.89	46.81	93.70	39928.49	39922.96	79851.45
104.5	96.00	1	1	46.87	46.77	93.64	39922.25	39899.95	79822.21
104.5	97.00	1	1	46.82	46.75	93.57	39910.85	39902.50	79813.35
104.5	98.00	1	1	46.78	46.72	93.50	39900.01	39899.92	79799.94
104.5	99.00	1	1	46.85	46.78	93.63	39916.83	39920.52	79837.35
104.5	100.00	1	1	42.87	42.82	85.69	38405.23	38407.46	76812.69
105	0.00	0	0	0.00	0.00	0.00	0.00	0.00	0.00
105	16.00	1	0	16.01	0.00	16.01	11884.47	0.00	11884.47
105	17.00	1	0	17.05	0.00	17.05	13097.60	0.00	13097.60
105	18.00	1	0	18.02	0.00	18.02	14188.54	0.00	14188.54

Gross Head	Available Discharge	Unit#1 Status	Unit#2 Status	Unit#1 Discharge	Unit#2 Discharge	Discharge Used	Unit 1 Power	Unit 2 Power	Total Power
m	m^3/s			m^3/s	m^3/s	m^3/s	MW	MW	MW
105	19.00	1	0	19.00	0.00	19.00	15282.00	0.00	15282.00
105	20.00	1	0	20.00	0.00	20.00	16448.86	0.00	16448.86
105	21.00	1	0	21.00	0.00	21.00	17622.83	0.00	17622.83
105	22.00	1	0	22.01	0.00	22.01	18913.14	0.00	18913.14
105	23.00	1	0	23.01	0.00	23.01	20104.46	0.00	20104.46
105	24.00	1	0	24.01	0.00	24.01	21318.03	0.00	21318.03
105	25.00	1	0	25.01	0.00	25.01	22432.60	0.00	22432.60
105	26.00	1	0	26.02	0.00	26.02	23532.38	0.00	23532.38
105	27.00	1	0	27.00	0.00	27.00	24509.76	0.00	24509.76
105	28.00	1	0	28.04	0.00	28.04	25615.82	0.00	25615.82
105	29.00	1	0	29.00	0.00	29.00	26601.99	0.00	26601.99
105	30.00	1	0	30.00	0.00	30.00	27624.32	0.00	27624.32
105	31.00	1	0	31.00	0.00	31.00	28714.20	0.00	28714.20
105	32.00	1	0	32.00	0.00	32.00	29750.49	0.00	29750.49
105	33.00	1	0	33.00	0.00	33.00	30756.38	0.00	30756.38
105	34.00	1	0	34.00	0.00	34.00	31771.16	0.00	31771.16
105	35.00	1	0	35.02	0.00	35.02	32862.00	0.00	32862.00
105	36.00	1	0	36.00	0.00	36.00	33870.82	0.00	33870.82
105	37.00	1	0	37.00	0.00	37.00	34871.78	0.00	34871.78
105	38.00	1	0	38.00	0.00	38.00	35794.52	0.00	35794.52
105	39.00	1	0	39.00	0.00	39.00	36672.88	0.00	36672.88
105	40.00	1	0	40.00	0.00	40.00	37488.53	0.00	37488.53

Gross Head	Available Discharge	Unit#1 Status	Unit#2 Status	Unit#1 Discharge	Unit#2 Discharge	Discharge Used	Unit 1 Power	Unit 2 Power	Total Power
m	m^3/s			m^3/s	m^3/s	m^3/s	MW	MW	MW
105	41.00	1	0	41.00	0.00	41.00	38094.74	0.00	38094.74
105	42.00	1	0	42.00	0.00	42.00	39057.89	0.00	39057.89
105	43.00	1	1	26.21	16.79	43.00	24332.10	15805.68	40137.78
105	44.00	1	1	27.99	15.98	43.97	25840.67	14995.45	40836.12
105	45.00	1	1	30.00	15.00	45.00	27687.93	14162.20	41850.13
105	46.00	1	1	30.98	15.00	45.98	28753.55	14230.71	42984.25
105	47.00	1	1	31.04	15.96	47.00	28815.88	15137.34	43953.22
105	48.00	1	1	33.03	15.00	48.03	30755.41	14279.90	45035.31
105	49.00	1	1	31.09	17.90	48.99	28858.69	16972.31	45831.00
105	50.00	1	1	35.00	15.00	50.00	32981.01	14487.51	47468.53
105	51.00	1	1	35.12	15.88	51.00	33097.62	15335.88	48433.50
105	52.00	1	1	35.12	16.88	52.00	33097.49	16296.89	49394.38
105	53.00	1	1	35.13	17.92	53.05	33099.33	17301.22	50400.55
105	54.00	1	1	35.14	18.86	54.00	33111.40	18199.01	51310.41
105	55.00	1	1	35.16	19.84	55.00	33129.07	19116.87	52245.95
105	56.00	1	1	38.08	17.92	56.00	35835.55	17376.87	53212.42
105	57.00	1	1	38.08	18.92	57.00	35836.52	18339.73	54176.25
105	58.00	1	1	38.08	19.91	57.99	35837.95	19268.47	55106.41
105	59.00	1	1	38.08	20.92	59.00	35838.45	20223.52	56061.97
105	60.00	1	1	38.08	21.93	60.01	35837.44	21175.10	57012.54
105	61.00	1	1	38.08	22.92	61.00	35838.74	22099.90	57938.65
105	62.00	1	1	38.07	23.93	62.00	35837.48	23040.65	58878.13

Gross Head	Available Discharge	Unit#1 Status	Unit#2 Status	Unit#1 Discharge	Unit#2 Discharge	Discharge Used	Unit 1 Power	Unit 2 Power	Total Power
m	m^3/s			m^3/s	m^3/s	m^3/s	MW	MW	MW
105	63.00	1	1	38.07	24.93	63.00	35837.29	23982.00	59819.29
105	64.00	1	1	38.07	25.93	64.00	35838.86	24883.79	60722.64
105	65.00	1	1	38.07	26.95	65.02	35836.77	25842.65	61679.42
105	66.00	1	1	38.07	27.93	66.00	35837.40	26756.77	62594.18
105	67.00	1	1	38.07	28.93	67.00	35837.14	27686.64	63523.78
105	68.00	1	1	38.06	29.94	68.00	35837.51	28628.26	64465.77
105	69.00	1	1	38.06	30.94	69.01	35838.74	29544.76	65383.50
105	70.00	1	1	38.06	31.94	70.00	35837.36	30455.14	66292.50
105	71.00	1	1	38.06	32.94	71.00	35836.49	31396.28	67232.77
105	72.00	1	1	38.05	33.95	71.99	35828.33	32318.22	68146.55
105	73.00	1	1	38.06	34.94	73.00	35837.58	33217.43	69055.01
105	74.00	1	1	38.05	35.95	74.00	35832.87	34108.67	69941.54
105	75.00	1	1	38.06	36.94	75.00	35839.14	34969.65	70808.79
105	76.00	1	1	38.05	37.95	76.00	35837.38	35860.35	71697.73
105	77.00	1	1	38.05	38.95	77.00	35836.58	36759.22	72595.80
105	78.00	1	1	38.05	39.95	78.00	35836.20	37658.34	73494.54
105	79.00	1	1	38.06	40.94	79.00	35842.76	38386.51	74229.27
105	80.00	1	1	36.81	43.19	80.00	34264.38	39899.89	74164.26
105	81.00	1	1	38.31	42.69	81.00	35958.87	39893.29	75852.17
105	82.00	1	1	39.00	43.00	82.00	36323.28	39902.67	76225.95
105	83.00	1	1	39.89	43.11	83.00	37035.68	39901.66	76937.34
105	84.00	1	1	40.84	43.16	84.00	37821.37	39907.67	77729.03

Gross Head	Available Discharge	Unit#1 Status	Unit#2 Status	Unit#1 Discharge	Unit#2 Discharge	Discharge Used	Unit 1 Power	Unit 2 Power	Total Power
m	m^3/s			m^3/s	m^3/s	m^3/s	MW	MW	MW
105	85.00	1	1	41.71	43.29	85.00	38455.44	39915.40	78370.84
105	86.00	1	1	42.50	43.50	86.00	38949.67	39900.00	78849.67
105	87.00	1	1	43.22	43.78	87.00	39338.49	39900.00	79238.49
105	88.00	1	1	43.89	44.11	88.00	39644.14	39900.00	79544.14
105	89.00	1	1	44.49	44.51	89.00	39821.90	39901.30	79723.21
105	90.00	1	1	45.04	44.98	90.02	39914.75	39916.51	79831.26
105	91.00	1	1	44.99	44.92	89.91	39908.60	39900.03	79808.63
105	92.00	1	1	45.25	45.14	90.38	39935.69	39900.12	79835.81
105	93.00	1	1	45.03	44.95	89.98	39913.54	39900.01	79813.55
105	94.00	1	1	44.95	44.88	89.84	39903.34	39903.28	79806.61
105	95.00	1	1	45.01	44.93	89.94	39910.86	39900.04	79810.90
105	96.00	1	1	45.17	45.07	90.24	39928.38	39900.00	79828.38
105	97.00	1	1	45.10	45.03	90.14	39921.42	39921.14	79842.56
105	98.00	1	1	45.08	44.99	90.06	39918.62	39900.04	79818.67
105	99.00	1	1	45.00	44.93	89.93	39909.66	39910.15	79819.81
105	100.00	1	1	50.00	50.00	100.00	40622.41	40681.47	81303.88
105.5	0.00	0	0	0.00	0.00	0.00	0.00	0.00	0.00
105.5	16.00	1	0	16.00	0.00	16.00	11931.18	0.00	11931.18
105.5	17.00	1	0	17.02	0.00	17.02	13133.64	0.00	13133.64
105.5	18.00	1	0	18.01	0.00	18.01	14283.82	0.00	14283.82
105.5	19.00	1	0	19.00	0.00	19.00	15338.24	0.00	15338.24
105.5	20.00	1	0	20.00	0.00	20.00	16489.69	0.00	16489.69

Gross Head	Available Discharge	Unit#1 Status	Unit#2 Status	Unit#1 Discharge	Unit#2 Discharge	Discharge Used	Unit 1 Power	Unit 2 Power	Total Power
m	m^3/s			m^3/s	m^3/s	m^3/s	MW	MW	MW
105.5	21.00	1	0	21.00	0.00	21.00	17689.52	0.00	17689.52
105.5	22.00	1	0	22.02	0.00	22.02	18978.76	0.00	18978.76
105.5	23.00	1	0	23.02	0.00	23.02	20182.45	0.00	20182.45
105.5	24.00	1	0	24.00	0.00	24.00	21360.27	0.00	21360.27
105.5	25.00	1	0	25.00	0.00	25.00	22491.45	0.00	22491.45
105.5	26.00	1	0	26.00	0.00	26.00	23556.51	0.00	23556.51
105.5	27.00	1	0	27.00	0.00	27.00	24581.65	0.00	24581.65
105.5	28.00	1	0	28.01	0.00	28.01	25640.77	0.00	25640.77
105.5	29.00	1	0	29.00	0.00	29.00	26695.38	0.00	26695.38
105.5	30.00	1	0	30.00	0.00	30.00	27714.47	0.00	27714.47
105.5	31.00	1	0	31.00	0.00	31.00	28794.82	0.00	28794.82
105.5	32.00	1	0	32.00	0.00	32.00	29850.55	0.00	29850.55
105.5	33.00	1	0	33.00	0.00	33.00	30854.39	0.00	30854.39
105.5	34.00	1	0	34.00	0.00	34.00	31857.04	0.00	31857.04
105.5	35.00	1	0	35.00	0.00	35.00	32914.52	0.00	32914.52
105.5	36.00	1	0	36.00	0.00	36.00	34000.17	0.00	34000.17
105.5	37.00	1	0	37.01	0.00	37.01	35044.67	0.00	35044.67
105.5	38.00	1	0	38.00	0.00	38.00	35955.45	0.00	35955.45
105.5	39.00	1	0	39.00	0.00	39.00	36840.43	0.00	36840.43
105.5	40.00	1	0	40.00	0.00	40.00	37608.52	0.00	37608.52
105.5	41.00	1	0	41.00	0.00	41.00	38370.45	0.00	38370.45
105.5	42.00	1	0	42.00	0.00	42.00	39095.08	0.00	39095.08

Gross Head	Available Discharge	Unit#1 Status	Unit#2 Status	Unit#1 Discharge	Unit#2 Discharge	Discharge Used	Unit 1 Power	Unit 2 Power	Total Power
m	m^3/s			m^3/s	m^3/s	m^3/s	MW	MW	MW
105.5	43.00	1	0	42.92	0.00	42.92	39904.41	0.00	39904.41
105.5	44.00	1	1	26.37	17.68	44.05	24371.59	16573.06	40944.64
105.5	45.00	1	1	26.36	18.67	45.03	24373.82	17501.67	41875.49
105.5	46.00	1	1	31.00	15.00	46.00	28726.85	14204.53	42931.37
105.5	47.00	1	1	31.16	15.90	47.06	28889.74	15057.88	43947.63
105.5	48.00	1	1	31.16	16.88	48.04	28884.19	15986.33	44870.53
105.5	49.00	1	1	34.00	15.00	49.00	31677.39	14298.40	45975.78
105.5	50.00	1	1	35.02	15.00	50.02	33105.50	14534.27	47639.77
105.5	51.00	1	1	26.35	24.65	51.00	24390.94	22943.52	47334.47
105.5	52.00	1	1	35.65	16.35	52.00	33829.16	15906.95	49736.11
105.5	53.00	1	1	35.66	17.34	53.00	33831.97	16872.92	50704.89
105.5	54.00	1	1	26.36	27.70	54.07	24406.68	25684.43	50091.11
105.5	55.00	1	1	35.69	19.31	55.00	33862.40	18764.97	52627.36
105.5	56.00	1	1	35.69	20.31	56.00	33865.56	19702.75	53568.31
105.5	57.00	1	1	35.62	21.38	57.00	33799.39	20711.88	54511.27
105.5	58.00	1	1	35.71	22.29	58.00	33882.49	21570.94	55453.43
105.5	59.00	1	1	35.68	23.32	59.00	33855.84	22530.18	56386.02
105.5	60.00	1	1	35.69	24.31	60.00	33863.53	23462.92	57326.46
105.5	61.00	1	1	35.72	25.28	61.00	33887.82	24368.22	58256.04
105.5	62.00	1	1	35.67	26.33	62.00	33845.38	25323.44	59168.82
105.5	63.00	1	1	35.70	27.30	63.00	33869.51	26239.38	60108.88
105.5	64.00	1	1	35.69	28.32	64.01	33861.15	27185.87	61047.02

Gross Head	Available Discharge	Unit#1 Status	Unit#2 Status	Unit#1 Discharge	Unit#2 Discharge	Discharge Used	Unit 1 Power	Unit 2 Power	Total Power
m	m^3/s			m^3/s	m^3/s	m^3/s	MW	MW	MW
105.5	65.00	1	1	35.68	29.32	65.00	33849.78	28121.73	61971.51
105.5	66.00	1	1	35.72	30.28	66.00	33886.26	29017.31	62903.57
105.5	67.00	1	1	35.71	31.29	67.00	33876.61	29937.39	63814.00
105.5	68.00	1	1	35.55	32.49	68.04	33725.93	31040.89	64766.83
105.5	69.00	1	1	35.71	33.29	69.00	33876.07	31796.71	65672.78
105.5	70.00	1	1	35.72	34.28	70.00	33887.00	32698.86	66585.85
105.5	71.00	1	1	35.76	35.24	71.00	33923.43	33559.46	67482.88
105.5	72.00	1	1	42.33	29.67	72.00	39370.64	28200.26	67570.89
105.5	73.00	1	1	35.72	37.26	72.98	33889.94	35331.36	69221.31
105.5	74.00	1	1	35.72	38.28	74.00	33882.81	36245.38	70128.19
105.5	75.00	1	1	42.29	32.71	75.00	39332.03	30980.84	70312.87
105.5	76.00	1	1	35.82	40.18	76.00	33974.91	37912.43	71887.34
105.5	77.00	1	1	35.67	41.33	77.00	33841.06	38821.17	72662.23
105.5	78.00	1	1	35.67	42.33	78.00	33840.12	39759.45	73599.57
105.5	79.00	1	1	36.32	42.68	79.00	34254.65	39902.73	74157.38
105.5	80.00	1	1	42.47	37.53	80.00	39494.92	35254.43	74749.35
105.5	81.00	1	1	42.41	38.60	81.01	39437.87	36207.24	75645.10
105.5	82.00	1	1	42.51	39.49	82.00	39529.63	36994.95	76524.58
105.5	83.00	1	1	42.94	40.06	83.00	39900.27	37470.74	77371.01
105.5	84.00	1	1	42.26	41.77	84.02	39302.03	38882.54	78184.57
105.5	85.00	1	1	42.25	42.75	85.00	39295.95	39795.00	79090.94
105.5	86.00	1	1	42.95	42.90	85.85	39907.41	39908.66	79816.07

Gross Head	Available Discharge	Unit#1 Status	Unit#2 Status	Unit#1 Discharge	Unit#2 Discharge	Discharge Used	Unit 1 Power	Unit 2 Power	Total Power
m	m^3/s			m^3/s	m^3/s	m^3/s	MW	MW	MW
105.5	87.00	1	1	42.94	42.91	85.85	39898.31	39922.20	79820.51
105.5	88.00	1	1	42.95	42.89	85.84	39901.73	39901.74	79803.47
105.5	89.00	1	1	42.95	42.89	85.84	39903.27	39904.54	79807.80
105.5	90.00	1	1	42.94	42.88	85.83	39897.64	39896.64	79794.28
105.5	91.00	1	1	42.95	42.89	85.83	39900.74	39899.99	79800.73
105.5	92.00	1	1	45.69	45.62	91.31	39900.36	39900.28	79800.64
105.5	93.00	1	1	45.68	45.63	91.31	39904.42	39913.79	79818.22
105.5	94.00	1	1	42.95	42.89	85.84	39904.92	39902.78	79807.71
105.5	95.00	1	1	42.95	42.89	85.83	39900.17	39900.19	79800.36
105.5	96.00	1	1	42.95	42.89	85.83	39900.00	39900.00	79800.00
105.5	97.00	1	1	42.95	42.89	85.84	39900.00	39903.71	79803.71
105.5	98.00	1	1	42.95	42.90	85.85	39902.96	39909.54	79812.50
105.5	99.00	1	1	42.95	42.89	85.84	39903.58	39904.26	79807.85
105.5	100.00	1	1	45.69	45.62	91.31	39901.58	39901.72	79803.30
106	0.00	0	0	0.00	0.00	0.00	0.00	0.00	0.00
106	16.00	1	0	16.00	0.00	16.00	11967.81	0.00	11967.81
106	17.00	1	0	17.01	0.00	17.01	13148.63	0.00	13148.63
106	18.00	1	0	18.00	0.00	18.00	14291.12	0.00	14291.12
106	19.00	1	0	19.01	0.00	19.01	15415.05	0.00	15415.05
106	20.00	1	0	20.00	0.00	20.00	16578.66	0.00	16578.66
106	21.00	1	0	21.01	0.00	21.01	17765.46	0.00	17765.46
106	22.00	1	0	22.00	0.00	22.00	19002.19	0.00	19002.19

Gross Head	Available Discharge	Unit#1 Status	Unit#2 Status	Unit#1 Discharge	Unit#2 Discharge	Discharge Used	Unit 1 Power	Unit 2 Power	Total Power
m	m^3/s			m^3/s	m^3/s	m^3/s	MW	MW	MW
106	23.00	1	0	23.00	0.00	23.00	20226.63	0.00	20226.63
106	24.00	1	0	24.00	0.00	24.00	21432.01	0.00	21432.01
106	25.00	1	0	25.00	0.00	25.00	22554.58	0.00	22554.58
106	26.00	1	0	26.01	0.00	26.01	23632.05	0.00	23632.05
106	27.00	1	0	27.00	0.00	27.00	24651.33	0.00	24651.33
106	28.00	1	0	28.00	0.00	28.00	25703.54	0.00	25703.54
106	29.00	1	0	29.00	0.00	29.00	26761.48	0.00	26761.48
106	30.00	1	0	30.01	0.00	30.01	27810.98	0.00	27810.98
106	31.00	1	0	31.00	0.00	31.00	28890.78	0.00	28890.78
106	32.00	1	0	32.00	0.00	32.00	29956.83	0.00	29956.83
106	33.00	1	0	33.00	0.00	33.00	30978.17	0.00	30978.17
106	34.00	1	0	34.00	0.00	34.00	31991.86	0.00	31991.86
106	35.00	1	0	35.00	0.00	35.00	33041.05	0.00	33041.05
106	36.00	1	0	36.01	0.00	36.01	34129.86	0.00	34129.86
106	37.00	1	0	37.00	0.00	37.00	35184.47	0.00	35184.47
106	38.00	1	0	38.00	0.00	38.00	36122.68	0.00	36122.68
106	39.00	1	0	39.00	0.00	39.00	36846.92	0.00	36846.92
106	40.00	1	0	40.00	0.00	40.00	37743.08	0.00	37743.08
106	41.00	1	0	41.00	0.00	41.00	38453.50	0.00	38453.50
106	42.00	1	0	42.01	0.00	42.01	39237.11	0.00	39237.11
106	43.00	1	0	42.87	0.00	42.87	39900.30	0.00	39900.30
106	44.00	1	0	42.91	0.00	42.91	39927.51	0.00	39927.51

Gross Head	Available Discharge	Unit#1 Status	Unit#2 Status	Unit#1 Discharge	Unit#2 Discharge	Discharge Used	Unit 1 Power	Unit 2 Power	Total Power
m	m^3/s			m^3/s	m^3/s	m^3/s	MW	MW	MW
106	45.00	1	1	29.86	15.11	44.98	27410.63	14182.21	41592.84
106	46.00	1	1	30.98	15.03	46.01	28579.35	14171.36	42750.71
106	47.00	1	1	31.58	15.41	46.99	29126.57	14524.17	43650.74
106	48.00	1	1	33.00	15.00	48.00	30534.81	14184.62	44719.43
106	49.00	1	1	26.70	22.26	48.96	24054.11	20231.30	44285.41
106	50.00	1	1	34.99	15.01	50.00	33024.52	14510.72	47535.24
106	51.00	1	1	35.73	15.27	51.00	33900.41	14862.04	48762.45
106	52.00	1	1	35.73	16.27	52.00	33897.91	15835.03	49732.94
106	53.00	1	1	35.73	17.27	53.00	33899.02	16803.82	50702.84
106	54.00	1	1	35.73	18.27	54.00	33897.05	17773.82	51670.86
106	55.00	1	1	35.77	19.23	55.00	33938.42	18691.01	52629.43
106	56.00	1	1	35.76	20.24	56.00	33932.40	19638.77	53571.17
106	57.00	1	1	35.75	21.25	57.00	33925.37	20591.00	54516.37
106	58.00	1	1	35.75	22.25	58.00	33923.92	21535.17	55459.10
106	59.00	1	1	35.76	23.24	59.00	33930.47	22461.91	56392.38
106	60.00	1	1	35.75	24.25	60.00	33926.08	23407.69	57333.76
106	61.00	1	1	35.79	25.21	61.00	33959.10	24307.95	58267.06
106	62.00	1	1	35.74	26.26	62.00	33909.38	25268.79	59178.17
106	63.00	1	1	35.75	27.25	63.00	33922.57	26197.61	60120.18
106	64.00	1	1	35.83	28.17	64.00	33994.24	27053.79	61048.03
106	65.00	1	1	35.77	29.25	65.02	33942.98	28058.91	62001.88
106	66.00	1	1	35.78	30.22	66.00	33950.29	28968.98	62919.27

Gross Head	Available Discharge	Unit#1 Status	Unit#2 Status	Unit#1 Discharge	Unit#2 Discharge	Discharge Used	Unit 1 Power	Unit 2 Power	Total Power
m	m³/s			m³/s	m³/s	m³/s	MW	MW	MW
106	67.00	1	1	35.75	31.25	67.00	33921.96	29908.24	63830.21
106	68.00	1	1	35.73	32.32	68.05	33908.20	30895.48	64803.68
106	69.00	1	1	35.75	33.25	69.00	33927.47	31763.72	65691.19
106	70.00	1	1	35.76	34.24	70.00	33936.93	32669.31	66606.24
106	71.00	1	1	35.79	35.22	71.01	33959.77	33554.70	67514.48
106	72.00	1	1	35.76	36.24	72.00	33937.45	34450.37	68387.82
106	73.00	1	1	35.80	37.24	73.04	33968.40	35326.48	69294.88
106	74.00	1	1	35.76	38.24	74.00	33936.37	36217.52	70153.90
106	75.00	1	1	35.74	39.26	75.00	33917.85	37135.41	71053.26
106	76.00	1	1	35.88	40.12	76.00	34035.30	37888.76	71924.06
106	77.00	1	1	35.72	41.28	77.00	33895.19	38795.17	72690.36
106	78.00	1	1	35.73	42.27	78.00	33909.67	39718.99	73628.66
106	79.00	1	1	42.91	36.09	79.00	39903.52	34007.66	73911.18
106	80.00	1	1	37.25	42.75	80.00	34999.17	39899.96	74899.13
106	81.00	1	1	38.37	42.63	81.00	35999.13	39824.78	75823.91
106	82.00	1	1	39.21	42.79	82.00	36688.85	39908.91	76597.76
106	83.00	1	1	42.93	40.07	83.00	39917.90	37511.49	77429.40
106	84.00	1	1	42.65	41.35	84.00	39667.31	38500.04	78167.34
106	85.00	1	1	42.70	42.30	85.00	39714.31	39382.51	79096.82
106	86.00	1	1	42.91	42.85	85.75	39897.55	39898.88	79796.43
106	87.00	1	1	42.92	42.88	85.80	39913.68	39928.96	79842.64
106	88.00	1	1	42.92	42.86	85.78	39909.89	39912.14	79822.03

Gross Head	Available Discharge	Unit#1 Status	Unit#2 Status	Unit#1 Discharge	Unit#2 Discharge	Discharge Used	Unit 1 Power	Unit 2 Power	Total Power
m	m^3/s			m^3/s	m^3/s	m^3/s	MW	MW	MW
106	89.00	1	1	42.90	42.85	85.75	39894.95	39899.91	79794.86
106	90.00	1	1	42.91	42.85	85.76	39900.00	39901.88	79801.88
106	91.00	1	1	44.57	44.48	89.05	39928.93	39900.00	79828.93
106	92.00	1	1	44.60	44.53	89.13	39900.00	39900.01	79800.01
106	93.00	1	1	44.60	44.51	89.11	39889.44	39861.59	79751.03
106	94.00	1	1	42.91	42.85	85.76	39899.95	39899.95	79799.91
106	95.00	1	1	42.91	42.85	85.76	39900.00	39900.00	79800.00
106	96.00	1	1	42.91	42.85	85.77	39904.09	39904.29	79808.38
106	97.00	1	1	42.91	42.85	85.76	39900.00	39900.00	79800.00
106	98.00	1	1	42.91	42.85	85.76	39900.84	39901.13	79801.97
106	99.00	1	1	42.91	42.85	85.76	39900.00	39903.65	79803.65
106	100.00	1	1	42.91	42.85	85.76	39900.00	39902.63	79802.63
106.5	0.00	0	0	0.00	0.00	0.00	0.00	0.00	0.00
106.5	16.00	1	0	16.01	0.00	16.01	12025.40	0.00	12025.40
106.5	17.00	1	0	17.04	0.00	17.04	13216.12	0.00	13216.12
106.5	18.00	1	0	18.01	0.00	18.01	14338.13	0.00	14338.13
106.5	19.00	1	0	19.00	0.00	19.00	15463.71	0.00	15463.71
106.5	20.00	1	0	20.06	0.00	20.06	16724.83	0.00	16724.83
106.5	21.00	1	0	21.00	0.00	21.00	17833.19	0.00	17833.19
106.5	22.00	1	0	22.00	0.00	22.00	19046.61	0.00	19046.61
106.5	23.00	1	0	23.00	0.00	23.00	20275.67	0.00	20275.67
106.5	24.00	1	0	24.00	0.00	24.00	21491.95	0.00	21491.95

Gross Head	Available Discharge	Unit#1 Status	Unit#2 Status	Unit#1 Discharge	Unit#2 Discharge	Discharge Used	Unit 1 Power	Unit 2 Power	Total Power
m	m^3/s			m^3/s	m^3/s	m^3/s	MW	MW	MW
106.5	25.00	1	0	25.00	0.00	25.00	22624.40	0.00	22624.40
106.5	26.00	1	0	26.01	0.00	26.01	23714.32	0.00	23714.32
106.5	27.00	1	0	27.00	0.00	27.00	24740.38	0.00	24740.38
106.5	28.00	1	0	28.02	0.00	28.02	25793.53	0.00	25793.53
106.5	29.00	1	0	29.00	0.00	29.00	26821.80	0.00	26821.80
106.5	30.00	1	0	30.00	0.00	30.00	27868.97	0.00	27868.97
106.5	31.00	1	0	31.00	0.00	31.00	28971.54	0.00	28971.54
106.5	32.00	1	0	32.03	0.00	32.03	30088.61	0.00	30088.61
106.5	33.00	1	0	33.01	0.00	33.01	31102.51	0.00	31102.51
106.5	34.00	1	0	34.00	0.00	34.00	32118.56	0.00	32118.56
106.5	35.00	1	0	35.00	0.00	35.00	33178.42	0.00	33178.42
106.5	36.00	1	0	36.00	0.00	36.00	34249.08	0.00	34249.08
106.5	37.00	1	0	37.01	0.00	37.01	35328.94	0.00	35328.94
106.5	38.00	1	0	38.00	0.00	38.00	36299.80	0.00	36299.80
106.5	39.00	1	0	39.00	0.00	39.00	37108.46	0.00	37108.46
106.5	40.00	1	0	40.00	0.00	40.00	37846.93	0.00	37846.93
106.5	41.00	1	0	41.00	0.00	41.00	38538.43	0.00	38538.43
106.5	42.00	1	0	42.00	0.00	42.00	39164.60	0.00	39164.60
106.5	43.00	1	0	42.79	0.00	42.79	39900.54	0.00	39900.54
106.5	44.00	1	1	27.14	16.86	44.00	24657.44	15542.86	40200.31
106.5	45.00	1	1	30.00	15.00	45.00	27589.59	14109.16	41698.75
106.5	46.00	1	1	27.15	18.85	46.00	24663.31	17370.71	42034.02

Gross Head	Available Discharge	Unit#1 Status	Unit#2 Status	Unit#1 Discharge	Unit#2 Discharge	Discharge Used	Unit 1 Power	Unit 2 Power	Total Power
m	m^3/s			m^3/s	m^3/s	m^3/s	MW	MW	MW
106.5	47.00	1	1	32.00	15.00	47.00	29620.47	14190.18	43810.65
106.5	48.00	1	1	33.00	15.00	48.00	30649.79	14238.51	44888.30
106.5	49.00	1	1	34.04	15.00	49.04	31733.36	14309.80	46043.16
106.5	50.00	1	1	35.02	15.00	50.02	32832.86	14409.15	47242.01
106.5	51.00	1	1	35.47	15.53	51.00	33284.04	14938.20	48222.24
106.5	52.00	1	1	36.90	15.10	52.00	34746.49	14616.99	49363.47
106.5	53.00	1	1	36.92	16.08	53.00	34760.77	15564.84	50325.61
106.5	54.00	1	1	36.91	17.09	54.00	34749.05	16542.42	51291.47
106.5	55.00	1	1	36.98	18.02	55.00	34816.10	17437.31	52253.41
106.5	56.00	1	1	36.96	19.04	56.00	34797.35	18413.55	53210.90
106.5	57.00	1	1	36.95	20.05	57.00	34790.28	19357.31	54147.59
106.5	58.00	1	1	36.96	21.07	58.03	34794.11	20319.35	55113.46
106.5	59.00	1	1	36.99	22.01	59.00	34826.23	21199.34	56025.56
106.5	60.00	1	1	38.68	21.32	60.00	36365.29	20593.89	56959.18
106.5	61.00	1	1	38.76	22.24	61.00	36445.53	21451.99	57897.52
106.5	62.00	1	1	38.72	23.28	62.00	36401.25	22425.73	58826.99
106.5	63.00	1	1	38.71	24.31	63.02	36395.29	23391.33	59786.61
106.5	64.00	1	1	38.89	25.11	64.00	36562.96	24132.70	60695.66
106.5	65.00	1	1	38.71	26.29	65.00	36390.98	25210.57	61601.54
106.5	66.00	1	1	35.93	30.06	65.99	33699.75	28497.71	62197.47
106.5	67.00	1	1	38.79	28.21	67.00	36466.46	26999.30	63465.76
106.5	68.00	1	1	38.73	29.27	68.00	36413.46	27982.59	64396.05

Gross Head	Available Discharge	Unit#1 Status	Unit#2 Status	Unit#1 Discharge	Unit#2 Discharge	Discharge Used	Unit 1 Power	Unit 2 Power	Total Power
m	m^3/s			m^3/s	m^3/s	m^3/s	MW	MW	MW
106.5	69.00	1	1	38.89	30.11	69.00	36557.73	28771.41	65329.14
106.5	70.00	1	1	38.85	31.14	70.00	36527.12	29708.36	66235.47
106.5	71.00	1	1	38.74	32.26	71.00	36425.53	30729.49	67155.02
106.5	72.00	1	1	38.81	33.19	72.00	36486.00	31602.62	68088.62
106.5	73.00	1	1	38.93	34.07	73.00	36594.67	32408.50	69003.17
106.5	74.00	1	1	38.98	35.02	74.00	36638.50	33263.59	69902.09
106.5	75.00	1	1	39.03	35.97	75.00	36680.08	34105.93	70786.01
106.5	76.00	1	1	39.09	36.91	76.00	36738.16	34912.99	71651.15
106.5	77.00	1	1	38.95	38.07	77.03	36615.61	35946.13	72561.74
106.5	78.00	1	1	38.95	39.05	78.00	36612.21	36822.92	73435.12
106.5	79.00	1	1	39.18	39.82	79.00	36811.77	37513.85	74325.61
106.5	80.00	1	1	40.00	40.00	80.00	37520.30	37627.70	75147.99
106.5	81.00	1	1	38.80	42.20	81.00	36478.63	39518.01	75996.64
106.5	82.00	1	1	39.38	42.62	82.00	36991.08	39900.00	76891.08
106.5	83.00	1	1	40.32	42.68	83.00	37784.21	39907.92	77692.13
106.5	84.00	1	1	41.24	42.76	84.00	38513.73	39900.00	78413.73
106.5	85.00	1	1	42.32	42.68	85.00	39423.74	39794.59	79218.33
106.5	86.00	1	1	42.87	42.81	85.69	39900.00	39900.00	79800.00
106.5	87.00	1	1	42.88	42.82	85.70	39903.81	39903.81	79807.62
106.5	88.00	1	1	42.87	42.81	85.69	39900.00	39900.00	79800.00
106.5	89.00	1	1	44.04	43.97	88.01	39910.99	39911.26	79822.25
106.5	90.00	1	1	42.88	42.83	85.70	39902.80	39913.60	79816.40

Gross Head	Available Discharge	Unit#1 Status	Unit#2 Status	Unit#1 Discharge	Unit#2 Discharge	Discharge Used	Unit 1 Power	Unit 2 Power	Total Power
m	m^3/s			m^3/s	m^3/s	m^3/s	MW	MW	MW
106.5	91.00	1	1	42.88	42.82	85.70	39904.32	39904.31	79808.63
106.5	92.00	1	1	42.87	42.81	85.69	39900.27	39900.13	79800.40
106.5	93.00	1	1	42.88	42.82	85.70	39905.58	39904.47	79810.05
106.5	94.00	1	1	44.04	43.98	88.02	39900.61	39900.64	79801.26
106.5	95.00	1	1	42.87	42.81	85.69	39900.19	39900.19	79800.38
106.5	96.00	1	1	42.87	42.82	85.69	39901.84	39902.17	79804.01
106.5	97.00	1	1	42.87	42.81	85.69	39900.00	39900.00	79800.00
106.5	98.00	1	1	42.87	42.82	85.69	39900.02	39901.17	79801.19
106.5	99.00	1	1	42.88	42.82	85.70	39904.13	39904.12	79808.25
106.5	100.00	1	1	50.00	50.00	100.00	38756.21	38811.69	77567.90
107	0.00	0	0	0.00	0.00	0.00	0.00	0.00	0.00
107	16.00	1	0	16.00	0.00	16.00	12070.93	0.00	12070.93
107	17.00	1	0	17.00	0.00	17.00	13221.48	0.00	13221.48
107	18.00	1	0	18.00	0.00	18.00	14384.92	0.00	14384.92
107	19.00	1	0	19.00	0.00	19.00	15520.48	0.00	15520.48
107	20.00	1	0	20.00	0.00	20.00	16725.95	0.00	16725.95
107	21.00	1	0	21.00	0.00	21.00	17895.63	0.00	17895.63
107	22.00	1	0	22.02	0.00	22.02	19132.39	0.00	19132.39
107	23.00	1	0	23.02	0.00	23.02	20341.18	0.00	20341.18
107	24.00	1	0	24.00	0.00	24.00	21534.38	0.00	21534.38
107	25.00	1	0	25.02	0.00	25.02	22701.95	0.00	22701.95
107	26.00	1	0	26.03	0.00	26.03	23801.32	0.00	23801.32

Gross Head	Available Discharge	Unit#1 Status	Unit#2 Status	Unit#1 Discharge	Unit#2 Discharge	Discharge Used	Unit 1 Power	Unit 2 Power	Total Power
m	m^3/s			m^3/s	m^3/s	m^3/s	MW	MW	MW
107	27.00	1	0	27.01	0.00	27.01	24839.06	0.00	24839.06
107	28.00	1	0	28.01	0.00	28.01	25865.37	0.00	25865.37
107	29.00	1	0	29.00	0.00	29.00	26870.57	0.00	26870.57
107	30.00	1	0	30.00	0.00	30.00	27939.64	0.00	27939.64
107	31.00	1	0	31.00	0.00	31.00	29055.25	0.00	29055.25
107	32.00	1	0	32.04	0.00	32.04	30191.72	0.00	30191.72
107	33.00	1	0	33.03	0.00	33.03	31235.95	0.00	31235.95
107	34.00	1	0	34.00	0.00	34.00	32244.59	0.00	32244.59
107	35.00	1	0	35.00	0.00	35.00	33305.16	0.00	33305.16
107	36.00	1	0	36.00	0.00	36.00	34376.41	0.00	34376.41
107	37.00	1	0	37.00	0.00	37.00	35453.15	0.00	35453.15
107	38.00	1	0	38.01	0.00	38.01	36472.09	0.00	36472.09
107	39.00	1	0	39.00	0.00	39.00	37335.79	0.00	37335.79
107	40.00	1	0	40.00	0.00	40.00	38037.33	0.00	38037.33
107	41.00	1	0	41.00	0.00	41.00	38727.74	0.00	38727.74
107	42.00	1	0	42.00	0.00	42.00	39257.62	0.00	39257.62
107	43.00	1	0	43.00	0.00	43.00	39764.78	0.00	39764.78
107	44.00	1	1	29.02	15.00	44.02	26480.07	13957.62	40437.69
107	45.00	1	1	29.99	15.01	45.00	27506.21	14070.18	41576.39
107	46.00	1	1	31.00	15.00	46.00	28633.60	14153.88	42787.48
107	47.00	1	1	32.00	15.00	47.00	29687.10	14220.27	43907.36
107	48.00	1	1	33.04	15.00	48.04	30757.56	14267.78	45025.34

Gross Head	Available Discharge	Unit#1 Status	Unit#2 Status	Unit#1 Discharge	Unit#2 Discharge	Discharge Used	Unit 1 Power	Unit 2 Power	Total Power
m	m^3/s			m^3/s	m^3/s	m^3/s	MW	MW	MW
107	49.00	1	1	34.00	15.00	49.00	31746.59	14330.33	46076.92
107	50.00	1	1	35.00	15.00	50.00	32835.31	14418.49	47253.80
107	51.00	1	1	35.98	15.00	50.98	33850.27	14485.03	48335.30
107	52.00	1	1	37.00	15.00	52.00	34922.45	14561.51	49483.96
107	53.00	1	1	37.88	15.12	53.00	35785.82	14725.79	50511.61
107	54.00	1	1	38.05	15.95	54.00	35954.44	15529.90	51484.34
107	55.00	1	1	38.09	16.91	55.00	35993.15	16460.36	52453.51
107	56.00	1	1	38.07	17.94	56.01	35967.06	17460.28	53427.33
107	57.00	1	1	38.10	18.90	57.00	36003.15	18382.93	54386.09
107	58.00	1	1	38.18	19.82	58.00	36076.40	19253.29	55329.69
107	59.00	1	1	38.17	20.83	59.00	36065.65	20207.79	56273.45
107	60.00	1	1	38.14	21.86	60.00	36039.04	21180.31	57219.36
107	61.00	1	1	38.29	22.71	61.00	36172.52	21980.74	58153.26
107	62.00	1	1	38.18	23.82	62.00	36071.31	23020.47	59091.78
107	63.00	1	1	38.20	24.80	63.00	36090.78	23942.64	60033.42
107	64.00	1	1	38.52	25.48	64.00	36381.08	24570.69	60951.76
107	65.00	1	1	38.16	26.84	65.00	36052.00	25828.17	61880.17
107	66.00	1	1	38.41	27.59	66.00	36277.73	26535.50	62813.23
107	67.00	1	1	38.44	28.56	67.00	36308.67	27434.89	63743.56
107	68.00	1	1	38.18	29.82	68.00	36066.97	28617.00	64683.97
107	69.00	1	1	38.65	30.35	69.00	36496.12	29111.24	65607.36
107	70.00	1	1	38.55	31.45	70.00	36408.02	30112.26	66520.28

Gross Head	Available Discharge	Unit#1 Status	Unit#2 Status	Unit#1 Discharge	Unit#2 Discharge	Discharge Used	Unit 1 Power	Unit 2 Power	Total Power
m	m^3/s			m^3/s	m^3/s	m^3/s	MW	MW	MW
107	71.00	1	1	38.20	32.80	71.00	36087.30	31366.75	67454.05
107	72.00	1	1	38.54	33.46	72.00	36395.88	31985.75	68381.63
107	73.00	1	1	38.72	34.32	73.04	36561.28	32768.91	69330.19
107	74.00	1	1	38.80	35.26	74.06	36635.92	33615.43	70251.36
107	75.00	1	1	38.92	36.08	75.00	36740.47	34338.59	71079.07
107	76.00	1	1	38.77	37.23	76.00	36604.94	35345.62	71950.56
107	77.00	1	1	38.71	38.29	77.00	36554.31	36290.27	72844.58
107	78.00	1	1	38.71	39.29	78.00	36551.42	37193.36	73744.77
107	79.00	1	1	39.07	39.93	79.00	36869.85	37766.90	74636.75
107	80.00	1	1	39.86	40.14	80.00	37552.67	37887.01	75439.68
107	81.00	1	1	38.60	42.40	81.00	36448.58	39876.16	76324.74
107	82.00	1	1	39.55	42.45	82.00	37288.03	39900.48	77188.51
107	83.00	1	1	40.46	42.54	83.00	38018.56	39900.00	77918.56
107	84.00	1	1	41.36	42.64	84.00	38714.67	39903.15	78617.82
107	85.00	1	1	42.54	42.46	85.00	39686.15	39656.47	79342.62
107	86.00	1	1	42.78	42.73	85.51	39900.12	39900.34	79800.47
107	87.00	1	1	42.78	42.73	85.52	39900.00	39903.98	79803.98
107	88.00	1	1	44.01	43.95	87.96	39900.11	39900.11	79800.22
107	89.00	1	1	42.79	42.73	85.52	39901.91	39901.91	79803.82
107	90.00	1	1	44.01	43.95	87.95	39902.32	39902.51	79804.83
107	91.00	1	1	42.78	42.73	85.51	39900.00	39900.00	79800.00
107	92.00	1	1	42.79	42.74	85.54	39908.24	39910.33	79818.57

Gross Head	Available Discharge	Unit#1 Status	Unit#2 Status	Unit#1 Discharge	Unit#2 Discharge	Discharge Used	Unit 1 Power	Unit 2 Power	Total Power
m	m^3/s			m^3/s	m^3/s	m^3/s	MW	MW	MW
107	93.00	1	1	44.00	43.94	87.95	39908.62	39908.88	79817.50
107	94.00	1	1	42.77	42.72	85.49	39888.44	39893.14	79781.58
107	95.00	1	0	42.51	0.00	42.51	39402.61	0.00	39402.61
107	96.00	1	1	42.78	42.73	85.51	39900.00	39900.00	79800.00
107	97.00	1	1	42.79	42.73	85.52	39901.58	39901.01	79802.59
107	98.00	1	1	42.80	42.75	85.55	39916.71	39916.72	79833.43
107	99.00	1	1	42.80	42.75	85.55	39914.31	39914.34	79828.65
107	100.00	1	1	42.78	42.73	85.51	39900.20	39900.65	79800.85
107.5	0.00	0	0	0.00	0.00	0.00	0.00	0.00	0.00
107.5	16.00	1	0	16.01	0.00	16.01	12089.11	0.00	12089.11
107.5	17.00	1	0	17.00	0.00	17.00	13261.06	0.00	13261.06
107.5	18.00	1	0	18.00	0.00	18.00	14429.85	0.00	14429.85
107.5	19.00	1	0	19.00	0.00	19.00	15565.55	0.00	15565.55
107.5	20.00	1	0	20.02	0.00	20.02	16783.69	0.00	16783.69
107.5	21.00	1	0	21.00	0.00	21.00	17943.94	0.00	17943.94
107.5	22.00	1	0	22.00	0.00	22.00	19147.30	0.00	19147.30
107.5	23.00	1	0	23.00	0.00	23.00	20373.56	0.00	20373.56
107.5	24.00	1	0	24.00	0.00	24.00	21582.87	0.00	21582.87
107.5	25.00	1	0	25.00	0.00	25.00	22743.32	0.00	22743.32
107.5	26.00	1	0	26.00	0.00	26.00	23831.10	0.00	23831.10
107.5	27.00	1	0	27.05	0.00	27.05	24934.91	0.00	24934.91
107.5	28.00	1	0	28.00	0.00	28.00	25912.90	0.00	25912.90

Gross Head	Available Discharge	Unit#1 Status	Unit#2 Status	Unit#1 Discharge	Unit#2 Discharge	Discharge Used	Unit 1 Power	Unit 2 Power	Total Power
m	m^3/s			m^3/s	m^3/s	m^3/s	MW	MW	MW
107.5	29.00	1	0	29.00	0.00	29.00	26927.92	0.00	26927.92
107.5	30.00	1	0	30.00	0.00	30.00	28006.84	0.00	28006.84
107.5	31.00	1	0	31.01	0.00	31.01	29147.10	0.00	29147.10
107.5	32.00	1	0	32.00	0.00	32.00	30249.87	0.00	30249.87
107.5	33.00	1	0	33.00	0.00	33.00	31321.99	0.00	31321.99
107.5	34.00	1	0	34.00	0.00	34.00	32359.76	0.00	32359.76
107.5	35.00	1	0	35.01	0.00	35.01	33439.80	0.00	33439.80
107.5	36.00	1	0	36.00	0.00	36.00	34515.97	0.00	34515.97
107.5	37.00	1	0	37.01	0.00	37.01	35594.64	0.00	35594.64
107.5	38.00	1	0	38.00	0.00	38.00	36607.80	0.00	36607.80
107.5	39.00	1	0	39.02	0.00	39.02	37525.75	0.00	37525.75
107.5	40.00	1	0	40.00	0.00	40.00	38165.00	0.00	38165.00
107.5	41.00	1	0	41.01	0.00	41.01	38853.24	0.00	38853.24
107.5	42.00	1	0	42.00	0.00	42.00	39528.53	0.00	39528.53
107.5	43.00	1	0	42.64	0.00	42.64	39907.92	0.00	39907.92
107.5	44.00	1	1	29.00	15.00	44.00	26528.34	13988.82	40517.16
107.5	45.00	1	1	30.00	15.00	45.00	27558.29	14087.97	41646.26
107.5	46.00	1	0	45.89	0.00	45.89	39900.00	0.00	39900.00
107.5	47.00	1	1	32.00	15.00	47.00	29746.38	14250.67	43997.05
107.5	48.00	1	1	33.00	15.00	48.00	30784.14	14296.76	45080.90
107.5	49.00	1	1	34.01	15.00	49.01	31836.05	14361.77	46197.82
107.5	50.00	1	1	35.00	15.01	50.01	32899.03	14451.57	47350.59

Gross Head	Available Discharge	Unit#1 Status	Unit#2 Status	Unit#1 Discharge	Unit#2 Discharge	Discharge Used	Unit 1 Power	Unit 2 Power	Total Power
m	m^3/s			m^3/s	m^3/s	m^3/s	MW	MW	MW
107.5	51.00	1	1	36.00	15.00	51.00	34010.26	14542.08	48552.34
107.5	52.00	1	1	37.00	15.00	52.01	35091.92	14628.52	49720.43
107.5	53.00	1	1	37.90	15.10	53.00	35993.49	14779.59	50773.07
107.5	54.00	1	1	37.96	16.04	54.00	36056.45	15694.24	51750.70
107.5	55.00	1	1	37.98	17.02	55.00	36071.48	16654.13	52725.61
107.5	56.00	1	1	37.99	18.01	56.00	36087.30	17612.58	53699.88
107.5	57.00	1	1	38.00	19.00	57.00	36094.20	18574.48	54668.69
107.5	58.00	1	1	38.01	19.99	58.00	36101.29	19513.41	55614.70
107.5	59.00	1	1	38.00	21.00	59.00	36089.49	20474.89	56564.38
107.5	60.00	1	1	38.01	21.99	60.00	36101.96	21414.08	57516.04
107.5	61.00	1	1	38.01	22.99	61.00	36105.79	22346.45	58452.25
107.5	62.00	1	1	38.01	23.99	62.00	36103.55	23294.89	59398.44
107.5	63.00	1	1	38.01	24.99	63.00	36103.19	24242.44	60345.63
107.5	64.00	1	1	38.01	25.99	64.00	36107.28	25145.99	61253.26
107.5	65.00	1	1	38.01	26.99	65.00	36103.38	26100.43	62203.81
107.5	66.00	1	1	38.02	27.98	66.00	36108.33	27030.36	63138.69
107.5	67.00	1	1	38.01	28.99	67.00	36104.94	27970.45	64075.39
107.5	68.00	1	1	38.02	29.98	68.00	36108.52	28914.72	65023.23
107.5	69.00	1	1	38.02	30.98	69.00	36113.26	29825.49	65938.75
107.5	70.00	1	1	38.01	31.99	70.00	36100.82	30760.86	66861.68
107.5	71.00	1	1	38.02	33.02	71.03	36109.12	31731.31	67840.43
107.5	72.00	1	1	38.01	33.95	71.96	36108.39	32590.73	68699.12

Gross Head	Available Discharge	Unit#1 Status	Unit#2 Status	Unit#1 Discharge	Unit#2 Discharge	Discharge Used	Unit 1 Power	Unit 2 Power	Total Power
m	m^3/s			m^3/s	m^3/s	m^3/s	MW	MW	MW
107.5	73.00	1	1	38.04	34.96	73.00	36130.39	33511.78	69642.17
107.5	74.00	1	1	38.03	35.97	74.00	36119.02	34417.22	70536.24
107.5	75.00	1	1	38.03	36.97	75.00	36120.16	35289.81	71409.97
107.5	76.00	1	1	38.02	37.98	76.00	36113.57	36193.06	72306.63
107.5	77.00	1	1	38.02	38.98	77.00	36111.88	37099.90	73211.78
107.5	78.00	1	1	38.02	39.98	78.00	36112.51	38004.76	74117.27
107.5	79.00	1	1	38.05	40.95	79.00	36140.46	38718.02	74858.48
107.5	80.00	1	1	38.01	41.99	80.00	36104.24	39690.97	75795.21
107.5	81.00	1	1	43.16	37.84	81.00	39900.40	35327.77	75228.17
107.5	82.00	1	1	39.62	42.38	82.00	37413.76	39900.10	77313.86
107.5	83.00	1	1	40.55	42.45	83.00	38193.71	39900.51	78094.22
107.5	84.00	1	1	41.39	42.61	84.00	38769.83	39899.88	78669.71
107.5	85.00	1	1	42.14	42.86	85.00	39206.35	39910.97	79117.31
107.5	86.00	1	1	43.15	42.85	86.00	39898.88	39668.89	79567.78
107.5	87.00	1	1	43.16	43.09	86.25	39900.00	39900.00	79800.00
107.5	88.00	1	1	43.16	43.10	86.26	39906.08	39906.06	79812.14
107.5	89.00	1	1	43.16	43.10	86.26	39907.70	39906.96	79814.65
107.5	90.00	1	1	43.16	43.09	86.25	39900.00	39900.00	79800.00
107.5	91.00	1	1	43.16	43.10	86.25	39900.00	39900.92	79800.92
107.5	92.00	1	1	45.71	45.65	91.36	39900.69	39900.58	79801.27
107.5	93.00	1	1	43.16	43.10	86.26	39907.81	39906.40	79814.21
107.5	94.00	1	1	43.16	43.10	86.26	39904.83	39904.46	79809.29

Gross Head	Available Discharge	Unit#1 Status	Unit#2 Status	Unit#1 Discharge	Unit#2 Discharge	Discharge Used	Unit 1 Power	Unit 2 Power	Total Power
m	m^3/s			m^3/s	m^3/s	m^3/s	MW	MW	MW
107.5	95.00	1	1	43.16	43.10	86.25	39902.35	39902.33	79804.68
107.5	96.00	1	1	43.19	43.12	86.31	39938.51	39933.77	79872.28
107.5	97.00	1	1	45.70	45.63	91.33	39917.53	39914.90	79832.43
107.5	98.00	1	1	43.16	43.10	86.25	39900.00	39903.31	79803.31
107.5	99.00	1	1	43.17	43.10	86.27	39913.48	39911.91	79825.40
107.5	100.00	1	1	43.16	43.09	86.25	39900.00	39900.00	79800.00
108	0.00	0	0	0.00	0.00	0.00	0.00	0.00	0.00
108	16.00	1	0	16.00	0.00	16.00	12104.00	0.00	12104.00
108	17.00	1	0	17.00	0.00	17.00	13297.70	0.00	13297.70
108	18.00	1	0	18.00	0.00	18.00	14460.91	0.00	14460.91
108	19.00	1	0	19.00	0.00	19.00	15615.07	0.00	15615.07
108	20.00	1	0	20.00	0.00	20.00	16817.02	0.00	16817.02
108	21.00	1	0	21.00	0.00	21.00	17996.40	0.00	17996.40
108	22.00	1	0	22.00	0.00	22.00	19180.57	0.00	19180.57
108	23.00	1	0	23.01	0.00	23.01	20435.89	0.00	20435.89
108	24.00	1	0	24.02	0.00	24.02	21659.30	0.00	21659.30
108	25.00	1	0	25.00	0.00	25.00	22809.01	0.00	22809.01
108	26.00	1	0	26.01	0.00	26.01	23912.35	0.00	23912.35
108	27.00	1	0	27.00	0.00	27.00	24970.26	0.00	24970.26
108	28.00	1	0	28.00	0.00	28.00	25990.59	0.00	25990.59
108	29.00	1	0	29.00	0.00	29.00	26980.84	0.00	26980.84
108	30.00	1	0	30.00	0.00	30.00	28063.03	0.00	28063.03

Gross Head	Available Discharge	Unit#1 Status	Unit#2 Status	Unit#1 Discharge	Unit#2 Discharge	Discharge Used	Unit 1 Power	Unit 2 Power	Total Power
m	m^3/s			m^3/s	m^3/s	m^3/s	MW	MW	MW
108	31.00	1	0	31.00	0.00	31.00	29223.74	0.00	29223.74
108	32.00	1	0	32.02	0.00	32.02	30362.14	0.00	30362.14
108	33.00	1	0	33.02	0.00	33.02	31444.69	0.00	31444.69
108	34.00	1	0	34.00	0.00	34.00	32465.63	0.00	32465.63
108	35.00	1	0	35.01	0.00	35.01	33561.76	0.00	33561.76
108	36.00	1	0	36.00	0.00	36.00	34635.75	0.00	34635.75
108	37.00	1	0	37.00	0.00	37.00	35707.48	0.00	35707.48
108	38.00	1	0	38.00	0.00	38.00	36728.00	0.00	36728.00
108	39.00	1	0	39.00	0.00	39.00	37643.70	0.00	37643.70
108	40.00	1	0	40.00	0.00	40.00	38300.97	0.00	38300.97
108	41.00	1	0	41.00	0.00	41.00	38930.92	0.00	38930.92
108	42.00	1	0	42.00	0.00	42.00	39582.66	0.00	39582.66
108	43.00	1	0	42.48	0.00	42.48	39908.43	0.00	39908.43
108	44.00	1	1	29.00	15.00	44.00	26614.25	14032.88	40647.13
108	45.00	1	1	30.01	15.00	45.01	27641.04	14125.10	41766.14
108	46.00	1	1	31.05	15.00	46.05	28811.87	14217.26	43029.13
108	47.00	1	0	42.47	0.00	42.47	39901.48	0.00	39901.48
108	48.00	1	0	46.27	0.00	46.27	39900.00	0.00	39900.00
108	49.00	1	1	34.00	15.00	49.00	31951.85	14415.25	46367.10
108	50.00	1	1	35.00	15.00	50.00	33014.94	14496.04	47510.97
108	51.00	1	1	36.03	15.00	51.03	34168.90	14598.71	48767.61
108	52.00	1	1	37.02	15.00	52.03	35257.71	14690.57	49948.28

Gross Head	Available Discharge	Unit#1 Status	Unit#2 Status	Unit#1 Discharge	Unit#2 Discharge	Discharge Used	Unit 1 Power	Unit 2 Power	Total Power
m	m^3/s			m^3/s	m^3/s	m^3/s	MW	MW	MW
108	53.00	1	1	37.83	15.16	52.99	36079.16	14892.87	50972.03
108	54.00	1	1	37.98	16.02	54.00	36229.20	15738.07	51967.27
108	55.00	1	1	37.99	17.01	55.00	36236.53	16708.82	52945.35
108	56.00	1	1	37.99	18.01	56.00	36237.62	17689.28	53926.89
108	57.00	1	1	38.01	18.99	57.00	36256.92	18638.29	54895.21
108	58.00	1	1	38.03	19.97	58.00	36270.42	19574.89	55845.31
108	59.00	1	1	38.02	20.98	59.00	36263.56	20534.98	56798.54
108	60.00	1	1	38.03	21.97	60.00	36274.40	21479.26	57753.66
108	61.00	1	1	38.05	22.95	61.00	36286.75	22407.14	58693.90
108	62.00	1	1	38.04	23.99	62.02	36277.38	23387.51	59664.89
108	63.00	1	1	38.04	24.96	63.00	36276.97	24317.08	60594.05
108	64.00	1	1	38.09	25.91	64.00	36322.36	25184.17	61506.53
108	65.00	1	1	38.02	26.98	65.00	36260.30	26198.84	62459.14
108	66.00	1	1	38.04	27.97	66.01	36282.02	27123.10	63405.12
108	67.00	1	1	38.03	28.97	67.00	36272.72	28065.57	64338.29
108	68.00	1	1	38.02	30.00	68.02	36257.99	29046.92	65304.91
108	69.00	1	1	38.05	30.95	69.00	36287.05	29922.43	66209.48
108	70.00	1	1	38.06	31.94	70.00	36300.44	30835.20	67135.65
108	71.00	1	1	38.03	32.97	71.00	36272.43	31814.12	68086.55
108	72.00	1	1	38.04	33.96	72.00	36283.11	32732.17	69015.28
108	73.00	1	1	38.05	34.95	73.00	36288.71	33639.39	69928.09
108	74.00	1	1	38.06	35.94	74.01	36301.21	34529.83	70831.04

Gross Head	Available Discharge	Unit#1 Status	Unit#2 Status	Unit#1 Discharge	Unit#2 Discharge	Discharge Used	Unit 1 Power	Unit 2 Power	Total Power
m	m^3/s			m^3/s	m^3/s	m^3/s	MW	MW	MW
108	75.00	1	1	38.07	36.93	75.00	36309.35	35394.15	71703.50
108	76.00	1	1	38.05	37.95	76.00	36290.69	36312.10	72602.79
108	77.00	1	1	38.05	38.95	77.00	36287.72	37223.50	73511.22
108	78.00	1	1	38.05	39.95	78.00	36285.23	38135.05	74420.29
108	79.00	1	1	38.55	40.45	79.00	36710.99	38475.72	75186.72
108	80.00	1	1	38.04	41.96	80.00	36279.17	39825.14	76104.32
108	81.00	1	1	38.87	42.13	81.00	36970.07	39918.37	76888.44
108	82.00	1	1	39.82	42.17	81.98	37757.53	39871.26	77628.79
108	83.00	1	1	40.71	42.29	83.00	38464.54	39900.82	78365.36
108	84.00	1	1	41.54	42.46	84.00	39040.88	39901.32	78942.21
108	85.00	1	1	42.38	42.62	85.00	39634.27	39901.60	79535.87
108	86.00	1	1	42.68	42.63	85.31	39900.02	39901.59	79801.61
108	87.00	1	1	42.68	42.63	85.31	39901.02	39900.91	79801.94
108	88.00	1	1	42.68	42.63	85.31	39900.13	39901.50	79801.63
108	89.00	1	1	42.69	42.64	85.32	39907.59	39906.94	79814.53
108	90.00	1	1	42.70	42.65	85.35	39920.60	39918.70	79839.29
108	91.00	1	1	42.68	42.63	85.31	39900.21	39902.04	79802.25
108	92.00	1	1	42.68	42.63	85.31	39900.04	39900.14	79800.18
108	93.00	1	1	46.28	46.22	92.50	39900.06	39900.07	79800.13
108	94.00	1	1	42.68	42.63	85.31	39900.00	39900.00	79800.00
108	95.00	1	1	46.27	46.19	92.46	39914.48	39900.00	79814.48
108	96.00	1	1	42.67	42.63	85.30	39895.07	39899.84	79794.91

Gross Head	Available Discharge	Unit#1 Status	Unit#2 Status	Unit#1 Discharge	Unit#2 Discharge	Discharge Used	Unit 1 Power	Unit 2 Power	Total Power
m	m^3/s			m^3/s	m^3/s	m^3/s	MW	MW	MW
108	97.00	1	1	42.75	42.67	85.42	39966.19	39938.40	79904.60
108	98.00	1	1	42.69	42.64	85.34	39914.26	39911.87	79826.13
108	99.00	1	1	42.75	42.67	85.43	39969.02	39941.03	79910.05
108	100.00	1	1	42.75	42.67	85.42	39967.83	39939.19	79907.02

APPENDIX 9: OPTIMIZATION OF HISTORICAL DATA

Table A9.1: Hourly summary of Primal optimization and Dual optimization for November 14, 2016

November 14, 2016								
Time	Actual Historical Data				Primal Optimization		Dual Optimization	
	Hourly Discharge	Cumulative Hourly Discharge	Hourly Generation	Cumulative Hourly Generation	Optimal Hourly Generation	Cumulative Optimal Hourly Generation	Optimal Discharge	Cumulative Optimal Discharge
hour	cubic meter	cubic meter	MWh	MWh	MWh	MWh	cubic meter	cubic meter
1:00:00	255,100.00	255,100.00	63.73	63.73	67.10	67.10	241,969.11	241,969.11
2:00:00	251,252.00	506,352.00	62.68	126.41	66.11	133.21	237,924.53	479,893.64
3:00:00	250,627.20	756,979.20	62.46	188.86	65.95	199.16	237,069.27	716,962.90
4:00:00	252,646.50	1,009,625.70	62.92	251.79	66.47	265.62	238,868.46	955,831.36
5:00:00	256,674.78	1,266,300.48	63.93	315.72	67.56	333.18	242,473.58	1,198,304.94
6:00:00	262,041.16	1,528,341.64	65.31	381.02	68.81	402.00	248,262.18	1,446,567.12
7:00:00	243,278.56	1,771,620.20	60.27	441.29	63.86	465.86	229,332.61	1,675,899.73
8:00:00	245,177.72	2,016,797.92	60.64	501.93	64.29	530.15	231,025.85	1,906,925.59
9:00:00	246,007.09	2,262,805.01	60.73	562.66	64.29	594.44	232,075.93	2,139,001.52
10:00:00	183,693.50	2,446,498.51	44.22	606.89	48.23	642.67	169,404.26	2,308,405.78
11:00:00	111,776.81	2,558,275.33	28.57	635.46	28.71	671.37	111,265.69	2,419,671.47
12:00:00	108,227.34	2,666,502.67	27.84	663.30	27.80	699.17	108,361.75	2,528,033.22
13:00:00	104,193.19	2,770,695.86	26.74	690.04	26.66	725.83	104,451.86	2,632,485.08
14:00:00	127,054.78	2,897,750.64	33.65	723.68	33.36	759.18	128,023.43	2,760,508.51
15:00:00	131,043.53	3,028,794.17	34.94	758.63	34.57	793.75	132,390.75	2,892,899.26
16:00:00	145,066.69	3,173,860.86	38.32	796.94	38.24	832.00	145,602.48	3,038,501.74
17:00:00	205,683.34	3,379,544.20	51.20	848.14	54.26	886.26	194,611.13	3,233,112.88

November 14, 2016								
Time	Actual Historical Data				Primal Optimization		Dual Optimization	
	Hourly Discharge	**Cumulative Hourly Discharge**	**Hourly Generation**	**Cumulative Hourly Generation**	**Optimal Hourly Generation**	**Cumulative Optimal Hourly Generation**	**Optimal Discharge**	**Cumulative Optimal Discharge**
hour	**cubic meter**	**cubic meter**	**MWh**	**MWh**	**MWh**	**MWh**	**cubic meter**	**cubic meter**
18:00:00	254,430.13	3,633,974.33	63.83	911.97	66.72	952.98	242,806.00	3,475,918.88
19:00:00	275,035.59	3,909,009.92	69.36	981.33	72.07	1,025.04	264,228.12	3,740,147.00
20:00:00	277,921.75	4,186,931.67	69.53	1,050.86	72.63	1,097.68	265,205.02	4,005,352.02
21:00:00	266,936.66	4,453,868.33	67.23	1,118.08	70.14	1,167.81	255,354.88	4,260,706.90
22:00:00	256,890.28	4,710,758.61	64.47	1,182.56	67.61	1,235.42	244,287.12	4,504,994.03
23:00:00	219,929.88	4,930,688.48	54.82	1,237.38	58.31	1,293.74	206,501.94	4,711,495.97
24:00:00	211,552.88	5,142,241.36	52.66	1,290.04	56.12	1,349.85	198,333.24	4,909,829.21
Gain/saving					**59.82**		**232,412.15**	
Gain/saving %					**4.64%**		**4.52%**	

Table A9.2: Hourly summary of Primal optimization and Dual optimization for November 15, 2016

November 15, 2016								
Time	**Actual Historical Data**				**Primal Optimization**		**Dual Optimization**	
	Hourly Discharge	**Cumulative Hourly Discharge**	**Hourly Generation**	**Cumulative Hourly Generation**	**Optimal Hourly Generation**	**Cumulative Optimal Hourly Generation**	**Optimal Discharge**	**Cumulative Optimal Discharge**
hour	**cubic meter**	**cubic meter**	**MWh**	**MWh**	**MWh**	**MWh**	**cubic meter**	**cubic meter**
1:00:00	214,966.91	214,966.91	53.49	53.49	57.01	57.01	201,533.94	201,533.94
2:00:00	207,403.44	422,370.34	51.47	104.96	55.00	112.01	194,101.01	395,634.95
3:00:00	210,987.50	633,357.84	52.51	157.47	55.89	167.90	198,173.67	593,808.62
4:00:00	220,195.84	853,553.69	55.05	212.51	58.24	226.13	208,047.32	801,855.94
5:00:00	239,940.72	1,093,494.41	60.38	272.89	63.36	289.49	228,477.63	1,030,333.58
6:00:00	256,932.81	1,350,427.22	64.81	337.70	67.73	357.22	245,443.78	1,275,777.35
7:00:00	255,251.00	1,605,678.22	64.31	402.01	67.40	424.62	243,150.10	1,518,927.45
8:00:00	225,178.47	1,830,856.69	56.21	458.22	59.71	484.33	211,705.56	1,730,633.00
9:00:00	220,166.94	2,051,023.63	54.85	513.07	58.42	542.75	206,437.68	1,937,070.69
10:00:00	220,726.38	2,271,750.00	54.96	568.04	58.56	601.31	206,885.20	2,143,955.89
11:00:00	232,543.63	2,504,293.63	58.14	626.18	61.61	662.91	219,155.19	2,363,111.08
12:00:00	196,514.63	2,700,808.25	48.46	674.63	52.22	715.13	183,354.70	2,546,465.78
13:00:00	145,027.22	2,845,835.47	37.92	712.56	38.17	753.30	145,206.86	2,691,672.63
14:00:00	127,994.94	2,973,830.41	34.06	746.62	33.80	787.10	129,423.13	2,821,095.77
15:00:00	125,633.78	3,099,464.19	33.41	780.03	33.17	820.27	126,757.88	2,947,853.65
16:00:00	132,365.69	3,231,829.88	35.56	815.58	35.01	855.28	134,650.92	3,082,504.57
17:00:00	183,780.41	3,415,610.28	46.51	862.10	48.53	903.81	176,276.82	3,258,781.39
18:00:00	254,773.41	3,670,383.69	63.90	926.00	67.02	970.84	242,332.58	3,501,113.98
19:00:00	281,897.75	3,952,281.44	71.00	996.99	73.89	1,044.73	270,454.33	3,771,568.31
20:00:00	271,455.53	4,223,736.97	68.67	1,065.66	71.24	1,115.97	261,436.46	4,033,004.76
21:00:00	262,527.13	4,486,264.09	66.35	1,132.01	68.92	1,184.89	252,429.15	4,285,433.91
22:00:00	259,510.94	4,745,775.03	65.51	1,197.52	68.24	1,253.13	248,870.71	4,534,304.62

November 15, 2016								
Time	Actual Historical Data				Primal Optimization		Dual Optimization	
	Hourly Discharge	Cumulative Hourly Discharge	Hourly Generation	Cumulative Hourly Generation	Optimal Hourly Generation	Cumulative Optimal Hourly Generation	Optimal Discharge	Cumulative Optimal Discharge
hour	cubic meter	cubic meter	MWh	MWh	MWh	MWh	cubic meter	cubic meter
23:00:00	256,703.44	5,002,478.47	64.72	1,262.24	67.63	1,320.75	245,398.06	4,779,702.68
24:00:00	246,619.69	5,249,098.16	62.00	1,324.24	65.12	1,385.88	234,551.98	5,014,254.66
Gain/saving					61.63		234,843.50	
Gain/saving %					4.65%		4.47%	

Table A9.3: Hourly summary of Primal optimization and Dual optimization for November 24, 2016

November 24, 2016								
Time	**Actual Historical Data**				**Primal Optimization**		**Dual Optimization**	
	Hourly Discharge	**Cumulative Hourly Discharge**	**Hourly Generation**	**Cumulative Hourly Generation**	**Optimal Hourly Generation**	**Cumulative Optimal Hourly Generation**	**Optimal Discharge**	**Cumulative Optimal Discharge**
hour	**cubic meter**	**cubic meter**	**MWh**	**MWh**	**MWh**	**MWh**	**cubic meter**	**cubic meter**
1:00:00	176,631.88	176,631.88	43.03	43.03	46.07	46.07	166,297.65	166,297.65
2:00:00	202,738.34	379,370.22	50.20	93.23	53.34	99.41	190,835.03	357,132.68
3:00:00	214,379.94	593,750.16	53.54	146.77	56.57	155.98	202,827.34	559,960.03
4:00:00	215,838.38	809,588.53	53.91	200.68	56.94	212.92	204,267.71	764,227.74
5:00:00	249,958.13	1,059,546.66	63.00	263.67	65.72	278.64	239,582.73	1,003,810.47
6:00:00	254,622.66	1,314,169.31	64.17	327.84	66.99	345.63	243,711.66	1,247,522.13
7:00:00	217,712.81	1,531,882.13	54.26	382.10	57.60	403.23	204,970.83	1,452,492.96
8:00:00	190,735.28	1,722,617.41	46.90	429.00	50.30	453.53	179,240.05	1,631,733.00
9:00:00	200,332.41	1,922,949.81	49.42	478.42	52.82	506.35	188,270.68	1,820,003.68
10:00:00	261,318.91	2,184,268.72	65.75	544.17	68.85	575.20	249,072.75	2,069,076.43
11:00:00	243,714.25	2,427,982.97	61.00	605.17	64.48	639.68	230,214.54	2,299,290.97
12:00:00	213,225.63	2,641,208.59	52.83	658.01	56.64	696.32	198,759.23	2,498,050.20
13:00:00	211,708.09	2,852,916.69	52.39	710.40	56.23	752.54	197,232.39	2,695,282.59
14:00:00	102,773.56	2,955,690.25	25.38	735.77	26.12	778.67	100,276.06	2,795,558.65
15:00:00	78,226.38	3,033,916.63	18.46	754.23	18.70	797.36	77,571.57	2,873,130.23
16:00:00	77,383.44	3,111,300.06	18.23	772.46	18.45	815.81	76,729.64	2,949,859.86
17:00:00	99,367.69	3,210,667.75	25.11	797.57	25.45	841.25	98,343.46	3,048,203.32

November 24, 2016								
Time	Actual Historical Data				Primal Optimization		Dual Optimization	
	Hourly Discharge	Cumulative Hourly Discharge	Hourly Generation	Cumulative Hourly Generation	Optimal Hourly Generation	Cumulative Optimal Hourly Generation	Optimal Discharge	Cumulative Optimal Discharge
hour	cubic meter	cubic meter	MWh	MWh	MWh	MWh	cubic meter	cubic meter
18:00:00	205,148.63	3,415,816.38	51.48	849.05	53.86	895.11	196,120.07	3,244,323.39
19:00:00	254,620.25	3,670,436.63	64.48	913.53	67.12	962.24	244,446.62	3,488,770.01
20:00:00	229,159.88	3,899,596.50	57.58	971.10	60.42	1,022.66	218,347.77	3,707,117.78
21:00:00	208,688.59	4,108,285.09	52.03	1,023.14	55.09	1,077.75	197,196.54	3,904,314.33
22:00:00	212,324.47	4,320,609.56	52.97	1,076.11	56.02	1,133.77	200,757.50	4,105,071.83
23:00:00	217,820.75	4,538,430.31	54.42	1,130.53	57.44	1,191.21	206,280.15	4,311,351.98
24:00:00	169,663.63	4,708,093.94	43.02	1,173.56	44.81	1,236.01	163,045.81	4,474,397.79
Gain/saving					**62.46**		**233,696.14**	
Gain/saving %					**5.32%**		**4.96%**	

Table A9.4: Hourly summary of Primal optimization and Dual optimization for December 01, 2016

December 01, 2016								
Time	Actual Historical Data				Primal Optimization		Dual Optimization	
	Hourly Discharge	Cumulative Hourly Discharge	Hourly Generation	Cumulative Hourly Generation	Optimal Hourly Generation	Cumulative Optimal Hourly Generation	Optimal Discharge	Cumulative Optimal Discharge
hour	cubic meter	cubic meter	MWh	MWh	MWh	MWh	cubic meter	cubic meter
1:00:00	203,685.69	203,685.69	50.75	50.75	53.97	53.97	191,743.71	191,743.71
2:00:00	204,393.84	408,079.53	50.91	101.66	54.13	108.11	192,429.97	384,173.68
3:00:00	193,337.22	601,416.75	47.93	149.59	51.10	159.20	182,477.70	566,651.39
4:00:00	206,032.66	807,449.41	51.34	200.92	54.52	213.72	194,282.27	760,933.66
5:00:00	235,431.00	1,042,880.41	59.20	260.12	62.12	275.84	224,217.22	985,150.88
6:00:00	253,089.59	1,295,970.00	63.49	323.60	66.50	342.34	241,306.98	1,226,457.87
7:00:00	233,859.34	1,529,829.34	58.58	382.18	61.51	403.85	222,240.00	1,448,697.87
8:00:00	197,612.19	1,727,441.53	48.79	430.97	52.16	456.01	185,499.30	1,634,197.17
9:00:00	117,012.25	1,844,453.78	30.08	461.05	35.13	491.14	116,246.42	1,750,443.59
10:00:00	100,380.13	1,944,833.91	25.90	486.95	33.48	524.62	101,098.52	1,851,542.10
11:00:00	116,906.09	2,061,740.00	30.93	517.88	33.60	558.22	118,040.49	1,969,582.59
12:00:00	141,327.34	2,203,067.34	36.15	554.03	38.31	596.54	137,470.14	2,107,052.73
13:00:00	209,355.03	2,412,422.38	52.33	606.36	55.49	652.02	197,535.37	2,304,588.10
14:00:00	201,073.84	2,613,496.22	50.02	656.38	53.25	705.28	189,304.30	2,493,892.40
15:00:00	187,949.06	2,801,445.28	46.39	702.77	49.55	754.83	177,496.31	2,671,388.72
16:00:00	207,610.59	3,009,055.88	51.64	754.41	54.83	809.65	195,653.24	2,867,041.95
17:00:00	219,191.06	3,228,246.94	54.90	809.31	58.29	867.95	208,371.20	3,075,413.16

December 01, 2016								
Time	**Actual Historical Data**				**Primal Optimization**		**Dual Optimization**	
	Hourly Discharge	**Cumulative Hourly Discharge**	**Hourly Generation**	**Cumulative Hourly Generation**	**Optimal Hourly Generation**	**Cumulative Optimal Hourly Generation**	**Optimal Discharge**	**Cumulative Optimal Discharge**
hour	**cubic meter**	**cubic meter**	**MWh**	**MWh**	**MWh**	**MWh**	**cubic meter**	**cubic meter**
18:00:00	104,561.38	3,332,808.31	26.99	836.30	33.48	901.43	105,268.92	3,180,682.07
19:00:00	120,590.97	3,453,399.28	32.08	868.38	33.48	934.91	121,802.23	3,302,484.30
20:00:00	120,825.34	3,574,224.63	32.20	900.58	33.48	968.39	122,071.97	3,424,556.27
21:00:00	165,223.47	3,739,448.09	41.67	942.25	44.57	1,012.96	157,768.03	3,582,324.31
22:00:00	239,385.44	3,978,833.53	60.31	1,002.57	63.34	1,076.30	227,781.47	3,810,105.78
23:00:00	222,936.38	4,201,769.91	55.94	1,058.51	59.01	1,135.32	211,275.96	4,021,381.74
24:00:00	208,985.06	4,410,754.97	52.20	1,110.71	55.33	1,190.64	197,178.70	4,218,560.43
Gain/saving					**79.93**		**192,194.53**	
Gain/saving %					**7.20%**		**4.36%**	

Table A9.5: Hourly summary of Primal optimization and Dual optimization for December 17, 2016

December 17, 2016								
Time	**Hourly Discharge**	**Cumulative Hourly Discharge**	**Hourly Generation**	**Cumulative Hourly Generation**	**Optimal Hourly Generation**	**Cumulative Optimal Hourly Generation**	**Optimal Discharge**	**Cumulative Optimal Discharge**
hour	**cubic meter**	**cubic meter**	**MWh**	**MWh**	**MWh**	**MWh**	**cubic meter**	**cubic meter**
1:00:00	135,976.06	135,976.06	35.20	35.20	35.77	35.77	133,877.14	133,877.14
2:00:00	233,498.34	369,474.41	57.76	92.96	61.83	97.60	217,901.23	351,778.37
3:00:00	260,580.06	630,054.47	64.66	157.62	68.60	166.20	244,392.63	596,171.00
4:00:00	181,486.34	811,540.81	45.88	203.50	47.80	214.00	174,080.17	770,251.17
5:00:00	111,378.28	922,919.09	28.85	232.35	28.74	242.74	111,850.87	882,102.04
6:00:00	116,275.53	1,039,194.63	30.35	262.70	30.26	273.00	117,056.50	999,158.54
7:00:00	127,261.03	1,166,455.66	33.66	296.36	33.51	306.51	128,546.64	1,127,705.17
8:00:00	114,414.44	1,280,870.09	29.84	326.20	29.63	336.14	115,425.78	1,243,130.95
9:00:00	100,800.09	1,381,670.19	25.84	352.03	25.73	361.86	101,251.29	1,344,382.24
10:00:00	103,520.16	1,485,190.34	26.69	378.73	26.63	388.49	103,995.09	1,448,377.34
11:00:00	107,506.16	1,592,696.50	27.92	406.65	27.83	416.33	108,088.81	1,556,466.15
12:00:00	187,363.66	1,780,060.16	46.23	452.87	49.34	465.67	175,708.77	1,732,174.92
13:00:00	253,921.78	2,033,981.94	63.21	516.09	66.97	532.64	239,333.57	1,971,508.50
14:00:00	200,516.94	2,234,498.88	49.18	565.27	53.28	585.91	185,471.68	2,156,980.18
15:00:00	204,531.22	2,439,030.09	50.15	615.42	54.31	640.23	189,227.22	2,346,207.40
16:00:00	150,225.63	2,589,255.72	38.87	654.29	39.53	679.75	148,168.96	2,494,376.36
17:00:00	130,709.56	2,719,965.28	34.68	688.97	34.45	714.20	132,269.07	2,626,645.43
18:00:00	211,779.94	2,931,745.22	52.28	741.25	55.72	769.92	198,394.78	2,825,040.21
19:00:00	258,107.16	3,189,852.38	63.80	805.04	67.86	837.78	241,565.66	3,066,605.87

December 17, 2016								
Time	**Hourly Discharge**	**Cumulative Hourly Discharge**	**Hourly Generation**	**Cumulative Hourly Generation**	**Optimal Hourly Generation**	**Cumulative Optimal Hourly Generation**	**Optimal Discharge**	**Cumulative Optimal Discharge**
hour	**cubic meter**	**cubic meter**	**MWh**	**MWh**	**MWh**	**MWh**	**cubic meter**	**cubic meter**
20:00:00	214,099.38	3,403,951.75	52.34	857.38	56.61	894.40	198,030.46	3,264,636.33
21:00:00	157,432.88	3,561,384.63	38.29	895.67	41.02	935.42	147,541.14	3,412,177.47
22:00:00	104,762.78	3,666,147.41	26.82	922.49	26.77	962.19	105,133.02	3,517,310.49
23:00:00	94,682.44	3,760,829.84	23.92	946.42	23.83	986.02	95,084.54	3,612,395.03
0:00:00	96,068.44	3,856,898.28	23.53	969.95	24.20	1,010.22	93,592.93	3,705,987.96
Gain/saving					**40.27**		**150,910.32**	
Gain/saving %					**4.15%**		**3.91%**	

Table A9.6: Hourly summary of Primal optimization and Dual optimization for December 30, 2016

December 30, 2016								
Time	**Hourly Discharge**	**Cumulative Hourly Discharge**	**Hourly Generation**	**Cumulative Hourly Generation**	**Optimal Hourly Generation**	**Cumulative Optimal Hourly Generation**	**Optimal Discharge**	**Cumulative Optimal Discharge**
hour	**cubic meter**	**cubic meter**	**MWh**	**MWh**	**MWh**	**MWh**	**cubic meter**	**cubic meter**
1:00:00	104,922.31	104,922.31	27.05	27.05	27.01	27.01	105,332.42	105,332.42
2:00:00	130,318.50	235,240.81	34.65	61.70	34.29	61.30	132,079.80	237,412.22
3:00:00	130,526.75	365,767.56	34.66	96.36	34.47	95.77	131,894.60	369,306.82
4:00:00	125,100.00	490,867.56	33.09	129.46	33.05	128.82	125,944.12	495,250.94
5:00:00	113,479.06	604,346.63	29.66	159.12	29.61	158.43	114,011.61	609,262.55
6:00:00	116,835.78	721,182.41	30.70	189.82	30.51	188.94	117,565.79	726,828.34
7:00:00	186,123.59	907,306.00	46.05	235.87	49.07	238.01	174,971.59	901,799.93
8:00:00	273,845.22	1,181,151.22	67.06	302.93	71.63	309.64	254,766.44	1,156,566.37
9:00:00	159,121.34	1,340,272.56	40.90	343.83	41.92	351.55	155,417.33	1,311,983.69
10:00:00	128,721.28	1,468,993.84	34.02	377.85	33.78	385.34	129,860.67	1,441,844.36
11:00:00	101,082.03	1,570,075.88	25.91	403.76	25.80	411.14	101,488.84	1,543,333.21
12:00:00	102,887.19	1,672,963.06	26.46	430.22	26.39	437.53	103,268.98	1,646,602.19
13:00:00	102,760.97	1,775,724.03	26.44	456.66	26.41	463.94	103,135.31	1,749,737.50
14:00:00	103,447.97	1,879,172.00	26.66	483.32	26.60	490.54	103,864.28	1,853,601.78
15:00:00	129,984.53	2,009,156.53	34.60	517.92	34.42	524.96	131,221.53	1,984,823.30
16:00:00	131,213.63	2,140,370.16	34.98	552.89	34.75	559.70	132,559.86	2,117,383.17
17:00:00	170,215.72	2,310,585.88	42.97	595.86	44.90	604.60	162,937.67	2,280,320.84
18:00:00	278,005.47	2,588,591.34	67.28	663.14	72.32	676.92	256,007.41	2,536,328.25

December 30, 2016								
Time	Hourly Discharge	Cumulative Hourly Discharge	Hourly Generation	Cumulative Hourly Generation	Optimal Hourly Generation	Cumulative Optimal Hourly Generation	Optimal Discharge	Cumulative Optimal Discharge
hour	cubic meter	cubic meter	MWh	MWh	MWh	MWh	cubic meter	cubic meter
19:00:00	117,427.09	2,706,018.44	30.39	693.53	30.52	707.44	117,176.11	2,653,504.36
20:00:00	87,259.38	2,793,277.81	21.81	715.34	21.67	729.11	87,708.76	2,741,213.12
21:00:00	85,747.53	2,879,025.34	21.23	736.57	21.10	750.21	86,190.02	2,827,403.15
22:00:00	116,968.09	2,995,993.44	30.68	767.26	30.60	780.80	117,800.92	2,945,204.07
23:00:00	123,132.50	3,119,125.94	32.51	799.77	32.35	813.15	124,237.96	3,069,442.03
0:00:00	87,550.50	3,206,676.44	21.55	821.32	21.79	834.94	86,691.71	3,156,133.74
Gain/saving					13.62		50,542.70	
Gain/saving %					1.66%		1.58%	

Table A9.7: Hourly summary of Primal optimization and Dual optimization for January 01, 2017

January 01, 2017								
Time	**Hourly Discharge**	**Cumulative Hourly Discharge**	**Hourly Generation**	**Cumulative Hourly Generation**	**Optimal Hourly Generation**	**Cumulative Optimal Hourly Generation**	**Optimal Discharge**	**Cumulative Optimal Discharge**
hour	**cubic meter**	**cubic meter**	**MWh**	**MWh**	**MWh**	**MWh**	**cubic meter**	**cubic meter**
1:00:00	198,362.97	198,362.97	48.20	48.20	52.57	52.57	184,597.82	184,597.82
2:00:00	232,821.94	431,184.91	57.08	105.28	61.58	114.15	215,432.83	400,030.65
3:00:00	122,450.88	553,635.78	32.08	137.36	32.15	146.30	122,906.31	522,936.96
4:00:00	109,119.13	662,754.91	28.18	165.55	28.26	174.56	109,333.51	632,270.47
5:00:00	96,817.63	759,572.53	24.63	190.18	24.53	199.09	97,218.86	729,489.33
6:00:00	101,116.53	860,689.06	25.91	216.08	25.80	224.89	101,495.28	830,984.61
7:00:00	106,000.59	966,689.66	27.36	243.45	27.31	252.20	106,352.38	937,336.99
8:00:00	126,827.78	1,093,517.44	33.53	276.98	33.30	285.50	128,098.55	1,065,435.54
9:00:00	100,362.00	1,193,879.44	25.75	302.73	25.68	311.18	100,807.92	1,166,243.45
10:00:00	109,693.38	1,303,572.81	28.55	331.28	28.50	339.68	110,242.86	1,276,486.32
11:00:00	84,661.72	1,388,234.53	20.98	352.26	20.83	360.51	85,129.31	1,361,615.63
12:00:00	104,502.34	1,492,736.88	27.01	379.28	26.90	387.41	105,003.52	1,466,619.16
13:00:00	120,413.28	1,613,150.16	31.80	411.08	31.72	419.13	121,103.15	1,587,722.30
14:00:00	96,946.41	1,710,096.56	24.85	435.92	24.71	443.84	97,541.97	1,685,264.27
15:00:00	124,493.72	1,834,590.28	33.07	469.00	32.92	476.76	125,505.83	1,810,770.10
16:00:00	132,278.22	1,966,868.50	35.40	504.40	34.98	511.74	134,074.75	1,944,844.85
17:00:00	135,409.00	2,102,277.50	35.99	540.39	35.67	547.41	136,913.47	2,081,758.32
18:00:00	134,299.75	2,236,577.25	35.30	575.70	35.43	582.83	133,876.43	2,215,634.74
19:00:00	189,975.88	2,426,553.13	46.32	622.02	50.01	632.84	177,463.43	2,393,098.18

January 01, 2017								
Time	**Hourly Discharge**	**Cumulative Hourly Discharge**	**Hourly Generation**	**Cumulative Hourly Generation**	**Optimal Hourly Generation**	**Cumulative Optimal Hourly Generation**	**Optimal Discharge**	**Cumulative Optimal Discharge**
hour	**cubic meter**	**cubic meter**	**MWh**	**MWh**	**MWh**	**MWh**	**cubic meter**	**cubic meter**
20:00:00	211,630.59	2,638,183.72	51.98	673.99	55.72	688.56	198,059.22	2,591,157.39
21:00:00	116,473.44	2,754,657.16	29.09	703.08	29.98	718.55	113,112.09	2,704,269.49
22:00:00	94,108.31	2,848,765.47	23.92	727.00	23.77	742.32	94,600.57	2,798,870.06
23:00:00	99,378.84	2,948,144.31	25.58	752.58	25.42	767.74	100,031.82	2,898,901.88
0:00:00	91,003.25	3,039,147.56	23.14	775.72	22.95	790.69	91,694.07	2,990,595.95
Gain/saving					**14.97**		**48,551.61**	
Gain/saving %					**1.93%**		**1.60%**	

Table A9.8: Hourly summary of Primal optimization and Dual optimization for January 29, 2017

January 29, 2017								
Time	**Hourly Discharge**	**Cumulative Hourly Discharge**	**Hourly Generation**	**Cumulative Hourly Generation**	**Optimal Hourly Generation**	**Cumulative Optimal Hourly Generation**	**Optimal Discharge**	**Cumulative Optimal Discharge**
hour	**cubic meter**	**cubic meter**	**MWh**	**MWh**	**MWh**	**MWh**	**cubic meter**	**cubic meter**
1:00:00	118,372.97	118,372.97	31.13	31.13	31.11	31.11	118,807.50	118,807.50
2:00:00	118,560.25	236,933.22	31.17	62.30	31.16	62.27	118,974.59	237,782.09
3:00:00	98,170.81	335,104.03	25.18	87.48	25.07	87.34	98,658.45	336,440.54
4:00:00	104,050.19	439,154.22	26.84	114.32	26.84	114.19	104,390.69	440,831.23
5:00:00	99,998.31	539,152.53	25.73	140.05	25.65	139.84	100,458.14	541,289.37
6:00:00	171,488.59	710,641.13	42.14	182.19	45.01	184.85	160,953.28	702,242.65
7:00:00	230,381.84	941,022.97	56.69	238.87	60.68	245.53	215,013.76	917,256.41
8:00:00	214,610.28	1,155,633.25	52.19	291.07	56.60	302.13	197,636.88	1,114,893.30
9:00:00	132,162.81	1,287,796.06	32.39	323.46	34.17	336.29	125,713.27	1,240,606.56
10:00:00	101,287.25	1,389,083.31	25.85	349.31	25.79	362.09	101,480.94	1,342,087.50
11:00:00	111,038.28	1,500,121.59	28.74	378.05	28.69	390.77	111,307.57	1,453,395.07
12:00:00	119,375.53	1,619,497.13	31.24	409.29	31.19	421.96	119,690.34	1,573,085.41
13:00:00	98,817.88	1,718,315.00	25.16	434.45	25.08	447.04	99,132.19	1,672,217.60
14:00:00	98,892.16	1,817,207.16	25.19	459.64	25.17	472.21	99,087.25	1,771,304.85
15:00:00	111,517.81	1,928,724.97	27.14	486.78	28.49	500.70	105,966.00	1,877,270.85
16:00:00	248,439.25	2,177,164.22	60.59	547.37	65.58	566.28	228,765.53	2,106,036.38
17:00:00	230,864.31	2,408,028.53	56.32	603.69	60.95	627.23	212,667.32	2,318,703.70
18:00:00	90,704.78	2,498,733.31	22.37	626.06	22.37	649.60	90,833.59	2,409,537.29
19:00:00	69,242.38	2,567,975.69	15.73	641.79	15.69	665.30	69,309.52	2,478,846.81

January 29, 2017								
Time	Hourly Discharge	Cumulative Hourly Discharge	Hourly Generation	Cumulative Hourly Generation	Optimal Hourly Generation	Cumulative Optimal Hourly Generation	Optimal Discharge	Cumulative Optimal Discharge
hour	cubic meter	cubic meter	MWh	MWh	MWh	MWh	cubic meter	cubic meter
20:00:00	79,982.94	2,647,958.63	19.27	661.06	19.18	684.48	80,295.99	2,559,142.80
21:00:00	86,705.66	2,734,664.28	21.55	682.62	21.38	705.86	87,207.94	2,646,350.74
22:00:00	91,660.06	2,826,324.34	23.03	705.65	22.93	728.79	92,015.02	2,738,365.76
23:00:00	104,558.63	2,930,882.97	26.84	732.49	26.85	755.64	104,671.21	2,843,036.97
0:00:00	105,253.81	3,036,136.78	27.13	759.61	27.10	782.74	105,467.52	2,948,504.50
Gain/saving						23.13		87,632.29
Gain/saving %						3.04%		2.89%