AUGMENTATION OF WATER SUPPLY FROM KOLDAM TO SHIMLA CITY

A PROJECT

Submitted in partial fulfilment of the requirements for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

Under the supervision of

Dr. Veeresh Gali
Professor

By

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to

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

WAKNAGHAT, SOLAN – 173 234

HIMACHAL PRADESH, INDIA

MAY 2018

CERTIFICATE

This is to certify that the work which is being presented in the project report titled **"AUGMENTATION OF WATER SUPPLY FROM KOLDAM TO SHIMLA CITY"** in partial fulfilment of the requirements for the award of the degree of Bachelor of Technology in Civil Engineering and submitted to the Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat is an authentic record of work carried out by

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during the period from July 2017 to June 2018 under the supervision of **Dr. Veeresh Gali,** Professor, Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

The above statement made is correct to the best of our knowledge.

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Abbreviations

CPHEEO – Central Public Health and Environmental Engineering Organization

DEM – Digital Elevation Model

DPR – Detailed Project Report

H.P – Himachal Pradesh

I&PH – Irrigation and Public Health

Lpcd – Litres per Capita Day

LWSS – Lift Water Supply Scheme

MLD – Million Litres per Day

PHED – Public Health Engineering Department

SMC – Shimla Municipal Corporation

ABSTRACT

In 1875 water was brought from Dhalli catchment area to Shimla via gravity main which served a population of around 16000 persons. The city grew over the years increasing its boundary as well as population with subsequent augmentation of water supply to match the needs of the growing population. With the commissioning of augmentation schemes of water supply i.e. Nauti Khad & Giri, the total quantity available is 54.54 MLD which was sufficient to meet with the requirement of Shimla upto 2016. The detail of available 54.54 MLD water has been incorporated in this report.

With the increasing growth in the population both existing and floating, the water requirement of Shimla City and its surrounding areas is expected to be 105.66 MLD for the year 2048, which creates a huge gap between present supply and expected demand. To fulfil the water demand of the citizens, the City Development Plan has proposed a rate of 135 lpcd water supply to the city. The total requirement of water for the ultimate year of 2048 has been calculated using Population forecasting and water demand was found to be 105.63 MLD. To tide over the crisis, and bridge the gap between the present and future water demand, the project has been conceived to lift water from Koldam reservoir built over river Sutlej to add additional 51.09 MLD water to Shimla town which will cater the demand of Shimla and proposed satellite towns up to the year 2048.

This report further incorporates the Design of various components of Lift Water Supply Scheme which includes Design of Economic Size of Rising Mains/Pumping Mains from Sunni to Shimla, Pump House Power Requirement and Cost Analysis of the Rising Mains/Pumping Mains, Pipe Material and Pumps excluding the installation and labour costs using the CPHEEO manual and the data acquired from the I&PH Department, Himachal Pradesh and Municipal Corporation, Shimla.

CHAPTER 1

INTRODUCTION

1.1 Shimla Town

The Municipal town of Shimla, the head quarter of the district and summer capital of India during British regime, is situated on a range of entirely mountainous Middle Himalayas, south of the river Sutlej. Geographically, Shimla lies at 30˚6' North latitude and 77˚11' East longitude, and its mean elevation is 2397.59m above mean sea level. The existing town resembles an irregular crescent with a 9.2km extension from one end to the other, covering a total area of 19.55sq.km.

There is no major source of water body in the vicinity of the main city and the closest river, the Sutlej, is about 21 km away. Other rivers that flow through Shimla district, are the Giri and Pabbar which are far from the city.

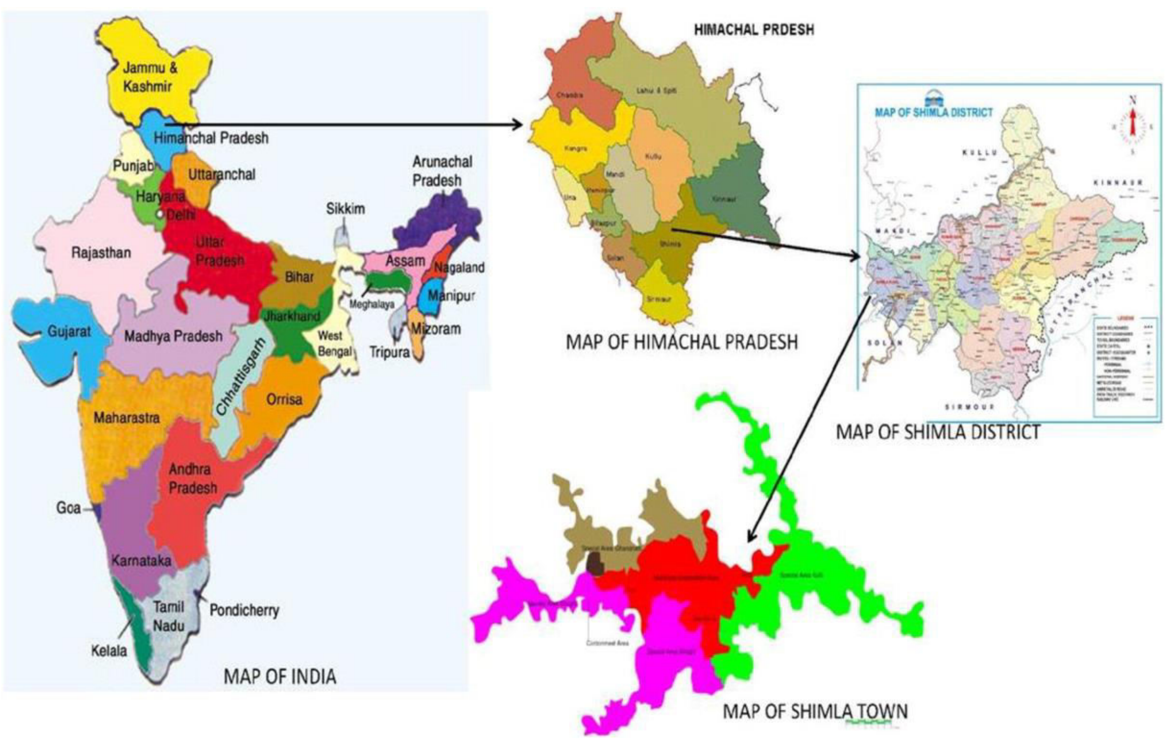


Figure 1.1 Map of Shimla Town

(Source: Kumar, Pushplata, 2015)

Table: 1 Shimla at a Glance

Area (Municipal Corporation)	19.99 Sq.km
Area (Urban Area)	35.34 Sq.km
Population(Municipal Corporation)	1,42,555 (2011 census)
Population(Urban Area)	1,60,000 (2011 census)
Total Floating Population/Year	75,000
Population Density	4,197 Persons/Sq.km
Existing Water Demand a) Water Available b) Deficit	40 MLD 33 MLD 7 MLD
Elevation (mean sea level)	2,276 m

1.2 Koldam

The Koldam Dam Hydropower Project also known as Koldam is an embankment dam. Built over the river Sutlej, it is 18 km away from Bilaspur off the Chandigarh-Manali Highway (NH-21) near Barmana, Himachal Pradesh. The principle use of the dam is to generate hydroelectric power which is bolstered up by an 800 MW power station. The dam was constructed by National Thermal Power Corporation (NTPC). Koldam hydropower project is located between 31°21’54" to 31°05’13" N latitude and 76°51’31" to 77°23’51" E longitude on Sutlej River, in Himachal Pradesh. It covers some part in Mandi and Bilaspur district of the state. The driving distance of Koldam to Shimla city is approximately 100km. It lies to the North West of Shimla and is situated in bilaspur district.

Figure 1.2 View of Koldam

1.3 Objectives of the Study

- To study the current potable water supply infrastructure in Shimla city.
- To identify the water demand for existing and future population growth.
- To study the techno-economic aspects of augmenting water from Koldam to Shimla.
- Designing the components of the Lift Water Supply Scheme (LWSS) from Sunni to Shimla.

The aims and objectives that are initially envisaged for formulation of any water supply plan are related to population of the area, socio-economic status of the people inhabiting the area, investigation of sources, their capacity and dependability on long term basis, future development plan of the region, existing and proposed level of water supply, its quality and history of epidemicity of water borne diseases.

- Examination of decadal population of the project area and estimation of future population to the end of the planning period.
- Total daily requirement of water for the present and future estimated population.
- Exploration of capable and dependable sources within or outside the project area.
- Planning and designing of collection and distribution system considering the topography and location of settlements of the project area.

CHAPTER 2

LITERATURE SURVEY

S. No.	Title of Paper	Year of Publication	Authors	Journal
1.	Resource assessment and strategic planning for improvement of water supply to Shimla city in India using geo-spatial techniques	2015	Sharma Kumar Sham, Sharma M.L and Tyagi Aditya	The Eqyptian Journal of Remote Sensing and Space Sciences
2.	Cities: "City Profile-Shimla"	2015	Kumar Ashwani and Pushplata	Elsevier
3.	Detailed Project Report (DPR)	2013	WAPCOS LTD.	
4.	Managing Water Scarcity in a Tourist City: "A case study of Shimla"		Autade S.E. and Soni P.K	

CHAPTER 3

METHODOLOGY OF THE STUDY

- Collection of necessary and relevant information on water supply from Municipal Corporation, Shimla and Irrigation and Public Health Engineering (IPH), Shimla.
- Analysis of the acquired data.
    - Utilization of the data to predict future population of the town as well as water demand.
    - Calculation of the water deficit or surplus before and after addition of availability of water from Koldam.
- Future prediction and calculation of water deficiency to be fulfilled by Koldam.
- Study of feasibility of Techno-economic aspects of augmenting water from Koldam to Shimla.
- Using the CPHEEO guidelines and Detailed Project Report (DPR) of the project given by the authorities to design the various components of the Lift Water Supply Scheme (LWSS).
    - Economic Design of Rising Mains/Pumping Mains
    - Pump House Power Requirement
    - Cost Analysis excluding the installation and labour costs

CHAPTER 4

ANALYSIS OF DATA

Shimla town extends over 7 hill spurs which are listed below in the table along with their elevation:

Table: 2 Hill spurs and their mean elevation

S. No.	HILL SPUR	ELEVATION (m).
1	Jakhu Hill	2454
2	Elysium Hill	2257
3	Museum Hill	2201
4	Prospect Hill	2177
5	Observatory Hill	2150
6	Summer Hill	2104
7	Potters Hill	2073

4.1 Existing Water Supply System of Shimla

4.1.1 Introduction

Water supply system of Shimla was established in 1875 to serve the population of 20,000. The water supply system was designed on pumping from nearby stream with the help of engineering structures. Today, water supply is one of the major hindrances in the growth and development of Shimla. This chapter provides overview of the water supply system, its delivery performance, issues and strategy for improvement in water supply.

Water supply scheme for Shimla town was constructed in the year 1875. Thereafter, its augmentation was done in 1889, 1914, 1923, 1974, 1982, 1992 and 2008. On an average 54.54 MLD Water is Supplied to Shimla town.

4.1.2 Policy, Legal and Institutional Framework

Shimla Municipal Corporation (SMC) and Department of Irrigation and Public Health (I&PH) are responsible for water supply to Shimla city. I&PH provides treated bulk water to SMC for local supply and distribution.

The role of I&PH is development of water related infrastructures for drinking water supply schemes, sewerage systems, irrigation systems through source development, lifting water, boring of tube wells & providing distribution systems and flood protection works to protect life and property in the state.

Presently, I&PH is involved in sourcing the water, treatment of water, and transmission of water through raising and gravity mains to storage reservoirs. The I&PH is also responsible for operation and maintenance of these systems.

I&PH supplies bulk water to SMC, which in turns distributes the water to domestic and commercial connections. SMC is responsible for releasing water connections, reading of water m., billing and receipt posting besides collection of water charges, attending public grievances.

4.1.3 History of Water Resource Development of Shimla

- First water supply scheme: 4.54 MLD, was implemented to utilize the water from the storage reservoir of 10.92 million liters (located at 12.85 km. from Shimla), which stores water from spring sources from Dhalli Catchment Area, during 1875 to support a population of 16,000.
- 1st Augmentation (Year 1914): With increase in the population of the city and the tourists, the first augmentation of Shimla Water Supply Scheme by provision of pump sets near Cherot Nallah (year 1889) and Jagroti Nallah (year 1914) to tap 4.80 MLD of water at these sources was implemented.
- 2nd Augmentation (Year 1914): The second augmentation of Shimla Water Supply Scheme (Year 1914) was executed by installing 2 pump sets at Chair Nallah to tap 2.50 MLD of water.

- 3rd Augmentation (Year 1924): The third augmentation of Shimla Water Supply Scheme was commissioned during the year 1924 to tap 7.72 MLD of water from Nauti Khad with further upgradation of pumps at various stages.
- 4th Augmentation (Year 1981-82): An additional 16.34 MLD of water was incorporated after the fourth augmentation of Shimla Water Supply Scheme by the installation of pump sets at Gumma and Darabla. Today, the system is designed to lift 24.06 MLD of water at source.
- 5th Augmentation (Year 1992): A two stage lifting at Ashwani Khad and at Kawalag was designed to pump 10.80 MLD of water on April, 1992.

4.1.4 Present Sources of Water

The water, which is received from different sources for Shimla Town for distribution, is detailed as under:

1. Dhalli Catchment

An average of 0.45 MLD water is received from this source under gravity condition at Dhalli filter.

2. Cherot & Jagroti

From this source an average of 3.50 MLD of water is received which is collected at dhalli filter.

3. Chair Nallah

From the source, an average of 1.70 MLD water is received.

4. Source at Gumma at Nauti Khad

This is the main source of water supply, which provides approximately 16.75 MLD of water

5. Source at Gumma at Nauti Khad near Bridge

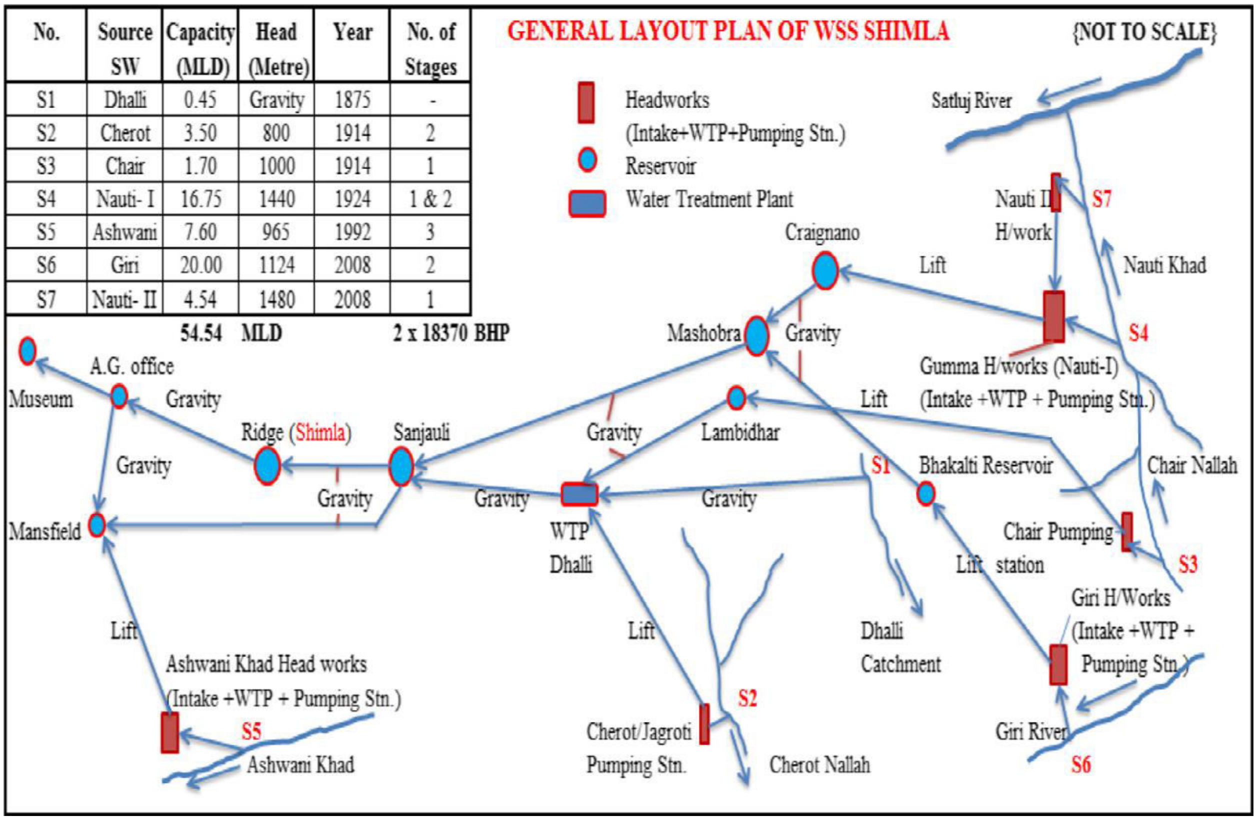
From this source, about 4.54 MLD of water is pumped

6. Ashwani Khad (SHUTDOWN AFTER THE JAUNDICE EPIDEMIC IN 2015-16)
From this source, about 7.60 MLD of water is pumped.

7. River Giri
From this source, about 20.00 MLD of water is pumped.

Table: 3 Present Sources of Water

S.No.	Name of source	Quantities drawn in MLD (Average)
1	Dhalli catchment	0.45
2	Churat Nallah	3.50
3	Chair Nallah	1.70
4	Nauti Khad	16.75
5	Nauti Khad near Bridge	4.54
6	Ashwani Khad	7.60
7	River Giri	20.00
	Total	**54.54**



No.	Source SW	Capacity (MLD)	Head (Metre)	Year	No. of Stages
S1	Dhalli	0.45	Gravity	1875	-
S2	Cherot	3.50	800	1914	2
S3	Chair	1.70	1000	1914	1
S4	Nauti- I	16.75	1440	1924	1 & 2
S5	Ashwani	7.60	965	1992	3
S6	Giri	20.00	1124	2008	2
S7	Nauti- II	4.54	1480	2008	1
		54.54 MLD			2 x 18370 BHP

Figure: 4.1 Existing Water Supply System in Shimla City

CHAPTER 5

POPULATION FORECASTING AND WATER DEMAND

5.1 Population Recorded

Table: 4 Past Decadal Population

Year	Population
1911	19405
1921	27213
1931	18144
1941	18348
1951	46150
1961	42597
1971	55326
1981	70604
1991	82504
2001	156127
2011	171640

5.2 Population of Shimla in 2017

As indicated by 2011 statistics, the city of Shimla extends over a range of 35.34 km^2 with a population of around 169,578 comprising of 93,152 males and 76,426 females.
In order to check out the population of Shimla in 2017, we need examine the population of the past 5 years. They are as per the following:

1. 2012 – 173,434
2. 2013 – 178,678
3. 2014 – 183,779
4. 2015 – 188,539
5. 2016 – 194,539

Examining the population of Shimla from the year 2012-16, it has been observed that there has been an increase of 21,105 in the past 5 years. Therefore, the population increases by 4221 every year. Hence, the population of Shimla in 2017 is forecasted to be 194,539 + 4221 = 198,760. So, the population of Shimla in the year 2017 as per estimated data = 198,760.

Shimla Population 2017 – 198,760 (Estimated)

5.3 Population Forecasting

The population of city has been projected up to the ultimate period-2048. The population projection by Decreasing rate of growth method and Logistic method has not been done here as this city does not show decreasing population trend and the city is not very large.

The different methods of population forecasting are:

1. Arithmetic Increase Method

This method is generally applicable to large and old cities. In this method, the average increase of population per decade is calculated from the past records and added to the present population to find out population in the next decade .This method gives a low value and is suitable for well settled and established communities.

Population after n^{th} decade will be P_n=P+n.C

where,

P_n=Population after 'n' decades

P=Present Population

Table: 5 Population Forecasted using Arithmetic Increase Method

Year	Value of 'n'	Forecasted Population
2011	0	171640
2012	0.1	174220
2013	0.2	176801.72
2014	0.3	179382.58
2015	0.4	181963.44
2016	0.5	184544.3
2017	0.6	187125.16
2018	0.7	189706.02
2019	0.8	192286.88
2020	0.9	194867.74
2021	1.0	197448.6
2022	1.1	200029.46
2023	1.2	202610.32
2024	1.3	205191.18
2025	1.4	207772.04
2026	1.5	210352.9
2027	1.6	212933.76
2028	1.7	215514.62
2039	1.8	218095.48
2030	1.9	220676.34
2031	2.0	223257.2
2032	2.1	225838.06
2033	2.2	228418.92
2034	2.3	230999.78
2035	2.4	233508.64
2036	2.5	236161.5
2037	2.6	238742.36

2038	2.7	241323.22
2039	2.8	243904.08
2040	2.9	246484.94
2041	3.0	249065.8
2042	3.1	251641.6
2043	3.2	254227.2
2044	3.3	256803.38
2045	3.4	259389.24
2046	3.5	261970.1
2047	3.6	264550.96
2048	3.7	267131.82

2. Incremental Increase Method

This is method is a modification of arithmetic increase method and it is suitable for an average size town under normal condition where the growth rate is found to be in increasing order. While adopting this method, the increase in increment is considered for calculating future population. The incremental increase is determined for each decade from the past population and the average value is added to the present population along with the average rate of increase.

Population after n^{th} decade is $P_n=P+n.X+\{n(n+1)/2\}.Y$

where,

P_n=Population after n^{th} decade

X=Average increase

Y= Incremental increase

Table: 6 Population Forecasted using Incremental Increase Method

Year	Value of 'n'	Forecasted Population
2011	0	171640
2012	0.1	174259.14
2013	0.2	176852.4
2014	0.3	179518.3

2015	0.4	182158.32
2016	0.5	184058.3
2017	0.6	187459.24
2018	0.7	190201.24
2019	0.8	192788
2020	0.9	195462.82
2021	1.0	198144.6
2022	1.1	200833.48
2023	1.2	203529.04
2024	1.3	206231.7
2025	1.4	208941.32
2026	1.5	211657.9
2027	1.6	214381.44
2028	1.7	217111.94
2039	1.8	219849.4
2030	1.9	222593.82
2031	2.0	225348.2
2032	2.1	228103.54
2033	2.2	230868.84
2034	2.3	233641.1
2035	2.4	236420.32
2036	2.5	239206.5
2037	2.6	241999.64
2038	2.7	244799.74
2039	2.8	247606.8
2040	2.9	250420.82
2041	3.0	253241.8
2042	3.1	256069.74
2043	3.2	258904.64
2044	3.3	261746.5
2045	3.4	264595.32
2046	3.5	267451.1
2047	3.6	270318.4
2048	3.7	273183.54

3. Geometric Increase Method

In this method the percentage increase in population from decade to decade is assumed to remain constant. Geometric mean increase is used to find out the future increment in population. Since this method gives higher values and hence should be applied for a new industrial town at the beginning of development for only few decades. The population at the end of n^{th} decade 'P_n' can be estimated as:

$P_n=P(1+I_G/100)^n$

where,

I_G=Geometric mean (%)

P=Present population

n=No. of decades

Table: 7 Population Forecasted using Geometric Increase Method

Year	Value of 'n'	Forecasted Population
2011	0	171640
2012	0.1	175874.78
2013	0.2	180214.04
2014	0.3	184006.37
2015	0.4	189216.40
2016	0.5	193884.83
2017	0.6	198668.45
2018	0.7	203570.09
2019	0.8	208592.67
2020	0.9	213739.16
2021	1.0	219012.64
2022	1.1	224416.22
2023	1.2	229953.18
2024	1.3	235626.63
2025	1.4	241440.12
2026	1.5	247397.05
2027	1.6	253500.94
2028	1.7	259755.44

2039	1.8	266164.24
2030	1.9	272731.17
2031	2.0	279460.12
2032	2.1	286355.09
2033	2.2	293420.18
2034	2.3	300659.58
2035	2.4	308077.60
2036	2.5	315678.63
2037	2.6	323467.20
2038	2.7	331447.94
2039	2.8	339625.58
2040	2.9	348004.98
2041	3.0	356591.12
2042	3.1	365389.10
2043	3.2	374404.15
2044	3.3	383641.63
2045	3.4	393107.01
2046	3.5	402805.93
2047	3.6	412744.15
2048	3.7	422927.57

Average of the Three Methods

The population projections for city obtained from three methods mentioned above, show that the population projections from Arithmetical Increase method is on lower side, while from Geometrical Increase method is on higher side. The population of city has been projected by taking average value of Arithmetic Increase, Incremental Increase and Geometric Increase Method.

Table: 8 Population Forecasted using Average of the Three Methods

Year	Average of the Three Methods
2011	171640
2012	174784.64
2013	177956.05
2014	180969.08

2015	184446.05
2016	187495.8
2017	191084.28
2018	194492.45
2019	197888.66
2020	201356
2021	204868
2022	208426
2023	212030
2024	215682
2025	219384.33
2026	223135.35
2027	226938
2028	230793.33
2039	234676.088
2030	238666.66
2031	242688.33
2032	246765.33
2033	250902.06
2034	255099.66
2035	259335
2036	263681.83
2037	268009.4
2038	272523
2039	277045
2040	281636
2041	286299.26
2042	291024
2043	295845.06
2044	300730
2045	305697
2046	310742
2047	315870.71
2048	321080.97

Table: 9 Population, Floating Population, Water Demand, Supply, Deficit

YEAR	POPULATION	FLOATING POPULATION	DEMAND w/o FLOATING POPULATION (MLD)	DEMAND with FLOATING POPULATION (MLD)	SUPPLY (MLD)	DEFICIT/SURPLUS (MLD)
1981	70,604	30000	15.1	21.6	22.40	+0.80
1991	82,504	40000	17.7	26.3	22.40	+3.9
2001	156,127	56000	33.5	45.6	30.00	+15.6
2011	171,640	76000	36.9	53.2	54.54	+1.34
2021	204,868	100000	44.0	65.5	54.54	-10.96
2031	242,688	131579	52.1	80.4	54.54	-25.86
2041	286,299	173130	61.5	98.7	54.54	-44.16
2048	321,080	227803	69.03	108	54.54	-54.46

NOTE: Surplus has been indicated by a (+) sign and Deficit by a (-) sign.

The water available i.e. 1.70 MLD from Chair Nallah is being supplied to Kufri under SPA Shimla. Also as mentioned above the water supply from Ashwani Khad has been suspended due to the Jaundice epidemic in the year 2015-16 as the water quality is still an issue. That means additional 7.60 MLD of water supply to Shimla has been cut down. Further, since the distribution lines are as old as before independence as a result water leakage is also a factor which amounts to approximately 10-15 MLD of water. Therefore the Total Water Available Currently in Shimla amounts to 33 MLD approximately.

5.4 Water Demand and Deficit

5.4.1 Present Water Demand

Due to the rise in the level of tourists and the increasing population of the city the water requirement per day during peak tourist season is approximately 39.85 MLD which has been calculated for a total population of 2,84,635 @ 140 lpcd. Since the current supply is around 33 MLD thus, there is deficit in water supply of about 7 MLD.

5.4.2 Future Water Demand

With the increasing growth in the population both existing and floating, the water requirement of Shimla City and its surrounding areas is expected to be 105.63 MLD for the year 2048, which creates a huge gap between present supply and expected demand. To bridge this gap between the future water demand of 105.63 MLD and present water supply of 33 MLD, 72.63 MLD of water has to be sourced.

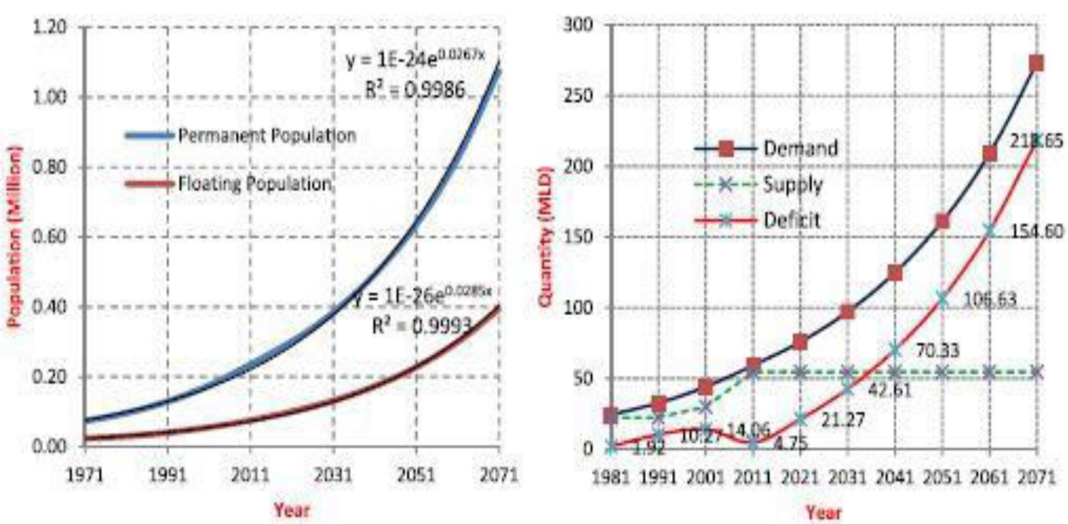


Figure: 5.1 (a) Projected Population (b) Demand-Supply

(Source: Sharma K.S., Kansal M.L., Tyagi A. 2015)

CHAPTER 6
PROPOSED DESIGN FOR AUGMENTATION

- **Project Description:** To source 51.09 MLD of water from river Sutlej **[KOLDAM]** by I&PH. The project shall include construction of intake weir, sedimentation tank, sump well, pump house, treatment plant, filtration plant, pumping stations, rising and gravity mains etc.
- **Project Benefits:** Increases water availability.
- **Estimated Project Cost:** Rs. 710 Crores
- **Financing Mechanism:** World Bank + Center Govt.
- **Preparatory Activity for Implementation:** Project development including preparation of detailed feasibility and detailed project report.
- **Additional Studies:** Detailed Project Report for augmentation of water resource from river Sutlej [Koldam Reservoir].

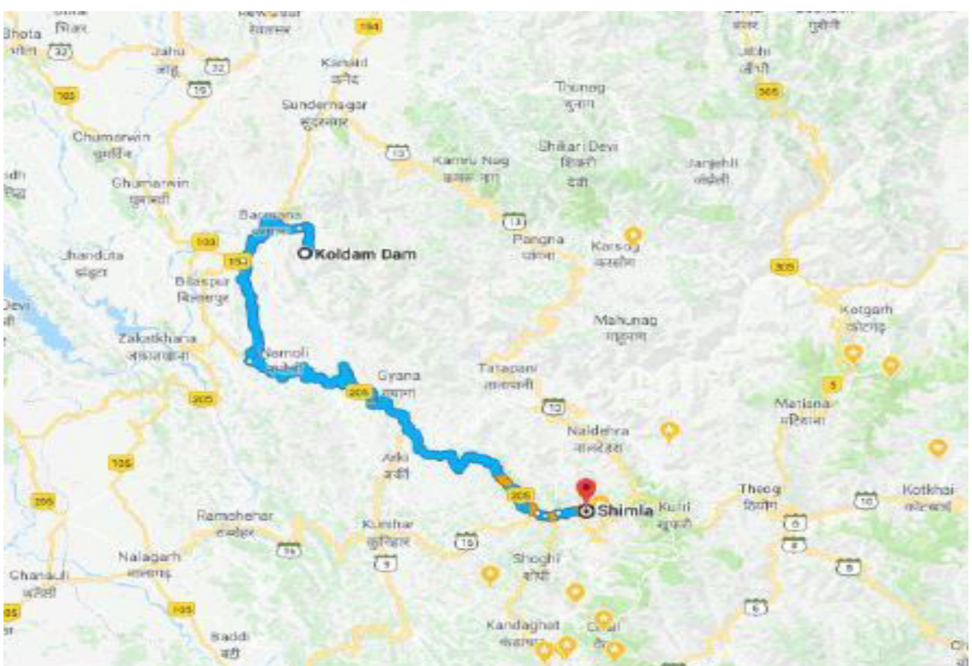


Figure: 6.1 SH 205+154 connecting Koldam and Shimla (Source: Google Maps)

6.1 Water crisis in Shimla

There is no major source of water body in the vicinity of the main city. The climate of Shimla is predominantly cold during winters and moderately warm during summers. The monthly precipitation ranges between 24mm in July to 415mm in November. The average total annual precipitation is 152cms. Snowfall generally takes place in the months of December, January and February. The people of the city of Shimla are facing acute shortage of water mainly due to steep sloping areas and lack of natural water reservoirs even though the average annual precipitation is significant (152cms.).

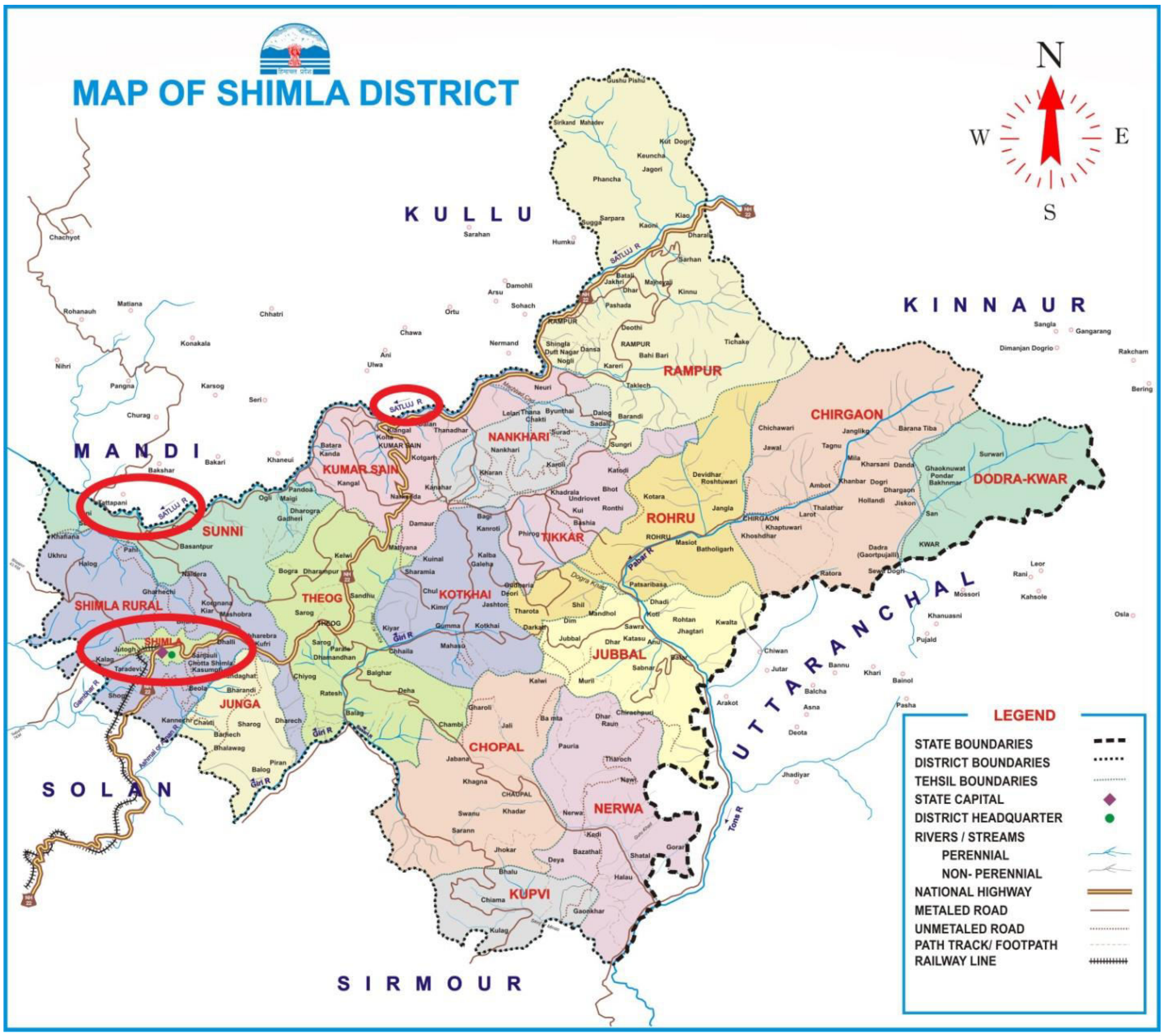


Figure: 6.2 Highlighted Areas of Shimla Town and Sutlej River (Source: Google Images)

6.2 Topographical Study and Digital Elevation Models

Topographic Surveys are used to identify and map the contours of the ground and existing features on the surface of the earth or slightly above or below the earth's surface (i.e. trees, buildings, streets, retaining walls etc.) Topographic Surveys require "benchmarks" to which ground contours are related, information regarding surface and underground utilities, determination of required setbacks etc.

A **DEM** can be represented as a raster (a grid of squares, also known as a heightmap when representing elevation) or as a vector-based triangular irregular network (TIN). The TIN **DEM** dataset is also referred to as a primary (measured) **DEM**, whereas the Raster **DEM** is referred to as a secondary (computed) **DEM**.

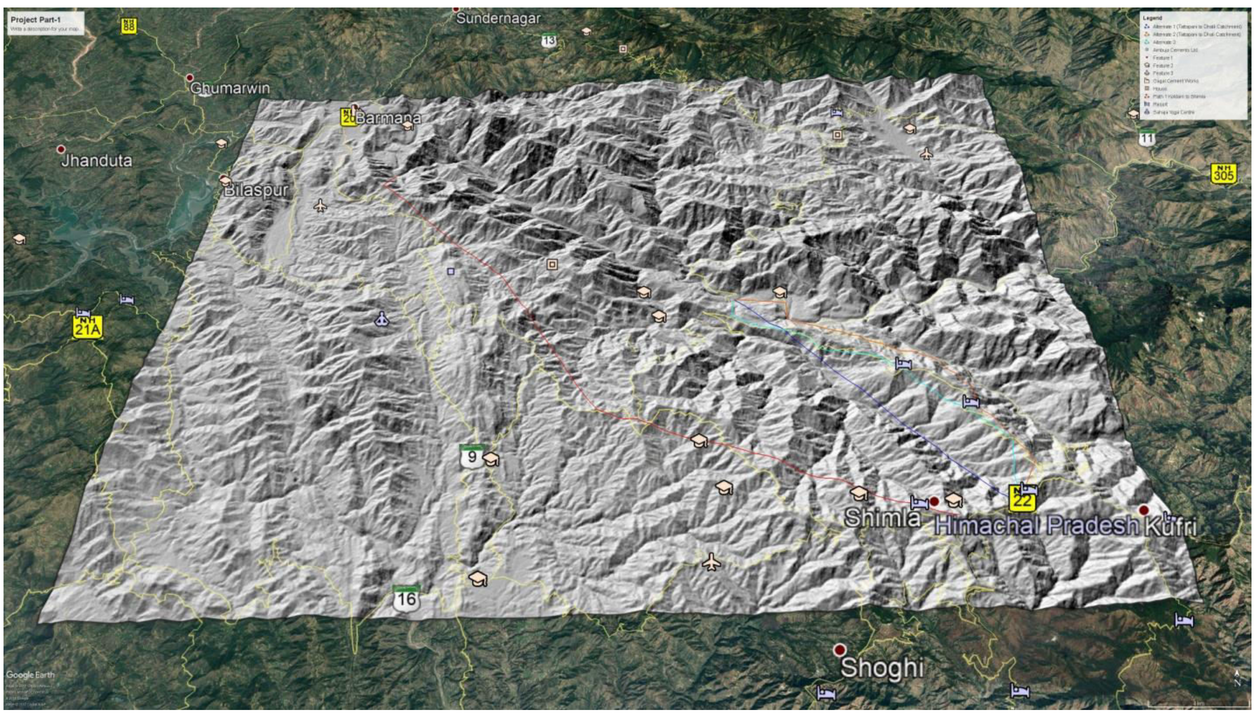


Figure: 6.3 Digital Elevation Model (DEM) of the Area using Google Earth

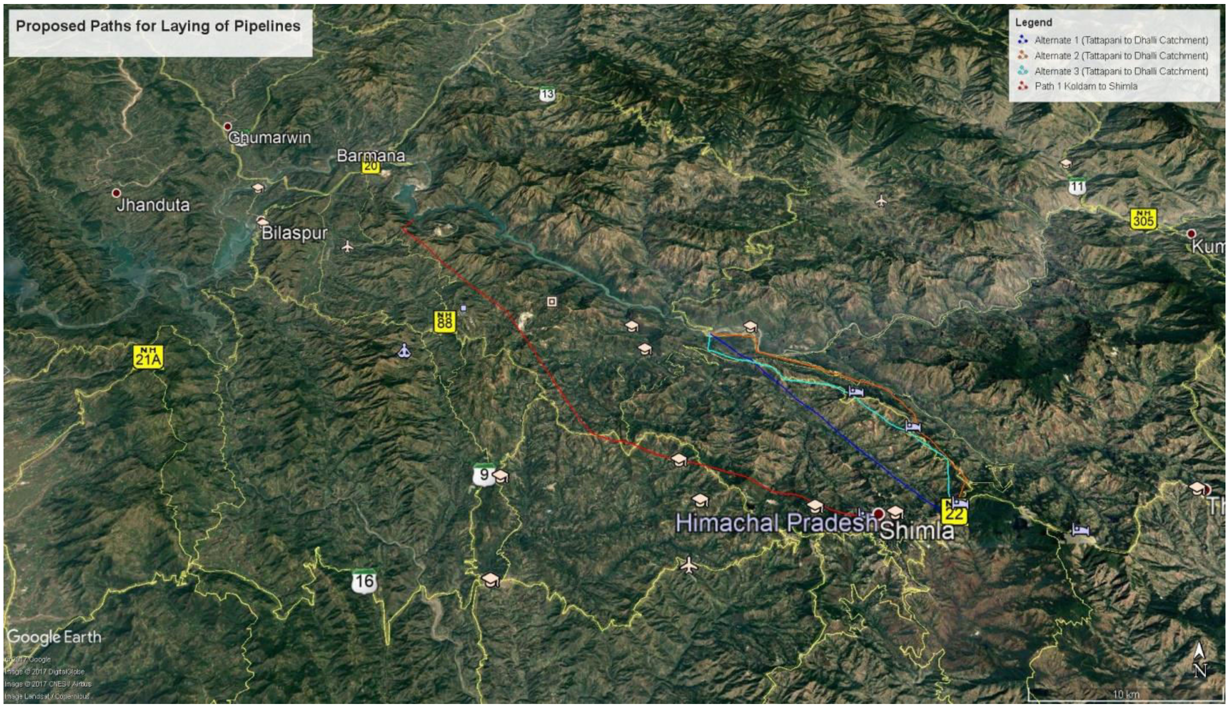


Figure: 6.4 Proposed Paths for Laying of Pipeline from Koldam Reservoir to Shimla

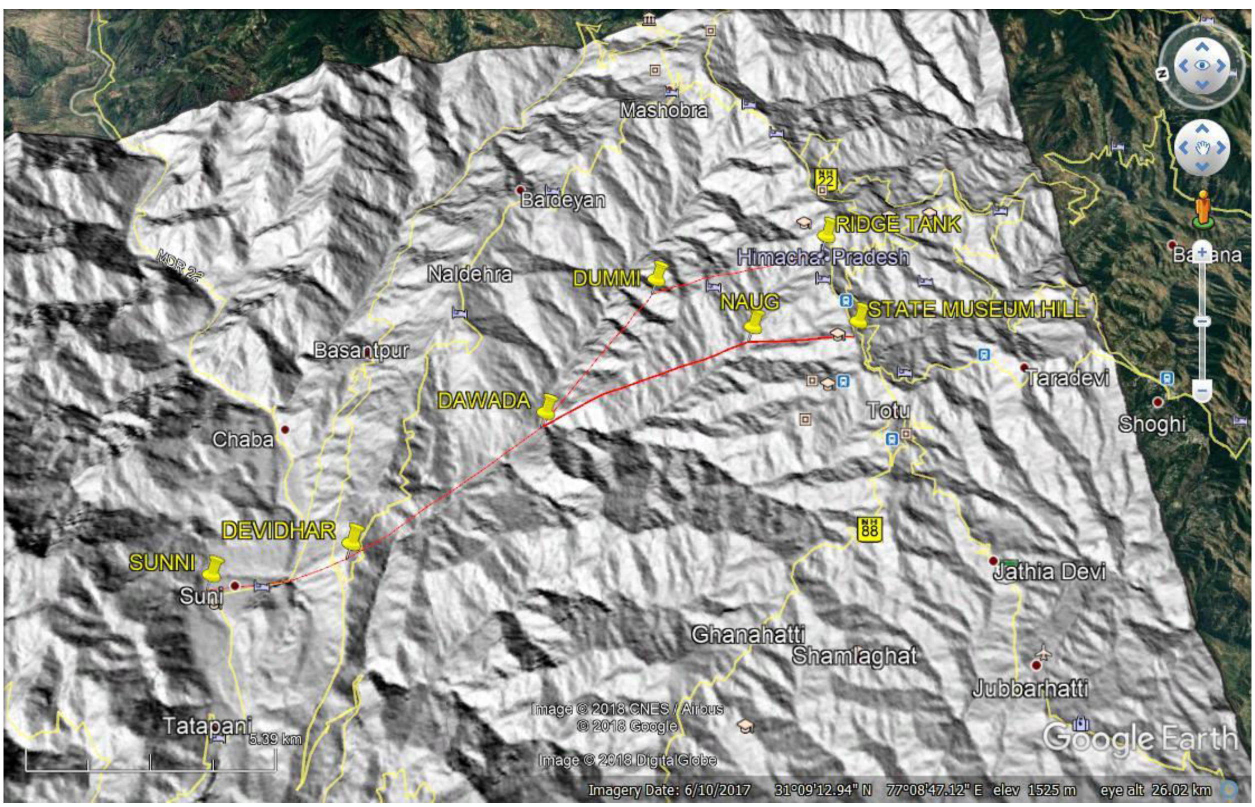


Figure: 6.5 Digital Elevation Model (DEM) of the Layout using Google Earth

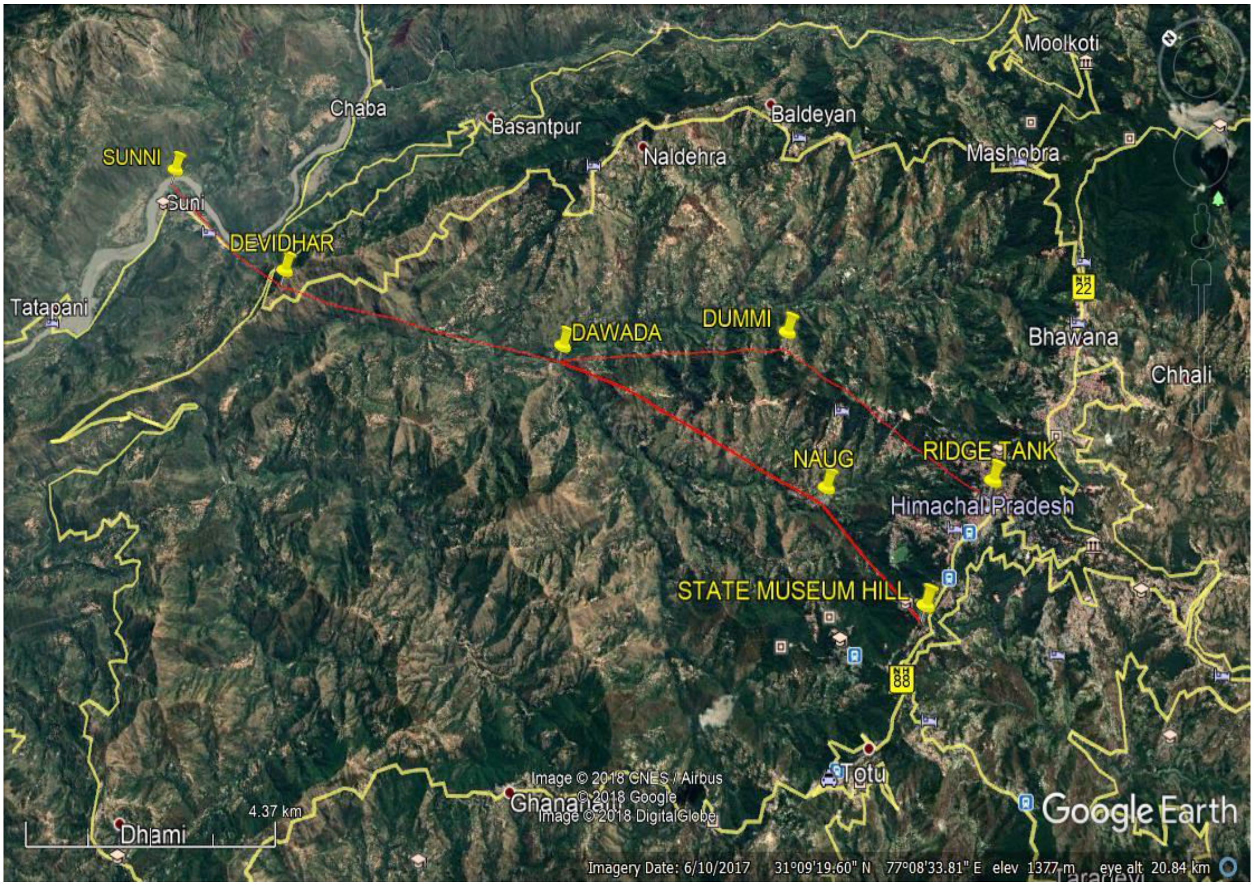


Figure: 6.6 Proposed Path for Lift Water Supply Scheme (LWSS) from Sunni to Shimla

6.3 Parameters used in Designing

- Supply Hours

  The ultimate objective is to provide all consumers within the project towns with a continuous water supply (24 hours), and all components of the water supply system shall be designed with this goal in mind. However, given the prevailing conditions in the project towns, as well as the situation in other similar towns in State of Shimla, it is not realistic to provide continuous water supply immediately after commissioning of the water supply scheme. Initially water supply duration may be intermittent, it is hoped that once the consumers in the project towns become accustomed to a regular, reliable water supply and wastage is reduced, the supply hours can be extended until continuous supply is achieved. Supply though short duration will lead to increased flow through distribution piping, which however will be nearly equal to ultimate storage flow for which the system is to be designed. Designs will be checked for shorter duration supply and adequate provisions will be made.

- Pumping Hours

  At present Public Health Engineering Department (PHED) considers 16 hrs supply in their schemes though availability of power per day is even lesser in actual practice. For a major project as being proposed, system designs adopting lesser duration of power availability will result substantial increase in the capacity/ dimensions of all units to achieve desired output, which will adversely affect the economic feasibility of the project. Considering various techno-economic aspects it has been proposed, an assured availability of power should be considered at 16 hrs every day either through a dedicated feeder line or an in house electricity generator, the proposed system will be designed accordingly.

- Design Formula

  A number of formulae are in use for hydraulic analysis of water networks. Most widely used among those is Hazen – William's formula, which involves flow through pipeline, diameter of pipeline velocity of flow and the loss of head due to friction.

  Hazen William's formula is given by the expression:

$V = 4.567 \times 10^{-3} \times cd^{0.63} \times S^{0.54}$

where,

V = Velocity of flow

C = Hazen Williams co-efficient of friction d = diameter of circular conduit

S = Slope of hydraulic Gradient

Hazen Williams Co-efficient ‘C’ is Recommended as standards as below:-

DI (Lined) pipe - New 140 Design 140

CHAPTER 7

PIPE MATERIALS AND APPURTENANCES

Pipe materials considered for the transmission network system are Cast Iron (CI), Ductile Iron (DI), Mild Steel (MS), High Density Polyethylene (HDPE) and Pre-stressed Concrete (PSC). The pipes have been compared on various parameters to evaluate their usefulness as a water carrying main in transmission and distribution system. The main parameters which have been discussed are available sizes and lengths, weight, flexibility, available working pressure ratings, tensile strength, impact strength, ease of tapping and repair, general availability in India, availability of plant and skilled man power for manufacturing, laying and maintenance, availability of corrosion control techniques, ease of locating underground pipes, special bedding requirements, laying speed, performance experience and basic cost economics.

7.1 Advantages and Disadvantages of Pipe Materials

The Advantages and Disadvantages of some of the most common pipe materials used are shown in the table below:

Table: 10 Advantages and Disadvantages of important pipe materials

S No.	Pipe material	Advantages	Disadvantages
1.	Mild steel	1. Superior mechanical strength and toughness. 2. Is quiet resistant to fatigue. 3. Can be customized accordingly to suit the local conditions and pressure ranges. 4. Impermeable to gas and organic contaminants.	1. Heavy 2. Welded joints require skilled installations and special high cost equipment. 3. Susceptible to corrosion if protection system is not provided. 4. Difficult to protect welded joints from inside.

		5. Easy to detect leakage and underground pipe location. 6. Easy repair by welding.	5. Potential rise in pH while carrying soft water. 6. Dependent on stable support from soil. 7. Installation of fittings/repair is difficult with non-standard sizes. 8. Protection given at site on corroded pipes is not much effective.
2.	Ductile iron	1. High mechanical strength and toughness. 2. High fatigue resistance 3. Simple to install joints. 4. Pipe joint deflection from 4^0 to 5^0. 5. Provided with corrosion protection internally. 6. Impermeable to gas and organic contaminants. 7. Easy to locate underground pipe and leakage. 8. Relatively unskilled labour can lay pipe. 9. Complete range of fitting available.	1. Relatively heavy. 2. Only standard bending 11.25^0,22.5^0,45^0,90^0 bends are available.
3.	Cast iron pipes	1. Moderate mechanical strength and toughness. 2. High resistance against compressive force. 3. High performance, simple	1. Relatively heavy. 2. Brittle, prone to development of hairline crack during handling and transportation.

		to install. 4. Pipe joint deflection from 2^0 to $5^{0.}$ 5. Not susceptible to corrosion under normal soil conditions. 6. Easy to locate underground and pipe leakage. 7. Relatively unskilled labour can lay pipe. 8. Complete range of fittings available.	3. Not good for high pressured application. 4. Susceptible to failure under surge conditions. 5. Tuberculation and incrustation take place after some years
4.	HDPE	1. Very good impact strength ,flexibility and is corrosion resistant. 2. Tough and resilient. 3. Can bend upto some extent thereby minimizing the use of special equipment like bends, elbows etc. Resulting in a reduction in the installation costs. 4. Their lightness makes them easy to carry and also makes their installation easy. 5. Has a very high C-value.	1. Requires skilled manpower. 2. Costliest material as compared to other pipes available.
5.	Pre-Stressed concrete pipes.	1. The C-value of these pipes is more the Cast iron. pipes. 2. Cheaper compared to cast iron pipes.	1. Requires higher level of quality control during its production. 2. Laying of these pipes with rubber rings also

			requires a skilled competence and supervision. 3. Only available with reputed contractors.

So concluding, it is observed that DI Pipes are technically highest ranked among all metallic pipes, and available in range of diameters of 80 mm and above and up to 1000 mm.

7.2 Appurtenances

7.2.1 Line Valves

Main line valves are used to stop and regulate the flow of water in an emergency. There are many types of valves for use in pipeline, the choice of which depends on the duty. The spacing varies principally with the terrain traversed by the line. In urban areas with connections in the distribution system, main aim is to partition the line in order to maintain reasonable service. In larger lines isolating valves are usually installed at intervals of 1 to 5 Km. The main considerations in locations of the valves are approachability and closeness to special points such as branches, stream crossings etc. Valve spacing is a function of economics and operating problems. Parts of the pipeline may have to be insulated to mend the leaks. The volume of water that would have to be discharged for disposal would be a role of spacing of isolation valves.

These valves are usually placed at major summits of pressure conduits. Summits identify the sections of the line that can be drained by gravity, and pressures are least at these points permitting cheaper valves and easier operations. Gravity conduits are provided with valves at points strategic for the operation of supply points, at the two ends of sag pipes and wherever it is convenient to drain the given section.

Normally valves are sized slightly smaller than the pipe diameter and installed with a reducer on either side. In choosing the size; the cost of the valve should be weighed against the cost of head loss through it, although in certain circumstances it may be desirable to maintain the full pipe bore (to erosion or blockage).

7.2.1.1 Sluice Valves

Sluice valves or gate valves are the normal type of valves used for isolating or scouring. They seal well under high pressures and when fully open, offer little resistance to fluid flow. There are two types of spindles for raising the gate; a rising spindle which is rotated in a screwed attachment in the gate. The rising spindle is easy to lubricate.

The gate may be parallel sided or wedge shaped. The wedge gate seals best, but may be damaged by grit. For low pressure, resilient or gun metal scaling faces may be used. For high pressure, stainless steel seals are preferred.

Sluice valves are not intended for continuous throttling, as erosion of the seats and body cavitation may occur. If small flows are required the bypass, valve is more suitable for this duty.

Sluice valves shall be located on at least three sides of every cross junction and at every kilometer on long mains. The size of the sluice valve shall be the same as the size of the main up to 300mm diameter and at least two-thirds the size of the main for larger diameters.

7.2.1.2 Butterfly Valves

These are used to regulate and stop the flow especially in large size conduits.Occasionally these cost less than the sluice valves for larger sizes and utilize a lesser area. Butterfly valves without sliding parts have the advantages of ease of use, compacted size, smaller chamber or valve house and better closing and retarding characteristics.

These involve a comparatively more head loss than sluice valves and also are not recommended for continuous throttling. The sealing is also not as effective as for sluice valves especially at higher pressures. They offer a high resistance to flow even in fully open state, because the thickness of the discs resists the flow even when it is changed to fully open position. Butterfly valves and sluice valves are not suitable for use in partly open position because they can erode the gates and seatings rapidly. Both the valves need high torques to open them against high pressure, they usually have geared hand wheels or power driven actuators.

Butterfly Valves with loose sealing ring are occasionally ineffective, especially at higher pressures. Butterfly valves with fixed liner can get over this deficiency, further the butterfly valves with fixed liner require no routinely maintenance for replacement of sealing ring as in the case of those valves with loose sealing ring. The fixed liner design butterfly valves are now available in India suitable for working pressures up to 16 kg/sq cm. Presently there is no IS code for the fixed liner Butterfly valves.

7.2.1.3 Globe Valves

Globe valves have a circular seal connected axially to a vertically and hand wheel. The seating is a ring perpendicular to the pipe axis. The flow changes direction through 90° twice thus resulting in high head losses. These valves are normally used in small bore pipe work and as taps, although a variation is used as a control valve.

7.2.1.4 Needle and Cone Valves

Needle valves are more expensive than sluice and butterfly valves are well suited for throttling flow. They have a gradual throttling action as they close, whereas sluice valves and butterfly valves offer flow resistance until practically shut and may suffer cavitation damage. Needle valves may be used with counter balance weights, springs, or actuators to maintain constant flow. They are resistant until practically shut and may suffer cavitation damage. They are resistant to wear even at high flow velocities.

The needle and cone valves are no commonly used in water supply but are occasionally used as water hammer release valves when coupled to an electric or hydraulic actuator.

7.2.2 Scour or Blow Off Valves

In pressure ducts, small gate switches known as blow-off or scour valves are used at low points above line valves located in the line on a gradient such that each section of the separation lies between the valves and can be emptied completely. They get discharged into natural drainage channel or into a sump from which water can be pumped to waste.

The exact position of scour valves is often influenced by opportunities to dispose off the water. Where main crosses the flow or drainage structure there will usually be a low point in the line, but if the main passes under the stream or drain it cannot be completely discharged into a channel. In that situation, it is better to locate a scour connection at a lower point that will be discharged by gravity and will alow pumping of the part below the drain pipeline.

There should be no direct connection to sewers or polluted water course except through a specially designed trap chamber or pit for safety to bow off valves are placed in series, The outlet into the channel should be above the high water lines. If the outlet must be below high water check valves must b e placed to prevent backflow.

The dimensions depend on local factors particularly when the provided section of line is designed to be emptied upon the resulting velocity of flow. Calculations depend on the discharge of orifice under a subsequent head equal to difference in elevation of the water surface in duct minus and the blow off minus the friction head. Frequency of the operation depends upon the quality of water carried especially on silt loads.

7.2.3 Air Valves

When a pipeline is filled, air could be trapped at peaks along the profile thereby incurring head losses and reducing the capacity of the pipeline. It is also undesirable to have pockets in the pipe as they may cause water hammer pressure fluctuations during operations of the pipeline. Other problems due to air include corrosion ,reduced pump efficiency, malfunctioning of valves or vibrations. Air valves are used to release the air automatically when a pipeline is being filled and also to allow air to enter the pipeline when it is emptied. Moreover air valves are also used to release any en trained air, which may have been gathered at high points in the pipeline during routine operations.

Without air valves vacuum may occur at peas and the pipe could collapse or it may not be possible to drain the pipeline completely.

Air valves require care in selection and even more care in sitting and it is good practice to plan the pipeline alignment to avoid air troubles altogether. A special study of the possible air problems is necessary at the design stage itself and provision should be made for suitable corrective measures rather than positioning arbitrary air valves at pipeline peaks.

Location of air valves can be at both sides of gates at summits, the downstream side of other gates and alterations in grade to steeper gradients in sections of line else guarded by air valves.

The valve usually takes the form of a rigid buoyant vulcanite or rubber-covered ball seated on a rubber or metal ring. The sealing element i.e. the ball is slated against an opening at the top of the valve when the pipe is full and seals the opening. When the pressure in the pipe goes down below the external pressure, the ball drops,hence allowing air to be drawn into the pipe. The valves are mainly available in two forms, either single-ball or double ball. The single ball type can have either a large orifice or a small orifice, the first is only suitable for draining and filling of pipes and the other one for releasing small amounts of en trained air. Double air valves are available which can be classified as dual purpose with a large orifice and small orifice in a single unit, with the same connection to the main. For large aqueduct pipelines, a triple orifice air valve can be used with two large orifices and a small. For high pressures, stainless steel floats can be used rather than the vulcanite-covered balls.

Special designs of air valves are also available which operate satisfactorily with high velocity air discharges. If normal air valves are utilized under these conditions, there is a danger of the ball beinf carried on to its swat by the air stream before the accumulated air has been fully released.

Air valves can be provided with an integral stop valve or alternatively and preferably, a standard sluice valve can be bolted to the inlet flange, which must be adequate size for its duty. Regular maintenance checks on at least an annual basis should be carried out to make sure that the balls are free to move and the seats do not leak. If an air valve is isolated for any reason in very cold weather, the body should be drained to prevent frost damage; a plug cock can be fitted at the base of the body for this purpose. Trapped chamber drainage is essential to prevent any possibility of stagnant or polluted water or air entering the pipeline.

Automatic air valves in urban streets present a serious contamination risk, since they must have air vents that could, in some circumstances, admit polluted surface water, constructing an air valve chamber as water tight as possible and fitting a ball valve interceptor as an outlet to a storm water sewer is a practice to obviate this possibility. Using annually operated air valves in the streets, it being the routine duty of a turn cock in the area to air the main, to minimize the risk of serious contamination, is yet another practice.

The following ratios of air valves to conduit diameter provide common but rough estimates of needed sizes:

For release of air only 1:12

For entry as well release of air 1:8

7.2.4 Air Release Valves

Air release valves are designed specifically to vent, automatically and when necessary, air accumulations from lines in which water is flowing. Such accumulations of air tend to collect at high points in the pipeline. Air which accumulates at such peaks, reduces the useful cross sectional area of the pipe, and therefore induces a friction head factor that lowers the pumping capacity of the entire line. The use of air release valves eliminates the possibility of this air binding and permits the flow of water without damage to the pipeline.

Small orifice air valves are designated by their inlet connection size, usually 12 to 50mm diameter. This has nothing to do wit the air release orifice size which may be from 1 to 50mm diameter. The larger the pressure in the pipeline, the smaller need be the orifice size. The volume of air to be released will be a function of the air en trained which is on the average 2% of the volume of water(at atmospheric pressure).

The small orifice release valves are sealed by a floating ball, or needle which is attached to a float. When a certain amount of air has accumulated in the connection on top of the pipe, the ball will drop or the needle valve will open and release the air. Small orifice release valves are often combined with large orifice air vent valves on a common connection on top of the pipe. The arrangement is called a double air valve. An isolating sluice valve is normally fitted between the pipe and the air valves.

Double air valves should be installed at peak in the pipeline, both with respect to the horizontal and the maximum hydraulic gradient. They should also be installed t the ends and intermediate points along a length of pipeline which is parallel to the hydraulic grade line. It should be borne in mind that air may be dragged along in the direction of flow in the pipeline and may even accumulate in sections falling slowly in relation to the hydraulic gradient.

Double air valves should be fitted every 1/2 to 1 KM along descending sections, especially at points where the pipe dip steeply.

Air release valves should also be installed all along ascending lengths of pipeline where air is likely to be released from solution due to the lowering of the pressure, again especially at points of decrease in gradient. Other places where air valves are required are on the discharge side of pumps and at high points on large mains and upstream of orifice plates and reducing tapers.

Air-relief valves are provided at the first summit of the line to remove air that is mechanically entrained as water is drawn in the entrance of the pipeline.

7.2.5 Air Inlet Valves

In the design and operation of large steel pipelines, where gravity flow occurs, considerations must be given to the possibility of collapse in case the internal pressure is reduced below that of atmosphere. Should a break occur in the line at the lower end of a slope, vacuum will in all probability be formed at some point upstream from the break due to the sudden rush of water from the line. To prevent the pipe from collapsing, air inlet(vacuum breaking) valves are used at critical points..

These valves normally held shut by water pressure, automatically open when this pressure is reduced to slightly below atmosphere, permitting large quantities of air to enter the pipe, thus effectively preventing the formation of any vacuum , they also facilitate the initial filling of the line by the expulsion of air wherever the valves are installed.

Air inlet valves should be installed at peaks in the pipeline, both relative to the horizontal and relative to the hydraulic gradient. Various possible hydraulic gradients, including reverse gradients during scouring should be considered. They are normally fitted in combination with an air release valve.

Often air release valves are used in conjunction with them, the purpose of them being to vent air accumulations that may occur at the peaks after the line has been put into operation.

7.2.6 Kinetic Air Valves

In case of ordinary air valve, single orifice(small or large) type, the air or liquid from the pumping mains is ushered in the ball chamber of the air valve from one part of the ball. The disadvantages with these type of valves are that (a) when the ball rises, it does not go down even when air gathers in ball chamber and (b) due to the incoming air, it shakes the ball causing it to adhere to the upper opening that does not fall down until the pressure in the main does not decrease.. The kinetic air valves, counters these deficiencies since the air or water comes from the lower part of the ball and the air rushes around the ball and exerts pressure and slackens the contact with the upper opening and allows the ball to descend..

7.2.7 Pressure Relief Valves

These, also called as overflow towers, are provided in one or more summits of the conveyance main to keep the pressure in the line below given value by causing water to flow to waste when the pressure builds up beyond the design value. Usually they are spring or weight loaded and is not sufficiently responsive to rapid fluctuations of pressure to be used as surge protection devices.

7.2.8 Check Valves

Check valves, also called non-return valves or reflux valves, instinctively averts the turnaround of flow in the pipe. These valves are particularly convenient in rising mains when placed close to pumping stations for the prevention of back-flow, when pumps shut down. The closure of the valves should be such that it will not set up excessive shock conditions within the system.

7.2.8.1 Dual Plate Check Valves

Dual plate check valves employ two spring loaded plates hinged on a central hinge pin. When the flow decreases, the plate close by torsion spring action without requiring reverse flow. As compared to conventional swing check valve which operates on mass movement, the dual plate check valve are provided with accurately designed and tested torsion springs to suit the carrying flow conditions. The Dual plate check valves are of non-slamming type and arrest the tendency of reversal of flow. Presently there is no IS code for the Dual Plate Check Valves.

CHAPTER 9

CONCLUSION

Shimla, having a current population of around 1,95,000 has an established water supply of 54.54MLD, out of which about 7.60 MLD of water supply from the Ashwani Khad is no longer contributing to the current supply and about 7 MLD of water is lost through leakages etc. Hence leaving Shimla with a supply of around 33 MLD. The current water demand being 40 MLD, Shimla is facing a deficiency of about 7 MLD. To bridge up this gap between the demand and water supply, this project has been undertaken to draw water from Koldam reservoir at Sunni.

In this project the design of the Lift Water Supply Scheme (LWSS) has been carried out which includes the design of the rising mains. The cost analysis of laying the rising mains(covering a length 25 km) and the pump system has been worked upon which amounts to about **15,84,137 thousand Rupees**. The most economical diameter of the rising mains has also been calculated which varies from **300mm-500mm**. Four pumping houses are to be installed each at Intake (Sunni), Dwada, Dummi and Naug. The power requirements of these pump houses has also been computed and mentioned in this report.

This project will be providing a measure to counter the current deficiency and also cater the future demands of water supply in Shimla upto the year 2048 by providing a total of 51.09 MLD of water.

CHAPTER 10

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ANNEXURE

Annexure A

Design of Economic Size of Rising Mains/Pumping Mains

Table: 1 Design of Rising Mains from Intake to Devidhar (51 MLD)											
1) Water requirement :					Peak Discharge	Units	Pipe Dia in mm	Material	Class	HWC	Rate Rs/m
A.	Initial				12.77	mld	250	DI	K9	140	2581
B.	Intermediate	(at the end of 1st Stage)			12.77	mld	300	DI	K9	140	3269
C.	Ultimate				25.55	mld	350	DI	K9	140	4075
2) Pumping main				LENGTH	7161	M	400	DI	K9	140	4914
3) Static head for pump				ST.HEAD	700.00	M	450	DI	K9	140	5880
4) Design period				YEAR	30	yr.	500	DI	K9	140	6840
5) Combined eff. of pump set				EFF. %	75	%	600	DI	K9	140	9021
6) Cost of pumping unit				Rs./KW	5000	Rs	700	DI	K9	140	11667
7) Interest rate				INTEREST	10.00	%	800	DI	K9	140	13092
8) Life of electric motor & pump set				P.Yrs	15	yr.	900	DI	K9	140	14445
9) Energy charges per kWh				P/KWH	500	paise	1000	DI	K9	140	17169
10) Pumping hours for discharge at the end of 1st Stage				hours	16	hrs	1100	DI	K9	140	20884
CALCULATIONS:					1st Stage		2nd Stage				
1) Discharge at Start OF PERIOD					12.77	mld	12.77	mld			
2) Discharge at the end of 1st stage					12.77	mld	25.55	mld			
3) Average Flow					148	lps	222	lps			
4) Average Discharge					12.77	mld	19.16	mld			
5) Avg.pumping hours during the period					16.00	hrs	12.00	hrs			
6) KW required at combined efficiency of pumping set					2.90	* H1	4.35	* H2			
7) annual charges for energy Rs.					84681	* KW1	95279	* KW2			
		Modified Hazen William's Formula									
				V=	143.534CR r0.6575 S0.5525						
				h=	[L(Q/CR)1.81]/[994.62D4.81]						

Friction Head Loss (First Stage)

Dia. in mm	L	Q	CR	Q/CR	(Q/CR)1.81	994.62	D	D4.81	h(First Stage)
250mm	1000	0.148	1.000	0.148	0.031	994.620	0.250	0.001	31.160
300mm	1000	0.148	1.000	0.148	0.031	994.620	0.300	0.003	10.380
350mm	1000	0.148	1.000	0.148	0.031	994.620	0.350	0.006	5.190
400mm	1000	0.148	1.000	0.148	0.031	994.620	0.400	0.012	2.591
450mm	1000	0.148	1.000	0.148	0.031	994.620	0.450	0.021	1.471
500mm	1000	0.148	1.000	0.148	0.031	994.620	0.500	0.036	0.886
600mm	1000	0.148	1.000	0.148	0.031	994.620	0.600	0.086	0.369
700mm	1000	0.148	1.000	0.148	0.031	994.620	0.700	0.180	0.176
800mm	1000	0.148	1.000	0.148	0.031	994.620	0.800	0.342	0.092
900mm	1000	0.148	1.000	0.148	0.031	994.620	0.900	0.602	0.052
1000mm	1000	0.148	1.000	0.148	0.031	994.620	1.000	1.000	0.032
1100 mm	1000	0.148	1.000	0.148	0.031	994.620	1.100	1.582	0.020

Velocity

Dia. in mm	143.534	CR	r=A/P=D/4	r0.6575	S	S0.5525	V
250	143.534	1.000	0.063	0.162	0.031	0.147	3.412
300	143.534	1.000	0.075	0.182	0.010	0.080	2.095
350	143.534	1.000	0.088	0.202	0.005	0.055	1.581
400	143.534	1.000	0.100	0.220	0.003	0.037	1.176
450	143.534	1.000	0.113	0.238	0.001	0.027	0.929
500	143.534	1.000	0.125	0.255	0.001	0.021	0.753
600	143.534	1.000	0.150	0.287	0.000	0.013	0.523
700	143.534	1.000	0.175	0.318	0.000	0.008	0.384
800	143.534	1.000	0.200	0.347	0.000	0.006	0.294
900	143.534	1.000	0.225	0.375	0.000	0.004	0.232
1000	143.534	1.000	0.250	0.402	0.000	0.003	0.188
1100	143.534	1.000	0.275	0.428	0.000	0.003	0.156

Friction Head Loss (Second Stage)

Dia. in mm	L	Q	CR	Q/CR	(Q/CR)1.81	994.62	D	D4.81	h(Second Stage)
250mm	1,000.000	0.222	1.000	0.222	0.065	994.620	0.250	0.001	65.350
300mm	1,000.000	0.222	1.000	0.222	0.065	994.620	0.300	0.003	21.549
350mm	1,000.000	0.222	1.000	0.222	0.065	994.620	0.350	0.006	10.266
400mm	1,000.000	0.222	1.000	0.222	0.065	994.620	0.400	0.012	5.401
450mm	1,000.000	0.222	1.000	0.222	0.065	994.620	0.450	0.021	3.065
500mm	1,000.000	0.222	1.000	0.222	0.065	994.620	0.500	0.036	1.846
600mm	1,000.000	0.222	1.000	0.222	0.065	994.620	0.600	0.086	0.768
700mm	1,000.000	0.222	1.000	0.222	0.065	994.620	0.700	0.180	0.366
800mm	1,000.000	0.222	1.000	0.222	0.065	994.620	0.800	0.342	0.193
900mm	1,000.000	0.222	1.000	0.222	0.065	994.620	0.900	0.602	0.109
1000mm	1,000.000	0.222	1.000	0.222	0.065	994.620	1.000	1.000	0.066
1100 mm	1,000.000	0.222	1.000	0.222	0.065	994.620	1.100	1.582	0.042

Velocity

Dia. in mm	143.534	CR	r=A/P=D/4	r0.6575	S	S0.5525	V
250	143.534	1.000	0.063	0.162	0.065	0.222	5.137
300	143.534	1.000	0.075	0.182	0.022	0.120	3.137
350	143.534	1.000	0.088	0.202	0.010	0.080	2.305
400	143.534	1.000	0.100	0.220	0.005	0.056	1.765
450	143.534	1.000	0.113	0.238	0.003	0.041	1.394
500	143.534	1.000	0.125	0.255	0.002	0.031	1.129
600	143.534	1.000	0.150	0.287	0.001	0.019	0.784
700	143.534	1.000	0.175	0.318	0.000	0.013	0.576
800	143.534	1.000	0.200	0.347	0.000	0.009	0.441
900	143.534	1.000	0.225	0.375	0.000	0.006	0.349
1000	143.534	1.000	0.250	0.402	0.000	0.005	0.282
1100	143.534	1.000	0.275	0.428	0.000	0.004	0.233

TABLE: 1.1 VELOCITY AND HEADLOSSES FOR DIFFERENT PIPE SIZES											
S No	Pipe Size in mm	friction head loss per 1000 m		Velocity in m/sec	Velocity in m/sec	Friction head loss	other losses at 10%	total losses (H1) including static head	Friction head loss in total pipe length	other losses at 10%	total losses (H2) including static head
		1st stage flow	2nd stage flow	1st stage flow	2nd stage flow	1st stage flow		700	7161.00		700
									2nd stage flow		
1	250	31.16	65.35	3.41	5.14	223.14	22.31	945.45	467.97	46.80	1214.77
2	300	10.38	21.55	2.10	3.14	74.33	7.43	781.76	154.32	15.43	869.75
3	350	5.19	10.27	1.58	2.30	37.17	3.72	740.88	73.52	7.35	780.87
4	400	2.59	5.40	1.18	1.76	18.56	1.86	720.41	38.68	3.87	742.54
5	450	1.47	3.07	0.93	1.39	10.53	1.05	711.58	21.95	2.19	724.14
6	500	0.89	1.85	0.75	1.13	6.34	0.63	706.98	13.22	1.32	714.54
7	600	0.37	0.77	0.52	0.78	2.64	0.26	702.90	5.50	0.55	706.05
8	700	0.18	0.37	0.38	0.58	1.26	0.13	701.38	2.62	0.26	702.88
9	800	0.09	0.19	0.29	0.44	0.66	0.07	700.73	1.38	0.14	701.52
10	900	0.05	0.11	0.23	0.35	0.38	0.04	700.41	0.78	0.08	700.86
11	1000	0.03	0.07	0.19	0.28	0.23	0.02	700.25	0.47	0.05	700.52
12	1100	0.02	0.04	0.16	0.23	0.14	0.01	700.16	0.30	0.03	700.33

TABLE: 1.2 KILOWATTS & COST OF PUMP SETS REQUIRED FOR DIFFERENT PIPE SIZES AND PIPE COST

			1st stage flow in MLD		12.77		2nd stage flow in MLD		19.16		
S No	Pipe Dia in mm	class of Pipe	H1 total head in meters	KW reqd plus 50% standby	pump cost at Rs per Kw		H2 total head in meters	Kw required plus 50% standby	Pump cost at Rs per KW	cost of pipe per meter	total cost of pipe in thousand Rs
									5000		7161
1	250	K9	945.45	4110	20550		1214.77	7923	39616	2581	18483
2	300	K9	781.76	3398	16992		869.75	5673	28364	3269	23409
3	350	K9	740.88	3221	16103		780.87	5093	25465	4075	29181
4	400	K9	720.41	3132	15658		742.54	4843	24216	4914	29181
5	450	K9	711.58	3093	15467		724.14	4723	23616	5880	42107
6	500	K9	706.98	3073	15366		714.54	4660	23302	6840	48981
7	600	K9	702.90	3056	15278		706.05	4605	23026	7015	50234
8	700	K9	701.38	3049	15245		702.88	4584	22922	9622	68903
9	800	K9	700.73	3046	15231		701.52	4576	22878	12550	89871
10	900	K9	700.41	3045	15224		700.86	4571	22856	15314	109664
11	1000	K9	700.25	3044	15220		700.52	4569	22845	18354	131433
12	1100	K9	700.16	3044	15218		700.33	4568	22839	21600	154678

TABLE: 1.3 COMPARATIVE STATEMENT OF OVERALL COST OF PUMPING MAIN FOR DIFFERENT PIPE SIZES											
	1st stage flow		12.77	mld	2nd stage flow		19.16	mld			
S No	Cost of pump set	Annual Energy Charges	capitalized energy cost	Pump cost+capitalized energy cost	Cost of pump set	Annual Energy Charges	capitalized energy cost	Pump cost+capitalized energy cost	Present cost of pump and capitalized cost of 2nd stage	Pipe Dia	Grand total cost first and second stage
	Thousand Rs	Thousand Rs	Thousand Rs	Thousand Rs	Thousand Rs	Thousand Rs	Thousand Rs	Thousand Rs	Thousand Rs	mm	Thousand Rs
1	20,550	80,062	6,08,951	6,29,501	39,616	1,15,742	8,80,331	9,19,947	2,20,241	250	8,68,224
2	16,992	66,201	5,03,523	5,20,515	28,364	82,868	6,30,298	6,58,661	1,57,688	300	7,01,612
3	16,103	62,739	4,77,191	4,93,295	25,465	74,400	5,65,889	5,91,355	1,41,574	350	6,64,050
4	15,658	61,006	4,64,008	4,79,666	24,216	70,749	5,38,115	5,62,331	1,34,626	400	6,43,473
5	15,467	60,258	4,58,321	4,73,788	23,616	68,996	5,24,780	5,48,396	1,31,289	450	6,47,184
6	15,366	59,868	4,55,355	4,70,721	23,302	68,081	5,17,824	5,41,127	1,29,549	500	6,49,252
7	15,278	59,523	4,52,730	4,68,008	23,026	67,272	5,11,669	5,34,694	1,28,009	600	6,46,251
8	15,245	59,394	4,51,751	4,66,996	22,922	66,970	5,09,373	5,32,295	1,27,435	700	6,63,334
9	15,231	59,338	4,51,329	4,66,559	22,878	66,840	5,08,383	5,31,260	1,27,187	800	6,83,617
10	15,224	59,312	4,51,126	4,66,350	22,856	66,777	5,07,907	5,30,763	1,27,068	900	7,03,081
11	15,220	59,298	4,51,020	4,66,240	22,845	66,745	5,07,659	5,30,504	1,27,006	1,000	7,24,679
12	15,218	59,290	4,50,961	4,66,179	22,839	66,726	5,07,521	5,30,360	1,26,972	1,100	7,47,828
			Minimum Capitalized cost Rs		6,43,473	thousands					

Table: 2 Design of Rising Mains from Dawada to Dummi (35%-17.85MLD)

1) Water requirement :					Peak Discharge	Units	Pipe Dia in mm	Material	Class	HWC	Rate Rs/m
A.	Initial				4.47	mld	250	DI	K9	140	2581
B.	Intermediate	(at the end of 1st Stage)			4.47	mld	300	DI	K9	140	3269
C.	Ultimate				8.94	mld	350	DI	K9	140	4075
2) Pumping main				LENGTH	1914	M	400	DI	K9	140	4914
3) Static head for pump				ST.HEAD	660.00	M	450	DI	K9	140	5880
4) Design period				YEAR	30	yr.	500	DI	K9	140	6840
5) Combined eff. of pump set				EFF. %	75	%	600	DI	K9	140	9021
6) Cost of pumping unit				Rs./KW	5000	Rs	700	DI	K9	140	11667
7) Interest rate				INTEREST	10.00	%	800	DI	K9	140	13092
8) Life of electric motor & pump set				P.Yrs	15	yr.	900	DI	K9	140	14445
9) Energy charges per kWh				P/KWH	500	paise	1000	DI	K9	140	17169
10) Pumping hours for discharge at the end of 1st Stage				hours	16	hrs	1100	DI	K9	140	20884
CALCULATIONS:					1st Stage		2nd Stage				
1) Discharge at Start OF PERIOD					4.47	mld	4.47	mld			
2) Discharge at the end of 1st Stage					4.47	mld	8.94	mld			
3) Average Flow					52	lps	78	lps			
4) Average Discharge					4.47	mld	6.71	mld			
5) Avg.pumping hours during the period					16.00	hrs	12.00	hrs			
6) KW required at combined efficiency of pumping set					1.01	* H1	1.52	* H2			
7) annual charges for energy Rs.					29642	* KW1	33347	* KW2			
		Modified Hazen William's Formula									
				V=	143.534CR r0.6575 S0.5525						
				h=	[L(Q/CR)1.81]/[994.62D4.81]						

Friction Head Loss (First Stage)

Dia. in mm	L	Q	CR	Q/CR	(Q/CR)1.81	994.62	D	D4.81	h(First Stage)
250mm	1000	0.052	1.000	0.052	0.005	994.620	0.250	0.001	5.027
300mm	1000	0.052	1.000	0.052	0.005	994.620	0.300	0.003	1.675
350mm	1000	0.052	1.000	0.052	0.005	994.620	0.350	0.006	0.837
400mm	1000	0.052	1.000	0.052	0.005	994.620	0.400	0.012	0.410
450mm	1000	0.052	1.000	0.052	0.005	994.620	0.450	0.021	0.220
500mm	1000	0.052	1.000	0.052	0.005	994.620	0.500	0.036	0.133
600mm	1000	0.052	1.000	0.052	0.005	994.620	0.600	0.086	0.055
700mm	1000	0.052	1.000	0.052	0.005	994.620	0.700	0.180	0.026
800mm	1000	0.052	1.000	0.052	0.005	994.620	0.800	0.342	0.014
900mm	1000	0.052	1.000	0.052	0.005	994.620	0.900	0.602	0.008
1000mm	1000	0.052	1.000	0.052	0.005	994.620	1.000	1.000	0.005
1100 mm	1000	0.052	1.000	0.052	0.005	994.620	1.100	1.582	0.003

Velocity

Dia. in mm	143.534	CR	r=A/P=D/4	r0.6575	S	S0.5525	V
250	143.534	1.000	0.063	0.162	0.005	0.054	1.245
300	143.534	1.000	0.075	0.182	0.002	0.029	0.765
350	143.534	1.000	0.088	0.202	0.001	0.020	0.577
400	143.534	1.000	0.100	0.220	0.000	0.013	0.425
450	143.534	1.000	0.113	0.238	0.000	0.010	0.325
500	143.534	1.000	0.125	0.255	0.000	0.007	0.263
600	143.534	1.000	0.150	0.287	0.000	0.004	0.183
700	143.534	1.000	0.175	0.318	0.000	0.003	0.134
800	143.534	1.000	0.200	0.347	0.000	0.002	0.103
900	143.534	1.000	0.225	0.375	0.000	0.002	0.081
1000	143.534	1.000	0.250	0.402	0.000	0.001	0.066
1100	143.534	1.000	0.275	0.428	0.000	0.001	0.054

Friction Head Loss (Second Stage)									
Dia. in mm	L	Q	CR	Q/CR	(Q/CR)1.81	994.62	D	D4.81	h(Second Stage)
250mm	1,000.000	0.078	1.000	0.078	0.010	994.620	0.250	0.001	10.054
300mm	1,000.000	0.078	1.000	0.078	0.010	994.620	0.300	0.003	3.351
350mm	1,000.000	0.078	1.000	0.078	0.010	994.620	0.350	0.006	1.675
400mm	1,000.000	0.078	1.000	0.078	0.010	994.620	0.400	0.012	0.807
450mm	1,000.000	0.078	1.000	0.078	0.010	994.620	0.450	0.021	0.458
500mm	1,000.000	0.078	1.000	0.078	0.010	994.620	0.500	0.036	0.276
600mm	1,000.000	0.078	1.000	0.078	0.010	994.620	0.600	0.086	0.115
700mm	1,000.000	0.078	1.000	0.078	0.010	994.620	0.700	0.180	0.055
800mm	1,000.000	0.078	1.000	0.078	0.010	994.620	0.800	0.342	0.029
900mm	1,000.000	0.078	1.000	0.078	0.010	994.620	0.900	0.602	0.016
1000mm	1,000.000	0.078	1.000	0.078	0.010	994.620	1.000	1.000	0.010
1100 mm	1,000.000	0.078	1.000	0.078	0.010	994.620	1.100	1.582	0.006

Velocity							
Dia. in mm	143.534	CR	r=A/P=D/4	r0.6575	S	S0.5525	V
250	143.534	1.000	0.063	0.162	0.010	0.079	1.836
300	143.534	1.000	0.075	0.182	0.003	0.043	1.122
350	143.534	1.000	0.088	0.202	0.002	0.029	0.846
400	143.534	1.000	0.100	0.220	0.001	0.020	0.618
450	143.534	1.000	0.113	0.238	0.000	0.014	0.488
500	143.534	1.000	0.125	0.255	0.000	0.011	0.395
600	143.534	1.000	0.150	0.287	0.000	0.007	0.274
700	143.534	1.000	0.175	0.318	0.000	0.004	0.202
800	143.534	1.000	0.200	0.347	0.000	0.003	0.154
900	143.534	1.000	0.225	0.375	0.000	0.002	0.122
1000	143.534	1.000	0.250	0.402	0.000	0.002	0.099
1100	143.534	1.000	0.275	0.428	0.000	0.001	0.082

TABLE: 2.1 VELOCITY AND HEADLOSSES FOR DIFFERENT PIPE SIZES											
S No	Pipe Size in mm	friction head loss per 1000 m		Velocity in m/sec	Velocity in m/sec	Friction head loss	other losses at 10%	total losses (H1) including static head	Friction head loss in total pipe length	other losses at 10%	total losses (H2) including static head
		1st stage flow	2nd stage flow	1st stage flow	2nd stage flow	1st stage flow		660	1914.00		660
									2nd stage flow		
1	250	5.03	10.05	1.25	1.84	9.62	0.96	670.58	19.24	1.92	681.17
2	300	1.68	3.35	0.76	1.12	3.21	0.32	663.53	6.41	0.64	667.06
3	350	0.84	1.68	0.58	0.85	1.60	0.16	661.76	3.21	0.32	663.53
4	400	0.41	0.81	0.42	0.62	0.78	0.08	660.86	1.55	0.15	661.70
5	450	0.22	0.46	0.33	0.49	0.42	0.04	660.46	0.88	0.09	660.96
6	500	0.13	0.28	0.26	0.40	0.25	0.03	660.28	0.53	0.05	660.58
7	600	0.06	0.11	0.18	0.27	0.11	0.01	660.12	0.22	0.02	660.24
8	700	0.03	0.05	0.13	0.20	0.05	0.01	660.06	0.10	0.01	660.12
9	800	0.01	0.03	0.10	0.15	0.03	0.00	660.03	0.06	0.01	660.06
10	900	0.01	0.02	0.08	0.12	0.02	0.00	660.02	0.03	0.00	660.03
11	1000	0.00	0.01	0.07	0.10	0.01	0.00	660.01	0.02	0.00	660.02
12	1100	0.00	0.01	0.05	0.08	0.01	0.00	660.01	0.01	0.00	660.01

TABLE: 2.2 KILOWATTS & COST OF PUMP SETS REQUIRED FOR DIFFERENT PIPE SIZES AND PIPE COST

			1st stage flow in MLD		4.47		2nd stage flow in MLD		6.71		
S No	Pipe Dia in mm	class of Pipe	H1 total head in meters	KW reqd plus 50% stand by	pump cost at Rs per Kw		H2 total head in meters	Kw required plus 50% stand by	Pump cost at Rs per KW	cost of pipe per meter	total cost of pipe in thousand Rs
									5000		1914
1	250	K9	670.58	1020	5102		681.17	1555	7774	2581	4940
2	300	K9	663.53	1010	5048		667.06	1523	7613	3269	6257
3	350	K9	661.76	1007	5035		663.53	1514	7572	4075	7800
4	400	K9	660.86	1006	5028		661.70	1510	7552	4914	7800
5	450	K9	660.46	1005	5025		660.96	1509	7543	5880	11254
6	500	K9	660.28	1005	5024		660.58	1508	7539	6840	13092
7	600	K9	660.12	1004	5022		660.24	1507	7535	7015	13427
8	700	K9	660.06	1004	5022		660.12	1507	7533	9622	18417
9	800	K9	660.03	1004	5022		660.06	1507	7533	12550	24021
10	900	K9	660.02	1004	5022		660.03	1507	7533	15314	29311
11	1000	K9	660.01	1004	5022		660.02	1506	7532	18354	35130
12	1100	K9	660.01	1004	5021		660.01	1506	7532	21600	41342

TABLE: 2.3 COMPARATIVE STATEMENT OF OVERALL COST OF PUMPING MAIN FOR DIFFERENT PIPE SIZES											
	1st stage flow		4.47	mld	2nd stage flow		6.71	mld			
S No	Cost of pump set	Annual Energy Charges	capitalized energy cost	Pump cost+capitalized energy cost	Cost of pump set	Annual Energy Charges	capitalized energy cost	Pump cost+capitalized energy cost	Present cost of pump and capitalized cost of 2nd stage	Pipe Dia	Grand total cost first and second stage
	Thousand Rs	Thousand Rs	Thousand Rs	Thousand Rs	Thousand Rs	Thousand Rs	Thousand Rs	Thousand Rs	Thousand Rs	mm	Thousand Rs
1	5,102	19,877	1,51,187	1,56,289	7,774	22,715	1,72,769	1,80,543	43,223	250	2,04,452
2	5,048	19,668	1,49,595	1,54,644	7,613	22,244	1,69,190	1,76,803	42,328	300	2,03,228
3	5,035	19,616	1,49,198	1,54,233	7,572	22,127	1,68,295	1,75,867	42,104	350	2,04,136
4	5,028	19,589	1,48,995	1,54,023	7,552	22,066	1,67,832	1,75,383	41,988	400	2,03,810
5	5,025	19,577	1,48,905	1,53,930	7,543	22,041	1,67,645	1,75,188	41,941	450	2,07,125
6	5,024	19,572	1,48,863	1,53,887	7,539	22,028	1,67,548	1,75,087	41,917	500	2,08,895
7	5,022	19,567	1,48,827	1,53,849	7,535	22,017	1,67,462	1,74,997	41,895	600	2,09,171
8	5,022	19,565	1,48,813	1,53,835	7,533	22,013	1,67,430	1,74,963	41,887	700	2,14,139
9	5,022	19,564	1,48,807	1,53,829	7,533	22,011	1,67,416	1,74,949	41,884	800	2,19,733
10	5,022	19,564	1,48,804	1,53,826	7,533	22,010	1,67,409	1,74,942	41,882	900	2,25,019
11	5,022	19,564	1,48,803	1,53,824	7,532	22,010	1,67,406	1,74,938	41,881	1,000	2,30,835
12	5,021	19,564	1,48,802	1,53,823	7,532	22,009	1,67,404	1,74,936	41,881	1,100	2,37,046
			Minimum Capitalized cost Rs		2,03,228	thousands					
			Optimum pipe size corresponds to minimum capitalized cost								

Table: 3 Design of Rising Mains from Dummi to Ridge Tank (17.85MLD)

			Peak Discharge	Units	Pipe Dia in mm	Material	Class	HWC	Rate Rs/m
1) Water requirement :									
A. Initial			4.47	mld	250	DI	K9	140	2581
B. Intermediate	(at the end of 1st Stage)		4.47	mld	300	DI	K9	140	3269
C. Ultimate			8.94	mld	350	DI	K9	140	4075
2) Pumping main		LENGTH	10000	M	400	DI	K9	140	4914
3) Static head for pump		ST.HEAD	370.00	M	450	DI	K9	140	5880
4) Design period		YEAR	30	yr.	500	DI	K9	140	6840
5) Combined eff. of pump set		EFF. %	75	%	600	DI	K9	140	9021
6) Cost of pumping unit		Rs./KW	5000	Rs	700	DI	K9	140	11667
7) Interest rate		INTEREST	10.00	%	800	DI	K9	140	13092
8) Life of electric motor & pump set		P.Yrs	15	yr.	900	DI	K9	140	14445
9) Energy charges per kWh		P/KWH	500	paise	1000	DI	K9	140	17169
10) Pumping hours for discharge at the end of 1st Stage		hours	16	hrs	1100	DI	K9	140	20884

CALCULATIONS:

	1st Stage		2nd Stage	
1) Discharge at Start OF PERIOD	4.47	mld	4.47	mld
2) Discharge at the end of 1st Stage	4.47	mld	8.94	mld
3) Average Flow	52	lps	78	lps
4) Average Discharge	4.47	mld	6.71	mld
5) Avg.pumping hours during the period	16.00	hrs	12.00	hrs
6) KW required at combined efficiency of pumping set	1.01	* H1	1.52	* H2
7) annual charges for energy Rs.	29642	* KW1	33347	* KW2

Modified Hazen William's Formula

$V = 143.534 CR\, r^{0.6575} S^{0.5525}$

$h = [L(Q/CR)^{1.81}]/[994.62 D^{4.81}]$

Friction Head Loss (First Stage)

Dia. in mm	L	Q	CR	Q/CR	(Q/CR)1.81	994.62	D	D4.81	h(First Stage)
250mm	1000	0.052	1.000	0.052	0.005	994.620	0.250	0.001	5.027
300mm	1000	0.052	1.000	0.052	0.005	994.620	0.300	0.003	1.675
350mm	1000	0.052	1.000	0.052	0.005	994.620	0.350	0.006	0.837
400mm	1000	0.052	1.000	0.052	0.005	994.620	0.400	0.012	0.410
450mm	1000	0.052	1.000	0.052	0.005	994.620	0.450	0.021	0.220
500mm	1000	0.052	1.000	0.052	0.005	994.620	0.500	0.036	0.133
600mm	1000	0.052	1.000	0.052	0.005	994.620	0.600	0.086	0.055
700mm	1000	0.052	1.000	0.052	0.005	994.620	0.700	0.180	0.026
800mm	1000	0.052	1.000	0.052	0.005	994.620	0.800	0.342	0.014
900mm	1000	0.052	1.000	0.052	0.005	994.620	0.900	0.602	0.008
1000mm	1000	0.052	1.000	0.052	0.005	994.620	1.000	1.000	0.005
1100 mm	1000	0.052	1.000	0.052	0.005	994.620	1.100	1.582	0.003

Velocity

Dia. in mm	143.534	CR	r=A/P=D/4	r0.6575	S	S0.5525	V
250	143.534	1.000	0.063	0.162	0.005	0.054	1.245
300	143.534	1.000	0.075	0.182	0.002	0.029	0.765
350	143.534	1.000	0.088	0.202	0.001	0.020	0.577
400	143.534	1.000	0.100	0.220	0.000	0.013	0.425
450	143.534	1.000	0.113	0.238	0.000	0.010	0.325
500	143.534	1.000	0.125	0.255	0.000	0.007	0.263
600	143.534	1.000	0.150	0.287	0.000	0.004	0.183
700	143.534	1.000	0.175	0.318	0.000	0.003	0.134
800	143.534	1.000	0.200	0.347	0.000	0.002	0.103
900	143.534	1.000	0.225	0.375	0.000	0.002	0.081
1000	143.534	1.000	0.250	0.402	0.000	0.001	0.066
1100	143.534	1.000	0.275	0.428	0.000	0.001	0.054

Friction Head Loss (Second Stage)

Dia. in mm	L	Q	CR	Q/CR	(Q/CR)1.81	994.62	D	D4.81	h(Second Stage)
250mm	1,000.000	0.078	1.000	0.078	0.010	994.620	0.250	0.001	10.054
300mm	1,000.000	0.078	1.000	0.078	0.010	994.620	0.300	0.003	3.351
350mm	1,000.000	0.078	1.000	0.078	0.010	994.620	0.350	0.006	1.675
400mm	1,000.000	0.078	1.000	0.078	0.010	994.620	0.400	0.012	0.807
450mm	1,000.000	0.078	1.000	0.078	0.010	994.620	0.450	0.021	0.458
500mm	1,000.000	0.078	1.000	0.078	0.010	994.620	0.500	0.036	0.276
600mm	1,000.000	0.078	1.000	0.078	0.010	994.620	0.600	0.086	0.115
700mm	1,000.000	0.078	1.000	0.078	0.010	994.620	0.700	0.180	0.055
800mm	1,000.000	0.078	1.000	0.078	0.010	994.620	0.800	0.342	0.029
900mm	1,000.000	0.078	1.000	0.078	0.010	994.620	0.900	0.602	0.016
1000mm	1,000.000	0.078	1.000	0.078	0.010	994.620	1.000	1.000	0.010
1100 mm	1,000.000	0.078	1.000	0.078	0.010	994.620	1.100	1.582	0.006

Velocity

Dia. in mm	143.534	CR	r=A/P=D/4	r0.6575	S	S0.5525	V
250	143.534	1.000	0.063	0.162	0.010	0.079	1.836
300	143.534	1.000	0.075	0.182	0.003	0.043	1.122
350	143.534	1.000	0.088	0.202	0.002	0.029	0.846
400	143.534	1.000	0.100	0.220	0.001	0.020	0.618
450	143.534	1.000	0.113	0.238	0.000	0.014	0.488
500	143.534	1.000	0.125	0.255	0.000	0.011	0.395
600	143.534	1.000	0.150	0.287	0.000	0.007	0.274
700	143.534	1.000	0.175	0.318	0.000	0.004	0.202
800	143.534	1.000	0.200	0.347	0.000	0.003	0.154
900	143.534	1.000	0.225	0.375	0.000	0.002	0.122
1000	143.534	1.000	0.250	0.402	0.000	0.002	0.099
1100	143.534	1.000	0.275	0.428	0.000	0.001	0.082

TABLE: 3.1 VELOCITY AND HEADLOSSES FOR DIFFERENT PIPE SIZES

S No	Pipe Size in mm	friction head loss per 1000 m		Velocity in m/sec	Velocity in m/sec	Friction head loss	other losses at 10%	total losses (H1) including static head	Friction head loss in total pipe length	other losses at 10%	total losses (H2) including static head
		1st stage flow	2nd stage flow	1st stage flow	2nd stage flow	1st stage flow		370	10000.00		370
									2nd stage flow		
1	250	5.03	10.05	1.25	1.84	50.27	5.03	425.30	100.54	10.05	480.59
2	300	1.68	3.35	0.76	1.12	16.75	1.68	388.43	33.51	3.35	406.86
3	350	0.84	1.68	0.58	0.85	8.37	0.84	379.21	16.75	1.68	388.43
4	400	0.41	0.81	0.42	0.62	4.10	0.41	374.51	8.07	0.81	378.88
5	450	0.22	0.46	0.33	0.49	2.20	0.22	372.42	4.58	0.46	375.04
6	500	0.13	0.28	0.26	0.40	1.33	0.13	371.46	2.76	0.28	373.04
7	600	0.06	0.11	0.18	0.27	0.55	0.06	370.61	1.15	0.11	371.26
8	700	0.03	0.05	0.13	0.20	0.26	0.03	370.29	0.55	0.05	370.60
9	800	0.01	0.03	0.10	0.15	0.14	0.01	370.15	0.29	0.03	370.32
10	900	0.01	0.02	0.08	0.12	0.08	0.01	370.09	0.16	0.02	370.18
11	1000	0.00	0.01	0.07	0.10	0.05	0.00	370.05	0.10	0.01	370.11
12	1100	0.00	0.01	0.05	0.08	0.03	0.00	370.03	0.06	0.01	370.07

TABLE: 3.2 KILOWATTS & COST OF PUMP SETS REQUIRED FOR DIFFERENT PIPE SIZES AND PIPE COST

			1st stage flow in MLD		4.47		2nd stage flow in MLD		6.71		
S No	Pipe Dia in mm	class of Pipe	H1 total head in meters	KW reqd plus 50% standby	pump cost at Rs per Kw		H2 total head in meters	Kw required plus 50% standby	Pump cost at Rs per KW	cost of pipe per meter	total cost of pipe in thousand Rs
									5000		10000
1	250	K9	425.30	647	3236		480.59	1097	5485	2581	25810
2	300	K9	388.43	591	2955		406.86	929	4643	3269	32690
3	350	K9	379.21	577	2885		388.43	887	4433	4075	40750
4	400	K9	374.51	570	2849		378.88	865	4324	4914	40750
5	450	K9	372.42	567	2833		375.04	856	4280	5880	58800
6	500	K9	371.46	565	2826		373.04	851	4257	6840	68400
7	600	K9	370.61	564	2820		371.26	847	4237	7015	70150
8	700	K9	370.29	563	2817		370.60	846	4229	9622	96220
9	800	K9	370.15	563	2816		370.32	845	4226	12550	125500
10	900	K9	370.09	563	2816		370.18	845	4225	15314	153140
11	1000	K9	370.05	563	2815		370.11	845	4224	18354	183540
12	1100	K9	370.03	563	2815		370.07	845	4223	21600	216000

TABLE: 3.3 COMPARATIVE STATEMENT OF OVERALL COST OF PUMPING MAIN FOR DIFFERENT PIPE SIZES										
	1st stage flow		4.47	mld	2nd stage flow		6.71	mld		
S No	Cost of pump set	Annual Energy Charges	capitalized energy cost	Pump cost+capitalized energy cost	Cost of pump set	Annual Energy Charges	capitalized energy cost	Pump cost+capitalized energy cost	Present cost of pump and capitalized cost of	Pipe Dia	Grand total cost first and second stage
	Thousan	Thousand	Thousand	Thousand	Thousand Rs	Thousand	Thousand Rs	Thousand Rs	Thousand	mm	Thousand Rs
1	3,236	12,607	95,885	99,121	5,485	16,026	1,21,896	1,27,381	30,496	250	1,55,427
2	2,955	11,514	87,572	90,528	4,643	13,568	1,03,195	1,07,838	25,817	300	1,49,035
3	2,885	11,240	85,494	88,379	4,433	12,953	98,519	1,02,952	24,647	350	1,53,777
4	2,849	11,101	84,435	87,285	4,324	12,635	96,099	1,00,422	24,042	400	1,52,076
5	2,833	11,039	83,964	86,797	4,280	12,506	95,124	99,404	23,798	450	1,69,395
6	2,826	11,011	83,747	86,573	4,257	12,440	94,616	98,873	23,671	500	1,78,644
7	2,820	10,985	83,555	86,375	4,237	12,381	94,166	98,403	23,558	600	1,80,083
8	2,817	10,976	83,484	86,301	4,229	12,358	93,998	98,228	23,516	700	2,06,037
9	2,816	10,972	83,453	86,269	4,226	12,349	93,926	98,152	23,498	800	2,35,267
10	2,816	10,970	83,438	86,254	4,225	12,344	93,891	98,116	23,490	900	2,62,883
11	2,815	10,969	83,430	86,246	4,224	12,342	93,873	98,097	23,485	1,000	2,93,271
12	2,815	10,968	83,426	86,241	4,223	12,341	93,863	98,086	23,483	1,100	3,25,724
			Minimum Capitalized		1,49,035	thousands					
			Optimum pipe size corresponds to minimum capitalized cost								

Table: 4 Design of Rising Mains from Dawada to Naug (65%-33.15MLD)											
1) Water requirement :					Peak Discharge	Units	Pipe Dia in mm	Material	Class	HWC	Rate Rs/m
A.	Initial				8.30	mld	250	DI	K9	140	2581
B.	Intermediate	(at the end of 1st Stage)			8.30	mld	300	DI	K9	140	3269
C.	Ultimate				16.60	mld	350	DI	K9	140	4075
2) Pumping main				LENGTH	6100	M	400	DI	K9	140	4914
3) Static head for pump				ST.HEAD	344.00	M	450	DI	K9	140	5880
4) Design period				YEAR	30	yr.	500	DI	K9	140	6840
5) Combined eff. of pump set				EFF. %	75	%	600	DI	K9	140	9021
6) Cost of pumping unit				Rs./KW	5000	Rs	700	DI	K9	140	11667
7) Interest rate				INTEREST	10.00	%	800	DI	K9	140	13092
8) Life of electric motor & pump set				P.Yrs	15	yr.	900	DI	K9	140	14445
9) Energy charges per kWh				P/KWH	500	paise	1000	DI	K9	140	17169
10) Pumping hours for discharge at the end of 1st Stage				hours	16	hrs	1100	DI	K9	140	20884
CALCULATIONS:					1st Stage		2nd Stage				
1) Discharge at Start OF PERIOD					8.30	mld	8.30	mld			
2) Discharge at the end of 1st Stage					8.30	mld	16.60	mld			
3) Average Flow					96	lps	144	lps			
4) Average Discharge					8.30	mld	12.45	mld			
5) Avg.pumping hours during the period					16.00	hrs	12.00	hrs			
6) KW required at combined efficiency of pumping set					1.88	* H1	2.83	* H2			
7) annual charges for energy Rs.					55039	* KW1	61919	* KW2			
		Modified Hazen William's Formula									
				V=	143.534CR r0.6575 S0.5525						
				h=	[L(Q/CR)1.81]/[994.62D4.81]						

Friction Head Loss (First Stage)

Dia. in mm	L	Q	CR	Q/CR	(Q/CR)1.81	994.62	D	D4.81	h(First Stage)
250mm	1000	0.096	1.000	0.096	0.014	994.620	0.250	0.001	14.070
300mm	1000	0.096	1.000	0.096	0.014	994.620	0.300	0.003	4.690
350mm	1000	0.096	1.000	0.096	0.014	994.620	0.350	0.006	2.340
400mm	1000	0.096	1.000	0.096	0.014	994.620	0.400	0.012	1.173
450mm	1000	0.096	1.000	0.096	0.014	994.620	0.450	0.021	0.674
500mm	1000	0.096	1.000	0.096	0.014	994.620	0.500	0.036	0.406
600mm	1000	0.096	1.000	0.096	0.014	994.620	0.600	0.086	0.169
700mm	1000	0.096	1.000	0.096	0.014	994.620	0.700	0.180	0.081
800mm	1000	0.096	1.000	0.096	0.014	994.620	0.800	0.342	0.042
900mm	1000	0.096	1.000	0.096	0.014	994.620	0.900	0.602	0.024
1000mm	1000	0.096	1.000	0.096	0.014	994.620	1.000	1.000	0.014
1100 mm	1000	0.096	1.000	0.096	0.014	994.620	1.100	1.582	0.009

Velocity

Dia. in mm	143.534	CR	r=A/P=D/4	r0.6575	S	S0.5525	V
250	143.534	1.000	0.063	0.162	0.014	0.095	2.199
300	143.534	1.000	0.075	0.182	0.005	0.052	1.351
350	143.534	1.000	0.088	0.202	0.002	0.035	1.018
400	143.534	1.000	0.100	0.220	0.001	0.024	0.759
450	143.534	1.000	0.113	0.238	0.001	0.018	0.604
500	143.534	1.000	0.125	0.255	0.000	0.013	0.489
600	143.534	1.000	0.150	0.287	0.000	0.008	0.340
700	143.534	1.000	0.175	0.318	0.000	0.005	0.250
800	143.534	1.000	0.200	0.347	0.000	0.004	0.191
900	143.534	1.000	0.225	0.375	0.000	0.003	0.151
1000	143.534	1.000	0.250	0.402	0.000	0.002	0.122
1100	143.534	1.000	0.275	0.428	0.000	0.002	0.101

Friction Head Loss (Second Stage)									
Dia. in mm	L	Q	CR	Q/CR	(Q/CR)1.81	994.62	D	D4.81	h(Second Stage)
250mm	1,000.000	0.144	1.000	0.144	0.030	994.620	0.250	0.001	30.162
300mm	1,000.000	0.144	1.000	0.144	0.030	994.620	0.300	0.003	10.050
350mm	1,000.000	0.144	1.000	0.144	0.030	994.620	0.350	0.006	5.027
400mm	1,000.000	0.144	1.000	0.144	0.030	994.620	0.400	0.012	2.475
450mm	1,000.000	0.144	1.000	0.144	0.030	994.620	0.450	0.021	1.405
500mm	1,000.000	0.144	1.000	0.144	0.030	994.620	0.500	0.036	0.846
600mm	1,000.000	0.144	1.000	0.144	0.030	994.620	0.600	0.086	0.352
700mm	1,000.000	0.144	1.000	0.144	0.030	994.620	0.700	0.180	0.168
800mm	1,000.000	0.144	1.000	0.144	0.030	994.620	0.800	0.342	0.088
900mm	1,000.000	0.144	1.000	0.144	0.030	994.620	0.900	0.602	0.050
1000mm	1,000.000	0.144	1.000	0.144	0.030	994.620	1.000	1.000	0.030
1100 mm	1,000.000	0.144	1.000	0.144	0.030	994.620	1.100	1.582	0.019

Velocity							
Dia. in mm	143.534	CR	r=A/P=D/4	r0.6575	S	S0.5525	V
250	143.534	1.000	0.063	0.162	0.030	0.145	3.351
300	143.534	1.000	0.075	0.182	0.010	0.079	2.058
350	143.534	1.000	0.088	0.202	0.005	0.054	1.553
400	143.534	1.000	0.100	0.220	0.002	0.036	1.147
450	143.534	1.000	0.113	0.238	0.001	0.027	0.906
500	143.534	1.000	0.125	0.255	0.001	0.020	0.734
600	143.534	1.000	0.150	0.287	0.000	0.012	0.510
700	143.534	1.000	0.175	0.318	0.000	0.008	0.374
800	143.534	1.000	0.200	0.347	0.000	0.006	0.287
900	143.534	1.000	0.225	0.375	0.000	0.004	0.226
1000	143.534	1.000	0.250	0.402	0.000	0.003	0.183
1100	143.534	1.000	0.275	0.428	0.000	0.002	0.152

TABLE: 4.1 VELOCITY AND HEADLOSSES FOR DIFFERENT PIPE SIZES

S No	Pipe Size in mm	friction head loss per 1000 m		Velocity in m/sec	Velocity in m/sec	Friction head loss	other losses at 10%	total losses (H1) including static head	Friction head loss in total pipe length	other losses at 10%	total losses (H2) including static head
		1st stage flow	2nd stage flow	1st stage flow	2nd stage flow	1st stage flow		344	6100.00		344
									2nd stage flow		
1	250	14.07	30.16	2.20	3.35	85.83	8.58	438.41	183.99	18.40	546.39
2	300	4.69	10.05	1.35	2.06	28.61	2.86	375.47	61.31	6.13	411.44
3	350	2.34	5.03	1.02	1.55	14.27	1.43	359.70	30.66	3.07	377.73
4	400	1.17	2.48	0.76	1.15	7.16	0.72	351.87	15.10	1.51	360.61
5	450	0.67	1.40	0.60	0.91	4.11	0.41	348.52	8.57	0.86	353.42
6	500	0.41	0.85	0.49	0.73	2.48	0.25	346.73	5.16	0.52	349.68
7	600	0.17	0.35	0.34	0.51	1.03	0.10	345.13	2.15	0.21	346.36
8	700	0.08	0.17	0.25	0.37	0.49	0.05	344.54	1.02	0.10	345.13
9	800	0.04	0.09	0.19	0.29	0.26	0.03	344.28	0.54	0.05	344.59
10	900	0.02	0.05	0.15	0.23	0.15	0.01	344.16	0.31	0.03	344.34
11	1000	0.01	0.03	0.12	0.18	0.09	0.01	344.10	0.18	0.02	344.20
12	1100	0.01	0.02	0.10	0.15	0.06	0.01	344.06	0.12	0.01	344.13

TABLE: 4.2 KILOWATTS & COST OF PUMP SETS REQUIRED FOR DIFFERENT PIPE SIZES AND PIPE COST

			1st stage flow in MLD		8.30		2nd stage flow in MLD		12.45		
S No	Pipe Dia in mm	class of Pipe	H1 total head in meters	KW reqd plus 50% stand by	pump cost at Rs per Kw		H2 total head in meters	Kw required plus 50% stand by	Pump cost at Rs per KW	cost of pipe per meter	total cost of pipe in thousand Rs
									5000		6100
1	250	K9	438.41	1239	6193		546.39	2316	11578	2581	15744
2	300	K9	375.47	1061	5304		411.44	1744	8719	3269	19941
3	350	K9	359.70	1016	5082		377.73	1601	8004	4075	24858
4	400	K9	351.87	994	4971		360.61	1528	7642	4914	24858
5	450	K9	348.52	985	4924		353.42	1498	7489	5880	35868
6	500	K9	346.73	980	4898		349.68	1482	7410	6840	41724
7	600	K9	345.13	975	4876		346.36	1468	7340	7015	42792
8	700	K9	344.54	973	4867		345.13	1463	7313	9622	58694
9	800	K9	344.28	973	4864		344.59	1460	7302	12550	76555
10	900	K9	344.16	972	4862		344.34	1459	7297	15314	93415
11	1000	K9	344.10	972	4861		344.20	1459	7294	18354	111959
12	1100	K9	344.06	972	4861		344.13	1458	7292	21600	131760

TABLE: 4.3 COMPARATIVE STATEMENT OF OVERALL COST OF PUMPING MAIN FOR DIFFERENT PIPE SIZES

	1st stage flow		8.30	mld	2nd stage flow		12.45	mld			
S No	Cost of pump set	Annual Energy Charges	capitalized energy cost	Pump cost+capitalized energy cost	Cost of pump set	Annual Energy Charges	capitalized energy cost	Pump cost+capitalized energy cost	Present cost of pump and capitalized cost of 2nd stage	Pipe Dia	Grand total cost first and second stage
	Thousand Rs	Thousand Rs	Thousand Rs	Thousand Rs	Thousand Rs	Thousand Rs	Thousand Rs	Thousand Rs	Thousand Rs	mm	Thousand Rs
1	6,193	24,130	1,83,532	1,89,725	11,578	33,832	2,57,326	2,68,904	64,377	250	2,69,847
2	5,304	20,666	1,57,183	1,62,487	8,719	25,476	1,93,769	2,02,488	48,477	300	2,30,905
3	5,082	19,798	1,50,582	1,55,663	8,004	23,389	1,77,896	1,85,900	44,506	350	2,25,027
4	4,971	19,367	1,47,304	1,52,275	7,642	22,329	1,69,832	1,77,473	42,488	400	2,19,620
5	4,924	19,183	1,45,903	1,50,827	7,489	21,884	1,66,449	1,73,938	41,642	450	2,28,336
6	4,898	19,084	1,45,150	1,50,048	7,410	21,652	1,64,684	1,72,094	41,200	500	2,32,972
7	4,876	18,996	1,44,484	1,49,359	7,340	21,447	1,63,122	1,70,462	40,810	600	2,32,961
8	4,867	18,963	1,44,235	1,49,102	7,313	21,370	1,62,540	1,69,853	40,664	700	2,48,461
9	4,864	18,949	1,44,128	1,48,992	7,302	21,337	1,62,289	1,69,591	40,601	800	2,66,148
10	4,862	18,942	1,44,076	1,48,938	7,297	21,321	1,62,168	1,69,465	40,571	900	2,82,925
11	4,861	18,939	1,44,050	1,48,911	7,294	21,313	1,62,105	1,69,399	40,555	1,000	3,01,425
12	4,861	18,937	1,44,035	1,48,895	7,292	21,308	1,62,070	1,69,363	40,546	1,100	3,21,202
			Minimum Capitalized cost Rs		2,19,620	thousands					
			Optimum pipe size corresponds to minimum capitalized cost								

Table: 5 Design of Rising Mains from Naug to Museum Hill (33.15 MLD)

		Peak Discharge	Units	Pipe Dia in mm	Material	Class	HWC	Rate Rs/m
1) Water requirement :								
A. Initial		8.30	mld	250	DI	K9	140	2581
B. Intermediate (at the end of 1st Stage)		8.30	mld	300	DI	K9	140	3269
C. Ultimate		16.60	mld	350	DI	K9	140	4075
2) Pumping main	LENGTH	3201	M	400	DI	K9	140	4914
3) Static head for pump	ST.HEAD	641.00	M	450	DI	K9	140	5880
4) Design period	YEAR	30	yr.	500	DI	K9	140	6840
5) Combined eff. of pump set	EFF. %	75	%	600	DI	K9	140	9021
6) Cost of pumping unit	Rs./KW	5000	Rs	700	DI	K9	140	11667
7) Interest rate	INTEREST	10.00	%	800	DI	K9	140	13092
8) Life of electric motor & pump set	P.Yrs	15	yr.	900	DI	K9	140	14445
9) Energy charges per kWh	P/KWH	500	paise	1000	DI	K9	140	17169
10) Pumping hours for discharge at the end of 1st Stage	hours	16	hrs	1100	DI	K9	140	20884
CALCULATIONS:		1st Stage		2nd Stage				
1) Discharge at Start OF PERIOD		8.30	mld	8.30	mld			
2) Discharge at the end of 1st Stage		8.30	mld	16.60	mld			
3) Average Flow		96	lps	144	lps			
4) Average Discharge		8.30	mld	12.45	mld			
5) Avg.pumping hours during the period		16.00	hrs	12.00	hrs			
6) KW required at combined efficiency of pumping set		1.88	* H1	2.83	* H2			
7) annual charges for energy Rs.		55039	* KW1	61919	* KW2			

Friction Head Loss (First Stage)

Dia. in mm	L	Q	CR	Q/CR	(Q/CR)1.81	994.62	D	D4.81	h(First Stage)
250mm	1000	0.096	1.000	0.096	0.014	994.620	0.250	0.001	14.070
300mm	1000	0.096	1.000	0.096	0.014	994.620	0.300	0.003	4.690
350mm	1000	0.096	1.000	0.096	0.014	994.620	0.350	0.006	2.340
400mm	1000	0.096	1.000	0.096	0.014	994.620	0.400	0.012	1.173
450mm	1000	0.096	1.000	0.096	0.014	994.620	0.450	0.021	0.674
500mm	1000	0.096	1.000	0.096	0.014	994.620	0.500	0.036	0.406
600mm	1000	0.096	1.000	0.096	0.014	994.620	0.600	0.086	0.169
700mm	1000	0.096	1.000	0.096	0.014	994.620	0.700	0.180	0.081
800mm	1000	0.096	1.000	0.096	0.014	994.620	0.800	0.342	0.042
900mm	1000	0.096	1.000	0.096	0.014	994.620	0.900	0.602	0.024
1000mm	1000	0.096	1.000	0.096	0.014	994.620	1.000	1.000	0.014
1100 mm	1000	0.096	1.000	0.096	0.014	994.620	1.100	1.582	0.009

Velocity

Dia. in mm	143.534	CR	r=A/P=D/4	r0.6575	S	S0.5525	V
250	143.534	1.000	0.063	0.162	0.014	0.095	2.199
300	143.534	1.000	0.075	0.182	0.005	0.052	1.351
350	143.534	1.000	0.088	0.202	0.002	0.035	1.018
400	143.534	1.000	0.100	0.220	0.001	0.024	0.759
450	143.534	1.000	0.113	0.238	0.001	0.018	0.604
500	143.534	1.000	0.125	0.255	0.000	0.013	0.489
600	143.534	1.000	0.150	0.287	0.000	0.008	0.340
700	143.534	1.000	0.175	0.318	0.000	0.005	0.250
800	143.534	1.000	0.200	0.347	0.000	0.004	0.191
900	143.534	1.000	0.225	0.375	0.000	0.003	0.151
1000	143.534	1.000	0.250	0.402	0.000	0.002	0.122
1100	143.534	1.000	0.275	0.428	0.000	0.002	0.101

Friction Head Loss (Second Stage)

Dia. in mm	L	Q	CR	Q/CR	(Q/CR)1.81	994.62	D	D4.81	h(Second Stage)
250mm	1,000.000	0.144	1.000	0.144	0.030	994.620	0.250	0.001	30.162
300mm	1,000.000	0.144	1.000	0.144	0.030	994.620	0.300	0.003	10.050
350mm	1,000.000	0.144	1.000	0.144	0.030	994.620	0.350	0.006	5.027
400mm	1,000.000	0.144	1.000	0.144	0.030	994.620	0.400	0.012	2.475
450mm	1,000.000	0.144	1.000	0.144	0.030	994.620	0.450	0.021	1.405
500mm	1,000.000	0.144	1.000	0.144	0.030	994.620	0.500	0.036	0.846
600mm	1,000.000	0.144	1.000	0.144	0.030	994.620	0.600	0.086	0.352
700mm	1,000.000	0.144	1.000	0.144	0.030	994.620	0.700	0.180	0.168
800mm	1,000.000	0.144	1.000	0.144	0.030	994.620	0.800	0.342	0.088
900mm	1,000.000	0.144	1.000	0.144	0.030	994.620	0.900	0.602	0.050
1000mm	1,000.000	0.144	1.000	0.144	0.030	994.620	1.000	1.000	0.030
1100 mm	1,000.000	0.144	1.000	0.144	0.030	994.620	1.100	1.582	0.019

Velocity

Dia. in mm	143.534	CR	r=A/P=D/4	r0.6575	S	S0.5525	V
250	143.534	1.000	0.063	0.162	0.030	0.145	3.351
300	143.534	1.000	0.075	0.182	0.010	0.079	2.058
350	143.534	1.000	0.088	0.202	0.005	0.054	1.553
400	143.534	1.000	0.100	0.220	0.002	0.036	1.147
450	143.534	1.000	0.113	0.238	0.001	0.027	0.906
500	143.534	1.000	0.125	0.255	0.001	0.020	0.734
600	143.534	1.000	0.150	0.287	0.000	0.012	0.510
700	143.534	1.000	0.175	0.318	0.000	0.008	0.374
800	143.534	1.000	0.200	0.347	0.000	0.006	0.287
900	143.534	1.000	0.225	0.375	0.000	0.004	0.226
1000	143.534	1.000	0.250	0.402	0.000	0.003	0.183
1100	143.534	1.000	0.275	0.428	0.000	0.002	0.152

TABLE: 5.1 VELOCITY AND HEADLOSSES FOR DIFFERENT PIPE SIZES

S No	Pipe Size in mm	friction head loss per 1000 m		Velocity in m/sec	Velocity in m/sec	Friction head loss	other losses at 10%	total losses (H1) including static head	Friction head loss in total pipe length	other losses at 10%	total losses (H2) including static head
		1st stage flow	2nd stage flow	1st stage flow	2nd stage flow	1st stage flow		641	3201.00		641
									2nd stage flow		
1	250	14.07	30.16	2.20	3.35	45.04	4.50	690.54	96.55	9.65	747.20
2	300	4.69	10.05	1.35	2.06	15.01	1.50	657.51	32.17	3.22	676.39
3	350	2.34	5.03	1.02	1.55	7.49	0.75	649.24	16.09	1.61	658.70
4	400	1.17	2.48	0.76	1.15	3.75	0.38	645.13	7.92	0.79	649.72
5	450	0.67	1.40	0.60	0.91	2.16	0.22	643.37	4.50	0.45	645.95
6	500	0.41	0.85	0.49	0.73	1.30	0.13	642.43	2.71	0.27	643.98
7	600	0.17	0.35	0.34	0.51	0.54	0.05	641.60	1.13	0.11	642.24
8	700	0.08	0.17	0.25	0.37	0.26	0.03	641.28	0.54	0.05	641.59
9	800	0.04	0.09	0.19	0.29	0.14	0.01	641.15	0.28	0.03	641.31
10	900	0.02	0.05	0.15	0.23	0.08	0.01	641.08	0.16	0.02	641.18
11	1000	0.01	0.03	0.12	0.18	0.05	0.00	641.05	0.10	0.01	641.11
12	1100	0.01	0.02	0.10	0.15	0.03	0.00	641.03	0.06	0.01	641.07

TABLE: 5.2 KILOWATTS & COST OF PUMP SETS REQUIRED FOR DIFFERENT PIPE SIZES AND PIPE COST

			1st stage flow in MLD		8.30		2nd stage flow in MLD		12.45		
S No	Pipe Dia in mm	class of Pipe	H1 total head in meters	KW reqd plus 50% stand by	pump cost at Rs per Kw		H2 total head in meters	Kw required plus 50% standby	Pump cost at Rs per KW	cost of pipe per meter	total cost of pipe in thousand Rs
									5000		3201
1	250	K9	690.54	1951	9755		747.20	3167	15834	2581	8262
2	300	K9	657.51	1858	9289		676.39	2867	14333	3269	10464
3	350	K9	649.24	1834	9172		658.70	2792	13958	4075	13044
4	400	K9	645.13	1823	9114		649.72	2754	13768	4914	13044
5	450	K9	643.37	1818	9089		645.95	2738	13688	5880	18822
6	500	K9	642.43	1815	9076		643.98	2729	13646	6840	21895
7	600	K9	641.60	1813	9064		642.24	2722	13610	7015	22455
8	700	K9	641.28	1812	9060		641.59	2719	13596	9622	30800
9	800	K9	641.15	1812	9058		641.31	2718	13590	12550	40173
10	900	K9	641.08	1811	9057		641.18	2717	13587	15314	49020
11	1000	K9	641.05	1811	9056		641.11	2717	13586	18354	58751
12	1100	K9	641.03	1811	9056		641.07	2717	13585	21600	69142

TABLE: 5.3 COMPARATIVE STATEMENT OF OVERALL COST OF PUMPING MAIN FOR DIFFERENT PIPE SIZES											
	1st stage flow		8.30	mld	2nd stage flow		12.45	mld			
S No	Cost of pump set	Annual Energy Charges	capitalized energy cost	Pump cost+capitalized energy cost	Cost of pump set	Annual Energy Charges	capitalized energy cost	Pump cost+capitalized energy cost	Present cost of pump and capitalized cost of 2nd stage	Pipe Dia	Grand total cost first and second stage
	Thousand Rs	Thousand Rs	Thousand Rs	Thousand Rs	Thousand Rs	Thousand Rs	Thousand Rs	Thousand Rs	Thousand Rs	mm	Thousand Rs
1	9,755	38,007	2,89,082	2,98,837	15,834	46,266	3,51,902	3,67,736	88,038	250	3,95,137
2	9,289	36,189	2,75,255	2,84,544	14,333	41,881	3,18,551	3,32,884	79,694	300	3,74,703
3	9,172	35,734	2,71,791	2,80,963	13,958	40,786	3,10,221	3,24,179	77,611	350	3,71,618
4	9,114	35,508	2,70,071	2,79,185	13,768	40,230	3,05,989	3,19,757	76,552	400	3,68,781
5	9,089	35,411	2,69,336	2,78,425	13,688	39,997	3,04,214	3,17,902	76,108	450	3,73,355
6	9,076	35,359	2,68,941	2,78,017	13,646	39,875	3,03,288	3,16,934	75,876	500	3,75,787
7	9,064	35,313	2,68,591	2,77,655	13,610	39,767	3,02,469	3,16,078	75,671	600	3,75,781
8	9,060	35,296	2,68,461	2,77,520	13,596	39,727	3,02,163	3,15,759	75,595	700	3,83,915
9	9,058	35,289	2,68,404	2,77,462	13,590	39,710	3,02,031	3,15,621	75,562	800	3,93,196
10	9,057	35,285	2,68,377	2,77,434	13,587	39,701	3,01,968	3,15,555	75,546	900	4,02,000
11	9,056	35,283	2,68,363	2,77,420	13,586	39,697	3,01,935	3,15,520	75,538	1,000	4,11,708
12	9,056	35,282	2,68,356	2,77,412	13,585	39,695	3,01,916	3,15,501	75,533	1,100	4,22,086
			Minimum Capitalized cost Rs		3,68,781	thousands					
			Optimum pipe size corresponds to minimum capitalized cost								

ANNEXURE B

Pump House Power Requirement

- Locations of Pump House

1. Sunni
2. Dwada
3. Dummi
4. Naug

- Kilowatts required for each rising main (including 50% standby)

a) From Sunni (intake) to Dwada

First stage	Second stage
1.5*2.90*H1	1.5*4.35*H2
1.5*2.90*720.41	1.5*4.35*742.54
3132 KW	4843 KW

b) From Dwada to Dummi

First stage	Second stage
1.5*1.01*H1	1.5*1.52*H2
1.5*1.01*663.53	1.5*1.52*667.06
1010 KW	1523 KW

c) From Dummi to Ridge tank

First stage	Second stage
1.5*1.01*H1	1.5*1.52*H2
1.5*1.01*390.27	1.5*1.52*410.55
594 KW	937 KW

d) From Dwada to Naug

First stage	Second stage
1.5*1.88*H1	1.5*2.83*H2
1.5*1.88*351.87	1.5*2.83*360.61
994 KW	1528 KW

e) From Naug to Museum hill

First stage	Second stage
1.5*1.88*H1	1.5*2.83*H2
1.5*1.88*645.13	1.5*2.83*649.72
1823 KW	2754 KW