Project Report (TD696)

on

Understanding Groundwater Flows in Hilly Watersheds of Jawhar and Mokhada from Water Security Perspective

Submitted in partial fulfilment for the degree of M. Tech.
in Technology & Development

by

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Dissertation Approval Sheet

This dissertation titled **"Understanding Groundwater Flows in Hilly Watersheds of Jawhar and Mokhada from Water Security Perspective"** prepared by Lakshmikantha N R (Roll no: 153350020) is approved for the degree of **Master of Technology** in Technology and Development.

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<u>Declaration</u>

I hereby declare that the report **"Understanding groundwater flows in hilly watersheds of Jawhar and Mokhada from water security perspective"** submitted by me, for the partial fulfilment of the degree of Master of Technology to CTARA, IIT Bombay is a record of the work carried out by me under the supervision of Prof. Milind A Sohoni.

I further declare that this written submission represents my ideas in my own words and where other's ideas or words have been included, I have adequately cited and referenced the original sources. I affirm that I have adhered to all principles of academic honesty and integrity and have not misrepresented or falsified any idea/data/fact/source to the best of my knowledge. I understand that any violation of the above will cause for disciplinary action by the Institute and can also evoke penal action from the sources which have not been cited properly.

Place: Mumbai

Date: 04-07-2017

Signature of the candidate

Acknowledgement

It is matter of great pleasure for me to submit this report on **“Understanding groundwater flows in hilly watersheds of Jawhar and Mokhada from water security perspective”** as a part curriculum of **TD-696** of Centre for Technology Alternatives for Rural Areas (CTARA) with specialization in Technology & Development from IIT Bombay.

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Abstract

This study is motivated by two key problems faced by rural citizens of Jawhar and Mokhada taluka of Palghar district in North Konkan, viz., year-round access to drinking water, and the question of year-around employment, particularly, the possibility of a second crop, in the area. Palghar is the northern most district of Konkan, and the area of interest is largely hilly, with thin soils, semi-forested and receives in excess of 2000mm rainfall in the monsoon months. However, beginning January, many of the streams are dry and there is substantial drinking water stress as well as hardly any second-cropping. It is though the watershed interventions, grouped as so-called area and drain-line treatments, will bring respite. Our study aims to add to the field understanding of these watersheds. We study 3 key watersheds in the area with different geo-morphologies and land use. We then (i) periodically measure and study the flows at several (16) locations, and (ii) locate and study well water levels in 83 locations, important from drinking water as well as hydrological viewpoint. Based on this study, we make the following observations. (1) Stream flows (base flows) diminish rapidly, halving roughly every 16-22 days. The time constants seem oblivious to forest cover or land use features. (2) The magnitude of these flows are small and are negatively correlated with forest cover. This is in consonance with several earlier studies. This also precludes the possibility of extensive second cropping. (3) Wells water level show a drop rate ranging from 0-80mm/day. However, forest cover and large well-watersheds, both separately seem to ensure low drop rates and perenniality. This indicates the benefits of area-treatment and also guides the choice of new well locations. Coming to drainage-line watershed interventions, we see that they seem to help in extending well water availability. However, a more detailed analysis is required.

The combination of well-levels and flows taken together also seem to indicate that soil-moisture as a stock and evapo-transpiration as a flow, are important to the understanding of regional water availability. Moreover, soil moisture seems to interact throughout the year with the deeper groundwater and contributes to post-monsoon stream-flows which are traditionally attributed to baseflows, i.e., groundwater flows discharging into streams. Using our stream-flow and well-data, we re-compute the groundwater assessment as would have been done by GSDA and analyse the discrepancy. We show that a periodic and seasonal estimation reveals the true drought-like conditions which prevail on the ground.

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Abbreviations

CCT	Continuous Contour Trenches
CGWB	Central Ground Water Board
CNBs	Concrete Nala Bunds
DEM	Digital Elevation Model
DW	Drinking Water
ENBs	Earthern Nala Bunds
ET	Evapotranspiration
FW	Farm Well
GEC 97	Groundwater Estimation Methodology 1997
GIS	Geographic Information System
GMS	Groundwater Modelling Software
GoI	Government of India
GoM	Government of Maharashtra
GP	Gram Panchayat
GRASS	Geographic Resources Analysis Support System
GSDA	Ground Water Surveys and Development Agency
HH	House Holds
IWMP	Integrated Watershed Management Programme
JYS	Jal Yukt Shivar Abhiyan
KT Weir	Kolhapur Type Weir
LBS	Loose Boulder Structures
LULC	Land Use and Land Cover
MFP	Minor Forest Produces
MGNREGS	Mahatma Gandhi National Rural Employment Guarantee Scheme
MODIS	Moderate Resolution Imaging Spectro radiometer
MRSAC	Maharashtra Remote Sensing Applications Centre
NRDWP	National Rural Drinking Water Programme
NTFPs	Non-Timber Forest Produces
PDW	Primary Drinking Water
QGIS	Quantum Geographic Information System
ROIs	Region of Interests
RPM	Rotation Per Minute
SCP	Semiautomatic Classification Plugin
SDW	Secondary Drinking Water
SRTM	Shuttle Radar Topography Mission
Sy	Specific Yield
USGS	United States Geological Survey

WF	West Flowing
WLF	Water Level Fluctuation

Chapter 1

1 Introduction

1.1 Motivation

Water, the life driving force, the entity/elementary part of nature is more than "Roti, Kapda, Makan". The availability and accessibility of water in the surroundings has driven civilizations. If water is not available(temporally) and not accessible(spatially), then a whole lot of things start to fall apart. This thesis aims to study the interaction between surface water and groundwater and its temporal and spatial availability in parts of Palghar district, in North Konkan.

Prior to 1980s groundwater stress was relatively insignificant in the state of Maharashtra (GoM, Report on dynamic Ground Water Resource 2011-12, 2014) but subsequently due to the limitations of availability of surface water, frequent occurrences of drought the state is gradually shifting towards groundwater for irrigation. As around 92% of the area in Maharashtra is of hard rock basalts, there is a limitation on the availability of groundwater based on terrain's basic characteristics (rainfall variability, physiography). As groundwater is a dynamic resource, assessing it is a tricky job, as it spreads according to natural gradient and the permeability of the soil matrix (Raghunath H M, 2002). So fair assessment/estimation of groundwater is very important for planners, policy makers, farmers and all other stakeholders (Michael J. Focazio, et. al, 2002) (Rana Chatterjee, et. al, 2014).As it is becoming a vital part of water management, it is also important to understand natural systems which determines and indicates good groundwater situations.

The motivation for selecting the present study area i.e., Mokhada and Jawhar (taluka's of Palghar district of Maharashtra) is their widespread drinking water scarcity (NRDWP web page, 2016) and very little rabi cropping (Census, 2011). Previous studies by CTARA shows acute severity for drinking water in this region.

Figure 1.1 Palghar District map

The table below (Table 1.1) shows the severity in drinking water availability in Mokhada and Jawhar (partially covered – non-availability of drinking water from the primary drinking water sources throughout the year)

Table 1.1 Palghar District Drinking Water Scenario

Palghar District Drinking Water Scenario					
Taluka Name	Population	Number of Habitations	Fully Covered	Partially Covered	Percentage of Partially Covered
Jawhar	128147	359	124	235	65.46
Mokhada	83453	236	14	222	94.07
Dahanu	351808	1084	1030	54	4.98
Palghar	481236	1099	818	281	25.57
Talasari	154818	243	201	42	17.28
Vasai	121012	179	168	11	6.15
Vikramgha	137625	570	466	104	18.25
Vada	178370	777	701	76	9.78

Total geographic area of Palghar district is 517634 Ha. According to 2011 Census, the Land Use pattern indicate that 42% is under cultivation and area sown more than once is 1.9%. This indicates that the Rabi cultivation in the district is very less. This leads to dry season migration to nearby cities in search of livelihood (Hemant Belsare, et. al, 2012).

Even the state-led programs like Jalyukt Shivar (GoM, Government Resolution, JalaA-2014) are failing to address this problem in particular (Jalyukt Shivar focuses on the convergence of different departments (like the Department of Agriculture, Forest department etc.) for solving the broader problem of drinking water and crop water through watershed interventions). (JYS has bigger objectives of livelihood generation through more cropping etc.,). But Drinking water problem prevails even after completion of the fully pledged program implementation in villages due to improper siting of the interventions (Annexure 5, 6 - tanker fed village data).

This region falls in the northern limits of Sahyadri ranges (Western Ghats of India) (AERF, 2013), which receives average annual rainfall of 2000-3000mm (http://maharain.gov.in/), but the shallow basaltic terrain leads to significant amount of direct runoff (surface runoff), adding very little to infiltration/groundwater component. Even the infiltrated water leaves the watersheds of Mokhada and Jawhar as quick baseflows, making the situation worse even though the region receives high rainfall (Parth Gupta, 2016).

The previous study by Parth Gupta shows the problems in Groundwater assessment methodology followed by GSDA (GoI, Ground Water Resource Estimation Methodology, 2009) which doesn't seem to capture the water stress in the study region (the major drawback of GSDA assessment is it's underestimation of natural discharge and inability to capture the seasonal/temporal variation/availability of groundwater), Parth Gupta's work involved hydrological modeling in highlighting the inappropriate assumptions in GSDA assessment, the Present study tries to extend Parth Gupta's work and findings using field level data.

Above facts and observations motivates to understand the working of natural systems in this region through primary study, and look at the efforts of state processes to assess the severity of the situation, and working towards a bigger goal to come up with planning for watershed interventions (for better siting of the interventions) considering the field observations and analysis in this region, which will help tackling the critical drinking water issue, hopefully for a better livelihood possibility in the dry months.

1.2 Problem Statement

The aim of the study is to understand the dynamics between baseflows, groundwater levels, forest cover, and their relation with drinking water and crop water availability in the hilly watersheds of Jawhar and Mokhada. The study computes water balance, both temporally and spatially for three watersheds in Mokhada/Jawhar. Input to the water balance model is the recharged groundwater due to rainfall during monsoon. Water balance starts post-monsoon (October 1st), the main components monitored are groundwater stocks, baseflows and evapotranspiration load and domestic load. The objective is to estimate these stocks and flows and its determinants such as forest cover, land use etc., and other geographical and anthropogenic properties using empirical data and geospatial analysis. The output of this analysis aims to serve two needs. The first are field implementation agencies who would like to improve the access to drinking water for the communities in Jawhar/Mokhada, here we try to suggest the important parameters that implementing agencies need to look for selecting/siting a sustainable drinking water source and the second are technical agencies such as GSDA whose is to estimate using various techniques, the availability of groundwater in a given area. Thus, it plans to supplement and improve such assessment techniques.

1.3 Objectives

- To measure groundwater and to understand the functioning of Watersheds of Mokhada and Jawhar Region with different Land Use and Land Cover and Physical Geology.
- To measure and understand the effect of land use (forest cover, cropping land, grassland etc.,) on the base flows and hydrogeological parameters (specific yield, infiltration etc.,)
- To verify the suitability of GSDA groundwater assessment methodology in the study area.
- To suggest the parameters that needs to be considered while planning watershed interventions in Mokhada and Jawhar Region.

1.4 Conceptual Model

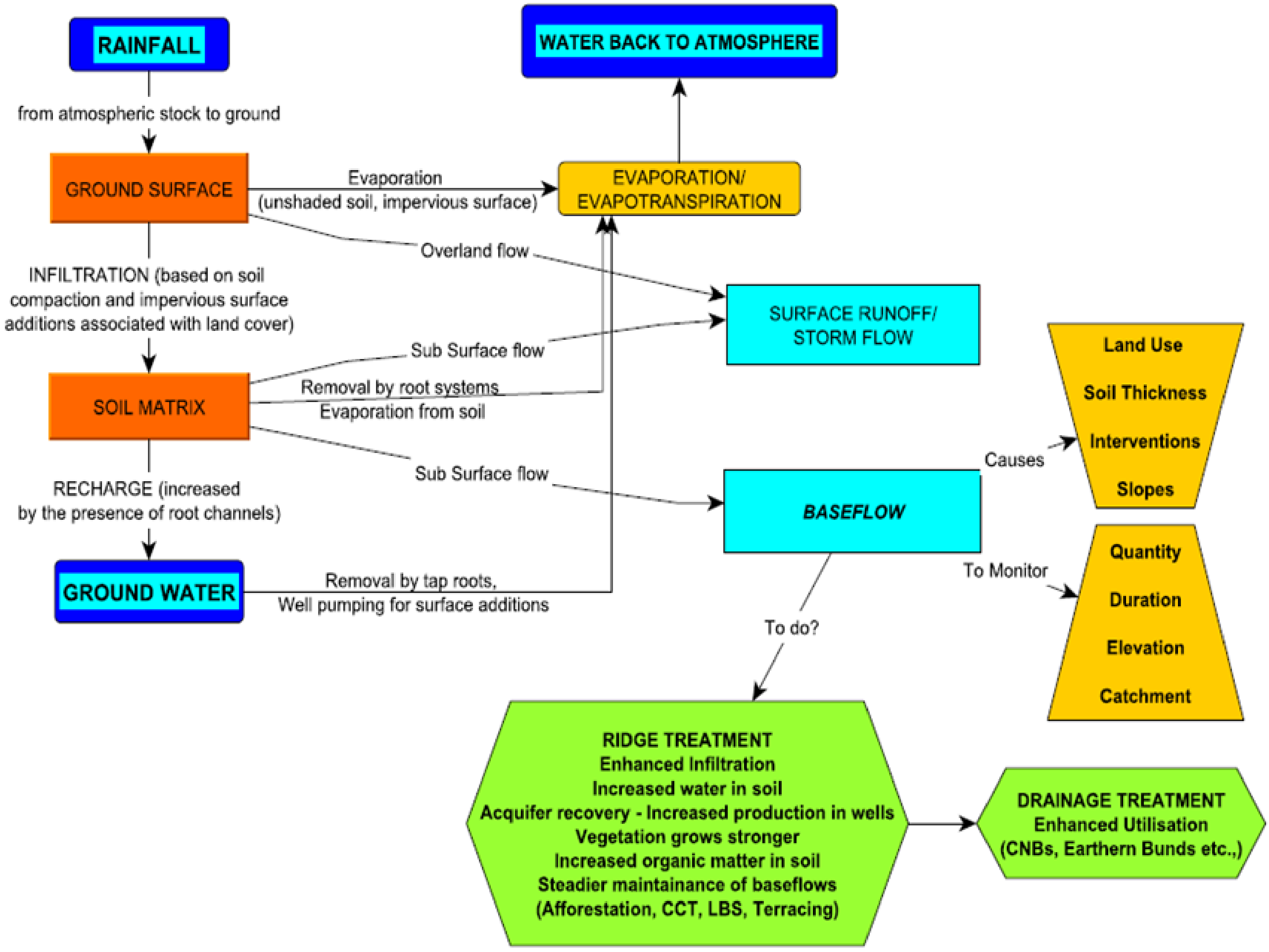


Figure 1.2 Conceptual Model

Above Model (Figure 1.2) (Katie Price, 2011) shows the interaction between different stocks and flows involved in the total water cycle. Rainfall from the atmospheric stock enters the ground surface during monsoon, some part of it leaving back to atmosphere through evaporation, some part adding to direct runoff/surface runoff and the remaining water infiltrates to soil matrix, which depends on the compaction and impervious nature of the soil. Water in the soil matrix is used by plants for evapotranspiration, some part of it travels in sub surface and joins the stream, and the remaining part adds to the groundwater, the addition of water from soil matrix to groundwater is governed or positively driven by the presence of "plant root channels" (Katie Price, 2011), the groundwater stock then adds to the component of baseflows and some part of it is taken by plant deep roots for evapotranspiration, and here in our study area, this groundwater is tapped by wells for anthropogenic use. As the study area faces dry season water crisis, it is important to understand the stocks and flows post-monsoon, the stock post monsoon is recharged ground water and the important flows are evapotranspiration, baseflows. To tackle post monsoon water crisis, it is important to understand the dynamics of post-monsoon stocks and flows, how they interact and understand the determinants of these stocks and flows (such as, forest cover), and how one can manage them sustainably by using watershed level area and drainage level treatment.

As described earlier, the conceptual understanding of the study region motivates to set an agenda to understand the post-monsoon water stocks and flows, their determinants.

1.4.1 Baseflows / Post-monsoon natural discharge (measurements)

Baseflows are the portion of stream flow, which is not direct runoff (storm flow), it constitutes water seepage from ground into a channel over time. In general, Baseflows are the primary source of running water in streams during dry weather. The initial understanding of baseflows/natural discharge in this study area comes from previous study by Mr Parth Gupta in this region. The Baseflows constituted the major portion of post-monsoon discharge (53% of the recharged water), which the planning agency like GSDA underestimates as 5-10% of total recharge. This leads to mis-interpretation of availability of the recharged ground water, which according to GSDA is 90-95% of the recharged groundwater is available throughout the year (post-monsoon).

Here the initial assumption is that the most of the water leaves watershed in the form of baseflows leading to drought like situation in dry months, which is seen in study area.

To understand the ground reality in more detail and see the proportion of baseflows and availability of groundwater over period – this study monitors baseflows at sixteen locations at every twenty-one-day interval (after monsoon), and eighty-three wells at twenty-one-day interval were monitored for water level drop over post-monsoon/dry months period, which strengthens the conceptual understanding of spatio-temporal variation of important post-monsoon stocks and flows, and see how quantity of baseflows impact the access to subsurface water.

1.4.2 Ground Water Stock relation with Land Use Land Cover (measurements)

From the conceptual understanding, it is a popular belief that presence of trees will add to more recharge (increased by the presence of root system). Forest cover adds more water to ground and creates more space to hold the water in sub surface. Hence according to initial conceptualisation of the study area, it was thought land use and land cover will be a good determinant of groundwater stocks and flows post monsoon.

To understand/test this concept the study area was classified in terms of land use and land cover, sixteen stream watersheds and eighty-three- well catchments were classified for forest cover and land use and they are monitored periodically for water levels. Then the groundwater stock, and flows (base flows and evapotranspiration loads) were monitored to see the correlation between the land use land cover and availability and prolongevity of the groundwater in sub surface.

For this, Specific Yield (a term used to indicate the storage space in the soil/murum matrix) is back calculated using GSDA methodology, the relationship between baseflows and land use and land cover is studied along with availability of water over time in the wells with different forest cover.

1.4.3 Ridge Treatment and Drainage Treatment (determinants)

From the conceptual understanding the baseflows constitute the major flows (outflow) of the total recharged water (stock). Hence there is a need to increase the availability (in the subsurface) of groundwater for the whole season. This involves traditional watershed development approach of ridge-valley treatment, which determines different stocks (groundwater stock) and flows (baseflows). In this method, the ridge area (which adds to the recharge) is treated first with the interventions like afforestation, contour trenching, terracing, etc., by doing this it increases the infiltration and water in soil matrix and also reduce the soil erosion. Valley/drain treatment follows the streams, obstructing the runoff at different points. Drainage line treatment reduces the velocity of stream flow, and serves as the storage structures. They also enhance the recharge or infiltration into surrounding area (based on the local soil and bedrock conditions), few examples of drainage treatment are loose boulder structures, CNBs, KT weirs, etc., Different Watershed development programs by government involve ridge to valley approach of treating watersheds (Annexure 14).

Here we try to know the effects of these ridge-valley treatment of watershed in Mokhada and Jawhar Region, and we study few cases of localised area treatment (shrubs, contour trenches) and valley treatment through different structures.

1.5 Study Area Description

1.5.1 Geography

Mokhada and Jawhar taluka are situated in the northern part of Western Ghats of India, the region is hilly with undulating slopes. The region is covered with forests. Waal, Wagh and Pinjal are the major rivers flowing in this region. All the rivers will be flooded in the monsoon but remain dry in late summer period, which leads to acute water problem. The elevation of Mokhada varies from 175-600m. Mokhada consists of 28 gram panchayats, 59 villages and 236 habitations. The area of Mokhada taluka is 494.83 km^2 and perimeter is 169.3 km. Total number of households in Mokhada taluka is 17789 with total population of 83453. Male population is 41691 and female population is 41762. Scheduled Tribe population of Mokhada taluka is 76842 which falls in rural category, only a bit of non-ST population is found in the Taluka headquarter Mokhada (Census, 2011).

The elevation of Jawhar varies between 115-453m. Jawhar consists of 50 Gram panchayats, 108 villages with 359 habitations. The area of Jawhar taluka is 609.32 km^2 and perimeter is 168.19 km. Total number of households in Jawhar taluka is 25358 with total population of 128147. Male population is 63206 and female population is 64941. Scheduled Tribe population of Jawhar is 124259 which is 97% of the total population (Census, 2011).

1.5.2 Climate

South-West monsoon winds bring the major chunk of rainfall to this region accounting for 2500mm to 3000mm annual average rainfall in the months of June to Sept. Though the region is getting high rainfall, because of steep slopes and hilly terrain most of the water will run off quickly leading to acute water scarcity in the later dry season (Parth Gupta, 2016).

The shallow hard rock terrain will lead to high surface runoff (slopes also play an important role) basaltic bedrock also results in very low infiltration. This leads to very low well recharge which are major source of drinking water in this region and they also go dry in few months post monsoon. Most of the habitations come under partially covered habitations (as per NRDWP standards) and many of them will be fed by tankers, to fulfill the drinking and domestic water needs.

1.5.3 Geology

Jawhar and Mokhada come under the region of Deccan Basalt which is formed by solidification of molten lava. The rock layers are made up of several successive flows of igneous rocks (basalt) of variable thickness and lateral extent known as Deccan Traps. The main hydrogeological properties like specific yield and infiltration are very low for the basaltic rocks which leads to very poor groundwater holding capacity. This is the main reason why there is major chunk of water goes as quick runoff, as the infiltration and specific yield are very less there is no natural structure/design in place to augment the rainwater and converting it into groundwater. This is how many wells even start to get dry by the beginning of February, and till the worse situation is observed in the months of April and May when most of the people need to walk a long distance to fetch the water in wells (some of the wells located along the streams will have water) (Lakshmikantha N R, 2016). Or else the village will be declared tanker fed.

1.5.4 Selected Watersheds for Study

Three Watersheds with different physical geology, land use and land cover are selected (Table 1.2) (Figure 1.3).

Chas Watershed in the northern part of Mokhada is of 7901 Ha catchment area, comprises of around ten (partially and fully in the watershed boundary) villages – Chas, Osarvira, Brahmagaon, Ghosali, Beriste, Hirve, Poshera, Morhande, Gonde Bk/Morchondi and Dandwal (MRSAC, Thane Shapefiles).

Dhanoshi Watershed in Jawhar is a part of IWMP WF15 watersheds, it is of 3184 Ha catchment area and comprises of eight villages (partially and fully in the watershed boundary) – Jawhar Rural, Juni Jawhar, Dhanoshi, Aptale, Akhar, Sakur, Kadachimet and Pathardi (MRSAC, Thane Shapefiles). The outlet of the watershed joins Kal Mandvi river which joins Pinjal river later.

Aine Watershed in Jawhar is having more amount of forest cover compared to other two watersheds, it is of 1407 ha catchment area, comprising of villages – Chauk (partially), Dongarwadi and Aine (MRSAC, Thane Shapefiles). The outlet of the Aine watershed joins Pinjal River.

Table 1.2 Watersheds under study

Sr. No	Watershed Name	Catchment Area in Ha	Villages In Watershed	Forest Cover
1	CHAS	7901	Chas, Osarvira, Brahmagaon, Ghosali, Beriste, Hirve, Poshera, Morhande, Gonde Bk/Morchondi and Dandwal	22%
2	DHANOSHI	3184	Jawhar Rural, Juni Jawhar, Dhanoshi, Aptale, Akhar, Sakur, Kadachimet and Pathardi	15%
3	AINE	1407	Chauk (partially), Dongarwadi and Aine	59%

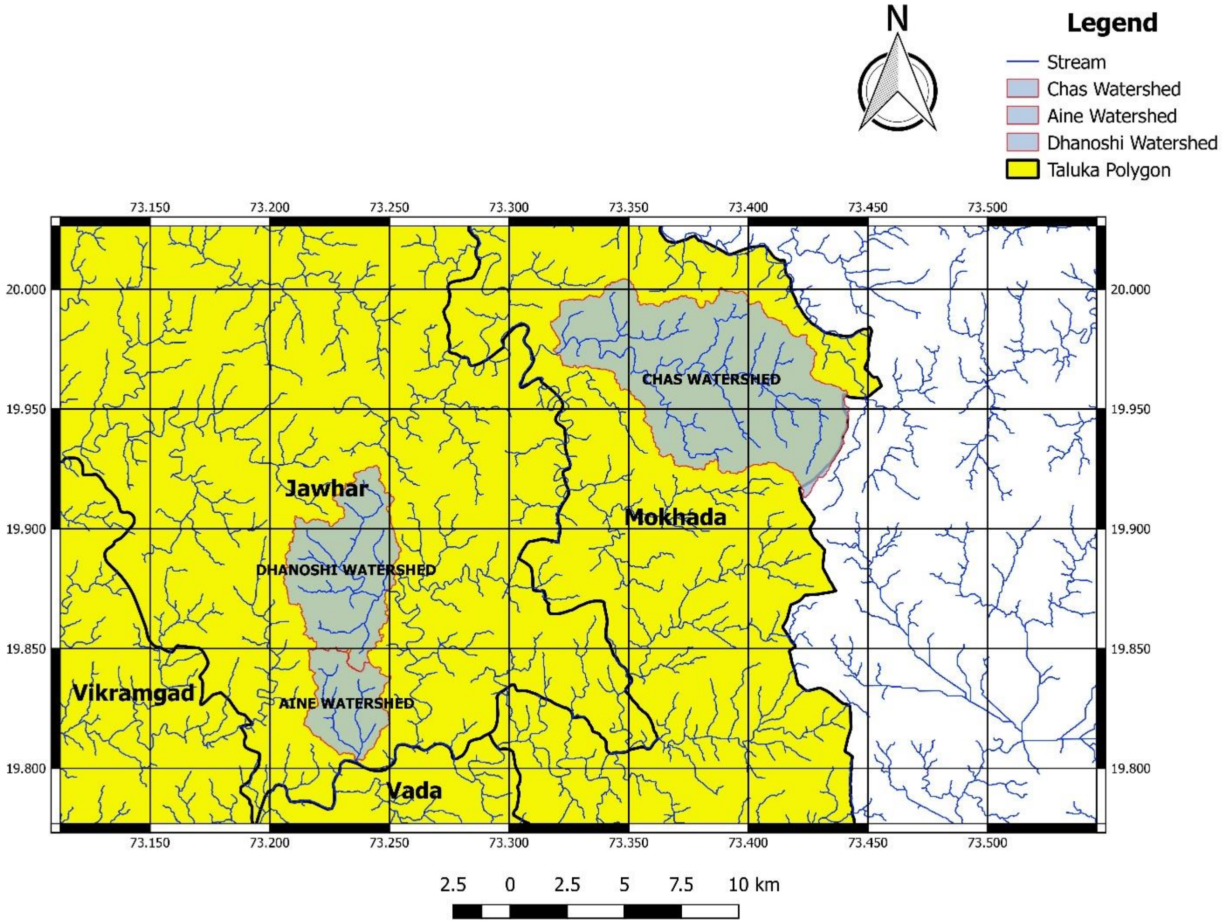


Figure 1.3 Study Region

1.6 Overview of the Report

Chapter 2

This Chapter focuses on understanding existing studies in Jawhar and Mokhada region, their outcomes and suggestions. A brief study of literature about the interaction between land cover (forest cover) and the dynamics of baseflows and other groundwater stocks is also made.

Chapter 3

This Chapter briefly explains the empirics involved in the study and the steps involved in selection of watershed. A brief note on the type of primary data collected by field visits, parameters monitored during baseflow measurements and well water level drop measurement is tabulated.

Chapter 4

In this chapter, the post-monsoon availability of groundwater (recharge happened due to rain) is estimated for sixteen watersheds by using GSDA methodology. The Baseflow volume leaving the watershed (from primary flow measurements) is compared with GSDA recharge and natural discharge claims.

Chapter 5

This chapter land use, land cover (evapotranspiration load), baseflow measurements and well data are used to back calculate the Specific Yield. Correlation between baseflows and the land use is also discussed. This chapter in a way sets an explanation to how forest cover changes the dynamics of baseflows and water availability in the ground.

Chapter 6

This chapter analyses the data gathered by well monitoring, and try to understand different parameters which determine good ground water situations. The effect of forest cover on the water availability in wells is also discussed. Some empirical study of area and drain treatment structures is also made.

Chapter 7

It includes the attempts made to simplify the watershed and stress mapping. Curve Number method for Annual water balance is documented.

Chapter 8

Includes all the above learnings (conclusions), limitations and scope for future work.

Chapter 2

2 Literature Review

In this chapter we will outline some of the existing literature, which we classify in two topics. These are (i) existing case-studies of CTARA within the target area of Konkan and their conclusions, (ii) studies by other authors in different geographies on relationship between forest cover and base-flows,

Water group at Centre for Technology Alternatives for Rural Areas (CTARA), Indian Institute of Technology Bombay has been working in the Palghar region on various water related issues mainly concerning rural drinking water. One of the main studies related to ground water modelling was done by Mr. Hemant Belsare as his MTech Project on Understanding, Analysing and Modelling Watershed Interventions (Hemant Belsare, 2012). The study focused on specific watershed intervention i.e., subsurface bund (subsurface bunds are the impermeable barriers made of reinforced concrete, stone masonry, clay, concrete, steel sheets or clay covered with plastic sheets constructed 2 to 6 m below till hard rock is touched, in regions like Mokhada which is basaltic hard rock is found at shallow depths makes subsurface bunds an easily implementable intervention) and its effect on increasing the life of water availability in drinking water well-constructed by NGO AROEHAN in a small hamlet of Ikharichapada in Mokhada block of then Thane district, Maharashtra for solving the drinking water problem of the hamlet. The study evaluated the impact of subsurface bunds at two locations that is one in the downstream of the well and other in the upstream. The study used Ground Water Modelling Software (GMS) (Alen W. Harbaugh, 2005) with MODFLOW (GMS is the most widely used Graphic User Interface to MODFLOW) the model ran for different scenarios of interventions (two downstream subsurface bunds and one up stream subsurface bund and their combinations) showed that the water level in the well has risen which matches with authors field observation data and showed that the interventions at Ikharichapada are successful, author also suggests that such conceptual model can be useful in modelling other watershed interventions such as check dams, contour trenches etc.,

Another study in CTARA related to watershed level was done by Mr. Parth Gupta as MTech Project – Ground Water Models for Watersheds (Parth Gupta, 2016), the study was setup in WF15 watershed (West Flowing) the main objective of the study was to suggest a better methodology to GSDA (Groundwater Surveys and Development Agency) for predicting the ground water in this region. Authors study mainly pointed out the importance of base flows (Base Flow is the portion of streamflow that is sustained between precipitation events, fed to stream channels by delayed (usually subsurface) pathways) which is significant in this region. The study had other objectives like to develop a conceptual model for groundwater budgeting using GIS, MODFLOW and other possible techniques, which can strengthen the current GSDA methodology. To model hard-rock terrain (where very less work has been done). The author also tries to incorporate cropping potentials that is how much cropping area can be brought under Rabi Crop for water that is captured by watershed or different watershed interventions. The Groundwater model developed by the author was in line with various field observations he made, author claims that the groundwater discharge through drains (base flows) is very significant and much larger than subsurface flows (through constant heads) and considering them in the process of modelling is very important especially while modelling hilly terrains. Author also come up with interesting results that the groundwater discharge is 54% whereas GSDA assumed only 5% as the natural discharge of the total recharge and the model was also able to provide the temporal variation of ground water availability which in term also explains the water scarcity in the months of March, April and May in this region. Author gives an insight into the great potential that can be tapped through various interventions at various elevations.

The relationship between forest cover in a catchment and water yield splitting into quick, slow and base flows and its temporal distribution is a complex/controversial phenomenon. A study by Mr Sharachchandra Lele and others on the influence of forest cover change on watershed functions in the Western Ghats: A coarse-scale analysis (Sharachchandra Lele, et. al., 2005) explores the complex relationship between forest cover and the watershed service variables. The study proposes major three objectives as characterising the hydrologic response of variety of catchments in Western Ghats region of Karnataka, Kerala and parts of Tamil Nadu using secondary data, assessing the influence of changing land cover (degradation of forest cover) on hydrologic response of the selected catchments and identifying the types of land-cover changes and regions which have more influence on hydrology response and for which hydrology is insensitive in macro scale.

The study was carried out in nineteen catchments (after filtering out for the reliable gauging stations). The study used land cover data generated from the remote sensing and stream-flow load data from existing gauging stations monitored and managed by state and central agencies, other data like rainfall, temperature, and other meteorological parameters were obtained from the nearest rain-gauge stations, Gauging locations, delineation of watershed and other geomorphologic parameters were obtained from toposheets and other GIS sources (such as SRTM for Digital Elevation Images), Land cover maps were generated by supervised classification using many training files (using IRS LISS-3 imageries), hydrologic responses such as rainfall-streamflow relationships, base flow index and flow coefficients, and the responses from sub-catchments are compared based on the forest cover area in the catchment area, rainfall patterns and catchment geomorphology, at the end the study attempted to make out the linkage in forest/landcover to the hydrological response of the catchments through statistical analysis. The study tried to use map of National Bureau of Soil Survey and Land Use Planning (NBSSLUP), Bangalore office but as the map was at the 1:5000000 scale (coarse scale) so, authors followed the soil map by French Institute Classification to come up with broad soil types, and the study also considered the Forest Survey of India classification of the Canopy Cover, and they were successful in sub-classifying the plantations into different species (as teak, eucalyptus, Acacia auriculiformis, coffee, tea and rubber plantations, Arecanut and cashew orchards, and seasonal croplands including paddy and several other crops) but at the stage of analysis some of this categories were combined (just as different forest plantations or different horticultural crops), different imagery from LANDSAT MSS and IRS-LISS 3 were used for different time period's classification (1973 and 1997), the land cover classification was done by using maximum likelihood algorithm of the supervised classification with visual interpretation. The forest cover change analysis was also made using the same method described above.

The study mainly used two parameters one is Runoff coefficient (amount of runoff to the amount of rain received) and Base Flow Index (BFI- is the measure of the ratio of long-term base flow to the total stream flow, it also represents the slow continuous contribution of Groundwater to the river flow). The study becomes enormously challenging because of many factors like difficulties in accessing the data, inadequate rain gauge network, poor gauging quality in many gauging stations at different points of time and huge diversity of land cover types and their transition over time. Authors give cautious conclusion saying that the rainfall is the major factor that governs the inter-annual variation in runoff and the runoff coefficient, impact of land cover on this factor was difficult to discern. And one more important observation is that wherever the forest cover degraded over time (from high-density forest to scrub) the runoff coefficient showed an increase, whereas when the forest cover was converted to plantations, the runoff coefficient showed a decrease (might be because of increase in evapotranspiration losses)

A study on Forest cover change, hydrological services, and economic impact: insights from the Western Ghats of India by Sharachchandra Lele, Jagdish Krishnaswamy et al., (Sharachchandra Lele, et. al., 2004) tries to understand the dynamics of tropical forest ecosystems and how it generates multiple benefits to society, including goods such as fodder, fuelwood, leaf manure, timber, food and medicines and environmental services such as carbon sequestration, shelter for wildlife habitats and biodiversity. Apart from this watershed services as hydrological regulation (groundwater recharge, low-flow augmentation, flood control) and soil erosion control which are most considerable benefits from forests.

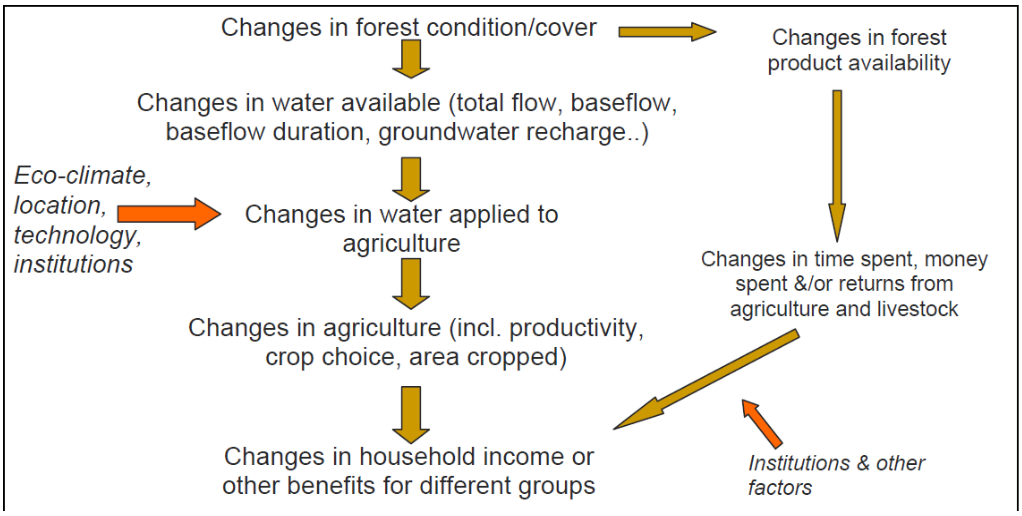


Figure 2.1 Forest Cover Change - Hydrological Services and Economic Impact
(Source: S Lele et. al., 2004)

In this study four different eco-climatic zones or blocks were selected and characterized based on Rainfall, Terrain, Elevation Range, Soil Type, Vegetation Type, Forest Plantation Type, Irrigation Systems, Major crops in downstream areas, major forest cover change, demographic and settlement pattern. It was observed that though Non-Timber Forest Produces (NTFPs) does not provide much direct income. But households get large amount of firewood for domestic use and Arecanut boiling. Forest land also serves as an important grazing field for livestock, and forest leave stock manure was also used in large quantities for Arecanut orchards. Author stresses the point that since the runoff during monsoon rain is significant and extent and productivity of the paddy will not likely to be affected by the changes in streamflow occurred due to forest cover change, but the cultivation of the second crop (paddy) depends heavily on the availability of streamflow that can be impounded, diverted or pumped to the field, and authors interaction with the farmers tells that the post monsoon crop is very sensitive to the magnitude and duration of post monsoon flows. Which depends on the type of forest cover on the slopes of catchment. Forest covers also ensure there is adequate soil moisture during the dry season too.

Some of the important observations made in this study are

- Under saturated conditions, the forest can generate more amount of runoff compared to other land use types
- Runoff analysis for different land use shows that the peak flow magnitude was observed in degraded watershed followed Acacia in comparison to Forested Watershed.
- The specific Discharge is highest in degraded watershed (24% more than forest) and lowest in a forested watershed.

A substudy the rain-runoff response of tropical humid forest ecosystems to use and reforestation in the Western Ghats of India by Jagdish Krishnaswany, Michael Bonell et al. (Jagdish Krishnaswamy, et. al., 2012) focuses on the effect of forest degradation, tree plantation on degraded or modified forest ecosystems with multidecadal time scales using tree plantations on the stream flow response. The study selected three ecosystems, (1) Tropical evergreen forest (NF), (2) heavily-used tropical evergreen forest now converted to tree savanna or degraded forest (DF), (3) exotic Acacia Plantations (AC) on degraded forest land. It was observed that more proportion of streamflow in the order of DF>AC>NF. Where Natural forest converted around 28.6% rainfall into total streamflow, Acacia plantation converted 32.7% and Degraded forest converted 45.3% of rainfall into stream flow. Compared to less disturbed evergreen forest, degraded forests lead to enhanced total stream discharge and quick flow both seasonally and by storm events whereas delayed (base) flow is reduced. Acacia plantations will not be effective in bringing back the hydrologic functions (as hydraulic conductivity) in short term. The study also observes that the potential and actual evapotranspiration is likely to be less in monsoon, hence the difference in stream flow and runoff responses between different land covers is highly dependent on differences in soil infiltration and hydrologic pathways.

Jagdish Krishnaswamy, Michael Bonell et al in their paper on The groundwater recharge response and hydrologic services of tropical humid forest ecosystems to use and reforestation: Support for the "infiltration-evapotranspiration trade-off hypothesis" (Jagdish Krishnaswamy, et. al., 2013) discuss about the ground water recharge capability of the different land covers (infiltration supported by the land use like forests is more than the evapotranspiration losses). The results showed that the flow duration curves had a higher frequency and longer duration of low flows under Natural Forest when compared to other degraded land covers in Malnad

(Western Ghats) and Coastal belt of Karnataka. Groundwater recharge using water balance during wet-season in the coastal basins under NF, AC and DF was estimated to be 50%,46% and 35% respectively and in Malnad region it was 61%, 55% and 36% respectively. These results were also comparable with the Soil Water Infiltration and Movement (SWIM) based recharge estimates too (46%, 39% and 14% for NF, AC and DF respectively) and Catchments with higher forest cover upstream are observed to sustain flow longer in the dry-season. The study here tells that “infiltration-evapotranspiration trade-off” hypothesis in which differences in infiltration between different land covers determine the amount of groundwater recharge, low flows and dry season flow rather than evapotranspiration, and it is also observed that the ground water recharge is most temporally stable under natural forest. Authors also tell that once rainwater penetrates the surface soil layers of lower permeability in disturbed land covers, then substantial recharge of the ground water can occur, and authors recommend that there is a need for similar work in different parts of Western Ghats of India to come up with the more regional figure for the Western Ghats.

A study by Chenxi Lu, Tingyang Zhao et al titled Ecological restoration by afforestation may increase groundwater depth and create potentially large ecological and water opportunity costs in arid and semiarid China (Chenxi Lu, et. al., 2016) gives a new turn to how one looks at afforestation and achieving water security issues. The study focuses on large-scale tree planting program in China to combat desertification and the trees selected for the program were not chosen based on the local environmental needs and the new tree species evapotranspiration exceeded the regional precipitation. The authors suggest that the water-use-efficiency of vegetation must be considered while planning otherwise it will lead to enormous opportunity costs. They also question China’s afforestation aim to increase Nation’s forest cover to 26% by 2050. This paper serves as a critique of attractive short-term gains in terms of forest regeneration and eco-restoration whereas natural succession processes take more time to achieve the same results. After study, they felt the need for quantifying the differences in evapotranspiration between new forests and natural vegetation, and suggest to limit the scale of afforestation until its consequences are better understood.

A similar study by K. Price and C.R. Jackson on Effects of forest conversion on baseflows in the southern Appalachians: a cross-landscape comparison of measurements (Katie Price, et. al., 2007) also focuses on Catchment forest cover and its influence on stream base flow in a variety of ways, most dominantly via increased soil infiltration and increased evapotranspiration (ET). As the study by Chenxi Lu et al, K. Price also cautious about extensive forestry experimentation and its negative relationship between forest cover with base flows as evapotranspiration losses due to forest cover exceeds the infiltration capacity. The study yielded results as more base flows associated higher forest cover, and an overall positive relationship was also demonstrated between forest cover and base flow but the study lacked the statistical significance between forested vs less forested areas. These values vary Spatio-Temporally and makes it more contextual phenomenon to observe to every region in small scales.

2.1 Inferences

- Study by Hemant Belsare Suggests building watershed level conceptual models and modeling of watershed interventions and Parth Gupta's study showed the significant contribution of baseflows to the post monsoon streamflow. Both these studies show that drain level interventions success will be based on the baseflows (subsurface flows).
- Study by Sharachchandra Lele and team in Karnataka shows the dependence of local community on forest for water and livelihood.
- Study by Sharachchandra Lele and team in Western Ghats of India shows that Natural Forests help in more ground water recharge, followed by planted forest (Acacia) and degraded forest (NF>AC>DF). Similarly higher Peak flows are observed in Degraded Forest followed by Acacia and Natural Forest. Which in fact shows the increase in infiltration due to forest cover presumably increasing the specific yield of the soil.
- A contrary study from arid and semi arid parts of China shows the negative impact of Forest on the regional water balance, but here the annual precipitation was observed to be 350-600mm which lead to a condition where evapotranspiration load exceeds infiltration benefit from the forest.
- Study by K Price and C R Jackson showed more base flows associated with higher forest cover.

All these studies indicate the relationship between forest cover and baseflows and their importance in the watershed level study. Our study focuses on understanding this relationship in our study area, considering different land use and land cover with other hydro-geological parameters (such as infiltration, conductivity, specific yield etc.,) contextually with respect to the watersheds of Konkan region of Maharashtra (with specific concern to Mokhada and Jawhar area) this will provide flow level analysis for Konkan area that will contribute to the knowledge of afforestation, land use land cover and its effect on baseflows, in a broader perspective this will feed to the planning of watershed interventions.

Chapter 3

3 Methodology

The motivation to select Mokhada and Jawhar for the purpose of study is clear by the acute severity of the problem. It is important to select different watersheds in this region based on the rationale considering different factors/parameters that play an important role in the behaviour of the groundwater, hence following steps were followed to select the watersheds based on their geological parameters like elevation, slope, Land Use and Land Cover (including agricultural land), villages/habitations, bunds/check dams and wells in the watersheds.

3.1 Key Steps Followed During selection of Watersheds

- Elevation analysis

- Slope Analysis

- LULC Analysis

- Villages/habitations

- Wells

In all this step, it is very important to understand the study area through primary field visits and then use tools such as GIS and remote sensing to document our observations and build a database of the study area.

Creation of GIS database

It is very important to have the primary data about land use land cover, Soil map data about hydrogeological parameters like hydraulic conductivity, specific yield etc., the study focuses to do primary study about these things in the second stage of the project or it will be based on the available literature. In this section, a set of GIS database is created for the study region

3.1.1 Elevation

The elevation map of the study was prepared using SRTM remote sensing data from earth explorer USGS website. Shuttle Radar Topography Mission (SRTM) 1 Arc-Second Global (30m) resolution is one of the freely available DEM in Earth explorer website (https://earthexplorer.usgs.gov/). The DEM can be used in QGIS and processed/analysed to get many useful information about the study area. The elevation image is developed for all the selected watersheds with stream lines on it in black colour. This image gives an idea about various elevation zones with in the watershed (Figure 3.1 to 3.3).

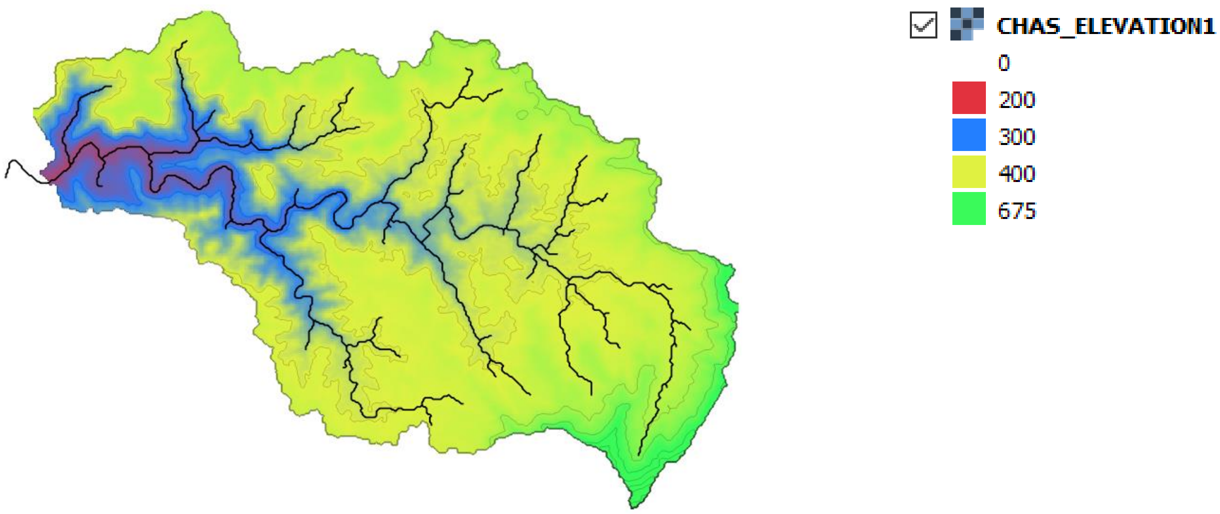


Figure 3.1 Chas Watershed Elevation map

Figure 3.2 Dhanoshi Watershed Elevation map

Figure 3.3 Aine Watershed Elevation map

3.1.2 Slope

For the ease of understanding the slope characteristics in watershed, all three watersheds are divided into slope category of 0-5%, 5-20% and greater than 20%. Here we get an idea about the slope profile of the watershed, up to 5% slopes are represented with green colour, 5 to 20% are represented with yellow and above 20% slopes are represented with red colour, it can be interpreted that up to 5% slope is cultivable land. And above 20% slope will be valleys of the streams and steep hills. (Figure 3.4 to 3.6)

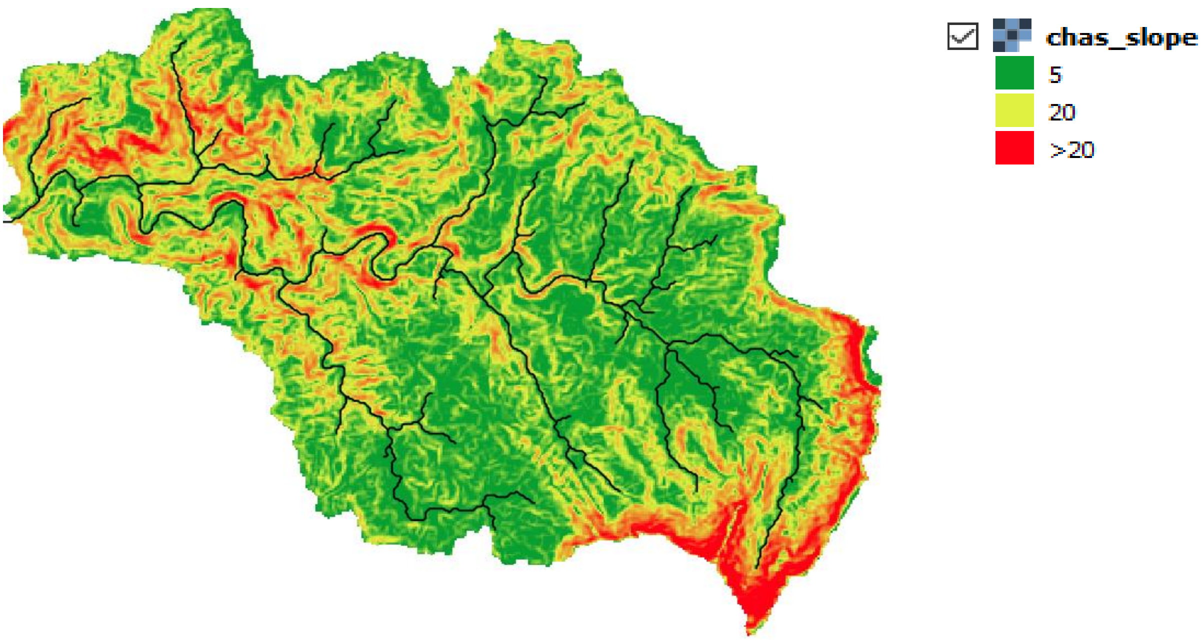


Figure 3.4 Chas Watershed % slope map

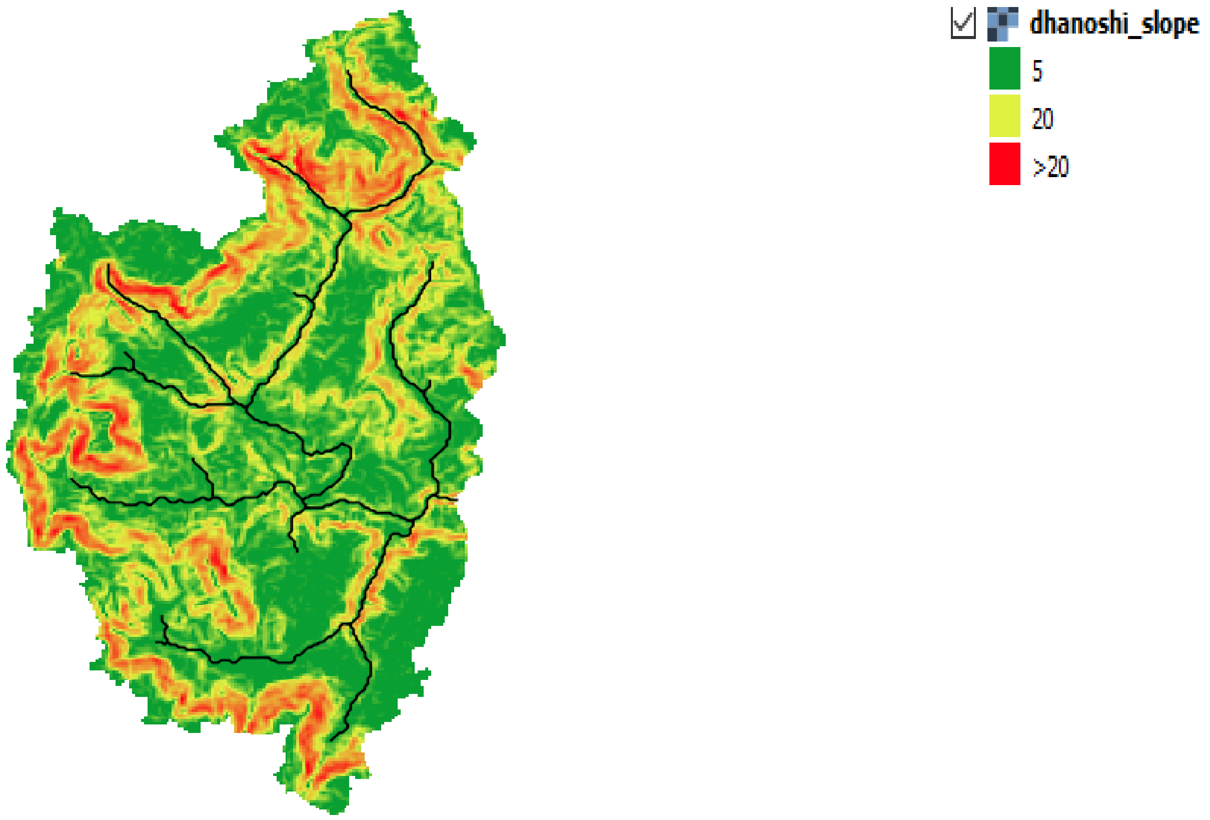


Figure 3.5 Dhanoshi Watershed % slope map

Figure 3.6 Aine Watershed % slope map

3.1.3 LULC

Land Use Land Cover map is available from Bhuvan but our field experience and Bhuvan's coarse classification was not matching, hence we did supervised classification of the LULC using semiautomatic classification plugin available for QGIS (Luca Congedo, 2017). Semiautomatic Classification Plugin (SCP) is a free open source plugin which allows to do semi-automatic classification and supervised classification of remote sensing images, it comes with many pre-and post-processing tools which are useful in classification and it also has built in raster calculator. SCP allows the user to create Region of Interest (ROIs) / Training areas using region growing algorithm which will be stored as shapefiles and can be used later for working in the same region. Semi-automatic plugin allows user to download and work with LANDSAT imagery (band sets), SENTINEL imagery and ASTER imagery, for our study purpose we are using LANDSAT 8 imagery which is of 30m resolution. The results put here are the classification reports for the classification done on the LANDSAT 8 imagery of 11-Nov-2016, which is immediately after monsoon, the sub-classification between grasslands, agricultural croplands are bit tricky while working with SCP. (Figure 3.7 to 3.9) (Table 3.1 to 3.3)

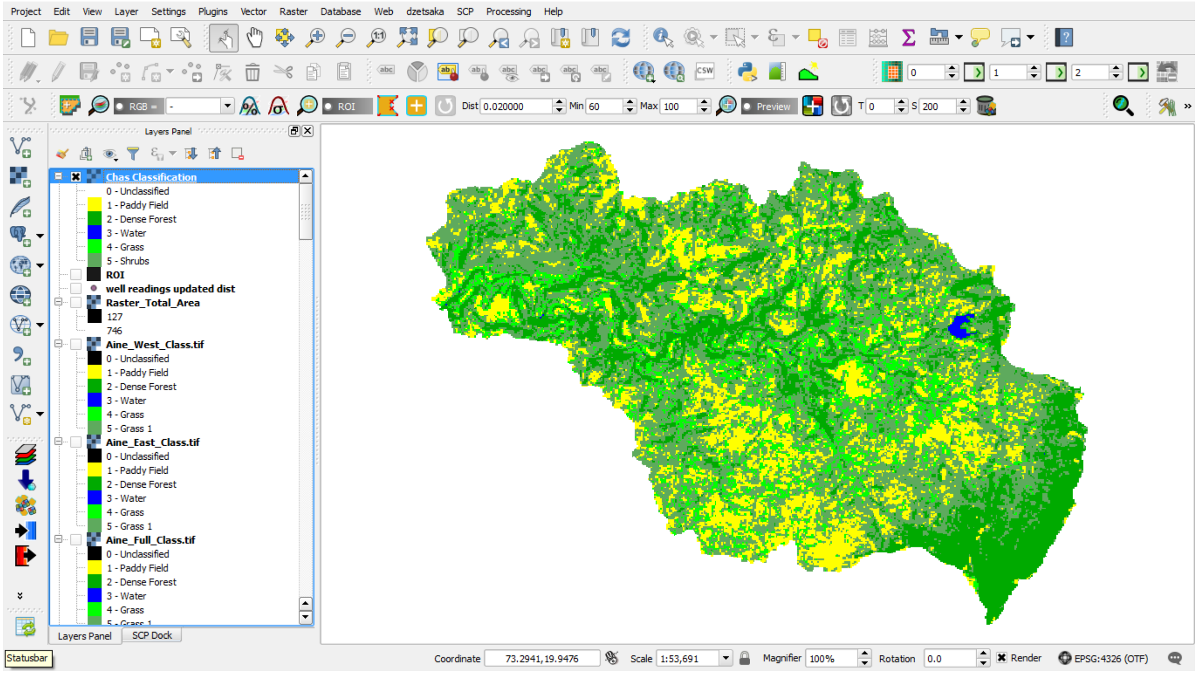


Figure 3.7 Chas Watershed Land Use Land Cover map

Table 3.1 Chas Watershed Land Use Land Cover classification

Class	Pixel Sum	Percentage %	Area [metre^2]
Paddy Fields	16242	19.79	14617800
Forest	18485	22.52	16636500
Water Body	167	0.20	150300
Grass	10015	12.20	9013500
Grass/Shrubs	37157	45.27	33441300

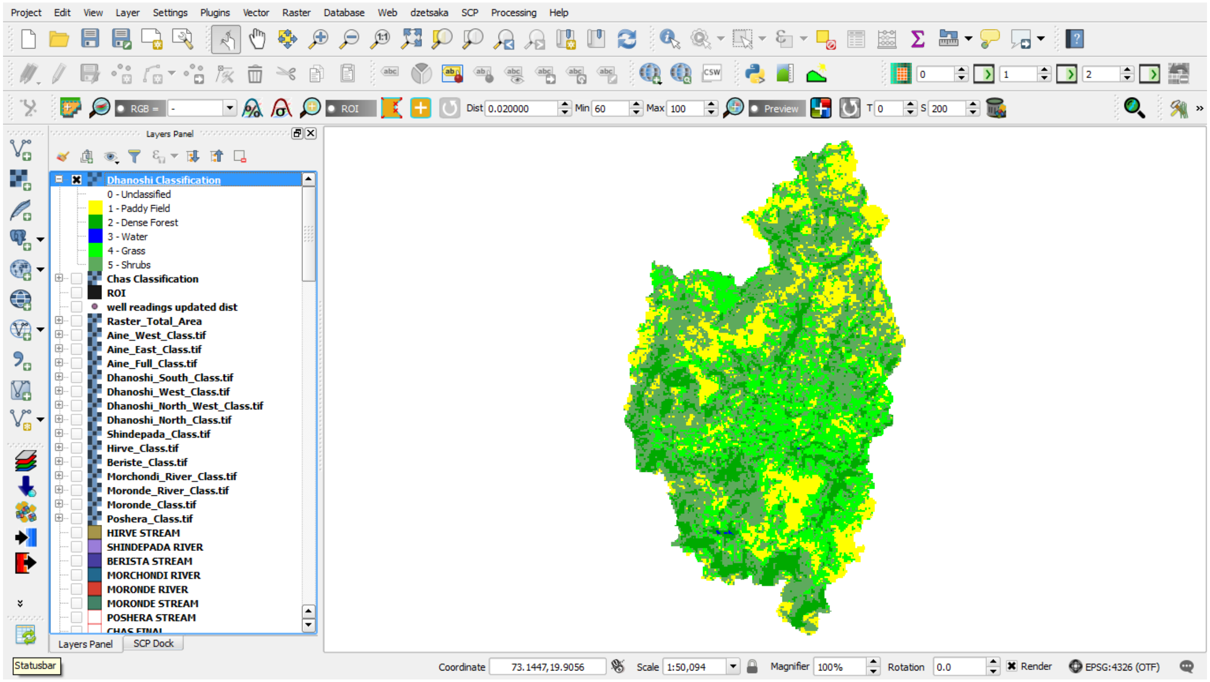


Figure 3.8 Dhanoshi Watershed Land Use Land Cover map

Table 3.2 Dhanoshi Watershed Land Use Land Cover classification

Class	Pixel Sum	Percentage %	Area [metre^2]
Paddy Fields	6682	20.18	6013800
Forest	5076	15.33	4568400
Water Body	12	0.03	10800
Grass	8677	26.21	7809300
Grass/Shrubs	12658	38.23	11392200

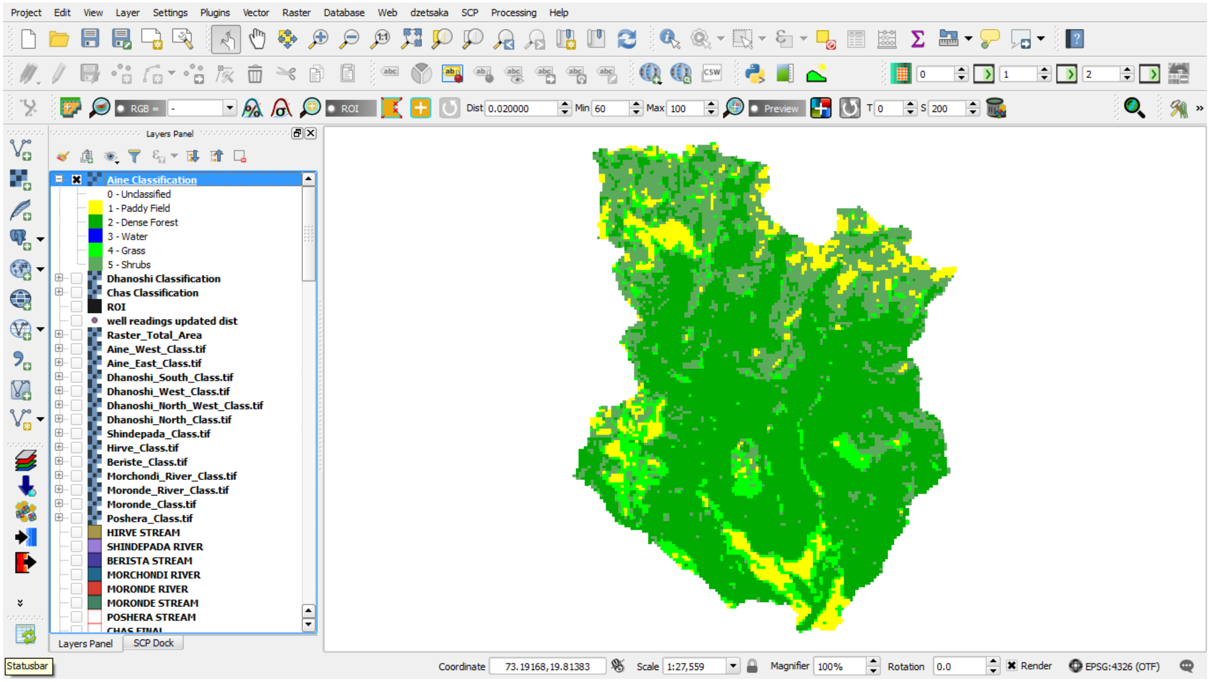


Figure 3.9 Aine Watershed Land Use Land Cover map

Table 3.3 Aine Watershed Land Use Land Cover classification

Class	Pixel Sum	Percentage %	Area [metre^2]
Paddy Fields	1315	8.99	1183500
Forest	8623	59.00	7760700
Grass	1405	9.61	1264500
Grass/Shrubs	3270	22.37	2943000

3.1.4 Villages/Habitations

Table 3.4 Villages in Study Region

Sr. No	Watershed Name	Catchment Area in Ha	Villages In Watershed	Forest Cover
1	CHAS	7901	Chas, Osarvira, Brahmagaon, Ghosali, Beriste, Hirve, Poshera, Morhande, Gonde Bk/Morchondi and Dandwal	22%
2	DHANOSHI	3184	Jawhar Rural, Juni Jawhar, Dhanoshi, Aptale, Akhar, Sakur, Kadachimet and Pathardi	15%
3	AINE	1407	Chauk (partially), Dongarwadi and Aine	59%

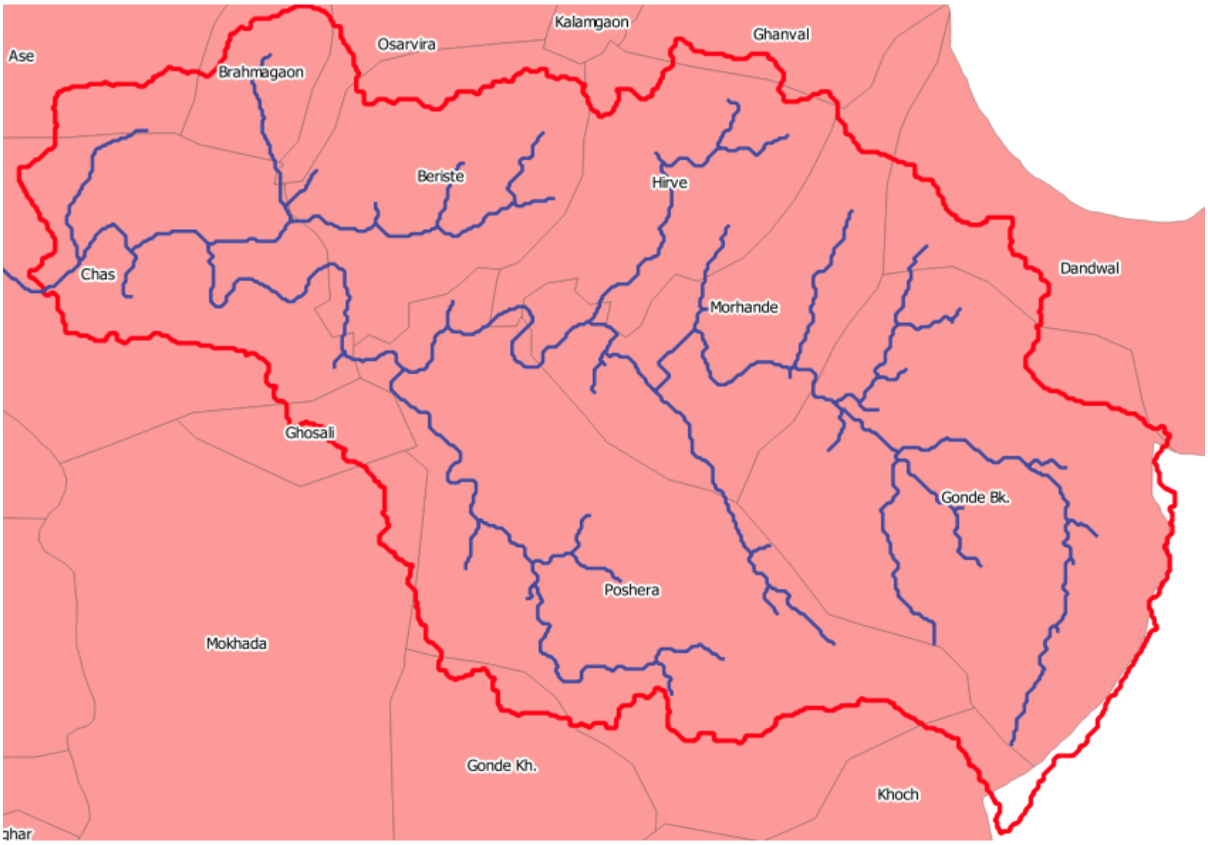


Figure 3.10 Chas Watershed Village Boundaries

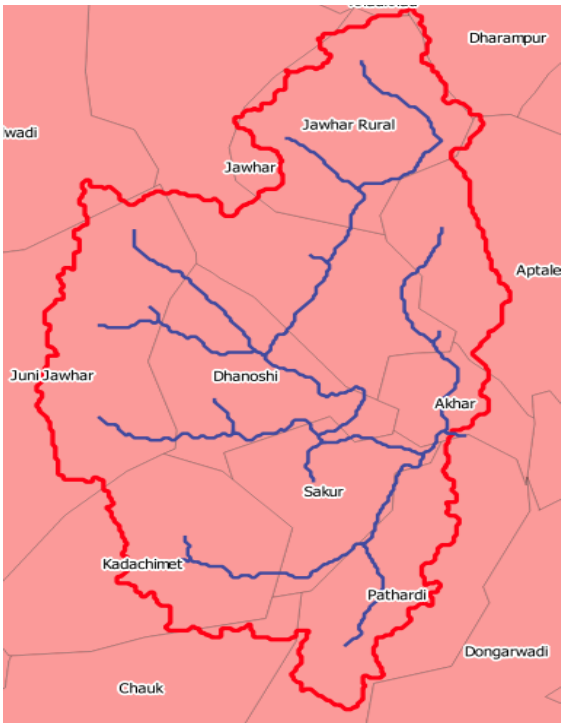


Figure 3.11 Dhanoshi Watershed Village Boundaries

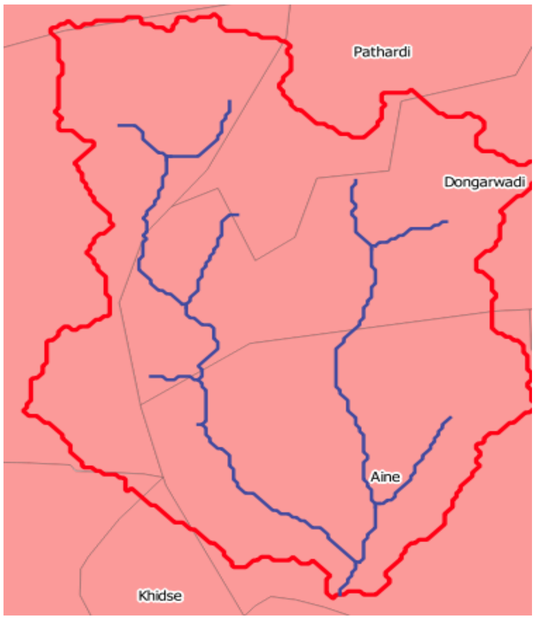


Figure 3.12 Aine Watershed Village Boundaries

3.2 Selection of Streams for flow measurements

It is important to take baseflow readings at different locations where sub streams join the main streams. So, Chas watershed readings for base flow was taken at eight locations including the main outlet out of eight four readings are of the streams joining the river (main stream) and other four points on the river (points where measurements are taken are- Morchondi River, Morande River, Morande Stream, Hirve Stream, Shindepada River, Poshera stream, Beriste Stream and Chas Outlet). Where as in Dhanoshi watershed, the main watershed was further divided into four sub watersheds and baseflow measurements are taken at each sub watersheds outlet (the sub watersheds are- Dhanoshi North, Dhanoshi Northwest, Dhanoshi West, Dhanoshi South and Dhanoshi Outlet) and Aine watershed is also divided into two sub watersheds as Aine East and Aine West. Apart from the Baseflow measurement from these outlets measurements at various other points are also taken using different methods such as bucket-time method, current meter etc., the main purpose of these extra measurements other than base flow is to have an idea how the base flows are going dry at different elevations at different places. Readings at all the outlets at every three-week interval is taken. The figures are given below (Figure 3.13 to 3.15) to represent the major reading points.

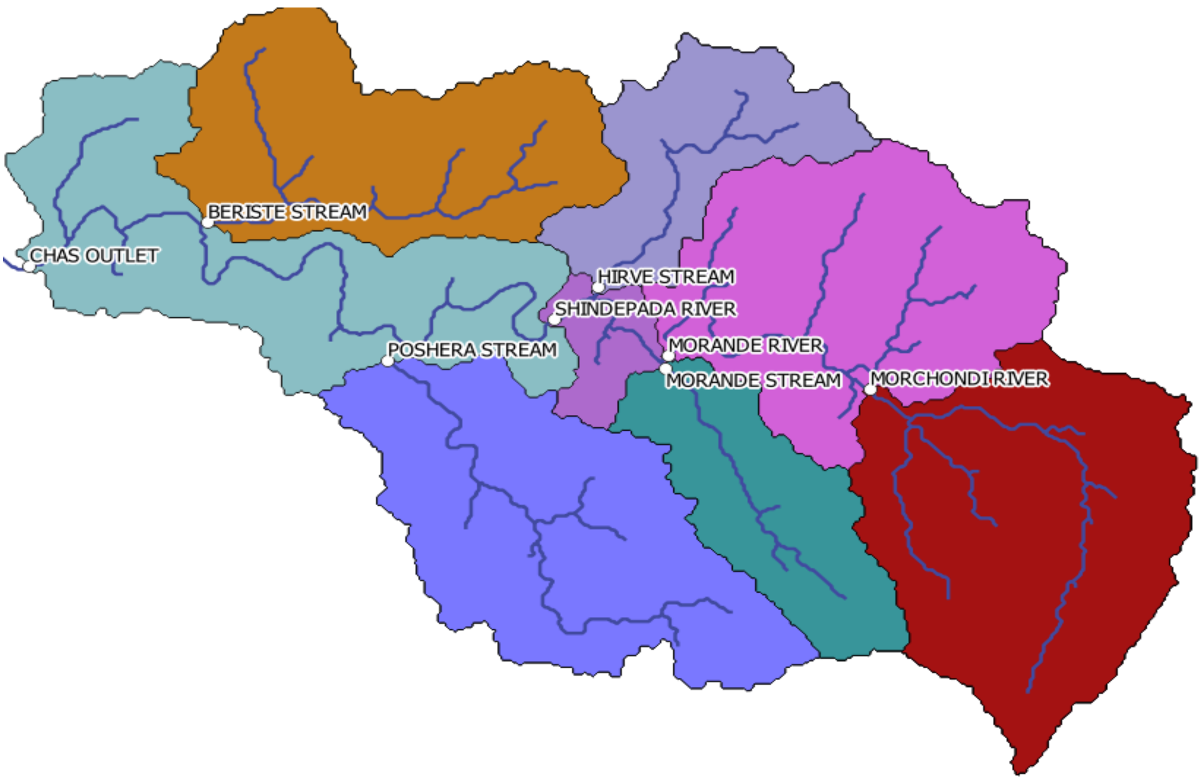


Figure 3.13 Chas Watershed sub watersheds for baseflow measurement

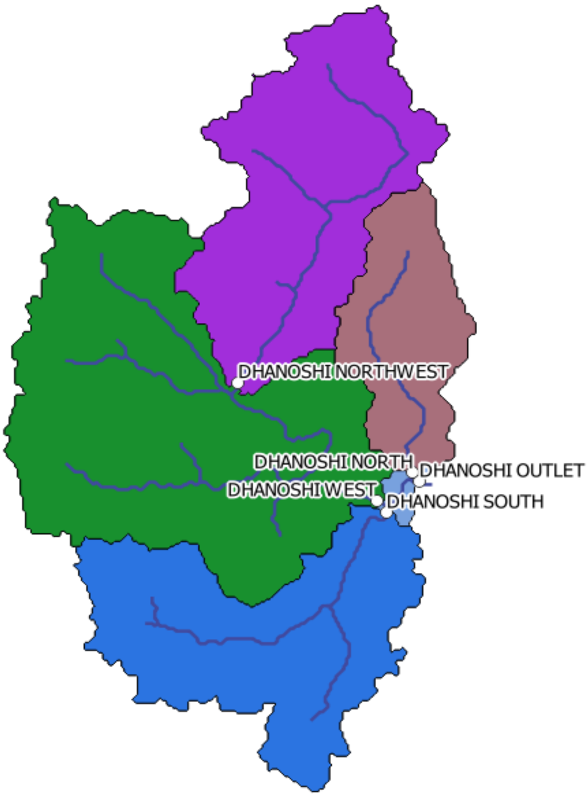


Figure 3.14 Dhanoshi Watershed sub watersheds for baseflow measurement

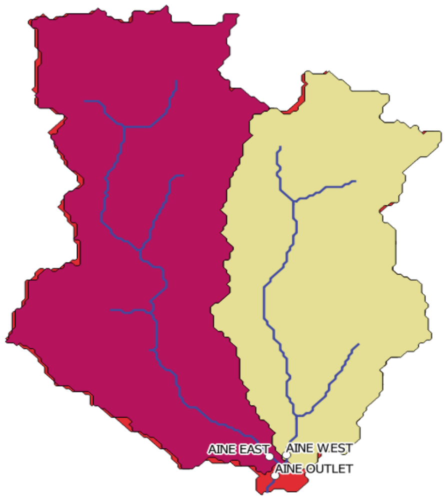


Figure 3.15 Aine Watershed sub watersheds for baseflow measurement

The flow in all the above streams is measured 21 days once till the streams go dry, the flow is measured using Pygmy/current meter (D. Phil Turnipseed, et. al., 2010).

3.2.1 Flow measurement using Pygmy meter

Here Area-Velocity method is used, in this method the area of canal and the velocity were measured at various cross-sections for calculating the discharge at a stream outlet.

Velocity is measured using current meter/pygmy meter, pygmy meter measures flow (rev/sec) through mechanical, tilt or acoustic means. The study used mechanical (cups-wheel type) current meter. The bigger current meter is used for measuring the velocity of rivers where velocity will be high and of the order up to 7.6 m/s, while the pygmy one is for low velocity where the range of measurement is between 0.03 to 2.5 m/s. As our study was involved in measuring small rivers and streams where velocity is measurable by pygmy meter, so pygmy current meter was selected.

The picture of the pygmy current meter (Figure 3.16) used in the study is attached

Figure 3.16 Pygmy current meter used for base-flow measurements

The components involved in pygmy current meter flow measurement are wading rod and Rev-Time counter (presetable). The RPM counter is used to measure number of revolutions in a given time with keeping time constant or time taken to revolve certain set of revolutions. The data obtained by measurement will be looked upon the calibrated rating table provided by the manufacturer to determine the velocity. The table is attached in the Annexure 2 and Annexure 3. The procedure used for measurement is discretisation method as shown in the figure below (Figure 3.17), a cross section of stream is divided into sub-sections as segments, velocities in each segment is measured at the midsection of the segment and the discharge at that segment is calculated by multiplying the cross-sectional area of the segment with the velocity later discharge at each segment is summed up to get the total discharge of the stream.

$$Q=\sum(a*v)$$

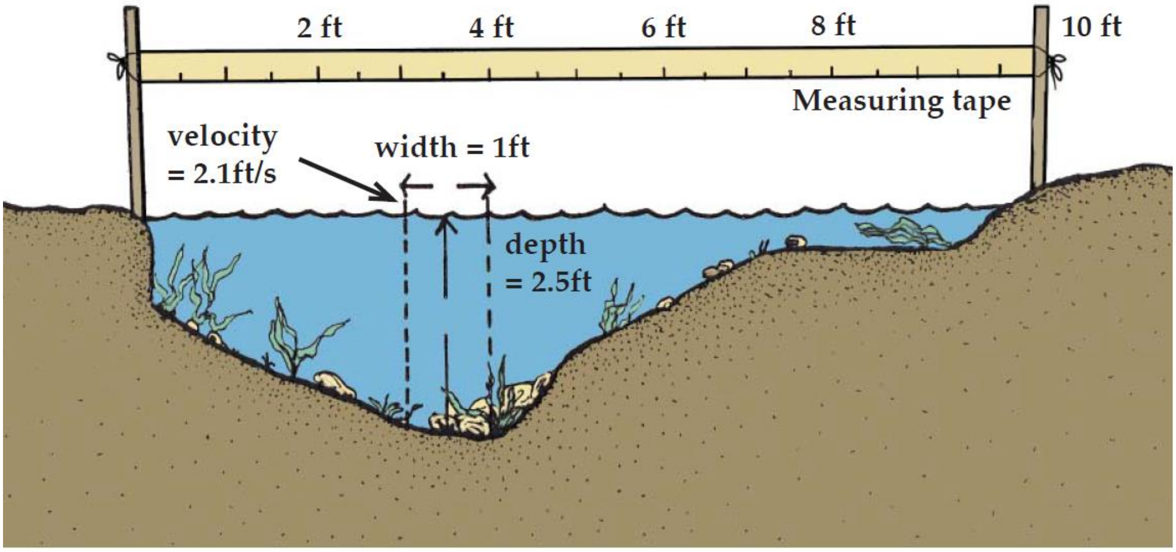


Figure 3.17 Representative cross section of a typical base-flow measurement point

Figure 3.18 Base-flow measurement at Dhanoshi Outlet (Nov-2016)

Table 3.5 Brief data collected by flow measurement

Sr. No	Watershed Name	Catchment Area (ha)	Slope Area (%)		Forest Cover %	Flow Readings (lit/sec) 1st, 2nd ,3rd, 4th, etc at 21 days interval	baseflow out (ham)	mm drop	Lamda	Half Life Days
			0-5%	>20%						
1	DHANOSHI NORTH	364.3	9.90	18.15	10.95		47.63	130.74	0.054	12.84
2	DHANOSHI NORTHWEST	778.5	7.66	21.22	9.94		102.74	131.97	0.043	16.12
3	DHANOSHI WEST	2061.6	8.67	6.33	13.64		167.37	130.44	0.038	18.24
4	DHANOSHI SOUTH	735.6	23.00	25.40	21.87		34.87	47.40	0.031	22.36
5	DHANOSHI OUTLET	3184.2	17.70	26.50	15.33		210.93	66.24	0.046	15.07
1	AINE EAST	804.5	0.00	46.23	63.83		19.70	24.48	0.053	13.08
2	AINE WEST	594.2	9.10	65.00	55.61		32.55	54.79	0.039	17.77
3	AINE OUTLET	1407	3.86	53.80	59.00		59.86	42.54	0.046	15.07
1	MORCHONDI RIVER	1464.1	12.15	40.84	41.50		72.91	49.80	0.044	15.75
2	MORONDE RIVER	2749.3	13.78	28.84	31.27		170.94	62.18	0.030	23.10
3	MORONDE STREAM	625.0	10.72	20.00	17.72		14.86	23.78	0.031	22.36
4	HIRVE STREAM	587.7	9.70	25.48	21.65		39.58	67.34	0.059	11.75
5	SHINDEPADA RIVER	4136.2	12.63	26.74	27.54		228.59	55.27	0.031	22.36
6	POSHERA STREAM	1350.2	18.44	13.55	4.29		21.57	15.97	0.033	21.00
7	BERISTE STREAM	1126.4	8.50	40.62	22.38		48.73	43.26	0.040	17.33
8	CHAS OUTLET	7901.4	11.82	29.75	22.52		549.37	69.53	0.046	15.07

3.3 Selection of Wells for monitoring

Total eighty-three (47 in Chas, 27 in Dhanoshi and 9 wells in Aine watershed) wells were monitored at an interval of twenty-one days, parameters like the stream order to which the well belongs, catchment area of the well, type of use of the well, type of load on the well, and water level drop in the wells are monitored. The method involved for monitoring is simple engineer's glass fibre tape. The wells were selected as such they cover most part of the watershed, but as wells were made near habitations or where there is a need by people, it is not possible to cover the whole watershed equally. Figure below (Figure 3.19 to 3.21) show the well locations.

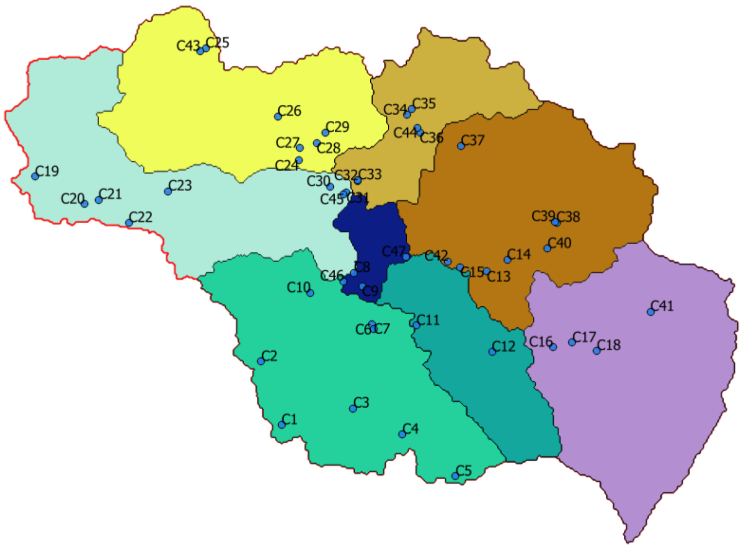


Figure 3.19 Chas Watershed Observation Wells (according to serial number)

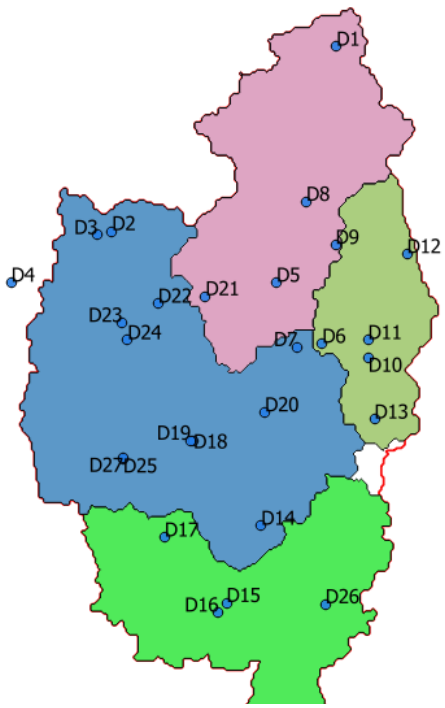


Figure 3.21 Dhanoshi Watershed Observation Wells (according to serial number)

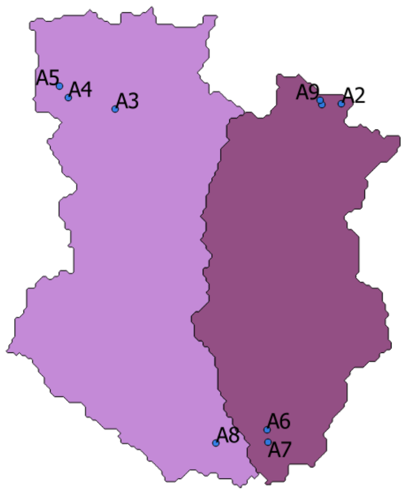


Figure 3.20 Aine Watershed Observation Wells (according to serial number)

Figure 3.23 Well A5 Vanganpada (measuring diameter with tape)

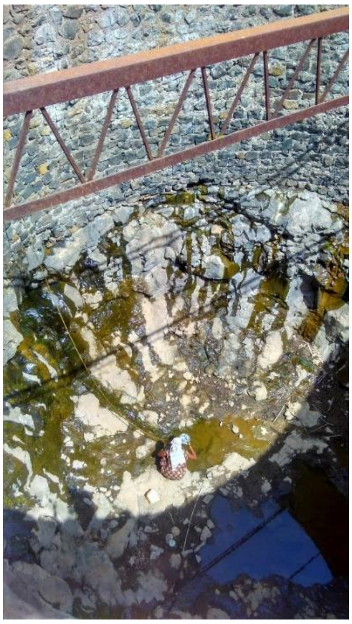


Figure 3.22 Well A2 Dongarwadi, A woman fetching water from the well (April 2017)

Table 3.6 Typical data collected during well reading

Sr. No	Location description	Lat	Long	Elevation from Mean Sea Level (m)	Order (10pixels)	Rock Depth (Metre Below Ground)	Hamlet Elev From Mean Sea Level(m)	mean drop (mm/day)
C1	Naviwadi	19.93305	73.36441667	412	2	7	437	13.40
C2	Wargadpada	19.94383333	73.36095	391	1	2	417	26.88

Sr. No	Location description	Height of Water Column (m) 1	Height of Water Column (m) 2	Height of Water Column (m) 3	Height of Water Column (m) 4	Height of Water Column (m) 5	Height of Water Column (m) 6	Height of Water Column (m) 7
C1	Naviwadi	5.5	5.10	4.89	4.66	4.48	3.92	3.46
C2	Wargadpada	4.2	3.06	2.65	2.33	1.60	0.45	0.30

Sr. No	Location description	Order (10pixels)	Well Catchment (ha)	Category	Distance to well (m)	Paddy %	Forest%	perinniality	total_load Cubic Metre
C1	Naviwadi	2	10.086	PDW	309	32.4	1.85	10	510.3
C2	Wargadpada	1	19.391	FW	418	17.61	1.42	8	0.0

Chapter 4

4 GSDA Assessment Methodology

Groundwater Surveys and Development Agency (GSDA) is a Government of Maharashtra organisation, reputed in national level for its work in the field of groundwater in Deccan Trap. It's one of the nation's leading institute concerned with activities like "groundwater surveys, exploration, assessment, monitoring, development, management and regulation of groundwater resources for irrigation, drinking and industrial needs" (https://gsda.maharashtra.gov.in/WorkArea.html). It's a knowledge based resource centre in water sector. Its main functions involve Systematic hydrogeological survey, Certification for drinking water supply, Water Conservation Programme etc., (GoM, Report on the dynamic Ground Water Resource of Maharashtra (2011-2012)).

GSDA follows Groundwater Resource Estimation Methodology (1997, GEC 97) (GoI, Ground Water Resource Estimation Methodology, 2009) to estimate state's groundwater resources. Many of the development programmes are planned based on the GSDA observations and recommendations. It is important to understand the methodology used by GSDA to estimate state groundwater resources and see whether they hold good in our present study region. It will help us plan better, especially when people's post-monsoon daily water needs are fulfilled by Groundwater.

4.1 Groundwater Resource Estimation Methodology

Here the summary of groundwater resource estimation methodology described as in Dynamic Groundwater Resources of Maharashtra, prepares by GSDA is written. They mainly use the method of Water Level Fluctuation (WLF) in groundwater recharge assessment. Watershed is used as groundwater assessment unit. While calculating the amount of recharge, the hilly areas of slope more than 20% are excluded from the total area that contributes to the recharge. Monsoon Recharge is expressed as

$$R=h*Sy*A+Dg$$

Where h is rise in water table in monsoon period, Sy is the specific yield, A is the area considered for computation of recharge and Dg is gross groundwater draft during monsoons. As rainfall is not the only source for groundwater recharge in monsoon, recharge from canals, ponds, irrigation etc., will improve the equation.

Once the recharge is estimated, GSDA computes the total availability of Groundwater using the below equation.

Net Groundwater Availability = Annual Groundwater Recharge – Natural Discharge in non-monsoon period.

Here as GSDA doesn't have the detailed data for quantitative assessment of natural discharge, it recommends that 5-10% of the total annual groundwater potential may be assigned to account for natural discharges in the non-monsoon season.

Using the net groundwater availability and groundwater draft, GSDA computes Stage of groundwater development percentage.

Stage of Groundwater Development% =Ground water Draft/Net groundwater availability*100

Stage of Groundwater development is % value is classified into four sub categories, i) Safe areas which have groundwater potential for development, ii) Semi-Critical areas where cautious groundwater development is recommended, iii) Critical areas, and iv) Over-exploited areas where there should be intensive monitoring and evaluation and future groundwater development be linked with water conservation measures (Table 4.1).

Table 4.1 GSDA Watershed Categories

Stage of GW Development	**Category**
70%	SAFE
>70 to 90%	SEMI CRITICAL
>90 to 100%	CRITICAL
>100%	OVER EXPLOITED

Then, the annual available groundwater is distributed between domestic, industrial and irrigation uses in priority order.

4.2 Situation of Groundwater in Study Area

Table 4.2 GSDA Groundwater Balance and Classification for Jawhar and Mokhada Talukas

Taluka	Recharge From Rain during monsoon (ham)	Provison for Natural Discharge (ham)	Net Ground Water Availability (ham)	Ground Water Available as % of Total Recharge (%)	Baseflows as % of Total Recharge (%)	Ground Water Draft for irrigation (ham)	Ground Water Draft for Domestic and Industrial Water Supply (ham)	Total Ground water Draft (ham)	Stage of Ground water Development (ham)	Category
Jawhar	3330.40	239.60	3090.80	92.81	7.19	103.05	61.03	164.08	5.31	SAFE
Mokhada	1680.65	84.88	1595.77	94.95	5.05	47.63	57.66	105.29	6.60	SAFE

* Source: Report on the dynamic Ground Water Resource of Maharashtra (2011-2012) (for non-command area)

Mokhada and Jawhar receive significant amount of rainfall (average 2000-3000 mm per year). Calculations show that the region is in 5 to 6% stage of development implying the watershed as SAFE watershed with plenty of opportunity for development (in terms of irrigation etc.,) (Table 4.2). But ground situation does not reflect this fact, region faces acute water problems in summer season, where even getting proper Drinking Water is a far goal, let alone rabi agriculture. Hence there is clearly room for a better estimation process. Natural discharge part of the groundwater availability estimation, seems to be the major unknown which has been assumed by GSDA (because of unavailability of stages, gauged data for the watersheds in the study region). In this study, an attempt is made to measure post-monsoon baseflows.

4.3 Groundwater Recharge for Jawhar and Mokhada Taluka

Table 4.3 GSDA Recharge Estimation

Taluka	Jawhar	Mokhada
Land Area (ha)	60994	50307
Non-Command, Non-Hilly land (ha)	32544	17385
Water Level Fluctuation (WLF) in metres	4.43	3.98
Recharge from rain during monsoon (ham) *	3330.4	1680.65

* Report on the dynamic Ground Water Resource of Maharashtra (2011-2012)

Estimation of Specific Yield from the above table

Specific Yield * Non-Hilly Area * WLF = Recharge

For Jawhar

Sy * 32544 * 4.43 = 3330.4

Sy = 2.31%

For Mokhada

Sy * 17385 * 3.98 = 1680.65

Sy = 2.43%

Above calculated Specific Yield are used to estimate the recharge in the sixteen watersheds we studied.

4.4 Baseflow Measurements

As mentioned earlier, baseflows post-monsoon were measured at an interval of twenty days till they go dry. The amount of water that is leaving the watershed is computed. The table below (Table 4.4) shows the baseflow readings taken over time. (Green readings are the ones considered to compute the volume of water leaving the watershed as baseflows, since at small flows, the measurements are error-prone)

Table 4.4 Base-flow Readings

Watershed Number	Sr. No	Watershed Name	Catchment Area (ha)	Slope Area (%)		Forest Cover %	1 Flow (Lit/Sec)	2 Flow (Lit/Sec)	3 Flow (Lit/Sec)	4 Flow (Lit/Sec)	5 Flow (Lit/Sec)	6 Flow (Lit/Sec)
				0-5%	>20%							
1 (DHANOSHI)	1	DHANOSHI NORTH	364.3	9.90	18.15	10.95	58.78	9.39	3.21	1.16	0.48	0.00
	2	DHANOSHI NORTHWEST	778.5	7.66	21.22	9.94	139.15	36.96	12.35	6.36	2.46	
	3	DHANOSHI WEST	2061.6	8.67	6.33	13.64	332.03	48.23	22.44	12.04	5.90	1.49
	4	DHANOSHI SOUTH	735.6	23.00	25.40	21.87	60.64	12.96	9.52	5.71	2.06	2.00
	5	DHANOSHI OUTLET	3184.2	17.70	26.50	15.33	419.84	66.56	26.34	18.92	8.44	2.50
2 (AINE)	1	AINE EAST	804.5	0.00	46.23	63.83	18.03	5.37				
	2	AINE WEST	594.2	9.10	65.00	55.61	36.30	14.24				
	3	AINE OUTLET	1407	3.86	53.80	59.00	68.72	19.9	5.79	3.00	1.50	
3 (CHAS)	1	MORCHONDI RIVER	1464.1	12.15	40.84	41.50	66.78	24.59	13.24	2.82	1.31	0.00
	2	MORONDE RIVER	2749.3	13.78	28.84	31.27	187.90	84.66	60.29	30.97	8.64	1.63
	3	MORONDE STREAM	625.0	10.72	20.00	17.72	22.52	6.23	5.52	0.72	0.10	0.00
	4	HIRVE STREAM	587.7	9.70	25.48	21.65	25.00	8.41	2.13	0.50	0.00	
	5	SHINDEPADA RIVER	4136.2	12.63	26.74	27.54	242.21	129.65	63.18	flow abstr	13.32	1.50
	6	POSHERA STREAM	1350.2	18.44	13.55	4.29	26.30	11.95	5.89	1.00	0.81	0.00
	7	BERISTE STREAM	1126.4	8.50	40.62	22.38	54.00	9.86	13.36	3.00	0.20	0.00
	8	CHAS OUTLET	7901.4	11.82	29.75	22.52	406.40	215.17	71.13	31.21	6.19	2.00

Using the above values, the graphs are plotted. The Baseflow Curves for three main watersheds (Dhanoshi Outlet, Aine Outlet, and Chas Outlet) are as below (Figure 4.1 to 4.3)

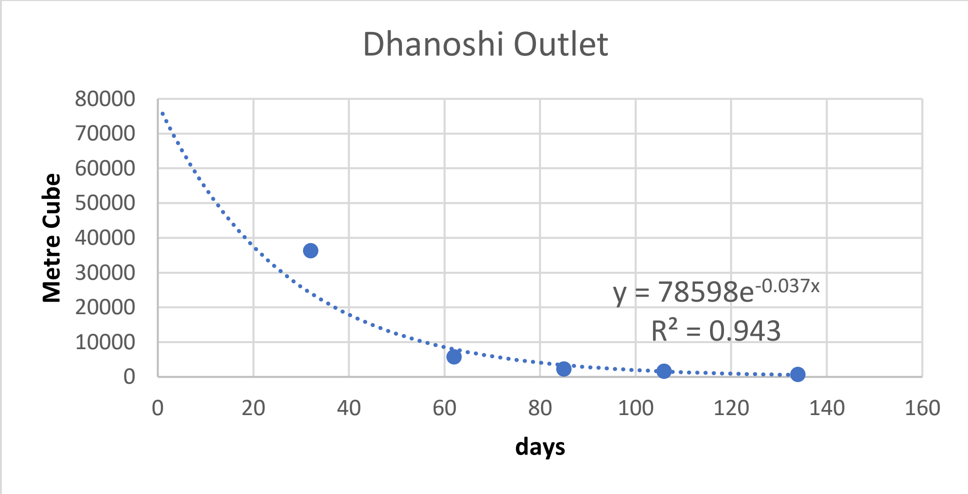


Figure 4.1 Dhanoshi Outlet Baseflow Profile

Volume of Water discharged as baseflow is calculated by integrating y = $78598e^{-0.037x}$ from 0 to 134 days,

$$\int_{0}^{134} 78598\mathrm{e}^{-0.037\mathrm{x}} dx \ = 210.93ham$$

Similarly,

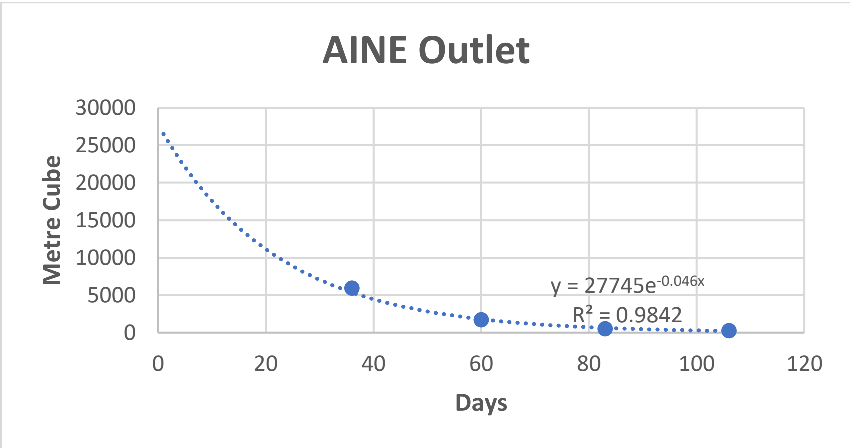


Figure 4.2 Aine Outlet Baseflow Profile

$$\int_{0}^{106} 27745\mathrm{e}^{-0.046\mathrm{x}} dx \ = 59.86ham$$

And,

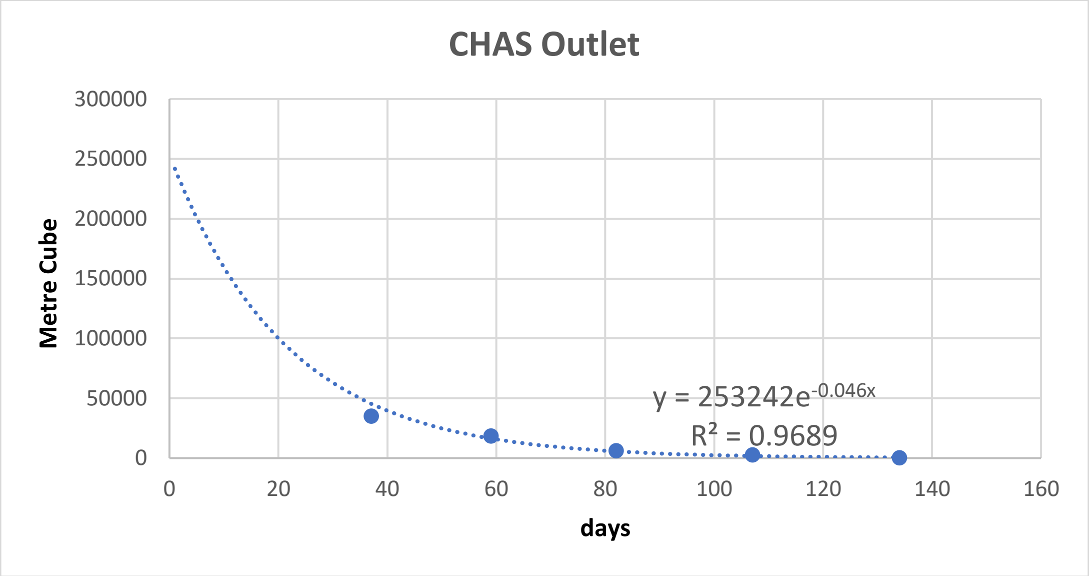


Figure 4.3 Chas Outlet Baseflow Profile

$$\int_0^{134} 253242\mathrm{e}^{-0.046\mathrm{x}} dx \ = 549.37ham$$

Similar calculations are made with other thirteen sub watersheds and the amount of natural discharge (baseflows) against the total groundwater recharged during monsoon are compared in the table give below.

Table 4.5 % Base-flow leaving the watershed as a fraction of total recharge, half-life for 16 watersheds

Watershed Number	Sr. No	Watershed Name	Catchment Area (ha)	Recharge (ham) by GSDA methodology	Baseflow out (ham) by Flow Measurement	% baseflow out	Half Life in Days	Water level drop (mm)
1 (DHANOSHI)	1	DHANOSHI NORTH	364.3	42.94	47.63	110.93	12.84	130.74
	2	DHANOSHI NORTHWEST	778.5	88.32	102.74	116.33	16.12	131.97
	3	DHANOSHI WEST	2061.6	173.07	167.37	96.71	18.24	130.44
	4	DHANOSHI SOUTH	735.6	79.02	34.87	44.13	22.36	47.40
	5	DHANOSHI OUTLET	3184.2	337.02	210.93	62.59	15.07	66.24
2 (AINE)	1	AINE EAST	804.5	62.29	19.70	31.62	13.08	24.48
	2	AINE WEST	594.2	29.95	32.55	108.71	17.77	54.79
	3	AINE OUTLET	1407	93.60	59.86	63.94	15.07	42.54
3 (CHAS)	1	MORCHONDI RIVER	1464.1	103.94	72.91	70.14	15.75	49.80
	2	MORONDE RIVER	2749.3	234.77	170.94	72.81	23.10	62.18
	3	MORONDE STREAM	625.0	60.00	14.86	24.77	22.36	23.78
	4	HIRVE STREAM	587.7	52.55	39.58	75.30	11.75	67.34
	5	SHINDEPADA RIVER	4136.2	363.62	228.59	62.86	22.36	55.27
	6	POSHERA STREAM	1350.2	140.07	21.57	15.40	21.00	15.97
	7	BERISTE STREAM	1126.4	80.26	48.73	60.71	17.33	43.26
	8	CHAS OUTLET	7901.4	666.09	549.37	82.48	15.07	69.53

From the above observations, It is heartening to note that the rough GSDA estimates for recharge are in the same range as what was observed in the discharge. However, there two very important issues. The first is that the recharge equals the discharge as well as the evapotranspiration losses in the non-monsoon months. The second is that around 69% of recharged water (calculated according to GSDA methodology) is leaving the watershed as baseflows itself.

4.5 Well Water level drop and Baseflow relationship

4.5.1 Study of Bersite stream watershed

Here we focus on the relationship between well level drop and baseflows, as baseflow monitoring and well monitoring didn't start together, we are considering the well drop between first and second reading (08-12-2016 to 07-01-2017) (Figure 4.4) (Table 4.6) and the baseflows leaving the watershed in the same period is also computed and compared with the well level drop. Each well watershed is assigned with the corresponding drop in height of water column. In the overlapping well watersheds, the overlap area is not considered while assigning the drop for downstream well catchment. As Beriste stream didn't had a well at the outlet of the watershed, well level drop in Bhoirpada well near to Beriste stream outlet is assumed.

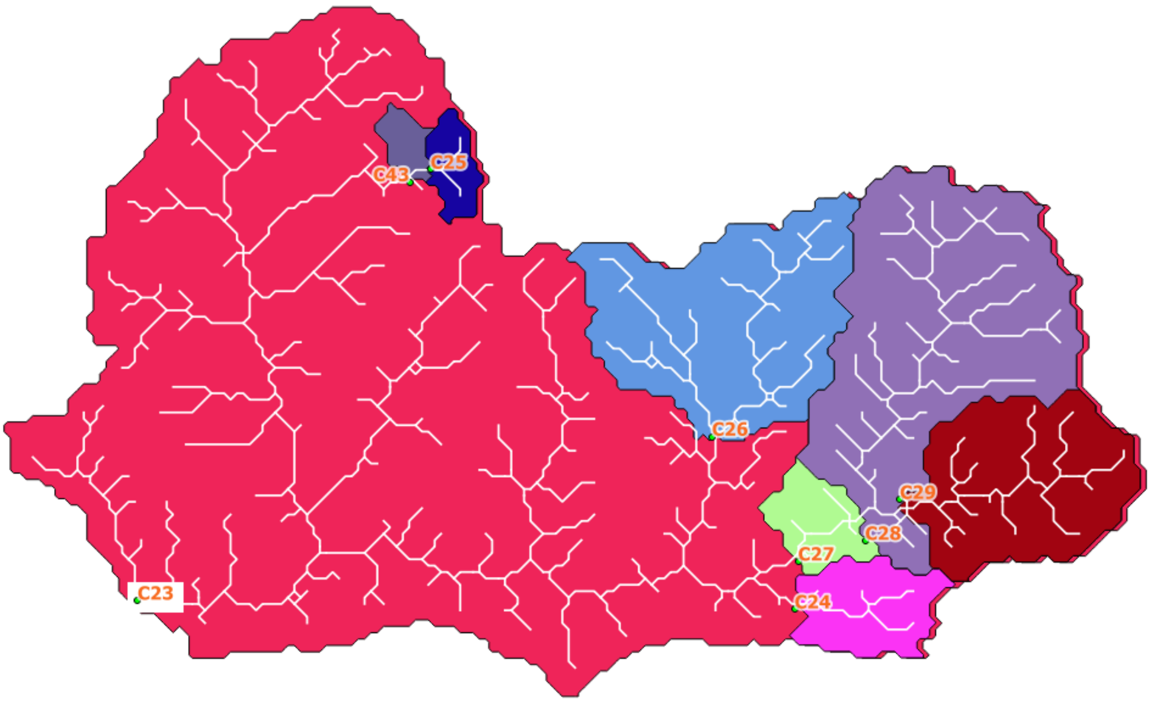


Figure 4.4 Beriste Stream Watershed with well watersheds

Volume drop by wells (between 08-12-2016 to 07-01-2017)

Table 4.6 Beriste Observation wells water level drop (between 08-12-2016 to 07-01-2017)

Well Number	Catchment area in (ha)	Differential Catchment area (ha)	Drop in water level (m)	Total Volume of water drop considering 2.4% Sy
C25	9	9	3.92	8467.2

C43	13	(13-9) = 4	1.00	960
C26	99	99	0.32	7603.2
C29	69	69	0	0
C28	209	(209-69) = 140	0	0
C27	226	(226-209) = 17	0.07	285.6
C24	26	26	1.60	9984
C23	1064	(1064-13-226-99-26) = 700	0.02	3360
Total Volume drop (cubic metre) =				30660

As this total drop is also has a component of anthropogenic load, the total Drinking Water load with in the watershed is computed (Table 4.7)

Table 4.7 Domestic load on Beriste Watershed (between 08-12-2016 to 07-01-2017)

Habitation Name	Households	Water Load per day (cubic metre) considering 140litres per HH Per day	Water Load for 29 days (between 08-12-2016 to 07-01-2017)
Brahmangaon	182	25.48	738.92
Beriste	65	9.10	263.90
Umberpada	58	8.12	235.48
Teli Umberpada	112	15.68	454.72
Total Load =			1693.02

By water balance, the amount of water leaving the watershed (baseflows) will be equal to,

Baseflows by well water level drop =Well drop volume – Domestic Load

= 30660 – 1693.02

= 28966.98 cubic metre

Now we verify this with the actual baseflows measured by our field study (Figure 4.5)

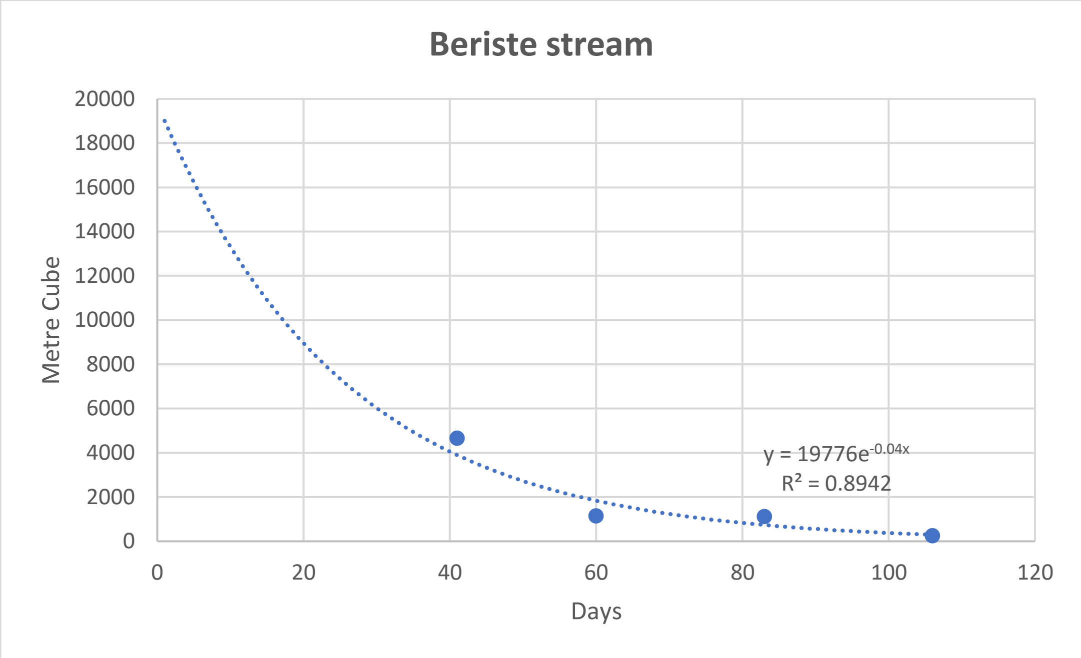


Figure 4.5 Beriste Stream Base-flow profile

$$\int_{69}^{99} 19776\mathrm{e}^{-0.04\mathrm{x}} dx \ = 21866.64 \ cubic \ metre$$

Baseflows measured = 21866.64 cubic metre

Baseflows/flows leaving watershed by well level drop = 28966.98 cubic metre

From the above results in the month of December, volume of water drops computed by well level drop is comparable with the baseflows.

But in the month of October and November, the well level drops will be lesser than December water level drops (from previous observations in the field it is claimed as negligible drop, present study has not data of well level drop in October and November 2016), but the baseflows quantity in the month of November will be more compared to the baseflows in December,

Baseflow out in November,

$$\int_{31}^{61} 19776\mathrm{e}^{-0.04\mathrm{x}} dx \ = 99979.23 \ cubic \ metre$$

So, it is evident that the baseflow coming out in the early months of after monsoon is having major contribution from the soil moisture, which is not seen/resulted in well level drops. But in the later months, like from December, the baseflows will get contributed from groundwater (below to soil matrix), which is evident and comparable with well level drops from the above results.

There is scope to understand this dynamics in a better way by collecting data immediately after monsoon, and check how it varies across different watersheds. The only limitation here is finding wells at regular intervals across the watershed area, which leads to better estimation of water volume leaving the watershed (by well level drop analysis).

4.6 Observations

- GSDA's assumption of natural discharge as 5-10% of total recharge is inaccurate for the study region.
- Around 69% of recharged water has left the watershed as baseflows by January end (according to our flow measurements)**.** This suggests that for hilly areas of Western Ghats, incorporation of a seasonal groundwater assessment will inform the administration about the ground situation which is likely to unfold in the summer months.
- Though the study area comes under safe watersheds according to GSDA's stage of development, it is clear why the people here are facing acute water problems in summer months.
- The flows in the early months post monsoon (October-November) are greater than what can be attributed to groundwater drop alone. This indicates that the excess must have come from seepage from soil moisture held in the top few meters of the surface.

Suggestion to GSDA

While it is difficult to have stage measurement at all small watershed level at all times, (due to economic constraints), one-time studies of all watersheds to capture key parameters such as half-times, afforestation fraction, soil-moisture vs. Groundwater fraction of stream flows. This would be helpful in yearly planning as well as in long-term monitoring of the health of watersheds.

Soil moisture and Evapotranspiration are important stocks and flows. GSDA should evolve methodologies to incorporate these in its overall assessment protocols.

Limitations of Present Study

- Baseflow measurement immediately after monsoon was not done, this should be taken care for further studies of this kind for more accurate measurement of baseflows.

- As we see the baseflow out column in our estimation table, Dhanoshi North, Dhanoshi Northwest and Aine west's baseflow exceeds the recharge (calculated as per GEC methodology), this might be because of the error in the recharge calculation, as we exclude hilly areas from recharge calculation, it might be a case where hilly slopes with good forest cover might have contributed to recharge, which is not considered.

Chapter 5

5 Land Use – ET load – Specific Yield (Water balance)

In previous chapter we observed that almost all the water recharged is getting discharged, if that is the case, it is neglecting evapotranspiration loads post monsoon. It is evident that there is no component of natural plants which are there whole year using the stored water. This motivates to back calculate Specific Yield from water level fluctuation method considering evapotranspiration.

Specific Yield here is treated as a storage term (https://water.usgs.gov/ogw/gwrp/methods/wtf/estimating_sy.html), independent of time in theory specific yield accounts for the instantaneous release of water from storage in soil matrix. But in reality, the release of water will not happen instantaneous, release duration depends on different soil structures.

In the present study, the ground water level fluctuation method for calculating recharge is used to back calculate Specific Yield.

$$\sum(Area * Depth) * Specific\ Yield = Baseflows + Evapotranspiration\ load$$

Here area is area of the watershed catchment, Depth is the depth of top unconfined aquifer (above the impervious basaltic bed rock), Specific Yield refers to storage capacity in the watershed, Baseflows are the measured Post-monsoon baseflows, Evapotranspiration(ET) load is the ET load post-monsoon in the given watershed.

In the Left-hand side of the equation difference in ground water level pre and post monsoon is used to consider the total water recharged during monsoon and which is available in ground for post-monsoon discharge and other loads in the watershed (Right hand side of the equation). Human load for Drinking water is neglected as the quantity is negligible (Annexure Well Reading)

5.1 Well Voronoi mapping

Well Voronois are used to consider the effective area that needs to be assigned to the observed water level fluctuations in the well, as there was no correlation between well thickness (top acquifer thickness and the location of the well (Annexure-Well Reading) here we are assuming the water level fluctuation of the well to the whole well voronoi area (may be a limitation). In the below figures the well voronoi map for three main watersheds are shown (Figure 5.1 to 5.3), similarly well voronoi maps are drawn using QGIS for the thirteen subwatersheds.

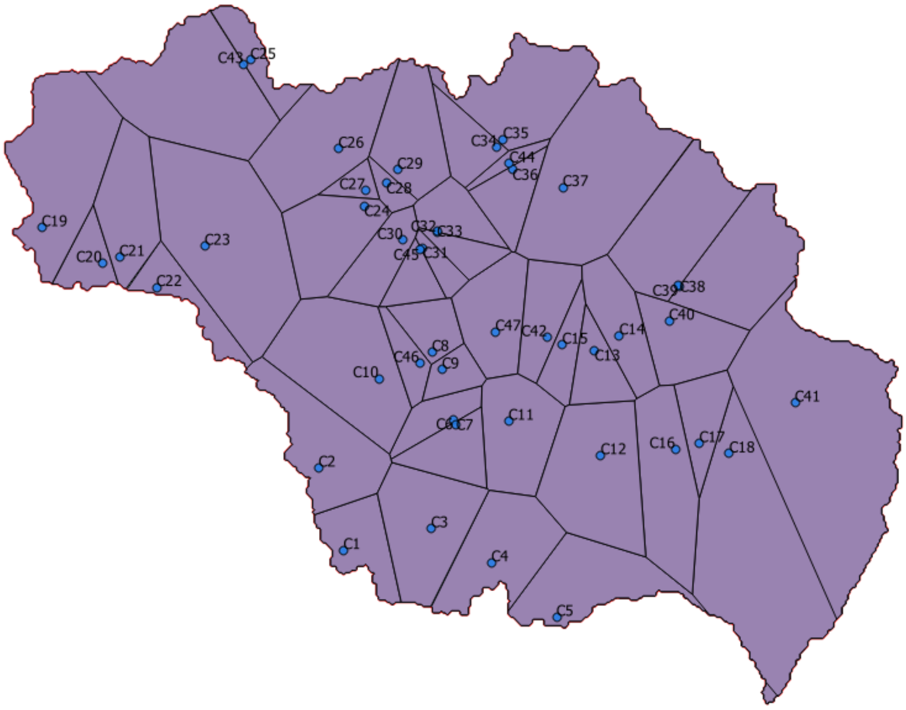


Figure 5.1 Chas Watershed Well Voronoi map

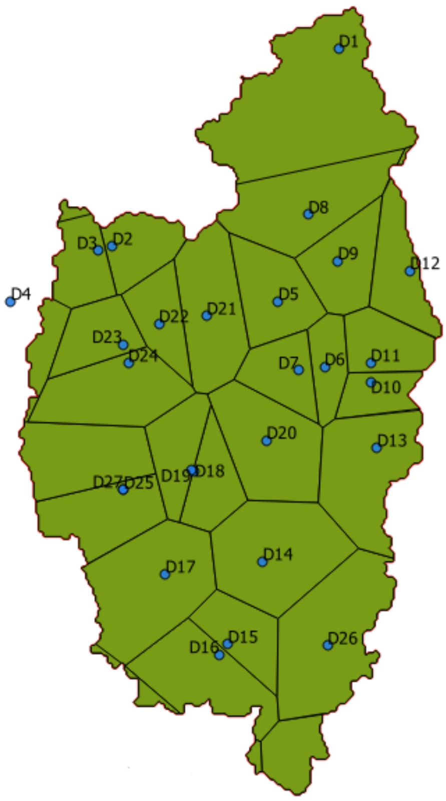


Figure 5.3 Dhanoshi Watershed Well Voronoi map

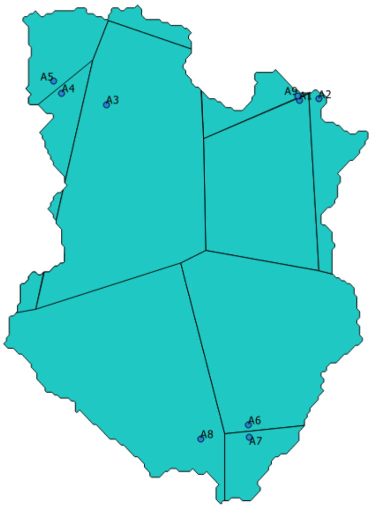


Figure 5.2 Aine Watershed Well Voronoi map

5.2 Post-monsoon ET load estimation

As we discussed earlier, it is important to consider the ET loads along with the baseflows as the discharge component of groundwater. Here Landsat 8 satellite imagery is used to classify land use in the study region. Landsat 8 image of 11/11/2016 is used to classify the land use in the study region, initially it was difficult to differentiate the Kharif crop (which will be harvested post monsoon) and the wild grass. As paddy is the significant kharif crop and it is usually harvested around last week of October, it was easy to identify the harvested paddy fields (which were giving different reflectance than the wild grass).

As there is not much study done in the seasonal variation of ET load of moist deciduous forest in this region, certain assumptions are made to proceed further, which needs to be rectified in further studies (like by using MODIS data and Land Surface Energy Balance, etc).

Classification for three main watersheds are being shown below (Figure 5.4 to 5.6), similarly the classification is done for the thirteen sub-watersheds.

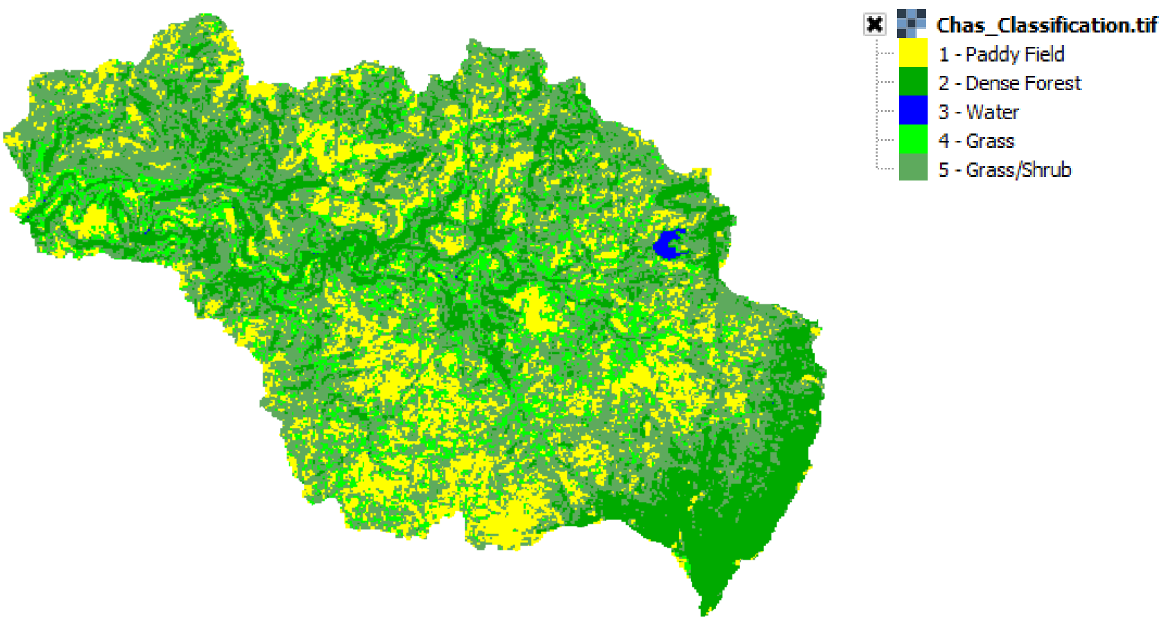


Figure 5.4 Chas Watershed LULC map

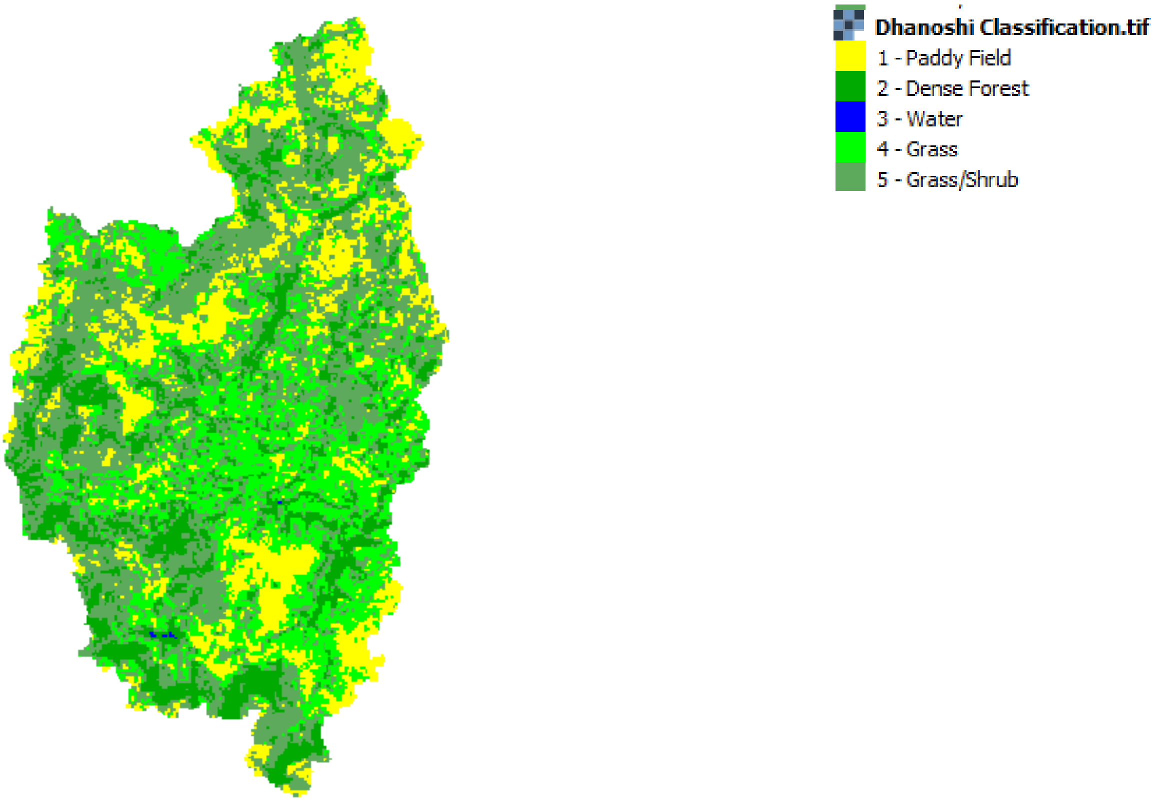


Figure 5.5 Dhanoshi Watershed LULC map

Figure 5.6 Aine Watershed LULC map

ET load assumptions

Table 5.1 Evapotranspiration Load Assumptions

Land Use/Cover	Number of Days (Post Monsoon)	mm/day ET load
Paddy	30	3.5
Grass	20	2
Natural Forest	243	2.5

As there was no standard literature available for ET loads in this area, Several Journals were referred and these values are (FAO, 2017) (N K Tyagi, et. al., 2000) (D K Sinha) (Lívia Cristina Pinto Dias, et. al., 2015) (George L. Vourlitis, et. al., 2015) It is assumed that paddy will be harvested by the end of October (Considering thirty days post monsoon), Grass is cut or goes dry by October 20th (September end is considered as the end of monsoon), as there was no proper literature for dry/moist deciduous natural forest ET load in this region, it 2.5 mm/day ET is assumed (post monsoon) (Table 5.1).

Now for back calculation of Specific Yield is done by using two types of Aquifer depths, 1st is considering soil/murum matrix till the start of the hard rock basalt. 2nd one is done by using the acquifer thickness as metre below ground level (water level) as on beginning of may.

$$Specific\ Yield = (Baseflows + Evapotranspiration\ load)/\sum(Area * Depth)$$

Table 5.2 Specific Yield back calculation using GSDA methodology

Watershed Name	Paddy ET (cubic metre)	Forest ET (cubic metre)	Grass ET (cubic metre)	Total ET Load (ham)	Baseflow (ham)	Specific Yield %	
						RD (Bed rock depth)	WL (water level)
DHANOSHI NORTH	63976.50	226354.50	96732.00	38.71	47.63	7.07	5.46
DHANOSHI NORTHWEST	222169.50	439587.00	177372.00	83.91	102.74	4.83	6.19
DHANOSHI WEST	420147.00	1599243.75	506016.00	252.54	167.37	4.25	4.77
DHANOSHI SOUTH	145530.00	916353.00	159660.00	122.15	34.87	4.00	6.03
DHANOSHI OUTLET	631449.00	2775303.00	768060.00	417.48	210.93	4.17	4.80
AINE EAST	41485.50	2157475.50	64692.00	226.37	19.70	15.49	14.63
AINE WEST	76545.00	2537466.75	104184.00	271.82	32.55	12.18	9.86
AINE OUTLET	124267.50	4714625.25	168300.00	500.72	59.86	13.61	11.67
MORCHONDI RIVER	202702.50	3450539.25	24300.00	367.75	72.91	7.42	8.71
MORONDE RIVER	411169.50	4884664.50	544500.00	584.03	170.94	6.44	8.02

Watershed Name	Paddy ET (cubic metre)	Forest ET (cubic metre)	Grass ET (cubic metre)	Total ET Load (ham)	Baseflow (ham)	Specific Yield %	
						RD (Bed rock depth)	WL (water level)
MORONDE STREAM	110092.50	628762.50	150264.00	88.91	14.86	**4.08**	**4.38**
HIRVE STREAM	101493.00	724443.75	133884.00	95.98	39.58	**5.54**	**5.98**
SHINDEPADA RIVER	646002.00	6476253.75	869688.00	799.19	228.59	**5.80**	**6.72**
POSHERA STREAM	497542.50	328596.75	293076.00	111.92	21.57	**2.21**	**2.49**
BERISTE STREAM	197221.50	1430844.75	251604.00	187.97	48.73	**5.70**	**5.52**
CHAS OUTLET	1534869.00	10106673.75	1698192.00	1333.97	549.37	**5.64**	**6.04**

5.3 Analysis

As major part of the ET load is of assumptions, so it is important to see whether there is a relationship between ET load and Baseflows. Plot below (Figure 5.7) is drawn to see the correlation between ET load and Baseflows.

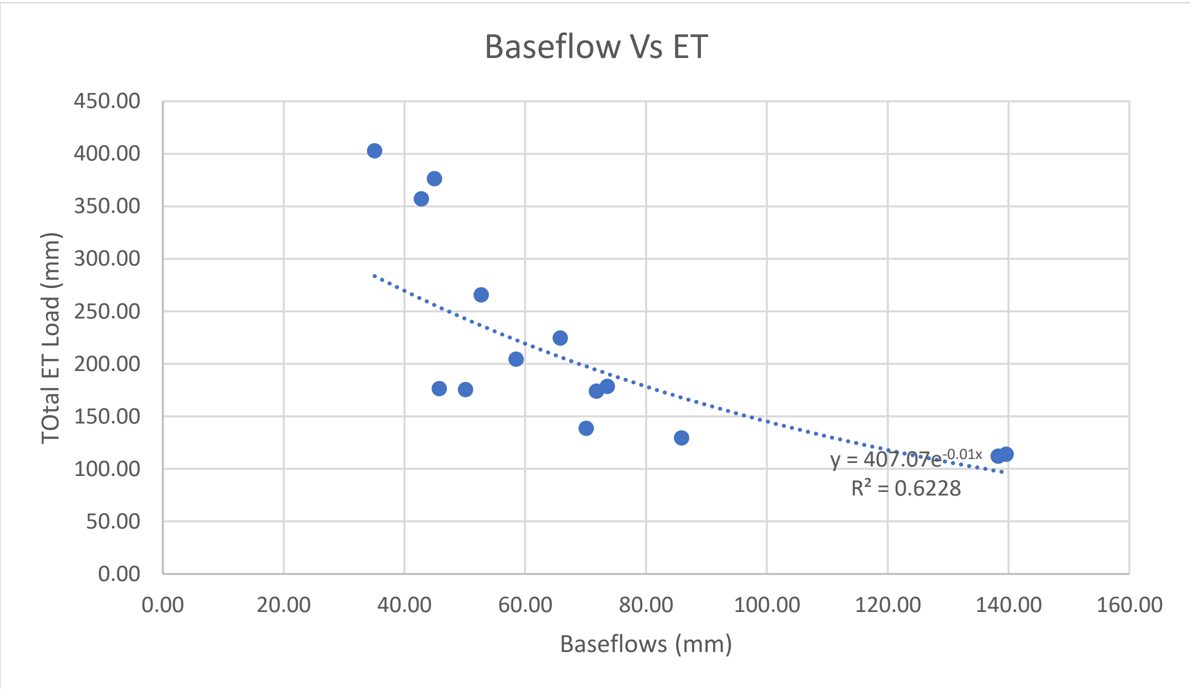


Figure 5.7 Variation of Base-flows with respect to Evapotranspiration Loads

It is observed that Baseflows are less in the higher ET load watersheds. So, there is a possibility where more ET load (due to more forest cover) leads to lesser natural discharge, implying more water stored within the soil/murum matrix of the watershed (more water stored in the subsurface) (Figure 5.8 and 5.9).

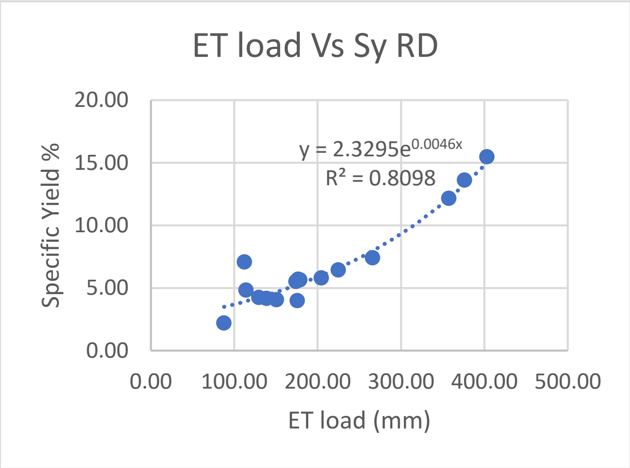


Figure 5.9 Variation in Specific Yield (RD-Full aquifer) with respect to ET load

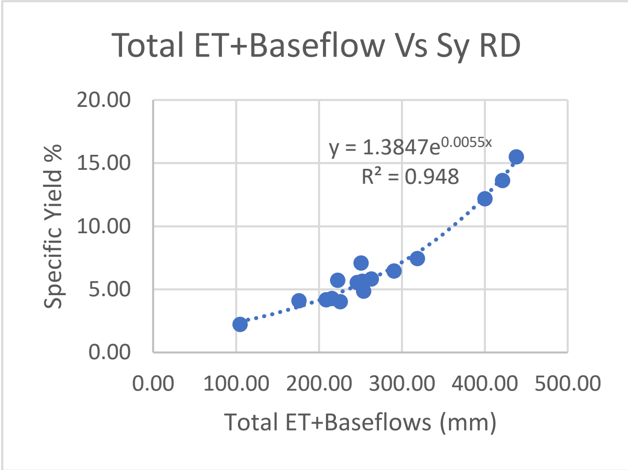


Figure 5.8 Variation in Specific Yield (RD-Full aquifer) with respect to Total flows

It is evident as the ET load (mainly dominated by forest cover) increases the Specific Yield also increases. Similar observations are made using the metre below ground level (water) as aquifer thickness, as shown below (Figure 5.10 and 5.11).

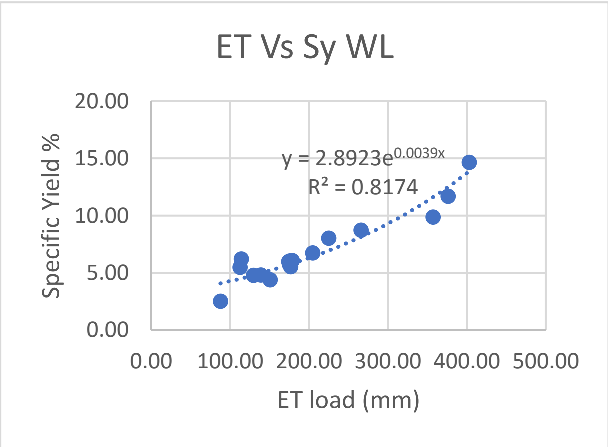


Figure 5.10 Variation in Specific Yield (WL - Water Level) with respect to ET load

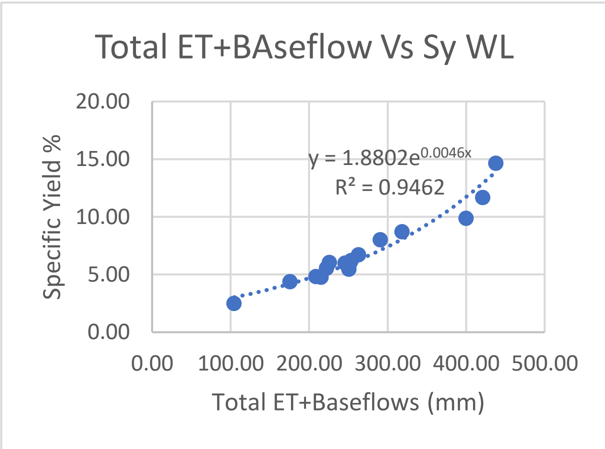


Figure 5.11 Variation in Specific Yield (WL - Water Level) with respect to Total flows

5.4 Observations

- It was observed that wherever the forest cover is good in the well watersheds, these wells have been perennial. Since, the natural forest roots were found to go as deep as 3-6 metres, creating a pathway for more water to infiltrate they create more space to store water. On the other hand, more forest cover does lead to more evapotranspiration load and less natural discharge of water (like in the form of baseflows). Thus, afforestation does increase local access to drinking water but may not contribute to bulk-water availability such as for rabi irrigation.
- The baseflows ceasing early in the dense forested watersheds (Aine) do explain this phenomenon.
- It is also observed that trees/shrubs help in reducing soil erosion and keep the soil intact.

Limitations

- As the current study completely done by assuming Evapotranspiration rates from existing literature, it may not match the true rate.

Scope for further study

- Estimation of on field evapotranspiration rates will help to understand the system better. And do better water balance.
- Better analysis of stream flows into its components, i.e., groundwater flows and seepage from soils, would be useful to understand the impact of afforestation and area-treatment watershed activities.
- Specific Yield Estimation using Well Hydrograph (by continuous monitoring of wells) and other Specific Yield determination methods can be tried in the study region (Lisa Shevenell, 1996) (Udayakumar G, et. al., 2015).
- ET load estimation and Seasonal change in ET load can be can be tried using surface energy balance method (Using MODIS remote sensing data) (Mark E. Savoca, et. al., 2013).

Figure 5.13 Trees controlling the soil erosion.

Figure 5.14 Grass and their root system in top soil layer

Figure 5.12 Roots from a natural forest, creating space in the murum strata (cut section)

Chapter 6

6 Well Analysis

6.1 Wells Monitoring Details

As mentioned earlier, this region faces acute drinking water problem in dry season. It is important to understand the dynamics of wells post monsoon. Hence eighty-three wells were considered for monitoring across three major watersheds, water level below ground level reading is taken at every 21-day interval from starting of December to beginning of May, and the distribution of load on wells was also taken under consideration over different period. Selection of wells was done by looking at google map, as wells are mainly near the hamlets, it was not possible to monitor ground water levels at remote locations where the wells are not present. Different types of wells selected are as in Table 6.1

Table 6.1 Categorisation of wells monitored

Watershed	Primary Drinking Water (PDW) Wells	Secondary Drinking Water (SDW) Wells	Farm Wells (FW)	Total Number of Wells
Chas	25	9	13	47
Dhanoshi	18	1	8	27
Aine	5	1	3	9
Total	**48**	**11**	**24**	**83**

The Details about the Selected such as – Gram Panchayat to which it belongs, Total Population, Households, Caste and Availability of water as per norms is tabulated in the table below (Table 6.2) (Source: NRDWP)

Table 6.2 Demography of the hamlets (location of observation wells)

Sr. No	Location description	Category	GP	Village Name	Habitation Name	Total Popln	% ST Popln	HH	Status
C1	Naviwadi	PDW	POSHERA	LAKSHIMINAGAR (N.V.)	NAVIWADI	391	99.5	73	Partial Covered
C2	Wargadpada	FW	MOKHADA	MOKHADA	WARGHADPADA	390	68.2	92	Partial Covered

Sr. No	Location description	Category	GP	Village Name	Habitation Name	Total Popln	% ST Popln	HH	Status
C3	Roadside well before Poshera	SDW	POSHERA	POSHERA	POSHERA	1638	94.6	355	Partial Covered
C4	Kathkarwadi (Poshera)	PDW	POSHERA	POSHERA	KATKARIWADI	174	89.1	39	Partial Covered
C5	Ridge Well (Poshera) People tree	FW	POSHERA	POSHERA					
C6	Vakarichapada (MNREGA)	FW	POSHERA	POSHERA	WAKHARICHAPADA	254	94.5	59	Partial Covered
C7	Vakarichapada	PDW	POSHERA	POSHERA	WAKHARICHAPADA	254	94.5	59	Partial Covered
C8	Dhamni Pada (Poshera)	PDW	POSHERA	POSHERA	DABHMIPADA	223	94.6	49	Partial Covered
C9	Dhamni Pada 2 (Poshera)	SDW	POSHERA	POSHERA	DABHMIPADA	223	94.6	49	Partial Covered
C10	Mordyachapada	PDW	POSHERA	POSHERA	MORDHYACHAPADA	315	94.6	69	Partial Covered
C11	Gaddichapada (interior)	PDW							
C12	Roadside (way to Morhande)	FW	MORHANDA GONDE BK	MORHANDA	MORHANDA	1817	94.2	357	Partial Covered
C13	Morhande (Main)	PDW	MORHANDA GONDE BK	MORHANDA	MORHANDA	1817	94.2	357	Partial Covered
C14	Morhande River well	SDW	MORHANDA GONDE BK	MORHANDA	MORHANDA	1817	94.2	357	Partial Covered
C15	Morhande Near Orchard	PDW	MORHANDA GONDE BK	MORHANDA	MORHANDA	1817	94.2	357	Partial Covered
C16	Vakichapada (Morchondi)	FW	MORHANDA GONDE BK	GONDE BK.	WAKICHAPADA	335	94.6	65	Partial Covered
C17	Gonde	PDW	MORHANDA GONDE BK	GONDE BK.	GONDE (BK)	501	94.4	96	Partial Covered
C18	Gaymukh (Temple) Gonde Badruk	PDW	MORHANDA GONDE BK	GONDE BK.	GAYMUKHPADA	129	94.6	25	Partial Covered
C19	Chas Outlet Jamdyachapada	PDW	CHAS	CHAS	JAMDYACHAPADA	484	98.3	98	Partial Covered
C20	Chas Pada 1	PDW	CHAS	CHAS	CHAS	255	98.0	49	Partial Covered
C21	Chas Pada (Ashram Shala Well)	PDW	CHAS	CHAS	CHAS	255	98.0	49	Partial Covered
C22	Chas Pada (road side)	FW	CHAS	CHAS	CHAS	255	98.0	49	Partial Covered
C23	Bhoir Pada	PDW	AASE	AASE	BHOIRPADA-WARGHADPADA	198	98.5	45	Partial Covered
C24	Beriste stream well next to road	PDW	BERISTE OSARVIRA	BERISTE	TELIUMBARPADA	550	96.2	112	Partial Covered
C25	Brahmangaon	PDW	AASE	BRAHMAGAON	BRAHMAGAON	860	99.3	182	Partial Covered
C26	Beriste Mulagaon Solar Powered well	PDW	BERISTE OSARVIRA	BERISTE	BERISTE	314	95.9	65	Partial Covered
C27	Beriste stream umberpada	SDW	BERISTE OSARVIRA	BERISTE	TELIUMBARPADA	550	96.2	112	Partial Covered
C28	Umberpada Solar well	PDW	BERISTE OSARVIRA	BERISTE	UMBARPADA	281	95.7	58	Partial Covered
C29	Umberpada Sub surface bund well	SDW	BERISTE OSARVIRA	BERISTE	UMBARPADA	281	95.7	58	Partial Covered

Sr. No	Location description	Category	GP	Village Name	Habitation Name	Total Popln	% ST Popln	HH	Status
C30	Shindepada well	PDW	HIRVE GHANVAL	HIRVE	SHINDEPADA	172	94.2	32	Partial Covered
C31	Shindepada well 2	FW	HIRVE GHANVAL	HIRVE	SHINDEPADA	172	94.2	32	Partial Covered
C32	Hirve stream well	FW	HIRVE GHANVAL	HIRVE	SHINDEPADA	172	94.2	32	Partial Covered
C33	Hirve stream (good)	SDW	HIRVE GHANVAL	HIRVE	SHINDEPADA	172	94.2	32	Partial Covered
C34	Pimpalpada	PDW	HIRVE GHANVAL	HIRVE	PIMPALPADA	125	93.6	25	Partial Covered
C35	Pimpalpada Stream	WASHING	HIRVE GHANVAL	HIRVE	PIMPALPADA	125	93.6	25	Partial Covered
C36	Hirve village well (Pimpalpada)	FW	HIRVE GHANVAL	HIRVE	PIMPALPADA	125	93.6	25	Partial Covered
C37	Patilpada	PDW	HIRVE GHANVAL	HIRVE	PATILPADA	78	92.3	14	Partial Covered
C38	Kelichapada near tulyachapada	PDW	MORHANDA GONDE BK	MORHANDA	KELICHAPADA	206	94.2	37	Partial Covered
C39	Tulyachapada stream (kelichapada) higher	FW	MORHANDA GONDE BK	MORHANDA	TULYACHAPADA	220	94.5	43	Partial Covered
C40	Tulyachapada roadside	FW	MORHANDA GONDE BK	MORHANDA	TULYACHAPADA	220	94.5	43	Partial Covered
C41	Munjyachimet (Morchondi)	PDW	MORHANDA GONDE BK	GONDE BK.	MUNJYACHIMET	493	94.3	96	Partial Covered
C42	Morhande Orchard Well	FW	MORHANDA GONDE BK	MORHANDA	MORHANDA	1817	94.2	357	Partial Covered
C43	Brahmangaon New	WASHING	AASE	BRAHMAGAON	BRAHMAGAON	860	99.3	182	Partial Covered
C44	Hirve New	PDW	HIRVE GHANVAL	HIRVE	HIRVE	1182	95.0	234	Partial Covered
C45	Shindepada DW	PDW	HIRVE GHANVAL	HIRVE	SHINDEPADA	172	94.2	32	Partial Covered
C46	Koldyachapada DW	SDW	MORHANDA GONDE BK	MORHANDA	KOLDHYACHAPADA	206	94.2	37	Partial Covered
C47	KoldyachapadaRiver	DW PROPOSED	MORHANDA GONDE BK	MORHANDA	KOLDHYACHAPADA	206	94.2	37	Partial Covered
D1	Karamba (Jawhar Nasik Highway side	PDW	RAITALE	RAITALE	KHARANBA	162	95.1	29	Partial Covered
D2	Kalidhond	PDW	JUNIJAWHAR	JUNI JAWHAR	KALIDHOND	146	95.9	28	Partial Covered
D3	Kalidhond (Takkar Bapa)	FW	JUNIJAWHAR	JUNI JAWHAR	KALIDHOND	146	95.9	28	Partial Covered
D4	Juni Jawhar on Ridge	PDW	JUNIJAWHAR	JUNI JAWHAR	JUNI JAWHAR	111	95.5	22	Partial Covered
D5	Well near Bridge on way to alimal	FW	SAKUR	AKHAR	ALIVMAL	306	97.4	60	Partial Covered
D6	Alimal DW well	PDW	SAKUR	AKHAR	ALIVMAL	306	97.4	60	Partial Covered
D7	Alimal Non DW well	FW	SAKUR	AKHAR	ALIVMAL	306	97.4	60	Partial Covered
D8	Tadachi machi	PDW	JUNIJAWHAR	JUNI JAWHAR	TADACHIMACHI	34	94.1	6	Partial Covered

Sr. No	Location description	Category	GP	Village Name	Habitation Name	Total Popln	% ST Popln	HH	Status
D9	Gorpatte	FW	APTALE	APTALE	GHORPADTEP	261	98.1	57	Partial Covered
D10	North stream well near akhar road	FW	SAKUR	AKHAR	AKHAR	764	97.8	147	Fully Covered
D11	Kelichapada in stream	PDW							
D12	Aptale DW well next to road	PDW	APTALE	APTALE	APTALE	773	98.3	164	Partial Covered
D13	Akhar stream well	FW	SAKUR	AKHAR	AKHAR	764	97.8	147	Fully Covered
D14	Sakur Interior well DW	PDW	SAKUR	SAKUR	SAKUR	1435	96.0	225	Fully Covered
D15	Ramkhind Ashram Shala Well	PDW	PATHARDI	PATHARDI	RAMKHIND	1004	99.2	193	Partial Covered
D16	Ramkhind DW well	PDW	PATHARDI	PATHARDI	RAMKHIND	1004	99.2	193	Partial Covered
D17	Kadachimet DW well	PDW	DHANOSHI	KADACHIMET	KADACHIMET	685	99.6	141	Fully Covered
D18	Dhanoshi Non DW	FW	DHANOSHI	DHANOSHI	DHANOSHI	695	98.8	129	Partial Covered
D19	Dhanoshi DW	SDW	DHANOSHI	DHANOSHI	DHANOSHI	695	98.8	129	Partial Covered
D20	Well in river (2 KT weir)	FW	DHANOSHI	DHANOSHI	DHANOSHI	695	98.8	129	Partial Covered
D21	Chautyachiwadi road side	PDW	JUNIJAWHAR	JUNI JAWHAR	CHOTHYACHIWADI	112	95.5	22	Partial Covered
D22	Chaudhri pada stream well	PDW	DHANOSHI	DHANOSHI	CHAUDHARIPADA	57	100.0	11	Fully Covered
D23	Paralipada SDW, Palvipada PDW - roadside	PDW	DHANOSHI	DHANOSHI	PALVIPADA	121	98.3	23	Partial Covered
D24	Paralipada in habitation	PDW	DHANOSHI	DHANOSHI	PALVIPADA	121	98.3	23	Partial Covered
D25	Dohare pada	PDW	DHANOSHI	KADACHIMET	DOHAREPADA	246	99.2	49	Partial Covered
D26	Pathardi DW	PDW	PATHARDI	PATHARDI	PATHRDAI	617	99.2	119	Partial Covered
D27	Doharepada DW	PDW	DHANOSHI	KADACHIMET	DOHAREPADA	246	99.2	49	Partial Covered
A1	Dongarpada DW	PDW	PATHARDI	DONGARWADI	DONGARWADI	660	99.5	139	Partial Covered
A2	Dongarpada DW big well	SDW	PATHARDI	DONGARWADI	DONGARWADI	660	99.5	139	Partial Covered
A3	Vanganpada	PDW	PATHARDI	PATHARDI	VANGANPADA	311	99.0	59	Partial Covered
A4	Vanganpada 2	PDW	PATHARDI	PATHARDI	VANGANPADA	311	99.0	59	Partial Covered
A5	Vanganpada 3	FW	PATHARDI	PATHARDI	VANGANPADA	311	99.0	59	Partial Covered
A6	Aine	PDW	AINE	AINE	AAINE	310	99.4	49	Fully Covered
A7	Aine 2	FW	AINE	AINE	AAINE	310	99.4	49	Fully Covered
A8	Paradi pada	PDW	AINE	AINE	PARADHIPADA	202	100.0	31	Partial Covered

Sr. No	Location description	Category	GP	Village Name	Habitation Name	Total Popln	% ST Popln	HH	Status
A9	Aine Frog Well	FW	PATHARDI	DONGARWADI	DONGARWADI	660	99.5	139	Partial Covered

Then the parameters like order of stream (stream generated by min basin size as 10 pixels of 30*30m) (Figure 6.1 to 6.3), catchment area of the well watershed of each well is done using QGIS using SRTM Digital Elevation Model (DEM) (Figure 6.4 to 6.6), and land use and land cover with in the well catchment for each well is done by using Landsat 8 imagery.

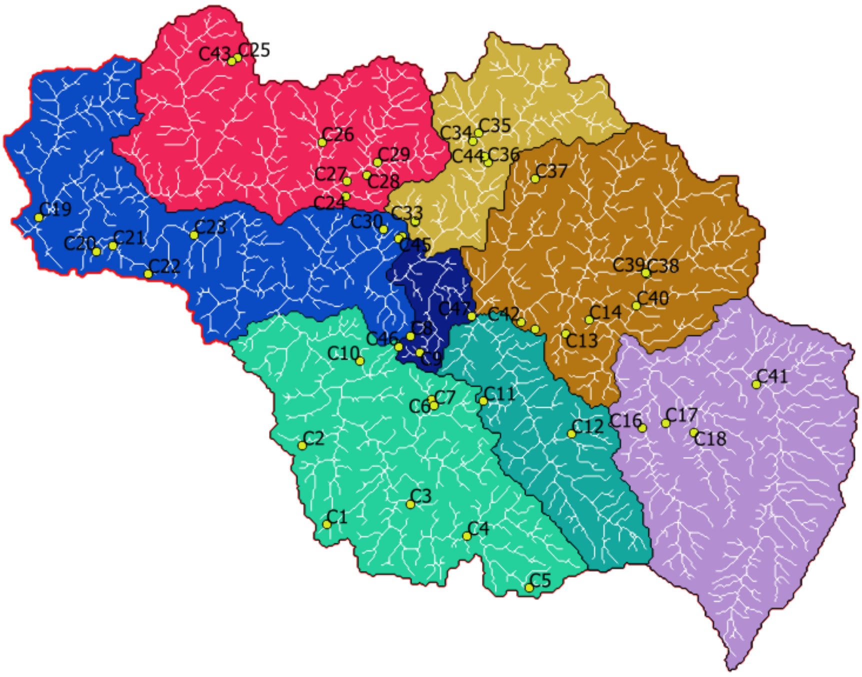


Figure 6.3 Location of Wells in Chas Watershed

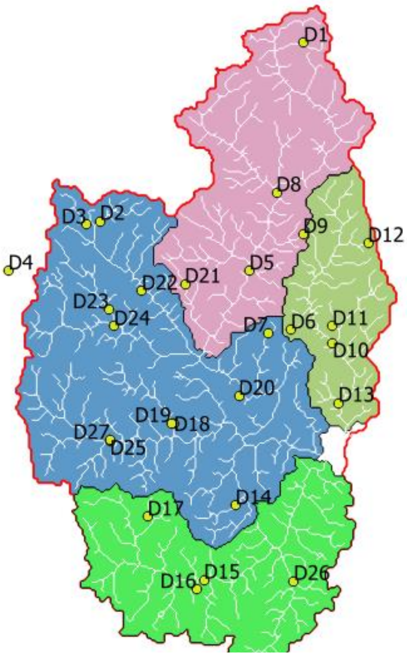


Figure 6.1 Location of Wells in Dhanoshi Watershed

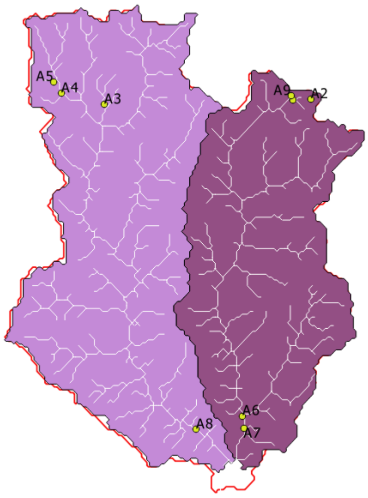


Figure 6.2 Location of Wells in Aine Watershed

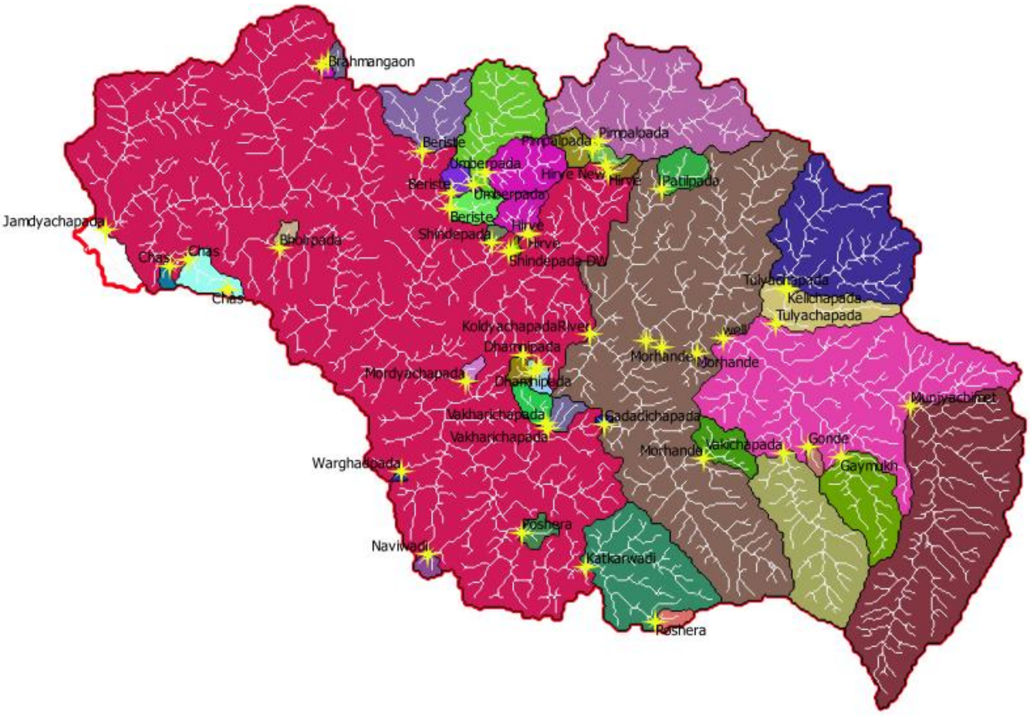


Figure 6.6 Chas Watershed with Well Watersheds

Figure 6.5 Dhanoshi Watershed with Well Watersheds

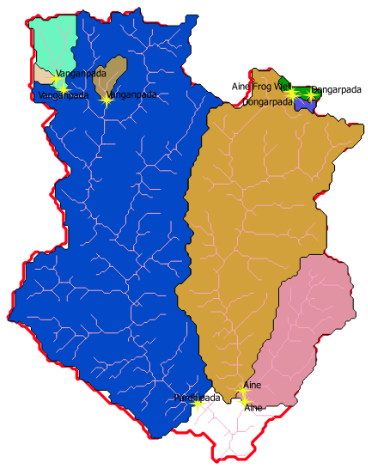


Figure 6.4 Aine Watershed with Well Watersheds

Similarly, land use and land cover is classified for each well catchment. Parameters like water level drop rate of well, Basaltic rock starting depth below ground level, well diameter, Drinking Water load on the well, watershed interventions near the well are tabulated and used for further analysis (Annexure-Well Reading)

6.2 Effect of Order of stream and well catchment area on water level drop in wells

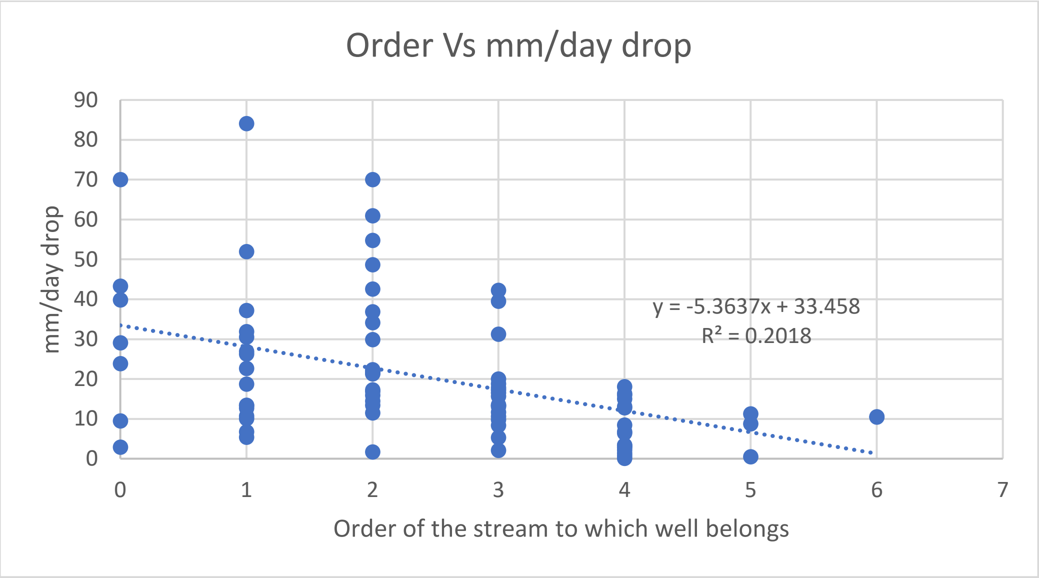


Figure 6.7 Order of the stream (in well location) Vs Water Level Drop Rate

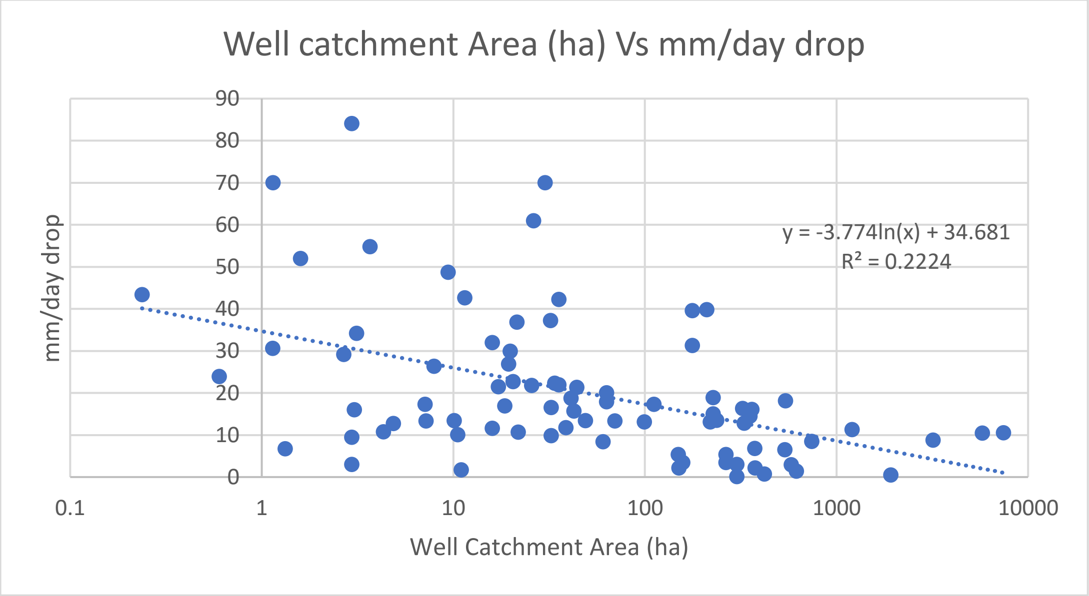


Figure 6.8 Well Watershed Catchment Area Vs Water Level Drop Rate

From the graph (Figure 6.7) of Order Vs mm/day drop it is evident that as the order of the stream in which well lies increases, the rate of water level drop decreases, the same effect is observed with the well catchment area Vs mm/day drop graph.

But it is interesting to note that some wells 0, 1st and 2nd order are also having less drop rate (less than 20mm/day), it motivates to look at which component is helping the well to have lesser drop rate.

Table Below (Table 6.3) containing wells of order 0, 1 and 2 with lesser drop rates, here we are looking at the land use practice and forest cover in those well catchments and usage/load on the well is also considered.

Table 6.3 Factors affecting sustainability of wells in lower order streams

Sr. No	Location description	Order (10pixels)	Well Catchment (ha)	Paddy %	Forest%	mean mm/day	Comment
C46	Morhande Orchard	0	2.947	34.375	31.25	2.95	Percolation from upstream farm, good forest cover in catchment, located in flat land
C22	Chas Pada (road side)	0	2.947		40.625	9.47	Farm well, Less used, has good forest cover
D16	Ramkhind DW well	1	264.5	11.69	25.32	5.37	Good forest cover, Percolation tank upstream
D9	Gorpatte	1	1.322	100		6.72	FW,No Load
D21	Chautyachiwadi	1	10.54	13.27	4.42	10.08	One person died drowning, so no DW load, or else drop would have been more
D6	Alimal DW well	1	4.304	8.51	38.29	10.71	Has Good Karwanda Forest Cover with Contour trenches in its catchment
C10	Mordyachapada	1	7.193	55		13.33	Sub Surface Bund helping to reduce drop rate
D11	Kelichapada in stream	1	48.861	17.89	4.51	13.43	Good Catchment area with moderate load
C20	Chas Pada 1	1	41.067	10.81	34.23	18.72	Good Catchment Area with significant load and has forest cover in its catchment
C5	People tree	2	10.99	69.67	0.81	1.69	No Load, in paddy fields flat land
C3	Roadside before Poshera	2	15.958	47.67		11.54	Flat land, Less load SDW
C1	Naviwadi	2	10.086	32.4	1.85	13.40	In good flat paddy field of a stream, with moderate load
A2	Dongarpada DW	2	3.04	25.8	3.22	15.95	SDW, Dry by 5th reading by constant load
A3	Vanganpada	2	18.499	31.03	21.67	16.87	House hold well in flat paddy field and has good plantation in its catchment
A9	Aine Frog Well	2	7.108	12	9.33	17.30	No load, Washing Clothes Only

From the Table 6.3, it is observed that the wells in lower order/catchment performing better (less mm/day drop) has good forest cover in their catchment, or located in flat lands of paddy or had less or no loads/extraction involved.

6.3 Effect of Land Cover (Forest Cover) on rate of water drop in wells

The wells were classified based on the time at which they go dry, like (Table 6.4)

Table 6.4 Perenniality Number

Perenniality Number	Going Dry By
1	December 8th
2	January 7th
3	January 28th
4	February 18th
5	March 11th
6	April 9th
7	May 1st
8	May 22nd
10	Sustains still June with similar load

A plot is drawn considering forest cover and longevity of water in wells (Figure 6.9),

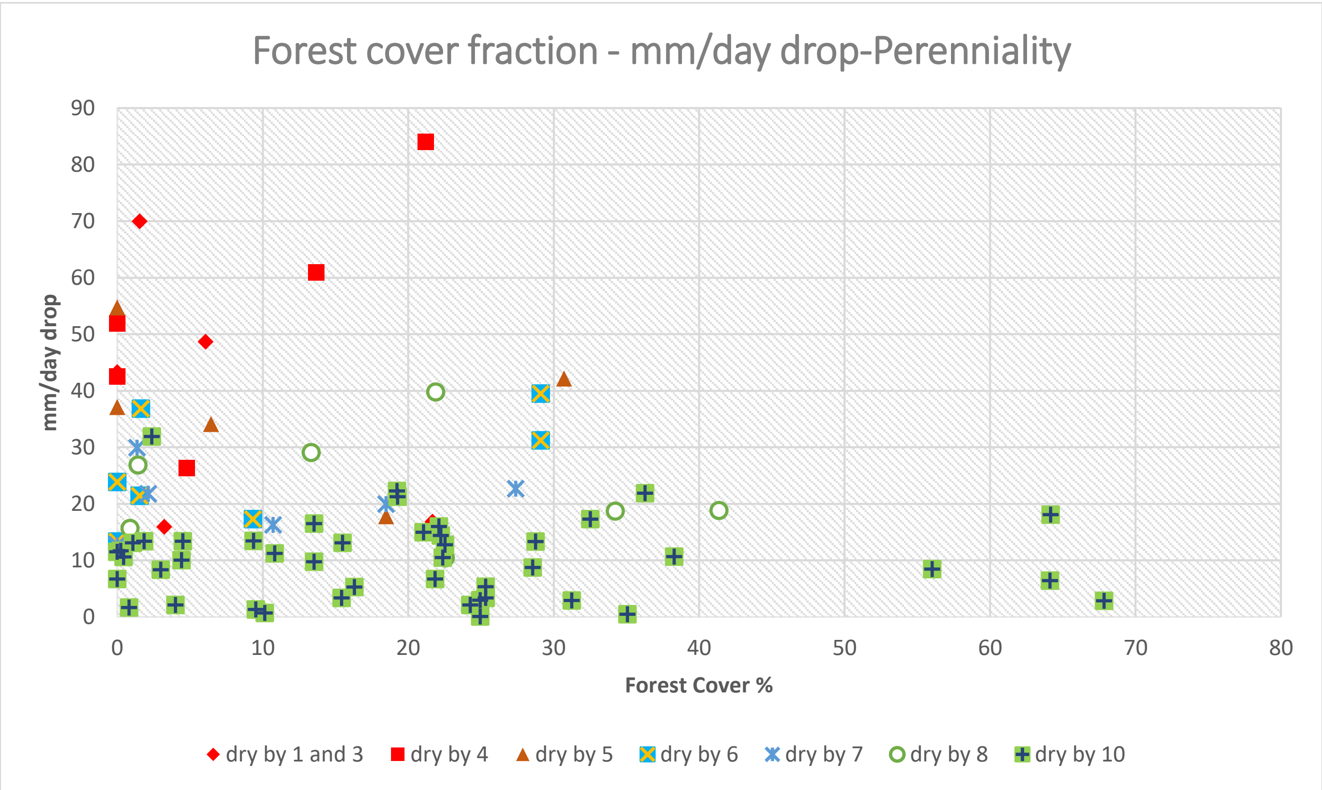


Figure 6.9 Forest Cover Fraction Vs Water Level Drop Rate and Perenniality

In the above graph (legend and axis will be added) it is observed that 82% of the wells which had more than 19% forest cover in their catchment were perennial and rate of drop of these wells is less than 20mm/day, only 6 (18%) wells out 33 wells were non-perennial and with higher drop rates, the good forest cover in wells catchment will help reducing the rate of drop and helps the wells to hold water for more time (making them perennial) (which explains presence of more sub surface water in well forested areas).

The effect of different parameters like order, catchment, forest cover on the perennial wells and non-perennial wells are tabulated below, and mean drop rate's dynamics is compared with perenniality of the wells (Figure 6.10 to 6.12).

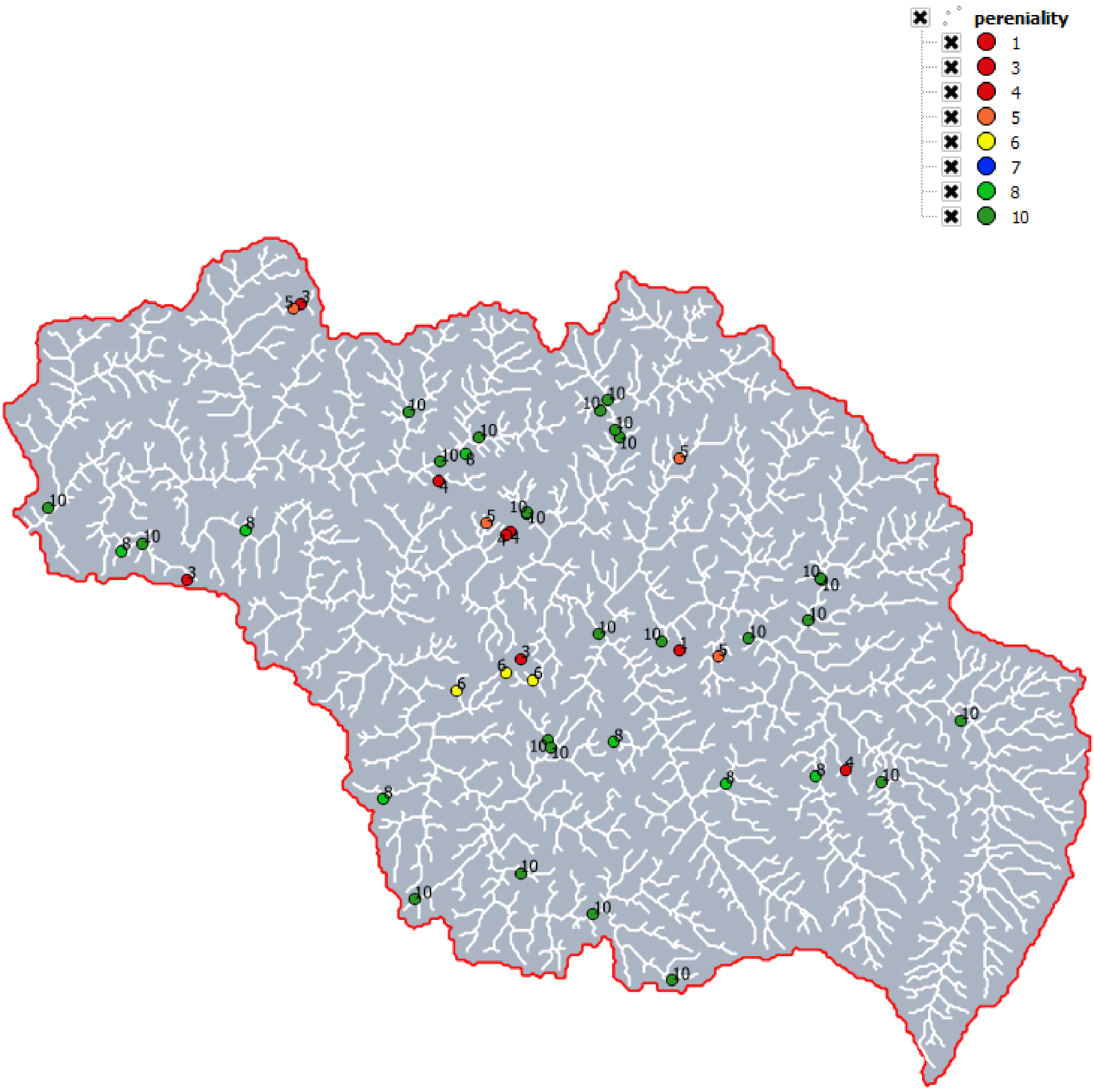
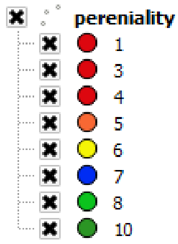


Figure 6.10 Perenniality of Wells mapped on Chas Watershed



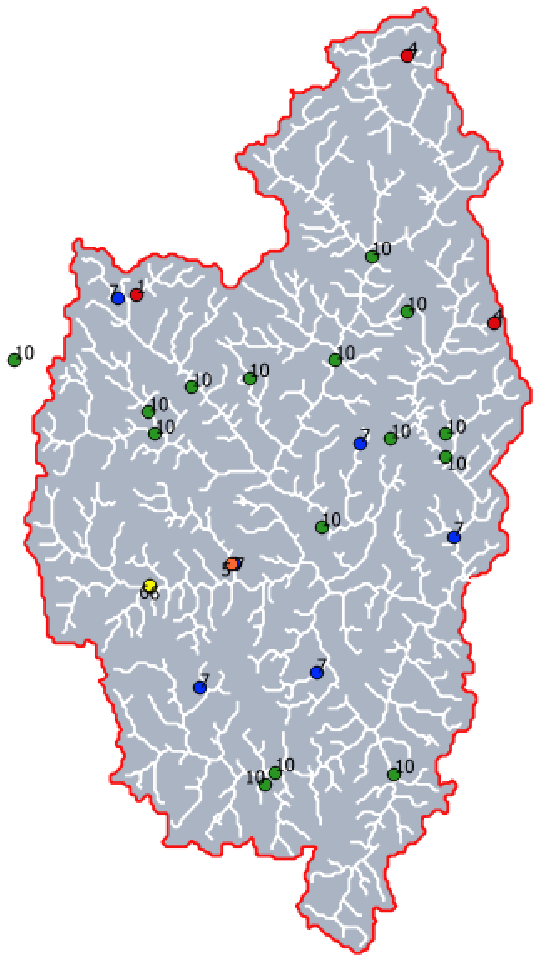


Figure 6.12 Perenniality of Wells mapped on Dhanoshi Watershed

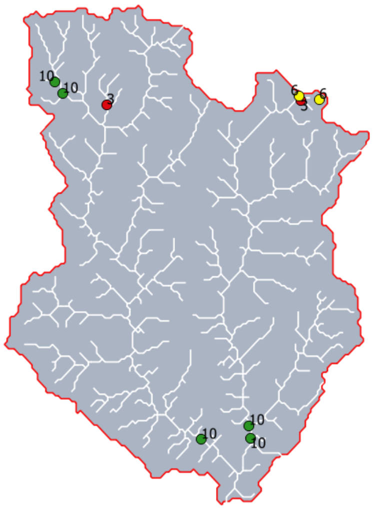


Figure 6.11 Perenniality of Wells mapped on Aine Watershed

6.4 Relationship between order of the well and perenniality of the well

Table 6.5 Statistical Mean-Median-Mode of Order of stream in which well is located and Perenniality of the wells

perinniality	Number of data points	Mode Order	Max Order	Min Order	Median Order	Mean Order
1	2	#N/A	2	0	1	1.00
3	5	2	2	0	2	1.20
4	6	1	2	1	1	1.33
5	5	1	3	1	2	2.00
6	7	2	3	0	2	1.86
7	6	2	4	1	2	2.17
8	7	1	6	1	3	2.71
10	45	4	6	0	3	3.07

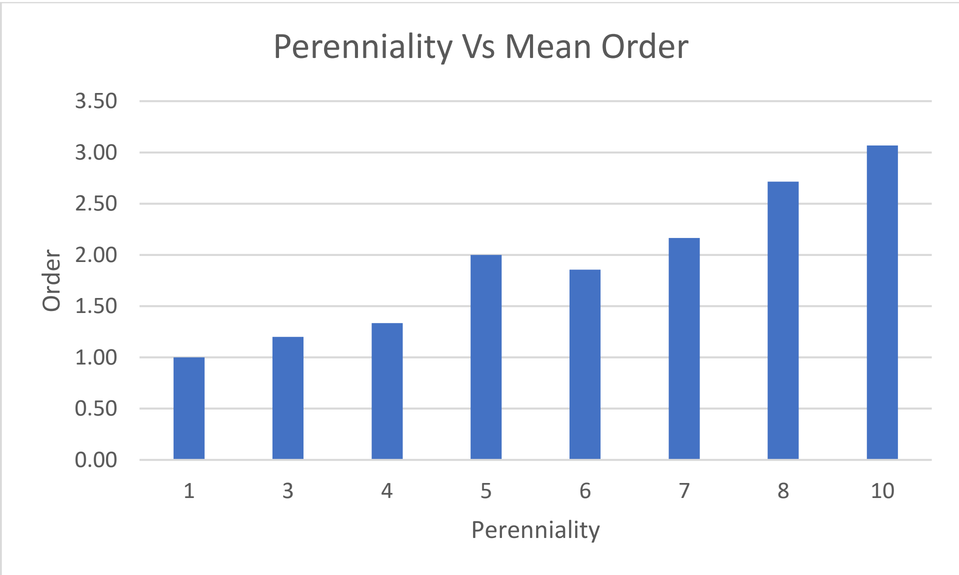


Figure 6.13 Perenniality of Wells Vs Mean Order

It is significant that most of the wells above in the stream of order 3 or above are perennial (Figure 6.13), this can serve for the planners to select the location for the sustainable wells which can serve the drinking water demand of the region. But one should consider other factors along with order of the well.

Colour coded stream maps for Gram Panchayat or Taluka level can serve the planners to select more appropriate location for water sources. A model colour coded map with perenniality of the wells mapped on it is as below (Figure 6.14 to Figure 6.16), 1st and 2nd order streams are marked with red colour (1st order thinner red and 2nd order thick red line), 3rd and 4th are marked with green colour (3rd with thin green and 4th with thick green line) , 5th and 6th are marked with blue line.

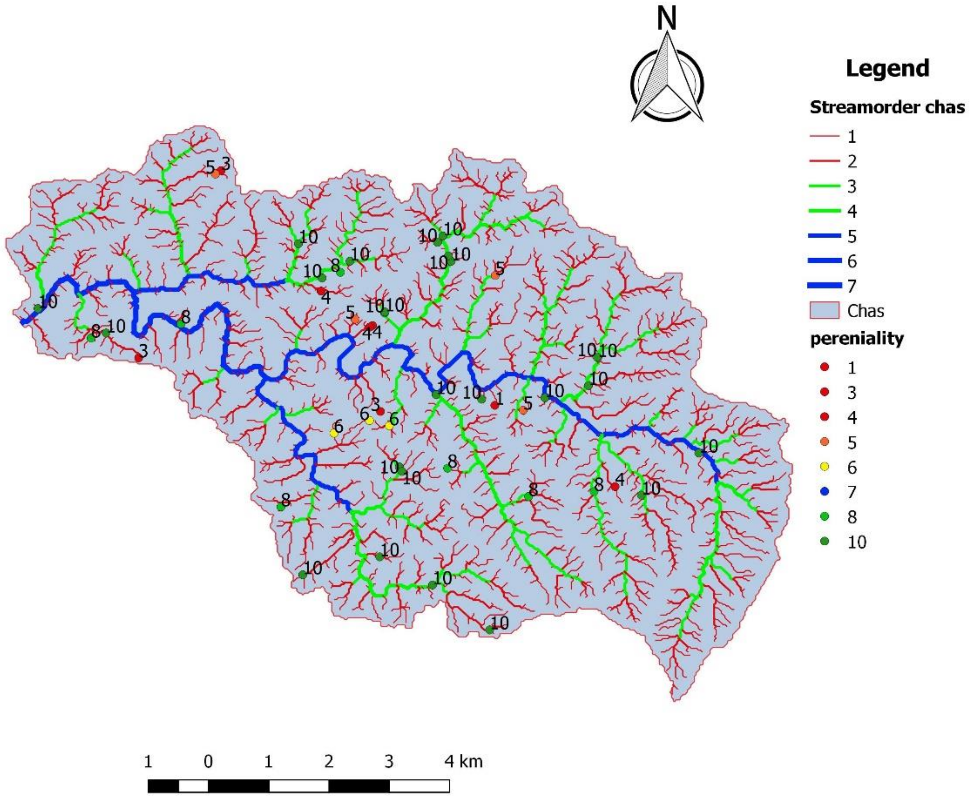


Figure 6.14 Perenniality of Wells mapped on Colour Coded Order map in Chas Watershed

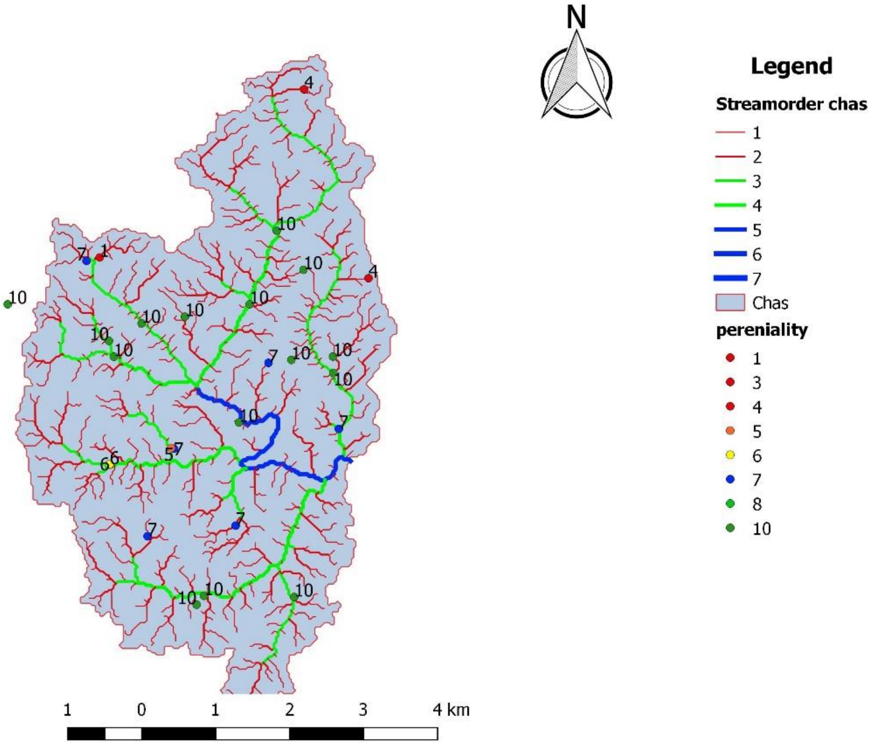


Figure 6.15 Perenniality of Wells mapped on Colour Coded Order map in Dhanoshi Watershed

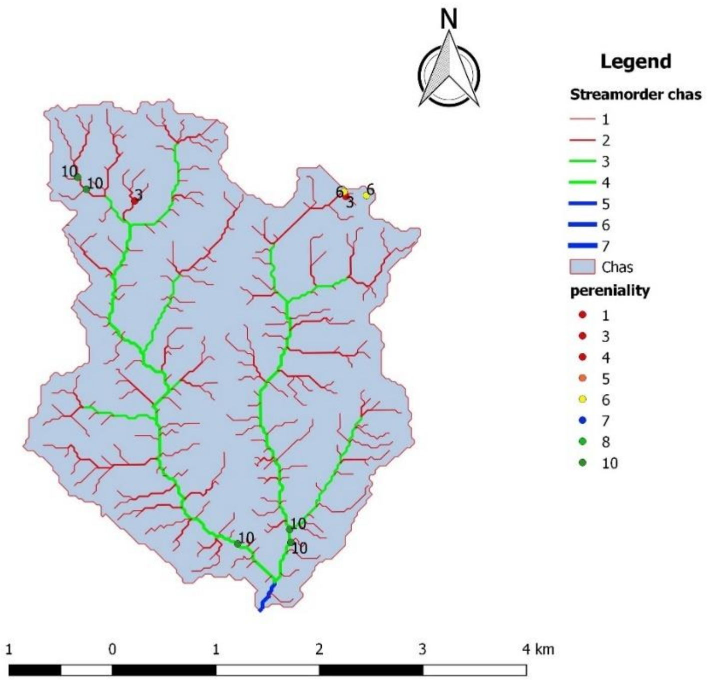


Figure 6.16 Perenniality of Wells mapped on Colour Coded Order map in Aine Watershed

6.5 Relationship between catchment of the well and perenniality of the well

Table 6.6 Statistical Mean-Median-Mode of Well Watershed Catchment Area and Perenniality of the Wells

perinniality	Number of data points	Mode Catchment (ha)	Max Catchment (ha)	Min Catchment (ha)	Median Catchment (ha)	Mean Catchment (ha)
1	2	#N/A	30.06	1.14	15.60	15.60
3	5	#N/A	18.50	0.24	3.04	6.82
4	6	#N/A	26.16	1.14	5.43	8.53
5	5	#N/A	62.96	3.12	32.13	27.49
6	7	176.8	176.80	0.60	17.13	58.16
7	6	#N/A	322.70	4.85	23.06	76.07
8	7	#N/A	226.50	2.68	41.79	90.31
10	45	32.30	7423.60	1.32	157.50	487.39

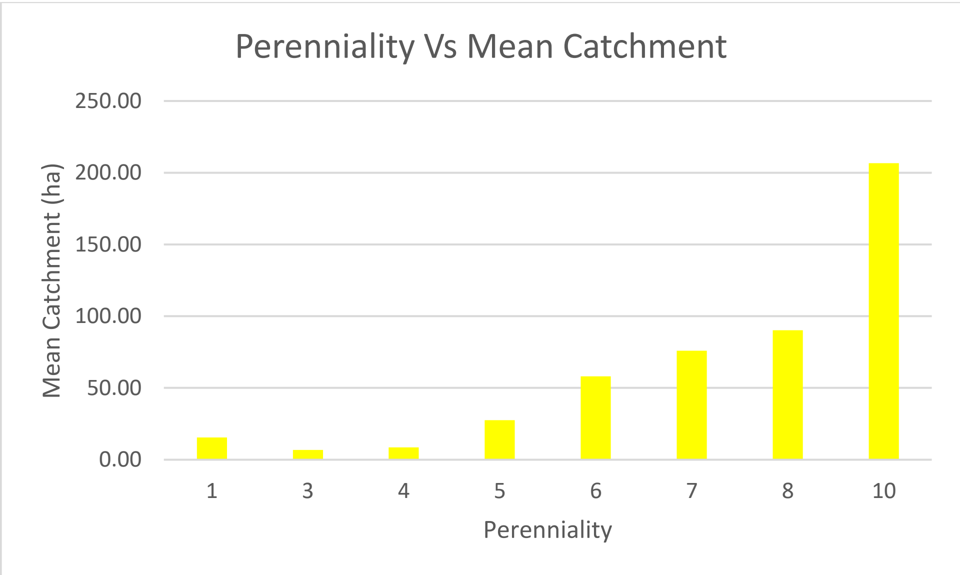


Figure 6.17 Perenniality Vs Mean Catchment

Here also the catchment area of the well is directly related to peranniality of the well, as catchment area increases well becomes more perennial (Figure 6.17), anyhow, order of the well is also directly related to the catchment area, this observation was expected.

6.6 Relationship between forest cover in well catchment and perenniality of the well

Table 6.7 Statistical Mean-Median-Mode of Forest Cover Fraction in Well Watershed and Perenniality of the wells

perinniality	Number of data points	Mode Forest %	Max Forest %	Min Forest %	Median Forest %	Mean Forest %
1	2	#N/A	1.54	0	0.77	0.77
3	5	0	21.67	0	3.22	6.19
4	6	0	21.21	0	2.38	6.61
5	5	0	30.72	0.00	6.45	11.13
6	7	29.1	29.10	0.00	5.48	11.78
7	6	#N/A	27.39	0.00	6.42	10.01
8	7	#N/A	41.37	0.86	21.90	19.38
10	45	0	67.85	0.00	19.27	20.34

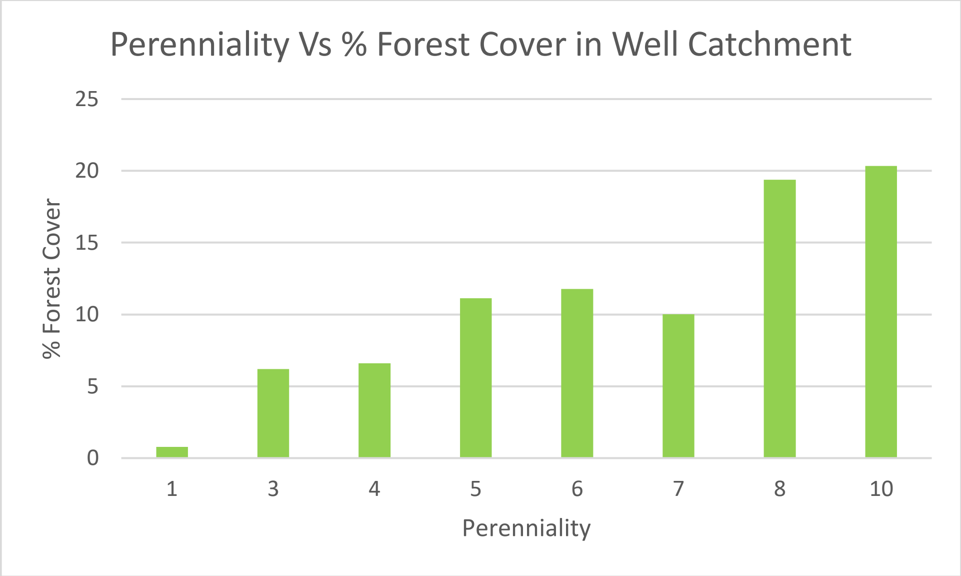


Figure 6.18 Forest Cover Fraction Vs Perenniality

As per our earlier observation we saw 82% of the wells above 19% forest cover were perennial, that argument is clearly observed here as well, as the mean forest cover increases well becomes more perennial. Above statistical detail strengthens that argument (Figure 6.18)

Now it is important to know that the forest cover is independent of the catchment area of the well, no good correlation found between the catchment area and 5 forest cover in it (Figure 6.19). Hence, we can say that Forest cover independently has its positive effects in holding more water in sub surface.

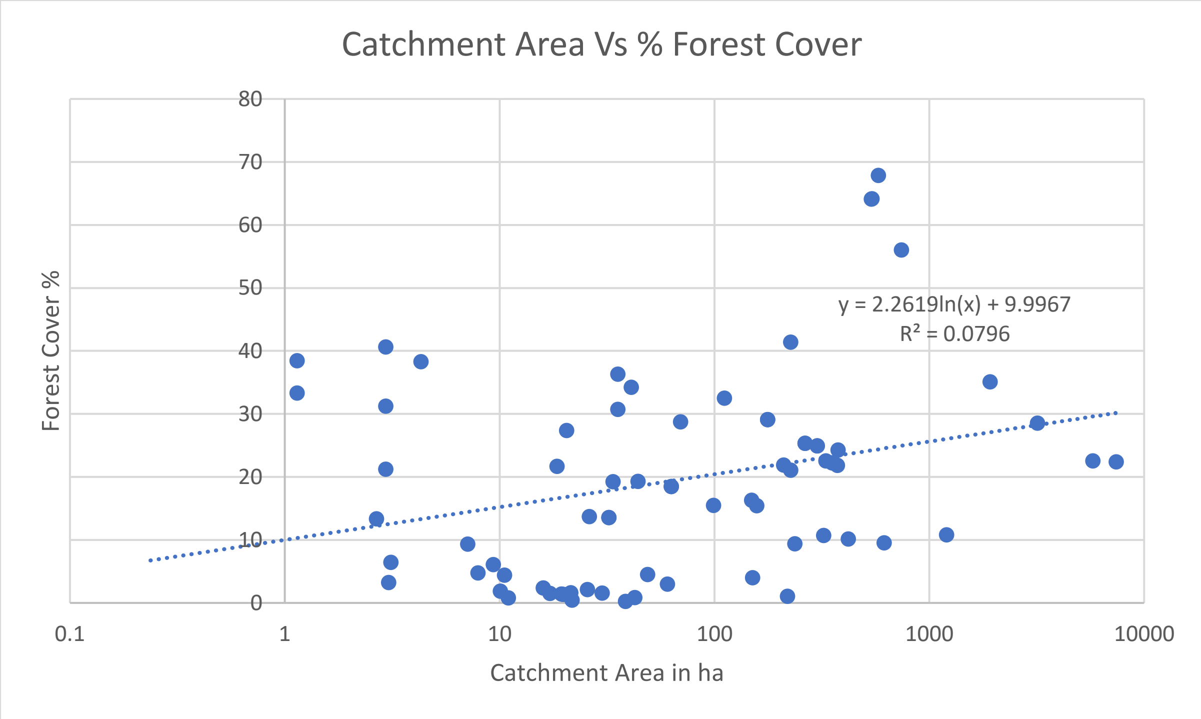


Figure 6.19 Well Watershed Catchment Area Vs Forest Cover Fraction in it

6.7 Relationship between rate of water level drop and perenniality of the well

Table 6.8 Statistical Mean-Median-Mode of water level drop rate and Perenniality of the wells

perinniality	Number of data points	Mode Drop Rate (mm/day)	Max Drop Rate (mm/day)	Min Drop Rate (mm/day)	Median Drop Rate (mm/day)	Mean Drop Rate (mm/day)
1	2	70	70.00	70.00	70.00	70.00
3	5	#N/A	48.71	9.47	16.87	26.86
4	6	#N/A	84.05	26.30	47.25	49.39
5	5	#N/A	54.76	17.85	37.16	37.22
6	7	#N/A	39.52	13.33	23.87	26.23
7	6	#N/A	29.92	12.73	20.89	20.57
8	7	#N/A	39.81	10.46	18.83	22.79
10	45	#N/A	31.93	0.08	10.50	10.09

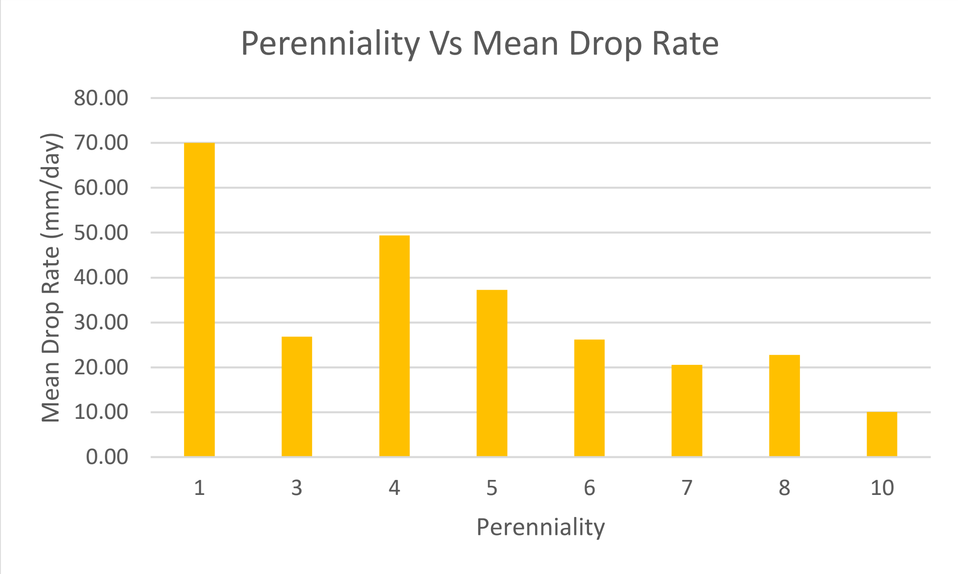


Figure 6.20 Mean water level drop rate Vs Perenniality of the wells

As we know rate of drop decides whether well is perennial or not, if rate of drop is more then the well becomes dry early, the above graph depicts the same (Figure 6.20).

6.8 Structural interventions

Though this study didn't include any detailed study of the structures in the region, it is important to understand the impacts of different watershed interventions which we see in the field. So here is an attempt to look and interpret the effect of different structures seen.

Table Below (Table 6.9) shows effect of different kind of interventions (GoM, Water Conservation) seen in field

Table 6.9 Structural Interventions in study region

Sr. No	Location description	Order	Category	Structure	Structure location	perinniality	HH	mean mm/day	Effect Good/Bad
D26	Pathardi DW	3	PDW	CNB	CNB downstream	10	49	5.29	Good
C27	Beriste stream umberpada	4	SDW	CNB	CNB downstream next to well	10	112	15.01	Good
D25	Dohare pada	3	PDW	KT Weir	KT weir upstream	6	49	31.24	Bad
D27	Doharepada DW	3	PDW	KT Weir	KT weir upstream	6	119	39.52	Bad
D15	Ramkhind Ashram Shala Well	4	PDW	Earthen Bund	Earthen Bund Upstream	10	40	3.40	Good
D16	Ramkhind DW well	1	PDW	Earthen Bund	Earthen Bund Upstream	10	193	5.37	Good

Sr. No	Location description	Order	Category	Structure	Structure location	perinniality	HH	mean mm/day	Effect Good/Bad
C38	Kelichapada	4	PDW	Earthen Bund	Earthen Bund Upstream	10	100	0.08	Good
C39	Tulyachapada	4	FW	Earthen Bund	Earthen Bund Upstream	10		3	Good
C40	Tulyachapada Road Side	4	FW	Earthen Bund	Earthen Bund Upstream	10		2.16	Good
C10	Mordyachapada	1	PDW	SSB	SSB downstream next to well	6	33	13.33	Good/Bad
C43	Brahmangaon New	2	WASHING	SSB	SSB downstream next to well and SSB upstream	5		34.13	Bad
C25	Brahmangaon	2	PDW	SSB	SSB upstream before well	3	150	48.71	Bad
C29	Umberpada Subsurface Bund Well	3	SDW	SSB	SSB Downstream	10	58	13.34	Good
D6	Alimal DW well	1	PDW	CCT + Shrubs	CCT with Shrub Forest upstream	10	30	10.71	Good

6.8.1 CNBs and KT Weirs

These are drain line interventions which obstruct the stream flow and create a pocket of water. If the structures are built in a way, so that the Drinking water well is in the submergence backwater area of the CNB or KT Weir, they help in recharging the well, So the wells will be perennial.

This effect is observed in field, and good results are seen wherever the CNB is built in near downstream of the well and well is within the backwater submergence of the CNB (Figure 6.21), Both Wells, Pathardi Drinking Water (148ha catchment) and Beriste stream well (226ha catchment) shown less rate of drop and were perennial (Table 6.9).

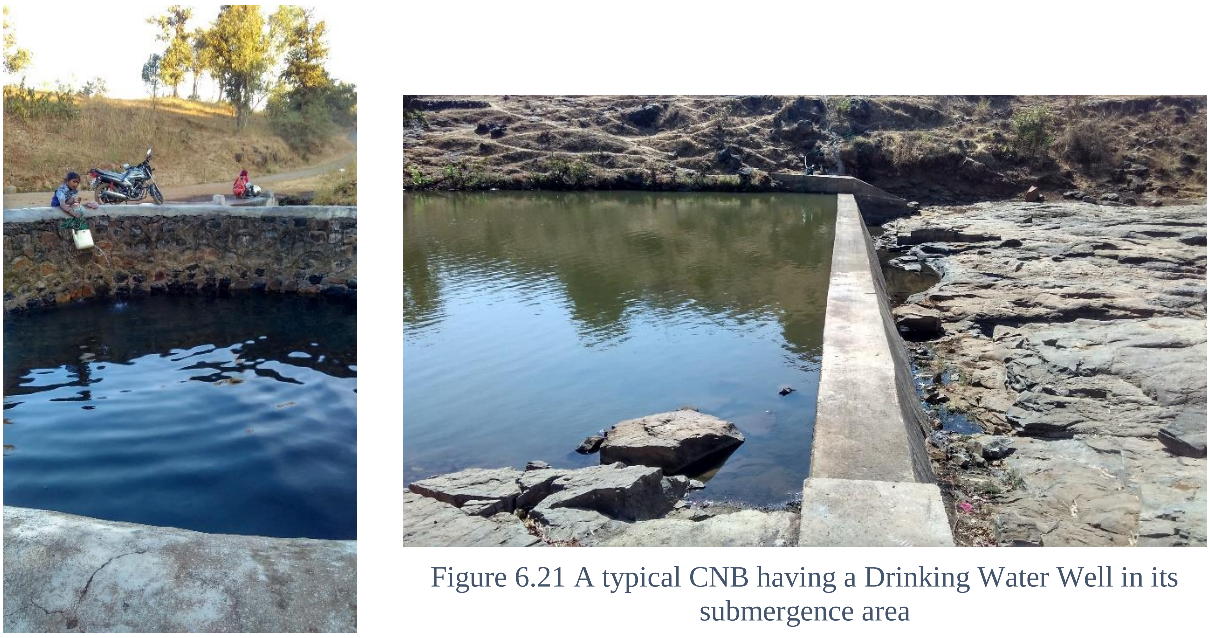


Figure 6.21 A typical CNB having a Drinking Water Well in its submergence area

The reverse effect will be found if the structures like CNB or KT weir are built on upstream of the well, A KT Weir upstream Doharepada wells (which are in 3rd order stream and has176ha catchment) will not help in recharging the wells downstream (Figure 6.22) (As KT weir was damaged, it was not storing water, but repairing the KT Weir upstream of the well will not help the Drinking Water Sources downstream).

Figure 6.22 Typical Upstream structure reducing the recharge to Drinking Water Well downstream

As many CNBs are broken, development of an alternative solution other than repairing CNBs (which is costly) by using plastic sheets to control leakage etc., will help a lot.

Recently Rebuilt CNB in Kalidhond (2nd Order stream, 30ha catchment) (Figure 6.23) should be monitored in the coming year to see whether it solves the problem or not.

Figure 6.23 Repaired/Rebuilt CNB at Kalidhond (D2)

6.8.2 Earthern Bunds (Tanks)

As Seen n the wells downstream Ramkhind earthen bund (earthern bund of storage area of 4.4 ha) (2 wells monitored) (Figure 6.24) and Tulyachapada Earthen Bund (3 Wells Monitored), all were perennial and maximum drop rate was 5.37mm/day with significant load. The coming from the spill way and percolation from the bund are adding to the recharge component of the wells making them perennial.

Figure 6.24 Upstream Percolation Tank benefiting Downstream wells in Ramkhind (D15 and D16)

6.8.3 Sub Surface Bund (SSB)

A detailed study on effects of sub surface bunds is done by Hemant Belsare (Ref). Sub Surface Bunds obstruct the flow of sub surface water and divert them to the wells by creating a holding space for water underground. They are suitable for the regions where hard rock is found at shallow depths from top surface. Study by Hemant Belsare noticed that the downstream subsurface bunds were more effective in increasing the net storage of water in well watershed and helped in increasing the water availability period, and the study showed that upstream subsurface bunds impacted the wells negatively/less effective.

As Sub Surface Bunds reduce the discharge from the well watershed, in such case if SSB is built upstream of the well, then it is bound to affect the downstream well badly. The same kind of results were found in the present study.

Both Brahmangaon wells which had SSB upstream (Figure 6.25) showed higher drop rates (34 and 48 mm/day) and went dry in the early summer. But properly designed downstream SSB of Umberpada Well Showed lesser drop rate (13 mm/day) and was perennial.

Selecting the proper location for the subsurface bund is important, and special care needs to be taken to avoid negative effects.

Figure 6.25 Upstream SSBs (red lines) negatively effecting Wells C25 and C43 in Brahmangaon

Figure 6.26 A typical SSB structure (Brahmangaon)

6.8.4 Contour Trenches and Shrub Forest

A micro watershed study comparing two wells on the same kind of terrain with similar sloping land but different land cover one with contour trenches and 38% shrub forest in its catchment area (D6, 4.3ha catchment area) (Figure 6.28) and another with 11% paddy land and remaining grassland with no forest cover (D7, 4.8ha catchment area) (Figure 6.27). The D6 well (Alimal DW) is perennial with 20 households depending on it. And D7 (Alimal Non DW) goes dry by beginning of April.

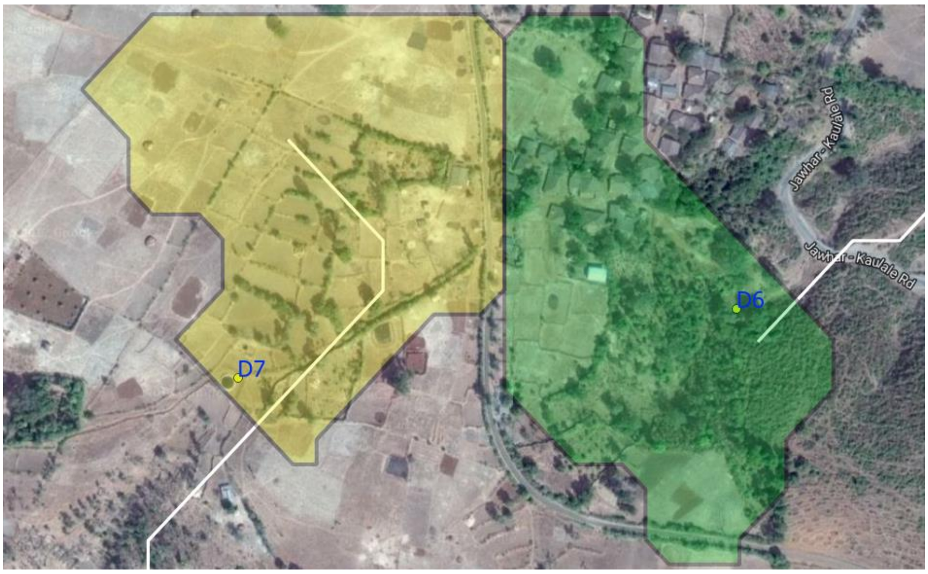


Figure 6.27 Micro Watersheds of Wells D6 (Forested with Contour Trenches, green polygon) and D7(without any treatment, yellow polygon)

Figure 6.28 Shrub Forest with Contour Trenches
(D6, Alimal Drinking Water Well)

6.9 Movement of people for Water (Few Examples of Drudgery)

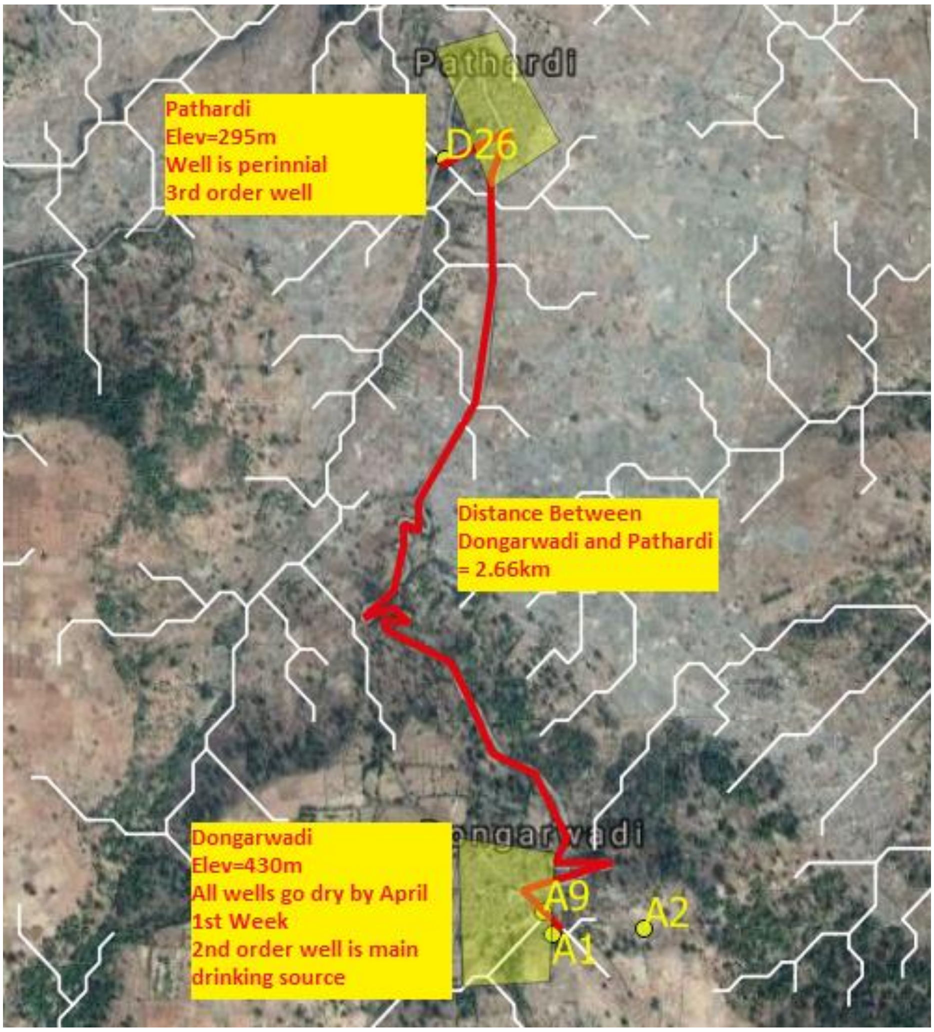


Figure 6.29 People move to higher order streams for water in April (Dongarwadi to Pathardi)

Dongarwadi is a hamlet at the ridge of aine watershed, which don't have any reliable water source post April, for which people from Dongarwadi travel to Pathardri (which has a reliable, perennial well). Dongarwadi people need to go from the elevation of 430m to 295m to fetch drinking water walking 2.6kms (Figure 6.29). The movement from primary drinking water source to secondary drinking water will be usually from lower order stream well to higher order stream well (which will be usually situated in the valley). Similar trend can be seen in other hamlets as well (Please refer distance travelled and elevation difference between hamlet and well to know more, Annexure-Well Reading)

Figure 6.30 People move from primary drinking water to secondary drinking water source (Shindepada)

Ex- Shindepada people moving from 1st order primary drinking water source to 2nd order secondary drinking water source (Figure 6.30)

6.10 Well water level drop rate and Water Column Curves

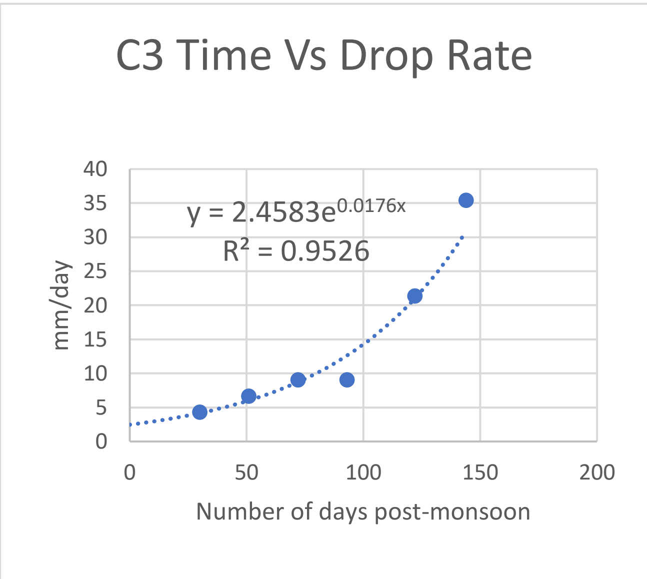


Figure 6.32 Well Water level drop rate Vs Time (C3, Poshera Road Side Well)

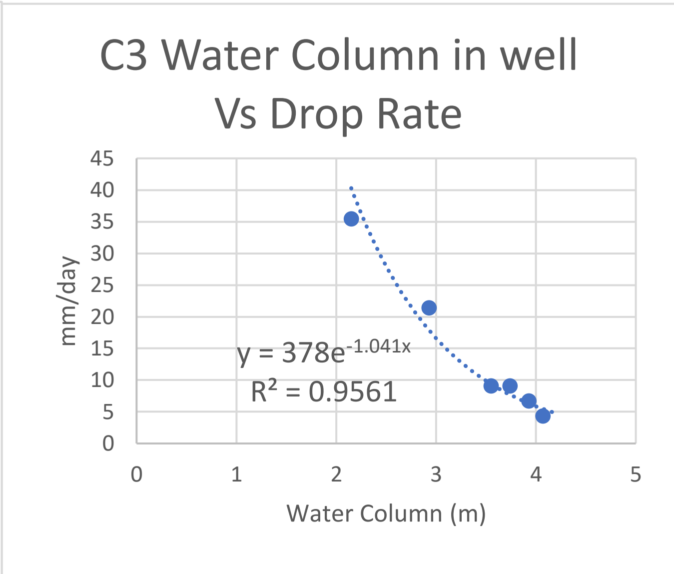


Figure 6.31 Well Water level drop rate Vs Water Column (C3, Poshera Road Side Well)

C3 is Poshera Road Side Well, which had no load in the beginning months of post monsoon season, later by Mid-January around 20 to 30 household starts to use the water from this well, this is being reflected on the graph (which has effect of load in it) (Figure 6.32). 2nd Graph (Figure 6.31) Shows the decrease in water column (read it backwards) with respect to change in drop rate.

Similarly,

Curve of farm well (A5 Vanganpada) which had constant load from beginning looks as below

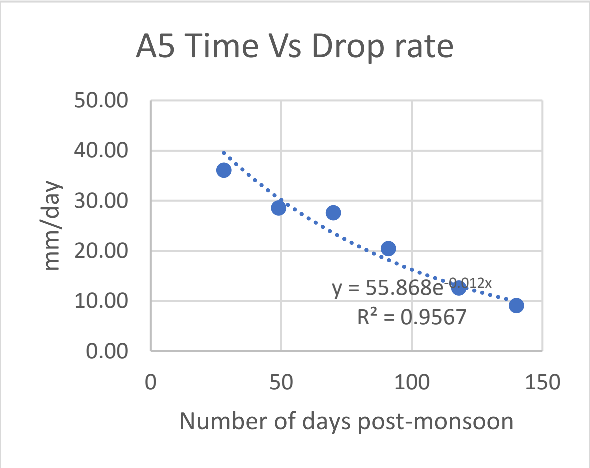


Figure 6.34 Well Water level drop rate Vs Time (A5, Vanganpada)

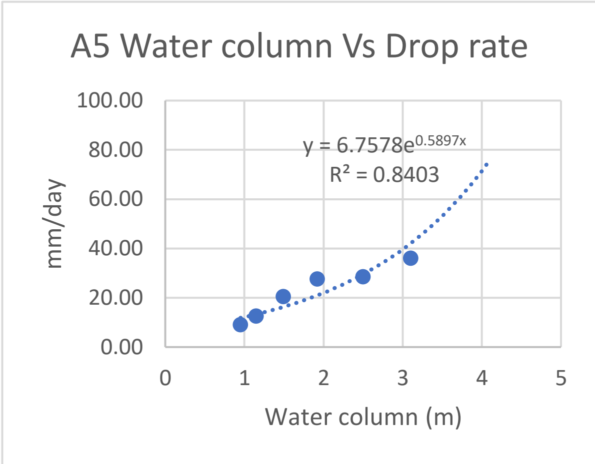


Figure 6.33 Well Water level drop rate Vs Water Column (A5, Vanganpada)

Please refer annexure – Well data, for drop rates at different period.

6.11 Observations

- It was observed that most of the wells in the stream of order 3 or above were perennial, this is even seen in the people movement from non-perennial wells (lower order) to perennial wells (higher order)
- Wells which are in lesser order but performing well had good forest cover in their catchment or had very less load
- Well watersheds seem to be an important determinant of perenniality. Thus, as in spring-sheds, well-sheds too deserve a systematic study, especially while proposing new locations. 82% of wells having more than 19% of forest cover were perennial.
- Empirical study showed that structures like CNBs and KT Weirs are effective in recharging wells only when the well is in the submergence area of the CNB or KT weir, or else the negative effect is seen

- Sub Surface Bunds also prove to be helpful when they are obstructing subsurface flow in downstream of the well, negative effects were seen if they are situated in the upstream of the well catchment. Implying the importance of selecting the location for the interventions.
- Localised area treatment like Contour trenching and afforestation were very helpful in creating sustainable water availability in wells (Alimal Karwanda forest Well, Vanganpada Drinking Water well)
- Wells in ridge area but having good soil/murum thickness in the flat land seems to be more sustainable.
- As CNBs and KT Weirs are usually located in valley, their use for post monsoon agriculture is very less. Instead CNBs and KT weirs should focus to create sustainable drinking water sources.
- Post Monsoon Horticulture practices and growing mogra (jasmine) look to be unsustainable (using well water for irrigating them, when drinking water source is going dry). But growing trees like mango and cashew looked to be more sustainable (they need to be watered for first one or two years only) and in fact helpful in holding more water in sub surface.
- Rural Drinking Water supply norms (availability of funds per capita) is a hurdle for selecting the sustainable drinking water source for ridge hamlets, where the scope for area and drainage treatment is very less.
- People Narrative about the reduction of forest cover over years and decrease in water availability draws focus.
- There is good scope to analyse the forest cover change (decadal) in the study area and study the water availability in past decades considering changing demography.

Chapter 7

7 Other Analysis Tried

7.1 Watershed Typology

Here the idea was to represent the watershed in a simple XY plot and map the habitation level/ well level stress, soil thickness on to that. We succeeded in coming up with the kind of plot we tried for, but mapping the stress and well depth were different.

The process involved dividing the watershed area into contour bands and measure the area in between two contour lines, example – area between contour 200 and 220, area between 220 and 240, so on and plot the cumulative area in X axis and elevation in Y axis leading to the XY profile plot of the watershed.

Below are the plots for the three main watersheds with hamlets marked on it (Figure 7.1 to 7.3).

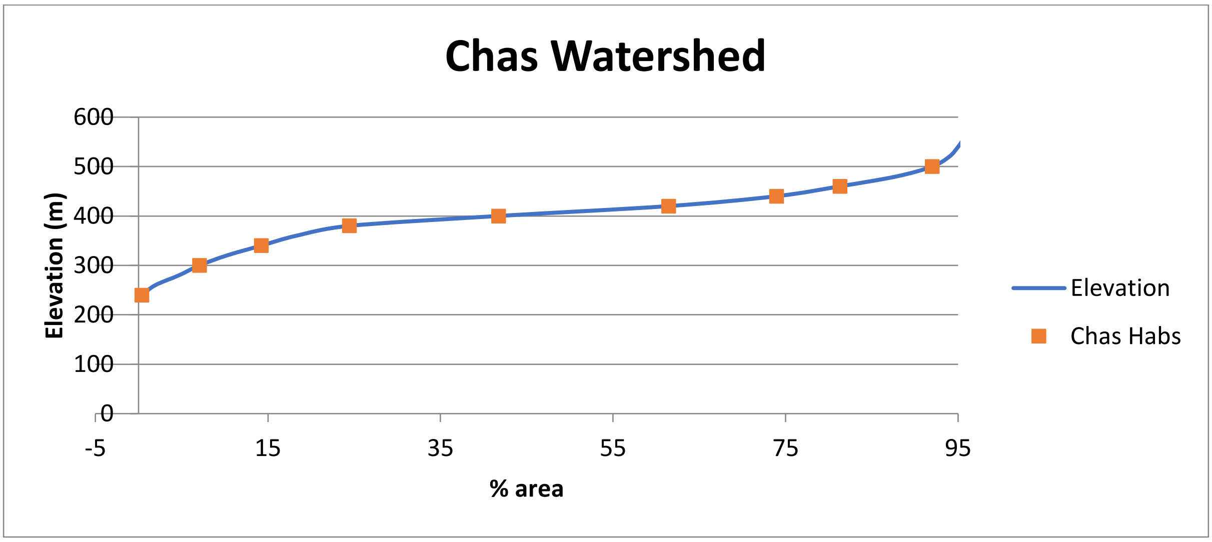


Figure 7.1 Chas Watershed Typology with Habitations marked on it

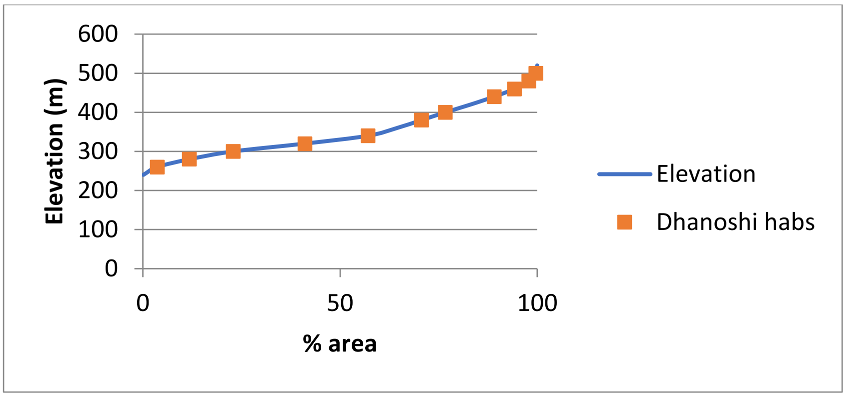


Figure 7.2 Dhanoshi Watershed Typology with Habitations marked on it

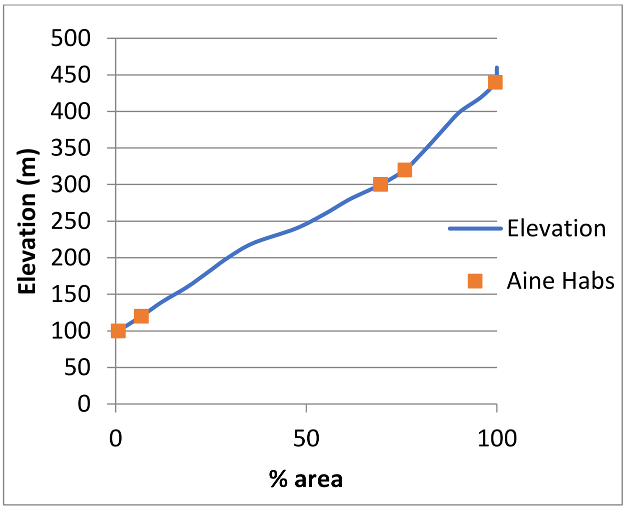


Figure 7.3 Aine Watershed Typology with Habitations marked on it

One can map the stressed habitation/habitation facing water stress on this graph as shown below (Figure 7.4).

Figure 7.4 Aine Watershed Typology with Habitations marked on it indicating the stress

But the problem comes when you have wells which are stressed and not stressed in the same contour band. Then it will be difficult to map them on the simple XY plot.

A Plot showing the profile of three watersheds is shown below (Figure 7.5), it represents the basic geometry od the watershed (how, steep or flat it is). As said earlier, it is not possible to map stress and other parameters on this as we have different types of wells (like one in ridge, one in valley) in the same contour band.

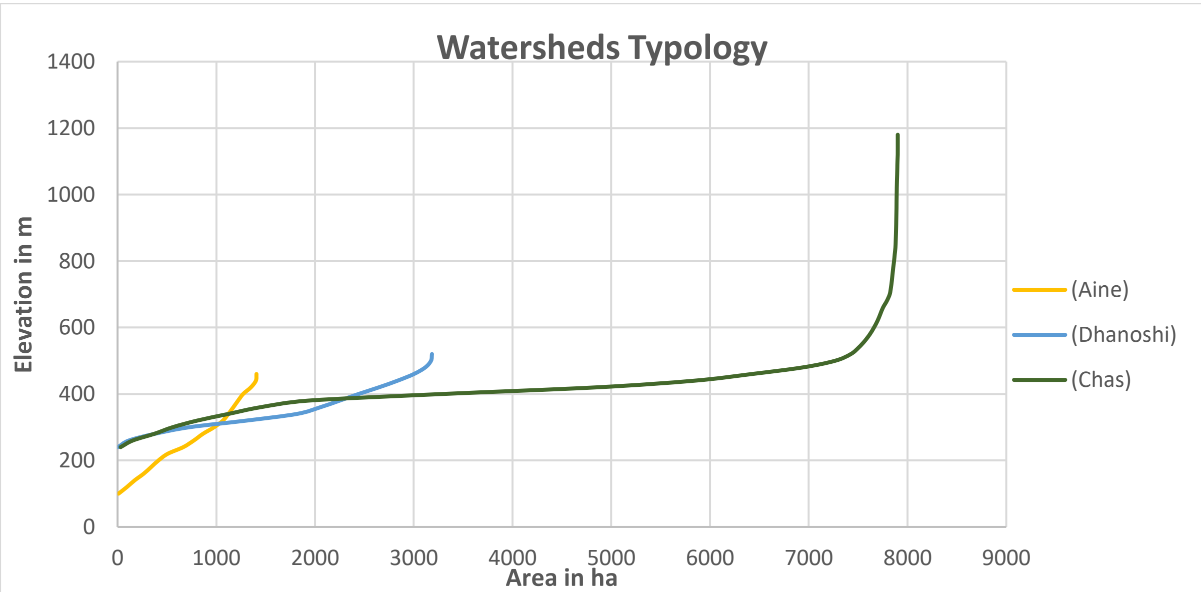


Figure 7.5 Typology of three main watersheds put together

7.2 Complete water balance using Curve number

Here attempt is made to do the complete water budget calculation for a sub watershed (Poshera), for these we need to know the direct runoff and ET load during monsoon. Curve number is (Runoff curve number computations, 1989) used to calculate the direct runoff in the given watershed, for calculating curve number one needs land use classification (Figure 7.6) and soil type (Figure 7.7). The land use map and soil map were obtained from MRSAC GSDA webpage, georeferenced and used for the given watershed.

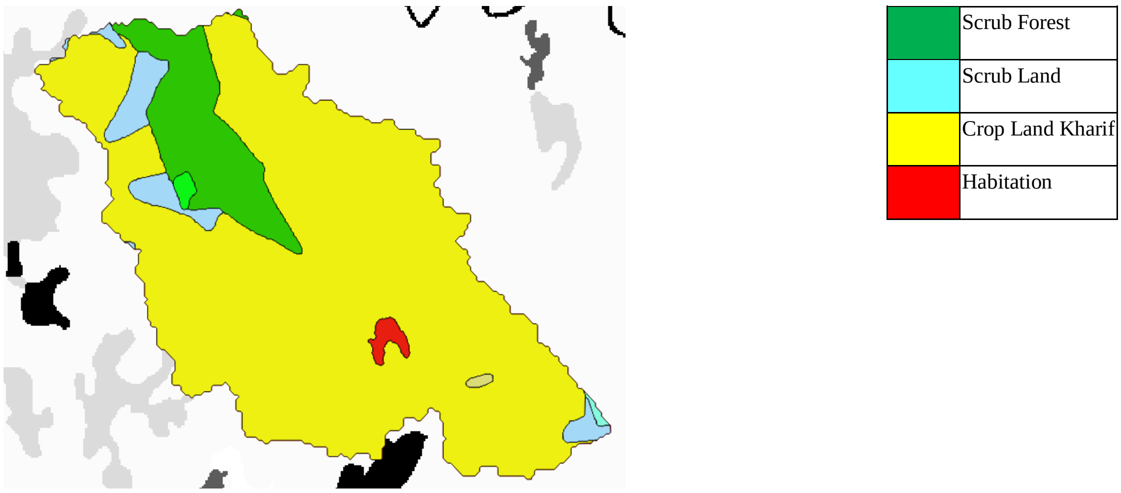


Figure 7.6 LULC classification of Poshera watershed (MRSAC)

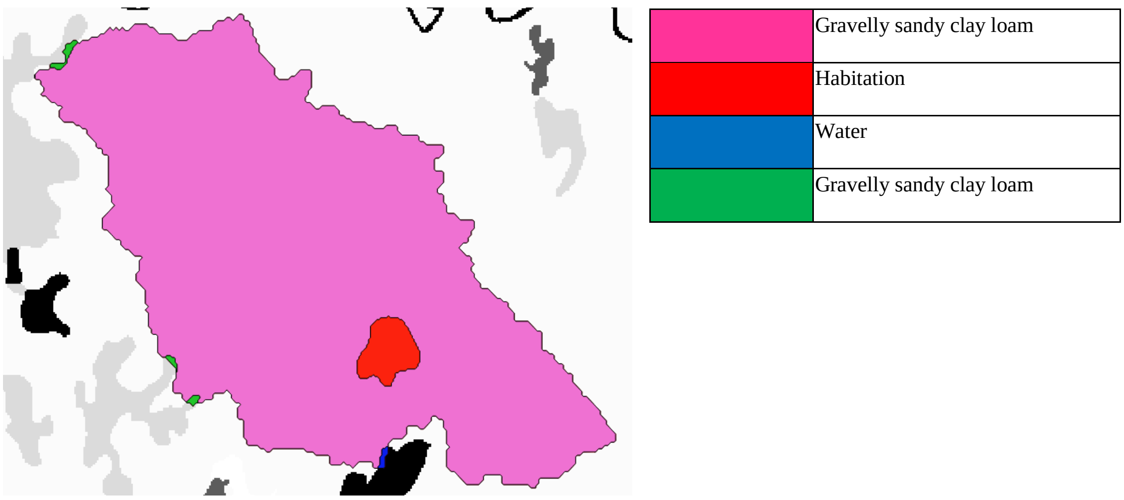


Figure 7.7 Soil Type of Poshera watershed (MRSAC)

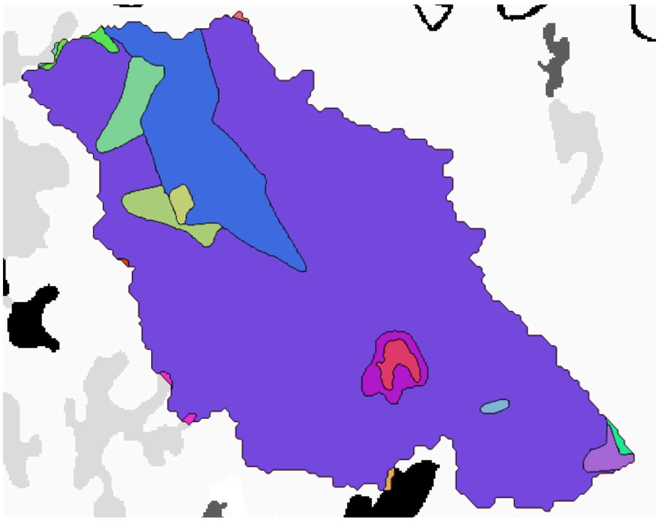


Figure 7.8 Combination map of LULC and soil type (Poshera Watershed)

Using the land use and soil intersection map curve number is calculated Curve Number (CN) 2 is 88.18, CN1 is 76.58 and CN3 is 94.58, based on daily rainfall data (Figure 7.9), Curve Number and Antecedent Moisture Condition direct runoff is calculated (Runoff Curve Number Computations, 1989).

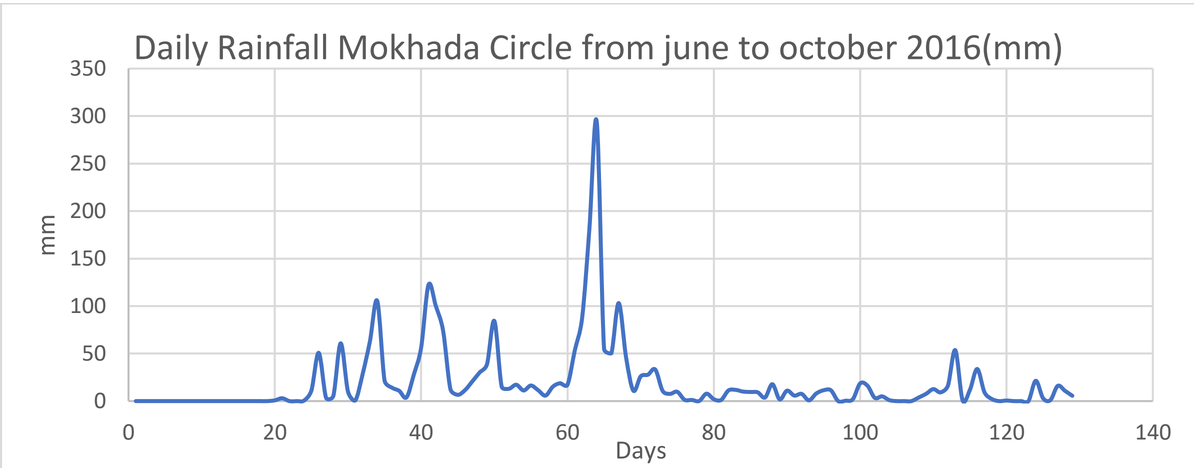


Figure 7.9 Daily rainfall data Mokhada Circle

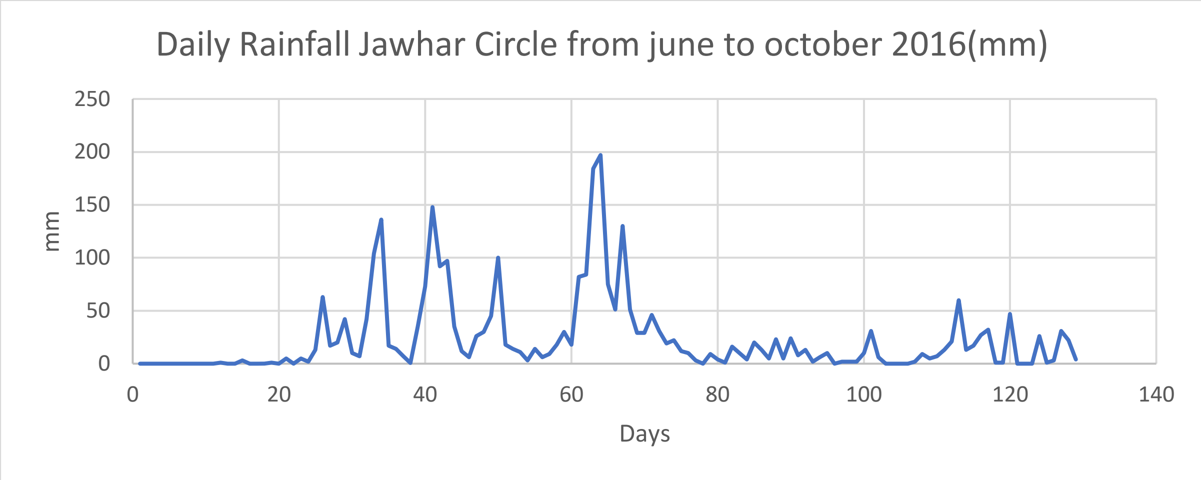


Figure 7.10 Daily rainfall data Jawhar Circle

Total Rainfall in Mokhada Region = 2530.9mm (in 2016)

Direct Runoff= 1590.71

Post Monsoon Water available = Total Rainfall- Direct Runoff – Baseflows during Monsoon.

(as we don't know the quantity of baseflows during monsoon, we are considering it as a unknown, and try to find that out by balancing the equation)

Water available excluding direct runoff =2530.9 - 1590.71

= 940.19 mm

Demand side of Post monsoon includes one month of paddy going to be harvested, twenty days of grass and forest for the rest of the year (still next monsoon)

$$Water\ available\ excluding\ Direct\ runoff\ = Baseflows\ during\ monsoon + Baseflows\ after\ monsoon + ET\ load\ during\ monsoon + ET\ load\ after\ monsoon$$

Calculating these things for Poshera (as we know baseflows after monsoon, and have assumed values for ET load during monsoon and ET load after monsoon), we got the value for Baseflows during monsoon as,

Baseflows during monsoon = 494 mm

As this method of calculating direct runoff didn't had the component of slope in it, and as our study area is basaltic and sloppy, we didn't continue with this calculation.

It is interesting and important to understand the different components involved in total water budget. So, there is scope to incorporate slope in curve number (Nam Won Kim, et. al., 2010) and continue the analysis of total annual water budget.

7.3 Distance to Stream Vs Well Soil/Murum Thickness

It was observed that the wells in stream had very less soil matrix, means basaltic layer is found at very lower depths, where as in wells that are far from the stream will have good soil/murum column/thickness in them. Hence, we calculated the distance of well from the stream (streams are generated with 500 and 1000 pixels as minimum basin size), But there was no significant correlation found between the well thickness (from ground level to depth at which basaltic bed rock starts). The correlation graphs are as shown below (Figure 7.11 and 7.12) (there is a slight increase in well thickness as they are far from streams, but it is no significant difference observed)

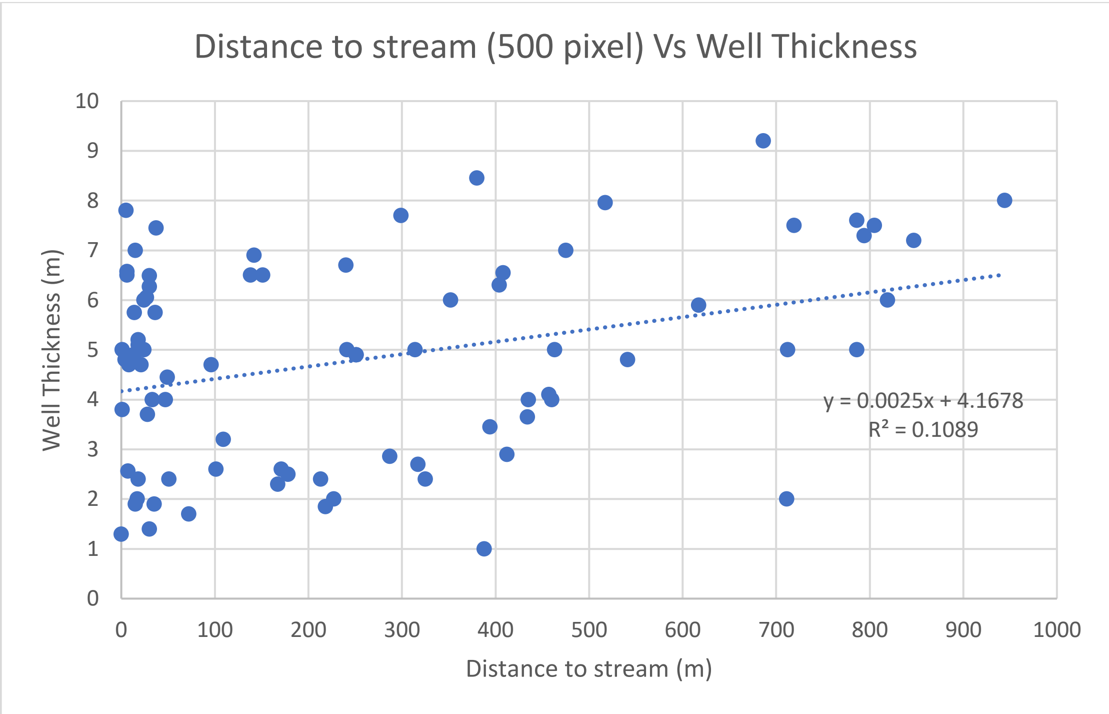


Figure 7.11 Distance to stream (500-pixel basin) Vs Well aquifer thickness

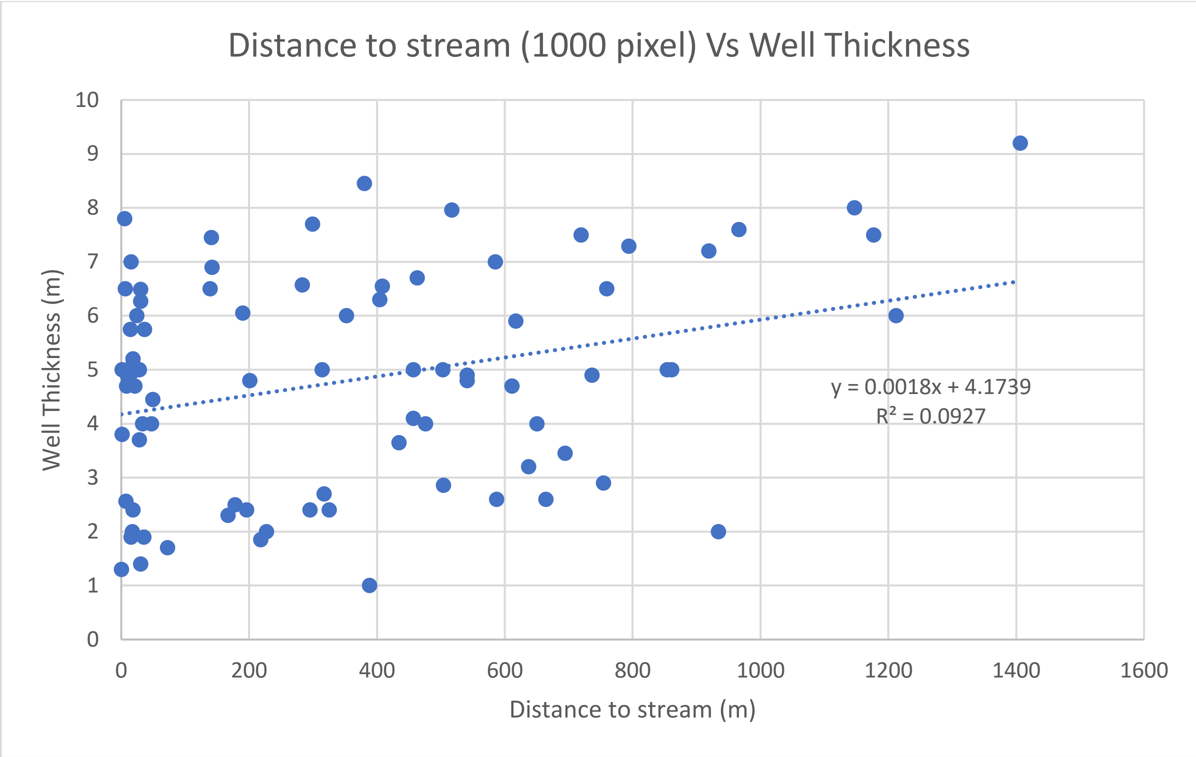


Figure 7.12 Distance to stream (1000-pixel basin) Vs Well aquifer thickness

This also helped us to consider well thickness as depth for its voronoi area while back calculating Specific Yield from water level fluctuation method.

Chapter 8

8 Conclusion and Scope for future work

In this thesis, we have attempted to connect the problems of drinking water stress and overall regional water security with actual watershed activities. Our basic framework has been of a detailed spatial and temporal water balance using both measured data and also various models and analytic tools. For field measurements, eighty-three dug-wells were chosen for regular monitoring and stream flows in sixteen locations were measured. The framework considered the impact of various attributes such as forest cover, drainage line interventions, slopes, well-watershed etc., and came up with guidelines of the selection of wells as well as area treatment and possible impacts. Besides these contributions, the detailed well-level and flow stream flow measurements have contributed to the field data and studies in the hilly regions of Konkan.

We now summarize the key take-aways from this study.

8.1 GSDA Assessment methodology

Observations

- In the studied watershed, groundwater balance is carried out as per GEC methodology (using water level fluctuation) i.e. using well levels monitored by GSDA, specific yield and area norms as per GSDA, except the natural discharge component which is measured at the outlet of sixteen watersheds during dry season.
- According to GEC methodology 90-95% of the of the total recharged groundwater (Calculated by GEC Methodology) is available during the whole dry season, which does not reflect reality. The reason as per GEC methodology is 1. Very less draft (Which is true) and 2. Very low natural groundwater discharge (which is contested).
- The measured natural discharge (base-flows) showed that around 69% of recharged water (as per GEC methodology) has left the watershed as baseflows by January end**.** This suggests that for hilly areas of Western Ghats, incorporation of a seasonal groundwater assessment will inform the administration about the ground situation which is likely to unfold in the summer months.
- GEC does not have a temporal component in water balance. The water availability is estimated at the end of monsoon and draft is numerically subtracted which does not reflect temporal reality.

- Though the study area comes under safe watersheds according to GSDA's stage of development (5-6%), it is clear why the people here are facing acute water problems in summer months.
- The flows in the early months post monsoon (October-November) are greater than what can be attributed to groundwater drop alone. This indicates that the excess must have come from seepage from soil moisture held in the top few meters of the surface.

Suggestion to GSDA

While it is difficult to have stage measurement at all small watershed level at all times, (due to economic constraints), one-time studies of all watersheds to capture key parameters such as half-times, afforestation fraction, soil-moisture vs. Groundwater fraction of stream flows. This would be helpful in yearly planning as well as in long-term monitoring of the health of watersheds.

Observation well water levels in Jan and May (already monitored by GSDA) can also be incorporated in the water balance, so that, it will show how water availability decreases with respect to time.

Soil moisture and Evapotranspiration are important stocks and flows. GSDA should evolve methodologies to incorporate these in its overall assessment protocols.

Limitations of Present Study

- Baseflow measurement immediately after monsoon was not done, this should be taken care for further studies of this kind for more accurate measurement of baseflows.
- As we see the baseflow out column in our estimation table, Dhanoshi North, Dhanoshi Northwest and Aine west's baseflow exceeds the recharge (calculated as per GSDA methodology), this might be because of the error in the recharge calculation, as we exclude hilly areas from recharge calculation, it might be a case where hilly slopes with good forest cover might have contributed to recharge, which is not considered.

8.2 Land Cover and Specific Yield (as storage indicator)

One important contribution of this study is to identify soil moisture, i.e., moisture held in the root zone, as an important stock which plays an important role in overall water balance. While the contribution of soil moisture in stream flows needs further analysis, it has a positive impact on well-water levels and thus on drinking water security.

Observations:

- It was observed that wherever the forest cover is good in the well watersheds, these wells have been perennial. Since, the roots natural forest roots were found to go as deep as 3-6 metres, creating a pathway for more water to infiltrate they creat more space to store water. On the other hand, more forest cover does lead to more evapotranspiration load less natural discharge of water (like in the form of baseflows). Thus, afforestation does increase local access to drinking water but may not contribute to bulk-water availability such as for rabi irrigation.
- The baseflows ceasing early in the dense forested watersheds (Aine) do explain this phenomenon.
- It is also observed that trees/shrubs help in reducing soil erosion and keep the soil intact.

Limitations

- As the current study completely done by assuming Evapotranspiration rates from existing literature, it may not match the true rate.

Scope for further study

- Estimation of on field evapotranspiration rates will help to understand the system better. And do better water balance.
- Better analysis of stream flows into its components, i.e., groundwater flows and seepage from soils, would be useful to understand the impact of afforestation and area-treatment watershed activities
- Specific Yield Estimation using Well Hydrograph (by continuous monitoring of wells) and other Specific Yield determination methods can be tried in the study region (Lisa Shevenell, 1996) (Udayakumar G, et. al., 2015).
- ET load estimation and Seasonal change in ET load can be can be tried using surface energy balance method (Using MODIS remote sensing data) (Mark E. Savoca, et. al., 2013).

8.3 Well Analysis

Observations

- It was observed that most of the wells in the stream of order 3 or above were perennial, this is even seen in the people movement from non-perennial wells (lower order) to perennial wells (higher order).
- Wells which are in lesser order but performing well had good forest cover in their catchment or had very less load.
- Well watersheds seem to be an important determinant of perenniality. Thus, as in spring-sheds, well-sheds too deserve a systematic study, especially while proposing new locations. 82% of wells having more than 19% of forest cover were perennial.
- Empirical study showed that structures like CNBs and KT Weirs are effective in recharging wells only when the well is in the submergence area of the CNB or KT weir, or else the negative effect is seen.
- Sub Surface Bunds also prove to be helpful when they are obstructing subsurface flow in downstream of the well, negative effects were seen if they are situated in the upstream of the well catchment. Implying the importance of selecting the location for the interventions.
- Localised area treatment like Contour trenching and afforestation were very helpful in creating sustainable water availability in wells (Alimal Karwanda forest Well, Vanganpada Drinking Water well).
- Wells in ridge area but having good soil/murum thickness in the flat land seems to be more sustainable.
- As CNBs and KT Weirs are usually located in valley, their use for post monsoon agriculture is very less. Instead CNBs and KT weirs should focus to create sustainable drinking water sources.
- Post Monsoon Horticulture practices and growing mogra (jasmine) look to be unsustainable (using well water for irrigating them, when drinking water source is going dry). But growing trees like mango and cashew looked to be more sustainable (they need to be watered for first one or two years only) and in fact helpful in holding more water in sub surface.
- Rural Drinking Water supply norms (availability of funds per capita) is a hurdle for selecting the sustainable drinking water source for ridge hamlets, where the scope for area and drainage treatment is very less.

- People Narrative about the reduction of forest cover over years and decrease in water availability draws focus.
- There is good scope to analyse the forest cover change (decadal) in the study area and study the water availability in past decades considering changing demography.

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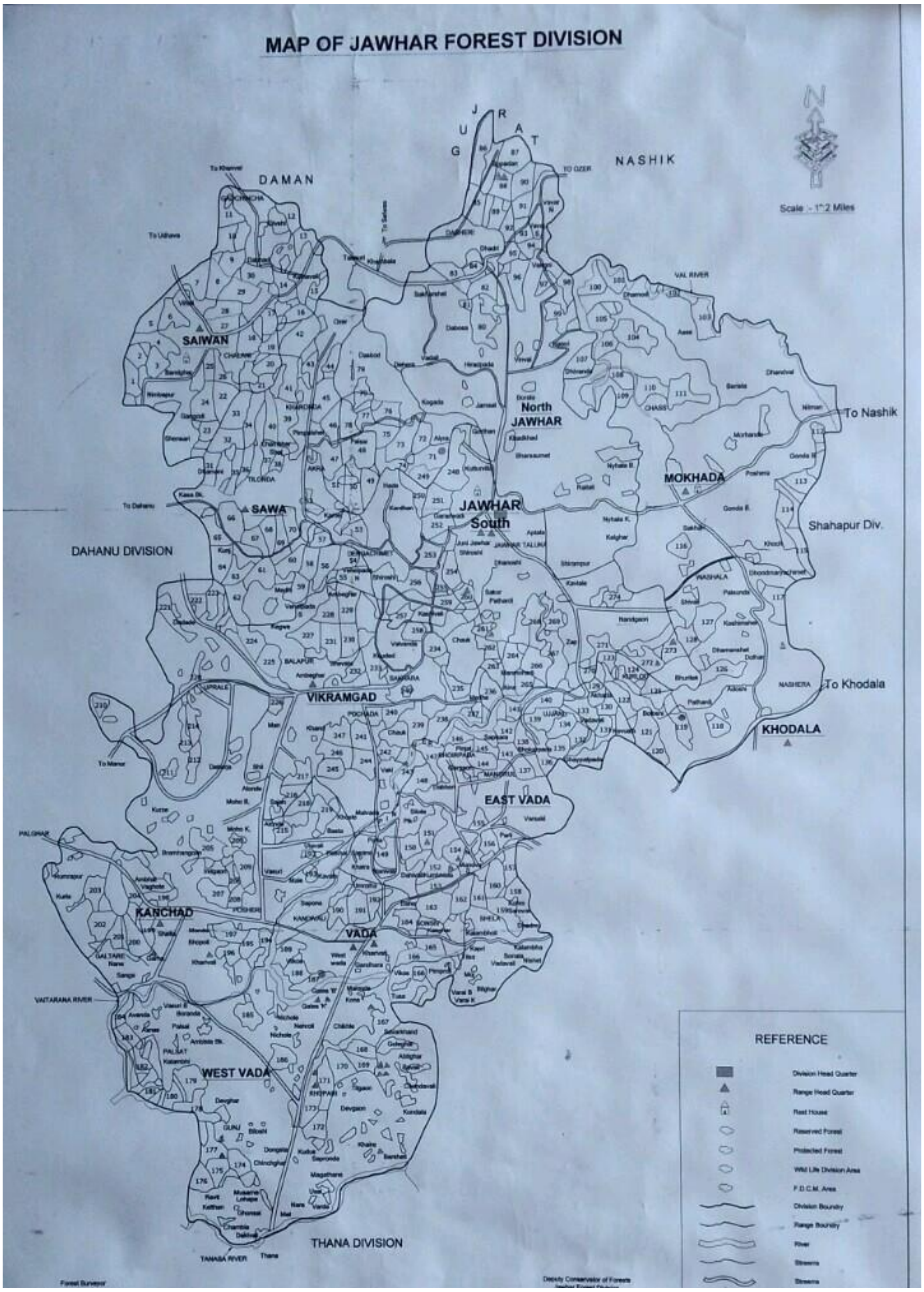
10 ANNEXURE

10.1 Jawhar Forest Division Map



10.2 Pygmy Calibration Table

...TRAL WATER AND POW... PUNE 411024

Service through Research

CURRENT METER CALIBRATION TABLE

CURRENT METER No. & MAKE	0 1551 NTI	CALIBRATION RANGE	0.01-3.5 m/s	SPIN TIME	30 s
CURRENT METER TYPE	Pigmy Cup	DATE OF CALIBRATION	30.07.13	THRESHOLD VELOCITY	0.101 m/s
CWPRS JOB No.	10085	TYPE OF SUSPENSION	RIGID ROD	WATER TEMPERATURE	23.4 °C

CALIBRATION EQUATIONS

For R <= 7.4802 V = 0.0368 + 0.2852R (SD = 0.007 PD = 0.639)

For R >= 7.4802 V = 0.1456 + 0.2707R (SD = 0.002 PD = 0.099)

TIME (sec)	REVOLUTIONS															TIME (sec)
	5	6	7	10	15	20	30	50	80	120	160	200	240	300	400	500	
	VELOCITY IN METRE PER SECOND																
40	0.072	0.080	0.087	0.108	0.144	0.179	0.251	0.393	0.607	0.892	1.178	1.463	1.748	2.176	2.853	~~3.529~~	40
41	0.072	0.079	0.085	0.106	0.141	0.176	0.245	0.385	0.593	0.872	1.150	1.428	1.706	2.124	2.787	3.447	41
42	0.071	0.078	0.084	0.105	0.139	0.173	0.241	0.376	0.580	0.852	1.123	1.395	1.667	2.074	2.724	3.368	42
43	0.070	0.077	0.083	0.103	0.136	0.169	0.236	0.368	0.567	0.833	1.098	1.363	1.629	2.027	2.664	3.293	43
44	0.069	0.076	0.082	0.102	0.134	0.166	0.231	0.361	0.555	0.815	1.074	1.333	1.592	1.981	2.607	3.222	44
45	0.068	0.075	0.081	0.100	0.132	0.164	0.227	0.354	0.544	0.797	1.051	1.304	1.558	1.938	2.552	~~3.155~~	45
46	0.068	0.074	0.080	~~0.099~~	0.130	0.161	0.223	0.347	0.533	0.781	1.029	1.277	1.525	1.897	2.500	3.088	46
47	0.067	0.073	0.079	0.097	0.128	0.158	0.219	0.340	0.522	0.765	1.008	1.250	1.493	1.857	2.449	3.025	47
48	0.067	0.072	0.078	0.096	0.126	0.156	0.215	0.334	0.512	0.750	0.987	1.225	1.463	1.819	2.401	2.965	48
49	0.066	0.072	0.078	0.095	0.124	0.153	0.211	0.328	0.502	0.735	0.968	1.201	1.434	1.783	2.355	2.908	49
50	0.065	0.071	0.077	0.094	0.122	0.151	0.208	0.322	0.493	0.721	0.949	1.178	1.406	1.748	2.311	2.853	50
51	0.065	0.070	0.076	0.093	0.121	0.149	0.205	0.316	0.484	0.708	0.932	1.155	1.379	1.714	2.269	2.800	51
52	0.064	0.070	0.075	0.092	0.119	0.146	0.201	0.311	0.476	0.695	0.914	1.134	1.353	1.682	2.228	2.748	52
53	0.064	0.069	0.074	0.091	0.118	0.144	0.198	0.306	0.467	0.683	0.898	1.113	1.328	1.651	2.189	2.699	53
54	0.063	0.068	0.074	0.090	0.116	0.142	0.195	0.301	0.459	0.671	0.882	1.093	1.304	1.621	2.149	2.652	54
55	0.063	0.068	0.073	0.089	0.115	0.141	0.192	0.296	0.452	0.659	0.866	1.074	1.281	1.592	2.111	2.607	55
56	0.062	0.067	0.072	0.088	0.113	0.139	0.190	0.291	0.444	0.648	0.852	1.055	1.259	1.565	2.074	2.563	56
57	0.062	0.067	0.072	0.087	0.112	0.137	0.187	0.287	0.437	0.637	0.837	1.038	1.238	1.538	2.038	2.520	57
58	0.061	0.066	0.071	0.086	0.111	0.135	0.184	0.283	0.430	0.627	0.824	1.020	1.217	1.512	2.004	2.479	58
59	0.061	0.066	0.071	0.085	0.109	0.133	0.182	0.278	0.424	0.617	0.810	1.004	1.197	1.487	1.970	2.440	59
60	0.061	0.065	0.070	0.084	0.108	0.132	0.179	0.274	0.417	0.607	0.797	0.987	1.178	1.463	1.938	2.401	60
61	0.060	0.065	0.070	0.084	0.107	0.130	0.177	0.271	0.411	0.598	0.785	0.972	1.159	1.439	1.907	2.364	61
62	0.060	0.064	0.069	0.083	0.106	0.129	0.175	0.267	0.405	0.589	0.773	0.957	1.141	1.417	1.877	2.329	62
63	0.059	0.064	0.068	0.082	0.105	0.127	0.173	0.263	0.399	0.580	0.761	0.942	1.123	1.395	1.848	2.294	63
64	0.059	0.064	0.068	0.081	0.104	0.126	0.170	0.260	0.393	0.572	0.750	0.928	1.106	1.374	1.819	2.260	64
65	0.059	0.063	0.068	0.081	0.103	0.125	0.168	0.256	0.388	0.563	0.739	0.914	1.090	1.353	1.792	2.228	65
66	0.058	0.063	0.067	0.080	0.102	0.123	0.166	0.253	0.382	0.555	0.728	0.901	1.074	1.333	1.765	2.196	66
67	0.058	0.062	0.067	0.079	0.101	0.122	0.165	0.250	0.377	0.548	0.718	0.888	1.058	1.314	1.739	2.165	67
68	0.058	0.062	0.066	0.079	0.100	0.121	0.163	0.247	0.372	0.540	0.708	0.876	1.043	1.295	1.714	2.134	68
69	0.057	0.062	0.066	0.078	0.099	0.119	0.161	0.243	0.367	0.533	0.698	0.863	1.029	1.277	1.690	2.103	69
70	0.057	0.061	0.065	0.078	0.098	0.118	0.159	0.241	0.363	0.526	0.689	0.852	1.015	1.259	1.667	2.074	70

V - Velocity (m/s) R - Current meter revolutions per second SD - Standard Deviation PD - Percentage Deviation

(R. R. Gupte)
CHIEF RESEARCH OFFICER
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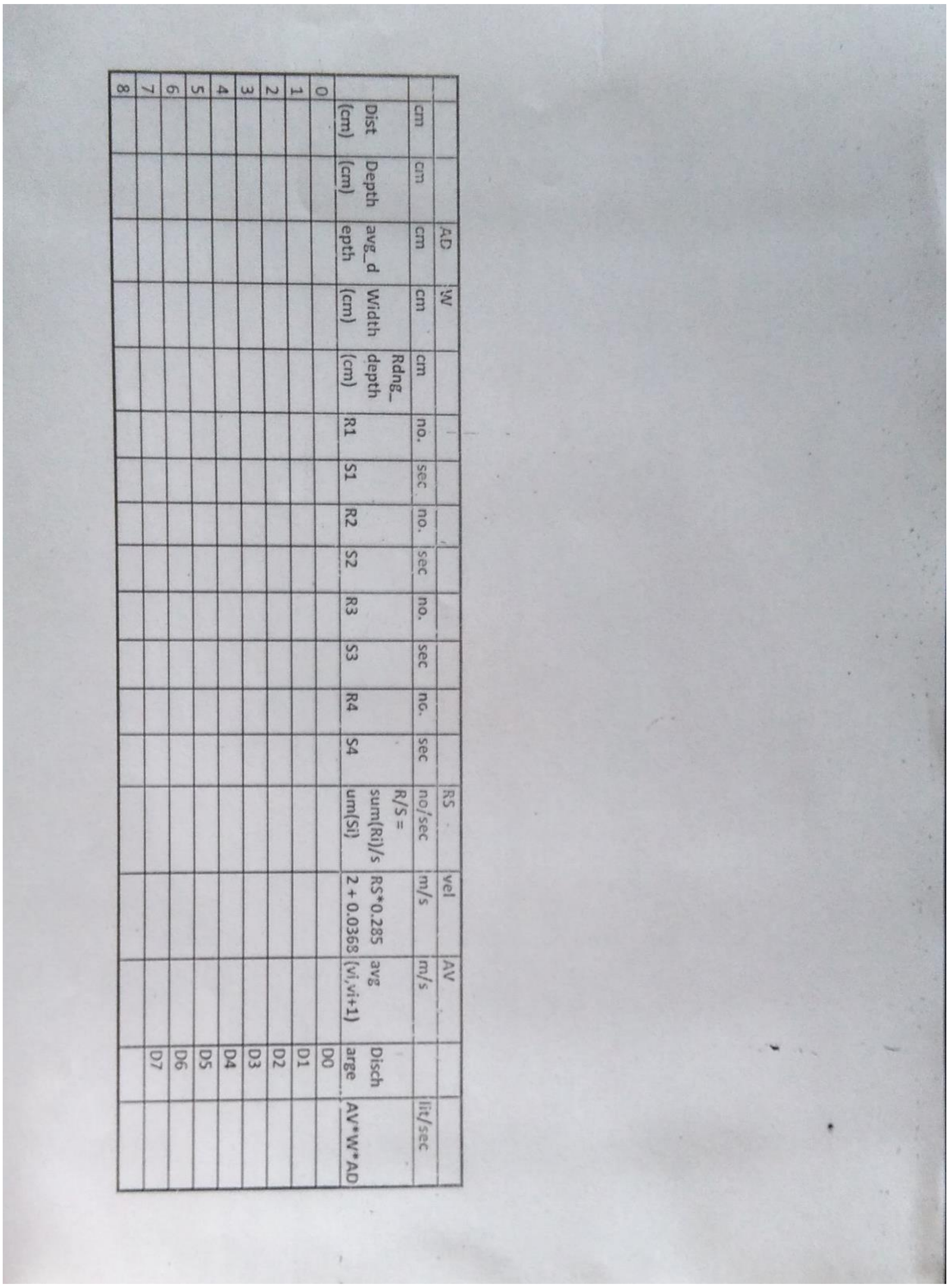
Time 40 5 Rev 500

10.3 Baseflow reading Table



			AD	W										RS	vel	AV		
	cm	cm	cm	cm	cm	no.	sec	no.	sec	no.	sec	no.	sec	no/sec	m/s	m/s		lit/sec
	Dist (cm)	Depth (cm)	avg_depth	Width (cm)	Rdng_depth (cm)	R1	S1	R2	S2	R3	S3	R4	S4	R/S = sum(Ri)/sum(Si)	RS*0.2852 + 0.0368	avg (vi,vi+1)	Discharge	AV*W*AD
0																	D0	
1																	D1	
2																	D2	
3																	D3	
4																	D4	
5																	D5	
6																	D6	
7																	D7	
8																		

10.4 Jawhar Division Forest Details

Sr. No.	Range	Forest Areas (Ha.)				Total (Ha.)
		Reserve Forest (Ha.)	Protected Forest (Ha.)	Acquired Forest (Ha.)	Aq.F.Pending for enquiry (Ha)	
1	South Jawhar	6701.985	1925.917	16.384	694.145	9338.431
2	North Jawhar	6800.23	1984.566	190.351	3438.902	12414.049
3	Mokhada	3971.578	1674.887	0	1338.691	6985.156
4	Khodala	2902.558	631.721	990.703	1709.629	6234.611
5	Sawa	10072.789	2269.432	9.29	263.727	12615.238
6	Saiwan	7523.979	3075.256	0	0	10599.235
7	West Wada	8425.602	2977.26	1336.087	1272.255	14011.204
8	Kanchad	5316.497	2786.181	227.996	307.48	8638.154
9	East Wada	7031.68	1739.896	141.183	1536.98	10449.739
10	Vikramgad	7624.188	2416.297	18.736	267.571	10326.792
GRAND TOTAL		**66371.086**	**21481.413**	**2930.73**	**10829.38**	**101612.609**

10.5 Tanker Fed Village Data Mokhada (as on 1/05/2017)

पाणी टंचाई-२०१७

अ.क्र	आदेश क्र.दि.	टँकर	गांव	पाडे	अ.क्र	आदेश क्र.दि.	टँकर	गांव	पाडे
१	(१)१/०३/१७	०१	आसे पैकी	गोळीचापाडा	४२	दि.	-	धामणशेत पैकी	सोनारवाडी
२	-	-	आसे पैकी	धोमोडी	४३	-	-	सायदे पैकी	हट्टीपाडा
३	(२)१/०३/१७	०१	नाशेरा पैकी	ढवळपाडा	४४	-	-	बेरिस्ते पैकी	नविवाडी
४	(३)७/०३/१७	०६	आसे पैकी	कुंडाचापाडा	४५	-	-	पोशेरा पैकी	नावळेपाडा
५	-	-	आसे पैकी	दापटी	४६	-	-	पाथर्डी पैकी	डोंगरवाडी
६	-	-	आसे पैकी	तुंगारवाडी	४७	-	-	निळमाती	-
७	-	-	चास पैकी	हट्टीपाडा	४८	(११)२९/०३/१७	-	आसे पैकी	कुडवा
८	-	-	बेरिस्ते पैकी	जांभळीचापाडा	४९	-	-	पोशेरा	-
९	-	-	बेरिस्ते पैकी	तेलीउंबरपाडा	५०	-	-	पोशेरा पैकी	ठाकुरपाडा
१०	-	-	धामणी	-	५१	-	-	पोशेरा पैकी	दाभणीपाडा
११	-	-	स्वामीनगर	-	५२	-	-	पोशेरा पैकी	मोरदयाचापाडा
१२	-	-	ब्राम्हणगांव	-	५३	-	-	पोशेरा पैकी	फणसपाडा
१३	(४)१०/०३/१७	०२	मोऱ्हांडा पैकी	कोलदयाचापाडा	५४	-	-	पोशेरा पैकी	पळसपाडा
१४	-	-	हिरवे पैकी	शिंदेपाडा	५५	-	-	लक्ष्मीनगर	-
१५	-	-	शास्त्रीनगर		५६	(१२) /०४/१७	बाकी	आसे पैकी	दापटी नं.२
१६	(५)१०/०३/१७	०१	धामणशेत पैकी	पेंडक्याचीवाडी	५७	-	-	आसे पैकी	नावळेचापाडा
१७	(६)११/०३/१७	०१	खोच पैकी	धोंडमाऱ्याचीमेट	५८	-	-	पाथर्डी	
१८	(७)११/०३/१७	०६	गोमघर पैकी	शेलमपाडा	५९	-	-	चास पैकी	ठाकुरपाडा
१९	-	-	गोमघर पैकी	बोटवाडी	६०	-	-	चास	-
२०	-	-	गोमघर पैकी	उंबरवाडी	६१	-	-	आसे	-
२१	-	-	गोमघर पैकी	डोंगरवाडी	६२	(१३) /०४/१७	बाकी	सायदे पैकी	आंधेखाडी
२२	-	-	गोमघर पैकी	सपोवाडी	६३	-	-	सायदे पैकी	हुडयाचीवाडी
[illegible]	-	-	गोमघर पैकी	बनाचीवाडी	६४			जोगलवाडी	-
[illegible]	-	-	गोमघर पैकी	वाघवाडी	६५	-	-	सायदे पैकी	राजेवाडी
२५	-	-	गोमघर	-	६६	-	-	बेरिस्ते	-
२६	-	-	दुधगांव	-	६७	-	-	निळमाती पैकी	चिंचुतारा
२७	-	-	वाशिंद	-	६८	-	-	सायदे पैकी	वाघ्याचीवाडी
२८	(८)११/०३/१७	-१	डोल्हारा	-	६९	--	-	पळसुंडा पैका	शेंडयाचीमेट
२९		-	डोल्हारा पैकी	साखरवाडी	७०	-	-	करोळ	--
३०	(९)१६/०३/१७	-	किनिस्ते पैकी	ठाकुरपाडा					
३१	-	-	किनिस्ते पैकी	गवरचरीपाडा					
३२	-	-	किनिस्ते -	--					
३३	-	-	मोऱ्हांडा पैकी	काकडपाडा					
३४	-	-	मोऱ्हांडा	--		नगर पंचायत		मोखाडा	पाणी टंचाई-१७
३५	-	-	खोच पैकी	पिंपळपाडा	१	१)दि.५/४/१७	०२	मोखाडा पैकी	लोहारपाडा
३६	-	-	खोच	--	२		-	-	राजीवनगर
३७	(१०)२९/३/१७	-०	केवनाळे	-	३	-	-	-	घोसाळी
३८	-	-	उधळे पेकी	हट्टीपाडा	४	-	-	-	चिंचेची विहिर
३९	-	-	सातुर्ली	-	५	-	-	-	घाटकरपाडा
४०	-	-	वाकडपाडा	-	६	-	-	-	गभालपाडा
४१	-	-	उधळे पैकी	पोऱ्याचापाडा	७	-	-	-	आंबेपाना

१७/०४/२०१७पर्यंत-गांव/पाडे-५४ टँकर-१६ फेऱ्या-६३ चालु मंजुर गांव/पाडे-५५ टँकर-१९ व १५ गांव/पाडे यांचा प्रस्ताव मंजुरीसाठी मा.जिल्हाधिकारी पालघर यांचे कडे मंजुरीसाठी पाठविले आहेत

तहसिलदार मोखाडा

10.6 Tanker Fed Village Data Jawhar (as on 1/05/2017)

साप्ताहिक अहवाल

टॅंकर / बैलगाडयांद्वारे पिण्यांचे पाण्यांचा पुरवठा करणेत येत असलेल्या गाव / पाडयांची नावे. ता. जव्हार UP TO [illegible]/०४/२०१७

अ.क्र	गावाचे नाव	पाडयांचे नाव	लोकसंख्या	टॅंकर सुरु झालेचा दिनांक	टॅंकर क्रमांक शासकिय	टॅंकर क्रमांक खाजगी	बैलगाडीद्वारे शासकिय	पाणी पुरवठा बंद केल्याचा तारिख	एकुण खेपा	शेरा
१	२	३	४	५	६	७	८	९	१०	११
१	जुनी-जव्हार	-	५९०	१७/०३/२०१७	-	MW-N ६३८	-	-	१ खेप	
२	वावर	सागपाना	५३२	१८/०३/२०१७	-	MH-१५ G २९१५	-	-	१ खेप	
३	वावर	रिठिपाडा	२७२	१८/०३/२०१७	-	MH-१५ G २९१५	-	-	१खेप	
४	कासटवाडी	गावठण	२१५	२५/०३/२०१७	-	MW-N ६३८	-	-	१खेप	
५	न्याहाळे खु	कुडांचापाडा	७५०	०५/०४/२०१७	-	MH ४ Q ५९९६	-	-	१ खेप	
६	घिवंडा	पिंपळपाडा	६५०	०५/०४/२०१७	-	MH ४ Q ५९९६	-	-	१ खेप	
७	कौलाळे	गावठण	६००	०५/०४/२०१७	-	MH-०४ CG ४८००	-	-	दिवसाआड १ खेप	
८	कौलाळे	पवारपाडा	९९०	०५/०४/२०१७	-	MH-०४ CG ४८००	-	-	१ खेप	
९	जुनिजव्हार	गुंडपाडा	१७६	१७/०४/२०१७	-	MW-N ६३८	-	-	१ खेप	
१०	धानोशी	करडईपाडा	१५१	१८/०४/२०१७	-	MH-०४ CG ४८००	-	-	दिवसाआड १ खेप	
११	जुनिजव्हार	काळीधोंड	६०५	१८/०४/२०१७	-	MH ४ Q ५९९६	-	-	१ खेप	
१२	रायतळे	खरंबा	३१५	२४/०४/२०१७	-	MH.१२ CH ९००६	-	-	१ खेप	
१३	कासटवाडी	जांभळीचामाळ	८५०	२५/०४/२०१७	-	MH.१२ CH ९००६	-	-	१ खेप	
१४	जुनीजव्हार	सडकपाडा	३१८	२५/०४/२०१७	-	MW-N ६३८	-	-	१ खेप	
१५	न्याहाळे खु	कोळस्याचापाडा	३१०	२५/०४/२०१७	-	MH-०४ CG ४८००	-	-	१ खेप	
१६	रुईघर	पाचबुड	२७५	२४/०४/२०१७	-	MH-१५ G २९१५	-	-	१ खेप	
१७	न्याहाळे बु	मोरगिळा	१८८	२७/०४/२०१७	-	MH ४ Q ५९९६	-	-	दिवसआड १ खेप	
१८	न्याहाळे बु	काष्टीचापाडा	२३६	२७/०४/२०१७	-	MH.१२ CH ९००६	-	-	दिवसआड १ खेप	
१९	न्याहाळे बु	शिवाकोरडयची	२६६	२७/०४/२०१७	-	MH.१२ CH ९००६	-	-	दिवसआड १ खेप	
२०	घिवंडा	पागीपाडा	२८६	२८/०४/२०१७	-	MH ४ Q ५९९६	-	-	१ खेप	
२१	न्याहाळे खु	धारणपाडा	७५०	२८/०४/२०१७	-	MH-०४ CG ४८००	-	-	दिवसआड १ खेप	
२२	न्याहाळे खु	नदंनमाळ	४०२	२८/०४/२०१७	-	MH.१२ CH ९००६	-	-	दिवसआड १ खेप	

एकूण गाव / पाड :- ~~१६~~ 22
गाव :- ०५
पाडे :- १७
टॅंकर संख्या :- ५ खाजगी

MW-N६३८
जी.पी.एस.प्रणाली नं.०१०१२०१४६३०६
कार्ड नं.९१४६०५२९५७
हजर दि.१७/०३/२०१७

MH-०४CG ४८०० मोबा
जी.पी.एस.प्रणाली नं.०१०१२०१४५६४४
कार्ड नं.७७२००५७८७३
हजर दि.४/०४/२०१७

MH १२ CH ९००६ मोबा ७७७००७९०५
जी.पी.एस.प्रणाली नं.०१०१२०१४५७४१
कार्ड नं.७८८८०३१३६९
हजर दि.२६/०४/२०१७

MH १५ G २९१५मोबा
जी.पी.एस.प्रणाली नं.०१०१२०१४५६४३
कार्ड नं.७७२००५६१६२
हजर दि.२०/०३/२०१७

MH-०४ Q ५९९६ मोबा
जी.पी.एस.प्रणाली नं.०१०१२०१४६३९३
कार्ड नं.७७२००५७८६९
हजर दि.१३/०४/२०१७

10.7 Wello Wheel, User friendly water carrier (push or pull type roller)

10.8 Flow Reading (1)

Sr No	Watershed Name	Catchment Area (ha)	1 Flow (Lit/Sec) 1/11/2016	2 Flow (Lit/Sec) 29/11/2016	3 Flow (Lit/Sec) 22/12/2016	4 Flow (Lit/Sec) 14/1/2017	5 Flow (Lit/Sec) 11/2/2017	6 Flow (Lit/Sec) 5/3/2017
1	DHANOSHI NORTH	364.30	58.78	9.39	3.21	1.16	0.48	0.00
2	DHANOSHI NORTHWEST	778.50	139.15	36.96	12.35	6.36	2.46	Almost Dry
3	DHANOSHI WEST	2061.60	332.03	48.23	22.44	12.04	5.90	1.49
4	DHANOSHI SOUTH	735.60	60.64	12.96	9.52	5.71	2.06	2.00
5	DHANOSHI OUTLET	3184.20	419.84	66.56	26.34	18.92	8.44	2.50
1	AINE EAST	804.50	18.03	5.37				Dry (Water Coming in Dowra)
2	AINE WEST	594.20	36.30	14.24				Dry
3	AINE OUTLET	1407.00	68.72	19.90	5.79	3.00	1.50	Dry
1	MORCHONDI RIVER	1464.10	66.78	24.59	13.24	2.82	1.31	0.00
2	MORONDE RIVER	2749.30	187.90	84.66	60.29	30.97	8.64	1.63
3	MORONDE STREAM	625.00	22.52	6.23	5.52	0.72	0.10	0.00
4	HIRVE STREAM	587.70	25.00	8.41	2.13	0.50	0.00	
5	SHINDEPADA RIVER	4136.20	242.21	129.65	63.18		13.32	1.50
6	POSHERA STREAM	1350.20	26.30	11.95	5.89	1.00	0.81	0.00
7	BERISTE STREAM	1126.40	54.00	9.86	13.36	3.00	0.20	0.00
8	CHAS OUTLET	7901.40	406.40	215.17	71.13	31.21	6.19	2.00

Flow Reading (2)

Sr. No	Watershed Name	Catchment Area (ha)	Slope Area (%)		Forest Cover %	baseflow out (ham)	mm drop	Lamda	Half Life Days
			0-5%	>20%					
1	DHANOSHI NORTH	364.3	9.90	18.15	10.95	47.63	130.74	0.054	12.84
2	DHANOSHI NORTHWEST	778.5	7.66	21.22	9.94	102.74	131.97	0.043	16.12
3	DHANOSHI WEST	2061.6	8.67	6.33	13.64	167.37	130.44	0.038	18.24
4	DHANOSHI SOUTH	735.6	23.00	25.40	21.87	34.87	47.40	0.031	22.36
5	DHANOSHI OUTLET	3184.2	17.70	26.50	15.33	210.93	66.24	0.046	15.07
1	AINE EAST	804.5	0.00	46.23	63.83	19.70	24.48	0.053	13.08
2	AINE WEST	594.2	9.10	65.00	55.61	32.55	54.79	0.039	17.77
3	AINE OUTLET	1407	3.86	53.80	59.00	59.86	42.54	0.046	15.07
1	MORCHONDI RIVER	1464.1	12.15	40.84	41.50	72.91	49.80	0.044	15.75
2	MORONDE RIVER	2749.3	13.78	28.84	31.27	170.94	62.18	0.030	23.10
3	MORONDE STREAM	625.0	10.72	20.00	17.72	14.86	23.78	0.031	22.36
4	HIRVE STREAM	587.7	9.70	25.48	21.65	39.58	67.34	0.059	11.75
5	SHINDEPADA RIVER	4136.2	12.63	26.74	27.54	228.59	55.27	0.031	22.36
6	POSHERA STREAM	1350.2	18.44	13.55	4.29	21.57	15.97	0.033	21.00
7	BERISTE STREAM	1126.4	8.50	40.62	22.38	48.73	43.26	0.040	17.33
8	CHAS OUTLET	7901.4	11.82	29.75	22.52	549.37	69.53	0.046	15.07

10.9 ET Load – Baseflows – Sy

Sr. No	Watershed Name	Area in ha	Paddy ET (mm)	Forest ET (mm)	Grass ET (mm)	Total ET (mm)	Baseflow (mm)	Specific Yield %	
								RD (rock depth)	WL (water level)
1	DHANOSHI NORTH	344.4	18.6	65.7	28.1	112.4	138.3	7.1	5.5
2	DHANOSHI NORTHWEST	735.8	30.2	59.7	24.1	114.0	139.6	4.8	6.2
3	DHANOSHI WEST	1948.7	21.6	82.1	26.0	129.6	85.9	4.3	4.8
4	DHANOSHI SOUTH	695.4	20.9	131.8	23.0	175.7	50.1	4.0	6.0
5	DHANOSHI OUTLET	3009.8	21.0	92.2	25.5	138.7	70.1	4.2	4.8
1	AINE EAST	561.8	7.4	384.0	11.5	402.9	35.1	15.5	14.6
2	AINE WEST	760.7	10.1	333.6	13.7	357.3	42.8	12.2	9.9
3	AINE OUTLET	1330.4	9.3	354.4	12.7	376.4	45.0	13.6	11.7
1	MORCHONDI RIVER	1383.4	14.7	249.4	1.8	265.8	52.7	7.4	8.7
2	MORONDE RIVER	2597.6	15.8	188.0	21.0	224.8	65.8	6.4	8.0
3	MORONDE STREAM	590.6	18.6	106.5	25.4	150.5	25.2	4.1	4.4
4	HIRVE STREAM	551.1	18.4	131.5	24.3	174.2	71.8	5.5	6.0
5	SHINDEPADA RIVER	3907.9	16.5	165.7	22.3	204.5	58.5	5.8	6.7
6	POSHERA STREAM	1275.8	39.0	25.8	23.0	87.7	16.9	2.2	2.5
7	BERISTE STREAM	1064.0	18.5	134.5	23.6	176.7	45.8	5.7	5.5
8	CHAS OUTLET	7465.0	20.6	135.4	22.7	178.7	73.6	5.6	6.0

10.10 Well Reading (1)

Sr. No	Location description	Lat	Long	Elevation from Mean Sea Level (m)	Order (10pixels)	Rock Depth (Metre Below Ground)	Hamlet Elev From Mean Sea Level(m)	mean drop (mm/day)
C1	Naviwadi	19.93305	73.36441667	412	2	7	437	13.40
C2	Wargadpada	19.94383333	73.36095	391	1	2	417	26.88
C3	Roadside well before Poshera	19.9359	73.37661667	384	2	5	417	11.54
C4	Kathkarwadi (Poshera)	19.93143333	73.385	398	4	5	414	13.12
C5	Ridge Well (Poshera) People tree	19.9243	73.39405	423	2	2.86		1.69
C6	Vakarichapada (MNREGA)	19.95018333	73.37971667	401	3	5	423	10.62
C7	Vakarichapada	19.94945	73.38011667	402	3	7.5	423	11.68
C8	Dhamni Pada (Poshera)	19.95898333	73.37673333	426	0	7.2	422	43.33
C9	Dhamni Pada 2 (Poshera)	19.9567	73.37813333	404	2	7.96	422	21.48
C10	Mordyachapada	19.95553333	73.36935	388	1	4.8	392	13.33
C11	Gaddichapada (interior)	19.94996667	73.38738333	416	0	6.7	433	29.12
C12	Roadside (way to Morhande)	19.94546667	73.40021667	393	3	3.65		15.67
C13	Morhande (Main)	19.95918333	73.39936667	388	1	5.1	399	37.16
C14	Morhande River well	19.96115	73.4028	373	5	5	399	0.48
C15	Morhande Near Orchard	19.95995	73.39486667	390	0	5.75	399	70.00
C16	Vakichapada (Morchondi)	19.94626667	73.41061667	404	3	2.7	415	18.83
C17	Gonde	19.94705	73.41393333	412	1	6.27	420	26.30
C18	Gaymukh (Temple) Gonde Badruk	19.9457	73.4181	410	3	4.45	420	17.30

Sr. No	Location description	Lat	Long	Elevation from Mean Sea Level (m)	Order (10pixels)	Rock Depth (Metre Below Ground)	Hamlet Elev From Mean Sea Level(m)	mean drop (mm/day)
C19	Chas Outlet Jamdyachapada	19.97531667	73.32243333	227	6	4.9	245	10.50
C20	Chas Pada 1	19.97063333	73.33085	264	1	4	334	18.72
C21	Chas Pada (Ashram Shala Well)	19.97143333	73.33323333	265	2	6.3	334	21.90
C22	Chas Pada (road side)	19.96748333	73.33838333	336	0	1.9		9.47
C23	Bhoir Pada	19.97288333	73.3451	255	6	1.85	281	10.46
C24	Beriste stream well next to road	19.97808333	73.36731667	370	2	7.6	404	60.92
C25	Brahmangaon	19.99721667	73.35146667	447	2	6.57	481	48.71
C26	Beriste Mulagaon Solar Powered well	19.9856	73.36371667	385	3	3.7	409	13.12
C27	Beriste stream umberpada	19.98016667	73.36746667	372	4	6.5	404	15.01
C28	Umberpada Solar well	19.98106667	73.37038333	382	4	7.45	412	39.81
C29	Umberpada Sub surface bund well	19.98285	73.3719	387	3	7.7	412	13.35
C30	Shindepada well	19.97363333	73.37273333	381	2	6.55	376	54.76
C31	Shindepada well 2	19.97261667	73.37546667	386	1	8.45		30.56
C32	Hirve stream well	19.97463333	73.3774	377	3	1		9.80
C33	Hirve stream (good)	19.97478333	73.37743333	379	3	1.7	388	16.52
C34	Pimpalpada	19.98581667	73.38578333	396	2	2.56	397	14.44
C35	Pimpalpada Stream	19.98683333	73.38663333	392	4	4	397	12.80
C36	Hirve village well (Pimpalpada)	19.98283333	73.38795	395	4	6.5	405	6.75
C37	Patilpada	19.98056667	73.39493333	390	3	6.5	405	42.21

Sr. No	Location description	Lat	Long	Elevation from Mean Sea Level (m)	Order (10pixels)	Rock Depth (Metre Below Ground)	Hamlet Elev From Mean Sea Level(m)	mean drop (mm/day)
C38	Kelichapada near tulyachapada	19.96753333	73.4112	380	4	2	403	0.08
C39	Tulyachapada stream (kelichapada) higher	19.96766667	73.41103333	384	4	5		3.00
C40	Tulyachapada roadside	19.96308333	73.40971667	372	4	2.4		2.17
C41	Munjyachimet (Morchondi)	19.95236667	73.42721667	407	4	4	427	2.86
D1	Karamba (Jawhar Nasik Highway side	19.92205	73.2429	486	2	4.7	491	42.56
D2	Kalidhond	19.90035	73.2165	432	2	3.2	448	70.00
D3	Kalidhond (Takkar Bapa)	19.8999	73.2148	423	2	9.2	448	21.77
D4	Juni Jawhar on Ridge	19.8943	73.20465	423	1	7	440	31.93
D5	Well near Bridge on way to alimal	19.8943	73.23585	299	4	2.4		1.37
D6	Alimal DW well	19.88711667	73.24123333	306	1	5.9	337	10.71
D7	Alimal Non DW well	19.88673333	73.23828333	325	1	4.87	337	12.73
D8	Tadachi machi	19.90381667	73.23935	307	4	5	316	0.71
D9	Gorpatte	19.89875	73.2428	345	1	4.7	377	6.72
D10	North stream well near akhar road	19.88543333	73.24665	260	3	2.3		13.49
D11	Kelichapada in stream	19.88755	73.24661667	265	1	2.9	293	13.43
D12	Aptale DW well next to road	19.89766667	73.2512	362	1	3.8	388	51.94
D13	Akhar stream well	19.87821667	73.24736667	251	4	2.6	269	16.30

Sr. No	Location description	Lat	Long	Elevation from Mean Sea Level (m)	Order (10pixels)	Rock Depth (Metre Below Ground)	Hamlet Elev From Mean Sea Level(m)	mean drop (mm/day)
D14	Sakur Interior well DW	19.86571667	73.23405	299	2	5.75	310	29.92
D15	Ramkhind Ashram Shala Well	19.85665	73.22996667	293	4	6.9	301	3.40
D16	Ramkhind DW well	19.85551667	73.22901667	314	1	3.45	312	5.37
D17	Kadachimet DW well	19.86435	73.22268333	333	1	6.05	361	22.68
D18	Dhanoshi Non DW	19.87563333	73.22608333	277	3	4.8	294	20.00
D19	Dhanoshi DW	19.87573333	73.22573333	277	3	1.4	294	17.85
D20	Well in river (2 KT weir)	19.87905	73.23448333	267	5	4.1		11.26
D21	Chautyachiwadi road side	19.8927	73.2275	322	1	4.9	338	10.08
D22	Chaudhri pada stream well	19.89183333	73.22191667	313	3	2.4	327	2.12
D23	Paralipada SDW, Palvipada PDW - roadside	19.88958333	73.2177	318	3	4.7	327	8.38
D24	Paralipada in habitation	19.88753333	73.21833333	306	4	5	326	3.41
D25	Dohare pada	19.87358333	73.21781667	289	3	6	295	31.24
D26	Pathardi DW	19.8565	73.2416	294	3	7.5	295	5.29
A1	Dongarpada DW	19.84138333	73.24381667	416	2	8	438	15.95
A2	Dongarpada DW big well	19.8415	73.24571667	426	0	2.4	438	23.87
A3	Vanganpada	19.84098333	73.22433333	278	2	2.6	316	16.87
A4	Vanganpada 2	19.84206667	73.21988333	279	2	4.9	316	21.31
A5	Vanganpada 3	19.84318333	73.21906667	287	2	7.8	316	22.31
A6	Aine	19.81065	73.23863333	103	4	1.9	114	6.46
A7	Aine 2	19.80945	73.23875	100	4	5.2	114	18.11
A8	Paradi pada	19.80933333	73.23383333	107	4	2.5	114	8.48

Sr. No	Location description	Lat	Long	Elevation from Mean Sea Level (m)	Order (10pixels)	Rock Depth (Metre Below Ground)	Hamlet Elev From Mean Sea Level(m)	mean drop (mm/day)
C42	Morhande Orchard Well	19.96091944	73.39277778	391	0	5	399	2.95
C43	Brahmangaon New	19.99667222	73.35055556	453	2	1.296	481	34.13
C44	Hirve New	19.98366944	73.3875	394	4	6	400	16.02
C45	Shindepada DW	19.97236389	73.375	381	1	7.2925	388	84.05
C46	Koldyachapada DW	19.95753611	73.375	405	2	6.491	403	36.84
C47	KoldyachapadaRiver	19.96164444	73.38555556	339	5	4	403	8.76
D27	Doharepada DW	19.87366667	73.21777778	294	3	6	312	39.52
A9	Aine Frog Well	19.841824	73.24364	425	2	2	438	17.30

Well Reading (2)

Sr. No	Location description	Height of Water Column (m) 1	Height of Water Column (m) 2	Height of Water Column (m) 3	Height of Water Column (m) 4	Height of Water Column (m) 5	Height of Water Column (m) 6	Height of Water Column (m) 7
C1	Naviwadi	5.5	5.10	4.89	4.66	4.48	3.92	3.46
C2	Wargadpada	4.2	3.06	2.65	2.33	1.60	0.45	0.30
C3	Roadside well before Poshera	4.2	4.07	3.93	3.74	3.55	2.93	2.15
C4	Kathkarwadi (Poshera)	4.9	4.70	4.50	4.24	3.96	3.46	2.60
C5	Ridge Well (Poshera) People tree	0.86	0.80	0.73	0.70	0.70	0.56	0.61
C6	Vakarichapada (MNREGA)	2.6	2.13	1.93	1.67	1.47	1.15	0.95
C7	Vakarichapada	6.5	6.35	6.16	5.90	5.68	5.25	4.18
C8	Dhamni Pada (Poshera)	5	1.90	0.50	0.08	0.08	0.00	0.00
C9	Dhamni Pada 2 (Poshera)	6.6	6.48	6.27	5.82	4.76	0.60	0.60
C10	Mordyachapada	3.8	3.60	3.46	3.19	2.62	0.00	1.25
C11	Gaddichapada (interior)	5.9	5.61	5.27	4.73	4.12	2.80	1.55
C12	Roadside (way to Morhande)	2.3	1.60	1.07	0.80	0.53	0.50	0.20
C13	Morhande (Main)	6.2	5.57	5.05	3.67	0.00	0.00	0.60
C14	Morhande River well	3.7	3.66	3.67	3.68	3.67	3.67	3.67
C15	Morhande Near Orchard	0	0.00	0.00	0.00	0.00	0.00	0.00
C16	Vakichapada (Morchondi)	3.65	3.14	2.78	2.59	2.32	1.47	0.10
C17	Gonde	2.8	1.68	0.87	0.05	0.12	0.03	0.00
C18	Gaymukh (Temple) Gonde Badruk	4.6	4.54	3.90	3.92	3.59	2.96	2.07

Sr. No	Location description	Height of Water Column (m) 1	Height of Water Column (m) 2	Height of Water Column (m) 3	Height of Water Column (m) 4	Height of Water Column (m) 5	Height of Water Column (m) 6	Height of Water Column (m) 7
C19	Chas Outlet Jamdyachapada	2	1.83	1.81	1.48	1.17	1.00	0.50
C20	Chas Pada 1	3.1	2.86	2.58	2.14	1.43	0.46	0.40
C21	Chas Pada (Ashram Shala Well)	5.4	5.05	4.45	3.73	2.92	2.54	3.35
C22	Chas Pada (road side)	1.4	0.94	0.81	0.66	0.26	0.00	0.20
C23	Bhoir Pada	2.2	2.18	2.16	2.10	1.75	0.82	0.35
C24	Beriste stream well next to road	5.25	3.65	2.25	0.05	0.05	0.05	0.00
C25	Brahmangaon	4.2	0.28	0.10	0.05	0.05	0.00	Tanker
C26	Beriste Mulagaon Solar Powered well	3.3	2.98	2.84	2.51	2.11	1.20	1.15
C27	Beriste stream umberpada	6.1	6.03	6.02	5.76	5.30	4.60	2.95
C28	Umberpada Solar well	6.8	6.80	6.49	5.77	5.22	2.70	0.55
C29	Umberpada Sub surface bund well	6.2	6.20	5.99	5.58	5.24	5.01	3.95
C30	Shindepada well	5.5	4.68	3.88	2.38	0.00	0.00	Tanker
C31	Shindepada well 2	3.3	2.10	1.33	0.30	0.30	0.30	0.00
C32	Hirve stream well	1.4	1.38	1.10	0.99	0.70	0.34	0.15
C33	Hirve stream (good)	3.2	3.18	3.04	2.71	1.72	0.75	0.50
C34	Pimpalpada	4.2	3.88	3.60	3.83	3.43	3.00	2.04
C35	Pimpalpada Stream	3.4	3.15	2.91	2.26	2.04	1.42	1.55
C36	Hirve village well (Pimpalpada)	3.9	3.70	3.52	3.46	3.48	3.22	2.84
C37	Patilpada	3.9	2.87	1.35	0.25	0.07	0.00	0.05

Sr. No	Location description	Height of Water Column (m) 1	Height of Water Column (m) 2	Height of Water Column (m) 3	Height of Water Column (m) 4	Height of Water Column (m) 5	Height of Water Column (m) 6	Height of Water Column (m) 7
C38	Kelichapada near tulyachapada	1.5	1.56	1.50	1.50	1.58	1.49	1.50
C39	Tulyachapada stream (kelichapada) higher	2.5	2.68	2.58	2.66	2.62	2.55	1.98
C40	Tulyachapada roadside	1.6	1.48	1.63	1.59	1.44	1.64	1.63
C41	Munjyachimet (Morchondi)	1.6	1.60	1.60	1.57	1.48	1.35	1.35
D1	Karamba (Jawhar Nasik Highway side	4.1	3.37	1.41	0.17	0.17	0.17	Tanker
D2	Kalidhond	0.25	0.25	0.25	0.25	0.25	0.25	Tanker
D3	Kalidhond (Takkar Bapa)	3.16	2.40	2.10	1.53	1.14	0.70	0.00
D4	Juni Jawhar on Ridge	6.05	5.40	4.90	4.23	3.46	8.80	2.96
D5	Well near Bridge on way to alimal	1.5	1.50	1.50	1.47	1.47	1.30	1.27
D6	Alimal DW well	3.6	3.30	3.19	2.96	2.86	2.42	1.57
D7	Alimal Non DW well	2.2	1.80	1.50	1.24	1.02	0.76	0.00
D8	Tadachi machi	3.1	3.10	3.10	3.06	3.04	2.95	3.00
D9	Gorpatte	2.5	2.36	2.33	2.25	2.10	1.80	1.10
D10	North stream well near akhar road	2.17	2.07	1.91	1.58	1.24	0.85	0.47
D11	Kelichapada in stream	3.07	2.32	2.02	1.76	1.65	1.46	1.00
D12	Aptale DW well next to road	3.8	2.12	0.32	0.30	0.42	0.28	0.00
D13	Akhar stream well	2.3	1.76	1.24	0.98	0.48	0.20	0.00

Sr. No	Location description	Height of Water Column (m) 1	Height of Water Column (m) 2	Height of Water Column (m) 3	Height of Water Column (m) 4	Height of Water Column (m) 5	Height of Water Column (m) 6	Height of Water Column (m) 7
D14	Sakur Interior well DW	4.9	4.53	4.25	3.83	2.99	1.32	0.30
D15	Ramkhind Ashram Shala Well	5.65	5.47	5.57	5.47	5.65	5.45	5.12
D16	Ramkhind DW well	2.6	2.53	2.54	2.50	2.28	2.10	1.65
D17	Kadachimet DW well	4.85	4.00	3.55	3.28	2.93	2.30	0.75
D18	Dhanoshi Non DW	2.8	2.50	2.45	2.15	1.56	0.60	0.00
D19	Dhanoshi DW	1.65	1.14	0.59	0.29	0.01	0.00	0.00
D20	Well in river (2 KT weir)	2.3	2.24	2.20	1.88	1.56	0.95	0.70
D21	Chautyachiwadi road side	2.85	2.07	1.79	1.58	1.48	1.15	1.10
D22	Chaudhri pada stream well	0.74	0.73	0.71	0.74	0.64	0.57	0.44
D23	Paralipada SDW, Palvipada PDW - roadside	4	3.85	3.67	3.49	3.32	3.08	2.60
D24	Paralipada in habitation	3.5	3.37	3.37	3.32	3.25	3.15	3.03
D25	Dohare pada	5	3.71	2.84	2.22	2.02	0.02	0.00
D26	Pathardi DW	7.08	7.10	7.08	7.03	6.85	6.60	5.90
A1	Dongarpada DW	1.2	0.42	0.11	0.13	0.02	0.02	0.05
A2	Dongarpada DW big well	5.7	5.07	4.67	4.35	3.79	0.60	0.00
A3	Vanganpada	1.25	0.50	0.18	0.00	0.00	0.00	0.00
A4	Vanganpada 2	4.75	4.15	3.75	3.23	2.81	2.35	0.75
A5	Vanganpada 3	4.11	3.10	2.50	1.92	1.49	1.15	0.95
A6	Aine	1.7	1.45	1.29	1.25	1.14	1.03	0.65
A7	Aine 2	2.65	1.89	1.08	0.71	0.70	0.48	0.05
A8	Paradi pada	4.4	4.32	4.29	4.17	3.98	3.54	3.05
C42	Morhande Orchard Well	0.6	0.55	0.50	0.46	0.34	0.40	0.27

Sr. No	Location description	Height of Water Column (m) 1	Height of Water Column (m) 2	Height of Water Column (m) 3	Height of Water Column (m) 4	Height of Water Column (m) 5	Height of Water Column (m) 6	Height of Water Column (m) 7
C43	Brahmangaon New	3	2.20	1.50	0.50	0.05	0.05	0.15
C44	Hirve New	4.7	4.70	4.70	4.66	4.34	3.10	2.42
C45	Shindepada DW	5	3.53	2.44	0.00	0.00	0.00	Tanker
C46	Koldyachapada DW	6	4.65	3.74	1.66	0.83	0.00	0.10
C47	KoldyachapadaRiver	1.5	1.50	1.43	1.27	1.36	0.90	0.47
D27	Doharepada DW	5	3.67	2.77	2.01	1.58	0.00	0.87
A9	Aine Frog Well	5	4.35	4.30	3.94	3.26	0.00	0.30

Well Reading (3)

Sr. No	Location description	Order (10pixels)	Well Catchment (ha)	Category	Distance to well (m)	Paddy %	Forest%	perinniality	total_load Cubic Metre
C1	Naviwadi	2	10.086	PDW	309	32.4	1.85	10	510.3
C2	Wargadpada	1	19.391	FW	418	17.61	1.42	8	0.0
C3	Roadside well before Poshera	2	15.958	SDW	623	47.67		10	280.0
C4	Kathkarwadi (Poshera)	4	218.6	PDW	362	59.21	1.07	10	1701.0
C5	Ridge Well (Poshera) People tree	2	10.99	FW		69.67	0.81	10	0.0
C6	Vakarichapada (MNREGA)	3	21.739	FW	269	53.19	0.4255	10	0.0
C7	Vakarichapada	3	38.6	PDW	221	51.4	0.233	10	1701.0
C8	Dhamni Pada (Poshera)	0	0.2371	PDW	90			3	241.5
C9	Dhamni Pada 2 (Poshera)	2	17.131	SDW	250	33.16	1.53	6	299.5
C10	Mordyachapada	1	7.193	PDW	194	55		6	1122.7
C11	Gaddichapada (interior)	0	2.676	PDW	231	20	13.33	8	126.0
C12	Roadside (way to Morhande)	3	42.519	FW		35.42	0.863	8	0.0
C13	Morhande (Main)	1	32.127	PDW	395	54.13		5	6930.0
C14	Morhande River well	5	1919.5	SDW	834	14.26	35.08	10	0.0
C15	Morhande Near Orchard	0	1.141	PDW	229	50	33.33	1	1260.0
C16	Vakichapada (Morchondi)	3	226.5	FW	361	8.5	41.37	8	409.5
C17	Gonde	1	7.917	PDW	183	14.28	4.76	4	2056.6
C18	Gaymukh (Temple) Gonde Badruk	3	111.4	PDW	403	17.44	32.51	10	1633.0
C19	Chas Outlet Jamdyachapada	6	7423.6	PDW	86	19.82	22.37	10	1224.7
C20	Chas Pada 1	1	41.067	PDW	514	10.81	34.23	8	4725.0
C21	Chas Pada (Ashram Shala Well)	2	35.467	PDW	802	7.57	36.29	10	1360.8
C22	Chas Pada (road side)	0	2.947	FW			40.625	3	0.0
C23	Bhoir Pada	6	5764	PDW	197	20.51	22.56	10	1417.5

Sr. No	Location description	Order (10pixels)	Well Catchment (ha)	Category	Distance to well (m)	Paddy %	Forest%	perinniality	total_load Cubic Metre
C24	Beriste stream well next to road	2	26.161	PDW	266	31.57	13.68	4	1019.2
C25	Brahmangaon	2	9.359	PDW	278	56.56	6.06	3	2310.0
C26	Beriste Mulagaon Solar Powered well	3	99.047	PDW	400	24.81	15.48	10	2211.3
C27	Beriste stream umberpada	4	226.4	SDW	560	20.62	21.06	10	1756.2
C28	Umberpada Solar well	4	209.7	PDW	345	18.73	21.9	8	1827.0
C29	Umberpada Sub surface bund well	3	69.515	SDW	380	18.33	28.75	10	146.2
C30	Shindepada well	2	3.67	PDW	115	22.5		5	630.0
C31	Shindepada well 2	1	1.14	FW		15.38	38.46	4	0.0
C32	Hirve stream well	3	32.303	FW		24.58	13.53	10	0.0
C33	Hirve stream (good)	3	32.303	SDW	551	24.58	13.53	10	416.6
C34	Pimpalpada	2	352.6	PDW	189	14.08	22.24	10	850.5
C35	Pimpalpada Stream	4	329.8	WASHING		13.59	22.52	10	850.5
C36	Hirve village well (Pimpalpada)	4	374	FW	173	14.94	21.85	10	0.0
C37	Patilpada	3	35.554	PDW	84	21.18	30.72	5	420.0
C38	Kelichapada near tulyachapada	4	301.2	PDW	590	14.72	24.95	10	3402.0
C39	Tulyachapada stream (kelichapada) higher	4	301.2	FW		14.72	24.95	10	0.0
C40	Tulyachapada roadside	4	375.5	FW		14.13	24.27	10	0.0
C41	Munjyachimet (Morchondi)	4	579.1	PDW	200	5.28	67.85	10	3265.9
D1	Karamba (Jawhar Nasik Highway side	2	11.442	PDW	242	91.73		4	709.8
D2	Kalidhond	2	30.06	PDW	195	18.88	1.54	1	235.2
D3	Kalidhond (Takkar Bapa)	2	25.632	FW	405	12.72	2.12	7	294.0
D4	Juni Jawhar on Ridge	1	15.963	PDW	573	39.28	2.38	10	756.0

Sr. No	Location description	Order (10pixels)	Well Catchment (ha)	Category	Distance to well (m)	Paddy %	Forest%	perinniality	total_load Cubic Metre
D5	Well near Bridge on way to alimal	4	617	FW		30.06	9.53	10	0.0
D6	Alimal DW well	1	4.304	PDW	136	8.51	38.29	10	1020.6
D7	Alimal Non DW well	1	4.847	FW	311	11.11		7	0.0
D8	Tadachi machi	4	419.7	PDW	85	31.98	10.13	10	340.2
D9	Gorpatte	1	1.322	FW	309	100		10	0.0
D10	North stream well near akhar road	3	236.3	FW		22.14	9.36	10	0.0
D11	Kelichapada in stream	1	48.861	PDW	257	17.89	4.51	10	1871.1
D12	Aptale DW well next to road	1	1.593	PDW	287	21.05		4	1492.4
D13	Akhar stream well	4	322.7	FW	379	18.83	10.71	7	0.0
D14	Sakur Interior well DW	2	19.762	PDW	233	44.79	1.35	7	3292.8
D15	Ramkhind Ashram Shala Well	4	264.5	PDW	135	11.69	25.32	10	1360.8
D16	Ramkhind DW well	1	264.5	PDW	125	11.69	25.32	10	6565.9
D17	Kadachimet DW well	1	20.485	PDW	275	7.76	27.39	7	4145.4
D18	Dhanoshi Non DW	3	62.964	FW	315	14.73	18.49	7	0.0
D19	Dhanoshi DW	3	62.964	SDW	315	14.73	18.49	5	420.0
D20	Well in river (2 KT weir)	5	1202.2	FW		25.89	10.82	10	0.0
D21	Chautyachiwadi road side	1	10.54	PDW	321	13.27	4.42	10	1020.6
D22	Chaudhri pada stream well	3	150.4	PDW	123	17.25	4	10	510.3
D23	Paralipada SDW, Palvipada PDW - roadside	3	60.338	PDW	220	29.83	2.99	10	850.5
D24	Paralipada in habitation	4	157.5	PDW	254	28.25	15.42	10	782.5
D25	Dohare pada	3	176.8	PDW	105	6.52	29.1	6	1234.8
D26	Pathardi DW	3	148.9	PDW	105	28.77	16.31	10	1667.0
A1	Dongarpada DW	2	3.04	PDW	206	25.8	3.22	3	2140.6

Sr. No	Location description	Order (10pixels)	Well Catchment (ha)	Category	Distance to well (m)	Paddy %	Forest%	perinniality	total_load Cubic Metre
A2	Dongarpada DW big well	0	0.598	SDW	370			6	1556.8
A3	Vanganpada	2	18.499	PDW	15	31.03	21.67	3	72.8
A4	Vanganpada 2	2	43.993	PDW	300	16.52	19.27	10	2925.7
A5	Vanganpada 3	2	33.777	FW	190	12.91	19.23	10	0.0
A6	Aine	4	536.5	PDW	341	6.81	64.12	10	1667.0
A7	Aine 2	4	541.6	FW	229	6.75	64.17	10	0.0
A8	Paradi pada	4	741.2	PDW	289	9.05	56.02	10	1054.6
C42	Morhande Orchard Well	0	2.947	FW/SDW	432	34.375	31.25	10	0.0
C43	Brahmangaon New	2	3.12	WASHING	209	38.7	6.45	5	0.0
C44	Hirve New	4	361.5	PDW	113	14.36	22.12	10	7960.7
C45	Shindepada DW	1	2.947	PDW	161	24.24	21.21	4	582.4
C46	Koldyachapada DW	2	21.467	SDW	235	28.57	1.63	6	252.0
C47	KoldyachapadaRiver	5	3189.9	DW PROPOSED	937	15.83	28.56	10	326.3
D27	Doharepada DW	3	176.8	PDW	129	6.52	29.1	6	2998.8
A9	Aine Frog Well	2	7.108	FW	155	12	9.33	6	0.0

10.11 Watershed Level Activities by Different Departments

A watershed is an area of land that drains all the rainfall and streams to a common point/outlet. The watershed word is also used interchangeably with catchment or drainage basin, hills or

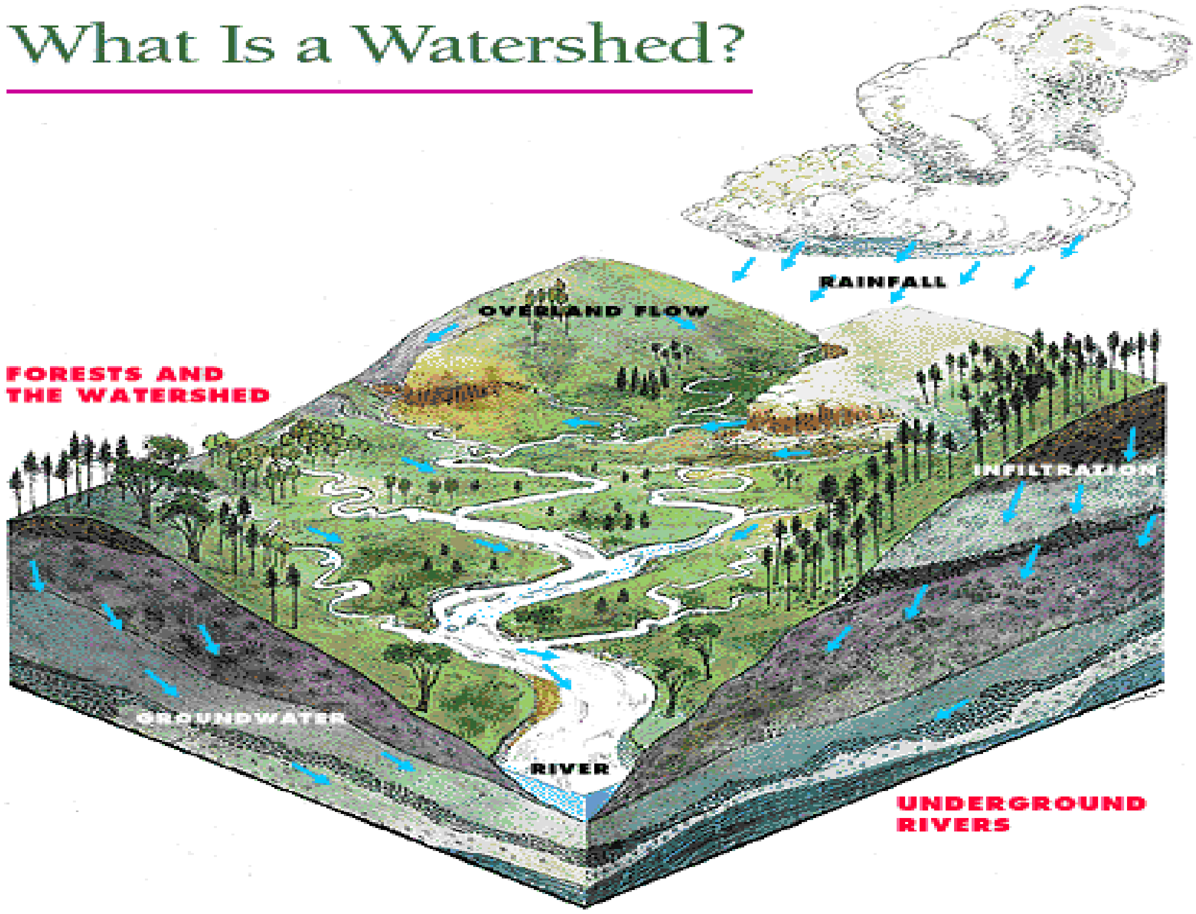


Figure 10.1 A typical Watershed

higher elevation points which separate two watersheds are called as ridge lines or in simple term one can call that as watershed boundary. The watershed in general terms is mainly dependent on outflow point, all the land contributing/drains the water to that outflow point makes the catchment for that watershed (http://water.usgs.gov/edu/watershed.html).

Main factors that determine the watershed's capacity to hold the rainfall are vegetation, land cover, physical geology, soil types, terrain, and different types of land uses (cropping, grass land).

The water that enters the watershed in the form of rainfall flows as surface runoff (rivers) fills the surface water bodies like lakes, ponds and a part of water infiltrated water flows in subsurface through underground channels or may accumulate in groundwater storage in shallow aquifers or it may flow in subsurface and come out and join the streams as baseflows or the ground water beneath the surface can move to different watersheds across the boundary.

Watershed intervention design/treatment plan refers to the different steps taken to conserve natural resources like soil, water through different measures such as physical (check dam etc.,) interventions or natural interventions such as afforestation.

Government Department Preferences for watershed activities

In the broader picture, we are trying to develop a water security planning framework for the region through watershed intervention design which are meant to address the following problems,

- Chronic problem of water scarcity in dry seasons
- lack of water for irrigation
- large forest lands without forest cover (thinking about afforestation as a solution) and
- large scale dry-season migration

Though all the problems described are related to water but they are under the canopies of different government departments which needs a collective effort to solve the problem of water.

Drinking Water

Looking at the drinking water scenario of Palghar District it is evident that the Mokhada and Jawhar are the two severely affected Talukas, and most of the hamlets in Mokhada and Jawhar are tanker fed in the months of April and May. Coming to the problem of solving drinking water stress programmes like NRDWP (National Rural Drinking Water Programme) focuses on Watershed management steps to optimise drinking water supply (GoI, National Rural Drinking Water Programme, 2010). Which includes

- Delineation and Resource inventory of watersheds
- Maximisation of water conservation and minimising environmental degradation (as soil erosion, sedimentation)
- Conjunctive use of water resources through development of *effective models* and
- Pilot studies on convergence of different centrally funded schemes for achieving water security

Crop Water

The potential of crop water or minor irrigation is also mainly depended on effective watershed management. Programs like PMKSY (Pradhan Mantri Krishi Sinchayeee Yojana) (GoI, Operational Guidelines of Pradhan Mantri Krishi Sinchayee Yojana, 2015-16) also has a sub wing which entirely focuses on watershed development activities as

- Effective management of runoff water and improved soil and moisture conservation activities such as ridge area and drainage line treatment, in-situ moisture conservation and other watershed basis activities.
- Converging with MGNREGS (Mahatma Gandhi National Rural Employment Guarantee Scheme) for the creation of water source to full potential in identified backward rain-fed blocks.

Total geographic area of Palghar district is 517634 Ha. According to 2011 Census the Land Use pattern indicate that 42% is under cultivation and Area sown more than once is 1.9%. This indicates that the Rabi cultivation in the district is very less.

Forest and Livelihood

The New National Forest Working Plan Code 2014 has its vision towards the complex interlinks between forest and water. It states that the forests are also sources of water (surface, sub-surface and groundwater), and stresses on urgent need to augment the groundwater resources through suitable management interventions dovetailed with principles of watershed-based development approach.

In the context of forest degradation due to natural causes and calamities, areas such as steep slopes and areas in the vicinity of perennial streams etc., which are susceptible to soil erosion should be focused for soil and water and soil conservation interventions irrespective of their overlapping working circle (GoI, National Forest Working Code – 2014)

According to forest rights act, community forest resources like minor forest produces (MFPs), grazing grounds, water bodies, etc. can be exercised within the frame of sustainable management. Which offers an additional livelihood option for the tribal community who are susceptible for migration in the non-working dry season. Jawhar Division has 66371 Ha under Reserve Forest, 21481 Ha under Protected Forest, 2930 Ha under Acquired Forest and 10829 Ha under Acquired Forest pending for inquiry summing up to 101612 Ha of total Forest area (Annexure 1 and 4)

Apart from this, programs like Jalyukt Shivar and MGNREGA also stress the importance of watershed development. The main points that Jalyukt Shivar Focuses are

- Increasing groundwater level
- Increasing assured water for farming
- Initiating new projects to create water storage capacity
- Encouraging tree plantation and planting trees, etc.,

All these programs and many more stress the need for watershed development. Understanding the impacts of different interventions (like afforestation etc.,) in this region (as watershed functions are highly contextual) will help the NGOs working in the water sector to plan their interventions accordingly and helps in policy level planning for the region.

Watershed Level Activity Chart (source: TDSC)

Table 10.1 Watershed Level Activity Chart (source: TDSC)

Watershed Activities by Different Departments					
Department of Minor Irrigation		Department of Agriculture		Forest Department	
Drain line Treatment	Area Treatment	Drain line Treatment	Area Treatment	Drain line Treatment	Area Treatment
Pukka Bunds	Village Ponds	CNB	CCT	CNB	Vanikaran
KT bunds	Recharge Ponds	ENB	Terracing	Gabion Bunds	Tree Plantation
Pukka Bund Repair	Village Pond Repair	Diverted Bund	Juni Bhaat Sheti	Forest Bund desilting	Samtalchar
KT bund repair	Recharge Pond Repair	CNB Repair	Horticulture		Forest Ponds
Concrete Nala Bund		ENB Repair	Tree plantation		LBS
		ENB Desilting	Farm Ponds		
		CNB Desilting	LBS		
			Farm Pond Repair		

Table 10.2 Departments-Activities-Benefits (Watershed Interventions)