

INVENTORISATION OF WATER RESOURCES IN SOLAN DISTRICT OF HIMACHAL PRADESH

Thesis

by

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(FORESTRY)

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CERTIFICATE-I

This is to certify that the thesis entitled, **“Inventorisation of water resources in Solan District of Himachal Pradesh”** submitted in partial fulfillment of the requirements for the award of degree of **MASTER OF SCIENCE (Forestry) ENVIRONMENT MANAGEMENT** to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni-173 230, Solan (HP) is a record of bonafide research work carried out by **Ms. Shalini Chauhan (F-2011-11-M)** under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of investigations has been fully acknowledged.

Place : Nauni-Solan
Dated: 24 July, 2013

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This is to certify that the thesis entitled, “**Inventorisation of water resources in Solan District of Himachal Pradesh**” submitted by **Ms. Shalini Chauhan (F-2011-11-M)** to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni-173 230, Solan (HP) in partial fulfillment of the requirements for the award of degree of **MASTER OF SCIENCE (Forestry) ENVIRONMENT MANAGEMENT** has been approved by the Student’s Advisory Committee after an oral examination of the same in collaboration with the internal examiner.

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ABBREVIATIONS

%	:	Per cent
⁰ C	:	Degree Celsius
APHA	:	American Public Health Association
bcm	:	Billion Cubic Meter
BOD	:	Biological Oxygen Demand
Ca ²⁺	:	Calcium
CD	:	Critical Difference
CGWM	:	Central Ground Water Management
Cl	:	Chloride
cm	:	Centimeter
COD	:	Chemical Oxygen Demand
CPCB	:	Central Pollution Control Board
Cv	:	Coefficient of Variation
dS/m	:	Desisiemen per meter
DWSS	:	Drinking Water Supply Scheme
EC	:	Electrical Conductivity
EPA	:	Environment Protection Agency
<i>et al</i>	:	And Co-workers
FCH	:	Fully Covered Habitations
FIS	:	Flow Irrigation Scheme
G	:	Ground Water Source
GIS	:	Geographical Information System
GPS	:	Geo-Position System
GWSS	:	Gravity Water Supply Scheme
ha	:	Hectare
HP	:	Himachal Pradesh
ICMR	:	Indian Council of Medical Research
INDG	:	Industrial Underground
INDS	:	Industrial Surface
INSG	:	Institutional Underground
INSS	:	Institutional Surface

IPH	:	Irrigation and Public Health
ISO	:	International Organization of Standardization
Km ³ yr ⁻¹	:	Cubic kilometer per year
KOH	:	Potassium Hydroxide
LIS	:	Lift Irrigation Scheme
LPS	:	Liter per second
LWSS	:	Lift Water Supply Scheme
M amsl	:	Metre above mean sea level
Mg	:	Magnesium
mg	:	Miligram
ml	:	Mililitre
MLD	:	Mega Liter per Day
mm	:	Milimeter
PCH	:	Partial Cover Habitation
PWS	:	Piped Water Supplies
RG	:	Rural/Agriculture Underground
RS	:	Rural/Agriculture surface
S	:	Surface Water Source
sq km	:	Square kilometer
TDS	:	Total Dissolve Solid
TH	:	Total Habitation
UG	:	Urban underground
UN	:	United Nations
US	:	United State
US	:	Urban Surface
USGS	:	U.S. Geological Survey
WHO	:	World Health Organization
WRI	:	Water Resource Inventory

Chapter-1

INTRODUCTION

Water is one of the most precious resources on earth without which there would be no life on this planet (Yadav and Kumar, 2011). In spite of the enormous volume of the water on the planet, only a small portion is available for use. About 97 per cent of the total water is present in oceans and seas which is saline water and is not useful, while fresh water makes up only 2.6 per cent and 4/5 of that is immobilized as ice (Karthick and Ramachandra, 2006). This meagre quantity of fresh water is responsible for sustaining all forms of life on this planet (Iqbal and Gupta, 2009). Surprisingly, the global consumption of water is doubling every 20 years at the rate of more than twice of human population growth. At present more than one billion people lack access to fresh drinking water.

India is rich in water resources, being endowed with a network of rivers and blessed with snow cover in the Himalayan range which can meet a variety of water requirements of the country. The available water resources in many parts of the country are getting depleted and the water quality has deteriorated. It has been predicted that by 2050 India is going to be water scarce due to the continuous and increasing demand for water (Gupta and Deshpande, 2004). With increasing population per capita water availability is decreasing (Sampath *et al.*, 2001) and demand for fresh water is increasing due to improved living standards and urbanization/industrialization. However, this important natural resource is still being used wastefully.

Rapid increase in the population of the country and increasing anthropogenic activities like mining, disposal of treated and untreated waste effluents containing toxic metals as well as metal chelates (Amman *et al.*, 2002; Meitei *et al.*, 2004) from different industries, indiscriminate use of heavy metal containing fertilizers and pesticides in agriculture, irrigation demands, urbanization, deforestation and technological advancement resulted in deterioration of water quality rendering serious environmental problems posing threat on human beings (Lantzy and Mackenzie, 1979; Nriagu, 1979) and sustainability of aquatic biodiversity (Ghosh and Vass, 1997).

Indian rivers particularly large ones have become highly polluted due to inflow of domestic, industrial and agricultural effluents. It has been reported that about 70 per cent of the surface water resources are already contaminated (Rao and Mamatha, 2004). The safe portable water is absolutely essential for healthy living. Presently depletion of groundwater sources as a result of more withdrawal rate than recharge is a matter of global concern. Groundwater is usually assumed to be a very good source of potable water due to purification property of soil (Odeyemi *et al.*, 2011). In many cases groundwater is polluted by the inflow of pollutants such as sewage and industrial wastewater (Khanfar, 2008). The evaluation of water quality in different countries has become a critical issue in recent years due to the population increase and the growing demand for water (Bhargava, 1985; Pesce and Wunderlin, 2000; Paliwal *et al.*, 2007). The degree of pollution is generally assessed by studying physical and chemical characteristics of the water bodies (Duran and Suicmez, 2007).

Distribution of water is highly uneven. The collection of basic data on water balance of the sea and river basins, continents and the planet as a whole is essential for rational utilization and protection of water resources and for understanding the evolution of our planet (Engman and Gurney, 1991). Since, water pollution and depletion of water sources due to various anthropogenic causes, as a result of changing climatic situation is increasing therefore documentation (inventorization) of various water bodies, their water yielding potential, availability for use, quality and identifying other related problems is essential for future planning and management (Anonymous, 2010). The Water resource inventory (WRI) is a process to identify the availability of water from different sources, water needs of different users, and the tools or facilities to store and/or carry water to the users (Ragab Abdel, 2008). As the human population continues to expand, to approach ten billion, there will be an increasing demand upon all Earth's resources. Of particular importance will be resources related to energy, soil and water, all of which involve geo-fluids. Problems associated with waste disposal also involve systems for protecting near-surface water quality. There is an urgent need to quantify the fluid inventory and fluid dynamics of the near surface, while understanding volatiles and their deep recycling is fundamental to our understanding of the major dynamic processes of the Earth (Fyfe, 2013).

Water is the most essential input in biological world. It relatively has been becoming more and more scarce with increasing number of its users and uses. Per capital availability of water has decline by about 65 percent in India during last about five and half decade (Anonymnous, 2007). There is no absolute scarcity of water, only the relative scarcity exists due to improper management practices while putting water for various uses.

Himachal Pradesh is situated at the altitudinal location of 30°22" to 33°13" North Latitude and 75°36' to 70°02' East Longitudes in the North West India. It has a total geographical area of 55,673 km². With an elevation of 350 m to 6816 m, it receives on an average about 1800 to 3000 mm of rainfall, yet scarcity of water exists in the state. Solan district of Himachal Pradesh is located between latitude 30°30" and 31°50" North Latitude and 76°42" to 77°20" East Longitude (Survey of India Toposheet No.53F/I) at an elevation ranging from 300 to 3,000 meters above mean sea level. The district comprises of five developmental blocks viz, Nalagarh, Dharampur, Solan, Kandaghat and Kunihar. Solan district of Himachal Pradesh has a population of 5,76,670 according to 2011 census, the district has a total of 1,23,353 households out of which 97,237 are rural and 26,116 are urban households. There are 2,536 villages in total. Upto 2011 there are 2109 registered factories in the district and 1,81,066 workers working in these units. During the years 2009, 2010 and 2011 the district has received average annual rainfall of 862.8 mm, 1377.1 mm and 911.1 mm respectively.

The rapid growth of Solan Block has enhanced the use of water and its demand has increased manifold in the recent past. Moreover, the changing lifestyle of people has not only increased the demand of water but has also deteriorated the quality of surface and ground water. The Solan city of Solan Block is growing rapidly and is generating about 17.51 tonnes of solid waste per day (Pathania, 2011). Moreover, the waste water effluents are discharged directly to the water bodies without treatment. Consequently, problem of drinking water contamination, water conservation and water quality management has assumed a very complex shape. Information on water availability, requirement, storage and quality under present conditions is very scanty. Therefore, information on all these aspects of water is necessary so that appropriate prevention and remedial measures can be undertaken. A comprehensive inventory of the surface and ground water sources is required to be prepared for assessing the potential as well as for

making future plans for this important natural resource. This will also assist in identifying optimum ground-water and surface-water use scenarios, in future. Keeping this in view, the present study “Inventorisation of Water Resources in Solan District of Himachal Pradesh” was undertaken with the following objectives:

OBJECTIVES

- i) To prepare a detailed inventory of water resources of the Solan block in District Solan of Himachal Pradesh.
 - a) Identification of the availability of water from different sources.
 - b) Identifying the water needs of different users.
 - c) Identifying the tools (facilities) to store and/or carry water to the users.
- ii) To determine the quality of surface and ground water sources of Solan Block.

Chapter-2

REVIEW OF LITERATURE

Since the beginning of the twenty first century, the earth with its diverse and abundant life forms, including over six billion humans is facing a serious water crisis. The condition is getting worse and will continue, unless corrective measures are taken. This crisis is one of water governance, essentially caused by the ways in which we mismanage water. Though industrialization, urbanization, agricultural and institutional development helps to meet the basic requirements of people, but simultaneously all the activities are the major determinants of water quality and quantity. Both surface and ground water bodies are prone to degradation by human activities around them. The problem of water pollution has further been worsened by the rapid population explosion leading to congestion, increased waste generation and extreme pressure on the available water resources. In India, due to lack of sewage treatment plants, untreated effluents are either directly used for irrigation or disposed off in nearby water bodies. Clean water is of paramount importance to the livelihood and health of the inhabitants. The literature pertaining to the present study is reviewed under the following heads.

2.1 Global and Indian scenario of water resources

2.2 Water resource inventory

2.3 Land-use systems and water quality

2.3.1 Rural/Agricultural Land-use

2.3.2 Urban/Sub-urban/Institutional land-use

2.3.3 Industrial land-use

2.1 GLOBAL AND INDIAN SCENARIO OF WATER RESOURCES

The amount of water on planet earth is estimated to be approximately 1388 million billion cubic meters, of this total amount part 1348 million billion cubic meters (97.3per cent) is constituted by the salt water in the oceans. Only 37.5 billion cubic meters (2.7per cent) water occurs in the form of fresh water. Of this total fresh water, 28200 thousand billion cubic meter (2.04 per cent) is in the form of polar ice and glaciers. 8450 thousand billion

cubic meter (0.61 per cent) as ground water and 127 thousand billion cubic meter in the form of lakes, river etc. (CGWM and CPCB, 2000).

India supports about 1/6th of world population, 1/50th of world's land and 1/25th of world's water resources. In India out of total rainfall in an area of 3290 lakh hectares, a rainfall of 4000 billion cubic meters annually occurs. Out of the total, 41% is lost by evaporation, 40% is lost as runoff, 10% is retained as soil moisture, 9% seeps in for recharging ground water. Of the 40% stream flow water, 8% is used for irrigation, 2% for domestic use, 4% for industry, 12% for electric generation. Out of total 1869 bcm available water resources, the usable water resources are only 1122 bcm, which consists of 690 bcm surface water, 432 bcm ground water. While at present per capita available water resources is 1122 bcm by 2050 it is likely to reduce to 748 bcm (Anjaneyulu, 2004). Groundwater is nation's principal reserve of fresh water. India is the largest user of groundwater followed by China & US. We irrigate 39 Million ha of land through groundwater. More than 90% of rural and more than 50% of urban water supply is being met by groundwater. The number of groundwater abstraction structures is 21 million with an estimated annual water withdrawal of about 221 bcm. (CGWB, MoWR, GOI, 2012)

2.2 WATER RESOURCE INVENTORY

Human Development Report on Himachal Pradesh (2002) predicted the water demand for the state. According to the report, water demand in the state in the year 1991 in urban area was 70.21 mld which increased to 75.04mld in 2001 and in rural area it was 384.32mld that increased to 399.01 mld in 2001. The report further predicted the water demand for the state which says that for urban area the water demand will increase to 150.49 mld in 2021 and 575.97mld for rural areas in the year 2021.

Rana *et al.* (2006) while inventorising the Glaciers and Glacial Lakes in Satluj River Basin of Himachal Pradesh reported that there are total 945 glaciers with a cumulative area of 1217.70 sq. km. and estimated ice reserve of 94.45 km³. The inventoried glaciers have been classified into seven types i.e. ice, apron, ice cap, mountain, mountain basin, niche and valley glaciers. Areas occupied by these glaciers were 697.51, 173.4 and 272.7 sq. km., respectively. Maximum number of glaciers (416) was of mountain basin type. There were 40 lakes identified in this basin with an area of 136.4 sq. km. About 35 were found to be associated with glaciers. Rate of rainfall amount to the tune of 17.01 mm annually based on the data for

past 15 years .The study clearly revealed that glacier reserves are depleting at a rate 12 times faster than the water inflow from the basin.

Sharma (2006) reported that Himachal Pradesh has provided piped drinking water to entire of its population. The study has shown that there are 7989 piped water supply schemes in Himachal Pradesh. In addition, Himalayan belt has a number of traditional drinking water sources. The main traditional sources for the drinking water in the state are wells, baolies, springs, ponds and khatries.

CPCB (2007) reported that the springs in the Solan District are mainly gravity, contact or fracture type and springs located along major thrust/faults or structurally weak planes are high yielding. The springs, locally called *Chasma*, discharge varies from seepages to as high as nine litres per second. *Bowries*, a type dug well, are another structure constructed in the hill slopes to tap the seepages. Such *Bowries* are very common and observed all over the district. State department have drilled shallow bore wells fitted with hand-pumps to provide domestic water. The hand pumps have depth up to average 50-60m depth have low discharges up to one lps.

In Himachal Pradesh during last 50 years drinking water demand has grown by 2.4 times in rural areas and 6.8 times in urban areas Sharma (2007). The demand for water has also been projected to further rise by 1.62 times in rural area as well as urban areas in the coming 30 years.

Reza and Singh (2009) found that in India, there are over 20 million private wells in addition to the government tube wells. Surface waters like streams and lakes are not the only water sources that suffer from pollution but even groundwater aquifers, which are critical sources of both drinking and irrigation water, are also affected. The usage of groundwater has gradually increased because of the increase of water demand and the shortage of surface water availability.

Water is a precious natural resource with fixed quantum of availability. Globally, approximately 97 per cent of the earth's water occurs in the oceans and only three per cent is available as fresh water. Out of three per cent fresh water, 75 per cent is locked up in ice sheets and glaciers and almost 25 per cent is present as groundwater. Lakes, reservoirs,

swamps, river channels, biospheric water, atmospheric water, and soil moisture together account for the remaining fresh water (Anonymous 2010).

Siebert *et al.* (2010) in their study revealed that globally, area equipped for irrigation is currently about 301 million ha of which 38% are equipped for irrigation with groundwater. Total consumptive groundwater use for irrigation is estimated as 545km³ yr⁻¹, or 43% of the total consumptive irrigation water use of 1277km³ per year. The countries with the largest extent of areas equipped for irrigation with groundwater, in absolute terms, are India (39millionha), China (19millionha) and the US (17millionha). Groundwater use in irrigation is increasing both in absolute terms and in percentage of total irrigation, leading in places to concentrations of users exploiting groundwater storage at rates above groundwater recharge.

Singh *et al.* (2010) in his their study reported that, the sources of only 22.3% of the piped water supply schemes get affected during summers. During the year 2009 the district which was affected most is the Solan, where 38.12% of habitations got affected during summer. The other districts which were affected i.e, where the discharge of drinking water sources is reduced are Sirmour 29.2%, Hamirpur 5.55%, Kangra 17.05%, Bilaspur 27.31%, Mandi 14.54%, Shimla 15.05%, Kullu 10.15%, Chamba 1.6% and Una 8.03%. Most of these schemes fall in Shiwalik hills. The total population affected during the summers is 768579. Thus 11.1% of the rural population feels scarcity of water due to reduction in discharge of sources.

The Comptroller Auditor General (2011) Audit report stated that only 10% of the waste water generated is treated, and rest is discharged as such into the rivers. In India all the rivers (14 major, 55 minor and several hundred small rivers) receive millions of liters of sewage, industrial and agricultural wastes.

The Comptroller Auditor General (2011) took up the performance audit of “Water Pollution in India” during 2010-11 and found out that out of the 1079 projects for pollution control of 24 rivers across 19 States being implemented, they scrutinized 140 projects being implemented for the control of pollution in respect of 24 rivers. Out of the projects meant for conservation of 58 lakes in 14 States, they studied the 22 projects for conservation of lakes across the 14 States. Out of a total of 6053 blocks across India, they examined 116 blocks for implementation and monitoring programmes relating to ground water pollution. They also

studied the administrative structures and the activities related to water pollution in 25 States of India

Scott (2011) concluded that Uttar Pradesh is the most populous state in India. Water resource quality is a growing concern which till now has not been well documented for the state. The State Water and Sanitation Mission (SWSM) are going to create a database of ponds, wells and hand pumps by using GIS and GPS technologies under National Rural Drinking Water Program with immediate focus on villages.

According to the State Environment Report Himachal Pradesh (2012) Solan district of Himachal Pradesh has emerged as a hub for industries; it has about 138 small scale and 6 large scale industries. The district receives annual rainfall of 1420.40 mm. it has 344 ground water sources, 1090 surface water sources, 1215 traditional water sources and 316 other conventional sources. Overall the state has 8186 ground water sources, 20,223 surface water sources, 10,512 traditional water sources and 2595 other conventional sources of water. In Himachal Pradesh there are six river basins with a total of 202 glaciers that covers an aerial extend of 1120.024 sq. km. Also there are 1094 snowfields with an aerial extend of 856.737 sq. km in the state.

CPCB (2012) in a report on aquifer system in HP concluded that the total ground water availability of the state which includes dynamic and in-storage resources (27713 MCM). Ground water resource estimates of the eight valleys of Himachal Pradesh as on March, 2009 reveals that overall the stage of ground water development is under safe category, except in Kala Amb and Una Valleys wherein ground water is highly exploited for irrigation and industrial uses. Based on the hydrogeological characteristics, the entire state has been classified into ten principal aquifer systems and 27 major aquifers. Alluvium is the most promising aquifer system which covers an area of 8% of the state. The sandstone aquifer occupies 16% area in the districts of Bilaspur, Chamba, Hamirpur, Kangra, Mandi, Una, Simaur and Solan. The rest of the state is covered with the other aquifers constituting around 76% of the area. Among these, schist aquifer covers maximum of around 32% area of the state predominantly in districts of Chamba, Kinnaur and Lahaul Spiti.

Singh and Kandari (2012) concluded that, Shimla City depends mainly on surface water available in the form of springs and streams to fulfill its water demand. However, during summers, the discharge from these sources is reduced leading to shortage of water

supply. Water is sourced from long distances, which involves high cost and wastage due to leakage during transportation and distribution from source to the consumer end. The demand of water increases from 42 MLD to 45 MLD during peak summer season due to additional pressure from the incoming tourists while the supply ranges between 24 to 27 MLD (DPR, 2009). This shows a huge water demand and supply gap.

2.3 EFFECT OF DIFFERENT LAND-USE SYSTEM ON WATER QUALITY

Research has shown that human-induced conversions (e.g. deforestation) and modification (e.g. changing land use management such as fertilizer use and irrigation practices) of land use have significance for the functioning of the earth system. Land use changes can also have an important impact on both water quantity and quality.

2.3.1 Rural/Agricultural Land-use

Natural processes and anthropogenic activities affect the land use and land cover. Land use change is a primary factor affecting water-quality and causing habitat degradation (UN 2003). Change in land-cover influence soil quality, water runoff, sedimentation rates, earth-atmosphere interactions, biodiversity, the hydrological cycle, and biogeochemical cycling of carbon, nitrogen and other elements at regional to global scales. There have been several investigations in recent years on the effect of land use on water quality.

Pionke and Urban (1985) carried out water quality analysis of small Pennsylvania watershed to study the effect of agriculture land-use system on ground water quality and found high concentration of nitrates and chlorides in ground water underlying cropland due to consistent use of fertilizer and manure on local cropland. They also found that nitrate was dominant anion only in the cropped siltstone area.

Hamilton and Helsel (1995) reported increased concentration of nitrates in the ground water at five different regions of United States which was due to application of commercial fertilizers and manure; it exceeded maximum containments level (MCL) for drinking water. They also reported increased level of potash, calcium and magnesium in ground water beneath agriculture areas.

Tabuchi *et al.* (1995) found that agricultural land use within catchments has been linked to increased concentrations of inorganic N in drainage waters. The concentration of

NO₃ – N in stream water has been strongly correlated with the proportion of agricultural land associated with grassland and common upland crops in the catchment.

Garg (1998) reported TDS, pH, and other parameter of water samples beyond permissible limits in ground water in village of southwestern, Haryana, India.

Randall (2000) reported high concentration of nitrates in surface water of Mississippi river basin, due to surface drainage from row crop agricultural production system. According to the study precipitation and mineralization of soil organic matter greatly influenced the drainage losses, nitrate concentration and nitrate loadings in subsurface drainage water.

Kurosawa and Ngoyen (2004) monitored ammonium-nitrogen (N), nitrate-N and the pH of surface and ground water in three rural communities in the central Red River Delta, Northern Vietnam. The communities differed in topography, soil type and cropping pattern. The results revealed that ammonium-N of surface and ground water was relatively high and exceeded the Vietnamese water standard for than drinking purpose. Whereas the nitrate-N concentration of surface and ground water was generally lower than 0.4 mg/L. The low pH of the ground water measured at some sites in the grey degraded soil area was out of the Vietnamese water standard for drinking use.

Robertson (2006) while studying the influence of agriculture land use system on water quality of water bodies in Jones Creek, Alberta, Canada reported great affect of agriculture land use system on water. Poor land management practices result in contamination of local waterways by runoff carrying excess fertilizers, herbicides, pesticides, and animal wastes.

Bishnoi and Arora (2007) studied the ground water quality in rural areas of Rohtak, India and reported that most of samples did not comply with WHO standard and overall water quality was unsatisfactory for drinking purpose.

Jeyaruba and Thushyanthy (2009) reported a good correlation between cropping system and nitrate concentration in ground water of Jaffana, Peninsula whereas, no correlation was found between land use, Electrical Conductivity, pH and Chloride ions. The concentration of Nitrate –N was influenced by cropping system. High concentration of Nitrate-N was found in high land crops land use followed by mixed crops though there was no significant difference between the two.

Suthar *et al.* (2010) reported NO_3^- and SO_4^{2-} contamination in ground water of rural areas of Rajasthan which was due to application of N- fertilizer, sewage, animal waste, organic manure, pit latrines etc.

Bhaskar *et al.* (2010) conducted studies on the suitability of water from different locations around Tumkar region in Karnataka for irrigation and drinking purpose. All surface water except Honnudike, Kadaba and Hebbur contain low concentration of heavy metals and mere suitable for irrigation. Similarly, the ground water also had low concentration of heavy metals (Fe, Ni, Zn) except Cu. Samples from Honnudike and Hebbur had high iron concentration ($> 5\text{mg/l}$) than that required for irrigation. Cd, Hg and Mg were not found in any of the tested samples.

2.3.2 Urban/Sub-urban/Institutional land-use

Long and Salem (1974) reported chlorine as most common source of contaminant to deteriorate water quality of urban and suburban areas.

Tripathi *et al.* (1991) analyzed physicochemical characteristics of sewage, discharged into river Ganga at different sites viz., Assi ghat, Shiwala ghat, Harischandra ghat, Chauki ghat, Rajendera Prasad ghat, and Rajghat at Varanasi, India. They reported that higher concentration of sewage was discharged during May and June. Rajghat sewage was highly concentrated having highest pollution load, whereas, sewage at Assi ghat was least concentrated and polluted.

Naidu and Raman (1993) analyzed 93 samples of ground water of urban aquifers in Madras. The samples were found to exceed Ca^{2+} , Mg^{2+} , TDS, SO_4^{2-} , NO_3^- limits. High concentration of heavy metals viz. As (0.42mg/l), Hg (0.02mg/l), Pb (1.82 mg/l) and Cd (1.31mg/l) were also reported.

Chari and Lavanya (1994) reported sodium salt (50mg/l) exceeding the permissible limit (WHO) in ground water of Cuddapah urban area, Andhra Pradesh.

Eckhardt and Stacklberg (1995) reported positive correlation of water quality of urban and sub-urban areas with land use pattern

Sivasubramani (1999) carried hydrological, physicochemical and the biological analysis of river Periyar in Tamil Nadu. The analysis revealed that due to urbanization, the quality of Periyar river water has deteriorated. It has high values of hardness (90.5 to 220 mg/l), phosphorous (0.05 to 0.23 mg/l), conductivity (200 to 350.9 Nmhos), total coliform etc. in the downstream area due to sewage contamination.

Ostrowska *et al.* (1999) studied Na, K, Ca, Mg, Zn, Fe, Mn, P, NO₃, NH₄, Cl, SO₄ and pH content in water samples from farm wells situated in six regions of Poland and reported that in wells of all provinces, an intolerable content of nitrate-nitrogen, potassium and manganese were present.

Kathikeyani *et al.* (2002) studied the water quality of the river Shanmuganadhi, Tamil Nadu and found the water unsuitable for drinking and irrigation purpose due to dispersal of sewage water from surrounding area.

Latha *et al.* (2002) analyzed 133 water samples from Avinashi, Pollachi and Palladam areas of Coimbatore district, Tamil Nadu, India, for water quality analysis. The electrical conductivity (EC) of water samples from these areas ranged from 0.45-4.50, 2.27-9.95 and 0.2-2.7 dsm⁻¹ respectively.

Ren *et al.* (2003) studied the relationship between water quality, urbanization and changing patterns of land use in Shanghai, China and reported that rapid urbanization corresponds with rapid degradation of water quality and urban land uses are positively correlated with the decline in water quality.

Yusuf (2007) reported high levels of water quality constituents (exceeding WHO standards for drinking water) in the wells penetrating the shallow alluvial aquifers in the Lagos city, Nigeria. The limits for TDS conductivity, lead, pH and salts (sodium & calcium) were 50 per cent, 27.8 per cent, 38.9 per cent and 11.1 per cent, respectively. Thus ground water from some of these wells required further purification for human consumption.

Bishnoi and Malik (2007) reported high concentration of dissolved salts and fluorides (higher than permissible limit) in most of the ground water samples from Panipat, India.

Esmail *et al.* (2009) analysed the groundwater sample of Mitm area, Ibb City, Yemen for various quality parameters and found that three out of five boreholes were contaminated.

Gupta *et al.* (2009) also studied physicochemical properties of ground water of Kaithal city, Haryana, the various quality parameters (pH, EC, Cl^- , TDS, Ca^{2+} , Mg^{2+} and Hardness) were below permissible limit prescribed by WHO and ICMR.

Iqbal and Gupta (2009) reported deterioration of ground water quality due to improper solid waste dumping as heavy metal ions present in it are potentially toxic to human health.

Jindal and Sharma (2010) carried out physicochemical water analysis of Sutlej river around Ludhiana during November 2006 to October 2007 and recorded relatively low values of TDS, turbidity, BOD, total alkalinity, total hardness, chlorides, nitrates, and phosphates at Ropar and Budha Nallah at Phillaour as compared to Budha Nallah at Ludhiana. Heavy metals (Pb, Zn, Cr, and Ni) were detected at Phillaour and Ludhiana and water of Phillaour and Ludhiana was unsafe for human consumption.

Orebiyi *et al.* (2010) carried out water quality analysis of Southwest, Nigeria to study the pollution hazards of groundwater resource from urban and peri-urban area of Abeokuta. The results revealed that the mean values of TDS, TS, EC and PO_4 were higher in well water collected from urban areas compared to peri-urban areas during wet season. It was also observed that during the dry season, TDS, TSS, TS, EC, Mg, Fe, Cl^- , PO_4 and total hardness were also higher in samples collected from urban areas relative to peri-urban well water samples. Water quality parameters such as Fe, Pb, NO_3 , EC have mean values greater than World Health Organization maximum permissible standards for drinking water. Elevated values of these parameters are of great concern to public health when the water from these wells is consumed by people without treatment.

Akoteyon *et al.* (2011) reported landfills as one of the major threats to the ground water resources in Alimosho, Lagos, Nigeria. Pb, Zn, Fe and Cu were found above the maximum permissible limit levels according to FAO standards.

Ayedun *et al.* (2011) while assessing groundwater quality of Ifo community of Ogun state, Nigeria found that 50 per cent of the wells recorded values greater than WHO standard for Fe (0.06-0.59 mg/L), 41 per cent had Cd (0.000-0.010 mg/L) level higher than WHO

standard while 82 per cent recorded high Pb (0.00-0.23 mg/L) levels greater than WHO standard in drinking water. Zinc was low in concentration. The ground water was not suitable for human consumption.

Charles and Okoro (2011) carried out physicochemical chemical analysis of sewage water of Port-Harcourt metropolis area and rivers at Nigeria. Most of the physical and chemical parameters of sewage water exceeded the ISI permissible level.

Eni *et al.* (2011) studied the impact of urbanization on sub-surface water quality in Calabar municipality, Nigeria and found high pH at some locations due to boreholes located very close to cemeteries and defunct sewages nitrate and chlorine concentration increased with increasing urbanization, whereas, sulphate ions concentration decreased. Bundela *et al.* (2012) reported high levels of nitrate, TDS, TS and in water samples taken from borewell and handpumps of Jabalpur near MSW (municipal solid waste). Pius and Happiness (2012) reported deleterious levels of all physio-chemical parameters in selected segments of the new Calabar river, Niger Delta, Nigeria.

Kamble (2011) reported excessive levels of fluoride, arsenic, nitrate, sulphate, heavy metals, salinity, hardness, pesticide etc. in water samples analyzed from different parts of India.

Murhekar (2011) while analyzing status of ground water at Akot, Maharashtra reported contamination of water samples of Shri Shivaji College and Mahalaxmi Nagar. Whereas, the water quality of Keshvaoraj vetal, Shaukatali Chok and Ramtek Pura was within the standards limits and fit for drinking purpose. Rai *et al.* (2011) studied water quality parameters of river Ganga at Bihar and reported that samples from sites I (Pahalwan Ghat and Bans Ghat) and II (Krishna Ghat and Gandhi Ghat) were not of good quality and river Ganga was moderately polluted.

2.3.3 Industrial land-use

Ajmal *et al.* (1984) analyzed the quality of effluents discharged by Glaxo Laboratory, West Bengal. The values of pH, BOD, COD, Ca⁺⁺, Cl, Mg⁺⁺, N and P were 7.90, 698, 1128, 134, 101, 0.30 and 1.25 mg/l respectively.

Somashekar *et al.* (1984) analyzed the physicochemical characteristics of Bengal pulp and paper mills in West Bengal. The pollution load of different drains with respect to BOD, COD, TSS was 10.9 mg/l, 38.4 mg/l and 59.1 kg/day, respectively.

Vijayram *et al.* (1988) assessed the effect of paper mill on water quality of Pagalur high level channel, a tributary of river Cauvery, Tamil Nadu. The results revealed that both raw and treated effluents possessed high value of total solids, BOD, COD, chlorides etc. and these contributed to toxicity of the effluent.

Road and Kelly (1994) reported heavy contamination of Shallow groundwater quality in the industrialized Calumet region of south Chicago.

Naidu and Raman (1995) reported that pH of distillery effluent was 7.6 and colour was dark brown. The distillery effluents had 0 dissolved oxygen, however BOD, TS, dissolved solids, undissolved solids, electrical conductivity were found 38,000 pp, 40,000, 34,650, 5,350 ppm and 1,221 u mho/cm, respectively and chloride and oil contents were 4,600 and 60 ppm in the distillery effluent, respectively. Vaidhyanathan *et al.* (1995) studied the physicochemical characteristics of distillery effluent. pH, dissolved solids and total solids ranged from 4.0-4.2, 90,000-1,11,000 mg/l and 86,1, 1,10,000 mg/l, respectively. COD and BOD ranged from 1,15,000-1,20, mg/l and 42,000-50,000 mg/l, respectively. Total nitrogen, phosphates and chlorides were in the range of 1800-2000 mg/l, 30,000-34,000 mg/l 2000-2100 mg/l and 7000-8000 mg/l, respectively.

Ali *et al.* (1996) reported variation in the quality of industrial effluents with industrial processes. Industrial effluents had high pH, EC, COD, TDS, cations (Ca^{++} and Mg^{++}), anions (Cl^- and NO_3^{2-}) heavy metals and trace elements. Chakravorty *et al.* (1996) while studying the quality of pulp and paper mill effluent, reported BOD and TS ranging from 1286 to 1769 mg/l and 3200-6940 mg/l, respectively. The levels were well below the minimum national standards. Patil (1998) reported the pH, EC, BOD and COD contents of spent wash as 4.42, 21.56 dSm^{-1} , 30450 and 73600 mg/l, respectively. Whereas, calcium, magnesium, sodium, potassium, nitrate, sulphate and chloride contents were 1603, 730, 3575, 7115, 4216, 3819, and 14250 mg/l, respectively.

Pande *et al.* (2000) studied the status of Ramganga river in about 25 km around Moradabad, India. The river was highly polluted with effluents from electroplating units, brass/stainless steel industry and domestic waste. Iron exceeding the permissible limit has been reported.

Patel *et al.* (2004) reported that the COD of effluents from industries at Ankleshwar, Gujarat was extremely high (12810 mg/l), while BOD (560 mg/l) was within the safe limit. The heavy metals in the effluents were Fe (25.5 mg/l), Cu (0.70 mg/l), Mn (4.83 mg/l), Cd (0.10 mg/l), Ni (0.73 mg/l), Co (0.56 mg/l) and Cr (2.76 mg/l).

Chattopadhyay *et al.* (2005) monitored water quality in Chalakudy river basin in Kerala in different land use types during four seasons and reported that urban land use had poor water quality throughout the year which was linked to fluctuations of drainage discharge and changes in land use patterns. Singh and Singh (2005) reported decrease in soil pH, EC and organic carbon with increasing level of paper mill effluent. The available nitrogen, however, decreases due to increasing microbial population.

Hazarika *et al.* (2007) reported pH (1.3 units higher), EC (more than three times), Chloride concentrations (197 mg/kg) higher in soils irrigated with effluents discharged from pulp and paper mill as compared to soils irrigated with water from shallow tube well in Assam.

A case study conducted in different areas of Rajasthan showed that there was deterioration in the groundwater quality which is due to quicklime units and cement industry. High EC values of groundwater have been recorded in different areas around the cement industry (3.02-7.45 ds/m) (Anonymous 2009).

Bayshakila and Usha (2009) analyzed the tannery effluents of leather processing industry in Dindigul of Tamil Nadu. The concentrations of BOD, COD, dissolved solids and suspended solids were 35, 318, 17150 and 258 mg/l, respectively. Whereas, concentration of Na⁺, Ca⁺⁺ and Mg⁺⁺ was recorded to be 600, 432 and 5100 mg/l, respectively. Deepali *et al.* (2009) reported higher limits (above prescribed levels) of various physicochemical parameters (pH, EC, TS, TDS, Alkalinity, Hardness, Calcium, Magnesium, Chloride, Bicarbonate, Nitrate, Fluoride, DO, BOD, COD) for tannery effluent from industries situated in Sansarpur and Anantpur villages of Roorkee.

Kumar and Bahadur (2009) carried out physicochemical analysis for three seasons in downstream of Kosi river at Rampur (U.P.) and reported alkaline pH (7.3 to 7.9), mild organic pollution (indicated by DO, 6.2-7.5 mg/l, BOD 5.0-6.0 mg/l) and industrial pollution (indicated by COD 25.0-40 mg/l).

Ullah *et al.* (2009) studied the quality of ground water of Sialkot Industrial area, Pakistan by taking into consideration 22 physicochemical parameter and reported high Turbidity, high level of Zn, Fe, and Pb (above permissible limits) in the ground water samples.

Gokulakrishnanam and Balamurigan (2010) studied ground water quality around tanning industries in Tamil nadu and reported high variability in total alkalinity, total hardness, chloride and total dissolved solids. pH, dissolved oxygen, biological oxygen demand, chemical oxygen demand were insignificant and concluded that ground water was polluted in this area due to discharge of partially treated effluents.

Kumar *et al.* (2010) while studying the impact of industrial effluents on water quality of Behgul river Bareilly reported the water of Bairam Nagar as non polluted, Basai village site highly polluted whereas, Thanpur village had mixed polluted water.

Nkansah *et al.* (2010) studied the status of ground water of Kwahu, West district of Ghana, and reported that because of low level of industrialization, the sample was relatively free from heavy metal contamination and if any present, were below permissible limit.

Chapter-3

MATERIALS AND METHODS

The present study entitled “**Inventorisation of Water Resources in Solan district of Himachal Pradesh**” was conducted during 2012-2013. Data regarding water resources was collected from District/Block/Panchayat level offices and using pre structured questionnaires and through personal interviews. The samples for analysis were taken from selected surface and ground water sources of the Solan Block. The physicochemical analysis of water samples was carried out in the laboratory of Department of Environmental Science, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni-Solan, Himachal Pradesh. The details of materials used and methods employed during the present study are described in this chapter.

3.1. GENERAL DESCRIPTION OF THE STUDY AREA

3.1.1 Location

The present study was carried out in the Solan Block of district Solan of Himachal Pradesh, which is located between 30⁰50'30" to 30⁰52'00" N latitude and 77⁰08'30" to 77⁰11'30"E longitude. This block is spread over an area of 21,053 ha., out of the 1936 sq km area of the entire district. Out of total area, 3366 ha is the cultivated area. The climatic conditions of the block are suited for cultivation of cereal crops, pulses, stone fruits and off-season vegetables like tomato, capsicum, ginger, french bean, cabbage, cauliflower, peas etc. besides animal husbandry. Major natural resources of this block are forests, fertile land, minor minerals, ground (chashma, bowries, hand pump) and surface (streams, rivers, ponds, tap water etc) water sources which serves the various requirements of the people. Location of study area is shown in figure 1.

3.1.2 Climatic and weather conditions

The climate of the district is sub-tropical in the valley and tends to be temperate in the hilltops. Maximum precipitation occurs during the months from July to September. Average annual rainfall in the district is about 1450 mm with average of 64 rainy days. In the winter season precipitation as snowfall also occurs in the higher reaches upto 1500 m elevation and

as rainfall in low hills and valleys of the district. Mean maximum and minimum temperature ranges between 34°C and 4°C.

The Solan Block falls in sub-temperate and sub-humid zone. The block experience four major seasons in the year. Winter season commences from November to February and ends in March; summer season extends from March to June followed by the rainy season from July to September and autumn from September to October. 70 per cent of rains are received during monsoon months in the region. The average annual rainfall in the block is about 1200mm which is received in 64 rainy days. In the winter season precipitation as snowfall also occurs at the higher reaches (above 1500 m amsl) of the block. Mean maximum and minimum temperature ranges between 0.5°C to 21°C (during winters) and 14°C to 37°C (during summers). During study period the maximum temperature ranged from 17.0°C to 34.2°C and minimum from 1.1°C to 20.7°C. During the study period this region experienced a total of 1178.6 mm rainfall (Table 1). The trend of air temperature and total rainfall is depicted in figure 2.

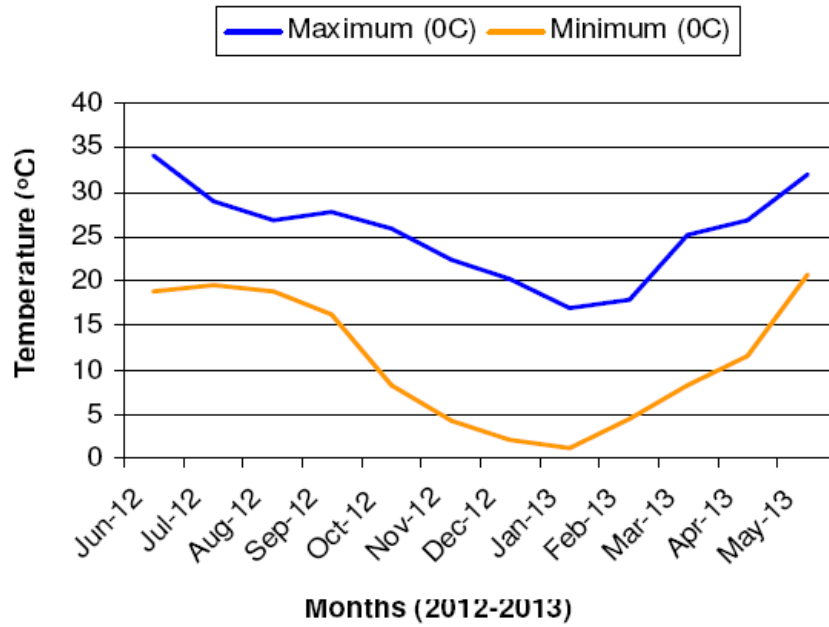
Table 1: Air temperature and total rainfall during the study period

Month	Maximum (°C)	Minimum (°C)	Rainfall (mm)
June-2012	34.2	18.8	19.3
July-2012	28.9	19.5	317.1
August-2012	26.9	18.8	269.8
September-2012	27.7	16.2	111.8
October-2012	25.9	8.2	3.5
November-2012	22.3	4.2	3.9
December-2012	20.3	2.1	18.4
January-2013	17.0	1.1	113.6
February-2013	17.8	4.5	184.3
March-2013	25.2	8.3	85.6
April-2013	26.9	11.5	5.4
May-2013	32.1	20.7	45.9

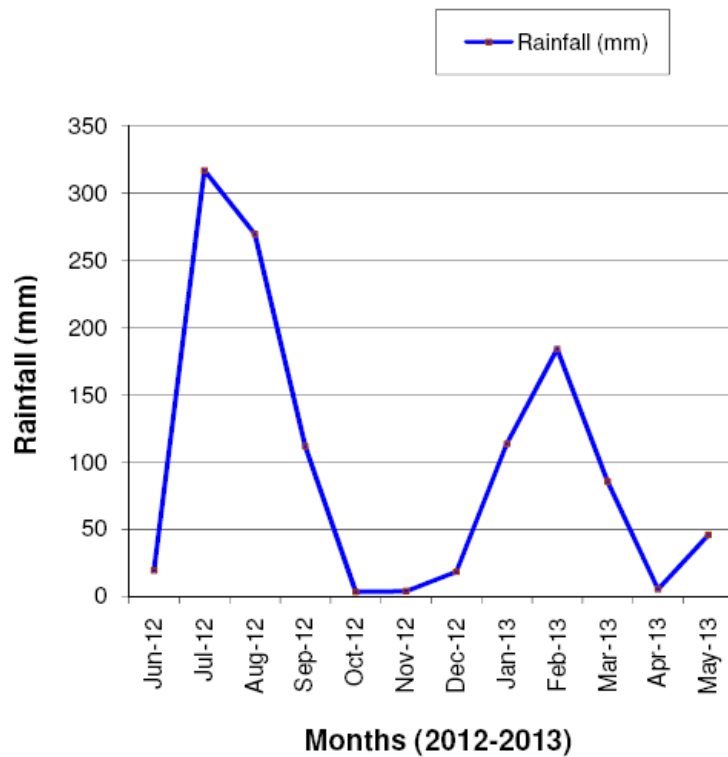
For better understanding of potential impacts of the climate change on water sources of the Solan Block a trend analysis of rainfall data of this region was done. Variations in temperature and precipitation was analysed season wise i.e. rainy (June, July, August),



Figure 1. Location of study area (Solan Block)



Air Temperature during the study period



Total Rainfall during the study period

Figure 2. Trend of air temperature and total rainfall during the study period in the study area

autumn (September, October, November), winter (December, January, February) and spring (March, April, May). The meteorological data w.e.f. 1971-90 was taken as base line. For better analysis of the climate conditions the data was divided into two periods i) 1991-2000 and ii) 2000-2011 (Figure 5).

3.2 COLLECTION OF DATA FOR INVENTORY

A detailed survey of Solan Development Block was conducted by using pretested performa and personal interview to inventorize the different water sources in the area. Documentation of existing water resources in the study area was done.

The secondary data was collected from the official certified records maintained by the following offices/departments: Irrigation and Public Health Department; District Water Testing Laboratory, Kandaghat; Deputy Commissioner Office; Office of the Block Development Officer; Office – Project Director & Deputy Director of Agriculture; Office of GM District Industries Center; Mid-Himalayan Watershed Development Division; Regional Hospital Solan; Ayurvedic Hospital Solan; Tehsil Office; Municipal Corporation Office; Solan and from each Panchayat Office. Relevant data was also collected from the HP Government websites.

3.2.1 Water requirement estimation

Water requirement was calculated separately for rural and urban area by multiplying the respective population of the rural and urban area by the standard values set up by the state government. To find out the requirement for rural area the population of each panchayat was multiplied by the state standard norm for rural area i.e. 70 liters per capita per day and was summed up to get the total water requirement of rural area in Solan Block. In order to calculate the water requirement of urban area falling in Solan Block the population of urban area (Solan town, Deonghat, Chambaghat, Shanti, By-pass area and Salogra) under the Municipal Corporation was recorded and multiplied by the state standard norms for the urban area i.e. 125 liters per capita per day. Finally the total water requirement of the Solan Block was calculated from the obtained data.

3.2.2 Estimation of availability/status of water sources

To assess the status of availability of water sources in different panchayats of Solan Block documentation of various water sources was done. The secondary data was also collected from different offices and the gap was documented.

Availability of water for irrigation was assessed by summarizing different irrigation schemes running in the block along with their flow rates and cultivable command area covered under each scheme. For the purpose data was collected from various departments. To record people's perception regarding the availability of water and constraints associated personal interviews were also conducted.

3.2.3 Storage and supply

To find out the number of storage structures and assess the total storage capacity in the block, data was collected from various departments and field observations. Water storage capacity of both rural and urban area was calculated separately. Documentation of various water harvesting structures constructed under various projects and their storage capacity was also done. The data regarding various water management and quality check practices followed in the study area were also recorded. Study was also conducted to find out the various projects running for water resource management in the area.

Documentation of lift, gravity feed and combined water supply schemes under different panchayats was also done. The data regarding types of sources exploited for the various schemes running in the area was also recorded.

3.3 SELECTION OF SITE FOR SAMPLE COLLECTION

To analyse the quality of water of the Solan Block under different land uses survey was conducted. Under each of rural, urban/suburban, institutional and industrial land uses sites were selected randomly (Table 2). From each selected site, water samples were collected for analysis. The map of study area is shown in figure 3.

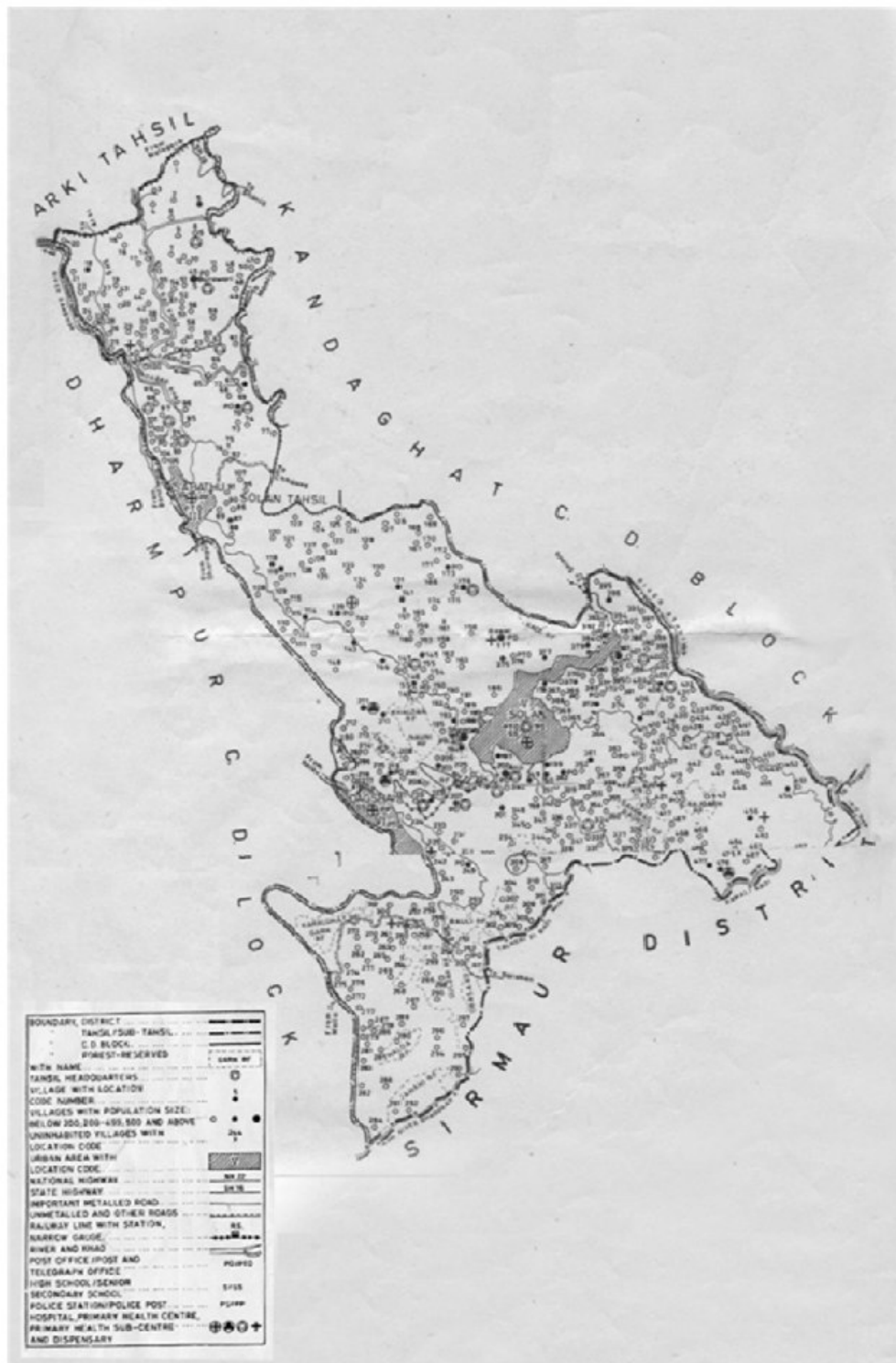


Figure 3. Map showing study area (Solan Block)

Table 2: Details of water sampling locations under different land uses in Solan Block**Table 2.1: Water sampling locations under industrial land use**

Industrial Land Use					
A. Corronna					
S.No.	Category	Water source	Latitude	Longitude	Elevation(m)
1.	INDG	Spring	N 30°52'495"	E 077°06'767"	1435
2.	INDG	Bawri	N 30°52'526"	E 077°07'699"	1378
3.	INDG	Spring	N 30°52'496"	E 077°07'711"	1387
4.	INDS	Storage tank	N30°52'519"	E077°07'712"	1401
B. Meridian					
5.	INDS	Pond	N30°53'326"	E 077°06'745"	1416
6.	INDG	Spring	N 30°53'292"	E 077°06'765"	1462
7.	INDS	Storage tank	N 30°53'243"	E 077°06'826"	1470
8.	INDS	Drainage pipe	N 30°53'235"	E 077°06'514"	1460
C. Brewery					
9.	INDS	Kuhl	N 30°55'620"	E 077°07'059"	1416
10.	INDG	Bawri	N 30°55'595"	E 077°07'045"	1479
11.	INDS	Storage tank	N 30°55'634"	E 077°06'963"	1440
12.	INDG	Spring	N 30°55'698"	E 077°06'913"	1455
D. Jyoti Remedies					
13.	INDS	Nala	N 30°54'844"	E 077°04'542"	1450
14.	INDS	Pond	N 30°54'902"	E 077°04'603"	1445
15.	INDS	Storage tank	N 30°54'978"	E 077°04'626"	1430
16.	INDG	Spring	N 30°54'992"	E 077°04'611"	1398
E. Base Cooperation					
17.	INDS	Tank	N 30°51'798"	E 077°08'210"	1332
18.	INDG	Bawri	N 30°51'759"	E 077°08'211"	1307
19.	INDS	Nala	N 30°51'688"	E 077°07'702"	1180
20.	INDS	Nala	N 30°51'649"	E 077°07'744"	1225

Table 2.2: Water sampling locations under institutional land use

Institutional Land Use					
A. UHF Campus					
S.No.	Category	Water source	Latitude	Longitude	Elevation(m)
1.	INSS	Tank	N 30°51'604"	E 077°09'922"	1247
2.	INSG	Spring	N 30°51'614"	E 077°09'917"	1245
3.	INSG	Spring	N 30°51'748"	E 077°11'179"	1233
4.	INSS	Khaltu Nala	N 30°51'024"	E 077°11'215"	921.3
5.	INSG	Handpump	N 30°51'981"	E 077°10'123"	984.9
B. LR Group of Institutes					
6.	INSS	Nala	N 30°52'060"	E 077°08'120"	1271
7.	INSG	Spring	N 31°52'046"	E 077°08'108"	1241
8.	INSS	Storage tank	N 31°52'056"	E 077°08'102"	1245
9.	INSS	Nala	N 30°52'077"	E 077°08'087"	1269
10.	INSG	Handpump	N 30°52'179"	E 077°08'004"	1319
C. Shoolini University					
S.No.	Category	Water source	Latitude	Longitude	Elevation(m)
11.	INSS	Storage tank	N 30°51'638"	E 077°07'390"	1141
12.	INSS	Nala	N 30°51'646"	E 077°07'354"	1126
13.	INSS	Nala	N 30°51'819"	E 077°07'347"	1150
14.	INSG	Bawri	N 30°51'778"	E 077°07'063"	1232
15.	INSG	Bawri	N 30°51'770"	E 077°07'183"	1248
D. Dental & Tatool College					
16.	INSS	Nala	N 30°51'601"	E 077°07'431"	1121
17.	INSS	Khud	N 30°51'570"	E 077°07'400"	1117
18.	INSS	KTS Khud	N 30°51'700"	E 077°07'366"	1174
19.	INSG	Bawri	N 30°51'863"	E 077°07'386"	1143
20.	INSG	Bawri	N 30°51'855"	E 077°07'488"	1232
E. Gurukul (By-pass) School					
21.	INSG	Spring	N 30°54'675"	E 077°05'934"	1436
22.	INSS	Drainage pipe	N 30°54'685"	E 077°05'685"	1448
23.	INSS	Nala	N 30°54'842"	E 077°05'520"	1405
24.	INSG	Bawri	N 30°54'838"	E 077°05'514"	1407
25.	INSS	Nala	N 30°54'995"	E 077°05'668"	1430

Table 2.3: Water sampling locations under urban land use

Urban Land Use					
A. Chambaghat					
S.No.	Category	Water source	Latitude	Longitude	Elevation(m)
1.	UG	Handpump	N 30°55'415"	E 077°06'027"	1494
2.	UG	Bawri	N 30°53'847"	E 077°05'749"	1396
3.	US	Nala	N 30°53'990"	E 077°05'415"	1443
4.	UG	Bawri	N 30°52'018"	E 077°10'225"	1259
5.	US	Storage tank	N 30°53'995"	E 077°05'668"	1436
B. Solan					
6.	UG	Handpump	N 30°54'578"	E 077°06'329"	1522
7.	UG	Bawri	N 30°54'560"	E 077°06'450"	1504
8.	UG	Spring	N 30°54'454"	E 077°06'068"	1532
9.	US	Waterfall	N 30°54'120"	E 077°06'306"	1485
10.	US	Nala	N 30°54'236"	E 077°06'412"	1492
C. Salogra					
11.	UG	Spring	N 30°56'233"	E 077°08'135"	1304
12.	US	Storage tank	N 30°56'036"	E 077°08'053"	1402
13.	UG	Bawri	N 30°55'840"	E 077°07'818"	1415
14.	UG	Spring	N 30°55'915"	E 077°05'879"	1459
15.	UG	Spring	N 30°55'727"	E 077°07'461"	1467
D. Deonghat					
16.	UG	Bawri	N 30°54'344"	E 077°04'953"	1475
17.	US	Waterfall	N 30°54'326"	E 077°04'960"	1529
18.	UG	Spring	N 30°53'765"	E 077°05'365"	1568
19.	UG	Handpump	N 30°53'863"	E 077°05'287"	1560
20.	UG	Spring	N 30°54'178"	E 077°05'165"	1518
E.Saproon					
21.	UG	Bawri	N 30°54'735"	E 077°05'200"	1303
22.	UG	Handpump	N 30°54'391"	E 077°05'280"	1364
23.	UG	Handpump	N 30°54'392"	E 077°05'091"	1459
24.	UG	Handpump	N 30°53'946"	E 077°05'413"	1478
25.	UG	Bawri	N 30°53'964"	E 077°05'600"	1411

Table 2.4: Water sampling locations under rural land use

Rural/Agricultural Area					
A. Sanhol					
S.No.	Category	Water source	Latitude	Longitude	Elevation(m)
1.	RG	Spring	N 30°53'646"	E 077°07'787"	1787
2.	RG	Spring	N 30°53'907"	E 077°06'844"	1756
3.	RG	Bawri	N 30°53'497"	E 077°07'420"	1827
4.	RG	Spring	N 30°52'591"	E 077°07'375"	1379
5.	RS	Tank	N 30°53'475"	E 077°06'839"	1647
B. Basaal					
6.	RS	Tank	N 30°55'620"	E 077°05'600"	1485
7.	RG	Spring	N 30°55'741"	E 077°05'668"	1546
8.	RG	Spring	N 30°55'706"	E 077°05'630"	1512
9.	RG	Handpump	N 30°55'202"	E 077°05'492"	1469
10.	RS	Nala	N 30°55'255"	E 077°05'636"	1442
C. Shamti & Kothon					
11.	RG	Spring	N 30°53'590"	E 077°06'302"	1489
12.	RS	Nala	N 30°53'621"	E 077°06'275"	1506
13.	RG	Bawri	N 30°53'439"	E 077°06'917"	1565
14.	RS	Tank	N 30°52'651"	E 077°07'359"	1423
15.	RS	Storage tank	N 30°53'951"	E 077°07'509"	1923
D. Anji & Barog					
16.	RG	Spring	N 30°53'574"	E 077°05'522"	1515
17.	RG	Bawri	N 30°53'627"	E 077°05'594"	1529
18.	RS	Nala	N 30°53'583"	E 077°05'548"	1459
19.	RG	Handpump	N 30°53'746"	E 077°05'548"	1472
20.	RS	Nala	N 30°52'503"	E 077°05'297"	1629
E. Shamlech					
21.	RS	Nala	N 30°53'342"	E 077°05'035"	1465
22.	RG	Spring	N 30°53'230"	E 077°05'277"	1493
23.	RS	Nala	N 30°53'435"	E 077°05'216"	1468
24.	RG	Bawri	N 30°53'216"	E 077°05'285"	1472
25.	RS	Nala	N 30°53'257"	E 077°05'268"	1463

F. Shamror					
26.	RS	Nala	N 30°52'197"	E 077°10'216"	1293
27.	RS	Nala	N 30°52'128"	E 077°10'301"	1303
28.	RS	Nala	N 30°52'067"	E 077°10'258"	1286
29.	RS	Storage tank	N 30°52'860"	E 077°10'165"	1328
30.	RG	Bawri	N 30°52'096"	E 077°10'241"	1288

INDS	-	Industrial Surface
INDG	-	Industrial Underground
INSS	-	Institutional Surface
INSG	-	Institutional Underground
US	-	Urban Surface
UG	-	Urban underground
RS	-	Rural/Agriculture surface
RG	-	Rural/Agriculture Underground

3.4 COLLECTION AND PREPARATION OF WATER SAMPLES

In each land use system water samples from different water sources were collected randomly during the year 2012 – 2013. Samples were collected in acid washed one litre plastic bottles as per standard procedure (APHA, 1998). Water samples of different sources viz. bore wells, spring, hand pump, storage tank, bawari, nullah, khud and river were collected and preserved for quality analysis. All samples were adequately labelled, taken to laboratory and analysed for pH, EC and BOD immediately and for further analysis the samples were stored in refrigerator at 4°C. 100 samples from different sources were collected for analysis. Out of the total samples, 20 samples were collected from industrial areas, 25 samples of water were collected from institutional areas, 25 water samples from urban land use and 30 water samples were collected from rural land use areas for analysis. The samples were collected during winter season.

3.5 WATER QUALITY ANALYSIS

The water samples were analyzed for physical and chemical Parameters by following standard procedure:

3.5.1 Physical Parameters

a) pH

The pH of the water was determined using microprocessor based pH meter (Model 510 of EIA make) in laboratory.

b) EC

The EC was measured by using microprocessor based conductivity/TDS meter (Model-1601 of EIA make).

3.5.2 Chemical Parameters

a) Biological Oxygen Demand

BOD was calculated by using BOD-System Oxidirect (Aqualytic make). Samples were taken into the beaker and pH of samples was adjusted between 6.5 to 7.5. Then 152ml of sample was poured into the BOD bottles, and 5-6 drops of nitrification inhibitor (ATH) was added with one magnetic stirrer. Then in the bottles gasket was kept, and 3-4 drops of KOH solution was added. After that sensor was attached to BOD bottle and bottles were loaded in the system. Finally BOD bottles loaded on BOD system was kept in incubator for five days at 20° C. The readings were recorded after 5 days.

b) Chemical oxygen demand

COD was determined by oxidising water sample with hot H₂SO₄ solution of potassium chromate with silver sulphate as the catalyst. The water samples were digested at 148⁰C in the preheated thermoreactor (TR 320) for 120 minutes. In the system chloride is masked with mercury sulphate the concentration of Cr³⁺ ions is then determined photometrically by using spectroquant Pharo 300 (Merck make) instrument after cooling samples at room temperature and expressed as mg/l. The method is analogous to EPA 410. US standard method 5220 D, and ISO 15705.

c) Calcium

Sample was prepared by pipetting out 0.10 ml sample into a test tube at 20 to 35 °C. Then, 5 ml of Ca - 1 reagent was added and mixed with the prepared sample. Then 4 drops of Ca-2 reagent was added and mixed and at last 4 drops of Ca-3 reagent were added and mixed with the sample. Sample was left for eight minutes and then filled into a 10 mm cell. In alcoholic –alkaline solution calcium ion react with modified glyoxal- bis (2-hydroxyamil) to form a red- violet complex. The red violet complex is measured photometrically by using spectroquant Pharo 300 of Merck make.



Plate 1. Sample collection sites in rural area of Solan Block



Plate 2. Sample collection sites in industrial area of Solan Block



Plate 3. Sample collection sites in urban/suburban and institutional area of Solan Block

d) Magnesium

Mg was determined by Magnesium cell test. In this method one ml of sample was prepared at 20 to 30 °C which was poured into a reaction cell and mixed properly. Then 1ml of reagent Mg-IK was taken and mixed into reaction cell. Sample was left for three minutes for reaction. Then three drops of reagent Mg- 2K were added to the cell and were mixed. In neutral solution magnesium ions react with phthalein purple to form a violet dye that is determined photometrically by using spectroquant Pharo 300 of Merck make.

e) Chloride

Chloride was estimated by pipetting out 5 ml of water sample into a test tube at 10 to 30° C and after that 2.5 ml of Cl -1 reagent was added and mixed properly and then Cl-2 reagent was added and left for one minute for reaction. Sample was filled in a 10 mm cell. In this method chloride ions react with mercury (II) thiocyanate to form slightly dissociated mercury (II) chloride. The thiocyanate released in the process in turn react with iron (III) ions to form red iron (III) thiocyanate that is determined photometrically by using Spectroquant Pharo 300 of Merck make. This method is analogous to EPA 325.1 and US standard method.

3.6 PERMISSIBLE LIMITS

The permissible limits prescribed by different agencies for drinking water quality were used to discuss the data regarding water quality parameters (Table 3).

Table 3: Permissible limits of water quality parameters for drinking and domestic purposes set by WHO, CPCB and ICMR

Sr. No.	Parameters	WHO	CPCB	ICMR
1.	pH	6.5-8.5	6.5-8.5	7.5-8.5
2.	EC (µs/cm)	Not-mentioned	750	Not-mentioned
3.	COD(mg/l)	Not-mentioned	Not-mentioned	20
4.	BOD(mg/l)	5	5	Not-mentioned
5.	Ca(mg/l)	75	75	75
6.	Mg(mg/l)	30	30	50
7.	Cl(mg/l)	250	250	200

3.7 STATISTICAL ANALYSIS

The data emanating from the above experiments were subjected to statistical analysis through two way classification.

Chapter-4

EXPERIMENTAL RESULTS

Present study entitled, “**Inventorisation of Water Resources in Solan district of Himachal Pradesh**” was conducted in the Department of Environmental Science, College of Forestry, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan (Himachal Pradesh) during the years 2012-2013. Data regarding water sources was collected from District/ Block/ Panchayat level offices and by using pre structured questionnaires and through personal interviews. In the present study water samples were collected from various water sources falling under different land uses in Solan Block of District Solan. The results obtained out of the present investigation have been described in this chapter under following heads:

4.1 Water resource inventory

4.1.1 Availability of water sources

4.1.2 Water requirement of rural and urban population

4.1.3 Storage and supply of water

4.2 Effect of different land uses on water quality

4.2.1 Effect of land uses on physical parameters of water

4.2.2 Effect of land uses on chemical parameters of water

4.3 Status of water quality under different land uses in Solan Block

4.3.1 Status of water quality under industrial landuse in Solan Block

4.3.2 Status of water quality under urban landuse in Solan Block

4.3.3 Status of water quality under institutional landuse in Solan Block

4.3.4 Status of water quality under rural landuse in Solan Block

4.1 WATER RESOURCE INVENTORY

4.1.1 Availability of water sources

The survey study conducted revealed that the occurrence of various water sources and availability of water in the block depends on various factors like rainfall, topography, slope, aquifer system and management of the sources. To meet the water requirement of the block mostly surface water sources have been tapped under various water supply schemes.

Table 4: Status of different water sources including handpumps in Solan Block

Sr. No.	Name of Panchayat	Number of observed sources	Number of recorded sources	Number of exploited sources	Number of handpumps	People's perception regarding water availability
1.	Anhech	158	158	157	39	Deficient
2.	Anji	35	30	28	5	Sufficient
3.	Basaal	86	85	82	22	Sufficient
4.	Barog	84	84	26	25	Sufficient
5.	Bharti	59	58	58	15	Sufficient
6.	Bhojnagar	171	171	165	21	Deficient
7.	Bohli	15	12	9	3	Deficient
8.	Chamat Bhadech	58	56	55	15	Sufficient
9.	Chewa	102	101	100	29	Sufficient
10.	Dangri	243	243	235	16	Sufficient
11.	Deothi	157	156	145	19	Sufficient
12.	Dharot	110	108	105	10	Sufficient
13.	Haripur	90	90	90	27	Deficient
14.	Jabal Jhamrot	70	70	70	22	Sufficient
15.	Jadli	262	262	260	24	Sufficient
16.	Jaunaji	150	148	147	7	Sufficient
17.	Kabakalan	55	55	53	4	Deficient
18.	Kakkerhatti	20	18	18	2	Sufficient
19.	Koron	5	4	4	1	Sufficient
20.	Kothon	94	94	92	21	Sufficient
21.	Mashiwer	93	93	91	8	Sufficient
22.	Nerikalan	65	65	65	10	Deficient
23.	Nauni Majhgoan	65	62	78	5	Sufficient
24.	Oachghat	51	50	49	8	Sufficient
25.	Parag	17	15	14	1	Sufficient
26.	Pattabravari	75	74	74	18	Sufficient
27.	Salogra	204	204	201	10	Sufficient
28.	Sanhol	70	69	69	11	Sufficient
29.	Saproon	71	71	61	30	Sufficient
30.	Serbnera	45	43	43	8	Sufficient
31.	Seri	70	70	64	10	Sufficient
32.	Shadiyana	82	82	82	36	Deficient
33.	Shamror	133	133	132	5	Sufficient
34.	Shamti	63	60	58	8	Sufficient
35.	Topkiber	90	90	90	4	Sufficient
Total		3218	3184	3070	499	

In the block springs, khuds, nullahs and rivers (Giri and Ghamber) are used for supplying the water. The availability of water was found to vary from one panchayat to other. The people's perception revealed that due to various developmental activities like construction of roads the water sources are drying up and deterioration of quality is being observed.

The perusal of data presented in table 4 revealed that on an average Solan Block is having 3184 sources of water as per official records. Out of that, only 3070 water sources have been exploited for various uses and to meet out the water requirement of the people. Whereas, data collected from the field revealed that Solan Block contained 3218 sources of water. In the block maximum number of sources (262) were recorded in Jadli panchayat out of which 260 sources of water are utilized. The number of water sources in Jadli were followed by Dangri panchayat (243) where 235 sources have been exploited for various uses and Salogra (204) where all the recorded sources are under utilization. Whereas minimum number of water sources (5) were recorded in Koron panchayat and Bohli (15).

In Solan Block a total of 499 handpumps have been installed in various panchayats. The maximum number of handpumps (39) were recorded in Anhech followed by Shadiyana (36). Whereas minimum number of handpumps (1) were found in Parag and Koron panchayat. The personal interview conducted in the area revealed that out of the total 35 panchayats in the Block there are a few panchayats that face water scarcity for most part of the year. On an average there are seven panchayats that are deficient in water namely Anhech, Bhojnagar, Bohli, Haripur, Kabakalan, Nerikalan and Shadiyana. Other panchayats are sufficient in water availability for different uses for most part of the year; however there are a few more panchayats that face deficiency in summers. A change in availability and utilization status scenario of various water sources was also recorded while interviewing the people. According to the people many perennial sources have changed to seasonal water source, many sources that were earlier used to fetch water for drinking are now only used for domestic and irrigation purposes and some sources are not used at all.

On an average there are 11 irrigation schemes in Solan Block covering an area of 303.4 ha which is 1.41% of the total irrigated area in the Solan District. There are seven Lift Irrigation Schemes and four Flow Irrigation Schemes running in the block. Nullahs, Khuds and Rivers are the water sources exploited for irrigation purpose. Table 5 revealed that the

irrigation scheme with maximum discharge (1,72,200 LPS) is LIS Goura followed by LIS Sawan Gaon with a discharge of 1,01,000 LPS. Both these schemes receive water from Giri River. Minimum discharge (6.10 LPS) was recorded in FIS Upper Dhillon. The extend of irrigated area covered under each scheme varies. Maximum area coverage was recorded under LIS Patta Brouri (91.26 ha) followed by FIS Dharot Kuhl (56.00 ha). Minimum area (3.60 ha) was recorded to be covered under FIS Upper Dhillon. During interview it was also found that in addition to these major schemes irrigation is also done by fetching water from other water sources like bawries, springs, rainwater harvesting tanks, etc.

Table 5: Status of various irrigation schemes running in Solan Block

Sr, No.	Name of scheme	Location of Source	Type of source	Area covered in ha.
1.	LIS Garkhola	Garkhola Nallah	Nallah	14.00
2.	LIS Patti Kolian	Patti Kolian Nallah	Nallah	24.00
3.	LIS Goura	Giri River	River	13.00
4.	LIS Sawan Gaon	Giri River	River	27.53
5.	LIS Gamjhoon	Gamber Khud	Khud	47.00
6.	LIS Patta Brouri	Gamber Khud	Khud	91.26
7.	LIS Sultanpur	Sultanpur Khud	Khud	12.41
8.	FIS Dharot Kuhl	Dharot ka Nallah	Nallah	56.00
9.	FIS Nouni	Nouni Nallah	Nallah	8.00
10.	FIS Reh Ki Katal	Ashwani Khud	Khud	6.60
11 .	FIS Upper Dhillon	Dhillon Ka Nallah	Nallah	3.60
Total				303.4

4.1.2 Water requirement of rural and urban population

In Solan Block water requirement differed for both rural and urban area depending upon the population, development, living standards and dependency of the people in different areas.

On an average the total area under all the panchayats in Solan Block was found to be 30,280 hectares. There are 488 villages inhabited by nearly 13000 families in 35 panchayats of the Block. The total population of rural area in Solan Block according to 2011 census was 62,753.

Table 6: Panchayat wise status of water requirement for rural area in Solan Block.

Sr. No.	Name of Panchayat	Area(ha)	No. of villages	No. of families	Total population	Requirement (liters)
1.	Anhech	608	15	361	1674	117180
2.	Anji	593	8	301	1497	104790
3.	Basaal	859	12	422	2000	140000
4.	Barog	560	12	429	1973	138110
5.	Bharti	858	12	310	1532	107240
6.	Bhojnagar	784	30	402	1956	136920
7.	Bohli	917	22	474	2565	179550
8.	Chamat Bhadech	620	13	309	1436	100520
9.	Chewa	302	13	376	1867	130690
10.	Dangri	816	28	673	3030	212100
11.	Deothi	654	19	385	2290	160300
12.	Dharot	536	11	292	1341	93870
13.	Haripur	674	21	306	1552	108640
14.	Jabal Jhamrot	1320	10	488	3179	222530
15.	Jadli	978	23	461	2169	151830
16.	Jaunaji	640	19	416	1976	138320
17.	Kabakalan	404	8	225	1106	77420
18.	Kakkerhatti	864	12	329	1541	107870
19.	Koron	356	5	231	1347	94290
20.	Kothon	624	10	240	1208	84560
21.	Mashiwer	691	25	385	1629	114030
22.	Nerikalan	292	15	235	1138	79660
23.	Nauni Majhgoan	318	9	178	937	65590
24.	Oachghat	655	10	300	1293	90510
25.	Parag	401	7	406	1950	136500
26.	Pattabravari	477	11	365	1888	132160
27.	Salogra	9614	27	722	4387	307090
28.	Sanhol	655	18	850	1731	121170
29.	Saproon	245	4	405	1820	127400
30.	Serbnera	609	6	287	1293	90510
31.	Seri	325	9	319	1360	95200
32.	Shadiyana	590	10	351	1757	122990
33.	Shamror	839	12	366	1671	116970
34.	Shamti	312	16	224	1270	88900
35.	Topkiber	290	6	177	1390	97300
Total		30280	488	13000	62753	4392710

Water requirement of rural area for a population of 62,753 was found out to be 43,92,710 liters per day. The data presented in table 6 revealed that in Solan Block of district Solan, Salogra panchayat registered the maximum water requirement to the tune of 3,07,090 liters with a population of 4387 followed by Jabal Jhamrot (2,22,530 liters per day) for a population of 3179 and Dangri panchayat having a population of 3030 and water requirement of 2,12,100 liters per day. The panchayat with minimum water requirement (65,590 liters per day) found was Nauni Majhgaon with a population of 937.

The water requirement of urban area differed significantly from that of rural area. Urban area of Solan Block has a total population of 37,935. The water requirement was found out to be 47,41,875 liters per day. Thus, total water requirement of Solan block comes out to be 91,34,585 liters per day for a population of 1,00,688. According to the people and IPH officials and officials of other departments this water requirement is increasing at a very fast rate everyday.

4.1.3 Storage and supply of water

Storage system of water in Solan Block is different for rural and urban area. For storage of water from different sources basically the following schemes have been used, Lift Water Supply Scheme (LWSS), Gravity Water Supply Scheme (GWSS) and combined.

Table 7: Status of water storage divisions for rural area in Solan Block

Sr. No.	Storage Division	No. of Tanks	Storage Capacity (liters)
1.	Jaunaji	45	13,56,400
2.	Chambaghat	23	12,16,400
3.	Kumarhatti	48	7,93.300
	Total	116	33,66,100

Water for rural area is stored and supplied by the IPH Department under various water supply schemes. For rural area water is stored in three different divisions i.e. Jaunaji, Chambaghat and Kumarhatti (Table 7). Jaunaji storage division has 45 tanks, each tank having different storage capacity and the total water storage capacity of this division is 13,56,400 liters. Storage division Chambaghat has 23 tanks and this division has a total water storage capacity of 12,16,400 liters. Whereas Kumarhatti storage division has 48 tanks and total storage is 793300 liters. Thus, the total storage capacity of all the three divisions is

33,66,100 liters. Maximum storage capacity is of Jaunaji division (13,56,400 liters) followed by Chambaghat (12,16,400 liters) and Kumarhatti (7,93,300 liters). The storage tanks in all the divisions are cleaned twice in a year. In addition to these storage tanks, the IPH department also undertakes cleaning of various other storage tanks in schools, panchayats, etc. For last three years, more than 233 tanks in addition to IPH tanks have been cleaned by the department. Water is supplied to the users after testing and treatment. The samples are tested at District Water Testing Laboratory, Kandaghat.

Water for urban area is stored by the Municipal Cooperation. There are nine storage tanks that receive water from various water supply schemes from where water is further supplied to the users after analysis and treatment in the urban area of the Block. The total water storage of these tanks is 20510000 liters (45,07,692.31 gallons).

Table 8: Status of water storage facilities for urban area in Solan Block

Tank No.	Storage capacity (liter)
1	85lakh
2	55lakh
3	40lakh
4	11lakh
5	11lakh
6	1.7lakh
7	50,000
8	50,000
9	40,000
Total capacity in liters	2,051,0000
Total capacity in gallons	45,07,692.31

These tanks receive water from the IPH schemes and there are two major schemes that are installed specially for supplying water to the urban areas in Solan Block. **Lift Water Supply Scheme (LWSS) Ashwani Khud** this scheme is exclusively for Solan town and nearby urban areas and **Drinking Water Supply Scheme (DWSS) Giri River** from which water is supplied to Solan town and surrounding 114 villages. Line plan of LWSS Ashwani Khud is depicted in figure 4. These committee storage tanks are cleaned once in every six months. Water is supplied to different users after testing and samples are tested weekly at CRI Kasauli.

In addition to this water storage has also been increased by creating water storage under various projects in the rural areas of the Block. Table 8 revealed that during 2008-2011 construction of various water harvesting structures has been done under various projects in the rural area that has further increased the storage capacity. Since 2008-2011, nearly 127 water storage tanks, 132 farm ponds and 95 check dams have been constructed on the community land in the rural area of Solan Block that has created a storage capacity of 756.01 lakh liters.

Table 9: Year-wise details of work executed under different projects and storage capacity created in the Block

Sr. No.	Name of Work	No. of Completed structures			Storage Capacity created (lakh liters)		
		2008-09	2009-10	2010-11	2008-09	2009-10	2010-11
A. Work done on community land							
1.	Water storage tanks	21	59	47	7.64	41.29	39.60
2.	Farm ponds	37	63	32	14.35	35.11	24.42
3.	Check dam	28	47	20	110.72	254.44	228.44
B. Work done on individual land							
1.	Water storage tanks	0	61	322	0.00	16.05	115.91
2.	Roof top harvesting structures	0	9	24	0.00	3.25	7.27

In addition to this nearly 383 water storage tanks and 33 rooftop harvesting structures have been constructed on individual land in rural area that has created a storage capacity of 142.48 lakh liters. A total of 510 water storage tanks have been constructed during 2008-2011. The total storage capacity thus created during the course is 898.49 lakh liters. Under these schemes and projects various water storage structures are also repaired. According to the various departments due to the unavailability of sufficient water in the area the total storage capacity created remains unutilized.

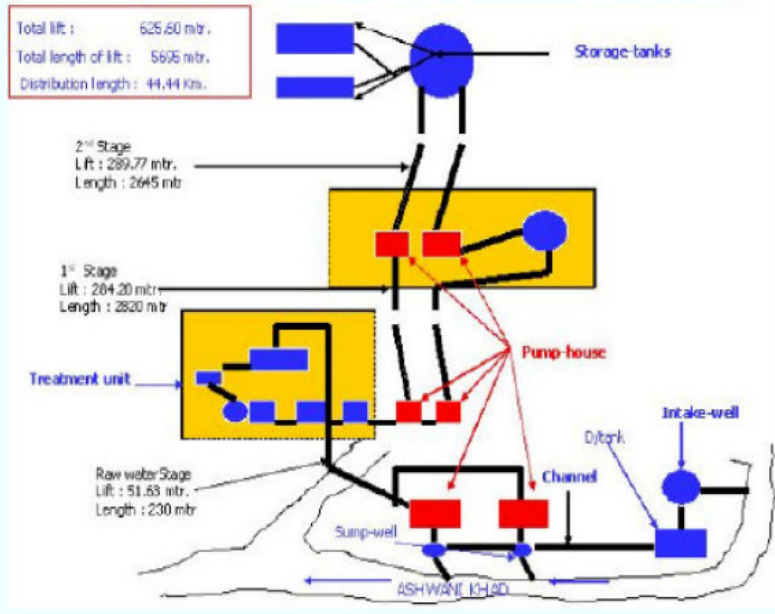
Water supply status in Solan Block

Water is supplied to the users through various piped water supply schemes. Water supply is done through the personnel connections as well as through the community taps

GOVERNMENT OF HIMACHAL PRADESH
IRRIGATION AND PUBLIC HEALTH DEPARTMENT

Resource

LINE PLAN OF LWSS SOLAN (URBAN)



Line Diagram of Lift Water Supply Scheme (Example: Solan (Urban))

Figure 4. Line diagram of Lift Water Supply Scheme (LWSS) for Solan urban area

periodically. The quantity of water supplied to a habitation depends upon the population and requirement. Table 10 presents the status of water distribution system in Solan Block. Water distribution system is different in the rural and urban areas. Data presented in table 10 evinced that the distribution system varies with the area and the distributing department. IPH department supply water at the rate of 70 liter per day per capita in rural areas and to the domestic supplies whereas to the urban population and commercial supply the department distributes 120 liters of water per day per capita. The distribution system of the municipal cooperation is 125 liters per day per capita to all the users except for the hospital (145 liter per day per bed) and to the hotels, PG's (140 liters per day per bed).

Table 10: Status of water distribution in Solan Block

Distribution Department	Category	Supply rate (liter per capita)
Irrigation and Public Health Department	Rural	70
	Urban	120
	Domestic	70
	Commercial	120
Municipal Corporation	Domestic	125
	Commercial	125
	Government Offices	125
	Hospital	145
	Hotels, PGs	140

Table 11 reveals that on an average there are 698 water sources that have been exploited for various water supply scheme in 35 panchayats of the Solan Block in District Solan. The total number of water delivery points are 961. The panchayat with maximum number of water supply scheme sources (43) in Solan Block is Anhech, followed by Shadiayna (42), Bhojnagar (33) and Saproon (32). The minimum number of water supply scheme sources are reported in Koron, Kothon and Parag, each of these panchayats have three water sources exploited for water supply schemes.

Out of the total 961 water delivery points maximum delivery points are in Bohli (95) followed by Anhech (56) and Jaunaji (47). The minimum number of water delivery points are recorded in Saproon (1), Anji (5) and Koron (5).

Table 11: Panchayat wise status of sources exploited for water supply schemes in Solan Block

Sr. No.	Panchayat	Water sources exploited with delivery points	
		Exploited Water Sources	Delivery Points
1.	Anhech	43	56
2.	Anji	8	5
3.	Basaal	24	9
4.	Barog	26	12
5.	Bharti	16	7
6.	Bhojnagar	33	45
7.	Bohli	28	95
8.	Chamat Bhadech	13	29
9.	Chewa	37	32
10.	Dangri	22	27
11.	Deothi	26	35
12.	Dharot	12	13
13.	Haripur	26	34
14.	Jabal Jhamrot	27	35
15.	Jadli	30	30
16.	Jaunaji	11	47
17.	Kabakalan	6	27
18.	Kakkerhatti	3	11
19.	Koron	3	5
20.	Kothon	25	21
21.	Mashiwer	22	36
22.	Nerikalan	16	18
23.	Nauni Majhgoan	14	8
24.	Oachghat	18	32
25.	Parag	3	9
26.	Pattabravari	25	34
27.	Salogra	17	43
28.	Sanhol	24	44
29.	Sapsoon	32	1
30.	Serbnera	18	25
31.	Seri	12	14
32.	Shadiyana	42	40
33.	Shamror	9	43
34.	Shamti	18	29
35.	Topkiber	9	10
	Total	698	961

The data presented in Table 12 reveals that there are 121 Water Supply Schemes in the Solan Block running in 28 panchayats. There are 57 lift, 58 gravity and 6 combined water supply schemes in the block. Out of total 57 LWSS maximum are in Bhojnagar (10) followed by Anhech (4), Chewa (4) and Jadli (4). Minimum number of LWSS is in Pattabrouri, Dharot, Kabakalan, Nerikalan, Parag, Sanhol, Saproon, Serbnera and Seri all of these panchayats possess one LWSS each. There are five panchayats which do not have any LWSS namely Basal, Chamat Barech, Haripur, Kotla and Top Ki Ber. On an average out of 58 gravity waters supply schemes maximum GWSS are in Chewa (5), Mashewer (5), Nerikalan (5) and Ser bnera (5). There are four panchayats which do not have GWSS namely, Jonaji,

Table 12: Status of various water supply schemes in different panchayts in Solan Block

Sr. No.	Panchayat	Type of scheme			
		Lift	Gravity feed	Combined	Total
1.	Anji	3	2	0	5
2.	Annetch	4	3	0	7
3.	Barog	2	2	0	4
4.	Basal	0	1	0	1
5.	Bhojnagar	10	3	0	13
6.	Patta Brouri	1	1	0	2
7.	Chamat Barech.	0	1	0	1
8.	Chewa	4	5	0	9
9.	Dangri	3	3	1	7
10.	Deothi	3	4	0	7
11.	Dharot	1	1	0	2
12.	Haripur	0	2	0	2
13.	Jadli	4	1	1	6
14.	Jonaji	3	0	1	4
15.	Kabakalan	1	1	0	2
16.	Kothon	2	2	0	4
17.	Kotla	0	2	0	2
18.	Mashewer	2	5	1	8
19.	Nerikalan	1	5	0	6
20.	Oachghat	3	0	1	4
21.	Parag	1	1	0	2
22.	Salogra	2	3	1	6
23.	Sanhol	1	0	0	1
24.	Saproon	1	0	0	1
25.	Ser bnera	1	5	0	6
26.	Seri	1	1	0	2
27.	Shamror	3	1	0	4
28.	Top ki ber	0	3	0	3
	Total	57	58	6	121

Oachghat, Sanhol and Saproon. The table also shows that there are only six combined water supply scheme in Dangri, Jadli, Jonaji, Mashewer, Oanchghat and Salogra panchayat of the Solan Block.

There are 821 habitations in Solan out of which 743 are fully covered under water supply schemes and 78 are covered partially. Table 13 revealed that there are 13 panchayats

Table 13: Status of habitations covered under water supply and number of piped water supply schemes running in Solan Block

Sr. No.	Panchayat	Water Supply Coverage Status (As On 01/04/2011)			Number of PWS
		TH	PCH	FCH	
1.	Anhech	39	11 (28.21)	28	36
2.	Anji	15	0	15	10
3.	Basaal	11	1 (9.09%)	10	11
4.	Barog	21	0	21	23
5.	Bharti	16	1 (6.25%)	15	1
6.	Bhojnagar	48	8 (16.67%)	40	58
7.	Bohli	14	0	14	4
8.	Chamat Bhadech	29	3 (10.34%)	26	4
9.	Chewa	28	2 (7.14%)	26	24
10.	Dangri	39	2 (5.13%)	37	38
11.	Deothi	34	0	34	21
12.	Dharot	18	1 (5.56%)	17	18
13.	Haripur	27	1 (3.7%)	26	8
14.	Jabal Jhamrot	20	7 (35%)	13	31
15.	Jadli	74	9 (12.16%)	65	35
16.	Jaunaji	28	1 (3.57%)	27	9
17.	Kabakalan	28	3 (10.71%)	25	13
18.	Kakkerhatti	7	3 (42.86%)	4	3
19.	Koron	4	0	4	2
20.	Kothon	30	0	30	28
21.	Mashiwer	29	0	4	23
22.	Nerikalan	20	0	20	22
23.	Nauri Majhgoan	8	0	8	3
24.	Oachghat	15	0	15	5
25.	Parag	9	0	9	3
26.	Pattabravari	20	0	20	5
27.	Salogra	45	3 (6.67%)	42	50
28.	Sanhol	27	4 (14.81%)	23	3
29.	Saproon	3	1 (33.33%)	2	5
30.	Serbnera	21	2 (9.52%)	19	7
31.	Seri	16	7 (43.75%)	9	10
32.	Shadiyana	13	3 (23.08%)	10	6
33.	Shamror	41	1 (2.44%)	40	43
34.	Shamti	12	0	12	5
35.	Topkiber	12	4 (33.33%)	8	5
	Total	821	78	743	572

that are fully covered and 22 that are partially covered under water supply. However on an average the extend of coverage is more than 70% in almost all the panchayats. There are 572 piped water supplies in the block out of which maximum PWS are in Bhojnagar (58) followed by Salogra (50) and minimum PWS were recorded in Bharti (1).

4.2 EFFECT OF DIFFERENT LAND USES ON WATER QUALITY

It is evident from the data presented in table 14 that the pH, EC, COD, BOD, Ca, Mg and Cl content of water sources under different land uses in Solan Block varied significantly.

4.2.1 Physical parameters

pH

The major landuses of Solan Block exerted a significant influence on pH of the water sources (Table 14). The data revealed that under different land uses the pH of water ranged from 7.24 – 7.92. Significantly highest value of pH (7.92) was noticed in the water sources under institutional landuse which was followed industrial (7.39) and rural area (7.25), whereas, minimum (7.24) was noticed under urban/sub-urban area. The pH under all the land uses was found to be within the permissible limit.

EC

Similarly, different land use systems were also found to exert significant influence on EC of water sources of Solan Block (Table 14). The data revealed that under different land uses the EC of water ranged from 0.41 – 0.92 dS/m. Significantly highest EC (0.92 dS/m) was recorded under institutional areas followed by industrial area (0.58 dS/m), whereas, minimum EC (0.41 dS/m) in water was noticed under rural land use.

4.2.2 Chemical Parameters

COD

The water sources under different land uses differed significantly in their COD values (Table 14). In Solan Block the COD of water sources ranged from 63.75 – 111.08 mg/l. Significantly highest value of COD (111.08 mg/l) was noticed in water sources of institutional areas followed by rural areas (83.36 mg/l), whereas, minimum (63.75 mg/l) was noticed under industrial areas. In all the landuses the COD of water sources was found above permissible limits as prescribed by WHO.

Table 14: Effect of different land uses on physico- chemical parameters of water

Land Use	Parameters						
	pH	EC (dS/m)	COD (mg/l)	BOD (mg/l)	Ca (mg/l)	Mg (mg/l)	Cl (mg/l)
Industry	7.39	0.58	63.75	12.35	63.05	37.76	37.2
Urban/Sub-urban	7.24	0.49	70.08	5.16	54.8	26.87	29.23
Institutional	7.92	0.92	111.08	2.92	90.48	32.43	38.06
Rural	7.25	0.41	83.36	1.44	51.28	27.76	14.05
CD_{0.05}	0.34	0.39	61.54	4.45	12.85	17.65	9.57
Permissible limits	6.5-7.5	NA	20	5	75	30	250

BOD

The BOD of water sources under different land uses in Solan Block also varied significantly. In Solan Block BOD varied from 1.44 – 12.35 mg/l. Water of industrial area was found to have significantly highest value of BOD (12.35 mg/l) followed by urban area (5.16 mg/l), whereas, minimum (1.44 mg/l) was noticed under rural area. BOD of the water samples was found to exceed the permissible limit under industrial and urban land use.

Calcium

The data in table 14 revealed that under different land uses the Ca content of water ranged from 51.28 - 90.48 mg/l. Water of institutional area was found to have significantly highest value of Ca (90.48 mg/l) followed by industrial area (63.05 mg/l), whereas, minimum Ca (51.28 mg/l) was noticed under rural area. Calcium content of water under industrial and institutional land use was found to exceed the permissible limit.

Magnesium

It is evident from the data presented in table 14 that under different land uses the Mg of water ranged from 26.87 – 37.76 mg/l. Water of industrial area was found to have significantly highest value of Mg (37.76 mg/l) followed by institutional area (32.43 mg/l), whereas, minimum Mg (26.87 mg/l) was noticed under urban land use area. Water samples collected from the industrial and institutional land use were found to exceed the permissible limit for magnesium.

Chloride

The data presented in table 14 evinced that under different land uses the Cl content in water ranged from 14.05 – 38.06 mg/l. Water of institutional area was found to have significantly highest value of Cl (38.06 mg/l) followed by industrial area (37.02 mg/l), whereas, minimum Cl content (14.05 mg/l) was noticed under rural land use. Chloride in water was found to be within the permissible limits in all the landuses.

4.3 Status of water quality under different land uses in Solan Block

During water quality analysis it was also observed that the water quality parameters also varied significantly within the same landuse at different locations in the Solan Block.

4.3.1 Status of water quality under industrial landuse in Solan Block

Data presented in table 15 revealed that under industrial landuse at different industrial locations surface and ground water sources varied in the values of the parameters analysed. The maximum pH (7.97) was recorded at Ghatti followed by Shamti (7.93) at both locations samples were taken from water sources around pharmaceutical industries. The minimum pH (5.61) was recorded at Oanchghat wherein a battery manufacturing industry is in operation. The mean pH value recorded was 7.38 and the cv calculated indicated that the variation within sample was low. The highest EC (1.59dS/m) in water was recorded at Oanchghat and minimum EC (0.32dS/m) was recorded near a brewery industry at Salogra and at Jatoli near the pharma-industry. Mean EC value was recorded to be 0.59 and medium variability was found within the samples according to the calculated cv. Highest COD (325mg/l) was found under a pharma-industry at Shamti and lowest (6 mg/l) at Oanchghat. Mean COD value found out was 67.1 mg/l and samples were having high variability among them. On the other hand maximum BOD (91mg/l) was found under the battery manufacturing industry at Oanchghat while the minimum BOD (3mg/l) was recorded near a pharma-industry at Ghatti. The mean BOD value under all the industries was 13.25 and the variability within the samples was high. Highest Ca content (163mg/l) came at Oanchghat where samples were collected near a battery manufacturing industry while minimum Ca content (4 mg/l) was found at Salogra near a brewery industry. The mean Ca content found out was 65.1 and the values of Ca were recorded with medium variability. Maximum Mg (184 mg/l) was recorded at Oanchghat while minimum Mg (6 mg/l) was found at Shamti. The mean Mg content found out was 40.25 mg/l and Mg contents were recorded with high variability. The

highest Cl value (86 mg/l) and the lowest Cl content (2.7 mg/l) were recorded at Shamti near a pharma industry. Mean Cl content value was 37.58mg/l and the values were recorded with medium variability in the industrial area.

Table: 15: Status of water quality under industrial area of Solan Block

S.No.	Location	Source of sample	Type of source	pH	EC (dS/m)	COD (mg/l)	BOD (mg/l)	Ca (mg/l)	Mg (mg/l)	Cl (mg/l)
1.	Jatoli	Spring	G	6.82	0.53	264	14	120	17	80
2.		Bawri	G	7.21	0.39	37	9	69	10	32.8
3.		Spring	G	7.36	0.32	80	7	72	40	55.5
4.		Tank	S	7.14	0.33	60	8	90	10	72.1
5.	Shamti	Pond	S	7.83	0.67	48	12	19	37	35
6.		Spring	G	7.71	0.77	51	8	29	6	86
7.		Tank	S	7.93	0.52	53	6	58	7	42.2
8.		Nala	S	7.62	0.83	325	38	118	31	2.7
9.	Salogra	Kuhl	S	7.42	0.51	78	7	73	126	17.7
10.		Bawri	G	7.52	0.32	104	12	4	57	20.4
11.		Tank	S	7.41	0.33	30	7	47	36	14.3
12.		Spring	G	7.22	0.31	39	8	64	36	18.1
13.	Ghatti	Nala	S	7.63	0.45	26	6	24	8	30.5
14.		Pond	S	7.64	0.35	11	4	67	9	42.1
15.		Tank	S	7.97	0.33	19	3	42	39	17
16.		Spring	G	7.63	0.62	8	4	35	23	43.3
17.	Oachghat	Tank	S	7.43	0.73	6	91	84	14	35.9
18.		Bawri	G	7.17	0.75	9	4	163	22	23
19.		Nala	S	5.61	1.07	12	6	82	184	47.2
20.		Nala	S	7.29	1.59	82	11	42	93	35.8
Mean				7.38	0.59	67.1	13.25	65.1	40.25	37.58
CV				6.59	54.04	124.16	153.68	58.96	112.85	58.25

4.3.2 Status of water quality under urban landuse in Solan Block

The perusal of data presented in table 16 revealed that the highest pH (7.72) in water samples was recorded at Salogra followed by Saproon (7.64), whereas the lowest pH (6.47) was recorded at Solan. The mean pH value calculated was 7.24 and cv revealed that the variability among the samples was low. Maximum (0.65 dS/m) and minimum EC (0.25 dS/m) was recorded at Deonghat. CV revealed low variability among the samples and mean

EC came out to be 0.49 dS/m. Significantly highest COD value (539 mg/l) was recorded at Deonghat while lowest COD (6 mg/l) was found out at Chambaghat. Mean COD value was 70.08 and cv revealed that the variability in values was high. Maximum BOD (38 mg/l) was recorded at Chambaghat and minimum BOD (0 mg/l) was found at a water source in Solan and Salogra. Mean BOD (5.16 mg/l) was also calculated and high variability was observed in the BOD value according to the cv.

Table 16: Status of water quality under urban area of Solan Block

S.No.	Location	Source of sample	Type of source	pH	EC (dS/m)	COD (mg/l)	BOD (mg/l)	Ca (mg/l)	Mg (mg/l)	Cl (mg/l)
1.	Chambaghat	Handpump	G	6.51	0.33	6	38	51	33.9	5.7
2.		Bawri	G	7.36	0.39	17	12	73	32.0	40
3.		Nala	S	7.28	0.53	151	5	54	14.4	20
4.		Bawri	G	7.12	0.29	22	7	62	46.4	19
5.		Tank	S	6.96	0.42	18	3	58	29.6	12
6.	Solan	Handpump	G	6.32	0.49	42	8	64	20.7	62
7.		Bawri	G	6.51	0.55	36	15	81	17.8	46
8.		Spring	G	6.47	0.36	24	4	80	9.5	37
9.		Waterfall	S	6.91	0.58	55	7	61	24.7	42
10.		Nala	S	6.53	0.63	37	0	47	25.5	44
11.	Salogra	Spring	G	7.72	0.43	121	0	60	30.3	33
12.		Tank	S	7.64	0.44	9	2	46	31.7	19
13.		Bawri	G	7.63	0.42	183	4	22	23.1	16
14.		Spring	G	7.51	0.42	25	6	29	22.3	24
15.		Spring	G	7.72	0.49	74	1	66	31	20
16.	Deonghat	Bawri	G	7.33	0.41	14	0	78	33.5	38
17.		Waterfall	S	7.47	0.27	51	0	61	32.8	5
18.		Spring	G	7.53	0.28	539	2	53	26.6	6
19.		Handpump	G	7.38	0.65	18	5	50	44.9	44
20.		Spring	G	7.56	0.25	26	1	106	10.9	17
21.	Saproon	Bawri	G	7.36	0.28	40	3	6	12.5	19
22.		Handpump	G	7.56	0.41	103	3	22	27.6	30
23.		Handpump	G	7.49	0.34	53	0	45	36.5	65
24.		Handpump	G	7.64	0.32	51	3	48	26.7	22
25.		Bawri	G	7.42	0.36	37	0	47	26.9	45
Mean				7.24	0.49	70.08	5.16	54.8	26.87	29.23
CV				6.12	27.54	153.24	151.84	38.65	34.77	56.80

The highest Ca content (106 mg/l) and lowest (6 mg/l) was recorded in samples collected from different water sources at Deonghat. Mean Ca content value calculated was 54.8 mg/l and cv evinced that low variability was there in the Ca value of the various samples. Maximum Mg (46.4 mg/l) was recorded at Chambaghat followed by Deonghat (44.9 mg/l). Minimum Mg (9.5 mg/l) was found at Solan. The value of cv calculated revealed that the variability among the samples for Mg value was low and the mean Mg content was 26.87 mg/l. Mean Cl content (29.23 mg/l) was calculated and the highest Cl (65 mg/l) was observed at Saproon and the lowest (5 mg/l) was recorded at Deonghat. The cv value depicted medium variability in Cl content value in urban area of the Solan Block.

4.3.3 Status of water quality under institutional landuse in Solan Block

Table 17 presents the status of surface and ground water quality in the institutional area of the Solan Block. Mean pH value of 7.92 was recorded with highest pH (9.04) at Nauni followed by Shoolini (8.97) and lowest pH (7.11) was again recorded in sample collected from a water source at Nauni. The cv revealed that low variability existed among the pH value. The highest value of EC (7.73 dS/m) was observed at Tatoon and minimum (0.32 dS/m) near bus stand Solan. Mean EC was 0.92 and cv depicted high variability in the EC values. CV calculated for COD values showed very high variability in the values of samples with mean COD of 111.08 mg/l. Highest COD (1087 mg/l) was recorded in water sample collected near Shoolini while lowest (4 mg/l) was also recorded in water sample collected near the same institutional area. The maximum BOD (22 mg/l) was recorded at bus stand and minimum (0 mg/l) in some water sources in all the locations. Mean BOD value was 2.92 mg/l and cv revealed high variability in BOD values in the water samples.

The highest Ca content (158 mg/l) was recorded at Tatoon and lowest (36 mg/l) was recorded in samples collected from different water sources at bus stand. Mean Ca content value calculated was 90.48 mg/l and cv evinced that low variability was there in the Ca value of the various samples. Maximum Mg (61.2 mg/l) was recorded at Oanchghat followed by Nauni (58.8 mg/l). Minimum Mg (5.5 mg/l) was found near bus stand. The value of cv calculated revealed that the variability among the samples for Mg value was medium and the mean Mg content was 32.43 mg/l. Mean Cl content (38.06 mg/l) was calculated and the highest Cl (123 mg/l) was observed at Oanchghat and the lowest Cl (2.5 mg/l) was recorded at Nauni. The cv value depicted medium variability in Cl content value in institutional area of the Solan Block.

Table 17: Status of water quality under institutional area of Solan Block

S.No.	Location	Source of sample	Type of source	pH	EC (dS/m)	COD (mg/l)	BOD (mg/l)	Ca (mg/l)	Mg (mg/l)	Cl (mg/l)
1.	Nauni	Tank	S	7.11	0.35	60	2	76	19.5	2.5
2.		Spring(Bagor)	G	7.63	0.49	45	7	82	29.4	11
3.		Spring (Nr)	G	8.08	0.55	62	3	129	34.8	6
4.		Khaltu Nala	S	9.04	0.48	69	2	67	21.1	18
5.		Handpump	G	8.02	0.84	16	0	84	58.8	9
6.	Oanchghat	Nala	S	7.51	1.11	311	3	50	59.2	123
7.		Spring	G	7.43	0.87	8	0	104	57.9	54
8.		Storage tank	S	8.11	0.63	18	0	105	42.3	25
9.		Nala	S	8.13	1.12	56	2	83	61.2	61
10.		Handpump	G	7.56	0.95	25	5	112	56.7	61
11.	Shoolini	Tank(pumphs.)	S	8.57	0.68	15	6	74	28.0	39
12.		Nala	S	8.97	0.61	4	1	79	27.9	39
13.		Nala	S	8.96	0.62	115	2	80	26.9	40
14.		Bawri	G	7.27	0.46	402	0	102	6.7	8
15.		Bawri	G	8.34	0.49	1087	1	123	9.7	25
16.	Tatool	Nala	S	8.41	0.89	5	4	162	51.8	66
17.		Khud	S	8.81	0.64	14	2	111	28.5	56
18.		KTS Khud	G	8.11	0.55	6	6	115	35.5	26
19.		Bawri	G	8.13	0.58	216	0	158	29.2	11
20.		Bawri	G	7.12	7.73	7	1	75	52.7	37
21.	Bus stand	Spring	G	7.52	0.75	57	0	53	25.7	52
22.		Nala	S	7.34	0.43	44	1	61	6.6	67
23.		Nala	S	7.24	0.36	51	22	47	14.6	32
24.		Bawri	G	7.32	0.52	49	0	81	21.1	47
25.		Nala	S	7.22	0.32	35	3	36	5.5	36
Mean				7.92	0.92	111.08	2.92	90.48	32.43	38.06
CV				7.91	156.04	203.13	153.76	36.93	55.82	70.29

4.3.4 Status of water quality under rural landuse in Solan Block

Data presented in table 18 revealed that under rural area surface and ground water sources varied in the values of the parameters analysed. The maximum pH (7.93) was recorded in Sanhol panchayat. The minimum pH (3.16) was recorded in Anji panchayat. The mean pH value recorded was 7.25 and the cv calculated indicated that the variation within sample was low. The highest EC (1.26 dS/m) in water was recorded in Shamlech panchayat and minimum EC (0.21 dS/m) was also recorded in the same panchayat. Mean EC value was

recorded to be 0.41 and medium variability was found within the samples according to the calculated cv.

Table 18: Status of water quality under rural area of Solan Block

S.No.	Location	Source of sample	Type of source	pH	EC (dS/m)	COD (mg/l)	BOD (mg/l)	Ca (mg/l)	Mg (mg/l)	Cl (mg/l)
1.	Sanhol	Spring	G	7.16	0.29	107	0	31	27.6	6
2.		Kuhl	S	7.61	0.26	233	0	29	22.6	6
3.		Spring	G	7.91	0.29	274	2	71	32.8	9
4.		Bawri	G	7.93	0.34	61	0	67	29.1	14.5
5.		Spring	G	7.41	0.29	30	0	52	25.4	11
6.	Basal	Bawri	G	7.34	0.38	126	0	22	22.7	17
7.		Spring	G	7.12	0.26	72	0	42	21.6	24
8.		Spring	G	6.42	0.33	43	0	113	22.9	18
9.		Handpump	G	7.48	0.63	20	0	31	20.7	35
10.		Bawri	G	7.66	0.52	32	0	32	35.0	33
11.	Shamti & Kothon	Spring	S	7.31	0.29	176	0	26	36.4	12
12.		Nala	S	7.33	0.35	9	0	25	24.6	16.7
13.		Bawri	G	7.32	0.39	51	0	22	24.5	11
14.		Tank	S	7.42	0.29	30	0	52	40	16
15.		Tank	S	7.21	0.29	49	0	62	12.9	8
16.	Anji & Barog	Spring	G	7.66	0.58	39	0	152	40.3	8
17.		Bawri	G	3.16	1.12	79	0	32	75	21
18.		Nala	S	6.51	0.81	54	1	39	61.5	9
19.		Handpump	G	6.82	0.62	7	0	82	9.5	6
20.		Nala	S	6.91	0.22	39	0	41	4.5	10
21.	Shamlech	Nala	S	7.0	0.25	374	0	60	10.7	6.1
22.		Spring	G	7.26	0.26	172	0	28	6.1	18
23.		Nala	S	7.14	1.26	250	0	143	73.3	14
24.		Bawri	G	7.24	0.24	32	6	61	12.1	12
25.		Nala	S	7.11	0.21	32	2	52	6.8	8
26.	Shamror	Nala	S	7.51	0.62	56	0	83	25.3	14
27.		Nala	S	7.52	0.74	68	0	26	17.7	13
28.		Nala	S	7.43	0.59	38	2	80	75.1	10
29.		Tank	S	7.41	0.26	41	0	42	14.2	9
30.		Bawri	G	7.32	0.22	29	1	29	7.4	12
Mean				7.25	0.41	83.36	1.44	51.28	27.76	14.05
CV				11.55	60.63	103.04	103.77	62.22	74.02	52.93

Table 18 also shows that the highest COD (374 mg/l) was found in Shamlech panchayat and lowest (7 mg/l) in Barog panchayat. Mean COD value found out was 83.36 mg/l and samples were having high variability among them. On the other hand maximum BOD (6 mg/l) was found in Shamlech while the minimum BOD (0 mg/l) was recorded in some water sources in all the panchayats. The mean BOD value under all the industries was 1.44 mg/l and the variability within the samples was high. Highest Ca content (152 mg/l) was recorded in Anji panchayat while minimum Ca content (22 mg/l) was found in Basal and Kothon panchayat. The mean Ca content found out was 51.28 mg/l and the values of Ca were recorded with medium variability. Maximum Mg (73.3 mg/l) was recorded in Shamlech panchayat while minimum Mg (4.5 mg/l) was found in Barog panchayat. The mean Mg content found out was 27.76 mg/l and Mg contents was recorded with medium variability. The highest Cl value (35 mg/l) was found in Basal and the lowest Cl (6 mg/l) was recorded in Sanhol and Barog panchayat. The mean Cl content value was 14.05 mg/l and the values were recorded with medium variability in the rural area.

Chapter-5

DISCUSSION

The present investigation entitled “**Inventorization of water resources in Solan district of Himanchal Pradesh**” was carried out during 2012 – 2013. The results obtained have been discussed in this chapter under different heads:

5.1 Water Resource Inventory

5.1.1 Availability of water sources

5.1.2 Water requirement of rural and urban population

5.1.3 Storage and supply

5.2 Water Quality under Different Land Uses in Solan Block

5.2.1 Physical parameters

5.2.2 Chemical parameters

5.1 WATER RESOURCE INVENTORY

5.1.1 Availability of water sources

The availability of water depends on various factors, one of the important factor being the number of water sources which ranged from 5 to 262 in different panchayats of Solan Block. Solan Block has about 3218 ground and surface water sources (Table 4). Out of the total water sources in Solan District 22% ground and 30% surface water sources are present in Solan Block. There is a gap of 34 water sources in the officially recorded sources and water sources recorded from the field. This gap may be due to the non inclusion of the small scale sources of water which are contributing less to the availability of water for utilization.

Out of the total water sources only 3070 sources have been exploited commercially at a large scale for use, this may be attributed to the unavailability of sufficient perennial water as confirmed by the people of the area during personal interview. Further the non-utilization of these sources may be due to the very high investment of money, time and labour that may be required for the lifting of water which may not be feasible. These non-exploited water sources however, play an important role in meeting out the water requirement of the local people for various uses who are utilizing these sources using traditional methods and thus

reducing the pressure on heavily exploited large water sources like rivers and nallahs. A total of 499 handpumps have been installed in the different panchayats of Solan Block. The number ranged from 1-39. This variation in the number of available and exploited water sources in different panchayats may be attributed to the topography, slope, terrain, total area under the panchayat, land use, water resource management, aquifer system, surface and ground water system, level of exploitation, extend of various constructions, developmental activities and area under forest. Rainfall is the major source recharge to the groundwater body apart from the influent seepage from the rivers, irrigated fields and inflow from upland areas. The discharge from ground water mainly takes place from wells and tube wells; effluent seepages of ground water in the form of springs and base flow in streams.

Water from many of the water sources is also being utilized for irrigation. 303.4 ha of cultivable area is covered under various lift and flow irrigation schemes in the Block. The area covered under various schemes ranged from 3.60 ha (FIS Upper Dhillon) to 91.26 ha (LIS Patta Brouri). The difference may be attributed to the type of source exploited, availability of water in the source alternative use of the source other than irrigation and to the total water discharge of the source (Table 5).

5.1.2 Water requirement of rural and urban population

Water requirement vary significantly in rural and urban area of the Solan Block. Total water requirement of rural area is 43,92,710 liters per day and that of urban area is 47,41,875 liters per day. The reason for this significant difference in the requirement of water in rural and urban area is due to the variation in population, dependency of the people on supplied water, extend of development activities in the region and state standard supply rate that vary for rural (70 liter/capita/day) and urban population (125 liters/capita/day).

Water requirement that also vary significantly from one panchayat to the other ranged from 65,590 liters per day in Nauni-Majhgaon to 3,07,090 liters per day in Salogra panchayat. This difference may be attributed to the difference in the population of the panchayats (Table 6).

5.1.3 Storage and supply of water

There is different water storage system for both rural and urban area in the Block. Mostly two types of schemes LWSS and GWSS have been installed to capture and store

water for supply to the users. There are three water storage divisions in the Block namely Jaunaji, Chambaghat and Kumarhatti. All the three divisions vary in water storage capacity that ranged from 7,93,300 liters (Kumarhatti division) to 13,56,400 liters (Jaunaji division). The difference in the storage capacity in the three divisions may be attributed to the difference in the number of tanks in each division (Table 7), storage capacity of individual tanks and availability of water sources and schemes feeding the storage division. Water storage for urban area is looked after by the municipal cooperation. Nine storage tanks have been constructed for water storage and supply to the urban areas in the Block. The storage capacity in these tanks ranged from 40,000 liters to 85,00,000 liters (table 8). The total storage capacity of 4,507,692.31 gallons is supplied from two major schemes LWSS Ashwani Khud and DWSS Giri river. Difference in water storage for rural and urban area may be attributed to the reason that it is not possible for a single department to look into the matters related to water storage and supply to such a large area and big population and also water is to be supplied according to different standards and norms on periodic basis. The storage structures are to be checked and cleaned periodically and water is to be analysed for various parameters and treated properly before supply to the users. So, storage divisions have to be separate and looked before by different departments for effective management.

Many times the water storage capacity created in the area remains unexploited due to the unavailability of water in the sources this may be attributed to the drastic change in the rainfall pattern experienced during the last few decades in the area. In the region the decade 2001-2010 experienced decrease in the rainfall during summer, spring and winter seasons, however, the maximum decrease of 115.73 mm was noticed in summer and winter season over the base period followed by 88.31 mm in spring and 25 mm in winter season. Whereas, in the decade of 2001-2010 an increase in rainfall to the tune of 53.37 mm was noticed in autumn season over the base period (Figure 5). The area as a whole is therefore, experiencing scanty rains during winter, summer and spring months resulting water scarcity which is affecting the recharge of water sources. Also the number of rainy days have reduced and the intensity of rainfall has increased that has lead to less time for percolation of water into the soil. This change in rainfall has also lead to increased runoff and soil erosion, thus, increasing the extend of silt accumulation in the downstream water sources that has reduced the water holding capacity of those sources and deterioration of water quality because the runoff water not only brings silt but also many organic and inorganic pollutants. The removal of top fertile loose soil during high intensity rainfall has resulted in the low rate of plant growth in the area.

All these factors have resulted in reduction of ground water recharge, less availability of water in the water sources like bawries and springs thus unutilization of water storage capacity created and more pressure on the large perennial water sources for water supply.

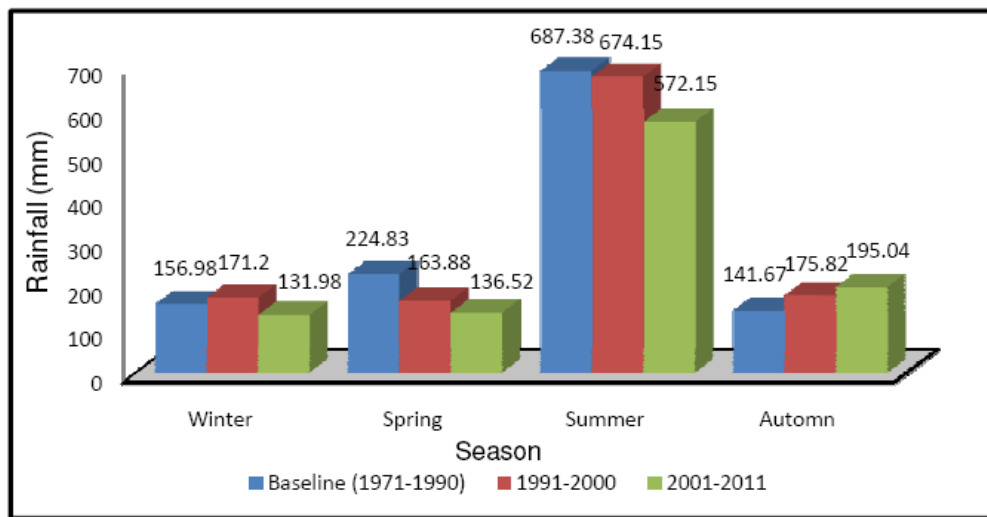
Under various government schemes and projects many water harvesting structures have been constructed in the Solan Block that further created and enhanced the total water storage capacity in the area. During past few years more than 510 water storage tanks, 132 farm ponds, 95 check dams and 33 rooftop water harvesting structures (Table 9) have been constructed on community as well as individual land in the study area. This has created a total water storage capacity of 898.49 lakh liters. Government introduces and funds various projects and schemes under various plans like watershed management, to improve the water quality and availability for different uses, to check soil erosion, to meet the requirements of the people and to reduce the pressure on large perennial water sources that are facing threat and high level of pollution. So, various departments undertake construction of different water harvesting structures to meet the objectives under government projects.

Water supply status in Solan Block

There are many water sources that have been exploited for various water supply schemes in the area. Water is supplied through piped water supplies to personal as well as community connections. It is not possible to connect all the households with personal piped water supply this may be because sometimes it is not feasible and also some people cannot afford the financial investment for the personal connection. There is a difference in the water distribution system for the rural and urban area in the Solan Block (Table 10). Supply to the urban area is more than that to the rural area this variation may be attributed to the difference in the dependency of people on the supplied water, standard of living, more number of commercial set ups in the urban area and supply rate. Another reason can be that in the rural areas there are traditional water sources available with the people that can meet the small scale water requirements.

In the block 698 water sources have been exploited for feeding the various water supply schemes (Table 11). The number of water supply scheme sources ranged from three (Koron, Koyhon and Parag) to 43 (Anhech), this may be attributed to the availability of perennial water sources that are feasible/suitable to be exploited economically for the purpose of water supply and availability of good amount of water in these sources.

Total Rainfall (mm)



Season wise rainy days distribution pattern

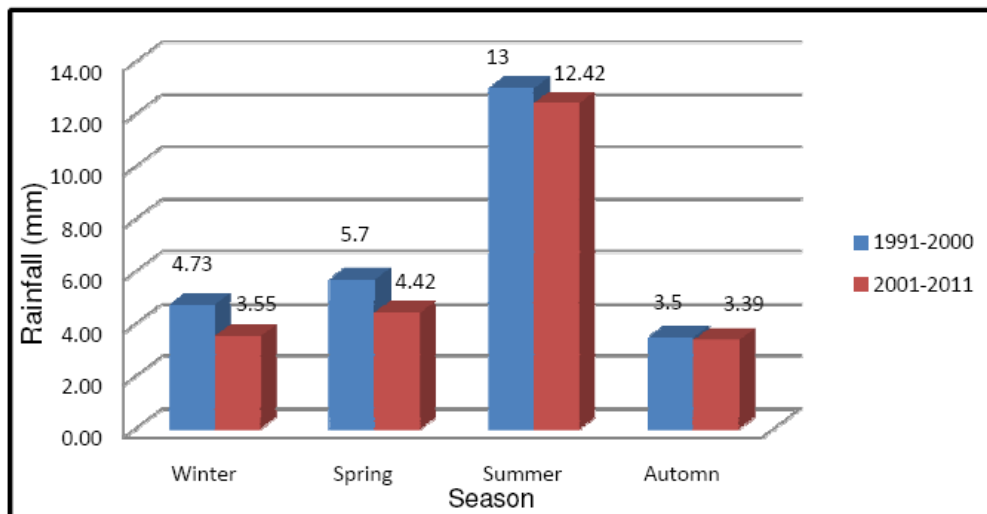


Figure 5. Total Rainfall (mm) and Season wise rainy days distribution pattern in Solan Block

There are 961 water delivery points that ranged from one in Saproon to 95 in Bohli (table 11). This variation may be due to the difference in the total number of habitations and difference in the availability of small scale alternative water sources in the panchayat that could meet the general water requirements of the people and difference in delivery points is also attributed to the living standard of the people and various commercial supplies like hotels, PG's, dhabas in the panchayat.

There are 121 water supply schemes running in the block and the number ranges from 1 to 10 in different panchayats. There are 58 GWSS, 57 LWSS and 6 combined water supply schemes (Table 12) in the Block. The difference in the water supply schemes in different panchayats may be attributed to the occurrence of water sources, type of water sources, availability of water in the sources and economic feasibility to extract water from the sources in the panchayat.

In different panchayats of Solan Block there are 821 habitations out of which 743 habitations are fully covered and 78 habitations are partially covered under piped water supplies (Table 13). However, the extend of coverage is more than 70 % in almost all the panchayats in the study area. The reason for partial coverage of few habitations may be the tough topography due to which it is not feasible to install the piped water supplies and also because people are using traditional water sources to meet their requirements. Another reason being that the IPH department is still under progress to install piped water supplies to the left habitations.

5.2 WATER QUALITY UNDER DIFFERENT LAND USES IN SOLAN BLOCK

5.2.1 Physical parameters

pH

pH being an important factor that determine the suitability of water for various purposes ranged from 7.24 to 7.92 in different water sources of Solan block. The pH of the water sources was however, within the permissible limit as per WHO standards (2008).

Institutional land use as compared to other land use systems in Solan Block resulted in the highest pH of water which was probably due to dumping of organic waste, direct discharge of sewage water and further percolation of sewage water that reached the water sources.

Electrical conductivity (EC)

Electrical conductivity is a measure of salt concentration. In Solan block of district Solan the mean EC value ranged from 0.41 to 0.92 dS/m in the water sources (Table 14). Water of institutional area was found to have significantly highest value of EC (0.92 ds/m). The present findings are in confirmation with the findings of Sharpley and Menzel (1987); Gupta *et al.* (2003) and Sanap *et al.* (2006) who reported that the conductance of water increases due to enrichment of organic conducting species from soaps and detergents of the bathing places.

5.2.2 Chemical parameters

Chemical oxygen demand (COD)

COD determines the amount of oxygen required for chemical oxidation. In Solan block of district Solan the value of COD on average ranged from 63.75 to 111.08 mg/l for water sources which exceeded permissible limit (ICMR1975) in all the land uses. High value of COD indicated high degree of organic pollution. Upkar and Vyas, (1992) also reported that high value of COD may be due to high degree of organic pollution.

Biochemical oxygen demand (BOD)

The BOD determines the amount of oxygen required for biological oxidation of organic matter with the help of microbial activities. In Solan block of district Solan the mean value of BOD ranged from 1.44 to 12.35 mg/l for various water sources. As per WHO standards (2008) the BOD of water in rural and institutional land use was within the acceptable limit. Whereas it exceeded permissible limits under industrial and urban land use. The higher BOD in water sources under industrial and urban/suburban landuse was probably due to release of high organic matter containing urban solid waste in the urban areas and effluents in the industrial region. The minimum BOD value of water sources under rural land use may be ascribed to relatively less production of solid waste and recycling of the waste material in the manures/compost preparation. The present investigations corroborate the findings of Trivedi and Goel (1986) who observed that low oxygen concentration were associated with heavy contamination by organic matter in the water.

Calcium (Ca²⁺)

In surface and ground water sources of Solan block calcium on an average varied widely from 51.28 to 90.48 mg/l. The water under institutional area exceeded the permissible

limits whereas water in all other land uses was in permissible limit as per WHO standards (2008). However, according to Ohle (1955) the water sources of Solan block may be considered calcium rich who have also reported water with calcium concentration of 25 mg/l as Ca^{2+} rich.

Magnesium

The water sources of the Solan block of district Solan contained Mg^{2+} to the range of 26.87 to 37.76 mg/l and as per WHO standards (2008) the concentration of Mg^{2+} in water under rural and urban land use falls in permissible limit. However the water under industrial and institutional land use exceeded the permissible limits. High magnesium in these areas may be due to landfill leachates and other wastes that may be the source of Mg^{2+} cations. The present findings are in accordance with the findings of Hackley *et al.* (1996).

Chloride (Cl⁻)

On an average the concentration of chloride ions ranged from 14.05 to 38.06mg/l in Solan block of district Solan. Water sources under all the landuse systems have chloride within the permissible limit as per WHO standards (2008). The higher content of chlorides was found under the institutional area that may be due to sewage, kitchen waste and man excrete which contains higher quantity of chloride. Similar results were also reported by Dwivedi and Odi (2003) and Sanap *et al.* (2006).

Chapter-6

SUMMARY AND CONCLUSION

The present investigation entitled “Inventorization of water resources in Solan District of Himachal Pradesh” was conducted during 2012-2013 in Solan Block, District Solan of Himachal Pradesh. In order to inventorize the water sources of Solan Block survey was conducted using pre structured proforma and the people’s perception regarding the water sources and their status with respect to the water availability was also recorded by conducting personal interviews. The secondary data regarding various sources in the block was also recorded from various development departments of the Panchayat, block and district. To assess the impact of different land uses on water quality, locations from each landuse were selected randomly and samples were analysed for various parameters like pH, EC, BOD, COD, Ca²⁺, Mg²⁺ and Cl⁻.

- In Solan Block the total water sources recorded were 3218, whereas, in official records only 3184 sources are available. After recording the additional small scale sources a gap of 34 sources was noticed in the region. Out of the total recorded water sources only 3070 are being commercially exploited for use in the region and 499 handpumps were installed. Out of the total water sources in Solan District, 22% ground and 30% surface water sources are present in Solan Block. The people perception indicated that out of 35 panchayats, seven panchayats namely: Anhech, Bhojnagar, Bohli, Haripur, Kabakalan, Nerikalan and Shadiyana were found to have scarcity of water.
- In Solan Block only 303.4 ha of total area is covered under 11 major irrigation schemes like Lift Irrigation and Flow Irrigation Schemes utilizing water from Nullahs, Khuds and Rivers. Out of the total 21610 ha irrigated area in the district 1.41% irrigated area is under these schemes in Solan Block.
- A total population of 62,753 in rural area in Solan Block has a water requirement of 43,92,710 liters per day whereas, that of urban population (37935) was 47,41,875 liters per day. The total water requirement of Solan Block comes out to be 91,34,585 liters per day for a population of 1,00,688.

- For rural area water is stored in three different water storage divisions i.e. Jaunaji, Chambaghat and Kumarhatti. The total storage capacity of all the three divisions is 33,66,100 liters.
- Water for urban area is stored by the Municipal Corporation. There are two major schemes that are installed specially for supplying water to the urban areas in Solan Block namely Lift Water Supply Scheme (LWSS) Ashwani Khud and Drinking Water Supply Scheme (DWSS) Giri River. The total water storage of water under the cooperation 20510000 liters (45,07,692.31 gallons).
- The total water storage in Solan Block is 23876100 liters (52,13,122.28 gallons) to meet the demand of 100688 inhabitants along with the water requirement for other purposes.
- The newly constructed 770 water harvesting structures in the Block under various projects and schemes have further created a total storage capacity of more than 898.49 lakh liters in the area.
- Water is supplied to the users through various piped water supply schemes. Water supply is done through the personnel connections as well as through the community taps periodically. On an average there are 698 water sources that have been exploited for various water supply schemes. There are 121 Water Supply Schemes in the Solan Block.
- The pH of the water sources on an average ranged from 7.24 to 7.92 which was found to be within the permissible limit as per WHO water quality standards. The highest value of pH (7.92) was found in institutional land use system.
- EC of surface and ground water on an average ranged from 0.41 to 0.92 dS/m. Therefore the concentration of salts in both the sources was found within the acceptable limit as per the water quality standards specified by WHO. The maximum value of EC (0.92 dS/m) was found in institutional land use.
- In Solan block of district Solan the mean COD value water sources was found to range from 63.75 to 111.08 mg/l. The highest COD value of 111.08 mg/l was noticed under institutional land use.
- The BOD for water sources in Solan block on an average ranged from 1.44 to 12.35 mg/l. BOD of water samples for industrial and urban land use exceeded the permissible limit as

per WHO standards. Industrial land use was recorded to have the maximum BOD value of 12.35 mg/l in the water.

- Calcium content on an average ranged from 51.28 to 90.48 mg/l for water sources. Calcium content of water under different land use except institutional area was within the permissible limit as per WHO standards. The maximum calcium content of 90.48 mg/l was found under institutional land use.
- Magnesium of water sources on an average ranged from 26.87 to 37.76 mg/l. Magnesium content of water under rural and urban land use was found within the acceptable limit as per WHO standards. The maximum concentration of magnesium (37.76 mg/l) was found under industrial land use.
- The Cl^- content of water sources of Solan block on an average ranged from 14.05 to 38.06 mg/l which was within the permissible limit as per WHO standards. The highest value of Cl^- (38.06 mg/l) was recorded in water under institutional land use system.

CONCLUSION

- The perception of people of Solan Block indicated reduction in total water availability during summers due to less rains being experienced in the region during the last two decades.
- Out of the total water sources in Solan District, 22% ground and 30% surface water sources are present in Solan Block.
- In rural and urban areas of Solan Block total of 100688 inhabitants require 19,94,450.87 gallons of water per day. Whereas the total water storage capacity in the area is 52,13,122.28 gallons, which however generally remains 50% unutilized due to less availability of water. Hence, water availability needs to be increased for supplying water as per requirement of the block.
- Industrialization and institutionalization in Solan Block has resulted BOD, COD, Calcium and Magnesium in the water sources above the prescribed standards of WHO. Therefore, study indicated that the developmental activities like industrialization and institutionalization have started impacting the water quality of the Solan Block.

Chapter-7

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ABSTRACT

The investigation entitled “Inventorization of water resources in Solan District of Himachal Pradesh” was conducted during 2012-2013 in Solan Block, District Solan of Himachal Pradesh. To inventorize the water sources, survey was conducted as per prestructured performa. People’s perception was also recorded to verify the inventorisation. To find out the water quality four dominant land use systems namely industrial, urban/suburban, institutional and rural were studied. The collected water samples were analyzed for various parameters like pH, EC, BOD, COD, Ca²⁺, Mg²⁺ and Cl⁻. In Solan Block the total water sources recorded in the field were 3218. After recording the additional small scale sources in the region additional 34 sources was inventorised as compared to the official records. Out of the total water sources only 3070 are being commercially exploited for use in the region and a total of 499 handpumps were installed. Out of the total water sources in Solan District, 22% ground and 30% surface water sources were in Solan Block. The people perception indicated that out of 35 panchayats, seven panchayats have water deficiency. In Solan Block only 303.4 ha of total area is covered under 11 major irrigation schemes utilizing water from Nullahs, Khuds and Rivers. A total population of 62,753 in rural area of Solan Block has a water requirement of 43,92,710 liters per day whereas, that of urban population (37935) was 47,41,875 liters per day. The total water requirement of Solan Block comes recorded was 91,34,585 liters per day for a population of 1,00,688. The total water storage capacity in Solan Block is 52,13,122.28 gallons to meet the demand of 100688 inhabitants along with the water requirement for other purposes. But this capacity remains unutilized many times due to less water availability.. The pH of the water sources ranged from 7.24 to 7.92. The highest value of pH (7.92) was found in institutional landuse system. EC ranged from 0.41 to 0.92 dS/m. Maximum EC (0.92 dS/m) was found in institutional land use. The mean COD value of water was found to range from 63.75 to 111.08 mg/l. The highest COD (111.08 mg/l) was noticed under institutional land use. The BOD for water on an average ranged from 1.44 to 12.35 mg/l. Under industrial land use highest BOD (12.35 mg/l) was recorded. Value of Calcium content ranged from 51.28 to 90.48 mg/l and the maximum calcium content of 90.48 mg/l was under institutional land use. Magnesium of water sources on an average ranged from 26.87 to 37.76 mg/l. The maximum concentration of magnesium (37.76 mg/l) was found under industrial land use. The Cl⁻ content of water sources of Solan block on an average ranged from 14.05 to 38.06 mg/l. The highest value of Cl⁻ (38.06 mg/l) was recorded under institutional land use. Therefore, industrialization and institutionalization in Solan Block has resulted BOD, COD, Ca and Mg content in the water sources above WHO standards. Study indicated that industrialization and institutionalization have started impacting the water quality of Solan Block.

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APPENDIX I
PROFORMA
(Section – A)

1. Name of the panchayat –
2. Total Population :
3. Average land holding/capita -
4. Total Area under panchayat –
5. Number of villages -
6. Total number of families -
7. Total no. of water sources –
8. Total number of handpumps -
9. My observations – _____

Information regarding water source for sample collection (Source no.)

1. Name of the village –
2. Type of the water body –
3. Classification (ground/surface) –
4. Whether the water body is seasonal or perennial –
5. Whether the water body is in working condition or dried -
6. If dried, what is the reason and duration of dryness –
7. If working, availability of water in the source –

Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec

8. Water used for the purpose (for particular water body) -
9. Change in water use scenario -
10. Source of pollution (if any) –
11. Land use pattern nearby –
12. GPS location –

Opinion of the User Groups

1. Availability of water

	Sufficient	Moderate	Deficient
For domestic use			
For irrigation			
For livestock			

2. Availability of water over the years

	Increase	Decrease	Constant
For domestic use			
For irrigation			
For livestock			

3. Reason for change in water availability

For domestic use	
For irrigation	
For livestock	

4. Different water related schemes/projects operational in your area –
5. What is the water distribution mechanism in your area?
6. What are the various water storage facilities in your area?
7. Do you have conflicts over water in your area? If yes what is the nature of conflict?
8. Do you have any other problem related to water?
9. What can be the solution?
10. What are your expectations from the state government/ IPH department?
11. What are the various anthropogenic activities impacting water sources in your area?
12. What initiatives have been taken by you to conserve and protect water sources?
13. Suggestions for conserving water and improving water availability in your area?

APPENDIX-II

Effect of different land use systems and seasons on pH of surface water sources of Solan block

Land use systems	Site						Mean
	1	2	3	4	5	Total	
Industry	7.74	7.72	7.39	7.23	6.85	36.93	7.39
Urban	7.64	7.49	7.45	7.05	6.55	36.18	7.24
Institutional	8.42	8.12	7.98	7.75	7.33	39.6	7.92
Rural	7.6	7.2	7.31	6.68	7.44	36.23	7.25
Total	31.4	30.53	30.13	28.71	28.17	148.94	
CD	0.05						

Annova for Table13: Effect of different land use systems and seasons on pH of surface water sources of Solan block

Source of Variation	DF	SS	MSS	Fcal	Ftab		CD
Site	4	1.76152	0.44038	7.280613	3.259167	SIG	0.34
Land use	3	1.56186	0.52062	8.607186	3.490295	SIG	
Error	12	0.72584	0.060487				
Total	19	4.04922					

APPENDIX-III

Effect of different land use systems and seasons on EC (dS/m) of surface water sources of Solan block

Land use systems	Site					Total	Mean
	1	2	3	4	5		
Industry	1.04	0.7	0.41	0.38	0.37	2.9	0.58
Urban	0.52	0.44	0.38	0.37	0.34	2.05	0.41
Institutional	2.08	0.94	0.57	0.54	0.48	4.61	0.92
Rural	0.55	0.49	0.42	0.3	0.29	2.05	0.41
Total	4.19	2.57	1.78	1.59	1.48	11.61	
CD	0.05						

Annova for Table 13: Effect of different land use systems and seasons on EC (dS/cm) of surface water sources of Solan block

Source of Variation	DF	SS	MSS	Fcal	Ftab		CD
Site	4	1.27237	0.318093	4.034531	3.259167	SIG	0.39
Land use	3	0.873815	0.291272	3.694348	3.490295	SIG	
Error	12	0.94611	0.078842				
Total	19	3.092295					

APPENDIX-IV

Effect of different land use systems and seasons on COD (mg/l) of surface water sources of Solan block

Land use systems	Site						Mean
	1	2	3	4	5	Total	
Industry	119.25	105.25	53	27.25	14	318.75	63.75
Urban	129.6	82.4	56.8	42.8	38.8	350.4	70.08
Institutional	324.6	83.6	50.4	49.6	47.2	555.4	111.08
Rural	141	107.8	63	58.6	46.4	416.8	83.36
Total	714.45	379.05	223.2	178.25	146.4	1641.35	
CD	0.05						

Annova for Table13: Effect of different land use systems and seasons on COD (mg/l) of surface water sources of Solan block

Source of Variation	DF	SS	MSS	Fcal	Ftab		CD
Site	4	54584	13646	6.841088	3.259167	SIG	61.54
Land use	3	6613.133	2204.378	1.105111	3.490295	NS	
Error	12	23936.54	1994.712				
Total	19	85133.68					

APPENDIX-V

Effect of different land use systems and seasons on BOD (mg/l) of surface water sources of Solan block

Land use systems	Site						Mean
	1	2	3	4	5	Total	
Industry	24.75	15	9.25	8.5	4.25	61.75	12.35
Urban	13	6.8	2.6	1.8	1.6	25.8	5.16
Institutional	6.6	3	2.2	2	0.8	14.6	2.92
Rural	2.6	1.4	1.2	1	1	7.2	1.44
Total	46.95	26.2	15.25	13.3	7.65	109.35	
CD	0.05						

Annova for Table13: Effect of different land use systems and seasons on BOD (mg/l) of surface water sources of Solan block

Source of Variation	DF	SS	MSS	Fcal	Ftab		CD
Site	4	241.8083	60.45206	5.808568	3.259167	SIG	4.45
Land use	3	350.8694	116.9565	11.23782	3.490295	SIG	
Error	12	124.8888	10.4074				
Total	19	717.5664					

APPENDIX-VI

Effect of different land use systems and seasons on Ca (mg/l) of surface water sources of Solan block

Land use systems	Site						Mean
	1	2	3	4	5	Total	
Industry	92.25	82.25	56	42.75	42	315.25	63.05
Urban	69.6	66.6	59.6	44.6	33.6	274	54.8
Institutional	126.8	91.6	90.8	87.6	55.6	452.4	90.48
Rural	69	52	50	48	37.4	256.4	51.28
Total	357.65	292.45	256.4	222.95	168.6	1298.05	
CD 0.05							

Annova for Table13: Effect of different land use systems and seasons on Ca (mg/l) of surface water sources of Solan block

Source of Variation	DF	SS	MSS	Fcal	Ftab		CD
Site	4	5081.847	1270.462	14.60155	3.259167	SIG	12.85
Land use	3	4726.366	1575.455	18.10688	3.490295	SIG	
Error	12	1044.104	87.00869				
Total	19	10852.32					

APPENDIX-VII

Effect of different land use systems and seasons on Mg (mg/l) of surface water sources of Solan block

Land use systems	Site						Mean
	1	2	3	4	5	Total	
Industry	78.25	58.5	19.75	17.5	14.8	188.8	37.76
Urban	31.26	29.74	27.68	26.04	19.64	134.36	26.87
Institutional	55.46	39.54	32.72	19.74	14.7	162.16	32.43
Rural	31.08	27.94	27.68	27.5	24.58	138.78	27.76
Total	196.05	155.72	107.83	90.78	73.72	624.1	
CD 0.05							

Annova for Table13: Effect of different land use systems and seasons on Mg (mg/l) of surface water sources of Solan block

Source of Variation	DF	SS	MSS	Fcal	Ftab		CD
Site	4	2521.779	630.4447	3.843057	3.259167	SIG	17.65
Land use	3	375.7202	125.2401	0.763437	3.490295	NS	
Error	12	1968.572	164.0477				
Total	19	4866.071					

APPENDIX-VIII

Effect of different land use systems and seasons on Cl (mg/l) of surface water sources of Solan block

Land use systems	Site						Mean
	1	2	3	4	5	Total	
Industry	55.95	41.48	35.48	35.45	17.63	185.99	37.2
Urban	46.2	36.2	22.4	22	19.34	146.14	29.23
Institutional	64.8	46.8	39.2	30.2	9.3	190.3	38.06
Rural	25.4	12.74	11.6	11.21	9.3	70.25	14.05
Total	192.35	137.22	108.68	98.86	55.57	592.68	
CD 0.05							

Annova for Table13: Effect of different land use systems and seasons on Cl (mg/l) of surface water sources of Solan block

Source of Variation	DF	SS	MSS	Fcal	Ftab		CD
Site	4	2561.65	640.4126	13.26517	3.259167	SIG	9.57
Land use	3	1856.187	618.7291	12.81603	3.490295	SIG	
Error	12	579.3332	48.27777				
Total	19	4997.171					

CURRICULUM VITAE

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