DEVELOPMENT OF CALCULATION METHODS OF HYDROLOGICAL PARAMETERS FOR THE SUSTAINABLE WATER MANAGEMENT IN ARID RIVER BASIN

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DEVELOPMENT OF THE CALCULATION METHODS OF HYDROLOGICAL PARAMETERS FOR THE SUSTAINABLE WATER MANAGEMENT IN ARID RIVER BASIN

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By

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CONTENTS

ABSTRACT

More than 85% of the area of Uzbekistan are in arid or semiarid conditions, including Kyzylkum desert, the largest desert of Central Asia. Uzbekistan is perhaps the most vulnerable of the Central Asian countries with respect to water resources and irrigated agriculture, because it has the largest irrigated area (4.3 million ha), the biggest rural population (more than 14 million) and the highest population density of 49.6 persons per square kilometer. Being an arid country, but a large consumer of water, derived from sources lying outside of its borders, Uzbekistan suffers heavy damages from water shortage. Most of the nation's water resources are used for farming, which accounts for nearly 84% of the water usage and contributes to salt damage. Heavy usage of pesticides and fertilizers for cotton growing caused soil and water pollution of the region.

The current research indicates the development of computation methods to management and evaluation of the condition of the hydrological parameters for the sustainable water management in the arid river basin. As a research area has been selected the Chirchik and Kashkadarya River basins, where the management of water resources and land salinization is a continuing problem. The Chirchik River basin is the largest right-hand bank tributary of the Syr-Darya River, and a population of more than 2.7 million of the Tashkent region depends on the sensitive water resources of the Chirchik River basin. No other viable alternative resources exist excluding the Chirchik River for providing potable water to residents in the Tashkent region. The second largest and strategically important area of the country is Kashkadarya province, the driest region of the Uzbekistan, whose annual precipitation is 300-350 mm/year and evaporation rate is 1300-1700 mm/year. In the past 70 years, the river flow of the Kashkadarya River did not reach the Amu-Darya River, because of the huge amount of water intake for the agricultural purposes and the river water is completely lost in the Kyzyl-Kum desert. In this context, water resources of the Kashkadarya River basin are fully mobilized for the irrigation purposes. The water balance model development is considered to be an important part in the establishment of sustainable water management policies for the Chirchik and Kashkadarya River basins. The water balance model is developed by using the ArcGIS and MIKESHE commercial software.

The ArcGIS provides a wide reach of powerful spatial modelling and analysis capabilities for producing and applying maps, compiling geographic data, managing of the geographic information in a database and etc., and the MIKE SHE is an integrated hydrological modelling system for creating and assuming the entire land phase of the hydrologic cycle and allows portions to be used independently and customized to the roles.

The developed model enables analysis of the complex hydrogeological regime in the regions, and forecasting of the environmental impacts on the various management options. The model simulates all hydrological processes in the Chirchik and Kashkadarya River basins, including evapotranspiration of a watershed, precipitation, overland flow, unsaturated and saturated flow and infiltration for both calibration and validation periods.

Chapter 1 explains the general framework and the background of the problem, as well as the detailed plan and a brief introduction of the method employed in this study.

The MIKESHE model and ArcGIS tools require reliable information about all components of both river basins, such as: actual evapotranspiration (ET) of a watershed, precipitation, overland flow (OL), unsaturated (UZ) and saturated (SZ) flow, infiltration and etc. As can be seen, all detailed information on the natural characteristics of the Chirchik and Kashkadarya River basins are described with spatial distribution of the different components of the river basins have been shown in Chapter 2. As a consequence of the comparison of the spatial distribution, water balance results of the two river basins show that the both river basin's environment is depleted and water management systems are worse situation.

Regarding the importance of the climatic factors in the runoff formation of water resources, in Chapter 3 have been introduced a new interpolation method of climatic parameters by using barycentre method. Analysis and evaluation of scientific and practical data determined that the existing methods of interpolation of climatic parameters of the territory due to the significant variability of the landscape of the surface does not contribute obtaining the accurate climate data. Under these conditions, the proposed interpolation method can produce a mixed system of climatic factors at the midpoint (center) of the motion of each climatic parameter, with a unique centre (barycentre). The calibration results of the current interpolation methods and new developed method (including the similar asumptions) with observed results showed that the developed method has the most similarity to the actual observed data. By using the developed interpolation method have been calculated the water balance of the Chirchik and Kashkadarya River basins and has been obtained acurate water balance errors.

In Chapter 4 described the method for forecasting groundwater level in an arid area according to climatic data. In the territories with an arid climate, productivity of irrigated agriculture largely determines the condition of the moisture of territory and groundwater levels. The numerical implementation of the water balance equation and by using the MIKESHE an integrated hydrological modelling system has been obtained the accurate hydrological water balance of the river basins to monitor the seasonal change of the spatial distribution of the groundwater levels through the basin. The monitoring of the ground water level in river basins can protect the soil from the salinization and erosion, which is the main problem in arid areas.

Moreover, in Chapter 5 have been presented the modeling of water and salt balance for sustainable water management in river basins for the sanitarization purposes. In arid areas the water and salt balance equations give the qualitative and quantitative management of the river basin and their sanitary protection. Development of the applicable formula for calculation allows forecasting and management of water quality in the rivers, especially in arid and semi-arid regions with crop irrigation systems.

In the final analysis, Chapter 6 summarizes all prepared conclusions according to the research findings. The obtained results in the framework of the research are useful for arid and semi-arid areas and along with to solve various problems associated with the sustainable use of water of the territories, as well as to analyze and assess their impact on different processes in the environment.

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The completion of my dissertation and subsequent Ph.D. has been a long journey. It’s true that “Life is what happens” when you are completing your dissertation. Life doesn’t stand still, nor wait until you are finished and have time to manage it. Much as happened and changed in the time I’ve been involved with this project. My dissertation has always been a priority, but as most know, there are several priorities in a person’s life at any one time. I could not have succeeded without the invaluable support of several. Without these supporters, especially the select few I’m about to mention, I may not have gotten to where I am today, at least not sanely. I’d like to give special thanks, beginning with my supervisor Professor Yasuhiro MITANI, who helped push me through the research activities.

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July 2015

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

The Aral Sea used to be the fourth-largest inland sea in the world, influencing humidity and aridity for land use around it. The water level of the Aral Sea began to decline dramatically in the 1960's after the Soviets diverted the two rivers that feed it to irrigate the desert to grow rice, melons, and cotton. Therefore, it has been shrinking and now it is less than 10% of its original area. Irrigation projects successfully transformed Uzbekistan into the world's top cotton exporter by 1988, but it was brought at a heavy cost.

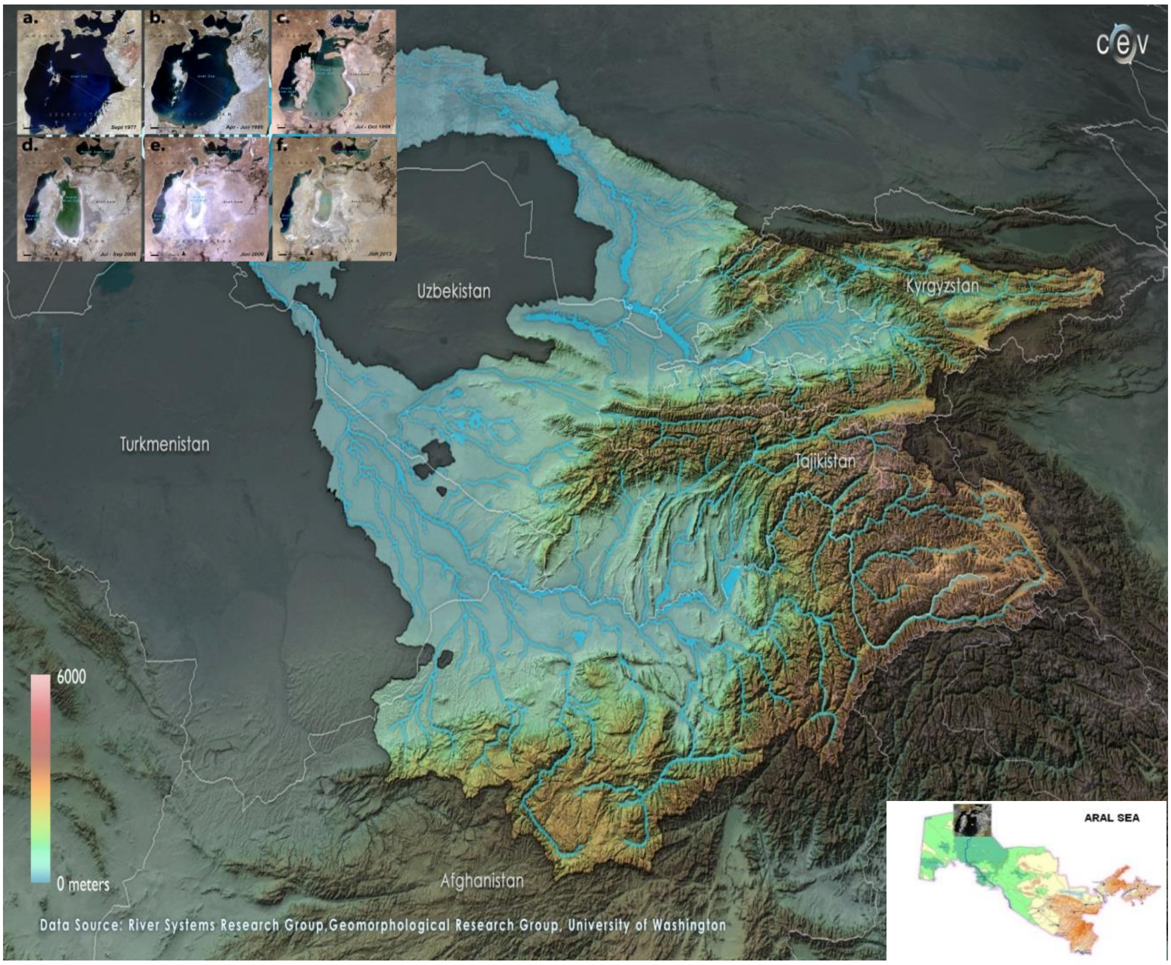


Figure 1.1: The Aral Sea 1960 and 2014 years (source: Geomorphological Research Group, University of Washington).

The shrinking sea leaves huge plains covered with salt and toxic chemicals from weapon testing, pesticides and fertilizers. Dust is carried away by wind and people living around in the area suffer from higher rates of cancer and lung diseases (Kashkarov 2008).

The most serious environmental problems threatening the country's natural resources are increasing salt damage and water contamination, wind and water erosion of farm land, overgrazing by livestock, deforestation and the loss of biodiversity, and a reduction in productivity of arable lands. Recognized causes of land degradation include inappropriate land use, mainly unsustainable agricultural practices, insufficient maintenance of irrigation and poor drainage infrastructure, and excessive use of surface and ground waters. During the past 15 to 20 years, there also has been widespread degradation of pasture lands due to overgrazing, lack of pasture maintenance, and other anthropogenic activities (Chub 200).

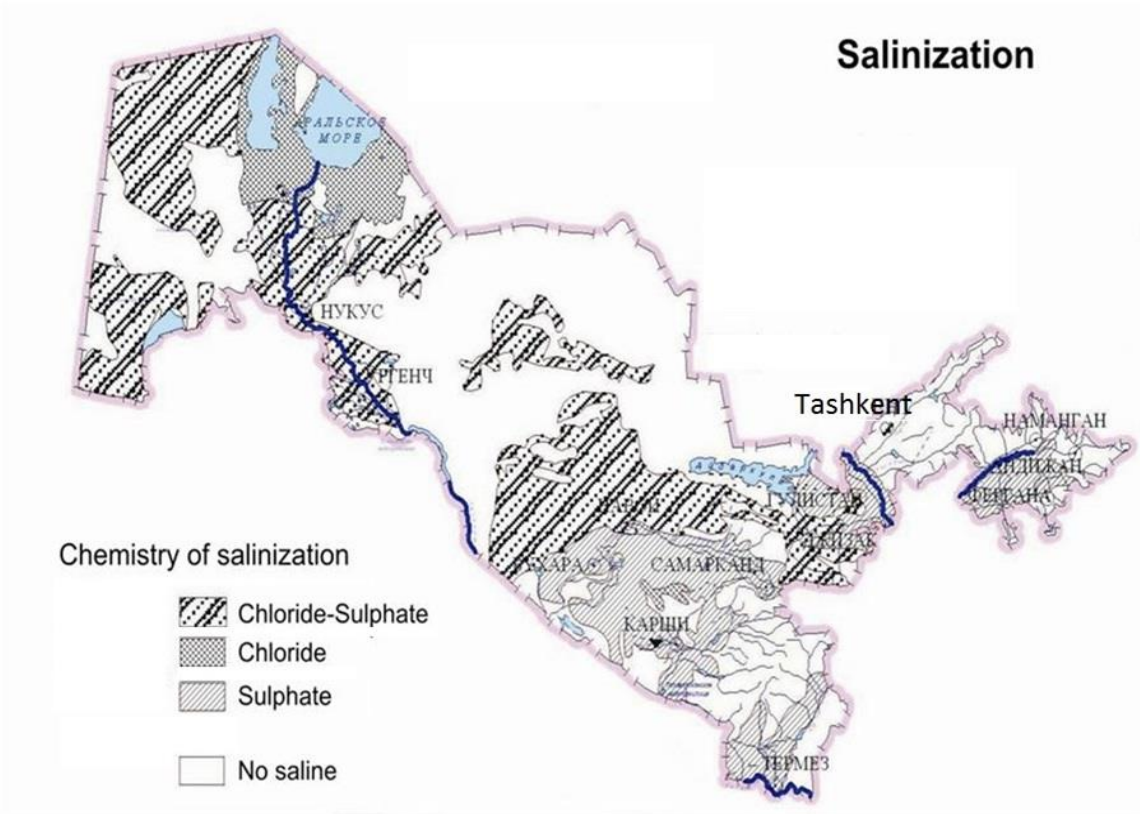


Figure 1.2: Salinization map of the Uzbekistan (source: Ministry of Agriculture of the Uzbekistan).

Up to 53% of the Uzbekistan's irrigated lands are exposed to varying degrees of salinization. Over 50% of the farmland suffers from erosion by wind and water, and continuing losses of the most fertile topsoil layer are experiencing continuing. The inappropriate irrigation practices by far surpass natural causes.

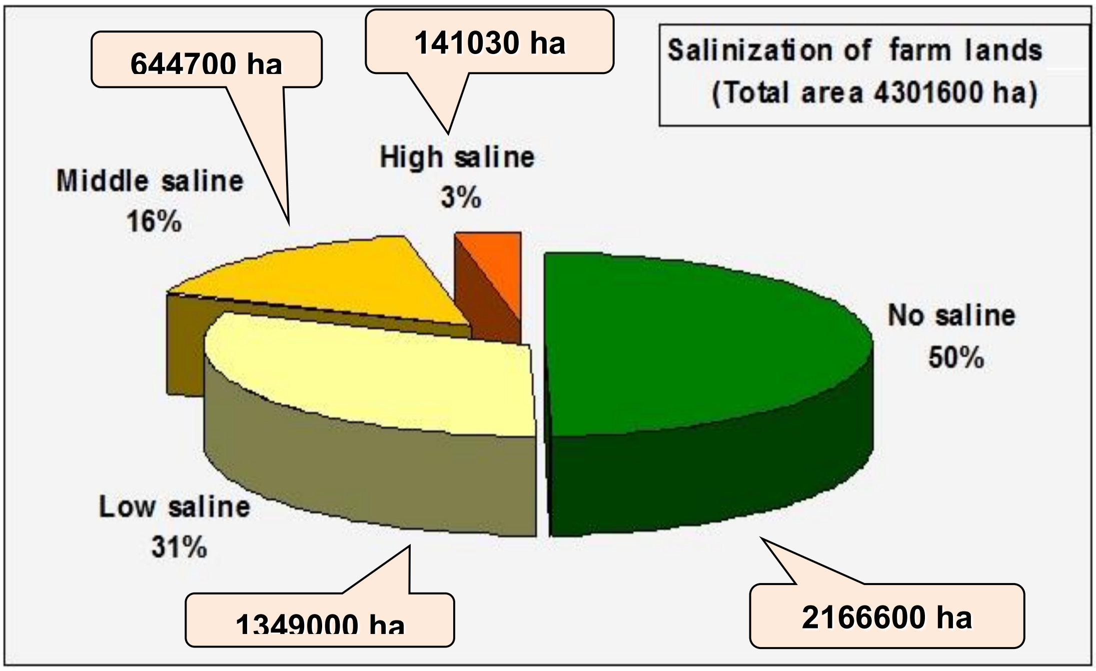


Figure 1.3: Salinization of farm lands in Uzbekistan (source: Ministry of Agriculture of the Uzbekistan).

Drying-up of the Aral Sea and subsequent exposure of the former seabed disperse toxic substances with dust storms and bring serious ecological and health problems to the region.

Therefore, the rational use and protection of farmland become national economic issues. To determine an appropriate strategy to control and use of water resources, reliable data are needed for the current conditions prevailing within the Chirchik and Kashkadarya River basins.

1.1.1 The Chirchik River Basin

The Chirchik River, the largest right-hand bank tributary of the Sirdarya River, a population of more than 2.7 million depends on the sensitive water resources for supply. Water is pumped from five large, well fields (about 45% of the Tashkent's domestic supply), numerous smaller well fields, and surface water. Deteriorated water quality brings a serious threat to human health and the environment in the basin. No other viable alternative resources exist excluding the Chirchik River for providing potable water to residents in the Tashkent region (Bedrincev 1975).

The development of Agra-industrial complex and its activity in the last few decades, especially during the period, 1975-1993, based on major national economic projects without environmental studies, brought negative impacts to the environment and water resources (Makhmudov 2010).

The most powerful and stable sources of anthropogenic impacts on the aquatic ecosystem within the cities and towns in the Chirchik River basin are industries, transportation and utilities. The degree of danger to human health and influential area differs place by place. Therefore, the real environmental situation in cities and towns of the basin has not cleared yet on contaminant sources and on influential area and its degree. But industrial effluents discharged into streams clearly result in environmental pollution, in particular, water pollution.

A highly diversified industrial complex of the Tashkent region has significant impacts on the environment. Especially water resources which are the basis for sustainable development of the district and at the same time, one of the most vulnerable components of life environment are to be protected.

The complexity of water problems is not only providing the necessary amount of water to meet growing demand there, but progressively deteriorating water quality under the influence of sewage and all sorts of the wastes. The development of ferrous metallurgy, chemical, petroleum, energy and mining industries occurs a significant problem with the environment in the capital city.

1.1.2 The Kashkadarya River basin

The most unfavourable area of water supply in Uzbekistan is the Kashkadarya region, in particular its old irrigated zone, where the main source of water is the Kashkadarya River.

It should be noted that the Kashkadarya River basin is an important part of the Amu Darya basin. For a full-scale use of water resources in the Kashkadarya River basin, large amount of reservoirs were built such as Chimkurgan (500 million m^3), Pachkamar (260 million m^3) and Gissarak (170mln. m^3) reservoirs. The potential volume of the reservoirs becomes 10 million m^3 (Hasanov 2005).

In addition to effective water use achieved by the complete regulation of the river flow, there is also two to three times of reuse of water for irrigation. Excessively high levels of the use of runoff brings Kashkadarya to severe degradation of river ecosystems and the midstream and downstream channels converted into the reservoir are needed to remove wastes and drained polluted waters. Ecosystems in the river and adjacent areas have been degraded more than the living conditions of the residents. The Kashkadarya region's economy depends essentially on the use of water resources. Most of the residents are engaged in irrigated agriculture in the basin and it gives almost all products of this area.

The Kashkadarya region is divided into two groups in the environmental characteristics: the western plain and eastern mountain zones. Most of the flat areas are in the Karshi desert area (altitude 200 - 400 m). The Karshi desert area includes the Dzham plain, which is composed of loess, with altitudes of 500 - 600 m. Intensive irrigated agriculture is found in the river basin, especially in the Kashkadarya River area. All the western part of the basin received water from the Amu Darya River through the centralized Karshi channel (Bedrincev 1975).

Dynamic change of current conditions in the Kashkadarya River along its water course within the flat basin area depends not only on the physical and geographical factors, but also from human activities.

1.2 OBJECTIVES OF THE RESEARCH

This study focuses on the analysis and evaluation of problems on the use and management of water resources in Uzbekistan. In connection with the above, to consider methods of sustainable management of water resources in the Chirchik and Kashkadarya River basins and efficient use of water resources are targeted for environmental protection and living conditions for the residents in the river basins. This also highlights the problems associated with the use of water resources in the sectors of the economy of Uzbekistan.

From a practical point of view, this research aims at development of recommendations for the prevention of negative actions, both on surface and ground waters and for the rational use of water and protection of living in the Tashkent and Kashkadarya regions. Analysis of field data undertaken makes possible to assess the current state of water sources and make recommendations for their effective and sustainable management.

The water balance model is developed by using the ArcGIS tools and MIKESHE integrated model. The developed model enables analysis of the complex hydrogeological regime in the regions, and prediction of the environmental impacts of various management options.

The main objectives of this study are to develop the water balance model by using the ArcGIS tools and MIKESHE integrated model in the Chirchik and Kashkadarya River basins in Uzbekistan. In order to achieve these objectives, the following research objectives are formulated:

- Analysis of natural and climatic characteristics of the Chirchik and Kashkadarya River basins;
- Study on the formation and use of water resources of the river basins;
- Calculation of the hydrological cycle in the Chirchik and Kashkadarya River basins to understand and obtain current problems on management;
- Development and modification of estimation methods for the calculation of water balance for the arid river basins;
- Conclusions and recommendations on sustainable water management for the arid river basins;

REFERENCES

1. Bedrincev K.N., Korjavin B.D.,(1975). Irrigation of Uzbekistan, Volume 1, Tashkent, Uzbekistan.

2. Kashkarov R.D., (2008). Ecological Atlas of Uzbekistan. UNESCO Office in Uzbekistan, Tashkent, Uzbekistan.

3. Makhmudov E.J, Ishanov X.X., (2010). Global Network for Water Development Information in Arid and Semiarid Regions of Asia, UNESCO, pp. 27-34.

4. Hasanov D. N., (2005). Development of Hydrogeology and engineering geology in Uzbekistan, Gidroingeo, Tashkent, Uzbekistan.

5. Chub V.E., (2000). Climate change and its impact on the natural resource potential of Uzbekistan, Tashkent, p. 127.

CHAPTER 2: GENERAL CHARACTERISTICS OF THE RIVER BASIN

2.1 INTRODUCTION

Uzbekistan lies between latitudes 37°N and 46° N, and longitudes 56°E and74° E. It stretches 1,425 km from west to east and 930 km from north to south. Bordering to Kazakhstan to the north and the Aral Sea to northwest, Turkmenistan to the southwest, Tajikistan to the southeast, and Kyrgyzstan to the northeast, Uzbekistan is one of the largest Central Asian countries. Uzbekistan also shares a short border (less than 150 km) with Afghanistan to the south (Kashkarov 2008).

Figure 2.1: Central Asia map (source: https://en.wikipedia.org/wiki/Central_Asia).

Tashkent is the capital of Uzbekistan and the largest city in Central Asia. It is located in the northeastern part of the country, between the Syr Darya River and the Tien Shan Mountains. It covers an area of 15,260 km². The population is around 4,450,000.

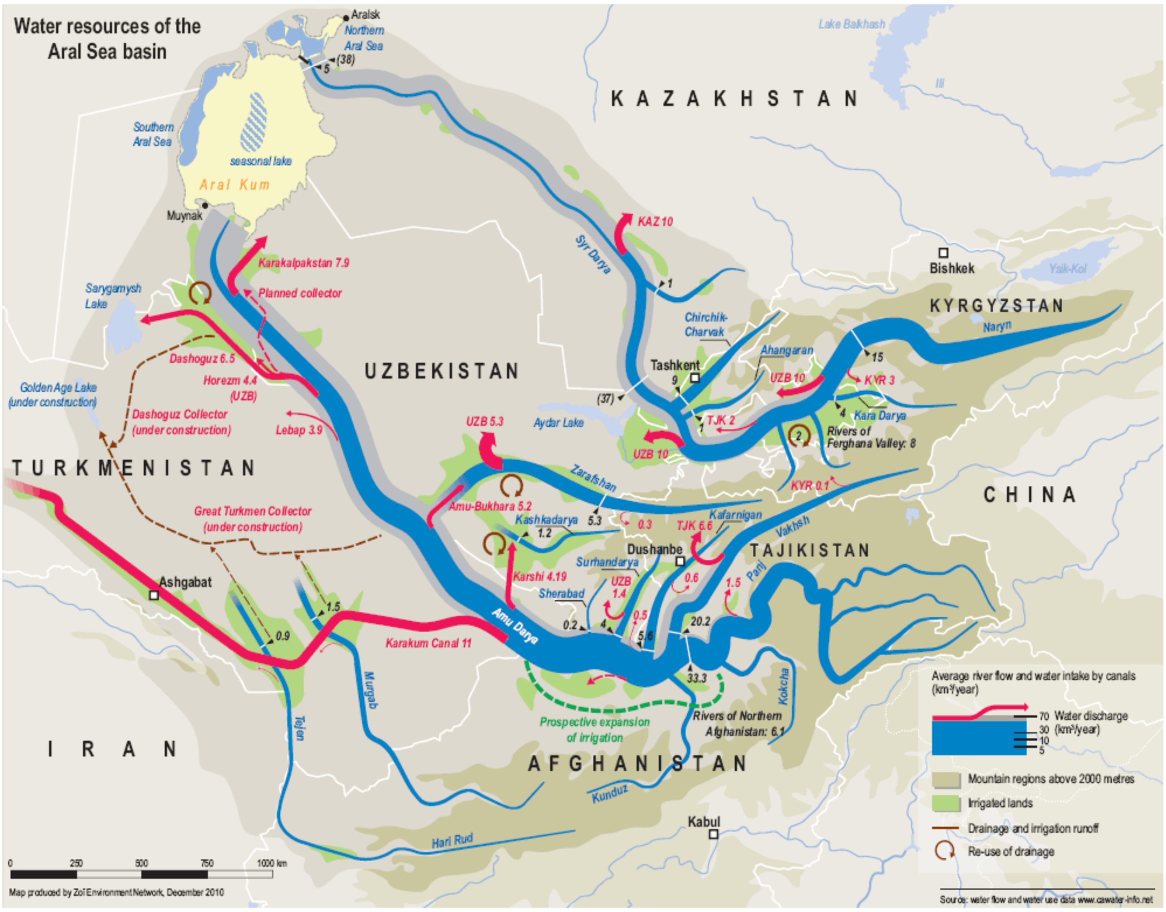


Figure 2.2: Water resources of the Aral Sea basin (source: http://geocurrents.info/Aral-Sea-Water-Map).

The target areas of this study are two river basins: the Chirchik River basin, which is the main water resource in the Tashkent region and the Kashkadarya River basin where water resources are limited.

In addition, since it is located in two endorheic basins, none of its rivers flow to the sea. Less than 10% of its area is intensively cultivated with irrigation in the river basins and oases. The rest consists of a vast desert (Kyzyl Kum) and mountainous areas.

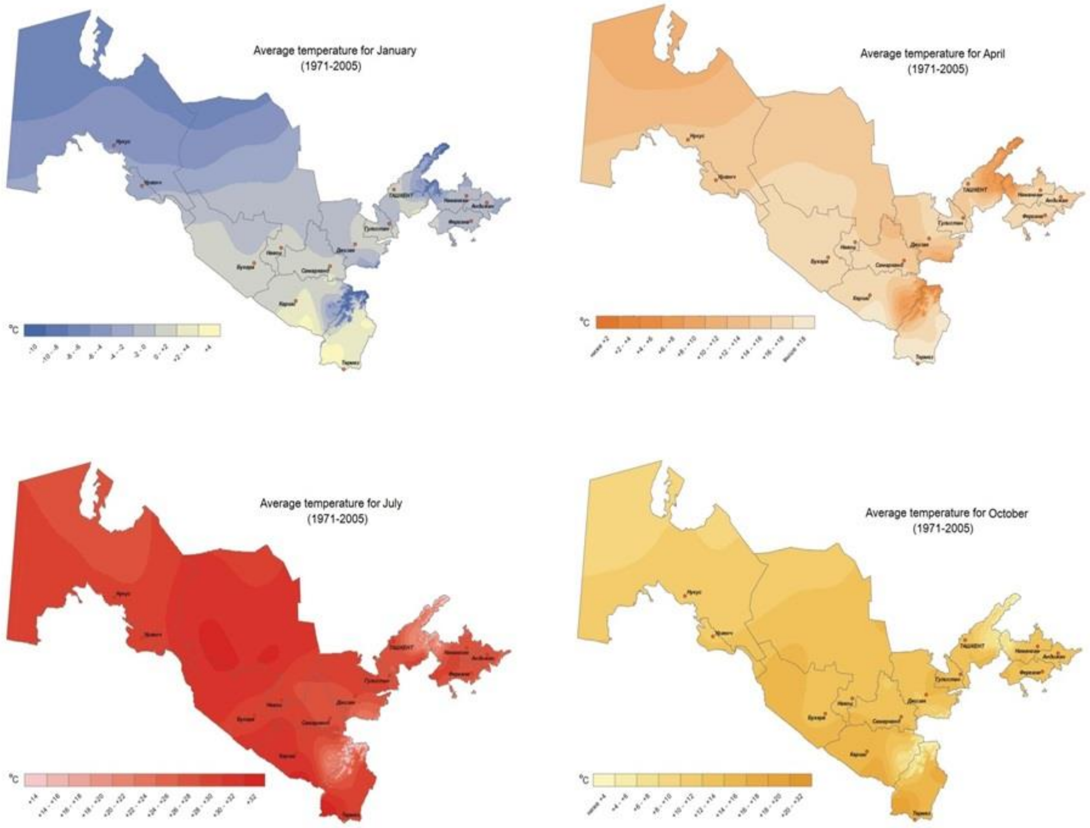


Figure 2.3: Seasonal change of the average air temperature in Uzbekistan (source: Uzbekistan Hydrometeorological Center).

Uzbekistan is continental in climate, with an annual precipitation of 100–200 mm. The average high temperature is 40 °C, while the average low temperature is around −23 °C.

2.1.1 The Chirchik River basin

The Chirchik River basin has cities including the capital of Uzbekistan, Tashkent, and about one hundred villages.

The main water source of the Tashkent region is the Chirchik River, which has a large catchment area in good conditions of flow. Natural water streams with alluvial deposits are the sources of groundwater. During the period of low water, a water shortage is observed in the river mouth. The Chirchik River formed in high mountainous areas due to snowfall and ice melting. In addition to natural watercourses in the areas a widespread network of ancient-artificial irrigation and collector-drainage canals exists in the Chirchik River basin which is 1424 km^2 in area (Bedrincev 1975).

Figure 2.4: Location of the Tashkent region (Source: http://www.maphill.com/uzbekistan/tashkent-oblast/).

Tashkent Province consists of 16 regions: Bostonlik, Tashkent capital, Tashkent, Qibray, Parkent, Yuqori Chirchik, Orta Chirchik, Quyi Chirchik Chinoz, Yangiyol, Oqqorgon, Piskent, Boka, Zangiota, Bekobod and Angren. The province has the borders with Kazakhstan in the north, Kyrgyzstan in the east and Tajikistan in the south (Figure 2.4).

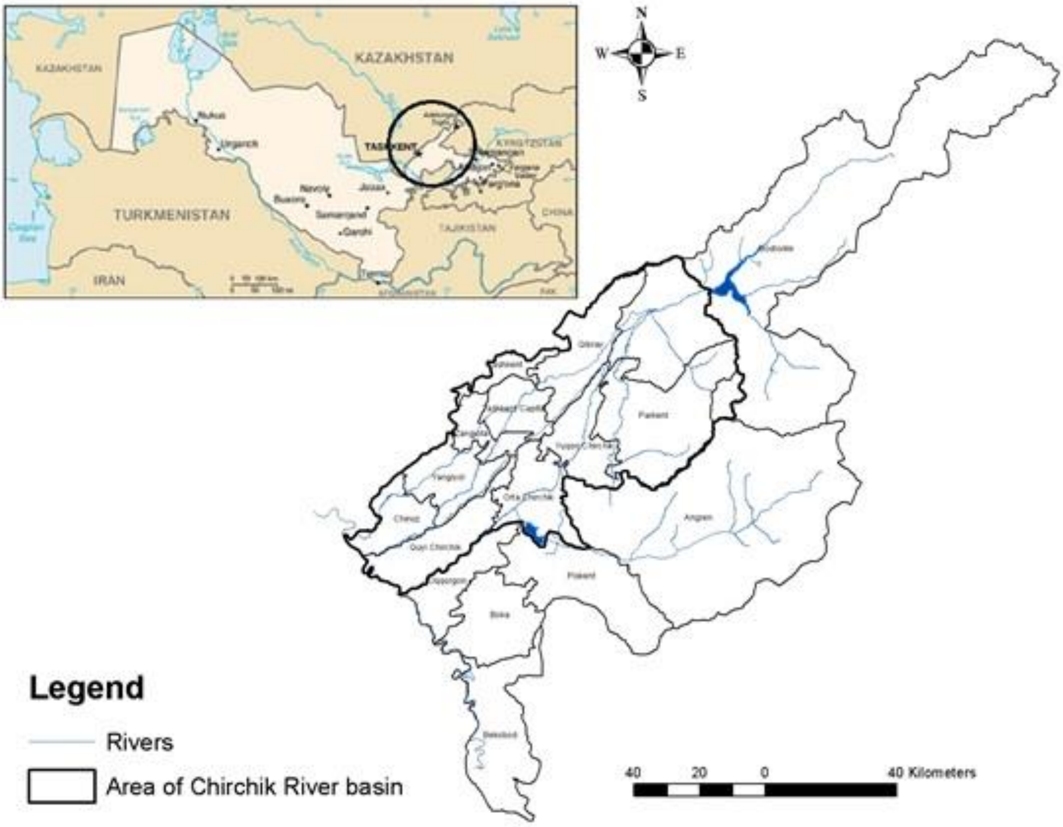


Figure 2.5: Tashkent Province.

The Chirchik River is formed by the conjunction of the Pskem and Chatkal Rivers. The Chirchik River is 161 km in length and 14240 km^2 in the catchment area and to which water inflows by snow and glacier melting. The Chirchik River flows with its maximum discharge in June. The mean annual discharge in the Chirchik River is 200 m^3/s and the annual flow rate is about 7.9 km^3. The Chirchik River takes water from two relatively big tributaries; the Ugam River (length 68 km long and 866 km^2 in the water catchment area) and the Koksu River (57 km long and 372 km^2 in the water catchment area) (Bedrincev 1975).

The area of the Chirchik River basin is 5626 km^2 and it covers almost one third of the region of Tashkent Province. The basin covers 11 regions (partially Bostonliq region) of Tashkent Province. As shown in Figure 2.5, the river direction arises from the southeast toward to northwest in the basin.

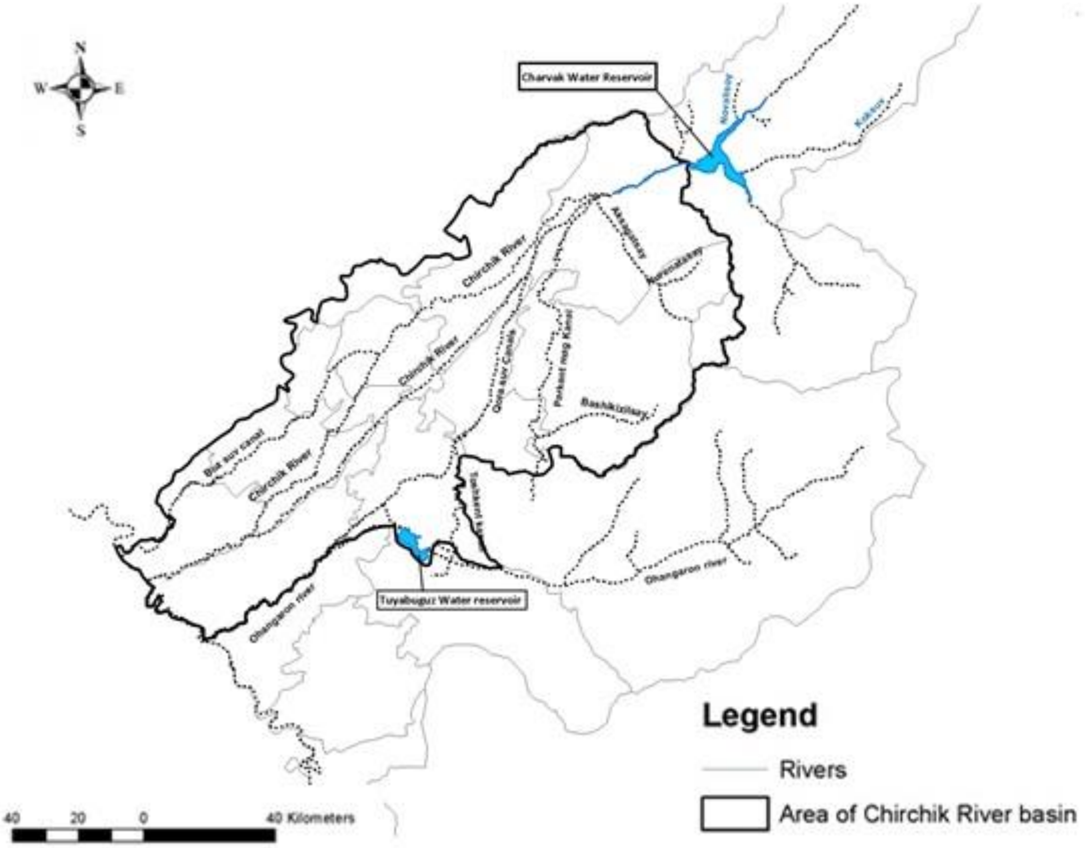


Figure 2.6: Location of the Chirchik and Ohangaron Rivers and their tributaries.

As Shown in Figure 2.6, the area of the Chirchik River basin consists of the upper stream in the northeast and downstream in the southwest part. The elevation ranges from 3500 m to 205 m and the total area is 5626.22 km^2. The southwestern part of the basin is almost topographically plain. Therefore the boundary of the basin in the upper stream is delineated along the mountainous range and the downstream part is done by the administrative boundary of the district of Tashkent Province. The Chirchik River is mainly formatted by water from the Charvak dam and the Ugam River. Therefore the water supply to the Chirchik basin through the Chirchik River is easily calculated by the sum of the flow rates of the Charvak and Ugam gauging stations. The locations of gauging stations are shown in Figure 2.7.

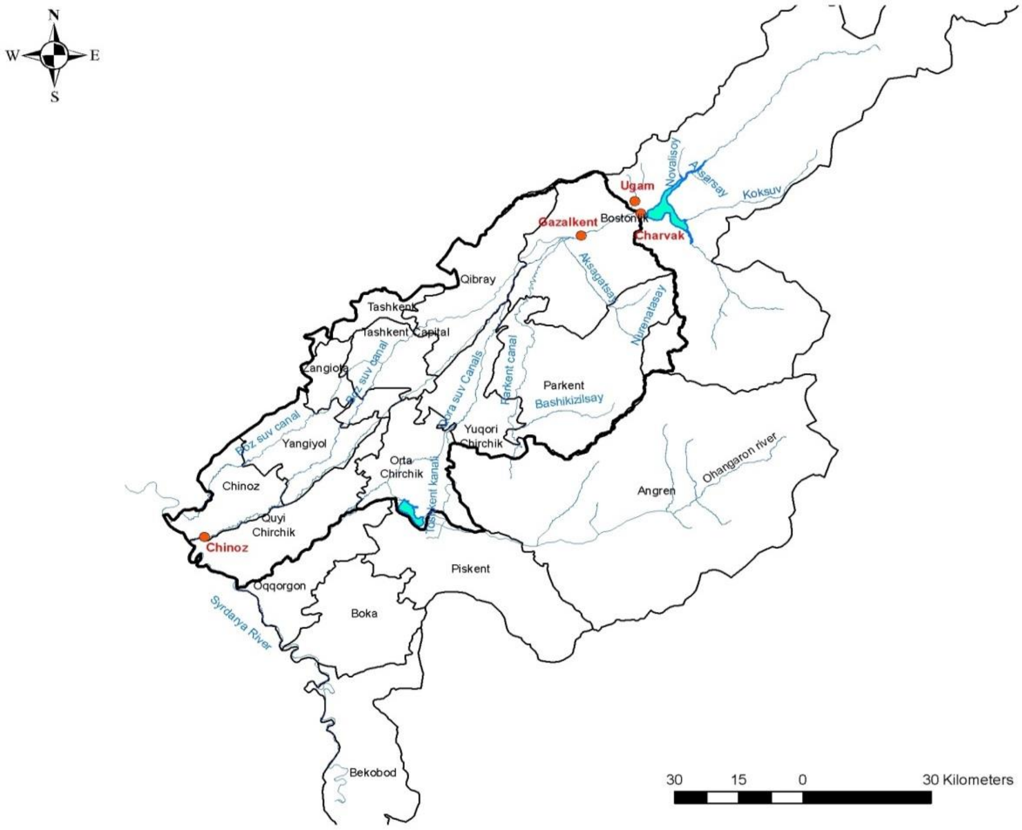


Figure 2.7: Water cause map of Tashkent Provinces.

After passing through Gazalkent gauging station, part of the water of the Chrichik River flows to Qarasuv, and the Parkent and Bozsuv canals distribute water to other districts. Rest of water of the Chirchik River with returning water from irrigated fields is discharged to the Syrdarya River through the Chinaz gauging station. The total water inflow to the Chirchik River basin via the Chirchik River and the total outflow from the basin via the Chinaz gauging station for 2007-2010 are given in Figure 2.7.

In most cases, groundwater is used for water supply to villages, towns and cities of Tashkent (Gazalkent, Chirchik Yangiyul, and Toytepa).

Environmental conditions of the area are not good and industrial factories, landfills, and chemicals in agriculture have given negative impact. At the same time, ground water is the only reliable source of drinking water supply (Chub 2000).

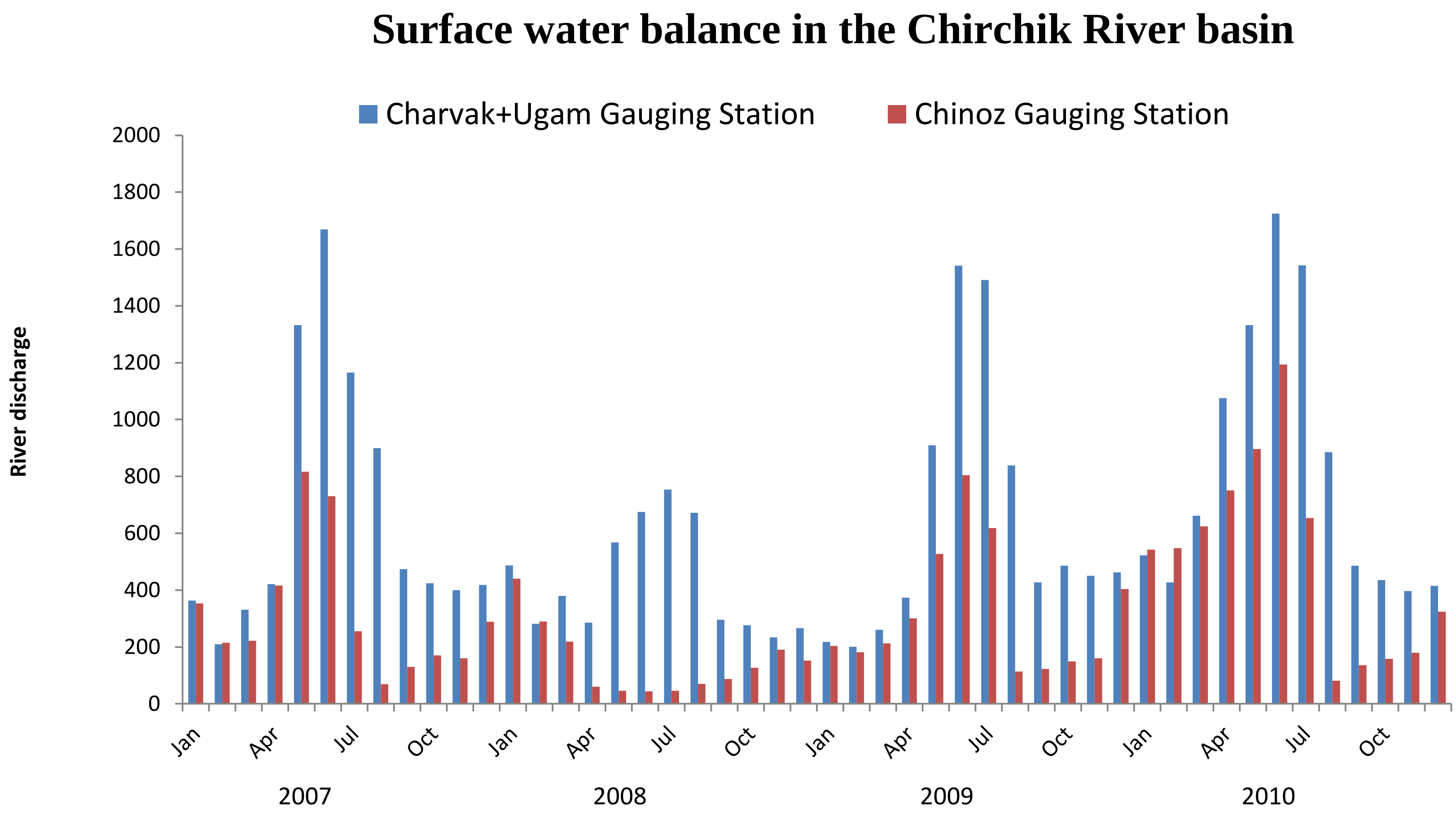


Figure 2.8: Total Inflow and outflow rates of the Chirchik River (source: Ministry of Agriculture of the Uzbekistan).

According to Figure 2.8, the water loss in the basin is not so much in the wintertime and increases from March as starting the vegetation period of main crops (cotton and wheat). The maximal use of water in the Chirchik River is observed in summer. Accurate estimation of the water balance can tell where all the lost water goes. But logically main part of water is evapo-transpired because the major part of river water is irrigated.

The highly diversified industrial complex in Tashkent region gives a significant impact to the environment. Water resources are, in essence, the basis for sustainable development of the district and at the same time, water is one of the most vulnerable components of life environment.

In the Chirchik River basin in addition to large group intakes and a powerful distribution network, and supplying drinking water to the city, an extensive sewerage system that collects sewage in the city and passing through to wastewater treatment plants (WWTPs). The largest sewage network is located in the city of Tashkent.

The lack of efficient technologies and industrial facilities for re-processing of industrial wastes has led to the creation of a large number of different kinds of special storage, lagoons and other facilities with natural and artificial impervious screens.

A particular danger of them is a toxic liquid waste from chemical industries, as well as major oil storage facilities and livestock farms. They contain significant amounts of toxic waste and nutrients (Chub 2000).

This study is provided by calculation in the evaluation of all factors that have an impact on the condition and use of water resources as well as developing a sustainable management model in where management of water resources could ensure sustainable aquatic ecosystems in the Chirchik River basin.

2.1.2 The Kashkadarya River basin

The Kashkadarya region is located in the southwestern part of the country and is bordered on the north by the Samarkand region, in the west and north-west of Bukhara, Navoi, and southeast of the Surkhandarya region (Figure 2.9).

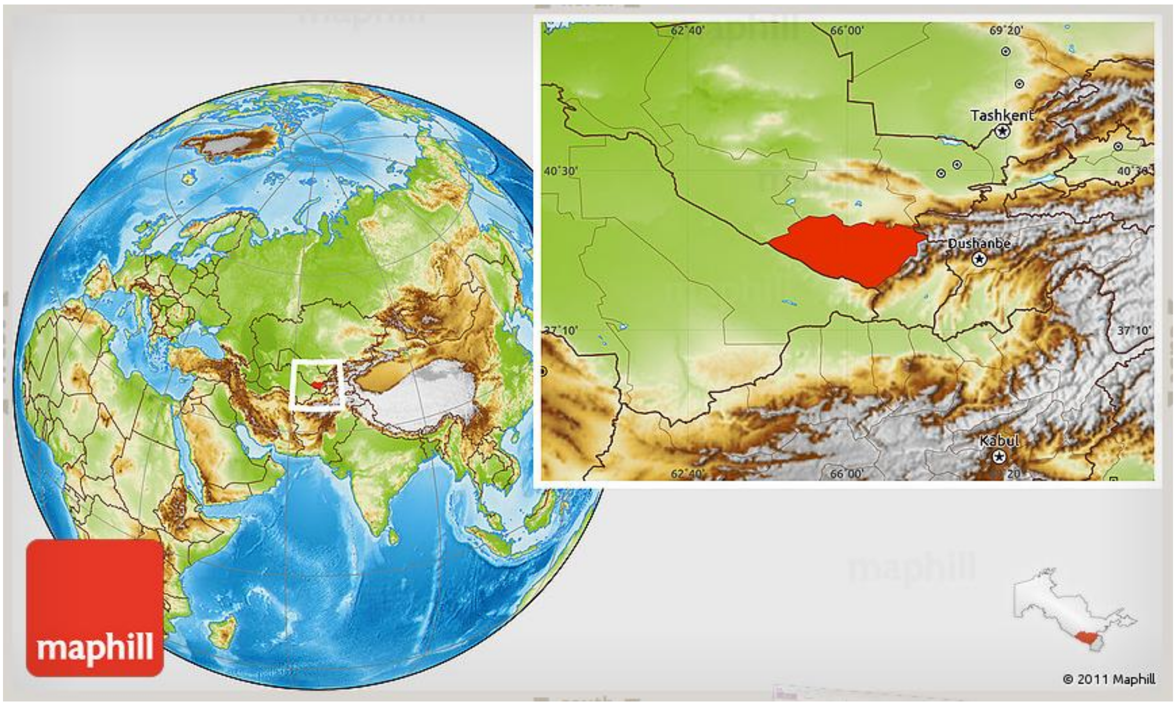


Figure 2.9: Location of the Kashkadarya region (Source:http://www.maphill.com/Uzbekistan/kashkadarya/).

The Kashkadarya region occupies 28,568 km^2 of the land that is more than 6.3% of the territory of Uzbekistan. The total population of the Kashkadarya region is 2,359,000 people, of whom 1,710,000 live in rural areas in 2009.

The Kashkadarya region of Uzbekistan named after its main water artery Kashkadarya River, which crosses the region of the mountain range in the Hissar.

The most densely populated areas in the north-eastern part of the province are Shahrisabz and Kitab. In Uzbekistan, the driest area is the Kashkadarya region, whose precipitation is 300-350 mm / year and evaporation rate is 1300-1700 mm / year (Petrov 2005).

However, at this moment, in the Kashkadarya region is only 5-10% of the area in sewage treatment service.

In this regard, for the irrigation area only water resources of the Kashkadarya River basin are fully mobilized for the purpose of irrigation (Bedrincev 1975).

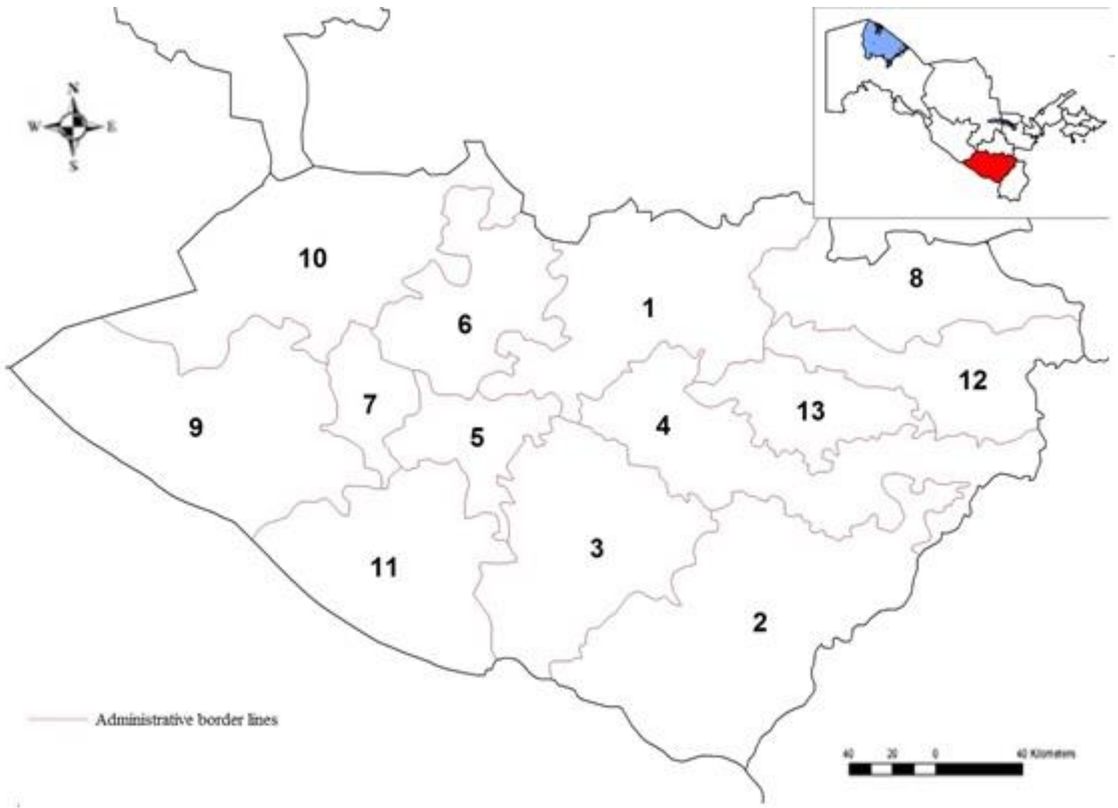


Figure 2.10: Administrative regions of Kashkadarya Province.

The Kashkadarya Province consists of 13 regions: 1-Chiroqchi District, 2-Dehkanabad District, 3-Guzar District, 4-Kamashi District, 5-Karshi District, 6-Kasby District, 7-Kitob District, 8-Koson District, 9-Myrishkor District, 10-Muborak District, 11-Nishon District, 12-Shakhrisabz District and 13-Yakkabog District (Figure 2.10).

The Kashkadarya River has recently become water inlet and drainage with a volume of about 600 Mm^3 / year. The hydro-chemical regime of the Kashkadarya River was formed under the influence of natural and anthropogenic functions.

Water pollution is caused by trace elements and soluble forms of nitrogen; copper up to 2.7 mg/l; zinc to 15.5 mg/l; nitrite to 0.023 mg/l; nitrate to 1.24 and ammonium nitrogen to 0.04 mg / l.

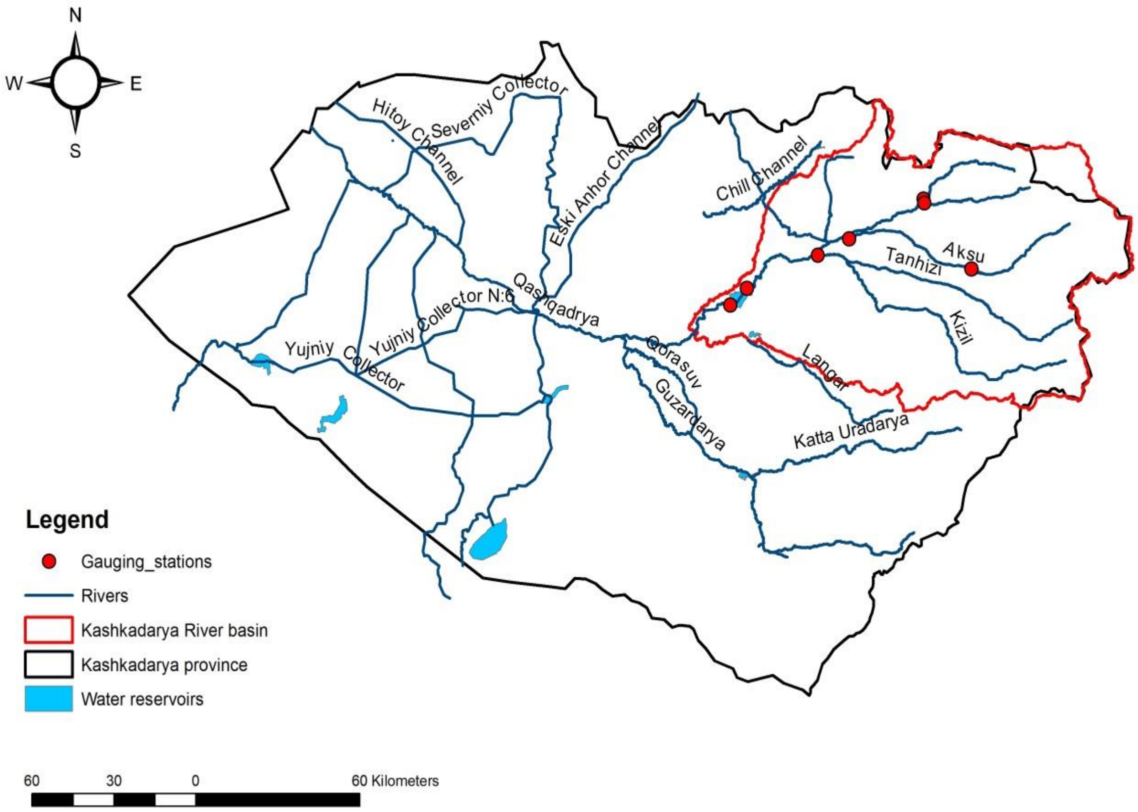


Figure 2.11: Location of river tributaries of the Kashkadarya region.

From Kashkadarya River's lower reaches, the concentration of minerals is 0.38 g/L and its main composition is sulfate-bicarbonate-calcium. By 2010 salinity in the lower reaches increased to 2.6 g/l with chloride, sulfate, calcium, magnesium, and sodium, which have a negative impact on water use in the river basin (Makhmudov 2010). The most important adverse impact is in the daily lives of residents. Location of river tributaries of the Kashkadarya region has been shown in Figure:2.11.

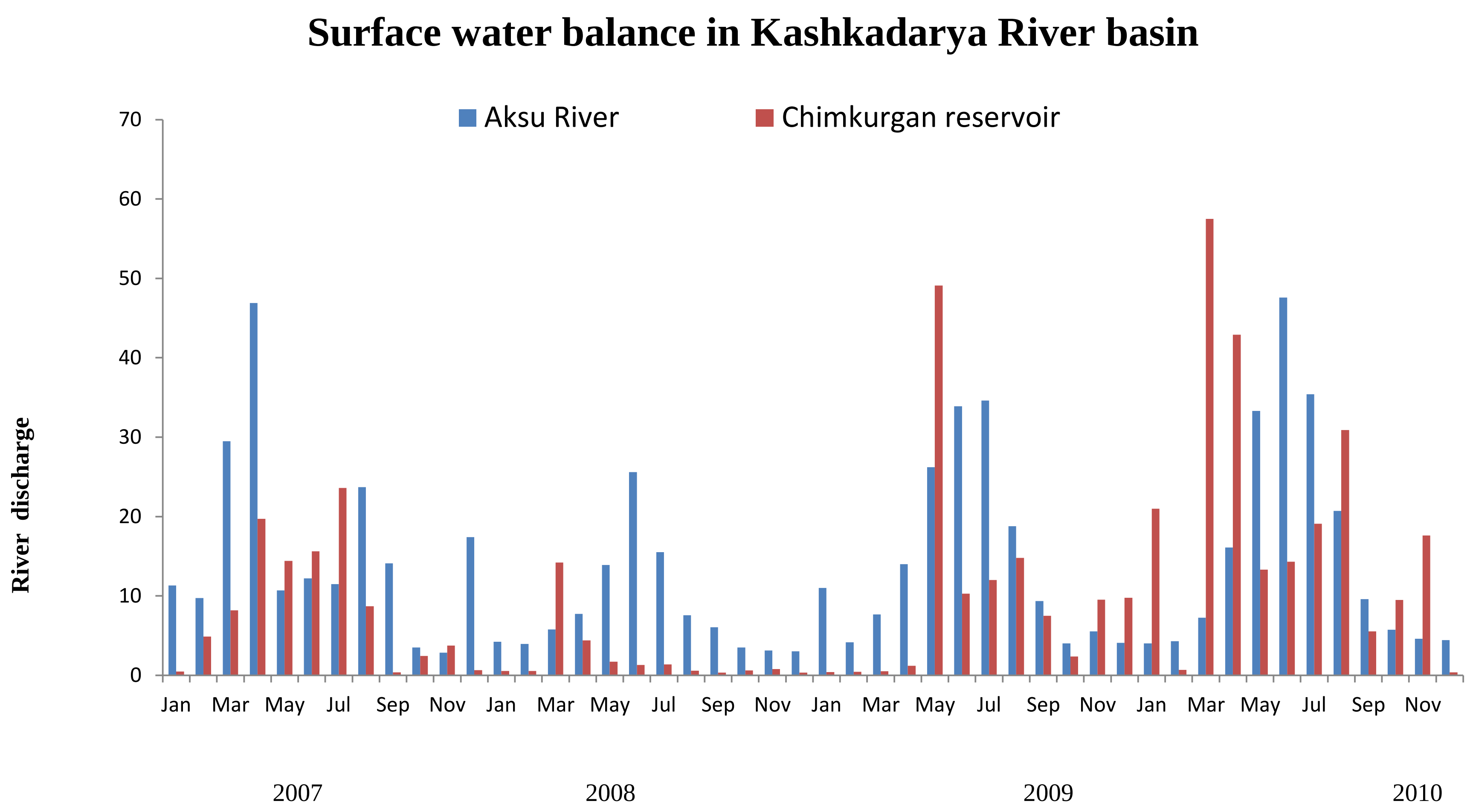


Figure 2.12: Total Inflow and outflow rates of the Kashkadarya River(source: Ministry of Agriculture of the Uzbekistan).

2.2 CLIMATE

2.2.1 The Chirchik River basin

The climate of upstream of the Chirchik River basin is characterized by relatively high precipitation and lower average temperature. The opposite climate characteristics could be seen in the downstream of the basin. MIKE SHE flow model requires daily precipitation and evapotranspiration data, therefore precipitation and other climate data were collected on a daily basis from 14 weather observation stations of Tashkent Province for 2009-2010. Reference evapotranspiration (ETo) was calculated with the Hargreaves model (HM) calibrated using collected climate data for each weather observation station.

Thiessen polygon method was used to spatially distribute daily basis precipitation and reference evapotranspiration. However, the Chirchik River basin has only 6 weather observation stations. By Thiessen polygon method, the coverage area of weather observation stations is as follows: Tashkent (1480.47 km^2), Chimgan (1266.95 km^2), Boshikizilsoy (405.72 km^2), Sokok (791.415 km^2), Tuyabuguz (330.71 km^2) and Kounchi (1350.94 km^2). Weather stations within the Chirchik river basin are highlighted in Figure 2.10. Monthly precipitation data for 2009 and 2010 from 4 weather observation stations of Tashkent Province are given in Figure 2.14– 2.17.

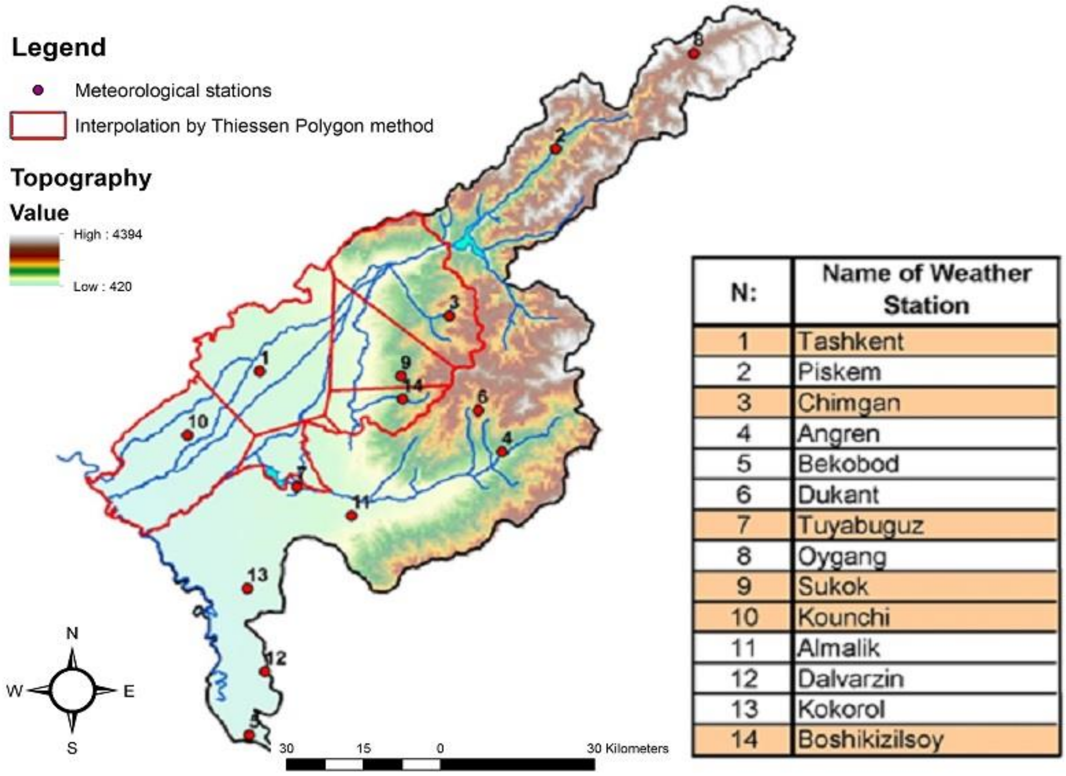


Figure 2.13: Hydrometeorological observation stations within the Chirchik River.

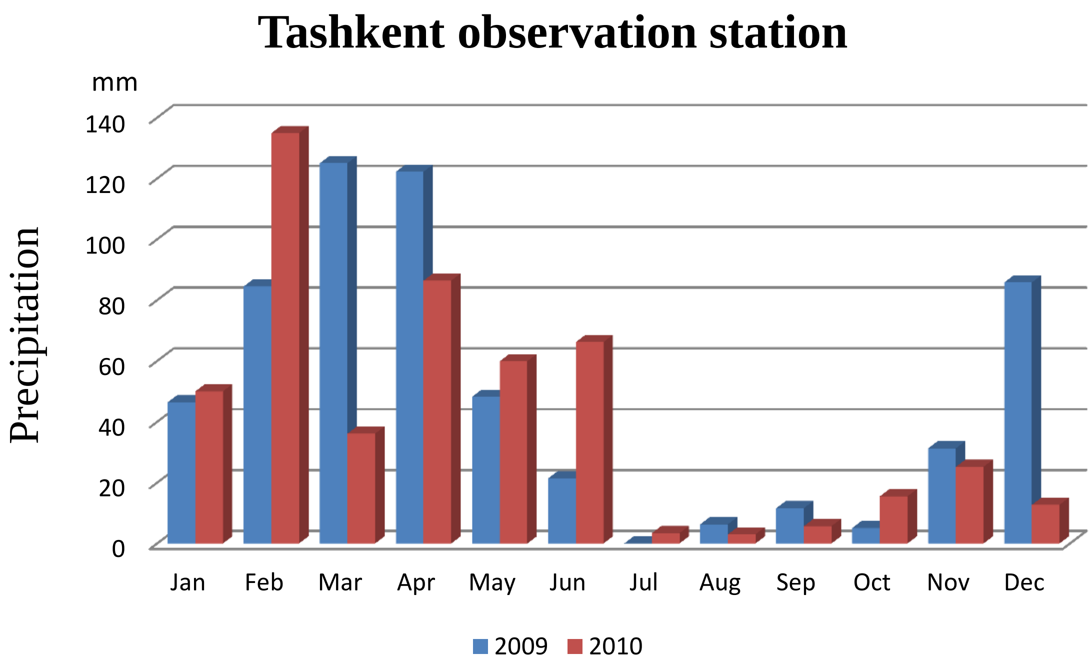


Figure 2.14: Precipitation for 2009-2010 in Tashkent observation station, mm/month.

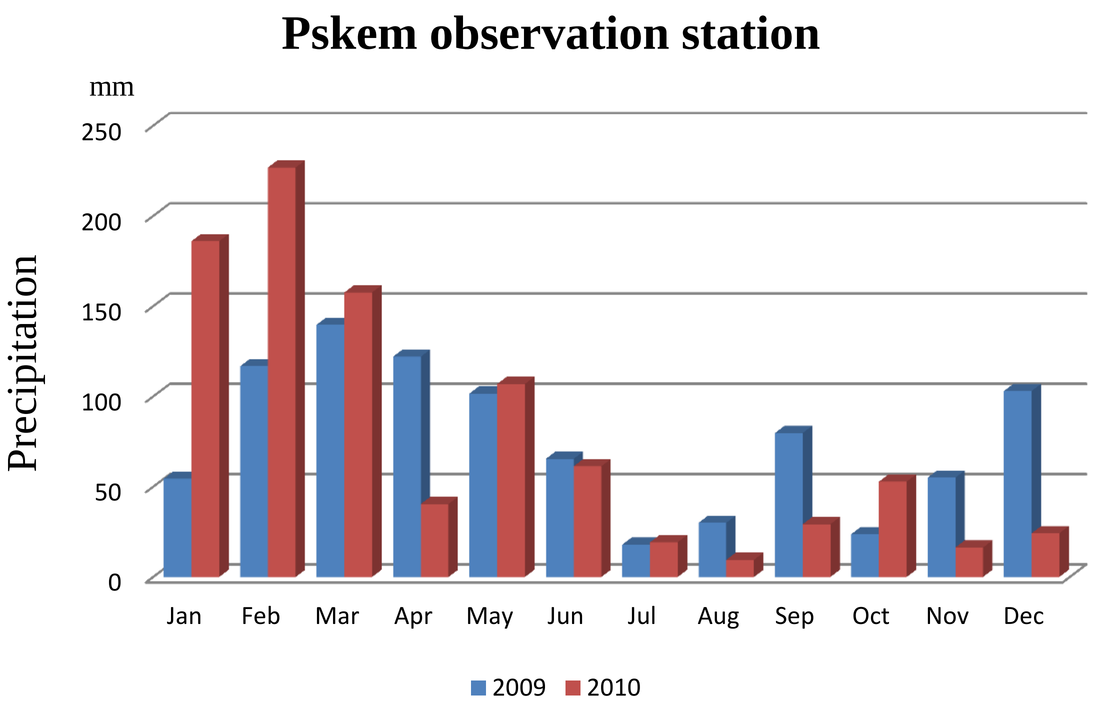


Figure 2.15: Precipitation for 2009-2010 at Pskem observation station, mm/month.

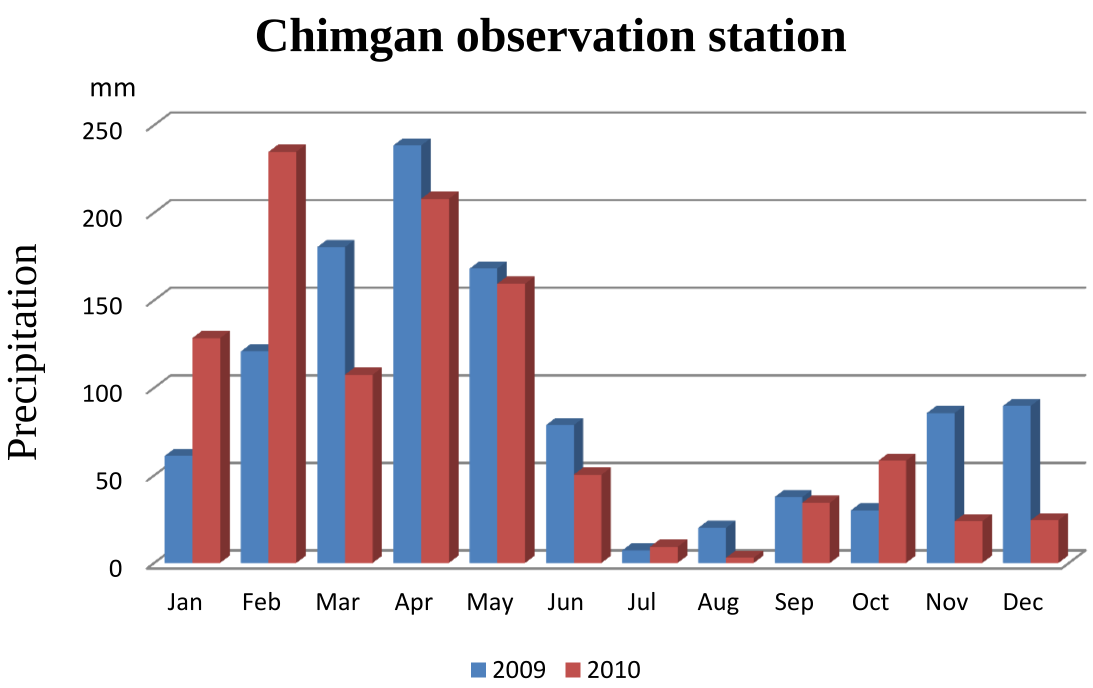


Figure 2.16: Precipitation for 2009-2010 at Chimgan observation station, mm/month.

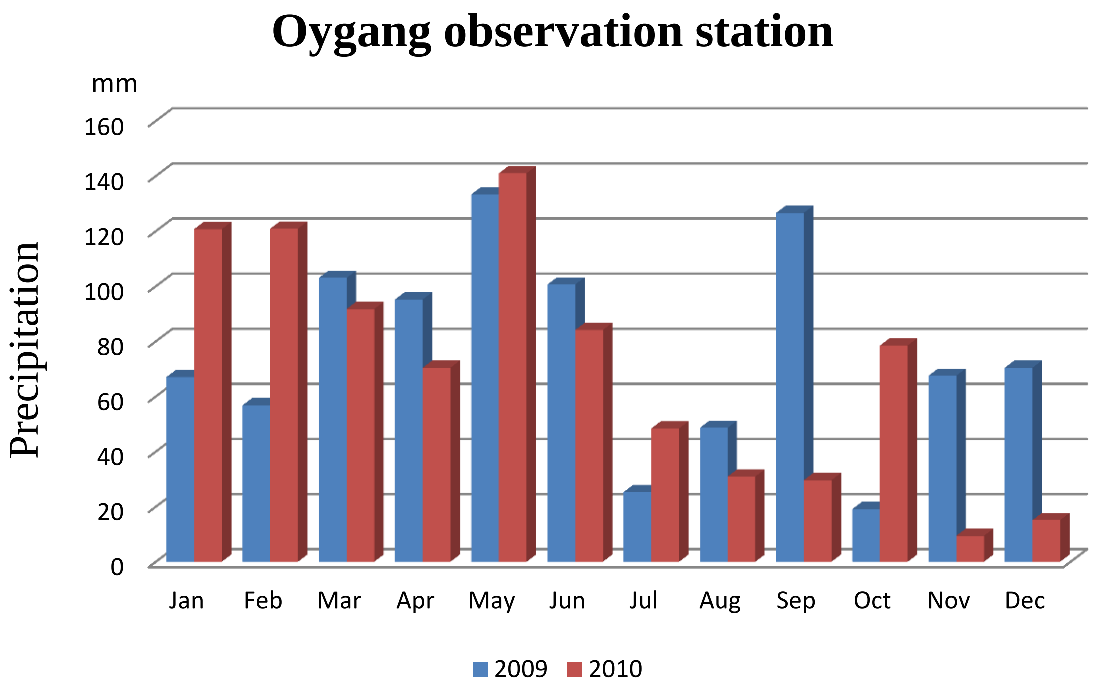


Figure 2.17: Precipitation for 2009-2010 at Oygang observation station, mm/month.

2.2.2 The Kashkadarya River basin

Climatic conditions of the foothills in the Kashkadarya River basin where water is abstracted from the Kashkadarya River are formed due to the summer heat resistant depression associated with overheating of the earth's surface and the influence of tropospheric air masses. The average annual precipitations at Chimkurgan reservoir and Kamashi observation stations in the Kashkadarya River basin range from less than 20 mm (from June to September) to 326 mm (Petrov 2005).

The Region as a whole has much rain in the winter and spring (November through May). As it is seen in the histograms for 2009-2011 (Figure 2.16 to 2.19) about one-half of the annual total precipitation falls from March through May. While winter and spring are considered as the rainfall season, the summer remains dry.

The wettest months are between December and April, the dry ones are between June and September, and the transitional months are November and May.

The average snow depth over the winter in the foothills can range from 30 to 40 cm; however, in the mountains it may exceed 150 cm.

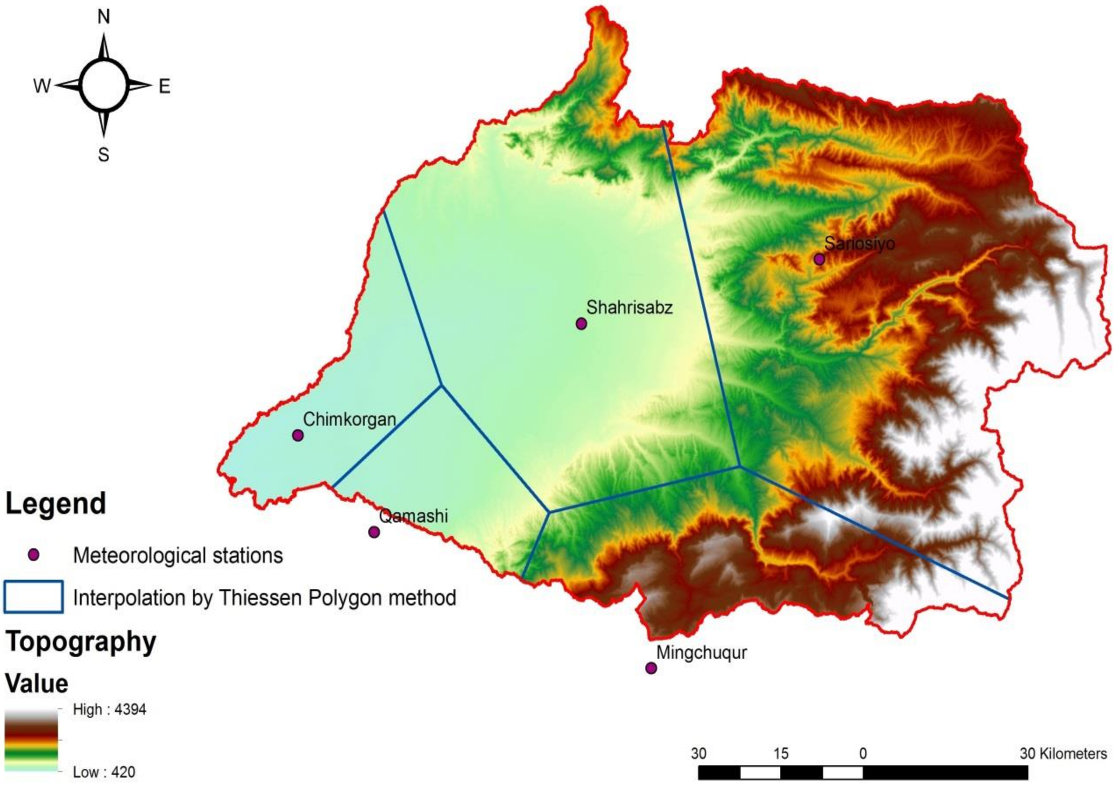


Figure 2.18: Weather stations within the Kashkadarya River basin.

In the foothills and plains of Intermountain basins the precipitation reduces significantly, and their importance in the formation of surface and ground water decreases sharply.

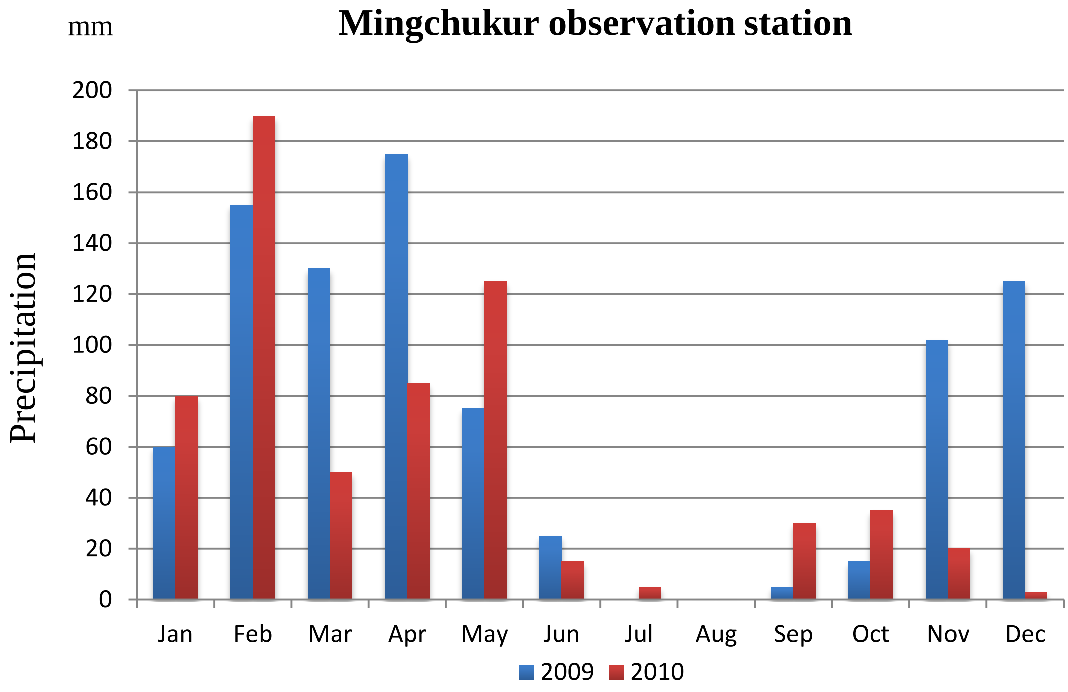


Figure 2.19: Precipitation for 2009-2011 at Mingchukur observation station, mm/month.

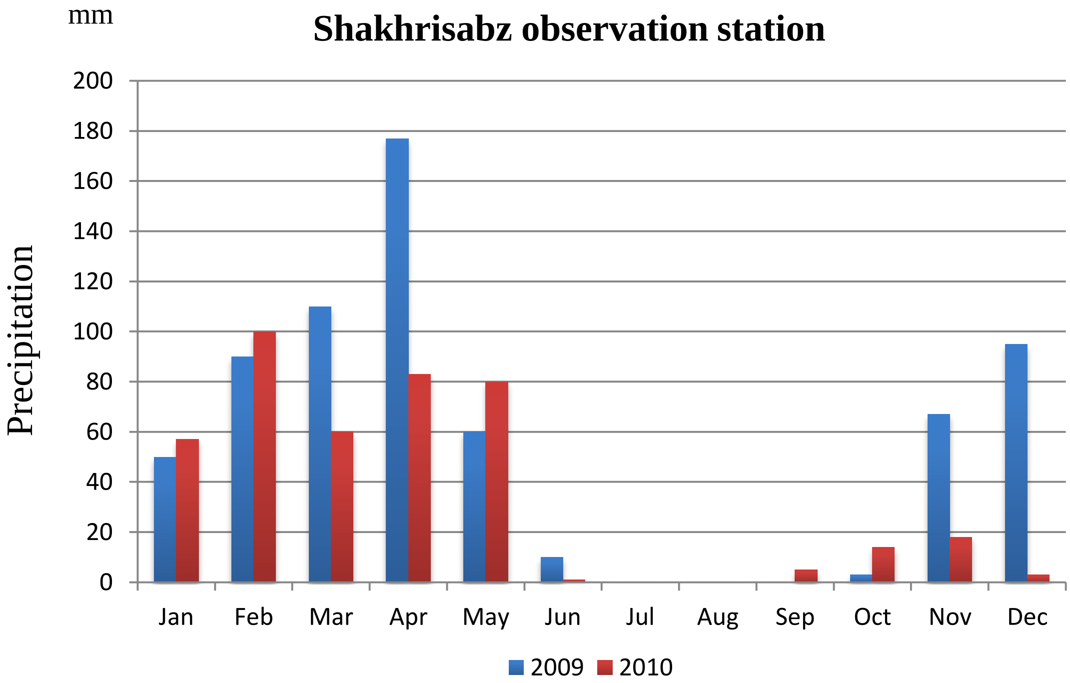


Figure 2.20: Precipitation for 2009-2011 at Shakhrisabz observation station, mm/month.

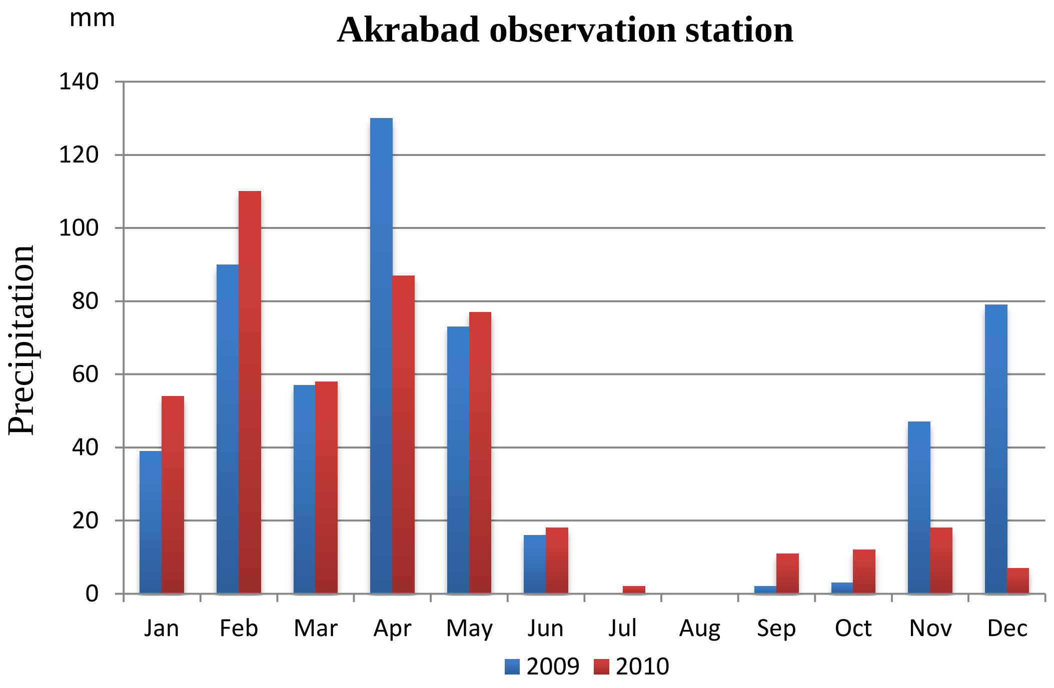


Figure 2.21: Precipitation for 2009-2011 at Akrabad observation station, mm/month.

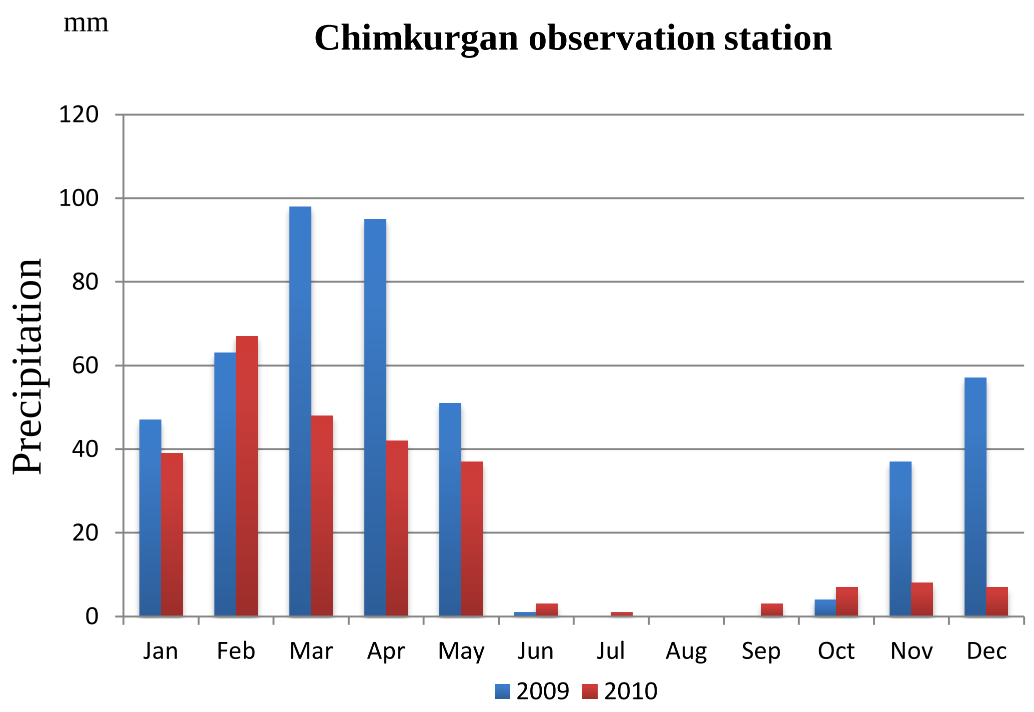


Figure 2.22: Precipitation for 2009-2011 at Chimkurgan observation station, mm/month.

The evaporation rate measured at the station Chimkurgan is 2-3 times higher than the precipitation rate. This is caused by dry and hot climate in summer. The average monthly atmospheric temperature change for the years 2009-2011 is shown by Equation 2.1 (source: Uzbekistan Hydrometeorological Center). Volatility in Uzbekistan is defined by both the temperature and humidity deficit:

$$\varepsilon o = 0{,}0014\ (25+t)^{2}\cdot(100-r) \qquad (2.1)$$

Where ε_o is the evaporation, mm/month; t is the average atmospheric temperature, ° C; r is the average monthly relative humidity, % (Chub 2000).

The average annual temperature in this case is 14,9 to 16,4 C., though the normal average annual temperature is 15°C, and in January it is about 20°C.

2.3 GEOLOGY

Topography of the study area was obtained from ASTER GDEM data. The initial pixel size of ASTER GDEM changed from 30 m to 500 m using a block statistics tool in ArcGIS. Then ASTER GDEM data with 500 m converted to the ASC II file format as input values in the MIKE SHE platform.

2.3.1 The Chirchik River basin

The water level in the top part of a valley of the Chirchik River from Gazalkent city up to Chirchik city is observed in a flood plain area. This area is considered 1st and 2nd terraces that frequently make width within 1-2 km.

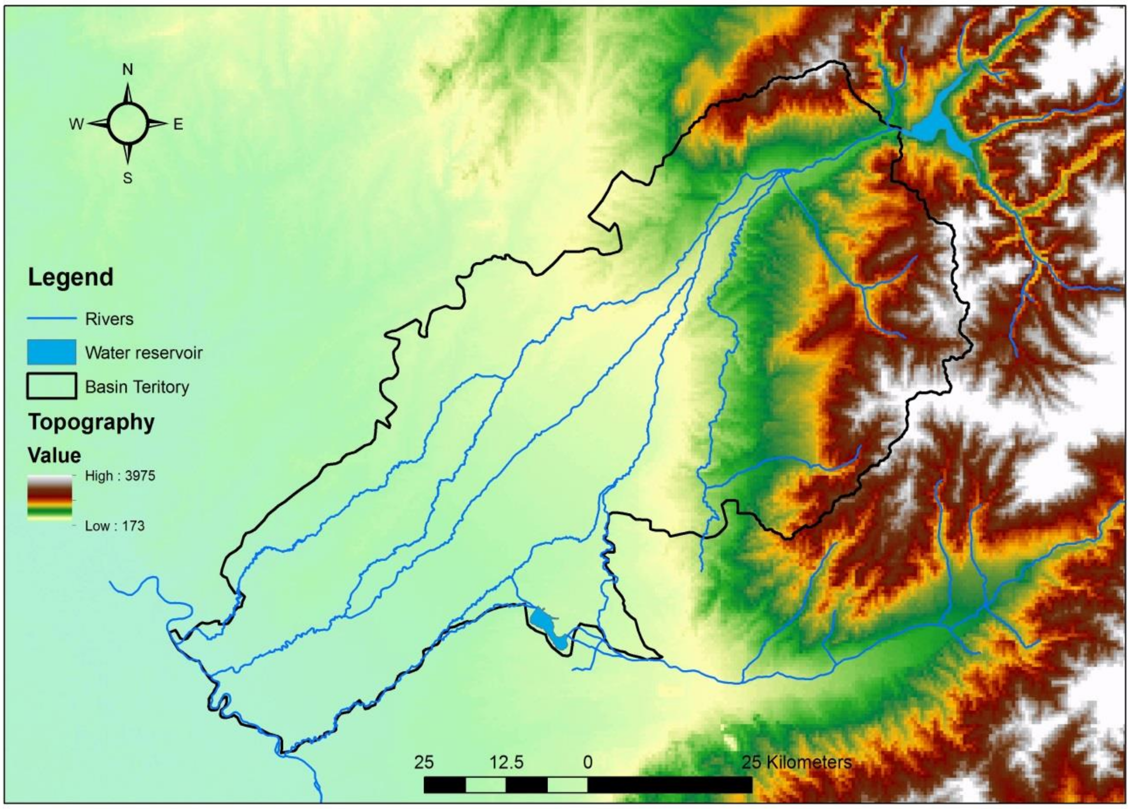


Figure 2.23: Boundary of the Chirchik River Basin and its topography in 500 m pixel size.

Geology of the top area of the valley is pebbles with sand-gravel filler of the modern age. Sometimes they spread with conglomerates and gravels.

In the middle area of Chirchik city up to Yangiyol city also covers the area of 3rd up-flood plain terraces. Due to expansion of the valley, its width increases up to 6-20 km. The total thickness of soil layer is 50-80m., alongside as the infiltration coefficient of the top and middle areas of the valley is 100-150 m/day and 150-250 m/day, respectively (Kashkarov 2008).

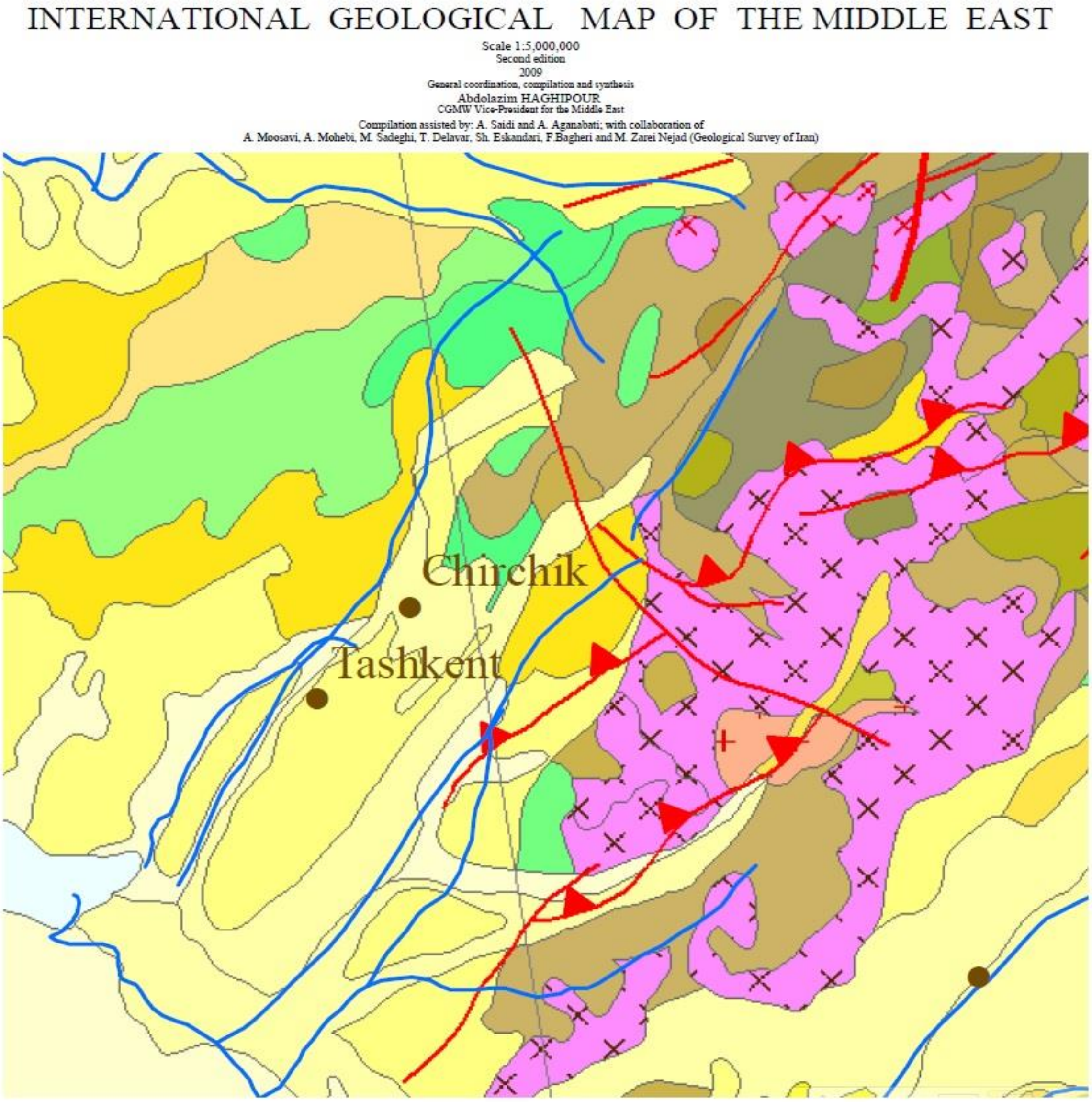


Figure 2.24: The source data on Geology Map of the Chirchik River basin area (International Geology of Middle East, 2009).

In the downstream area of the valley from Yangiyol city up to Sir-Darya River, the water, soil layer is outlined not only by actual same as the Chirchik River basin's other territories, but also due to development of alluvial sedimentation of Chirchik and Keles watersheds in the early Pliocene, where the middle and late Pleistocene borrow a part of the watersheds. Hence, the bottom layer of the valleys with pebbles with sandy thin and fine-grained filler is characterized by permeability of 10-21 m/day and 35-160 m/day, respectively.

The ancient alluvial gravels and sands of Chirchik and Angren, were traced by drilling deep into the north-eastern area of Hungry Steppe, it indicates the position of the Syr Darya River in the recent geological history in the south - west of its current channel. As the displacement of the river to the northeast of the Chirchik-Angren River's gravels and sands were buried under the alluvium of the Syr Darya River.

A geological map of the Chirchik River basin is compiled from the data of International Geological Map of Middle East, 2009, scale 1: 5,000,000. The current map is spatially registered to the coordinate systems of the Chirchik River basin; WGS 84 UTM 84 the same as soil data, moreover, this map is digitized and the following layers are prepared using ArcGIS technique. The finalized map was transformed to 1km mesh size format. This geological data provides the figures about rock layers, type, depth and the structure of the geology of the Chirchik River basin.

2.3.2 The Kashkadarya River basin

Usually it is difficult to build a geological structure in the same time mountain and flat basins. Chirchik and Kashkadarya River basins are the result of tectonic movements.

Formed and developed, since the Tertiary, mainly Neogene mountain valleys are broad synclinal or trough-shaped, often complicated by faults and made Upper Tertiary and Quaternary continental deposits (proluvial, alluvial, lesser extent, lake, talus, Aeolian, etc. types of soil) (Hasanov 2005).

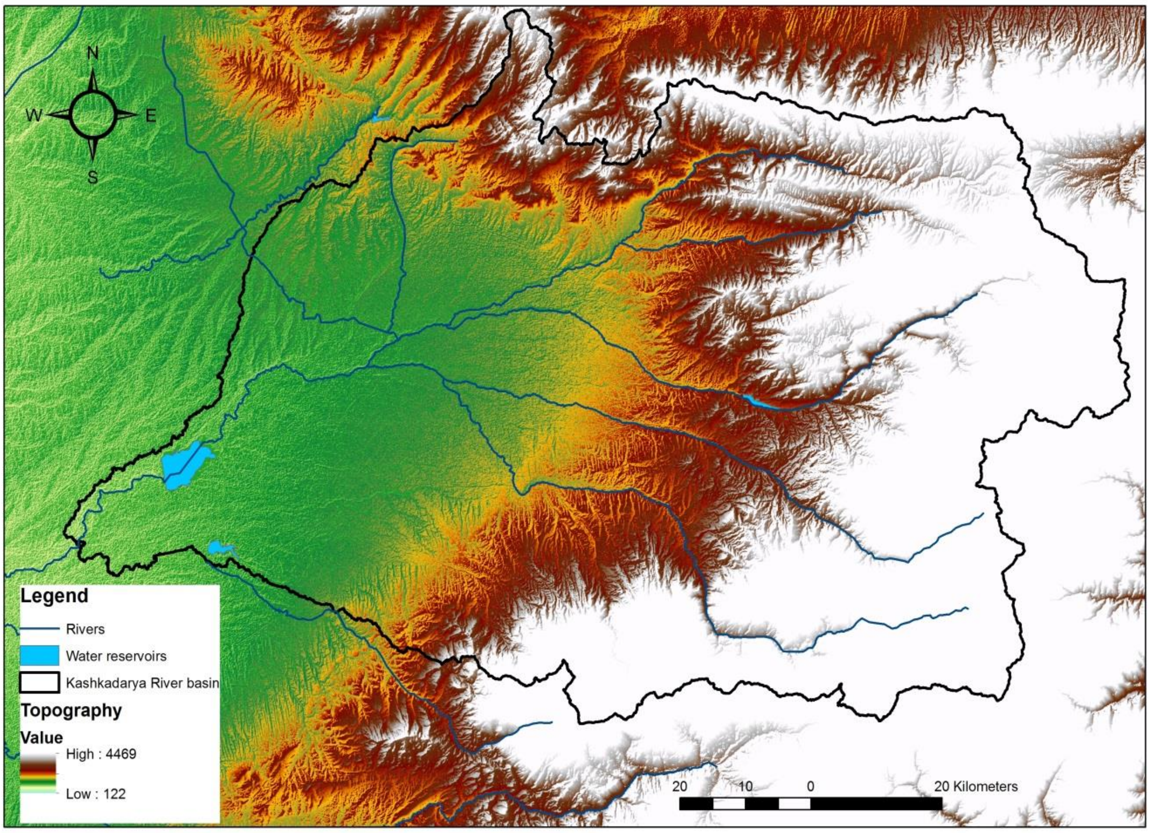


Figure 2.25: Boundary of the Kashkadarya River Basin and its topography in 500 m pixel size.

The thickness of these deposits is in the hundreds or thousands of meters. In the process of development of cavities on the background of jump tectonic movements, accompanied by abundant demolition debris from the mountains and its accumulation in the plains.

This led to the difference of material alluvial zones on the particle size distribution ranging from pebble in their upper areas to sand-clay sediments in the lower pro-alluvial. It is pebbly areas are alluvial zones, spanning the central part of the depression, and serve as the main area of the power not only the groundwater but also partly artesian water and irrigated zone of the mountain basin (Hasanov 2005).

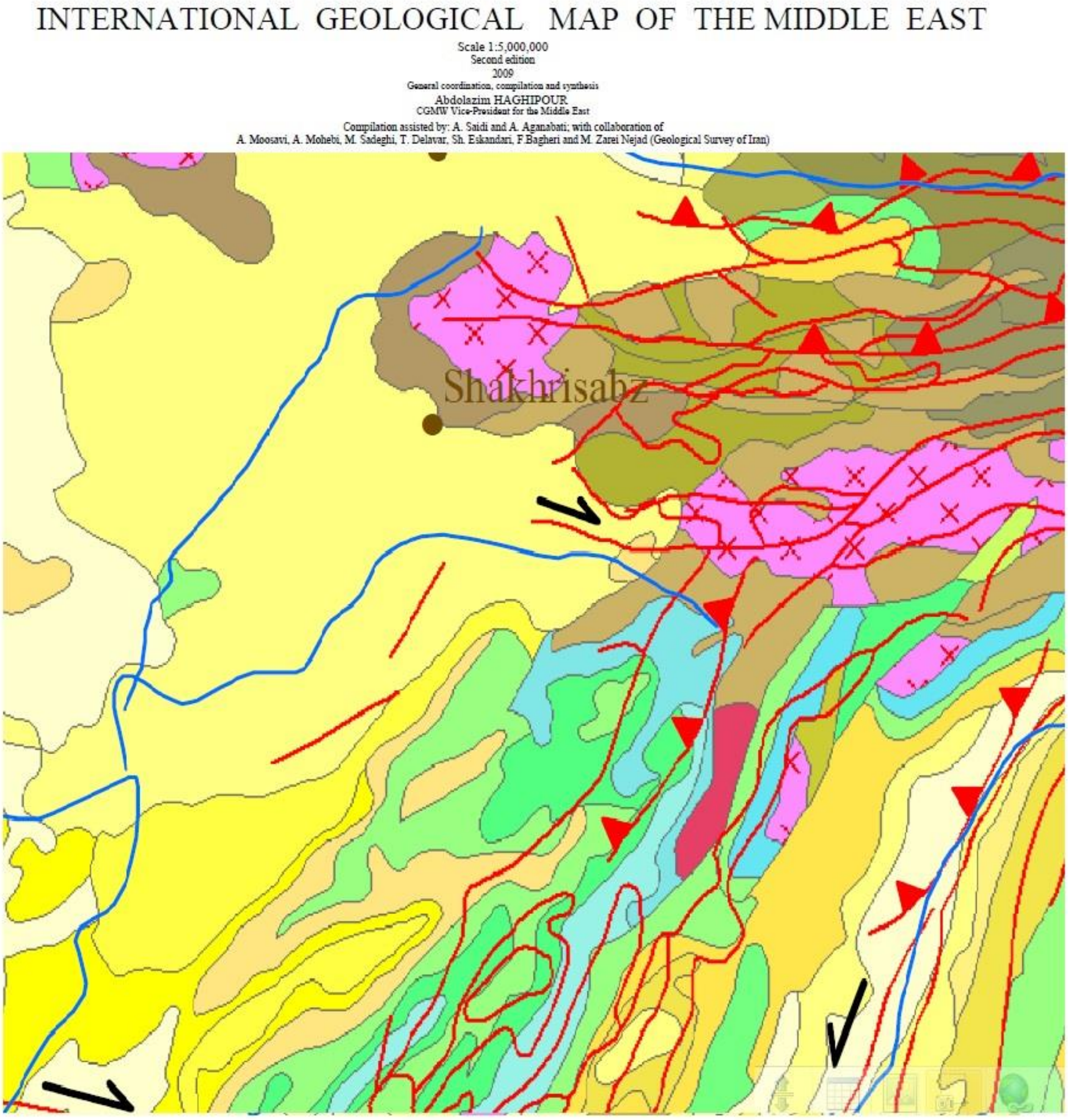


Figure 2.26: The source data on Geology Map of the Kashkadarya River basin area (International Geology of Middle East, 2009).

From physical and geographical points of view, Kashkadarya River basin is the lower zone of the inland. The irrigated areas are characterized by extensive development of alluvial, details, lacustrine and sometimes deflated layered sediments underlain by Tertiary or Cretaceous rocks.

Erosion of the bedrock surface in Zarafshan and Kashkadarya was significantly weaker.

This explanation does not correspond to reality in full, because of the bottom erosion. These fluctuations cannot cause any significant deep erosion.

The layers of sand in the clay and loam occurring at a certain depth often are associated with the main body of riverbeds. Therefore, vertical drainage dedicated to the sandy channel deposits, which is technically the most profitable.

2.4 SOIL

2.4.1 The Chirchik River basin

According to the soil, climatic zoning of the Eurasian continent, the northern and northwestern parts of Uzbekistan is attributed as an arid and semiarid zone. A geomorphologic zoning of Chirchik River basin reflects the geographic distribution of soils according to relief and depending on types of soil-forming rocks. The soil type of Chirchik River basin is stronger depends on geographic location, and therefore the basin is classified to geomorphologic areas. The following soil types of the Chirchik River basin are determined as: light-brown grassland-steppe soils, mountain brown soils and dark and typical Sierozem.

In addition, soils classifications are identified as sierozem-grassland soils. In terms of hydro-morphological series, there are: grassland dark, grassland light, grassland-marsh and marsh soils. The soils of the basin have been formed in various soil-climatic zones, such as: Subnival (high mountainous light-brown soils); Humid-climate-formed type (mountainous brown woodland and mountainous brown soils); Sub-arid (dark sierozem soils); semiarid (typical sierozem soils) (Hasanov 2005).

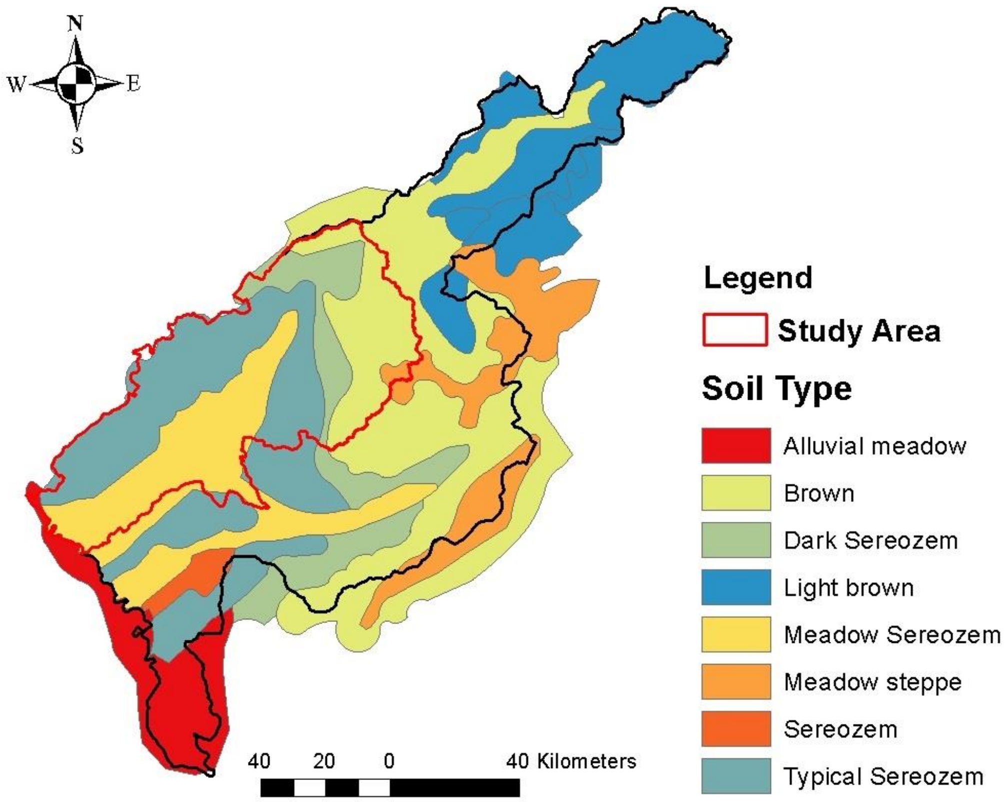


Figure 2.27: Soil type of Tashkent province and study area.

MIKE SHE requires spatially distributed soil data to simulate the water balance of the Chirchik River basin. A raw image of soil map of the study area was obtained from the Institute of Water Problems of Uzbekistan. The ArcGIS technique was used to prepare a digital soil map as an input parameter to MIKE SHE platform. The soil map of the Chirchik River basin presented in Figure 2.27 the thematic layer processing of soil in the Chirchik River basin.

2.4.2 The Kashkadarya River basin

The eastern part of the Karshi steppe at elevations of 440-1000 m above sea level, including the tract Kokdalya, sloping foothills of Hissar Range and Kitab-Shahrisyabzskuyu cavity is occupied by typical serozem plains (up to 300m), including Guzar apron, hilly sloping piedmont Hissar range, the upper part of the Kashkadarya alluvial fan and a vast array of land, located on the foothill sloping Zarafshan range. The soil cover is composed of tacky soil, gray-brown soils, desert sandy soils and their complexes (Bedrincev 1975).

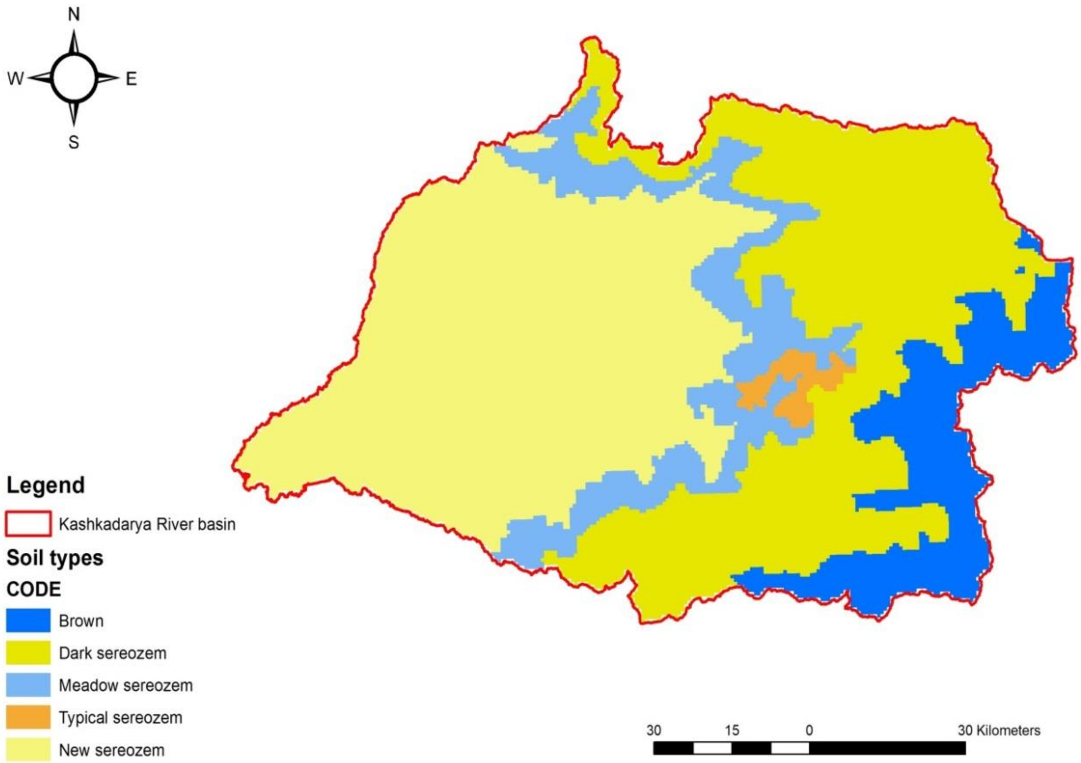


Figure 2.28: Soil type of the Kashkadarya River basin and study area.

The irrigated soils and ancient deposits are presented in the Kitab-Shahrisabz depression alluvial fans of Guzar River and the Kashkadarya River. On the lower terraces, common meadow is floodplain alluvial soils, meadow and marsh-meadow are soils with patches of salt marshes. The highest interest for the development of agriculture soil is located in the high altitude plane below the dark grey soils. An upstream land mainly is characterized as a rain fed land below irrigated land (Bedrincev 1975).

2.5 WATER RESOURCES

The location of Chirchik and Kashkadarya River basin is in the arid zone, which mainly serve two watercourses the Chirchik and Kashkadarya Rivers. Surface water resource of Uzbekistan is water coming down the rivers from the mountainous regions of neighboring countries and emerging water resources in its region. In addition, part of the river flow comes by channels (Bedrincev 1975).

2.5.1 The Chirchik River basin

However, almost 90% of river water are spent for irrigation of agricultural crops, some parts of used water back to atmosphere via evapotranspiration. Therefore, the model estimated that actual evapotranspiration is almost two times higher than precipitation in the Chirchik River basin.

In the mountainous, area groundwater mainly is recharged by precipitation because irrigation fields are very rare and they use only precipitation for irrigate crops.

In downstream site, the main recharge source of groundwater is infiltration of irrigated water and partly recharging from a narrow strip of channels of the Chirchik and Ahangaran Rivers. The general direction of groundwater flow is from Northeast to Southwest and partly along the Syrdarya River. Runoff mainly occurs in the mountainous part of the Chirchik River basin in spring and fall when heavy rain occurs in low permeability of the ground surface layer and join two streams which flows into the beginning of the Chirchik River (Gidroingeo 2010).

Comparison of physical based actual evapotranspiration, precipitation and infiltration showed that in arid and semiarid area, these factors strongly depend on each other. Apart from soil moisture and humidity, actual evapotranspiration and infiltration are a function of precipitation. Figure 2.29 and Figure 2.30 shows a comparison of above mentioned three hydrological factors.

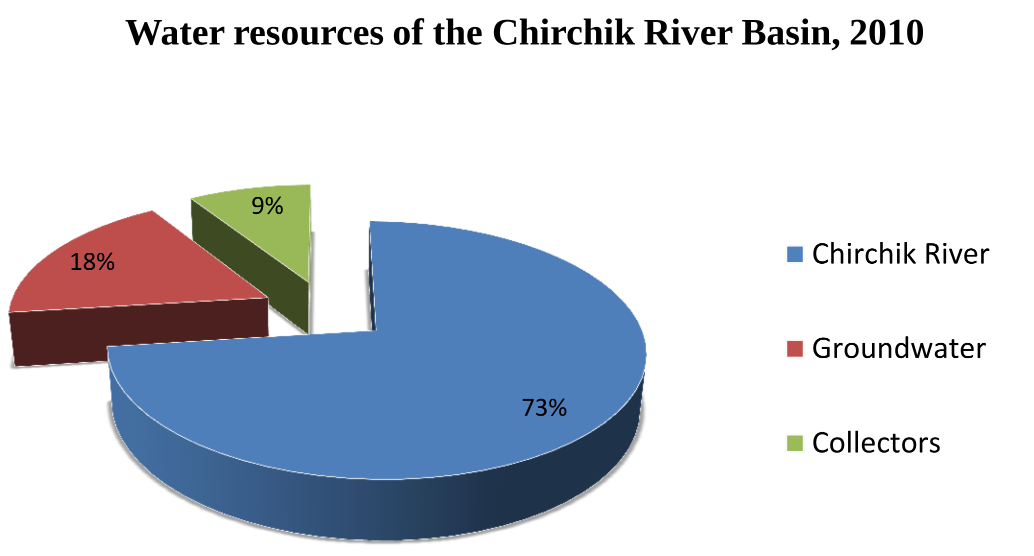


Figure 2.29: Water intake from resources in the Chirchik River basin, 2010.

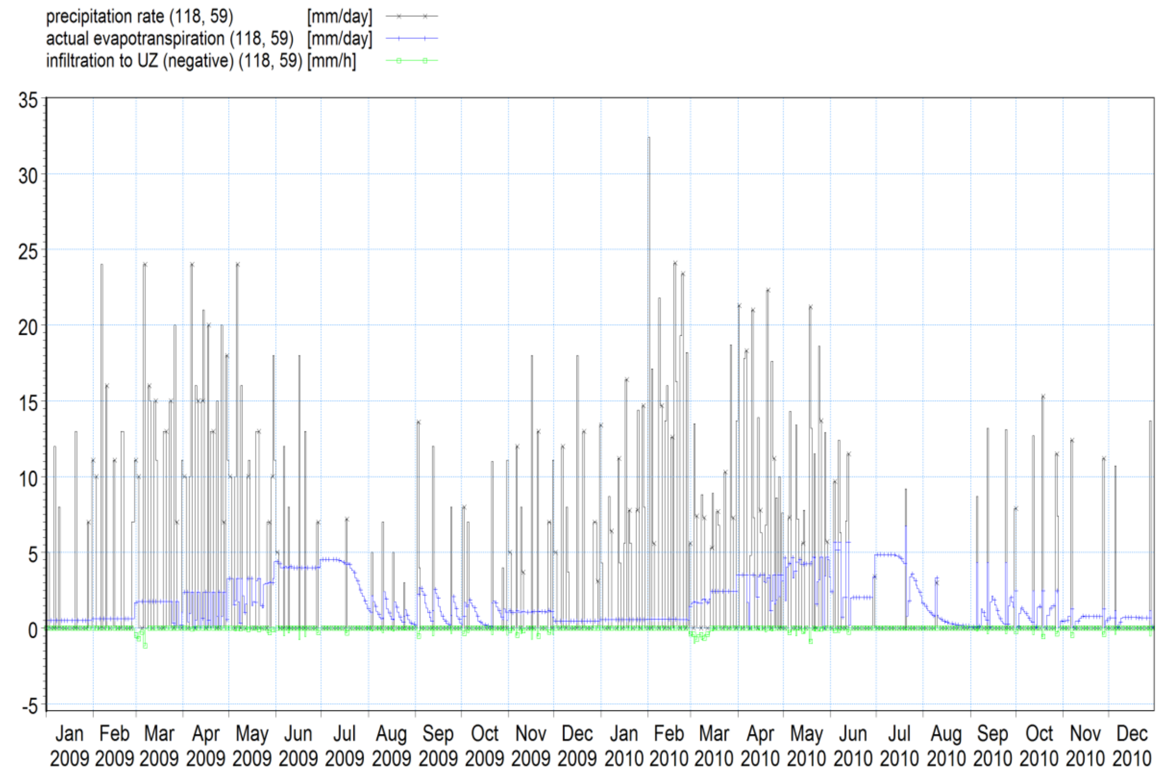


Figure 2.30: Hydrological parameters relationship (source: MIKESHE water balance simulation results for the Chirchik River basin, 2009-2010).

2.5.2 The Kashkadarya River basin

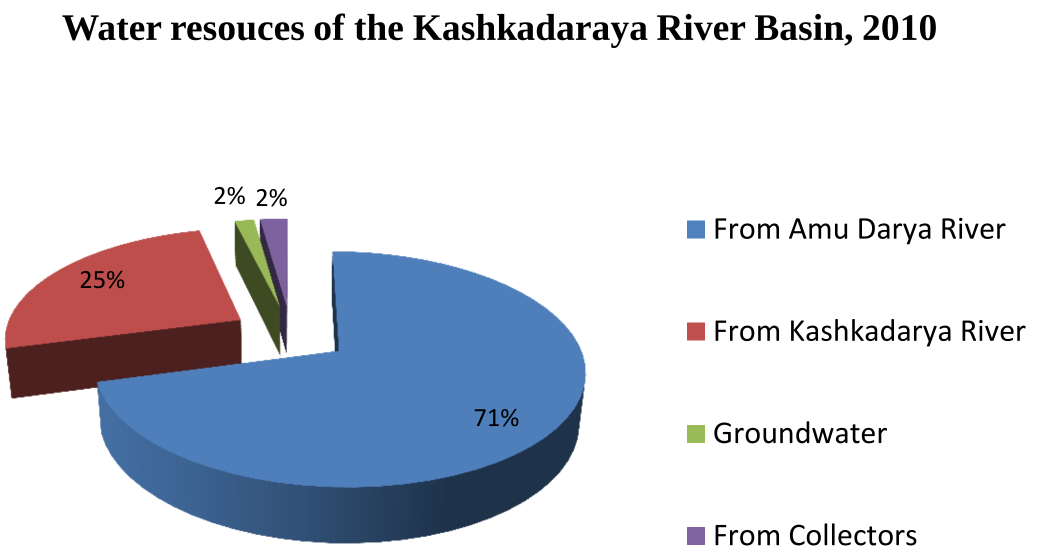


Figure 2.31: Water intake from resources in the Kashkadarya River basin, 2010.

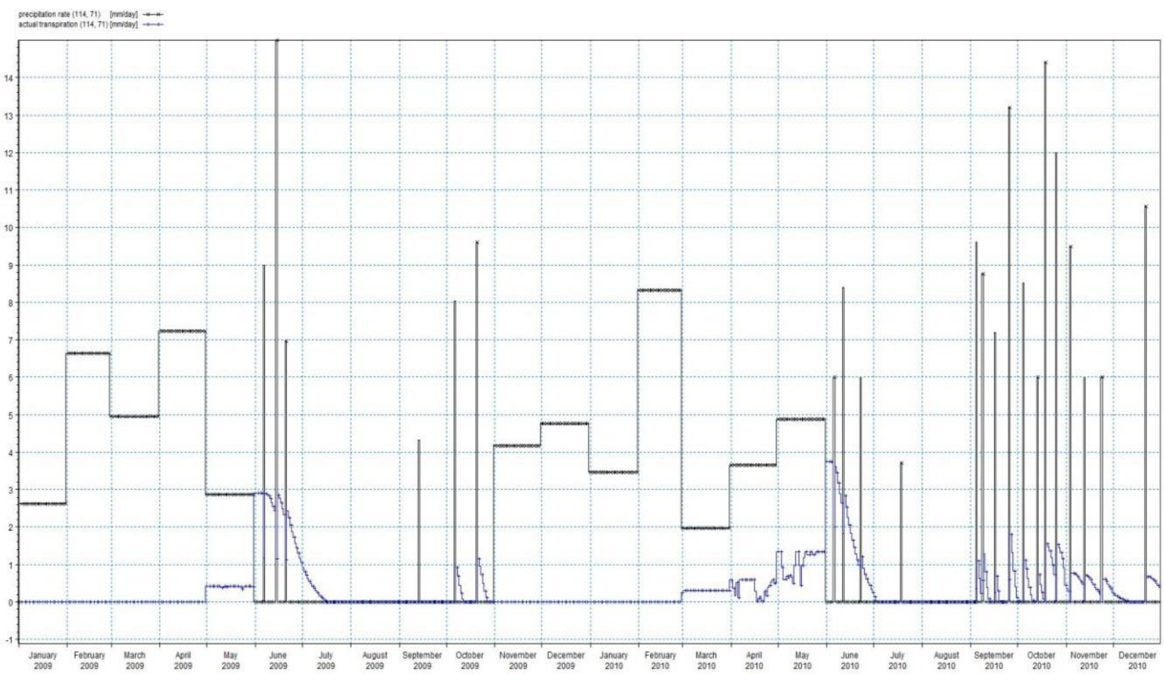


Figure 2.32: Hydrological parameters relationship (Evapotranspiration to Precipitation) (source: MIKESHE water balance simulation results for the Kashkadarya River basin, 2009-2010).

2.6 SURFACE WATER

2.6.1 The Chirchik River basin

Distribution of the Chirchik River has clearly expressed depends on the average of the heights of the river basin, this case is especially for alpine rivers. On these rivers, winter ends at the end of March beginning of April, when starts melting of seasonal snow in mid mountain zone watersheds, and in early April flood increases to peak. Peak glacial runoff takes place in July and then to the end of November flow is decreased.

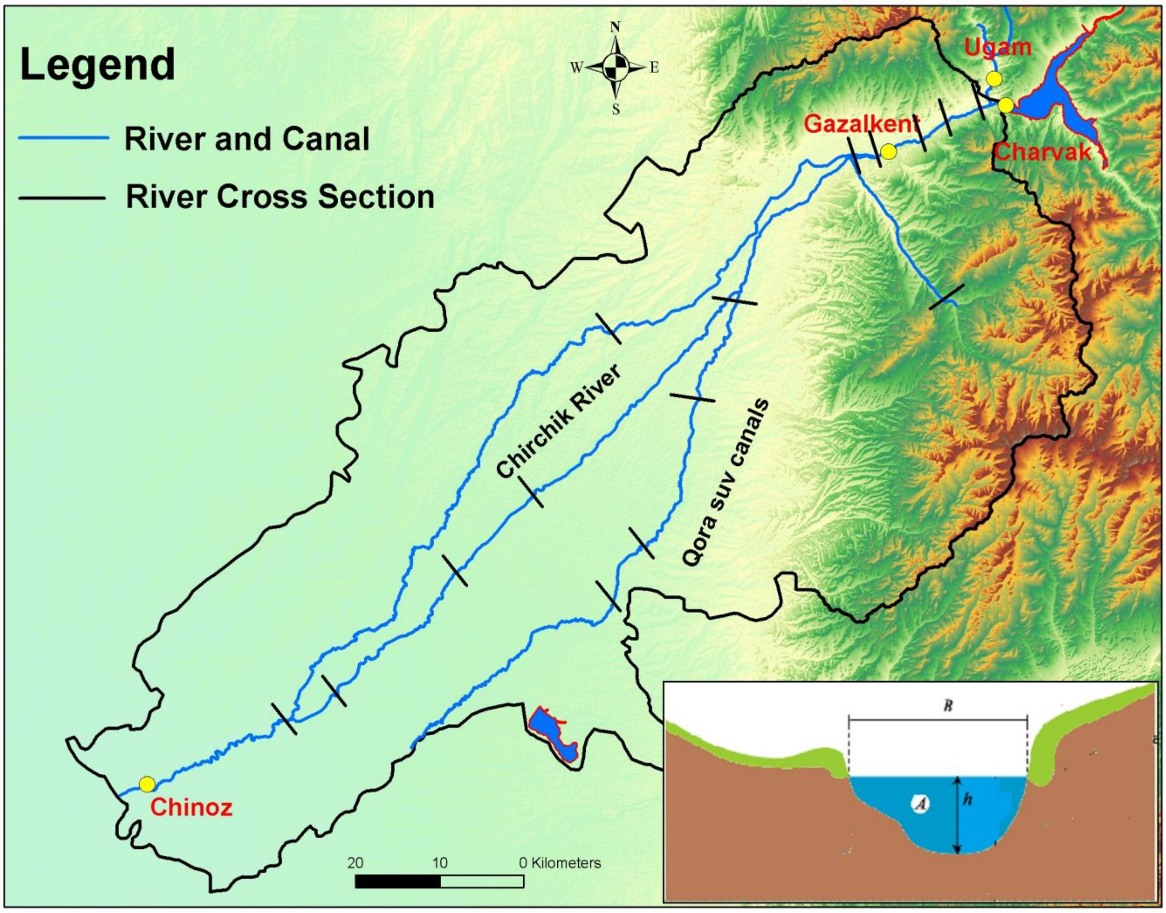


Figure 2.33: Surface water cross-section measurement points of the Chirchik River basin.

The MIKE 11 river network is made up to simulate the cross section points of the streams. The Chirchik River's streams obtained from Aster GDEM (30 m resolution) stream segmentation process in ArcGIS platform. The geographic locations of streams are corrected using topographic and aerial maps. The Figure 2.33 and Table 2.1 show the Chirchik River network and river cross-section points. In MIKE 11 simulation was selected only main rivers and canals in the Chirchik River basin. All other small streams are ignored because of insufficient data and facilitate computational burden in the simulation process.

Table 2.1: Description of Branch network in MIKE 11 model

N:	Name of Branch	ID	Upstream (Km)	Destination from upstream (Km)	Branch type
1	Aksagatsay River	A1	0	23.267	Regular
2	Bozsuv Canal	B1	0	122.332	Regular
3	Chirchik River	C1	0	135.596	Regular
4	Qorasuv Canal	Q1	0	83.800	Regular

The flow rates of selected streams for MIKE 11 simulation are compiled from four gauging stations for 2008-2010 (Ugam, Charvak, Gazalkent and Chinoz gauging stations). Figure 2.31 shows the locations of four gauging stations along the river network. The three gauging stations: Ugam, Charvak and Gazalkent are located in the upstream the Chirchik River basin and only one Chinoz station are located at the downstream of the basin. In terms of the measurement of the flow rate at Gazalkent and Chinoz gauging stations quantity of water lost within the Chirchik River basin is estimated.

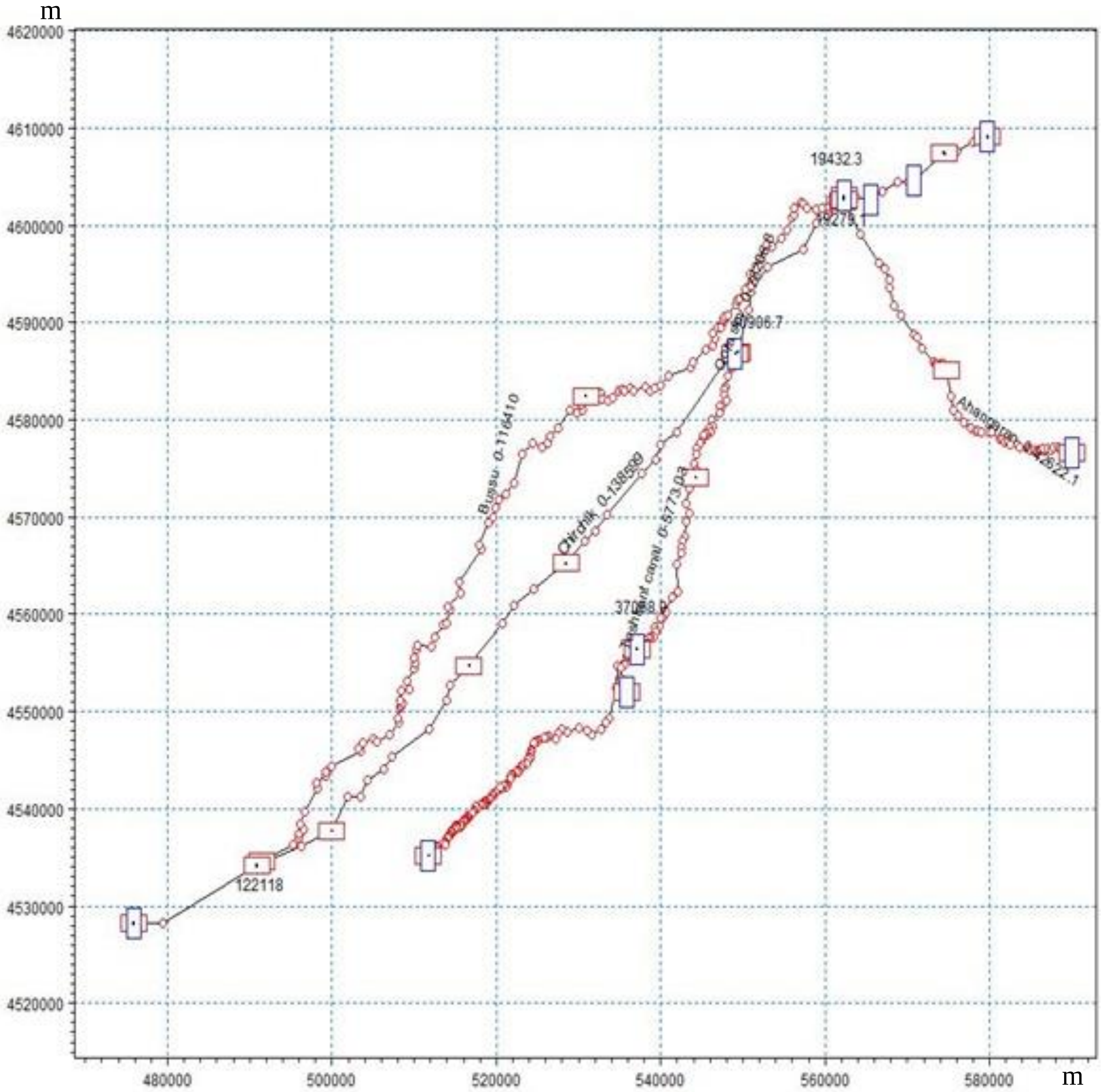


Figure 2.34: Chirchik River networks and location of cross-section points of MIKE 11 platforms, cross section points are specified for each branch along the MIKE 11 river network. The total 18 cross section data were collected in winter 2012 (a unit of the map is converted from the coordinates to meters).

2.6.2 The Kashkadarya River basin

The surface water resources of the Kashkadarya River basin consist of the total flow of the rivers: the Kashkadarya River, Dzhinydari, Aksu, Karasu Shurabsaya, Tanhazdari, Yakkabag, Turnabulaka, Chuldari and Jara Rivers. The Kashkadarya River is 310 km long and its catchment is 8780 km^2 in area. The largest flow appears generally in April, the lowest in late summer and early autumn (Bedrincev 1975).

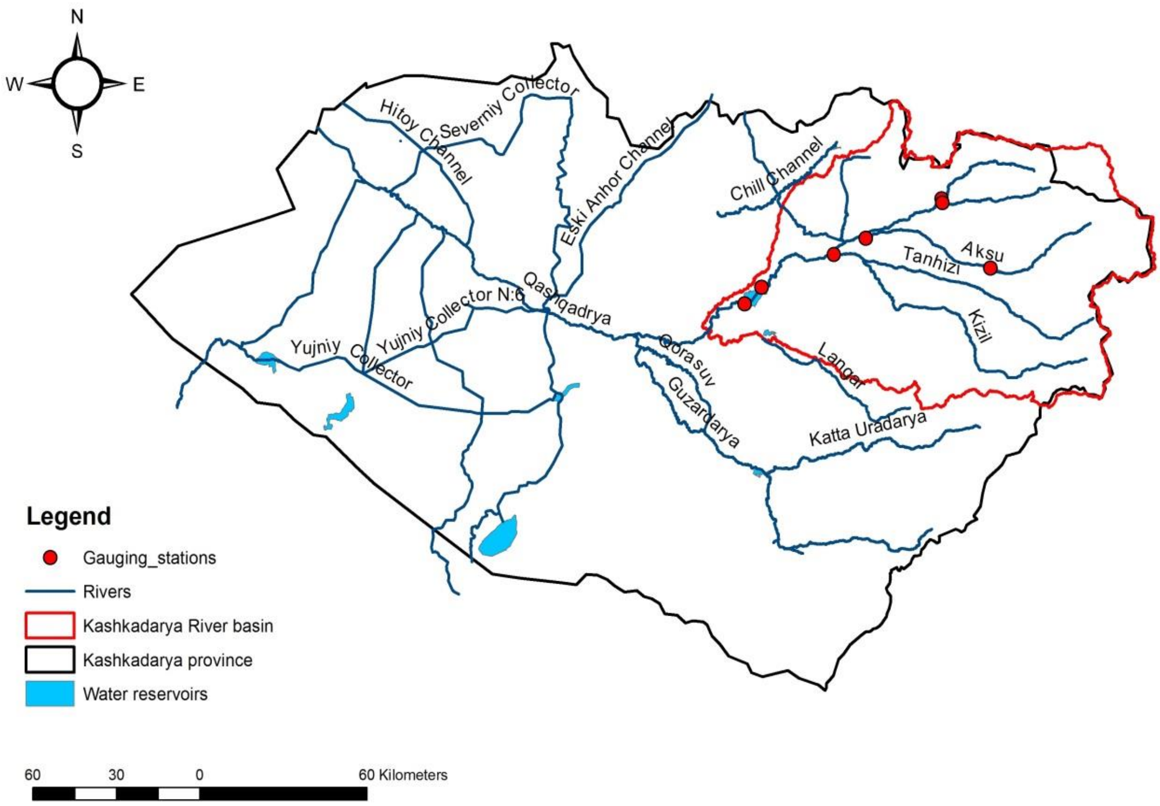


Figure 2.35: Surface water cross-section measurement points of the Kashkadarya River basin.

Currently available water resources in Kashkadarya region are obtained from the river (Amu-Darya and locally), and underground drainage waters.

The irrigation and land development of Karshi Steppe began after the Governmental Decree "On the development of irrigation and land development Karshi Steppe" in 1967.

Karshi main channels were built with a length of 178 km and 6 pumping stations with a total installed capacity of 450 thousand kW. Karshi channel is divided into two parts: the head and working, at the junction of them built Tallimardzhan reservoir with a capacity of 1.5 km^3 (Bedrincev 1975).

The head of the Karshi channel is 78 km long with 6 pumping stations raising water from the Amu Darya River to a height of 132.2 m with a flow rate of 175 m^3 / s.

Table 2.2: Description of Branch network in MIKE 11 model.

N:	Name of Branch	ID	Upstream (Km)	Destination from upstream (Km)	Branch type
1	Kashkadarya River (Qash river)	1	0	0	Regular
2		2	0	19.31	Regular
3		3	0	34.07	Regular
4		4	0	57.25	Regular
5		5	0	75.98	Regular
6		6	0	95.90	Regular
7		7	0	119.41	Regular
8	Aksu river (Qash river trib)	Trib1	0	0	Regular
9		Trib2	0	18.29	Regular
10		Trib3	0	31.35	Regular

Figure 2.35 and Table 2.2 shows the Kashkadarya and Aksu River networks and river cross-section points. In MIKE11 simulation only main rivers of the Kashkadarya River basin were selected.

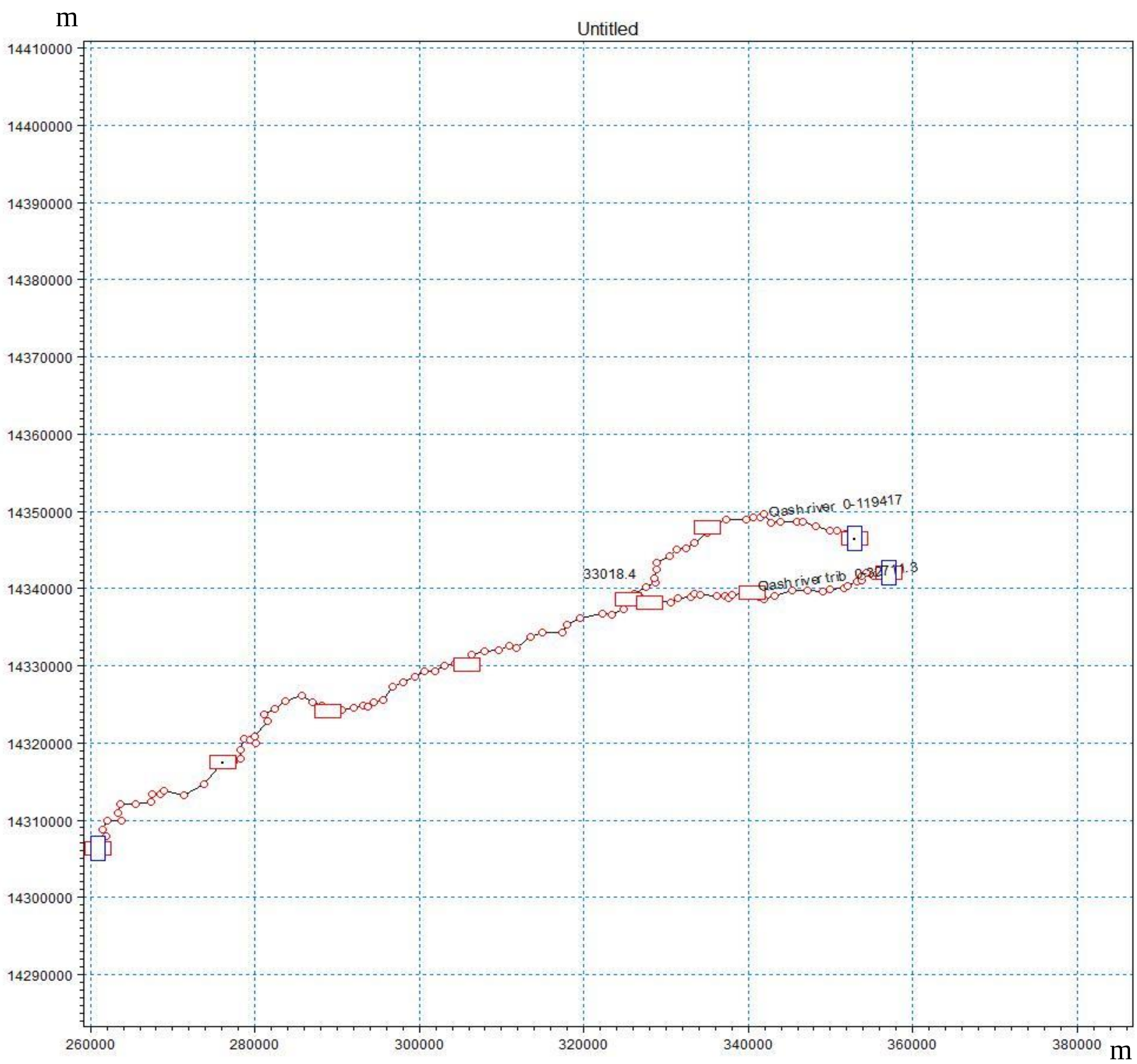


Figure 2.36: The Kashkadarya and Aksu River networks and locations of cross-section points on MIKE 11 platforms, cross section points are specified for each branch along the MIKE 11 river network (a unit of the map is converted from the coordinates to meters), (Data source: Ministry of Agriculture of Uzbekistan).

2.7 GROUNDWATER

2.7.1 The Chirchik River Basin

In most cases, Chirchik River basin's groundwater is used for water supply for administrative regions and cities of Tashkent, Gazalkent, Chirchik and Yangiyul.

The anthropogenic adverse influence of ground water bodies occurred by nitrogen compounds, heavy metal ions, pesticides, oil products, phenols, organic (toluene, caprolactam), etc.

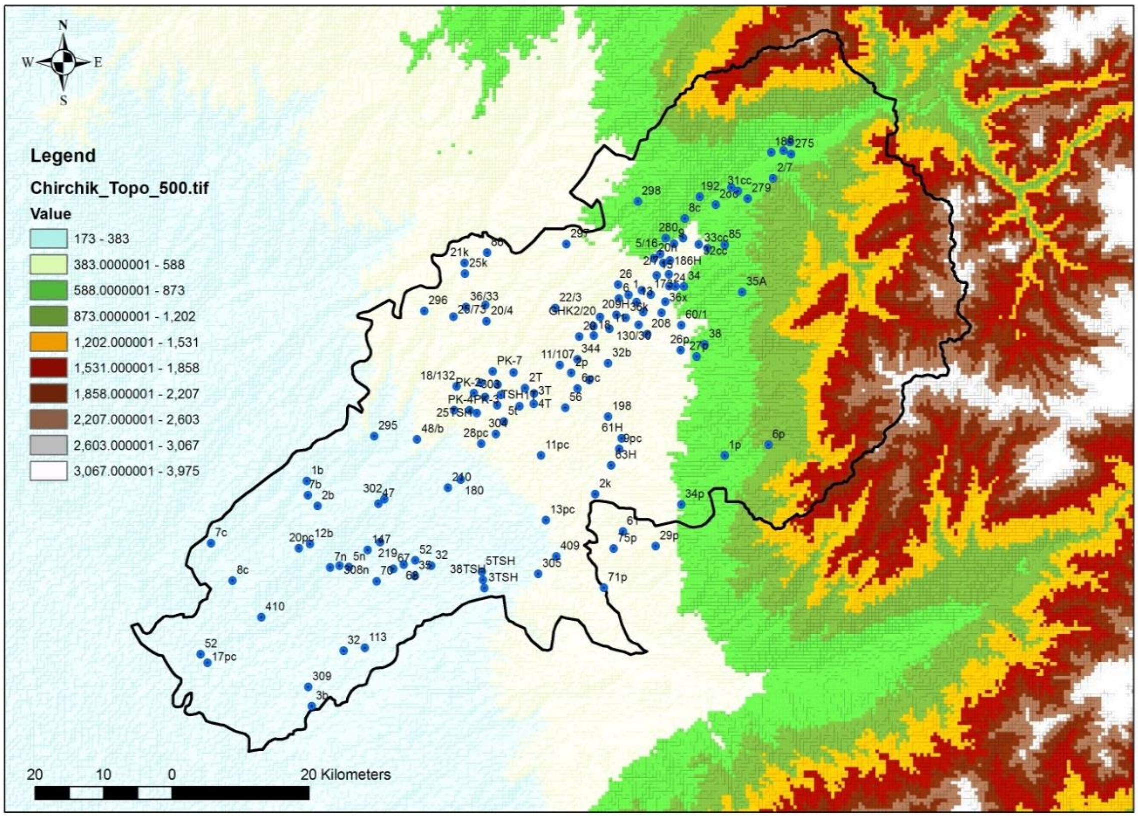


Figure 2.37: Location of groundwater wells in the Chirchik River basin territory.

Groundwater wells in rural areas are in bad conditions. Violation of the natural previously existing environmental conditions of the area, because of industrial factories, quarries, landfills, tailings pond, ponds, using of chemicals in agricultural production, regulation of river flow and other objects of human impact on the nature of the environment. Adverse impact affects ground water, which is the main source of drinking water supply of the River basin.

The economy of the area is carried out based on natural resources, including surface water and groundwater.

The highly diversified industrial complex in Tashkent region has a significant impact on the environment. In essence water resources are the basis for sustainable development of the district and at the same time one of the most vulnerable components of environment (Gidroingeo 2010).

2.7.2 The Kashkadarya River Basin

Formation of groundwater in the Kashkadarya River basin occurs mainly due to seepage losses from the Kashkadarya River, irrigation canals and irrigated fields. Basin groundwater resources amount around 919300 m^3 / day (10.64 m3 / s).

Groundwater in Kitab and Shahrisabz regions is fairly stable and largely in quality and meets Government Standards of pollution of Uzbekistan "Oz DST 950-2000 "Ichimlik Suvi"". An exception is the small amount of fluorine (0.12-0.27 mg / l or less, at a rate of 0.7) (Chub 2000).

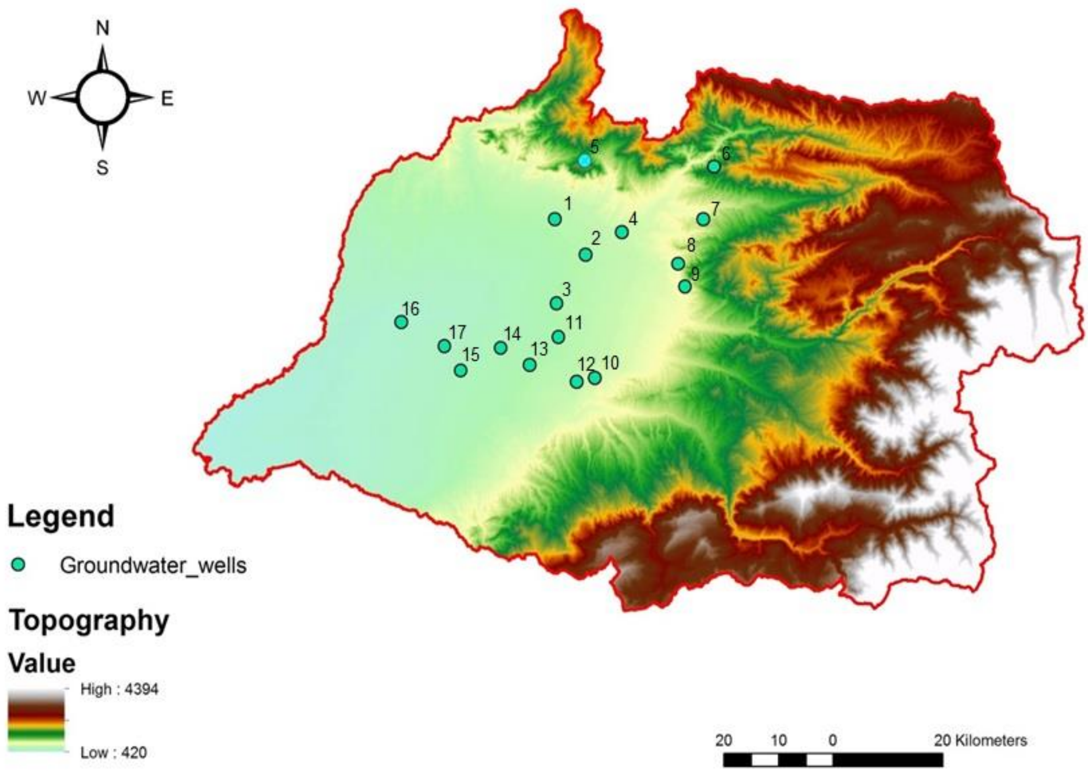


Figure 2.38: Location of groundwater wells in the Kashkadarya River basin territory.

2.8 WATER CONSUMPTIONS IN THE RIVER BASINS

2.8.1 Agriculture

At present more than 60 % of farmers in Uzbekistan occupied in the agrarian sector. Fertile soil forms the base for the well-being of working population. The total area of the land suitable for processing makes 44 million ha. Only 4.3 million ha is actually used.

Irrigated agriculture of Uzbekistan is a huge complex, which consists of most complicated engineering constructions with 61 large water basins whose capacity is 15 Bm^3 distributed by 165463 km of irrigation channels, 23768 km of them are conduits, trays and pipes, 29786 km of collectors, 104433 km of an inter-economic drainage network, including 42734 km of the closed horizontal collectors. In the area 4.22 million ha, the arable land is irrigated by using of large and average size pump stations (Makhmudov 2010).

2.8.1.1 The Chirchik River basin

Large irrigation channels in the Chirchik River basin intend to deliver water for irrigation. The right bank irrigating system of the Chirchik River basin is 1335 km long, including the channels with a concrete covering (30 km). The left-bank irrigating system is 1175 km long, including parts of concrete covering (40 km). On the right bank of the Chirchik River 10 irrigating systems exist: 9 of them are mainly for agricultural production, and one for water supply in Tashkent city. The largest channels are Bozsu with the water flow 140 m^3/s, Zakh 56 m^3/s, Kolkauz 45 m^3/s and Djun 33 m^3/s.

Channel Iskander, the uppermost on a right bank, originates from the derivational channel above the Tavaksay hydroelectric power station, and its flow rate is 5 m^3/s and the total length is 15 km.

Gun and Salar channel water divider located in a place below of merge of channels Salar, Karasu and Burdjar. Length of the channel of old Djun is 36 km, and new Djun is 14 km.

Channel Kalkauz and Damashi consist of three main channels: Kalkauz, Damashi and Ramadan channels. Kalkauz with length 1.5 km passes the city of Tashkent. The total length of channel Damashi is 15 km, the settlement flow 40m^3/s. The width of the channel up to 8 m, in the case of Ramadan channel, throughput 40 m^3/s and the width of the channel reaches up to 8 m.

The largest main channel in the city is Ankhor with the flow 10 m^3/s, irrigates a southwest part of the city, has an earthen channel and only in separate sites is made by modular concrete plates. Other main channels are Koncha, Katiran, Darbazaken, Godragan, Shaykhontohur and Akkurgan. Channels pass mainly in extending in connection with the necessity of an increase in throughput and reconstruction of city building. The general irrigated area about 21800 hectares.

Largest channels of the Chirchik River basin are located on the left bank of the River Chirchik: Karasu, with the flow rate 180 m^3/s and Tashkent channel with a flow rate 26 m3/s. The total length of the Karasu channel is 87 km, the irrigated area about 170000 ha. Throughput of each distributor to 20 m^3/s their general extent of 100 km, they have an earthen channel and pass in dredging, width around 2-5 m, depth with 3-5 m.

Hamdam channel's waterway is 49 km with flow channel 23 m^3/s. The width of the channel is around 2-4 m and the irrigated area about 10000 hectares.

Tashkent channel has two large branches left and right. The distributed water in the right bank is 12 m^3/s (Bedrincev 1975).

2.8.1.2 The Kashkadarya River basin

The economy of the region is focused on agriculture. The share of agricultural production in the gross regional product is more than 40%. The gross agricultural output of the region is 796.1 billion UZS (607.7 million U.S. dollars).

Natural and climatic conditions in the region are connected to a higher average temperature than that in other regions. The long warm period and fertile soil give opportunity to produce heat loving plants as cotton, sugar cane and persimmon. Favorable climatic conditions and irrigation system in Kashkadarya region allow to have multiple cropping.

Kashkadarya region is a main granary of grain, cotton and other agricultural products in the country. All agricultural products by 10.2%, more than 10% of cotton, 11% of grain, 19% of astrakhan in the country come from this region.

Growing fine-fiber differences of cotton and breeding cattle and small livestock are considered to be the most important direction of agricultural production in Kashkadarya region.

The total field of the region makes 2.857 thousand ha in area and 1.381 thousand ha are pastures. About one million ha of the field is suitable for irrigation.

The most important areas of agriculture in the region are dry and spray grain cultivation and sheep breeding.

In the region, alongside with cotton cultivation also silk production is developed. The region takes one of the leading places in the sphere of astrakhan (fur) production. Expansion of pastures, increasing of corn and lucerne sowing and using of industrial wastes promote the further development of animal industry.

The main branch of animal industry is astrakhan (fur) production, which is developing basically in the west, southwest and central areas. Fat-tail sheep and goats are giving meat and wool which are on pastures of north and northeast foothill and mountainous areas. For developing productive cattle breeding in foothills and steppes they cultivate something fleece sheep and long fur coats. The quantity of large horned livestock is satisfied of the needs of residents in the area on dairy products.

Kashkadarya region has potential to grow agricultural products. Mostly flat and fertile land creates good conditions for the development of agriculture, animal husbandry, and highly profitable cotton.

The main agricultural products produced in the province are cotton, grain, fruits and vegetables, grapes, wool (Bedrincev 1975).

2.8.2 Industry and Energy

2.8.2.1 The Chirchik River basin

In Tashkent region, about 680 factories, representing 160 kinds of industries give 45% of gross industrial output of the country. Rapid development in the Chirchik River basin in construction, chemicals, energy, steel and iron production, as well as industries related to processing of cotton and raw kenaf brings large amounts of different kinds of waste which are disposed in landfill sites. Industrial effluents are discharged into watercourses which result in environmental pollution and groundwater pollution in particular.

A water reservoir and hydraulic engineering were constructed for management of water resources of the Chirchik River basin. Water reservoirs intend the storage of a winter drain to the river and seasonal regulation of discharged water to the irrigated area and improvement of water supply to residents and industries such as hydraulic power generation necessary for providing water for irrigation.

The Charvak reservoir is located on top of the Chirchik River in connection of two rivers. The basic figures of the water reservoir:

- Total capacity - 2000 M m^3;

- Effective capacity - 1580 M m^3;

- The maximum depth – 166.0 m;

-Length of a dam - 768.0 m;

-Capacity of hydroelectric power station - 600 MW.

The water reservoir was constructed for the purpose of irrigation in Tashkent region, for water supply to cities and industries, for development of hydropower resources and for reduction in struggling against high waters (Makhmudov 2010).

2.8.2.2 The Kashkadarya River basin

Industry in Kashkadarya region is deeply connected with agriculture. Basic manufacturers are cotton cleanest, dairy processing, canned food processing such as fruits and vegetables and so on. Also about 150 industrial enterprises, including 45 large enterprises in oil and gas, light industry, food-processing industry, mechanical engineering and building materials industry exist in this region.

The largest of them is Shurtan gas-chemically complex, Mubarek management of oil-and-gas deposits, Mubarek oil refining factory, the joint venture «Oksaroy tukumachi», the joint venture «Cotton road», Shahrisabz vine-vodka factory, Shahrisabz cannery, the joint venture «Qarshi oil - extraction factory», the joint venture «Kasan oil - extraction factory » and others (Makhmudov 2010).

Putting into operation in 2004 of the first block Talimardzhan hydroelectric power station with 800 MW, has solved electricity supply shortage in the region.

Kashkadarya Province is a fundamental fuel-energy base of the country, supplying more than 90% of natural gas, condensate gas and oil (Makhmudov 2010).

In 2001, Shurtan gas-chemical complex that is the largest enterprise on processing of gas was put into operation in the province. Currently the activity of Shurtan gas-chemical complex extends processing natural gas with the production of ethylene, production of polyethylene by Sclairtech technology. The production capacity of the Complex is processing of approximate 4 Bm^3 of natural gas, output of 125 thousand tons of different kinds of polyethylene of low and high consistence (meaning?), 137 thousand tons of liquefied gas and 37 thousand tons of gas condensate, about 4 thousand tons of sulfur. On the base of products of Shurtan gas-chemical complex, the Qarshi plant in Termoplast produces modern polyethylene pipes for water and gas supply.

Muborak gas refinery with the capacity of 30 Bm^3 of gas which comprises significant part of gas processed in the country, about 17% of stable condensate and 11% of liquefied gas. Currently, the enterprise is undergoing reconstruction of production such as construction of propane-butane blend plant for the production of liquefied gas.

Kashkadarya River basin’s water is used irrigation and electricity: the total capacity of hydraulic power generation is 251 MW (Makhmudov 2011).

2.8.3 Drinking water supply

2.8.3.1 The Chirchik River basin

In the Chirchik River basin, a number of major cities and industrial centers of Uzbekistan are located. Most of the enterprises in the region affect the quantity and quality of water resources in this area (Chub 2000).

Table 2.13: Water supply in Tashkent region

№	Water source	2009	
		Mm^3	Ratio, %
1	Total	584.3	100.0
2	Chirchik River	89.9	13.7
3	Groundwater	504.4	86.3

2.8.3.2 The Kashkadarya River basin

The main source of fresh water in Kashkadarya region is in the Kashkadarya River basin, whose catchment area is 8780 km^2 in area, which corresponds of 1/3 of the whole region (28500 km^2). The Kashkadarya River starts near Dautash pass whose altitude is 3000 m and which is in the western part of the Hissar ridge and ends in Karshi steppe, forming a dry delta. Tributaries in the Kashkadarya River basin; Aksu, Yakkabag and Tanhaz play an important role in supplying water. The Kashkadarya River basin formed by an average of 1.27 km^3 / year of water is completely taken for irrigation (Chub 2000).

Table 2.12: Water supply in Kashkadarya region

№	Water source	2009		2010	
		Mm^3	Ratio, %	Mm^3	Ratio, %
1	Total	6171	100.0	6031	100.0
2	Amudarya and Zarafshan	4411	71.5	4275	70.9
3	Kashkadarya River basin	1540	25.0	1530	25.4
4	Ground water in Kashkadarya River basin	94	1.5	96	1.6

2.9 CONCLUSION

1. Examined and evaluated total hydrological processes, including evapotranspiration of a watershed, precipitation, overland flow, unsaturated and saturated flow and percolation in the Chirchik and Kashkadarya River basins for 2009 and 2010 years.

2. According to obtained results, The Chirchik River basin’s climate is semi-arid and Kashkadarya River basin’s is arid, and water resources of both river basins are the social, economical and environmental indicators of the development of Uzbekistan.

3. As a result of the comparison of the spatial distribution, water balance information of the two river basins shows that the both river basin's environment and water management organisations are different and in vital condition.

4. Has been obtained that, the Chirchik and Kashkadarya River basins are different in characteristics and formation:
    - The Chirchik River flows into the Syr-Darya River, which the main artery of the Aral Sea basin.
    - The flow of the Kashkadarya River breaks toward the Amu Darya River and cannot reach to the second artery of the Aral Sea.

    In this case, it is necessary to develop applicable simulation models to calculate the water cycle in arid river basins.

REFERENCES

6. Bedrincev K.N., Korjavin B.D.,(1975). Irrigation of Uzbekistan, Volume 1, Tashkent, Uzbekistan.

7. Kashkarov R.D., (2008). Ecological Atlas of Uzbekistan. UNESCO Office in Uzbekistan, Tashkent, Uzbekistan.

8. Makhmudov E.J, Ishanov X.X., (2010). Global Network for Water Development Information in Arid and Semiarid Regions of Asia, UNESCO, pp. 27-34.

9. Hasanov D. N., (2005). Development of Hydrogeology and engineering geology in Uzbekistan, Gidroingeo, Tashkent, Uzbekistan.

10. Chub V.E., (2000). Climate change and its impact on the natural resource potential of Uzbekistan, Tashkent, p. 127.

11. Petrov V., Egamberdiev H., Kholmatzhonov B., (2005). Meteorology, The journal of the NUU, p.330.

12. Makhmudov Kh., (2011). Integrated River Basin Management in the Chirchik River basin, The University of Kitakyushu, Japan.

13. The Institute of Groundwater, (2010). Report of the GP"Gidroingeo", Tashkent.

CHAPTER 3: INTERPOLATION OF CLIMATIC PARAMETERS BY USING BARYCENTRIC COORDINATES

ABSTRACT

In the Chapter 3, a new method of interpolation of climatic parameters has been proposed, where territory spread value point measurements of meteorological data on the territories of its space. The method is based on the representation of the territories affected by hydro-meteorological stations as the mechanical integrity, consisting a lot of material particles having a common effect of motion. An instance of such a substance is known in practice barycenter (center of force per unit area). Similarity features of change in the value space of meteorological parameters: pressure, rain, humidity and other parameters allowed us to develop an interpolation method, based along the well-known method of classical mechanics, a method for finding centers systems. Centre Systems: barycenter, center humidity, precipitation, and so forth, as reference points from which climate data set gradients (gradient is a vector indicating the direction of change of a scalar quantity, the pressure, rain, temperature and humidity are known as scalars). Gradients and equation are describing the basis methods for the proposed interpolation. Graphical method of calculations carried applicability straight-line equation for the interpolation of climate information. The method is all founded on the utilization of proven analytical dependences and therefore reliable results.

3.1 INTRODUCTION

Provision and management of water for irrigation in the Arid Areas implemented depending on the type of plants on the footing of their way of irrigation. Therefore, management of water for irrigation is performed using meteorological data areas: atmospheric pressure, precipitation, evaporation, humidity areas, etc. Currently meteorological data fields are established through point measurements on specially equipped weather stations. Each weather station receives a coverage radius that reaches 15-35 km and more. Meanwhile meteorological parameters territories are heavily hooked on the terrain and crossing an area meteorological parameter value may undergo substantial changes in the field. Use not sufficiently accurate weather information reduces the efficiency of the ground water and a negative impact on crop yields. And coverage of the total territory of the necessary number of weather stations from both a technical and economic point so the persuasion is not possible.

Thus, several methods of interpolation of climate information, which are applied as a basis for weather information. An assortment of methods known interpolation areas, the most common of these are: the method of inverse distance weighted method kriging and trend surface. The method points which are closer to those, in which the assessment is made, have a greater impact as compared to distant points. For a more accurate description of the topography of a set of points, which will be interpolated, chosen in a neighbourhood defined point, as they have the greatest influence on her height is based on the reduction of the required point lying near to the reference point. The method is the foundation for defining the radius of influence of meteorological stations (Valipour 2014).

In the method of trend surface, a set of points inside a given locality. Within each neighbourhood built surface of best approximation based on mathematical equations, such as polynomials or splines. For this function, usually the least squares. These equations are described by nonlinear dependencies, replacing curves or other kinds of numerical sequences into simpler. To make the surface of the trend in each value is substituted into equation vicinity. As a result, we obtain one value that is assigned to the interpolated point. For other target points continue this procedure.

A common method of interpolation of natural factors of the territories is by using the Kriging method. It involves the use of spatial continuity model or relationship (in the form of covariance - scalable version which is semivariogram correlation or a model landscape of the area), and the sample surface data to determine trends, statistics on which holds interpolation (extrapolation) of the points. Quantitative representation of spatial data structures, known as building variogram or semivariogram, enables users to select the data model of spatial dependence. To calculate the (forecast) of the unknown value of a variable at a given point kriging will use the appropriate (matched) model variograms, spatial information and configuration values in the measurement points around the placement (Valipour 2014).

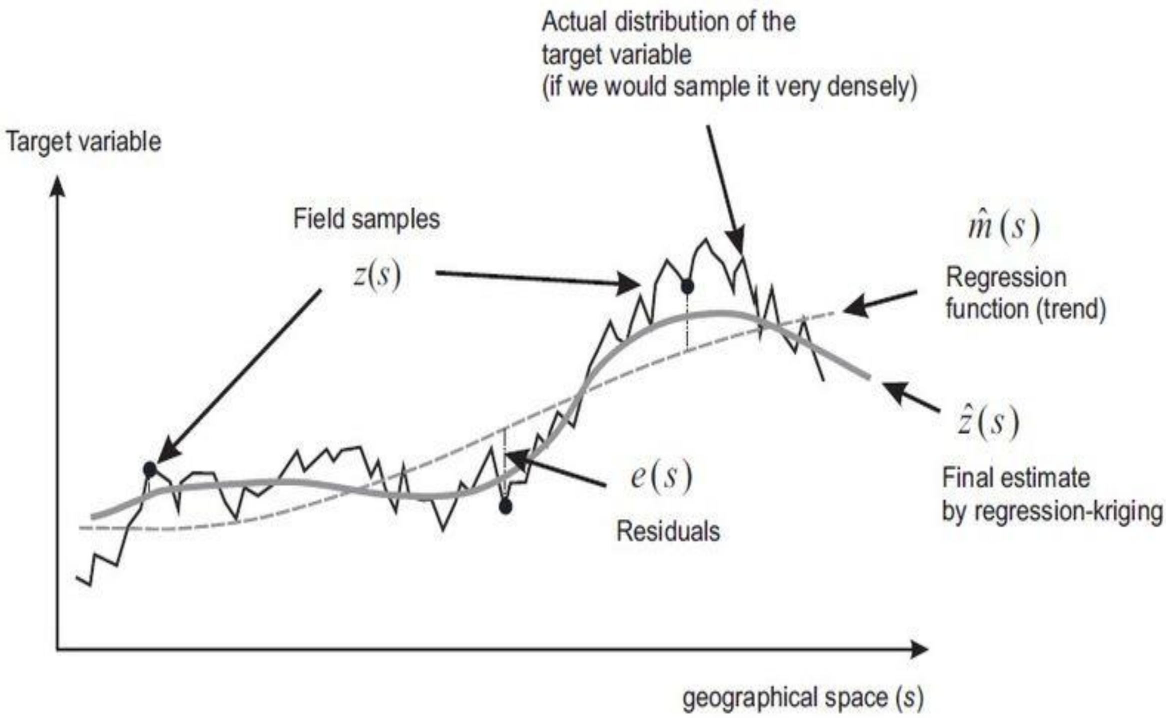


Figure 3.1: The general example of spatial variation scheme (source: https://en.wikipedia.org /Regression-kriging).

Co-kriging interpolation method which allows to estimate the surface cubes and maps using the statistics for multiple information sets that this method of interpolation adds additional correlation between the data analysis capabilities.

Above mentioned interpolation methods are based on the original date of the reference station and a reference station while may not reflect all features of the basin. In the case of the Chirchik river basin region, weather station, which qualify the total territory of features. And the transition from zone to another meteorological parameters undergo serious changes.

Widespread methods of the Kriging and Co-kriging, has great opportunities, in particular for the utilization of GIS technology, but they are really complicated and time-consuming. Kriging and Co-kriging methods based on natural features of the territory, and is more useful to describe the landscapes and their characteristics. A meteorological data in addition to the natural features of the territories are also related spatial arrangement of interpolated parameters of the territories. The complexity of the kriging and cokriging methods primarily due to the need to create variograms and semivariogram, but for different landscape areas as arid and semiarid zones, which in particular is a Chirchik River basin is not possible.

In this respect, the proposed interpolation method became necessary to produce a combined system consisting of a landscape, and the natural component of a system of point system of a moving mess, with a single center. In this territory meteorological components are accepted as elements of mass and each climate factor has own centre of movement.

3.2 MATERIALS AND METODS

The object of investigation adopted Chirchik River basin region in the Uzbekistan. In this territory to monitor hydro-meteorological factors installed and operated four meteorological stations (Figure 3.2).

Location Hydrometeorological stations in the Chirchik River basin caused by primarily of natural and climatic conditions of the zone. Hydrometeorological Station Tashkent is located in the centre of the Tashkent city and is naturally significantly influenced by anthropogenic factors. The Chimghan Hydrometeorological Station is in the hilly portion of the watershed, where anthropogenic factors, aren't significantly involving the natural processes.

Hydrometeorological Station Yangiyo'l is on the flat part of the watershed, where anthropogenic influences are significant compared with the mountain arena. On the territory of irrigated agriculture, for reliable meteorological parameters play a substantial role in the planning and management of water for irrigation. Hydrometeorological station Number 4 is located near Tuyabuguz reservoir, and in the sphere of the transition zone of the mountain landscape of the plains were developed rain-fed and irrigated agriculture. Although meteorological stations located in the most characteristic areas of the basin with matching radius coverage, but the applicable interpolation methods do not allow to obtain reliable meteorological information, and it is necessary to develop the new interpolation methods of the territory.

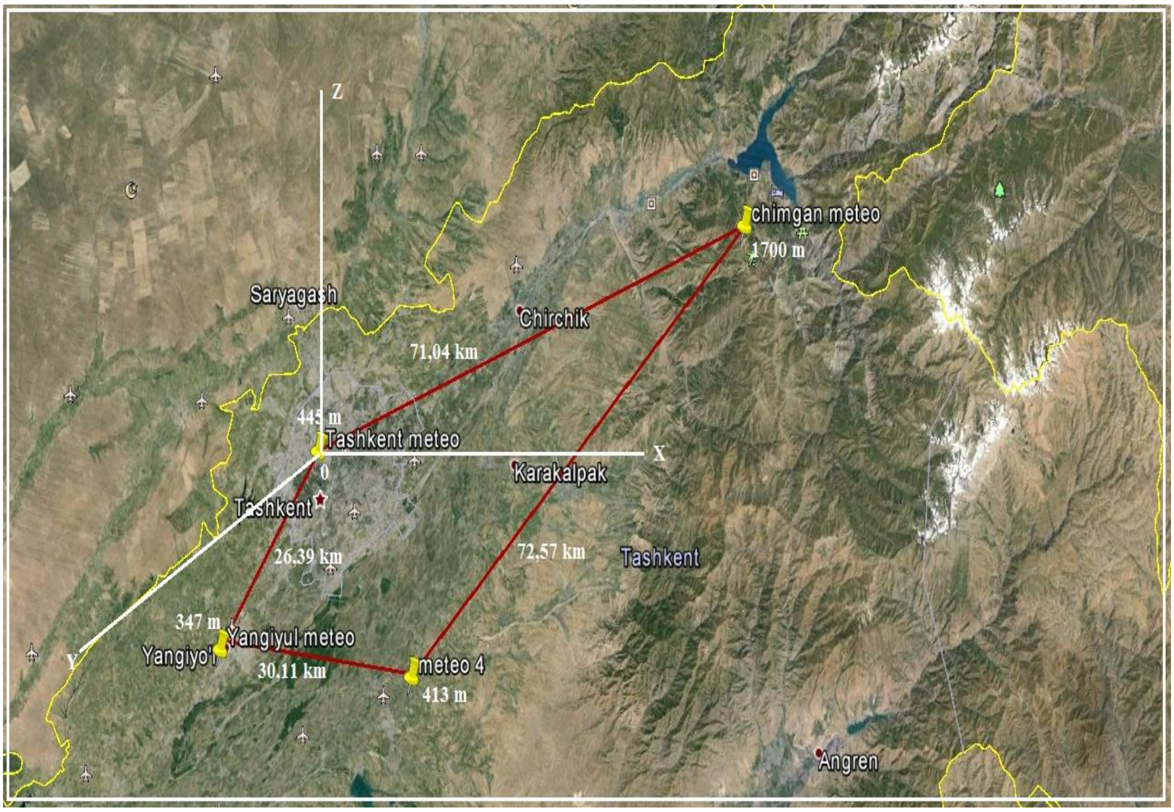


Figure 3.2: Layout of the Hydrometeorological stations in the Chirchik river basin in Uzbekistan.

Our proposed new interpolation method based Hydrometeorological data territories, especially the consideration of the pool area as a system consisting of material points and is in a single movement and the whole in a single space. For such a system is the center point of the material, which characterizes the motion of the whole system, if the applied pressure is a point called the barycenter or the center of the system to establish the Center of the Hydrometeorological parameters from the outset of the report - weather station adopted as origin point on the dominion of the Chirchik River basin (Figure 3.2).

The proposed method of understanding the actual parameters of the Chirchik River basin is to support the results of the work, for this used monthly averages for two months observing the different seasons in 2012 (Table 3.1 Uzhydromet Source).

Table 3.1: Weather stations location and its data.

№	Meteo-stations	Coordinates (x, y, z), changed to metric	T^0C	Precipitation	Evaporation (Month)	Atmospheric pressure,	Humidity %
February							
1	Tashkent	0,0,0	-0,6	63,6		964,4	72
2	Yangiyul	-15006,6; -21707,9; -98	-1,8	57,7		982,6	88
3	Chimgan	66381,1; 25302,9; 1255	-5,9	85,9		830,5	47
4	Tuyabuguz	14827,8; -25772,3: -32	-1,2	55,4		975,9	82
June							
1	Tashkent	0,0,0	26,6	18,5		958,3	40
2	Yangiyul	-15006,6; -21707,9; -98	27,1	2,6		967,4	45
3	Chimgan	66381,1; 25302,9; 1255	18,1	66		830,2	47
4	Tuyabuguz	14827,8; -25772,3: -32	27,0	10,8	165,6	961,3	45

The values of the coordinates of hydro-meteorological stations positioned relative origin Tashkent weather station in meters. To establish the coordinates of the center of pressure and other meteorological parameters (the point at which the average set of meteorological parameters) as the origin or as a reference point also agreed location meteorological stations of Tashkent used depends (Zhuravlev 2001):

$$\vec{r}_c = \frac{\sum\limits_i m_i \vec{r}_i}{\sum\limits_i m_i}, \tag{3.1}$$

Where $\vec{r}_c$ - the radius vector of the center of mass, $\vec{r}_i$ - radius vector of the i -the point of the system, m_i the mass of the i -the point (Zhuravlev 2011). Then the coordinates of the center of mass can be rewritten as follows:

• For pressure coordinates of the center of pressure:

$$x_c = \frac{1}{P} \sum p_i x_i$$

$$y_c = \frac{1}{P} \sum p_i y_i$$

$$z_c = \frac{1}{P} \sum p_i z_i \tag{3.2}$$

Where the P -sum monthly averages of atmospheric pressure (P_i) for 4 meteorological stations

• For temperature- T0C, coordinates of the center:

$$x_c = \frac{1}{T} \sum_{i=1}^{i=4} T_i \, x_i$$

$$y_c = \frac{1}{T} \sum_{i=1}^{i=4} T_i \, y_i$$

$$z_c = \frac{1}{T} \sum_{i=1}^{i=4} T_i \, z_i \tag{3.3}$$

Where T is the sum of mean monthly temperature (T_i) air for 4 meteorological stations

• For precipitation-O, the center coordinates:

$$x_c = \frac{1}{O}\sum O_i x_i$$

$$y_c = \frac{1}{O}\sum O_i y_i$$

$$z_c = \frac{1}{O}\sum O_i z_i \tag{3.4}$$

Where O- is the sum of the average monthly precipitation (O_i) for 4 meteorological stations.

For humidity, the center coordinates of humidity, where the humidity is equal to its average value:

$$x_c = \frac{1}{B}\sum B_i x_i$$

$$y_c = \frac{1}{B}\sum B_i y_i$$

$$z_c = \frac{1}{B}\sum B_i z_i \tag{3.5}$$

Where, B - is the amount of average monthly humidity (B_i) for 4 meteorological stations x_i, y_i, z_i -coordinates of Hydrometeorological stations relative to the origin (Tashkent station).

3.3 THE MAIN PART OF THE RESEARCH

Using data of Uzhydromet (Table 3.1) and equation (3.2-3.5) produce estimates coordinates of the centre (mass) of meteorological parameters in an area (system) of the Chirchik river basin.

• Coordinates of the center of pressure (according to the month of February, 2012):

$$x_{pF} = \frac{1}{964{,}4 + 982{,}6 + 830{,}5 + 975{,}9} \sum 964{,}4 * 0 + 982{,}6 * (-15006.6) + 830{,}5 * (66381.1) + 975{,}9 * (14827.8) = \\ = 14614.61\text{м}$$

$$y_{pF} = \frac{1}{964{,}4 + 982{,}6 + 830{,}5 + 975{,}9} \sum 964{,}4 * 0 + 982{,}6 * (-21707{,}9) + 830{,}5 * (25302{,}9) + 975{,}9 * (-25772{,}3) = \\ = -6785.13\text{м}$$

$$z_{pF} = \frac{1}{964{,}4 + 982{,}6 + 830{,}5 + 975{,}9} \sum 964{,}4 * 0 + 982{,}6 * (-98) + 830{,}5 * (1255) + 975{,}9 * (-32) = \\ = 243.71\text{м} \tag{3.6}$$

While the average value of the atmospheric pressure, corresponding to the center of mass is equal to:

$$p_{av.F} = \frac{P}{4} = \frac{964{,}4 + 982{,}6 + 830{,}5 + 975{,}9}{4} = \frac{3753{,}4}{4} = 938{,}35 mm.Hg \tag{3.7}$$

• Coordinates of the center of pressure (according to data for the month of June 2012):

$$x_{pJ} = \frac{1}{958{,}3 + 967{,}4 + 830{,}2 + 961{,}3} \sum 958{,}3 * 0 + 967{,}4 * (-15006{,}6) + 830{,}2 * (66381{,}1) + 961{,}3 * (14827{,}8) =$$
$$= 14754.7\text{м}$$

$$y_{pJ} = \frac{1}{958{,}3 + 967{,}4 + 830{,}2 + 961{,}3} \sum 958{,}3 * 0 + 967{,}4 * (-21707{,}9) + 830{,}2 * (25302{,}9) + 961{,}3 * (-25772{,}3) =$$
$$= -6663.26\text{м}$$

$$z_{pJ} = \frac{1}{958{,}3 + 967{,}4 + 830{,}2 + 961{,}3} \sum 958{,}3 * 0 + 967{,}4 * (-98) + 830{,}2 * (1255) + 961{,}3 * (-32) =$$
$$= 246.51\text{м}$$

(3.8)

While the average value of the atmospheric pressure, corresponding to the center of mass is equal to:

$$p_{av.J} = \frac{P}{4} = \frac{958{,}3 + 967{,}4 + 830{,}2 + 961{,}3}{4} = \frac{3717{,}2}{4} = 929{,}3mmHg$$

(3.9)

• Coordinates of the center of humidity (according to data for the month of February, 2012):

$$x_{pF} = \frac{1}{72 + 88 + 47 + 82} \sum 72 * 0 + 88 * (-15006{,}6) + 47 * (66381{,}1) + 82 * (14827{,}8) = 10433.26\text{м}$$

$$y_{pF} = \frac{1}{72 + 88 + 47 + 82} \sum 72 * 0 + 88 * (-21707{,}9) + 47 * (25302{,}9) + 82 * (-25772{,}3) = -9807.57\text{м}$$

$$z_{pF} = \frac{1}{72 + 88 + 47 + 82} \sum 72 * 0 + 88 * (-98) + 47 * (1255) + 82 * (-32) = 165.18\text{м}$$

(3.10)

The average value of moisture%, corresponding to the center of mass is equal to:

$$b_{av.F} = \frac{B}{4} = \frac{72+88+47+82}{4} = \frac{289}{4} = 72{,}25\% \qquad (3.11)$$

Coordinates of the center of humidity (according to data for the month of June 2012):

$$x_{pJ} = \frac{1}{40+45+47+45}\sum 40*0+45*(-15006{,}6)+47*(66381{,}1)+45*(14827{,}8) = 17581.16\text{м}$$

$$y_{pJ} = \frac{1}{40+45+47+45}\sum 40*0+45*(-21707{,}9)+47*(25302{,}9)+45*(-25772{,}3) = -5352.39\text{м}$$

$$z_{pJ} = \frac{1}{40+45+47+45}\sum 40*0+45*(-98)+47*(1255)+45*(-32) = 300.19\text{м} \qquad (3.12)$$

The average value of moisture%, corresponding to the center of mass is equal to:

$$b_{cp.J} = \frac{B}{4} = \frac{40+45+47+45}{4} = \frac{177}{4} = 44{,}25\% \qquad (3.13)$$

So, as a test case using monthly averages (data Uzhydromet) in February and June 2012 received the centre of mass for atmospheric pressure and humidity at which the atmospheric pressure and humidity, respectively, are equal to their fair value. Conducted test calculations have shown that the difference of meteorological parameters influences the position of their core, each parameter: barometric pressure, rainfall, humidity and temperature, etc. has its own essence. When this variability values of meteorological parameters in time also affects the location of their centres. In this respect, the proposed method for each meteorological parameter for a point in time (when the measurements) calculations must be done according to this process separately. Table 3.2 gives examples of the results of calculations for two parameters: for atmospheric pressure and humidity, respectively, for two months of monthly data of different seasons in 2012. As the table demonstrates the values of coordinates of the centre of pressure and humidity and different at the same time they also differ on estimates of months.

Plugging in the centre of mass with points (gradients) vectors expressing the direction of change of meteorological parameters or gradients of atmospheric pressure and humidity.

Table 3.2: The results of the coordinate system movements.

№	Months	Atmospheric pressure		Humidity	
		Coordinates of center, m	Annual mean, mmHg	Coordinates of center	Annual mean
1.	February	14614,61; -6785,13; 243,71	938,35	10433,33; -9807,57; 165,18	72,25
2.	June	14754,7; -6663,26; 246,51	929,3	17581,16; -5352,29; 300,19	44,25

For spatial interpolation of meteorological parameters are parallel transport coordinate system from the initial point "Tashkent Meteo " on the center of mass C. Parallel transport of the coordinate system to atmospheric pressure is indicated in Figure 3.2. Set up the coordinates of points of Hydrometeorological stations relative new coordinate system with the origin - C were performed using known relationships of course analytic geometry:

$$
\begin{aligned}
X_c &= X_T - a \\
Y_c &= Y_T - b \\
Z_c &= Z_T - d
\end{aligned}
\tag{3.14}
$$

By using Formula 3.14, estimated with respect to the coordinate values of weather-origin C and the corresponding monthly average meteorological parameters. In especial, the coordinates of the meteorological station «Chimghan meteo» atmospheric pressure (in meters) measured in relation to monthly averages for February 2012 are Pch (51766,49; 32088,03; 1011,29).

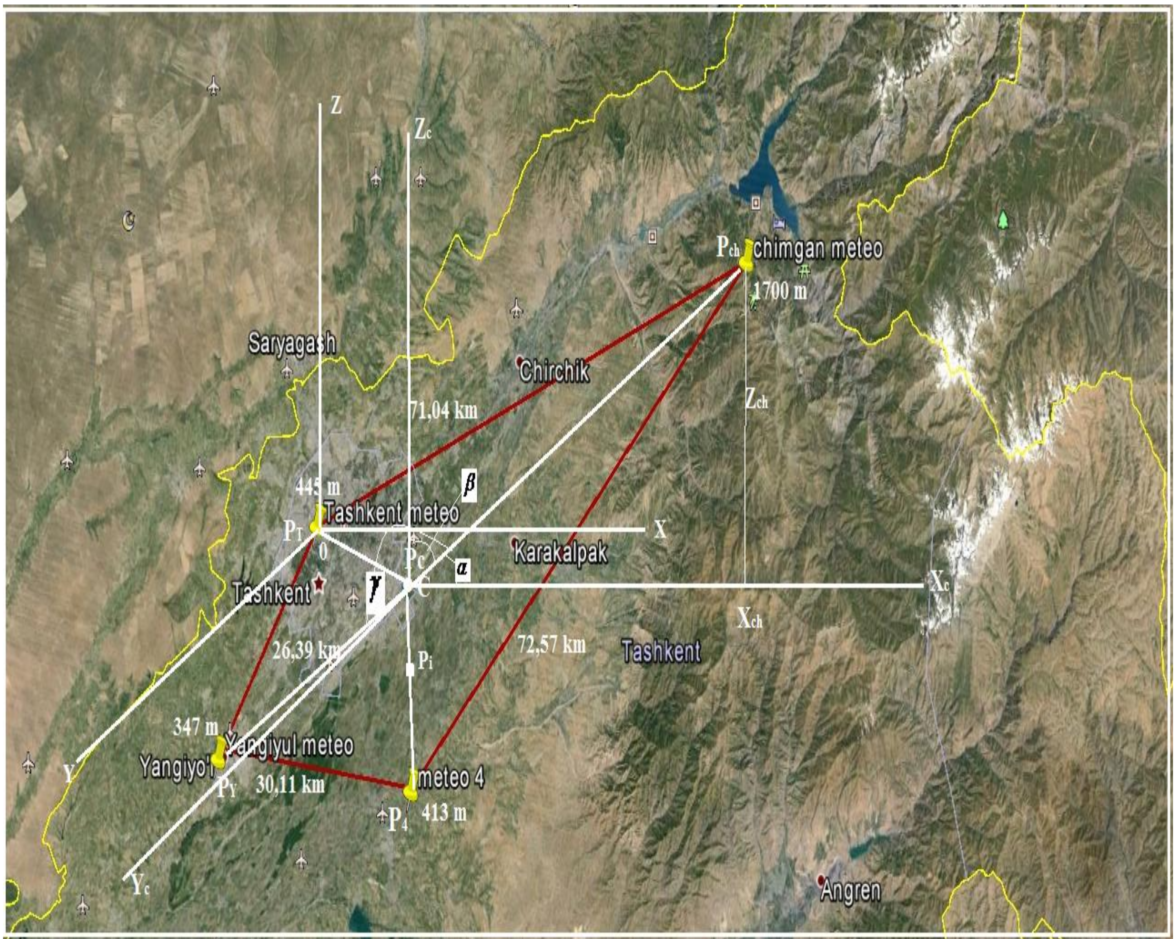


Figure 3.3: Center of pressure and pressure gradients (mm Hg).

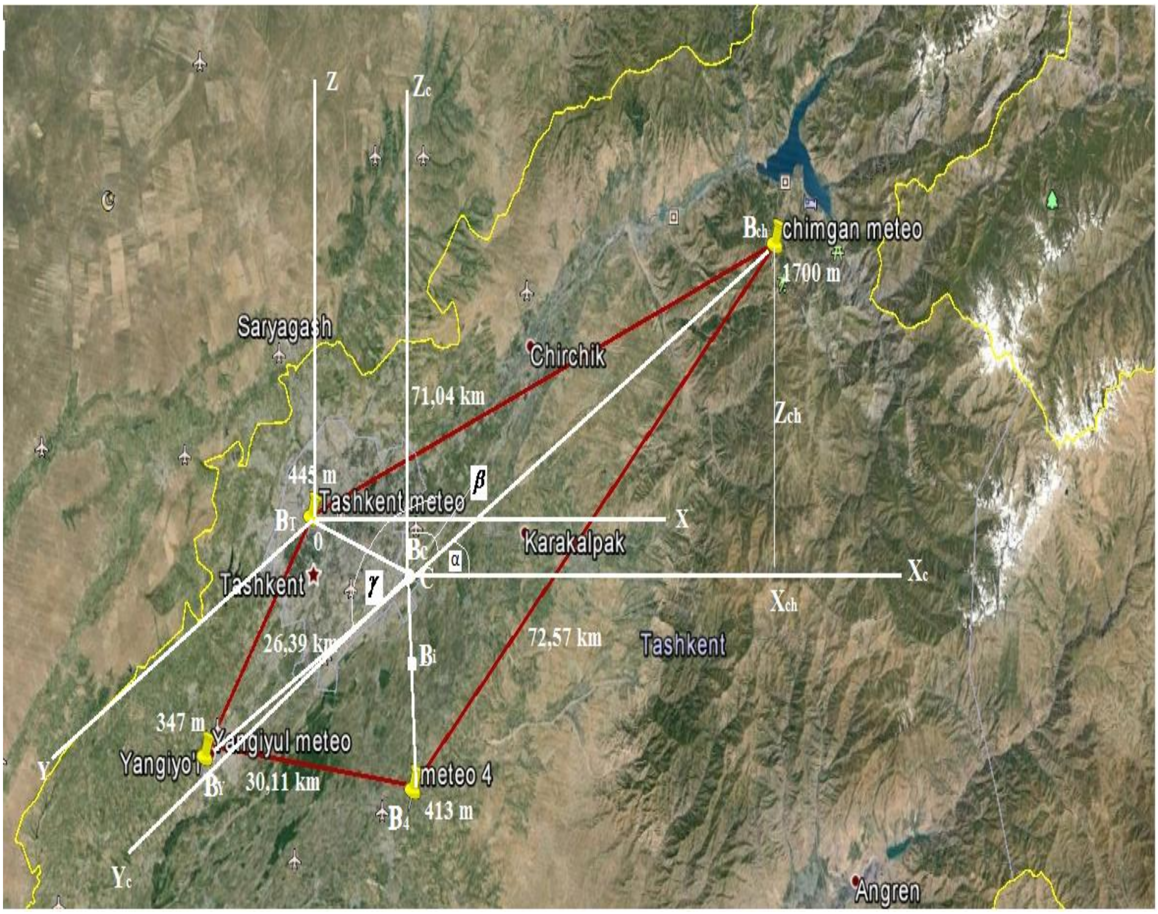


Figure 3.4: Center of the humidity and moisture gradients (in %).

A parallel transport coordinates system for humidity is shown in Figure 3.3. Similarly, calculated values of the coordinates of all the weather stations in the basin relative to the center of humidity Chirchik River basin. In particular coordinate meteorological station Chimghan relative humidity center (system) areas (in meters) Sun-point with respect to the measured monthly averages for February 2012 are Bch (55947,77; 35110,47; 1089,82).

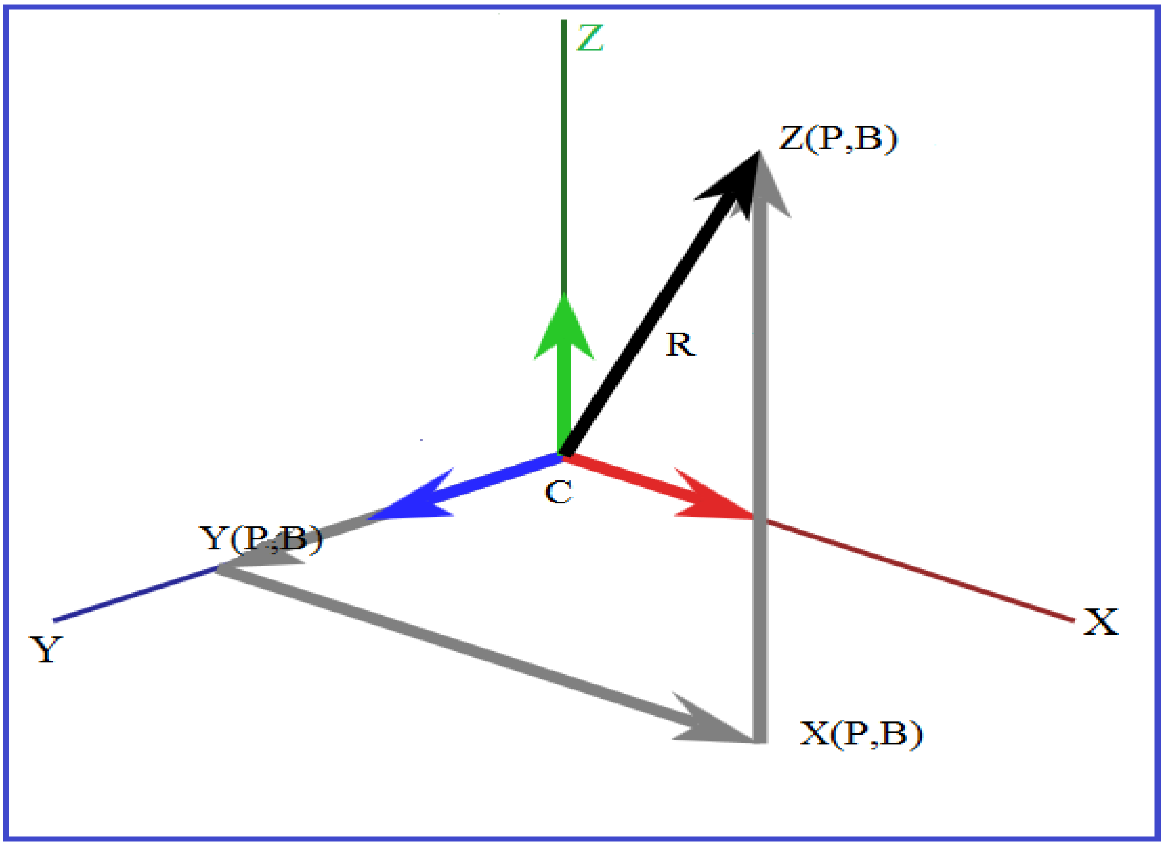


Figure 3.5: Scheme of the focal point of change of scalar quantities: atmospheric pressure and humidity).

$\vec{P}_c\vec{P}_{ch}; \vec{P}_c\vec{P}_T; \vec{P}_c\vec{P}_Y; \vec{P}_c\vec{P}_4$ pressure gradients.

$\vec{B}_c\vec{B}_{ch}; \vec{B}_c\vec{B}_T; \vec{B}_c\vec{B}_Y; \vec{B}_c\vec{B}_4$ - gradients of humidity.

Figure 3.5 shows the vector and vector projections on the coordinate axes.

Using the Figure 3.5 makes a slope calculation unit (in terms of coordinates, length of a line on which the change in force per unit area) to meteorological station Chimghan using the estimated values for the month of February Pch (51766,49; 32088,03; 1011,29).

$$|R| = \sqrt{X^2 + Y^2 + Z^2} = \sqrt{51766{,}49^2 + 32088{,}03^2 + 1011{,}29^2} = \sqrt{2679{,}72 + 1029{,}64 + 1{,}022} = \\ = 60912{,}91m \tag{3.15}$$

Then the angles between (vector) gradient and its projections on the coordinate axes are as:

$$\cos\alpha = \frac{X}{|R|} = \frac{51766{,}49}{60912{,}9} = 0{,}8498$$

$$\cos\beta = \frac{Y}{|R|} = \frac{32088{,}03}{60912{,}9} = 0{,}5268$$

$$\cos\gamma = \frac{Z}{|R|} = \frac{1011{,}29}{60912{,}9} = 0{,}0166 \qquad (3.16)$$

Therefore, we can estimate the cosinus of the respective modules and angles on the data for the month of June, and besides for the humidity and climatic parameters for any district.

The equation describing the vector (gradient) is the equivalence of a straight course (Figure 3.6).

Then the equation for the interpolation of atmospheric pressure:

$$P_i = P_c + X_i tg\alpha \qquad (3.17)$$

$$tg\alpha = \frac{P_{ch} - P_c}{X_{ch}} \qquad (3.18)$$

Where,

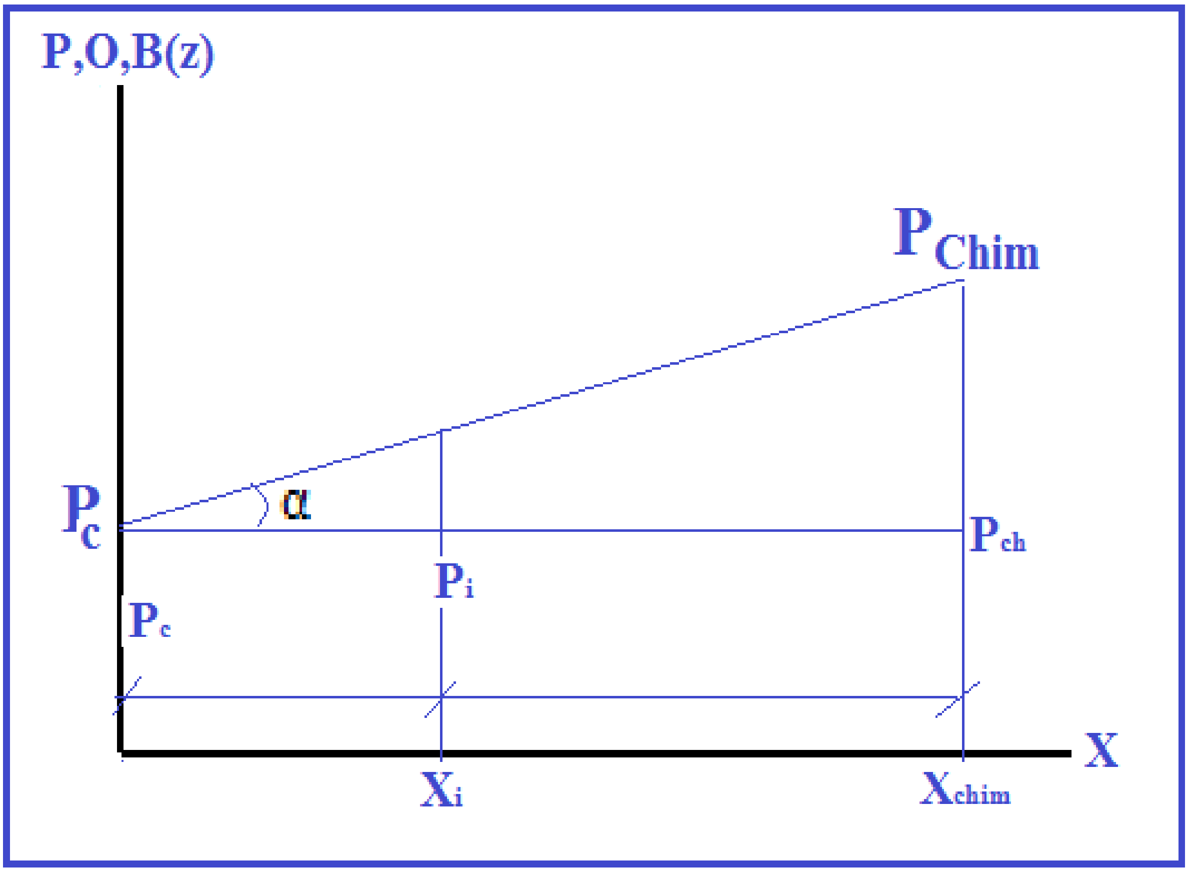


Figure 3.6: Scheme for the establishment of the gradient equation (or line interpolation plane, Y-axis as the axis is perpendicular to XOZ).

Using of the equation (3.19) to interpolate the atmospheric pressure in the direction vector $\vec{P_c}\vec{P_{ch}}$ for the billing month accept February 2012,

$$tg\alpha = \frac{P_{ch} - P_c}{X_{ch}} = \frac{830,5 - 938,35}{66381,1 - 14614,61} = -\frac{107,85}{51766,49} = -0,00208 \qquad (3.19)$$

From the equation (3.19) In case of $X_i = 0 \rightarrow P_i = P_c$ and in $X_i = X_{chim} \rightarrow P_i = P_{chim}$

$$P_i = P_c + X_i tg\alpha = 938,5 - 51766,49 * 0,00208 = 938,5 - 107,85 = 830,5 mmHg \qquad (3.20)$$

Example, $X_i = 0{,}5\ X_{ch} = 0{,}5x51766{,}49 = 25883{,}245m$

$$P_i = P_c - X_i tg\alpha = 938{,}35 - 25883{,}245 * 0{,}00208 = 938{,}35 - \\ - 53{,}8371 = 884{,}479 mmHg \tag{3.21}$$

Like a shot through the magnitude of the vector (gradient) find the coordinates of the point I, relative to which the interpolated value of the atmospheric pressure.

$$|R| = \frac{X}{\cos\alpha} = \frac{25883{,}245}{0{,}8498} = 30458{,}043m \tag{3.22}$$

Then,

$$Y = |R| * \cos\beta = 30458{,}043 * 0{,}5268 = 16045{,}297m \tag{3.23}$$

$$Z = |R| * \cos\gamma = 30458{,}043 * 0{,}0166 = 505{,}603m \tag{3.24}$$

For the interpolated value of the atmospheric pressure in the basin Chirchik point i with

Pi = 884,479 mm. Hg. Article coordinates are: X_i = 25883,45; Y_i = 16045,297; Z_i = 505,603.

Therefore, when calculating compliance with the above rules interpolated value of the atmospheric pressure on the place of any district, take any stage through the origin and can be found by analytical values and coordinates interpolated climate data.

To support the applicability of the proposed method for other climatic parameter, for example to create humidity. Calculation algorithm similar to the calculation for the atmospheric pressure.

- The equation for interpolation humidity:

$$B_i = B_c + X_i tg\alpha \tag{3.25}$$

$$tg\alpha = \frac{B_{ch} - B_c}{X_{ch}} = \frac{47 - 72,25}{55947,77} = -\frac{25,25}{55947,77} = -0,000451 \tag{3.26}$$

Where,

- Verification of applicability:

In Xi =0→Bi=Bc =72,25% and in Xi =Xchim

$$B_i = B_c + X_i tg\alpha = 72,25 - 55947,77 * 0,000451 = 47\% \tag{3.27}$$

- Specify the desired point interpolation: Xi =0, 5 Xchim=0, 5x55947,77=27973,885m then,

B_i=72,25 - 27973,885x0,000451 = 72,25 - 12,616=59,634 % (3.27)

- Calculation of vector modules. To show the coordinates of the desired point-I construct the gradient module (the coordinates, length of the line on which the changes in humidity) to meteorological station Chimghan using the estimated values for the month of February Bch (55947,77; 35110,47; 1089,82).

$$|R| = \sqrt{X^2 + Y^2 + Z^2} = \sqrt{55947,77^2 + 35110,47^2 + 1089,82^2} = \sqrt{3130,067 + 1232,71 + 1,1877} =$$
$$= \sqrt{4363,9647} = 66060,31m \tag{3.28}$$

- Calculation of the cos of angle between the vector (gradient) and its projections on the coordinate axes:

$$\cos\alpha = \frac{X}{|R|} = \frac{55947,77}{66060,31} = 0,847$$

$$\cos\beta = \frac{Y}{|R|} = \frac{35110,47}{66060,31} = 0,532$$

$$\cos\gamma = \frac{Z}{|R|} = \frac{1089,82}{66060,31} = 0,0165 \qquad (3.29)$$

- Establish coordinates interpolated point on the site. Using the magnitude of the vector (gradient) finds the coordinates of the point I, relative to which the interpolated values of humidity.

$$|R| = \frac{X}{\cos\alpha} = \frac{27973,885}{0,847} = 33027,019m \qquad (3.30)$$

And so,

$$Y = |R| * \cos\beta = 33027,019 * 0,532 = 17570,37m \qquad (3.31)$$

Interpolated value for humidity in the basin Chirchik point i with B_i = 59.634% and the coordinates are: X_i = 27973,885; Y_i = 17570,3; Z_i = 544,95.

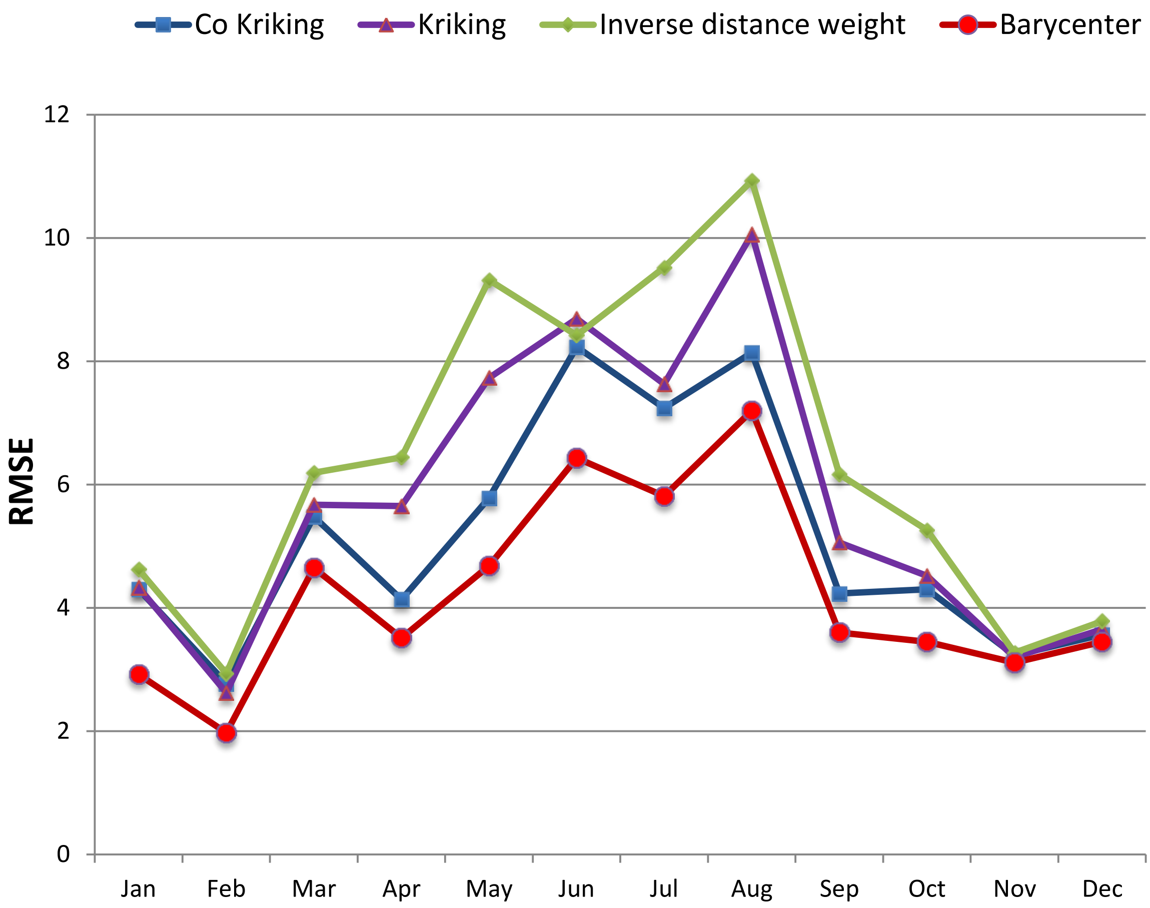


Figure 3.7: RMSE between current interpolation methods and the new interpolation method (barycentric method).

The Figure 3.7 shows the comparing the observed and simulated data by using the RMSE of the each interpolation method (Co-Kriging, Kriging, Inverse distance weight method and barycentric method), the results shows that the barycnetric method has the lowest error.

Thus, interpolation is performed in other climatic elements. It is proposed to give the following calculation algorithm (Figure 3.8).

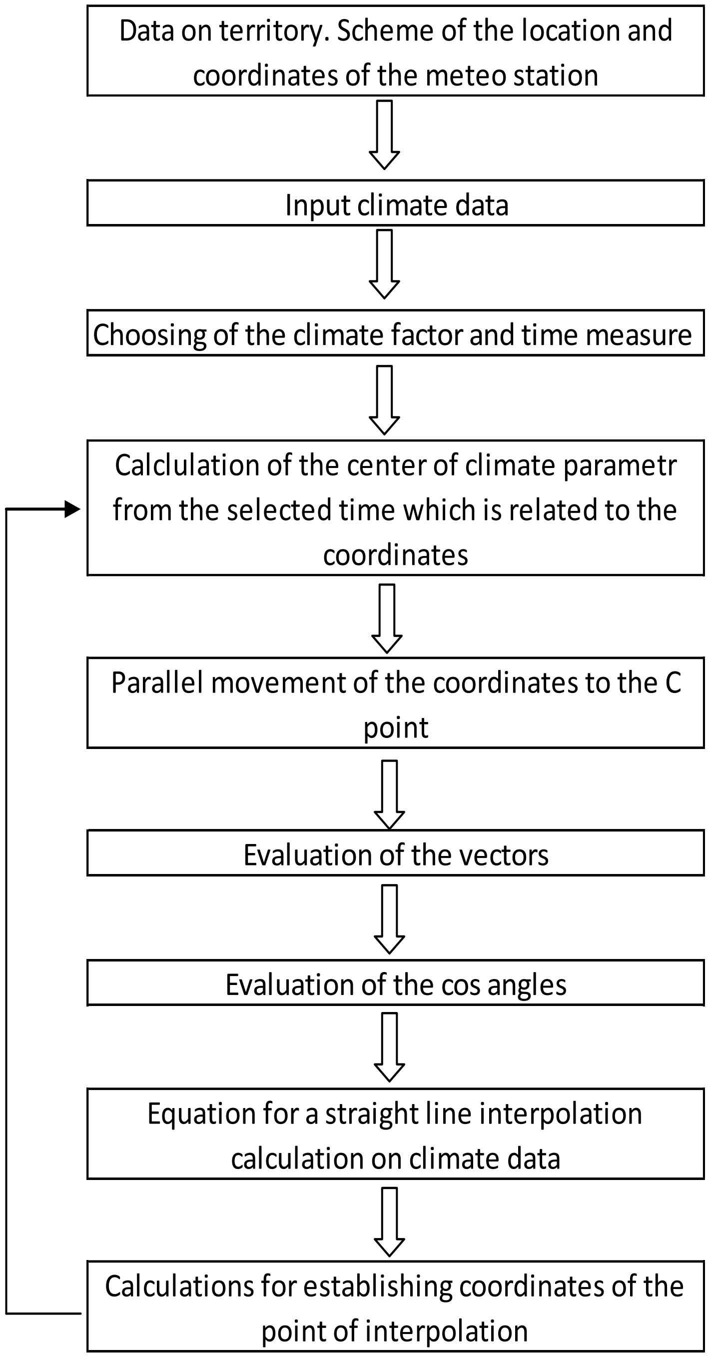


Figure 3.8 The algorithm for the calculating of the interpolation by using barycentric method.

3.4 CONCLUSION

1. Nevertheless, for the use of the kriging methods and cokriging is necessary to create a variogram or semivariogram, and they require a model landscape and its mathematical formulation. What makes them effective for the interpolation of climate data in the decidedly less complicated engineering tasks scheduling irrigation of arid states.

2. Methods inverse distance weighted and the method of trend surface almost in different variations is used to interpolate the climate of these arenas, but they give large errors in the interpolation of data along the transition zones with arid climate areas. Hence the transition from the mountain to the foothills and the plains affect sensitive to changing climatic parameters, and these methods can not contract into account peculiarities of the transition zones with arid conditions of the region.

3. Binding interpolation to one character level of measurement in all existing interpolation methods, in particular methods of Kriging, Co-kriging and methods of surface trend make them less accurate than when the reference point is the centre of the system. So centre where climatic parameter is the average of the entire number of measurements is known purity parameter, depends on the number of quantified information.

4. Suggested method of interpolation with reference to the central reference point and applying recognised and proven approaches graphoanalitical simplify the computation procedure and eradicate errors in setting the estimated climatic parameters territory. Above algorithm allows to produce a mere computer program for the output of the proposed interpolation method.

REFERENCES

1. Blyutgen I, (1973). Geography and climates, 2nd Ed, Progress, Moscow, Russia.

2. German M. A., (1985). Space methods in meteorology. Gidrometeoizdat, Leningrad, Russia.

3. Zhuravlev V.F., (2001). Foundations of Theoretical Mechanics. 2nd Ed, FIZMATLIT, Moscow, Russia.

4. Valipour M., (2014). Comparative Evaluation of Radiation-Based Methods for Estimation of Potential Evapotranspiration, Journal of Hydrological Engineering, 5-20, pp 1247-1271.

5. Phillips N.A.,(1956). A coordinate system having some special advantages for numerical forecasting, Journal of Meteorology, 14, pp 184-185.

6. Valipour M., (2014). Analysis of potential evapotranspiration using limited weather data, Journal of Applied Water Science (Springer), pp 1-12.

7. Lorenz E. N., (1970). Nature and the theory of the general circulation of the atmosphere, Gidrometeoizdat, p.259.

8. Petrov V., Egamberdiev H., Kholmatzhonov B., (2005). Meteorology, The journal of the NUU, p.330.

9. Khandozhko L.A., (1981). Meteorological Service in the Economy, Gidrometeoizdat p.232.

CHAPTER 4: FORECASTING GROUNDWATER LEVEL IN AN ARID AREA ACCORDING TO CLIMATIC DATA

ABSTRACT

In connection with the intensive development of the economy of the Uzbekistan, water use for irrigation, industry, heat power engineering, domestic water supply, industrial communities and rural settlements is continuously increasing.

At the same time, the uneven distribution of water resources of the territory of the Chirchik and Kashkadarya River basin became necessary to develop new approaches in the development of sustainable water resources management.

In particular, for the Chirchik River basin with enough amounts of water resources, there are possibilities to limit the potential values of the river watershed management for the deviation to other regions of Uzbekistan, where there is an urgent demand for water.

Water resources of the Kashkadarya River basin are completely consumed, but for the growth of the regions is needed to remove the necessary quantity of water from the watershed. In this instance, as the method of water residue is the instrument with which we can get the needed quantity of water, which is transported to the catchment area from another river basin, in particular from the Amu Darya River basin.

Subject fields of the water balance of river basins devoted a bunch of research studies, the water balance equations of river basins made taking into account water and irrigation facilities and the influence of anthropogenic factors on water balance in particular. Presented research methods are to calculate the parameters of the water balance of the river basin arid areas.

Development of a prediction method on groundwater level in a river basin depending on climatic data is the purpose of this study. The roots of the prediction method are water balance calculation, transient filtering an interpolation method on climatic data developed and showed in the chapter 3. The maturation of a method for predicting the ground water level depending on precipitation, abstraction and so on was carried out utilizing the simulation model MIKE SHE. In parliamentary law to present the outcomes

of this survey, topographic maps and the geographic information system (GIS) were employed. The calibrated predictive values of the groundwater level were compared with actual data measured in observation wells. As an outcome, the values of the root-mean-squared error in the calculated points are less than 0.66.

4.1 INTRODUCTION

Equally it is known, in areas with an arid climate with groundwater runoff determine the primary conditions of crop yield. In demonstrating the style of an irrigation plant, especially cotton, the state of groundwater determines the amount of water-supply via irrigation canals. Soil, affected by salt and in the presence of groundwater toxic salts can give condition of groundwater, which defines the principal conditions of plant life, for example: a small distance from the ground surface leads to salinization and soil degradation, and induces a rich state of increased need for irrigation water. Anticipation of the soil, water regime is a scientific challenge. The challenge is made by the comportment of a sort of genes that bear on the groundwater regime; the most influential of them are precipitation and runoff. At the same time of the groundwater regime has a significant impact the area where it is located, if the territory is turned up along the river valley, the factors which have an impact on the groundwater regime, more than the areas in the steppe zone, etc. In this respect, the purpose of the research was proven in the Chirchik River basin in the Tashkent region of Uzbekistan.

As a subject research, the main influence of precipitation was seen in conjunction with other parts of the water balance of a river basin in groundwater areas. The aims of this chapter are predicting the ground water regime in the area with less groundwater observation wells. Also the results of the prediction are applied to protect land from erosion and soil salinization.

4.2 MATERIALS AND METHODS

Delineation of study boundary is really significant to understand hydrological and represent a full hydrological cycle. To study hydrological cycle, subject area extracted from river catchments. Catchments shape is extremely dependant on the topography and location of rivers. Catchments delineation requires topography or digital elevation model

(DEM) of the survey region. Hydrological analyst in ArcGIS tool in ArcGIS platform is capable to automatically delineate the catchments and transform them to vector formats. One of hydrological tool of ArcGIS is “terrain pre-processing”has been utilised in the creating of database for catchments/watershed delineation (Johnson and Labadie, 2008). A DEM in ArcGIS raster format is required as input for terrain pre-processing.

In this study ASTER (Advanced Space borne Thermal Emission and Reflection Radiometer) GDEM (Global Digital Elevation Model) was employed to extend the terrain pre-processing tool to delineate Chirchik and Kashkadarya River basins. The ASTER GDEM was developed jointly with the Ministry of Economy, Trade, and Industry (METI) by Japan and the United States National Aeronautics and Space Administration (NASA). Characteristics of ASTER GDEM are given to a lower place:

Table 4.1: ASTER GDEM.

1	Geographic coordinates	Geographic latitude and longitude
2	DEM output format	Geo-Tiff, signed 16 bit, and 1 m/DN Referenced to the WGS84/EGM96 Geo-id.
3	Special DN values	-9999 for void pixels, and 0 for seawater body.
4	Pixel size	30 m

Extraction of the river drainage area should pass following steps: Fill sinks, flow management, flow accumulation, stream definition, stream segmentation, catchment grid delineation, catchments polygon processing. These instruments are available in hydrology terrain pre-processing tool set to calculate above counted hydrological parameters was used ASTER GDEM of Chirchik and Kashkadarya River basin.

In this study boundary of the Chirchik and Kashkadarya River basins was delineated using catchments and administrative boundary of regions of Tashkent province.

Region of the Chirchik and Kashkadarya River basin consists of upper stream and in the northeast site and downstream in the southwestern region. Southwest portion of the watershed is almost topographically plain. Hence, the limit of the drainage area in upper stream is defined according to watershed concepts and downstream port is described through the administrative boundary of the districts of Tashkent and Kashkadarya provinces. In Figure 4.1 and 4.2 are shows extraction of basin boundary in ArcGIS platform.

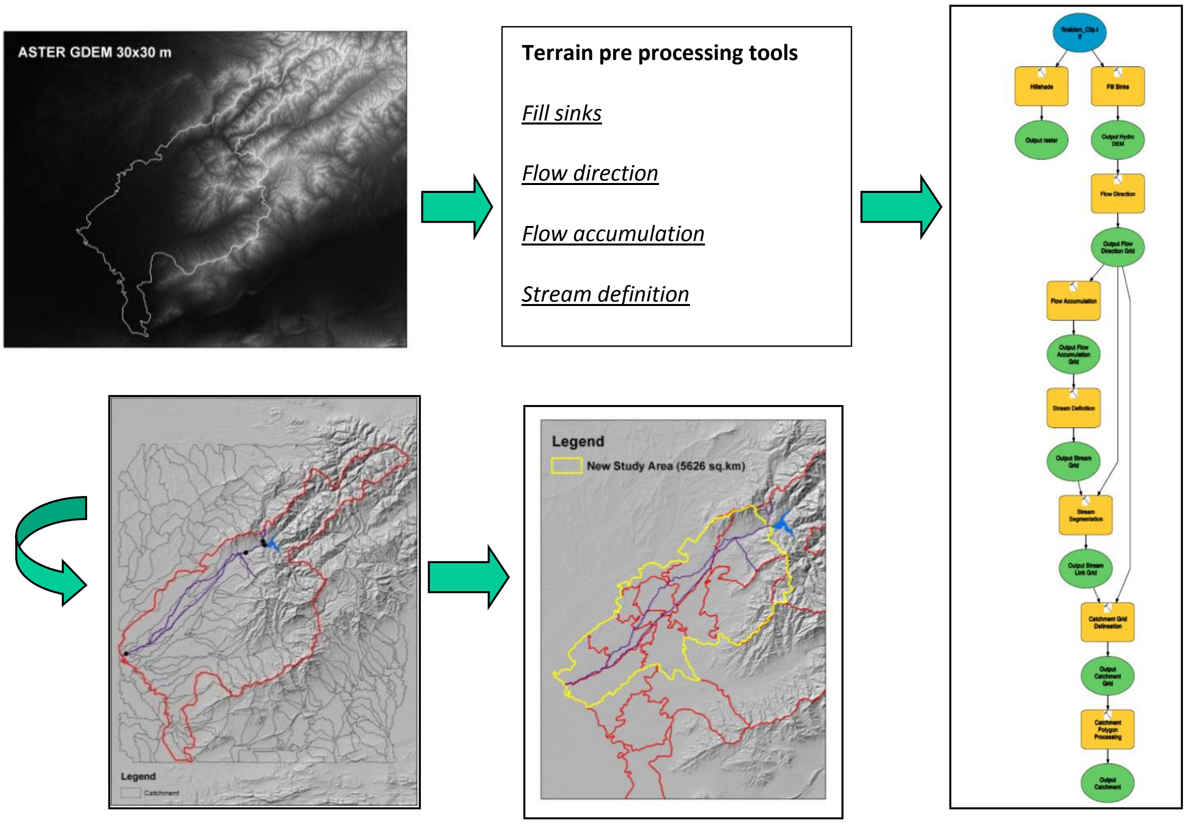


Figure 4.1: Chirchik river basin extractions from ASTER GDEM in ArcGIS platform.

After catchments to polygon process all sub catchments converted to vector format. And so these sub catchments overlaid with hill shade, Chirchik and Kashkadarya Rivers and its tributaries and administrative boundaries of Tashkent province. In last extracted basin boundary overlaid with grid mesh in vector format to take the final basin boundary. In the present research, carrying into action of the model as a subroutine of the grid size and the running time suggest that, has been considered to utilise a 1000 m grid-square model.

The size of each mesh is 1000 m2. Area of the basin equal to 5626.226 km2 and reference projections is WGS 1984 UTM zone 42 N.

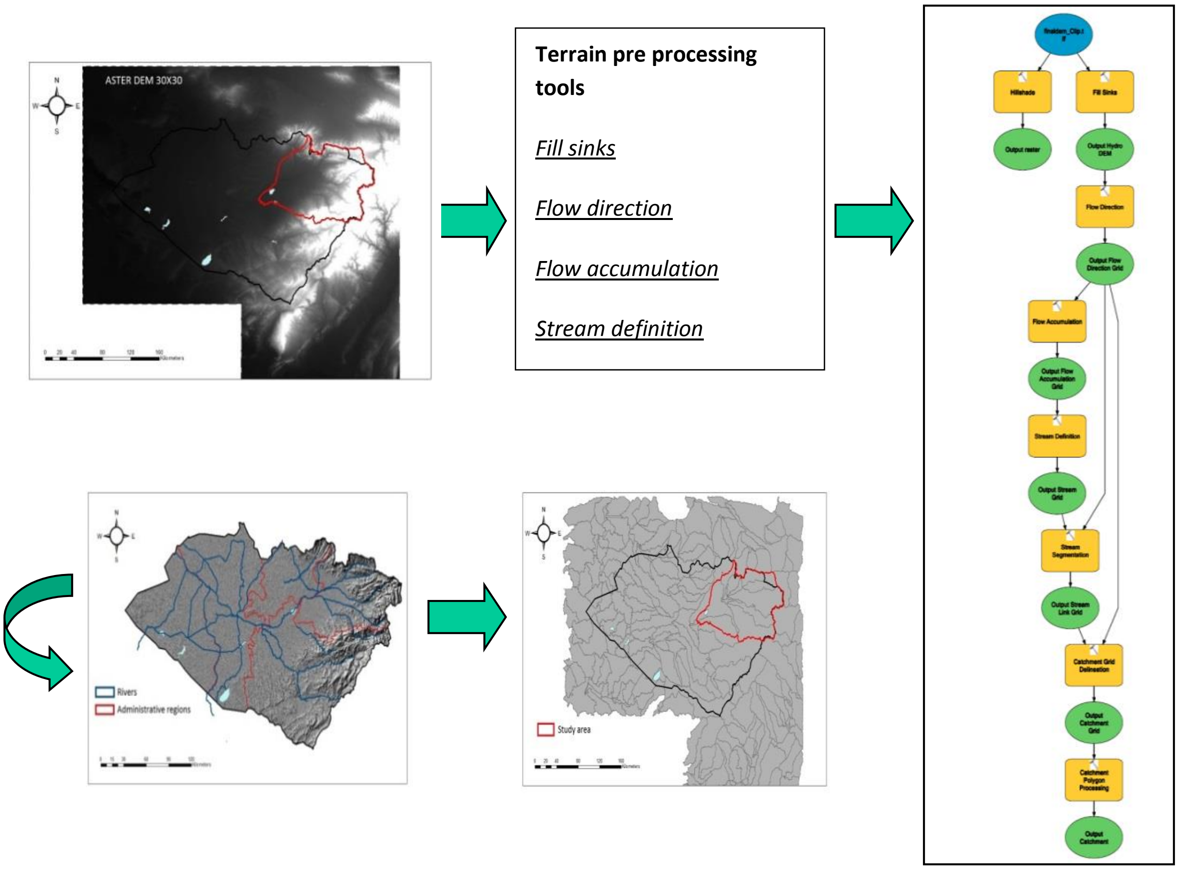


Figure 4.2: Kashkadarya River basin extractions from ASTER GDEM in ArcGIS platform.

Topography of study area obtained from ASTER GDEM data. Initially the pixel size of ASTER GDEM changed from 30 m to 1000 m using block statistics tool in ArcGIS. Then ASTER GDEM data with 1000 m converted to the ASC II file format as input parameters in the MIKE SHE platform.

The example information is defined in a diversity of formats independent of the model domain and grid, including native GIS formats. At run time, the spatial data are mapped onto the numerical grid, which builds it easy to modify the spatial discretization. All the hydrologic processes are solved implicitly at a uniform time step, which can lead to intensive computational effort for watershed scale models. The brief description of methods for each procedure is shown in Figure 4.3.

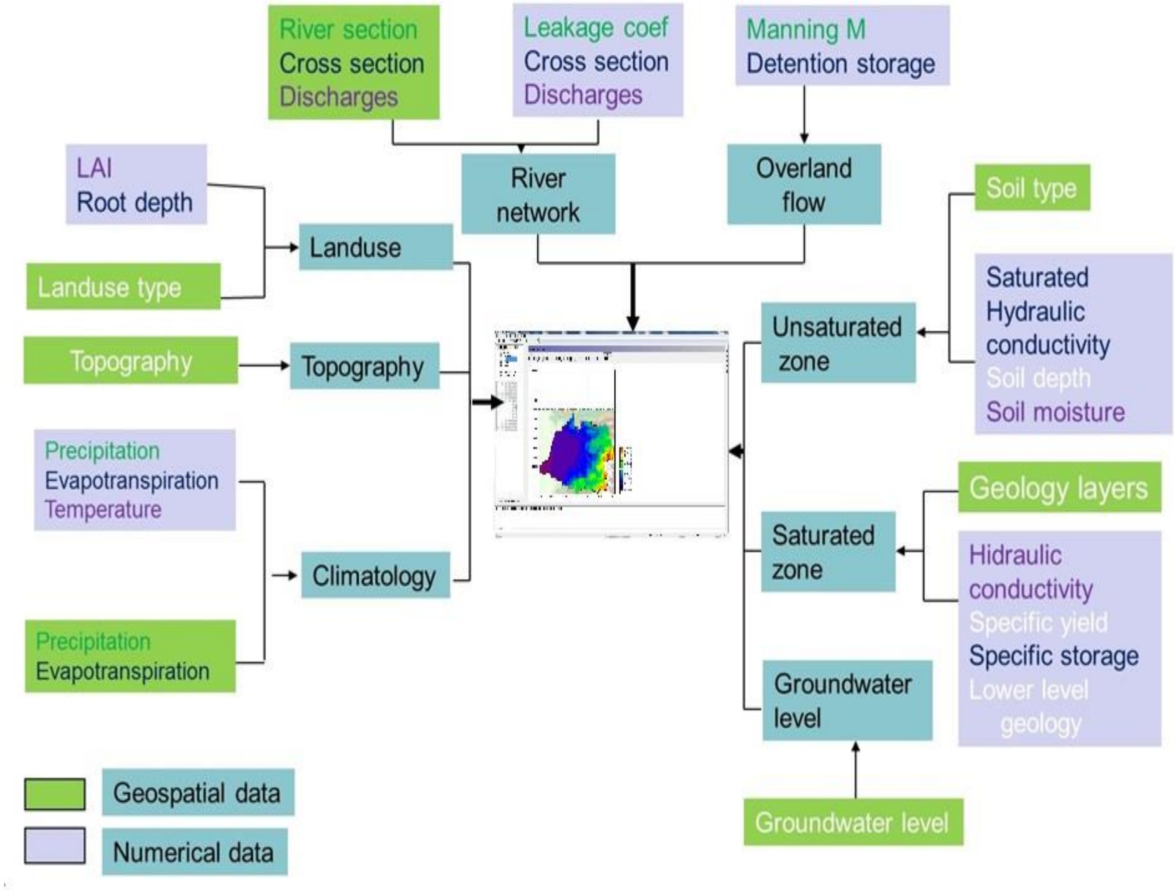


Figure 4.3: Data input of MIKESHE model.

MIKE SHE is an innovative, flexible framework for the hydrologic modelling. It admits a broad suite of pre and post processing tools, plus a flexible mixture of modern and simple solution techniques for each of the hydrologic processes. MIKE SHE covers the major operations in the hydrologic cycle and includes process models for evapotranspiration, overland flow, unsaturated flow, groundwater flow, and canal flow and their interactions. MIKE SHE uses MIKE 11 to simulate channel flow. MIKE 11 includes comprehensive facilities for modelling complex channel networks, lakes and reservoirs, and river structures, such as gates, sluices, and weirs.

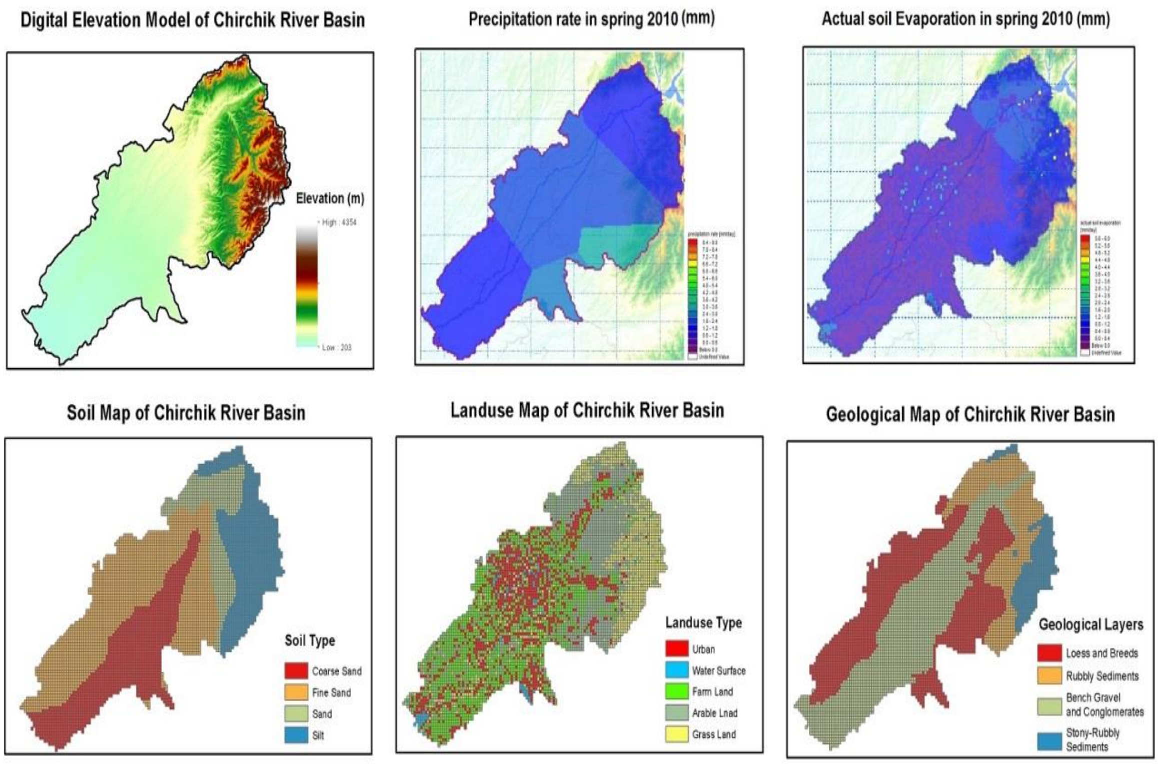


Figure 4.4: Geo Spatial Hydrological Data of the Chirchik River basin was prepared and transformed to 1000 x1000 m Vector Format as an input factor to simulate the water balance with MIKE SHE technique.

Each of these procedures can be interpreted at different layers of spatial distribution and complexity, according to the goals of the modelling study, the availability of field information and the model choices shown in Figure 4.4 and Figure 4.5. The MIKE SHE user interface permits the user to intuitively build the model description based on the user's conceptual model of the basin.

MIKE SHE has been employed in a wide scope of applications. It is being used operationally in many nations about the world by organizations ranging from universities and research centres to consulting engineers companies (Refsgaard & Storm, 1995). MIKE SHE has been practiced for the analysis, provision and management of a broad range of water resources and environmental and ecological problems related to surface water and groundwater.

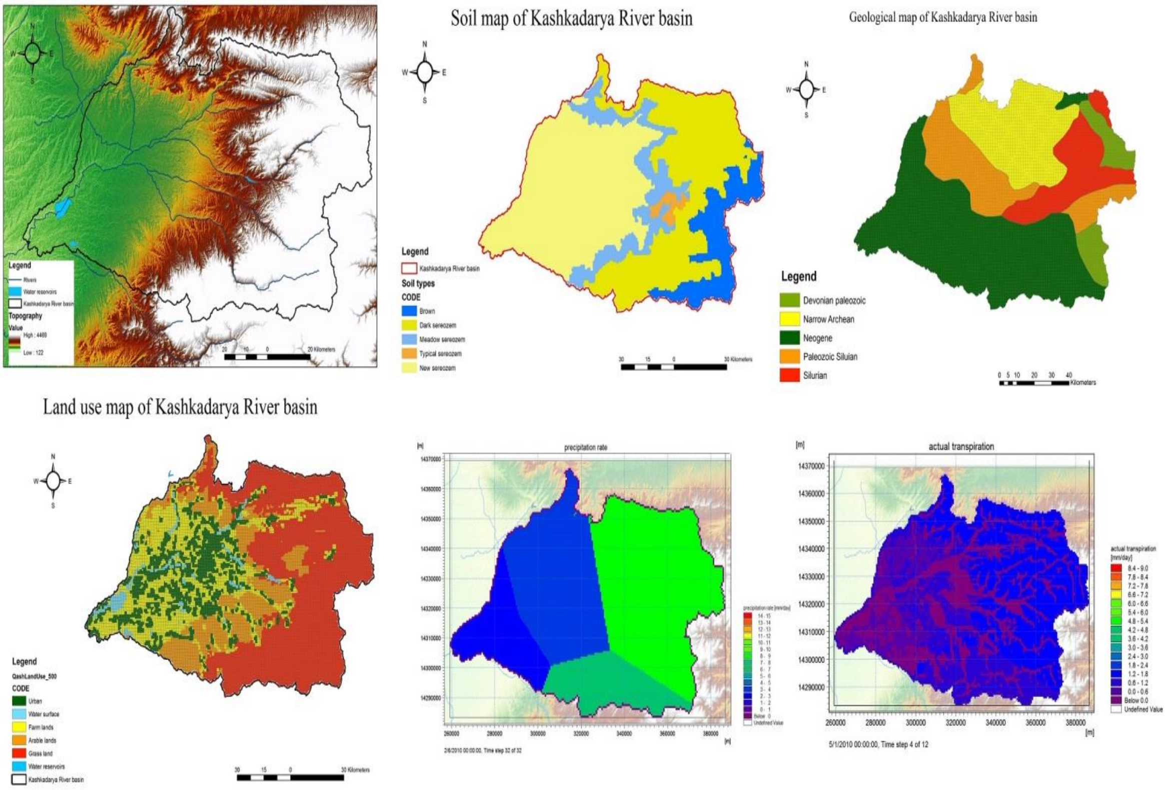


Figure 4.5: Geo Spatial Hydrological Data of the Kashkadarya River basin was prepared and transformed to 1000 x1000 m Vector Format as an input factor to simulate the water balance with MIKE SHE technique.

The quarry area of enquiry is the field of the Chirchik and Kashkadarya River basins, where crop production is carried out only by irrigation. Thus, foretelling of the state of groundwater enhances the strength of water management in the production of crops and particularly of cotton. Cotton in the mentioned region is the primary plant and occupies more than 60% of the irrigated region of the Syrdarya river basin. As the research methods defined the water-balance method of the river basin, the method of unspecified filtering and interpolation method of climatic factors.

The water balance equation of the Chirchik river basin:

$$Q_{gw} = W + Q_{Char+Ugam} + Q_{Ohan} + P + Q_{return} - Q_{Chinoz} - Q_{use} - Q_{syr-darya} - ET - E \qquad (5.1)$$

W: water increment of groundwater

$Q_{char+Ugam}$: Water Inflow to the Chirchik River Basin from the Ugam River and the Charvak reservoir

Q_{ohan}: Water Inflow to the Chirchik River Basin from the Akhangaran River.

P: Precipitation.

Q_{chinaz}: Water abstraction in the Chinaz station.

Q_{use} : Water use in the Chirchik River Basin.

ET: Total amount of transpiration.

E: Total amount of soil evaporation.

Q_{gw} : Ground water discharge and expenditure.

Q_{return}: Return water from collector.

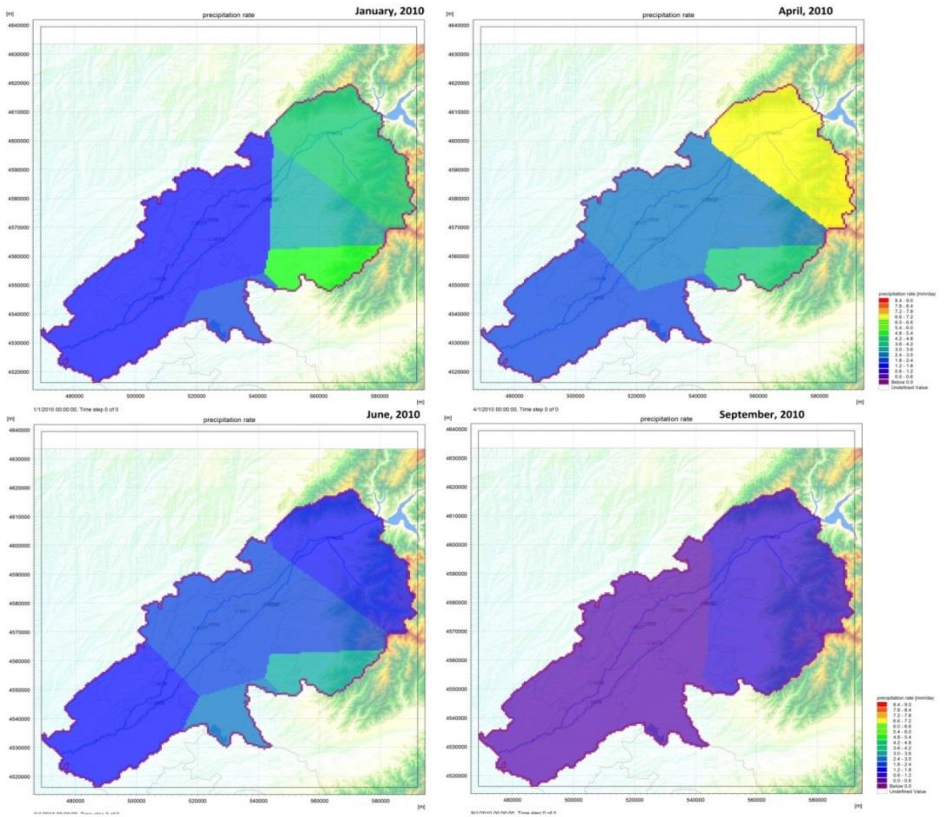


Figure 4.6: Seasonal changes and distributions of rainfall in the Chirchik River basin in 2010.

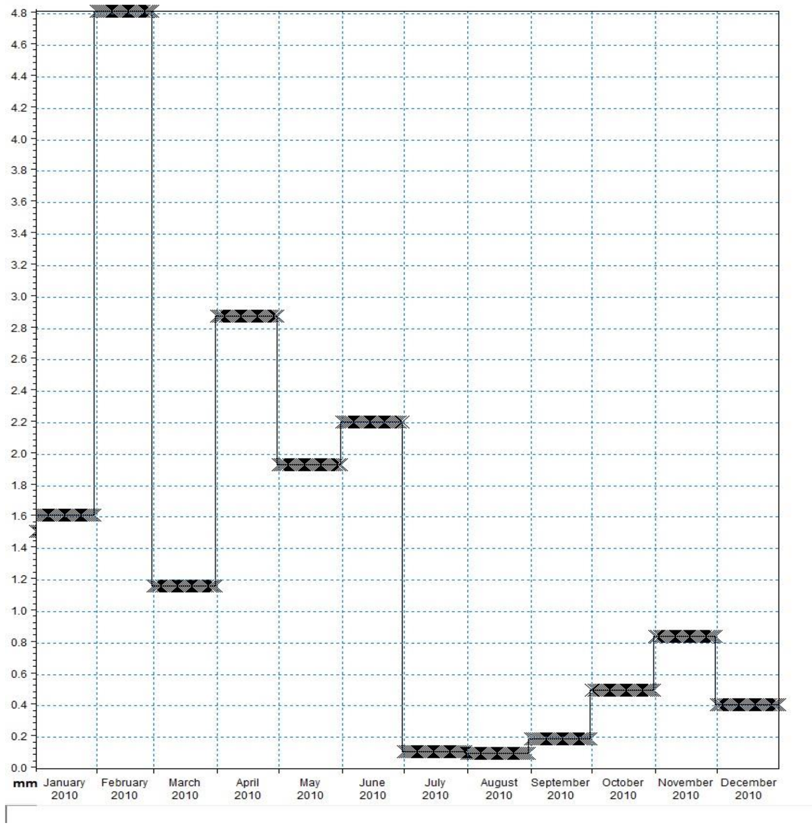


Figure 4.7: The total rate of the precipitation rate in Tashkent (MIKE SHE, total balance in The Chirchik River basin in 2010).

Accumulated seasonal change of the rainfall in the Chirchik River basin has been presented in Figure 4.6 and Figure 4.7, the shown results are the one of the master data which should be input for running the MIKESHE commercial software. To understand the initial potential head of the groundwater level, has been obtaining the data of the observed walls of the Chirchik River basin for its locations Figure 4.8 and the initial potential head data has been shown in Table 4.2 which has been obtained by field surveys in 2009 and 2010.

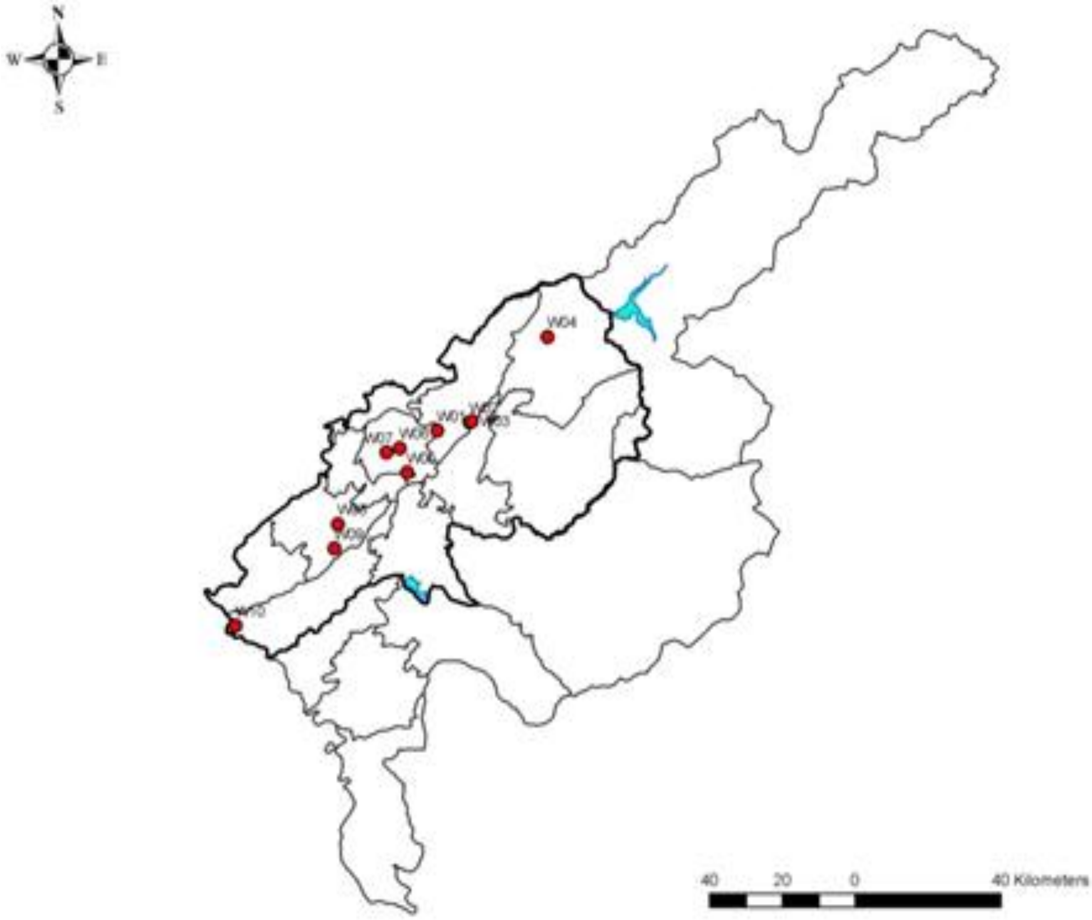


Figure 4.8: Location network of the groundwater observation wells.

Table 4.2: Initial data for the assessment of groundwater monitoring wells in 2010, (m).

Wells	W03	W06	W09
Coordinates	69.50517 41.36778	69.26844 41.30378	69.05472 41.05992
Altitude	519	461	244
Observed data			
JAN	515.7	451.3	320.6
FEB	515.4	451	320.5
MARCH	516.1	451.1	320.6
APRIL	516.7	451.3	320.6
MAY	516.8	451.6	320.8
JUNE	516.9	451.7	320.8
JULY	517.0	452.0	320.8
AUG	517.1	452.1	320.7
SEPT	517.0	452.1	320.7
OCT	516.9	452.1	320.6
NOV	516.8	452.0	320.5
DEC	516.7	451.9	320.4

Data on the soil layers of the Chirchik River basin shown Figs. 4.9 - 4.12, which has been obtained by the Ground Water Institute at time of geological exhibition. By the interpolation of the obtained data by using the ArcGIS and MIKESHE commercial programms has been obtained the Horizontal and Vertical conductivity in the saturated zone of the Chirchik River basin, shown in Figs. 4.13 and 4.14. Thickness of computational layers in the saturated zone of the Chirchik River basin has been showed in Figure 4.15. Transmissivity in the saturated zone of the Chirchik River basin illustrated in Figure 4.16.

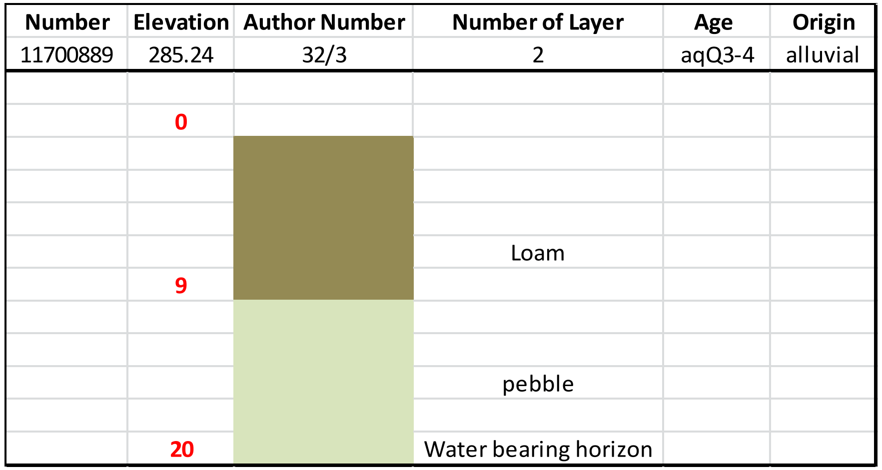


Figure 4.9: Geological structure of the sampled point in the Chirchik River basin (ID: 32/3).

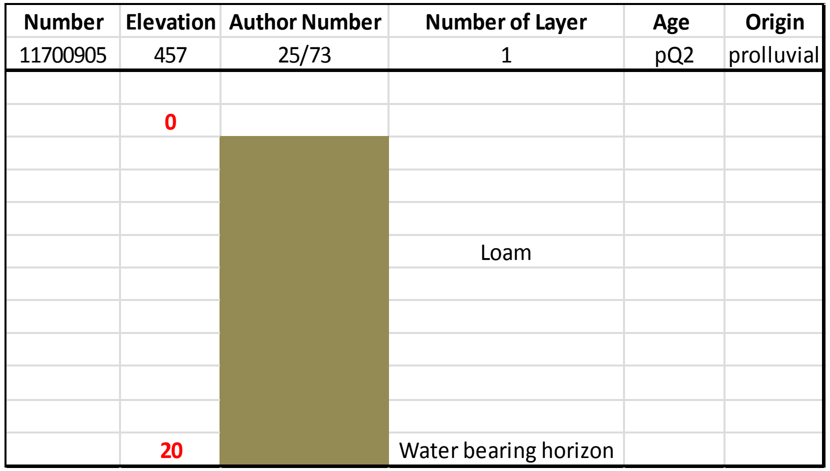


Figure 4.10: Geological structure of the sampled point in the Chirchik River basin (ID: 25/73).

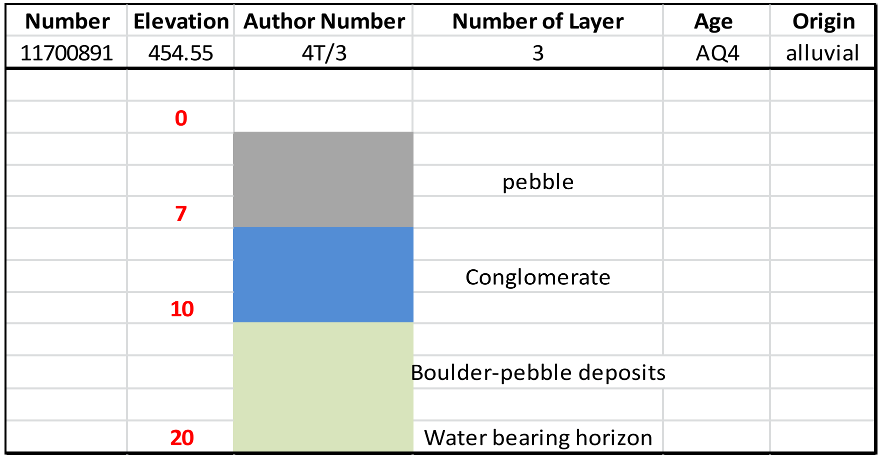


Figure 4.11: Geological structure of the sampled point in the Chirchik River basin (ID: 4T/3).

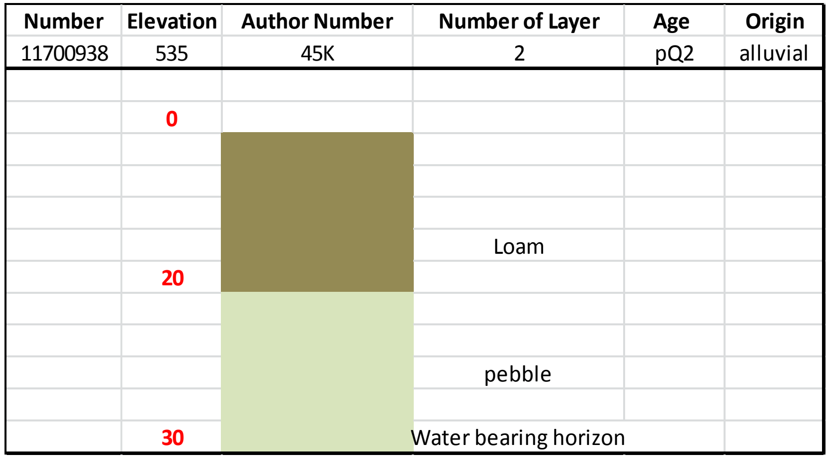


Figure 4.12: Geological structure of the sampled point in the Chirchik River basin (ID: 45K).

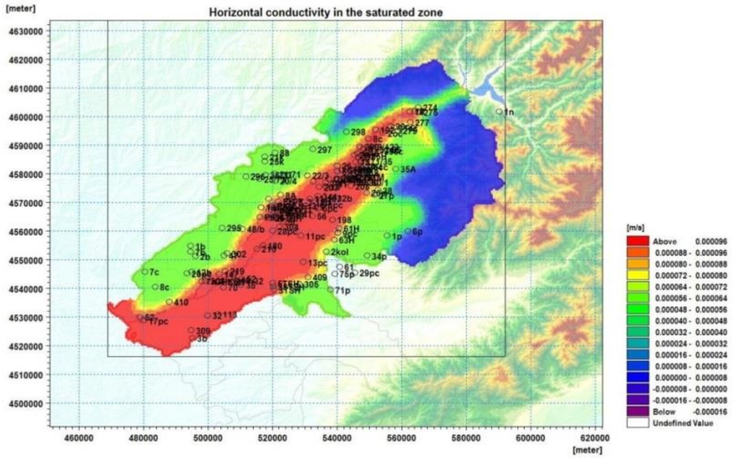


Figure 4.13: Horizontal conductivity in the saturated zone of the Chirchik River basin (MIKESHE simulation results).

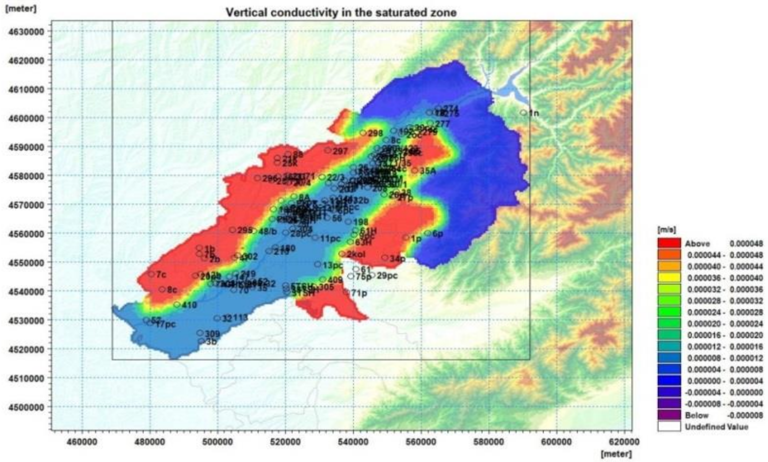


Figure 4.14: Vertical conductivity in the saturated zone of the Chirchik River basin (MIKESHE simulation results).

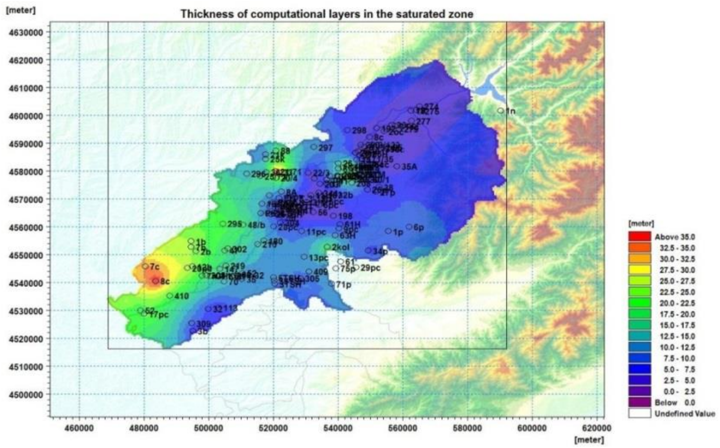


Figure 4.15: Thickness of computational layers in the saturated zone of the Chirchik River basin (MIKESHE simulation results).

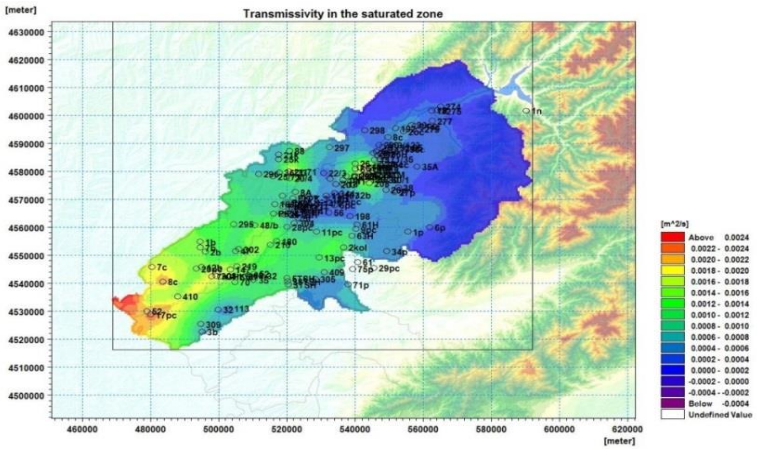


Figure 4.16: Transmissivity in the saturated zone of the Chirchik River basin (MIKESHE simulation results).

4.3 RESULTS AND DISCUSSIONS

Using the parameters of the water balance Chirchik River basin, topographic maps using the program MIKESHE simulation model to make a model of the of the water balance throughout the of the Chirchik River basin in 2009 and 2010.

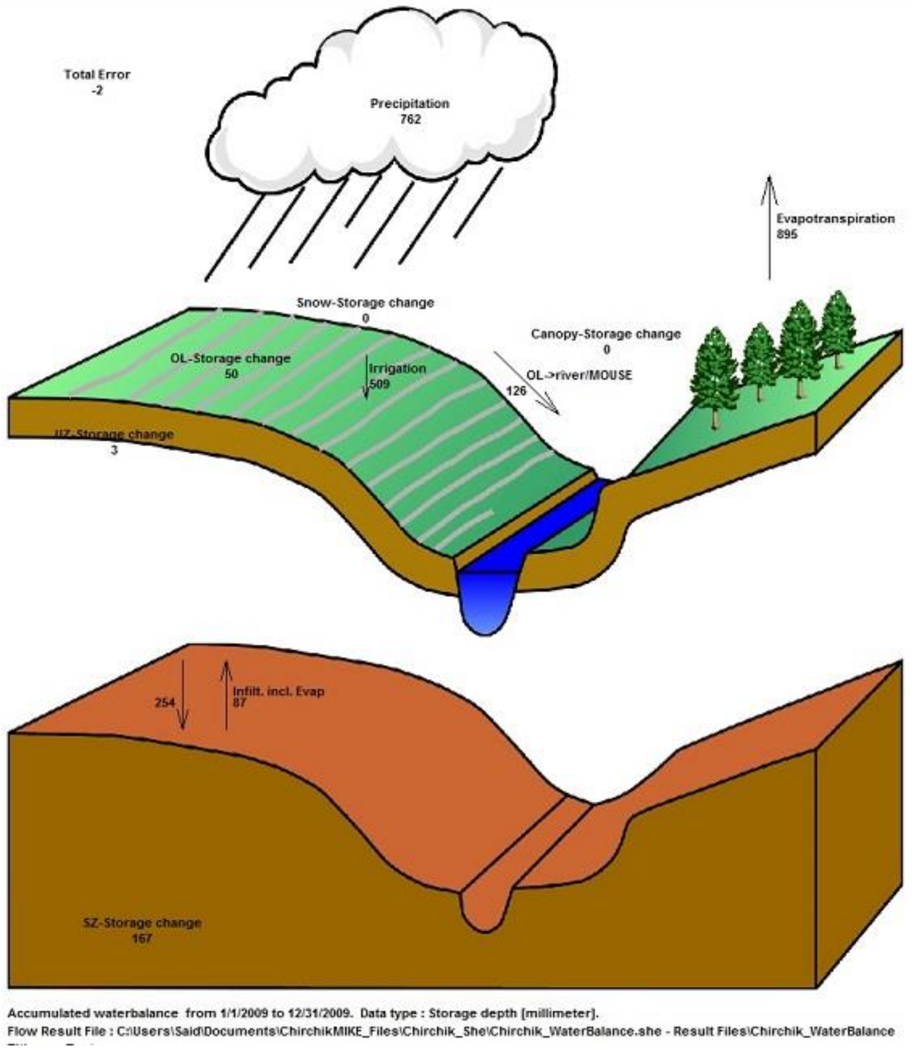


Figure 4.17: Simulated results of the water balance in in the Chirchik River basin for 2009 by using MIKE SHE simulation model.

In the Figure 4.18 has been shown the total accumulated water balance of the Chirchik River basin for 2009, in the figure illustrated the ratios between the precipitation, evapotranspiration, irrigation water consumption and lost and the total error of the water balance for 2009.

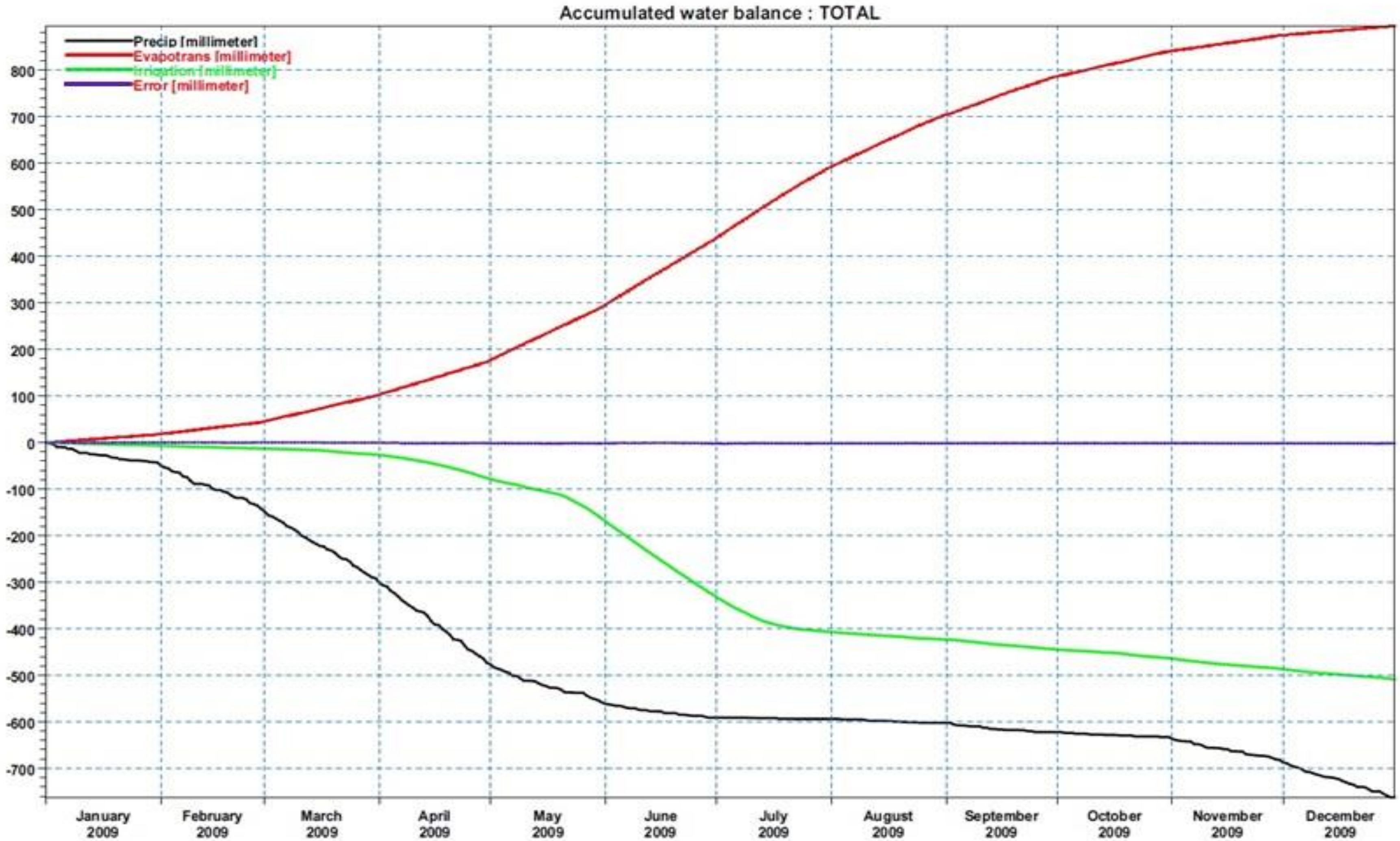


Figure 4.18: Total accumulated water balance of the Chirchik River basin for 2009 (MIKESHE simulation results).

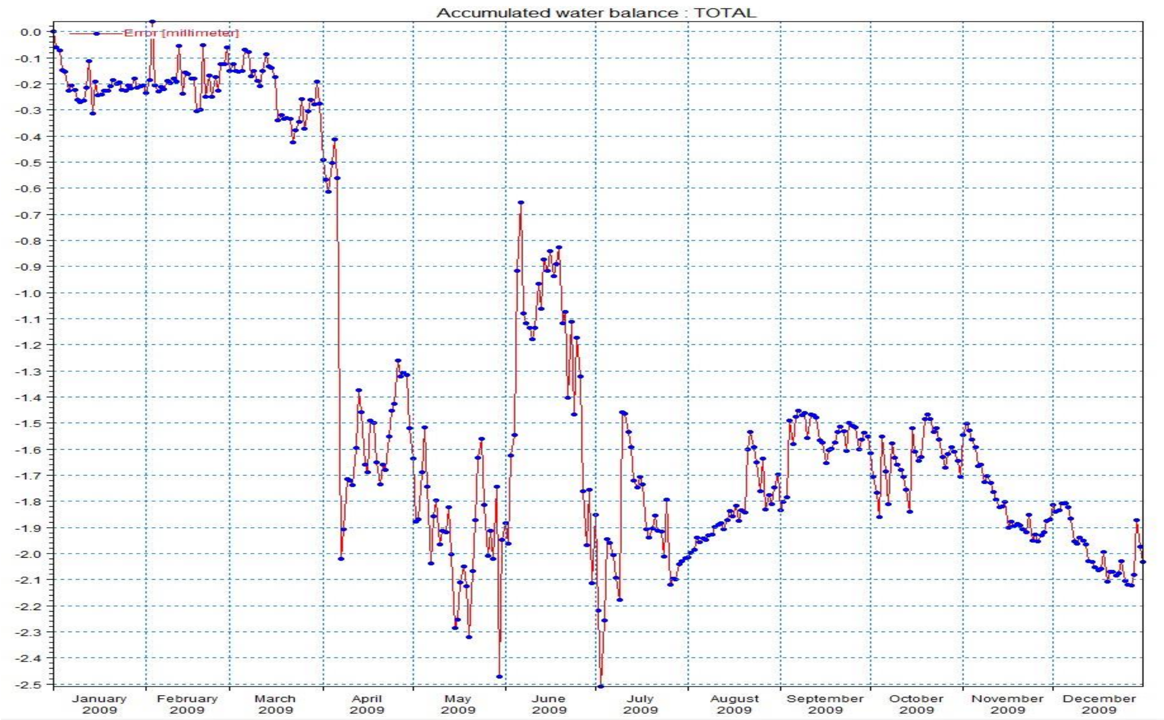


Figure 4.19: Total accumulated water balance error of the Chirchik River basin for 2009 (MIKESHE simulation results).

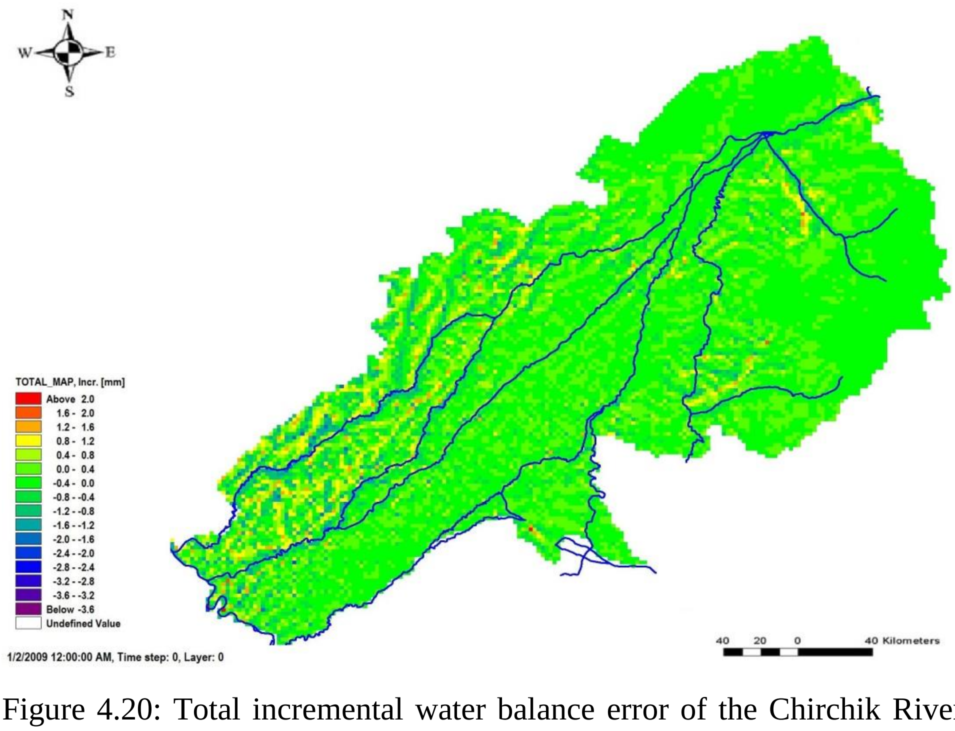


Figure 4.20: Total incremental water balance error of the Chirchik River basin for 2009 (MIKESHE simulation results).

The Figure 4.19 shows the total water balance error in the Chirchik River basin for 2009, in the figure has been indicated the change of the total water balance error in 12 months of the year. Total water balance error -0.1 mm to -1 mm in the January to April, because of the water in the river basin is considered along the saving water for the vegetation period. From the April month has been started the dynamical change of the total water balance error, due to abstraction, high temperature which occurs to high evapotranspiration in the semi-arid territories, irrigation for the purpose of cotton and wheat and etc. Due to data limitation on the water use on the different sectors of the economic system in the river basin, the incremental error occurs. Figure 4.20 shows the spatial distribution of the total water balance incremental error of the Chirchik River basin since 2009.

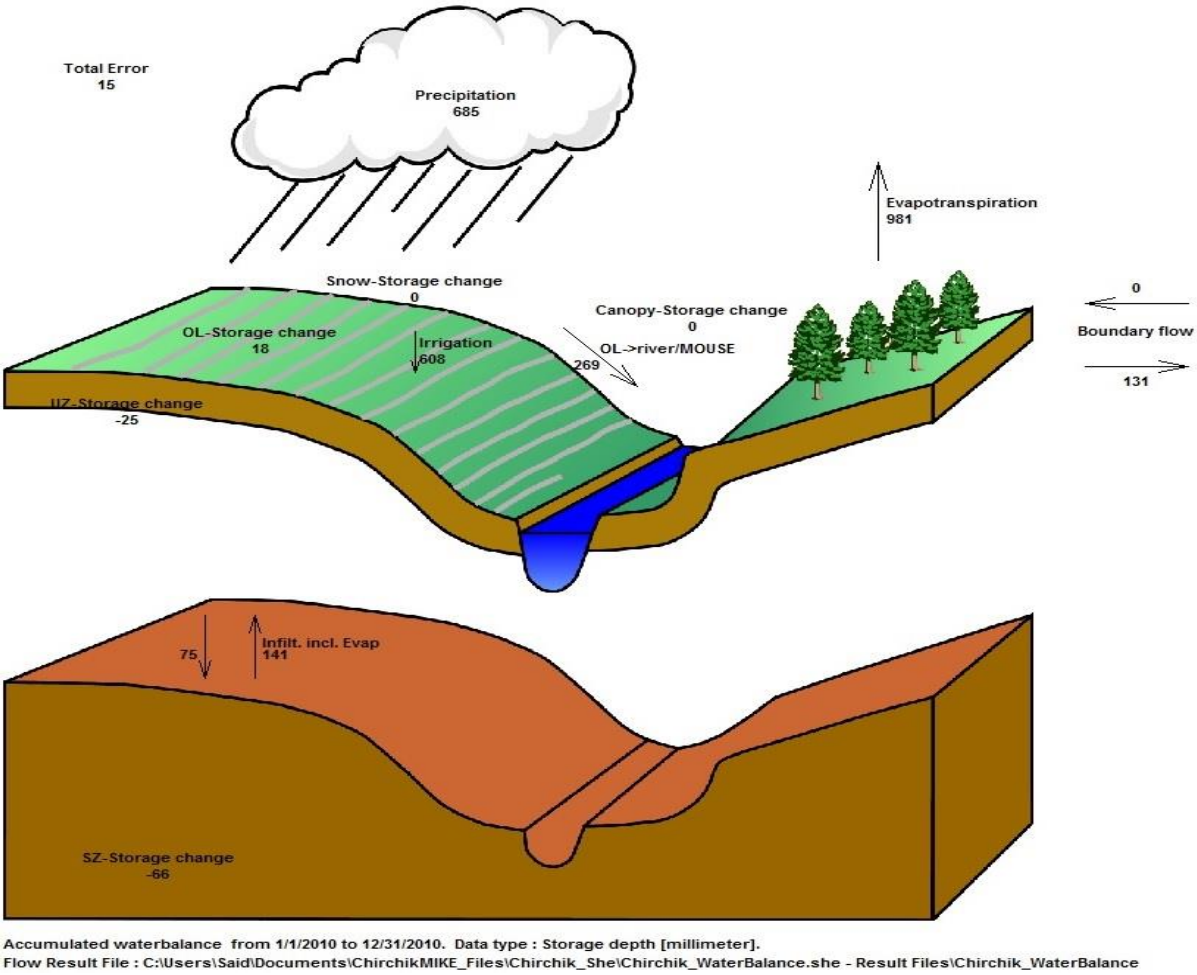


Figure 4.21: Simulated results of the water balance in in the Chirchik River basin for 2010 by using MIKE SHE simulation model.

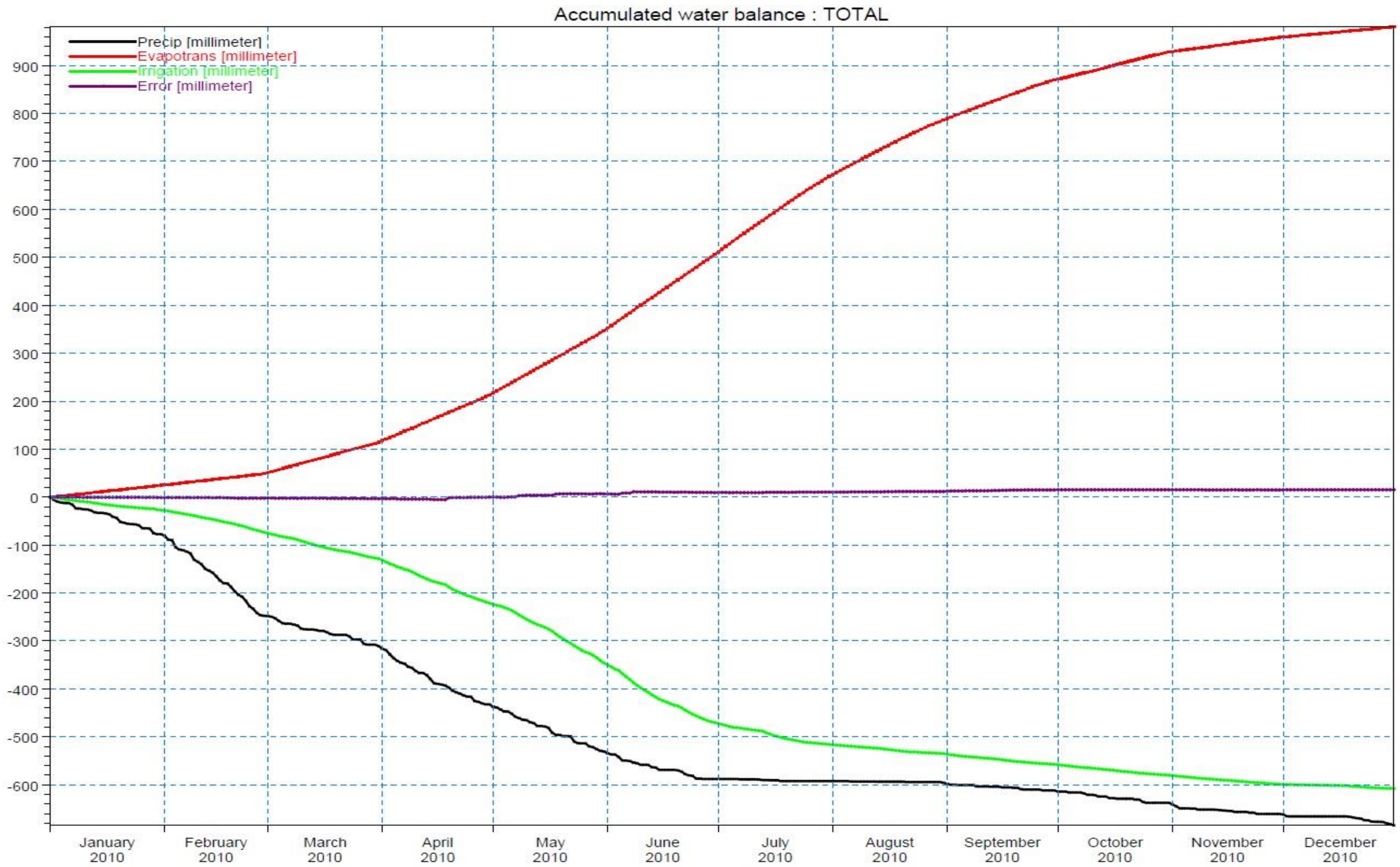


Figure 4.22: Total accumulated water balance of the Chirchik River basin for 2010 (MIKESHE simulation results).

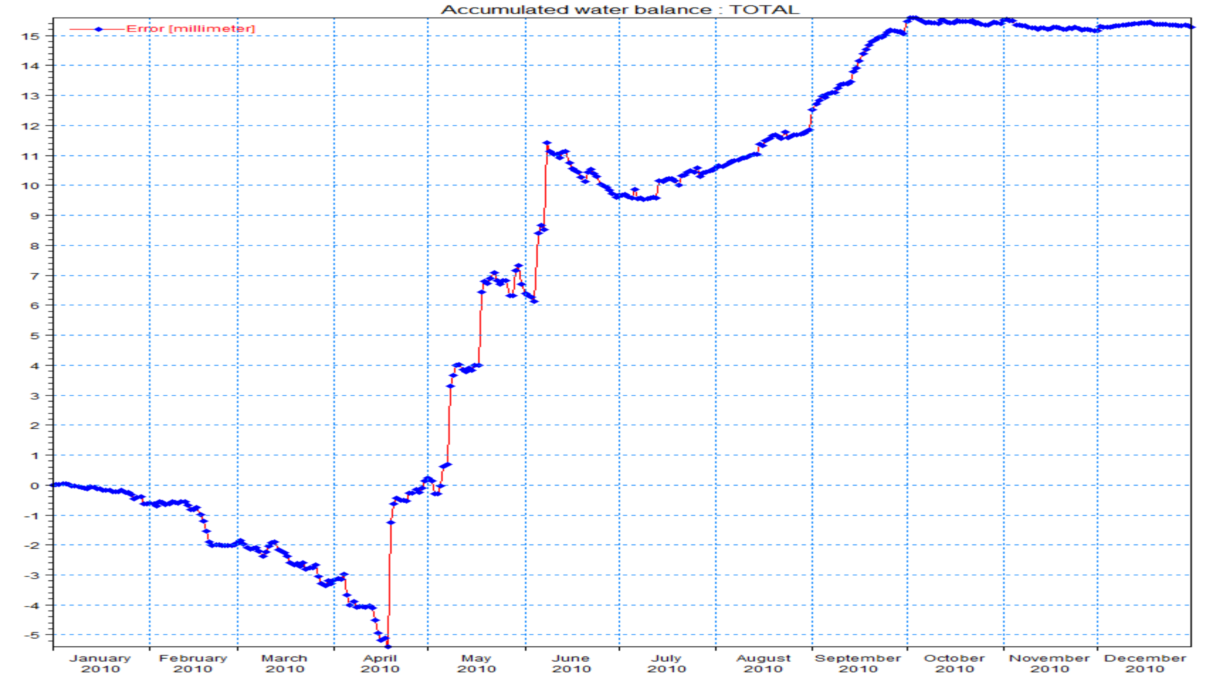


Figure 4.23: Total accumulated water balance error of the Chirchik River basin for 2010 (MIKESHE simulation results).

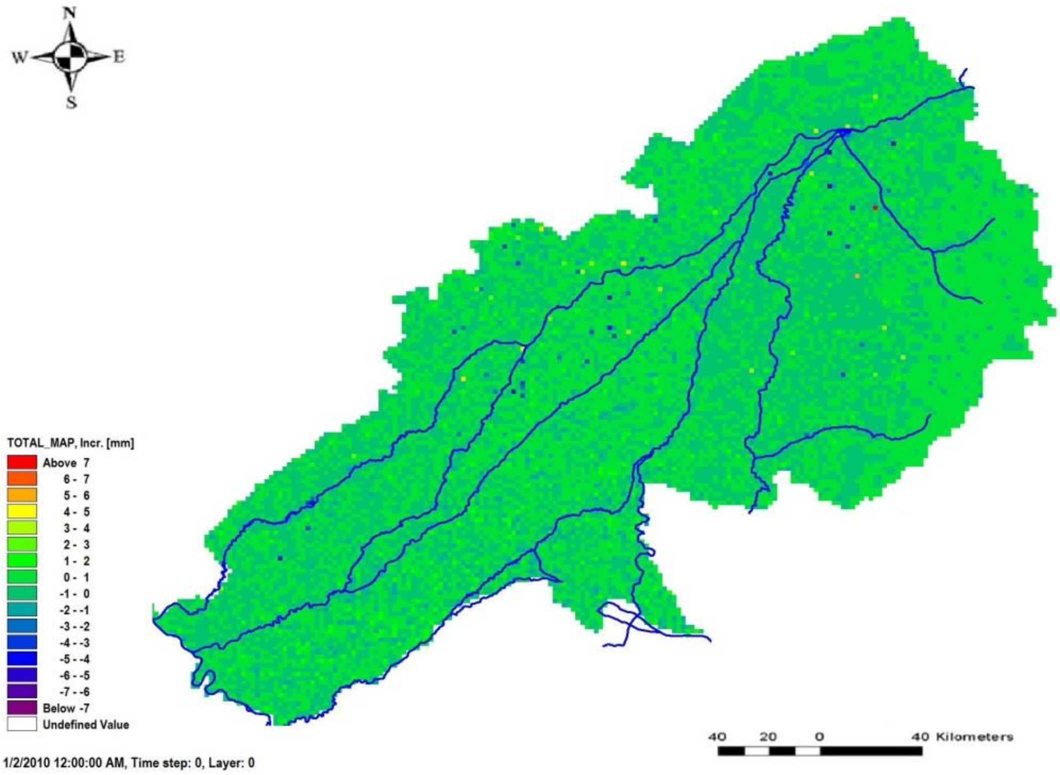
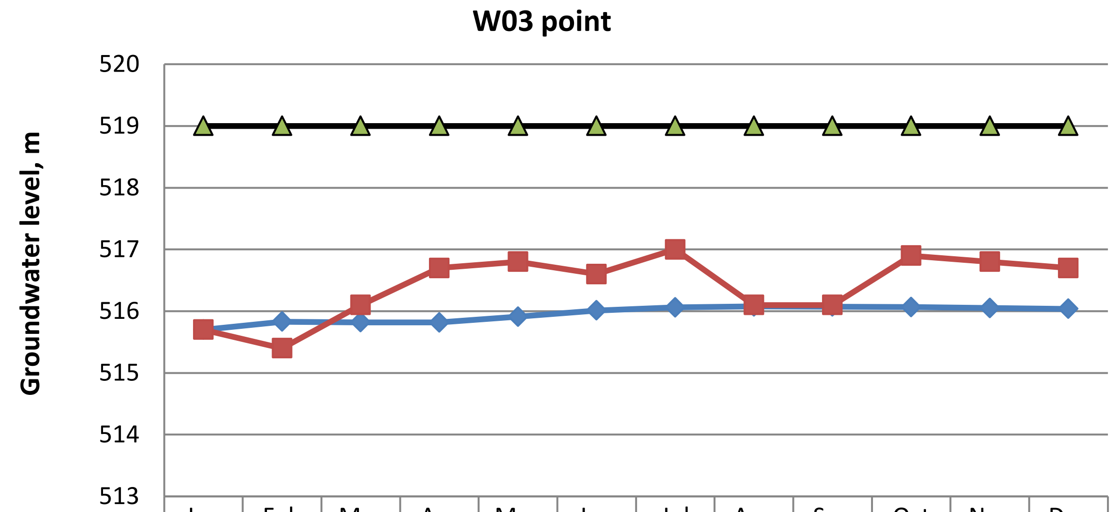


Figure 4.24: Total incremental water balance error of the Chirchik River basin for 2010 (MIKESHE simulation results).

In the Figs. 4.21 to 4.24 the same scenario as 4.17 to 4.20 has been illustrated, but for 2010 year. The Figure 4.23 shows that the total accumulated water balance error of the Chirchik River basin in 2010 is rapidly decreased from the January to April, the assumption analytical data shows that the basin territory is established mainly from the morphology of the river basin, but the main water income is detected from the mouth of the Charvak reservoir, where the Chirchik River starts. So considered from this situation the error from January to April occurs due to infiltration of the highest mountains to the basin territory, where melted ice and rainfall also moving to the basin territory beside the Charvk reservoir. The error in figure rapidly increases from the April to December, due to data limitation on water use and outflows from the groundwater of the river drainage area to the main Syr-Darya River. Figure 4.24 shows the spatial distribution of the total water balance incremental error of the Chirchik River basin since 2010.

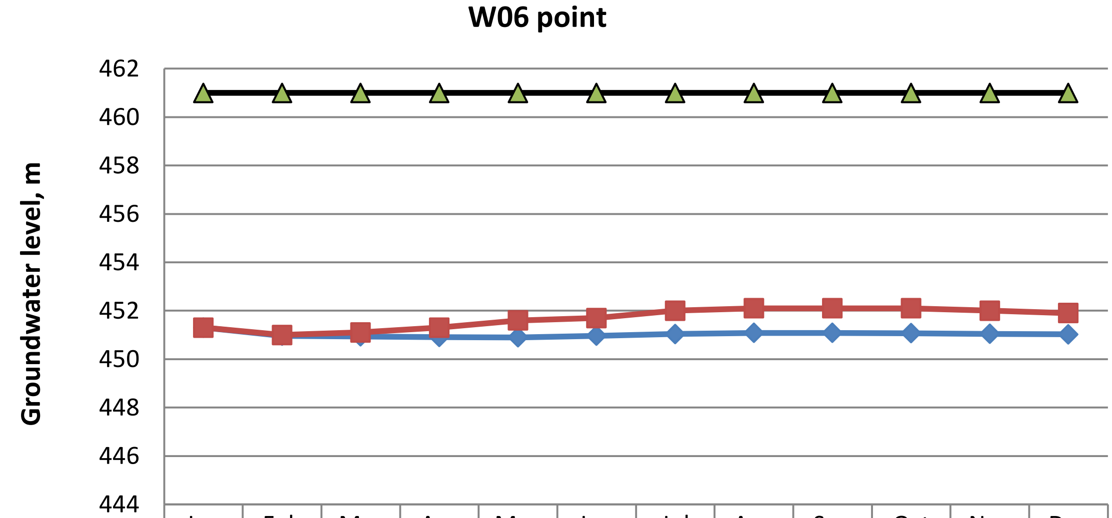
Table 4.3: Simulated results of the level of groundwater by using MIKE SHE simulation model of river basin balance.

Wells	W03	W06	W09
Coordinates	69.50517 41.36778	69.26844 41.30378	69.05472 41.05992
Altitude	519	461	244
Simulated results			
JAN	515.7	451.3	320.6
FEB	515.82	450.96	321.14
MARCH	515.82	450.93	321.28
APRIL	515.81	450.91	321.43
MAY	515.91	450.89	321.4
JUNE	516	450.96	321.36
JULY	516	451.03	321.31
AUG	516	451.08	321.26
SEPT	516.1	451.08	321.22
OCT	516.06	451.06	321.19
NOV	516.05	451.04	321.18
DEC	516.03	451.02	321.17



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Simulated	515.7	515.83	515.82	515.82	515.91	516.01	516.06	516.08	516.07	516.07	516.05	516.04
Observed	515.7	515.4	516.1	516.7	516.8	516.6	517	516.1	516.1	516.9	516.8	516.7
Altitude	519	519	519	519	519	519	519	519	519	519	519	519

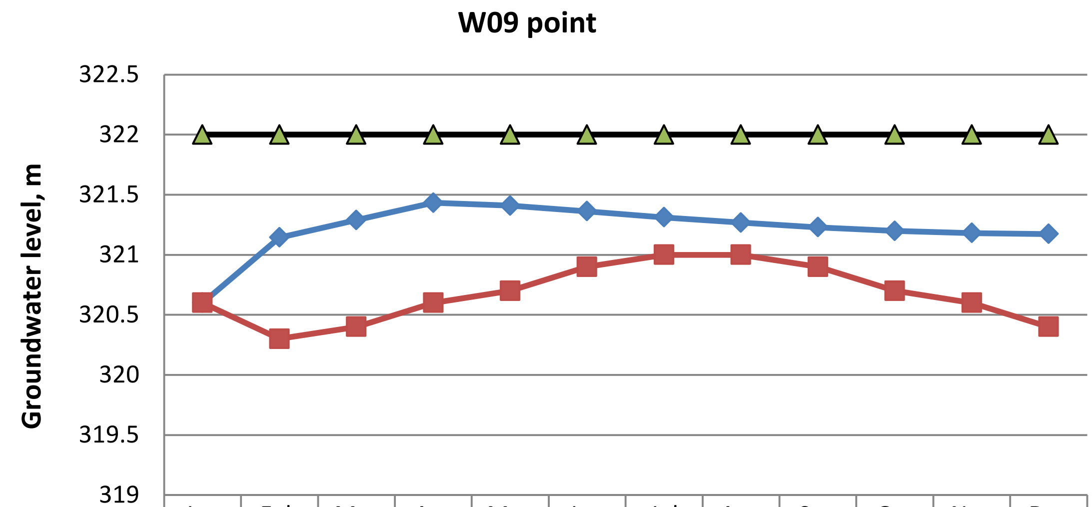
Figure 4.25: Calibration results of calculation methods with the results of measurements on the well 03.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Simulated	451.3	450.96	450.94	450.91	450.9	450.96	451.04	451.08	451.09	451.07	451.05	451.02
Observed	451.3	451	451.1	451.3	451.6	451.7	452	452.1	452.1	452.1	452	451.9
Altitude	461	461	461	461	461	461	461	461	461	461	461	461

Figure 4.26: Calibration results of calculation methods with the results of measurements on the well 06.

To establish the reliability of data on the changes in groundwater levels were the measured values of the groundwater level according to data on observation wells in the basin with the results obtained by the simulation model (Table 4.3, Figure 4.22). Calibration and comparison of the solutions obtained by reflection and calculation method of characteristic points in the river basin are shown in Figs. 4.25-4.27.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Simulated	320.6	321.14	321.29	321.43	321.41	321.36	321.31	321.27	321.23	321.2	321.18	321.17
Observed	320.6	320.3	320.4	320.6	320.7	320.9	321	321	320.9	320.7	320.6	320.4
Altitude	322	322	322	322	322	322	322	322	322	322	322	322

Figure 4.27: Calibration results of calculation methods with the results of measurements on the well 09.

In Figs. 4.25, 4.26 and 4.27 the dark lines show the land surface and the red and blue lines groundwater levels, determined by different methods. As the graphs show similar values to predict (Table 4.3) and actual (Table 4.2) values of soil water level fluctuations within acceptable RMSE for W06 point is 0.58, RMSE for W03 point is 0.65 and RMSE for W09 point is 0.64.

4.4 CONCLUSION

The chapter described the method for forecasting groundwater level in an arid area according to climatic data. In the territories with an arid climate, productivity of irrigated agriculture largely determines the condition of the moisture of territory and groundwater levels. The numerical implementation of the water balance equation and by using the MIKESHE an integrated hydrological modelling system has been obtained the accurate hydrological water balance of the river basins to monitor the seasonal change of the spatial distribution of the groundwater levels through the basin. The monitoring of the ground water level in river basins can protect the soil from the salinization and erosion, which is the main problem in arid areas.

As a result, the model developed makes it potential to reliably estimate ground water layer by using climatic data in the river basin. Taking into consideration that groundwater together with irrigation water are sources of water use plants, prediction method can effectively manage water resources for irrigation of crops, particularly cotton. The forecast for the groundwater level contributes to the adoption of scientific and technical measures to protect water and soil from the salinization.

REFERENCES

1. Makhmudov Kh., Mitani Y., Kusuda T., (2015). Interpolation of Climatic Parameters By Using Barycentric Coordinates, World Journal of Environmental Engineering, Vol. 3, No. 1, pp 1-6.

2. Petrov V., Egamberdiev H., Kholmatzhonov B., (2005). Meteorology, The journal of the NUU, p.330.

3. Valipour M., (2014). Comparative Evaluation of Radiation-Based Methods for Estimation of Potential Evapotranspiration, Journal of Hydrological Engineering, 5-20, pp 1247-1271.

4. MIKESHE User Manual and Reference guide, (2012). DHI, Volume-1.

5. Makhmudov Kh., (2011). Integrated River Basin Management in the Chirchik River basin, The University of Kitakyushu, Japan.

6. MIKESHE User Manual and Reference guide, (2012). DHI, Volume-2.

7. The Institute of Groundwater, (2010). Report of the GP"Gidroingeo", Tashkent.

1. Phillips N.A., (1956). A coordinate system having some special advantages for numerical forecasting, Journal of Meteorology, 14, pp 184-185.

Table 5.3: Calculated data of groundwater resources of the Chirchik River basin (source: Institute of Groundwater).

Deposit and its resources on the revaluation, m3 / s	The calculation period	The arithmetic mean of the oscillation amplitude (m) by:		The coefficient of water loss breeds share of units	Deposit area, km2	Resources of deposits of groundwater (m3 / s) for:			The value of the accumulation (+) consumption (-) of groundwater resources (3 = 31,546x106x ΔQ); 106m3 per year
		Infiltration	Expenditure			Infiltration	Expenditure	Difference between infiltration and expenditure	
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Ahangaran, 22.773	Previous	3.32	-2.83	0.2	1023	21.53	-18.35	3.18	100.3
	Reported	2.38	-2.56			15.44	-16.6	-1.16	-36.6
Pskent, 2.0	Previous	1.34	-1.29	0.075	688	2.19	-2.11	0.08	2.52
	Reported	1.28	-1.34			2.09	-2.19	-0.10	-3.15
Chirchik, 38.2	Previous	2.23	2.48	0.25	1949	33.44	38.3	-3.86	-121.77
	Reported	2.48	2.29	0.25		38.3	35.37	+2.93	+92.43

CHAPTER 5: MODELING OF WATER AND SALT BALANCE FOR SUSTAINABLE WATER MANAGEMENT IN THE KASHKADARYA RIVER BASIN, UZBEKISTAN

ABSTRACT

The territory of the Republic of Uzbekistan being arid, suffers high deficiency of atmospheric moisture which is essential for the cultivation of crops. The lowest humidity ratio, specific to the soil of the Kashkadarya region of Uzbekistan, ranges within 0.2-0.5 PI. Hence, the only surface source that provides plant growth within its drainage area is the river Kashkadarya. Referable to the low atmospheric precipitation level, ranging within 300-350 mm per year and high evapotranspiration rate standing at 1,300-1,700 mm per year, water resources formed on the soil of the area within the Kashkadarya River basin are entirely mobilized for irrigation of crops. It is the consequence of quantitative and qualitative depletion of water resources. The chapter 5 presents results of the on-site survey conducted in the Kashkadarya River basin, the role of the river flows formation, and water management. A simulation model of water utilisation in the river basin has been transmitted, and measures of qualitative and quantitative water parameters identified. The findings of the research can be employed for more effective water resources management as well as in irrigation of arid states.

5.1 INTRODUCTION

The current research was conducted in the Kashkadarya River basin, which is the main irrigation water supplier in the Kashkadarya region. Taking its name from the river Kashkadarya, the region covers 28,568 km2 of the land area, or occupies 6.3% of the total area of the Republic of Uzbekistan. Nowadays the population of the region stands at more than 2.4 M people, 1.7 M of which resides in the rural area. The land resources of the Kashkadarya region suitable for agricultural production reach 2.8 M ha, including 0.66 M ha under cultivated crops and 1.48 M ha of rangeland.

A deficiency of water resources as easily as their significant deterioration are the major challenges that some countries and in particular in Uzbekistan face nowadays.

Water is an indispensable component of the economic and social-ecological systems of the nation, and its rapid deterioration, caused by human and anthropogenic impact on water schemes. The most deficit water areas in Uzbekistan reports to be the Kashkadarya region, and in particular the ancient irrigated lands where the only water source is the Kashkadarya River. A number of large reservoirs for the function of streamflow waters of the Kashkadarya River have been fabricated. These are: Chimkurgan (with the volume of 500 million. m3) (Figure 5.1), Pachkamar (260 million. m3), Hissar (170 million. m3) (Figure 5.2) and many other medium and small water reservoirs with storage capacity of 1 million. m3 to 10 m3, as well as hydraulic structures.

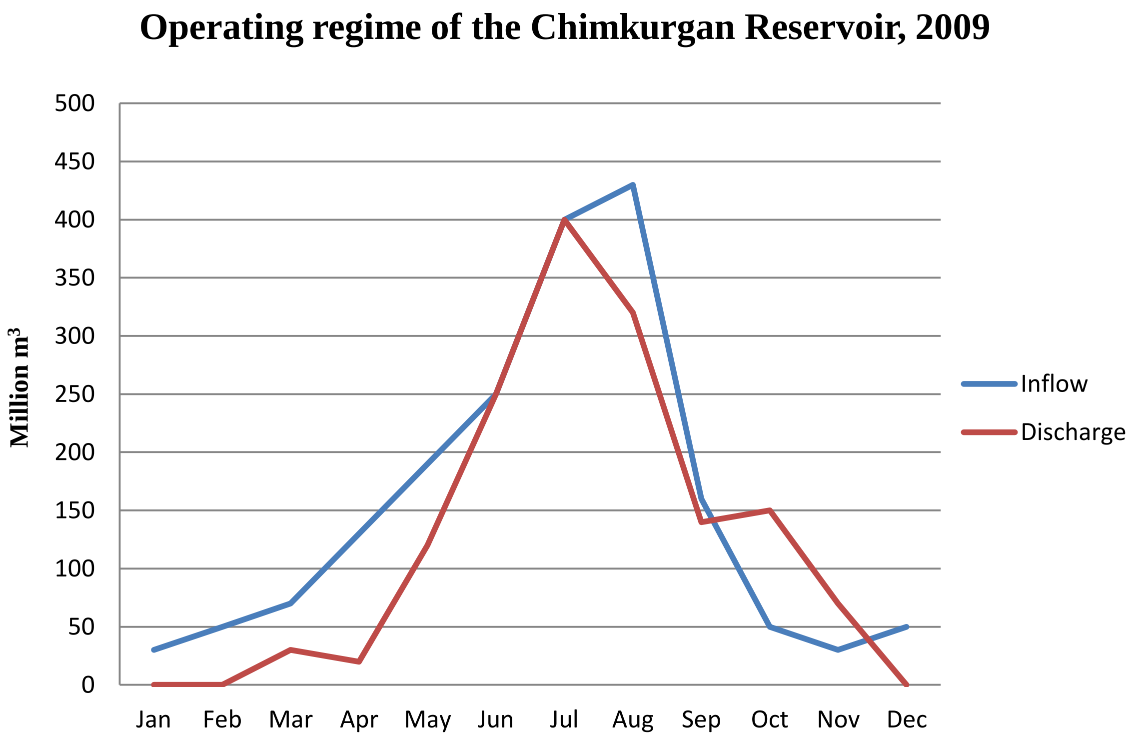


Figure 5.1: Operating regime of the Chimkurgan Reservoir.

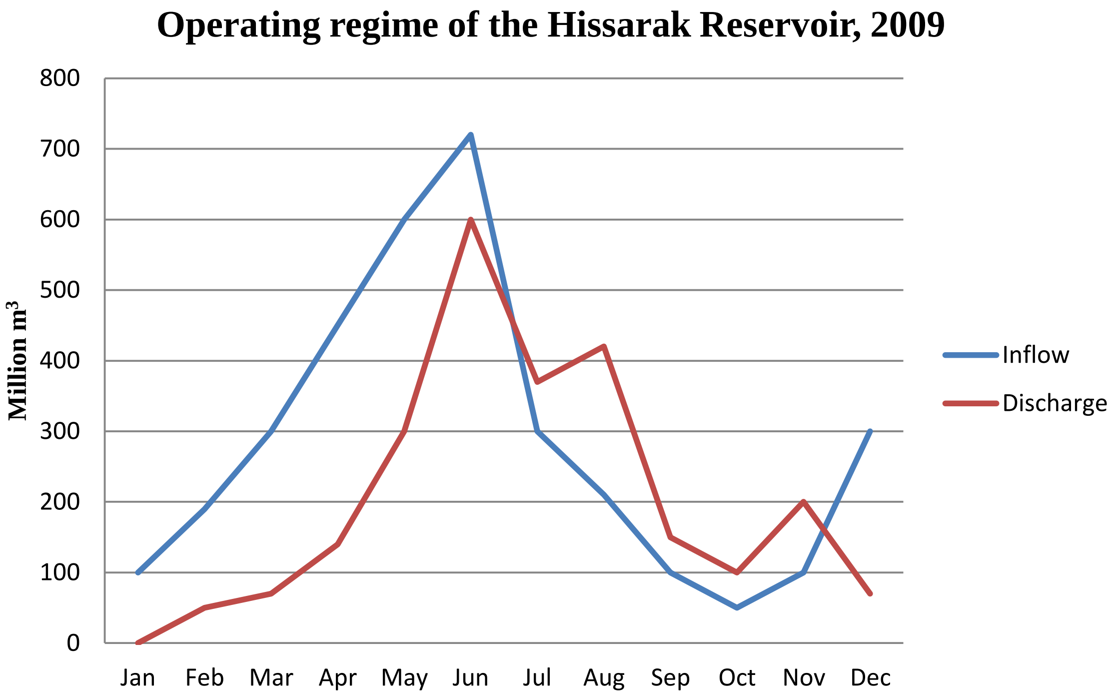


Figure 5.2: Operating regime of the Hissarak Reservoir.

The length of Kashkadarya River is 310 km, takes origin in the westernmost tips of the Zarafshan and Hissar mountains and covers the watershed area of 8,780 km2. The main tributaries are the rivers Aksu, Yakkabag, Tanhaz, which play a dominating role in the formation of the streamflow to the Kashkadarya oasis. One more river, Guzar, existing in the basin, currently does not flow into the Kashkadarya River.

The Kashkadarya River basin embraces more than 3,000 stream flows, only 33 of which are 20 km long or longer km. At the same time, some significant parts of the river bed in its middle and lower reaches have become collectors of tail and drain water.

Thus, a complete river control system has been established allowing for a double and triple water reuse for irrigation needs. Overuse of the Kashkadarya River flows resulted in absolute degradation of the river ecosystem.

The main objective of the research presented in the article has been to seek solutions for improving the quality and productivity of water use as to increase agricultural production and living standards of the rural population under lower water availability and for the sake of environmental sustainability and social stability in the Kashkadarya River basin.

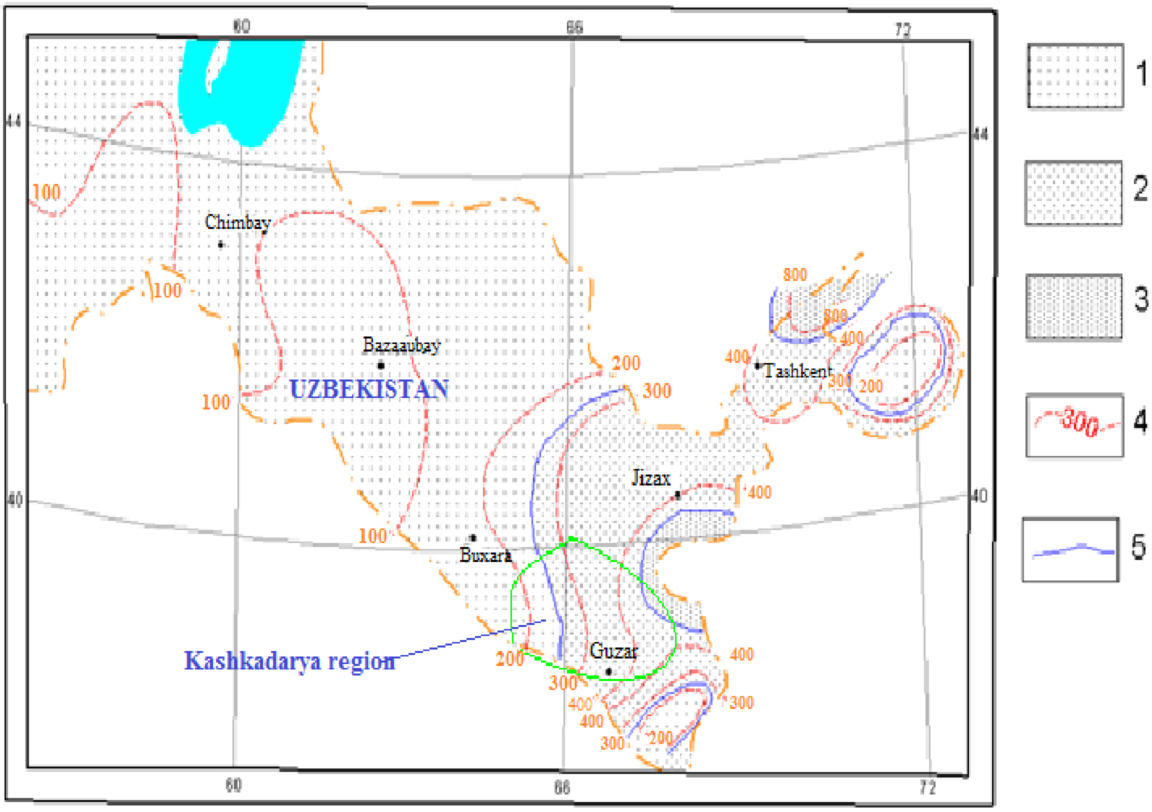


Figure 5.3: Distribution of natural moisture over the territory of the Republic of Uzbekistan (Davranova 2006). Legend of Figure 5.3 refers to: 1 – extra-arid zones with the moister content index of less than 0.2 PI*; 2 – natural arid zones with the moister content index of 0.2-0.5 PI; 3 – semi-arid zones with the moister content index of 0.5-0.7 PI; 4 – annual precipitation in mm; 5 – borders of the areas with the same moister content index. *The plasticity index (PI) is a measure of the plasticity of a soil. The plasticity index is the size of the range of water contents where the soil exhibits plastic properties (Sowers 1979).*

The Kashkadarya River basin, the main irrigation water supplier in the region, by the 1960s has completely exhausted its potential for further development of the region caused by the rapid increase in irrigated area. Moreover, due to the high moisture deficiency, the vapor content index in the area ranges at 0.2-0.5 PI or less, which is quite low compared to other regions of the Republic of Uzbekistan (Figure 5.3).

The climatic factors, an atmospheric temperature evapotranspiration rate of the area are quite high, especially during the vegetative period, which drastically hampers the improvement of land use and management in the region.

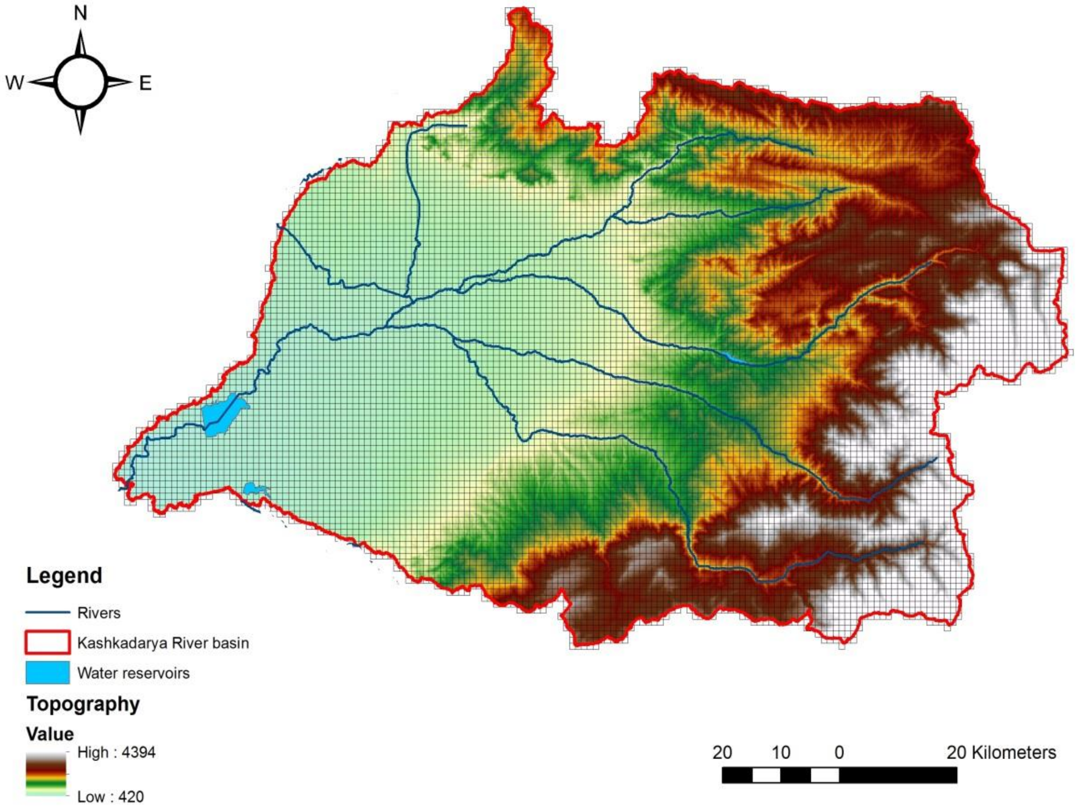


Figure 5.4: The main water resource of the Kashkadarya River basin, Kashkadarya River, including information input points (MIKE SHE simulation software).

The Kashkadarya region has the potential to rapidly development of the economy, while preserving natural environment, especially water resources, avoiding by pollution. The climatic factors and inefficient use of available water resources of the Kashkadarya River basin required the elaboration of measures on effective water management.

5.2 MATERIALS AND METODS

For modeling the management process of the qualitative and quantitative water parameters in the Kashkadarya River basin the balance method was applied, which included equations of water and water-salt balances.

The water and salt balance equation applicable for the Kashkadarya River basin takes the following form:

$$W_{kashk}(t)=W_{chimk}(t)+W_{hiss}(t)+[Q^0_{river}(t)*t+Q^0_{precip}(t)*t+Q^0_{inflow}(t)*t+W_{drain}(t)]-[E^0_{evap}(t)*t+Q^0_{outflow}(t)*t+W_{watersuppl}(t)+W_{irr}(t)] \quad (5.1)$$

The water-salt balance can be calculated as:

$$(W_{kashk}*C_k)(t)=W_{chimk}*C_{ch})(t)+(W_{hiss}*C_{hiss})(t)+(W_{drain}*C_{drain}(t)+[Q^0_{river}*C_p)(t)*t+(Q^0_{precip}*C_{precip})(t)*t+(Q^0_{gw/inflow}*C_{gw})(t)*t]-[E^0_{evap}*C_{precip})(t)*t+(Q^0_{outflow}*C_{gw})*t+(W_{water\ suppl}*C_w)(t)+(W_{irr}*C_{irr})(t)] \quad (5.2)$$

The equation of change in water salinity level against impact on the Kashkadarya River basin water condition is derived from the water-salt balance equation:

$$C_k(t)=\frac{(W_{chimk}*C_{ch})(t)+W_{hiss}*C_{hiss})(t)+W_{drain}*C_{drain}(t)+[Q^0_{river}*C_r)(t)*t+(Q^0_{precip}*C_{precip})(t)*t+(Q^0_{gw/inflow}*C_{gw})(t)*t]-[(E^0_{evap}*C_{precip})(t)*t+(Q^0_{outflow}*C_{gw})*t+(W_{water\ suppl}*C_w)(t)+(W_{irr}*C_{irr})(t)}{W_{kash}} \quad (5.3)$$

In the equations (5.1,5.2 and 5.3) the following notations are used to indicate:

Wkashk (t) - the Kashkadarya River streamflow change of time ***t;***

C_k- water salinity at the river outlet;

W_{hiss} (t) and W_{chim} (t) - water storage capacity at Hissar and Chimkurgan reservoirs, time t;

C_{hiss}, C_{ch}- water salinity at the Hissar and Chimkurgan reservoir discharge;

(W^{+}_{drain} * C_{gw}) - a part of the water used in industry, drinking water supply and irrigation with water salinity- C_{gw};

Q^{0}_{river} **(t)** - water discharge formed in the drainage area of the Kashkadarya River basin and disposed in the midwoods of the Hissar and Chimkurgan reservoirs with the relevant water salinity – C_r;

$(W^{0}_{precip} * C_{precip})$ **(t)** - the amount of precipitation with the relevant water salinity.

$(W^{+}_{inflow} * C_{gw})(t)$ - groundwater inflow with water salinity-C_{gw};

$(W_{evap} * C_{evap})$- the Kashkadarya River basin surface evapotranspiration;

$(W_{outflow} * C_{gw})(t)$- groundwater outflow with water salinity level- C_{gw};

$(W_{irr} * C_{irr})$- a public and industrial water supply with water salinity level - C_{irr};

$(W_{irr} * C_{irr})$ - an irrigation water use with salinity level- C_{irr}.

Table 5.1: Water-salt balance of irrigated land throughout the Kashkadarya region (water of Kashkadarya River basin with the recharge from the Amu Darya River) (source: Ministry of Agriculture of the Uzbekistan).

Years	The cultivated area of cotton Thousand hectares	Productivity Centner / ha	Water abstraction, million m3	Number of received salts, g / l		Discharge water, million m3	Number of received salts, g / l		Removal of salts during the year, thousand tonnes
				Solid residue	Chlorine		Solid residue	Chlorine	
1	2	3	4	5	6	7	8	9	10
2000			4117,33	1,07		1365,27	6,10		8330,37
2001			3692,94	1,06		1004,77	5,40		5425,02
2002			4340,28	1,06		1597,30	4,98		7951,49
2003			4572,76	1,03		1956,30	4,99		9771,75
2004			5016,30	1,06		1896,68	4,87		9223,86
2005			5303,12	1,11		1996,43	4,44		8864,10
2006			4661,10	1,35		1551,29	4,63		5895,12
2007	171592	26,9	4336,26	1,31		1458,43	4,39		6389,80
2008	172908	26,0	4067,10	1,11		1292,79	4,56		5895,12
2009	160400	25,0	4426,73	1,19		1536,51	4,41		6775,7
2010	160400	27,10	4957,62	1,14		1657,51	4,16		6892,19

5.3 RESULTS AND DISCUSSION

A software program for modeling purposes has been developed for equations (5.1) and (5.2), data from 2009 was used for parameters: average monthly rate atmospheric precipitation and evapotranspiration at the river watershed area; average monthly water discharge at the streamflows formation area; water reservoirs operating regimes; water use by different economic sectors of the region; groundwater inflow and outflow data calculated based on the analysis of the observation wells within the basin area; and operating regime of the reservoir acquired from the archives of reservoir management organizations.

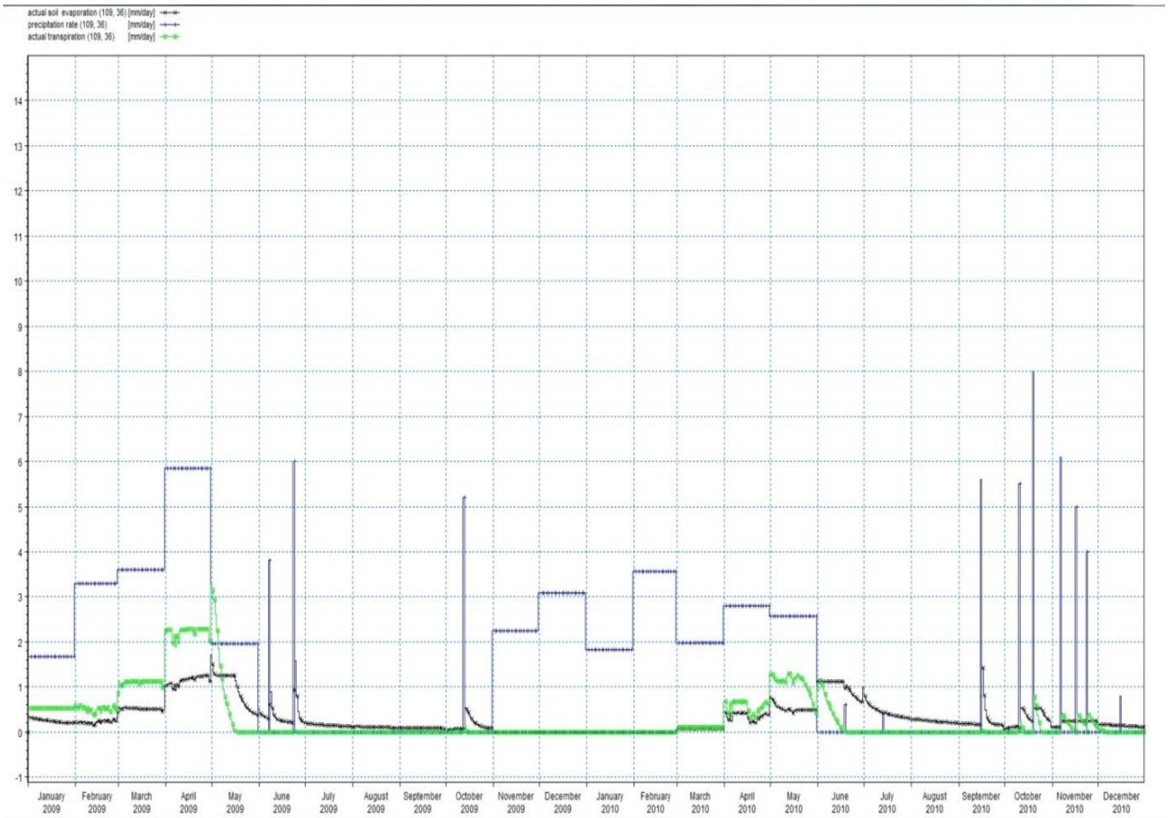


Figure 5.5: Monthly precipitation, soil evaporation and evapotranspiration rates in the Kashkadarya River basin for 2009-2010, MIKE SHE simulation software.

Water salinity data, which have been obtained from the water protection organization database. Numerical experiments based on equations (5.1) and (5.3) enabled constructing graphs of the annual change of the river water salinity levels Figure 5.6.

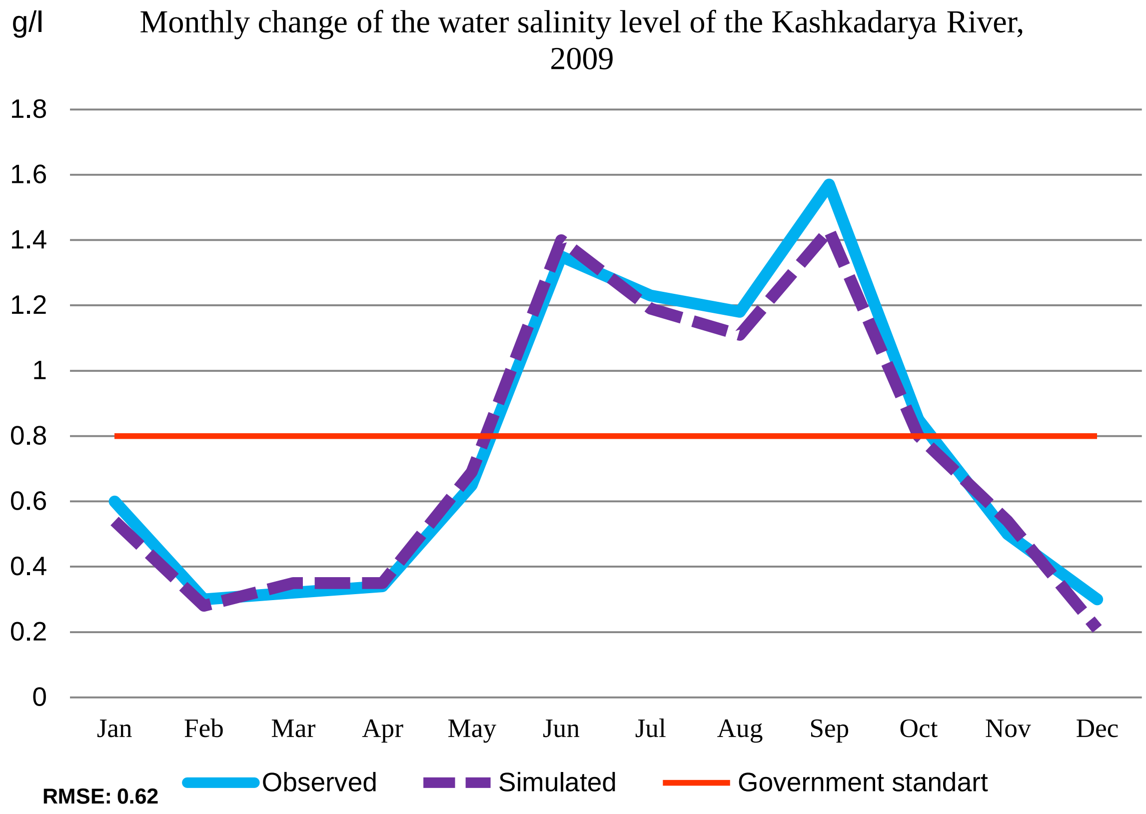


Figure 5.6: Monthly change of the water salinity level of the Kashkadarya River.

Research demonstrates that overuse of the river water for irrigation purposes causes major burden on the river ecosystem in the vegetation period of in particular cotton.

Moreover, formation of drain water by means of water losses from irrigation system, as well as discharge of industrial and public water supply systems and further junction with the river water. This fact implies that the main and traditional occupation of the population of this extra arid part of the Kashkadarya River basin, which is occupied by irrigated agriculture. Furthermore, depletion of water resources deteriorates the quality of water in the river.

Deteriorated water quality adds to soil salinity and calls for additional irrigation water use for leaching the accumulated salts.

The current situation of the Kashkadarya River affects the living standards of the population residing within the river basin area and carries socio-ecological impacts. To improve the situation of the study area, the priority is to increase the water management efficiency.

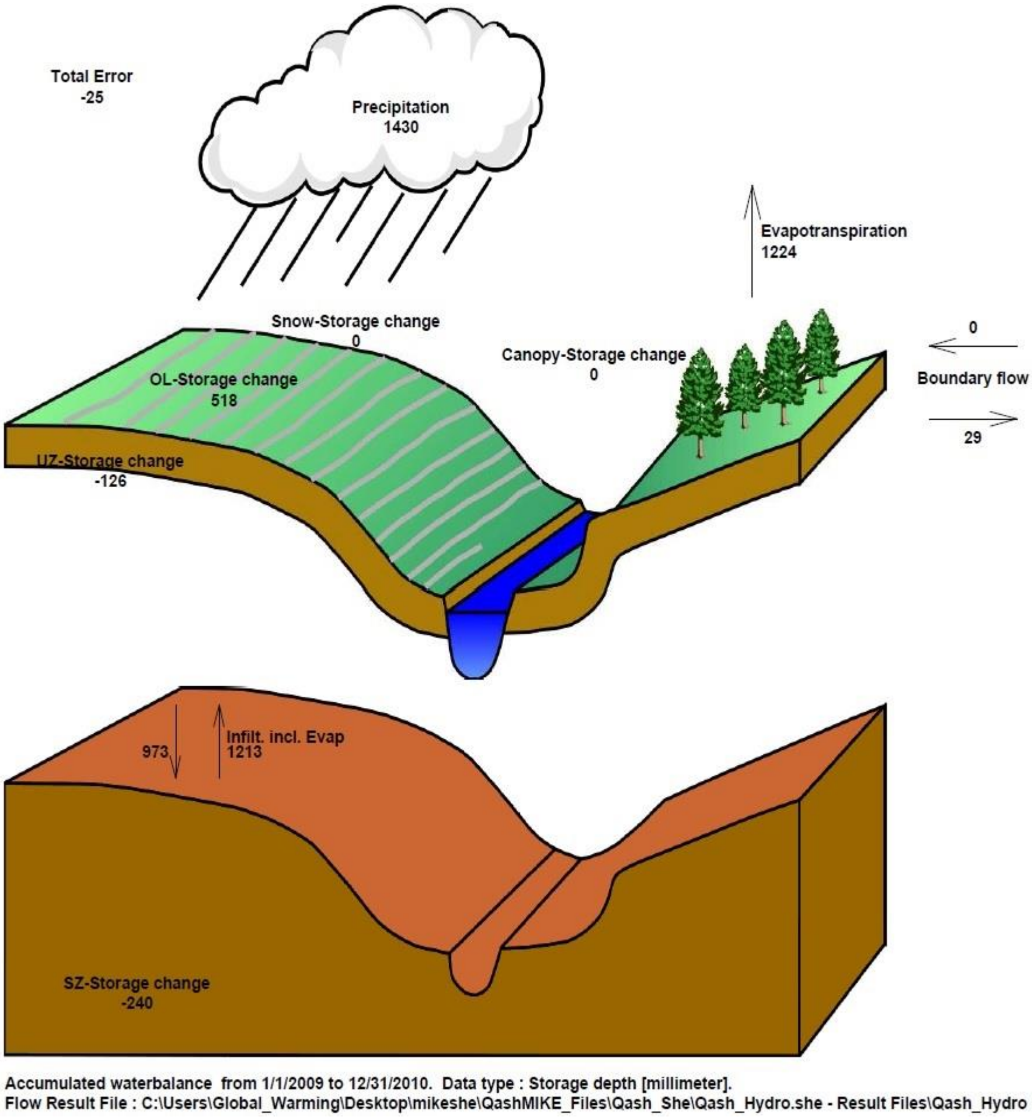


Figure 5.7: Water balance in the Kashkadarya River basin for 2009-2010 (MIKE SHE simulation software).

5.4 CONCLUSION

1. Obtained results show that in the Kashkadarya River basin the main pollution from the chemical consists of the water bodies occurs due to agricultural farmlands and industrial enterprises.

2. For the efficient and sustainable management of water, especially in arid areas the application of the salt and balance equations gives a proper management option from the point of view of sanitarization. The sensitivity analyses of the each hydrological factor of the salt and water balance gives to understand and detect the pollution sources trough the river basin for their proper management.

3. The proposed formula on salt and water balance can control the amount of the fertilizer supplement for the irrigation purposes to protect the river pollution and fertilizer saving in Uzbekistan.

REFERENCES

1. Davranova N.G., Makhmudov E.J., (2006), Desertification of extra-arid regions, Ecological Journal of Uzbekistan, 8. pp. 31-35.

2. Makhmudova D.E., Ernazarov A.T., (2006). Change of water salinity level in the circulating water reservoirs, The Problem of the Mechanics, pp. 72-76.

3. Makhmudov Kh., (2011). Integrated River Basin Management in the Chirchik River basin, The University of Kitakyushu, Japan.

4. The Institute of Groundwater, (2010). Report of the GP"Gidroingeo", Tashkent.

5. Zhuravlev V.F., (2001). Foundations of Theoretical Mechanics. 2nd Ed, FIZMATLIT, Moscow, Russia.

6. Blyutgen I., (1973). Geography and climates, 2nd Ed, Progress, Moscow, Russia.

7. Makhmudov E.J, Ishanov X.X., (2010). Global Network for Water Development Information in Arid and Semiarid Regions of Asia, UNESCO, pp. 27-34.

8. Bedrincev K.N., Korjavin B.D.,(1975). Irrigation of Uzbekistan, Volume 1, Tashkent, Uzbekistan.

9. Kashkarov R.D., (2008). Ecological Atlas of Uzbekistan. UNESCO Office in Uzbekistan, Tashkent, Uzbekistan.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

1. The developed model enables analysis of the complex hydrogeological regime in the regions, and forecasting of the environmental impacts on the various management options. The model simulates all hydrological processes in the Chirchik and Kashkadarya River basins, including evapotranspiration of a watershed, precipitation, overland flow, unsaturated and saturated flow and infiltration, for both calibration and validation periods.

2. As a result, all detailed information on the natural characteristics of the Chirchik and Kashkadarya River basins are described with the spatial distribution of the different hydrological components. As a consequence of the comparison of the spatial distribution, water balance results of the two river basins show that the both river basin's environment is depleted and water management systems are worse situation.

3. Alongside as characteristics and formation of the river basins are different: The Chirchik River is flowing and connected to the Syr-Darya River, which is the main artery of the Aral Sea basin, Kashkadarya River is flowing and streams of Amu Darya River, but the water lost in desert areas and cannot reach to the second artery of the Aral Sea, Amu-Darya River. Characteristics of these rivers and their economic, environmental and societal importance for Uzbekistan were the foundation for selection of research subjects as objects of study of present thesis.

4. In the Chirchik and Kashkadarya River basins the formation of the water stream is combined stream with prevalence of the snow, the landscape and topography of the territory significantly volatile. In this regard proper accounting of climatic parameters, especially their correct interpolation has a particular importance in the establishment of hydrological parameters of the rivers. Under these conditions, the proposed interpolation method can create a mixed system of climatic factors at the midpoint (centre) of the movement of each climatic parameter, with a unique

centre (barycentre). The calibration results of the current interpolation methods and new developed method (including the similar assumption) with observed results showed that the developed method has the most similarity to the actual observed data. By using the developed interpolation method have been calculated the water balance of the Chirchik and Kashkadarya River basins.

5. The numerical implementation of the water balance equation and by using the MIKESHE an integrated hydrological modelling system has been obtained the accurate hydrological water balance of the river basins to monitor the seasonal change of the spatial distribution of the groundwater levels through the basin. The monitoring of the ground water level in river basins can protect the soil from the salinization and erosion, which is the main problem in an arid areas.

6. In arid areas the water and salt balance equations give the qualitative and quantitative management of the river basin and their sanitary protection. Development of the applicable formula on salt and water balance allows forecasting and management of water quality in the rivers, especially in arid and semi-arid regions with crop irrigation systems.

7. The obtained results in the framework of the research are useful for arid and semi-arid areas and along with to solve various problems related to the sustainable use of water of the territories, as easily as to analyse and measure their impact on the different processes of the environment.

6.2 RECOMMENDATIONS

1. The developed interpolation method of climate data, wherein the spatial distribution of scalar quantities taken as: temperature, precipitation, atmospheric pressure, potential evaporation, air humidity, etc. are recommended to use in predicting of runoff of the river basins, as well as for decrease of a number of measures on environmental protection, in particular for land degradation and flood phenomena due to the less climatic data.

2. Compiled on the basis of the MIKESHE an integrated hydrological modelling system, the water balance results can be as recommended for forecasting of a condition of the aeration zone of the subsoil, which is claimed for management of irrigation of crops in arid areas.

3. Developed on the basis of the ArcGIS commercial software and MIKESHE an integrated hydrological modelling system spatial distribution map of the each hydrological factor in the water balance of the territories is recommended to maintain the level of groundwater in the range when on the soil surface due to evaporative concentration does not form toxic mineral salts. The proposed maps allow to take the necessary measures not an assumption to salinization of soil, which is undoubtedly very important for arid areas.

4. Simulation models of water-salt balance of river basins is recommended for the sustainable management of water resources of river basins in arid areas, the most important thing point is, the model prevents excessive salinity of the river water.