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JAPAN INTERNATIONAL COOPERATION AGENCY

CAPITAL DEVELOPMENT CORPORATION
THE CITY OF ASTANA

THE FEASIBILITY STUDY ON WATER SUPPLY AND SEWERAGE IN THE CITY OF ASTANA IN THE REPUBLIC OF KAZAKHSTAN

FINAL REPORT

VOL. II MAIN REPORT

MARCH 2001

KISHO KUROKAWA ARCHITECT & ASSOCIATES
NIPPON KOEI CO., LTD.
INTERNATIONAL DEVELOPMENT CENTER OF JAPAN

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LIST OF REPORTS

Vol. I	EXECUTIVE SUMMARY
Vol. II	MAIN REPORT
Vol. III	SUPPORTING REPORT
Vol. IV	DRAWINGS
Vol. V	DATA BOOK

Exchange Rate Applied

US$1.00 = Kazakhstan Tenge 144.00

= ¥110.00

(as of October 2000)

PREFACE

In response to a request from the Government of the Republic of Kazakhstan, the Government of Japan decided to conduct The Feasibility Study on Water Supply and Sewerage in the City of Astana and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA selected and dispatched a study team headed by Mr. Kisho Kurokawa, Kisho Kurokawa Architect & Associates to the Republic of Kazakhstan from July 2000 to March 2001. In addition, JICA set up an advisory committee that examined the study from specialist and technical points of view.

The team held discussions with the officials concerned of the Government of the Republic of Kazakhstan and conducted field surveys at the study area. Upon returning to Japan, the team addressed comments from the Kazakhstan side and prepared the final report.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relationship between our two countries.

Finally, I wish to express my sincere appreciation to the officials concerned of the Government of the Republic of Kazakhstan for their close cooperation extended to the team.

March, 2001

Kunihiko Saito
President
Japan International Cooperation Agency

March 2001

Mr. Kunihiko Saito
President
Japan International Cooperation Agency
Tokyo, Japan

Dear Sir,

LETTER OF TRANSMITTAL

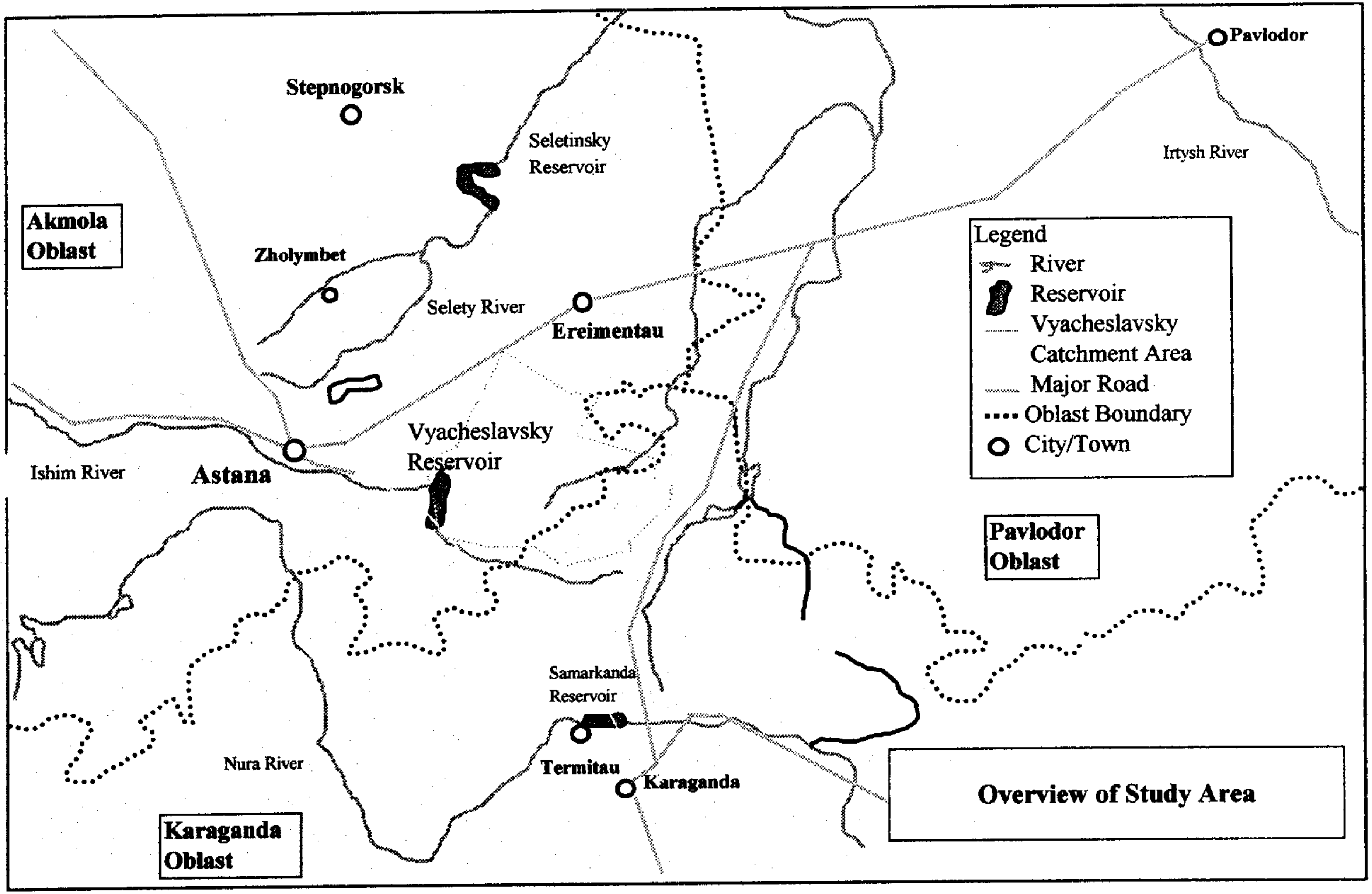
It is with great pleasure that we submit to you the Final Report of The Feasibility Study on Water Supply and Sewerage in the City of Astana in the Republic of Kazakhstan completed by the Study Team with cooperative efforts of the Capital Development Corporation (CDC) and other parties concerned. The report has been prepared for the Government of the Republic of Kazakhstan for implementing water supply and wastewater facilities in the new capital city of Kazakhstan, Astana City.

The report consists of four volumes, those being the Executive Summary, Main Report, Supporting Report and the Drawings. The Executive Summary presents the outline of the study results. The Main Report provides all the study results regarding water supply and wastewater from technical, environmental, organizational, financial and economical viewpoints. The Supporting Report provides investigation findings, assessment calculations and relevant agreements made with the Kazakhstan side. The Drawings present conceptual drawings in order to visualize both the existing and proposed facilities.

Taking this opportunity, on behalf of the Study Team, I would like to express my heartfelt gratitude to the personnel from JICA, Advisory Committee, Ministry of Foreign Affairs, Embassy of Japan in Kazakhstan and Kazakhstan officials participating in the State Expertise review who extended their kind assistance and cooperation for the entire study period to the Study Team. The Study Team hopes that the results of this study contribute to the future implementation of water supply and wastewater system in the City of Astana.

Yours faithfully,

Kisho Kurokawa
Team Leader
The Study for the Feasibility Study on Water Supply
And Sewerage in the City of Astana



Overview of Study Area

THE FEASIBILITY STUDY ON WATER SUPPLY AND SEWERAGE IN THE CITY OF ASTANA IN THE REPUBLIC OF KAZAKHSTAN

FINAL REPORT
VOL. II MAIN REPORT

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List of Abbreviations

ASA	Astana Su Arnasy
BOD,BOD_5	Biochemical Oxygen Demand
BOD_{total}	Total Biochemical Oxygen Demand
BOQ	Bill of Quantity
CDC	Capital Development Corporation
CIF	Cost including Insurance and Freight
COD	Chemical Oxygen Demand
CPI	Consumer Price Index
Dia	Diameter
DIP	Ductile Cast Iron Pipe
DO	Dissolved Oxygen
DS	Dry Solids
DWF	Dry Weather Flow
EBRD	European Bank for Reconstruction and Development
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
F.C.	Foreign Currency
FIRR	Financial Internal Rate of Return
F/M	Food/Microorganisms
FOB	Free On Board
F/S	Feasibility Study
GAC	Granular Activated Carbon
GDP	Gross Domestic Product
GM	General Manager
GRDP	Gross Regional Domestic Product
H	Height
IBRD	International Bank for Reconstruction and Development
ICB	International Competitive Bidding
IKIC	Iritysh-Karaganda-Ishim Canal
IMF	International Monetary Fund
JSC	Joint Stock Company
JICA	Japan International Cooperation Agency
L	Length
L.C.	Local Currency
MAC	Maximum Allowable Concentration
MCM	Million Cubic Meters
MLSS	Mixed Liquor Suspended Solids
MPN	Most Probable Number
M/P	Master Plan
O&M	Operation and Maintenance
OECD	Organization for Economic Development and Cooperation
pe	Population Equivalent
PEA	Project Executing Agency
PCWD	Per Capita Water Demand
PMUWP	Project Management Unit for Water Projects
P/S	Pumping Station
PVC	Polyvinyl Chloride Pipe

Q	Quantity
Q_{DA}	Daily Average Flow
Q_{DM}	Daily Maximum Flow
Q_{HM}	Hourly Maximum Flow
RAS	Return Activated Sludge
RC	Reinforced Concrete
RCP	Reinforced Concrete Pipe
RND	Research and Development
RK	Republic of Kazakhstan
SanPiN	Sanitary Norms and Regulations
SAR	Sodium Adsorption Ratio
SAS	Surplus Activated Sludge
SNiP	Construction Norms and Regulations
SS	Suspend Solid
USSR	Union of Soviet Socialist Republic
VSS	Volatile Suspended Solids
VAT	Value Added Tax
W	Width
WHO	World Health Organization
WPI	Water Pollution Index
WTP	Water treatment Plant
WWTP	Wastewater Treatment Plant

List of Units

ha	hectare
hr	hour
J	joule
kJ	kilo joule
kW	kilowatt
kWh	kilowatt-hour
m^3/day	cubic meter per day
m^3/hr	cubic meter per hour
m^3/s	cubic meter per seconds
m^2	square meter
m	meter
mm	millimeter
μ g/l	micrograms per liter
Nm^3	normalized cubic meter of air
km^2	square kilometer
m/s	meter per second
mg/l	milligram per liter
mol/l	moles per liter
MPa	mega pascal
MPN/100ml	most probable number per 100ml
NTU	nephelometric turbidity units
pc/100ml	population count per 100ml
ppm	parts per million
TCU	true colour units
TG	Kazakhstan Tenge
USD	United States Dollar

CHAPTER 1
INTRODUCTION

CHAPTER 1 INTRODUCTION

1.1 Background of the Study

The capital city of the Republic of Kazakhstan was shifted in December 1997 from the City of Almaty to the City of Astana. Since then, development in the City of Astana has progressed at a rapid rate in order to meet standards of an international level. With the aim of proper development for the City of Astana, the Kazakhstan Government established the Capital Development Corporation (hereinafter referred to as "CDC") in May 1999. The Government of Kazakhstan then requested the Government of Japan (GOJ) for assistance in formulating an overall master plan for city development.

Based on this request, the Japan International Cooperation Agency (hereinafter referred to as "JICA") decided to carry out "The Study on the Master Plan for the Development of the City of Astana in the Republic of Kazakhstan" (hereinafter referred to as the "Master Plan Study"). Accordingly, JICA dispatched a preparatory mission to discuss and agree the contents of the Scope of Work for the Master Plan Study. A meeting was concluded with Minutes of Meeting signed between the Ministry of Foreign Affairs, the Agency for Strategic Planning and Reforms, CDC, the City of Astana and JICA on October 5 1999 as shown in Supporting Report F 1. At this meeting, it was agreed that a Feasibility Study would be implemented in compliance with the results of the Master Plan Study, however the Scope of Works for the Feasibility Study would be selected by the time of the presentation of the Progress Report in the Master Plan Study.

The Master Plan Study commenced in January 2000 and the meeting for the Progress Report was held on April 12 2000. The Minutes of Meeting was signed between the Ministry of Economy, the Ministry of Foreign Affairs, CDC, the City of Astana and JICA on April 14 2000 as shown in Supporting Report F 2. Following the proposals in this Progress Report, it was agreed that the Feasibility Study be carried out for the sectors of water supply and sewerage. The Minutes of Meeting for the Scope of Work for the Feasibility Study (hereinafter referred to as "the Study") were signed between the aforementioned Kazakhstan organizations and JICA on April 14 2000 as shown in Supporting Report F 3.

1.2 Objective of the Study

The objectives of the Study are as follows:

(1) To assess the technical, financial and economic viability, environmental and social soundness of the priority projects in water supply and sewerage, and
(2) To pursue technology transfer to the counterpart staff in the course of the Study.

1.3 The Study Area

The Study area agreed between JICA and the Kazakhstan side is defined by the existing city configuration as shown in Figure 1.3.1. The area basically covers the entire City of Astana including the surrounding suburban areas, together with the upstream and downstream of the Ishim River basin.

1.4 Target Year and Development Area for the Study

The target year for the Study is set for 2010. The development area for the target year is shown in Figure 1.4.1 as determined by the Master Plan.

1.5 Agreements with the Kazakhstan Side

Throughout the duration of the Study, a number of key agreements were made with the Kazakhstan side. First, the Inception Report Meeting to present the outline of the Study to concerned Kazakhstan organizations was held on July 14, 2000. The Minutes of Meeting for the approval of the Inception Report were signed as shown in Supporting Report F 4.

The Terms of Reference for the Study were subsequently defined and confirmed. The agreement with Akimat is shown in Supporting Report F 5.

In order to set the foundation of the Study, the unit water demand had to be agreed upon. The agreement with the Construction Committee, part of the Ministry of Energy, Industry and Trade, is shown in Supporting Report F 6.

An Interim Report was prepared and the results were presented during a meeting held on November 30, 2000 in Kazakhstan. The Minutes of Meeting for the approval of the Interim Report is shown in Supporting Report F 7.

The Draft Final Report was prepared and the results were presented during a meeting held on January 29, 2001 in Kazakhstan. The Minutes of Meeting for the approval of the Draft Final Report is shown in Supporting Report F 8.

1.6 Organization of The Study Team

The organization of the Study consists of the Study Team under the direction of JICA, located in JICA headquarters in Tokyo.

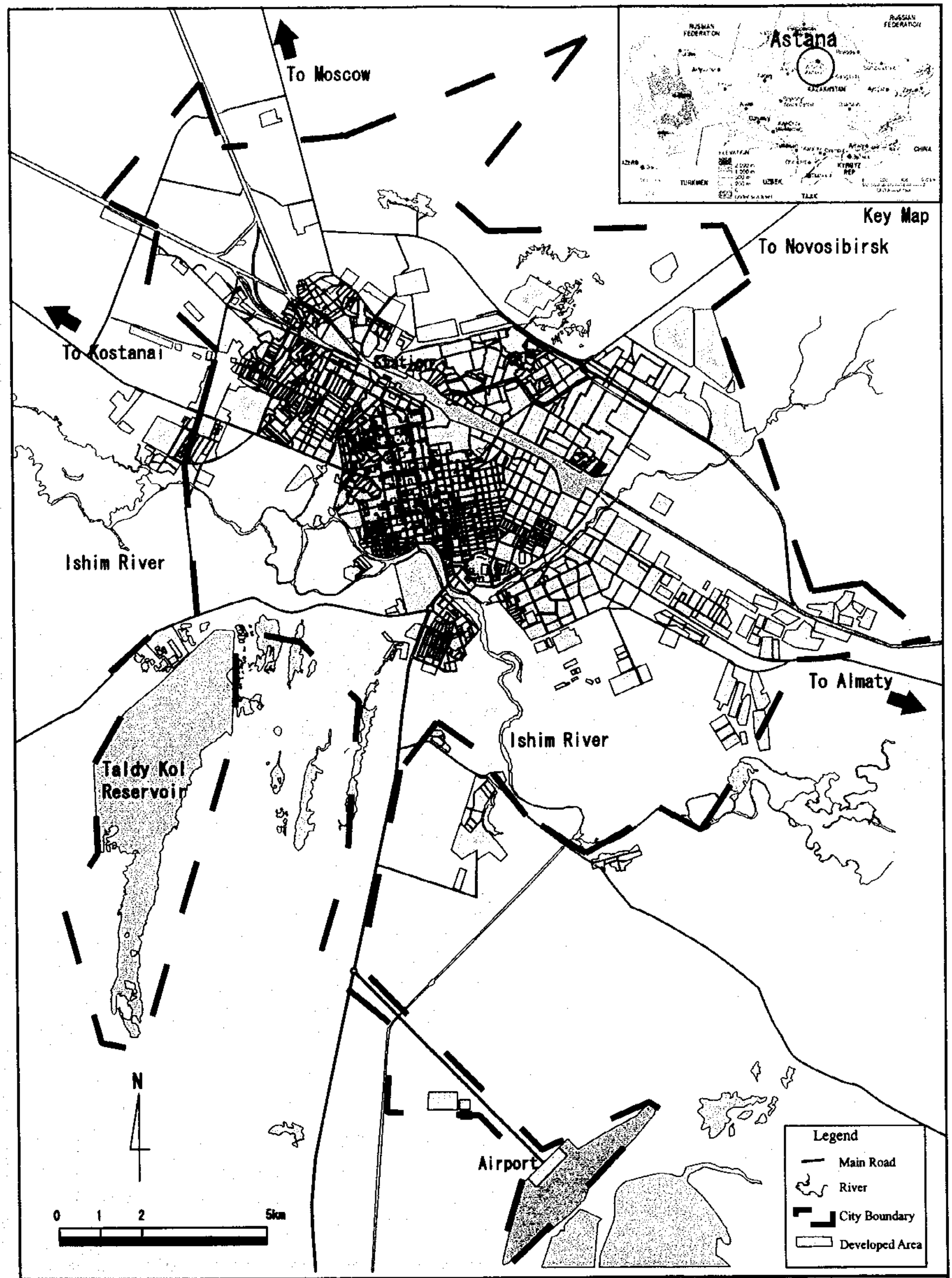
<u>Study Team</u>

1) Team Leader	Kurokawa, Kisho
2) Co-team Leader/Water Supply and Sewerage Planning Expert	Okazaki, Keisuke
3) Water Supply Designer I	Watanabe, Takashi
4) Water Supply Designer II	Fujiwara, Masao
5) Sewage Designer I	Jean Claude Ah Man
6) Sewage Designer II	Inabe, Yoshiharu
7) Geotechnical Engineer/Land Surveyor	Matsuoka, Keiji
8) Institutional & Organizational Expert	Fujimoto, Noboru
9) Economic & Financial Analyst I	Kouprianov, Victor
10) Economic & Financial Analyst II	Nagao, Daisuke
11) Water Quality & Environmental Expert I	Sato, Shinsuke
12) Water Quality & Environmental Expert II	Naganuma, Kengo
13) Construction Planner/Cost Estimator	Otsuka, Yasushi
14) Interpreter	Akasaka, Yoshio
15) Coordinator	Yajima, Kaoru

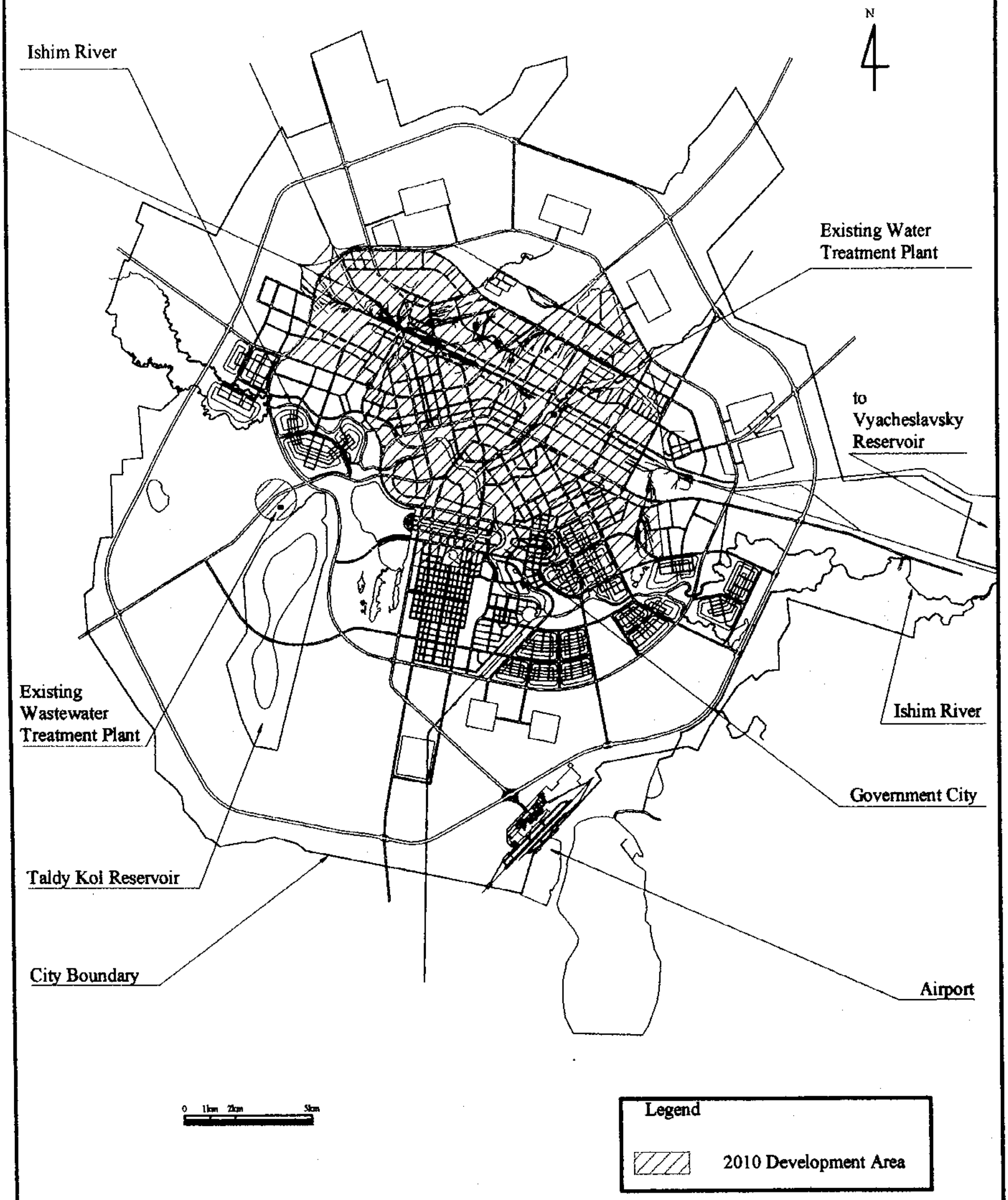
<u>JICA</u>

1) Vice President	Izumi, Kenjiro
2) Managing Director, Social Development Study Department (until June 2000)	Sakurada, Yukihisa
3) Managing Director, Social Development Study Department (from July 2000)	Jibiki, Takanori

4)	Director, Planning Division, Social Development Study Department	Kikuchi, Fumio
5)	Director, 1st Social Development Study Division, Social Development Study Department (until September 2000)	Kaibara, Takao
6)	Director, 1st Social Development Study Division, Social Development Study Department (from October 2000)	Hirai, Toshio
7)	Deputy Director, 1st Social Development Study Division, Social Development Study Department	Honda, Eri
8)	1st Social Development Study Division, Social Development Study Department	Ishiguro, Jitsuya
9)	Development Specialist	Koyama, Nobuhiro
10)	Development Specialist	Yamamoto, Keiko
11)	Development Specialist	Inagaki, Tomikazu



Feasibility Study for Water Supply and Sewerage in the City of Astana	Figure 1.3.1 Location Map
JAPAN INTERNATIONAL COOPERATION AGENCY	



The Feasibility Study on Water Supply and Sewerage in the City of Astana	Figure 1.4.1 2010 Development Area
JAPAN INTERNATIONAL COOPERATION AGENCY	

CHAPTER 2
GENERAL CONDITIONS

CHAPTER 2 GENERAL CONDITIONS

2.1 Natural Conditions

2.1.1 Topography

Astana City is located at the southern region of the steppes of Central Asia, which is characterized by an immense plain with little geomorphologic relief. The general features of the topography in Astana City are characterized by gentle slopes from the east to the west with the highest elevation of 370 m at the east and the lowest of 345 m at the west.

There are three major river systems around the City, the Ishim River flowing through the center, the Nura River to the south and the Seleti River to the north. The Ishim River originates in the Niyaz Mountains in the Karaganda Oblast and flows through Akmola, Kokshetau and North Kazakhstan Oblasts having an upstream length of 562 km and a catchment area of 48,100 km2. Downstream of Astana, the Ishim River flows for another 1,100 km before crossing the Tumen and Omsk region of the Russian Federation, joining the Irtish River.

The Ishim River runs through the center of Astana City from the east to the west dividing the city into two parts. The right bank of the river consists of the old city area and the left bank consists of grass and marshy lands having low elevations. The western side of the left bank is currently being developed for establishing the government city and new commercial and residential areas targeting completion by the year 2030. Whereas, the eastern side, presently occupied by grass and marshy lands will remain as a natural conservation area of water, grass and forest lands.

The Nura River originates in the hills in Karaganda Oblast and flows through the Oblasts of Akmola and Kostanai having a length and catchment area of 407 km and 55,100 km2, respectively. The Nura River discharges into the Kurgalginsky Reservoir about 200 km to the south west of Astana City.

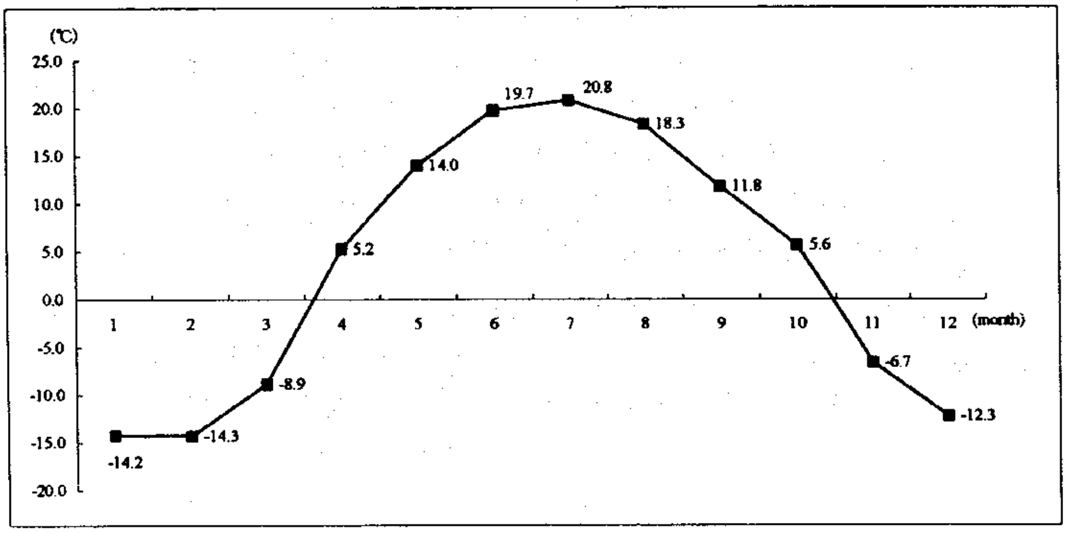
The Seleti River has a length of 407 km and a catchment area of 18,500 km2 with the major tributaries such as the rivers of Akmurza and Ashyly-Airyk. The Seleti River ends its course at the Seletinsky reservoir about 300 km to the north of Astana.

2.1.2 Meteorology

Kazakhstan is situated in the center of Eurasia and the large distance from oceans and openness of land influences the climate of the City. The Study area lies in a typical continental climate zone. It is characterized by large fluctuation of temperature and small amount of precipitation. The features of several climatic parameters from 1990 to 1999 are introduced here under.

(1) Temperature

The monthly average temperature of the Study area is shown in Figure 2.1.1. The temperature during the summer time from June to August is around 20 °C, and below −10 °C from December to February fluctuating more than 30 °C through the year. In spring and autumn season, abrupt change of temperature generally appears and the increase and decrease of the temperature within a month reaches more than 10 °C.



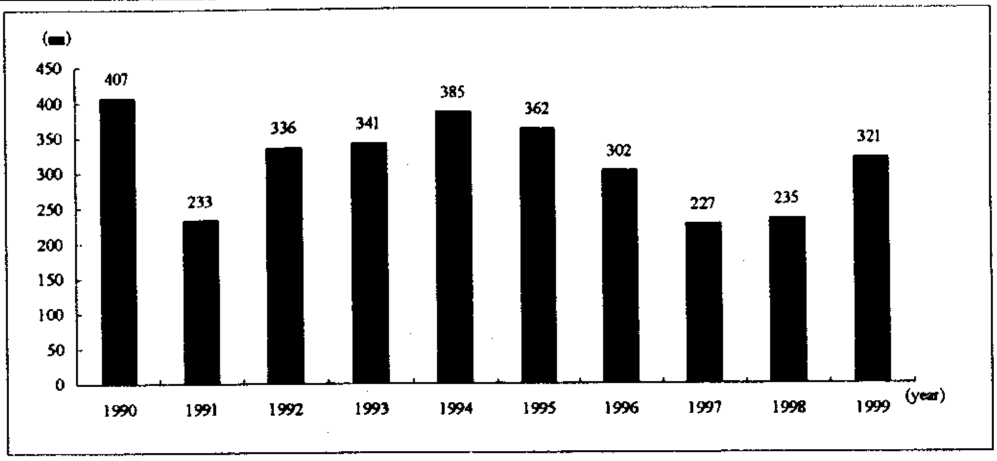
Source : Hydro-meteorological Monitoring Center of Astana City

Figure 2.1.1 Monthly Average Temperature from 1990 to 1999

(2) Precipitation

The annual precipitation including snowfall of about 315 mm and snowfall reaches only 100 mm. It means that one-third of the annual precipitation consists of snowfall, and this melts during the thaw period resulting in noticeable increase of river flow in spring.

The average annual precipitation is shown in Figure 2.1.2. From 1990 to 1999, the maximum annual precipitation recorded 407mm in 1990 and the minimum was 227 mm in 1997.



Source : Hydro-Meteorological Monitoring Center of Astana City

Figure 2.1.2 Annual Precipitation from 1990 to 1999

(3) Humidity

Monthly average humidity is comparatively low throughout the year as shown in Table 2.1.1 having an annual average figure of 67%. From May to September, the humidity is particularly low, since evapotranspiration during the summer time is largely due to strong solar radiation.

Table 2.1.1 Monthly Average Humidity from 1990 to 1999

Month	1	2	3	4	5	6	7	8	9	10	11	12	Annual Average
Average Humidity (%)	78	77	77	65	52	52	61	60	61	66	76	78	67

Source : Hydro-Meteorological Monitoring Center of Astana City

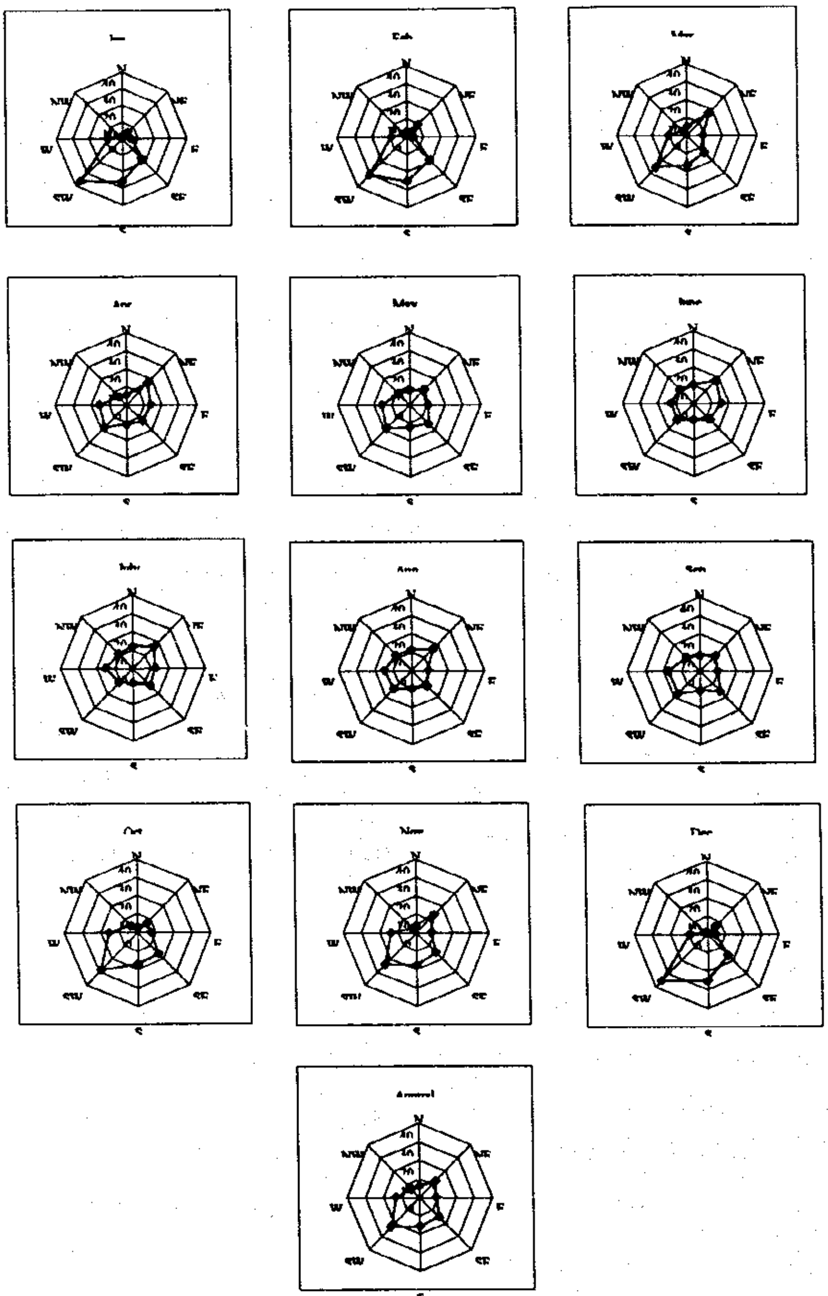
(4) Wind Speed and Direction

The annual average wind speed is 3.6m/s as shown in Table 2.1.2. The figures in winter season are little larger than those in summer season exceeding 4.0m/s. The annual main wind direction is from the south-west as shown by the "wind rose" in Figure 2.1.3. In winter season, this tendency is prominent, occupying more than 30%, while during the summer season from June to August, turns to the north-east.

Table 2.1.2 Monthly Average Wind Speed from 1990 to 1999

Month	1	2	3	4	5	6	7	8	9	10	11	12	Annual Average
Average Wind Speed (m/s)	4.0	4.1	4.1	4.0	3.7	3.2	2.9	2.8	3.0	3.6	3.8	4.0	3.6

Source: Hydro-meteorological monitoring center of Astana City



Source : Hydro-meteorological monitoring center of Astana city

Figure 2.1.3 Wind Rose (Average ratio from 1990 to 1999)

2.1.3 Water Resources

(1) Annual Yield of Vyacheslavsky Reservoir of the Ishim River

The Vyacheslavsky Reservoir has been in operation since 1970 for water supply to the City of Astana and its vicinity. The reservoir has a catchment area of 5,310 km2 with a long term annual mean flow of 171 MCM/year. Spring thaw contribute about 80 to 85 % of the annual resources to the basin. Presently drinking water is conveyed to Astana City through a 55 km long pipeline, while technical water (water supplied to industries for uses such as cooking, washing, etc) of Astana City, irrigation water and sanitary flow are provided by the Ishim River. Besides, a minimal amount of water of the reservoir is used for irrigation in the area surrounding the reservoir.

The Construction Norms and Regulations CN and R 2.04.02-84 stipulates the availability of the minimal average monthly water discharge for water supply should be 95 %. Presently water supply of the Astana City for drinking purposes depends entirely on the water resources of the Ishim River. It is noted that the hydrographic survey by design institute “Astanagorproject” in the beginning of the year 2000 revealed that the effective storage capacity of the reservoir has been reduced from 411 MCM to 390 MCM due to siltation at normal water level of 403 m of the reservoir. The annual yield of the reservoir is reviewed based on the past inflow records as input to the reservoir in the 30-year period between 1970 and 1999 which resulted in an annual yield of 89.2 MCM is with 95 % dependability.

The flow rate of the Ishim River is controlled at the Vyacheslavsky Reservoir by a dam and by weirs in Astana City. Around Astana city, the velocity of flow is quite low because of the downstream weir of Astana City. In winter season, thick ice covers the river, and the flow is hardly observed. Table 2.1.3 shows the monthly average flow rate from 1993 to 1995.

(2) Nura River

The Nura River originates in Karaganda Oblast and flows into the Tengiz Lake in Akmola Oblast. The discharge at 50% flow availability is 17.5 m^3/sec based on long period observation data at Romanovka, located upstream of the intake of Nura-Ishim Canal, with a catchment area of 45,100 km^2.

Table 2.1.3 Flow Rate of Ishim River from 1993 to 1995

Unit : m^3/s

Station	Year	1	2	3	4	5	6	7	8	9	10	11	12
Volgodonovka	1993	3.1	3.3	2.8	121	16.7	5.7	6.0	6.3	2.5	6.0	6.1	3.9

(Astana upstream)	1994	2.7	2.1	3.0	1.7	-	-	-	-	-	1.4	2.6	-
	1995	-	-	-	2.1	2.8	3.2	6.6	3.8	2.2	2.8	3.4	3.1
Astana City	1993	0.4	0.4	0.9	110	22.1	3.6	3.0	3.6	1.7	2.7	4.5	3.6
	1994	3.3	3.3	2.9	3.0	1.2	0.6	0.6	0.6	0.6	0.4	0.8	0.4
	1995	0.1	0.1	0.9	-	1.5	0.8	2.9	2.2	2.0	2.5	2.9	3.3

Source : Hydro-Meteorological Monitoring Center

The Nura River had been used for water supply to Astana City through the Nura-Ishim canal since 1974. The river however has been contaminated by industrial wastes from the upstream industrial sites. The carbide factory in Temirtau discharged large quantities of mercury into the river for 25 years. Astana City has stopped the use of the Nura River water since 1992. With the objective to provide users in the Nura-Ishim basin with a safe, reliable and affordable water supply, the World Bank has committed to provide funding for the clean-up project. The World Bank started the feasibility study of the clean-up program in August 2000, which will reportedly take one year to complete.

(3) Irtysh-Karaganda Canal (IKC)

The Irtysh-Karaganda Canal (IKC) started its operation in 1975 connecting the Irtysh River and the industrial city of Karaganda. The total length is 458 km including 354 km of canal, 101 km of reservoirs and 3 km of pumping stations. The level of water lift is 418 m. The quality of water of the canal is categorized as Class III "moderately contaminated water" which is worse than the Ishim River water.

In view of the rapidly decreasing water storage during the past three years of the Vyacheslavsky Reservoir, which is the sole water source of Astana City, the government decided to construct the pipeline to divert IKC water to the upstream of the Ishim River. The project plans to divert water of the canal at the point upstream from No. 19 pump station of the IKC. The pipeline is 19.6 km in total length consisting of 9.6 km of pressure pipe with a diameter of 1,400 mm, 3.2 km of box culvert and 6.8 km of gravity flow by pipe with a diameter of 1,200 mm.

(4) Groundwater

The following four aquifers are recognized in the vicinity of Astana City:

a) Akmolinsky aquifer 60 km to the north of the city
b) Tselinogradsky aquifer along the Ishim River
c) Rojdestvensky aquifer about 25 to 45 km to the south of the city
d) Nurinsky aquifer about 80 km to the southwest of the city

The total groundwater yield of the above four aquifers was formerly estimated to be

128,300 m3/d (46.83 MCM). For development of the groundwater, however, the estimates should be confirmed by conducting detailed hydrogeological investigations including aquifer testing programs and groundwater modeling.

The Ministry of Natural Resources and Environment has recently carried out a study regarding the possibility of groundwater use for Astana City. The study confirmed the possible yields of 12,000 to 17,000 m3/d of potable water at Koyandinsky and Sofievsky Occurrences of the Aknmolinsky aquifer that was previously confirmed with a yield of 31,100 m3/d.

Meanwhile, the groundwater aquifer along the Nura River is not considered as a water supply source of Astana City until large-scale engineering-ecological work of the Nura River is accomplished.

(5) Water Availability for Water Demand in 2010

The water demand of Astana City in 2010 is projected to be 104.9 MCM/year by the JICA Master Plan Study Team, as shown below:

Water Demand for Astana City 2010

Item	Volume,MCM
Drinking Water	55.4
Technical Water	8.5
Irrigation	20.7
Greenery	0.3
Sanitary Flow	5.0
Landscaping and miscellaneous use	3.0
Water Loss	12.0
Total	**104.9**

As previously explained in this Section, the Vyacheslavsky Reservoir has been evaluated to provide an annual yield of 89.2 MCM (resulting in a deficit of 15.7MCM). From the water balance, it is essential to provide an additional water source for 2010. Water from the IKC has been selected to be the second source of water supply through alternative study of development of water resources by the JICA Master Plan Study. The IKC-Ishim pipeline project to deliver the IKC water to a location upstream of the Ishim River is scheduled to be completed by July 2001.

The IKC-Ishim pipeline is designed to transfer up to 90MCM/year of IKC water with 60MCM/year available at the Vyacheslavsky Reservoir. As a result of water loss through evaporation and seepage between the end of the pipeline and Vyacheslavsky reservoir, only 70% of the transferred volume are estimated to be available in the reservoir. The simulation analysis of reservoir operation of the Vyacheslavsky Reservoir of the JICA Master Plan Study suggests that replenishment by the IKC is required at the end of extreme cases of water deficit in the Ishim River basin. This results in a 3.7% average contribution to the water supply for Astana City in 2010.

2.1.4 Geology

At the beginning the pre-Paleozoic era, a considerable part of the Akmolinsky oblast was covered by sea with numerous volcanic islands. Through intensive volcanic activity, a great volume of volcanic sediments has accumulated. In the interior part of Akmolinsky oblast, several minerals, such as gold, bauxite, antimony, copper were deposited.

The area of Kazakhstan mostly belongs to the Urals-Mongol fold belt comprising of Paleozoic formations such as silt stones and sand stones. The formations of the Urals-Mongol fold belt occurred as a stable continental block during the Caledonian and Hercynian orogenies. In the depressions of Tengiz and Turnay, Paleocene and Neocene formations are overlaid exclusively with continental sediments within the Paleozoic massif, and Quaternary sediments occur in the river courses and lakeshores.

Alluvium Quaternary sediments accumulated in river valleys and lakes, which were distributed on the flood plain of the Ishim and other river basins. Modern alluvium is characterized by thin thickness and a motley granular structure. Fluvial alluvium sediments are also characterized by a heterogeneous granular structure. Loam, sandy loam and sands are observed in this alluvium layer. Beside the river, clays, heavy silt loam deposits with scattered penetration of rocks.

The geology in northern Kazakhstan, where Astana City is located, is composed of various rocks of geological ages and types as shown in Table 2.1.4.

North Kazakhstan is technologically affected by the following systems:

- A pre-Cambrian fold system characterized by intensive folds and dislocations. The anticlinorium limbs are covered with Paleozoic rocks.
- A Caledonian fold system characterized by a series of large synclinorium and anticlinorium.
- A Hercynian fold system characterized by narrow blocks of folds. These blocks of folds were originated by movement along the Caledonian faults and had folds axes whose main trend is northwest to southeast.
- An Alpine fold system that controls the valleys and depressions in Kazakhstan. The Ishim River basin is controlled by a deep fault zone.

Table 2.1.4 Geology of Northern Kazakhstan

Geological Age/Period		Type	Depth (m)	Characteristics
Archaeozoic	Pre-Cambrian			Oldest and hardest rocks
Proterozoic			4,500 - 5,000	Intensely metamorphic volcanic and sedimentary rocks
Palaeozoic	Cambrian	Siney	800 - 4,000	Tuffs, quartzites and dolomitic limestone. The rocks occur in northeast of the region.
		Lower	2,000	Sand stone, conglomerates, chart, clayey schist, Jaspar limestone and tuffs
		Middle	1,200	Sand stone, conglomerates, chart, clayey schist, Jaspar limestone and tuffs
	Ordovician	Lower	2,500	Jasper, Jasper quartzite, schists, sand stones and tuffs. These rocks are exposed near Dezzhavinsk.
		Middle	700	Brown and yellow sand stone with beddings of Jaspers and chart
		Upper	1,000 - 2,000	Greywache, sandstone, chart, schist, calcareous argillites, conglomerates and lenses of limestone.
	Silurian		2,000	Interbedded sediments
	Devonian		800 - 5,000	Volcanic rocks. The lower part has limited exposure, but the middle and upper parts are widely developed.
	Carboniferous		1,200 - 1,800	Carbonates sometimes interbedded with clastics, including volcanic material, sandstones, coal and shales.
	Permian	Upper	500 - 1,800	Red-brown sandstone with layer of grey limestone
		Lower	500 - 1,800	Dark gray limestone with layers of calcarerous sandstone and argillites
Mesozoic	Triassic		60	Kaolin clays, upper instrusive rocks
	Cretacceous			Kaolin, sandy clayey sediments
Cenozoic	Tertiary	Paleocene		Fine sediments, clays and lake deposits of the upper Eocene and lower Oligocene
		Neocene		Clays
	Quaternary	Eolian		Debris, loams, clayey sands and sandy clays
		Alluvium		Various sizes of sands with lenses of pebbles
			15 - 20	Silty sands, sandy loams and sandy clays

2.1.5 Geo-technical Condition

In the course of this Study, a geo-technical investigation and an analysis, based on existing data, borings and subsequent laboratory tests were carried out. However, due to a difficulty of acquisition of the existing data, the geo-technical conditions could only be verified for those sites on which the boring and laboratory test were carried out. The boring and laboratory test supervised by the Study Team was sublet to a local contractor as a part of the Study.

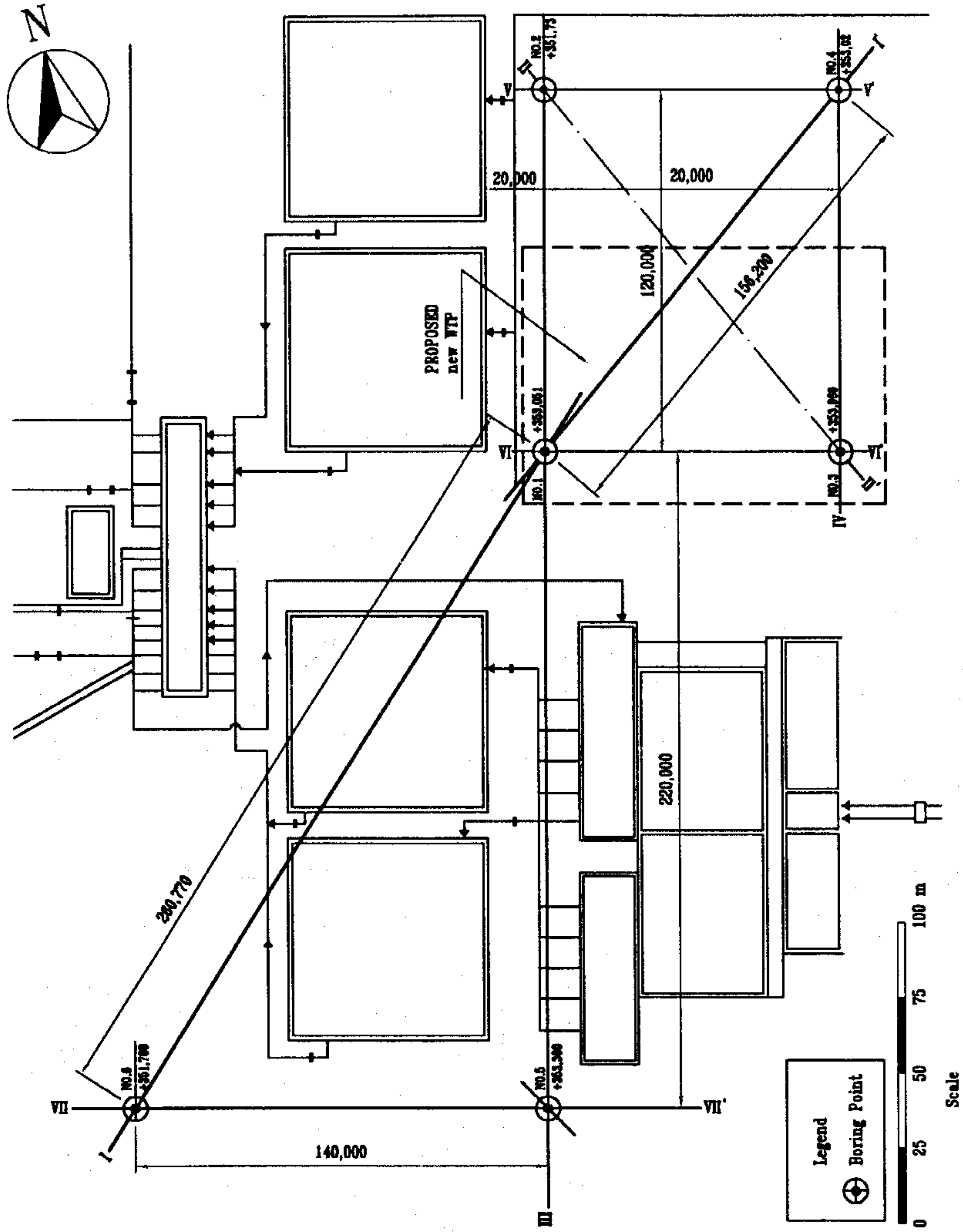
20 borings were carried out, 6 at WTP, 7 at WWTP and the remaining were at the water intake and wastewater pumping stations. The geo-technical conditions at the WTP and WWTP are summarized as follows. Further detailed characteristics together with other boring sites are provided in Volume V..

(1) Water Treatment Plant (WTP)

The locations of the borings in the premises of WTP are shown in Figure 2.1.4. Geo-technical characteristics of the site and laboratory tests are summarized in Table 2.1.5. The subsurface layer comprised of loose coarse sand of 1.5 to 2.0 m thickness under the sandy clay surface. Major facilities to be constructed in this area are water-retaining structures. Most of them are founded at the elevation of GL -0.5 to 2.0 m. Soil characteristics of layers under the structures show the surface layer as sandy clay having sufficient bearing capacity, however the second loose sand layer does not. Based on these conditions, piled foundations are recommended for WTP.

(2) Wastewater Treatment Plant (WWTP)

The locations of the borings at WWTP are shown in Figure 2.1.5. Geo-technical characteristics for the site and laboratory test are summarized in Table 2.1.6. The subsurface layer comprised of loamy sand 2.0 to 3.0 m thickness under the sandy clay surface. Major facilities to be constructed in this area are water basin structures. And most of them are founded at the elevation of GL 1.0 to 2.0 m. Soil characteristics of layers under the structures show that the surface layer as sandy clay has enough bearing capacity, however the second loamy sand with plastic to liquid consistency does not. Based on these conditions, piled foundations are recommended for WWTP.



Feasibility Study for Water Supply and Sewerage in the City of Astana	Figure 2.1.4 Location of Borings at WTP
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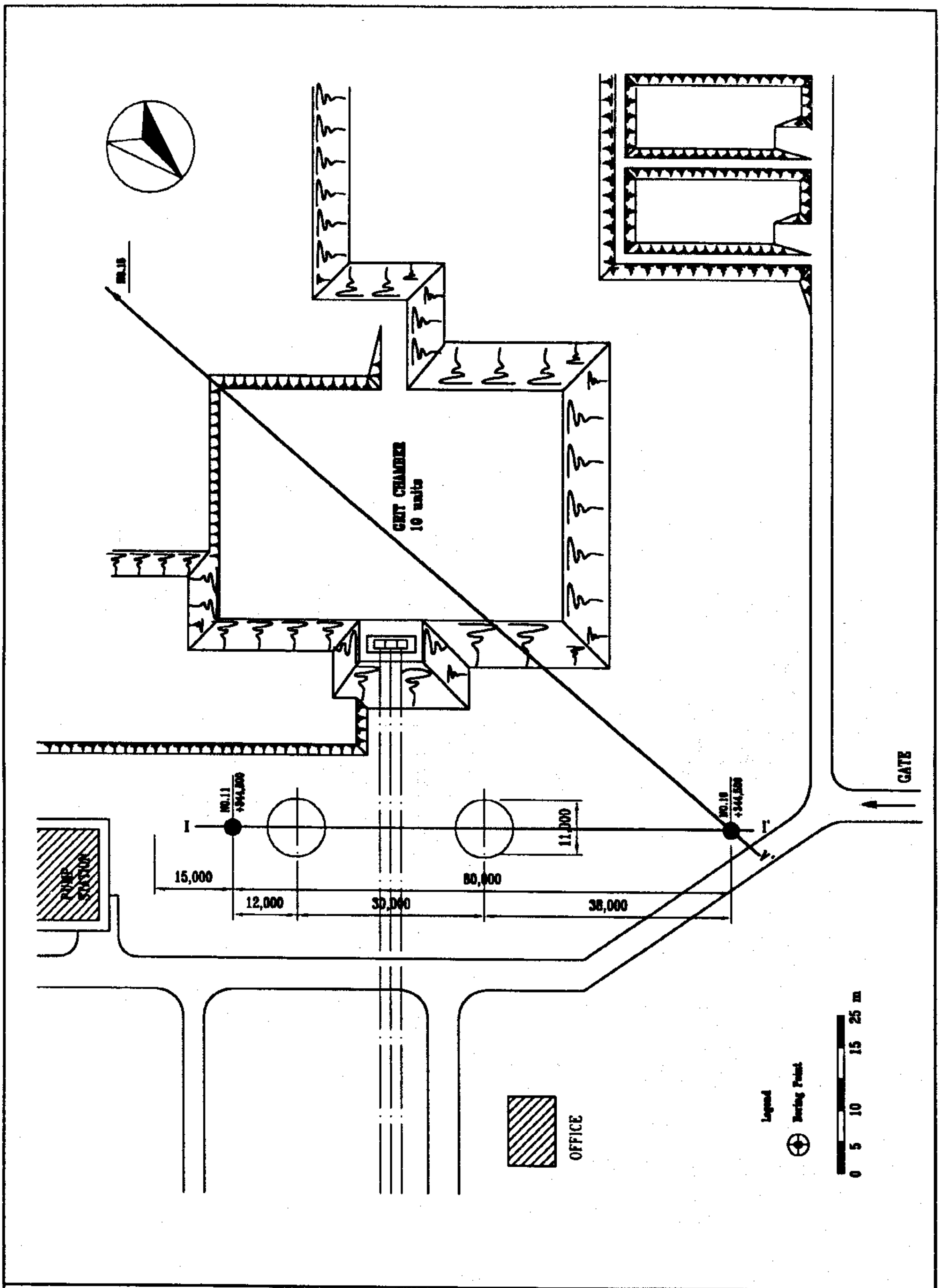


Feasibility Study for Water Supply and Sewerage in the City of Astana

JAPAN INTERNATIONAL COOPERATION AGENCY

Figure 2.1.5

Location of Borings at WWTP

Table 2.1.5 Summary of Soil Parameters for WTP

Boring No.	Description	Depth of bottom of layer from the Ground	Thickness of layer	Liquid Limit	Plastic Limit	Plasticity Index	Natural Water Contents	Natural Density	Cohesion	Internal Friction Angle	Permeability	Ground Water Level (GL-)	Recommended Pile Length	Pile Bearing Capacity
		m	m	%	%	%	%	g/cm2	kg/cm2	degree	m/d	m	m	ton
No.1	Solid Sandy Clay	1.00	1.00	-	-	-						2.07	4.2	20.5
	Light Sandy Clay	2.70	1.70	24	15	9	15	2.03	0.25	19	0.18			
	Coarse Sand with Sandy Clay or Loamy Sand	4.50	1.80	-	-	-		1.6	0.02	38	0.80			
	Loose Coarse Sand with Sandy Clay	6.50	2.00	-	-	-		1.6	0.04	30	1.22			
	Coarse Sand with Sandy Clay or Loamy Sand	8.00	1.50	-	-	-		1.6	0.02	38	0.80			
	Sandy Clay	10.20	1.80	31	20	11	20.7	2.1	0.25	19	0.18			
	Sandy Clay	15.00	4.80	41	29	12	23.6	1.97	0.33	19				
No.2	Light Sandy Clay	3.20	3.20	24	15	9	15	2.03	0.25	19	0.18	2.40	5.5	34.9
	Loose Coarse Sand with Sandy Clay	4.70	1.50	-	-	-		1.6	0.04	30	1.22			
	Sandy Clay	10.50	5.80	31	20	11	20.7	2.1	0.25	19	0.18			
	Sandy Clay	14.00	3.50	41	29	12	23.6	1.97	0.33	19				

Table 2.1.6 Summary of Soil Parameters for WWTP

Boring No.	Description	Depth of bottom of layer from the Ground	Thickness of layer	Liquid Limit	Plastic Limit	Plasticity Index	Natural Water Contents	Natural Density	Cohesion	Internal Friction Angle	Permeability	Ground Water Level (GL-)	Recommended Pile Length	Pile Bearing Capacity
		m	m	%	%	%	%	g/cm2	kg/cm2	degree	m/d	m	m	ton
No.11	Topsoil with vegetation	0.30	0.30	-	-	-						2.63	5.5	38.5
	Light Sandy Clay	3.00	2.70	25	16	9	18.5	2.01	0.3	22	0.18			
	Loamy Sand with consistency from plastic to liquid	6.00	3.00	20	15	5	21.3	2.12	0.15	26	0.23			
	Coarse Sand with Gravel	8.80	2.80	-	-	-		1.70	0.02	38	2.07			
	Sandy Clay with Organic	9.30	0.50	28	16	12	16.7	2.12	0.42	25	0.18			
	Coarse Grained Sand	11.00	1.70	-	-	-		1.70	0.01	40	14.28			
	Weathered Siltstone			42	23	19	23.2	2.03	0.39	21				
No.10	Topsoil with vegetation	0.30	0.30	-	-	-						2.63	5.5	48.1
	Light Sandy Clay	3.20	2.90	25	16	9	18.5	2.01	0.3	22	0.18			
	Loamy Sand with consistency from plastic to liquid	5.20	2.00	20	15	5	21.3	2.12	0.15	26	0.23			
	Coarse Grained Sand	11.80	6.60	-	-	-		1.70	0.01	40	14.28			
	Weathered Siltstone			42	23	19	23.2	2.03	0.39	21				

2.1.6 Water Quality of Existing Water Sources

(1) Water Quality of Vyacheslavsky Reservoir and Ishim River

Surface water sampling and testing was carried out by Hydrometeorological Monitoring Center in Astana City (state enterprise "Kazgidromet") during the period from April to December 1999. The sampling was carried out at the Vyacheslavsky Reservoir and three locations along the Ishim River i) at Telman village, ii) central part of Astana City and iii) Kirov Village. Telman and Kirov village are located at 3 km upstream and 8 km downstream of the Ishim River from the City center, respectively.

Laboratory test results for biochemical oxygen demand (BOD) at these sampling points are shown in Figure 2.1.6. Almost all the BOD values, except the samples taken in the middle of the City are lower than the maximum allowable concentration (MAC) for domestic use and therefore satisfactory as the source water for drinking purposes.

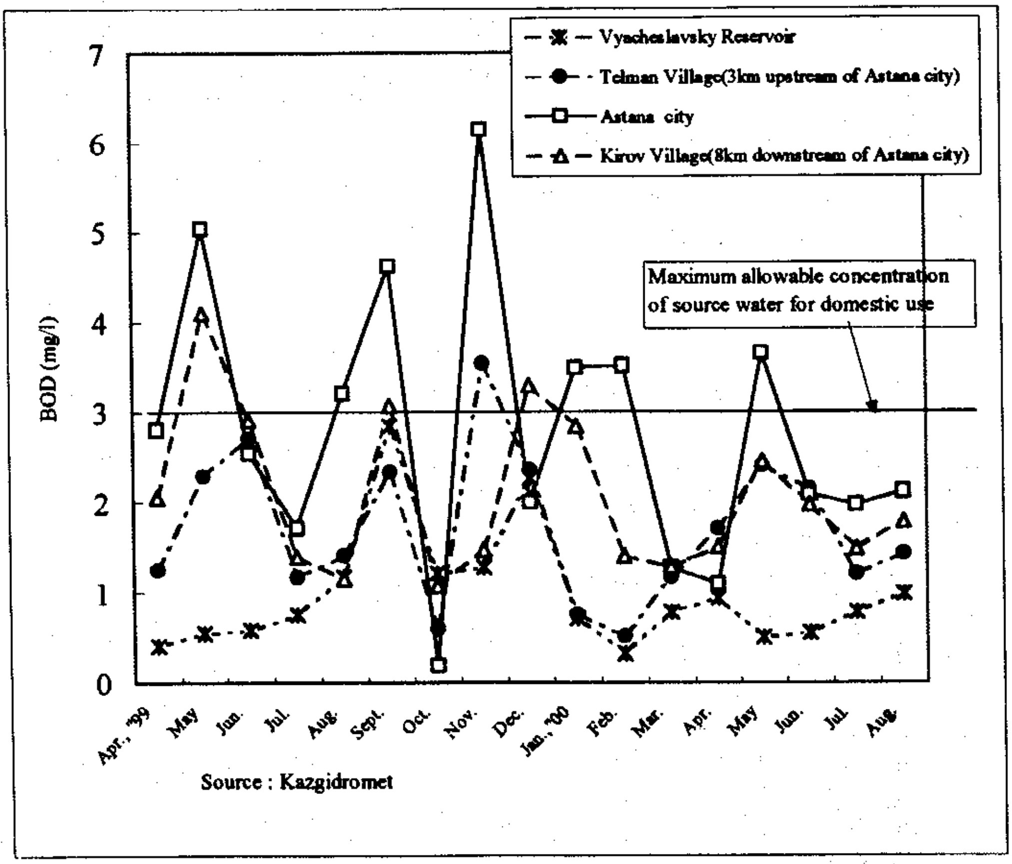


Figure 2.1.6 BOD of the Vyacheslavsky Reservoir and the Ishim River

However, the chemical oxygen demand (COD) values shown in Figure 2.1.7 are much higher than the MAC. When compared with the BOD values aforementioned, the COD values are not in proportion to BOD. As for as the comparison between the BOD and COD values is concerned, it is difficult to judge the degree of contamination of the river water.

In addition, the suspended solids (SS) as shown in Figure 2.1.8, is stable as a whole except for a few cases where abnormal values are obtained. This means that the water quality reveals inconsistency and is difficult to determine if the water is contaminated.

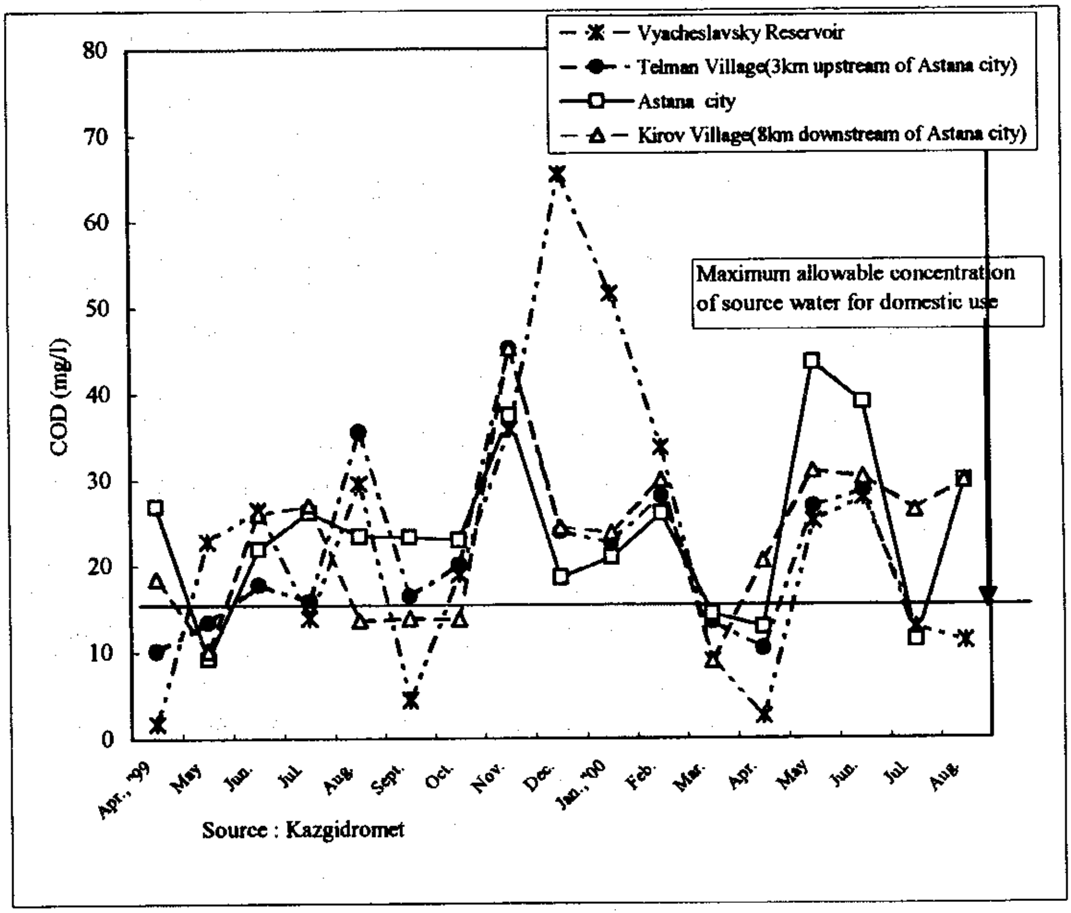


Figure 2.1.7 COD of the Vyacheslavsky Reservoir and the Ishim River

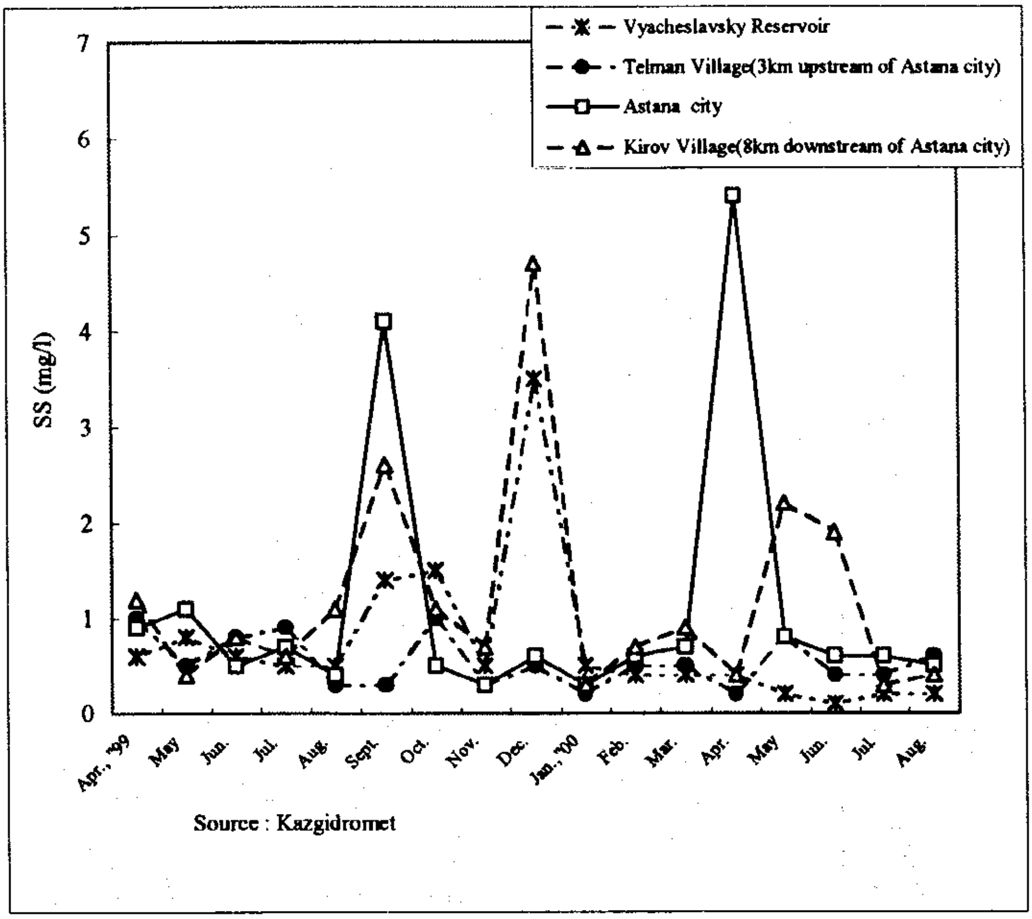


Figure 2.1.8 SS of the Vyacheslavsky Reservoir and the Ishim River

Meanwhile, there is an useful method to judge the degree of contamination that is commonly used in Kazakhstan. The level of pollution is estimated by the Water Pollution Index (WPI) which is calculated by the averaged summed ratio of six parameters. These six parameters include BOD, DO, and sulfate as common items and other three parameters depend on the features and objectives of the use of water bodies. The formula for the calculation is given as follows.

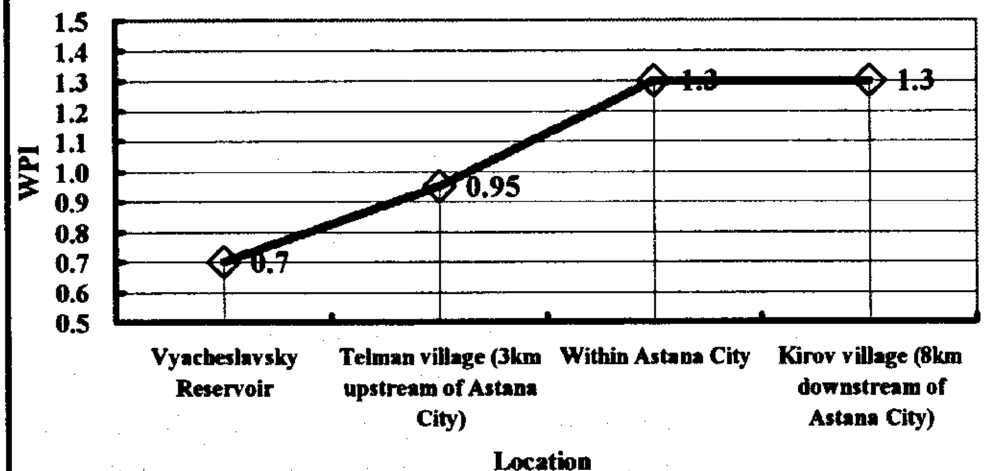
$$WPI = \sum_{i=1}^{6} Ci / (MAC)i \times 1/6$$

where,

Ci is the concentration of water pollution substance i,
(MAC)i is the MAC of water pollution substance i.

According to the data collected by Kazgidromet, the water quality of the Ishim River is categorized as moderately polluted with the values of WPI from 0.95 to 1.3. Water in the Vyacheslavsky Reservoir is polluted by sulfate (1.1 – 1.4 times of

MAC), iron (1.6 – 2.7 times of MAC). However, the values of WPI, 0.55 to 1.02, show that the water quality falls into the class 2 of "pure" category. Figure 2.1.9 shows the changes in WPI in the Ishim River. The water in the Ishim River is polluted gradually from the Vyacheslavsky Reservoir down to the Kirov Village located downstream of Astana City.



(Source: Kazgidromet)

Figure 2.1.9 Changes in WPI in the Ishim River

(2) Water Quality of Nura River

The values of WPI of the Nura River range between 1.25 and 2.44 with an average value of 2.1, and the water quality is classified into class 3, moderately polluted. This also shows that the water in the Nura River is more polluted than that of the Ishim River.

The Nura river has been polluted by mercury from the wastewater of the factory in Temirtau for a long time. Presently, although the discharging has stopped, the pollutant is still detected. Around Astana City, the mercury concentration has decreased during the last six years, with the ratio of the exceeding MAC approximately 30 % in 1994 compared to 20 % in 1999. However, in 1998 and 1999, mercury was still detected in the Nura River and the Nura-Ishim Canal, with concentration between 3 and 5 mg/l based on the survey by the Sanitary Epidemiological Center. The concentration of mercury should be continuously monitored hereafter.

(3) Groundwater Quality

The groundwater around Astana City tends to have high mineral concentration. The mineral concentration in Akmolinsky aquifer varies between 400 to 1,300 mg/l. Tselinogradsky aquifer is also high in mineral concentration, between 800 mg/l to 1,000 mg/l. Presently, the groundwater quality in the Nura River basin, which includes the Rojdestvensky aquifer and the Nurinsky aquifer, has deteriorated as a result of contamination by toxic substances. The concentrations of phenols, oil products, and mercury has exceeded MAC in the Rojdestvensky aquifer. The Nurinsky aquifer is also polluted by mercury.

2.2 Socio-economic Conditions

2.2.1 Population

Paramount to the planning of the water supply and sewerage system is the population forecast for Astana City. The forecast should comply with Astana City's overall goal of becoming a government, business and industrial city. Therefore, the forecast developed by the Master Plan Study Team, which considers these goals, is adopted for the Study. The said forecast is for the 30-year duration, starting from 2000 and with an initial population of 321,600.

Unlike conventional forecasts which are based solely on past natural growth trends, the adopted forecast was based on both natural growth and social growth to forecast the population. Natural growth refers to the difference between birth rate and death rate, while social growth refers to the increased influx of people to the new capital city as a result of new governmental and commercial activity. The main reason for incorporating social growth to the forecast is that, past experience of other newly established capital cities, tended to have larger social growth than natural growth.

The forecast was divided into two parts, namely a short-term forecast up to 2010 and a long-term forecast until 2030. The former relies on relatively concrete figures of past natural and social trends whereas the latter relies more on plausible and accountable economic indicators of projected population. The following is a summary of the forecasts.

(1) Short-term Forecast (until 2010)

The short-term forecast assumes a natural growth rate of 1.16 per 100 people per year, together with lump-sum figures for social inflow and outflow. On this basis the population of 2005 and 2010 was estimated to be 400,000 and 490,000 respectively.

(2) Long-term Forecast (from 2010 to 2030)

The long-term forecast is a four-step process, namely i) clarifying the growth of actual annual GDP in Kazakhstan and GRDP in Astana between 1995-2000, ii) determining the value added multiplier on investments between 1995-2000, iii) estimating the annual growth of GDP in Kazakhstan and GRDP in Astana between 2001-2005 and iv) analyzing and selecting a long-term population scenario based on a four case simulation using population, investment multiplier, annual growth of GRDP, GRDP per capita and added value per worker in selected sectors.

The most likely scenario selected assumed that the population would grow to 800,000 in 2030, a multiplier increase from 1.06 in 2005 to 1.50 in 2030 and an annual investment to upkeep a GRDP growth of 7.2%. Reference is made to the Master Plan Study Interim Report for a comprehensive explanation of the forecast.

In summary, the overall forecast adopted for the Study is given below.

Population Forecast for Astana City

Year	2000	2005	2010	2020	2030
Population	321,600	400,000	490,000	690,000	800,000

2.2.2 Economic Activities

With substantial natural resources and a rapid rate of market reforms, Kazakhstan occupies a strong position in Central Asia. The county has some 60% of the former USSR's mineral resources, exporting large quantities of oil, gas, iron, coal, various metals, etc. Kazakhstan accounted for 20 % of the cultivated land in the former USSR. Much of the north area was turned into one big wheat field in the 1950s Virgin Lands campaign. Despite little success, Kazakhstan continues to grow a large amount of wheat, up to a third of the former USSR total.

The outlook for most of the industries in Kazakhstan is mixed. However, certain industries show large potential for growth, particularly oil and gas. In 1999, GDP of the country grew by 1.7% as compared to 1998. Export of fuel and oil, which accounts for approximately 40% of the total exports, increased by 1.6% in Dollar terms for the same period. The index of physical volume for industrial manufacture for the first half-year of 2000 is equivalent to 116% of that for the corresponding period of 1999. Growth was observed in all sectors of industry: including mining, manufacturing industries, and production and distribution of electric power, gas and water. The maximum growth rates were observed in mining of iron ore (3.8 times) and production of services related to oil and gas industry (4.0 times). For the period from the beginning of 2000, consumer goods index rose by 4.9%.

The current government, operating in a relatively stable economic environment, is committed to introducing economic reforms and attracting foreign investment. Since 1992, Kazakhstan's economic policy has emphasized management of the country's transition from a centrally planned economy, in which the state owned almost all assets, to a more market-oriented economy with a greater emphasis on private enterprise. As far as the economy is concerned, the government's consistent policy has been privatization and price liberalization. Much of Kazakhstan's economy has now already been privatized. The private sector is dominated by big companies, from banking and investments to shops and restaurants. Privatization of land and agriculture has been slower so far. In 1993, Kazakhstan introduced its own currency, the Tenge, which was floated in 1999.

The economic emphasis of Kazakhstan is to achieve sustainable development and spread the wealth around the population, which is not easy in a country with existing corruption and regionalism. Poor infrastructure also presents a major obstacle to further economic growth. The country's poorly maintained roads and inadequate distribution systems tend to cause logistical problems. Although the antiquated telecommunication system is being modernized, its quality of function is currently limited. Other barriers to economic growth include an unwieldy and inconsistent taxation and customs systems and a weak and inefficient judiciary. But in order to continue growing further, Kazakhstan must resolve these problems and attract the foreign investments.

2.2.3 Water Supply and Sewerage Organization of Astana City

Provision of water and wastewater services in Astana is the responsibility of "Astana Su Arnasy" (hereinafter referred to as ASA), a State Municipality Enterprise owned by Astana City Government (Akimat).

2.2.4 Sanitary Condition

(1) General Condition of Public Health

There are 37 public and 44 private medical facilities in Astana City. One public and 2 private medical college provides training facilities for specialists on public health. The City implements the program named "Health of the People" to improve the healthcare system and management of medical facilities. The important issues in this program are to carry out measures for decreasing the number of tuberculosis cases, prevention of infection, and upgrade of healthcare for pregnant women and children.

(2) Incidence of Water-borne Infectious Disease

Water-borne infectious diseases, such as typhoid, dysentery, hepatitis, and cholera can infect people as a result of using water polluted by bacteria or viruses. The prevalence of these diseases in Astana City is shown in Table 2.2.1. According to statistical data for the past two years, cases of typhoid and cholera are non-existent. The occurrences of dysentery and hepatitis are between 0.05% to 0.3%, and are high by normal standard.

Table 2.2.1 Prevalence of Water-borne Infectious Disease

Water Borne Diseases	1998		1999	
	No of Cases	Index Per 100,000	No of Cases	Index Per 100,000
Hepatitis A	573	208.1	161	50
Dysentery	765	277.8	658	204.4

Source: State Sanitary and Epidemiological Supervision

(3) Final Solid Waste Disposal Site

Astana City has only one final solid waste disposal site located about 6 km to the north from City center. According to the information of the management staff, the site accepts solid waste of about 1,000m^3 per day. Industrial waste makes up about 20 % of the total. It is estimated that this site will be full by 2010 from domestic and industrial solid wastes.

This final solid waste disposal site does not have any liner facilities to protect the groundwater. The site has been operating since 1972 and it is therefore expected that the surrounding ground water be probably polluted by leachate from this site.

2.2.5 Agriculture

The agricultural region surrounding Astana City is the Tselinogradski Rayon, which has a population of about 41,000. In recent years the number of people registered as working in the agricultural sector has decreased from 11,100 in 1995 to 6,010 in 1999. In addition it is estimated that there are about 70,000 people working on about 22,000 smallholdings (dachas).

The reduction in employment in the agricultural sector is the result of the reorganization of agriculture in Kazakhstan with the introduction of the market economy since 1993. All state farms were privatized. Agricultural production in the oblast fell as can be seen in Table 2.2.2.

Table 2.2.2 Agricultural Production in Akmola Oblast

Units: thousand tons

Produce	1993	1994	1995	1996	1997	1998	1999
Potatoes	19.4	12.8	8.1	14.1	12.0	9.7	20.7
Vegetables	5.8	5.4	3.2	2.6	4.3	2.6	4.8
Fodder Corn	219.7	101.8	39.3	59.6	25.1	23.1	18.8
Milk	37.2	31.8	20.9	13.4	11.5	7.7	5.5
Beef	7.2	7.3	7.0	3.9	4.3	2.3	1.5
Pork	1.8	1.4	8.2	5	2.5	2.0	1.1

It can be noted that the reduction in agricultural production is mainly in meat and milk production. Although there was reduction in the production of potatoes and vegetables the reduction has not been significant and production appears to be growing again.

The areas employed for the main crops are presented in Table 2.2.3.

Table 2.2.3 Areas Employed for Main Agricultural Crops in Akmola Oblast

Units: hectares

Crop	1993	1994	1995	1996	1997	1998	1999
Potatoes	2,564	1,533	1,242	1,352	1,551	1,244	1,244
Vegetables	743	472	362	562	461	410	408
Fodder Corn	30,600	23,900	15,400	16,500	7,840	5,140	3,420

It can be noted that the present production of potatoes and vegetables is comparable to production in 1993 although the area of land under cultivation for each crop is almost half. This increase in productivity is mainly happening at the more efficient private farms.

Distribution and use of chemical fertilizers, herbicides and pesticides used to be under state control but their importance has now diminished as the demand for their products reduced. In many cases the distribution centres have now closed. There is little data on present use of such products. Table 2.2.4 presents limited data for chemical fertilizer use in 1999.

Table 2.2.4 Use of Chemical Fertilizer in 1999 in the Region

Units: Tons

Crop	Fertilizer Used
Grain	80
Potatoes	24.4
Vegetables	36.6

The soil around Astana, being in the moderately arid zone, cannot support agriculture without irrigation. Two types of irrigation, liman and overhead are practiced. Liman irrigation takes place during the spring thaw when flood waters are allowed to cover the flood plains and pastures are allowed to grow for grazing. Overhead irrigation makes use of central pivot machines up to 800m in diameter. There is very little surface irrigation because soil characteristic is not favorable. The areas of irrigated land in the Akmola oblast and Tselinogradski are shown on Table 2.2.5.

Table 2.2.5 Area of Irrigated Land

Units: hectares

Irrigation	**Akmola Oblast**	**Tselinogradski Rayon**	
Year	**1993**	**1993**	**1999**
Liman	83,025	23,200	Not available
Overhead	39,737	15,700	3,500
Total	**122,762**	**38,900**	-

The whole of the agricultural industry is still in a state of flux, reorganization of the agricultural enterprises is still ongoing with new private farms still emerging from the large agricultural enterprises. Although overall agricultural production has declined over the last few years the prospect in some agricultural sectors looks promising, especially in the production of potatoes and vegetables. Production of wheat although small at present, it is on the increase. However, irrigation, which was an important factor for agricultural production in the past, will still play an important role in future.