GEF - UNDP - UNOPS Project
Integrated Natural Resources Management in the Baikal Basin Transboundary Ecosystem

Groundwater Resources in Transboundary Aquifers in the Baikal Basin: Current Knowledge, Protection and Management

A Contribution to the Transboundary Diagnostic Analysis of the Lake Baikal Basin

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UNESCO-IHP

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Abbreviations

BCPC	Baikal Cellulose-Paper Combine (Russia)
GEF	Global Environment Facility
IHP	International Hydrological Programme (UNESCO)
IWRM	Integrated Water Resources Management
JICA	Japan International Cooperation Agency
MARCC	Mongolia Assessment Report on Climate Change
MoMo	Model Region Mongolia
MUST	Mongolian University of Science and Technology
SCCC	Selenga Cellulose-Cardboard Combine (Russia)
TDA	Transboundary Diagnostic Analysis
WSSA	Water Supply and Sewerage Authority (Mongolia)
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNOPS	United Nations Office for Project Services

Introduction

The present report is a contribution to the Project *Integrated Natural Resources Management in the Baikal Basin Transboundary Ecosystem*, implemented by UNDP and funded by the GEF. It was prepared by UNESCO-IHP, one of the project's Executing Agencies and partners, in cooperation with the UNESCO Chair on Water Resources, the Irkutsk State University, Russia, the Russian Academy of Sciences – Siberian Branch, the Geological Institute of SB RAS, the UNESCO Chair on Sustainable Groundwater Management, Mongolian Academy of Sciences - Institute of Geo-Ecology, the Institute of Meteorology, Hydrology and Environment of Mongolia, the Mineral Resources Authority of Mongolia, the Tsukuba University, Japan, and other national and international partners.

The report consolidates the results of activities under Output 1.3 of the Project, which were focused the assessment of the integrated groundwater and surface water management in the Baikal Basin, as well as the role of groundwater in sustaining the functioning of the Baikal Basin ecosystem, considering both quantitative (groundwater level decline) and qualitative (pollution) aspects. Priority was given to unravelling the hydrological, hydraulic and hydro-chemical interactions between surface and groundwater, with specific regard to shallow aquifers in fluvial/alluvial deposits and their interactions with adjacent rivers and lakes.

UNESCO project activities have been discussed in occasion of the first meeting with partners and national experts involved in the execution of the groundwater project activities. The meeting was organized in Ulaanbaatar from 20-22 November 2012 and its main objectives were to:

- Discuss in detail the activities, work plan, and overall structure of the groundwater related work.
- Hold interviews with and select national groundwater experts to be contracted.
- Discuss and agree upon partner roles and contributions.
- Agree on deadlines, to coherence with the overall schedule of preparation of the Transboundary Diagnostic Analysis (TDA) in the framework of the Lake Baikal Project.

Discussions focused on the best modalities to carry out an assessment of the transboundary problems in the Baikal Basin relatable to groundwater, due to the deterioration of groundwater quality in the Baikal Basin; flaws in groundwater protection/management policies; and to the vulnerability of groundwater and dependent ecosystems.

The structure of the final deliverables for the activity, and the structure of the reports (Preliminary and Final) were discussed and agreed upon. Responsibilities for the completion of each chapter were also assigned.

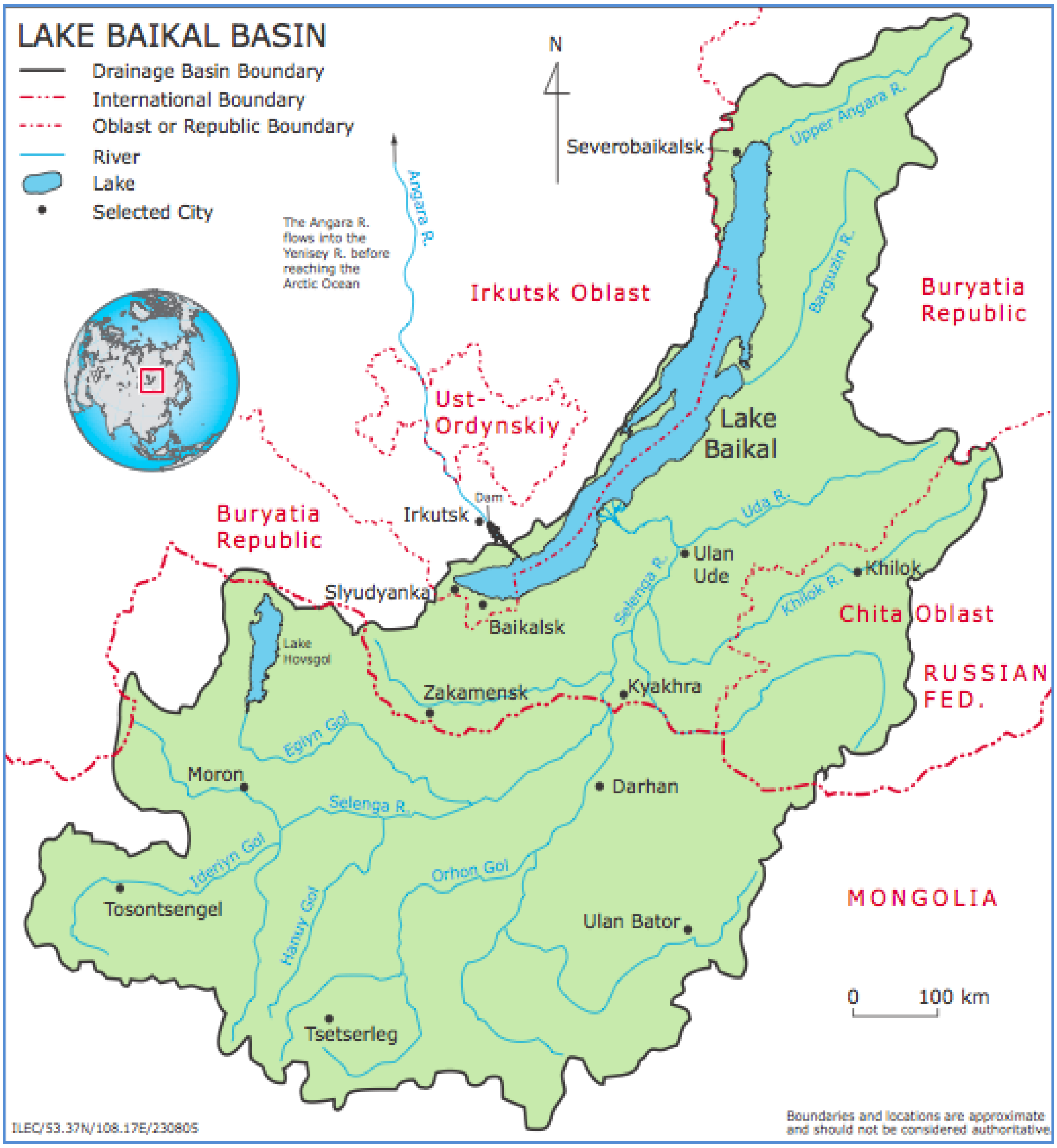
The *Preliminary Report*, completed on January 30, includes two parts with similar structures relative to the Mongolian and Russian territories of the Baikal Basin and contains the results of the gathering and evaluation of all the existing and accessible information.

A second meeting of the working group of the project was organized by the Baikal Institute of Natural Management, Russian Academy of Science - Siberian Branch in Ulan-Ude from 20 March to 22 March 2013, inclusive of one-day field trip on the border of the Baikal Lake. The project manager, UNESCO representatives, national experts and other international and Russian partners participated to the meeting.

The discussion tackled groundwater-related issues of transboundary concern, such as upstream groundwater resources degradation, potential transboundary transport of pollutants, groundwater pollution, groundwater depletion due to aquifers overexploitation, risk and uncertainty of climate change impact on different types of aquifers and prioritization of groundwater transboundary issues.

The following contents of the *Final Report* have been discussed and agreed on the meeting:

- Hydrogeological conditions and present status of groundwater resources development
- Interaction between groundwater of shallow aquifers and surface water
- Man-made threats on groundwater resources
- Vulnerability of groundwater dependent ecosystem
- Transboundary and site specific groundwater monitoring in the Baikal Basin
- Climate change influence on groundwater resources
- Groundwater priority issues of transboundary concern.



The map shows the Lake Baikal Basin, and political boundary between Russia and Mongolia, main cities, big rivers and their confluence areas, Selenga River Delta and Lakes Baikal and Hovsgol (map produced by the Global Environment Facility)

Executive Summary

General considerations regarding the role of groundwater in the sustainability of Lake Baikal ecosystems

Deep groundwater circulation

Lake Baikal is part of one of the world's largest active continental rifts. The rift is emplaced in extremely ancient rock complexes of crystalline, volcanic and metamorphic nature, which are generally impervious. In such geological environment rainwater infiltrates preferentially along the vertical permeability pathways represented by the many active faults that characterize the rifting process (frequent powerful earthquakes are typical of the Baikal region).

The bulk of this water reaches great depths, increasing its heat content, and feeds the active geothermal systems that since the beginning of the rifting process and of the lake itself have affected water circulation patterns, including within the lake.

The heat pulses due to the uprising of hot fluids along faults within the lake sediments cause dissociation of gas hydrates (CH4 – the largest continental deposits of hydrates are those of contained in Lake Baikal sediments) within the lake sediments column, and originate hot gas seepages on the bottom of the lake, and associated localized heat flow anomalies. These thermal disturbances within the water column are at the origin of convective circulation, and hence of the total lack of stratification in the lakes water, and possibly of the high transparency of its waters. They control the overall characteristics of the Baikal ecosystem. Because of these unique characteristics lake Baikal is the object of intense international research efforts related to plate tectonics, climate change, and gas hydrates thermodynamics (dissociation of hydrates is possibly the largest natural source of gas emissions to the atmosphere, which global warming could dramatically increase), and also of global ecological interest (see for example the Tahoe – Baikal Institute).

Shallow groundwater circulation

A large part of the meteoric groundwater recharge in the Baikal Basin circulates through shallower horizons within the alluvial sediments of the many rivers draining into the lake, and of the limited aquifers represented by sedimentary formations bordering the lake in some sectors. One of them is the Maloye More Strait where karst formations constitute an important aquifer draining into the lake.

The concentration of human activities along valley floors has determined widespread contamination of the unconfined alluvial aquifers of the many rivers constituting the transboundary Selenge river basin, the main tributary of the lake, which includes the Tuul River and the city of Ulan Bator. The sources of pollution are many, primarily mining (also artisanal gold mining), industry and urban wastes. The growing pollution of aquifers and rivers poses serious threats to human health, since groundwater is the main source of drinking water, and contributes together with surface runoff, to the pollution of the lake in correspondence of the Solenga delta. It has to be noted that the Solenga Basin includes the Hovsgol lake in Mongolia, an important monitoring site for the impacts of global climate change on forest and steppe: the Hovsgol region represents the southern boundary of continuous permafrost and therefore it is an international monitoring site for the study of changes in permafrost temperature and change in active layer depths[1].

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[1] The lake is the site of a Global Environment Facility study of Climate Change and Nomadic Pastoral use impacts on the regional biodiversity and on permafrost thaw

Main Findings

The work carried out by UNESCO IHP as part of the UNDP-GEF project *Integrated Natural Resources Management in the Baikal Basin Transboundary Ecosystem* with the objective of assessing the main causes of transboundary degradation in the Basin related to groundwater and its interactions with surface waters, has allowed to reach three main conclusions that are highly relevant for the sustainability of the Lake Baikal Basin ecosystems.

(i) Waste disposal and discharge of wastewaters, in particular those from mining activities, are the main pollution sources of surface and groundwater with potential transboundary implications on the Lake Baikal ecosystems.

(ii) The cumulative effects of these various pollution sources on the Lake Baikal ecosystems may be compounded by increased climatic variability and change affecting river flows and groundwater levels.

(ii) While situations of over-exploitation of the abundant groundwater resources do not presently exist in the Basin, the lack of proper measures to monitor and protect water quality in shallow alluvial aquifers used for drinking water supply and inextricably linked to surface waters, may pose threats to sustainability and human health.

Mining Wastes

Mining and minerals processing (gold, molybdenum, tungsten, zinc, coal and others), has been carried out on a large scale for a long time by both Mongolia and Russia in the Baikal Basin. Mining of the mineral deposits is pursued by open pit and deep mines with a large use of water. Some private mining companies illegally use mercury for gold separation and produce water toxic pollution. Only a few per cent of useful mineral components are extracted from the host rocks, and 90-95% of mined rocks are handled as the wastes. Tens of millions of tons of ore tailing with 3-4% sulphide mineralization are stored in the River Selenga catchment and due to on-going oxidation processes they are a dangerous source for groundwater pollution. Storage of wastes is often realized by so called dam method that only protects deposits of tailing from mechanical dispersion in the surrounding area, but does not solve the problem of the migration of toxic substances into the river flow, and into the groundwater system. Ore components are leached by atmospheric and surface water as well as by groundwater, generally in the absence of site-specific groundwater monitoring systems to control surface and groundwater quality.

Treated or untreated mine waste waters are generally discharged into surface streams and shallow aquifers. This can seriously degrade the quality of surface and groundwater, and of dependent ecosystems in many mining areas in the Baikal Basin. Toxic constituents contained in mine waste waters can also pollute drinking water sources and thus affect human health. In Russia cadmium, zinc, copper, and iron have been found in groundwater in the Zakamensk urban area (in the wells and shallow boreholes) where groundwater is used as the source of municipal drinking water supplies. In Mongolia in the Boroo and Kharaa River catchments elevated levels of mercury have been detected in water resources and in the urine of the area's inhabitants. Considering enormous gold and other minerals mining activities in Russian and particularly in Mongolian territory of the Baikal Basin and expected expansion of mineral and coal mining in both countries high priority has to be given in the next years to the groundwater resources protection by regular control and monitoring of the quality of waste water produced by ore mining and ore processing. *It must be pointed that discharge of polluted mine waste water into surface streams and aquifers can affect groundwater and surface water over wide areas and can be considered as potential causes of water related transboundary conflicts, particularly if pollution occurs nearby the Mongolian-Russian* *border.* Environmentally sound mine operation must be a mandatory provision of concessions granted by governmental authorities. Control and monitoring must guarantee that wastewater is continuously treated and toxic constituents are not present in wastewaters discharging from mine facilities into the surface water and groundwater. Owners of mine facilities have to take responsibility for investments in relevant modern mining and wastewater treatment technologies and construction and operation of groundwater monitoring networks.

Urban and Industrial Liquid Wastes

Priority has to be given also to the discharge of untreated or not sufficiently treated wastewaters from municipal and rural settlements. Both can affect groundwater in shallow aquifers and degraded its quality as well as groundwater dependent ecosystems. Significant investments on construction of treatment plants with modern treatment technology and capacity relevant to the current and future needs, training of human resources responsible for treatment plants operation as well as significant improvements of waste water management will be needed within next years to reduce the impacts of municipal and rural waste waters on the quality of groundwater resources and the environment. Municipal and industrial waste disposal sites without relevant protections and monitoring networks, and particularly illegal uncontrolled waste disposal sites are significant point sources of pollution in the Baikal Basin that can seriously degrade the Basin ecosystems. They are often located in floodplains or fluvial terraces where groundwater level in shallow aquifers is closely to the ground. Leakage from disposal sites located above the shallow aquifers affects groundwater quality because the unsaturated zone in such areas is permeable and thin, and polluted leachate rapidly reaches the aquifer. During the wet seasons groundwater level rises and wastes deposited at the bottom of the disposal site can become water saturated. During river low flows polluted groundwater may instead discharge into the surface water and pollutants be carried by the rivers and finally reach the Lake Baikal. Site-specific monitoring networks are only rarely established around waste disposal sites and movement of pollution plume into the aquifer is not controlled. *It is urgent that operation of uncontrolled disposal sites be discontinued, and toxic wastes from closed disposal sites be removed, particularly when they are located above productive and vulnerable shallow aquifers exploited for drinking water supply purposes.*

Agriculture and Livestock

Groundwater pollution by nitrate or pesticides due to agricultural activities has not been identified as a major problem in the Baikal Basin. However, the intention to increase crop production by application of growing quantity of nitrogen fertilizers and pesticides, construction of new irrigation schemes, the replacement of traditional crop rotation by continuous cultivation of financially more valuable crops and expansion of arable lands will increase the risk of soil organic matter degradation and groundwater diffuse pollution in the next years. Potential impact on groundwater quality has to be therefore carefully controlled and monitored in areas where intensive crop cultivation is currently realized or planned. Groundwater pollution from disposal sites of poultry and pig farms wastes has been detected in many areas of the Russian territory of the Baikal Basin.

Solid Urban Wastes

Leakage from solid wastes deposited in the generally uncontrolled disposal sites of municipal waste of the Basin show only local impacts on groundwater and related ecosystems. Serious hazards can instead be posed by leakages from uncontrolled disposal sites containing toxic wastes.

Climate Variability and Change

The comparison of average annual rivers runoff in the period 2000-2010 with the relevant data from the previous years indicates a marked decrease in the runoff in the Rivers Selenga, Chikoy, Khilock and Uda. In winter season the rivers runoff is growingly supported by groundwater, with an increase varying between 6 and 19%. The reduced flow of rivers draining to the Lake, in particular of the winter flow of the Selenga River, and the consequent increased concentration of pollutants may pose additional threats to the Basin ecosystems.

1 | Hydrogeological conditions and present status of groundwater resources development

Overview of hydrogeological conditions on the territory of the Baikal Basin is focused on description of groundwater and aquifers occur in older geological units. Groundwater resources in shallow aquifers are evaluated in the chapter 2 related on the interaction between surface water in large rivers and groundwater in shallow aquifers in adjacent floodplains and river terraces composed by permeable fluvial deposits of Quaternary age.

1.1 Hydrogeological conditions and present status of groundwater resources development on the Mongolian territory of the Baikal Basin

The Mongolian territory of the Baikal Basin is composed by two major geological units: Northern Mongolia unit geologically formed in ancient Caledonian orogenic phase and Mongolia-Transbaikal unit formed in the late Hercynic orogenic phase. Both units are affected by deep tectonic structures Tamir and Bayangol and by some other deep tectonic faults (Jadambaa, 2006).

Northern Mongolia unit

Groundwater in Northern Mongolia geological unit occurs in fluvial deposits of Quaternary age, sedimentary rocks of Mesozoic age and fractured rocks of pre-Mesozoic age (Figure 1.1).

Shallow aquifers in highly permeable fluvial deposits contain significant groundwater resources widely used for water supplies of municipalities and rural settlements.

Deep aquifers in sediments of Cenozoic and Mesozoic age occur in medium elevated area of the Orkhon-Selenge Basin. It consists of conglomerates, sandstones, argillites, siltstones, clays and sands. Groundwater level in the sediments of the Cretaceous age significantly differs (from 4 to 80 m), wells yield vary from 0.15 to 10.4 l/s. Groundwater quality does not meet often the requirements for drinking water standards because of its high hardness and TDS.

Continuous permafrost rocks of 200-500 m or even more thick are widely developed in high massifs of the Huvsgul, Khangai and Hentii mountain ranges. Non-continuous permafrost islands of 15-25 m and 50-100 m average thickness are spread in the small river basins and valleys. Aquifers in permafrost have not been studied as yet in Mongolia. However, groundwater in the permafrost is a valuable source of drinking water for several small rural settlements and for pasture livestock.

N.Jadambaa (2012) calculated renewable and potential exploitable groundwater resources in the frame of the project “Strengthening Integrated Water Management in Mongolia” (2010). Renewable groundwater resources amount to 5.08 billion cubic meters (13,931 thousand m^3/day), the total potential exploitable groundwater resources amount to 2.36 billion m^3 (6,473thousand m^3/day) in the Northern Mongolia groundwater unit.

Mongolia-Transbaikal unit

The Mongolia Transbaikal geological unit consists by variety of deposits and rocks of different age and permeability (Figure 1.1).

In sediments (limestones, sandstones, siltstones and conglomerates) of Permian, Triassic, Jurassic, Cretaceous, Paleocene, Neogene age, and deposits of Quaternary age are developed at different depth, extension, thickness, lithology and permeability (Table 1.1) local aquifers as well as aquifer systems with significant groundwater resources.

Groundwater occurrence in metamorphic and intrusive rocks depends on the tectonic exposure of the rocks. In fractured zones rocks fissure permeability is high and significant groundwater resources have been registered in several boreholes located in these zones

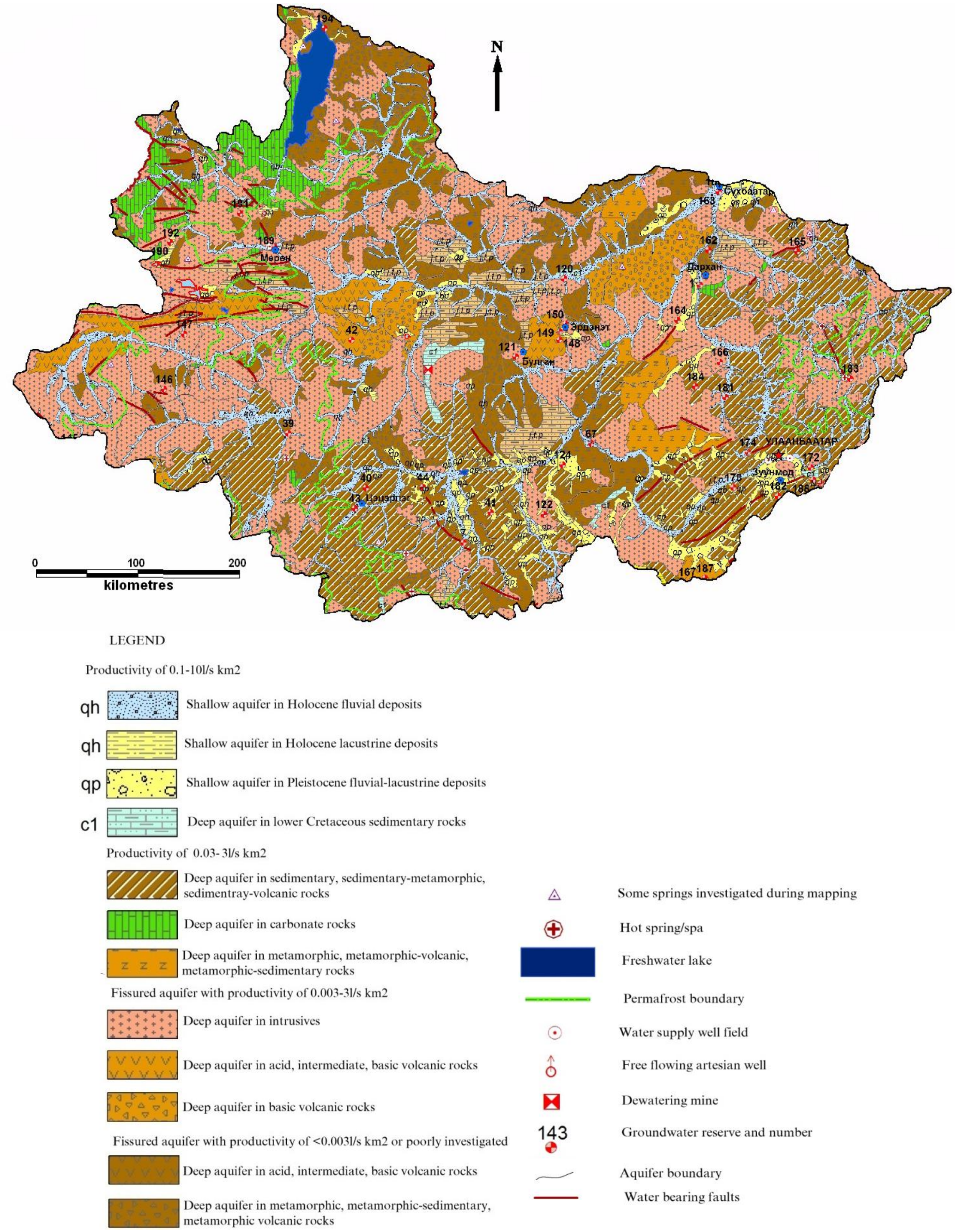

Figure 1.1. Hydrogeological map of Mongolian territory of the Baikal Basin

Water bearing sediments and rocks	*Water bearing rocks and sediments*	*Type of aquifer*	*Well yield, l/s*	*Spring yield, l/s*	*Drawdown, m*	*Specific yield, l/s*	*Chemical type of groundwater*	*TDS, g/l*
Neogene sediments and sedimentary rock	Sand, clay, gravel	confined	0.5-3.8	-	2.0-40.0	0.2-0.09	SO_4-HCO_3-Na, Ca	0.5-1.6
Cretaceous sedimentary rocks	Gravestone, conglomerate, sandstone, coal	confined	0.15-12.4 Up to 24.0	-	1.2-8.0	0.01-2.4	SO_4-HCO_3-Na	0.2-1.4
Triassic-Jurassic volcanic, sedimentary and metamorphic rocks	Basalt, andesite, sandstone, conglomerate, coal	confined unconfined	0.3-0.4	<5.0	1.0-1.5	0.3	HCO_3-Mg, Na, Ca SO_4-HCO_3-Na	0.2-0.3
Paleozoic sedimentary, metamorphic and volcanic rocks	Sandstone, shale, gneiss, conglomerate, andesite	unconfined	0.02-10.0	<14.0	4.5-17.0	0.01-0.7	HCO_3-Ca, Mg HCO_3-SO_4-Ca, Mg	0.1-1.2
pre-Paleozoic sedimentary, metamorphic and carbonate rocks	limestone, dolomite, shale, sandstone, conglomerate	confined unconfined	0.3-10.0	0.1-20.0 Up to 70.0	Up to 15.0	<0.7	SO_4-HCO_3-Na	0.3-1.0
intrusives with different ages	Granite, granodiorite, syenite	unconfined	0.1-4.3	0.6-20.0	2.6-5.1	0.03-0.84	HCO_3-Na, Ca	0.1-0.7 Rare 1.3

Table1.1 Hydraulic characteristics and chemical composition of groundwater in aquifers in Mongolian territory of the Baikal Basin

Calculated (2011) potential exploitable groundwater resources amount to 1.29 billion m^3 (3,558 thousand m^3/day) and renewable groundwater resources 2.96 billion m^3 (8,134 thousand m^3/day) in the Mongol Transbaikal groundwater unit.

Hydraulic characteristics and chemical composition of groundwater in aquifers in Mongolian territory of the Baikal Basin are shown in the Table 1.1.

Groundwater resources in Mongolian territory of the Baikal Basin

The total calculated potential exploitable groundwater resources in the Mongolian territory of Baikal Basin amount to 3.53 billion m^3 per year (9.78 million m^3/day), that is about 44 % of total renewable groundwater resources (8.05 billion m^3 per year) in Mongolian territory of the basin. The current groundwater exploitation in Mongolian territory of the basin reaches 5.3% of total exploitable groundwater resources. The estimated exploitable groundwater resources of shallow aquifer in Mongolian territory of the Baikal Basin amount to 2.76 billion m^3/year or 7.58million m^3/day. Groundwater investigations have not been realized in the wider scale as yet in the river floodplain areas. Exploitable groundwater resources from shallow aquifers approved by Mongolian Water Resources Commission amount to 1.12 million m^3/day in the Mongolian territory of the Baikal Basin.

	Sub basin name	*Area km²*	*Calculated renewable groundwater resources*		*Calculated exploitable groundwater resources*	
			billion m³/year	*l/s /km²*	*billion m³/year*	*l/s /km²*
1	Selenge	30,983	1.104	1.13	0.697	0.7
2	Khovsgol-Eg	41,321	1.276	0.98	0.432	0.33
3	Delgermurun	23,018	0.435	0.60	0.229	0.32
4	Ider	22,757	0.507	0.71	0.129	0.18
5	Chuluut	19,813	0.296	0.47	0.086	0.14
6	Khanui	15,549	0.131	0.27	0.096	0.20
7	Orkhon	52,753	1.448	0.87	0.842	0.50
8	Tuul	49,416	0.960	0.62	0.641	0.41
9	Kharaa	17,463	0.381	0.69	0.182	0.33
10	Eroo	21,986	1.516	2.19	0.239	0.34
	Total	295,059	8.05		3.573	

Table 1.2 **Renewable and exploitable groundwater resources**
(*Source:* Groundwater Resources Assessment, in IWM, National Assessment report, 2012)

Renewable and potential exploitable groundwater resources are estimated in water resources assessment handbook produced by the project “Strengthening Integrated Water Resources Management in Mongolia”. The methodology consists on the determination of the specific groundwater runoff (Table 1.2), aquifer potential yield per unit area (l/s / 1 km^2).

1.2 Hydrogeological conditions and present status of groundwater resources development on the Russian territory of the Baikal Basin***

In the Russian territory of the Baikal Basin description of groundwater resources includes three administrative areas which coincide with geological units. The south-eastern part of the Irkutsk region coincides with the Lena – Kirenga Basin and partly with the Baikal Rift zone on south bank of the Lake Baikal, Republic of Buryatia coincides with main part of the Baikal Rift zone and Buryat territory of Transbaikalia and south-western part of the Transbaikal region coincides with small part of former Chita oblast, now Transbaikalia. On the table 1.1can be seen geological structures on Russian territory of the Baikal Basin.

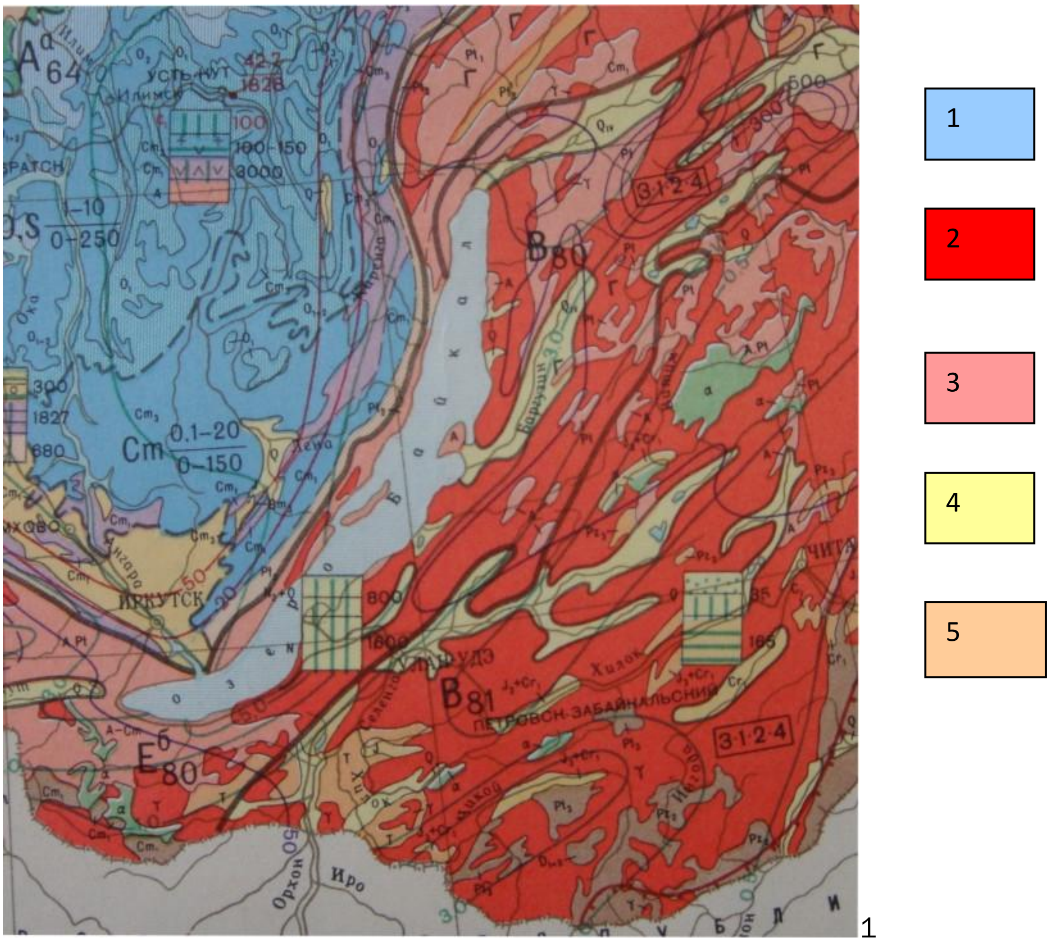

Figure 1.2. The schematic hydrogeological map of the Baikal Basin and adjacent territories (1:7,500,000). 1 – aquifer systems in carbonate, terrigenous deposits of Paleozoic age; 2 – aquifer systems in granites; 3 - aquifer systems in metamorphic rocks; 4 – aquifers in unconsolidated deposits of Cenozoic age; 5 - aquifer systems in consolidated deposits of Jurassic-Cretaceous age.

Irkutsk area of the Baikal Basin.

The direction and magnitude of groundwater flows are controlled by the size, density, orientation and permeability of tectonic faults and fractures in metamorphic and igneous rocks of the Proterozoic and Archean age and consolidated sedimentary formations of the Paleozoic age. Aquifers in fluvial and lacustrine sediments of the Quaternary and Neogene age occur only locally.

Groundwater resources have been estimated in the year 2011 on about 2,789 thousands m^3/day and exploitable groundwater resources 820 thousands m^3/day. Exploitable groundwater resources have been assessed in 12 Irkutsk areas and amount to 33.74 thousands m^3/day.

Total extraction of groundwater resources reached 9.9 thousands m^3/ in the year 2011; for drinking water supplies have been used 7.43 thousands m^3/day of groundwater. The main drinking water users are the towns Slyudyanka (2.38 thousands m^3/day) and Baikalsk (4.11 thousands m^3/day). The groundwater quality meets the requirements of the drinking water standard. Available groundwater resources satisfy current and future needs for drinking water supplies. Groundwater extraction from mines of Khamar-Daban reached about 2.46 thousands m^3/day in the year 2011.

Buryat area of the Baikal Basin.

Exploitable groundwater resources in the Republic of Buryatia were estimated on about 103million m^3/day in the year 2005. Estimated exploitable groundwater resources in shallow aquifers inclusive of bank infiltration from the Selenga and other big rivers amount to 4 million m^3/day (the surface water runoff in winter season was not considered from Mongolia and Trans-Baikal region in calculations). Groundwater in shallow aquifers meets the requirements of drinking water standards.

The TDS of groundwater in aquifers in central districts of Buryatia (the Borgoi, Low Orongoi, Ivolga intermountain depressions) due to low groundwater recharge reach 1-3 g/l. The estimated resources of slightly brackish groundwater amount to 10 thousands m3/day.

Exploitable groundwater resources have been evaluated in 76 groundwater aquifers however, only in 33 aquifers groundwater resources are exploited. Total exploitable groundwater resources calculated in the year 2012 reached 1369.56 thousands m3/day.

The distribution of exploitable groundwater resources is extremely irregular:

- 963.6 thousands m^3/day in the valley of the River Selenga and its big tributaries (752.4 thousands m^3/day are located in the vicinity of Ulan-Ude town);
- 316.6 thousands m^3/day in intermountain basins;
- 54.3 thousands m^3/day in hydrogeological massifs.

The available groundwater resources for person per day reach 1.4 m^3. However, in some rural settlements in the Ivolga and Selenga districts drinking water deficiency is registered.

Total extraction of groundwater resources reached 266.13 thousands m^3/day in the year 2011 and 194.38 thousands m^3/day in the year 2010. For drinking water supply purposes have been used 138.38 thousands m^3/day of groundwater (134.22 thousands m^3/day of groundwater resources were extracted for water supply of Ulan-Ude town), for industry 44.37 thousands m^3/day and for agriculture (inclusive of irrigation) 7.20 thousands m^3/day. About 27.49 thousands m^3/day of groundwater has been pumped from mines. The remaining groundwater resources were used for other purposes.

Transbaikalian area of the Baikal Basin

The exploitable groundwater resources in Transbaikalian area of the Baikal Basin have been estimated on about 1121 thousands m^3/day. The exploitable groundwater resources estimated in 2 areas in the Petrovsk-Zabaikalsk and Khilok districts located in the Selenga-Dauria hydrogeological basin amount to 35.4 thousands m^3/day. In the Petrovsk-Zabaikalsk district groundwater development is realized from water-bearing rocks of the Lower Cretaceous age (17.9 thousands m^3/day) and from fractured zone of intrusive formations (9.5 thousands m^3/day). In the Khilok district, extraction of groundwater is realized from water-bearing rocks of the Lower Cretaceous age in the amount of 6.24 thousands m3/day, and 1.76 thousands m3/day from water-bearing fluvial deposits in the river valley.

The total amount of usable groundwater resources in Russian territory of the Lake Baikal Basin has been calculated on about 5 941 thousands m3/day in the year 2011. Exploitable groundwater resources amount to 1438.7 thousands m3/day, 1405.06 thousands m3/day occur in shallow aquifers, 33.64 thousands m3/day in deep ones.

The whole area of the Russian territory of the Baikal Basin is supplied by groundwater resources, excluding the Selenga and Ivolga districts of Republic of Buryatia, where a shortage of groundwater for drinking water supply of local populations is registered.

Hydraulic and chemical characteristics of deep aquifers in Russian territory of the basin and amount of groundwater resources currently used for different purposes can be seen it the Tables 1.3 and 1.4.

Water-bearing rocks	*Sandstones, sands and coals*	*Conglomerates, sands, loams, sandy loams*	*Fissured sandstones, conglomerates, coals and coal schists*	*Fissured con-glomerates, sandstones and grit-stones*	*Fissured metamorphic and lithified sedimentary rocks*	*Fault zones in sedimentary, magmatic and meta-morphic rocks*
Age of water-bearing rocks	Neogene	Paleogene-Neogene	Lower Cretaceous	Jurassic	Upper Proterozoic - Lower and Middle Cambrian	Mezozoic and Cenozoic tectonic activizations
Type of aquifer	unconfined-confined	confined	confined	confined	confined	
Hydraulic conductivity m/day	0.25	0.01-5.4	0.06-0.3 up to 120.0	less 0.02 up to 2	0.07-1.0	0.01-1.8
Transmissivity m^2/day	26.0-52.0	0.4-39.0	1.3-11.0	from 0.26-50 to 250	2.5-400 even 2000	from 0.0 to 50-1500
Porosity	0.1-0.49	0.1-0.7	0.06-0.1	0.17-0.3	0.03-0.05	0.01-0.15
Specific yield l/s/m	0.2-0.4 up to 4.0	0.003 up to 0.1-0.3	0.01-0.2 up to 3.0-8.8	0.002-0.4 up to 1.0-2.4	0.03 up to 2.0-3.0 even 26.8	0.13
Chemical type of ground water	HCO_3 – Ca, Mg, Na; HCO_3, Cl–K; Cl- K, CaCa, Na;	HCO_3 – Ca, Na, K; SO_4,HCO_3-Ca;	HCO_3 – Ca, Na	HCO_3 –Na	HCO_3, HCO_3 -SO_4 – Ca, Na, Mg	HCO_3 , HCO_3-SO_4 – Ca, Rn, Fe, F, NH_4
TDS g/l	0.2-0.4 up to 2.0-3.0	0.5-3.5	0.2-3.5	0.4	0.1-0.2 up to 0.8	0.1-0.2 up to 0.6

Table 1.3 Hydraulic and chemical characteristics of deep aquifers in Russian territory of the Baikal Basin

	Amount, thousands m^3/day
The total groundwater intake	311.43
drinking purposes	181.21
industrial water supply	44.37
mining extraction	29.95
agricultural water supply	7.20
other purposes	48.7
losses (groundwater discharge without use)	60.09

Table 1.4 The amount of groundwater resources currently used for different purposes.

2 | Interaction between groundwater of shallow aquifers and surface water in Mongolian and Russian territories of the Baikal Basin

Significant groundwater resources in shallow aquifers occur in Mongolian and Russian territories of the Baikal Basin. Their interaction with adjacent rivers is registered in floodplain areas and in low river terraces. Almost synchronous correlation between water level rise or decrease in the rivers and shallow aquifers exists. Hydraulic gradients between groundwater and surface water control the possibilities of bank infiltration of surface water to adjacent aquifers and vice versa however, there are scare or not available water level data for evaluation of 1/ interaction between both resources, 2/ share of surface water on groundwater in shallow aquifers and 3/ amount of groundwater discharge into surface streams, particularly in drought seasons.

Portion of groundwater runoff on total water runoff that discharge Mongolian territory of the Baikal Basin is not possible to evaluate because groundwater monitoring networks in Mongolian – Russian transboundary areas are not established and relevant groundwater data are not available.

Economic advantages and social and environmental benefits of conjunctive use of surface water and groundwater resources can’t be efficiently utilized because seasonal and longer term interaction between both resources is not observed.

Development of groundwater supply systems based on river bank infiltration techniques (e.g. the multiple –well system placed adjacent to water body, infiltration galleries with one or more horizontally laid screens placed beneath the river bed or adjacent to water body) also depends on availability of surface water and groundwater level data; however, lithology and thickness of fluvial deposits, hydraulic properties of shallow aquifers, river beds permeability and morphology and others are not well known and have to be investigated too.

Interaction between groundwater and surface water described in this chapter has been focused on areas with potential occurrence of significant and economically accessible groundwater resources. Such areas with productive shallow aquifers are known in confluence areas of big rivers and in the valleys of the rivers where thick and permeable fluvial deposits exist. Priority was given on description of shallow aquifers adjacent to surface streams in Mongolian – Russian transboundary areas. However, it has been found that hydrogeological investigation of such shallow aquifers has been realized only in few areas and data about thickness, vulnerability, permeability and hydraulic properties of shallow aquifers as well as data about regular groundwater level measurements and groundwater chemistry and quality are almost missing.

Hydrogeological investigation and establishment and operation of groundwater monitoring networks in above described areas are proposed (see chapter 5) with the scope to support evaluation of groundwater resources, their sustainable development and management and implementation of environmentally sound groundwater protection policy. Groundwater and surface water monitoring networks will also provide data about seasonal changes of water levels of both resources and for construction of groundwater flow maps. Evaluation of such data helps to 1/clarify the interaction between groundwater and surface water, 2/ identify pollution threats on groundwater and potential transboundary pollution transport, and 3/ support assessment (quantitative and qualitative) of exploitable groundwater resources in shallow aquifers in fluvial deposits of big rivers in Mongolian-Russian transboundary areas and on territories of both countries belong to the Baikal Basin.

2.1 Interaction between groundwater of shallow aquifers and surface water in Mongolian territory of the Baikal Basin

Shallow aquifers in fluvial deposits composed mostly by porous sands and gravels of Quaternary age in Mongolian territory of the Baikal Basin contain significant, well accessible groundwater resources mostly of good quality. They are widely used in the Mongolian part of the Baikal Basin for drinking water supplies as well as for industrial and agricultural purposes. Shallow aquifers occupy large areas of the floodplains of the Eg, Tuul, Orkhon, Selenga,Delger, Ider, Khanui, Chuluut, Kharaa and Yeroo Rivers. The major Mongolian cities, Ulaanbaatar, Erdenet, Darkhan, Murun, Sukhbaatar, Tsetserleg and Zuunkharaa use groundwater from shallow aquifers for drinking water supplies. However, groundwater investigations specifically oriented on shallow aquifers in transboundary areas and evaluation of groundwater resources in highly productive shallow aquifers in the confluence areas of big rivers have not been realized yet.

Confluence area of the Rivers Delgermurun, Ider, and Chuluut

Intrusive and volcanic rocks of Pre-Permian age are locally overlain by fluvial deposits of Quaternary age (Figure 2.1). The fluvial deposits in the confluence area of the Rivers Delgermurun, Ider and Chuluut consist mostly of permeable gravels, sands, and sandy loams. Shallow aquifers thickness in these deposits ranges between 30 and 48m. The average hydraulic conductivity is 139.9 m/d. The wells yield ranges from 7 to 15 l/s with a drawdown of 3.56-5.63 m. Total dissolved solids (TDS) reaches 0.3 g/l and dominant groundwater and surface water chemical type is bicarbonate-calcium and magnesium. That indicates groundwater interaction with surface water.

Groundwater level in the well drilled on floodplain of Delgermurun River was 5.0 m below ground. TDS of groundwater in shallow aquifer amount to 0.4 g/l, well yield 4.5 l/s with a drawdown of 16 m. In the Ider River floodplain groundwater level was 9.5 m below ground. According to the "Integrated Water Management Model on the Selenge River Basin, Status Survey and Investigation - Phase I (2008) the flow of the Ider River is composed of 30% by groundwater, 25% snow water, and 45 % rain water. The flow of Delgermurun River is supported by 30% of groundwater, 17 % snow water, and 53 % rain water. Groundwater of shallow aquifers interacts with surface water in the confluence area; however, there are no data available to quantify the interaction between both water bodies.

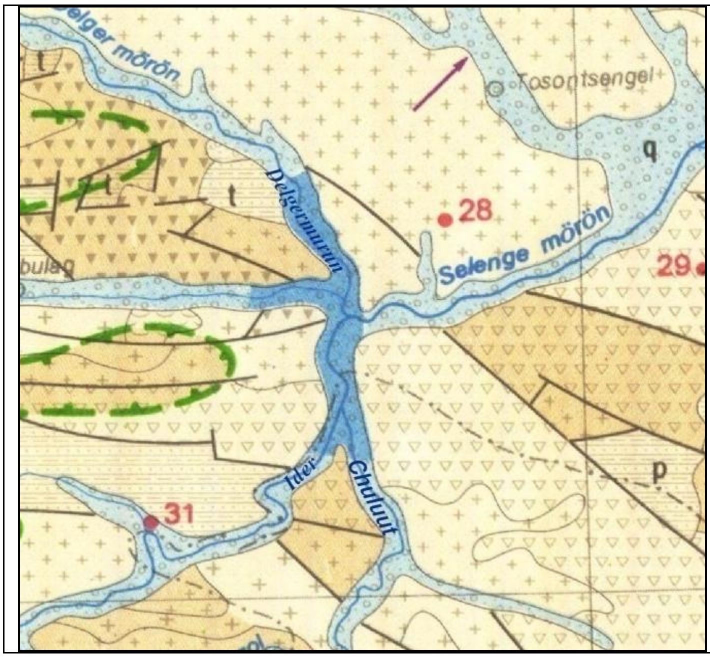

Figure 2.1 Confluence area of the Rivers Delgermurun, Ider and Chuluut (q-fluvial deposits of Quaternary age, t-sedimentary rocks of Triassic age, p- intrusive and volcanic rocks of Permian age)

Confluence area of the River Selenga and River Eg

The Eg River discharges Khovsgol Lake, which is the deepest lake in Mongolia. The confluence area of the Rivers Selenge and Eg is composed by fluvial deposit of Quaternary age underlying by sedimentary rocks of Mesozoic age and volcanic, metamorphic-volcanic and metamorphic sedimentary rocks of pre-Permian age (Figure 2.2).

Yield of test wells drilled in the floodplain of the Selenge River for water supply of the town of Erdenet ranging from 99 to 144 l/s with drawdown from 0.7 to 2.7 m respectively. The thickness of the aquifer varies between 9 – 44 m, 36 m on the average. Groundwater level in the floodplain area is 4.0 m below ground, groundwater TDS 0.3 g/l. According to the “Integrated Water Management Model on the Selenga River Basin, Status Survey and Investigation Phase I (2008) the flow of the Eg River is composed of 30% by groundwater, 17% snow water, and 53% rain water. Erdenet city exploited 97,800 m^3/day of groundwater extracted from 23 wells located in shallow aquifers composed by permeable fluvial deposits. Dominant chemical type of groundwater is bicarbonate-sodium-magnesium.

Groundwater monitoring network is not established yet and relevant data about interaction between groundwater and surface water are not available. However, groundwater level is closely to the ground and the probability of interaction between surface streams and shallow aquifers is high.

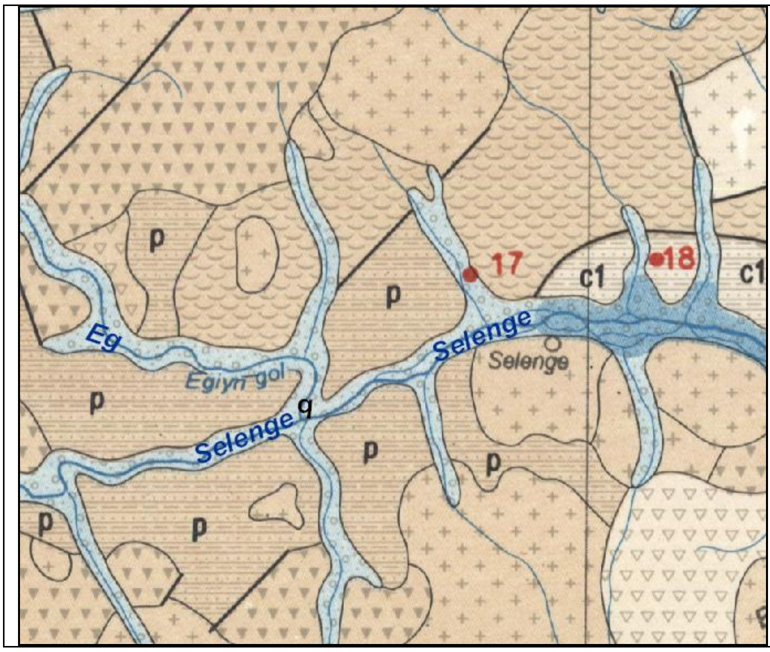

Figure 2.2 Confluence area of the River Selenge and River Eg (q-fluvial deposits of Quaternary age, c1-sedimentary rocks of Cretaceous (Mesozoic) age, p- metamorphic-volcanic and metamorphic sedimentary rocks of Permian age)

Confluence area of the River Orkhon and River Tuul

The Orkhon River head is on the south slope of the Suvrag Khairkhan Mountain. The source of the Tuul River is the Nergui River that rises at Shoroot Mountains. Intrusive, volcanic, metamorphic, meta-volcanic, meta-sedimentary and sedimentary rocks of Pre-Permian age are widely spread near the confluence area of Orkhon and Tuul Rivers. Fluvial deposits of Holocene age are found along the rivers floodplain. Fluvial and lacustrine deposits and carbonate rocks of Pleistocene age are partially distributed in the confluence area too (Figure 2.3).

The largest tributary of the Selenge River is the Orkhon River, the longest river in Mongolia. Orkhon River water is of bicarbonate-calcium type. The flow of the Orkhon River around Bulgan area consists of 39% by groundwater, 11% snow water, and 50% rain water. Groundwater level in shallow aquifer in floodplain of the Orkhon River is 1.3 m below ground.. Groundwater is of bicarbonate-calcium type, TDS reach 0.5 g/l. Water levels in groundwater and surface water as well as chemical composition of both resources indicate interaction between shallow aquifer and river water. However, regular groundwater level monitoring does not exist till this time.

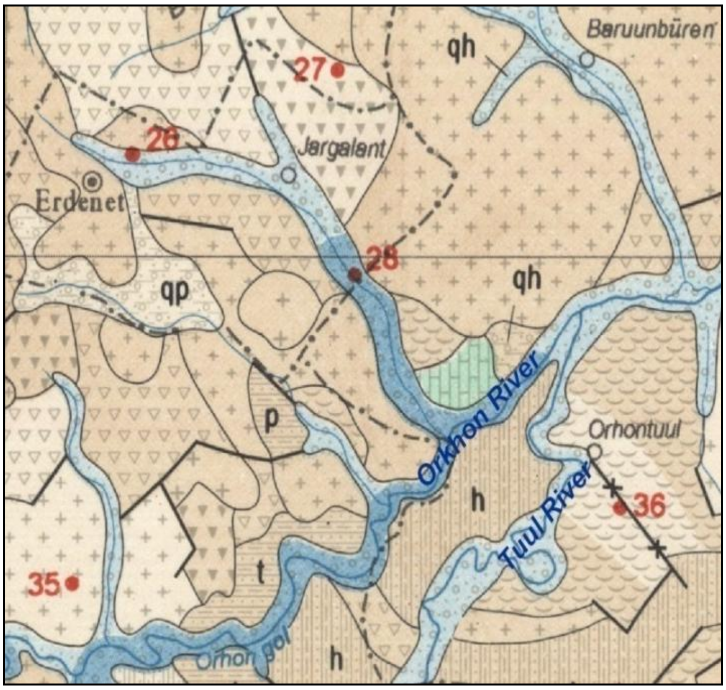

Figure 2.3 Confluence area of the River Orkhon and River Tuul (qh-fluvial deposits of Holocene age, qp-lacustrine deposits and carbonate rocks of Pleistocene age, t- sedimentary rocks of Triassic age, h- meta-sedimentary rocks of Carboniferous age, p- sedimentary rocks of Permian age)

In fluvial deposits of the Tuul River floodplain dominate gravels, sands and clays of irregular thickness (5-65 m) and composition. In coarse-grained deposits are developed productive aquifers which groundwater level changes considerably during the year. When supply wells are not in operation the groundwater level in the Tuul River floodplain near the Ulaanbaatar city is from 2 to 6 m below ground in the winter season and 0.5 to 5.0 m in the summer season. Groundwater level in shallow aquifer in floodplain of confluence area is 5.0 m below ground, TDS amount to 0.3-0.4 g/l. According to the recent isotopic and chemical analyses, interaction between shallow aquifer in fluvial deposits in floodplain area and surface water in Tuul River near Ulaanbaatar city exists. Shallow aquifer receives seasonal recharge from Tuul river water (Naranchimeg and et al, 2011).

Confluence area of the River Orkhon and River Kharaa

The Kharaa River head lies in Khentii Mountain with occurrence of intrusive, volcanic, metamorphic and sedimentary rocks. The area near the confluence of the River Orkhon and River Kharaa is composed by sedimentary rocks of Mesozoic age, carbonate rocks of Pre-Permian age and fluvial-lacustrine deposits of Pleistocene age. Fluvial deposits of Holocene age are widespread along the floodplain of both rivers (Figure 2.4). Shallow aquifers in fluvial deposits of the Orkhon River occur in floodplains and in older terraces of the Orkhon River. Groundwater investigation realized in the vicinity of Kharkhorin city verified in shallow aquifer groundwater level 2 m below ground. By pumping test made on investigation borehole has been proved the yield 6.8 l/s with groundwater level drawdown 1.8 m.

According to the “Hydrogeological Map at the scale on 1:500 000 of the northeast part of Mongolia” (Koldisheva and et al, 1991) shallow aquifers in the fluvial deposits of Holocene age in the Orkhon River valley provide groundwater to the Hotol town from 7 water supply wells. Their specific yield is variable, ranges between from 11.9 to 33.4 l/s/m. At the site called “Barjgar Ulaan” hydrogeological studies confirmed the aquifer thickness of 50 - 60 m, specific yield of 0.3 - 6.8 l/s/m, hydraulic conductivity of 4.0-26.4 m/day, and transmissivity of 123.0-776.4 m^2/day. Previous studies indicated that the Kharaa river water is composed of 43% by groundwater, 15% snow water, and 42% rain water. Water type of both groundwater and surface water is of bicarbonate-calcium type with higher content of magnesium. That indicates interaction between groundwater in shallow aquifer and river water. However, regular groundwater monitoring is not realized as yet.

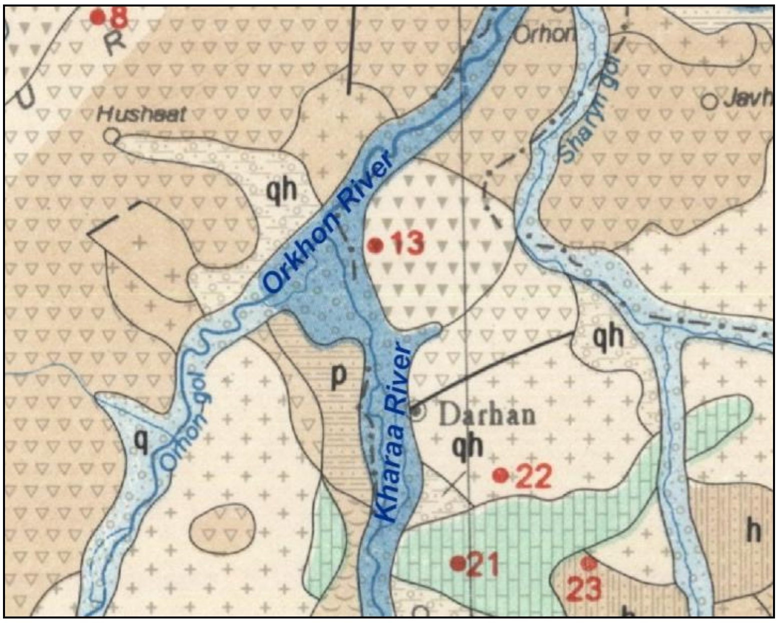

Figure 2.4 Confluence area of the of River Orkhon and River Kharaa (q- fluvial deposits of Quaternary age, qh- lacustrine deposits of Holocene age, p-sedimentary rocks of Permian age, h-meta-sedimentary rocks of Carboniferous age)

Confluence area of the River Selenga and River Orkhon and River Selenga shallow aquifer closely to Russian-Mongolian border

Intrusive, metamorphic, meta-volcanic, meta-sedimentary rocks of different ages are mainly distributed in the confluence area of the River Selenga and River Orkhon. There are partially covered by fluvial-lacustrine deposits of Pleistocene age and fluvial deposits of Holocene age (Figure 2.5).

Highly productive shallow aquifers of the thickness over 100 m are developed in floodplains of the Selenga River closely to the Mongolian – Russian border. The pumping test confirmed the yield of the production well located in this area 38.4-48.2 l/s with a drawdown 2.45-3.73m and hydraulic conductivity 42.5 m/d. Groundwater level was observed 1.3 m below ground and groundwater TDS reach 0.5 g/l (Jadambaa, 2012).

Groundwater level in the well No. 3 drilled near Sukhbaatar city has been observed 1.3 m below ground. Pumping test confirmed well yield 4.5 l/s with a drawdown of 1.5 m and groundwater TDS 0.5g/l. Around Sukhbaatar the flow of Selenga River consists of 36% by ground water, 18% snowmelt, and 46% rain water. Groundwater monitoring network has not been established till this time and there is a lack of information about potential interaction between groundwater in shallow aquifers and surface water in confluence areas of the rivers as well as in the area closely to the Mongolian – Russian border.

Hydrogeological parameters of the above described shallow aquifers in fluvial deposits in the Mongolian territory of the Baikal Basin are summarized in the Table 2.1.

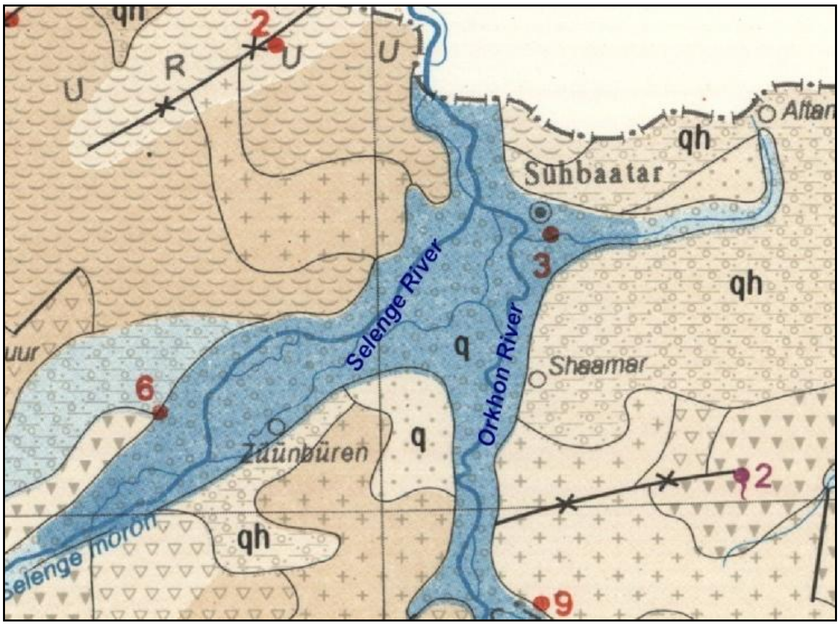

Figure 2.5 Confluence of River Selenga and River Orkhon (q- fluvial deposits of Quaternary age, qh- fluvial deposits of Holocene age, qp- fluvial-lacustrine deposits of Pleistocene age)

Sub basin (settlements, cities)	Well yield, l/s	Drawdown in m	Aquifer thickness, in m	Hydraulic conductivity, m/d	Transmissivity, m^2/d
Selenge (Erdenet)	40-144	0.7-2.7	9-44	276.2	7319.3
Delgermurun (Murun, Burenkhaan)	7-45	3.5-5.6	30-48	139.9	5456.1
Orkhon (Sukhbaatar)	40-83.3	2.4-3.7	50-100	42.5	3187.5
Tuul (Ulaanbaatar)	23.7-48.8 up to 105	0.24-3.3	35-48	131	4847
Kharaa (Darkhan)	17-117.6	1.0-2.97	55.4	87.7	4654.3

Table 2.1 Hydrogeological parameters of shallow aquifers in fluvial deposits in the Mongolian part of the Baikal Basin

Future hydrogeological studies have to be focused on investigation and evaluation of groundwater resources in productive shallow aquifers in fluvial deposits in confluence areas of large rivers like Tamir and Orkhon Rivers, Orkhon and Selenga Rivers, and Tuul and Orkhon Rivers as well as in shallow aquifers in floodplains with occurrence of thick and wide permeable fluvial deposits.

Some studies realized in the past showed interaction between groundwater in shallow aquifers and rivers water. E.g. near Ulaanbaatar city, during rainy season surface water discharges into shallow aquifers, in dry, cold season groundwater discharges into surface streams. Pollution and depletion of one resource can affect the other one. Conditions for interaction between both resources during dry and wet seasons in some areas affected by pumping have to be therefore carefully studied by implementation of relevant models.

2.2 Russian territory of the Baikal Basin

Shallow aquifers in fluvial deposits of Quaternary age contain significant, well accessible groundwater resources mostly of good quality. They are exploited for drinking water purposes in several cities and rural areas in the Russian territory of the Baikal Basin. E.g. interaction between groundwater in shallow aquifers and the River Selenga led to establishment of water supply system in the city Ulan-Ude based on advantages of bank infiltration of surface water into adjacent aquifers owing to series of wells located along the river bed. Available data from monitoring wells supported evaluation of the influence of seasonal changes on interaction between surface water and groundwater. However, in many confluence areas with occurrence of productive shallow aquifers groundwater data are not available for the study of potential interrelation between both resources. Establishment of groundwater monitoring networks and additional hydrogeological investigation both will support knowledge about groundwater resources in shallow aquifers and their sustainable development for social and economic benefit of local populations.

River Selenga shallow aquifer closely to the Russian – Mongolian border

The Selenga River crosses the Burguntuj ridge on the Mongolian – Russian border. The valley is narrow and the river is characterized by rapid flow. Fluvial deposits of small thickness have been identified in the river valley. They are composed by sands of various granularity up to 10 m thick. Underlying rocks form fractured and monolithic gneisses. The well drilled in the north-western margin of Naushki railway station on the floodplain area reached the sandy loam 10 m thick followed by the crushed rock material of 20 m thick, and then entered into granite and gneisses. The well yield 3.4 l/s relates to 21 m groundwater level decline (Hydrogeology USSR, 1970).

Groundwater level observed in three wells indicated seasonal fluctuation depending on precipitations and surface runoff. One well is located in floodplain and other two wells in the higher terrace. Groundwater level depends on well location and has been observed in the depths 2.6, 3.5. and 12.1 m below ground. Groundwater level decline is observed from October, continues to mid-November and slight groundwater level increase is observed in December due to seasonal freezing of rocks. Groundwater level does not change from January to April. In May and following wet season groundwater level continuously increase. Seasonal groundwater level fluctuation is associated with water level and related runoff in the River Selenga. However, interactions between River Selenga and adjacent shallow aquifers as well as transboundary groundwater runoff crossing the Mongolian-Russian border and potential transboundary movement of pollution plume are not possible to evaluate or detected because groundwater monitoring network was not established and relevant groundwater data are not available.

Confluence of river Selenga and River Chickoy

The Chickoy River confluence with the River Selenga occurs in the area of the Novoselenginsk village, crossing the ridge Chernaya Griva. The river valley is narrow and bounded by steep slopes on both banks. The thickness of the fluvial deposits composed by the coarse gravels and sands filling reaches 35 m. The deposits are underlying by the fractured syenite. The well yield 3.3 l/s corresponds to the groundwater level decline 7 m. The Chickoy River drains the groundwater artesian basin of the same name. Aquifers occur in fissured porous conglomerates, sandstones, aleurolites and coals of the Low Cretaceous age. The groundwater level occurs 13-65m below ground. In the fractured sandstones and conglomerates interlayered by coals are developed highly yielding aquifers. The yields of some wells reach 10-15 l/s, in some cases up to 60 l/s. Shallow aquifers are developed in fluvial deposits in the Chickoy River valley and its tributaries. Their thickness is vary from 1.5 to 45 m. The wells yield reaches 5-10 l/s by groundwater decline 2-3 m. The groundwater is of HCO_3-Mg-Ca type, and its TDS is up to 200 mg/l.

For evaluation of interaction between surface and ground water relevant data are not available.

Confluence of river Selenga and River Djida

The estuary of the River Djida lies within the Borgoiskaya intermountain depression of the Mesozoic age. The maximum thickness of the Quaternary deposits in the Djida valley reaches mostly 60-70 m. The groundwater level occurs from 0,3-0,5 to 3-5 m below ground. The amount of groundwater in Quaternary deposits depends on their granulometrical composition. The highest yields (3-4 l/s) have been registered in the coarse-grained sands and gravels where the filtration coefficient achieves 127 m/day. Groundwater resources in shallow aquifer in Quaternary deposits decrease with the increasing content of dusty and clay fractions. The low wells yield 0,0004-0,0005 l/s (groundwater level decline 2-3 m) has been found in the sandy clays of the fluvial-proluvial genesis, where the average filtration coefficient amounts to 1,85 m/day only.

The deposits of the Gusinoozerskaya series represented by argillites, conglomerates, aleurolites and sandstones prevail among the sedimentary rocks of Mesozoic age. The main groundwater-bearing rocks are fractured argillites, the other above mentioned sediments are less developed. The groundwater level in the deposits of the Mesozoic age varies from 0 - 7 m below ground in the central part of the depression and from 30 to 47 m in its flanks. The aquifer productivity in these sedimentary deposits is low and depends on the degree of rock fracturing. The yield is 0,01-0,1 l/s, related groundwater level decline 3-10m. The groundwater occurrence in effusive formations of the Mesozoic age is associated by their exogenous fracturing that can be registered to the depth of 100 m below ground, in deeper environment rocks fracturing decrease. The specific yield reaches 1-3,5 l/s/m. Occurrence of groundwater in metamorphic and intrusive formations is irregular due to the variable fissuring. The highest yields (up to 1,5 l/s) have been registered in the fractured shales, gneisses and granites. The aquifer system in the unconsolidated formations (predominantly boulder-pebble deposits, 50 – 60 m thick) of the Quaternary age is most productive, particularly in the upstream reach of the River Djida near Zakamensk town. The groundwater level has been observed from 5 to 50 m below ground. The well yield amounts to 5-6 l/s.

The River Djida is characterized by sharp changes in water discharge and water levels that can reach almost 5.60 m. Hence, significant variations in groundwater levels in adjacent shallow aquifers are observed too. Groundwater level increase over the land surface during floods is registered in the floodplain areas. However, regular groundwater level monitoring is not realized as yet.

Confluence of River Selenga and River Temnick

Aquifer system is spread in the northern and south-western parts of the Temnick River Basin in the rocks of the Proterozoic and Low Cambrian age. Groundwater levels vary between 30-40 m below ground. The well yields amount to 0.3-0.5 l/s in the downstream reach of the Temnick River, values of filtration coefficient reach 0.01-3.6m/ day. Aquifer system is also developed in the central part of the Temnick river Basin in the intrusive fractured rocks of the Paleozoic and Proterozoic age. Aquifers occur from 10 to 80 m below ground, and their productivity depends on the nature of fractures. The wells yield is from 0.05 to 0.4 l/s, filtration coefficient is in the order of tenths meters per day. The groundwater is of HCO_3-Ca and HCO_3-Ca-Na types, TDS 800 mg/l,

The estuary of the Temnick River lies within the Gusinoozeorskaya depression of the Mesozoic age. The aquifer systems in fluvial, fluvial - proluvial and deluvial-proluvial psephite deposits are 2.5-8 m thick. The groundwater level occurs at the depth 0.8-2.5 m below ground. The yield of wells reach 2.8-3.1 l/s, related groundwater level decline is from 9 to 23m. TDS of the groundwater is from100 to300 mg/l, and water is of HCO_3-Ca-Mg type.

Two groundwater flows of different direction occur in the area of the River Temnick estuary. The first one connected with the River Tsagan-Gol is directed to the Lake Gusinoe. The other one in the shallow aquifer in floodplain of the River Bayan—Gol is directed to the River Selenga. Groundwater and surface water discharging toward the Tsagan-Gol tributary are influenced by the hydrological regime of the River Temnick. The return flow from existing irrigation canals into shallow aquifer is registered as well as groundwater discharge from shallow aquifers into the River Bayan-Gol. Significant amounts of sulfate ion enter from coal-bearing rocks into aquifer and affect groundwater quality. Hydrological regime of the Lake Gusinoe influences quantitatively and qualitatively on adjacent aquifer. However, regular groundwater monitoring does not exist and data about potential interrelation between groundwater and surface are not available.

Confluence of the River Selenga and River Khilok

The thickness of fluvial and fluvial-proluvial deposits reaches up to 50m. The yield of the wells located closely to the surface streams amount to 5 l/s, exceptionally 10-15 l/s. The groundwater level occurs from 3 to 5 m below ground. The permeability of the deluvial-proluvial, lacustrine-fluvial and aeolian deposits is generally low. Sands, sandy loams, disintegrated rock material with sandy loam are well permeable sediments. The yield of wells usually does not exceed 2-3 l/s, however, groundwater level decline is significant (several tens of meters). Aquifers in the deposits of the Gusinoozerskaya series (conglomerates, sandstones, argillites) are under confined and unconfined conditions. The permeability of the rock matrix depends on spatial distribution and degree of its fracturing. The yield of the wells drilled in fractured rocks amount to 0.5 l/s however, yield of wells located out of the fractured zones is significantly lower (0.001-0.0001 l/s). In the effusive formations of the Mesozoic and Neogene age fissured aquifers occur at the depth from 3 to 80 m below ground. The wells yield is from 0.2 to 3 l/s (groundwater level decline 10-20 m). The groundwater TDS does not exceed 500 mg/l, and water is of HCO_3-Na-Ca type. Groundwater and surface water data are not available for the study of interactions between rivers and shallow aquifers.

Confluence of river Selenga and River Uda

The aquifer systems in the confluence area of Rivers Selenga and Uda are developed in rocks of different origin, age and permeability and their productivity and chemistry are widely variable. Hydrological interaction between groundwater and surface water exists in case of shallow aquifers in floodplains and lower terraces composed by Quaternary deposits.

The thickness of the recent fluvial deposits of the River Uda reaches 20-30 m, in case of the River Selenga locally exceeds 100 m. Groundwater levels in shallow aquifers in fluvial deposits (gravels, pebbly river drifts and grained sands with interlayers of sandy loams) vary from 0.5 to 6 m below ground. The amount of groundwater depends on granularity and permeability of fluvial deposits. The yield of wells located in the sandy deposits amounts to 0.5-1 l/s, in the pebble deposits 5-10 l/s. Filtration coefficient varies from 1-5 to 30-50 m/day respectively. Groundwater TDS in the aquifers in recent fluvial deposits does not exceed 500 mg/l, and HCO_3-Ca and HCO_3-Ca-Na types of groundwater prevail.

Aquifers in the Upper Quaternary and recent deposits are spread in the northern part of Ulan-Ude town in the valleys of small rivers and also within aprons and deluvial plains. Aquifers occur in sands, sands with crushed rocks, sandy loams and pebbles, and their productivity depends on their granularity and filtration properties. The yield of the wells is variable (from hundredth of l/s to 2-3 l/s) as well as groundwater level decline (up to 10 m). Filtration coefficient does not exceed 2-3 m/day.

The aquifer system in the lacustrine-fluvial mostly sandy deposits of Low-Middle Quaternary age is spread within floodplain terraces 1-3 km wide developed on the left bank of the River Uda. Aquifers thickness varies from 30-40 to 90-120 m. The average water well yield is from 2 to 6 l/s, groundwater level decline reaches up to 20 m. Filtration coefficient varies from tenths to a few meters per day.

The thickness of the aquifer system in the deposits of the Neogene-Low Quaternary age underlying the above described aquifers is between 10 – 65 m. The wells yield is up to 10-12 l/s, related groundwater level decline is from 5 to15m. Filtration coefficient is from 0.2 to 5 m/day.

The aquifer system in the Sotnikovskaya strata deposits of the Cretaceous age is spread in the northern part of the Ulan – Ude town at the slopes of the ridge Ulan Burgasy. The groundwater-bearing rocks are represented by coarse conglomerates with sandy and clayey cementation. The groundwater level occurs at depth from 3 to 40 m below ground. The well yields are from 0.08 to 5 l/s, related groundwater level decline 10-5m. Filtration coefficient rarely exceeds 1m / day.

The aquifer system in the Gusinoozerskaya sedimentary deposits composed by sandstones, argillites, aleurolites and conglomerates of the Low Cretaceous age is widespread in Ulan-Ude area. The groundwater level is widely variable from 1 to 50 m below ground and locally up to 70m. The wells yield is from a few tenths to 10-20 l/s. Filtration coefficient reaches 10m / day.

The aquifers in the fissured zones of intrusive and metamorphic rocks are spread in the northern and southern parts of the Ulan – Ude town within the mountain frame. The groundwater level is registered about 80 m below ground. The wells yield vary from 0.1 to 2-3 l/s, related groundwater level is from 3 to 50-60 m. The filtration coefficient does not exceed 0.5-1 m / day.

Hydraulic interaction between groundwater and surface water of the River Selenga is rather close. The width of the river channel near the studied area is 300-320 m, depth up to 5 m, average monthly river water discharge is 77 -3070 m^3/s (minimum in February and maximum in late July caused by summer floods), annual amplitude of groundwater level fluctuation is 144 – 249 cm. Replenishment of groundwater resources occurs in the period of high river runoff. The sediments of the river channel are permeable. Erosional river activity and erosion rate on the right bank of the river are high (about 6 m/year) and river bad isn't clogged with sand. A close relationship between groundwater in shallow aquifers and the River Selenga and higher permeability of the riverside sediments led to the decision to established water supply system based on advantages of bank infiltration of surface water into adjacent aquifers. Linear series of wells have been drilled along the right bank of the river at the distance of 160 m from the channel. The maximal extent of the zone where river waters influence on groundwater level has been registered in the River Ivolga valley (1, 4 km). Additional studies and models have to be applied to determine factors that influence on groundwater level rise in the riverside territory and to better understand seasonal changes in the interface between surface water and groundwater.

Selenga River Delta

The delta of the Selenga River lies within the Usty-Selenginskaya depression of the Cenozoic age. Variety in permeability of groundwater-bearing deposits, their large thicknesses, and presence of faults involve jointly on hydrogeological conditions of the delta area. In the Usty-Selenga artesian basin, the following groundwater zones may be distinguished: 1/ zone with active groundwater exchange between aquifers occur in the deposits of the Quaternary age up to the depth 500 m below ground, 2/ zone of slow water exchange with confined aquifers in the deposits of the Neogene age up to the 3000 m below ground, 3/ groundwater in fractured crystalline rocks in the basement of the basin. Some aquifer systems are each other hydraulically connected due to the groundwater flow on the fractures in crystalline rocks.

The aquifer system in the lacustrine and swamp deposits of the Holocene age occurs only in the Delta and Kaltus flexures. The thickness of the groundwater-bearing zone reaches 3-5 m. The depth of groundwater table below ground during the year seasonally change from 0,2-0,3 to 1,0-1,6 m. The lacustrine and swamp deposits are characterized by low permeability and limited occurrence of groundwater resources. The wells yield in sandy loams reaches 0,08-0,4 l/s by groundwater level decline 2.3-3.5 m, in turfs wells yield (0,2-0,6 l/s) and groundwater level decline (1,5-2,0 m) are similar. Groundwater occurrence in wells located in the sandy environment increases up to 1-2 l/s. Permeability of rocks in saturated zone is from 0,01-0,03 to 0,4-0,8 m/day in loams, 0,4-0,9 to 3,5 m/day in sandy loams and 0,1 to 4,5 m/day in turfs. The consolidated loams and clays 2-4 m thick form the aquitard of the lacustrine and swamp deposits.

The aquifers in fluvial deposits of the Upper Pleistocene and Holocene age composed by highly permeable boulders, gravels and sands are extended in the floodplain areas and low valley terraces of the Selenga and Kabanya Rivers. The thickness of the groundwater-bearing formations reaches 80-120 m. Groundwater level occurs 2-3 m below ground in floodplains and 8-15 m below ground in the low river terraces. Groundwater is under local pressure in the Kaltus flexure where can be found in the depth 8-12 m under impermeable clays and loams. Groundwater piezometric level is recorded 1,2-2,5 m below ground. The above described aquifer system is very productive. The yield of wells located in the River Selenga floodplain areas reaches 26-40 l/s by small groundwater level decline (Domracheev, Moiseeva, 1964). The wells yield sited in in the pebble-sandy deposits in the floodplain terraces reaches mostly 2-3 l/s, rarely 7-9 l/s. The average values of filtration coefficient are 30-70 m/day in pebbles, 8-20 m/day in sandy-pebble deposits and 5-10 m/day in sands. The groundwater resources in the shallow aquifer system are the significant source of drinking water. However, their wider use is often limits high content of ferrous iron (up to 30-50 mg/l).

The aquifer system in the deluvial and proluvial deposits of the Upper Pleistocene age is associated to the gently sloping margins of the depressions. Deposits are composed by the weakly sorted material of variable lithological composition: crushed rock, gruss, pebbles, gravel, sand, sandy loams and loams. Sorting of the unconsolidated material becomes evident from marginal parts to the centre of the basins. The aquifer system is split up by low permeable layers of clays and loams several meters thick into several local aquifers, some each other interconnected. The groundwater level occurs 1,2 - 8,5 m below ground. The wells yield is very variable: 7,5-10 l/s in the pebble deposits (groundwater level decline 2,8-5 m), 0,001-0,8 l/s in sands and loams (groundwater level decline 1-24 m). Filtration coefficient of the deposits is 21-93 (pebbles) and 0,05-1,0 m/day (sands and loams) respectively.

Aquifer system in the deposits of the Neogene-Eopleistocene age occurs under groundwater-bearing deposits of the Quaternary age in the depth more than 300 m (zone 1). Due to their lithology there are of different permeability. The groundwater-bearing sediments are sands (sometimes with gravels), sandstones and aleurolites. They often alternate with low permeable carbonaceous shales, loams and clays. Deep aquifers are confined, their piezometric levels are 32,5 m and less below ground. Groundwater overflowing pressure in the head of the wells reached 5 to 20 atm. The confined regime of aquifers is caused by 1/ frequent alternation of groundwater-bearing permeable rocks with interlayers of low permeable clay, 2/ synclinal structure of the basin and 3/ position of groundwater recharge area on the boarders of the basin. The amount of groundwater resources in the aquifer system differs. Wells yield reaches 1,2-6,4 l/s in sandstones and sandy-gravel deposits and 0,1-0,9 l/s in the fine-grained sediments.

Zone 2 is characterized by slow groundwater exchange and reductive conditions in the aquifer. By log measurement methane in the composition of groundwater gases has been identified at a depth slightly above 100 m below ground. The groundwater chemical composition is characterized by high content of ferrous iron (up to 48 mg/l).

In the Selenga River Delta seasonal interaction between the surface water in the Lake Baikal and shallow groundwater has been observed. The Baikal depression drains shallow groundwater flowing from the surrounding areas to the lake as well as deep aquifers. In the central part of the delta bogy areas are extensive. In marginal parts of the Usty-Selenga basin insular permafrost with thickness up to 30 m occurs. Additional hydrogeological investigation and groundwater monitoring are needed to improve knowledge about groundwater and surface water relation in the Selenga River Delta and groundwater dependent ecosystems. However, groundwater investigations specifically oriented on evaluation of groundwater resources in highly productive shallow aquifers in the confluence areas of big rivers has not been realized as yet.

River Berguzin above its inflow to the Lake Baikal

The hydrogeological conditions of the Cenozoic Barguzin intermountain depression are largely determined by the wide occurrence of permafrost rocks. Three types of permafrost areas may be distinguished: 1/ areas without permafrost rocks, 2/ areas with near-surface permafrost and 3/ areas with deep permafrost.

The areas without permafrost are found along the north-western part and in the southern final part of the depression. The width of the melt rock band at the foothill trail of the Barguzin ridge side reaches 5-7 km, and broaden up to 8-10 km in the river valley. Thawed zone has been formed owing to the warming impact of the infiltrating surface water and intense underground runoff. A powerful aeration zone has been formed there.

Area with occurrence of near-surface permafrost rocks is known in the floodplains and low river terraces. It occupies the central part of Barguzin depression. The minimum depth of the permafrost strata achieves 6 -7 m and expands ed into the north-eastern direction. In the final part of the depression the thickness of permafrost rocks reaches up to 300 m.

The aquifer system in the lacustrine and lacustrine-swamp deposits of the Upper Quaternary and recent age has been identified in the Barguzin River valley and in its left bank tributaries. The groundwater-bearing sediments are represented by boulders, pebbles, sands of various grain-size and sandy loams and loams. Coarse deposits prevail in the River Barguzin tributaries. Their thickness varies from several meters at the flanks of the basin to 130-150 m in zones of the latest tectonic activities in the center of the depression. These deposits are frozen in the large area. In the above-permafrost horizon there are form seasonally thawed layers in the warmer months of the year. Its thickness is 0.6-0.8 m. The wells yield does not exceed 0.4 l/s. Above-permafrost ‘taliks’ (thawed sediments) are distributed only locally. Their thickness is up to 22 m. Sub-permafrost water has been found from 7 to 46 m below ground.

The Barguzin depression is characterized by surface water drainage into groundwater in the foothill trails. Many rivers that flow from the Barguzin and Ikat ridges successively infiltrate in the coarse sediments of aprons. The amount of infiltrated river water reaches 3-6 m^3/s. The zone of influence of groundwater recharge by surface water level attains 15 km. Regular groundwater monitoring is needed to precise calculations about surface water and groundwater interface.

River Upper Angara above its inflow to the Lake Baikal

The thickness of sedimentary formations of various geneses has been estimated from 700 to 2500 m in the estuary of the Upper Angara. The fluvial -proluvial sediments of Upper-Pleistocene age are 25-40 m thick. They are compost by boulder- and gravel-pebble deposits with sandy and loamy fillers. The alluvial sands of the Mid-Pleistocene age are more than 26 m thick and are overlain by pebbles. The groundwater level occurs in the depth 1-4,5 m below ground and thickness of the aquifer amount to 23,5 m. The presence of the loamy filler is reflected in lower occurrence of groundwater resources, e.g. the yield of the wells is from 2,9 to 4,8 l/s and related groundwater level decline is from 1,6 to 6,8 m. The coefficient of filtration reaches 9,8 m/day. Range of seasonal groundwater level variations is up to 3 m. Regular groundwater monitoring is needed to collect data about the relations between groundwater and surface water (river and lake).

	Thickness of aquifer, m	Specific yield, l/s/m	Hydraulic conductivity, m/day	Transmissivity, m^2/day	Porosity	Chemical type of ground water	TDS, g/l

River Selenga shallow aquifer closely to the Russian-Mongolian border	30	0.16	0.7	20.8		HCO_3,SO_4 – Ca,Mg,Na	0.3-0.5
Confluence of river Selenga and river Chickoy	1.5-45	1.7-5		221-650		HCO_3 – Ca,Mg	Up to 0.2
Confluence of river Selenga and river Djida	50-60	0.0002-4.0	1.85-127	0.026-650	0.35-0.72	HCO_3 – Ca	up to 0.5
Confluence of river Selenga and river Temnick	2.5-8	0.12-0.3	0.1-3.6	15.6-39		HCO_3 – Ca,Mg	0.1-0.3
Confluence of river Selenga and river Khilock	50	3-5 up to 10-15	7.8-39	390-1950		HCO_3 – Ca,Na	0.2-0.4
Confluence of river Selenga and river Uda	20 - 100	0.3 - 10	1-5 - 30-50			HCO_3 – Ca,Na	0.3-0.5
Selenga river Delta	80-120	2-3 up to 40	5-70			HCO_3 – Ca,Na	0.2-0.4
River Barguzin	130-150					HCO_3 – Ca,Na	0.1-0.2
River Upper Angara	140-200			230		HCO_3 – Ca,Na	0.1

Table 2.1 Hydraulic and chemical characteristics of shallow aquifers in Russian territory of the Baikal Basin

3. Man-made threats on groundwater and groundwater dependent ecosystems

Solid and liquid wastes of different origin are significant sources of groundwater pollution in the Baikal Basin. In Mongolian territory of the basin domestic and mining wastes and in Russian territory industrial and domestic wastes are the main potential pollutants of water resources. However, rapid development of mining activities in Russia and industry in Mongolia are registered and waste threats on groundwater resources are growing.

Environmental sound management of mine solid wastes and waste waters is particularly important in the Baikal Basin because mining and processing of gold, copper, molybdenum, coal and other mineral resources produce wastes mostly with high content of toxic constituents. Sources of wide range of impacts on groundwater quality are uncontrolled leakages of waste water from ore washing and dressing facilities, post-extraction processing of mining material, coal preparation, uncontrolled leakages from tailings, piles, evaporation ponds and other disposal sites. Excessive pumping of mine waters may produce impact on groundwater quality too.

The engineering design of landfills, installation of impermeable layers and drainage systems at the base of the landfills and establishment of site specific groundwater monitoring networks around the mining and processing facilities as well as construction of treatment plants to treat liquid waste leakages and mine waste water are the essential protective measures for reducing or even eliminating impact of mining wastes on groundwater system. Use of environmental sound mining and processing technologies, often financially demanding, which restrict production and amount of wastes and toxic constituents together with regular control of landfills environmental safety have to be included in regulations of mining concession and mining operation.

Similar approach requires environmentally sound control over industrial wastes. Design of landfills and applied chemical treatment technologies have to be related to the chemical composition of produced wastes as well as the leakage and waste water volume and concentration have to be reduced as much as possible and regularly monitored.

Only few disposal sites of domestic wastes fulfill the requirements for safe management of produced wastes in the Baikal Basin. Environmental sound policy has to be applied particularly in construction and location of new safe landfills described above. Comprehensive hydrogeological investigation has to be realized before decision about landfills siting is made. Impermeable geological environment, groundwater level deep below ground, groundwater flow direction, landscape morphology, distance of the landfill from water supply systems and the nearest population centers and other criteria have decisive influence on landfill site siting and operation. However, waste selection, wastes recycling, organic wastes composting are some of activities and technologies which should be used to reduce amount of produced wastes. Treatment technologies applied for collected domestic waste waters have to include physical, biological and chemical treatments and capacity of the treatment plants has to correspond to the contemporaneous and future requirements on waste water safe management. Reuse of treated waste water has to be applied in the wider scale for aquifers replenishment and irrigation and industrial purposes.

Diffuse nitrate and pesticide pollution of groundwater by agricultural activities is not registered in the Baikal Basin as yet, because amount of used fertilizers and chemicals is low in comparison with e.g some European countries and USA. A coordinated effort between agricultural and water sectors is however needed to define in time policy for sustainable management of agricultural production and protection of groundwater resources. Control measures depend above all on the steps taken in the agricultural sector. Maintain traditional crop rotation system, control fertilizers and pesticides application (e.g. type, amount and doses applied, time of application with respect to the crops type), selection of suitable cultivation techniques (especially tillage), soil quality conservation (e.g. maintain of soil organic matter), and groundwater quality monitoring (monitoring of unsaturated zone and vertical profile of the aquifer to control nitrate transport and transformation processes) are the main attributes in establishment environmental friendly agricultural production. Keeping dynamic stability of the soil organic matter is pointed out with respect to the protection of groundwater. The nitrogen and carbon balance is essential for gaining insight to the physical, chemical and biological processes which take place in the soil-unsaturated zone and which control the amount of nitrogen leached in the saturated zone.

Irrigation of arable soils has been applied in several areas of the Baikal Basin. Monitoring of the return flow is needed because irrigated water contributes to the growing salinity of the soil and leached salts are transported to the underlying shallow aquifers and degrade the quality of groundwater.

Groundwater resources depletion has been registered locally in Mongolian territory of the Baikal Basin. Recognition of the impact of intensive abstraction of groundwater resources for irrigation, drinking water supplies and other purposes is almost always based on hydraulic phenomena. However, subtle changes in groundwater chemical composition caused by pumping may be often observed before becoming evident from groundwater level decline. Groundwater monitoring both quantity and quality should be therefore implemented and targeted on the specific groundwater quality problem caused by intensive aquifer exploration.

Groundwater protection zones around drinking water supplies and recharge areas lead to the consecutive reduction of human activities. Particularly crop and root farming have to be often limited and controlled in areas where protection zones are established. The objective evaluation of farmers' past production and allocation of costs and benefits between agricultural and water sectors are the key factors in the strategy of sustainable utilization of soil and water resources and in establishment of environmental sound protection policy of both resources.

In highly productive arable lands in the Kharaa River valley and downstream of the Orkhon River and in other areas in the Baikal Basin with intensive agricultural activities as well as in areas with mining operations and in industrial centers comprehensive cooperation between agricultural, mine, industrial sectors and water sector has to be established in Mongolian and Russian territories of the Baikal Basin with the scope to control and prevent the man-made threats on groundwater resources and groundwater dependent ecosystems on the transboundary and countries levels.

3.1 Management of solid and liquid wastes in Mongolian territory of the Baikal Basin

Uncontrolled leakages of solid and liquid wastes from municipal waste disposal sites and mining facilities and are the main sources of groundwater pollution in Mongolian territory of the Baikal Basin. Particularly in large cities e.g. Ulaanbaatar, Erdenet, Darkhan and Sukhbaatar are registered many potential point pollution sources, uncontrolled waste disposal sites and discharge of poorly treated or untreated waste waters. Data about the impact of mining activities on groundwater quality are missing because site specific monitoring networks around mining centers are not established. However, at present there are projected many activities focused on improvement of waste management, waste water treatment plants, landfill sites, recycling of solid wastes and others. E.g. Japanese project on development of Master plan for solid waste management in Ulaanbaatar financing by JICA (Japan International Cooperation Agency) has been realized.

Management of solid and liquid domestic wastes

Cities and rural settlements often located along or closely the rivers are the main producers of solid wastes in the Mongolian territory of the Baikal Basin. More than half of Mongolian populations live in the cities and produced wastes are disposed in 490 mostly uncontrolled waste disposal sites (dumps).

In Ulaanbaatar 1,500-1,800 m^3 daily and y 650-700 thousand m^3 annually of solid wastes are produced. According to the World Heath Organizations the daily production of solid wastes per person in Ulaanbaatar amount to 0.334 kg (MARCC, 2009). Two disposal sites are available in Ulaanbaatar. The older one is uncontrolled waste disposal site without relevant protective constructions and drainage systems. The new sanitary landfill called Narangiin Enger has been constructed within Japanese Governmental Grant and its operation started in the year 2008. About 75 % of produced wastes is collected and transported by municipal companies on both disposal sites, 15 % wastes is managed by private companies and 10% wastes are deposited on many illegal uncontrolled waste disposal sites in the urban area of Ulaanbaatar. Illegal waste dumping has become a serious issue particularly in Ger (traditional tent-like housing) district of Ulaanbaatar where many nomadic people are living. Open garbage disposals are linked to the environmental degradation, including the pollution of soil and groundwater. Similar situation in solid waste management exists also in other Mongolian cities.

Totally, 58 waste water treatment plants are located in the Mongolian territory of the Baikal Basin. In some major towns, as well as aimag and soum centers, basic sewerage networks were constructed. Waste water mechanical and biological treatment systems consisting of aeration, sedimentation and chlorination are established in many waste water treatment facilities, while simple pond systems are used in the smaller treatment schemes. About 91 million m^3 of wastewater is treated annually in the Mongolian territory of the Baikal Basin.Treatment of waste waters produced by the cities Darkhan, Zuunkharaa and Ulaanbaatar (160,000m^3/day) is not on the adequate level and waste water is registered as important source of chemical pollution of the Kharaa and Tuul Rivers.

In Ulaanbaatar operate 2 chemical, 4 mechanical and 7 biological waste water treatment plants. In total, 62.1% of waste waters are treated biologically, 37.6% mechanically and only 0.3% chemically. Almost all (95%) treated waste water is discharged into the Tuul and Bayangol Rivers. Efficiency of the central waste water treatment plant in Ulaanbaatar is only 60-70%.

In the Mongolian- Russian transboundary area a waste water treatment plant with a capacity to carry out biological treatment of 450 m^3 wastewater per day was established in Altanbulag soum of Selenge aimag in 1970. However, wastewater treatment plant is out of operation and its only function is to collect and discharge untreated wastewater into the river.

The waste water treatment plant of Darkhan city came into operation in the year 1965 and was reconstructed in 1998. The capacity of the treatment plant amount to 50,000m^3/day however, only 18,000 m^3/day of waste water is treated.

For expanding Erdenet city waste water treatment plant construction started in the year 2009 with technical and financial contribution of France. The intention is to increase twice existing treatment plant capacity and to treat up of 48,000 m^3 wastewater per day. Recently, the plant treats 31,400 m^3 per day of wastewater. A modern treatment technology applied increased treatment efficiency up to 98 %. Reuse of treated waste water was proposed by Baldangombo (2012). In the past waste water was discharged into the Khangal River. According to the analyses carried out by the Geoecological Institute of the Academy of Science of Mongolia pollution of the Khangal River was higher than the treated waste water from the treatment plant of Erdenet city (Baldangombo, 2012).

Under the project of UNEP partnership quality of surface water in the Selenga River Basin was studied in the year 2008.Chromium content (0.26μg/l) was detected near the discharge of treated water from Darkhan waste water treatment plant.

There is no information about groundwater pollution by municipal wastes, liquid or solid. However, site specific groundwater monitoring networks around waste disposal sites have not been established till this time and potential leakages are not controlled.

Management of solid and liquid mining wastes

In the Selenga River Basin over 400 gold-mining companies were registered in the year 2006. Among the main pollutants produced by gold mining activities are mercury and cyanide. In the Boroo and Kharaa River catchments, in the area of 37.35 hectares, have been found pollution of soil and surface water due to the uncontrolled deposit of almost 200,000 tons of mercury-containing slime. Elevated levels of mercury have also been detected in the urine of the area's inhabitants. Wastewater and sludge produced by Boroo gold mining activities and stored in reservoirs can be considered as extremely danger potential toxic pollution sources.

Cooper mining and associated tailing dams are other potential pollution sources of groundwater.Mining companies such as the joint Russian-Mongolian copper and molybdenum ore processing plant in Erdenet have also been identified as important potential polluters. The Erdenet ore dressing plant has been identified as the source of elevated chemical pollution of the Orkhon River. In surface water samples from the nearest area to the tailing dam pollution by arsenic has been recorded. The mean content of arsenic in water sample near the tailing dam was 2.17μg/l and it ranges from 0.4μg/l to 20.2 μg/l in tailing water (NDEP- NISD, 2008).

Data about groundwater quality in mining areas are scare and extent of potential groundwater pollution is not well known. However, pollution of shallow aquifers by heavy metals has to be considered as a serious environmental issue in mining areas. Groundwater quality monitoring and other activities have to be implemented to protect groundwater against pollution, especially in the river basins where use of mercury or cyanide for gold mining activities are registered.

Management of solid and liquid industrial wastes

Wood and cashmere processing factories and tanneries are operating in the floodplains of the Tuul River and produce the wastes with significant amount of heavy metals and toxic substances. Tanneries are concentrated in the bigger urban centers such as Ulaanbaatar, Darkhan, and Erdenet. E.g. 46 tanneries were registered in Ulaanbaatar in the year 2008 (26 functioning permanently and others operate during winter time only). They use chromium-based technology to process skin and wool. All tanneries are obliged to pre-treat their waste water and to be connected to the municipal waste water treatment plant. However, in Ulaanbaatar most of the new settled tanneries do not have waste water pre-treatment plants and there are not connected to the municipal sewerage network (Lkhasuren, 2008).

Content of chromium in surface water have been reported in the in the Kharaa river downstream of Darkhan city. Chromium content does not exceed yet the drinking water standards however, site specific monitoring of surface water and groundwater quality does not exists. Potential impact of tanneries on surface water and groundwater quality is not regularly observed and relevant groundwater protection policy to control impact of industrial pollution on water resources is not implemented.

Impact of agricultural activities on groundwater quality

The Selenga River Basin is the main Mongolian area focused on various farming activities. However, the size of farm lands is very small in comparison to the whole river basin. There were not conducted any special studies focused on the impact of nitrogen fertilizers or pesticides on the soil and groundwater quality in the Selenga River Basin. In 2002 have been applied on 1 hectare of arable land 4.9 kg per year of fertilizers and in 2008 amount of applied fertilizers increased on 8.2 kg/ha/year. Mainly industrial fertilizers such as ammonium nitrate, super phosphate and potassium chloride are used (Demeusy, 2012). Various chemicals (herbicide, fungicide, and others) are also applied; however, application of slowly decomposed chemicals is prohibited.

Nutrients concentration in surface water and groundwater are still low the Selenga River Basin. Increasing concentrations of phosphorus and nitrate are reported downstream of the Orkhon River and in the Kharaa River Basin, but there are still below the drinking water standards.

However, crop farming is rapidly developing in Mongolia. Increasing use of fertilizers and chemicals with the scope to increase crop production will involve on soil and groundwater quality in shallow aquifers. Groundwater diffuse pollution by nitrate registered worldwide may occur in Mongolia too. In areas where agricultural activities depend on irrigation, irrigation return flow has to be controlled because leads to recirculation of dissolved salts and groundwater pollution.

Intensive use of groundwater resources and depletion impact

Groundwater shortages due to the population growth and groundwater pollution are registered in several parts of the Mongolian territory of the Baikal Basin. Hydrogeological investigation and evaluation of potential impact of mining and industrial activities on groundwater resources both quantity and quality have not been realized on the relevant level till this time. Furthermore, the sustainable rate of exploitation of local surface and groundwater resources has already been exceeded in many high water demand areas, including the Tuul and Shariin River Basins close to Ulaanbaatar. Establishment and operation of site specific monitoring networks around water supply systems and other groundwater abstraction sites and groundwater data evaluation will support evaluation of exploitable groundwater resources and their sustainable development and management.

3.2 Management of solid and liquid wastes of Baikal Basin in Russian territory

Man- made threats on groundwater are related to the leakages from uncontrolled waste disposal sites and poorly treated or untreated waste waters. Domestic and industrial waste disposal sites and waste water from municipalities, industrial centres and mining areas are the main sources of pollution which can affect on different levels and geographic scope groundwater and groundwater dependent ecosystems.

Management of solid and liquid domestic wastes

In the central part of the Baikal Basin (areas on the Lake Baikal shoreline), several companies are licensed to provide various services for municipalities and industrial sectors, such as treatment of municipal and industrial wastewater, and collection and disposal of solid wastes in the Irkutsk region (Slyudyanka and Irkutsk towns, Olkhon Island) and Buryat Republic (Kabansk, Pribaikalie, Barguzin and Severobaikalsk areas and Severobaikalsk town).

In the area of the Slyudyanka administrative region, the two authorized disposal sites for municipal wastes are located. One disposal site (4.0 hectares) is sited 300 m away from the Talaya River and 5 km from Lake Baikal. Groundwater monitoring network is not established around the disposal site. The surface water quality control is conducted by sampling analyses of the Talaya River. The other disposal site of solid wastes in Baikalsk town (4.6 hectares) is located 4 km away from the town, 0.4 km from the Babkha River and 2 km from the Lake Baikal. The site-specific groundwater monitoring network has been established to control potential pollution leakages from the disposal site. Chemical analyses include 30 components in order to regularly control groundwater quality. The current low contents of ammonium nitrogen (0.1-0.25 mg/l) and nitrite nitrogen (0.07-0.15 mg/l) as well as other analyzed constituents indicate that groundwater quality is not affected in the area around the waste disposal site.

In the territory of the Buryat Republic, about 50 % of total wastes generated by household and communal services in Ulan Ude town are deposited on the authorized waste disposal site.

Approximately 75% of wastes from the remaining 50 % are reused. In Selenginsk settlement, 50% of wastes are reused, and only 3% placed on the authorized disposal site.

Waste water treatment facilities in Buryat Republic have been constructed in 18 cities and 23 rural settlements (that is only 7 % of total number settlements). The discharge of insufficiently treated wastewater into rivers amounted to 48.24 million m^3 in the year 2005.

The higher contents of organic substances, zinc, and manganese have been found in the stream near the Selenga River, where the treated sewage water from Ulan-Ude town is discharged. Some part of sewages is treated on filtration fields in Kabansk, Novaya Bryan' and Zaigraevo.

Wastewater treatment of Ulan-Ude town is realized by specialized organization 'Vodokanal'. The capacity of municipal wastewater treatment plants amount to 185 thousands m^3/per day. The treatment scheme includes combined mechanical and biological facilities. Mechanical treatment of wastewater is made on grit, sand traps and in primary sedimentation tanks. The average efficiency of wastewater mechanical treatment amount to 53 %. Biological treatment is performed in aerotanks with regenerators, secondary sedimentation tanks and bioreactors. The average efficiency of biological treatment is 92%. The treated wastewater is discharged into the River Selenga.

Management of solid and liquid mining wastes

Mining of the ore deposits provides numerous environmental problems in catchment basin of the Lake Baikal. Mining impact depends on the extent of mining operations, type of minerals, and proximity of mining operations to the Lake Baikal or surface streams.

The most serious environmental impacts are associated with waste processing of the Djida tungsten-molybdenum plant, where more than 40 million tons of wastes are stored. They contain 3-4 % of oxidized sulfide minerals and products of their decompositions are carried into the surface water and groundwater and pollute the surrounding area. Cadmium, zinc, copper, and iron have been found in groundwater of the Zakamensk urban area (in the wells and shallow boreholes) where groundwater is used as the source of municipal drinking water supplies. Contents of the above hazardous elements exceed the drinking water standards. The chemical composition of the groundwater changed from the hydro-carbonate type to sulphate one in the zone of the waste impacts. Acid water with high content of some toxic constituents (cadmium, zinc, copper, fluorine) has been identified in effluents from the tailing deposits in the Modonkul' River valley.

Intensive coal exploration is going on in the Tugnuisky, Okino-Klyuchevsky, Daban-Gorkhonsky and Zagustaisky mines. Highly mineralized groundwater of sulfate-hydrocarbonate-sodium type with content of fluorine up to 4.5 mg/l is pumped from deep levels on to the surface. The volume of extracted groundwater amounted to 322.7 thousand m^3/per day in the year 2005.

The gold mining is highly developed in the River Selenga catchment area. The employed technology of washing the gold-containing sands requires significant volume of water and produces considerable amount of wastes. At present the gold-mining companies use the multi-stage system of water purification from suspensions by sedimentation. The experience of using such technology for many years showed that treatment resulted both in reducing the contents of suspended substances and depositing the toxic heavy metals from solution. Such positive effect of treatment is observed in the quality of the Gudzhirka River. Its catchment basin suffers from the overburden effect of the Inkurskoe tungsten-molybdenum ore deposit. Drainage water collected in storage ponds is treated from toxic heavy metals during sedimentation.

Management of solid and liquid industrial wastes

In Pribaikalie, 64 industrial objects are developed in southern Baikal and northern Baikal. The southern Baikal industrial centre, including the Slyudyanka and Irkutsk areas, causes pollution of air, water and soil. In Baikalsk city the main polluters are the Baikal Cellulose-Paper Combine (BCPC) and companies that produce construction materials. In Slyudyanka city pollution is caused by companies that produce construction materials and by electric power industry and transport companies that cause soil pollution with heavy metals. In Kultuk village, a meat-packing plant, transport companies, and oil deposits are potential sources of groundwater pollution. In Listvyanka companies of housing and communal services may cause pollution of groundwater by nitrogen compounds, phosphorus, iron and others. Operations of harbour facility on the shore of Lake Baikal may be associated with pollution by oil products.

The Baikal Cellulose-Paper Combine (BCPC) causes the major impact on environment in the southern part of Lake Baikal. In the area, where BCPC is located, the polluted aquifer discharging groundwater into the Lake Baikal is composed by lacustrine and fluvial sediments of the Quaternary age. The mineralization of groundwater in the zone influenced by BCBK amounts to 2.5-3.3 g/l (compared to background value of 0.2 g/l) and varies seasonally. High contents (above maximum allowable concentrations, MAC) of formaldehyde, phenols, aluminum, and sulfate soap were recorded in the groundwater pollution area in the year 2005. Analyses of groundwater samples taken from monitoring well No.6a located near the shore of Lake Baikal showed that groundwater mineralization reached 0.9 g/l, the content of sulfate amounted up to 364 mg/l.

In the treated wastewater the total amount of mineral substances defined from the sum of basic ions varied from 283 to 409 mg/l (363 mg/l in average). In terms of chemical composition the treated wastewater of BCPC is of the sulfate-sodium type. The Lake Baikal natural water mineralization varies from 86.3 to 102.6 mg/l (depends on location, depth and time of water sampling).

The groundwater area of 32 km^2 has been polluted due to the BCPC activities. Waste water sampling revealed the presence of non-sulfate sulfur (up to 0.21mg/l), volatile phenol (0.005 mg/l), suspended particles (1.8 mg/l), and mercury (0.001 mg/l).

BCPC constructed facility for treatment of residues produced by its water treatment plant in the year1988. The quality of the treated wastewater produced by BCBK remains relatively stable. The increasing trend in the content of mineral phosphorus, silicon, ammonium nitrogen and suspended substances and decreasing trend in the content of sodium, COD, nitrate nitrogen, magnesium, organic phosphorus, synthetic surfactants, chlorine, petroleum products, potassium, nitrite nitrogen, and hydro-carbonate have been recorded.

Eight groundwater wells were drilled to protect Lake Baikal from the pollution impact of BCPC in the year 2000. About 2.0 – 2.2 m^3 of groundwater has been pumped per day from the wells located aboutb the pollution plume. The area of groundwater pollution significantly reduced after five years of continuous pumping and treatment of polluted groundwater. However, occasional discharges of contaminated groundwater into Lake Baikal cannot be excluded.

The temperature of groundwater reaches 14-21^{0}C. An unfrozen patch of water in ice (the so-called ‘polynia’) occurs in the area near the shoreline of Lake Baikal due to discharges of warm water from BCPC. In the year 2005 the ‘polynia’s length was reduced from a few hundred metres to only 60-70 m.

The Selenga Cellulose-Cardboard Combine (SCCC) located 40 km from the Lake Baikal operates with a closed waste water cycle. Solid wastes produced by SCCC are stored and subjected to stage-by-stage treatment on the authorized site. However, the monitoring studies show that complete treatment of wastewater does not occur in sedimentation tanks. Waste water penetrates into groundwater in shallow aquifer and pollutes them by sulfate, organic substances and other toxic components such as zinc and cadmium. The higher concentrations of the components that are specific for pulp production, i.e. lignin, methanol, sulfate, etc. have been identified too.

The groundwater pollution exists also within the industrial zone of Ulan-Ude. Contents of oil hydrocarbons in groundwater highly exceed the limited values for drinking water in the area of fuel and lubricant storage of Open Joint Stock Company ‘Ulan-Ude Aviation Plant’. In two monitoring wells 5 m and 6 m deep, located 10 m and 15 m from the fuel and lubricant storage area the contents of oil products (kerosene) in groundwater reached 1450 mg/dm^3 in the year 2011.In the year 2012 kerosene was detected in the boreholes as a separate phase on the groundwater level surface. The second area where groundwater is polluted by oil products is ‘Buryat-Terminal’ managed also by Open Joint Stock Company. The content of oil hydrocarbons reached 0,278-1,478 mg/dm^3 in the year 2012 in the observation wells located on the right bank of the River Selenga under the pollution source. Lens of oil products as well as groundwater pollution plume move in the direction to the River Selenga and during the dry seasons are drained by the Uda and Selenga rivers.

Gas emissions impact on groundwater quality

Oxides of carbon, sulfur, nitrogen, and hydrocarbons enter the atmosphere together with industrial emissions. Hundreds of thousands tons of those compounds are annually emitted on the territory of

Buryatia Republic. In addition, the territory of Buryatia is also affected from other regions located on the leeward side (Irkutsk, Krasnoyarsk regions). Acidic precipitations (pH= 4.06) with high content of sulfur (up to 62.9), chloride (13.8), fluorine (1.23), nitrogen (14.2), ammonium (17.6 mg/l) has been observed in some areas of Buryatia, including the Usty-Selenga depression. In areas affected by polluted precipitations, soils and shallow groundwater contain elevated concentrations of the above components and some heavy metals that are leached from the rocks by acidic solutions.

Pollution of atmosphere takes place not only in Russia, but in Mongolia as well (Ulaanbaatar). Further studies are needed to identify areas impacted by acid rains, evaluate and predict their influence on soil and groundwater qualities.

Impact of agricultural activities on groundwater quality

In the Kabansk drainage-irrigation system of the area of 5670 hectares makes influence on underground drainage discharges from bogs into Lake Baikal has been observed. It carries runoff of 27.6 million m^3 /year of water from bogs. Groundwater is polluted by nitrogen-containing compounds due to the turf

decomposition by low temperature in aeration zone. The content of ammonium in groundwater attain 16.5 mg/l and nitrite ion 3.5 mg/l. The content of manganese, lithium, molybdenum and copper in groundwater exceeding standards for water in fishery ponds has been found in groundwater from bogs.

Extensive groundwater pollution by nitrogen-containing compounds has been identified in the areas surrounding the cattle farms. E.g. treatment of wastewater takes place only on filtration fields in the Zaigraevskaya poultry farm situated in the River Uda Basin. The movement of large nitrate (700 mg/l) pollution plume has been registered in groundwater in the shallow aquifer. Groundwater diffuse nitrate pollution due to uncontrolled application of fertilizers on arable land has not been registered.

Intensive use of groundwater resources and depletion impact

Groundwater resource depletions have not been identified in the Russian territory of the Baikal Basin till this time.

3.3 Rating criteria for prioritization of groundwater pollution threats in the Mongolian and Russian territories of the Baikal Basin

Rating criteria for prioritization have been applied with respect to the impact of point pollution sources on groundwater, dependent ecosystems and human health. Diffuse groundwater pollution by nitrate or pesticides due too agricultural activities has not been identified in the Baikal Basin in Mongolia as well as in Russia. However, the intention to increase crop production by application of growing quantity of nitrogen fertilizers and pesticides, construction of new irrigation schemes, the replacement of traditional crop rotation by continuous cultivation of financially more valuable crops and expansion of arable lands, will increase the risk of soil organic matter degradation and groundwater diffuse pollution in the next years. Potential impact on groundwater quality has to be therefore carefully controlled and monitored in areas where intensive crop cultivation is currently realized or planned.

Waste disposal sites and discharge of waste waters are the main point pollution sources of groundwater. In Mongolia uncontrolled domestic and mine waste disposal sites and discharge of untreated or poorly treated municipal and particularly mine waste waters are significant groundwater pollution sources. In Russia both industrial waste disposal sites and waste waters are registered as most significant source of groundwater pollution, follow by pollution produced by mine activities and big cities. However, groundwater pollution from waste disposal sites of poultry and pig farms has been also found in many areas of Russian territory of the Baikal Basin.

Sustainable management of solid and liquid wastes has to be established therefore, to conserve groundwater quality and dependent ecosystems and to protect human health.

Overall rating derived by combining the results of the severity and the scope proved that not sufficiently treated or untreated mine waste waters (particularly from gold, copper and molybdenum mines), often with the content of toxic constituents, discharged into surface streams and shallow aquifers can moderately or even seriously degraded (severity 2 and 3 respectively) quality of groundwater and surface water resources and dependent ecosystems in many mining areas in the Baikal Basin (scope 3). Toxic constituents contain in mine waste waters can also pollute drinking water sources and thus affect human health. E.g in Russia cadmium, zinc, copper, and iron have been found in groundwater in the Zakamensk urban area (in the wells and shallow boreholes) where groundwater is used as the source of municipal drinking water supplies. In Mongolia in the Boroo and Kharaa River catchments elevated levels of mercury have been detected in water resources and in the urine of the area's inhabitants.

Leakage from wastes deposited in uncontrolled municipal waste disposal sites can affect groundwater and related ecosystems only slightly (severity 1) and in limited parts of the basin (scope 1). However, leakage from uncontrolled disposal sites where toxic wastes are disposed can degraded groundwater and related ecosystems moderately or even seriously (severity 2 and 3 respectively) in limited parts of the basin (scope 1).

Overall rating

Considering enormous gold and other minerals mining activities in Russian and particularly in Mongolian territory of the Baikal Basin and expected expansion of mineral and coal mining in both countries high priority (overall rating 5 and 6) has to be given in the next years to the groundwater resources protection by regular control and monitoring of the quality of waste water produced by ore mining and ore processing. It must be pointed that discharge of polluted mine waste water into surface streams and aquifers can affect groundwater and surface water in the wider scale and can be also considered as potential water related transboundary conflict, particularly if pollution occurs nearby the Mongolian - Russian boarder. Environmentally sound mines operation must be obligatory issue of mining concessions afforded by governmental and aimag authorities. Control and monitoring must guarantee that waste water are continuously treated and toxic constituents are not present in waste waters discharging from mine facilities into the surface water and groundwater. Owners of mine facilities have to take responsibility for investments into relevant modern mining and waste water treatment technologies and construction and operation of groundwater monitoring networks.

Priority (overall rating 4) has to be given also to the discharge of untreated or not sufficiently treated waste waters from municipal and rural settlements. Both can affect groundwater in shallow aquifers and degraded its quality as well as groundwater dependent ecosystems. Significant investments on construction of treatment plants with modern treatment technology and capacity relevant to the current and future needs, training of human resources responsible for treatment plants operation as well as significant improvements of waste water management will be needed within next 10 years to reduce impact of municipal and rural waste waters on the quality of groundwater resources and environment.

Municipal, mine and industrial waste disposal sites without relevant protective impermeable liners, drainage scheme, and monitoring networks and particularly illegal uncontrolled waste disposal sites are significant point pollution sources in the Baikal Basin in both countries. Both can moderately (overall rating 2 – 3) or even seriously (overall rating 3) degraded part of the ecosystems. There are often located in floodplains or fluvial terraces where groundwater level in shallow aquifers is closely to the ground. Leakage from disposal sites located above the shallow aquifers affects groundwater quality because unsaturated zone in such areas is permeable and of small thickness and polluted leachate rapidly reaches the aquifer. During the wet seasons groundwater level increases and wastes deposited on the base of the disposal site can be even saturated. Site specific monitoring networks are only rarely established around waste disposal sites and movement of pollution plume into the aquifer is not controlled. Establishment of landfills constructed with protective liners, drainage system and site specific monitoring network and located on sites where groundwater level is deep below ground and low permeable geological environment and thick impermeable unsaturated zone occur will require investments from municipalities and mining and industrial companies in the course of the next ten years. Existing disposal sites have to be evaluated with respect to their potential impact on water resources. Where will be possible, relevant protective measures have to be implemented with the scope to prolong disposal site operation. However, operation of uncontrolled disposal site has to be closed, or toxic wastes from closed disposal sites have to be removed if there are located above productive and vulnerable shallow aquifers exploited for drinking water supply purposes.

Generally, solid wastes impact on groundwater and related ecosystems in case of domestic wastes is limited (overall rating 2), in case of mine and industrial wastes medium or exceptionally high in case of toxic wastes (overall rating 3, exceptionally 4).

In Russian territory of the Baikal Basin severity and scope criteria have been applied to designate overall rating for the impact of industrial gas emissions on groundwater quality

Tables 3.1 and 3.2 show overall rating based on evaluation of rating criteria for prioritization of different pollution sources with respect to their impact on groundwater resources quality

ISSUE	SEVERITY	SCOPE	OVERALL RATING
Domestic solid wastes	1: limited	1: limited	2
Mine and industrial solid wastes	2: medium 3: high	1: limited 1: limited	3 4
Municipal waste waters	2: medium	2: medium	4
Mine and industrial waste waters	3: high	2: medium	5
Waste waters with toxic constituents	3: high	3: high	6
Russia - Industrial gas emission	3: Limited	3: Medium	3

Table 3.1 Overall rating of groundwater pollution sources in Russian and Mongolian territories of the Baikal Basin

SEVERITY	SCOPE			
	4: Very high	3: High	2: Medium	1: Limited
4: Very high	8	7	6	5
3: High	7	6	5	4
2: Medium	6	5	4	3
1: Limited	5	4	3	2

Table 3.2 Overall rating of groundwater pollution sources (solid wastes in black circles, liquid wastes in red circles) in Russian and Mongolian territories of the Baikal Basin

4 Vulnerability of groundwater dependent ecosystem

There are few data available about groundwater dependent ecosystems in both Mongolian and Russian territories of the Baikal Basin. Groundwater level decline or pollution of shallow aquifers both may significantly affect groundwater dependent ecosystems. Relation between shallow aquifers and wetlands and other ecosystems is possible to presume in several areas of the basin, particularly in the delta of the River Selenga and in floodplains of the rivers. Research and monitoring are needed to identify potential groundwater dependent ecosystems and to better understand the processes occur between groundwater and wetlands and other ecosystems.

4.1 Vulnerability of groundwater dependent ecosystems in Mongolian territory of the Baikal Basin

There are not data available about groundwater dependent ecosystems in Mongolian territory of the Baikal Basin. There are two wetlands in the Mongolian part of the Basin registered under Ramsar list of wetlands however, their potential dependence on groundwater has not been studied as yet.

Ogii Lake, Ramsar site with the area of 2,510 ha. A freshwater lake located in the valley of the Orkhon River, comprising extensive alluvial areas of grassland, river channels, pools and marshes surrounded by grassy steppe. The maximum depth of the lake is 16 meters, but about 40% of the lake is less than 3m deep. The lake supports an intensive fishery and livestock grazing. Concentration of livestock around the lake led to the loss of habitats for migratory birds nesting around the lake. Lake is also important breeding and staging area for a wide variety of waterfowl, particularly ducks, geese and swans, highly vulnerable to the water pollution..

Terhiyn Tsagaan Lake, Ramsar site with the area of 6,110 ha. A freshwater and nutrient-poor lake formed owing to past volcanic activity is located in the Suman River valley in the Central Khangai Mountains. Small fishery activities (mainly pike and perches) have been practiced many years, but have been stopped in the year 1991. The extensive marshes in the west part of the lake are an important breeding and staging area for migratory waterfowl. Most recent Ramsar Information Sheet (RIS) is available from the year 1998.

4.2 Vulnerability of groundwater dependent ecosystems in Russian territory of the Baikal Basin

Forest-plantations have been produced to prevent erosion in steppe landscapes of many areas with previous agricultural activities on the Russian territory of the Baikal Basin. Poplar seeds have been used as the main planting material. The groundwater level decreased significantly in many places due to climate changes, particularly long term (more than 15 years) continuous arid period and changes in nature of atmospheric precipitation (rain showers). Ecosystems of forest-plantations due to the shortage of moisture gradually degraded. Woody vegetation disappeared in some areas.

Efflorescence of various salts that contains the toxic elements (cadmium, copper, zinc, fluorine, nickel, chromium) is formed on the soil surface in the areas adjacent to the mining activities where groundwater evaporation occurs in shallow aquifers with groundwater level closely to the ground. Degradation of vegetation and local ecosystems has been registered in such areas.

Investigation and mapping of groundwater dependent ecosystems in Russian part of the Baikal Basin can be proposed particularly in the delta of the River Selenga where groundwater level decline or groundwater pollution may have destructive impact on wetlands and ecosystems.

5 Transboundary and site specific groundwater monitoring in the Baikal Basin

Groundwater monitoring provides a valuable base for assessing the current state of and trends in groundwater system and helps to clarify and analyse the extent of natural processes and human impacts on groundwater in space and time. Credible, accurate and consistent groundwater monitoring data should be available and readily accessible by GIS data management system to planners, regulators, decision and policy makers and managers. The monitoring activities should also help to increase active public participation in the process of groundwater resources planning, sustainable development and quality conservation.

Groundwater monitoring is technically demanding, time consuming and costly process however, with growing urbanization, economic development and presumed impact of climate change, threats on groundwater are increasing and groundwater monitoring programmes are justifiable economically, socially and environmentally.

Groundwater monitoring programmes operate at the international, transboundary, national (basin scale), site specific and early warning levels. The objective of each of the above programme governs the extent of the monitoring activities, such as the number and construction of monitoring wells, design of monitoring networks, number of variables analysed, monitoring frequency and methods of groundwater observation and sampling.

Transboundary groundwater monitoring networks are essential for a joint data collection, assessment and sharing between riparian countries and for sustainable management and effective protection policy of transboundary aquifers. The UN Convention on the protection and use of transboundary watercourses and international lakes (Helsinky, 1992) and UNECE Guidelines on Monitoring and Assessment of Transboundary Groundwaters (2000) both endorsed harmonization of rules and standardization of methods for establishment and operation of transboundary monitoring networks. Monitoring networks of transboundary aquifers have to cover recharge area, groundwater storage in transition zone and groundwater upward flow in discharge area. Recharge and discharge areas of transboundary aquifers are almost always in different countries.

National (basin scale) groundwater monitoring networks are designated to measure, collect and assess groundwater data for evaluation of the current status and trends of groundwater resources on the country / basin level. The design of monitoring wells has to permit separate measurement, testing and sampling of individual aquifers.

Site-specific (local) groundwater monitoring networks are established for specific purposes, around e.g. 1/ point pollution sources (waste disposal sites, gas stations, industrial centres) to control pollution plume generation and movement, 2/ groundwater abstraction sites to control groundwater levels decline and spreading of cones of depression, 3/ groundwater dependent ecosystems to timely identify potential groundwater pollution or depletion impact. They also serve for detection of the response of polluted or depleted aquifers to the remediation activities. Great density and special design of monitoring wells related to the pollutant properties, multilevel groundwater sampling of both unsaturated and saturated zones and high observation and sampling frequency are typical for site-specific monitoring programmes.

Early warning groundwater monitoring is an activity or a sequence of activities that makes it possible to identify and to foresee the outcome of a process leading to groundwater pollution and depletion with enough anticipation for measures to be taken in order to change or reduce the magnitude of the impact of the said process. Design of an early warning monitoring system depends on the time needed to take appropriate action with respect to the potential groundwater pollution or depletion problem. This strategy helps in identifying human impacts on groundwater quality while they are still controllable and manageable.

5.1 Mongolian – Russian transboundary groundwater monitoring networks

Absence of groundwater monitoring networks on transboundary and Baikal Basin scale, only few site-specific monitoring networks and groundwater data scarcity are the main obstacles for assessment and transboundary management of groundwater resources both quantity and quality and for elaboration of groundwater related TDA. Establishment and operation of groundwater monitoring networks by implementation of standardized methodology of groundwater observations and sampling as well as establishment of common transboundary database in GIS to facilitate mutual groundwater data sharing between Russia and Mongolia is therefore high priority task of UNESCO Baikal Basin project.

Cooperation between the governments of the Russian Federation and Mongolia on the Selenga River and Baikal Basin scale is currently governed by the "Agreement on the Protection and Use of Transboundary Waters" signed in Ulaanbaatar 11 February 1995. The agreement established a Joint Task Force, chaired at the Minister-level, to facilitate mutual cooperation and to protect Selenga River Basin.

The following specific joint issues have been formulated within Russian and Mongolian transboundary water agreement related to the Selenga watershed: hydro-meteorological observations, studies of water quality and quantity, protection of waters against pollution and depletion, pollution monitoring, regulation and protection of high-flow and low-flow period waters, ice passing, agreement of and awareness on the water-industry related activities, protection of fish habitat and ecosystems.

Baikalpriroda, Russian Federal Environmental Agency on Baikal, has been entrusted to coordinate with Mongolia all transboundary water issues and Selenga River watershed in particular. With respect to the significant Mongolian portion of the Selenga River watershed federal funding support is oriented on strengthening monitoring capacity in the Selenga and Tuul River Basins, restoring water quality on the Tuul River (especially downstream reach affected by urban areas and mining sites), and treatment of waste water discharging into these two rivers.

The development project "On the joint activities to provide the sustainable use and protection of the Selenga River Basin" was the main topic of the meeting of the Commission in the frameworks of the Agreement (Ulan-Bator, April 17-18, 2008). The Parties discussed the perspectives of extension of the Selenga river basin SIUPWO concept up to the level of the joint programme "Integrated Selenga River Transboundary Basin Management". The impact of the whole complex of environmental factors on the Selenga river basin ecosystems condition has been proposed to be solved under the project.

Transboundary water monitoring network has been established and is operating however, only in case of **surface water**. Groundwater transboundary monitoring system both quantity and quality has not been established till this time. There is no evidence about groundwater quality and quantity flowing across Mongolian – Russian boundary, particularly in shallow aquifers hydraulically connected with surface water in Selenga and other transboundary rivers.

To fulfil the Russian and Mongolian "Agreement on the Protection and Use of Transboundary Waters" the proposal on establishment of **transboundary groundwater monitoring networks** as well as standardized methodology for groundwater observation and sampling, monitoring frequency and monitoring data management and assessment in GIS and mutual groundwater data accessibility and exchange between Russia and Mongolia is one of TDA priority of UNESCO IHP project.

Proposal on transboundary groundwater monitoring network in shallow aquifer in Selenga and Orkhon Rivers floodplain

Transboundary surface water monitoring network has been established in Selenga River and surface water quality and surface water outflow from Mongolian territory both are regularly observed. However, total water runoff on Mongolian – Russian border can only be estimated because transboundary groundwater monitoring was not established as yet and relevant groundwater data are not available. Implementation of transboundary integrated surface water and groundwater resources management requires therefore, establishment and operation of groundwater monitoring network with the scope to: 1/observe and calculate on Mongolian - Russian border transboundary groundwater runoff and quality and 2/ timely identify and control potential groundwater transboundary pollution transport.

Based on hydrogeological investigation shallow and deep aquifers have been mapped in transboundary floodplain of Selenga River and its confluence with Orkhon, Kharaa and Eroo Rivers. The thickness of highly productive shallow aquifer in fluvial deposits of the Selenga River amounts according to the resistivity survey 100 – 150 m. The yield of tested boreholes was in the order of tens litres per sec.

Shallow aquifers of moderate productivity compost by permeable (sands, gravels) and low permeable (silt and clay) unconsolidated deposits are developed along the Selenga River floodplain. Deeper aquifers in sandy loam and effusive, magmatic and metamorphic rocks are generally of low permeability and productivity. Groundwater movement in these aquifers is registered on fractured zones only. With respect to the transboundary groundwater flow, deeper aquifers with long term residence time are not considered to be included in the monitoring system.

Eight monitoring wells have been proposed in the transboundary groundwater monitoring network on Mongolian territory of the Baikal Basin. Wells location in shallow aquifer in fluvial deposits of floodplain areas of the rivers Selenge and Orkhon) and their design and depth (in average 100 m) both respect hydrogeological condition on the transboundary area (Figure 5.1). Sitting of monitoring wells will be correlated with surface water monitoring stations and it can be expected that in the transboundary meteorological station is also in operation. Loggers for automatic measurement of groundwater level, temperature, pH, electric conductivity, redox potential, salinity are proposed to be installed on monitoring wells. Measurements of such parameters will provide data for evaluation of transboundary groundwater runoff and groundwater quality and will also serve as early warning in changes of groundwater quality owing to pollution. Seasonal, specifically oriented groundwater chemical analyses (2-4 per year) are proposed to control potential transboundary pollution transport related to the mining and industrial activities on Mongolian territory of the Baikal Basin.

Establishment of 2–3 monitoring wells located closely to the border in shallow aquifers in floodplain area of Selenga River on Russian territory is recommended, to make possible mutual control of monitoring data acquired from monitoring wells on both sides of the boundary.

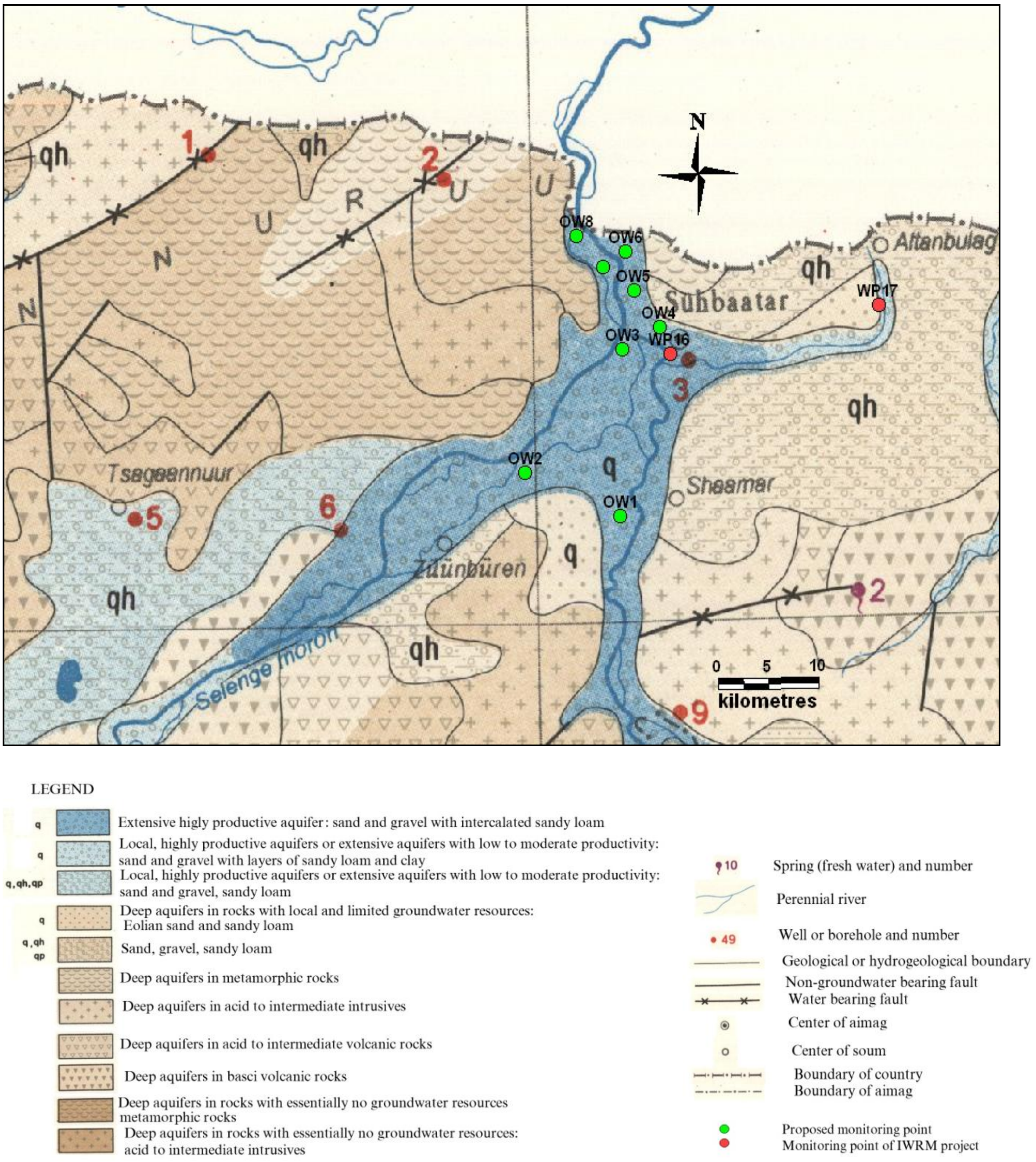

Figure 5.1 Proposed transboundary groundwater monitoring network in shallow aquifer in Selenga and Orkhon Rivers floodplain

Proposal of transboundary groundwater monitoring networks in shallow aquifer in the floodplain of the River Kyakhtinka

The River Kyakhtinka, one of the most polluted river in Buryatia Republic, flows from Russia to Mongolia. On Mongolian territory the river Kyakhtinka joins the River Buryn Gol, the tributary of the River Orkhon. Waste waters from Kyakhta town are only poorly treated and there are the main source of Kyakhtinka River pollution. In the year 2006 uncontrolled discharge of untreated waste water occurred and river has been heavily polluted. Construction of new waste water treatment facility is planned in the year 2014.

The shallow aquifer in Kyakhtinka River floodplain is composted by middle-grained sands with crushed rocks of 8m thick. Deeper weathered schist and gneisses are heavily fractured. Deep tectonic structures (the North-Mongolian fault, the Khilokskiy fault) affect groundwater flow and formation of deeper aquifers. Groundwater flow depends on degree of permeability of fissures and cracks however, aquifer productivity is generally low as well as groundwater recharge due to low precipitations (200– 300 mm per year). The wells yield is in order of tenths l/sec and groundwater mineralization is up to 240 mg/l.

Establishment of transboundary groundwater monitoring network is proposed to control potential pollution transport from Kyakhta town. Polluted river water may seasonally infiltrate into adjacent shallow aquifer and degrade groundwater quality. Four monitoring wells located in shallow aquifer on both banks of Kyakhtinka River on the Russian – Mongolian border are proposed to regularly control groundwater quality and potential pollution transport from Russian territory to Mongolia. However, location of the monitoring wells has to be based on hydrogeological and geophysical investigations.

Proposal of transboundary groundwater monitoring networks in shallow aquifer in the floodplain of the Chikoy River

The Chikoy River stretch about 90 km length forms the boundary between Russia and Mongolia. The boundary area is only little populated and agricultural activities prevail. Hydrogeological investigation of shallow aquifer in the floodplain of the Chikoy River may be proposed to identify possible hydrological interaction between surface water and shallow groundwater and decide if construction of transboundary groundwater monitoring network will be needful.

5.2 Proposal of groundwater monitoring network on Mongolian and Russian territories of the Baikal Basin

In **Mongolia** groundwater monitoring networks on the Baikal basin scale as well as on the country scale have not been established as yet. However, surface water monitoring network on the country level operates several year. Social and economic development in Mongolia depends very much on groundwater resources. Establishment and operation of groundwater monitoring network on the Baikal Basin scale is therefore proposed to provide data for sustainable development and management of groundwater resources, groundwater protection policy and integrated water resources management in Mongolia.

In **Russia** groundwater monitoring network established on the Baikal Basin scale does not exist. However, groundwater monitoring networks on the Federal and National levels operate and several monitoring wells are located in the Baikal Basin. Monitoring data from these wells can be used for evaluation of quantity and quality of groundwater resources in Russian territory of the Baikal Basin.

In the **Irkutsk part of the Baikal Basin** monitoring of ground water both quantitative and qualitative is implemented by Irkutsk Regional Centre of monitoring of geological environment on 16 monitoring wells which are part of the Federal monitoring network (Figure 5.2). Monitoring wells are located in areas where groundwater regime is under different human impact. On 5 monitoring wells (Sludyanka, Talaya, Kulktuk, Onguryen, Popovo) groundwater system is observed in natural conditions, 3 monitoring wells (Kharantzy, Buguldeika, Shara-Tagot) are located in the area where groundwater regime is only slightly impacted and 2 monitoring wells in areas (Baikalsk, Angarskie Khutora)where groundwater regime is heavily man-made affected.

Measurements of groundwater level, groundwater sampling and extent of chemical analysis are regulated by Federal Directive issued by Ministry of Natural Resources of Russian Federation. Due to reduced financial resources groundwater monitoring is made actually one time in 3 months in winter and one time per month in summer seasons. Basically shallow aquifers are observed. Monitoring wells design and measurements are made according to the monitoring directive.

The Federal groundwater monitoring network established at the Baikal watershed in the **Buryatia Republic** in the year 2011 and 2012 (Figure5.3) includes 8 regional profiles composed by 35 monitoring wells located in the central, southern and western areas of Pribaikalia. All monitoring wells are sited in the Baikal Basin and groundwater quantity and quality is observed. Groundwater monitoring in Transbaikalia, is realized many years under the Federal monitoring network on 17 monitoring wells. During last years continuous groundwater level decline has been registered.

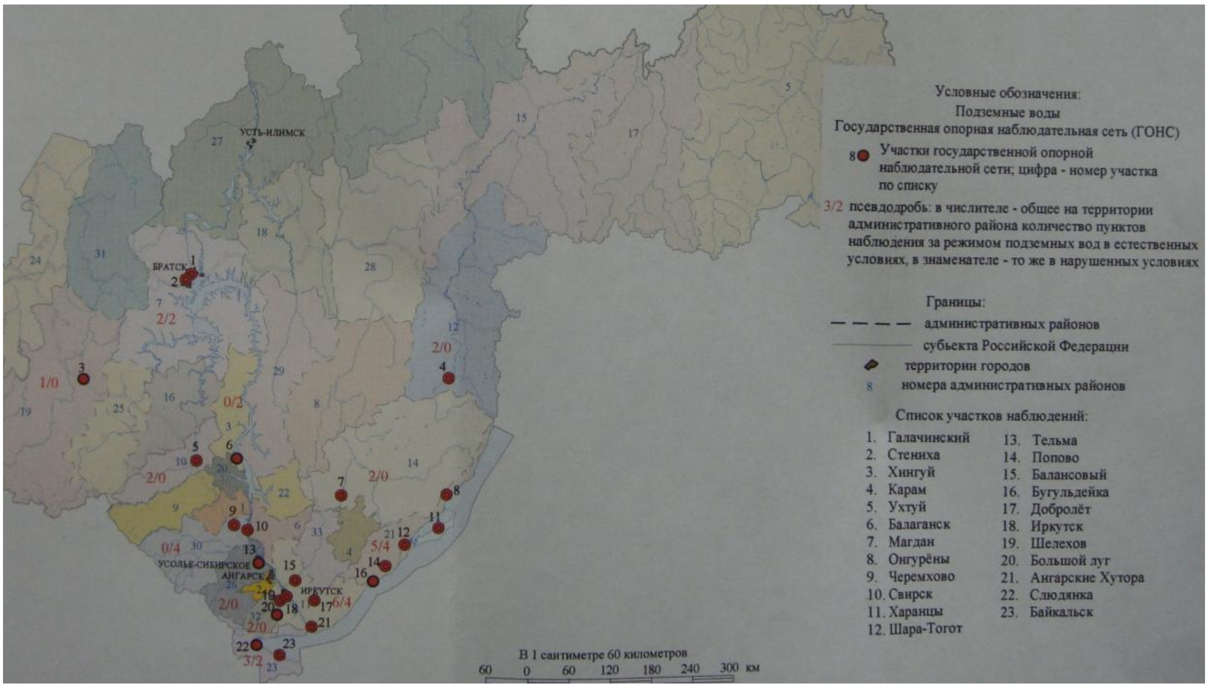

Figure 5.2 Federal ground water monitoring network in Irkutskaya oblast

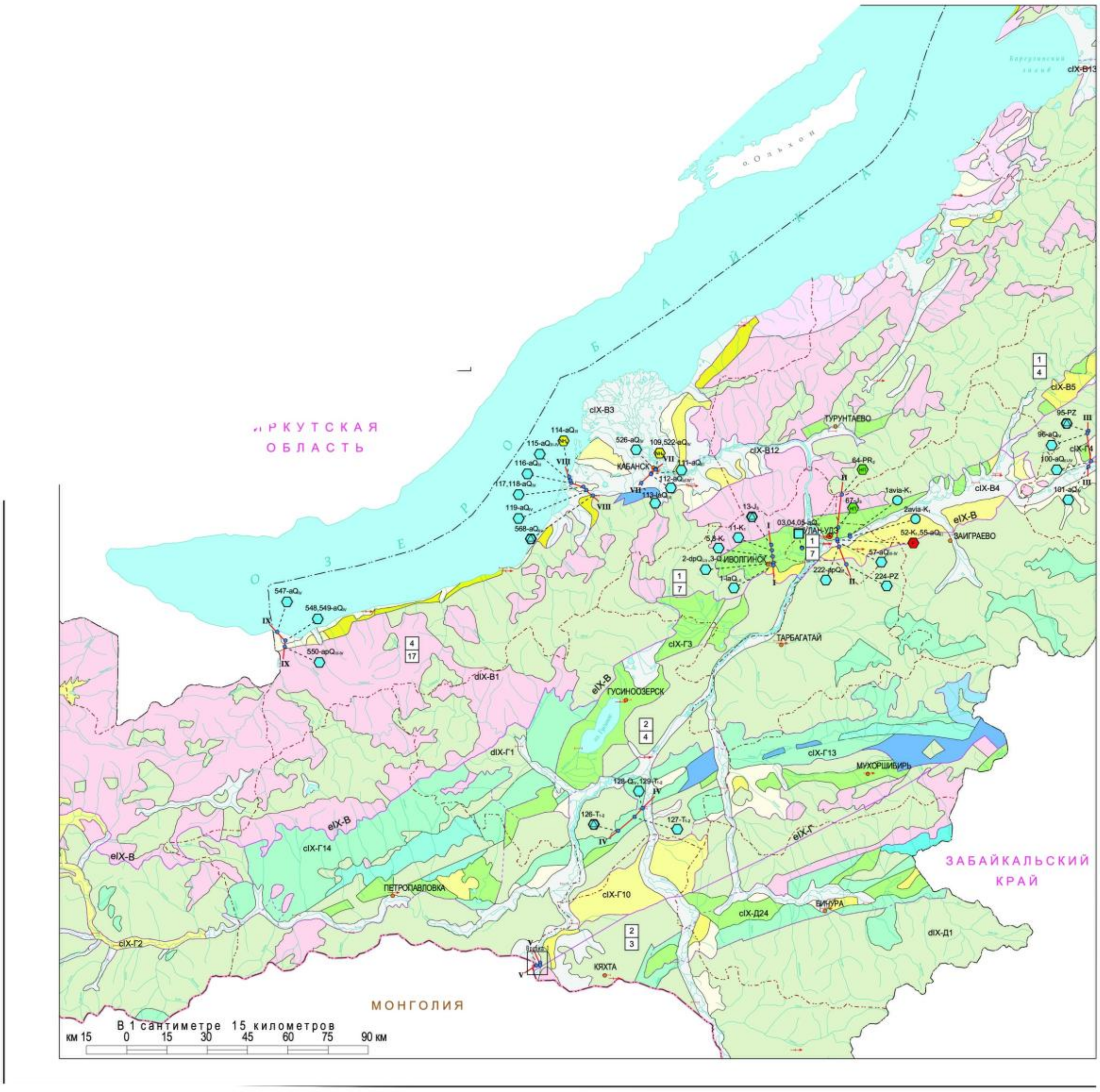

Figure 5.3 Federal ground water monitoring network in the Buryatia Republic

Data from monitoring wells located in the Baikal Basin and observed under the Federal and National monitoring networks may be also used for assessment and management of groundwater resources in the Russian part of Baikal Basin. Such monitoring wells have to be identified and data from these wells included in the Baikal Basin water database. Drilling of additional monitoring wells will complete groundwater monitoring network on the Russian territory of the Baikal Basin encompassing also existing monitoring wells of Federal monitoring network located in basin.

5.3 Site specific groundwater monitoring networks

Site- specific groundwater monitoring networks are established around different types of existing or potential point pollution sources and groundwater abstraction sites. However, till this time the site-specific groundwater monitoring networks in both countries, Russia and Mongolia, have been established only around few potential pollution sources and water supply facilities. Many industrial, mine and municipal waste disposal sites are not well constructed and leakages of liquid wastes are not controlled and monitored. Waste water from many cities, factories and mines are not or only poorly treated and their potential impact on groundwater environment is not regularly observed. Depletion of groundwater resources and decline of groundwater levels are not observed in many groundwater abstraction sites.

Control over the potential pollution sources and groundwater abstraction sites have to be strengthened by obligatory monitoring of groundwater quantity and quality to support groundwater protection policy and management. Related financial resources have to be settled by potential polluters, based on polluters pay principle policy. Governmental institutions, water supply organizations and potential polluters from industrial, mining and agricultural sectors in both countries have to be prepared to accept the need for operation of site–specific and early warning groundwater monitoring networks. The reality in the field and the costs of restoration of polluted aquifers suggest that groundwater monitoring may be considered as an important cost-benefit approach for preserving the good state of groundwater as a strategic source of drinking water and valuable component of the environment.

Site-specific groundwater monitoring networks in Mongolia

In some large cities site–specific groundwater monitoring networks have been established around groundwater supply systems. In the Tuul River basin groundwater monitoring is realized around water supply wells of the Central and Upper water supply systems of Ulaanbaatar by Water Supply and Sewerage Authority of Ulaanbaatar (USUG), by Institute of Geoecology of Academy of Science (4 monitoring wells), Mongolian University of Science and Technology (MUST) 3 monitoring points and Water Authority in the Central water source of Ulaanbaatar. Groundwater level fluctuation and on some monitoring wells also temperature, pH, electric conductivity are observed. On groundwater supply wells are regularly analysed groundwater chemical and biological parameters.

Under the Mongolia and the Netherlands project focused on integrated water resources management (IWRM) in Mongolia 17 monitoring wells have been drilled and screened in Tuul-Orkhon River Basins and 16 wells are regularly observed (Figure 5.4). Two wells are located closely to the Mongolian – Russian border (Figure 5.1) and may be included in the planned groundwater transboundary monitoring network. Monitoring wells realized within IWRM project control significant area of the Mongolian territory of the Baikal Basin and can be included in the Baikal Basin groundwater monitoring network that establishment is strongly proposed. All wells are well documented and groundwater level is automatically measured from the year 2012.

In the Kharaa River Basin 4 monitoring wells have been constructed under the project called “MoMo” (Model region Mongolia) supported by the German Ministry of Education and Research. Groundwater level and temperature are measured in 3 wells located inside the water supply system and 1 monitoring well in the Power Station of Darkhan city.

Some large mining companies operate groundwater and surface water monitoring networks to control mining impact on water resources. E.g. Erdenet copper mine observes on monitoring wells groundwater quantity and quality. Boroo gold monitoring network is composed by 5 monitoring wells and groundwater level is regularly observed.

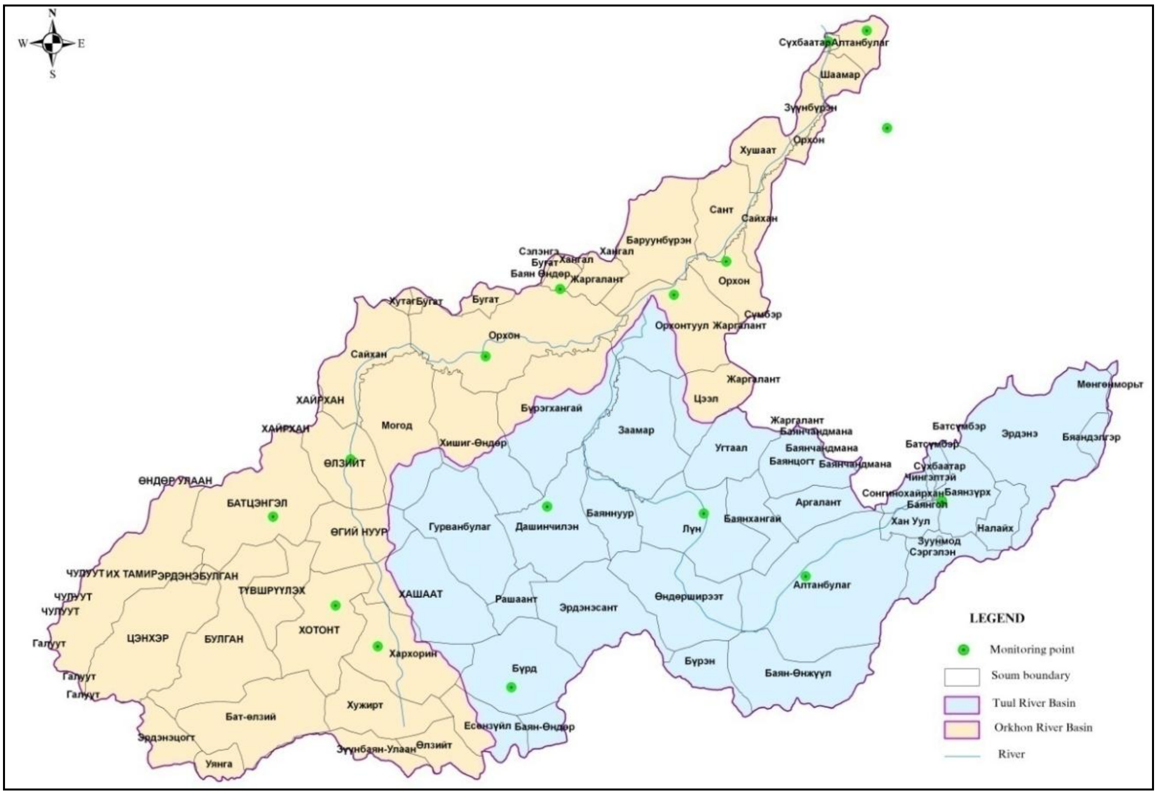

Figure 5.4 Location of groundwater monitoring wells established under IWRM programme

Site specific groundwater monitoring networks in Russia

In Irkutsk part of the Baikal Basin site-specific groundwater monitoring networks have been developed and operate around Kultuk municipal waste disposal site, Sludyanka water supply system and Baikalsk Cellulose-Paper Combine. On 40 monitoring wells is regularly observed groundwater level and selected chemical components.

In the Buryatia Republic site-specific groundwater monitoring networks compost by 14 monitoring wells have been developed and operate around industrial sites in Ulan – Ude and Gusinoozersk. In Transbaikalia groundwater monitoring system composed by 5 monitoring wells is in operation around water supply system of Petrovsk-Zabaikalsky several years. Groundwater level and chemistry are recorded.

Generally, in the above mentioned three territories site-specific groundwater monitoring networks are established around some water supply systems and groundwater level and selected chemical components are regularly observed. Monitoring activities realized around groundwater abstraction sites for public water supplies are controlled by Rospotrebnadzor authority. Groundwater monitoring to control groundwater pollution is realized also in the Baikal Cellulose-Paper Kombine (BCBK) and the Selenga Cellulose-Cardboard Combine (SCKK).

6. Climate change influence on groundwater resources

Influence of climate change on groundwater resources is not regularly monitored on the Baikal Basin. Generally two types of aquifers can be distinguished with respect to the potential impact of the climate change.

Deep aquifers with groundwater long term residence time and renewal period in thousands of years or even millennia in case of fossil groundwater infiltrated under the past hydrological and climatic conditions. Influence of climate change (registered last decades) has not been observed in case of deep aquifers with renewable and non-renewable groundwater resources.

Shallow aquifers with groundwater residence time in days up to hundreds of year. Influence of changes of temperature and precipitations on river runoff and adjacent shallow aquifers have been observed in both Mongolian and Russian territories of the Baikal Basin. Decrease of groundwater levels and groundwater storage has been registered in several shallow aquifers however, in some areas where precipitations increased reverse trend in groundwater levels has been observed too.

Specific attention should be given to the groundwater occurrence and groundwater resources availability in permafrost areas where seasonal thawing of the soil layer is continuously increasing.

Establishment of monitoring networks and regular groundwater level and quality observation of shallow aquifers in floodplain areas and aquifers in permafrost correlated with climate and surface water monitoring networks will significantly support the studies focused on climate change influence on groundwater recharge and shallow and permafrost aquifers.

6.1 Climate change influence on groundwater in Mongolian territory of Baikal Basin

Changes in glacier extent and volume, water level, water temperature and shifting of freezing and thawing dates of rivers are significant indicators of climate variability and change. With respect to the groundwater, shallow aquifers in fluvial deposits in floodplains of the rivers are most vulnerable to the climate change.

According to the records from 48 meteorological stations distributed over the territory of Mongolia, the annual mean temperature of Mongolia increased by 2.1ºC during the last 70 years. Precipitations changes in Mongolia differ regionally: since 1961 in the Altai mountain region, Altai Gobi and in the eastern part of the country precipitations increased, and in all other country regions decreased by 0.1-2.0mm/year [MARCC, 2009].

Groundwater level measurements in shallow aquifers indicate decreasing trend in correlation with current changes occurring in surface water runoff. E.g. groundwater levels within last 12 years (1997-2009) dropped in the Muren (forest steppe zone) by 0.55 m, in Arvaiheer (steppe zone) by 3.0 m, and in Ulaanbaatar by 2.0-6.0m.

Recent groundwater monitoring study of the Tuul River floodplain shows dependence of recharge of shallow aquifers on precipitations. 70 % of precipitations occur during the summer months (April - August) and related groundwater level rise is recorded (Figure 6.1). Groundwater level declines in the winter and spring seasons, when precipitations are low. Above described relation between amount of precipitations and groundwater level fluctuation have been registered by regular observation on monitoring wells (Naranchimeg., et al, 2011).

Seasonal changes in groundwater flow and chemical composition are observed too. During summer seasons river water discharges in the shallow aquifer, during winter seasons groundwater discharges in the rivers. The groundwater chemistry also slightly seasonally change; Ca-Mg-HCO3and Ca-Na-HCO3 types of water prevail during summer and Ca-HCO3 type in winter.

Soil moisture increases due to melting of permafrost has been observed in some areas of the Mongolian territory of the Baikal Basin. Seasonal thawing of the soil layer in the permafrost region has increased by 0.1-0.6 cm in the Khentii and Khangai mountains and by 0.6- 1.6 cm in the Khuvsgul Mountains over the past 30 years. Permafrost phenomenon such as thermokarst, solifluction, thermo erosion has been registered over the last 50 years too. The thermokarst process advances approximately 5-10 centimetres per year and in some places reaches even 20-40 cm per year [MARCC, 2009].

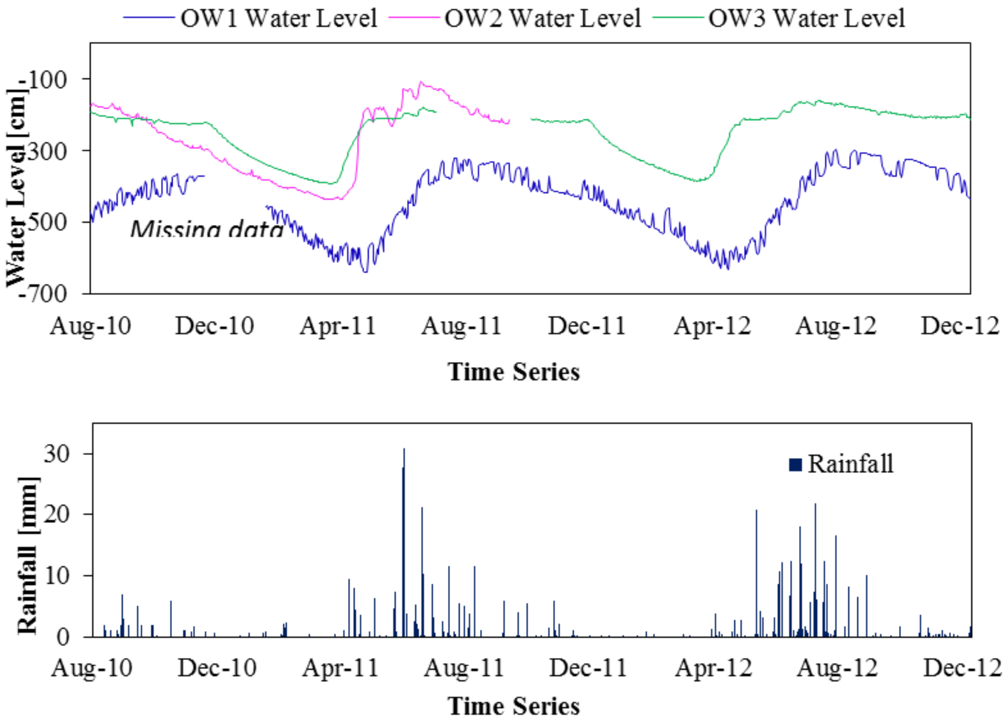

Figure 6.1 Groundwater level fluctuation registered on monitoring wells OW1, OW2 and OW3 and daily rainfall data both valid for Ulaanbaatar central groundwater supply area (21 Aug 2010 to 30 Dec 2012)

Rivers flow decrease by 30-40% of their long-term average has been registered in last 40 years in the rivers flowing from Khangai, Hentii and Ikh Khyangai mountain ranges. Slight increase of Selenga River flow has been observed in autumn and winter seasons. It may be expected that similar changes occurred also in groundwater levels. However, groundwater level monitoring was not realized.

According to the surface water inventory conducted in 2011, about 641spring (Bulgan-206, Selenge-56, Khovsgol-170, Arkhangai-202, Darkhan-2, Orkhon-5) dry up in Mongolian territory of the Baikal Basin.

6.2 Climate change influence on groundwater resources in Russian territory of the Baikal Basin

The statistically based reliable trend has been registered in air average annual temperatures in the studied area (Fig.6.2).

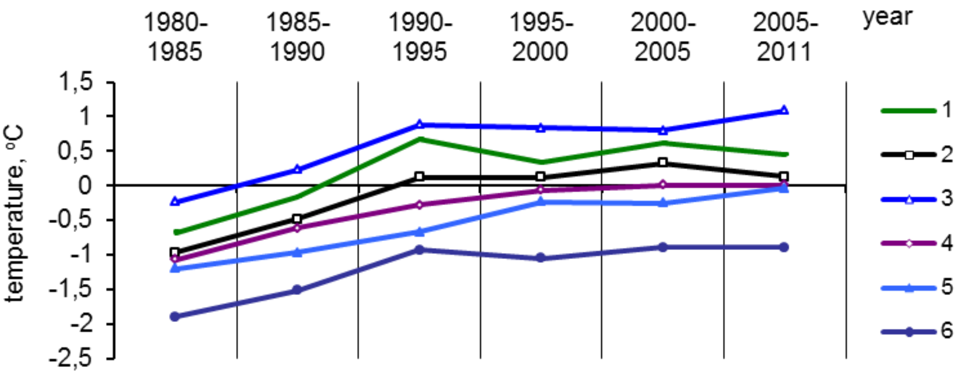

Figure.6.2 Average annual temperatures observed from 1880 to 2011 on monitoring stations in Kabansk (1), Ulan-Ude (2), Kyakhta (3), Novoselenginsk (4), Petropavlovka (5), and Novaya Kurba (6).

The changes in annual precipitations vary in monitoring stations located in different areas of the studied basin. Precipitations without changes or with slight decrease have been observed in the forest-steppe and steppe zones of the studied area (Ulan-Ude, Novoselenginsk, Kabansk, Kyakhta, Novaya Kurba). Continuing precipitations increase has been registered in the southern mountain areas (Petropavlovka) of Russian territory of the basin. Based on evaluation of data of annual precipitations, the precipitation increase reached 11, 6 mm in last 30 years in Petropavlovka station (River Djida basin). The decreases of precipitations amount to 47,7 mm in Kabansk station and 25,5 mm in Novoselenginsk station during the last 30 years; both above stations are located in low and middle reaches of the Selenga River. The slight long-term trend in precipitations decrease has been observed at the other monitoring stations located in the basin.

The comparison of average annual rivers runoff in the period 2000-2010 with the relevant data from the previous years indicates decrease in the runoff from 24-39 % in the Rivers Selenga, Chikoy, Khilock and Uda. In winter season the rivers runoff is largely supported by groundwater. Based on available data the groundwater discharge increased in the Rivers Selenga (on the Russian – Mongolian border), Chikoy, and Uda over the last decade of about 17,6, 10,5 and 19,2 % respectively. The share of groundwater discharge in the total runoff of the Rivers Khilock, Djida and Temnik corresponds to 6,6, 4,3 and 4,8 % respectively (Khazheeva and Plyusnin, 2012). The revealed climatic changes influenced the river runoffs and decrease of groundwater level and resources in the shallow aquifers in many areas of the River Selenga Basin.

7 Groundwater priority issues of transboundary concern

At present, little is known about the quality and quantity of transboundary groundwater resources shared between Mongolia and Russia. Groundwater data scarcity is the main obstacle for the assessment, sustainable management and environmentally sound protection of groundwater resources in the Baikal Basin, inclusive of basin transboundary areas. However, lack of coordination in transboundary groundwater resources management and protection policy and insufficient knowledge about surface water and groundwater hydrological interface are other challenges which has to be address as important transboundary groundwater priority issues.

The following groundwater priority issues of transboundary concern are proposed and endorsed within the UNESCO project:

- Design and operation of a groundwater monitoring programmes for the Baikal Basin and transboundary area on both sides of Mongolian – Russian boundary including establishment of a standardized methodology for groundwater observation and sampling and harmonization of monitoring frequency in both countries.

- Establishment of a transboundary water database in GIS and formulation of legal and technical principles of transboundary water related monitoring data assessment and management and their mutual accessibility and free exchange between Russia and Mongolia.

- A transboundary evaluation of the existing and potential pollution and depletion threats on groundwater resources.

- Investigation and evaluation of conditions of interface between surface water and groundwater with respect to the potential conjunctive use of groundwater and surface water resources at the transboundary level and Baikal Basin scale

- Hydrogeological investigation and groundwater monitoring and mapping with the scope to collect reliable data for groundwater resources evaluation both quantity and quality on the transboundary level and Baikal Basin scale

7.1 Russian–Mongolian transboundary agreement on the protection and use of transboundary waters

Transboundary bilateral cooperation between the government of the Russian Federation and the government of Mongolia on the Selenga River and Lake Baikal Basin scale is currently governed by the “Agreement on the Protection and Use of Transboundary Waters” signed in Ulaanbaatar in February 1995 and the Treaty on the Regime of the Russian-Mongolian State Boundary (Section II “The regime of utilization of the boundary waters…” Arts. 10-14) signed in September in 2006 in Moscow.

The agreement established a Joint Task Force, chaired at the Minister-level, to facilitate cooperation in protection of Selenga River. The goal was to complete a land-use plan and its implementation schedule between the two countries by 2010. On April and May of 2008 two other meetings of the Joint Russian-Mongolian Task Force have been realized. Baikalpriroda, Russian Federal Environmental Agency on Baikal, has been entrusted to coordinate with Mongolia all transboundary water issues and Selenga River watershed in particular.

The following specific joint transboundary topics have been formulated within Russian and Mongolian water related agreement: hydrometeorological observations, studies of water quality and quantity, protection of waters against pollution, littering and depletion, regulating and protection of high-flow and low-flow period waters, ice passing, agreement of and awareness on the water-industry related activities. At the same time, the objective to develop the general scheme for the Selenga river basin waters is not setting till now.

With respect to the Mongolian portion of the Selange River watershed federal funding support is oriented on strengthening monitoring capacity on the Selenga and Tuul Rivers, restoring water quality of the Tuul River (especially downstream reach affected by urban areas and mining sites), and purifying waste water discharged in the above two rivers.

7.2 Groundwater transboundary monitoring programmes and groundwater database in GIS

Transboundary surface water monitoring network has been established and is operating however, groundwater transboundary monitoring network has not been developed and there is no evidence about groundwater quality and quantity flowing across Mongolian – Russian boundary, particularly in shallow aquifers hydrologically connected with surface water in Selenga and other transboundary rivers.

To obtain the necessary data for informed management decisions it would be recommended for Mongolia and Russia Governments to establish a transboundary network for monitoring changes in groundwater both quality and quantity. Together with already existing surface water transboundary monitoring system data from regular groundwater monitoring network will facilitate and support calculation of total transboundary water runoff (surface water and groundwater), assessment of exploitable groundwater resources and identification of transboundary water pollution transport. Transboundary and other monitoring programmes and networks have been discussed and proposed in the chapter 5.

The following high priority groundwater issues of TDA are pointed out as an important outcome from UNESCO IHP project:

- proposal on design and operation of groundwater monitoring networks on the Baikal Basin scale and transboundary level on both sides of Mongolian – Russian boundary and on establishment of a standardized methodology for groundwater observation and sampling and for harmonization of monitoring frequency in both countries,
- proposal on establishment of transboundary water database in GIS, and
- formulation of legal and technical principles of transboundary monitoring data collection, assessment and management and their mutual accessibility and free exchange between Russia and Mongolia.

Such a collaborative effort would link closely to the “Agreement on Protection and Use of Transboundary Waters “signed by the Governments of Mongolia and Russia.

7.3 Pollution and depletion threats on groundwater system

Pollution threats on groundwater are registered both in Russia and Mongolia. Toxic pollutants may originate particularly from mining and processing of gold and molybdenum ore bodies and from some industry activities. Even if groundwater pollution from above sources is mostly of local (site – specific) extent, due to the groundwater hydrological interface with streams, surface water may be polluted by groundwater and pollution transported over Mongolian – Russian boundary. However, similar process of transboudary pollution may occur also by leakages from uncontrolled municipal waste disposal sites. Particularly due to location of the mining and industrial facilities and uncontrolled waste disposal sites on floodplains in the rivers valley highly vulnerable shallow aquifers may be polluted and appreciable probability of groundwater pollution transboundary transport exists.

7.3.1 Impact of mining activities on groundwater

Mining activities have the strongest impact on groundwater resources in Baikal Lake Basin. Mining and minerals processing (gold, molybdenum, tungsten, zinc, coal and others), have been carried out on a large scale for a long time both in Mongolia and Russia. Mining of the mineral deposits is pursued by open pit and deep mines with plenty use of water. Some private mining companies illegally use mercury for gold separation and produce water toxic pollution. Only a few per cent of useful mineral components are extracted from the rocks, and 90-95% of recovered rocks are handled as the wastes. Tens of millions of tons of ore tailing with 3-4% sulphide mineralization are stored in the River Selenga catchment and due to on-going oxidation processes there are extremely danger source for groundwater pollution. Storage of wastes is often realized by so called dam method that only protects deposits of tailing from mechanical dispersion in the surrounding area, but it does not solve the migration problem of toxic components in solutions in groundwater system. Ore components are leached by atmospheric and surface water as well as by groundwater. Site specific groundwater monitoring systems to control water quality and groundwater depletion around mines and disposal sites of mine wastes are mostly missing both in Russia and Mongolia.

The following activities are proposed to control groundwater and surface water quality against pollution produces by mining activities with the scope to protect water resources quality and to support environmentally sound protection policy:

- investigate and evaluate the extent of groundwater pollution in the large mining districts in Mongolia and Russia,
- evaluate mineral compositions of large disposal sites of mining wastes (often toxic) and chemical composition of their leachates and propose effective protective technology for waste disposal sites passive isolation or active containment, and possible treatment,
- study of transport and transformation processes of toxic components produced by mining activities in the unsaturated and saturated groundwater system with the scope to reduce pollution impact on groundwater resources quality,
- establish and operate site specific monitoring system around mining districts to control pollution leakages and protect groundwater resources quality, and
- by the same monitoring system control impact of mine dewatering and groundwater abstraction for ore processing on local private and public water supply systems, irrigation facilities or ecosystems (groundwater level decline, groundwater resources depletion).

7.3.2 Impact of industrial and municipal waste disposal sites on groundwater quality

Impact of industrial and municipal waste disposal sites on groundwater quality is registered in the Lake Baikal catchment in many industrial areas and municipal and rural settlements. Produced wastes are stored in the waste disposal sites surrounding the industrial facilities and closely to municipal areas and rural settlements. Over the time wastes are transformed under influence of the weathering agents, partially dissolved and produced fluids or leachates migrate through the unsaturated zone and pollute saturated aquifer.

Many waste disposal sites are sited in the fluvial deposits in the floodplain areas where groundwater level fluctuation is under the influence of surface water flow in the rivers. Fluctuation of groundwater table may reach several meters and depends on seasonal changes in the river flows. Toxic substances and other pollutants may be therefore washed out from uncontrolled waste disposal sites in the river valleys, move through to unsaturated zone and pollute the aquifer. Further, during river low flows polluted groundwater may discharge into the surface water. Pollutants are carried by the rivers and finally reach the Lake Baikal.

The following activities are proposed to protect groundwater against industrial and municipal pollution of groundwater:

- investigate and evaluate waste disposal sites of big industrial facilities or industrial factories or services producing toxic wastes and propose measures for pollution control and protection of groundwater quality,
- identify uncontrolled disposal sites of industrial or municipal hazardous wastes located closely the water supply systems or aquifers with significant groundwater resources and propose measures for safe operation of disposal sites inclusive of proposal on disposal site closing,
- propose technology for construction of controlled landfills encapsulated by impermeable barrier of low transmissivity and high attenuation and adsorption capacity for potentially leachate fluids, in the landfill bottom with drainage leachate system and treatment technologies for leachates recycling, neutralization and/or decreasing of their toxicity, and
- establish and operate site specific monitoring system around waste disposal sites both controlled and uncontrolled to observe potential pollution leakages and propose groundwater site – specific protective measures.

7.3.3 Impact of turf degradation processes on groundwater quality in shallow aquifers and on Baikal Lake

Intensification of processes of turf degradation has been registered on the areas with drained land. Turf degradation occurs with formation of large quantities of ammonium under low temperature conditions. The groundwater polluted with ammonium and other products of turf decomposition (i.e. toxic components) discharges into shallow groundwater, rivers and the Lake Baikal. Such pollutants have been identified by regular monitoring of coastal water of the Lake Baikal. The extent of turf decomposition by processes occurring in the drained land in the coastal zone of the Lake Baikal has not been investigated till this time.

Usefulness of the study and monitoring of processes occurred due to the turf degradation and related pollution transport by groundwater runoff from drained land into the surface water and the Lake Baikal is pointed out.

7.4 Investigation and evaluation of conditions for interaction between surface water and groundwater with respect to their potential conjunctive use on the transboundary level and Baikal Basin scale

In the Baikal Basin little is known about surface water and groundwater interface. Groundwater and surface water monitoring stations are not available and relevant data about both resources are missing. At the transboundary level and Baikal Basin scale there are proposed therefore comprehensive studies and groundwater investigation focus on evaluation of hydrological interactions between surface water (rivers, lakes) and groundwater (aquifers) and on potential of conjunctive use of both resources for social and economic development. Such interactions may be expected in extensive valleys of the Rivers Selenge, Orkhon and other big rivers and in their confluence areas mostly with thick and permeable fluvial deposits. Interactions between surface water and groundwater seasonally change, during dry season groundwater discharges into the streams, in wet season surface water discharges into adjacent shallow aquifers. Such situation is known e.g. in dry seasons in Tuul River below Ulaanbaatar. Surface water flow as well as groundwater base flow disappeared (also by groundwater level decline due to pumping) and river is seasonally drying. However, river flow composts by waste water from Ulaanbaatar temporary exists.

Evaluation of groundwater-surface water interaction considering the seasonal changes in groundwater discharge in or groundwater recharge from adjacent river requires establishment and operation of river monitoring stations and groundwater monitoring wells and observation of water level fluctuations (natural and man-made) and water quality of both resources in time and space. Such data will be used for setting up of conceptual model as a first step in GIS data (and their attributes) entry process and grid-based numerical model generation.

Groundwater priority issues of UNESCO project are focused on transboundary and confluence areas of big rivers with extensive development of flood plains and thick permeable fluvial deposits with significant groundwater resources in the shallow aquifers. Establishment of joint surface water and groundwater monitoring networks and start with regular observations of both resources is pointed out. Collection and assessment of monitoring data is a prerequisite for the calibration of a conceptual model and generation of mathematical model, calculation of groundwater resources in shallow aquifers and evaluation of their hydrological interface with surface water considering temporal and longer term changes due to seasonal climate influences (dry and wet seasons) and potential human impacts.

7.5 Hydrogeological investigation and groundwater monitoring and mapping - significant support for groundwater resources evaluation both quantity and quality on the transboundary level and Baikal Basin scale

Groundwater is significant natural resource for social and economic development of Mongolia and Russia. In the Mongolian part of the Baikal Basin almost all big cities as well as many rural areas depend on groundwater supply for drinking purposes. In Russian part of the Basin groundwater is also source of drinking water of many cities and rural areas and supports agriculture and industry development. Assessment of groundwater resources on the transboundary level and Baikal Basin scale based on reliable groundwater data will support sustainable groundwater resources management and environmentally sound protection policy. The main objective of this process is to ensure quantity, quality, safety and sustainability of groundwater as a strategic source for human life (for drinking and other sanitary purposes), economic development (e.g. agriculture, industry), and conservation of groundwater dependent ecosystems. Groundwater intangible value related to the ethical, religious and cultural traditions of the societies living in the Baikal Basin has to be also respected. For some small rural and mountain communities groundwater resources are the key to the poverty alleviation.

However, reliable and and consistent groundwater data about groundwater resources quantity and quality are very scare in the Baikal Basin in this time and with respect to the transboundary shallow aquifers groundwater data are not available at all. Groundwater monitoring programmes and networks at the transboundary level and Baikal Basin scale are not established yet. Knowledge about aquifers property and productivity and groundwater quality is not on the level required for sustainable groundwater resources development, management and protection, calculation of groundwater reserves and resources, control of groundwater pollution and evaluation of groundwater - surface water interface. Understanding aquifer recharge mechanisms and linkage groundwater resources protection with land use planning are further data dependent issues. Due to groundwater data insufficiency there is not possible to 1/observe and evaluate on Mongolian - Russian border transboundary groundwater runoff and groundwater quality and 2/ timely identify and control potential groundwater transboundary pollution transport.

Groundwater monitoring will provide data for assessing the current state of and trends in groundwater system and helps to clarify and analyse the extent of natural processes and human impacts on groundwater in space and time. Credible, accurate and consistent groundwater monitoring data are also needed for formulation of groundwater governance policy and for decision making in emergency situations during natural disasters (floods, droughts, earthquakes).

Hydrogeological investigation and groundwater monitoring activities are therefore important UNESCO priorities which realization will significantly support sustainable development and management of groundwater resources and their efficient protection in the Baikal Basin.