STATE COMMITTEE OF WATER ECONOMY
MINISTRY OF ENERGY INFRASTRUCTURES AND NATURAL RESOURCES
THE REPUBLIC OF ARMENIA

PREPARATORY SURVEY FOR YEGHVARD IRRIGATION SYSTEM IMPROVEMENT PROJECT

FINAL REPORT
(FR)

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JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

SANYU CONSULTANTS INC. (SCI)
ORIENTAL CONSULTANTS GLOBAL CO., LTD. (OCG)

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SUMMARY

OUTLINE OF THE PROJECT

1. Objectives
   1) To distribute stable irrigation water to the Project area,
   2) To improve agricultural productivity in the Project area by the stable irrigation water,
   3) To fulfill the national policies such as; a) conservation of Lake Sevan and b) shifting pump-based to gravity-based irrigation system.

2. Project area and beneficially
   1) Irrigation area: 12,347 ha of agricultural land
   2) 27 communities in Kotayk, Aragatsotn and Armavir Marzes
   3) Number of farm households: 13,574 HHs (Approx. 61,000 persons) as of 2014

3. Main construction facilities

Reservoir		Irrigation System			
1 Capacity	94 MCM	1 Feeder canal 1	Approach canal	L=1,160m	Q=1.11 - 9.0 m^3/s
			Pipeline	φ=1.60m, L=1,600m φ=1.72m, L=1,940m	
2 Dam height	H=25.55m	2 Feeder canal 2	Concrete open canal	W=ave 4.0m, L=330m	Q=2.20 - 13.0 m^3/s
3 Full Water Level	EL.1,305m	3 Outlet canal 1	Pipeline	φ=1.20m, L=730m	Q=0.22 - 2.33 m^3/s
4 Low water level	EL.1,290m	4 Outlet canal 2	Pipeline	φ=1.72m, L=4,700m	Q=0.16 - 12.82 m^3/s (Maximum 13.7m^3/s)
			Dissipater	L=500m	
5 Reservoir area	8.08 km^2	5 Other canals	Rehabilitation	Approx. 65km	-

4. Project cost and schedule (provisional)
   1) Project cost: xxx million USD (including VAT)
   2) EIRR: 7.09% (Based on base case 1)
   3) Implementation; Detailed design: 2017 to 2018, Construction: 2019 to 2022 (4 years)

5. Indicators (Year 2027: 5 years after completion of the construction)
   1) Irrigable area; 8,391ha →→ 12,347ha,
   2) Agricultural production increase (Wheat, Alfalfa, Potato, Grape),
   3) Energy saving by “shifting pump-based to gravity-based irrigation system”, and
   4) Water conveyance from Lake Sevan; 50MCM →→ 0 MCM.

6. Rationale
   - ✓ Government of Armenia places this Project as one of the important projects to fulfill the national policies which are; 1) conservation of Lake Sevan and 2) shifting pump-based to gravity-based irrigation system.
   - ✓ While one-third (1/3) of population in Armenia is living in the capital city of Yerevan, taking accessibility and marketing into considerations, agricultural activities in the Yeghvard directly connect not to only farmers’ income generation, also food security for inhabitants of the capital.
   - ✓ Since Armenian agricultural development strategy towards promoting; 1) cooperated and competitive market-oriented and 2) export-oriented productions for international trading by shaping favorable conditions, farmers concerned in Yeghvard have much advantage to involve in opportunities obtaining agricultural training/information, extension/machinery services, credit and techniques through research institutes available in Yerevan.
   - ✓ While irrigation projects; Kaps and Vedi are under the process of detailed design and tendering stages prior to construction, government will concur in developing infrastructural projects in relation to water resource on agriculture/irrigation sectors.

1. INTRODUCTION

Background of the Survey

After a request for Official Development Assistance (ODA) Loan to the government of Japan was made by the Government of the Republic of Armenia (hereinafter referred to as "Armenia") in June 2012, JICA had executed to gather information related to the construction of Yeghvard reservoir by sending the contact missions as well as sending questionnaire in order to formulate the Project.

In June 2014, JICA dispatched a consultant team for a preliminary feasibility study (Pre-F/S). Since the consultant team conducted a field survey including data/information collection and had a series of discussions with related agencies in Armenia from June through August 2014 and analyzed the collected information prior to prepare a draft final report (DFR) for the Pre-F/S, JICA sent a mission to Armenia in November 2014 for the purpose of explanatory discussion on the DFR. In March 2015, JICA, consequently, sent an official letter decided to dispatch a consultant team for the Full-scaled F/S of Yeghvard Irrigation System Improvement Project (hereinafter referred to as "the Project"). Then, the consultant team (hereinafter referred to as "the Survey Team") have started a preparatory survey for the Project (hereinafter referred to as "the Survey").

**** Since this report was developed based on the situation and the information as of end of September 2016, before the government restructuring, the name and the structure of the government institutions which appear in this report may not coincide with the current ones.***

Project Area

Project area is located in the surrounding area of Yerevan within 20km from the capital city, with 22,754 ha of land area of which 12,200 ha or 53.6 % of the land area is registered as a farmland in cadaster. The Project area expands to 27 communities in three (3) Marzes (regions), i.e. Kotayk, Aragatsotn and Armavir. While the whole territory of 22 communities belongs to the Project area, a part of the territory belongs to the area in other 5 communities. Consequently, 91.2 % of total land area in the 27 communities is included in the Project area.

In terms of WUA category, the Project area is divided into 4 (four) WUA command areas, namely; Yeghvard, Ashtarak, Vagarshapat and Khoy. Potential farmland area for irrigation in the Project area is estimated at 12,347 ha by the Survey Team. The area is larger than the registered farmland area in cadaster as actual cultivated area has extended to non-registered farmland area in many communities in Vagarshapat and Khoy command areas.

2. BACKGROUND OF THE PROJECT

Background of the Project

Water volume stored in Lake Sevan measured 58,000 MCM in late 1940s was reduced to 33,000 MCM in early 1970s due to the heavy water use by domestic/industrial sectors as well as irrigation, as a result water level in the Lake dropped by as much as 19 m. As the conservation measures for Lake Sevan suffering from heavy drawdown of water level, the Government of Armenia constructed a water tunnel for diverting water from other watershed areas during the period 1960s to 1980s and it also implemented the policy of limiting annual water use for irrigation. However, during the period of energy crisis in 1990s, the lake water was again overused, lowering water level.

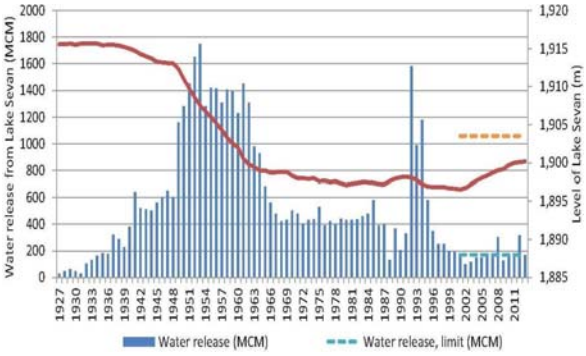
Yeghvard reservoir project was planned during 1970s as one of the conservation measures for Lake Sevan. Later in 1980s, the work with a scale of 228 MCM had been started, but it was later interrupted due to difficulty in fund supply. Later in 1990s, coping with second recession of water

level, reservoir construction plans were studied at 16 sites throughout the country from water conservation point of view. Yeghvard reservoir project was included as one of these countermeasure-plans. The scale of this reservoir was reviewed by the country and reduced to around 90 MCM.

Policy on Water Resources

The Water Code is the principal document adopted by the National Assembly. The main purpose of this Code is the conservation of the national water reserve, the satisfaction of water needs of citizens and economy through effective management of useable water resources, securing ecological sustainability of the environment. And the National Water Policy pursues aim to provide accessibility for sufficient quantity, regime and quality of water resources to maintain basic human well-being for present and future generations, socio-economic system development, and to meet economic and ecological needs. Agricultural water usage priority is higher than the energy and industrial production uses.

Furthermore, in 2001, Armenia launched an environmental improvement strategy for Lake Sevan with the target of elevating its water level by 6m (up to 1,903.5m) by 2030 as shown in Figure 2-1. Additionally, the country has not only determined the upper limit of annual releasing (intake) water volume from Lake Sevan to an irrigation network at 170MCM, but it also decided to operate hydropower stations located along the Hrazdan River only during the period of distributing irrigation water.



Source) World Bank (2014),Towards Integrated Water Resources Management : Revisited

Figure 2-1 Change in Water Level in Lake Sevan

Policy on Agricultural Development

The Armenian people focused their economic activity back to the agricultural sector in order to make utmost efforts to accommodate themselves to the economic crisis after the independence. As a result, the sector was headed for recovery and GDP ratio of the sector grew to 46.3% in 1993. Currently, however, GDP ratio is reduced to lower than half of that of 1993. The current state of agriculture in the country shows that the sector has surpassed the stage of self-subsistence and has entered the next stage of commercialized agriculture that includes vegetables, fruits, industrial crops and livestock, as seen in the USSR era. It is reported that approx. 80% of domestic agricultural production was from irrigated land. Irrigation is a significant infrastructure supporting the country's agriculture.

The government launched its SADS covering the period 2010-2020 as the national policy in order to respond to the commercial-oriented agriculture. SADS aims to enhance productivity and value of agricultural products; to improve food security for the population by distributing products appropriately both to domestic and international markets, and to promote its export (targeting 3.5 times increase in the current export volume). More details of SADS are described as follows;

Sustainable Agricultural Development Strategy (SADS)

Vision (in 2020)

- ✓ Sustainability and competitiveness agriculture,
- ✓ Cooperated and highly competitive, market-oriented production,
- ✓ Sustainable provision of food to the population and meeting the demands of the processing industry,
- ✓ Increase in gross farm produce though increasing labor productivity,
- ✓ Development in SMEs in rural communities,

- ✓ Positive change of intrans sectoral structure of plant and livestock production,
- ✓ Utilization of agricultural potential, especially land resources, and
- ✓ Improvement of food security for the population.

Strategy goal

- ✓ Promotion of industrialization of agriculture (value-addition),
- ✓ Increase in the food security, and
- ✓ Shaping favorable conditions for promoting export-oriented productions.

Production goals of major crops

SADS attempts to increase production of all major crops from the level of 2007, with special focus on increasing production of fruits and grapes, industrial crops, sheep and poultry. Fruits, grapes, industrial crops and sheep are expected to be the driving force of value-addition and exporting of agricultural products. On the other hand, poultry is seen as an import substitute. In addition, SADS aims to increase cultivating areas of forage crops rapidly, as a response to high demand in forage crops from livestock sub-sector.

Agricultural Development Strategy in the Project Area

The SADS specifies agricultural strategies in respective Marzes where beneficial communities of the Project belong to Table 2-1 shows the development strategies of three (3) Marzes, i.e. Aragatsotn, Armavir, and Kotayk.

Table 2-1 Agricultural Development Strategy of Concerned Marzes

Marz	Current Situation	Prospective Situation
Aragatsotn	Dairy-and-meat cattle breeding; potato and fruits production; and cereals farms	Dairy-and-meat cattle breeding; fruits and potato production; sheep breeding; and fodder production
Armavir	Vegetable production; cereal farms; grapes production; meat-and-dairy cattle breeding; potato and fruits production	Production of grapes, vegetables and fruits; dairy cattle breeding: early ripe potato production
Kotayk	Meat-and-dairy cattle breeding; vegetable and potato production; and cereals farms and fruits production	Meat-and-dairy cattle breeding; poultry farming: fruits production; cereals farms; vegetable production; and fodder production

Source) 2010-2020 Sustainable Agricultural Development Strategy, RA

Recent Situations of International River Treaty

Water distribution of the Hrazdan River is managed by the Sevan-Hrazdanyan Jrar (“Jrar” means intake) Closed Joint Stock Company (CJSC) under the SCWE, and Water Resource Management Agency (WRMA) under the MNP. The Hrazdan River flows within the Armenian territory, therefore, the Hrazdan River is regarded as an in-country river in Armenia and there is no international treaty on utilization of water of the Hrazdan River.

3. CURRENT CONDITIONS AND ISSUES ON IRRIGATION/AGRICULTURE SECTORS IN ARMENIA

Status of the Project to the National Development Plans

Irrigation sector

With regards to irrigation policies, the government aggressively deploys the policy of converting irrigation methods from pump to gravity-based system. There lies a background behind the strategy of “breakaway from energy intensive agriculture”, and an issue of decreasing the groundwater level which causes the difficulty for pumping up irrigation water. In particular, the groundwater level has been drawing down in the Ararat Plain.

Agriculture sector

The government recognizes that the Project area is a strategic area to achieve the goals of SADS, which is the highest level of agricultural development policy in Armenia, by the following reasons;

- ✓ The area belongs to a production center of vegetables, fruits and grapes which are expected to be main products for promoting industrialization of agriculture and export-oriented productions declared in SADS.
- ✓ The area is located on the suburbs of Yerevan city, where many agro-industries are developed and is the main market of the products.

Table 3-1 implies that crop production, especially vegetables/melons and grapes, in the Project area contributes much to the national production, though the total land area is only 0.8% of the national land area.

Table 3-1 Production of Major Crops in Armenia and in the Project Area in 2014

Crop	Armenia (A)		Project Area (B)		(B)/(A)	
	Area (x1000 ha)	Production (x1000 ton)	Area (x1000 ha)	Production (x1000 ton)	Area (%)	Production (%)
Grains	188.7	590.6	1.8	6.9	1.0	1.2
Potatoes	31.6	733.2	0.7	29.1	2.2	4.0
Vegetables/Melons	32.2	1,200.4	2.9	91.6	9.0	7.6
Fruits	40.1	291.0	0.9	6.3	2.2	2.2
Grapes	17.2	261.3	1.3	17.5	7.6	6.7
Total land area	2,974.3	-	22.8	-	0.8	-

Source) Statistical Yearbook of Armenia, 2015
27 communities concerned (Crop Area and Production in Project Area 2014)

Food Security

Armenian recent trend of self-sufficiency ratio reveals polarized tendency. Basic foods such as cereals, edible oils and pork meats are at a lower level. In contrast, other foods like vegetables and fruits/grapes show a high rate. The SADS emphasizes that a rise in cereals production and promotion of animal husbandry with an increase in forage crops should be the main strategy of domestic food security. Actually, the self-sufficiency ratio of cereals, especially wheat shows a trend toward the improvement in recent years. Nevertheless, since major cereals and forage crops are internationally commercialized, it is inevitable to rely on cheap imported products in order to pursue economic efficiency. It is crucial to keep a careful balance between the improvement of food self-sufficiency ratio and economic efficiency.

International Trade of Agricultural Products

Since Armenia's independence, the government has promoted agricultural sector with some successes. However, the production of many crops cannot meet domestic demands; the country still depends on substantial amount of imported products. Regarding major exporting crops, both the variety of exporting commodities; mainly vegetables, fruits and alcoholic beverages, and the volume are limited. Alcoholic beverages are the highest exported item which is mainly composed of brandy made from grapes. Export destinations are dominated by Russia and other CIS countries, mainly because of the strength of the Armenian brand established during the USSR era, which remains in high demand.

Marketing of Agricultural Products

Farm products are classified into two (2) categories as for personal consumption (including gift and barter exchange) and for market sales. Cereals, potatoes, eggs and sheep wool are mainly consumed by producers themselves. On the other hand, comparatively high percentage of vegetables (including melon), fruits, grapes and meats are marketed. These commodities are recognized as important cash income sources of farmers. Many farmers sell their products to the middlemen at the farm-gate.

Organized cooperatives or group marketing by farmers are not common. Although all farmers recognize the difficulties for securing advantaged selling channels and favorable selling prices of their products, no one can figure out the certain images or ideas of solution for the problems.

Agricultural Processing

According to the Ministry of Agriculture (MOA), there are about 1,500 agricultural processing companies in Armenia as of 2014, if unrecognized tiny companies are also counted. Alcoholic & non-alcoholic beverage, meats & dairy products and preserved foods are the priority commodities in the government policy. Rehabilitation of Armenian agricultural processing industries is still only at the halfway mark despite of vigorous supportive policies of the government.

The Department of Agro-Processing Development recognizes the following problems on the development of agricultural processing industries.

1) Limited market (the industries have over processing capacity)
2) High production-cost structure (raw materials, energy, management, etc.)
3) Inconvenient loan condition (financial institutions reluctant to provide a long-term loan)
4) Limited transportation routes due to geopolitical constraint

Agricultural Inputs

Fertilizers

The government of Armenia is importing fertilizers in order to provide cheaper fertilizers to farmers under the subsidy system. Most of farmers heavily depend on the subsidized fertilizers for their crop farming, and a limited volume of miscellaneous compound fertilizers mainly used for vegetables and flowers are distributed through the private channel. According to the MOA, the subsidized fertilizers cover more than 95% of the annual domestic demand. Farmers are demanding mainly on nitrogen fertilizers, and the demands of other fertilizers are quite limited. Farmers tend to input more volume of nitrogen fertilizers, probably due to its immediate effect on their crop productivity.

Agricultural chemicals

All agrochemicals are imported from foreign countries, as same as fertilizers, in Armenia. In contrast to fertilizers, agrochemicals are marketed only through the private channel, as the government are not subsidizing for them. The government has imposed a registration system of agrochemicals which prohibits importation and distribution of unregistered agrochemicals in Armenia. A division in charge of agrochemicals under the MOA inspects agrochemical shops periodically in order to control unregistered or obsolete agrochemicals.

Agricultural machinery

Most of current workable agricultural machinery in Armenia was procured in the former USSR era. There have been about 11,000-12,000 workable tractors since 2005 and there was no drastic change of those figures in the last decade. The government has played a significant role in the import of agricultural machinery, though there are several private dealers importing agricultural machinery. Actual market demand for the agricultural machinery on commercial basis is still limited, mainly due to weak paying capacity of each individual farmer, despite the high potential demand.

Agricultural research and extension

According to the MOA, there are three (3) agricultural research institutions; 1) Scientific Centre for Agriculture, 2) Scientific Centre of Vegetables and 3) Industrial Crops and Experimental Centre for Technical Crops, under the Ministry. In Armenia, agricultural extension services are implemented by specialized agencies; the ASRC (Agricultural Support Republic Centre) and ASMCs (Agricultural Support Marz Centres). ASRC is placed at the central level and one ASMC is established in each

Marz at the regional level. ASMCs are responsible for agricultural extension services to individual farmers in respective Marzes, and 130 agricultural extension agents are allocated to ASMCs in total. According to the results of survey against farmers, most of the farmers recognized that they've never had any opportunities of agricultural extension or supporting services.

4. CURRENT CONDITIONS OF YEGHVARD IRRIGATION PROJECT SITE

4-1 Meteorological and Hydrological Conditions

Meteorological data

Data of the average annual rainfall in Hrazdan and Yeghvard stations are 742 and 439mm, respectively. The maximum average temperature is observed around July to August. The average temperature from December to February is negative in all the meteorological stations. Monthly rainfall is in maximum on April and May and decreases to August. Evaporation is in maximum on June as shown in Figure 4-1. Around latest ten (10) years , annual rainfall in 2008, 2012 and 2013 are less than the average at the Hrazdan station and in 2004, 2012 and 2013 at Yeghvard station is less than average as well

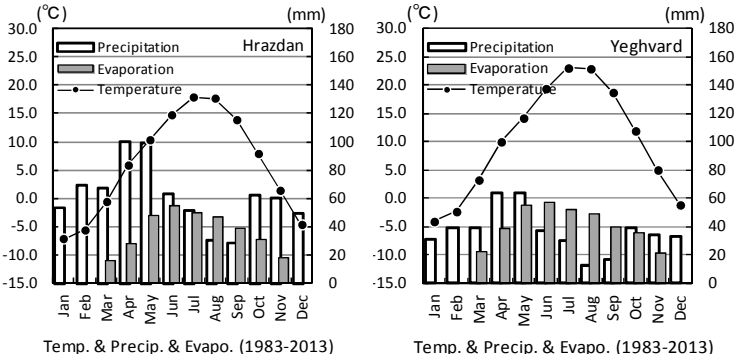


Figure 4-1 Meteorological Data at Hrazdan and Yeghvard Station

For the evaluation of rainfall trend at Hrazdan station, probability of annual rainfall is calculate. One is long-term from 1983 to 2013, and the other one is latest 10 years from 2004 to 2013. The reason to evaluate by the Hrazdan station's data is that Yeghvard reservoir will be filled by the river flow from Hrazdan River's watershed area, so Hrazdan station's data will be presumed that it has relationship between rainfall and river flow. Year of 2008 is extremely low amount of rainfall, especially in the latest 10 years.

Hydrological data

Monthly river flow at Hrazdan and Lusakert stations along Hrazdan River and Ashtarak station along Kasakh River from 1983 to 2013 was collected. Discharge of river flow rise up from March and maximum on April or May. Runoff ratio at Hrazdan station along Hrazdan River and Ashtarak staion along Kasakh River is respectively 43% and 25%.

Probability of Hrazdan River flow is evaluated through 2004 to 2013, and the target of evaluation month's data are sum-up the river flow discharge from March to October. Probability of 75% is 2009 based on the calculation, and this result shows that 2008 and 2012 are the relatively dry year.

4-2 Current Water Utilization Conditions

Lake Sevan

Outline

In the Project area, the main water sources of main canals are Hrazdan and Kasakh Rivers. When the water is short to the demand, water is supplemented from Lake Sevan through Sevan-Hrazdan Hydropower Plants Cascade. The release water from Lake Sevan for irrigation has been limited to 170 MCM/year for the preservation of Lake Sevan since 2001. In addition, the hydropower generation along Hrazdan River is allowed to operate only during the irrigation period.

These limitations are aimed to restore water level of Lake Sevan, which is planned to increase to

EL.1903.5 m by 2030. The water level has successfully been raised from 1896.32 m on January 1st, 2002 to 1900.13m on January 1st, 2015 and 3.4m remains to reach to the target level. However, the limitation of the usage of lake water for irrigation would not be applied in case of drought year. Most use of the lake water is released to Sevan-Hrazdan Hydropower Plants Cascade and the released water is used for power generation and irrigation. Around 100 to 170 MCM has been used in each year except the drought ones - 2008, 2012 and 2014.

Prospects of water balance and water level in future

The Llake water level rose by approx. 3.7m in ten years until 2011 under the circumstances that sufficient water comes from Arpa-Sevan conduit and the release to Sevan-Hrazdan HPPs Cascade is limited basically to 170 MCM/year. The required water level rise to the target is 3.4m at present, so that if the circumstances are the same, the water level probably reaches the target level within next 10 years.

That is, if the released amount of water can be controlled under 170 MCM/year for a non-drought year after completion of rehabilitation work of Arpa-Vorotan tunnel, the release exceeding 170 MCM in a drought year probably doesn't affect the restoration plan of the lake water level as far as many drought years do not repeat successively.

Hrazdan and Kasakh Rivers

Water Resource Management Agency (WRMA) is the responsible organization to permit the water right regarding irrigation, hydropower, drinking water, fish breeding and industries. WRMA has been reported summary report of water use permits every year. The major water user along Hrazdan River is irrigation and hydropower plant, and the major user along Kasakh River is irrigation. Water source for drinking water is ground water and the discharge volume of utilization for industries is very few compare to irrigation use. Thus, irrigation and hydropower plant is considered as major water user along Hrazdan and Kasakh Rivers.

The water user along Hrazdan and Kasakh Rivers is Sevan-Hrazdanyan Jrar CJSC. The water right for this CJSC has been already permitted by WRMA, and there is no conflict among hydro power plants. The agricultural water usage has higher priority than the energy and industrial production use.

Yeghvard Irrigation Project Site

From the evaluation of the ratio of supplied water source for current Yeghvard Irrigation Project Site, current Yeghvard area depends on more than fifty percent of pump-based irrigation water. The 26% of supplied water comes from pump stations and 25% of it comes from small pumps and deep wells. Shift from pump-based to gravity-based irrigation has an important role in this area.

Aknalich Lake's water comes from ground water. Aknalich pump station is taking irrigation water from this lake. It is cleared that the discharged volume has been decreasing year by year. Energy reduction by shifting to gravity-based irrigation from pump-based irrigation is the important policy in agriculture sector. In addition, from the view point of ground water resources, abolishment of pump facilities contributes not only energy reduction but also conservation of ground water resources in the Project site.

4-3 Current Situation of Planned Reservoir

Outline of Geological, Hydrogeological and Soil Investigations

Major purposes of the initial investigation works were 1) reconfirming the ex-USSR's geological/hydrogeological investigation results, followed by 2) checking the permeability and its anisotropy, and 3) Revealing the groundwater condition in dam site, so that the investigations were

distributed widely but rather shallow in and around the reservoir. Through the consideration on the initial investigation, both Recent Alluvium (called; ① layer in Stratigraphy) and Pleistocene Alluvium (called; ⑥ layer) were regarded as an aquiclude. Based on these facts and their significances, the additional geological/hydrogeological investigation works were conducted.

The investigation works were separated into four (4) categories of; 1) Initial geological boring, 2) Monitoring well drilling, 3) Geophysical prospecting and soil investigation boring and 4) Additional geological boring. Work volumes actually conducted were as follows;

1) Initial geological boring;
   a) All-core boring: 10 holes (depth 30 – 50m, total 320m)
   b) In-situ tests: - Standard Penetration Test (SPT) (every 1.0m)
      - Permeability Test <Horizontal test> (3.0 – 5.0m span)
      - Permeability Test <Vertical test> (every 5.0m)
      - Natural γ-ray Logging (every hole)

2) Geophysical prospecting and soil investigation boring;
   c) Geophysical prospecting: 53 points (VES, 120m analyses)
   d) All-core boring: 5 holes (depth 17 – 30m, total 137m)
   e) In-situ tests: - Standard Penetration Test (SPT) (every 1.0m)
      - Permeability Test <Horizontal test> (3.0 – 5.0m span)
      - Permeability Test <Vertical test> (every 5.0m)

3) Additional geological boring;
   f) All-core boring: 6 holes (depth 60 – 100m, total 480m)
   g) In-situ tests: - Standard Penetration Test (SPT) (every 1.0 – 2.0 m)
      - Permeability Test <Horizontal test> (3.0 – 5.0m span)
      - Permeability Test <Vertical test> (every 5.0m)

4) Monitoring well drilling;
   h) Deep well drilling: 5 wells (depth 120 – 150m, total 660m)
   i) In-situ tests: - Natural γ -ray Logging (every well)
      -Resistivity Logging with SP log (3 wells but partially)
   j) Completion to monitoring Wells: 5 wells
   k) Installation of Automatic Water Level Recorder (AWLR): 5 wells

Results of Geological/Hydrogeological Investigation

Initial geological boring

Major works conducted under this category were 10 holes of all-core boring together with in-situ tests of; Standard Penetration Tests (SPT), Permeability Test (PT), and Gamma-Ray Logging (GRL). Two (2) kinds of PT were tried to know a horizontal (HPT) and a vertical permeability (VPT). Results of core-boring were arranged into boring log, several geological cross-sections and profiles which were provided to understand the geological condition of dam site.

The geological investigation boring revealed a distribution and properties of major geological formations such as many volcanogenic layers, mainly fluvial sand and gravels (pebbles and cobbles), and rather impervious loamy soil layers. Anisotropy of permeability of these formations was clarified.

Geophysical prospecting and soil investigation boring

Under the category of “Soil investigation boring”, total 53 points of geophysical prospecting were conducted, and based on their results, total five all-core boring with in-situ tests were drilled as Soil

Investigation Boring. In these boring, soil samples taken by SPT were sent to a laboratory to make 3 kinds of soil tests (1.Moisture contents, 2.Specific Gravity and 3.Grain-size Distribution Analysis).

Geophysical prospecting was carried out as Vertical Electric Sounding (VES). Results of VES revealed the wide and deep distribution of very thick low apparent resistivity zone ($\rho\ \alpha < 25\ \Omega$m), which can be considered as almost impervious clayey layer in the central portion of planned reservoir.

Soil investigation boring (total 5 holes) were drilled, consequently, to the depth of 30m as a rule. They found out deep loamy layers showing rather low permeability of both VP and HP.

Additional geological boring

Major targets of additional geological boring are Alluvial deposits of Holocene (① layers in Figure 4-2) and Pleistocene (⑥). The work contents were 6 holes of all-core boring up to maximum 100m, VPT and HPT, SPT, and soil laboratory analysis by SPT samples.

Additional boring made clear the distribution of thick clayey layer with very low permeability (VP: 1.28 x 10^{-6} cm/sec, average) in the central and west central parts, and distribution of sand-and-gravelly ❼ layer in the central east part of the reservoir. Through the additional boring, the distribution of these mostly impervious loamy layers (① and ⑥) was more clearly distinguished, and then, enough permeability coefficients on ① and ⑥ layers were obtained.

Based on the results of additional geological boring, most of geological cross-sections and profiles were modified. Both VP and HP of ①, ⑥ and ❼ layers were rearranged. All boring and in-situ tests results are arranged into boring log.

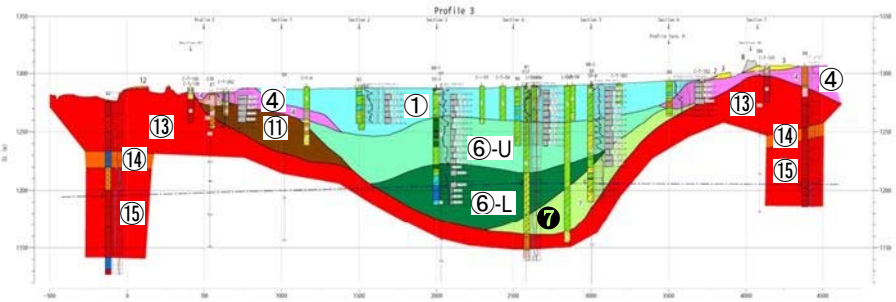


Figure 4-2 Sample of Modefied Geological Profile

Monitoring well drilling

Five (5) monitoring wells were drilled in and surrounding the reservoir area. Well depths were 120 – 150m. Monitoring W1 was drilled at the center of the reservoir to check the groundwater table in the reservoir center, then the other wells were drilled at N, S, E and W of the outside of dam-site, which remained and controlled as monitoring wells after the dam construction completed (except W1 well).

Wells were drilled by 244mm drilling bit, and steel casing/slotted screen with 114mm dia. were installed. After the well development, γ-Ray Logging throughout the well depth was carried out. Groundwater table was detected in the all monitoring wells but depths were varying from around 80 to 131m, mainly because of the differences of the ground elevations. Results of these deep well drilling were rearranged into "Well Log" together with all γ-ray and resistivity logging results.

In the all monitoring wells, an Automatic Water Level Reorder (AWLR) was installed. AWLR measure the groundwater depth at every two (2) hours. However, the groundwater depth must be calibrated comparing manual measurement whenever the recorded data were read up.

Geological/Hydrogeological Conditions of Dam-site

Geological/Hydrogeological conditions

Partially referring to USSR's results, the Survey Team built up the stratigraphy based on the field reconnaissance and newly obtained geological/hydrogeological information(see Table 4-1). Major

differences from Rusian stratigraphy were as follows: Lowest Pliocene Gravel formation (old⑫) was changed to Pyroclastic flow consisting the base of Volcanic Breccia (⑪) and merged into Volcanic Breccia (new ⓫), then, Lower Quaternary sediments series (⑦ to ⑧) are combined into new ❼. Holocene Proluvial-alluvial sediments (②) is renamed as Moraine deposit (new ❸), and Eluvial-diluvial sediments of the same age is renamed from Gravel to as Surface Gravels (②).

Practical geologic basement of the Yeghvard reservoir area is a sedimentary rock formation belonging to Miocene, consisted of Sandstones, Clays and Marls (⑱). This formation forms impervious basement in this area. On a significant scale, the surface of Miocene was dissected and heavily covered by many volcanic formations erupted from the Aragats and Alairer Volcanos in Pleistocene.

These volcanic activities were quite active throughout the Pliocene and continued to the almost end of the Pleistocene. The oldest volcanic formation in this area is Dacites (⑰) in late Miocene, covering the Miocene sediments (Hrazdan Suite) but dissected strongly so as merely cropping out on some gentle hill tops.

Covering the oldest Dacites, several volcanogenic formations together with a few sedimentary formations, were accumulated in the Yeghvard Highland in early Pliocene. At first, amphibole Andesite (⑮) filled after the Dacites lava, and a little later, andesite-basalt slags (pyroclastic flow (⑭) covered them. Then, Olivine-basaltic Andesites in middle Pliocene (⑬) emerged in large scale and formed the framework of southern and western banks of dam-site. Covering the olivine-basaltic andesite lava, Andesites slags (⓫) were deposited.

Table 4-1 General Stratigraphy of Yeghvard Dam Site

Age			Genetic Classification	Symbol	No.	Main Facies	New No.	Main Facies
Quaternary	Holocene		Aeolian-Diluvial-Proluvial Formation	$_{Vdp}Q_{IV}$	①~1a	Sandy Loam and Loam	①	Sandy Loam and Loam
			Eluvial and Deluvial Sediments	$_{ed}Q_{IV}$	2^a	Gravel	②	Surface Gravel
			Proluvial-Alluvial Sediments	$_{pa}Q_{IV}$	②	Gravel	❸	Moraine Deposits
	Pleistcene	Upper	Volcanogenic Formations	$_{\beta}Q_{III}$	④	Welded Tuff	④	Welded Tuff
		Middle	Volcanogenic Formations	$_{\beta}Q_{II}$	⑤	Lava	⑤	Lava (North bank)
		Lower middle	Lacustrine-alluvial-proluvial Sediments	$_{lap}Q_{I-II}$	⑥	Loamy Sand and Loam	⑥	Loamy Sand and Loam
		Lower	Alluvial-proluvial Sediments	$_{ap}Q_{I}$	⑦-7^a	Sand - Loamy Sand	❼	Sandy Loam to Loamy Sand
			Lacustrine-alluvial-proluvial Sediments	$_{lap}Q_{I}$	⑧	Loamy Sand and Loam		
			Volcanogenic Formations	$_{\beta}Q$	⑨	Lithoidal Pumices	⑨	Lithoidal Pumices
			Volcanogenic Formations	$_{\beta}Q_{I}$	⑩	Welded Tuff	⑩	Welded Tuff
Tertiary	Pliocene		Volcanogenic Formations	$_{\alpha}N_{II}$	⑪	Volcanic Breccia (Scoria)	⓫	Volcanic Breccia (Scoria)
			Alluvia deposits		⑫	Gravel		Pyroclasic flow deposits
			Volcanogenic Scoria Formation	$_{\alpha+\beta}N_{II}$	⑬	Lava	⑬	Lava (South bank)
			Volcanogenic Formations		⑭	Volcanic Breccia	⑭	Volcanic Breccia
			Volcanogenic Formations	$_{\alpha}N_{II}$	⑮	Lava	⑮	Lava
	Mio-cene		Volcanogenic Formations	$_{\alpha}N_{I}$	⑰	Dacites	⑰	Dacites
			Sarmation Sediments (Hrazdan Suite)		⑱	Sandstone, Clay, Marls	⑱	Sandstone, Clay, Marls

In the early Quaternary (lower Pleistocene), volcanic activities were still continued and some volcanogenic formations, such as Welded Tuff (⑩) and Welded (or Lithoidal) Pumices (⑨) were formed. After this, there was a rather long rest of volcanic activities, and in this period, a thick alluvial, diluvial and proluvial deposits accumulated thickly, filling up the deep valley dissected on the andesite lava (⑥ and ❼). The base of these layers (❼) is mostly sandy to gravelly sediments with rather high permeability. Covering these Pleistocene alluvium to diluvium, more younger Olivine-basaltic Andesites in middle Quaternary (⑤) flowed down as lavas formed the main body of

the northern bank of reservoir area. And, directly covering the Andesite lava, characteristic brick red color Scoria (or Welded Tuffs) is distributing (④). Notably, the tuffs show quite high gamma-ray radiation. The formation changes its facies from hard rock to rather soft scoria, and pyroclastic flow deposits looking like sand-and-gravels.

The low-land of planned reservoir was an enormous dissected valley in lower Quaternary and buried several volcanogenic and alluvial deposits through upper Pleistocene to Holocene. At the end of Pleistocene, huge volume of moraine deposits were left in northwest bank of the reservoir area (❸). The deposits were consisted of huge basalt blocks, boulders, cobles, pebble, sand and gravels, without selection. Moraine deposits are now covered by recent eluvial and diluvial sediments (② or ① sometime) thinly.

Recent Aeolian diluvial-proluvial formations (①) cover almost all of the central portion of the reservoir area, represented by gray Sandy Loam with comparatively impervious property. Thin sand or clay layers are intercalated everywhere. Thickness of the formation is said from 35 to 40m in the central portion but the total thickness of relatively impervious layers including Lower to Lower-middle Pleistocene Lacustrine-alluvial deposits (series ⑥) shall be beyond 120m in the central portion.

Permeability and its anisotropy of reservoir basin

The Survey Team made a special attention to the anisotropic permeability of the all formations, because dam water shall flow to vertical direction, not horizontal. In accordance with a refernce, there are two methods to evaluate the permeability in the test hole: a piezometer method and a tube method. The piezometer method indicates horizontal permeability and the tube method showed vertical permeability, mainly.

The anisotropic of permeability was clearly detected, mostly the VP were lower than the HP around 1/4 to more than one order. There were some exceptions that VP was higher than HP, mainly in volcanogenic formations and moraine deposits. HP of moraine deposits (❸), young volcanogenic formations (④,⑤), and surface gravels (②) were rather high. However, VP of relatively impervious formations such as Holocene Sandy Loam (①) or Lower middle Pleistocene Sediments (⑥) indicated low VP: the former showed 8.3×10^{-6} and the later showed 6.2×10^{-6} cm/sec in an average. Especially, the lower clay in ⑥ layer (called as ⑥-Low) showed very low VP as 1.28×10^{-6} cm/sec on the average.

In accordance with AWLR measuring results, the maximum fluctuation was only 56.7cm (in W5) for around a half year. Besides that, small fluctuations in each hydrograph are daily tidal fluctuations, and a long span movements of groundwater level are large scale areal groundwater movements, and partly getting an influence of leaking water flow from the Arzuni-Shamiram canal.

Measured groundwater depth suggested that the groundwater table is almost flat but slightly tilted from north to south and east to west. Groundwater movement near the dam-site flows from north to south totally, however, the maximum inclination is less than 14m for around 4km of distance.

From the prepared hydrogeological cross sections in Yeghvard basin, it's clear the groundwater table in the reservoir area is very flat and deep. These aspects and the groundwater hydrograph indicate that a) groundwater table in the reservoir area is very deep (more than 80m), b) permeability of the Yeghvard highland in between Kasakh and Hrazdan Rivers are very high as a total, and 3) rainfall and snowmelt in the reservoir area give almost no influence to the groundwater table.

Investigation on Dam Body Materials

Investigation on impervious materials

The ground of the reservoir area is widely covered by the thick soil layer so called "loamy sand or sandy loam" which was investigated and planned as the impervious materials for the dam body in the USSR era. The excavation of ten (10) test-pits were planned this time in the reservoir area and also the drilling of 10 hand-augers in the area, defined as the spare borrow area, outside of the reservoir. The location map of the survey points is shown in Figure 4-3. In these test-pits, the field permeability tests by the pit method and by the cylinder method were carried out to grasp the differential between the horizontal permeability coefficient and the vertical one. The former, for the horizontal permeability, was the test done in the excavated pit where seepage through the pit wall is predominant; the latter, for the vertical permeability, was done to the soil column sculptured in the ground where seepage was forced to occur from the top of the column to its foot.

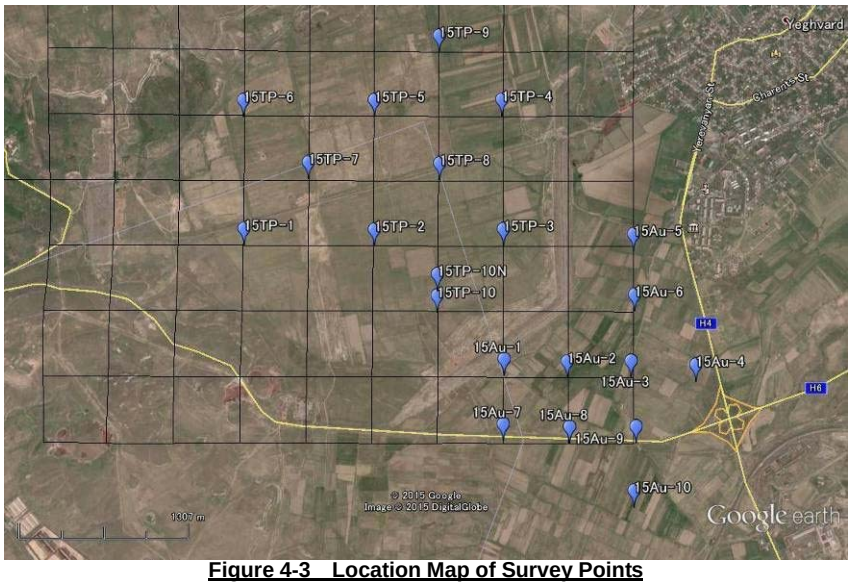


Figure 4-3 Location Map of Survey Points

Laboratory Soil Test

Tests to impervious materials (sandy loam)

[Moisture content]

Most of the soils have the field moisture content lower than the optimum moisture content by 5% to 12% except for the some exceptional ones with the field moisture content higher than the optimum moisture content by 1% to 2% as shown in Figure 4-4, so that to conduct the compaction work to the soils with optimum moisture content condition, a large amount of water shall be needed for moisture content adjustment.

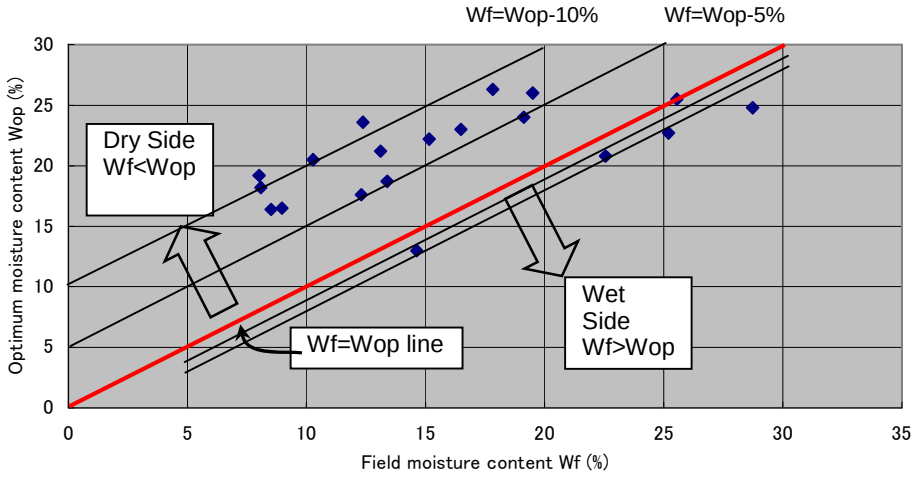


Figure 4-4 Relationship between Field Moisture Content and Optimum Moisture Content

[Grain size distribution test]
The results of the grain size distribution test are shown in Figure 4-5. Most of the samples contain fine particles more than 50%, but it ranges wide from 50% to 95%.

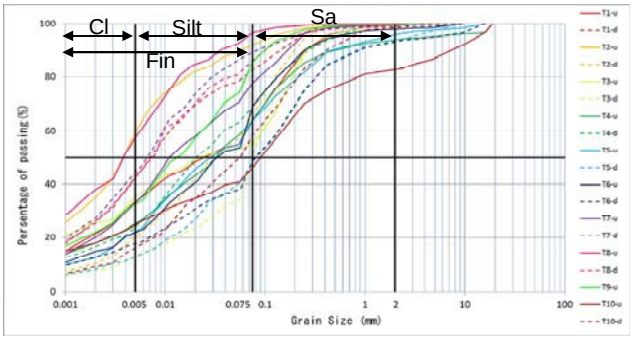


Figure 4-5 Grain Size Distribution Curve of Sandy Loam

[Standard compaction test]
The coarser soils with a wide range of particle size generally form sharp curves and tend to indicate higher maximum dry densities and lower optimum moisture contents. On the other hand, the finer soils with a narrow range of particle size form flat curves and tend to indicate lower maximum dry densities and high optimum moisture contents as shown in Figure 4-6.

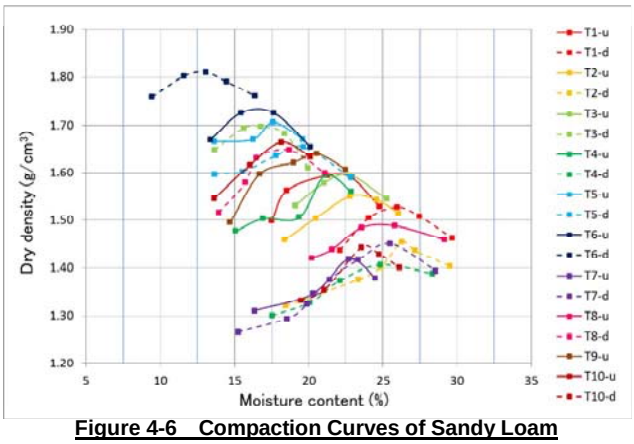


Figure 4-6 Compaction Curves of Sandy Loam

[Direct shear test and tri-axial compression U-U ／C-Ubar test]
Shear strength of the sandy loam is evaluated to be medium class, not good but not so bad as shown in Figure 4-7. It should be noted that a relatively definite differential between the UU strength and the CU strength.

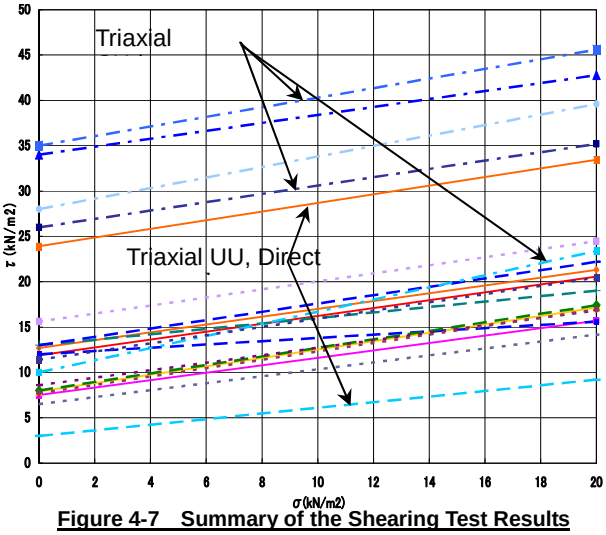


Figure 4-7 Summary of the Shearing Test Results

[Permeability test]

The sandy loam (G-1, G-2, G-3) is highly impervious showing the permeability coefficient to be in the order of 10^{-7} cm/sec; on the other hand the loamy sand (G-4, G-5) shows the higher value to be in the order of 10^{-6} cm/sec as shown in Figure 4-8. Once saturation degree of the compacted soil in both cases being a little bit low, the permeability coefficient becomes to be in the order of 10^{-5} cm/sec; therefore, compaction under high compaction energy by a heavy compactor shall be needed.

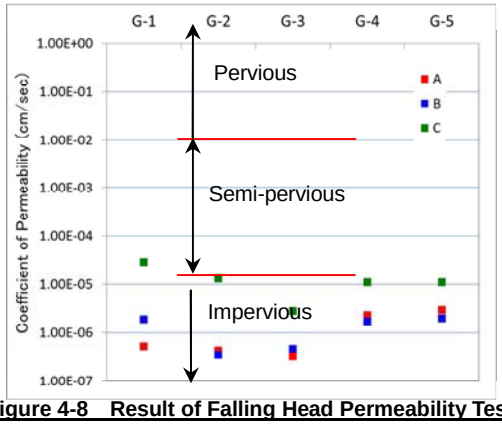


Figure 4-8 Result of Falling Head Permeability Test

Test results of bentonite soil mixture
Contrary to our expectation of the bentonite-soil mixture being improved to show the permeability coefficient in the order of 10^{-8} cm/sec, the lowest value was the one in the order of 10^{-7} cm/sec. When recognizing that the mechanism of gravelly soils' permeability being improved by bentonite mixing depends on the swelling of bentonite powder that fills up the voids among gravelly soils' particle, it is assumed that the reason why bentonite mixing cannot function is the voids among sandy loam's particle are too small for bentonite powder to intrude and swell. Room to pursue the permeability improvement by

arranging the gradational conditions of sand-and-gravel is left but at this stage it has not yet been succeeded.

Test results of soil-cement

[Improvement degree in permeability by mixing with cement]
Satisfactory results showing permeability coefficients of k=7.7 x 10^{-7} cm/sec- 3.9 x 10^{-8} cm/sec were obtained.

[Materials to be mixed with cement]
From the view point of stable test values in imperviousness and definitely larger unconfined compression strength, the material "sand-and-gravel coarse" is superior to others.

[Mixing ratio of cement]
As a safety side decision, 10% of mixing ratio shall be adopted.

[Importance of curing]
The influence of specimens being cured or not being cured appears as the differential of two orders, i.e. from 10^{-8} cm/sec order to 10^{-6} cm/sec order in the permeability coefficient, so that curing is very important at the construction stage.

[Durability of soil-cement]

The permeability coefficient becomes larger by half an order, i.e. 5 times, as the influence of freezing/thawing; the unconfined compression strength is not influenced by freezing/thawing. Based on the test results of Slaking Test and Sodium Sulfate Soundness Test, soil-cement made of materials "sand-and-gravel fine" and "sand-and-gravel coarse" shall be estimated to have as stable enough quality as the coarse aggregate for concrete, so that soil-cement is available not only for the anti-infiltration work but also for the slope protection work (Refer to Figure 4-9).

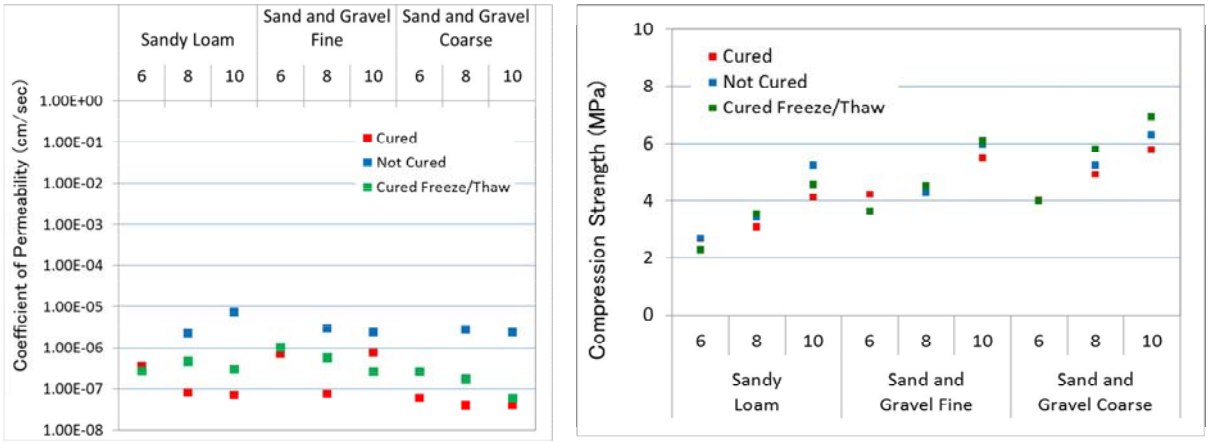


Figure 4-9 Results of falling head permeability (left) and Unconfined Compression Tests (right) to Soil-cement

Investigation for the Anti-infiltration Works to the Reservoir Basin

Field survey of the existing range of sandy loam
This survey was conducted to confirm visually the existing range/condition of sandy loam based on the geological plane map obtained from the investigation results in USSR era. As the survey result, it was confirmed that the area of low terraces extending north-eastern side of the reservoir would have the basement of sand-and-gravel and that at the south side of the reservoir, the edge of the existing range of sandy loam corresponded to the changing point of gradient between the reservoir bottom and the slope.

Field survey to confirm the layer conditions in terms of piping phenomenon

In case of a soil layer receiving water pressure and its basement having cracks or voids, there is a possibility that piping phenomenon occurs. This survey was done to confirm the basement conditions. The results are as follows;

1) There is no possibility of the piping phenomenon arising into the sand-and-gravel layers because of its half-consolidated condition by the gypsum-like materials or the predominance of silty sand that makes the gravels to be compared to the balls floating in the ocean of silty sand.
2) There is a high possibility of the piping phenomenon arising into the volcanic rock layers which are rich with cracks in case of lava or voids in case of pyroclastic flow.

Field survey of ground water seeping out of the slope surface

When the ground surface of the reservoir is covered by an anti-infiltration works, there suspected breaking of this works by the back pressure pushing up from behind due to the light weight of the works. This survey was done to grasp the possibility of ground water acting as the back pressure against an unti-infiltration works. The result is shown as follows.

1) Ground water which maintains two ponds on the reservoir bottom just upstream side of the Dam No.1 might function as a back pressure against as anti-infiltration works.
2) It should be considered that the geological formation in the northern slope of the reservoir with an alternation of gravel layers and silty sand layers might cause the back pressure when seeping out surface is closed by an anti-infiltration work.
3) The surface gravel layer on the south slope seems to be pervious. When an anti-infiltration work covers this layer and the welded tuff layer lying below is impervious, the back pressure would arise against this works.

Snow melting condition survey

Snow melting water is one of the origins that cause the back pressure. This survey was done to grasp the snow melting condition around the reservoir during the snowmelt season in 2016. The result is shown as follows;

The northern catchment area of the reservoir composed of the two main watersheds, one is 18 km^2 and the other 7.2 km^2, is 30 km^2 approximately; waters from these watersheds are concentrated into two valleys over which Arzni-Shamiram canal goes across by the water-way bridge. According to the field observation, small stream appears only in the valley from the 18 km^2 watershed only at the peak of the snowmelt season; and the stream disappeared in the downstream meadow but created groundwater in the sand-and-gravel layer on north-eastern slopes of the reservoir.

Wind velocity survey

8 records of mean wind velocity for ten minutes and 8 records of the instantaneous maximum wind velocity during ten minutes observed in 2014 at Yeghvard Weather Station were obtained. The study result is summarized as follows;

1) Occurrence of high wind velocity, mean and instantaneous, becomes more frequent in June, July and August.
2) In terms of the instantaneous maximum wind velocity, the peak of occurrence frequency is the velocity around 5 to 6 m/sec all through a year.
3) Even under the breeze conditions, a gusting wind with velocity of 10 m/sec or more blows down all through a year.

Conditions of Existing Dam Bodies

[Test-pit excavation]

Five (5) test-pits were excavated on the crest of Dam No.1 and No.2. Findings are as follows;

1) The maximum grain size of cobbles is about 40 cm.
2) The rock sort of cobbles and gravels is basalt.
3) The quality of cobbles is hard and not weathered so that the metallic sound is emitted from them by the hit of the geologist hammer.
4) The compacted layers are rich with fine particles composed of sand and silt that fills up almost completely and densely voids among gravels and cobbles.

[Field density test]
The field density tests by the water-replacement method were carried out on the bottom surface of the test-pits. The values obtained range from 1.88 g/cm^3 to 2.13 g/cm^3 in dry density.

[Field permeability test]
The field permeability tests by pit-method were carried out on the bottom surface of the test-pits. The values obtained range from 5.8 x 10^{-3} cm/sec to 1.9 x 10^{-4} cm/sec.

[Repose angle of sand-and-gravel materials]
Repose angles were measured on the natural slope caused by the backhoe's dumping work of excavated materials. The values obtained range from 33° to 41.2° .

[Laboratory test]

Table 4-2 Summary of the Laboratory Tests to Sand-and-gravels from the Existing Dam Bodies

pit No.	Field moisture	Spe. gravity	Spe. Gravity/absorption		praticle size distribution			Compaction test	
	Wf (%)	(−37mm)	Bulk density	absorption (%)	fine (%)	sand (%)	gravel (%)	D_{max}(t/m3)	W_{opt}(%)
TP−1	5.97	2.69	2.34	1.87	5.00	23.26	71.74	1.95	11.0
TP−4	7.04	2.57	2.34	1.67	7.88	22.78	69.34	1.73	14.6
TP−14	9.50	2.59	2.25	2.52	10.20	24.98	64.82	1.77	16.0
TP−15	11.48	2.53	2.17	1.91	11.50	23.38	65.13	1.65	17.2
TP−16	7.81	2.64	2.35	1.68	6.87	23.99	69.14	1.95	12.7

[Evaluation of the compaction degree]
Compaction tests were carried out to the samples of which grain size was smaller than 37 mm. The relative density is evaluated as the ratio of "the density of the portion of which grain size is smaller than 37 mm in the dam boy" to "the maximum dry density in compaction test". Evaluated values range from 91.6 to 93.7%, which shall be expressed to be "not loose but not so dense".

4-4 Current Conditions of Irrigation Network System with Related Structures

Overview of Current Irrigation System

Current irrigation system distributes water to 8,391 ha through Arzni-Shamiram canal, Lower Hrazdan canal and Ranchpar pump station, divided to two (2) parts. First part is the east side of Kasakh river before Arzni-Shamiram canal crossing Kasakh river, which area irrigated by Arzni-Shamiram canal. And the second part is the west side of Kasakh river after Lower Hrazdan canal passing the Kasakh river, which are irrigated by Lower Hrazdan canal.

The Ranchpar pump station consists of two (2) pumps; i.e. No.1 in Ararat Marz and No.2 in Armavir Marz. The station No.1 lift up the collected drain water near lower part of Hrazdan river to pump station No.2, and lifted water distributes to Lower Hrazdan canal through the No.2. These pump stations are operated by Water Supply Agency (WSA).

Most of the area is irrigated by furrow irrigation method. However, the area lower part of Lower Hrazdan canal has issues about water shortage. It is caused by difficulty of pump's water distribution due to deficit of ground water, conveyance water loss and so on. The current situation of ground water level and amount of collected water volume by drain canal for irrigation use becomes worse year by year, especially in Akanalich and Metsamor pump stations, which located in Ararat Plain.

As a countermeasure to the water shortage, especially in Khoy and Vagharshapat WUAs, those WUAs install a lot of wells and tackle with water shortage issues by themselves. Consequently, WUAs strongly hope to shift from pump-based irrigation to gravity system.

Current Conditions of Irrigation Network System

Irrigation areas targeted by the Yeghvard irrigation system are divided into two (2) areas, those are;

1) The area is composed of Yeghvard and Ashtarak WUAs which are located at east of Kasakh river and are irrigated by a) Arzni-Branch canal and b) Takahan canal through Kasakh river.
2) The other area is composed of Vagharshapat and Khoy WUAs which are located at west of the Kasakh river and are irrigated by c) Shah-Aru and d) Lower Hrazdan canals through Kasakh intake and Ranchpar pump station No.1 and No.2. These area, also, are irrigated by e) Upper Akhnalich, f) Inner Aknalich and g) Metsamor canals sourced by two (2) pump stations (Aknalich and Metsamor PSs).

The aim of the irrigation facility survey to understand current irrigation situation for the targeted areas including the above seven (7) canals, "a)" to "g)", by field surveys as well as to interviews to related WUAs and organizations.

Current Operation and Maintenance on the Irrigation Network System

One is WSA belonging to SCWC, the other one is WUA. Under WSA, two (2) of the organizations of the Sevan-Hrazdanyan Jrar CJSC and Akhuryan-Araks Jrar CJSC are related to collecting irrigation fee.

Operation and maintenance in the Project area has been carried out by the Sevan-Hrazdanyan Jrar CJSC. This WSA has been carrying out the operation and maintenance (O/M) for Arzni-Shamiram canal, Lower Hrazdan canal, Ranchpar and Aknalich pump stations. One of the major activities of the WSA is proper water distribution for irrigation system. WSA is a responsible organization for distributing irrigation water from main canal to secondary canal.

WUA has a responsible for appropriate water distribution for farmers, and O/M along the secondary and tertiary canals. WUA also collect the water fee from farmers. There are Yeghvard, Ashtarak, Vagharshapat and Khoy WUAs in the Project area.

Administrative responsibility demarcation point between WSA and WUA is an intake gate facility where the irrigation water is distributed from the main canal to branch canal. At the gates of the secondary canal' intakes, the operation and management are carried out by the WSA. This is the reason that WSA is the only organization to distribute irrigation water equally along the main canal. WUA has been operated and maintained the gates and canals after the secondary canal's intake gate.

Water supply method

WUA has a responsible of water distribution technical support for farmers, maintenance of irrigation facilities, safety operation, discharge measurement by measuring-record equipment and others. WUA collects the water fee based on the cropped contracted area. Regarding the water fee for irrigation, WSA sells the gravity-based irrigation water by 1.01 AMD/m^3 and the pump-based irrigation water by 11.52 AMD/m^3 to WUA.

On the other hand, WUA sells water to users by 11.00 AMD/m^3 for both gravity-based and pump-based irrigation water. The cost of pump-based irrigation water is differed according to the location by location. However, WSA sells the constant price of pump-based water fee to every WUA in Armenia. Based on the interviewing to PIU, the water fee by pump-based irrigation costs around 50 AMD/m^3 in actual maximum cases. Therefore, the difference cost between the actual cost and the

selling price from WSA to WUA has been paid by Armenian government as subsidy.

Maintenance with monitoring (inspection) method

Water level is monitored at the major points along the main canal. These monitored data are observed twice a day by WSA's remote staff and are reported to the WSA's head office. The staff of WSA observes the water level at boundary point between each WUA, and inspects so that irrigation water is diverted to each WUA appropriately. There are six (6) monitoring points along Arzni-Shamiram canal and four (4) monitoring points along Lower Hrazdan canal, respectively. The observed data are converted to the discharge and the 10 day's average data have been recorded and stored.

Maintenance cost

While maintenance cost is different from the size of irrigation area and irrigation facilities, 40% to 50% of total maintenance cost spends for canal cleaning, and remaining percentage used for the rehabilitation works for canals, pumps and deep wells. Vagharshapat WUA spends a lot for maintenance in comparison with other WUAs.

Current Issues on Irrigation Network System

Current situation and issues on target canals are observed by irrigation facility survey. In the basis of results of irrigation facility survey, findings on current situations and issues are summarized below;

1) Deteriorated/damaged due to cracks and exfoliated concrete panels on canals at a number of sections,
2) Lack of cross-section area to convey the design discharge at a number of sections,
3) Sections of open canal replaced by pipeline system due to changing WUA administrative boundary,
4) Areas where substitution new canals are required in the case that existing pumping stations (such as Aknalich PS and Metsamor PS) is abolished due to the policy of the Project, and
5) Some areas irrigated by unclear water source.

4-5 Agricultural Production and Farm Management

Agricultural Surveys Carried Out

The survey team carried out the following surveys in order to collect necessary information for the agricultural planning.

1) Farm household survey
2) WUA workshops
3) Data/information collection (MOA, Marz Agricultural Support Centers, Community Offices, marketing & processing agents, inputs sellers & dealers, etc.)

Number of Farm Households and Family Size

Number of households in the Project area is increasing in recent years, even slightly. The number in agrarian sector, however, stays constant. Total number of households and the number of farm households in the Project area is 16,849 and 13,574, respectively in 2014. The average size is stable in recent years at approx. 4.5 person/family. The percentage of farm households is about 80% in the Project area.

Farmland

Table 4-3 Farmland in the Project Area

Land Category	Yeghvard		Ashtarak		Vagharshapat		Khoy		**Total**	
	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)	Area (ha)	(%)	**Area (ha)**	**(%)**
1. Registered Farmland in Cadaster (Crop field & backyard)	2,427.9	53.8	1,738.9	48.2	2,797.1	63.1	5,236.9	51.4	**12,200.8**	**53.6**
(1) Irrigated land (WUA contract 2013)	1,050.6	23.3	915.0	25.4	2,161.0	48.7	5,093.0	49.9	**9,219.6**	**40.5**
(2) Non-irrigated land	1,377.3	30.5	823.9	22.8	636.1	14.3	143.9	1.4	**2,981.2**	**13.1**
2. Non-farmland	2,084.6	46.2	1,869.6	51.8	1,637.9	36.9	4,961.1	48.6	**10,553.2**	**46.4**
Total Project Area	4,512.5	100.0	3,608.5	100.0	4,435.0	100.0	10,198.0	100.0	**22,754.0**	**100.0**

Source) PIU

Farmland use

The Survey team made an estimation average farmland size per farm household in the Project area with available information. It is estimated that the average farmland size is about 0.97 ha.

Crop farming mostly concentrates on irrigated farmland, and majority of farmland are used for growing annual crops in the Project area. Only a few annual crops, maybe cereals in plateau areas, are grown in non-irrigated farmland. While home garden is generally used for growing vegetables, herbs and some fruits mainly for home consumption, substantial number of farm households generates a certain amount of cash income from surplus production from their home gardens.

Farmers in Vagharshapat and Khoy WUAs are more active in renting in farmland than farmers in Yeghvard and Ashtarak WUAs.

Profile of Farmers and Farm Household Economy

Profile of sample farmers of farm household survey

The average age of head of the sample farm households is 55.8 years old. As regard to farming experience, the average is 25.9 years. It shows that many farmers have a certain long experience in farming. Majority of head of the sample farm households are well educated. Most of them completed their secondary school education, and the percentage of university graduates or more accounts 21%.

The average number of family members of the sample farm households is 5.81 persons/family. Out of 5.81 persons, about 4 persons are categorized into the working active age (15-64 years old). It is interesting that an ordinary farm household may have at least 1 person of permanent employee, including self-employment. It implies that many farm households depend on not a small income from non-farming activities.

Income and expenditure

Average annual income in 2014 declared by sample households is AMD 5,979.1, while the average expenditure is AMD 4,103.3. The highest average income WUA is Vagharshapat and the lowest average WUA is Yeghvard and Ashtarak.

Income source

Naturally, income from farming, especially from crop sales, is the most important income source. It is interesting that salary or wages from non-agriculture sector is the second important income source, while salary or wages from agriculture sector is a very minor source for the farm households. It implies that many farm households in the Project area have family members who have off-farm side-jobs or have main jobs in non-agricultural sector.

Expenditure items

The first priority expenditure item is “agricultural inputs and management”. After it, “food and beverage” and “housing, home-consumables and public services” are second priority items. In

Yeghvard & Ashtarak WUA, the priority for “food and beverage” is very high, maybe, due to high % of low income families.

Strategy to increase living standards of family

There are many farm households who maintain good motivation to continue crop farming, while majority of them has a negative vision for livestock farming. Simultaneously, a substantial number of households look for a good job opportunity in local area. Many farm households also consider that education for children is important for increasing living standards of family, because education brings a good job opportunity. Such conditions imply that a movement to abandon farming is slowly progressing among farm households in the Project area.

Agricultural Production

Various kinds of crops are grown in about 8,500-9,000 ha in total every year in the 27 communities, while the annual average is 8,713ha during 2010-2014. In terms of planted area, wheat is the largest crop, while vegetables and fruits including grapes are also widely grown. Considering a price advantage of vegetables and fruits over cereals, many farmers in the 27 communities generate agricultural profit mainly from vegetables and fruits. The Project area is characterized as a leading area of vegetables and fruits production in the country. Higher productivity of many crops in the 27 communities comparing the national average proves that the Project area is a leading crop farming area in the country.

Out of 13,574 farm households in the communities, only 4,749 farm households or 35% of total farm households are growing some sort of livestock in 2014. In general, livestock farming is not popular among farmers in the 27 communities.

Cropping Calendar

Cropping season of most crops begins in April and May, as rainfall increases when spring season starts in the Project area. The cropping ends in September and October before cold winter season comes. Wheat is an exception since it is widely sowed in autumn, when a certain rainfall is expected. In any case, the farming system in the Project area is designed based on timing with appropriate climate. Irrigation is required for growing all crops in Ararat plain where the Project area is located due to small amount of rainfall and high temperature.

Use of Farm Inputs

Inputs Use

According to the result of farm household survey, 82% and 61% of sampled farmers use fertilizers and herbicides respectively for their crop production, and those percentages are relatively higher compare to other inputs. While fertilizers are commonly used for almost all crops, herbicides are not much used for cereals and sweet pepper. Other farm inputs such as compost, pesticides and commercial seeds are used only by 20-35% of sampled farmers. As regard to fertilizers, there might be growing concern about an excessive use of nitrogen fertilizers in Armenia. A result of the survey implies that many respondents use only nitrogen fertilizers and overuse them to their crops.

Many farmers has recognized that pests and diseases are serious problem for their crop production when the Survey team interviewed about their problems, but pesticides and fungicides are still not popular among them. They are still used selectively by limited farmers to limited crops.

As for commercial seeds and seedlings, those of cereals, potato, tomato, cucumber, cabbage and watermelon are often procured from market. It is noted that many growers of tomato and cucumber under greenhouse depend much on commercial seedlings.

Number of Farm Machinery

Many farmers in the Project area expressed serious shortages of farm machinery during an interview survey with them. Though there are agricultural machinery services by service providers in the Project area, shortages of farm machinery and improper timings of the services are serious issue for appropriate crop management works as planned. In Armenia, many over aged farm machinery such as tractors are still used at field, even from the Soviet time continuously. Present farm machinery services cannot properly cope with requirements for managing a large number of fragmented farmlands owned by individual farmers.

Procurement Sources

Private market is the major source of farm inputs for farmers. Besides, government program is another major source of chemical fertilizers, as there is a government subsidy system of fertilizers to encourage farmers in their intensive farming.

Greenhouse

Almost 95 % of total greenhouse areas in Armenia are concentrated in Ararat Marz and Armavir Marz which are located in Ararat plain. Vagharshapat WUA and Khoy WUA areas, located in Armavir Marz, are the center of greenhouse crop production in the Project area. According to interviewed farmers and the Greenhouse Association, RA, tomato and cucumber are the most popular crops for greenhouse cultivation.

Marketing of Agricultural Products

The Project area has an advantage location for marketing agricultural products to Yerevan city which is the biggest consuming place of agricultural products in the country. Middleman is the most major buyers for farmers in the Project area. Middleman is playing the role of filter to collect up enough volume of products from farmers for retailer’s demand. Middleman are generally selling the purchased products from farmers to other buyers with 20~30 % higher price. The seasonal farm-gate prices show that there are huge gaps between minimum price and maximum price in every crop. The prices of vegetables and fruits are staying at the bottom due to the saturated situation in the market during in the peak harvesting season.

Agricultural Cooperatives

According to the result of the farm household survey, agricultural cooperatives are not active in the Project area. Agricultural cooperatives are not yet became ingrained in farmers not only in the Project area but also in Armenia.

Agricultural Credit

Since April 2011, the government has been implementing an agricultural finance supporting program which compensates the interest rate of agricultural credit. The subsidized agricultural credit is provided through three private banks. According to the result of interviews to farmers in the target area, nearly 40% of interviewed farmers regard access to credit is a considerable issue of farm management. There are subsidized agricultural credit systems in Armenia but many surveyed farmers presumed that those credit systems are not applicable due to its repayment conditions.

Difficulties Confronting Farmers

The Survey team collected information about farming issues through farm household survey WUA workshops and direct interviews with farmers. Major issues pointed out by farmers are shown as follows in the order of seriousness.

1) Marketing issues
2) Pests & diseases issues
3) High cost issues
4) Machinery issues and Irrigation issues

Figure 4-10 shows an image of current circumstance of farmers in the Project area by compiling the issues.

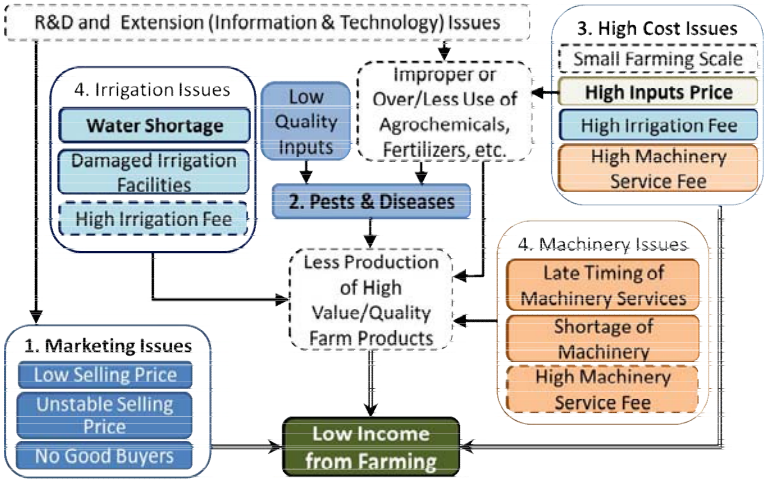


Figure 4-10 Constrains of Farmers in the Project Area

4-6 Information on Cost Estimate and Procurement

Conditions of Cost Estimate

Preconditions for estimating of the project cost are decided as follows;

Table 4-4 Condition of Cost Estimate

No.	Expense and cost	percentage	Source
1	Overhead expenses	13.3 %	Armenian Construction Law
2	Contractor's profit	11.0 %	
3	Expenses on temporary building and Climate impact	4.1 %	
4	Consultant services	6.0 %	Estimation
5	Price contingency	10.24 %	Calculation from price escalation
6	Physical contingency	5.0 %	General rule
7	Exchange rate (1 US dollar = 486.99 AMD		Armenian central bank
8	Exchange rate (1 US dollar = 113.65 JPY		Bank of Tokyou-Mitsubishi UFJ

Procurement of the Construction Machinery

Several construction machinery manufacturers in Japan and Europe have agents in Armenia and general construction machineries are distributed in the market. These machineries are used under lease mainly. These agents have workshops for maintenance of machineries and provides the service of repairing. Only soil-cement mixing machine is import through a machinery agent in Armenia.

Procurement of the Construction Materials

Bentonite

Bentonite mine is located in Ijevan, north east part of Armenia. Mined bentonite includes montmorillonite over 80% and has enough quality for using anti-infiltration works. Capacity of produce is 2,000 ton/month but this volume is to be increased up to 20,000 ton/month by future investment in equipment and facilities. However, even enhanced product from Ijevan is not enough considering the necessary volume of the reservoir construction. Georgia also exports good quality bentonite which contains montmorillonite over 85%. Bentonite is mined in Mitispri, western part of Georgia. Estimated amount of deposit is 50,000,000 ton and annual product is 400,000 ton. This amount is enough for the consumption in the construction in Yeghvard reservoir. Also part of produced bentonite is transported to Belarus and manufactured to bentonite sheet. This bentonite

sheet is imported and available in construction market in Armenia.

Cement and aggregate
Raw materials of concrete such as cement, fine aggregate and coarse aggregate are produced in Armenia. Product of these materials is enough for demand of the construction in the Project.

Pipe, gate and valve
Pipes can be procured in Armenia. Some factories have a laboratories for quality control and tensile test, water pressure test and compression test are conducted. Gate and valve are exported from Europe, Russia and China so that products made in Russia and China are inferior in quality, European product are installed for significant facilities in Armenia. Some European valve companies had their factories in Slovenia and valves distributed in Armenia widely.

5. ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

5-1 Environmental and Social Considerations

Institutional and Legislative Framework for Environmental Consideration

In Armenia, the "Law on Environmental Impact Assessment and Expertise was formulated in 2014. Based on the Law, the Project is classified into "Category A", which requires preparation of an Environmental and Social Assessment (ESIA) Report, and it is needed to get a positive conclusion from the Ministry of Nature Protection (MNP). There are some gaps between Armenian laws and the JICA Guidelines for Environmental and Social Considerations (the JICA Guideline).. Specific standard for irrigation water quality, water/soil quality standard for agrichemical have not been prepared, and international standards such as FAO standards are applied for those matters.

Examination of Alternatives

Some alternatives of the Project in terms of water resources, construction site, scale and anti-infiltration works are examined. As a conclusion, the current location of the Reservoir basin is the most suitable to store a large amount of water, and utilization of free water from the Hrazdan River is the most sustainable as water resource. Concerning reservoir scale, around 800ha reservoir area is selected, since the existing dikes can be used and the cost is lower than that of 600ha. As anti-infiltration works, in terms of reliability and cost, "Soil-Cement with a sandwiched bentonite sheet" is proposed as the best option.

Scoping and TOR for Environmental Examination

Considering the conditions around the construction sites and proposed components, some environmental negative impacts, namely, pollutions during construction works, increase of agrichemicals & fertilizers, impacts on ecosystem and so on in construction stage are expected and they are judged as "B-". Moreover, some parameters, namely, possibility of the conflict between the beneficiaries and affected persons, impacts on groundwater, cultural assets & heritages and so on are unknown and they are judged as "C". Those environmental parameters have to be studied in detail, and based on the scoping result, Terms of Reference for the environmental studies is proposed.

Results of Environmental Examination

Impacts before construction
Before construction, land acquisition will be caused by the Project, and in total, 819.36ha will be influenced by the Project and most of the area is communal land. Compensation policy for land loss, crop loss and so on is established, and it is needed to compensate for the impacts based on the policy.

Impacts during construction

During construction works, air pollution, mud water, noise, road closure, waste generation and so on will be caused in and around the construction sites by the Project. It is necessary to take some countermeasures to minimize the impacts. However, they are temporary and the scale will be relatively small. As a whole, the expected impacts are not very significant.

Impacts during operation

Due to the expansion of irrigation area, application of chemical fertilizer and agrichemical will be increased, and pollution of groundwater and soil can be caused. It is important to promote awareness of suitable agrichemical and fertilizer application methods through the MOA staff. Especially, control of illegal agrichemical is essential.

In and around the Reservoir basin, some endangered species (birds and a snake) are identified, however, they can move to outside of the Reservoir basin by themselves, and there are similar places around the Reservoir. Therefore, it is not difficult for them to survive after the Project, and no severe impacts on fauna and flora by the Project is expected. On the contrary, after the Project, the Reservoir will be attractive for migratory water birds, which can contribute to biodiversity of the area.

The Project will divert 103 MCM from the Hrazdan River, however, it will not cause severe hydrological change, since the River has already been utilized for irrigation and power generation. Even in the downstream, the peak discharge in spring will be kept after the Project. In case of Kasakh River, discharge will be increased, however, the section is very short, only 14km, and significant impact is not expected. Regarding the Lake Sevan, the Project can contribute to save the water of the lake, however, and estimated water level increase by the Project is limited to only 4cm per year.

Concerning impacts on fish in the Hrazdan River, it is possible to category 1) upstream, 2) middle stream and 3) downstream. Fish in the upstream will not be damaged, since the upstream section is located on upper of the water intake point of the Arzni-Shamiram Canal. In the middle stream, natural river and canal flow in parallel, most of the water is taken to canal for irrigation and power generation at present, and the conditions will not be changed after the Project. In the downstream, there is no weir and no canal. The most important season for fish is spawning, namely, spring. In general, spawning triggers of fresh water fish are water temperature change and discharge peak, and sufficient water depth is also necessary. As mentioned before, discharge peak will be kept after the Project and water temperature will be increased as ever. At the Masis Observatory in the downstream, the lowest depth through the year is around 3m, which is enough for fish spawning. Thus, the Project will not give a damage to fish in the downstream neither. Therefore, the damage to the ichthyological system Hrazdan River by the Project will be small.

At the Reservoir, some fish can be flushed away from the Hrazdan River and they can mix to fish in the Kasakh River through the planned Outlet Canal-2. However, there are some common fish between the Hrazdan and Kasakh Rivers, therefore, significant impacts on ichthyological system in the Kasakh River is not expected.

Hrazdan River is mainly used for irrigation and power generation, and even though the Project will take 103 MCM for the Reservoir, the impact will be small, considering that water discharge for hydro power generation in 2013 was 1,875 MCM. In Hrazdan River, around 500 million kWh is generated on average per year, while total power generation in Armenia is around 7,800 million kWh annually. The influenced power generation by the Project will be 27million kWh, which accounts for only 0.35% of total national power generation. Therefore, the impact by the Project on the power generation will be very limited.

Evaluation

During construction period, air pollution, water pollution, noise & vibration, impacts on ecosystem within the Reservoir and waste will be generated, while groundwater pollution, soil contamination and impacts on ichthyological system in the Hrazdan River are concerns during the operation stage. However, these impacts are not significant and irreversible. It is possible to manage to some extent by implementation mitigation measures. Therefore, it can be judged that the impact by the Project will not cause severe environment and social impacts.

Mitigation Measure

Before construction, the compensation measurement should be established and it is to be implemented properly. During construction period, the construction contractor should take measures to minimize the expected impacts. PIU/SCWE will supervise the mitigation measures taken by the contractor in collaboration with the technical consultant. During operation period, MOA, WUA and WSA will be key organizations to mitigate the impacts. MOA is requested to control the proper farming management, while WUA and WSA are recommended to comply with regulation for water use. During operation period, the MNP will be responsible for supervision.

Monitoring Plan

In the process of implementation of EMP, regular monitoring is to be practiced by the responsible organizations. The monitoring results will be complied as a monitoring report by using proposed monitoring indicators and formats. In addition, it is important to record how the implementation agency takes measures against any problems in the process. The report should be submitted to the supervising agency regularly.

Stakeholder Meeting

According to the Law on Environmental Impact Assessment and Expertise, Public Hearing shall be organized at two stages, namely, initial stage and draft ESIA report preparation stage. At the initial stage, the project outline and environmental expected impacts were presented on 20th October 2015. The second Public Hearings were organized to share the Draft ESIA Report and RAP, and to gain comments from the participants. As a whole, the Draft ESIA Report was accepted by the participants.

5-2 Involuntary Resettlement and Land Acquisition

Necessity of Resettlement and Land Acquisition

Physical relocation will not be caused by the Project, while the land acquisition will be caused by construction of Yeghvard reservoir and related irrigation canals. Especially, the permanent land acquisition is needed for construction of the Reservoir and planned Feeder Canal 2 which is planned to be an open canal. On the other hand, expected impacts by other proposed canals are limited to the construction period, since they will be constructed as pipelines.

Legal and Administrative Framework

There are some gaps to be mitigated between the Armenian laws and JICA Guidelines/WB OP.4.12. It is not needed to prepare Resettlement Action Plans (RAP) in Armenia, while it is necessary to prepare RAP according to the JICA Guidelines. The main gaps between Armenian laws and JICA Guidelines/WB OP.4.12 are followings;

- ✓ There is no grievance redress system except for complaint about property evaluation result in Armenian laws;
- ✓ There is no provision for cut-off date, and implementation of socioeconomic survey. Cut-off

date cannot be set at F/S stage. However, it can be set at D/D stage after concluding Loan Agreement;

✓ In the Armenian legislation, only legal property owners are eligible for compensation.

Scope of Resettlement

The population survey, assets and lands survey, and socioeconomic survey were carried out from March to April 2016. As shown in Table 5-1, there are 75 Project Affected Households (PAHs) with 418 Project Affected Persons (PAPs) in the Project Affected area.

Table 5-1 Numbers of PAHs and PAPs

Type of loss	No. of PAHs			No. of PAPs		
	Legal	Illegal	Total	Legal	Illegal	Total
1. Required for physical relocation						
1-1. HH (Structure owner on Gov. land)	Nil	Nil	Nil	Nil	Nil	Nil
1-2. HH (Structure owner on Private land)	Nil	Nil	Nil	Nil	Nil	Nil
1-3. HH (Tenants)	Nil	Nil	Nil	Nil	Nil	Nil
1-4. CBEs (Structure owner on Gov. land)	Nil	Nil	Nil	Nil	Nil	Nil
1-5. CBEs (Structure owner on Private land)	Nil	Nil	Nil	Nil	Nil	Nil
1-6. CBEs (Tenants)	Nil	Nil	Nil	Nil	Nil	Nil
1-7. Community owned structures including physical cultural resources	Nil	Nil	Nil	Nil	Nil	Nil
Sub-total (1)	Nil	Nil	Nil	Nil	Nil	Nil
2. Not required for physical relocation						
2-1. State or Community owned land[1]	-	60	60	-	340	340
1) Canal area	-	7	7	-	44	44
2) Reservoir area	-	53	53	-	296	296
2-2. Private owned land	15	-	15	78	-	78
1) Canal area	12	-	12	64	-	64
2) Reservoir area	3	-	3	14	-	14
2-3. Labor*	-	-	-	-	-	-
Sub-total (2)	15	60	75	78	340	418
Total (Sub-total 1~2)	15	60	75	78	340	418

Source) JICA Survey Team, March-April of 2016

Remarks) In the Project, farming labors are not included to PAPs.

As shown in Table 5-2, total Project affected area is 819.36 ha, including all three categories, namely, a) State Lands, b) Communal Lands, and c) Private Lands.

Table 5-2 Project Affected Area by Land Ownerships

Category	Plots	Affected Area (ha)
1. State	2	54.49
2. Community	77	738.94
3. Private	25	25.93
Total	104	**819.36**

Source) JICA Survey Team, March-April of 2016

Accordingly, the result of socioeconomic survey is analyzed by three groups of cultivators, namely, 1) cultivators in only Reservoir basin, 2) cultivators in only area along the proposed canal, and 3) cultivators in both Reservoir basin and area along the proposed canal. The lowest income is "1. Cultivators in only reservoir basin." However, it is also unveiled that they have much higher income from cultivation in non-affected area.

Compensation Measures

By considering the gap between Armenian law and JICA Guidelines/WB OP.4.12 and results of census, assets and lands, and socioeconomic surveys, entitlement matrix was established as shown in Table 5-3.

[1] If the illegal users have cultivated one plot, there would be 53 illegal land users in maximum. Hence, the number of affected households are assumed as 53 households. In addition, according to the socioeconomic survey, the average number of family members in the Project affected area is 5.59 person. Then, the number of PAPs of illegal land users within the Reservoir area is assumed approximately 296 persons.

Table 5-3 Summary of Entitlement Matrix

	Legal land owners	Illegal land users
1. Land loss	Cash compensation at the market price (or official rate, higher of them) +15 %	-
2. Crop loss	Perennial Crop compensation for expected harvest in cash at market rate	-
3. Tree loss	Cash compensation at market rate based on type, age and productive value of the trees	
4. Loss of livelihood means	-	Employment priority in project-related jobs
5. Vulnerable people	1. Allowance equivalent to 6 months of minimum salary 2. Employment priority in project-related jobs	
6. Temporary land loss	1. For land; Cash compensation at the market price (or official rate, higher of them) + 15% 2. For crop; Crop compensation for expected harvest in cash at market rate. 3. For tree; Cash compensation at market rate based on type, age and productive value of the trees	-

Grievance Redress Mechanism

It is recommended to use existing grievance redress system in Armenia for the Project implementation process. Three (3) patterns for grievance redress system, namely, 1) directly applying to the court, 2) directly applying to PIU, and 3) applying to local government or WUA, can be proposed. PAPs can choose the most convenient and accessible way for them to lodge grievance.

Implementation Structure

PIU/SCWE is the Implementation Agency in charge of implementation of the proposed RAP. PIU is requested to cover the final RAP preparation, implementation of the RAP, coordination with concerned organizations. Based on the proposed cost for compensation and support to the PAPs, PIU will apply the necessary budget allocation to the Government. The social expert of PIU is responsible for the general management of the planning and implementation of the RAP. In the process of the monitoring, private consultants will be employed separately, for internal and external monitoring. The main activities of the consultants for internal monitoring are providing technical support to the PIU for RAP implementation. And the external monitoring consultant is required to confirm the progress of compensation payment, living conditions of PAPs.

Implementation Schedule

At the D/D stage, it will take about 14 months to facility design. After the determination of the affected area in the period, the final census survey will be started and it will take two months for the survey. Then, the Cut-off date of the Project will be established as the first day of final census survey.

Before construction, compensation and land acquisition should be done. It is required to discuss on the amount to be paid and to make a compensation agreement between the Government of Armenia and PAPs before compensation implementation. In addition, the monitoring will be started during payment period and it will be continuously done during the construction stage.

Cost and Financial Resources

The total compensation cost for the Project, excluding compensation to state and communal lands, is estimated at 437,720,390 AMD, which is equivalent to 898,828 USD. If the state and communal lands is compensated, the compensation cost can be 5,668,306,790 AMD, which is equivalent to 11,639,473 USD.

Monitoring Structure and Monitoring Form

It is required the internal and external monitoring by different organizations for the RAP implementation. Internal monitoring will be carried out by PIU and private consultants. In the

internal monitoring process, following indicators could be proposed;

- ✓ Number of people raising grievances in relation to the Project and number of unresolved grievances;
- ✓ Progress of compensation payment;
- ✓ Whether the payment is properly done; and
- ✓ Change of the living conditions of PAPs.

External monitoring will be carried out by private consultants hired by the PIU/SCWE, who are independent from internal monitoring to confirm whether the compensation progress, considerations to the vulnerable people, grievance redress and so on are properly implemented in accordance with the RAP. The monitoring form is proposed based on the JICA Guidelines.

Public Consultation

The series of stakeholder meetings on ESIA and RAP were organized altogether. Based on the Armenian law on Environmental Impact Assessment and Expertise, public consultation shall be organized at two stages. The first Public Hearing was held on 20th October 2015 in Yeghvard city office. There was no objection against the Project. The participation of the residents at the meeting was relatively small, the seminar to explain the Project outline was also organized in Nor-Yerznka village on 5th November 2015. The people were also interested in the environmental impacts and transportation of soil within the Reservoir. Some of have concern about safety of the Reservoir. On 23rd December 2015, based on the Law, the MNP organized the public consultation at Yeghvard city to confirm the situation. So far, no person who is against the Project has been identified.

Regarding explanation of ESIA Report and proposed compensation policy on the Project, a series of public consultations was organized from the end of May 2016 to the beginning of June 2016. The participants are interested in anti-infiltration works, compensation measure for land loss, scale of the Reservoir and irrigation canals, and so on. In general, negative opinion for the Project was not presented at the public consultations. It is noted that communities concerned have a request that the State will implement some small scale project for the communities, since the communities have to provide their lands for the Project.

5-3 Climate Changes

Armenia has cooperated with international climate change frameworks for a long time. The government ratified the United Nations Framework Convention on Climate Change (UNFCCC) in May 1993 as Non-Annex I party and the Kyoto Protocol in December 2002. MNP has been appointed as the Designated National Authority (DNA) for the Clean Development Mechanism (CDM) of the Kyoto Protocol by a decree of Government of Armenia. One of the main functions is to approve the compliance Kyoto Protocol, as well as to ensure effective participation of Armenia in international CDM processes. In 2010, the Republic of Armenia submitted a statement to the Convention Secretariat for association with the Copenhagen Accords. This statement presents the position of the Republic of Armenia on the continuation of the Kyoto Protocol and the limitation of greenhouse gas (GHG) emissions. In September 2015, the RA approved the Intended Nationally Determined Contribution (INDC) under the UNFCCC. According to this, the climate change mitigation actions should not reverse the social and economic trends, but contribute to the socioeconomic development of the RA.

Agriculture sector is one of the most climate sensitive sectors in the economy. Even in the current conditions, the sector is affected by adverse weather phenomena such as drought, hail, early frost, spring floods, and landslides. In recent decades, extreme weather events have been becoming more frequent and lasting longer. Agriculture accounts for about 20% of the country's total GDP, and the

sector has a role of ensuring food security, targeting 75-80% of self-produced basic foods. Therefore, the TNC notes that the strategy for this sector should be aimed at enhancing competitiveness and sustainable development, and at implementing preventive adaptation measures.

Mitigation Strategy

After the project, it is expected that existing deep wells and pump stations will be converted to gravity irrigation systems. The abolishment of them may reduce GHG emission through saving in energy use. The estimated GHG emission reduction of the project is 16,575.02 t-CO2/year.

Adaptation Strategy

Water loss due to wasting of water resource has not been observed in the Project area so far, however, deterioration of the existing irrigation facilities cause water loss, e.g. water leaking from the canals. It is necessary to rehabilitate those facilities and the proposed project components include the rehabilitation works. In the future, it is possible to introduce water saving irrigation system such as drip irrigation and sprinkler irrigation. During the Project implementation, a pilot project to verify the water saving irrigation system can be implemented in collaboration with the MOA.

6. PLAN OF YEGHVARD IRRIGATION SYSTEM IMPROVEMENT PROJECT

6-1 Agricultural Plan

Cropping Area

Table 6-1 Cropping Plan in the Project Area in 2023

WUA	Crop groups (unit: ha)							
	Wheat	Alfalfa	Other food & forage	Potatoes	Vegetables /Melons	Fruits	Grapes	Total
Yeghvard	156	491	64	18	51	758	481	2,019
Ashtarak	77	137	85	8	165	302	851	1,625
Vagarshapat	724	274	160	88	1,701	32	148	3,127
Khoy	944	550	292	737	1,725	527	801	5,576
Project Area Total	**1,901**	**1,452**	**601**	**851**	**3,642**	**1,619**	**2,281**	**12,347**

Crop Productivity

Table 6-2 Crop Productivity

No.	Crop	Yield (ton/ha)		
		Without project	With project	Difference (increase)
1	Wheat	3.6	3.8	0.2
2	Barley	2.7	3.4	0.7
3	Maize (grain)	2.4	2.6	0.2
4	Alfalfa	11.3	11.5	0.2
5	Potato	36.3	41.8	5.5
6	Tomato, open	47.7	50.4	2.7
7	Tomato, green-house	100.0	100.0	0.0
8	Cucumber, open	38.4	42.0	3.6
9	Cucumber, green-house	80.0	80.0	0.0
10	Eggplant	49.8	53.7	3.9
11	Sweet pepper	38.9	41.4	2.5
12	Cabbage	29.7	32.6	2.9
13	Water melon	42.7	45.3	2.6
14	Grape	11.2	13.5	2.3
15	Apricot	7.1	7.6	0.5
16	Apple	7.7	8.9	1.2

Recommended Agricultural Plans Supporting the Project

Summary of Issues Confronting Farmers and Policy Direction is shown in Table 6-3.

Table 6-3 Policy Direction Addressing Farmers' Issues

Farmers' Issues	Policy Direction
1 Difficulty in accessing reliable information on farming technology	To encourage research activity to address the technical issues at farmer level, i.e. fertilization, pest-control, farm-mechanization, water management & saving, etc.
	To enhance agricultural extension activity to be more friendly to individual farmers
2 Lack of promising crop-varieties to meet the market demand	To encourage research activity to develop or introduce new varieties
	To promote seed/seedling growing and importing business
3 High cost of agricultural inputs and farm machinery services & Shortage of farm machinery and spare-parts	To exempt or reduce import duties
	To ease regulations in order to accelerate the private sector entering the business
	To promote a competitive business environment by fostering private business operators and by phasing out of the government intervention from actual business transactions
	To promote a farm mechanization service managed by the private sector/cooperatives
	To introduce affordable credit-schemes to farmers and business operators including cooperatives
4 Low quality inputs are in the market & Banned agrochemicals are used	To educate business operators and farmers (regulations, good practice in handling & storage)
	To create a competitive business environment by increasing the number of business operators
	To practice periodical monitoring and inspection at market and field levels
5 Improper use (overuse or less use) of fertilizers and agrochemicals	To encourage research activity to define an appropriate dosage of fertilizers and agro-chemicals
	To educate farmers how to use fertilizers and agrochemicals properly
6 Shortage of irrigation water	To rehabilitate irrigation canals and networks
	To regulate grand water use
	To develop and introduce water saving technology acceptable to farmers
	To educate farmers the water saving technology
7 Low and unstable selling price of crops	To encourage research activity to develop or introduce new varieties with high market demand
	To develop and introduce forcing or inhibiting cultivation technology of crops
	To educate farmers how to adjust themselves to the present free-market economy system
	To disseminate updated market information to farmers including price information
	To promote a group marketing/processing among farmers by changing their negative mindset against cooperatives
	To interface farmers/cooperatives with private traders to develop a partnership in marketing and processing
	To encourage the development of agricultural marketing and processing industries in rural area
	To disseminate an international-competitive hygiene technology in marketing and processing industries
	To develop a cold chain system in the distribution of agricultural products

Recommended Projects

Followings projects are drafted as priority agricultural projects supporting the Yeghvard Irrigation Project based on the discussion with MOA staffs.

(1) Pilot Agricultural Cooperatives Development
(2) Enhancement of Agricultural Credit System
(3) Establishment of Monitoring and Inspection System of Pesticide Residue
(4) Enhancement of Agricultural Research to Promote a Market Oriented Agriculture
(5) Vitalization of Agricultural Extension

6-2 Irrigation Plan

Water Resources Utilization Plan

Hrazdan is a major river in Armenia. There are hydro power generation systems along Hrazdan river. Most of other countries in the world, irrigation and hydro power generation always have conflict because of mismatching period of demand needs between irrigation and hydro power generation respectively. However in Armenia, the hydro power generation is allowed its operation during irrigation period only, therefore it is no conflict between irrigation and hydro power generation.

The canal parallel to Hrazdan river is used for the Hydro Power Cascade System. The water is distributed from Lake Sevan for irrigation purposes prior to hydro power generation. During the water flow from Lake Sevan to Lake Yerevan, irrigation system take the water for irrigation and remaining water generate the hydro power at each power station.

Irrigation Area and Water Requirement

The total area of Yeghvard Irrigation Improvement Project is 12,347 ha. The target area can be characterized into two (2) areas, one is higher altitude land located around 1,000-1,300m, and the other one is lower altitude land located around 800-1,300m. Altitude of 1,000m is the boundary of higher and lower altitude land. Yeghvard and Ashtarak WUAs are located in higher altitude land belong to Kotayk and Aragatsotn Marzes. Vagharshapat and Khoy WUAs are located lower altitude land belong to Armavir Marz. This lower altitude land is well known as a major agricultural production area, which is called as Ararat plain.

Crop water requirement is calculated by the Irrigation Norm in Armenia, the Institute of Water Problems and Hydraulic Engineering, Yerevan, which was published from Ministry of Agriculture in 2007. In the irrigation norm, crop water requirement is mentioned in consideration of rainfall probability for 50% and 75%. The probability of 75% was used as criteria for management of irrigation schedule as well as for designing of the Yeghvard irrigation system. Water demand for 12,347 ha is equivalent to 154.2 MCM with 46.8% of canal conveyance efficiency factor into the calculation.

Water Balance Calculation

The concept of water distribution from Hrazdan river through Arzni-Shamiram canal is to store the snow melted river flow water to Yeghvard reservoir during March to May. The difference between available water and demand is the maximum water volume which can be diverted to Yeghvard reservoir. However, the maximum discharge to Yeghvard reservoir is calculated with the limited maximum condition of 22.0m^3/s according to the 80% of current canal cross section.

The water balance is calculated combining with hydro-meteorological data, water demand of Yeghvard Improvement Project area and other irrigation systems along Hrazdan river. Year of 2013 is decided as a reference year for definition of the capacity of Yeghvard reservoir. 2013 is matched to the criteria of 75% probability from the view point of rainfall and river flow.

Based on the result of calculation for reference year, the capacity of Yeghvard reservoir is defined as 94MCM. On the reference year, total area of 12,347ha could be irrigated by Yeghvard reservoir. The distributed water from Arzni-Shamiram canal to Yeghvard reservoir is diverted start from 1st decade of March to 2nd decade of May. And from the result of water distribution plan for four targeted WUA, Yeghvard reservoir starts to irrigate from 3rd decade of May and end to 2nd decade of October.

Improvement Plan of Irrigation Network System

Improvement plan of irrigation network system is planned as shown in Tables 6-4 and 6-5.

Table 6-4 Plan of Irrigation Facilities around Yeghvard Reservoir

Name of Facilities		Purpose	Type	Specification			Target Discharge
Feeder Canals	Feeder Canal 1	Inflow to Reservoir	Pipeline	Diameter	φ=	1.60(1.6km), 1.72(1.94km)) m	1.11 *- 9.00 m³/s *) Except Arzni-branch 0.39m³/s
				Length	L=	4.70=1.16(approach canal)+ 3.54(pipe) km	
	Feeder Canal 2	Inflow to Reservoir	Open Canal	Width	B=	ave. 4.00 m	2.20 - 13.00 m³/s
				Length	L=	0.33 km	
Outlet Canals	Outlet Canal 1	Outflow to Yeghvard WUA	Pipeline	Diameter	φ=	1.20 m	0.22 - 2.33 m³/s
				Length	L=	0.73 km	
	Outlet Canal 2	Outflow to Kasakh River	Pipeline and canal	Diameter	φ=	1.72 m	0.16 - 12.82 m³/s (for irrigation purpose) Maximum 13.7m³/s (in case of emergency)
				Length	L=	4.70(pipe)+0.5(dissipater) km	

Table 6-5 Plan of Rehabilitation Facilities in Irrigation Field

Facilities and structures	Rehabilitation outline	Responsibility Organization
Arzni-Shmiram canal	・Section between approx. PK14 and PK17, PK28 and PK32, PK64 and PK69, PK85 and PK93, PK94 and PK96. PK96 and PK97, PK101 and PK105 (L=2.7km) ・Remove concrete panel and line with concrete	WSA
Lower Hrazdan canal part2, BP. to PK219	・Section between PK10 and PK188 (L=17.8km) ・Add the concrete for raising to the sidewall ・Installation of 2 pipes that connect Upper Aknalich canal (φ400mm) at PK10 and Inner Aknalich canal (φ1,000mm) at PK13 with Lower Hrazdan canal at PK188 .	
Aknalich PS	・Abolish	
Metsamor PS	・Abolish	
Ranchaper PS 1	・Abolish	
Ranchaper PS 2	・Abolish	
Arzni-Branch canal, BP. to PK120	・Section between BP and PK23 (L=2.3km) ・Remove the current canal and construct the lining concrete and/or install the precast concrete canal ・Replace 1 gate	Yeghvard WUA
Arzni-Branch canal, PK120 to EP.	・Section between PK123 and PK234. (L=12.1km) ・Remove the current canal and construct the lining concrete and/or install the precast concrete canal ・Replace 22 gates, 1 water measurement facility and 2 aqueduct bridges	Ashtarak WUA
Takahan canal, BP. to PK130	・Section between PK69 and PK126 (L=5.4km(except pipeline 0.3km) ・Remove the current canal and construct the lining concrete and/or install the precast concrete canal ・Replacement 17 gate and 2 aqueduct bridges	
Shah-Aru canal, BP. to PK118	・Section between BP. and PK31 PK62 and PK70, PK82 and PK112 (L=6.9km) ・Remove the current canal and construct the lining concrete and/or install the precast concrete canal ・Replace 16 gates	Vagharshapat WUA
Inner Aknalich canal	・No rehabilitation in the Project	
Upper Aknalich canal BP to PK104	・Section between PK6 and PK104 (L=9.8km) ・Install the precast concrete canal in existing canals ・Replacement 39 gates and 2 aqueduct bridges	Khoy WUA
Metsamor canal	・No rehabilitation in the Project ・Facilities and structures were rehabilitated under the assistance of the World Bank.	

6-3 Reservoir Plan

Comparative Study of the Reservoir Scale

Facility layout around private orchard area

There is a private orchard area at the west edge of northern slope and a part of this area will be submerged after impounding. Since this area has high permeability, an anti-infiltration measure is required against this area to reduce leakage volume.

The following two (2) plans can be considered as anti-infiltration measure and Plan-A is selected due to economical advantage.

Plan-A: A part of orchard area is covered by slope protection with anti-infiltration capacity and some land compensation is requires.

Plan-B: Dam structure is constructed along the toe of slope and no land compensation is required.

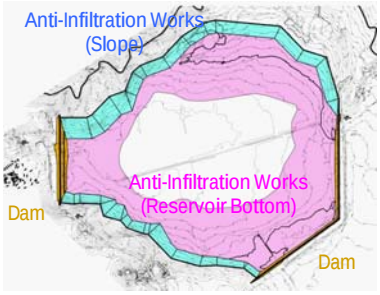
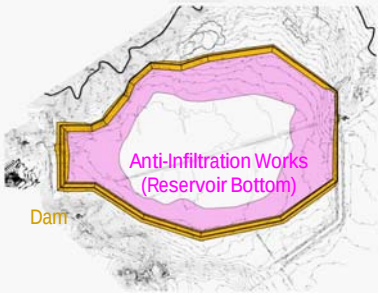
Facility layout to reduce total construction cost

Anti-infiltration works on reservoir bottom, north slope and south slope to reduce leakage volume account high ratio of total construction cost. While dam along the toe of slopes instead of anti-infiltration works can be considered as leakage control structure. Therefore the following two (2) plans can be considered and Plan-A is selected due to economical advantage (Refer to Table 6-6).

Plan-A: Reservoir bottom, north slope and south slope are covered by anti-infiltration works.

Plan-B: Reservoir bottom is covered by anti-infiltration works and dam is constructed along the toe of north and south slope as leakage control structure.

Table 6-6 Results of Comparison Study to Minimize Anti-Infiltration Area

			Plan A 900ha	Plan B 600ha
Outline				
Reservoir Properties	Reservoir Capacity		94 MCM	Same as on the left
	LWL		EL. 1290m	Same as on the left
	FWL		EL. 1305m	EL. 1307m
	Dam Height		25.55m	27.55m
	Reservoir Area		7.96km^2	5.42km^2
Direct Construction Cost	Total	(USD)	87,768,086	89,853,972
		(Million USD)	87.8	89.9

Estimation of Leakage Rate from Reservoir

1) In order to grasp the efficiency of the anti-infiltration layer with which the reservoir must be covered to reduce leakage, the leakage rate was estimated for alternative cases of reservoir layout and covering extents of the anti-infiltration layer.
2) Two (2) methods are applied for the estimation: the “2-D Simple Method” and the “3-D FEM Method”. The 2-D method is basically the same as used in the past D/D in 1985, but the zoning for the calculation is finer. The calculation for all cases was carried out with the 2-D method. The 3-D method was applied only for the main cases to infer the three-dimensional flow condition.
3) The coefficient of permeability obtained by in-situ test in the present and past investigations were all collected and analyzed. The geometric mean was used for the representative value of each geologic layer.

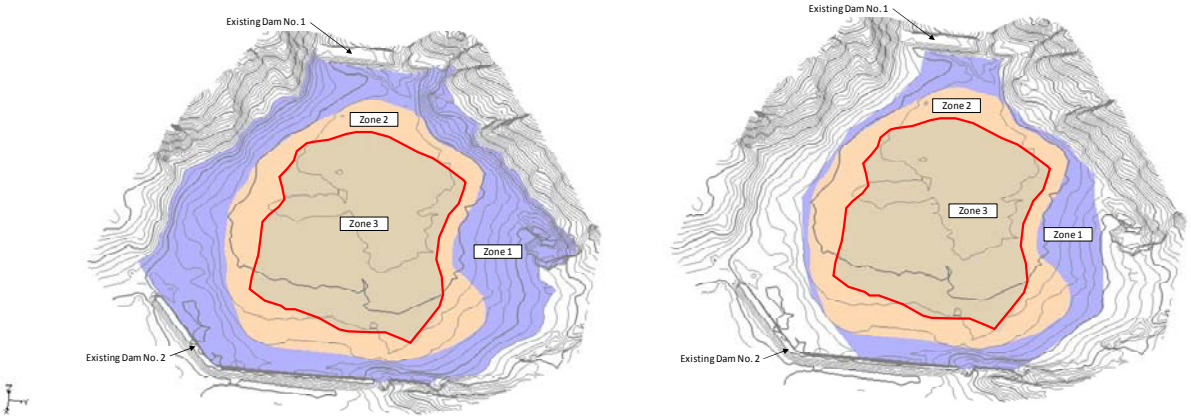
4) There are two geologic layers which mainly consist of sandy loam or loam and possibly work as the natural anti-infiltration layer. Their representative coefficient of vertical permeability and thickness in the central area of reservoir are as follows;

Layer 1 $k_v = 8.3 \times 10^{-6}$ cm/s, $t_1 = 15$ m ~ 40 m (Upper 10 m : $k_v = 4.3 \times 10^{-4}$ cm/s)
Layer 6 $k_v = 7.5 \times 10^{-6}$ cm/s, $t_6 = 15$ m ~ 90 m ($t_1+t_6 = 30$ m ~ 110 m)

5) Table 6-7 shows the estimation cases and their estimated leakage rates. The rate is larger in the 900 ha plan than the 600 ha plan, but the difference is small. The leakage rate itself is a little large, but probably does not affect the reservoir function significantly, because the ratio to the full reservoir capacity; 94 MCM is near or smaller than 0.05%/day which is the Japanese guideline for reservoir construction. Difference is not so large between the whole and partial coverage cases of anti-infiltration layer. Therefore the central part of the reservoir may not be covered with the layer considering the cost efficiencies.

Table 6-7 Estimated Leakage Rate from Reservoir

Reservoir Layout Plan	Anti-infiltration Layer Coverage	Infiltration Rate at 94MCM			Average Infiltraion rate in Irrigation Period of Standard Year		
		Amount (m^3/day)	Ratio	Ratio to 94 MCM (%/day)	Amount (m^3/day)	Ratio	Ratio to 94 MCM (%/day)
900 ha	Whole	45,900	100%	0.049	29,599	100%	0.031
	Partial	52,196	114%	0.056	34,614	117%	0.037
600 ha	Whole	43,190	94%	0.046	28,809	97%	0.031
	Partial	49,712	108%	0.053	33,908	115%	0.036



900 ha Plan 600 ha Plan

Note) Layer 1 exposes on the ground in zone 2 and 3. The partial coverage case doesn't cover the zone 3 (263 ha).

Outline of the Reservoir Plan

Natural and structural conditions

Meteorological conditions to be considered in the reservoir planning are minus (-) monthly mean temperature in December, January and February, small amount of precipitation shown as 445 mm/year of the average annual precipitation for 30 years (1983~2012), and strong wind accompanied by gusts with 10 m/sec or more of wind velocity. Topographically the reservoir area expanding 3 km long from north to south and 3 km wide from east to west is composed of the wide central plane and gentle slopes at both northern and southern side with the inclination of 1 to 100 or so in average. Geologically and physically, the central plane is composed of thick sandy loam which has low permeability coefficient totally; and the north and south slopes of the reservoir are composed of volcanic products which are pervious totally.

Topic items to be considered in the Reservoir planning

Consideration/study shall be needed to slope protection works against wave actions and against the freezing-thawing effect, anti-infiltration works to the reservoir slopes/bottom, and shape-arrangement to the existing dams and the anti-infiltration works to them.

Comparative Study on the Anti-infiltration Works to the Reservoir

Candidates of the anti-infiltration works

As candidates, seven methods are reckoned up such as 1) earth blanket coverage method, 2) watertight asphalt concrete coating method, 3) polyethylene sheet (rubber sheet) coating, 4) bentonite sheet coating, 5) Soil-cement coverage, 6) Blanket coverage by the compacted layer of bentonite-soil mixture, and 7) soil-cement with a sandwiched bentonite sheet; but these 7 methods are confined into the latter four methods from 4) to 7) because of obvious disadvantages in cost and construction conditions.

Allowable leakage quantity and required permeability coefficient/thickness of anti-infiltration works

Allowable leakage quantity is decided empirically considering the efficiency as a reservoir and the capability or the limit of improvement of the treatment works. In Japan's case, the target of this allowable quantity is '0.05 % of the total reservoir capacity a day'. This target value shall be applied to this reservoir. Then, allowable leakage quantity to 94MCM of the reservoir total capacity is 47,000 m^3/day and the required permeability coefficient/thickness of the anti-infiltration works to two reservoir plans of average depth 10 m and 15m are as follows.

Table 6-8 Quantity and Thickness Required for Anti-infiltration work

Reservoir model	Allowable Q (m3/day/m2)	H (m)	A (m2)	k (cm/sec)	k (m/day)	L (cm)
A=9,400,000 m2 Av. Depth=10m	0.005	10.0	1.0	5.E-05	4.E-02	8640.0
	0.005	10.0	1.0	5.E-06	4.E-03	864.0
	0.005	10.0	1.0	5.E-07	4.E-04	86.4
	0.005	10.0	1.0	5.E-08	4.E-05	8.6
	0.005	10.0	1.0	5.E-09	4.E-06	0.9
A=6,267,000 m2 Av. Depth=15m	0.0075	15.0	1.0	5.E-05	4.E-02	8640.0
	0.0075	15.0	1.0	5.E-06	4.E-03	864.0
	0.0075	15.0	1.0	5.E-07	4.E-04	86.4
	0.0075	15.0	1.0	5.E-08	4.E-05	8.6
	0.0075	15.0	1.0	5.E-09	4.E-06	0.9

Permeability coefficient confirmed through information collection or laboratory tests

Table 6-9 Permeability Coefficient Obtained/Confirmed through Information Collection and/or Laboratory Tests

Candidate	Permeability coefficient (cm/sec)	Source
Bentonite sheet	5×10^{-9}	Producer's catalog
Soil-cement	7.7×10^{-7} - 3.9×10^{-8}, Sufficiency/insufficiency of curing influences the permeability.	Laboratory test
Bentonite-soil mixture	7.0×10^{-6} - 4.6×10^{-7}, Possibility to improve the imperviousness is left.	Laboratory test

Thickness of the anti-infiltration works and its total structural formation

Table 6-10 Thickness of Anti-infiltration works

Candidate	Required thickness/ permeability coefficient (cm/sec)	Adopted
Bentonite sheet	9 mm / 5×10^{-9}	Two-layer application (6 mm×2)
Soil-cement	86.4 cm / 5×10^{-7}	90 cm
Bentonite soil mixture	86.4 cm / 5×10^{-7}	90 cm
Soil-cement with a sandwiched bentonite sheet	Soil-cement; 45 cm, bentonite sheet; one sheet Soil-cement; 5×10-7cm/sec, t=45cm⇒5×10-7cm/sec, t=45cm Bentonite sheet; 5×10-9cm/sec, t=0.6cm⇒5×10-7cm/sec, t=60cm Total; 105 cm>86.4 cm	

Comparison of anti-infiltration workss

In case of bentonite sheet and bentonite-soil mixture, a bed layer work as the filter against piping phenomenon and the slope protection work against wave action and freezing/thawing phenomenon must be considered. The differential in construction cost from the reservoir bottom to the south slope comes from necessity /non-necessity and the sort of these works.

Table 6-11 Comparison of Anti-infiltration Works

Item / Method	Design (k: cm/sec)	A. Construction cost: item	A. Construction cost: cost	B. Construction work	C. Reliability	Judgment	A	B	C	Total
Bentonite sheet	k=5×10-9 t=6 mm	Bottom	12.6 $/m2	Frequent interruptions by strong wind	Low because of easiness of connection works done hurriedly in the strong wind condition	Bottom	10	5	3	18
		North	22.4 $/m2			North	5	5	3	13
		South	24.1 $/m2			South	5	5	3	13
Bentonite-soil mixture	k=5×10-7 t=90 cm	Bottom	18.3 $/m2	No problem	Complete enclosure is needed; if not, compscted body of bentonite- soil mixture loses its component.	Bottom	5	10	7	22
		North	28.1 $/m2			North	3	10	7	20
		South	30.4 $/m2			South	3	10	7	20
Soil-cement	k=5×10-7 t=90 cm	Bottom	15.3 $/m2	No problem	Lack of curing brings the compacted body incomplete imperviousness.	Bottom	8	10	7	25
		North	15.3 $/m2			North	9	10	7	26
		South	15.3 $/m2			South	9	10	7	26
Soil-cement with a sandwiched bentonite sheet	k=5×10-7 t=45 cm Bentonite sheet 1	Bottom	14.5 $/m2	The additional work of fixing the sheet by driving concrete nails Fewer occurrence of wind interruptions	Mistake in connection works of bentonite sheets can be covered by the continuous layer of soil-cement. Incomplete imperviousness of soil-cement can be covered by the low permeability of bentonite sheet.	Bottom	9	8	10	27
		North	14.5 $/m2			North	10	8	10	28
		South	14.5 $/m2			South	10	8	10	28
						adopted due to economy and reliability				

As the result of comparison study, soil-cement with a sandwiched bentonite sheet is adopted. However there will still remain some risks of leakage more than design value. To mitigate the hazards of risks, trial construction shall be carried out.

Anti-infiltration Works to the Dam Body

The anti-infiltration works to the dam body shall be given as the usual ‘core zone’ made of compacted sandy loam considering the sustainability against damages caused by earthquake and lack of experience of soil-cement being used as the anti-infiltration works of the dam in earthquake countries.

Basic Design of the Dams and the Reservoir

Slope protection

[Estimation of wind velocity/direction]

Based on the interview to the villagers, the field reconnaissance in and around the reservoir, and the observation record at Yeghvard Weather Station, twenty meter per second (20 m/sec) of the maximum mean wind velocity shall be adopted; as for the wind direction, deflection to from the north or the north-eastern shall be taken into account in the reservoir planning.

[Estimation of the wave height]

The height of the significant wave is estimated by S.M.B. method based on the wind velocity and the blow-over distance. The wind velocity 20m/sec and the blow-over distance 3.7 km (from the north-eastern end to the south-western end of the reservoir) give the point of wave height 0.85 m.

[Estimation of the rock’s weight as the slope protection work]

By the Hudson’s formula, the rock’s weight to the wave height H1/3=0.85 m and the damage percentage 0 - 1 % (KD=3.2) is calculated to be 0.057 tf/m^3 and the grain diameter is about 40 cm when reckoning the rock to be sphere.

[Protection thickness against the freezing/thawing effect]

According to the Armenian construction standard for pipe lines, Construction Norms IV -10.01.01-2006, the required thickness of cover layer to protect the pipe from being frozen is 79 cm in Yeghvard area. The thickness of 80 cm shall be applied to the protection coverage over the compacted soil layer on the slopes of the reservoir and the dam body.

[Candidate of the slope protection works]

Rock rip rap ; this protection work shall be composed of lava rocks with the grain size of the passing percentage 50% larger than 40 cm and shall have the layer thickness of 80 cm. And moreover, the rock rip rap shall be bedded by the 50 cm thick sand-and-gravel layer, i.e. 30 cm from 80 cm in total of the rock rip rap is assumed to be effective against freezing/thawing effect, as the anti-freezing buffer in case of the slope being provided with the soil layer of anti-infiltration works.

Soil-cement protection; the performance of the US Bureau of Reclamation (USBR) soil-cement test section in the Bonny reservoir built in 1951 provides a positive example of the one exposed long to the wave action and an average of 140 freeze-thaw cycles per year. And the test results of freezing/thawing test, slaking test and sodium sulfate soundness test conducted in this preparatory survey stage indicate high durability of soil-cement against weathering.

Cobble-gravel rip rap; an advantage of this work is that the layer can function not only as the protection against wave actions but also as the coverage against the freezing/thawing effect. But this type of protection work is applicable only to the north and the east slopes where wave actions are little because the grain size/weight of cobbles is not enough to stand wave actions on the slopes on the lee.

[Selection of slope protection works and their application plan]

Table 6-12 Selection of Slope Protection and their Application Plan

Slope / Protection work	Dam No.1		Dam No.2		North slope		South slope	
	Wave action hard	Freezing-thawing	Wave action not hard	Freezing-thawing	Wave action not hard	Freezing-thawing	Wave action hard	Freezing-thawing
Rock rip rap	work	not work	work	not work	work	not work	work	not work
Cobble-gravel rip rap	not work	work	work	work	work	work	not work	work
Soil-cement	work	work	work	work	work	work	work	work
Adoption	Soil-cement		Cobble-gravel rip rap (due to economy)		Cobble-gravel rip rap (due to economy)		Soil-cement	

Dam crest protection

In Armenia, in the area around Yerevan, roofs of residential houses are made of concrete with a 25 cm thick heat-insulating layer of coarse Scoria between the outer slab and the inner slab. According to this manner, a 25 cm thick Scoria layer shall be provided to the crest as the protection against the freezing and thawing effect. Over this Scoria layer, 30 cm thick sand-and-gravel layer shall be provided as the protection against the vehicles' wheels. This sand-and-gravel layer shall have the supplemental effect to the heat-insulating function of the Scoria layer.

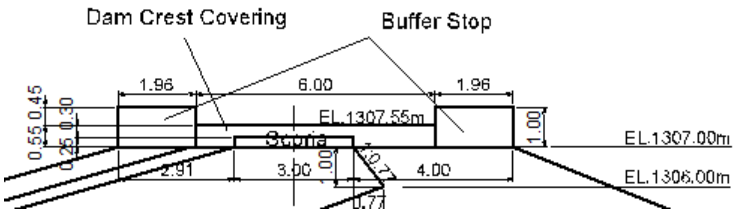


Figure 6-1 Illustration of the Dam Crest Protection

Freeboard elevation of the dam body

Considering the height of wave run-up estimated by the calculation formula shown by Van der Meer and Janssen and the earthquake wave height estimated by Sato's formula, the freeboard elevation of the dam body is adopted to be E.L.1,307.00 m.

Dam crest elevation

The dam crest elevation can be given by adding the dam crest protection thickness to the freeboard elevation of the dam body. Then, Dam crest elevation = Freeboard elevation + Crest protection thickness.

= E.L. 1,307.0 + 0.55 = EL. 1,307.55

Typical cross-section of dams

Inclined core type is selected as dam type for both Dam No.1 and Dam No.2. Those typical cross section is decided as shown in the Figure 6-2 by stability analysis and utilizing physical properties decided according to the results of laboratory and field test.

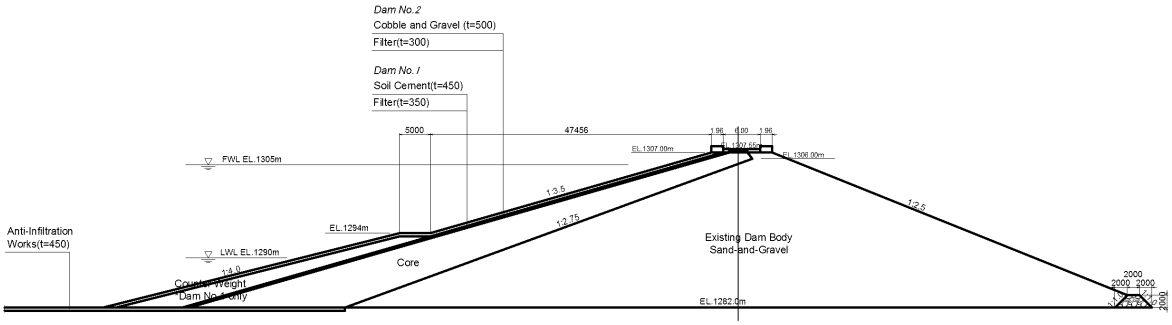


Figure 6-2 Typical Cross Section

Basic Design of Related Facilities (Emergency Discharge Structure)

Emergency discharge facility is designed taking into account the specific conditions of Yeghvard reservoir below;

1) Facilities along Kasakh river will suffer from flood damage in case huge volume of water is discharged from Yeghvard reservoir and,
2) For Nor Yerznka village, water level shall be lowered as fast as possible (emergency discharge volume shall be as much as possible) to mitigate risk of dam collapse and damage in case dam collapse.

Here sets two (2) kinds of emergency situations shown as below and discharge volume is set for each condition.

Low Emergency (Low possibility of dam collapse)

✓ Some observed parameters indicate mild abnormal tendency such as increasing of leakage volume or decreasing of water pressure regardless of the fluctuation of water level.

Total volume of discharge from Yeghvard reservoir and flow from upstream side shall be less than flow capacity of Kasakh river, 13.7m^3/s. Under this condition, discharge volume can be discharged from Yeghvard reservoir varies according to the season as shown in the Figure 6-3 and relation of those and water level of Yeghvard reservoir are shown in the Figure 6-4. Discharge facility is designed to be able to discharge at least volume at each water level shown in the Figure 6-4.

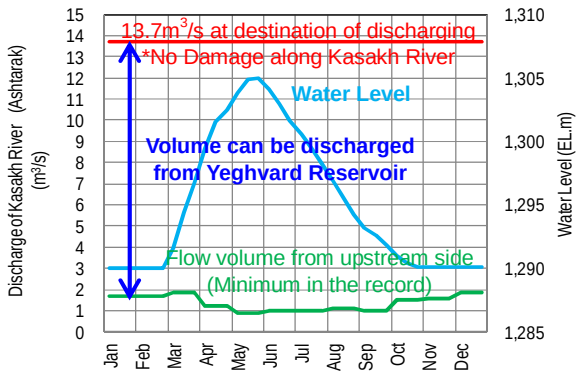


Figure 6-3 Discharge volume from Yeghvard Reservoir

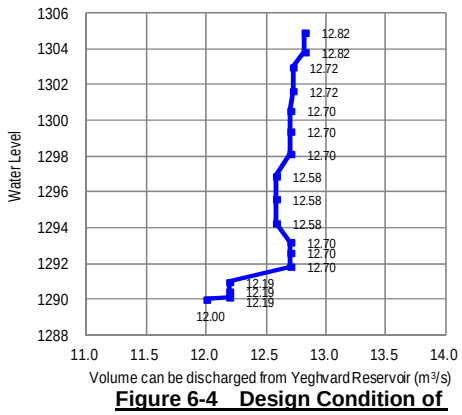


Figure 6-4 Design Condition of Emergency Discharge Facility

High Emergency (High possibility of dam collapse)

- ✓ Some observed parameters indicate serious abnormal tendency such as sudden increasing of leakage volume or sudden decreasing of water pressure regardless of the fluctuation of water level.
- ✓ Some deformations which indicate sliding failure of dam body such as faulting at upper area or swelling at lower area.

Discharge control valve is fully opened and maximum volume of water is discharged. The maximum discharge volume of each water level is shown in the Figure 6-5. Alarming system to Nor Yerznka Village and along Kasakh river is required because there is a possibility of flood caused by dam collapse and by discharge from Yeghvard reservoir.

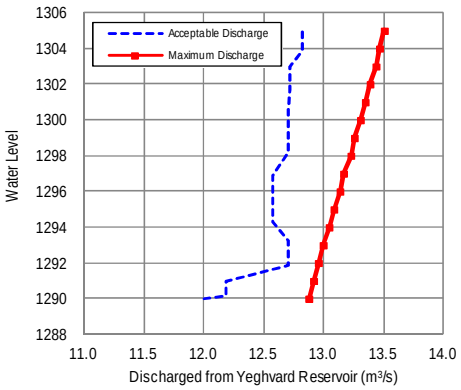


Figure 6-5 Discharge volume under High Emergency Condition (=Maximum discharge volume)

6-4 Project Cost Estimate

Project Cost

(Confidential)

Construction Schedule

The Project will start from 2-year Detail Design and tender of construction after the Feasibility study. Then start 4-years construction which calculated necessary construction vehicle. After completion of the reservoir and irrigation facilities, initial impoundment is plan to conduct taking 1 year. Total project period is estimated 7-years as shown in Figure 6-3.

Construction items	Detail Design		Construction				Initial impoundment
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
Detail design, Tendering							
Consultant supervision							
Anti-Infiltration work							
Dam No.1 filling							
Dam No.2 filling							
Feeder canal 1							
Feeder canal 2							
Outlet canal 1							
Outlet canal 2, 3							
Control house							
Feeder Tunnel							
Procurement of Fixed Cone Valve							
Arzni-shamiran Canal							
Irrigation systems							
Initial impoundment							

Figure 6-6 Construction Schedule

6-8 Operation and Maintenance (O&M) Plan

O&M Plan of the Reservoir

Yeghvard reservoir will be administration of the Sevan-Hrazdanyan Water Supply Agency CJSC. It should be responsible for the operation and arrangement of staff for Yeghvard reservoir. While, two of Feeder canals and three of Outlet canals should be demarcated to WSA and WUAs in the view of operation. However, the maintenance for the related facilities of reservoir shall be conducted by WSA because the integrated maintenance by single organization could be smooth and effective to interactive relation in each facility of reservoir. **WSA shall be recommended to be main responsible agency for reservoir and related facilities.** The suggested demarcation for operation is shown in Table 6-13.

Table 6-13 Operation Demarcation of Reservoir and Related Facilities around Yeghvard Reservoir

Facility	Conveyance	Maintenance	Operation				
				WUAs			
		WSA	WSA	Yeghvard	Ashtarak	Vagars hapat	Khoy
1. Gate of F.C. 1	Pipeline	●	●				
2. Switching valve box of F.C.1 and O.C.1	Pipeline	●	●				
3. Operation valve house of F.C.1 and O.C.1	Pipeline	●	●				
4. Gate of F.C. 2	OP. canal	●	●				
5. Operation valve box of O.C.1	Pipeline	●		●			
6. Operation valve box of O.C.2 at Dike 1	Pipeline	●					
7. Operation valve house of O.C.2 at connection	Pipeline	●			●		
8. Operation valve house of O.C.2 at Kasakh	Pipeline	●				●	●
9. Main control house of Yeghvard Reservoir		●	●				
Reservoir body		●	●	-			

Yeghvard reservoir as large irrigation facility could seriously affects to social environment, if an unexpected accident may arise. To avoid these damages and serious situation, necessary persons shall be stationed at reservoir facilities to regular observation and report, in addition, unexpected situation shall be taken measure and/or secured safety by these assigned experts. Especially, in case of consultation on engineering matters for reservoir, PIU should be supported and assist the operation unit.

Maintenance of reservoir

To secure the safety situation of reservoir, following items should be observed by visual and or equipment. All data regarding reservoir observation and maintenance records in digital should be documented as evidence of safe operation and maintenance. In addition, design construction document shall be stored in main control house in order to use as required.

1. Leakage water volume at dike and foundation
2. Deformation at dike and foundation
3. Pore water pressure at dike and foundation
4. Water level in reservoir
5. Water level in deep well around reservoir
6. Reaction of dike and foundation for earthquake
7. Visual observation for pipeline

In unusual situation, all of facilities in relation with reservoir shall be inspected by eligible and experienced engineer. Especially, the inspection should be performed not only analyze the seismometer and/or measurement equipment but also visual investigation.

Operation of each Canal at reservoir

To convey the irrigation water to irrigation filed, five of canals connected reservoir should be dully

operated to in-flow and out-flow. These canals have the different discharge and have to be operated in accordance with following water allocation. In addition, special attention has to be shortly after the earthquake and similar situation. To prevent the dangerous situation for reservoir, the emergency operation shall be executed.

Table 6-14 Water Allocation of Feeder and Outlet Canals (m^3/s)

	Jan.			Feb.			Mar.			Apr.			May			Jun.		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
Arzni-Shami.note1)	0.00	0.00	0.00	0.00	0.00	0.00	7.00	15.5	14.4	22.0	19.2	11.2	18.5	15.4	5.50	7.00	5.00	6.00
Arzni-Branch note2)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	1.16	1.33	1.00	0.39	0.00	0.00	0.00
Feeder C. 1	0.00	0.00	0.00	0.00	0.00	0.00	7.00	9.00	9.00	9.00	8.72	7.84	7.67	8.00	1.11	0.00	0.00	0.00
Feeder C. 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.50	5.40	13.00	10.20	2.20	5.90	3.40	0.00	0.00	0.00	0.00
total inflow	0.00	0.00	0.00	0.00	0.00	0.00	7.00	15.5	14.4	22.0	18.92	10.04	13.57	11.40	1.11	0.00	0.00	0.00
Outlet C. 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	1.66	2.10
Outlet C. 2 for Ashtarak	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.28	0.32	0.24	0.09	0.12	0.40	0.51
Outlet C. 2 for Kasakh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.66	0.75	0.56	0.22	6.48	8.24	8.99
total outflow											0.23	0.94	1.07	0.80	0.31	7.10	10.30	11.60
Operation	no-operation						Inflow to Reservoir						Outflow from Reservoir					

	Jul.			Aug.			Sep.			Oct.			Nov.			Dec.		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
Arzni-Shami.note1)	6.00	7.00	13.0	13.0	13.0	13.0	8.00	8.00	8.00	5.00	5.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00
Arzni-Branch note2)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feeder C. 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feeder C. 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
total inflow	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Outlet C. 1	2.33	2.27	2.22	2.22	2.11	1.83	1.72	0.33	0.22	0.22	1.05	0.44	0.00	0.00	0.00	0.00	0.00	0.00
Outlet C. 2 for Ashtarak	0.56	0.55	0.54	0.54	0.51	0.44	0.42	0.08	0.05	0.05	0.25	0.11	0.00	0.00	0.00	0.00	0.00	0.00
Outlet C. 2 for Kasakh	6.61	6.88	6.74	5.94	5.68	5.13	3.36	2.39	3.33	3.03	0.59	0.25	0.00	0.00	0.00	0.00	0.00	0.00
total outflow	9.50	9.70	9.50	8.70	8.30	7.40	5.50	2.80	3.60	3.30	1.90	0.80	0.00	0.00	0.00	0.00	0.00	0.00
Operation	Outflow from Reservoir												no-operation					

Note1) Arzni-Shamiram convey water to only Part2 section from 1st period June to3rd period October. Other area is irrigated by Reservoir water
Note2) Arzni-Branch of intake is available from 2nd period April to3rd period May to Yeghvard WUA.

O&M Plan of the Facilities in Irrigation Filed

In the target area, open canal, pipeline and distribution gates compose the irrigation system. Regular inspection and maintenance of these structures and facilities should be conducted. In the Project, some structures will be rehabilitated and reconstructed, but the works do not install new function and unseen structure. Most of structures succeed to the original function and structural form. An irrigation engineers has been assigned at each WUAs, and those engineers can fix irrigation facilities when the facilities are damaged. In addition, all of WUA have established their own internal rules related to operation and maintenance of irrigation facilities. Therefore, present inspection and maintenance will be continuously implemented by WUAs.

7. PROJECT IMPLEMENTATION ASPECTS

7-1 Project Implementation Structure

Related Agencies to the Project Implementation

State Committee of Water Economy (SCWE)

While SCWE is the state agency to take responsibility for the planning, implementation and operation of the large scale of water infrastructures including reservoir, irrigation system and water supply/sanitation investments, the SCWE is placed as implementing body of this F/S of the Project

and recognized as the undertaker on ESIA towards the Project implementation. Budget of SCWE in recent last 4 years is steady with a level of 70 million USD annually.

Water Sector Project Implementation Unit (PIU)

PIU was created by the SCWE in 1994 supported by WB to manage the implementation of irrigation improvement projects mainly with dam/reservoir construction funded by international agencies, such as Kaps by KfW, Vedi by AFD, Mastara by EDB and other donors. Out of total number of 36 PIU staff currently, 12 specialists are engaged with financed by AFD loan, and 5 specialists and other staff are engaged their works with burden of Armenian national budget.

Main tasks of PIU are; a) preparation of preliminary project schedule and cost estimate, b) assessment of planning and facility design, c) preparation of tender documents, tendering and its evaluation, d) construction supervision / monitoring of project implementation, e) quality control of construction works, f) assistance to ESIA and RAP assessment, g) assistance to applications for loan and grant projects, h) clarification for contents of loan agreement, etc.

Ministry of Agriculture (MOA)

MOA is a superstructure to agencies of SCWE and PIU. It is suggested that the MOA should conduct following five (5) agricultural supporting projects by national fund or other sources, through "Agricultural Projects Implementation Unit" in accordance with the progress of implementation in order to be the Project sustainable and effective. It is, therefore, recommended to allocate budget in appropriate timing for conducting agricultural supporting projects;

1) Pilot agricultural cooperatives development,
2) Enhancement of agricultural credit system,
3) Establishment of monitoring and inspection system of pesticide residue,
4) Enhancement of agricultural research to promote market oriented, and
5) Vitalization of agricultural extension.

Proposed Implementation Structure and Procedure

Project implementation agency as well as undertaker on ESIA will be SCWE in cooperation with PIU which will supervise international consultant to be selected by International Competitive Bidding (ICB). Since PIU has enough specialists within their office with experience of international funded projects, a new organization body is not required to mobilize for the Project implementation.

Concerned ministries to the Project implementation, those are; MOF, MFA and MOA will assist to SCWE in coordination with MIEIR after the Loan Agreement signed by and between MOF and JICA which will be financial agency to disburse Japanese ODA Loan.

Contents of D/D including design, drawing, cost estimate, construction schedule and so on to be prepared by the selected consultant, will be applied for their approval by WRMA/MNP and Ministry of Urban Development (MUD). Also, ESIA and RAP reports to be prepared by the international consultants will be applied for their approval by SNCO/MNP.

Tender documents for the selection of construction contractors for both international and national will be prepared by the international consultant through the consultation of PIU. And tendering will be carried out by PIU assisted by the international consultant so that contractors will be selected through ICB and National Competitive Bidding (NCB). It is recommended that Yeghvard reservoir and related facilities around would be under the ICB and rehabilitation of Arzni-Shamiram canal including other main/secondary canals under the NCB respectively.

In C/S stage, Environmental Management Plan which prepared by international consultant and approved by SNCO/MNP and RAP will be monitored by MNP, MOA MES and Yeghvard City.

Cost Burden of the Armenian Government

Since most of consultant fee, cost of civil works will be eligible for Japanese ODA Loan sponsored by JICA during D/D and C/S stages, 1) technical supervisor fees of EMP/RAP monitoring, 2) general administration expenses of Armenian staff, 3) Tax and duties including VAT, 4) compensation for resettlement/crops are non-eligible portions under the JICA guideline. Also, it is recommended that costs of; 1) agricultural supporting projects and 2) on farm level irrigation system improvement are burden of Armenian government which would be 38 to 49 million USD.

8. PROJECT EVALUATION

Project evaluation is carried out in order to determine the economic viability of the Project. The analysis compares the situations "without" and "with" Project, and is carried out on the point of view of the national economy. As indicators of project efficiency, Economic Internal Rate of Return (EIRR), net present value (NPV), and benefit-cost ratio (B/C) have been calculated.

There are another important indicator; FIRR, which is an indicator evaluating projects on the point of view of private companies, however, the Project does not profit-oriented. In fact, the main proposed beneficiaries are farmers, on the other hand, Armenian government is planning to be fully responsible for initial investment, and WSA will be in charge of O&M of the reservoir and other main facilities. It means that the beneficiary is not consistent with the burdens. In this respect, the Project cannot be evaluated in terms of financial costs and returns, therefore, FIRR is out of analysis in this evaluation.

Estimated Project Costs

(Confidential)

Expected Project Benefits

(Confidential)

Results of Economic Evaluation

Table 8-1 summarizes the economic evaluation by the options. As already mentioned, the economic Project cost consists of base cost and physical contingency. In the economic analysis, benefits and costs are standardized in economic terms using conversion factors. Three indicators have been applied: economic internal rate of return (EIRR), net present value (NPV), and benefit-cost ratio (B/C). NPV and B/C are calculated with 12.0% opportunity cost of capital.

All of the options cannot exceed 12.0% opportunity cost of capital which may reflect the little improvement in yield because the Project components consist only of irrigation systems, and not taking account any agricultural extension and/or other soft components. The Project might produce fruits more if there were other components such as agricultural extension to promote more-profitable but more water-intensive products such as vegetable and fruits.

Comparing the four (4) options, "soil-cement with bentonite sheet" marked highest on EIRR, indicating 5.15 % of EIRR in base 0 case. Still, it is not regarded as viable even the base 1 case (including the benefit from conservation of Lake Sevan) as the EIRR is 7.09% against 12.0% referenced opportunity cost of capital.

Table 8-1 Summary of the Economic Evaluation by the Options

Indicators	Options			
	Bentonite Sheet	Bentonite-Soil mixture	Soil-Cement	Soil-cement with bentonite sheet
EIRR (Base 0, %)	4.94%	2.91%	4.74%	5.15%
EIRR (Base1, %)	6.86%	4.70%	6.64%	7.09%

Source) The Survey Team

Other Qualitative Benefits

For economic evaluation, benefits have to be limited only on “direct”, ”quantitative”, and “not tentative”. Still, there are other important Project benefits such as; 1) Cultivation of groundwater; 2) Encourage some industries around the Yeghvard area; 3) Creating job opportunity; 4) Contribution for climate change mitigation; and 5) Contribution for tourism and leisure industries.

Proposed Indicators

Several indicators should be established in order to monitoring the Project’s status. There are two (2) kinds of indicators; operational indicator is an indicator measuring whether the output of the Project has been operated and utilized appropriately, while effect indicator is an indicator that aims at measuring whether the Project impact would have been realized as expected. For the usage of these indicators, “proposed indicators” are established based on the expected values of 5 years after the project implementation. In the plan, the year of the completion of construction is 2022, so the proposed indicators are evaluated in 2027.

9. PROCUREMENT PLAN

Condition of Procurement and Contract

During detailed designs stage, there is an approval process to follow making documents of detailed design effective from the governmental agencies under the Ministry of Urban Development (MUD). For the environmental assessment, MNP takes responsibility on document of ESIA.

Two (2) ways; the one is inspected by independent expertise, the other one is done by state expertise due to technical level of the Project. The documents to be prepared by a consultant selected by international bidding shall apply for the approval to the private company who has the license issued by the governmental agency. Which processes whether inspected by private company or government agency, are described in the contract to be signed by and between an implementation agency (PIU/SCWE) and the consultant.

Procurement of Consultant

The expected consultant service is mainly divided into the detailed design (D/D) and the construction supervision (C/S) stages. In case of applying Japanese ODA Loan, the borrower shall be in accordance with the "HANDBOOK for the Procurement under Japanese ODA Loans, April 2012". In addition, the Project shall be suitable harmony with FIDIC.

D/D stage

The consultant for the Project should conduct the investigation, examination and design in this stage. In addition, the consultant should prepare the tender documents for the implementation as the result of D/D. The target facilities for designing are recommended separating by areas, namely; "Target Area 1" for reservoir and "Target Area 2" for irrigation system. Therefore, it is recommended having

two packages, one is for "Target Area 1" by International Competitiveness Bidding (ICB), the other one is for "Target Area 2" by National Competitiveness Bidding (NCB). In addition, related ESIA works should be conducted by ESIA consultant selected by NCB with D/D consultant. Therefore, the recommended project Packages are divided into three.

The necessary services for the D/D are summarized as followings;

1) Topographical and geological/hydro-geological field investigations and laboratory test,
2) Review of preliminary designs done during the Feasibility Study (F/S) stage,
3) D/D includes all required hydraulic, structural and hydro-geological calculations, preparation of drawings such as reservoir, feeder, outlet canals and operation manual,
4) Preparation of the pre-qualification documents for tendering,
5) Preparation of tender documents,
6) Preparation of irrigation water management manual including Target area 1 and 2,
7) Preparation of reservoir operation manual, instrumentation of observation and emergency preparedness plans, and
8) Assistance to the conduction of ESIA.

In the D/D stage, the supplemental surveys for finalizing and updating the designs should be conducted due to the changed policy and other unexpected matters.

C/S stage

The consultant shall assist the undertaker in Armenian government for the tender procedure by preparing invitations for pre-qualifications and prior to short listing for the prospective bidders. The consultant shall then accompany the tender procedure and participate in the evaluation of the bids. Assist and task in tender and construction during this stage are suggested, hence bidding and supervision shall be conducted to each package.

ESIA consultant

The regal regulations for ESIA are derived for a number of international conventions in Armenia are a part of and regulated in the Law on Environmental Expert Examination (Law on EEE) adopted in 1995.

The timing for the ESIA is preferably during the early D/D stage to have effective results and to be taken into account before finalizing the designs. The activities of ESIA should be conducted by the international consultant. In the C/S, monitoring and procedure by stipulated in ESIA can be conducted by the construction supervision consultant or by the employed external expertise. The necessary services for the ESIA consultant are summarized as followings;

1) Data collection and investigations such as natural and social conditions
2) Land acquisition and resettlement activities
3) Preparation of draft ESIA report
4) Monitoring of the EMP implementation

Procurement of Contractor

Japanese ODA Loan is the base of request from the government of Armenia. After the request for the Project implementation, JICA will send a Fact Finding (FF) mission and plural appraisal missions prior to Exchange of Note (E/N) and L/A.

10. CONCLUSIONS AND RECOMMENDATIONS

10-1 Viability and Necessity of the Project Implementation

Government of Armenia places this Project; that is “Yeghvard Irrigation System Improvement” as

one of the important projects to fulfill the national policies which are; 1) conservation of Lake Sevan being a fundamental source of the livelihood for Armenian people as well as the environmental circumstances, and 2) shifting pump-based to gravity irrigation system prior to reducing governmental subsidies to agricultural water users due to a high rate of electricity.

While one-third (1/3) of population in Armenia is living in the capital city of Yerevan, taking accessibility and marketing into considerations, agricultural activities in the Yeghvard directly connect not to only farmers' income generation, also food security for inhabitants of the capital because of its location within 20 km to the Yerevan.

Also, since Armenian agricultural development strategy towards promoting; 1) cooperated and competitive market-oriented and 2) export-oriented productions for international trading by shaping favorable conditions, farmers concerned in Yeghvard have much advantage to involve in opportunities obtaining agricultural training/information, extension/machinery services, credit and techniques such water saved irrigation through research institutes under MOA available in Yerevan.

Furthermore, while irrigation projects; Kaps in Shirak Marz and Vedi in Ararat Marz, assisted by KfW and AFD respectively, are under the process of detailed design and tendering stages prior to construction, government of Armenia will concur in developing infrastructural projects in relation to water resource on agriculture/irrigation sectors.

10-2 Conclusions

Scale of the planned reservoir capacity

Alternatives to capacity of the Reservoir is limited since considerable factors for designing is narrowed by 1) demand of crop water requirement of agricultural land with 12,347ha, 2) availability of free water (snow melted water) from March through May in Hrazdan river and 3) capacity of existing Arzni-Shamiram canal which is planned feeding water to the proposed Yeghvard reservoir, while policies to the water resources made by the government of Armenia, i.e. 4) conservation of Lake Sevan and 5) shifting from pumping system to gravity irrigation. Capacity of the planned reservoir, therefore, is fixed with 94MCM from the initial stage of the Survey.

Area of planned reservoir basin (900ha plan or 600ha plan)

Table 10-1 shows advantages and disadvantages in each case of the reservoir basin with 900ha plan and 600ha plan respectively.

Table 10-1 Advantage and Disadvantage by Options of Reservoir Basin Area in Cases of 900ha and 600ha

	900 ha plan	600 ha plan
1) Construction easiness	(Disadvantage) Since area of anti-infiltration works is larger than the case of 600ha, construction period of this work is longer comparatively.	**(Advantage)** Construction period of this work is shorter than the case of 900ha comparatively.
2) Environmental aspect	**(Advantage)** Swampy areas are not formed.	(Disadvantage) Enclosing southern and northern slopes by new dams might form swampy areas at those back side.
3) Acceptance of Armenian side	**(Advantage)** Both existing Dam No.1 and No.2 constructed at USSR era are reused so that past investments are fully utilized.	(Disadvantage) A part of existing Dam No.2 is not reused due to the planning of new dike construction.

While direct construction costs of planned reservoir are not much differed between options of 900ha and 600ha with area of reservoir basin, the one of 900ha is recommended adopting, because the case of 900ha has more advantages than the one of 600ha.

Measure on anti-infiltration works to the reservoir basin

Given conditions geologically and hydro-geologically that the location of the proposed reservoir is located at its high permeability, the cost for anti-infiltration works is occupied approx. more than 60% of the direct construction cost, the Survey team has been conducting alternative studies carefully from the beginning of the Survey period, through investigation of drilling, its in-situ test as well as laboratory soil test, etc. in consideration with results of investigation done in USSR era. Also, simulation for water leakage rate estimation from the reservoir bottom was carried out prior to identifying the most cost-efficiency of necessity area for anti-infiltration works.

Table 10-2 summaries outline of the Project evaluation by examined options done during the Survey. Case by using soil-cement with a sandwiched bentonite sheet for anti-infiltration works is the most economical option, with 900ha of reservoir basin and capacity of reservoir with 94MCM.

Table 10-2 Outline of the Project Evaluation by Options(Reservoir basin: 900ha)

	Bentonite sheet with 2 layers	Bentonite soil mixture	Soil-cement	Soil-cement with a sandwiched bentonite sheet
EIRR (Base1: Including Lake Sevan)	6.86%	4.70%	6.64%	7.09%
(Base 0: Not Including Lake Sevan)	(4.94%)	(2.91%)	(4.74%)	(5.15)%

10-3 Recommendations

Trial Construction for Anti-Infiltration Works

Although soil-cement with a sandwiched bentonite sheet is the best option for anti-infiltration works, some risks of leakage more than design value still remain. Additionally, there are no reservoirs having this structure as anti-infiltration works. Therefore trial construction to find appropriate measures to mitigate hazards of leakage risks and to identify difficult/important points to note on the construction shall be carried out before/during Detail Design stage.

Abolish of Existing Pump Stations

In accordance with national policy in Armenia, i.e. “shifting pump system to gravity irrigation”, the capacity of reservoir is designed in the Project including of proposed new connection canals (by pipelines) and rehabilitation of existing main/secondary canals. While current irrigation system in some areas, however, is dependent on pumping, it is recommended that delays and/or gradual abolishing existing pump facilities with considering the effect of gravity irrigation, especially of deep tube wells should be allowed.

Pilot Farms for Water Saved Irrigation

Two (2) communities are recommended for pilot farms for water saved irrigation, one for fruit and the other one for vegetable cultivation. Water saved irrigation is not adopted in order to reduce water demand in the Project, however, they are recommended for new technology such as reducing an amount of fertilizer and chemical for decreasing expenditure of the agricultural inputs by sprinkler and/or drip as well as the climate changes in future as agricultural supporting projects.

Measures on influences to other utilizations of free water (snow melted water) at the downstream of Hrazdan River

Even though it is evaluated that influences by taking free water with a volume of 103MCM including losses (canal conveyance and evaporation/infiltration from Yeghvard reservoir, etc. with 94MCM) through Arzni-Shamiram canal from March to May annually with the Project, would not be anticipated, by following findings, the Survey Team recommended that;

Since the Project is expected to contribute the conservation of Lake Sevan by reducing water use of

approx. 50MCM annually, a part of water volume from the 50MCM is released to Hrazdan river in March to May annually as the substitution of diverting free water to the Project by taking consideration into the influences on the current ecology in the downstream of Hrazdan river.

Emergency Discharge Facility

The Survey team suggests setting up an awareness program for emergency during the detailed design of the Project whenever the natural calamity occur such a large earthquake by establishing a structure of committee.

Compensation for Communities (RAP)

It is recommended to examine request from Yeghvard City and Nor-Yerznka Village, namely, any possible supports to mitigate the land loss within the planned Reservoir before the Loan Agreement (L/A) , since the lands for the Project currently belong to those communities.

YEGHVARD IRRIGATION SYSTEM IMPROVEMENT PROJECT
FINAL REPORT (FR)
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ABBREVIATIONS

ADS	Armenia Development Strategy
ADB	Asian Development Bank
AFD	Agence Française de Developpement
ASMC	Agricultural Support Marz Center
ASRC	Agricultural Support Republic Center
AWLR	Automatic Water Level Reorder
B/C	Benefit-Cost Ratio
CARD	The Center for Agribusiness and Rural Development
CGIAR	Consultative Group on International Agricultural Research
CDM	Clean Development Mechanism
CIMMYT	Centro Internacional de Mejoramiento de Maíz y Trigo
CIP	International Potato Center
CIS	Commonwealth of Independent States
CJSC	Closed Joins Stock Company
C/S	Construction Supervision
D/D	Detailed Design
DFR	Draft Final Report
DNA	Designated National Authority
EDB	Eurasian Development Bank
EEU	Eurasian Economic Union
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
EMP	Environmental Management Plan
E/N	Exchange of Notes
ESIA	Environmental and Social Impact Assessment
EU	European Union
FAO	Food and Agriculture Organization
FF	Fact Finding mission
FIRR	Financial Internal Rate of Return
F/S	Feasibility Study
GDP	Gross Domestic Product
GHQ	Greenhouse Gas GHG
ICARDA	International Center for Agricultural Research in the Dry Areas
IFAD	International Fund for Agricultural Development
IMF	International Monetary Fund
INDC	Intended Nationally Determined Contribution
IPGRI	International Plant Genetic Resources Institute
IRR	Internal Rate of Return
ISNAR	International Service for National Agricultural Research
ITR	Interim Report
JICA	Japan International Cooperation Agency
KfW	Kreditanstalt für Wiederaufbau
NPV	Net Present Value
ODA	Official Development Assistance
O&M	Operation and Maintenance
OP.	Open Canal
PAH	Project Affected Household
PAP	Project Affected Person
PIU	Water Sector Project Implementation Unit State Agency
Pre-F/S	Preliminary Feasibility Study
RA	Republic of Armenia
RAP	Resettlement Action Plan
SADS	Sustainable Agriculture Development Strategy of the RA
SCF	Standard Conversion Factor
SCWE	State Committee of Water Economy

SMEs	Small and Medium Enterprises
SNC	Second National Communication on Climate Change
TIN	Triangulated Irregular Network
TIWRM	Towards Integrated Water Resources Management
TNC	Third National Communication on Climate Change
UNDP	United Nations Development Program
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
USSR	Union of Soviet Socialist Republics
WB	World Bank
WRMA	Water Resources Management Agency
WSA	Water Supply Agency
WUA	Water User Association

Unit

mm	:millimeter	m^2	:square meter	m^3	:cubic meter
cm	:centimeter	km^2	:square kilometer	MCM	:million cubic meter
m	:meter	km	:kilometer	ha	:hectare
g	:gram	cm/s	:centimeter per second	Kcal	:kilocalorie
kg	:kilogram	m^3/s	:cubic meter per second	kWh	:kilowatt hour
g/cm^3	:gram per cubic centimeter	lit/sec	:litter per second	Ωm	:ohm meter

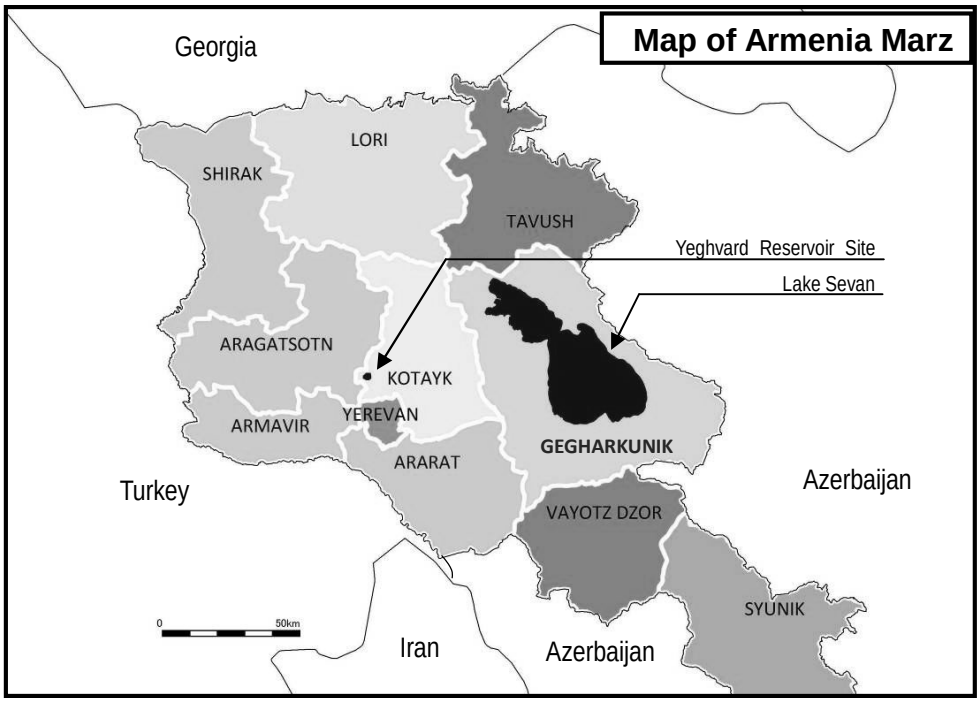
Currency

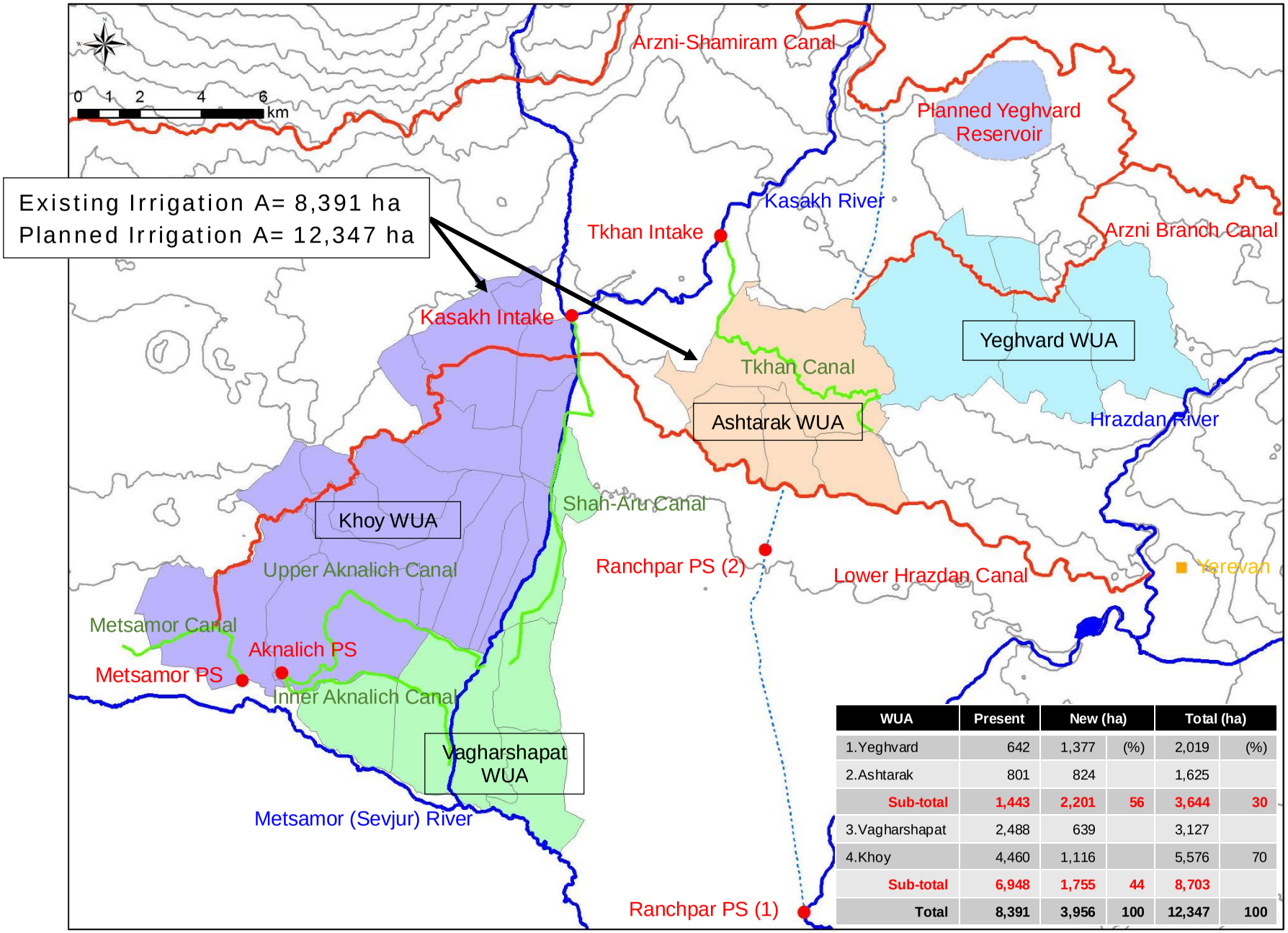
Japanese Yen	(JPY)
US Dollar	(USD)
Armenia Dram	(AMD)

Exchange rate (as of April 2016)

1 USD = 113.65 JPY (Bank of Tokyo-Mitsubishi UFJ)

1 USD = 486.99 AMD (Central Bank of Armenia)





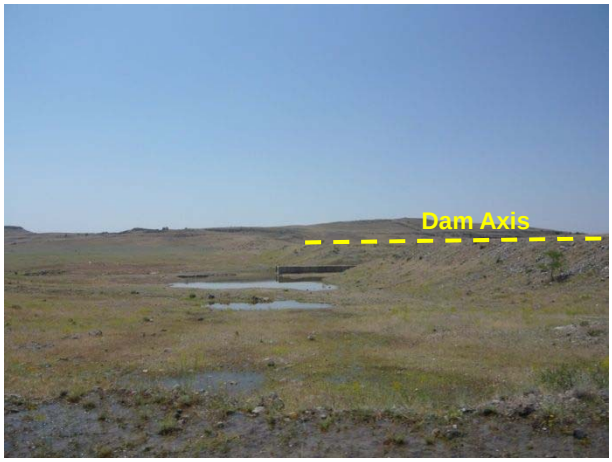
WUA	Present	New (ha)		Total (ha)	
1.Yeghvard	642	1,377	(%)	2,019	(%)
2.Ashtarak	801	824		1,625	
Sub-total	**1,443**	**2,201**	**56**	**3,644**	**30**
3.Vagharshapat	2,488	639		3,127	
4.Khoy	4,460	1,116		5,576	70
Sub-total	**6,948**	**1,755**	**44**	**8,703**	
Total	**8,391**	**3,956**	**100**	**12,347**	**100**

LOCATION MAP

Photos of the Project

[Photo-1] Kick off Meeting

[Photo-2] Lake Sevan

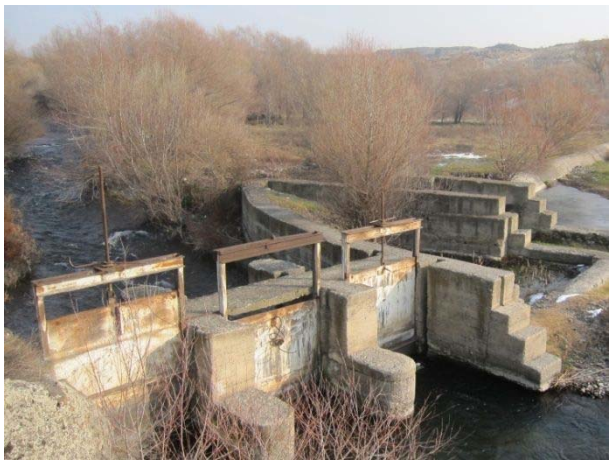


[Photo-3] Existing Dam No.1

[Photo-4] Existing Dam No.2

[Photo-5] Arzni-Shamiram Canal

[Photo-6] Arzni Branch Canal



[Photo-7] Kasakh Intake

[Photo-8] Takahan Intake

[Photo-9] Ranchapar Pump Station

[Photo-10] Farm Land (Vagharshapat WUA)

[Photo-11] Explanatory Meeting of DFR

[Photo-12] Stakeholder Meeting for Environmental and Social Considerations (Nor-Yerznka village office)

CHAPTER 1 INTRODUCTION

1-1 Background of the Survey

After the request for Official Development Assistance (ODA) loan to the government of Japan was made by the Government of the Republic of Armenia (hereinafter referred to as "Armenia") in June 2012, JICA had executed to gather information related to the construction of Yeghvard Reservoir by sending the contact missions as well as sending questionnaire in order to formulate the Project.

Based on the information that JICA obtained through the above, JICA proposed two-phased studies; a) Data Collection Survey on Agriculture and Irrigation Sectors in relation to the Project (Pre-feasibility Study: Pre-F/S) and b) Full-scaled Feasibility Study (F/S), and the Government of Armenia agreed the above mentioned proposal.

And JICA dispatched a consultant team as place of the above a) Pre-F/S in June 2014. The consultant team, then conducted a field survey including data/information collection and had a series of discussions with related agencies in Armenia from June through August 2014, and analyzed the collected information prior to prepare a draft final report (DFR) of the Pre-F/S in Japan during September to October 2014. JICA sent a mission to Armenia in November 2014 for the purpose of explanatory discussion for the DFR of the Pre-F/S for the Project, then, the government of Armenia accepted it. In March 2015, JICA sent an official letter decided to dispatch a consultant team for the F/S of Yeghvard Irrigation System Improvement Project (hereinafter referred to as "the Project"). Then, the consultant team (hereinafter referred to as "the Survey Team") have started the Preparatory Survey for Yeghvard Irrigation System Improvement Project (hereinafter referred to as "the Survey").

**** Since this report was developed based on the situation and the information as of end of September 2016, before the government restructuring, the name and the structure of the government institutions which appear in this report may not coincide with the current ones.***

1-2 Objectives of the Project

Objectives of the Project are shown as below;

1) To distribute stable irrigation water to the Project area,
2) To improve agricultural productivity in the Project area by the stable irrigation water,
3) To fulfill the national policies such as; a) conservation of Lake Sevan and b) shifting pump-based to gravity-based irrigation system.

1-3 Scope of the Survey

Scope of the Survey for the Project is shown as below;

Up to Interim Report (ITR)

1. Reconfirm the background and current situation of the Project
2. Study natural condition of the Project site
   1) Topographic survey (reservoir, emergency canal)
   2) Geological, hydro-geological and soil mechanical surveys (around and within reservoir site)
   3) Groundwater level survey (reservoir site)
   4) Hydrological and water resources survey
   5) Fish ecology survey (Hrazdan and Kasakh Rivers)
   6) Water quality survey
3. Study adoptable material and method of construction
4. Study seismic design standard and emergency discharge system
5. Suggest agriculture plan for the Project area

   1) Future farming plan
   2) Cost-benefit analysis
   3) Suggestion of governmental program to promote/support agriculture for the Project area
6. Suggest irrigation plan (management plan) for the Project area
7. Confirm the Project scope
8. Consider alternative options of the Project

Up to Draft Final Report (DFR)

9. Confirm the Project outline
   1) Purpose of the Project
   2) Contents of main facilities (reservoir, dam, irrigation canals)
   3) Contents of consulting service (detailed design, management of construction)
10. Develop preliminary design
11. Study suitable construction method for the Project
12. Formulate the implementation schedule of the Project
13. Study and formulate the implementation system of the Project
14. Study and formulate the maintenance system of the Project
15. Study environmental considerations including support of development of Environmental and Social Impact Assessment (ESIA) report (draft)
16. Study social considerations including support of development of Resettlement Action Plan (RAP) report (draft)
17. Estimate the Project cost
18. Study mitigation and adaptation on climate change
19. Study gender issue considerations
20. Suggest the effective technical cooperation to expand the Project outcome
21. Collect information on the situation of local procurement
22. Set quantitative and qualitative evaluation indexes of the Project

1-4 Project Area

The Project area is located in the surrounding area of Yerevan city within 20km from the capital city of Yerevan, with 22,754 ha of land area of which 12,200 ha or 53.6 % of the land area is registered as a farmland in cadaster. The Project area expands to 27 communities in three (3) Marzes (regions), i.e. Kotayk, Aragatsotn and Armavir. As shown in Table 1-4.1, the whole territory of 22 communities belongs to the Project area, while a part of the territory belongs to the Project area in other 5 communities. Consequently, 91.2 % of total land area in the 27 communities is included in the Project area.

In terms of WUA category, the Project area is divided into 4 (four) WUA command areas, namely; Yeghvard, Ashtarak, Vagharshapat and Khoy. Potential farmland area for irrigation in the Project area is estimated at 12,347 ha by the Survey Team. The area is larger than the registered farmland area in cadaster as actual cultivated area has extended to non-registered farmland area in many communities in Vagharshapat and Khoy command areas.

Table 1-4.1 Project Area by Communities

No	Community	Marz	WUA	Land Area			Registered Farmland (ha)	Potential Farmland for Irrigation (ha)
				Total (ha)	The Project Area (ha)	% of the Project Area		
1	Zovuni	Kotayk	Yeghvard	1,532.0	1,532.0	100.0	654.2	538
2	Kasakh			1,287.5	1,032.0	80.2	634.0	545
3	Proshyan			2,189.0	1,948.5	89.0	1,139.7	936
4	Sasunik	Aragatsotn	Ashtarak	1,989.5	1,989.5	100.0	1,045.8	934
5	Norakert	Amarvir		1,356.0	609.0	44.9	130.0	98
6	Baghramyan			1,071.0	464.0	43.3	200.0	172
7	Merdzavan			879.0	546.0	62.1	363.1	421
8	Mrgastan		Vagharshapat	296.0	296.0	100.0	173.6	114
9	Tsakhkunk			405.0	405.0	100.0	138.4	154
10	Artimet			636.0	636.0	100.0	327.3	444
11	Taroniq			716.0	716.0	100.0	404.9	528
12	Aratashen			976.0	976.0	100.0	723.8	813
13	Khoronk			695.0	695.0	100.0	481.7	562
14	Griboyedov			711.0	711.0	100.0	547.4	512
15	Lernamerdz		Khoy	164.0	164.0	100.0	105.4	97
16	Amberd			451.0	451.0	100.0	352.5	350
17	Aghavnatun			1,139.0	1,139.0	100.0	475.5	462
18	Doghs			384.0	384.0	100.0	285.2	276
19	Aragats			875.0	875.0	100.0	452.7	645
20	Tsaghkalanj			795.0	795.0	100.0	312.0	469
21	Hovtamej			268.0	268.0	100.0	215.3	176
22	Tsiatsan			311.0	311.0	100.0	205.1	202
23	Geghakert			659.0	659.0	100.0	532.6	491
24	Haytagh			1,261.0	1,261.0	100.0	647.6	606
25	Ferik			402.0	402.0	100.0	159.0	167
26	Arshaluys			1,746.0	1746.0	100.0	1,023.0	973
27	Aknalich			1,743.0	1743.0	100.0	471.0	662
	Total			**24,937.0**	**22,754.0**	**91.2**	**12,200.8**	**12,347**

Source) PIU, SCWE

CHAPTER 2 BACKGROUND OF THE PROJECT

2-1 Outline of Armenia

(1) Main geography of Armenia

Armenia is a landlocked country located in Caucasian Region, surrounded by 4 neighboring countries consisting of Georgia in the northern border, Turkey in the west, Azerbaijan in the east and Iran in the south. Lake Sevan (38 billion m^3 as of 2013), the largest natural lake in Armenia, is situated at the center of the territory as shown in Figure 2-1.1.

Figure 2-1.1 Map of Armenia

Yerevan is a capital city of Armenia with approx. 1.2 million of population (as of 2015) which is one-third (1/3) of the country. And Yeghvard irrigation areas are extent within 5 to 20km at north-west of Yerevan.

Lake Sevan is situated at a highland with its elevation of about 1,900m, flowing down to Hrazdan River that runs through the central part of the Armenian. Water in the Lake has been utilized for irrigation over a vast and flat irrigated farm-area of Ararat Plain (at the altitude of about 500 to 1,000m) with gentle topographical gradient through Hrazdan River.

The irrigation water conveyed from the Lake Sevan has also been used as hydro-power generation utilizing difference of elevation between the Lake and Ararat Plain, however, the period of power-generation is limited from April through November during which irrigation water is distributed to the beneficiary. Thus, Lake Sevan has been regarded as one of precious water resources and from the use of (water) energy point of view though the priority has been given to the side of irrigation.

(2) Background of the request for the Project

Water volume stored in Lake Sevan measured 58,000 million m^3 (MCM) in late 1940s was reduced to 33,000 MCM in early 1970s due to too heavy water use by domestic/industrial sectors as well as irrigation, as a result water level in the Lake dropped by as much as 19 m. As the conservation measures for Lake Sevan suffering from heavy drawdown of lake water level, the Government of Armenia constructed a water tunnel for diverting water from other watershed areas during the period 1960s to 1980s and it also implemented the policy of limiting annual water use for irrigation. However, during the period of energy crisis in 1990s, the lake water was again overused, lowering lake water level.

Yeghvard reservoir project was planned during 1970s as one of the conservation measures for Lake Sevan. Later in 1980s, the work with a scale of 228 MCM had been started, but it was later interrupted due to difficulty in fund supply. Later in 1990s, coping with second recession of lake-water level, reservoir construction plans were studied 16 sites throughout the country from water conservation point of view. Yeghvard reservoir project was included as one of these countermeasure-plans. The scale of this reservoir was reviewed by the country and reduced to around 90 MCM. The plan with this reduced scale has been requested from the Government of Armenian to the Government of Japan as a

loan aid project in May 2012.

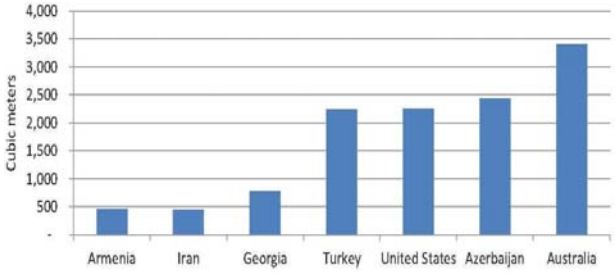
In the Pre-F/S carried out in 2014, physical strength of dam body of which had been interrupted its construction in 1980s was identified and reports on geological/hydro-geological surveys carried out at the times of Union of Soviet Socialist Republics (USSR) were reviewed as well studies were made on the existing agricultural policies and the state of irrigation practices. It has been identified through this "Survey" that in addition to the necessity of introducing gravity irrigation (abolishing pump irrigation) with the objective of mitigating the government-subsidized operation and maintenance (O/M) cost of pumps, the importance of constructing a reservoir has again been reviewed to mitigate excessive dependency on water in Lake Sevan that suffers from excessive drawdown of lake water-level due to overexploitation of lake water beyond the annual limit of water use (170 MCM) during drought period.

On the other hand, as for the evaluation of current hydro-geologic state of the reservoir and the selection of construction method for anti-infiltration, necessity of further survey has been confirmed since only the review of reports is not enough. As of the date of issuing the request for the loan aid to the Government of Japan in 2014, the Government of Armenia had an idea, namely, covering reservoir basin area with fairly impervious artificial sheet (Bentonite-sheet) as measures of preventing water leakage. According to the stakeholders of the Government of Armenia, an artificial sheet producing factory will domestically start its operation in near future. Because the Government plans to make use of domestically produced inexpensive sheet as anti-infiltration measures for the reservoir basin, the Project is to identify the period of starting the construction of the factory as well as of producing the product and its quality, comparing this sheet-covering method with the other shielding methods reviewed in the Project, thereby examining the applicability of the planned sheet.

2-2 Policy of Water Resources

The average annual rainfall in Armenia is around 600mm and the climate belongs to semi-arid and arid zone area. From the point of sustainable water resources development, construction of reservoir and proper water management has an important role in Armenia. There are 87 medium to small scaled reservoirs in the country, which have been constructed since the period of Soviet time.

However, despite such reservoir construction, the storage capacity of reservoirs/water storage facilities per capita in Armenia is smaller as compared to that in Turkey, one of the neighboring countries, only about 20% of that in the Turkish territory, lying on the opposite side of Ararat Plain. Accordingly, given limited land resources and meteorological conditions, it is imperative for Armenia to secure water resources efficiently and appropriately.



Source) WB (2014),Towards Integrated Water Resources Management : Revisited

Figure 2-2.1 Capacity of Water Storage Capacity per Capita in Armenia and Neighboring Countries

The Government of Armenia has been formulated Water Code in 2002, National Water Policy in 2005 and National Water Program in 2006. Table 2-2.1 shows representative example Code and Laws related to the water management.

Table 2-2.1 Code and Law Related to Water Resource Management in Armenia

Name of Code and Laws	Adoption Year
Water Code	2002
National Water Policy	2005
Water Program	2006
Law on Lake Sevan	2001
Law on Water Users Societies and Associations of Water Users Societies	2002

The Water Code is the principal document adopted by the National Assembly. The main purpose of this Code is the conservation of the national water reserve, the satisfaction of water needs of citizens and economy through effective management of useable water resources, securing ecological sustainability of the environment. And the National Water Policy pursues aim to provide accessibility for sufficient quantity, regime and quality of water resources to maintain basic human well-being for present and future generations, socio-economic system development, and to meet economic and ecological needs.

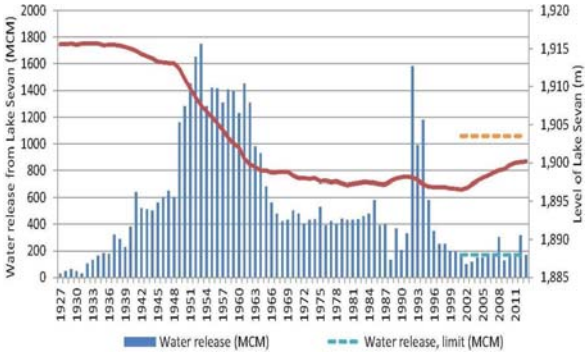
In addition, the National Water Program has been developed, which will guide the water basin management plans and the classification of water resources. The law will serve as the basis for integrated water resources management, and will support more efficient management and protection of water resources.

The National Water Policy defines that water resource allocation among water users shall be performed base on the following order of priorities, which are listed as shown in Table 2-2.2. Agricultural water usage priority is higher than the Energy and Industrial production use.

Table 2-2.2 Priority of Water Usage Defined by National Water Policy

No	Order of Priorities for Water Usage	
1	National water reserve	Conservation and usage of sufficient water resources, to ensure basic needs of population, reduce disease and so on.
2	Traditional use	Historical use for non-industrial purposes
3	Water resources use	Set in the Armenia legislation and international commitments
4	Vital	To ensure vital and cultural water need of population
5	Agricultural	To ensure water need in irrigation, pasture irrigation, animal breeding and other non-industrial purposes
6	Energy	To ensure water needs in energy production
7	Industrial	Water for industrial production needs
8	Recreation	Water use for sports, fishing, swimming and so on.
9	Anti-drought activities	To minimize damage caused by droughts

Together with conservation of river flow, Lake Sevan is also important water resource in Armenia, which has the largest water storage capacity. Armenia has diverted watersheds by constructing the Arpa-Sevan and Vorotan-Arpa tunnels as conservation measures of Lake Sevan, thus keeping relevant use of the Lake, learning from lessons of dropping water levels in this lake that occurred in the past. Furthermore, in 2001, Armenia launched an environmental improvement strategy for Lake Sevan with the target of elevating its water level by 6m (up to 1,903.5m) by 2030. Additionally, the country has not only determined the upper limit of annual releasing (intake) water volume from Lake Sevan to an irrigation network at 170MCM, but it also decided to operate hydropower stations located along the Hrazdan River only during the period of distributing irrigation water, thereby addressing the recovery of the lake-water level is shown in Figure 2-2.2.



Source: World Bank (2014),Towards Integrated Water Resources Management : Revisited

Figure 2-2.2 Change in Water Level in Lake Sevan

As mentioned above, the Government of Armenia has taken the initiative to conserve Lake Sevan in such an integrated manner as watershed diversion by tunnels and practice of limiting intakes from the Lake, in contrast with the current state in neighboring countries where environmental problems have taken place including descending water levels in lakes. As a result, the water level in Lake Sevan tends to have been increasing since 2003, with visible fruit of its strategic effort for recovery. Such a

desirable concept will continuously be handed down to younger generations. At the same time, the Government of Armenia not only constructs new reservoirs and conserves natural water resources including the Lake Sevan, but also considers watershed management as an important strategy to relevantly utilize its limited water resources. In the future, it will envisage efficient use of water resources by adequately managing watersheds of individual streams.

2-3 Agricultural Development Policy

The Armenian people focused their economic activity back to the agricultural sector in order to make utmost efforts to accommodate themselves to the economic crisis after the independence. As a result, the sector was headed for recovery and the GDP ratio of the sector grew to 46.3% in 1993. Currently, however, the GDP ratio is reduced to lower than half of that of 1993. This is not attributed to the stagnation of the sector, but rather the smooth recovery and growth of other economic sectors. The current state of agriculture in the country shows that the sector has surpassed the stage of self-subsistence and has entered the next stage of commercialized agriculture that includes vegetables, fruits, industrial crops and livestock, as seen in the USSR era. It is reported that approx. 80% of domestic agricultural production was from irrigated land. Irrigation is a significant infrastructure supporting the country's agriculture.

The government launched its Sustainable Agricultural Development Strategy (SADS) covering the period 2010-2020 as the national agricultural development policy in order to respond to the commercial-oriented agriculture. SADS aims to enhance productivity and value of agricultural products; to improve food security for the population by distributing products appropriately both to domestic and international markets, and to promote its export (targeting 3.5 times increase in the current export volume). More details of SADS are described as follows.

2-3-1 Sustainable Agricultural Development Strategy (SADS)

Vision (in 2020)

- Sustainability and competitiveness agriculture,
- Cooperated and highly competitive, market-oriented production,
- Sustainable provision of food to the population and meeting the demands of the processing industry,
- Increase in gross farm produce though increasing labor productivity,
- Development in SMEs in rural communities,
- Positive change of intrans sectoral structure of plant and livestock production,
- Utilization of agricultural potential, especially land resources, and
- Improvement of food security for the population.

Strategy goal

- Promotion of industrialization of agriculture (value-addition),
- Increase in the food security, and
- Shaping favorable conditions for promoting export-oriented productions.

Production goals of major crops

SADS attempts to increase production of all major crops from the level of 2007 (see Table 2-3-1.1), with special focus on increasing production of fruits and grapes, industrial crops, sheep and poultry.

Fruits, grapes, industrial crops and sheep are expected to be the driving force of value-addition and exporting of agricultural products. On the other hand, poultry is seen as an import substitute. In addition, SADS aims to increase cultivating areas of forage crops rapidly, as a response to high

demand in forage crops from livestock sub-sector.

It is interesting that SADS does not plan to increase planted areas of cereals much, though SADS declares “increase in the food security” as a strategy goal, and the country imports a large amount of wheat which is the most important people’s staple diet every year. It seems that SADS has a realistic wheat policy which aims to streamline the production instead of to increase the planted area blindly considering a gap between domestic and international prices of wheat.

Table 2-3-1.1 Expected Outcomes of the Strategy (2007-2020)

Crop/Livestock	Planted Area(ha)/Heads (x 1,000)			Production (x 1,000 ton)		
	2007	2020	±(%)	2007	2020	±(%)
Cereals	176.2	190.0	107.8	452.5	662.5	147.0
Potatoes	31.6	30.0	94.9	583.9	750.0	128.4
Vegetables/Melons	31.5	31.0	98.4	1,051.6	1,357.5	129.1
Forage crops	65.0	155.0	238.5	–	–	–
Industrial crops	1.6	15.0	937.5	–	–	–
Fruits	38.0	53.0	139.5	260.2	586.3	225.3
Grapes	15.9	33.2	208.8	218.9	451.2	206.1
Cattle/Beef	629.1	667.0	106.0	78.6	97.0	123.4
Cows/Milk	310.6	328.5	105.8	598.9	850.5	142.0
Pigs/Pork	86.7	210.0	242.2	20.4	24.0	117.6
Sheep & Goats/Mutton	637.1	1,550.0	243.3	15.5	46.5	300.0
Sheep & Goats/Milk	–	–	–	42.3	123.7	292.4
Sheep & Goats/Wool	–	–	–	1.277	3.560	278.8
Poultry/Meat	4,018.2	8,000.0	199.1	7.8	16.0	205.1
Poultry/Egg	–	–	–	545.4 mil. pcs	750.0 mil. pcs	137.5

Source: 2010-2020 Sustainable Agricultural Development Strategy, RA

2-3-2 Agricultural Development Strategy in the Project Area

The SADS specifies agricultural strategies in respective Marzes where beneficial communities of the Project belong to Table 2-3-2.1 shows the development strategies of three (3) Marzes, i.e. Aragatsotn, Armavir, and Kotayk

Table 2-3-2.1 Agricultural Development Strategy of Concerned Marzes

Marz	Current Situation	Prospective Situation
Aragatsotn	Dairy-and-meat cattle breeding; potato and fruits production; and cereals farms	Dairy-and-meat cattle breeding; fruits and potato production; sheep breeding; and fodder production
Armavir	Vegetable production; cereal farms; grapes production; meat-and-dairy cattle breeding; potato and fruits production	Production of grapes, vegetables and fruits; dairy cattle breeding: early ripe potato production
Kotayk	Meat-and-dairy cattle breeding; vegetable and potato production; and cereals farms and fruits production	Meat-and-dairy cattle breeding; poultry farming: fruits production; cereals farms; vegetable production; and fodder production

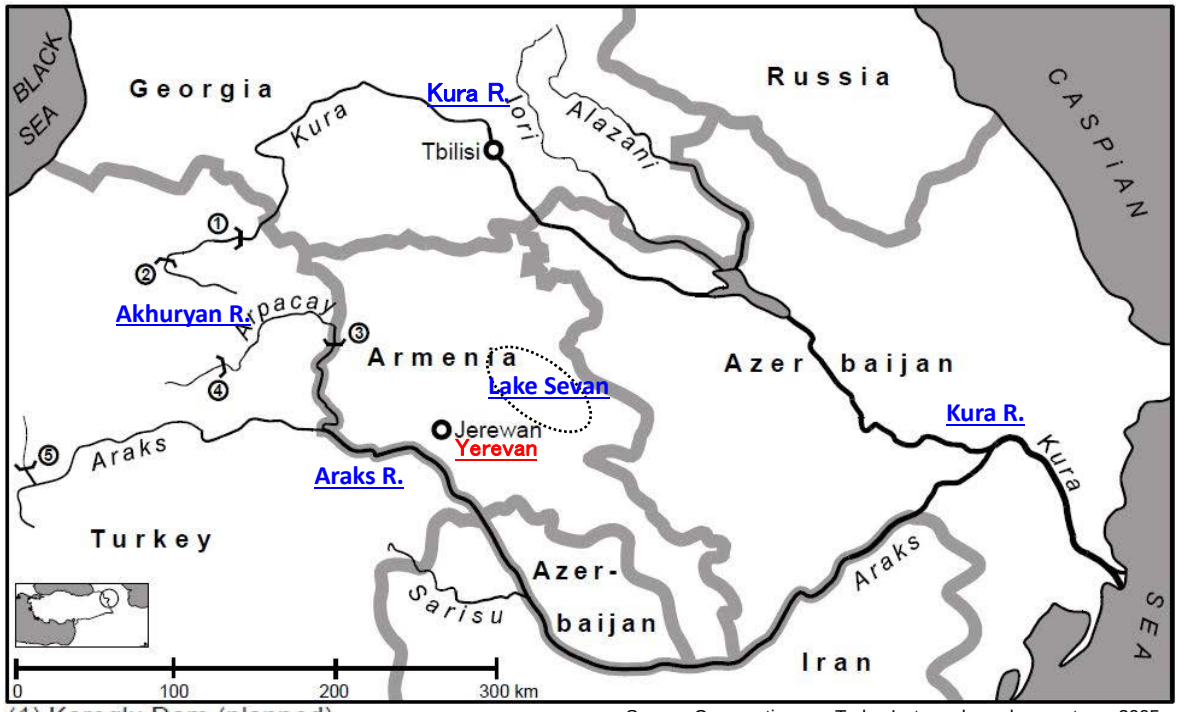
Source) 2010-2020 Sustainable Agricultural Development Strategy, RA

The promotion of animal husbandry, including forage crops, is a major strategy in Aragatsotn Marz as well as cropping of fruits and potatoes. In Armavir Marz, the present major crops such as vegetables, grapes and other fruits will be promoted as well as dairy industries and early varieties of potatoes. In Kotayk Marz, livestock and chicken industry including forage crops and diversification of agriculture with the combination of cereal crops, vegetables, and fruits will be prioritized for promotion.

As the Project area belongs to or borders on the territory of Armavir Marz, the strategy of Armavir Marz should prevail among the area.

2-4 Recent Situations of International River Treaty

The Araks River, which is the main stream of the Hrazdan River, rises from the highland of Armenia, runs through the Turkish territory toward the east, and then flows down along the borders of Armenia with Iran and Azerbaijan, merging into the Kura River, finally flowing into the Caspian Sea (refer to Figure 2-4.1). Ratios of area of the Hrazdan River basin (around 1,200 km^2) to that of the Araks River basin (around 102,000 km^2) and sum of Araks River basin and Kura River basin (around 188,000 km^2) are 1.2% and 0.6%, respectively, very small.



(1) Koroglu Dam (planned)
(2) Besikkaya Dam (planned)
(3) Arpacay Dam **(Akhuryan Dam)**
(4) Bayburt Dam (under constructon)
(5) Demirdoven Dam

Source: Cooperation on Turkey's trans-boundary waters, 2005

Figure 2-4.1 Trans-boundary Rivers in and around Armenia

The overall water use agreements on the Araks River, a trans-boundary river, are summerized in the Table 2-4.1;

Table 2-4.1 Past Water Use Agreements on the Trans-boundary Rivers in Armenia and Adjacent Countries

	Related countries	Agreed period	Outline
1.	Armenia under Soviet Union	January, 1927	Quantity of water intake from Araks River & Akhuryan River was agreed at 1,230 million m^3/year/country (share of water right 50:50)
2.	Turkey, Armenia under Soviet Union	January, 1927	Agreement on the survey & construction of headworks traversing Araks River. Identification on the scale of the facility & joint development by both countries (share of water intake 50:50)
3.	Turkey, Armenia under Soviet Union	October, 1973	Agreement on the joint development of a dam of Akhuryan River (share of water intake 50:50)
4.	Iran, Armenia under Soviet Union	August 1957	Share of water intake for irrigation, power generation and domestic water from Araks River and Atrak River is agreed at 50:50 & the dam is jointly developed.
5.	Republic of Georgia & Republic of Armenia under Soviet Union	November 1971	Detailed agreement on the share of water intake after constructing headworks in Debed River (a tributary of Kura River)
6.	Republic of Azerbaijan and Republic of Armenia under Soviet Union	October 1962	Agreement on the use of water power generation in Arpa River flowing into Lake Sevan
7.	Republic of Azerbaijan and Republic of Armenia under Soviet Union	April 1990	Agreement on controlling discharge in Vorotan River, a tributary of Araks River, the river discharge as of 1990 shared by both countries at the rate of 50:50
8.	Republic of Georgia & Republic of Azerbaijan & republic of Armenia	February 1997 (as a bilateral agreement)	Consultation on monitoring evaluation on the conservation of natural environment / river water conservation of Kura River (though already agreed between Georgia ^ Armenia, still pending between Azerbaijan and Armenia)

Source) Armenia Integrated Water Resources Management Plan (Reference distributed by JICA)

Three (3) Caucasian countries including Armenia participated in the establishment of USSR in 1922 (independence from USSR was achieved in 1991), while Armenia at that time under USSR and Turkey concluded “Convention on Water Use from Transboundary Rivers, Small Rivers and Brooks of USSR and Turkey” in January 1927. It was agreed in this Convention to equally share the quantity of water intake from the Araks River and the Akhuryan River (also called “Arpacay”) 50:50, or 1,230 MCM per year per country. Besides, in the same year, USSR planned to construct a head-works in the Araks River, and obtained the agreement with Turkey in which water was shared 50:50 with joint management of the facility after construction. Later, in October 1973, an agreement was also closed to construct a reservoir in the Akhuryan River (at a site of the border between Turkey and Armenia).

All of the above-cited agreements had been exchanged before the independence of Armenia (1991). However, the stakeholders of SCWE understand they are now still valid. In its background, even though no diplomatic relations have not been established yet between Armenia and Turkey, there lies a fact that water sector stakeholders in both countries have regular meetings as to the application of Akhuryan reservoir located between both countries where the share of 50:50 for water use has been identified.

Also, the Akhuryan reservoir was completely constructed in the 1980s during the regime of USSR, and after the independence of Armenia, it has jointly been utilized. When the reservoir was constructed, it was agreed between both countries that water should be released to Akhuryan reservoir for its conservation with the rate of 150MCM/year for the side of Armenia and 350MCM/year for the side of Turkey in compliance with the share of the territorial watershed area of the reservoir between the two countries. Further, as to the Kaps project, which F/S is completed the Government of Armenia is now planning forward by observing releasing volume of 150MCM/year.

Water distribution of the Hrazdan River is managed by the Sevan-Hrazdanyan Jrar (“Jrar” means intake) Closed Joint Stock Company (CJSC) under the SCWE, and Water Resource Management Agency (WRMA) under the MNP. The Hrazdan River flows within the Armenian territory, therefore, the Hrazdan River is regarded as an in-country river in Armenia, instead of an international river. Therefore, there is no international treaty on utilization of water of the Hrazdan River.

CHAPTER 3 CURRENT CONDITIONS AND ISSUES ON IRRIGATION /AGRICULTURE SECTORS IN ARMENIA

3-1 Armenian Ministries/Agencies related to the Project

The administrative system of Armenia is composed of 19 ministries as shown in Figure 3-1.1, where the State Committee of Water Economy (SCWE), the implementing agency of the Survey, belongs to the Ministry of Agriculture. This committee consists of 1) State Agencies of the System and 2) Organizations of the System. The former takes charge of project formation, design and construction work of irrigation development and is also responsible for the rehabilitating work of the Arpa-Seven water tunnel constructed in 1980 for the purpose of restoring the storage capacity of Lake Sevan. The latter superintends 8 Water Supply Agencies (WSAs) in the field of operating irrigation facilities, domestic water supply and the sewage water system after construction. Out of these 8 WSAs, a) Sevan-Hrazdayan Jrar CJSC (Closed Joint Stock Company) and b) Akhuryan-Araks Jrar CJSC execute operation and maintenance (O/M) of the irrigation system by collecting water fees. WSAs other than these two operate and manage the domestic water supply and the sewage water system.

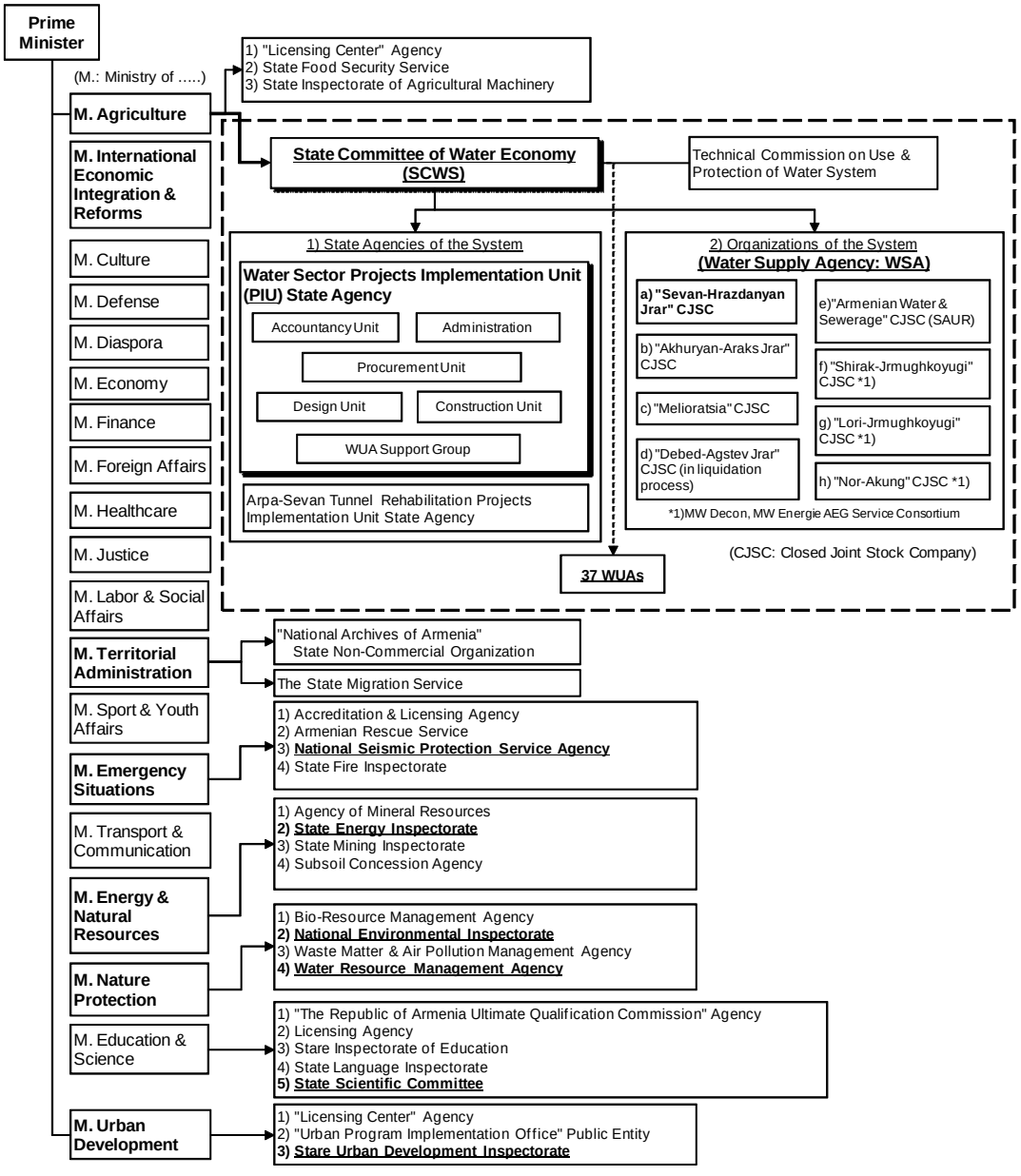


Figure 3-1.1 Administrative System of Armenia

The Water Sector Project Implementation Unit (PIU) State Agency in charge of this survey and is also responsible for the Yeghvard Irrigation System Improvement Project in total staffed with 36. Other than the Project, it currently handles the appraisal of the F/S contents for the Kaps Project with German (KfW) assistance and the Vedi Project with French (AFD) assistance. Major service duties of the PIU include formal actions of project implementation, more concretely, 1) formulation of working schedules required for implementing projects, project cost estimation, provision of tender documents, bidding and bidding evaluation; 2) procurement of services including construction, materials/machinery and consultants; 3) provision of construction contract documents and contract action; and 4) construction supervision, monitoring, etc.

As to related line-ministries in this survey, they include 1) the Ministry of Agriculture in charge of formulation of agricultural development policies, farming extension and assistance, research/educational organizations, 2) the Ministry of Emergency Situations that evaluates existing dams from the aspect of human and social damages in such occasions as collapse of dams, 3) the Ministry of Urban Development that is now revising standard criteria for designing earthquake seismic structures including buildings and dams, and 4) the Ministry of Nature Protection that appraises environmental and social impact assessment applied to the materialization of projects.

In addition, the Ministry of Education and Science takes charge of diversified Institutes in technical sectors. Originally, these institutes were once governmental organizations under the Communist Regime of the Soviet Union, but they were privatized into foundations after the independence in 1991 and have now become profit-making organizations.

As a related institute, four (4) institutes are counted as follows: 1) the Armvod Proekt (Project) Institute that engaged in the F/S study of the Yeghvard reservoir project under the regime of the Soviet Union, later handling a wide spectrum of irrigation projects including planning/designing; 2) the Hayjrnakhagits (Water design) Institute that reviewed the F/S study of the project (water storage capacity: 90MCM), in 1999; 3) the Institute of Geological Science that took part in a geological survey at the time of the F/S study of the the project and is now holding a wide range of hydrology as well as geology related information in Armenia; and 4) the Institute of Geophysics and Engineering Science which is a research institute related to seismology and also handles earthquake seismic designs for structures (located in Gyumuri, the second largest city in Armenia near the epicenter of the Spitak earthquakes).

Table 3-1.1 shows trends of the fiscal budget of the Government of Armenia.

Table 3-1.1 Trends of Annual Budget of Armenian Government

1USD= 410 AMD Unit: USD

Sector / Year	2009	2010	2011	2012	2013	2014	Percent In 2014
1. Public services	300	341	374	403	510	532	17.5%
2. Defense	365	331	357	377	446	473	15.6%
3. Safety and legal cooperation	157	138	148	150	177	201	6.6%
4. Economic relations	251	276	237	278	320	264	8.7%
5. Environmental advocacy	16	15	22	13	13	11	0.4%
6. Housing construction and municipal services	45	113	118	48	63	65	2.2%
7. Health	161	135	152	159	176	197	6.5%
8. Leisure, Culture and Religion	48	40	44	55	44	51	1.7%
9. Education	310	244	264	257	264	312	10.3%
10.Social advocacy	616	596	663	749	743	883	28.9%
11.Other	37	53	63	58	55	49	1.6%
Total	**2,306**	**2,282**	**2,442**	**2,547**	**2,811**	**3,040**	100.0%
(Increased rate based on 2009)	(Base)	(0.99)	(1.06)	(1.10)	(1.22)	(1.32)	

Source) Government of Armenia (Website)

The budget for the 2014 fiscal year indicates an amount equivalent to 3 billion USD, or increased by

32% as compared to 2009 (5 years ago), thus showing steady growth from year to year. As to a sector-wise breakdown, about 29% of the total amount of the budget is allocated to Social advocacy, followed by public services expenses accounting for about 17.5%.

In agriculture sector, an amount of 17.01 million USD is allocated in 2014 fiscal year (Source: Website, Ministry of Agriculture, RA)

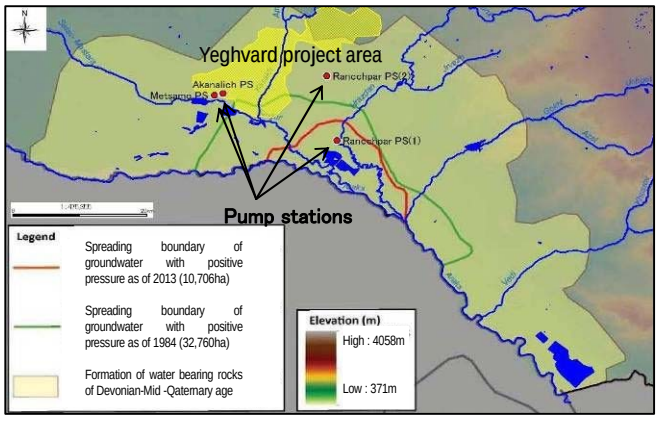
3-2 Status of the Project to the National Development Plans

3-2-1 Irrigation Sector

According to the Armenia Development Strategy for 2014-2015, the expansion of irrigated land areas was quite slow in recent years. However, agriculture in Armenia depends on irrigation. 80 % of agricultural production produced in irrigated lands. And irrigation systems will continue to remain a priority for public investment. The target of the investment policy will be the expansion of irrigated land areas and higher efficiency of the system. Expansion of irrigated land area is to take place in the frames of existing irrigation systems.

With regards to irrigation policies, the government aggressively deploys the policy of converting irrigation methods from pump to gravity-based system. There lies a background behind the strategy of "breakaway from energy intensive agriculture", and an issue of decreasing the groundwater level which causes the difficulty for pumping up irrigation water. In particular, the groundwater level has been drawing down in the Ararat Plain.

Figure 3-2-1.1 shows the distributed range of artesian ground water map provided by the WB, on which the sites of facilities related to the Yeghvard irrigation improvement project are superposed. The green line in this figure indicates the spreading area of artesian groundwater as of 1984, while the red line shows the area as of 2013. Also, the yellow part indicates the beneficiary of the Yeghvard irrigation improvement project (12,347ha) and the red dots show the location of the pumping stations related to the Project. The prevailing state of groundwater drawdown around the sites of pumping stations related to the Project is clearly marked in Figure 3-2-1.1. As such, irrigation policies have been initiated, intending to get the country itself free from agriculture which is heavily dependent on energy, while at the same time focusing on a shift from dependence on groundwater to effective use of surface water.



Source) Base Map: World Bank (2014), Towards Integrated Water Resources Management (Revised)

Figure 3-2-1.1 Groundwater Drawdown in Ararat Plain

3-2-2 Agriculture Sector

Many crops especially vegetables and fruits including grapes are concentrated in the Ararat Plain where the major part of the Project area belongs to. The plain is blessed with plenty of sunshine, relatively higher temperatures and a lower amount of rainfall, in addition to the well-developed irrigation networks. Such condition in the area highly contributes to form a production area of vegetables and fruits. Farm sizes in Ararat Plain are the smallest in the country, but many farmers enjoy the high profitability of those crops. The farmers actively apply new technologies, including greenhouses or drip irrigation, which makes the area an advanced agricultural region. Almost crops in the area record a higher yield.

The government recognizes that the Project area of Yeghvard irrigation project is a strategic area to achieve the goals of SADS, which is the highest level of agricultural development policy in Armenia, for the following reasons.

- The area belongs to a production center of vegetables, fruits and grapes which are expected to be main products for promoting industrialization of agriculture and export-oriented productions declared in SADS.
- The area is located on the suburbs of Yerevan city, where many agro-industries are developed and is the main market of the products.

Table 3-2-2.1 implies that crop production, especially vegetables/melons and grapes, in the Project area contributes much to the national production, though the total land area is only 0.8% of the national land area. Statistical information on agricultural production in Armenia in 2010-2014 is attached in Appendix B-1. Details of agricultural activities in the Project area are discussed in Chapter 4.

Table 3-2-2.1 Production of Major Crops in Armenia and in the Project Area in 2014

Crop	Armenia (A)		Project Area (B)		(B)/(A)	
	Area (x1000 ha)	Production (x1000 ton)	Area (x1000 ha)	Production (x1000 ton)	Area (%)	Production (%)
Grains	188.7	590.6	1.8	6.9	1.0	1.2
Potatoes	31.6	733.2	0.7	29.1	2.2	4.0
Vegetables/Melons	32.2	1,200.4	2.9	91.6	9.0	7.6
Fruits	40.1	291.0	0.9	6.3	2.2	2.2
Grapes	17.2	261.3	1.3	17.5	7.6	6.7
Total land area	2,974.3	-	22.8	-	0.8	-

Source) Statistical Yearbook of Armenia, 2015
27 communities concerned (Crop Area and Production in Project Area 2014)

3-2-3 Activities of Other Donors related and their Project Contents

Table 3-2-3.1 indicates trends of ODA performances to Armenia by five major donors. Amounts of ODA have tended to decrease since 2009 as the total amount, and the amount in 2012 remained at about 50% of the performance in 2008. Year after year, USA and Germany ranked highest for the past 5 years; however, Japan, which occupied a higher rank in the past reduced the amount of ODA to Armenia since 2011.

Table 3-2-3.1 Trends of ODA Performances by Major Donors (Highest Five)

Unit: million USD

Year	2008	2009	2010	2011	2012
First	USA: 93.8	Japan: 98.7	USA: 91.6	USA: 90.5	Germany :44.9
Second	Japan: 57.7	USA: 78.5	Japan: 77.5	Germany: 40.9	USA :37.6
Third	Germany:27.9	Germany: 31.0	Germany:16.7	Japan: 7.4	France :8.1
Fourth	England: 6.6	France: 5.7	France: 4.5	France: 5.6	Switzerland :3.9
Fifth	France: 5.5	Norway: 3.1	Norway: 3.6	Denmark: 4.2	Norway :3.3
Total amount	208.9	235.0	205.8	164.7	108.4

Source) DAC, International Development Statistics (Since only highest ranked 5 countries were listed, total amount does not match)

The state of external assistance by donors and international organizations since 1994 in the agricultural/irrigation sectors is shown in Table 3-2-3.2. Major contents of already implemented projects include the existing dams and intake facilities, rehabilitation/improvement of main/branch canals. In addition, the most important task in this sector aims at the shift from pump irrigation to gravity irrigation in almost all rehabilitation/improvement projects. In this context, the background of this issue includes the fact that WUAs in irrigation project areas, in which pumps are the main water sources, are obliged to depend on the government subsidy, and the subsidy also seriously places a heavy burden on the government budget. Besides, the elevated irrigation efficiency brought about by

the consolidation of intake facilities and canals leads to reduction of irrigation water consumption. Thus, the envisaged shift to gravity irrigation has a goal to contribute to the conservation of Lake Sevan, that is, a national policy component.

As to F/S studies, the Kaps irrigation project (assisted by Germany) in the Shirak Marz and the Vedi irrigation project (assisted by France) in the Ararat Marz are currently in the final stage. As for Kaps, it has a main objective of averting risk of dam collapse, but it also envisages lower dependency on pump irrigation. In the case of the Vedi project, the beneficiary of which presently depends on pump irrigation as heavily as 80%, it mainly aims at the conversion into gravity irrigation by means of constructing reservoirs.

In this connection, Germany (KfW) announced that it plans to begin a study on climatic changes and the effect of global warming starting from 2015.

Table 3-2-3.2 External Assistance by Donors and International Organizations for Agriculture/Irrigation Sector

Name of project		Project outline, target area, perimeter area, beneficiary etc.	Donor	Stage of aid (NR /R*)	Project cost (M.USD)	Project period
1.	Irrigation Rehabilitation Project (IRP)	Emergency assistance project to 8 irrigation project (including 4 reservoirs) in the whole country: the work of rehabilitation was implemented including: total length of canals; 260km, appurtenant structures; 126 sites, total length of drainage canals; 310km and 238 wells.	WB/ IFAD	Implemented (reimbursable)	52	1994 -2001
2.	North-West Agricultural Support Project	Assistance for improving water management techniques in north-western Armenia by participatory approach: Issue extraction on WUA and instruction on efficient water management to WUA were carried out.	IFAD	Implemented (non-reimbursable)	n.a.	n.a.
3.	Two Dam Safety Projects (DSPs) and IDSP (Irrigation Dam Safety Program) II	Rehabilitation project of the existing 74 reservoirs in the country taking account of safety aspect for beneficiary people in their downstream: Safety state of 420,000 beneficiary people in total was improved.	WB	Implemented (reimbursable)	37	2000 -2009
4.	Irrigation Development Project (IDP)	Rehabilitation/ extension of intake facilities in Araks River and main canal with 28km in total length was executed and intake/ conveyance volume was increased from 27 to 53m^3/s. Also, assistance on organization was executed therein, leading to establishment of WUA.	WB	Implemented (reimbursable)	36	2002 -2009
5.	Program of Millennium Challenge in Armenia, Irrigated Agriculture Project	Rehabilitation/ improvement of irrigation systems in the country and strengthening of WUA: Main and secondary/ tertiary canals were improved and the shift from pumping to gravity irrigation was realized in some systems. Also, some pumps were renewed in Ararat Plain and drainage network was improved.	USAID	Implemented (non-reimbursable)	109	2006 -2011
6.	Irrigation Rehabilitation Emergency Project (IREP)	Emergency irrigation facilities rehabilitation project in Aragatsotn & Armavir Marz: Total canal length of 90km was rehabilitated, saving 97MCM/ year (for 8,000ha).	WB	Implemented (reimbursable)	36	2009 -2011
7.	Additional Financing for Irrigation Rehabilitation Emergency Project (IREP)	Emergency irrigation facilities rehabilitation assisting project: Canals were rehabilitated for 110km in total (main canal 58km, tertiary 52km), leading to alleviating conveyance loss by 44MCM/ year.	WB	Implemented (reimbursable)	22	2011 -2013
8.	Construction of Kaps Reservoir and Gravity Irrigation System	A F/S study on the completion of a dam construction of which had been started in 1980s but later suspended in a tributary of Akhuryan River in Shirak Marz, and improvement of the existing irrigation facilities: now the project is put under appraisal, its storage capacity is 25MCM with the beneficiary of 2,280ha, project cost amounting to 94 million USD (Stage-1) as of September 2014. River water is diverted by the dam under suspension during years of Soviet regime where river discharge is released through a water tunnel, but it was choked as it gets dilapidated, thus collapsing risk arises.	Germany (KfW)	F/S Study (non-reimbursable)	n.a.	2012 -2014
9.	Construction of the Vedi Reservoir for Irrigation in the Ararat Valley	F/S study on dam construction and improvement of the existing irrigation system in Vedi River in Ararat Marz: it's now on the way to report finalizing stage (as of September 2014), with the maximum water storage of 40MCM, beneficiary perimeter of 2,820ha, project cost amounting to 197million USD (Option-2 but also another option exists). Though 77% of the intake volume of the	France (AFD)	F/S Study (non-reimbursable)	n.a.	2012 -2014

Name of project		Project outline, target area, perimeter area, beneficiary etc.	Donor	Stage of aid (NR /R*)	Project cost (M.USD)	Project period
		existing irrigation system presently depend on pumps, the project mainly aims at shift from pump irrigation system to gravity one.				
10.	Toward Integrated Water Resources Management: Revisited	The first edition was published in 2002 targeting to the whole country. Based on change in water resource environment after 2002 and also on the result of review study in 2014 as well as current state of irrigation, the revised edition suggests future outlook of water resources and irrigation strategy.	WB	Policy assistance F/S Study (non-reimbursable)	n.a.	2013 -2014
11.	1st and 2nd Crediting Programs of Community Agricultural Resource Management and Competitiveness (CARMAC)	CARMAC Project is designed to improve the productivity and sustainability of pasture-based livestock farms in 55 mountainous communities in six Marzes of RA by increasing milk production, improving pasture management, and enhancing farm sales of livestock products.	WB	n.a.	1st: 0.9 2nd: 42.67	1st: 2013 -2016 2nd: 2014 -2020
12.	The European Neighborhood Programme for Agriculture and Rural Development (ENPARD)	ENPARD project is providing service to improve capacity of farmers associations and cooperatives and to establish agricultural and non-agricultural pilot value chains contributing to the development of rural areas, development of improved agricultural inputs and production systems in particular for livestock, fruits and vegetables, improve access to local and international markets in Shirak, Lori, Gegharkunik, Aragatsotn, Kotayk, Vayots Dzor Marzes of RA	UNDO, UNIDO	n.a.	European Union:1.35 Austrian Development Agency :0.51	2015 -2017
13.	Market for Meghri (M4M), Rural development project in the region of Meghri	Targets of the project are small-scale producers of fig, persimmon and pomegranate. The project aim at increasing their production & profitability and thereby generate increased and sustainable income.	Swiss	n.a.	CHF 3.5	1st: 2009 -2012 2nd: 2012 -2015
14.	Support for pesticide quality control and residue monitoring in Armenia	The project aim at enabling the country to control the quality of pesticide products on the market in line with international standards and to carry out pesticide residue surveillance monitoring programmes in order to improve the quality of agricultural products.	FAO, the Greek government	n.a.	2.0	
15.	Climate change	(not yet)	Kaps			

Source) MOA and Document of reply from Armenia to the JICA questionnaire, also. F/S reports of Kaps, Vedi irrigation reports
*NR/R: non-reimbursable / reimbursable.

3-3 Food Security

Table 3-3.1 shows the recent food self-sufficiency ratio in the country. It can be said that self-sufficiency ratio of basic foods such as cereals, edible oils and pork meats are at a lower level. In contrast, other foods like vegetables and fruits/grapes show a high rate.

It is difficult to define the adequate food self-sufficiency ratio, as a policy simply pursuing the higher ratio is not always the best strategy to accomplish a sound national food security system. As Table 3-3.1 shows, major foods that constantly reached the level of self-sufficiency (higher than 95%) are potatoes, vegetables, grape, eggs, and meats of sheep/goat. The reason why the ratio of sugar sharply increased after 2012 was the development of sugar processing factories. A large amount of sugar beet is, however, still imported every year according to the MOA. The self-sufficiency ratio of beef and milk is relatively high. However, it is evaluated that beef and milk have still weak production foundations considering a lower self-sufficiency ratio of cereals which should be a major feed for cattle when the commercial production will be developed.

Table 3-3.1 Self-sufficiency (%) of Major Foods & Per-capita Calorie Supply (2010-2014)

Food	2010	2011	2012	2013	2014
Wheat	33,5	36,5	32,9	46.8	48.7
Barley	78.3	90.3	96.6	93.1	95.4
Maize	20,8	26,5	32,6	20.3	27.9
Potatoes	100,2	98,2	99,0	102.5	101.1
Vegetables	98,3	98,2	99,3	99.5	99.1
Fruits	79,8	90.0	96,1	99.6	93.8
Grape	101,1	101,4	102,6	102.0	101.9
Leguminous crops	41,7	47,3	56,0	54.3	51.9
Oil crops	4,1	2,8	9,1	15.1	13.2
Sugar	24,6	43,9	93,1	92.6	93.1
Eggs	99,2	94,1	99,5	96.3	97.2
Milk	87,0	82,9	83,1	85.0	84.2
Beef	85,1	78,4	81,6	86.2	87.9
Pork	41,1	43,3	38,3	46.0	54.2
Mutton and goat meat	100,0	100,0	100,0	100.0	103.4
Poultry meat	12,4	12,2	19,1	19.8	20.0
Per capita calorie supply (kcal/day)	2,786	2,809	2,849	2,808	2,899

Source) MOA, RA and FAOSTAT

The SADS emphasizes domestic food security as a strategic pillar. Taking the given circumstances into consideration, a rise in cereals production and promotion of animal husbandry with an increase in forage crops should be the main strategy. Actually, the self-sufficiency ratio of cereals, especially wheat shows a trend toward the improvement in recent years. Nevertheless, since major cereals and forage crops are internationally commercialized, it is inevitable to rely on cheap imported products in order to pursue economic efficiency. It is crucial to keep a careful balance between the improvement of food self-sufficiency ratio and economic efficiency.

Total calorie supply remains at reasonable level in recent years as per capita calorie supply reached 2,800 kcal per day in 2011, while it was about 2,200 kcal per day in 2000. It is evaluated that sufficient amount of food is supplied to the population at national level. With regard to the breakdown, the calorie supply from animal products is increasing, while the supply from vegetable products is gradually decreasing from 2006.

3-4 International Trade of Agricultural Products

Since Armenia's independence, the government has promoted agricultural sector with some successes. However, as mentioned above, the production of many crops cannot meet domestic demands; the country still depends on substantial amount of imported products.

As Table 3-4.1 shows, wheat is the most imported product. While wheat is regarded as a major staple food, it has a low self-sufficiency ratio as demonstrated by the country's unceasing importation of wheat. Because wheat is less profitable, it cannot be considered by farmers as a priority crop in terms of effective land utilization. Though an increase in wheat production is a key to improve domestic food security, the current situation necessitates continuous importing of wheat to meet domestic demand. Besides wheat, a substantial amount of barley and maize, used for food and feed, is imported every year. In addition to the cereals, a great amount of meats and milk are also imported. Given this background and current import pattern, it is understandable why the SADS highlights the enhancement of production of forage crops and promotion of livestock farming. Among meats, poultry meat (mostly chicken) is the most imported product. Oil crops are another notable commodity in terms of importation. Imported fruits likewise show high import volume but they are probably tropical or semi-tropical fruits which are unable to grow in Armenia. Imported vegetables are seen only during the limited season of winter (January-March) when the domestic production is scarce.

Table 3-4.1 Import & Export of Agricultural Products (2012-2014)

No	Food Commodity* (fresh & processed)	Import (x 1000 ton or liter)			Export (x 1000 ton or liter)		
		2012	2013	2014	2012	2013	2014
1	Wheat	502.7	371.4	367.3	7.8	17.5	10.9
2	Barley	6.9	14.7	10.4	0.9	0.7	0.7
3	Maize	39.5	82.3	52.1	0.0	0.0	0.0
4	Rice	10.4	10.3	10.6	0.0	0.0	0.0
5	Leguminous crops	4.0	4.3	5.1	0.0	0.0	0.0
6	Potatoes	7.8	7.6	12.9	1.1	23.5	21.2
7	Tomatoes	0.3	0.5	2.7	5.1	5.3	2.5
8	Cucumber	1.5	1.2	1.7	0.3	1.4	0.6
9	Cabbage	0.1	0.6	3.0	0.9	0.3	2.4
10	Water melon	0.3	0.3	0.4	0.4	0.8	1.6
11	Other vegetables/melons	19.1	19.0	19.8	6.9	9.0	10.6
12	Oil crops	26.9	26.4	26.2	0.0	0.0	0.0
13	Apples	1.6	1.4	1.8	0.6	1.4	0.6
14	Apricot	0.4	0.2	0.3	13.4	23.0	2.0
15	Grapes	4.0	2.9	3.0	10.2	7.6	7.8
16	Other fruits	37.2	37.8	39.6	11.6	13.6	19.7
17	Beef	11.3	8.8	8.4	0.6	0.2	0.3
18	Pork	15.5	15.0	14.0	0.2	0.2	0.3
19	Mutton/goat meat	0.0	0.0	0.0	0.0	0.0	0.3
20	Poultry meat	35.3	33.4	33.8	0.1	0.2	0.2
21	Eggs	0.2	1.3	1.0	0.0	0.0	0.0
22	Milk	134.8	133.6	151.9	9.0	17.8	20.8
23	Alcoholic beverages	2.9	3.2	3.3	21.5	21.9	22.7
24	Sugar (processed)	3.8	4.9	5.6	0.4	0.9	0.2

Note) * Processed products are converted to equivalent weight of fresh products. Alcoholic beverages are not counted.
Source) MOA, RA and National Statistical Service

Table 3-4.1 also shows the major exporting crops in Armenia. Both the variety of exporting commodities, mainly; vegetables, fruits and alcoholic beverages, and the volume are limited. The volume of potato export has jumped since 2013. Alcoholic beverages are the highest exported item which is mainly composed of brandy made from grapes. Brandy is one of the three most exported goods from Armenia. Vegetables show excess of imports over the amount of exports every year although the balance is changeable year to year.

The data on imports and exports indicate that vegetables and fruits/grapes have a certain level of competitiveness in international market. According to private traders, most vegetables and fruits are exported to Russia, followed by the Commonwealth of Independent States (CISs), such as Georgia, the Ukraine, and Belarus (Iran and Turkey may be importing from Armenia, including through unofficial channels). Export destinations are dominated by such traditional markets, mainly because of the strength of the Armenian brand established during the USSR era, which remains in high demand. This is particularly evident with Armenian fruits. It is expected that an economic partnership between Armenia and the traditional markets shall be consolidated further after Armenia became a full member of the EEU (Eurasian Economic Union) which comprises Russia, Belarus and Kazakhstan from January 2nd, 2015.

The well-established relationship between Armenia and the traditional markets, on the downside, has kept Armenia from exploring new markets since its independence. The dependency on limited markets creates a vulnerable trade structure of Armenian agricultural products. For this reason, it is essential to exploit new markets with a long-term perspective. Geopolitically speaking, the European Union (EU) is a promising alternative market. However, there are a number of challenges to tackle that include diversification of the products in accordance with the market needs, strict quality regulation, food hygiene (security and safety) and stable supply in order to export the country's products to the EU market. A mid- to long-term comprehensive engagement is necessary, not only by individual farmers but also by the nation as a whole.

3-5 Marketing of Agricultural Products

Farm products are classified into two categories as for personal consumption (including gift and barter exchange) and for market sales. As shown in Table 3-5.1, cereals, potatoes, eggs and sheep wool are mainly consumed by producers themselves. On the other hand, comparatively high percentage of vegetables (including melon), fruits, grapes and meats are marketed. These commodities are recognized as important cash income sources of farmers.

Table 3-5.1 Marketing of Major Agricultural Products

Agricultural products	Selling (%)	Personal Consumption and others (%)	Total (%)
Cereal and legume crops	21.9	78.1	100
Potato	38.0	62.0	100
Vegetable	71.3	28.7	100
Melons	84.2	15.8	100
Fruit and berries	58.0	42.0	100
Grape	76.5	23.5	100
Meat	80.9	19.1	100
Milk	44.7	55.3	100
Eggs	37.8	62.2	100
Wool	26.2	73.8	100
Honey	49.7	50.3	100

Source) MOA, RA

Many farmers sell their products to the middlemen at the farm-gate. Regarding grape producers, they tend to sell their products directly to the neighbor processing company. Organized cooperatives or group marketing by farmers are not common. Although all farmers recognize the difficulties for securing advantaged selling channels and favorable selling prices of their products, no one can figure out the certain images or ideas of solution for the problems. Not a few numbers of farmers still hold a way of thinking that expecting someone to purchase all products at an appropriate price as they experienced in USSR era. As a result of this rigid mind, general farmers have little awareness of agricultural marketing. SADS aims at improving the distribution of agricultural products to the domestic and the international markets. However, farmers have difficulty to market their products sometimes in a peak harvesting season due to saturation of the domestic market after the increased production in recent years.

Middlemen are playing significant role in the distribution of farm products, since most of farmers are selling their products to them. Generally, farmers regard the middlemen's work as extortionate profit-making as indicated by farmers' criticism of them. However, many farmers are also recognizing that selling their products to middlemen is more rational than selling the products by themselves at the market according to the last survey. While middlemen vary from permanent workers to side business workers with farmers, most of them run a business on an individual basis. They are divided into different hierarchies, and the trading between them is commonly practiced.

Wholesalers and traders are not as small-scale as middlemen, but most of them run their businesses under private or family management. Generally, they purchase farm products through specified middlemen, and sell them to retailers and supermarkets, to middlemen from other regions and to exporters. Some wholesalers also work as traders, and they are exporting or importing seasonally advantageous fruits and vegetables. However, importation of some crops such as banana and pineapple are monopolized by the government control policy. In Armenia, there is only one company to trade vegetables and fruits on a certain large scale, so other traders are remaining at a private enterprise level.

It is estimated that a substantial percentage of marketed vegetables and fruits are transacted at Yerevan

markets. The reason of this assumption is that about one third of national population is densely concentrated in Yerevan city and the main producing areas of vegetables and fruits are located next to the city. The Malatia market is the biggest market in Yerevan city, and the prices of vegetables and fruits in the country are basically based on the Malatia market prices. Many middlemen from various places in the country gather in the market.

3-6 Agricultural Processing

Table 3-6.1 and 3-6.2 show domestic production and international trade of agricultural processed products in 2012-2014.

Table 3-6.1 Production of Major Agricultural Processed Products and Their Market Share

Products	Unit	Production			Domestic Market Share of Local Products (%)		
		2012	2013	2014	2012	2013	2014
Meat products, including sausages	Ton	4,757	4,944	5,718	43.6	45.9	47.2
Cheese	Ton	17,658	17,375	18,317	94.1	92.7	93.4
Canned fruits and vegetables	'000 lit.	8,356	9,990	11,715	14.2	19.9	19.9
Juice	Ton	16,742	19,544	21,106	72.0	79.8	85.9
Confectionery	Ton	14,320	16,544	18,093	46.8	48.5	49.7
Macaroni	Ton	3,563	4,093	4,468	44.1	44.9	44.8
Brandy	'000 lit.	18,514	20,383	18,726	87.4	98.2	44.6
Wine	'000 lit.	6,193	7,217	6,765	91.6	93.9	94.1
Beer	'000 lit.	13,668	19,848	23,717	82.8	86.5	88.4
Vegetable oil	Ton	2,656	4,650	3,968	9.0	15.0	13.1
Sugar	ton	69,267	69,625	89,189	94.7	93.4	94.0

Source) National Statistics Service, RA

Table 3-6.2 International Trade of Major Agricultural Processed Products

Products	Unit	Export			Import		
		2012	2013	2014	2012	2013	2014
Meat products, including sausages	Ton	625	367	412	5,345	5,388	5,943
Cheese	Ton	904	1,541	1,542	1,053	1,244	1,188
Canned fruits and vegetables	'000 lit.	7,242	7,955	9,600	6,661	8,175	8,520
Juice	Ton	2,126	2,013	2,942	5,685	4,430	2,992
Confectionery	Ton	793	1,119	1,536	15,403	16,374	16,765
Macaroni	Ton	154	157	128	4,315	4,825	5,338
Brandy	'000 lit.	17,518	18,188	18,556	143	41	211
Wine	'000 lit.	1,186	1,399	2,121	459	380	289
Beer	'000 lit.	2,795	2,346	1,988	2,263	2,731	2,838
Vegetable oil	Ton	4	2	1	26,964	26,431	26,205
Sugar	ton	400	899	200	3,830	4,851	5,644

Source) National Statistics Service, RA

During USSR era, agricultural processing industries had been well developed in Armenia due to the high demand for brandy, wine and canned fruits and vegetables from other republics. However, the country had lost those dominant markets since its independence in 1991, and numerous processing factories had been forced to close their operation because of devastating impacts of the markets lost. As a result of those transfigurations, agricultural processing had only been carried by small scale cottage industries and home manufacturing. Since 1998, the country has actively utilized overseas' assistance (the WB, IFAD, USDA, USAID, etc.) to rebuilt agricultural processing industries. Table 3-6.3 shows number of agricultural processing companies recognized by the Department of Agro-Processing Development of MOA. According to the department, there are about 1,500 agricultural processing companies in Armenia as of 2014, if unrecognized tiny companies are also counted. Alcoholic & non-alcoholic beverage, meats & dairy products and preserved foods are the priority commodities in the government policy.

Table 3-6.3 The Number of Agricultural Processing Companies Recognized by the Ministry of Agriculture

Sector	Number
Foods & juice processing	35
Dry foods processing	100
Grape processing (including winery)	50
Dairy and meat processing	70
Slaughtering	20
Flour mill	60
Fish processing	10
Bakery	More than 500
Confectionery	135
Beverages (non-alcohol)	More than 50
Beer brewery	7
Tea and coffee	30
Vegetable oil	3
Sugar	2
Salt	1

Source) Department of Agro-Processing Development, Ministry of Agriculture, RA

As a result of the promotion policies, the total purchased volume of vegetables, fruits and grapes by agro-processing industries had increased since 1998. The increase, however, has been stagnating from around the late 2000s. The volumes of agricultural processing products are still well below the recorded volumes before independence, with exception of brandy. This indicates that the rehabilitation of Armenian agricultural processing industries is still only at the halfway mark despite of vigorous supportive policies of the government. The reason of this stagnation is due less to material shortages and more to the failure of agricultural products' market penetration. The first thing the industries need to do is to develop the market not only by recovering the shrunken traditional markets in CIS countries but also by developing new markets, including domestic markets as Armenia still depend on imported products for considerable amount of the domestic demand. While Armenia became a member of the EEU in January, 2015, it is anticipated that the accession would have a positive impact on recovering and developing the markets in the Russian economic bloc.

The Department of Agro-Processing Development recognizes the following problems on the development of agricultural processing industries.

1) Limited market (the industries have over processing capacity)
2) High production-cost structure (raw materials, energy, management, etc.)
3) Inconvenient loan condition (financial institutions reluctant to provide a long-term loan)
4) Limited transportation routes due to geopolitical constraint

3-7 Agricultural Inputs

3-7-1 Fertilizers

Armenia is an importing country of fertilizers. Currently, there is no domestic manufacturer of fertilizers. The government is importing fertilizers in order to provide cheaper fertilizers to farmers under the subsidy system. Most of farmers heavily depend on the subsidized fertilizers for their crop farming, and a limited volume of miscellaneous compound fertilizers mainly used for vegetables and flowers are distributed through the private channel. According to MOA, the subsidized fertilizers cover more than 95% of the annual domestic demand.

Table 3-7-1.1 shows volume and price of fertilizers procured by the government in 2015. The procurement volume of the fertilizers is decided by MOA based on the request from individual farmers. The requested volume collected through each community office is finally integrated by the Ministry. Then, the fertilizers are distributed through the reverse process of the request. Several private companies are selected for the procurement and distribution by the Ministry through international bidding. While farmers can order a nitrogen fertilizer maximum 300 kg per hectare farmland, there is

no limitation volume of order about other fertilizers. Following figures indicate that farmers are demanding mainly on nitrogen fertilizer, and the demands of other fertilizers are quite limited. Farmers tend to input more volume of nitrogen fertilizer, probably due to its immediate effect on their crop productivity. The government is, however, subsidizing more on phosphate and potassium fertilizers than a nitrogen fertilizer in order to set similar price ranges of fertilizers for farmers.

Table 3-7-1.1 Volume and Price of Fertilizers under the Government Subsidy in 2015

Fertilizer	Procurement volume (ton)	Origin country	Procurement price (A) (AMD/50kg)	Selling price (B) (AMD/50kg)	Subsidy (A-B) (AMD/50kg)
Ammonium nitrate	35,300	Iran, Russia, Georgia	9,215	6,000	3,215
Double superphosphate	3,100	Iran, Russia, Georgia, China	13,800	7,000	6,800
Potassium chloride	1,600	Iran, Russia, Georgia, China	13,800	7,000	6,800

Source) MOA, RA

"Agrochemical Service" which is a state non-profit agency under MOA researches soil condition of farmland all over the country. The agency has been inspecting soil samples from all communities in Armenia. It also provides consultancy service of proper fertilization to farmers in collaborating with the Agricultural Support Centers by using the result of the soil analyses. According to the agency, there are growing concerns about overuse of nitrogen fertilizers counting the imported amount of nitrogen fertilizers and total cropped area in the country. On the other hand, the agency concerns about less use of phosphate and potassium fertilizers. Appendix B-2 shows the result of soil analysis on phosphate and potassium components compiled by Marzes. The result shows that less than 15% of the soil samples are in good condition about potassium and phosphate. Especially, more than 65% of the samples show weak condition of phosphate fertilizer content. The Ministry of Agriculture is trying to encourage balanced fertilization through agricultural extension activity. However, not only the extension activity but also reviewing the current subsidy system would be an effective countermeasure to address the issue.

3-7-2 Agricultural Chemicals

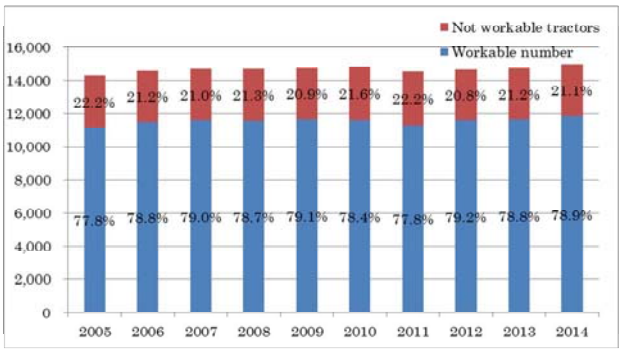
All agrochemicals are imported from foreign countries, as same as fertilizers, in Armenia. In contrast to fertilizers, agrochemicals are marketed only through the private channel, as the government are not subsidizing for them. The government has imposed a registration system of agrochemicals which prohibits importation and distribution of unregistered agrochemicals in Armenia. A division in charge of agrochemicals under MOA inspects agrochemical shops periodically in order to control unregistered or obsolete agrochemicals.

MOA pays serious attention to the use of such prohibited agrochemicals at present. The standards of pesticides residue for agricultural products were established in Armenia based on the European standards. All agricultural products beyond the norm for the standards are prohibited to distribute in Armenian markets. Then, a pesticide testing laboratory was established with FAO's assistance. FAO also extended its technical cooperation for the proper management of agrochemicals in collaboration with the EU. However, there is no workable system to monitor the pesticide residue at the harvest points or in the markets in the country. Establishment and implementation of the workable system is a challenging issue of the government.

3-7-3 Agricultural Machinery

Most of current workable agricultural machinery in Armenia was procured in the USSR era. According to the Figure 3-7-3.1, there have been about 11,000-12,000 workable tractors since 2005 and there was no drastic change of those figures in the last decade. Table 3-7-3.1 indicates the number of brand-new tractors procured from 1976 to 2015. The table shows that a limited number of tractors

were procured, mainly by assistances from donor countries including Japan, after the independence. Those assistances encouraged the renewal of decrepit machinery, but still at least 90% of workable tractors in Armenia are more than 25 years old. The situations of other agricultural machinery such as combine harvesters are similar to tractors. Renewal of decrepit agricultural machinery is a pressing issue in Armenia.



Source) MOA

Figure 3-7-3.1 Total Numbers of Tractors

Table 3-7-3.1 Numbers of Procured Tractors through Normal Channel (Commercial & Aid)

Year	1976-91	1992-96	1997	1998	1999	2000	2001	2002	2003	2004
Total	17,469	0	15	43	63	156	45	35	40	51
Year	2005	2006	2007	2008	2010	2011	2012	2013	2014	2015
Total	99	240	67	88	61	0	0	20	200	72

Source) Ministry of Agriculture

The agricultural machinery was imported through the government channel including international assistance programs and the private channel since 1997. While 1,295 units of tractors were imported in 1997-2005 (see Table 3-7-3.1), only above 200 units were procured through the private channel, according to MOA. It implies that the government has played a significant role in the import of agricultural machinery, though there are several private dealers importing agricultural machinery. The private dealers usually deal in construction machinery, etc. other than agricultural machinery, as actual market demand for the agricultural machinery on commercial basis is still limited, mainly due to weak paying capacity of each individual farmer, despite the high potential demand. There is no agricultural-machinery manufacturer in Armenia, while a joint venture company with a Chinese company assembles tractors and their attachments imported from China.

The agricultural machinery has been imported from, Russia, Belarus, China, India, Japan, etc. Russia and Belarus machinery is widely used in Armenia, as they have the following historical, technical and economic advantages over the machinery from other countries.

1) Familiarity with the machinery for long time (convenient for O/M)
2) Easy procurement of main body and spare-parts (established distribution channels)
3) No import tax after becoming a full member of the EEU

3-8 Agricultural Research and Extension

3-8-1 Agricultural Research

According to the Ministry of Agriculture, there are three agricultural research institutions under the Ministry (See Table 3-8-1.1).

Table 3-8-1.1 Research Institutions under the Ministry of Agriculture

Name of Institution	Location	Main Research Activity/Crop
The Scientific Centre for Agriculture	Ejmiatsin, Amarvir Marz	Growing of wheat, barley and leguminous crops
The Scientific Centre of Vegetables and Industrial crops	Darakert, Ararat Marz	Selection of varieties and seed production (solanaceous, cucurbitaceous and cabbage crops)
Experimental Centre for Technical Crops		Selection of varieties and seed production (soya, tobacco, linseed and sugar beet)

Source) MOA

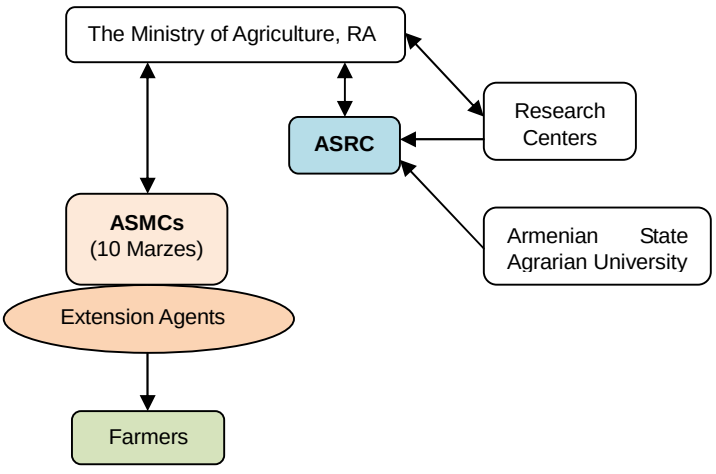
According to “Agricultural and Food Processing in Armenia (USDA & CARD)” written by Samvel Avetisyan in 2010, there are the “Research Center for Soil Science”, the “Research Center for Horticulture, Viticulture and Winemaking”, the “Research Center for Livestock Management and Veterinary” and the “Research Center for Agri-Bio Technology” in addition to the research institutions shown in the table above. As of 2010, the number of agricultural researchers in Armenia was 249, and only 25 of them hold a doctoral degree (122 are doctoral candidates). Thus, an increased number of agricultural researchers must be one of the critical challenges of Armenian agricultural development. Dealing with this circumstance, the government is aggressively promoting research cooperation programs with international agricultural research institutions such as CGIAR, ICARDA, CIMMYT, IPGRI, ISNAR and CIP as well as institutions in other countries.

In addition, the government also promotes to foster domestic agricultural researchers and experts. MOA manages the Armenian State Agrarian University, which is the only agricultural university in the country, and 10 State agricultural colleges which are located in 7 Marzes across the country. The state agricultural colleges aim to develop human resources to work as a bridge between research institutions and the actual field.

Breeding of promising varieties is the most expectative task to the agricultural research sector, especially, in the situation that the Armenian government promotes export oriented agriculture. The researchers should give full attention to dissatisfaction of agribusiness with the present crop-varieties popularly grown in Armenia. According to an agricultural products exporter, popular crop-varieties in Armenia often don’t match to requirements in the international market. For instance, indigenous grape varieties for fresh consumption popular in Armenia are not highly evaluated internationally, while a red grape variety “red glove” is highly demanded due to its good taste and storage stability. One of the leading wine breweries also said that they had difficulty in procuring appropriate grape varieties for wine brewing in Armenia. Therefore, they introduced several grape varieties from foreign countries by themselves. The government commitment to conscientious research on the development and introduction of new crop-varieties will expand the possibility of future development not only of agricultural production but also of agribusiness industry.

3-8-2 Agricultural Extension

In Armenia, agricultural extension services are implemented by specialized agencies: the ASRC (Agricultural Support Republic Centre) and ASMCs (Agricultural Support Marz Centres). ASRC is placed at the central level and one ASMC is established in each Marz at the regional level (10 ASMCs in a country). The ASRC and ASMCs are autonomous body under the jurisdiction of the Ministry of Agriculture. There is no official hierarchical relation between them, but the ASRC plays a role of umbrella administration for agricultural extension programs in the country (See Figure 3-8-2.1). ASMCs are responsible for agricultural extension services to individual farmers in respective Marzes, and 130 agricultural extension agents are allocated to ASMCs in total (The total number of ASMCs staff is 240, including the agricultural extension agents). It seems that the number of extension agents is too small to implement elaborate



Source: MOA, RA

Figure 3-8-2.1 Agricultural Extension System in Armenia

agricultural extension services, as there are 914 communities in Armenia.

Table 3-8-2.1 indicates a list of agricultural consultancy services provided by ASMCs/ASRC in 2013. Those extension activities were decided from the result of farmers' demand survey. The survey is implemented by the collaboration between ASRC and ASMCs. However, farmers regard that the agricultural extension programs are not adequate for them even though the agencies provide such a wide variety of services.

Table 3-8-2.1 Agricultural Consultancy Services provided by ASMCs/ASRC in 2013

Activity	Times/Numbers
Workshops	1,119
Field trainings	872
Technical consultancy events	22,049
Demonstration experimental activities	173
Radio and TV programs	96
Number of topics published in leaflets/brochures	466
(Printing quantity)	(115,270)
Edit materials	158
(Printing quantity)	(209,100)

Source) Ministry of Agriculture, RA

Table 3-8-2.2 shows the results of a questionnaire survey conducted by the JICA team on Data Collection Survey on Agriculture and Irrigation Sector in Armenia in 2014. According to the results, most of the farmers recognized that they've never had any opportunities of agricultural extension or supporting services. Farmers, who are even experienced in the extension services, are thinking that they are not provided their demanded services at the time of need. Some farmers insisted that when damage of plant occurred by pest or disease in their farmland, they really need consultancy services about how to use agrochemicals or prevention measures. But it is difficult to make a contact with extension agents when necessary. Many farmers also do not understand the contents of agricultural extension services properly. During the Soviet era, farm management was prescribed by agronomists who are allocated in Kolkhoz and Sovkhoz, and there were no agricultural assistance services for individual farmers. Therefore, some farmers misunderstand that an agricultural extension service is assistance from the government providing some materials or goods to farmers.

Table 3-8-2.2 Agricultural Consultancy Services Provided by ASMC/ASRC in 2013

Service	Number of Farmers	
	Yes	No
Crop production	2	18
Vegetable production	1	19
Fruits/grape production	0	20
Animal husbandry	1	19
Food processing	0	20
Agricultural; credit	5	15

Source) Final Report, Data Collection Survey on Agriculture and Irrigation Sector in Armenia, JICA

CHAPTER 4 CURRENT CONDITIONS OF YEGHVARD IRRIGATION PROJECT SITE

4-1 Meteorological and Hydrological Conditions

4-1-1 Outline of Investigation for Meteorological and Hydrological Data

Meteorological and hydrological data have been observed by Armenia State Hydro-meteorological and Monitoring Service, Ministry of Territorial Administration Development. Table 4-1-1.1 shows the meteorological stations located in and around the Project Sites. Thirty years period data were collected through this investigation. Meteorological data include rainfall, average temperature, relative humidity, wind speed and evaporation by monthly based data. Table 4-1-1.2 shows the Hydrological data which is 10 days decade based river discharge data at each observation station. Figure 4-1-1.1 and 4-1-1.2 describe the location map of meteorological and hydrological observation station, respectively.

Table 4-1-1.1 Meteorological Stations in and around the Project Sites

N	Station name	Opened (Year)	Elevation (meter)	Geographic coordinates	
				latitude	longitude
1	Hrazdan	1936	1,765	40°32'12"	44°46'16"
2	Fantan	1891	1,800	40°23'54"	44°41'13"
3	Yeghvard	1936	1,337	40°19'14"	44°28'44"
4	Ashtarak	1957	1,090	40°17'17"	44°20'55"
5	Yerevan agro	1951	942	40°10'47"	44°24'18"

Table 4-1-1.2 Hydrological Stations in and around the Project Sites

N	River	Station name	Opened (Year)	Catchment Area (km^2)	Geographic coordinates	
					latitude	longitude
1	Outflow from Sevan to HPP	Geghamavan	1949	-	40° 34' 05"	44° 53' 58"
2	Hrazdan	Hrazdan	1965	806	40° 31' 13"	44° 46' 04"
3	Hrazdan	Lusakert	1965	1,292	40° 22' 51"	44° 36' 19"
4	Kasakh	Ashtarak	1932	1,018	40° 17' 25"	44° 21' 32"

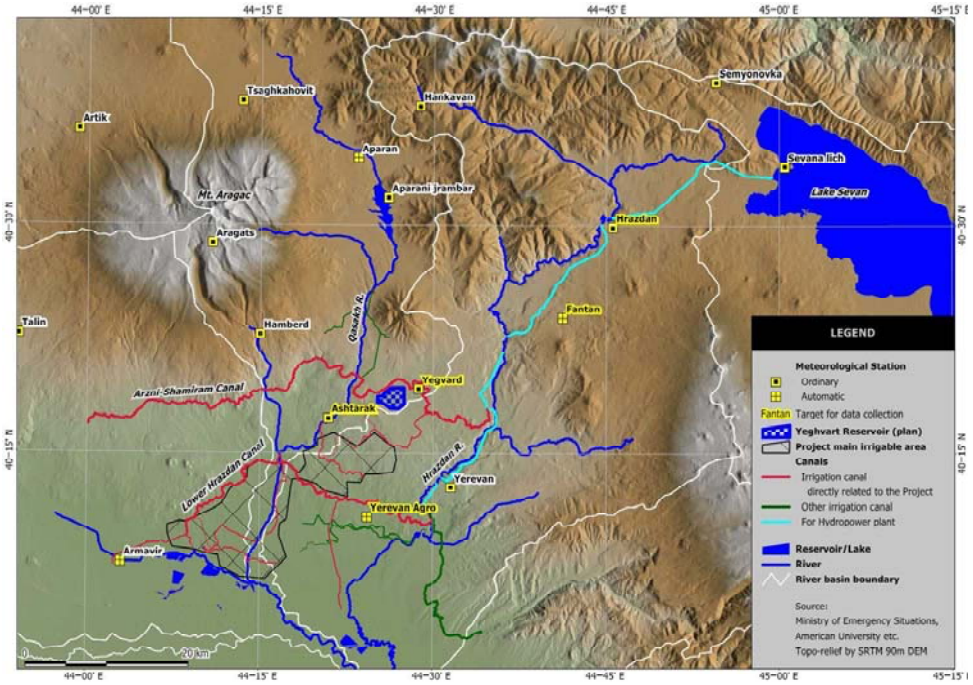


Figure 4-1-1.1 Meteorological Stations in and around the Project Sites

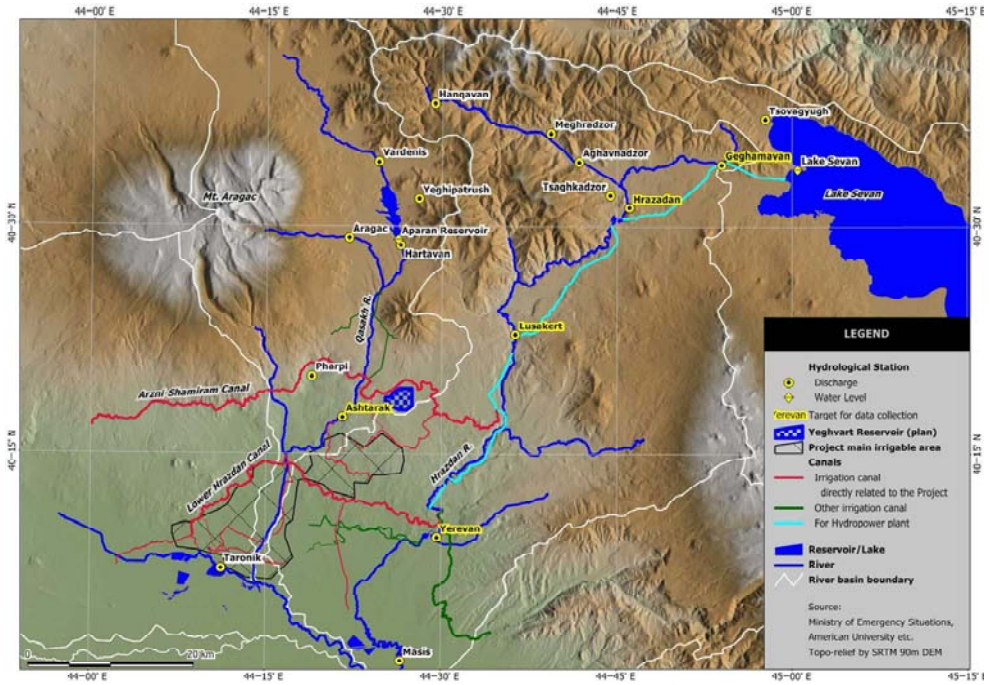


Figure 4-1-1.2 Hydrological Observation Stations in and around the Project Sites

4-1-2 Current Meteoro-hydrological Conditions

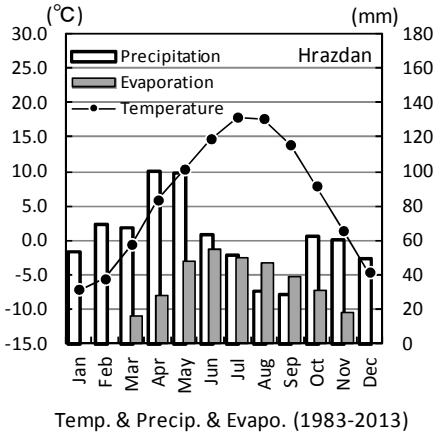
(1) Meteorological data

Table 4-1-2.1 shows the characteristics of each station. The average rainfall data in Hrazdan and Yeghvard station is 742 mm and 439 mm, respectively. The maximum average temperature is observed around July or August. The average temperature from December to February is negative in all meteorological stations.

Table 4-1-2.1 Annual Rainfall and Average Temperature

Station name	Annual Rainfall (mm)	Average Temperature (°C)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Hrazdan	742	-7.1	-5.7	-0.5	5.9	10.4	14.7	17.9	17.7	13.9	7.8	1.3	-4.6
Yeghvard	439	-4.1	-2.3	3.2	10.0	14.2	19.4	23.0	22.9	18.7	11.9	5.0	-1.2
Fantan	669	-6.0	-4.8	-0.2	6.3	10.7	15.1	18.3	18.6	14.9	8.9	2.3	-3.6
Ashtarak	387	-3.0	-0.7	5.3	11.6	16.0	21.2	24.8	25.2	20.3	13.8	6.1	-0.7
Yerevan agro	311	-4.3	-0.8	5.9	12.6	17.1	22.2	26.0	25.9	21.0	13.7	5.9	-1.1

Figure 4-1-2.1 shows the monthly data of rainfall, evaporation and average temperature at Hrazdan and Yeghvard stations. Monthly rainfall is in maximum on April and May and decrease to August. Evaporation is in maximum on June.



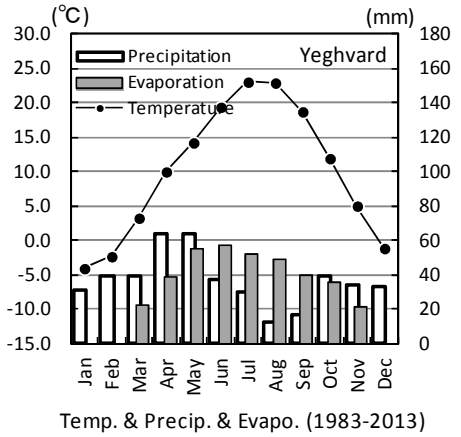
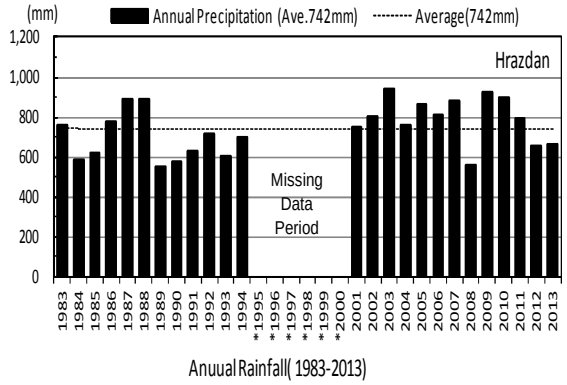


Figure 4-1-2.1 Meteorological Data at Hrazdan and Yeghvard Stations

Figure 4-1-2.2 shows the yearly trend of annual rainfall at Hrazdan (EL.742m) and Yeghvard (EL.439m) station, and dotted line indicate the long-term average. At the Hrazdan station around latest ten years, annual rainfall in 2008, 2012 and 2013 are less than the average (742mm). Annual rainfall in 2004, 2012 and 2013 at Yeghvard station is less than average (439mm) around latest 10 years.



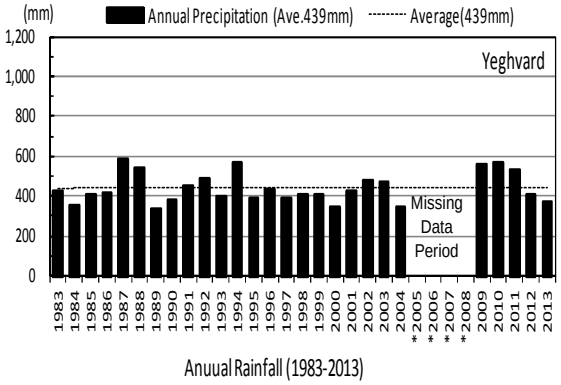


Figure 4-1-2.2 Annual Rainfall Data at Hrazdan and Yeghvard Stations

For the evaluation of rainfall trend at Hrazdan station, probability of annual rainfall is calculated. Calculation is done for two kind of period. One is long-term from 1983 to 2013, and the other one is latest 10 years from 2004 to 2013. The reason to evaluate by the Hrazdan station's data is that Yeghvard reservoir will be filled by the river flow from Hrazdan River's watershed area, so Hrazdan station's data will be presumed that it has relationship between rainfall and river flow. Based on the following result, year of 2008 is extremely low amount of rainfall, especially in the latest 10 years.

Table 4-1-2.2 Return Period and Probability of Non-Exceedance for Rainfall at Hrazdan Station

Year	Target Period	
	1983-2013	2004-2013
2004	-	1/3 (66%)
2005	-	-
2006	-	-
2007	-	-
2008	1/16 (94%)	1/6 (84%)

Year	Target Period	
	1983-2013	2004-2013
2009	-	-
2010	-	-
2011	-	-
2012	1/3 (70%)	1/16 (94%)
2013	1/3 (66%)	1/4 (74%)

Note) 1983 - 2013 (except no data period of 1995-2000), 2004 – 2013

(2) Hydrological data

Table 4-1-2.3 shows the monthly river flow at Hazdan and Lusakert station along Hrazdan River and Ashtarak station along Kasakh River from 1983 to 2013. Figure 4-1-2.3 shows fluctuation of the 10 days decade data. Based on Table 4-1-2.3 and Figure 4-1-2.3, it comes out that discharge of river flow rise up from March and maximum on April or May. Table 4-1-2.4 shows runoff ratio at Hrazdan station along Hrazdan River and Ashtarak station along Kasakh River and those are respectively 43% and 25%.

Table 4-1-2.3 Monthly Average River Flow

Observation Station	Monthly Average River Flow (MCM)												Total (MCM)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Hrazdan [1)]	8.4	7.4	16.7	55.5	77.5	30.2	13.0	9.7	9.0	9.7	10.1	9.4	257
Lusakert [2)]	7.9	7.6	12.1	21.0	20.8	11.2	9.1	8.6	8.4	10.6	10.0	8.7	136
Ashtarak [3]	7.0	6.3	10.5	17.7	8.1	6.7	6.4	6.5	6.2	6.9	7.4	7.2	97

1)Averaged period is 1983-2013 except data missing year of 1998
2)Averaged period is 1983-2013 except data missing year from 1990 to1998
3)Averaged period is 1983-2013

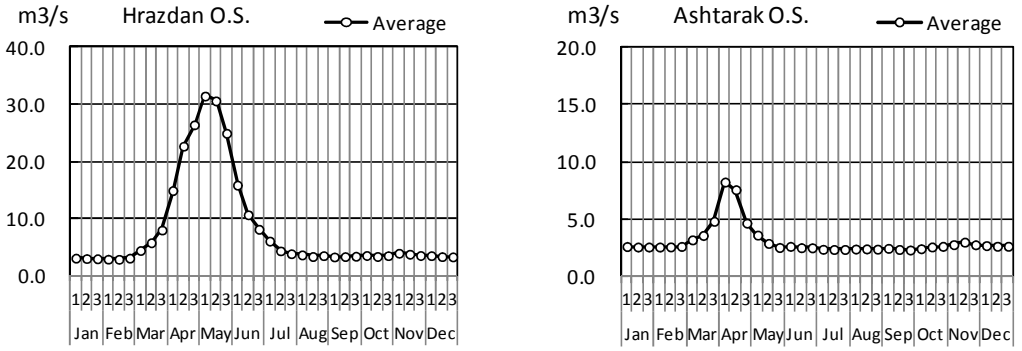


Figure 4-1-2.3 River Flow of Average 10 Days Decade at Hrazdan and Ashtarak Stations

Table 4-1-2.4 Runoff Ratio

Observation Station	Catchment Area (km^2)	Annual Rainfall (mm)	Annual Average Flow (MCM)	Runoff Ratio (%)
Hrazdan O.S. [1)]	806	742	257	43%
Ashtarak O.S. [2)]	1,018	387	97	25%

1)Averaged period is 1983-2013 except data missing year of 1998
2)Averaged period is 1983-2013

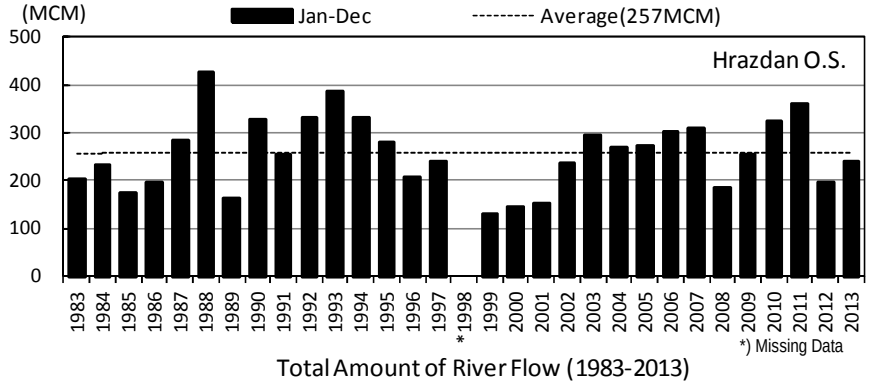


Figure 4-1-2.4 Yearly Trend of River Flow at Hrazdan Station

Above mentioned Figure 4-1-2.4 shows the yearly trend of river flow at Hrazdan station, and dotted line indicate the long-term average. Yearly river flow in 2008, 2012 and 2013 are less than the average (257 MCM) through the latest ten years. Since the river flow changed the fluctuation pattern, the meteorological and hydrological data for data analysis will be evaluated focus to the latest 10 years (2004-2013).

Probability of Hrazdan River flow is evaluated through 2004 to 2013, and the target of evaluation month's data are sum-up the river flow discharge from March to October. To be precise, irrigation starts from April and ends in October. River flow water to Yeghvard reservoir's distribution will start from March in this project. Therefore the evaluated period for probability include March. Based on the Table 4-1-2.5, probability of 75% is 2013, and it shows that 2008 and 2012 are the relatively dry year.

Table 4-1-2-5 Return Period and Probability of Non-Exceedance for River Flow at Hrazdan Station from March to May

Year	March to October		Year	March to May	
	River Flow (MCM)	R.P. and Probability		River Flow (MCM)	R.P. and Probability
2004	234	-	2009	216	1/3 (65%)
2005	234	-	2010	277	-
2006	269	-	2011	320	-
2007	275	-	2012	160	1/6 (84%)
2008	154	1/16 (94%)	2013	205	1/4 (74%)

Note) Latest 10 years from 2004 to 2013.

Figure 4-1-2.5 shows the distributed water from Lake Sevan, which has been observed at Geghamavan station. Geghamavan station is located between Lake Sevan and observes all the water comes from Lake Sevan. As mentioned before, Armenia Government launched an environmental improvement strategy for Lake Sevan in 2001 for rising up the water level by 2030. However, especially in 1993 after independent from Soviet Union, the distributed water is 1,699MCM which was ten times of latest volume (170MCM) under government control.

Figure 4-1-2.6 shows the comparison of 1993 and 2013 about the distributed water from Lake Sevan. It is clearly shown in Figure that the maximum discharge was around 70m^3/s in 1993 and it was used for hydropower generation. In contrast with its situation, the maxim discharge is about 30m^3/s in 2013 and this water is used for irrigation prior to hydropower generation. The operation of Lake Sevan and hydropower generation is completely changed in the past 20 years.

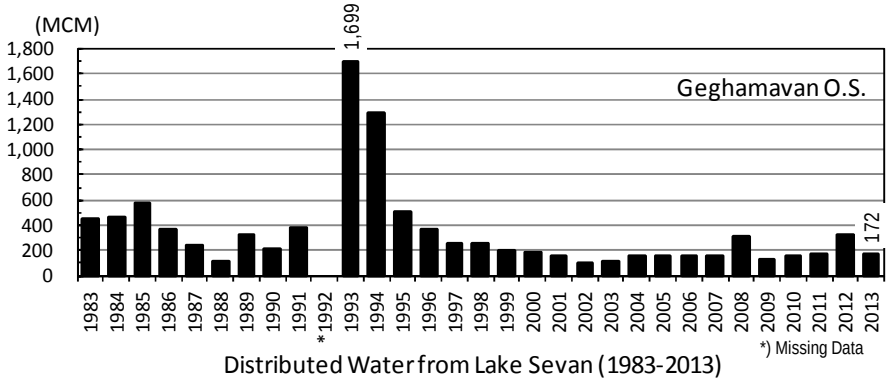


Figure 4-1-2.5 Yearly Trend of Distributed Water from Lake Sevan

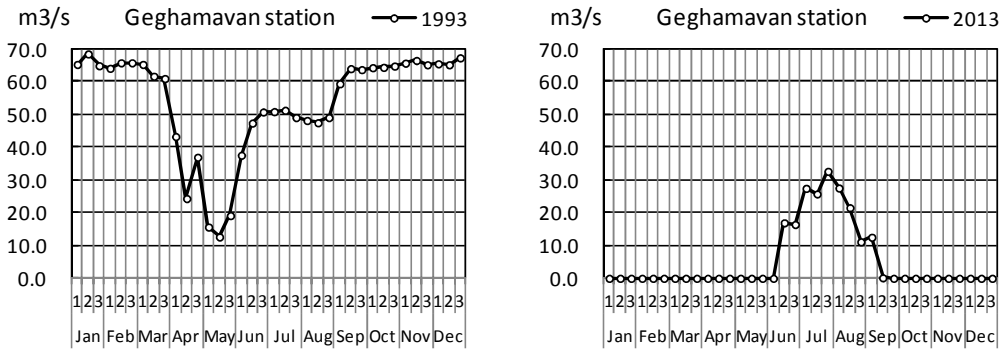


Figure 4-1-2.6 Comparison of Distributed Water from Lake Sevan between 1993 and 2013

4-2 Water Utilization Conditions

4-2-1 Current Conditions of Lake Sevan

(1) Outline

In the Project area, main water sources of main canals are Hrazdan and Kasakh Rivers. When the water is short to the demand, water is supplemented from Lake Sevan through Sevan-Hrazdan Hydropower Plants Cascade Scheme. The release waterfrom Lake Sevan for irrigation has been limited to 170 MCM/year for the preservation of Lake Sevan since 2001. In addition, the hydropower generation along Hrazdan River is allowed to operate only during the irrigation period.

These limitations are aimed to restore water level of Lake Sevan, which is planned to increase to EL.1903.5 m by 2030. The water level has successfully risen from 1896.32 m on January 1st, 2002 to 1900.13m on January 1st, 2015 and 3.4m remains to reach to the target level. However, the limitation of the usage of lake water for irrigation would not be applied in case of drought year.

If the restoration of water level proceeds well, the limitation would be weakened. What amount of water of Lake Sevan can be used in a drought year affects largely to the reservoir planning of the present project. Therefore the data on water use and controlled discharge information of Lake Sevan were collected in this stage.

(2) Water use

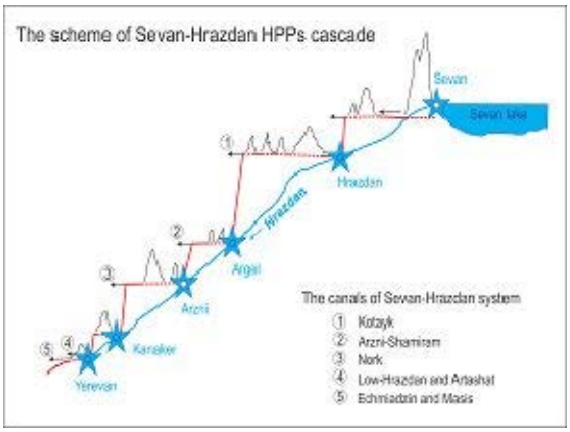
1) Release to Sevan-Hrazdan Hydropower Plants Cascade

Most use of the lake water is released to the Sevan-Hrazdan Hydropower Plants Cascade (see Figure 4-2-1.1) and the released water is used for power generation and irrigation. Table 4-2-1.1 shows its amount and duration of use since 2001. Around 100 to 170 MCM has been used in each year except the drought ones - 2008, 2012 and 2014.

Table 4-2-1.1 Water Release Amount and Duration to Sevan-Hrazdan HPPs Cascade

Year	Start Date	Duration (days)	Total Discharge (MCM)
2002	18.06	117	99.46
2003	13.06	129	118.31
2004	14.06	149	149.00
2005	14.06	141	149.55
2006	7.06	110	152.00
2007	11.06	122	155.00
2008	23.04	174	303.69
2009	11.06	99	126.49
2010	11.06	110	157.74
2011	21.06	96	168.33
2012	2.05	147	317.62
2013	11.06	90	169.95
2014	23.04	130	269.63

Source: Ministry of Emergency Situations of RA (2015)



Source: ATLAS(2007)

Figure 4-2-1.1 Sevan-Hrazdan HPPs Cascade

2) Irrigation to Farmland near Lake Sevan

In the watershed of Lake Sevan, there are three WUAs as shown in Figure 4-2-1.2. Only Martuni WUA is using the lake water for irrigation among them. As shown in Table 4-2-1.2, the amount is very small compared with the released water above-mentioned.

Table 4-2-1.2 Water Amount of Lake Sevan to Used by Martuni WUA for Irrigation

Years	Water volume, (MCM)
2007	1.4
2008	2.1
2009	1.1
2010	1.7
2011	1.6
2012	2.6
2013	2.4
2014	3.5
Average	***2.05***

Source) Martuni WUA

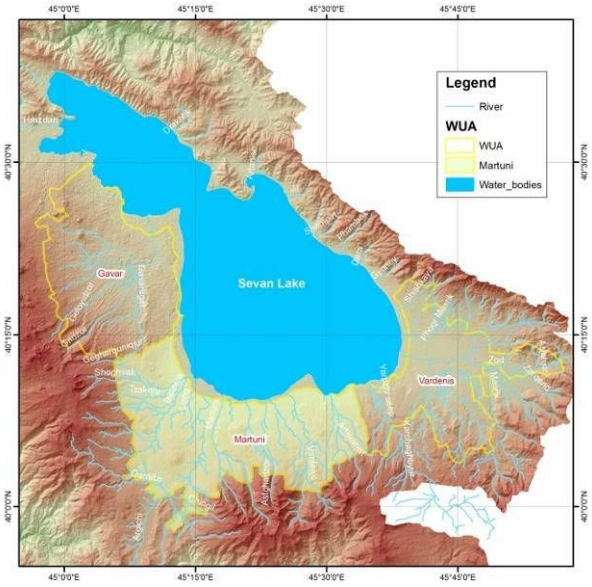


Figure 4-2-1.2 Location of Martini WUA

3) Others

Lake Sevan is used for sightseeing, recreation and fishery etc., but there is no significant water intake amount than that of for irrigation.

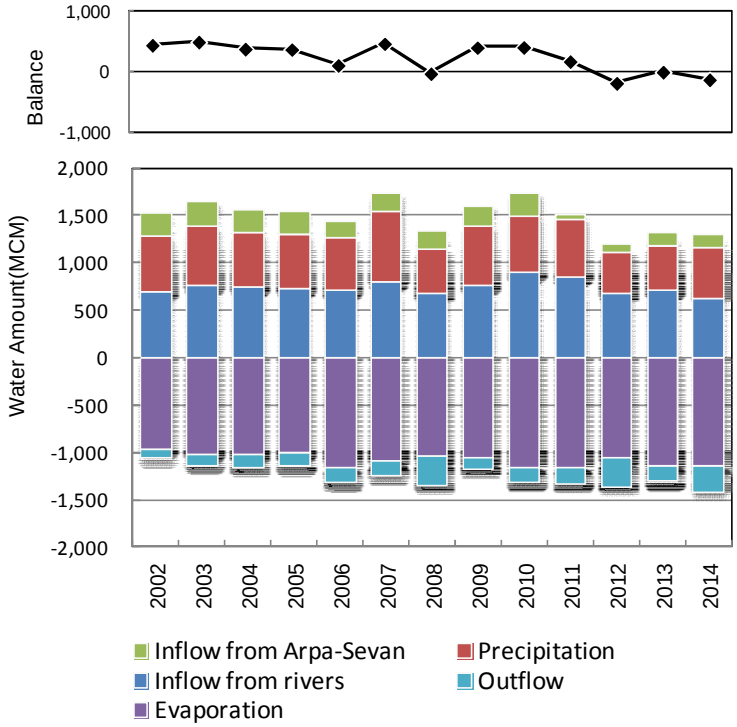
(3) Water balance and annual change of water level

Figure 4-2-1.3 shows the estimated annual water balance of tLake Sevan during 2002 to 2014. The large components in the balance are inflow from rivers in the watershed, precipitation to the lake and evaporation from the lake. The remaining components are the released water to Sevan-Hrazdan

Hydropower Plants Cascade and the inflow from Arpa-Sevan Conduit. Base on the black line drawn in Figure 4-2-1.3, the water balance on 2008, 2012, 2013 and 2014 is being balanced or negative balance. The inflow from the conduit comes from the different watersheds of Arpa River and Vortan River as shown in Figure 4-2-1.4.

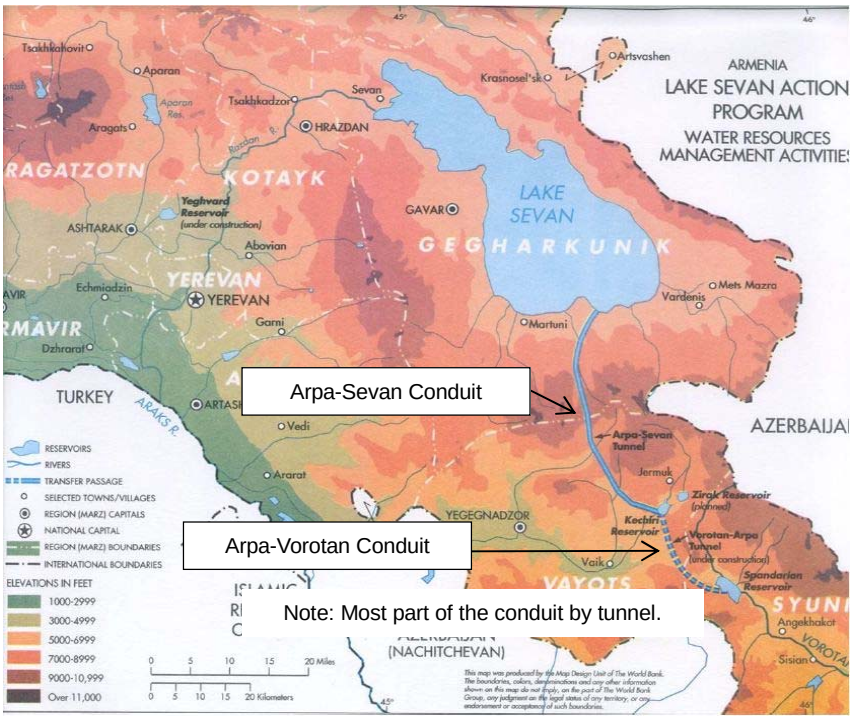
Figure 4-2-1.5 and 4-2-1.6 show the annual amount of the released water and the inflow from the conduit. The released water volume ranges from 100 to 170 MCM/year except drought years, whereas the inflow from the conduit ranges from 170 to 260 MCM/year and exceeds the released amount until 2010. However, since 2011, the released water has exceeded the inflow, because the Arpa-Vorotan conduit has been closed for rehabilitation and inflow comes only from watershed of Arpa river.

Figure 4-2-1.7 shows the variation of lake water level on the first day of year since 2002. The water level has increased gradually until 2011, but was held almost constant since 2012. This change looks well reflected to the reduction of inflow from Arpa-Sevan conduit.



Source) Ministry of Territorial Administration Development, RA

Figure 4-2-1.3 Estimation of Water Balance of Lake Sevan



Source) European Environmental Agency (2015); original figure by WB; retouched.

Figure 4-2-1.4 Location of Arpa-Sevan and Arpa-Vorotan Conduits

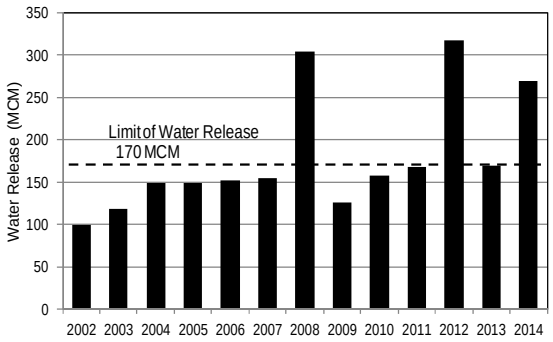


Figure 4-2-1.5 Water Release from Lake Sevan to Sevan-Hrazdan HPPs Cascade

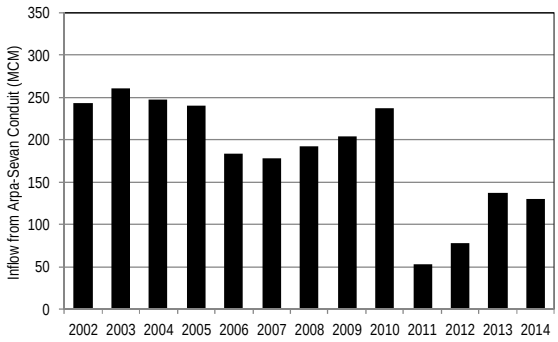
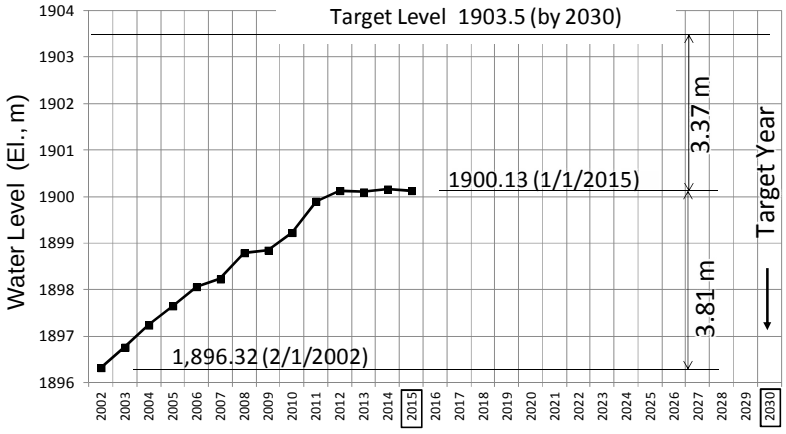


Figure 4-2-1.6 Inflow to Lake Sevan from Arpa-Sevan Conduit



Source) Ministry of Territorial Administration and Emergency Situations of RA

Figure 4-2-1.7 Annual Change of Water Level of Lake Sevan

(4) Prospects of water balance and water level in future

The lake water level rose by approx. 3.7m in ten years until 2011 under the circumstances that sufficient water comes from Arpa-Sevan conduit and the release to Sevan-Hrazdan HPPs Cascade is limited basically to 170 MCM/year. The required water level rise to the target is 3.4m at present, so that if the circumstances are the same, the water level probably reaches the target level within next 10 years.

That is, if the released amount of water can be controlled under 170 MCM/year for a non-drought year after completion of rehabilitation work of the Arpa-Vorotan tunnel, the release exceeding 170 MCM in a drought year probably doesn't affect the restoration plan of the lake water level as far as many drought years do not repeat successively.

4-2-2 Water Utilization along Hrazdan and Kasakh River

Water Resource Management Agency (WRMA) is the responsible organization to permit the water right regarding irrigation, hydropower, drinking water, fish breeding and industries. WRMA has been reported summary report of water use permits every year. In generally, surface water is used for irrigation, hydropower and production facility. Ground water is used for irrigation, drinking water and fish breeding.

Current situation of water utilization along Hrazdan and Kasakh Rivers is same as general condition in Armenia. The major water user along Hrazdan River is irrigation and hydropower plant, and the major user along Kasakh River is irrigation. Water source for drinking water is ground water and the discharge volume of utilization for industries is very few compare to irrigation use. Thus, irrigation and hydropower plant is considered as major water user along Hrazdan and Kasakh River. Table 4-2-2.1 shows the water utilization by surface water or ground water along Hrazdan and Kasakh Rivers.

Table 4-2-2.1 Water Utilization along Hrazdan and Kasakh River

	Irrigation	Hydro Power Plant	Drinking water	Fish breeding	Industries
Surface water	x	x			x (very few)
Ground water	x		x	x	x

The water user along Hrazdan and Kasakh Rivers is Sevan-Hrazdanyan Jrar CJSC. The water right for this CJSC has been already permitted by WRMA, and there is no conflict among hydro power plants. As it was mentioned in "2-2 Policy of Water Resource" in Chapter 2, the agricultural water usage has higher priority than the energy and industrial production use.

4-2-3 Current Water Utilization of Yeghvard Irrigation Project Site

Table 4-2-3.1 indicates the flow discharge and ratio of supplied water source for the current Yeghvard Irrigation Project Site. The water sources are classified into two main canals, one river, three pumps which belong to WSA and other pumps and deep wells. The period of collected data is from 2012 to 2014 and all data were received from WUA.

Table 4-2-3.1 Water Source for Current Yeghvard Irrigation Project Area

2012-2014	WUA				Total (MCM)	Ratio (%)	Total (MCM)	Ratio (%)
	Yeghvard	Ashtarak	Vagarshapat	Khoy				
Arzni-Shamiram	7.871	1.737			9.608	8	38.389	34
Low er Hrazdan				28.781	28.781	25		
Kasakh River		2.699		12.993	15.692	14	15.692	14
Ranchpar Pump				10.666	10.666	9	29.791	26
Aknalich Pump			4.639	8.917	13.556	12		
Metsamor Pump				5.569	5.569	5		
Other Pumps			1.642	5.900	7.542	7	30.142	26
Deep Well			11.125	11.475	22.600	20		
Total					114.014	100	114.014	100

Figure 4-2-3.1 shows the ratio of supplied water volume for current Yeghvard Irrigation Project Site by sourece. Based on the figure, current Yeghvard area depends on more than fifty percent of pump-based irrigation water. The 26% of supplied water comes from pump station and 25% of it comes from small pump and deep well. Shift from pump-based to gravity-based irrigation has an important role in this area.

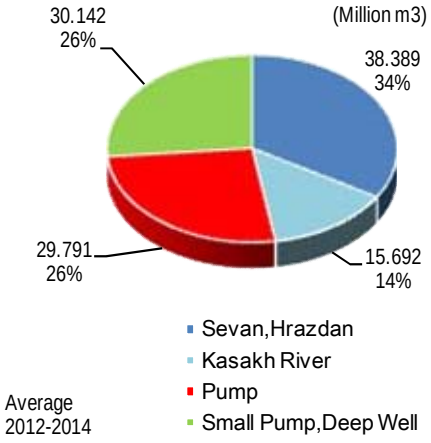
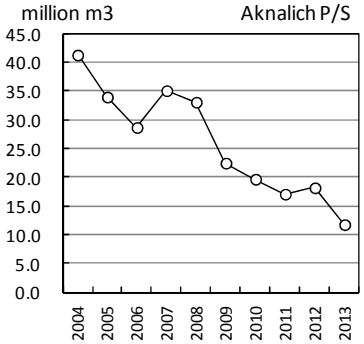


Figure 4-2-3.1 Ratio of Water Source

Figure 4-2-3.2 shows the distributed water volume of Aknalich Pump Station from Lake Aknalich. This lake's water comes from ground water. Aknalich pump station is taking irrigation water from this lake. It is cleared that the discharged volume has been decreasing year by year.

Energy reduction by shifting to gravity-based irrigation from pump-based irrigation is the important policy in agriculture sector. In addition, from the view point of ground water resources, abolishment of pump facilities contributes not only energy reduction but also conservation of ground water resources in the Project site.



Source) WUA, WSA, JICA Survey Team

Figure 4-2-3.2 Annual Change of Water Level of Lake Aknalich

4-3 Current Situation of Planned Reservoir

4-3-1 Outline of Geological/Hydrogeological/Soil Investigation

In the early stage of the field work on the Project, a series of field geological, hydrogeological, and soil investigation works were conducted in and around the planned reservoir, which is called as "Initial Geological Investigation". After the completion of initial series of investigation work, some additional geological/hydrogeological investigation work has been carried out to complement the initial investigation, which is called as "Additional Geological Investigation".

Major purposes of the both initial and additional investigations, contents, and schedules of these works shall be explained in this section.

(1) Purposes of the initial geological/hydrogeological investigation

Major purposes of the initial geological, hydrogeological, and soil investigation works were summarized as below;

a) Reconfirming the ex-USSR's geological and hydrogeological investigation results,
b) Checking the permeability and its anisotropy of the reservoir ground, and
c) Revealing the groundwater condition on dam-site.

As it was well known, a huge volume of geological, hydrogeological investigation, and a geophysical prospecting were carried out in both Feasibility Study (F/S: 1979-80) and Detailed Design Study (D/D: 1984-85) periods. Based on the D/D, a part of dam bodies had been constructed (No.1 and No.2 Dams in Yeghvard reservoir). The first purpose of the investigation was to reconfirm and review the results of their investigation works.

In the previous geological/hydrogeological investigation, many permeability tests were conducted through mainly a pressure water injection method and there were no consideration on anisotropy of the permeability. However, the anisotropy on permeability is very significant to consider water seepage into the ground, through the reservoir bottom or slopes. The second major purpose of the investigation was to check and study the anisotropy of the ground permeability.

Then, the third major purpose of the investigation was to reveal a groundwater condition of the reservoir area in detail. It's also well known that the groundwater level near around the dam-site is quite deep, and because of such reason, a little information on groundwater condition are available right now, even though the groundwater condition is one of the quite significant factors on seepage analysis. Drilled holes for groundwater investigation were completed as an observation well and served as "Groundwater Monitoring Wells" after the investigation work.

In accordance with the consideration on the results of initial geological and hydrogeological investigation (these are explained later in detail), the anisotropy of ground permeability was emphasized. And, the fact that the layer regarded as an aquitard (almost impervious layer) in the reservoir area was not only "Recent Alluvium" (① layer: refer to Table 4-3-3.1) but "Pleistocene Alluvium" (⑥ layer: same) also was revealed. Based on these facts and their significance related to the dam water seepage analysis, the additional geological/hydrogeological investigation works, mainly targeting to "Pleistocene Alluvium" (⑥ layer), were conducted.

(2) Contents of the investigation

Those investigation works were actually conducted under "Sub-contract". To make the contract, the investigation works were separated into four categories of; 1) Geological Investigation Boring, 2) Monitoring Well Drilling, 3) Soil Investigation Boring, and 4) Additional Investigation Boring. Work

volumes actually conducted were as follows:

1) Geological investigation boring;

a) All-core Boring: 10 holes (depth 30 – 50m, total 320m)
b) In-situ Tests: - Standard Penetration Test (SPT) (every 1.0m)
- Permeability Test <Horizontal test> (3.0 – 5.0m span)
- Permeability Test <Vertical test> (every 5.0m)
- Natural γ-ray Logging (every hole)

2) Monitoring well drilling;

c) Deep Well Drilling: 5 wells (depth 120 – 150m, total 660m)
d) In-situ Tests: - Natural γ -ray Logging (every well)
-Resistivity Logging with SP log (3 wells but partially)
e) Completion to Monitoring Wells: 5 wells
f) Installation of Automatic Water Level Recorder (AWLR): 5 wells

3) Geophysical prospecting and soil investigation boring;

g) Geophysical prospecting: 53 points (VES, 120m analyses)
h) All-core Boring: 5 holes (depth 17 – 30m, total 137m)
i) In-situ Tests: - Standard Penetration Test (SPT) (every 1.0m)
- Permeability Test <Horizontal test> (3.0 – 5.0m span)
- Permeability Test <Vertical test> (every 5.0m)

4) Additional investigation boring;

j) All-core Boring: 6 holes (depth 60 – 100m, total 480m)
k) In-situ Tests: - Standard Penetration Test (SPT) (every 1.0 – 2.0 m)
- Permeability Test <Horizontal test> (3.0 – 5.0m span)
- Permeability Test <Vertical test> (every 5.0m)

(3) Actual works schedule

Total work schedule of the Project was, originally, from early June 2015 to the beginning of August 2016. The Sub-contract of the initial geological and hydrogeological investigation works were concluded on 1st July, 2015, and the actual field and laboratory works had been completed in January, 2016. Then, the additional geological/hydrogeological investigation works were commenced in the middle of February, and completed by the end of April, 2016. The actual work schedules on all geological/hydrogeological investigation works are shown in the Figure 4-3-1.1.

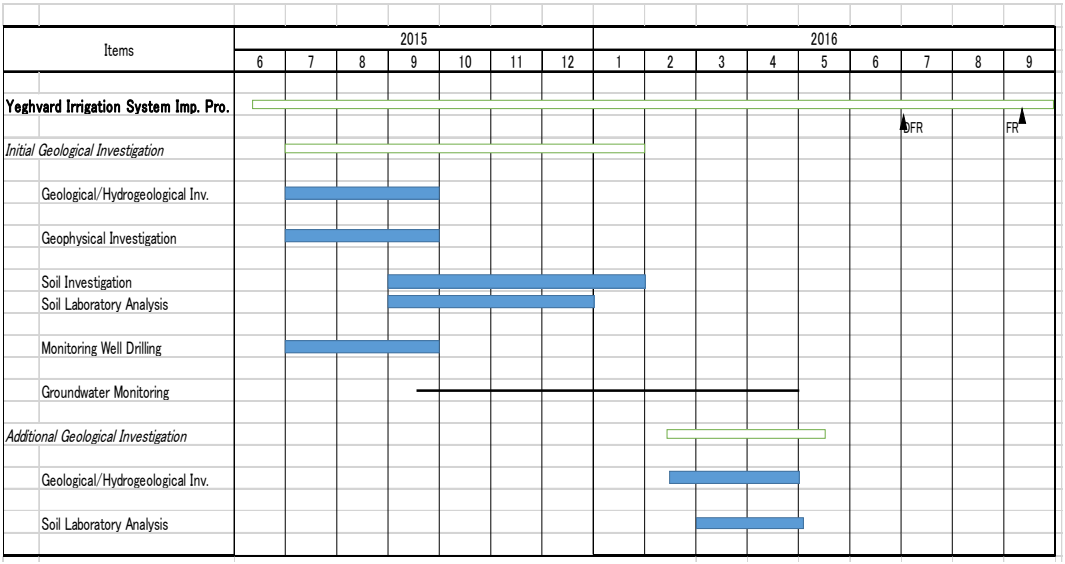


Figure 4-3-1.1 Work Schedule on Geological/Hydrogeological Investigation

4-3-2 Results of Geological/Hydrogeological Investigation

In this section, a methodology and a result of each investigation work such as investigation boring (not only geological/hydrogeological but soil investigation also), in-situ tests conducted in every boring hole, monitoring well drilling, and so on, are to be explained. And finally, results on "review of the previous geological investigation" by ex-USSR, one of the major purposes of the initial investigation, shall be considered.

Drilling Rig

(1) Geological/Soil investigation results

(a) Geological investigation boring

Major works conducted under this category were 10 holes of "all-core boring" together with in-situ tests of; "Standard Penetration Tests" (SPT), "Permeability Test" (PT), and "Gamma-Ray Logging" (GRL). Two kinds of PT were tried to know a horizontal (HPT) and a vertical permeability (VPT). All of the investigation holes have been buried completely by clayey soil after completion of all boring and tests. Drilling rigs used in this job were top-drive rotary drilling rig; type "УРБ 2A2" model made in USSR (refer to the right picture).

Location of geological investigation boring is shown in Figure 4-3-2.1.

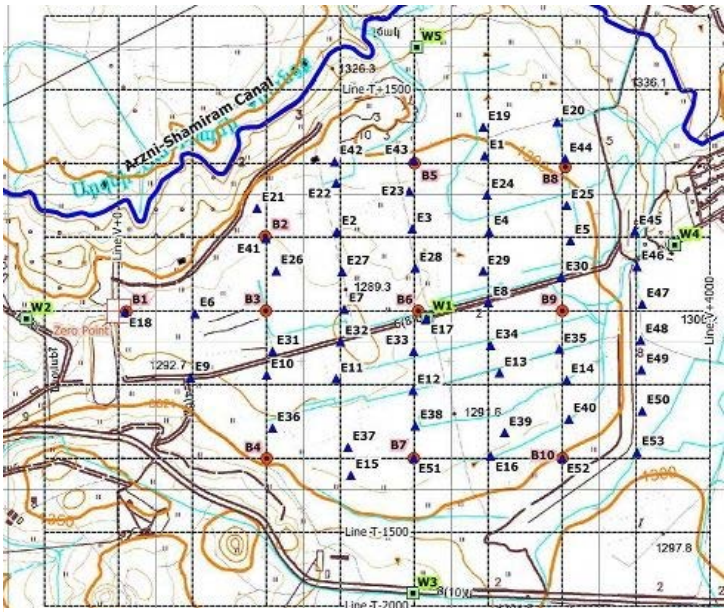


Figure 4-3-2.1 Location Map of Geological Investigation

Results of core-boring in this category were arranged into “Boring Log” together with all results of in-situ tests such as SPT, VPT and HPT (refer to Figure 4-3-2.2), and attached in Appendix F-1 all together.

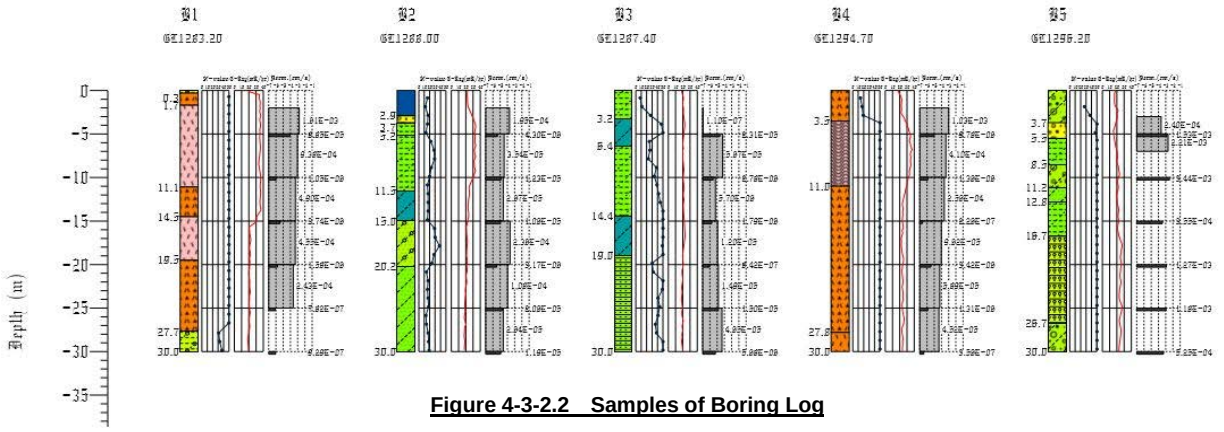


Figure 4-3-2.2 Samples of Boring Log

Based on these boring log (but including other geological log obtained through other investigation), several geological cross-sections (N-W sections) and profiles (E-W sections) were provided to understand the total geological condition of the dam-site. A sample of the section is shown as Figure 4-3-2.3 (Profile No.3). All geological cross-sections and profiles are attached in Appendix F-2, and explained partially in the following section.

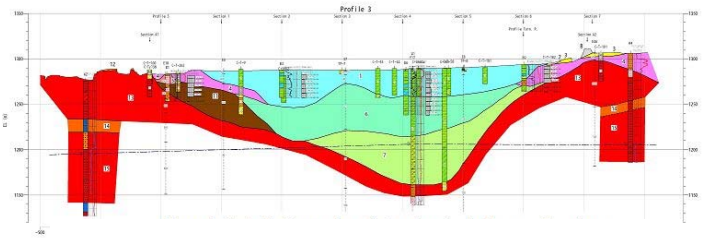


Figure 4-3-2.3 Sample of Geological Cross Section

The geological investigation boring revealed a distribution and properties of major geological formations consisting the site, such as many volcanogenic layers, mainly fluvial sand and gravels (pebbles and cobbles partially), and rather impervious loamy soil layers. Anisotropy of permeability of these formations was clarified. Furthermore, quite high Gamma-ray radiations were detected at some of the boring in their upper portion. This phenomena was observed in some holes of “Soil investigation boring” and “Monitoring well drilling” also, and it shows a characteristics of Tuff-breccia erupted in the same timing from, supposedly, Mt. Arailer standing in just north.

(b) Geophysical prospecting and soil investigation boring

Under the category of “Quality/Quantity Survey on Embankment Materials”, total 53 points of geophysical prospecting were conducted, and based on the analyses of the prospecting, total five (5) “all-core boring” with a series of in-situ tests (same with geological/hydrogeological investigation) were drilled as “Soil Investigation Boring”. However in these boring, soil samples taken by a SPT (one meter interval) were sent to a laboratory to make three (3) kinds of soil tests (1.Moisture contents, 2.Specific Gravity and 3.Grain-size Distribution Analysis).

VES Equipment

Geophysical prospecting was carried out as so-called “Vertical Electric Sounding” (VES). Electrode arrangement was “Schlumberger Method”, with electrode distances of 340m (AB). The maximum analysis depth was 70m originally but extended to 120m

later. Equipment used in this prospecting was Electric Auto-compensator "АЭ-72", Russian made (1980); measuring limit 1000 MV (refer to the picture in the previous page). Field observation data were analyzed into ρ - α curve through a standard curve fitting method (refer to Figure 4-3-2.4).

Results of VES revealed the wide and deep distribution of very thick low apparent resistivity zone (ρ α < 25 Ωm), which can be considered as almost impervious clayey layer, in the central portion of planned reservoir (it was confirmed by additional geological investigation, later). All of these results were used as reference to build up geological cross-sections and profiles.

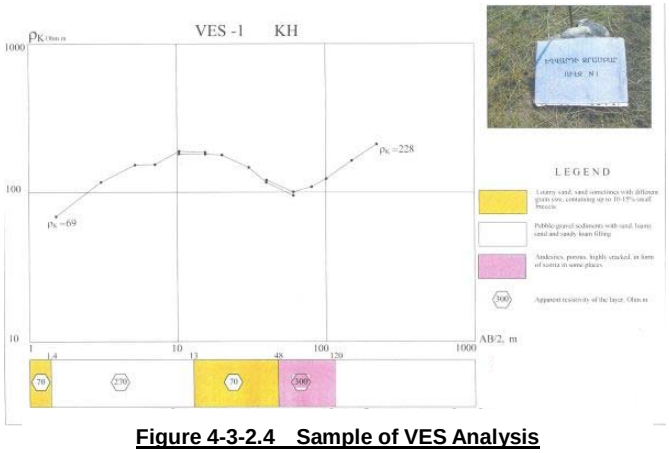


Figure 4-3-2.4 Sample of VES Analysis

Soil investigation boring, drilled consequently to the depth of 30m (as a rule) near around the center of the planned reservoir, found out deep loamy layers showing rather low permeability of both vertical and horizontal, to the bottoms of holes excepting SB-5 which reached to volcanic rocks at shallow depth.

Results of the laboratory analyses indicate clearly loamy zones, clayey zones, and sandy zones, and these information are quite useful to zoning the geological layers (details are explained in the following section).

Location of VES and Soil Investigation Boring are shown in Figure 4-3-2.5. Then, boring log on soil investigation boring are also attached in Appendix F-1, together with the boring log of geological/hydrogeological investigation.

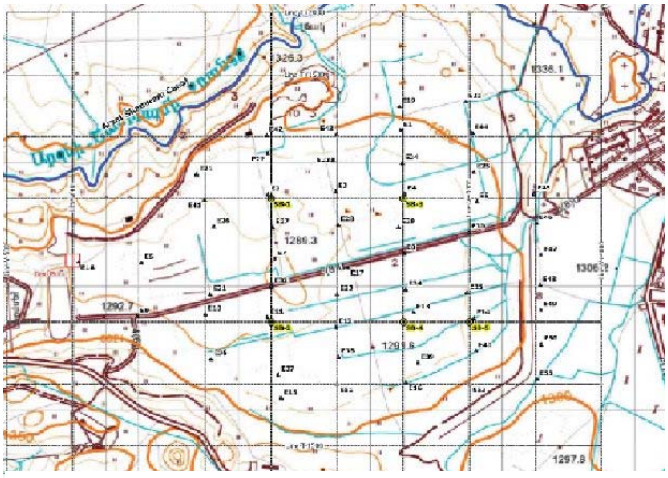


Figure 4-3-2.5 Location Map of VES & Soil Investigation

(c) Additional geological /hydrogeological boring

The main purposes of the initial geological investigation work were to reconfirm the results of previous geological investigation work, therefore, investigation boring were distributed widely but rather shallow.

Major targets of Additional Geological Investigation are Alluvial deposits of "Holocene" and "Pleistocene" (① and ⑥ in Stratigraphy: Table 4-3-3.1 shown later), and the work contents were; "all-core boring" up to 100m depth at maximum to know their properties and distribution, "VPT and HPT" to measure a permeability and their anisotropy, "SPT" to check a toughness of the layer and to take soil samples, and "Soil Laboratory Analysis" to grasp the soil properties of each layer.

Additional boring, from 60 to 100m depths, made clear the distribution of thick (more than 25m) clayey layer with very low permeability (VPT: 1.28 x 10^{-6} cm/sec in an average) in the central and west central parts, and distribution of sand-and-gravelly ❼ layer in the central east part of the reservoir. The ❼ layer was consisted of rather course materials but vertical permeability (VP) was not so high, around 2.1 x 10^{-5} cm/sec in an average, against rather high horizontal permeability (HP). Through the total six (6) additional boring, the distribution of these mostly impervious loamy layers

(① and ⑥) was more clearly distinguished, and then, enough numbers of permeability coefficients on impervious ① and ⑥ layers, and on semi pervious ❼ layer were obtained.

The two 100m-depth boreholes (AB-1 and AB-2) drilled along with Profile No.3, which expected to reach the practical basement of the area (⑬ Basalt Lava), however, did not arrived at the basement within 100m depth. That the ①, ⑥ and ❼ layers have the total depth of more than 100m was one of the quite important information. The second deepest borehole, AB-3 (on the Profile No.5: 80m depth), also could not reach the basement (⑬), and very thick ⑥ layer continued from 40m depth to the bottom. Borehole AB-4 (along the same profile), originally planned to drill 70m, was stopped to drill at 60m because it reached to the volcanic layer (Welded tuff in ⑬ layers) at around 57 m. Along with the Profile No.1, AB-5 and AB-6 were drilled to the depth 70m, respectively. AB-5 (in the western side) drilled thin surface gravel at first, then, drilled volcanic formations of ④ and ⑤ layers till 26m. Then, it passed through thin ⑥ layer (around 7m thickness) and drilled through rather thick ❼ layer. It reached to the basement of ⑬ at the depth of 63m. AB-6 (eastern side) drilled through the thick volcanic formations of ④ and ⑤ for nearly 33m, and then, drilled through only 3m of ⑥ layer and rather thick ❼ layer the bottom of 70m.

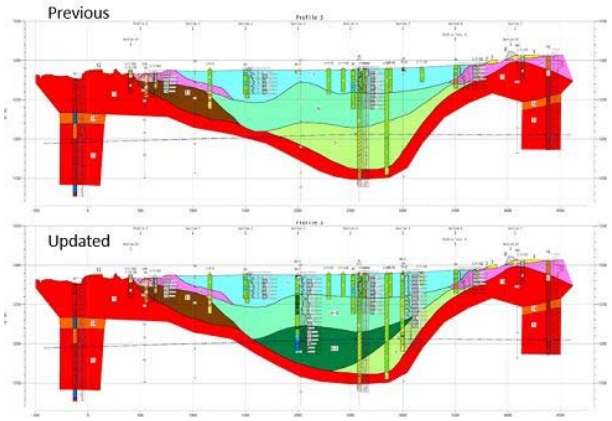


Figure 4-3-2.6 Sample of Modified Profile

Based on the results of additional geological investigation, most of geological cross-sections and profiles were modified, and both VP and HP of these ①, ⑥ and ❼ layers were rearranged, and sent to the expert of water seepage analysis. As a sample of modification, a supposed geological profile No.3, before and after the additional investigation were shown as Figure 4-3-2.6.

Location map of the additional investigation boring are shown in Figure 4-3-2.7. All boring and in-situ tests results are arranged into boring log, and attached in Appendix F-1.

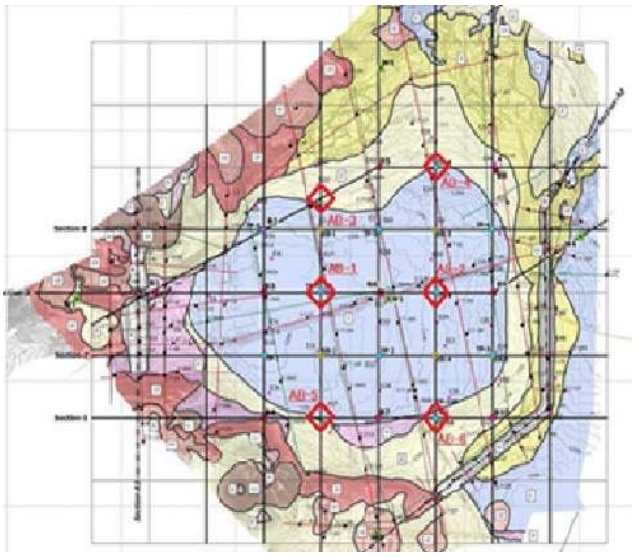


Figure 4-3-2.7 Location Map of Additional Investigation

(2) In situ-tests

(a) SPT and Soil laboratory analyses

Standard penetration tests (SPT) were conducted in the all core-boring holes, in one meter (1.0m) interval until 50m depth and in two meters (2.0m) interval till the borehole bottom (max. 100m depth).

Technical specification on the test was mainly compliant with ASTM (D 1586 – 99, USA). However, N-value was calculated by summing up of blows in every 10cm penetrations x 3 spans (Japanese Standard), and Results of SPT are figured out in each boring log. Remarks are N-values at just below the permeability test spans where usually saturated by test water and show not true value. Soil samples taken through a split barrel (refer to Figure 4-3-2.8) were send to a soil laboratory for a series of laboratory tests (moisture contents, specific gravity, and grain size distribution test). All results of SPT (N values) are attached in the every boring log.

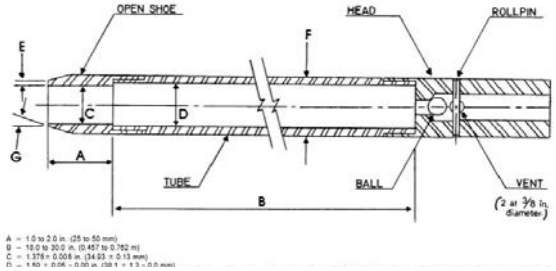


Figure 4-3-2.8 Split Barrel (STM, D 1586)

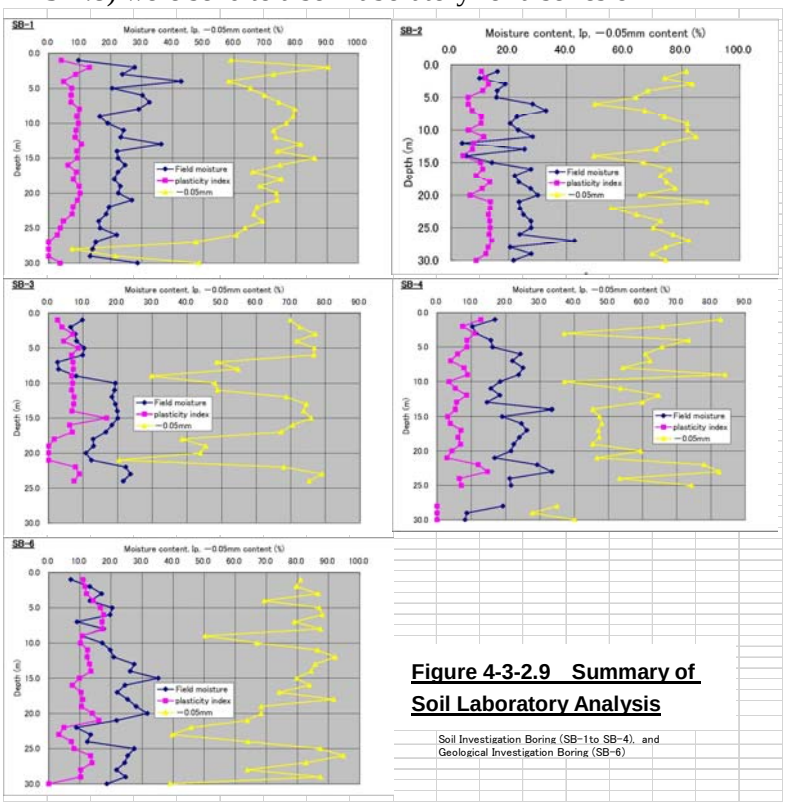


Figure 4-3-2.9 Summary of Soil Laboratory Analysis

Soil Investigation Boring (SB-1 to SB-4), and Geological Investigation Boring (SB-6)

Results of laboratory tests in every boring hole are summarized as Figure 4-3-2.9. As shown in those figures, a field moisture contents were around 20% or somewhat higher than 20%. However, it's strongly affected by a permeability tests conducted in almost 5.0m interval. A plasticity index and 0.05mm grain contents suggest the layers are consisted of mostly loamy soil but including several thin sand layers and clay layers partially.

(b) Permeability test (VPT and HPT)

As explained before, two types of permeability tests were conducted; vertical (HPT) and horizontal (VPT) permeability tests. For HPT, a popular permeability method of "Packer Method" was employed, and for VPT so-called "Tube Method" was introduced (refer to section 4-3-3 (4) for further detail).

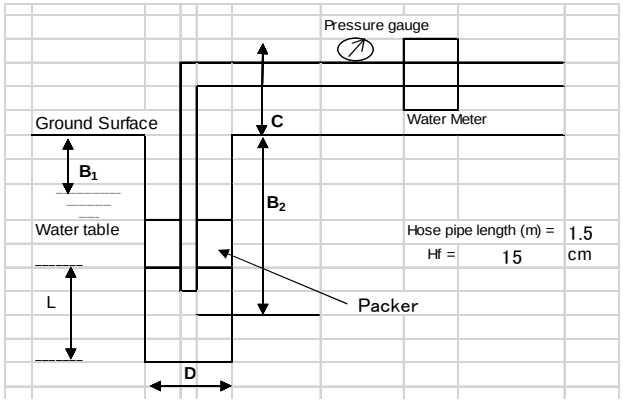


Figure 4-3-2.10 Horizontal Permeability Test

Packer method is to inject water into a certain span of boring (usually 5.0m span), using a packer (air packer in this case) to separate the test span from the other portion. Water is injected into the test span by a certain pressure and measured the injected volume (water loss) by a water meter (refer to Figure 4-3-2.10). Horizontal Permeability Coefficient (*k*), in the packer method, is calculated by the following equation:

k = **(q x 10^3 ln (L/r)) / (2∏LH x 60)**

Where k: Permeability coefficient (cm/sec)

q: water loss (lit/min)

L: Length of test section (cm)

r: radius of the test hole (cm)

H: Total water head (cm)

While in the case of VPT, a water loss injected through the bottom of core-tube is measured by a measuring cylinder at the top of the rod connected to the core-tube (refer to Figure 4-3-2.11), in the case of "Constant Head Method". In the case of "Falling Head Method", the water level falling down to the bottom of the hole shall be followed by water-level meter (refer to the same figure). Vertical permeability k is calculated by the equation used in laboratory permeability test for falling head or constant head.

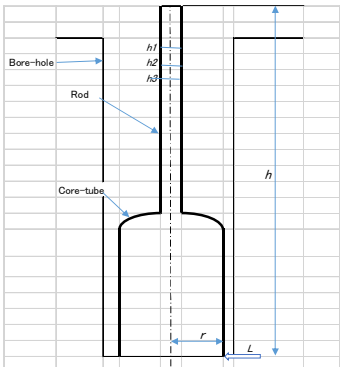


Figure 4-3-2.11 VPT System

Table 4-3-2.1 Average Permeability in Layer

Layer	Geology	VPT (cm/s)	HPT (cm/s)
①	Surface cover	8.25E-06	5.19E-05
②	Alluvial S/G	2.48E-05	4.06E-04
❸	Morane Dep.	6.32E-05	5.99E-04
④	Welded Tuff	1.63E-05	2.28E-04
⑤	Basalt Lava	1.92E-06	2.13E-04
⑥	Dilluvial Sediment	6.21E-06	2.52E-05
❼	Dilluvial S/G	2.13E-05	6.38E-05
⑪	Basalt Lava	9.09E-06	1.76E-04
⑬	Tuff Breccia	6.39E-06	1.17E-04

All results of both horizontal and vertical permeability tests were arranged and analyzed. VPT and HPT calculated are attached in all boring log, illustrated. Further details on the permeability and its anisotropy shall be discussed in the section "4-3-3 (4) Permeability and its anisotropy in the reservoir area", and only the summarized permeability on each geological classification are shown as Table 4-3-2.1.

(c) Natural γ -ray logging and Resistivity/SP logging

In all initial geological/hydrogeological and soil investigation boring (total 15 holes) and in all monitoring wells (total 5 wells), a natural γ -ray logging was conducted. In the three wells among 5 monitoring wells, a resistivity logging associated with SP logging was also carried out because some of groundwater or drilling fluid was remained in the wells. The other two wells could not be logged by resistivity/SP because they were dry.

Logging Car

Both γ -ray logging and resistivity logging were carried out using a serial issued logging station "CK-1-74" mounted on "GAZ-66 Truck" (refer to the left picture), and logging cable and winch was "КГ-30-40-90", all of these were made in USSR. Measurement unit of γ -ray was "m-R (milli-Roentgen)" and resistivity logging was "Ωm".

Results of γ -ray logging were attached into boring log and well log, illustrated in accordance with the depth. Results of resistivity/SP logging were also attached in three well log, respectively. Figure 4-3-2.12 shows γ -ray, resistivity, and SP logging results in the three wells which had water in wells.

(3) Monitoring well drilling and Groundwater measurement

(a) Monitoring well drilling

In the category of initial geological investigation, five (5) monitoring wells were drilled in and surrounding the reservoir area. Originally planned depths were 120m because USSR Report noted that the groundwater level were detected in between 96m to 106m in their boring. However, three wells among five (5) were drilled more 30m (up to 150m depth) due to confirm the groundwater table.

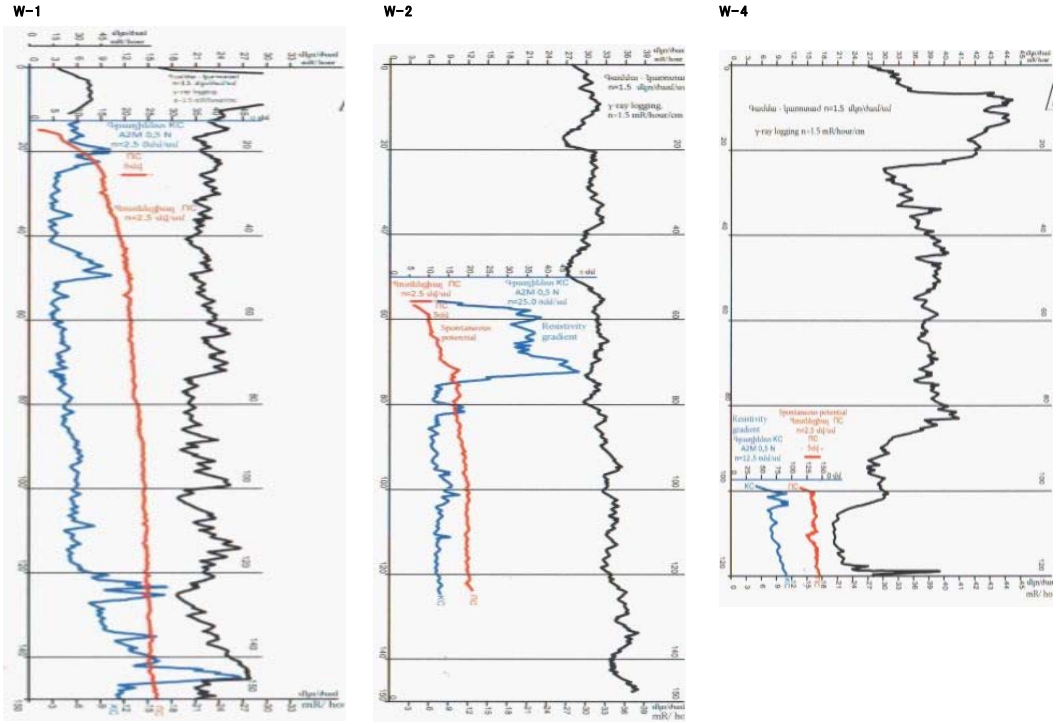


Figure 4-3-2.12 Results of γ -ray and Resistivity Logging

Monitoring well No.1 (called W1) was drilled at almost center of the reservoir area, to check the groundwater table in the reservoir center, then the other wells were drilled at N, S, E, and W of the dam-site but outsides the planned reservoir, because they must be remained and controlled as monitoring wells even after the dam has been completed (except W1 well).

Wells were drilled by 244mm drilling bit in the most part and reduced its diameter to 215mm in the lower portion. Steel casing and slotted screen with diameter of 114mm were installed. At the bottom 30m, screen was installed and filter gravels were set surrounding the screen. Figure 4-3-2.12 shows a standard monitoring well structure. After the well development, Gamma-Ray Logging throughout the well depth was carried out. And, only when the well has high water level inside, a Resistivity/SP logging was also conducted from the bottom to the depth of mud or ground-water.

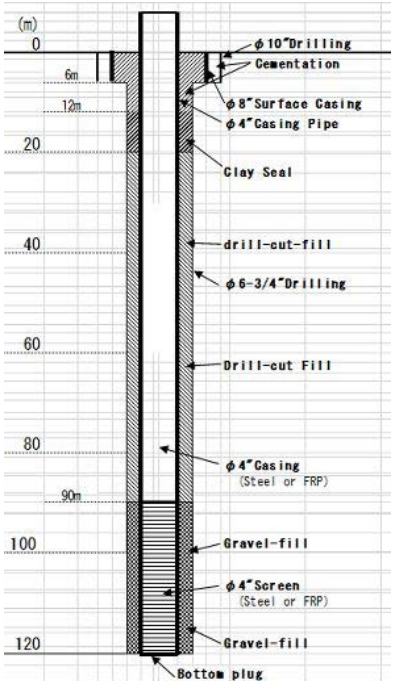


Figure 4-3-2.13 Monitoring Well

Groundwater table was detected in the all monitoring wells but depths were varying from around 80m to 131m, mainly because of

the differences of the ground elevations at where they drilled.

W1 well drilled in the center of reservoir penetrated trough very thick Sandy Loam up to 127m depth and encountered to volcanogenic formation at last. It was Welded-tuff with characteristic brick red color. In this well, very high Gamma-ray radiation was observed at the uppermost 7m. W2 was drilled at the downstream of dam-site, near the entrance to the lower village. It drilled through almost volcanogenic formations from the mouth to the bottom. It was including some clayey formations but they should be weathered volcanic ash. From 55m to 75m, it had quite pervious portion, which was detected by Resistivity Logging. W3 well was drilled at along the national road passing the south of reservoir area. Because of its high elevation, the well was also drilled to 150m depth, and the groundwater table was touched at 129.9m depth. The well drilled through all volcanic rocks without the top of the well. W4 was drilled just upstream of the dam-site, near the church of Yeghvard under construction (as of October 2015). It also drilled through rather hard rock formation. It had quite high gamma-ray radiation at its 6m to 22m span, mostly brown to red Tuff. Below the Tuff, it had pyroclastic portion where need cementation to stop full seepage out of drilling mud-water. W5 was drilled at northern hill surrounding the reservoir. It also drilled through volcanic formations, hard and crackly, and needed sometimes heavy cementations. Only at top 2 meters, the well had high gamma-ray radiation. Results of these deep well drilling were rearranged into "Well Log" together with all γ-ray and partially resistivity logging results. These are attached in Appendix F-1. Groundwater depth and Air pressure measured by AWLR are shown in Appendix F-3.

(b) Groundwater level measurement

Table 4-3-2.2 Depth of Groundwater Table (manual)

Well No.	Elevation (m)	2015				2016	
		4-Sep	8-Sep	22-Sep	12-Oct	3-Mar	15-Apr
W1	1288.97	83.25	83.18	83.16	83.16	82.23	83.27
W2	1275.58	81.4	80.3	79.98	79.84	80.188	80.20
W3	1322.77	129.9	130	130.30	130.735	132.95	132.95
W4	1305.97	100.2	100.2	100.10	100.065	100.515	100.54
W5	1318.15	-	-	104.04	104.01	104.39	114.40

In the all monitoring wells, an Automatic Water Level Reorder (AWLR) was installed after their completion. AWLR was set to measure the groundwater depth at every two (2) hours interval. However, the groundwater depth must be measured manually whenever the data were read up to convert the records to real groundwater depth. Table 4-3-2.2 shows the depths of groundwater tables measured manually. Results of AWLR measuring are shown later (in Figure 4-3-3.4). AWLR measures the water table through sensing water head above the pressure sensor of each AWLR, therefore, the true depth and elevation of groundwater table must be converted/compensated through the actual ground elevation and air pressure near around the site. The maximum fluctuation was, which occurred in W5, only 56.7 cm for around a half year.

(4) Review of the previous geological investigation

(a) Outline of previous geological investigation

The first systematic geological investigation under the concept of Yeghvard Reservoir was carried out from 1931 to 1932. In 1940, additional geological investigation in the planed reservoir area was conducted by the "TVIAGIDEP" Institute of ex-USSR, and the need of counter measurement for infiltration was reported. After the long remoteness, in 1979, "GiproVodStroy" conducted systematic geological and hydrogeological investigation for the Feasibility Study (F/S) on Yeghvard Reservoir. Then, in 1984, "ArmGiproVodxoz" performed again large scale systematic geological, hydrogeological, and geophysical investigation for the Detail Design Study (D/D) of the Yeghvard Reservoir (in this time the planned reservoir capacity was 228 MCM). Table 4-3-2.3 shows summary of geological investigation works carried out in the above mentioned F/S and D/D by ex-USSR. As shown in the table, nearly 7,660m of core-boring, around 600m of test-pits and trench excavation, and 340 points of VES, were conducted only for the reservoir area in D/D stage.

(b) Geological investigation results

Miocene to Pliocene, and Quaternary formations mainly consist the designed water reservoir. A general stratigraphy is shown in Table 4-3-2.4.

The Miocene is represented by Hrazdan Stratum and is composed of Clays, Marls and Sandstone occurring at the depth of 200-230m in the reservoir, representing a basement for the entire effusive rocks complex of the Late Neogene to Quaternary systems.

The bottom of the reservoir is composed by macro-porous, pulverscent loamy sand and loams with overall thickness of ranging up to 120m (layer ①, ⑥ and ⑧). These are underlain with Pliocene Alluvial soils of Gravel and Pebble-stone (layer ⑫), that are up to 150m thick. The latter cover lava formations - Basaltic Andesites of the lower cover, their Scoria diversities and Dacites.

Dam bodies shall be lied on rather firm and stable rock or on semi-hard rock layers such as Basaltic Andesite, Pyroclasic Tuff and scarified diversities of the Andesite, characterized by various rates of fracturing and relatively high water permeability.

Table 4-3-2.3

Quantities of Geological/Geophysical Investigation Works

No.	Activity	Quantity F/S	Quantity D/D	Unit
1	Geological Reconnaissance Survey			
	(Damsite, 1:5,000. scale)	2	12	km^2
2	Geological Reconnaissance Survey			
	(Canal, roads,and others, 1:5,000. scale)	–	45	km^2
3	Core Boring for Damsite Investigation			
	a) By "ArmGiproVodKhoz" Institute	1,152.0	4,510.4	(run) m
	b) By "ArmGIIGIS" Institute		1,443.0	(run) m
4	Core Boring for seismic micro-zoning			
	By "ArmGiproVodKhoz" Institute	–	209.7	(run) m
5	Non-core Boring for Damsite	344.3	–	(run) m
6	Core Boring 3			
	(for pumping station and canal route)	–	1,150.0	(run) m
7	Test Pit Excavation			
	(in the reservoir area)	32.2	435.8	(run) m
8	Trench Excavation			
	(in the reservoir area)	–	135	(run) m
9	Water Filtration Test			
	a) Pouring/injection tests in boreholes	44	145	times
	b) Pouring tests in Test Pits	2	52	times
10	Lithological Logging			
	(for boreholes)	51	290	holes
11	Geophysical Prospectings			
	a) Vertical Electrical Soundings			
	(Reservoir area, AB=2,000m)	–	150	points
	b) Vertical Electrical Soundings			
	(Quarry site, AB=2,250m)	–	190	points
	c) Geoelectric Borehole Loggings	–	300	(run) m
	d) Vertical Electrical Soundings			
	(Interfluve area, AB=3,000m)	–	70	points
	e) VES Interpretations	–	410	points
12	Soil/Rock Sampling for Laboratory Test	194	123	samples

Table 4-3-2.4 General Stratigraphy of Yeghvard Dam Site

Age			No.	Mark*	Lithology	Thickness	Note
Quaternary	Holocene		①	$_{Vdp}\ Q_{IV}$	Aeolian-Diluvial-Proluvial Formation	35-40m	
			2*	$_{pa}\ Q_{IV}$	Proluvial-Alluvial Sediments	2-27m	Embank materials
			②	$_{ed}\ Q_{IV}$	Eluvial and Deluvial Sediments	1-5m	
	Pleistcene	Upper	④	$\beta\ Q_{III}$	Volcanogenic Formations	5-25m, 30m	
		Middle	⑤	$\beta\ Q_{II}$	Volcanogenic Formations	10-50m	
			⑥-⑧	$_{lap-ap-lap}\ Q_{I-II}$	Alluvial-Proluvial-Lacustrine Sediments	110-120m***	
		Lower	⑨	$\beta\ Q_{I}$	Lithoidal Pumices	10m	
			⑩	$\beta\ Q_{I}$	Volcanogenic Pyroclastic Tuffs	＜10m	no-outcrop**
Tertiary	Pliocene		⑪	$\beta\ N_2$	Volcanogenic Scoria Formation	100-150m	
			⑫	$\alpha\ N_2$	Pliocene Alluvial Sediments	40-150m	no-outcrop
			⑬	$\alpha+\beta\ N_2$	Olivine Basaltic Andesite	50-160m	
			⑮	$\alpha\ N_2$	Hornblend-Hyperthene Andesite	50-160m	no-outcrop
			⑰	$\alpha\ N_1$	Pliocene Dacites	100-300m	
	Miocene		⑱	N_1	Sarmation Sediments (Hrazdan Suite)	300-350m	no-outcrop

(c) Hydrogeological conditions

Hydro-geologically, groundwater within the reservoir area were drilled by three boreholes in the central part of the reservoir, at the depths ranging from 80.0 to 120.5m. In addition, Borehole T-56 located in the central part of the reservoir drilled a local horizon of "perched groundwater" at the depth of 25.1m, which indicates the presence of a limited lens-like confining bed. It formed as a result of infiltration from the Arzni-Shamiran canal and from irrigation waters.

The main direction of the underground water flow is to the southwest, toward the Kasakh River canyon. The underground water is fresh, with TDS of 0.21 - 0.54 g/lit, belonging to HCO3-Mg-Ca type and does not have aggressive properties with respect to concrete.

The lack of permanent natural water flow in the area of reservoir, presence of rather highly water-permeable soils on its banks and bottom parts, big depth of groundwater occurrence and the features of wide stretching design of reservoir determine special conditions of filtration in case it is filled with water.

(d) Permeability and infiltration analysis

The Soviet survey revealed that the permeability of each geological formation were very high, as listed Table 4-3-2.5. As shown in the Table, permeability coefficients of the formations are varying from 10^{-2} cm/sec order to 10^{-5} cm/sec order but mostly in 1 x 10^{-3} cm/sec order, rather permeable. Furthermore, the layers having high permeability (sand and gravel/pebble) lay in the northern part of the reservoir area, and in surrounding slop zone, other highly pervious volcanic formations are distributed.

Table 4-3-2.5 Permeability Coefficients of Major Formation

No.	Formations	Permeability Coefficient (cm/s)
1	Recent Loamy sand, loam ($vdpQ_{IV}$)	1.97×10^{-4}
2	Sand and gravel/pebble (paQ_{IV})	5.03×10^{-3}
3	Recent Eluvial, Deluvial formation ($_{ed}Q_{IV}$)	1.63×10^{-3}
4	Late Quaternary Tuffs (βQ_{III})	4.68×10^{-3}
5	Middle Qua. Andecite lava (βQ_{II})	8.04×10^{-3}
6	Early Qua. Lap-ap-lap Q_{IV}	1.16×10^{-5}
7	Early Qua. Alluvial/proluvial sediments	3.08×10^{-3}
8	Late Pliocene, volcanic rocks	3.24×10^{-4}
9	Middle Pliocene,Pumices ($_{\beta}Q_{I}$)	1.57×10^{-2}
10	Andecite/Scoria ($_{\beta}N_{2}$)	9.83×10^{-3}
11	Andecite layer (N_1)	2.83×10^{-3}

Based on the calculations of losses by infiltration from the central part of the reservoir, bounded by a vast zone with filtration without confinement and, with the need for unconditional reliable counter-filtration measures, comprises 311 MCM/year over an area of 391.5 ha; this emphasizes that the use of reliable counter-filtration measures also in the central part, hence, over the entire water reservoir, is inevitable.

4-3-3 Geological/Hydrogeological Conditions of Dam Site

Based on the results of every investigation works explained so far, in the above sections, geological conditions on the dam site shall be explained here, in accordance with the geological stratigraphy. A permeability and hydrogeological circumstance of the reservoir area shall also be explained coincidentally. Then, the permeability of the ground and groundwater condition are considered to furnish those data to the field of seepage flow analysis.

(1) Revised geological stratigraphy

Through their F/S (1979) and D/D (1985) Studies, USSR geologists formulated a standard stratigraphy of Yeghvard Reservoir area. The stratigraphy started from Holocene and traced back to Miocene. This was explained already in the previous section 4-3-2 (4) and shown as Table 4-3-2.3. The Survey Team also followed to this stratigraphy as a general but modified their naming and interpretations for some parts, based on the field reconnaissance and newly obtained geological information.

Major modifications were as follows. Lowest Pliocene Gravel formation (old series ⑫) was changed to Pyroclastic flow consisting the base of Volcanic Breccia (series ⑪) and merged into Volcanic Breccia (series new ❶❶), then, Lower Quaternary sediments series (series ⑦ to ⑧) are combined into new series ❼. Holocene Proluvial-alluvial sediments (series ②) is renamed as Moraine deposit (new series ❸), and Eluvial-diluvial sediments of the same age is renamed from Gravel to as Surface Gravels (series ②). Thus, a comparison table on the old and new stratigraphy of the study area is summarized as Table 4-3-3.1.

Table 4-3-3.1 General Stratigraphy of Yeghvard Dam Site

Age			Genetic Classification	Symbol	No.	Main Facies	New No.	Main Facies
Quaternary	Holocene		Aeolian-Diluvial-Proluvial Formation	$_{Vdp}Q_{IV}$	①~1a	Sandy Loam and Loam	①	Sandy Loam and Loam
			Eluvial and Deluvial Sediments	$_{ed}Q_{IV}$	2^a	Gravel	②	Surface Gravel
			Proluvial-Alluvial Sediments	$_{pa}Q_{IV}$	②	Gravel	❸	Moraine Deposits
	Pleistocene	Upper	Volcanogenic Formations	$_{\beta}Q_{III}$	④	Welded Tuff	④	Welded Tuff
		Middle	Volcanogenic Formations	$_{\beta}Q_{II}$	⑤	Lava	⑤	Lava (North bank)
		Lower middle	Lacustrine-alluvial-proluvial Sediments	$_{lap}Q_{I-II}$	⑥	Loamy Sand and Loam	⑥	Loamy Sand and Loam
		Lower	Alluvial-proluvial Sediments	$_{ap}Q_{I}$	⑦-7^a	Sand - Loamy Sand	❼	Sandy Loam to Loamy Sand
			Lacustrine-alluvial-proluvial Sediments	$_{lap}Q_{I}$	⑧	Loamy Sand and Loam		
			Volcanogenic Formations	$_{\beta}Q$	⑨	Lithoidal Pumices	⑨	Lithoidal Pumices
			Volcanogenic Formations	$_{\beta}Q_{I}$	⑩	Welded Tuff	⑩	Welded Tuff
Tertiary	Pliocene		Volcanogenic Formations	$_{\alpha}N_{II}$	⑪	Volcanic Breccia (Scoria)	⓫	Volcanic Breccia (Scoria)
			Alluvia deposits		⑫	Gravel		Pyroclasic flow deposits
			Volcanogenic Scoria Formation	$_{\alpha+\beta}N_{II}$	⑬	Lava	⑬	Lava (South bank)
			Volcanogenic Formations		⑭	Volcanic Breccia	⑭	Volcanic Breccia
			Volcanogenic Formations	$_{\alpha}N_{II}$	⑮	Lava	⑮	Lava
	Mio-cene		Volcanogenic Formations	$_{\alpha}N_{I}$	⑰	Dacites	⑰	Dacites
			Sarmation Sediments (Hrazdan Suite)		⑱	Sandstone, Clay, Marls	⑱	Sandstone, Clay, Marls

(2) General geology of the dam site

Based on the geological stratigraphy, explained above, general geology of the dam-site shall be described;

Practical geologic basement of the Yeghvard Reservoir area is a sedimentary rock formation belonging to Miocene, usually called as "Hrazdan Suite," which is consisted of Sandstones, Clays and Marls (series ⑱ in the Table 4-3-3.1). The Suite forms impervious basement in this area, hydro-geologically. Upper surface of the Miocene sediments near around the reservoir area inclined from east to west, and the maximum inclination of the basement is located just near the dam site. On a significant scale, the surface of Miocene was dissected and heavily covered by many volcanic formations emerged from the Aragats and Alairer Volcanos in mainly Pleistocene age.

Volcanic activities of these volcanos were quite heavy throughout the Pliocene and continued to the almost end of the Pleistocene in the Quaternary age. The oldest volcanic formation in this area is Dacites (series ⑰) in late Miocene, covering the Miocene sediments (Hrazdan Suite) but dissected strongly so as merely cropping out on some gentle hill tops.

Covering the oldest Dacites, several volcanogenic formations together with a few sedimentary formations, were accumulated in the high land between Kasakh and Hrazdan rivers in early Pliocene. At first, amphibole Andesite (⑮ series) filled after the Dacites lava, emerging in the Kasakh canyon. A little later than the amphibole andesite lava, andesite-basalt slags (pyroclastic flow (⑭ series) covered them. Then, Olivine-basaltic Andesites in middle Pliocene (series ⑬) emerged in large scale and formed the framework of southern and western banks of dam site. Then, covering the olivine-basaltic andesite lava, Andesites slags including volcanic breccia, scoria, pumices, and volcanic sand, accompanied with basal pyroclastic flow deposits (⓫ series).

In the early Quaternary (lower Pleistocene), volcanic activities were still continued and some volcanogenic formations, such as Welded Tuff (⑩ series) and Welded (or Lithoidal) Pumices (⑨ series) were formed. However, these formations were not so developed and not cropped out widely.

After this, there was a rather long rest of volcanic activities, and in this period, a thick alluvial, diluvial and proluvial deposits accumulated thickly, filling up the deep valley dissected on the andesite lava (⑥ and ❼ series). Those are mainly sandy loam but at lower portion of ⑥ series, there was almost impermeable clay layer, which can be evaluated as an aquitard (⑥low series). The base of these layers (❼ series) is mostly sandy to gravelly sediments with rather high permeability. Covering these Pleistocene alluvium to diluvium, more younger Olivine-basaltic Andesites in middle Quaternary (series ⑤) flowed down as lavas formed the main body of the northern bank of reservoir area. And, directly covering the Andesite lava, characteristic brick red color Scoria (or Welded Tuffs) is distributing (series ④). Notably, the tuffs show quite high gamma-ray radiation. The formation changes its facies from hard rock to rather soft scoria, and pyroclastic flow deposits looking like sand-and-gravels.

The low-land of planned reservoir was an enormous dissected valley in lower Quaternary and buried several volcanogenic and alluvial deposits through upper Pleistocene to Holocene. At the end of Pleistocene, huge volume of moraine deposits were left in northwest bank of the reservoir area (series ❸). The deposits were consisted of huge basalt blocks, boulders, cobles, pebble, sand and gravels, without selection. They were diverted as dam body materials during the ex-USSR time. Moraine deposits are now covered by recent eluvial and diluvial sediments (series ② or ① sometime) thinly, but it is rather difficult to distinguish in the site.

Recent Aeolian diluvial-proluvial formations (series ①) covers almost all of the central portion of the reservoir area, represented by gray Sandy Loam with comparatively impervious property. Thin sand or clay layers are intercalated everywhere. Thickness of the formation is said from 35 to 40m in the central portion, however, the total thickness of relatively impervious layers including Lower to Lower-middle Pleistocene Lacustrine-alluvial deposits (series ⑥) shall be beyond 120m in the central portion.

(3) Geological map and cross-section/profiles

In accordance with such modifications, and referenced to the information obtained through newly drilled boreholes, a geological map of the reservoir area was revised Based on the revised geological map, and results of two terms of geological investigations, as well as monitoring well drilling, geological cross sections and profiles were drawn up to understand the general geology of the area and a distribution of relatively impervious formations in the planned reservoir.

A cut-down sized geological map as shown in Figure 4-3-3.1. A typical cross-section is shown as Figure 4-3-3.1, and the other sections and profiles are attached as Annex F-2. As results, Holocene Loamy soils (series ①), Lower middle Pleistocene alluvial sediments (series ⑥), and Lower

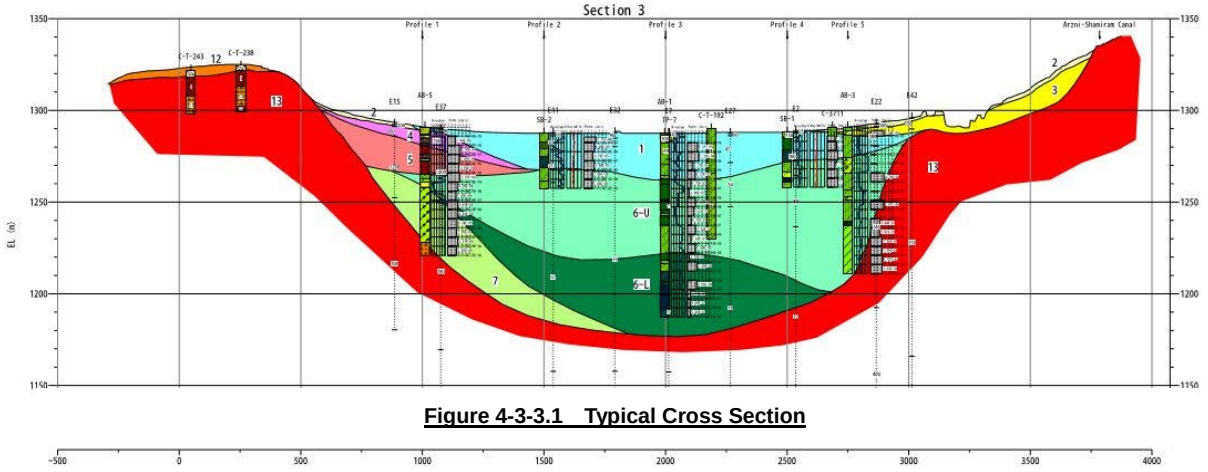


Figure 4-3-3.1 Typical Cross Section

Pleistocene sediments (❼), were deposited very thickly in the central portion of the reservoir area with more than 120m depth in maximum. Among them, a permeability on ①and ⑥ layers were rather low and seemed to be almost impervious layer. Such comparatively impervious formations were abruptly reduced its thickness at near around the peripheral zones in various directions. The situations are almost same with the Soviet Report, however, the bottom of the impervious layer was more clearly confirmed by this new investigation.

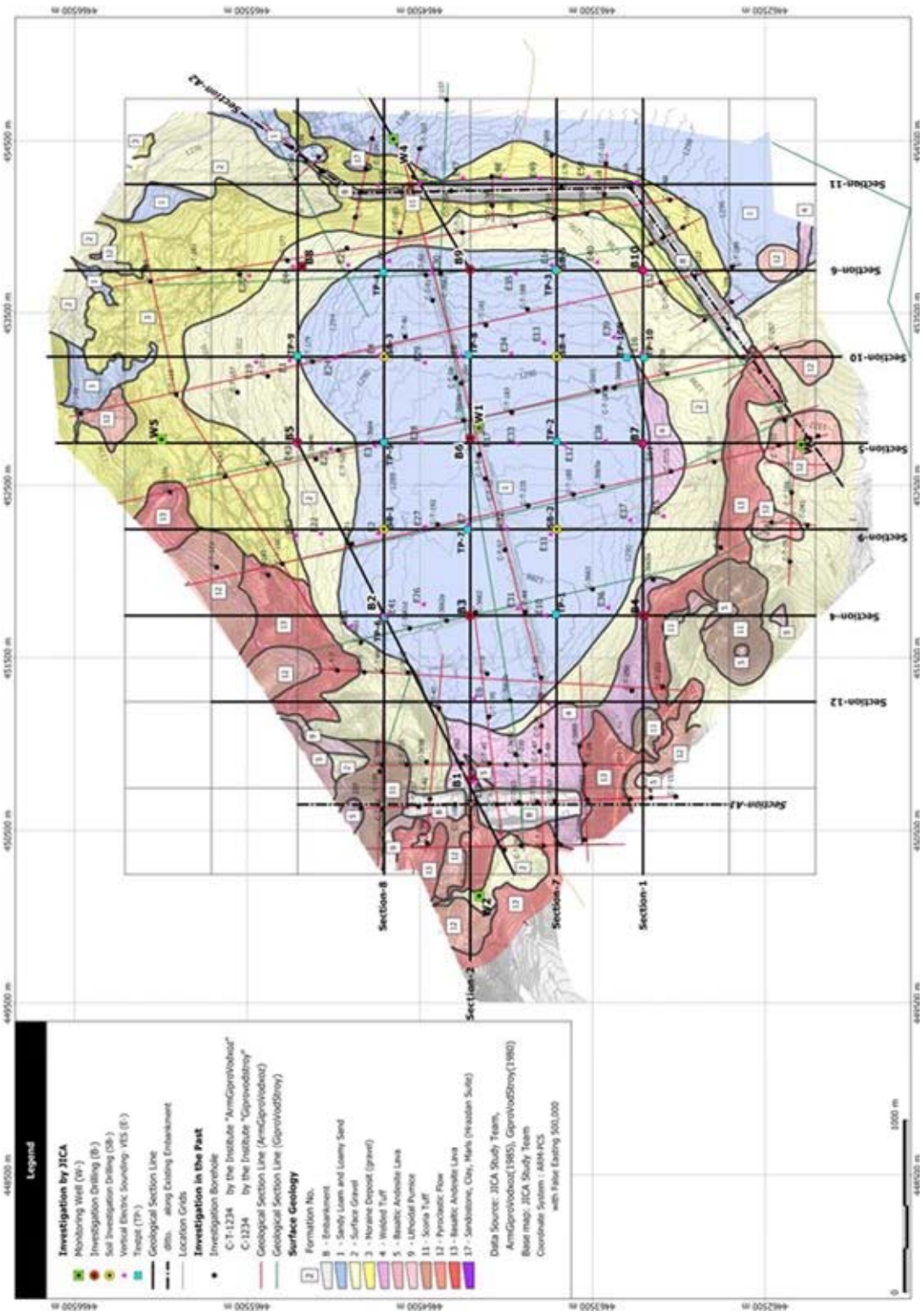


Figure 4-3-3.2 Geological Map & Locations of Cross-section/Profiles

(4) Permeability and its anisotropy of reservoir basin

In and around the planned Yeghvard Reservoir, three major categories of geological facies are distributing: 1) volcanogenic formations forming mainly slopes surrounding the depression, 2) moraine deposits distributing north-western corner of the reservoir area, and 3) relatively impervious Loamy Sediments distributing in the main part of the depression. However, both moraine deposits and Loamy sediments are underlain by volcanogenic formations at several depths. In accordance with the previous USSR Study, all of volcanogenic formation, Proluvial-Alluvial Sediments (Gravels; ②), and moraine deposits (❸) had quite high permeability. On the other hand, permeability of Loamy formation (such as ①) showed rather low permeability. However, the permeability tests conducted by USSR Team were so-called packer method: injecting water in the test span through a packer under high pressure. This method is very popular in Japan also but the permeability obtained through this way is horizontal permeability. Although they did not distinguished an anisotropic of permeability, the Survey Team made a special attention to the anisotropic permeability of the relatively impervious formation, because seepage of dam water shall happen into vertical direction, not horizontal.

Anisotropy of permeability in sedimentary formation was well known in Japan. In this study, we made two papers as main references: 1) “Proposed method for field measurement of horizontal and vertical permeability of soil,” and 2) “Some Studies on the Analyses of In-situ Permeability Tests“, both by Professors M. Nishigaki and I. Khono, (1984).

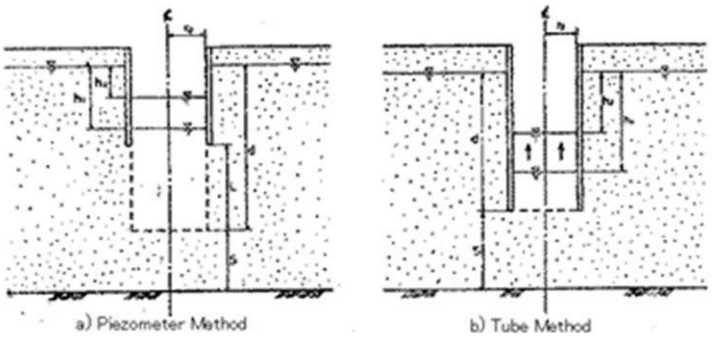


Figure 4-3-3.3 Geometory of Permeability Tests

They suggested there mainly are two methods to evaluate the permeability in the test hole, one is so-called a “piezometer method” and another is a “tube method” which is a special case of piezometer method (refer to Figure 4-3-3.3). They said the piezometer method indicates mainly horizontal permeability (abbrev. as HP) and the tube method showed vertical permeability (abbrev. as VP) mainly. In the actual investigation work, we made both permeability tests, a horizontal permeability test (HPT) by packer method (refer to Figure 4-3-2.10), in the previous section) and a vertical permeability test (VPT) by tube method (refer to Figure 4-3-2.11). In the tube method test, two kinds of water injection were tries; one was constant head method to keep water head steady, and the other was falling head method to follow the water heads in time. To evaluate the vertical permeability in tube method, in the falling head method, the following formula was adopted (by Schmid, 1967, original):

$$k = \frac{r0}{4(t2 - t1)} * ln\left(\frac{h1}{h2}\right)$$

Where r0: radius of the hole (cm)
t1, t2: measuring times (sec)
h1, h2: water heads from the bottom(cm).

In the case of constant head method, following formula was adopted;

$$k = qL/\pi r^2 h$$

Where *r:* radius of the hole (cm)
q: water volume injected in unit time (cm^3/sec)

L: Length of the test span (1 cm in this case))

h; constant water head from the bottom (cm).

Table 4-3-3.2 Summary of Permeability Tests (Unit: cm/sec)

No.	Dep .(m)	AB-1			AB-2			AB-3			AB-4			AB-5			AB-6		
		Lith*	VPT**	HPT***	Lith	VPT	HPT	Lith	VPT	HPT	Lith	VPT	HPT	Lith	VPT	HPT	Lith	VPT	HPT
1	5	①	1.46E-06	S.O	①	9.24E-06	1.81E-03	②	1.18E-05	4.06E-04	②-❸	2.04E-05	9.79E-04	①-②	3.40E-05	S.O	④	1.90E-05	4.97E-04
2	10	①	4.86E-06	5.37E-05	①	1.10E-06	1.15E-04	①	5.14E-06	S.O	❸	7.33E-07	1.01E-03	④	1.47E-05	1.06E-05	④	1.58E-05	1.12E-05
3	15	①	3.29E-06	1.29E-04	①	4.51E-06	8.83E-05	①	3.37E-06	S.O	❸	7.46E-05	8.67E-04	⑤	4.27E-07	3.00E-04	④⑤	2.49E-05	1.03E-04
4	20	①	2.87E-05	3.11E-06	①	1.23E-05	5.95E-05	①-⑥	5.08E-06	S.O	⑥	1.56E-06	6.72E-04	⑤	2.26E-05	1.65E-04	⑤⑥	6.99E-05	1.92E-04
5	25	①	1.01E-05	1.27E-05	①	7.16E-06	2.11E-04	⑥	3.24E-05	S.O	⑥	5.16E-07	S.O	⑤	1.49E-06	1.05E-04	⑥	5.61E-05	9.42E-03
6	30	⑥u	3.05E-07	7.77E-07	①	5.79E-06	1.06E-04	⑥	4.41E-05	4.79E-04	⑥	1.67E-04	S.O	⑥	1.78E-05	2.32E-04	⑥	4.57E-05	1.08E-04
7	35	⑥u	8.34E-06	2.98E-07	①⑥u	1.82E-06	1.97E-04	⑥	2.23E-05	S.O	⑥	1.61E-07	4.59E-04	⑥	2.73E-06	4.30E-05	⑥	2.93E-06	1.10E-04
8	40	⑥u	6.50E-08	1.52E-05	⑥u	2.40E-06	3.04E-05	⑥	7.87E-04	S.O	⑥	1.60E-07	S.O	⑥	1.59E-07	1.83E-05	⑥❼	1.53E-05	1.27E-04
9	45	⑥u	2.99E-07	4.63E-06	⑥u	2.11E-05	2.83E-04	⑥	1.17E-05	3.97E-04	⑥	2.83E-06	1.13E-05	⑥	1.20E-06	4.63E-05	❼	3.56E-05	1.02E-04
10	50	⑥u	9.94E-07	9.77E-07	⑥u	1.63E-05	2.83E-04	⑥	2.57E-06	S.O	❼	5.09E-07	3.99E-04	❼	1.15E-05	4.53E-05	❼	6.15E-06	7.09E-05
11	55	⑥u	8.47E-06	1.70E-05	⑥u	8.25E-06	2.92E-04	⑥	2.32E-05	3.64E-05	❼	1.08E-05	5.44E-04	❼	6.07E-06	3.28E-05	❼	1.48E-05	3.68E-05
12	60	⑥u	4.93E-05	7.65E-07	⑥u	8.33E-05	1.88E-05	⑥	2.01E-05	2.91E-05	⑬	5.31E-07	N.D	❼	1.86E-05	2.59E-05	❼	1.26E-05	5.00E-05
13	65	⑥u	1.08E-05	1.50E-05	⑥u	1.60E-05	2.14E-04	⑥	4.03E-05	1.38E-04				❼⑫	5.69E-06	5.21E-05	❼	6.92E-06	6.23E-05
14	70	⑥u	3.67E-07	2.70E-07	⑥u	5.69E-06	2.43E-04	⑥	3.39E-05	1.29E-04				⑬	1.27E-05	2.50E-05	❼	2.56E-06	1.25E-05
15	75	⑥l	1.48E-07	3.32E-05	⑥❼	N.D	S.O	⑥	1.66E-05	1.97E-04									
16	80	⑥l	1.92E-06	S.O	❼	N.D	S.O	⑥	1.60E-05	1.43E-04									
17	85	⑥l	1.36E-05	3.05E-05	❼	N.D	S.O												
18	90	⑥l	9.88E-07	6.11E-07	❼	N.D	S.O												
19	95	⑥l	1.25E-06	4.90E-07	❼	N.D	S.O												
20	100	⑥l	9.41E-07	5.50E-07	❼	N.D	S.O												

Lith* : Lithology (Layer No.)
VPT** : Vertical Permeability
HPT*** : Horizontal Permeability

Lith	Initial Investigation			Additional Investigation			All (Geomean) Average		
	NOS	VPT	HPT	NOS	VPT	HPT	No.	VPT	HPT
①	32	9.86E-06	4.39E-05	13	5.32E-06	7.83E-05	45	8.25E-06	5.19E-05
②	1	1.10E-04	–	2	1.18E-05	4.06E-04	3	2.48E-05	4.06E-04
❸	4	1.85E-04	4.80E-04	2	7.40E-06	9.36E-04	4	6.32E-05	5.99E-04
④	10	2.09E-05	3.25E-04	2	4.62E-06	3.89E-05	12	1.63E-05	2.28E-04
⑤	1	3.74E-06	4.90E-04	4	1.62E-06	1.73E-04	5	1.92E-06	2.13E-04
⑥	15	1.38E-05	2.53E-05	42	4.67E-06	2.52E-05	57	6.21E-06	2.52E-05
❼	3	9.23E-04	–	11	7.64E-06	6.38E-05	14	2.13E-05	6.38E-05
⑪	0	–	–	6	9.09E-06	1.76E-04	6	9.09E-06	1.76E-04
⑬	15	7.21E-06	1.97E-04	2	2.60E-06	2.50E-05	3	6.39E-06	1.17E-04

Results of all permeability tests were summarized as Table 4-3-3.2. The anisotropic of permeability was quite clearly detected, mostly the VP were lower than the HP around one third to more than one order. Of course there were some exceptions that VP was higher than HP, mainly in volcanogenic formations and moraine deposits. These can be easily considered through the cause or origin of the formations.

As shown in the above Table 4-3-3.2, HP of moraine deposits (❸), young volcanogenic formations (④,⑤), and surface gravels (②) were rather high. Sand and Gravel of moraine showed high 6.0 x 10^{-4} cm/sec order, and young Tuff and Lava showed 2.1 - 2.3 x 10^{-4} cm/sec. These values are almost same with the test results made by USSR Team. However, VP of relatively impervious formations such as Holocene Sandy Loam (①) or Lower middle Pleistocene Sediments (⑥) indicated low VP: the former showed 8.3 x 10^{-6} cm/sec and the later showed 6.2 x 10^{-6} cm/sec in an average, less than 1/4 of HP. Especially, the lower clay in ⑥ layer (called as ⑥low) showed very low VP as 1.28 x 10^{-6} cm/sec in an average. The minimum VP of 1.48 x 10^{-7} cm/sec was observed in the formation ⑥low in AB-1 Borehole. VP of volcanic formations are not so much meaningful because of the test method (water injection through only φ114mm of casing pipe), however, the fact that VP of these volcanic rocks were very low even in an average value suggests the volcanogenic formations underlain impervious soil formation (or pervious Sand and Gravel) may have rather low permeability. At least, they shall not have such very high permeability of 4.7 x10^{-3} - 1.6 x 10^{-2} cm/sec of VP as they introduced in the previous D/D Study Report.

(5) Monitoring wells and groundwater condition

As alrady descrived before, in the category of geological/hydrogeological investigation, five (5) monitoring wells were drilled in and surrounding the reservoir area. In the all monitoring wells, an Automatic Water Level Reorder (AWLR) was installed after their completion. AWLR was set to measure the groundwater depth every two (2) hours. It can measure and record groundwater level for 5 years without changing the battery. AWLR measures the water head above the pressure sensor together with an air-pressure, therefore, the depth of groundwater table must be compensated by air pressure near by the wells. Results of AWLR measuring are shown in Figure 4-3-3.4. These wells shown in the

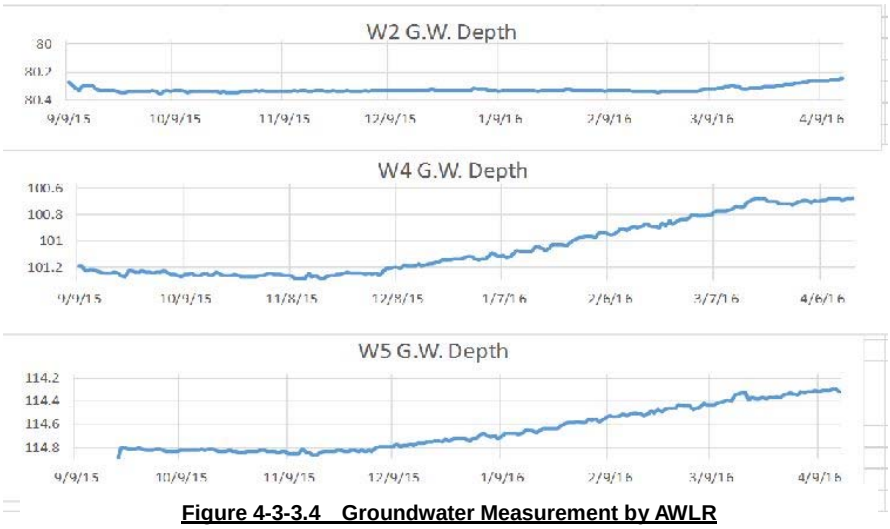


Figure 4-3-3.4 Groundwater Measurement by AWLR

figure were showing the heaviest groundwater movement among the five wells. However, the maximum fluctuation was only 56.7cm (in W5) for around a half year. Small fluctuations in each hydrograph are daily tidal fluctuations, and a long span movements of groundwater level, in W4 and W5, are large scale areal groundwater movements, and partly getting an influence of leaking water flow through the Arzuni-Shamiram canal.

Based on the results of monitoring well drilling, groundwater table near around the Yeghvard Reservoir area is illustrated as Figure 4-3-3.5. As shown in the Figure, groundwater table is almost flat but slightly tilted from north to south and east to west. Groundwater movement near the dam-site is, as shown in the contour map, flowing from north to south as a total, however, the maximum inclination is less than 14m for around 4km of distance. The results was almost consistent with the results of previous large scale Geo-electric Sounding (by ex-USSR), that total groundwater movement in the Yeghvard Highland is from NE to SW direction.

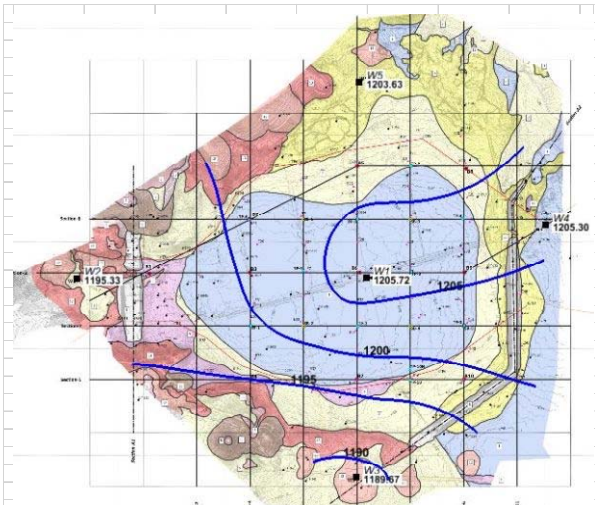


Figure 4-3-3.5
Groundwater Contour Map Of Yeghvard Basin

Figure 4-3-3.6 shows a wide range hydrogeological cross section of Yeghvard Basin, crossing the reservoir area from the opposite bank of the Kasakh to also the opposite side of the Hrazdan River. As shown in these figures, the groundwater table in and around the reservoir area is very flat, and very deep. The figures, together with the groundwater hydrograph, indicates that a) groundwater table in the reservoir area is very deep (more than 80m), b) permeability of the Yeghvard highland in between Kasakh and Hrazdan rivers are very high as a total, and 3) rainfall and snowmelt in the reservoir area gave almost no influence to the groundwater table.

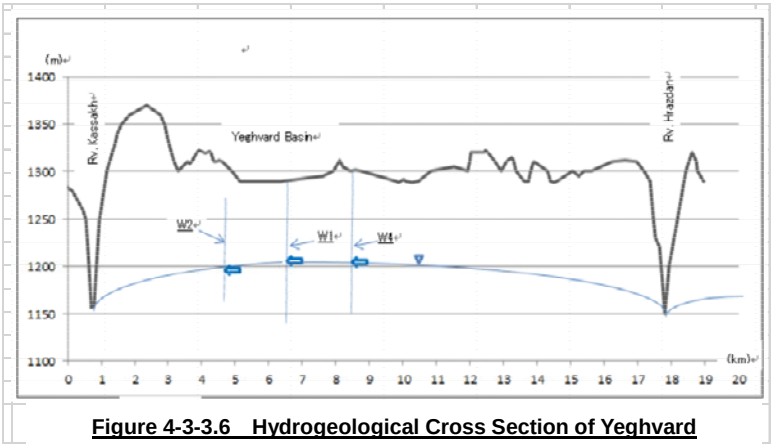


Figure 4-3-3.6 Hydrogeological Cross Section of Yeghvard

4-3-4 Investigation on Dam Body Materials and Laboratory Soil Test

(1) Investigation on impervious materials

(a) Outline of the survey

The ground of the reservoir area is widely covered by the thick soil layer so called “loamy sand or sandy loam” which was investigated and planned as the impervious materials for the dam body in the ex-USSR era. The excavation of ten test-pits were planned this time in the reservoir area and also the drilling of 10 hand-augers, defined as the spare borrow area, outside of the reservoir. The location map of the survey points is shown in Figure 4-3-4.1. In these test-pits, the field permeability tests by the pit method and by the cylinder method were carried out to grasp the differential between the horizontal permeability coefficient and the vertical one. The former, for the horizontal permeability, was the test done in the excavated pit where seepage through the pit wall is predominant; the latter, for the vertical permeability, was done to the soil column sculptured in the ground where seepage was forced to occur from the top of the column to its foot.

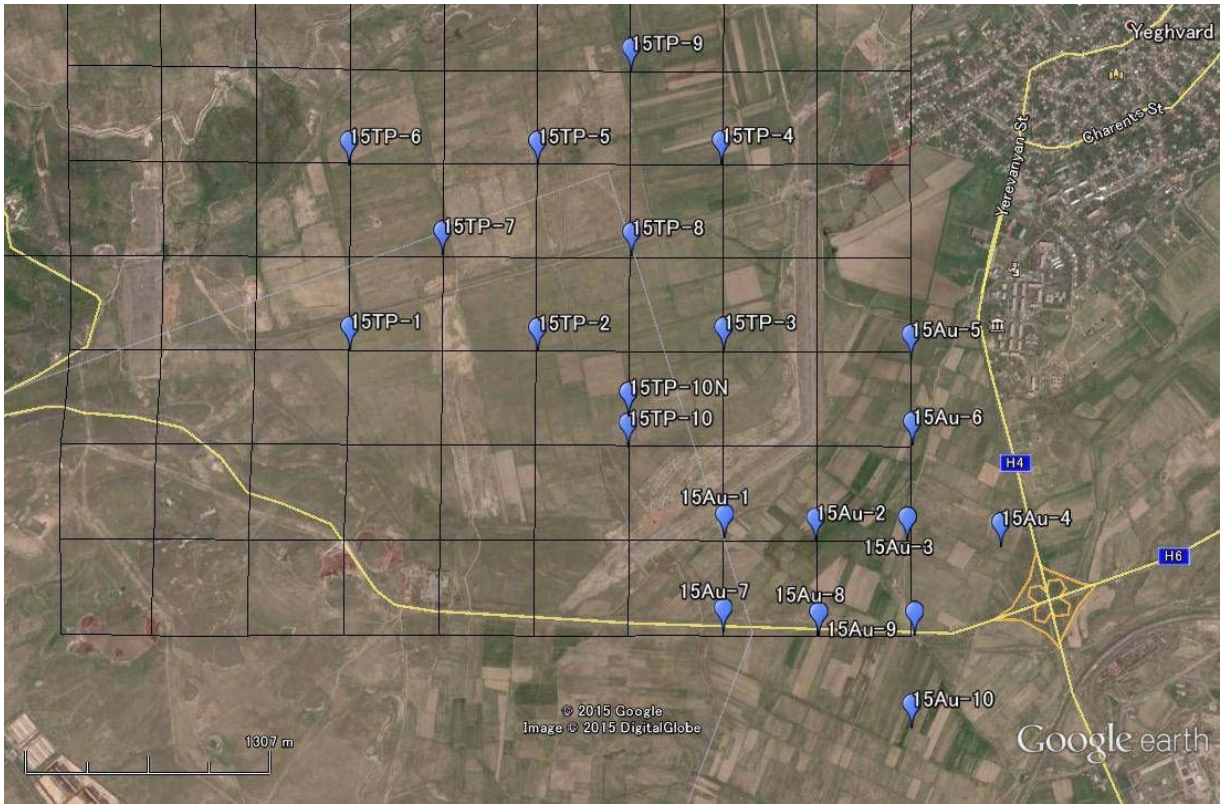


Figure 4-3-4.1 Location Map of Survey Points

(b) Typical features in the test-pit excavation

Test Pit ; 15TP-5

Depth (m)	Color	Classification etc.	Moisture content	Cohesion
	greyey black	top soil		
0.5	yellowish blown	silt (SM)	low	a little
1.0				
1.5	black	coarse/volcanic sand		
2.0		sand-and-gravel	dry	
2.5				
3.0	yellowish blown	silty sand	low	almost non
3.5				
4.0				

Figure 4-3-4.2 Typical Test Pit Log and the Profile Photos

(c) Findings

1) The thickness of top soil ranges from 0.5m to 1.0m approximately, and the latter case is predominant. It takes on greyish black which comes from organic material.
2) Soil layer of silty sand with scarce cohesion to sandy silt with cohesion a little, which would be classified into SM in the unified soil classification system, is predominant in the soil so called "loamy sand or sandy loam".
3) Sometimes a thin sand-and-gravel layer or volcanic sand layer with the thickness of 0.5m to 1.0m is sandwiched; the continuity of them seems to be poor.
4) The soil layer of volcanic sandy silt/clay, which seems to be called "loam" in the ex-USSR investigation and of which characteristics is its light unit weight, appeared on rare occasions.
5) Any sedimentation formation could not be seen clearly in the soil layer. A soil clod with macro-porous vacant holes which suggested the eolian sediment formation was found only one time, and the alternation of thin deposits which suggested the aqueous sediment formation was found also only one time.
6) The soils on the test-pit wall were dried up except for the test-pit excavated in well-cultivated area or excavated in a vacant lot of borrow pit where the ground level was about 4 m below the ground surface around.
7) The location of test-pit 15TP-10 was shifted toward north by 100m approximately because of the rock formation appearing at the depth of 0.5m in excavation. This rock formation seems to be lava layer, which would be cracky so that considerations shall be requested in the reservoir planning.
8) The permeability coefficients by the pit method, the values of 10^{-3} cm/sec class, are larger apparently by 2 to 5 times than the ones, the values of 10^{-4} cm/sec class, by the cylinder method.
9) The same kind of soil layer was confirmed by the auger-drillings in the spare borrow area.

(2) In-situ falling test of sand-and-gravel

(a) Outline of the survey

Granular materials ranging from boulders/rocks to sand/soil such as sand-and-gravels or blasted weathered rocks segregate in granularity through being fallen down along a cliff slope; and there are deposits of sand-and-gravels on the northern slope outside of the reservoir that were used as the construction materials of existing dam bodies; and there exist cliffs as a vacant lot of quarry site. On the other hand, filter materials and rock/riprap materials are needed for the dam body materials of the zoned fill-type dam. Based on such circumstances and conditions, this in-situ falling test of sand-an-gravels was carried out in a manner of sand-and-gravels excavated from the vacant lot of quarry site being fallen down along the cliff left in the vacant lot. The location map of the survey point is shown in the Figure 4-3-4.3.

Figure 4-3-4.3 Location Map of the In-situ Falling Test

(b) Existing conditions of the sand-and-gravel

The sand-and-gravels exist as layers about 30 to 50 cm thick sandwiched by silty sand layers. Voids among gravels are filled completely by half-consolidated sand to silt, so that the sand-and-gravel layer can keep the overhang condition (refer to Figure 4-3-4.4).

Figure 4-3-4.4 Profile of the Sand-and-Gravel Layer

(c) Findings

1) Due to the alternate structure between the sand-and-gravel layers and silty sand layers, the prepared materials for testing were not uniform in gradational conditions. The first materials fallen were silty sands; next were sand-and-gravels. The sand-and-gravels did not roll down on the slope and not segregated because of the interruption of silty sands (refer to Figure 4-3-4.5).

Figure 4-3-4.5 Conditions of Sand-and-Gravel

2) While relatively uniform sand-and-gravels kept rolling down; and the segregation proceeded shown in Figure 4-3-4.6 and 4-3-4.7.

Figure 4-3-4.6 Mounded Sand-and-Gravels after Excavation

Figure 4-3-4.7 Segregation through Falling

3) Large size of cobbles suitable for the rip-rap materials with the grain size of 40 cm or so were few.
4) The materials to be fallen down should be uniform as the mixture of sand-and-gravel and silty sand excavated at the same time. A mass of silty sand interfere the segregation of sand-and-gravel.

(3) Test-pit excavation survey of sand-and-gravel

(a) Outline of the survey

According to the achievement of geological investigations done in the ex-USSR era, the area with the deposits of sand-and-gravel extends widely on the hills north side to the reservoir; and there extend widely the vacant lots of quarry site from where the dam body materials of existing dams were excavated. To obtain more information about these sand-and-gravels, 3 test-pits were excavated and samples for the sieving test were taken out. The locations of these test-pits are as shown in Figure 4-3-4.8.

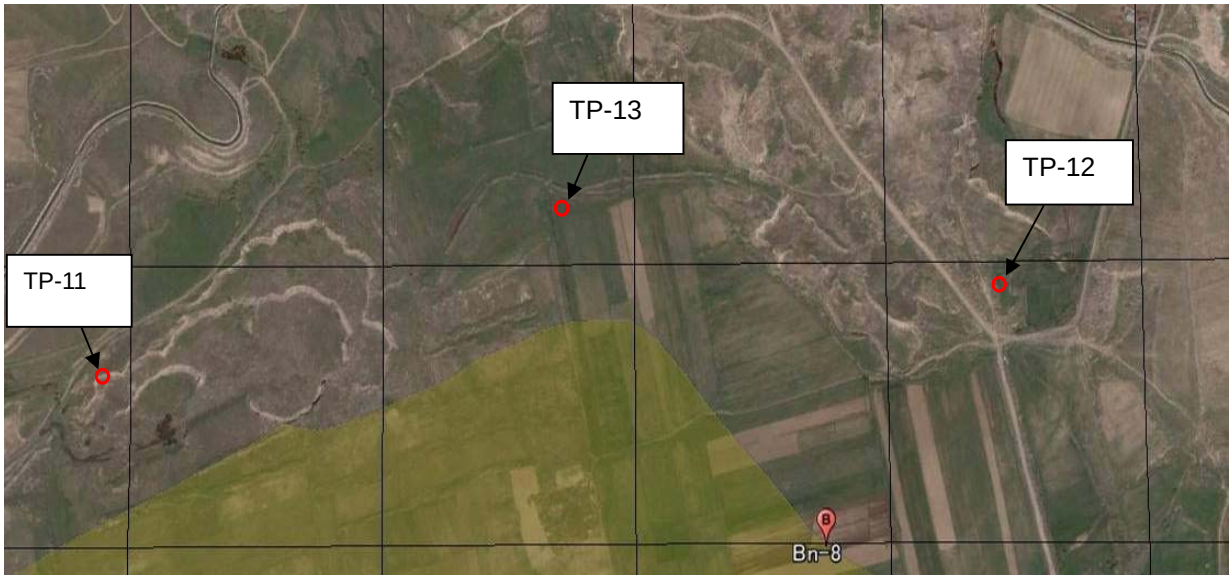


Figure 4-3-4.8 Location Map of Test-pits

(b) Conditions and findings

1) Area with the predominance of volcanic sand:

From the point excavated as TP-11 in the original plan, since thick layers of volcanic sand appeared with a thin sand-and-gravel layer at the top, sampling was canceled. The area which was classified to have the sand-and-gravel layer in the existing geological plane map must be carefully treated. The existing degree of sand-and-gravel differs much even if classified as the sand-and-gravel zone (This area is revised to be “Basaltic andesite lava” zone in the new geological plane map.) as shown in Figure 4-3-4.9 and 4-3-4.10

Figure 4-3-4.9 Test-pit Excavated into Volcanic Sand

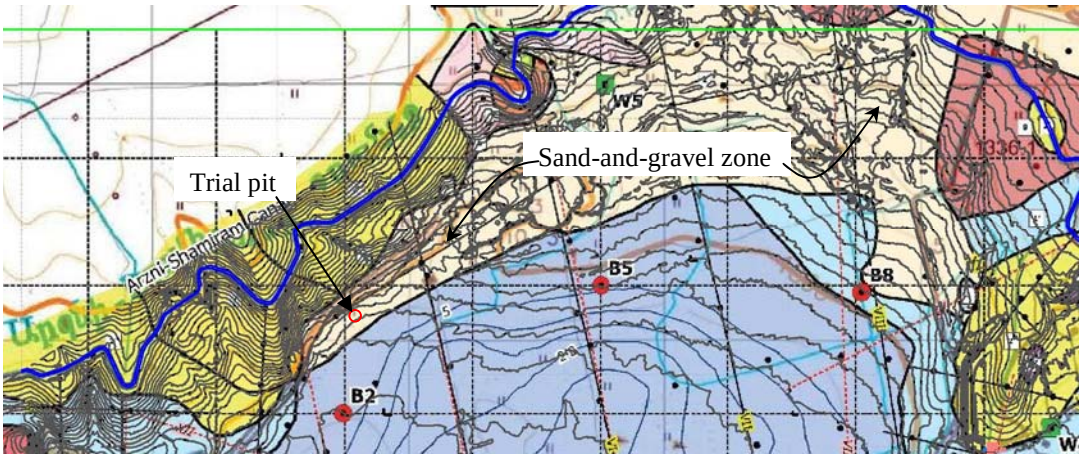


Figure 4-3.4.10 Sand-and-Gravel Zone and the Location of the Trial Test-pit

2) TP-11; Half-consolidated sand-and-gravel layer:

Under the naming of TP-11 to the cliff left in the old quarry site of sand-and-gravel, sampling was done out of the materials scraped down from the cliff surface. The sand-and-gravel layer was composed of cobbles to gravels and the silty sand and was half-consolidated totally as shown in Figure 4-3-4.11.

Figure 4-3-4.11
Half-consolidated sand-and-gravel

3) TP-12, TP-13; Sand-and-gravel layer rich with silty sand:

The layer was rich with silty sand. The maximum gravel size was 15 cm approximately as shown in Figure 4-3-4.12.

TP-12

TP-13

Figure 4-3-4.12 Sand-and-gravel with Rich Silty Sand

(4) Scoria with a possibility to be utilized as the filter material

There are reddish brown high cliffs along the regional road, H6 line, on the hill south side to the reservoir from where Scoria has been being mined for the use of pumice blocks to the fine portion and heat insulating layer of the building roof to the coarse portion. This scoria layer is estimated geologically to exist under the uppermost lava layer and extend widely with about 20 meter of the layer thickness. To examine the possibility of utilizing this scoria as the filter material, sampling was done in the mining site. The layer's feature and the locations of scoria cliffs around the reservoir are as shown in Figure 4-3-4.13 to 4-3-4.15.

Figure 4-3-4.13 Outcrop of Scoria

Figure 4-3-4.14 Mining Site of Scoria

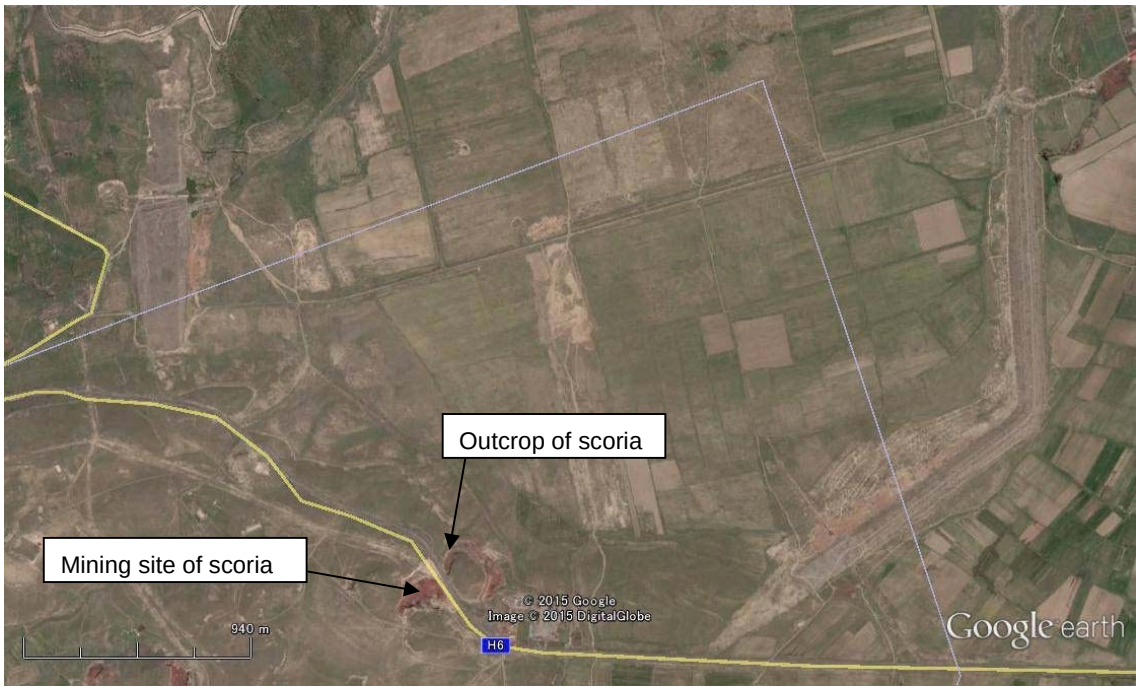


Figure 4-3-4.15 Location Map of Scoria Site

(5) Pit excavation survey on the slopes

(a) Purpose of the survey

The surveys and soil tests done in 2015 were the ones to the sandy loam or loamy sand lying thick in the reservoir basin area. On the other hand, the study result at the ITR was that constructing the suitable scale dikes at along the foot of the north and the south slopes became more economical than extending the anti-infiltration works with slope protection works wide and long on the gentle slopes of both the north and the south sides. This interim study result might change according to the cost of the anti-infiltration work, which would be decided through the additional soil tests to the bentonite-soil mixture and the soil-cement, but it is necessary to grasp the cover layers conditions as the dike materials to conduct the further study in terms of the reservoir shape or the way how to provide the reservoir with anti-infiltration works. Based on such recognition, the pit excavation surveys were conducted mainly on the slopes of both sides. The surveys are composed of three (3) phases.

Phase-1; Pit excavations ranging from TP.21 to TP.47 were done on the north and the south slopes or terraces in the reservoir to grasp the cover layers conditions.

Phase-2; Pit and trench excavations ranging from TP.48 to TP.55 were carried out on the south slope of the reservoir to observe the condition of the welded tuff stratum. The most impotent problem is how to design the anti-infiltration works against the back pressure caused by the ground water or seepage water and then how to provide the slope surface behind the anti-infiltration work with the drainage system; but if the welded tuff stratum is impervious, there is no way to release the water gathered by the drainage system. To this matter, the quantity of water that might be brought by the snow melting or heavy rain is related much. This survey was conducted in late February, which was the snow melting season, and the condition of welded tuff stratum, snow melting condition on the south slope of the reservoir and the seepage condition of melted water on to the welded tuff surface were observed.

Phase-3; Pit excavations ranging from TP.56 to TP.71 were done on the slopes and the terraces of the north side of the reservoir to grasp the lying conditions of sand-and-gravel as its too much disposal left

in the old quarry site made the engineer unconfident in the available quantity of sand-and-gravel for the future construction works.

(b) Findings

[Phase-1 survey]

1) From the upstream area of Dam No.1 to the northern slope composed of low hills, the geological formation of the ground surface is made of welded tuff. On the reservoir basin, the surface is fresh; on the slope, weathered materials lie. (TP.21 - TP.23)

2) Along the foot of the north slope of the reservoir, the road made of sand-and-gravel is provided as the temporary work for construction. (TP.24, TP.26, TP.29, TP.30)

3) The north side slope to this road has the rock formation in case of the ground having no trees (TP.25, TP.28), a thick soil layer in case of the fruit farm existing (TP.27) and sand-and-gravel deposits or gravelly soil layers in other case even though the ground surface is full of lava rocks (TP.30, TP.31).

4) On the low terraces at the north-eastern corner of the reservoir, the sand-and-gravel layer appears at the depth of 2m to 3m (TP.32 - TP.38).

5) The low hill in front of Dam No.2 is covered with “Surface Gravel” geologically of which content is made of soil and gravel mixture originated from lava and welded tuff (TP.39).

6) The ground surface of the south slope of the reservoir is covered with “Surface Gravel” geologically of which content is made of soil and gravel mixture with the layer’s thickness to be 2m to 3m, where gravels are predominant usually except the area cultivated as the farmland. Gravels are originated mainly from welded tuff (TP.40 - TP.47).

7) As the conclusion to say, it is possible to construct the pervious embankment anywhere at the foot of the slope or on the slope by gathering gravelly soils from its surrounding area.

[Phase-2 survey]

1) From the bottom of all the pits or trenches excavated, welded tuff stratum appeared at the depth of 0.5m to 3m.

2) Any seams or cracks were not found on the surface of the welded tuff stratum, so that the welded tuff stratum supposed to be impervious due to the massive and consolidated condition in spite of the composition of sandy particles.

3) The top soil layer 0.3m thick seemed to be wet; the lower layer of “Surface Gravel” was dry and dusty in spit of the snow melting had already started (date of survey; 22/2/2016).

[Phase-3 survey]

1) On the low terraces at the north-eastern corner of the reservoir, the sand-and-gravel layer appears at the depth of 2m to 3m (TP.56 - TP.61).

2) On the slopes north side of the temporary road, the fundamental geological formation is composed of the base layer of pyroclastic flow or lava and the its coverage layer of moraine deposit, so that the existence of sand-and-gravel, i.e. moraine deposit, seems to be unstable (TP.62 - TP.68).

3) At TP.67, the excavated material was wet and damp due to high moisture content condition and the water seeping out on to the bottom of the pit was observed. The water was supposed to be originated from the snow melted water gathered to the swamp below the water-way bridge of the

Arzni-Shamiram canal. This fact must be emphasized to the design of anti-infiltration work.

4) From beneath the ground left in the old quarry site, a layer of pyroclastic flow, a thick sand layer and a volcanic sand layer appeared. It would be supposed to be difficult to obtain sand-and-gravel from the old quarry site area.

5) As the conclusion to say, the area extending from the gentle slope to the low terrace between the eastern and the western old quarry sites are preferable as the new quarry site for sand-and-gravel than the hilly area extending north side to the old quarry sites.

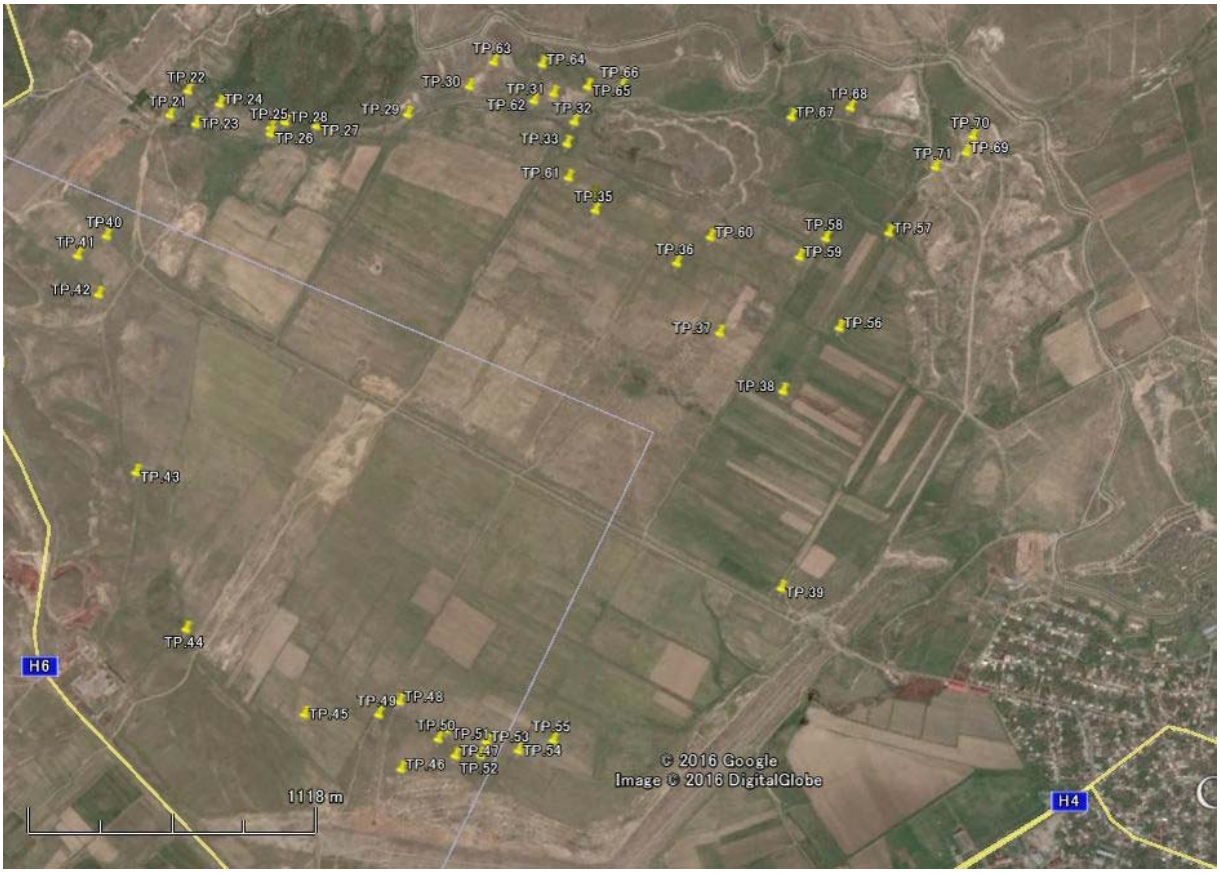


Figure 4-3-4.16 Location Map of the Pit Excavation

Welded tuff in front of Dam No.1 (TP.21)

Surface gravel on the foot slope of north hill (TP.24)

Basaltic Andesite lava on the north slope (TP.28)

Sand-and-gravel composing the construction road lying along the foot of the north slope (TP.29)

Sand-and-gravel on the northern low terrace (TP.33)

Surface gravel on the south-eastern end of the reservoir (TP.40)

Surface gravel on the south slope (TP.44)

Welded tuff on the south slope (TP.48)

Figure 4-3-4.17 Representative Profiles of the Excavated Material

4-3-5 Laboratory Soil Test

(1) Outline

Two (2) series of laboratory soil tests were conducted in this preparatory survey stage. One was to the disturbed soil samples of sandy loam and sand-and-gravel obtained from the test-pits excavated in the reservoir bottom and surrounding area, of which locations are shown in Figure 4-3.4.1 and Figure 4-3.4.8, under the purpose of grasping the characteristics of impervious materials and sand-and-gravels and examining the possibility of the soil's imperviousness being improved by adding and mixing bentonite or cement. The other was the ones conducted additionally to study the details about the imperviousness improvement by mixing sandy loam or sand-and-gravel with bentonite or cement. The former one shall be called "laboratory test phase-1" in this report and the latter "laboratory test phase-2".

(2) Laboratory test phase-1

(a) Tests to impervious materials (sandy loam)

1) Physical soil test and standard compaction test

The test results are summarized on the Table 4-3-5.1.

Table 4-3-5.1 Summary of Physical Soil Tests and Standard Compaction Test to Sandy Loam

	Specific Gravity ρs (g/cm3)	Moisture Content Wn (%)	Atterberg Limit (%)			Grain Size Distribution (%)				Standard Compaction	
			Liquid Limit WL	Plastic Limit Wp	Plastic Index Ip	Gravel 2~75mm	Sand 0.075~ 2mm	Silt 0.005~0.075mm	Clay <0.005 mm	Maximum Dry Density (g/cm3)	Optimum Moisture Content (%)
15TP-1u	2.64	13.11	22.5	17.1	5.4	0.9	34.9	31.2	33.0	1.60	21.2
15TP-1d	2.59	19.50	28.5	24.5	4.0	0.0	17.4	40.5	42.1	1.53	26.0
15TP-2u	2.58	16.48	33.9	23.9	10.0	0.2	7.7	32.8	59.3	1.56	23.0
15TP-2d	2.55	17.83	28.6	25.3	3.3	0.1	34.0	46.1	19.8	1.45	26.3
15TP-3u	2.57	15.15	30.0	20.2	9.8	0.6	44.3	19.5	35.6	1.60	22.2
15TP-3d	2.66	8.97	-	-	-	1.0	47.8	38.8	12.4	1.70	16.5
15TP-4u	2.57	22.56	-	-	-	6.2	29.8	39.0	25.0	1.60	20.8
15TP-4d	2.55	28.73	-	-	-	0.6	30.2	45.6	23.6	1.41	24.8
15TP-5u	2.63	12.30	21.9	17.5	4.4	4.5	31.5	41.9	22.1	1.71	17.6
15TP-5d	2.67	8.01	-	-	-	6.6	44.9	35.8	12.7	1.66	19.2
15TP-6u	2.64	8.51	20.1	16.8	3.3	2.2	28.4	47.7	21.8	1.73	16.4
15TP-6d	2.60	14.63	-	-	-	7.0	43.9	31.5	17.5	1.81	13.0
15TP-7u	2.58	25.20	30.2	27.6	2.6	0.3	21.9	45.1	32.7	1.42	22.7
15TP-7d	2.49	25.56	34.1	29.5	4.6	1.3	9.5	45.3	43.9	1.45	25.5
15TP-8u	2.59	19.12	38.5	22.2	16.3	0.0	3.4	39.2	57.4	1.49	24.0
15TP-8d	2.64	13.38	24.5	20.5	4.0	0.5	13.1	44.6	41.8	1.65	18.7
15TP-9u	2.60	10.28	25.0	20.0	5.0	0.5	13.6	53.5	32.4	1.64	20.5
15TP-10u	2.53	8.08	23.8	20.0	3.8	17.4	36.1	21.9	24.5	1.66	18.2
15TP-10d	2.52	12.37	-	-	-	1.6	39.8	42.7	15.9	1.44	23.6

[Moisture content]

The moisture contents range from 8.01 % to 28.73%. Samples taken from the upper wall, u-group, indicate comparatively the lower moisture content percentage than the ones taken from the lower wall, d-group.

Most of the soils have the field moisture content lower than the optimum moisture content by 5% to 12% except for the some exceptional ones with the field moisture content higher than the optimum moisture content by 1% to 2%, so that to conduct the compaction work to the soils with optimum moisture content condition, a large amount of water shall be needed.

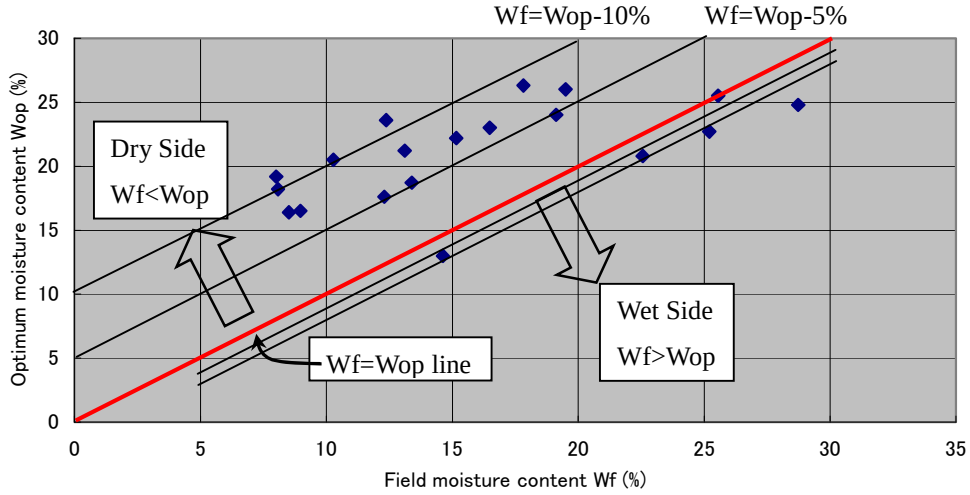


Figure 4-3-5.1 Relationship between Field Moisture Content and Optimum Moisture Content

[Specific gravity]

The specific gravities range from 2.49 to 2.67. Considering the value of common soil to be around 2.60 to 2.75, the low values of specific gravity around 2.49 or so would be related to its origin, i.e. volcanic ash. An obscure positive-relativity exists between the specific gravity and the maximum dry density in the standard compaction test according to Figure 4-3-5.2.

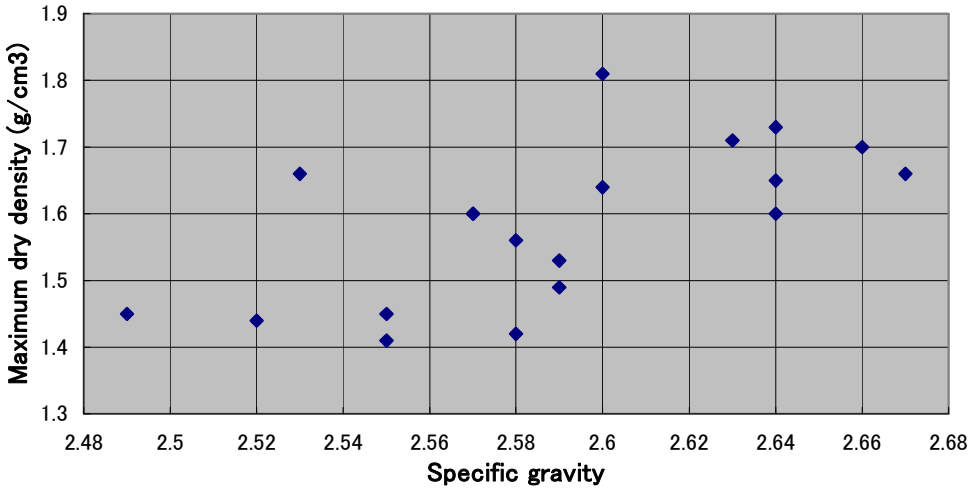


Figure 4-3-5.2 Relationship between Specific Gravity and Maximum Dry Density

[Grain size distribution test]

The results of the grain size distribution test are shown below. Most of the samples contain fine particles more than 50%, but it ranges wide from 50% to 95%.

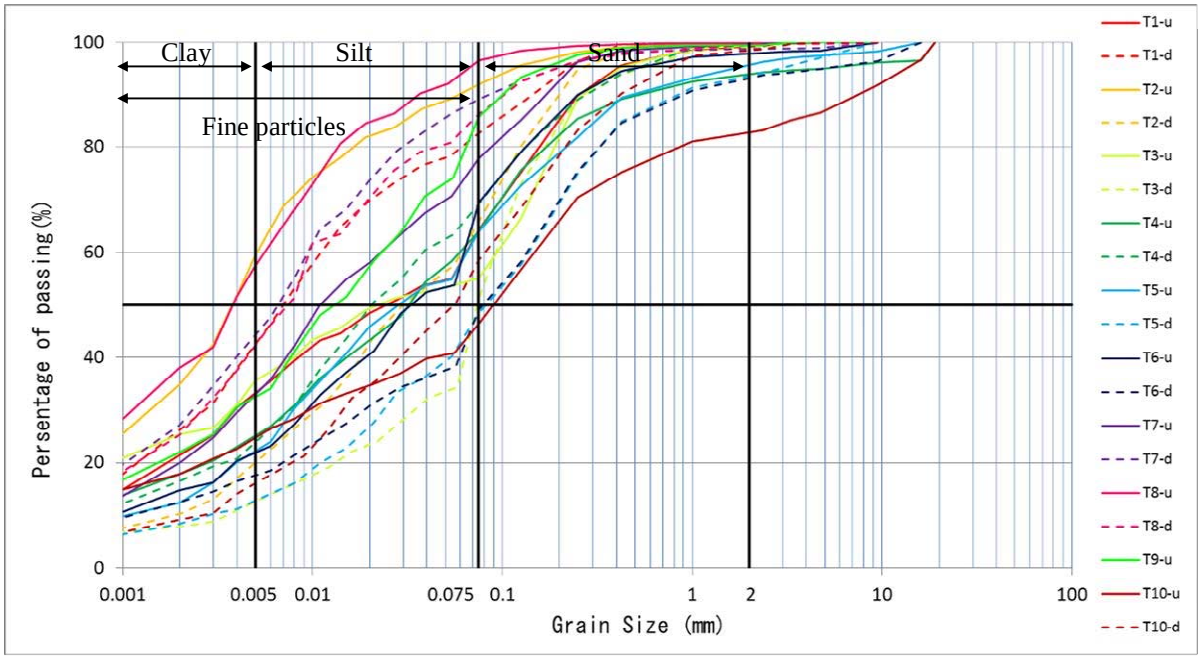


Figure 4-3-5.3 Grain Size Distribution Curve of Sandy Loam

[Atterberg limit test]

The values of liquid limit range from 20.1% to 38.5%; Plastic limit From 16.8% to 25.3%. Field moisture contents are situated lower than the plastic limits so that these soils are considered to be in "Semi solid" condition in the field. Therefore, water must be added when being used as the embankment materials; but careful work shall be required at that time because the small PI values ranging from 3.3 to 16.3 shall lead the soils into liquid condition under excessive water being added. The relationship between Atterberg limits and field moisture contents is shown in Figure 4-3-5.4.

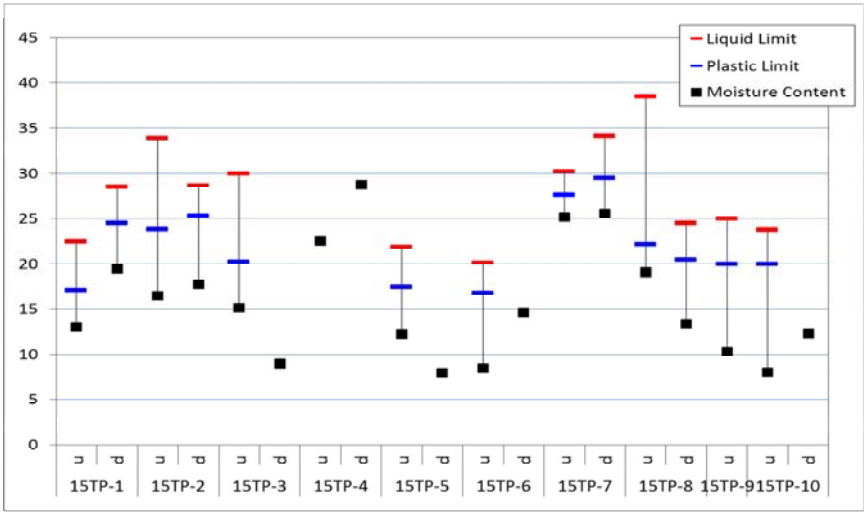


Figure 4-3-5.4 Relationship between Atterberg Limits and Field Moisture Contents

[Standard compaction test]

The compaction curves obtained as the results of the test are shown in Figure 4-3-5.5. The coarser soils with a wide range of particle size generally form sharp curves and tend to indicate higher maximum dry densities and lower optimum moisture contents. On the other hand, the finer soils with a narrow range of particle size form flat curves and tend to indicate lower maximum dry densities and high optimum moisture contents.

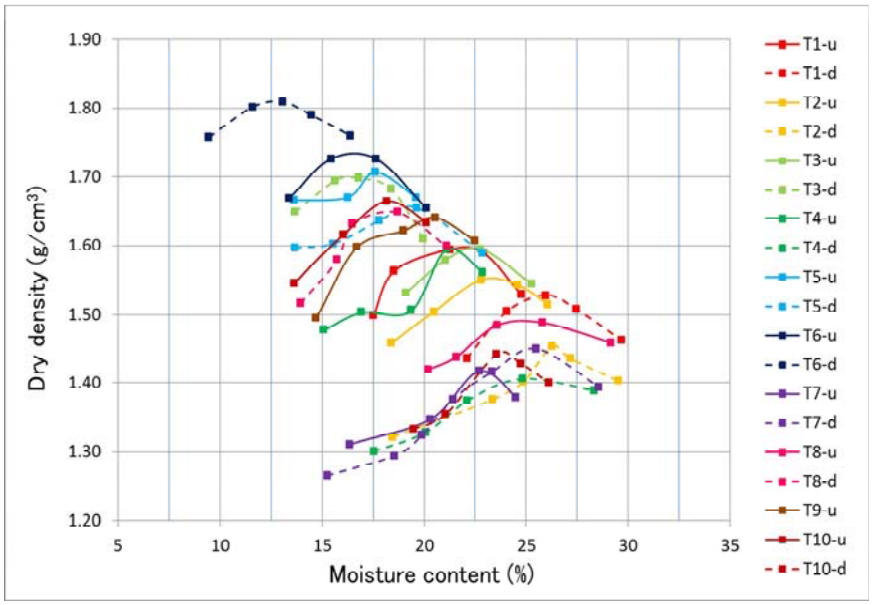


Figure 4-3-5.5 Compaction Curves of Sandy Loam

An obscure positive-relativity exists between the content percentage of sand and the maximum dry density as shown in Figure 4-3-5.6.

Sample number [u] indicates the sample to be taken from the upper wall at the depth of around 1.5 m. and Sample number [d] indicates the sample to be taken from the lower wall at the depth of around 3 m.

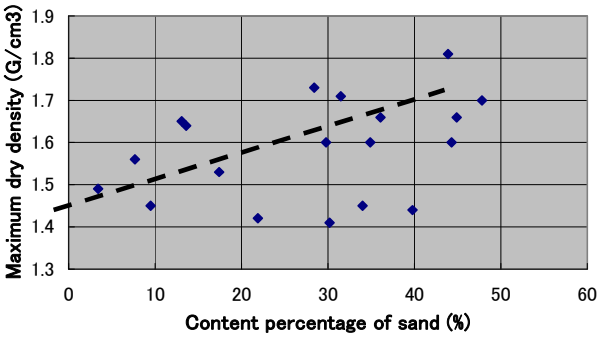


Figure 4-3-5.6 Relationship between Sand % and ρdmax

2) Mechanical soil test

The results of mechanical soil test done to the five samples are summarized as shown in Table 4-3-5.2.

Table 4-3-5.2 Summary of the Mechanical Soil Tests

Point	Sample name	Standard Compaction		Permeability			Direct shear test				Consolidation test						Triaxial test (UU)				Triaxial test CU-bar	
				Specimen condition		Result	Specimen condition		Result		Specimen condition		% of settlement				Specimen condition		Result		Result	
		OMC, %	ρ_{dmax}, t/m^3	ρ_d, t/m^3	M.C., %	K, cm/sec	ρ_d, t/m^3	M.C., %	C, KN/m^2	φ, ^{o}	ρ_d, t/m^3	M.C., %	50 KPa	100 KPa	200 KPa	400 KPa	ρ_d, t/m^3	M.C., %	C, KN/m^2	φ, ^{o}	C, KN/m^2	φ, ^{o}
A point	**T-1d**	26.0	1.53	1.53	26.0	**4.3 x 10^{-7}**	1.53	26.0	**12.7**	**23.3**	-	-	-	-	-	-	-	-	-	-	-	-
	T-2up	23.0	1.56	1.56	23.0	**3.2 x 10^{-7}**	1.56	23.0	**7.5**	**22.3**	-	-	-	-	-	-	-	-	-	-	-	-
	T-4d	24.8	1.41	1.41	24.8	**2.9 x 10^{-6}**	1.41	24.8	**11.9**	**23.4**	-	-	-	-	-	-	-	-	-	-	-	-
	T-5d	19.2	1.66	1.66	19.2	**2.3 x 10^{-6}**	1.66	19.2	**7.9**	**24.8**	-	-	-	-	-	-	-	-	-	-	-	-
	T-10up	18.2	1.66	1.66	18.2	**5.2 x 10^{-7}**	1.66	18.2	**23.9**	**25.5**	-	-	-	-	-	-	-	-	-	-	-	-
B point	**T-1d**	26.0	1.53	1.48	29.0	**3.5 x 10^{-7}**	1.48	29.0	**11.4**	**24.3**	1.48	29.0	**3.29**	**4.45**	**5.56**	**7.68**	1.48	29.0	**12**	**10.2**	**26**	**24.7**
	T-2up	23.0	1.56	1.51	26.0	**4.7 x 10^{-7}**	1.51	26.0	**6.5**	**21.0**	1.51	26.0	**2.22**	**3.24**	**5.09**	**7.29**	1.51	26.0	**13**	**16.7**	**34**	**23.7**
	T-4d	24.8	1.41	1.37	29.0	**2.0 x 10^{-6}**	1.37	29.0	**8.6**	**22.4**	1.37	29.0	**2.38**	**3.25**	**5.50**	**6.67**	1.37	29.0	**13**	**24.7**	**35**	**27.9**
	T-5d	19.2	1.66	1.61	22.0	**1.7 x 10^{-6}**	1.61	22.0	**7.7**	**24.8**	1.61	22.0	**2.30**	**3.16**	**4.77**	**7.29**	1.61	22.0	**3**	**17.2**	**10**	**33.8**
	T-10up	18.2	1.66	1.61	21.0	**1.9 x 10^{-6}**	1.61	21.0	**15.6**	**23.9**	1.61	21.0	**2.04**	**3.25**	**4.87**	**6.97**	1.61	21.0	**8**	**25.2**	**28**	**30.1**
C point	**T-1d**	26.0	1.53	1.40	19.0	**1.3 x 10^{-5}**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	T-2up	23.0	1.56	1.37	17.8	**2.8 x 10^{-6}**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	T-4d	24.8	1.41	1.33	23.0	**1.1 x 10^{-5}**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	T-5d	19.2	1.66	1.64	15.5	**1.1 x 10^{-5}**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	T-10up	18.2	1.66	1.54	13.5	**2.9 x 10^{-5}**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

[Grouping and selection of representative sample]

The samples obtained from the test-pits were grouped into five (5) groups according to the plasticity index (P.I.) and the content percentage of fine particles' portion as shown in Table 4-3-5.3 and one sample was chosen as the representative from each group.

Table 4-3-5.3 Grouping of the Samples and Selection of the Representative Sample

Group	Characteristics	Samples belonging to	Representative sample
G-1	Low P.I. Medium - Low percentage of 0.005mm content	1u, 2d, 5u, 6u, 10u	15TP -10u
G-2	Low P.I. High percentage of 0.005mm content	1d, 7u, 7d, 8d, 9u	15TP -1d
G-3	Medium P.I High-Medium percentage of 0.005mm content	2u, 3u, 8u	15TP -2u
G-4	Non Plastic Low percentage of 0.005mm content	3d, 5d, 6d	15TP -5d
G-5	Non Plastic Medium percentage of 0.005mm content	4u, 4d, 10d	15TP-4d

[Conditions of specimen to conduct the tests]

Three (3) conditions of soil specimen were defined as follows for the mechanical soil tests; and the density/mass and the moisture content of each specimen, which was made up through compaction, were adjusted to the defined value according to the compaction curve.

Point-A: Dry density condition = Maximum dry density, Moisture content condition = Optimum moisture content

Point-B: Dry density condition = Maximum dry density×0.97 (= relative density: D-97%), Moisture content condition = Moisture content corresponding to D-97% on the compaction curve in wet side

Point-C: Dry density condition = Maximum dry density×0.97 (= relative density:D-97%), Moisture content condition = Moisture content corresponding to the intersection point between the D-97% line and the saturation rate curve of 85%

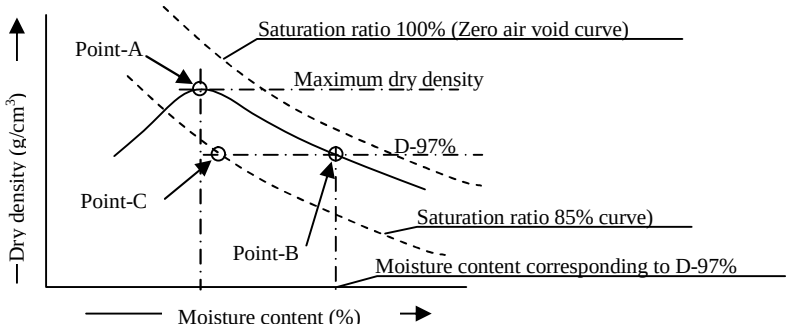


Figure 4-3-5.7 Testing Point (Specimen Conditions)

[Direct shear test]

Direct shear tests are conducted at two (2) testing points (Point-A and point-B) per one sample. In terms of shearing strength factors, the shear resistance angle (φ) ranges from 21.0° to 25.5° and cohesion (C) from 7.0 kN/m2 to 15.0 kN/m^2 approximately in Point B's case. In all of the samples, cohesion (C) at Point A tends to be higher than the one at Point B as shown in Figure 4-3-5.8

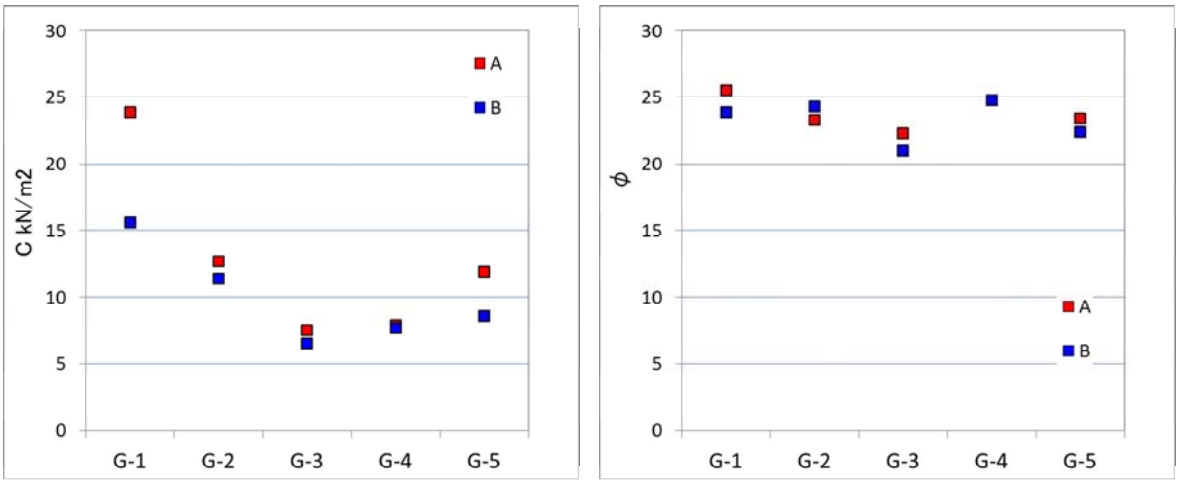


Figure 4-3-5.8 Result of Direct Shear Test

[Triaxial UU and CU-bar test]

Triaxial tests are conducted at one (1) testing point, Point-B, per one sample considering the wettest-side condition in moisture content making the specimen the weakest in shear strength comparing with other specimens with the same dry density level. The triaxial UU test is conducted to the specimen under unconsolidated and undrained condition, so that the shear strength factors obtained through this test are used for the stability analyses of dam body under unconsolidated condition, i.e. dam body just after completion. The triaxial CU-bar test is conducted to the specimen under consolidated and undrained condition, so that the shear strength factors obtained through this test are used for the stability analyses of dam body under consolidated and partially-saturated condition, i.e. the embankment under usual operation. Figure 4-3-5.9 shows the results of Triaxle UU test and CU-bar test where the shear strength factors of CU-bar test are dominantly larger than the ones of UU test.

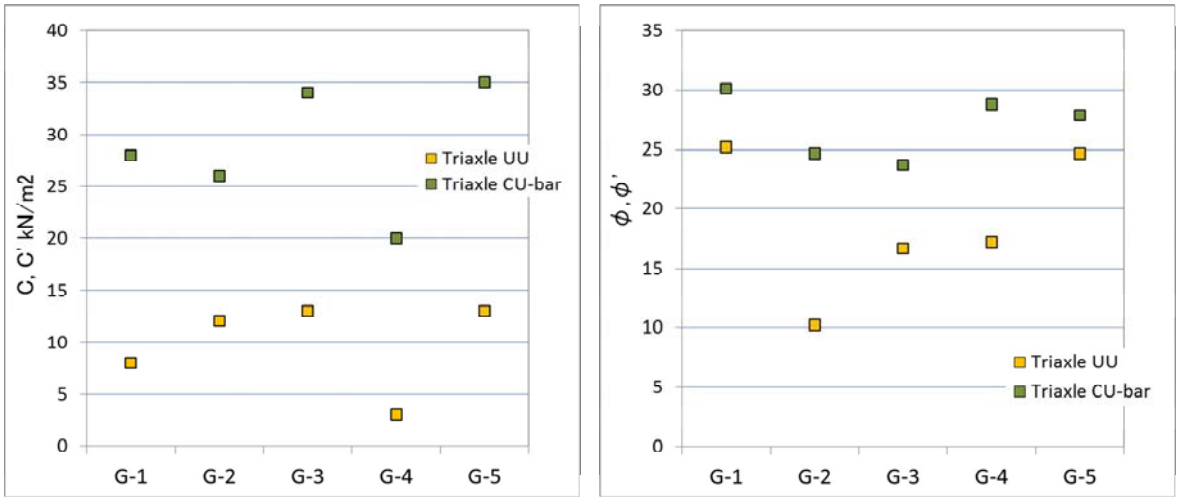


Figure 4-3-5.9 Results of Triaxial UU Test and Triaxial CU-Bar Test

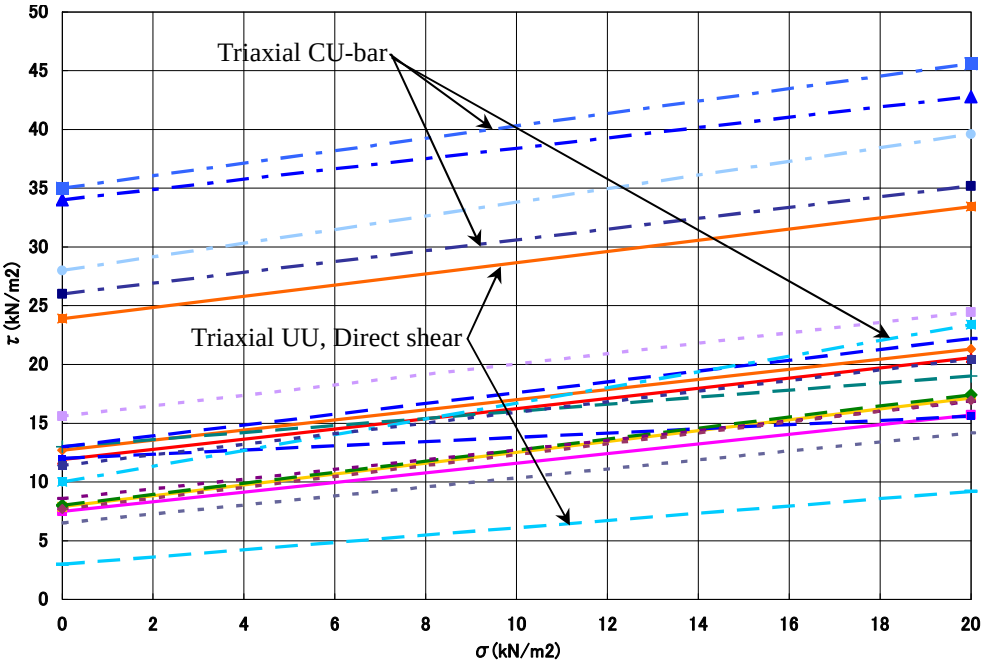


Figure 4-3-5.10 Summary of the Shearing Test Results

[Consolidation test]

Consolidation tests are conducted at one (1) testing point, Point B, per one sample considering the wettest-side condition in moisture content making the specimen's consolidation settlement maximum comparing with other specimens with other moisture content conditions and the same dry density level. In spite of the specimens having different void ratios, all specimens reach the consolidation yield stress at around 100 kPa and indicate almost the same compression index Cc as shown in Figure 4-3-5.11.

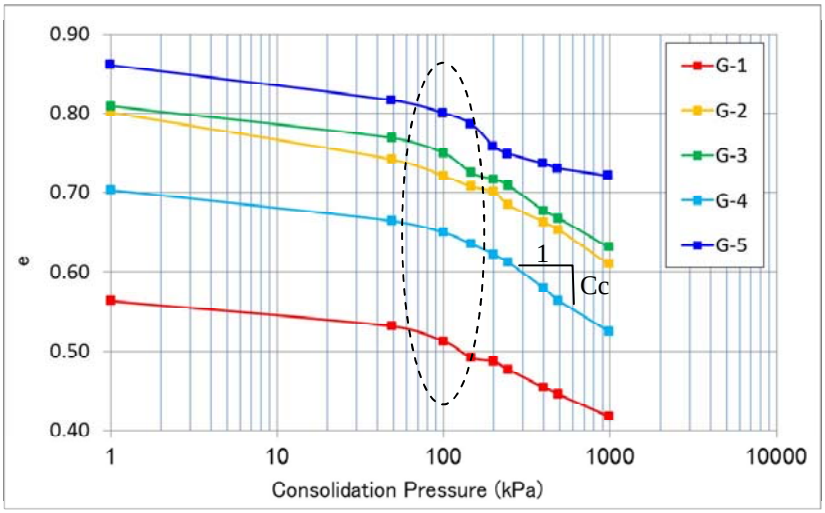


Figure 4-3-5.11 Result of the Consolidation Test

[Permeability test]

Permeability tests are conducted at three (3) testing points per one sample. The results are shown in Figure 4-3-5-12. As the impervious materials used to the core zone of the fill-type dams, the permeability coefficient required shall be in the order of 10^{-7} cm/sec or in the low level of 10^{-6} cm/sec order in the laboratory test considering the differential of permeability coefficient between in the laboratory and in the field. From this view point, the permeability coefficient values at C-point are

insufficient. The compaction under high compaction energy by a heavy compactor shall be needed to prevent such circumstances from appearing.

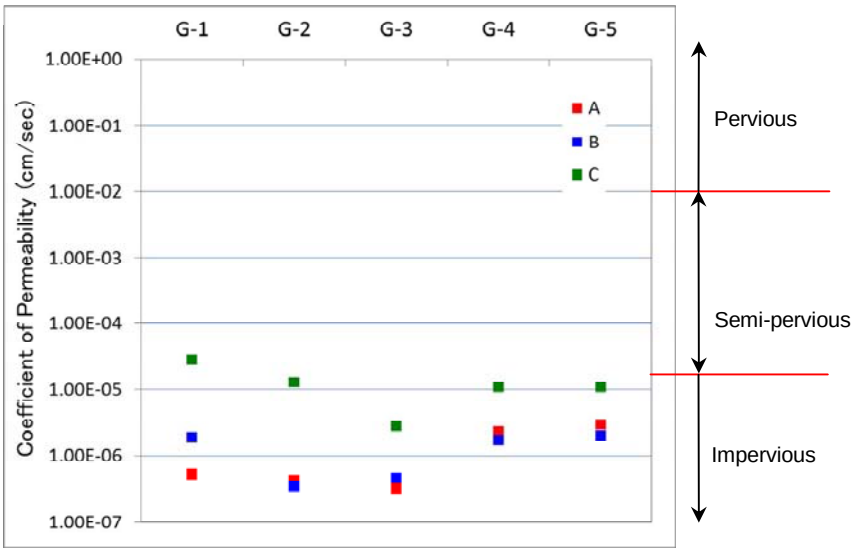


Figure 4-3-5.12 Results of the Falling Head Permeability Test

(b) Test to sand-and-gravels

In case of TP-11, the components are coarse sand, gravels and cobbles (refer to Figure 4-3-4.11). In case of TP-12 and TP-13, content percentage less or more than 10 % gives the observer the impression of fine, i.e. silt and clay, component being lower than the actual condition in the field (refer to Figure 4-3-4.12). This gap comes from the fact that the visual impression is caused by the volume ratio on one hand and the particle size distribution curve is drawn by the ratio of dry weight on the other hand. The fine portion of sand-and-gravels is composed of sandy loam which is volcanic soil and its dry weight is characteristically light. Therefore, we must be careful not to misunderstand the volume of fine portion to be merely 10 % or so based on the content percentage of the particle size distribution curve showing 10 % or so. Content percentage of 10 % of the particle size distribution curve might mean 30 % of fine portion in volume as shown in Figure 4-3-5.13.

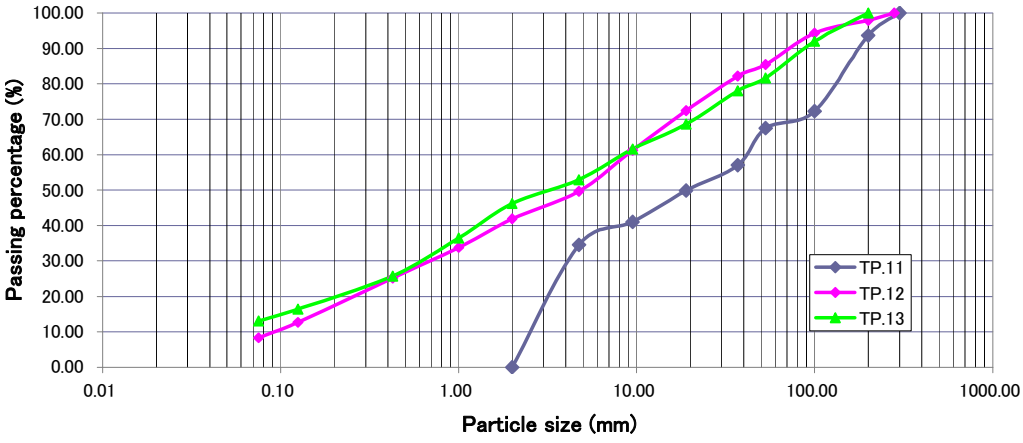


Figure 4-3-5.13 Particle Size Distribution of Sand-and-Gravels

(c) Possibility of the improvement of sandy loam's imperviousness

The possibility of the sandy loam being improved in its permeability coefficient by mixing cement or bentonite was confirmed as shown in Table 4-3-5.4.

Table 4-3-5.4 Result of Possibility Confirmation Test to be Improved by Mixing Cement/Bentonite

Sample name	k (cm/sec)	Sample name	k (cm/sec)
Soil + 3.4% cement	1.9×10^{-7}	Soil + 5.0% bentonite	3.9×10^{-7}
Soil + 6.8% cement	4.3×10^{-8}	Soil + 15.0% bentonite	8.3×10^{-7}
Soil + 10.0% cement	2.4×10^{-8}	Soil + 15.0% bentonite	4.3×10^{-7}

(3) Laboratory test phase-2

(a) Outline

Following the achievement of successful confirmation of the possibility for sandy loam's imperviousness to be improved by mixing with bentonite or cement as shown in Table 4-3-5.4, more detailed laboratory tests to the bentonite-soil mixture and the soil-cement were conducted aiming to determine the suitable soil's condition, the better additive substance and the appropriate mixing ratio of the additive substance. In case of soil-cement, the tests to estimate the durability such as the freezing/thawing test were conducted to judge the adequacy of soil-cement as the slope protection work. And also together with the pit-excavation survey (refer to 4-3-4 (5)), fundamental laboratory tests were conducted to the samples excavated from the pits. The contents of the laboratory tests planned and conducted are shown in Table 4-3-5.5 and the test results to the excavated materials are summarized in Table 4-3-5.6.

(b) Test results of bentonite soil mixture

The results are summarized in Table 4-3-5.7. Contrary to expectation, the permeability of sandy loam, sand-and-gravel fine and sand-and-gravel coarse could not be improved by mixing with bentonite. When recognizing that the mechanism of gravelly soils' permeability being improved by bentonite mixing depends on the swelling of bentonite powder that fills up the voids among gravelly soils' particle, it is assumed that the reason why bentonite mixing can not function is the voids among sandy loam's particle are too small for bentonite powder to intrude and swell. Room to pursue the permeability improvement by arranging the gradational conditions of sand-and-gravel is left but at this stage it has not yet been succeeded.

(c) Test results of soil-cement

The results are summarized in Table 4-3-5.8.

[Improvement degree in permeability by mixing with cement]

The permeability coefficients of raw materials are sandy loam: k=3.3 x 10^{-5} cm/sec, sand-and-gravel fine: k=5.3 x 10^{-4} cm/sec and sand-and-gravel coarse: k=3.4 x 10^{-5} cm/sec (refer to Table 4-3.5.6); and after being mixed with cement, all of them become k=7.7×10^{-7} cm/sec ~ 3.9 x 10^{-8} cm/sec (refer to Table 4-3.5.8) to the mixture ratio of cement 6 % - 10 % showing remarkable degree of improvement in imperviousness.

[Materials to be mixed with cement]

From the view point of the improvement degree and the stable test values in imperviousness, the material "sand-and-gravel coarse" is better than the others (refer to Figure 4-3.5.14). And also from the view point of unconfined compression strength, the material "sand-and-gravel coarse" is obviously superior to others (refer to Figure 4-3.5.15).

[Mixing ratio of cement]

The differential is small or not observed in the permeability coefficient between 8% and 10% of

mixing ratio of cement all through the cases of “cured”, “not cured” and “freezing/thawing” of falling head permeability tests (refer to Figure 4-3.5.14) though clear differentials are recognized in unconfined compression strength (refer to Figure 4-3.5.15). It would be the safety side decision to adopt 10% of mixing ratio at this stage but the final answer shall be given considering the quality variation based on the further laboratory test in future.

[Importance of curing]

The influence of specimens being cured or not being cured appears as the differential of two orders, i.e. from 10^{-8} cm/sec order to 10^{-6} cm/sec order in the permeability coefficient (refer to Figure 4-3.5.14), so that it would be said that the curing is very important at the construction stage and that the design permeability coefficient of soil-cement shall be decided considering the deferential of curing conditions between in the laboratory and in the field.

[Durability of soil-cement]

Based on the test results of Slaking Test and Sodium Sulfate Soundness Test, soil-cement made of materials “sand-and-gravel fine” and “sand-and-gravel coarse” shall be estimated to have as stable enough quality as the coarse aggregate for concrete provided the mixing ratio 8% or 10% of cement is assured (refer to Figure 4-3.5.16, Figure 4-3.5.17). Therefore, it would be said that a series of test conducted this time could make it clear for the soil-cement to be available not only for the anti-infiltration work but also for the slope protection work though it is a matter to study what meaning the distinct differential in unconfined compression strength between 8% and 10% of the mixing ratio have in future.

Table 4-3-5.5 Contents of Laboratory Tests Planned and Conducted

Test item \ Sample name	Pit	Sandy loam	Sand/ gravel	Bentonite-soil mixture									Soil-cement									Additional		Surface gravel			Total
				sandy loam mix			sand/gravel fine			sand/gravel coarse			sandy loam mix			sand/gravel fine			sand/gravel coarse			soil-cement		South		North	
				7.5*	10.0	12.5	7.5*	10.0	12.5	7.5*	10.0	12.5	6.0	8.0	10.0	6.0	8.0	10.0	6.0	8.0	10.0	Portland 8%,,7days	slag × 2 type 8%,10%,7days	raw	cement mix	raw	
Excavations by a backhoe		1	4	(backhoe: 1 day)																							1
Sampling by big polyethylene bag		1	4																								5
Transportation by a truck with crane		1 lump-sum																									1
Observation-pit excavations by a backhoe	20	(backhoe: 3 days)																					31(backhoe: 2 days)				5
Moisture content		1	4																					5		8	18
Specific gravity		1	4																					5		8	18
Particle size distribution (full)		1																						5			6
Sieving test			4																							8	12
Spe. gravity & Water absorption			4																					5		8	17
Sample arrangement							1			1						1			1								4
Atterberg limit		1	4	1	1	1	1	1	1	1	1	1												5			19
Standard compaction		1	2																				12	5	5		25
Falling head permeability		1	2																					5			8
Modified compaction			4																								4
																											0
Apparatus preparation: Falling head permeability		1 lump-sum																									0
Apparatus preparation: Unconfined compression		1 lump-sum																									0
Standard compaction				1	1	1	1		1	1	1	1	1	1	1	1		1	1	1	1						16
Preparatory compaction test								5									5										10
Preparatory permeability test								3									3										6
Falling head permeability (cured)													1	1	1	1	1	1	1	1	1				5		14
Unconfined compression (cured)													1	1	1	1	1	1	1	1	1				5		14
Falling head permeability (not cured)				2	2	2	2	2	2	2	2	2		1	1		1	1		1	1						24
Unconfined compression (not cured)		1			2			2			2			1	1		1	1		1	1						13
Freezing/ thawing: Falling head permeability		1			2			2			2		1	1	1	1	1	1	1	1	1						16
Freezing/ thawing: Unconfined compression		1			2			2			2		1	1	1	1	1	1	1	1	1						16
Observation in water					2			2			2																6
Slaking test													1	1	1	1	1	1	1	1	1				5		14
Soundness of aggregate			2										1	1	1	1	1	1	1	1	1				5		16
Hexavalent chromium dissolution (Color comparison method)															2			2			2	3	12				21
Hexavalent chromium dissolution (IC-PC method)																						3	12				15

Table 4-3-5.6 Test Results to the Excavated Materials and the Aranged Samples of Sand-and-Gravel

N	Sample name	Moisture content, %	Specific gravity	Specific gravity & water absorption			Atterberg limits			Proctor test		Permeability, cm/sec.
				Bulk Specific Gravity	Apparent Specific Gravity	Water absorption	Liquid limit, %	Plastic limit, %	Plastic index	Max. Dry density, g/cm^3	OMC, %	
1.	Sandy loam	9.88	2.66	-	-	-	21.0	17.4	3.6	1.75	16.5	3.3E-05
2.	TP-17	9.31	2.59	2.23	2.30	2.41	Non-Plastic			1.77	14.5	-
3.	TP-18	4.69	2.59	2.35	2.41	2.06	Non-Plastic			1.56	10.5	-
4.	TP-19	16.16	2.62	2.32	2.38	1.82	33.1	20.6	12.5	1.79	17.0	-
5.	TP-20	16.77	2.60	2.32	2.40	2.42	Non-Plastic			1.83	15.8	-
6.	TP-22	11.04	2.41	1.42	1.52	15.16	Non-Plastic			1.31	17.0	3.1E-04
7.	TP-35	10.76	2.61	2.15	2.21	2.50	Non-Plastic			1.88	14.5	1.8E-04
8.	TP-41	24.79	2.75	2.17	2.36	7.14	32.2	20.9	11.3	1.59	22.7	1.5E-06
9.	TP-45	19.41	2.57	1.25	1.33	23.32	Non-Plastic			1.48	23.1	3.6E-05
10.	TP-50	22.44	2.78	2.06	2.39	12.98	Non-Plastic			1.57	24.0	1.8E-04
11.	TP-57	16.51	2.60	2.25	2.32	2.34	-	-	-	-	-	-
12.	TP-58	13.36	2.64	2.34	2.41	1.94	-	-	-	-	-	-
13.	TP-59	7.52	2.65	2.42	2.49	1.87	-	-	-	-	-	-
14.	TP-60	8.76	2.65	2.27	2.33	2.05	-	-	-	-	-	-
15.	TP-62	16.17	2.40	2.20	2.26	2.40	-	-	-	-	-	-
16.	TP-65	13.64	2.48	2.26	2.37	3.65	-	-	-	-	-	-
17.	TP-68	17.53	2.61	2.16	2.36	7.20	-	-	-	-	-	-
18.	TP-69	10.34	2.70	2.32	2.44	3.54		-	-	-	-	-
19.	Sand/gravel fine	-	-	-	-	-	Non-Plastic			1.65	14.5	5.3E-04
20.	Sand/gravel coarse	-	-	-	-	-	Non-Plastic			1.76	16.5	3.4E-05

Table 4-3-5.7 Test Results of Bentonite Soil Mixture

N	Mixture	Compaction	Standard compaction		Permeability, cm/sec.		Unconfined compression strength, KPa		Atterberg limits			Observation in water
			Max. dry density, g/cm^3	OMC, %	Not cured	After freezing/ Thawing	Not cured	After freezing/ Thawing	LL, %	PL, %	PI	
1.	Sandy loam	D-100	1.75	16.50	3.3E-05	5.1E-04	374.5	947.2	21.0	17.4	3.6	-
2.	Sandy loam+7.5 % bentonite	D-100	1.65	20.20	1.8E-06	-	-	-	34.5	17.0	17.5	-
		D-97			2.2E-06	-	-	-				-
3.	Sandy loam+10 % bentonite	D-100	1.65	19.00	1.7E-06	4.4E-06	276.9	531.8	38.2	17.4	20.8	Destroyed after 0.5-1 hour
		D-97			2.6E-06	2.3E-06	88.1	487.8				
4.	Sandy loam+12.5 % bentonite	D-100	1.53	23.00	2.9E-06	-	-	-	43.5	18.4	25.1	-
		D-97			2.0E-06	-	-	-				-
5.	Sand/gravel fine	D-100	1.65	14.50	5.3E-04	-			Non-Plastic			-
6.	Sand/gravel fine+7.5 % bentonite	D-100	1.61	21.00	2.2E-05	-	-	-	39.5	39.2	0.3	-
		D-97			1.1E-06		-	-				-
7.	Sand/gravel fine+10 % bentonite	D-100	1.62	21.00	7.0E-06	1.7E-05	239.2	207.7	43.5	42.2	1.3	Destroyed after 0.5-1 hour
		D-97			4.7E-07	3.0E-05	66.1	192.0				
8.	Sand/gravel fine+12.5 % bentonite	D-100	1.56	24.00	2.5E-06	-	-	-	46.5	45.0	1.5	-
		D-97			4.6E-07	-	-	-				-
9.	Sand/gravel coarse	D-100	1.76	16.50	1.6E-05	-			Non-Plastic			-
10.	Sand/gravel coarse+7.5 % bentonite	D-100	1.65	19.20	3.1E-06	-	-	-	41.0	39.0	2.0	-
		D-97			1.8E-06	-	-	-				-
11.	Sand/gravel coarse+10 % bentonite	D-100	1.63	20.30	1.4E-06	4.4E-06	129.0	119.6	46.0	39.3	6.7	Destroyed after 0.5-1 hour
		D-97			1.4E-06	2.9E-06	75.5	179.4				
12.	Sand/gravel coarse+12.5 % bentonite	D-100	1.57	23.00	1.9E-06	-	-	-	49.0	40.6	8.4	-
		D-97			1.4E-06	-	-	-				-

Table 4-3-5.8 Test Results of Soil-cement

N	Mixture	Standard compaction		Permeability, cm/sec.			Unconfined compression strength, MPa				Degree of slaking, %	Sound-ness, %	Hexavalent chromium content, mg/L	
		Max. dry density, g/cm^3	OMC, %	Cured	Not cured	After freezing/ Thawing	Cured 7 day	Cured 28 day	Not cured	After freezing/ Thawing			By color comparison method	By Ion Chromatography
1.	Sandy loam + 6 % cement	1.67	19.00	3.6E-07	-	2.8E-07	1.7	2.7	-	2.3	4.1	11.3	0.11	-
2.	Sandy loam + 8 % cement	1.70	18.00	8.0E-08	2.2E-06	4.7E-07	2.4	3.1	3.4	3.5	3.5	6.4	0.10	0.1144
3.	Sandy loam + 10 % cement	1.71	17.61	7.0E-08	7.2E-06	3.0E-07	3.5	4.1	5.2	4.6	2.7	4.1	0.12	-
4.	Sand/gravel fine + 6 % cement	1.72	18.92	7.2E-07	-	1.0E-06	2.2	4.2	-	3.6	3.3	4.3	0.17	-
5.	Sand/gravel fine + 8 % cement	1.72	17.58	7.6E-08	3.0E-06	5.7E-07	3.5	4.3	4.3	4.5	2.6	2.8	0.094	0.092
6.	Sand/gravel fine + 10 % cement	1.70	18.95	7.7E-07	2.4E-06	2.6E-07	2.5	5.5	6.0	6.1	1.4	1.8	0.15	-
7.	Sand/gravel coarse + 6 % cement	1.77	17.42	5.9E-08	-	2.6E-07	3.1	4.0	-	4.0	3.6	4.1	0.12	-
8.	Sand/gravel coarse + 8 % cement	1.72	16.50	3.9E-08	2.8E-06	1.7E-07	4.6	4.9	5.3	5.8	2.2	2.8	0.056	0.057
9.	Sand/gravel coarse + 10 % cement	1.74	16.00	4.1E-08	2.4E-06	6.1E-08	2.4	5.8	6.3	6.9	1.9	2.1	0.13	-
10.	TP-22 + 8 % cement	1.35	19.00	4.5E-05	-	-	1.4	-	-	-	2.1	3.6	-	-
11.	TP-35 + 8 % cement	1.88	14.62	9.0E-08	-	-	4.5	-	-	-	3.6	6.1	-	-
12.	TP-41 + 8 % cement	1.52	24.00	9.5E-08	-	-	1.5	-	-	-	7.4	8.1	-	-
13.	TP-45 + 8 % cement	1.43	19.50	6.4E-08	-	-	2.9	-	-	-	6.4	10.6	-	-
14.	TP-50 + 8 % cement	1.49	20.90	3.2E-07	-	-	3.2	-	-	-	6.8	6.9	-	-
15.	Sandy loam + 8 % slag-cement 1	1.69	18.00	-	-	-	2.0	-	-	-	-	-	0.061	0.065
16.	Sand/gravel fine+8 % slag-cement 1	1.62	19.00	-	-	-	3.6	-	-	-	-	-	0.072	0.070
17.	Sand/gravel coarse+8 % slag-cement 1	1.67	15.80	-	-	-	4.6	-	-	-	-	-	0.066	0.064
18.	Sandy loam + 8 % slag-cement 2	1.62	17.40	-	-	-	2.0	-	-	-	-	-	0.062	0.0596
19.	Sand/gravel fine+8 % slag-cement 2	1.66	21.00	-	-	-	3.0	-	-	-	-	-	0.064	0.068
20.	Sand/gravel coarse+8 % slag-cement 2	1.70	16.00	-	-	-	3.9	-	-	-	-	-	0.050	0.051
21.	Sandy loam + 10 % slag-cement 1	1.70	18.00	-	-	-	2.5	-	-	--	-	-	0.052	0.065
22.	Sand/gravel fine+10 % slag-cement 1	1.69	21.00	-	-	-	3.6	-	-	-	-	-	0.066	0.068
23.	Sand/gravel coarse+10 % slag-cement 1	1.72	19.83	-	-	-	3.3	-	-	-	-	-	0.064	0.068
24.	Sandy loam + 10 % slag-cement 2	1.66	19.50	-	-	-	2.4	-	-	-	-	-	0.058	0.059
25.	Sand/gravel fine+10 % slag-cement 2	1.67	20.50	-	-	-	3.4	-	-	-	-	-	0.076	0.081
26.	Sand/gravel coarse+10 % slag-cement 2	1.77	18.50	-	-	-	3.5	-	-	-	-	-	0.070	0.071

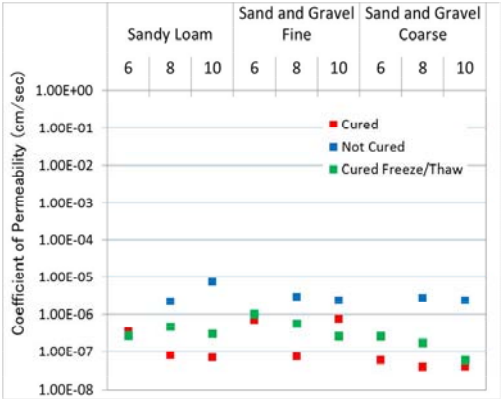


Figure 4-3.5.14 Result of Falling Head Permeability Tests to Soil-cement

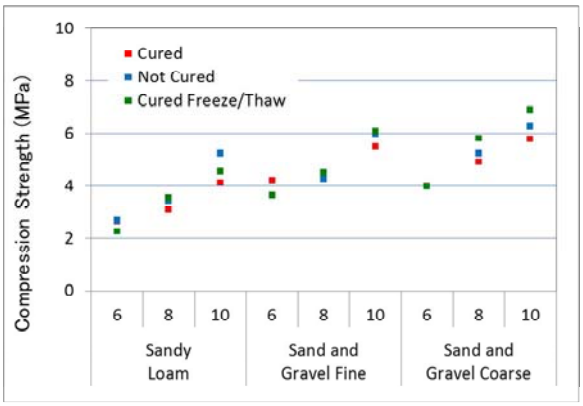


Figure 4-3.5.15 Result of Unconfined Compression Tests to Soil-cement

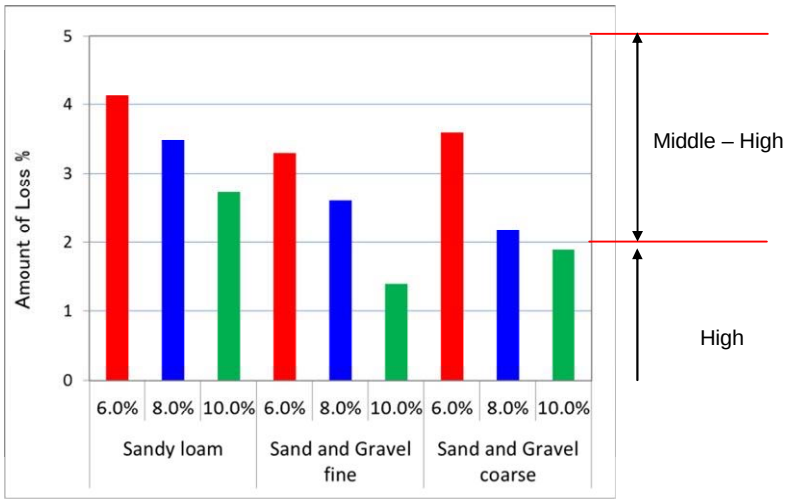


Figure 4-3.5.16 Result of Slaking Tests to Soil-cement

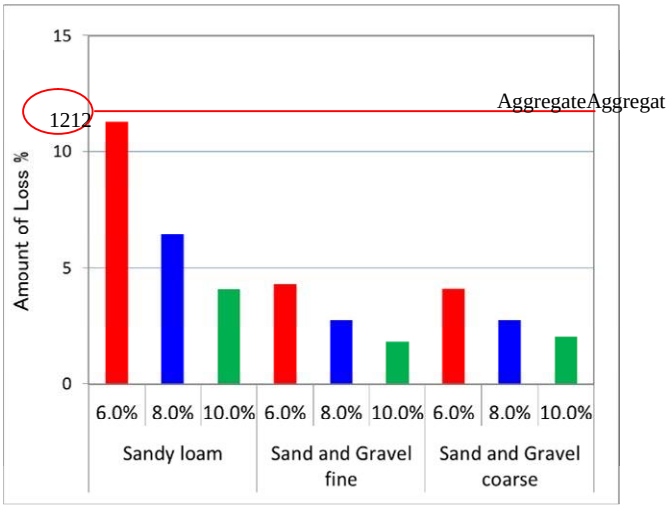


Figure 4-3.5.17 Result of Sodium Sulfate Soundness Tests to Soil-cement

4-3-6 Investigation for the Anti-infiltration Works to the Reservoir Basin

(1) Field survey of the existing range of sandy loam

(a) Outline of the survey

As the achievement of the geological investigations carried out in ex-USSR era, drawings of the geological cross-sections of the reservoir basement had been left. Based on these drawings, the geological plane map was drawn this time where the existing range of the sandy loam in the reservoir basin was shown. It is considered to be important to confirm this range of existence for studying the anti-infiltration method to the reservoir bottom/slope in case of the sandy loam having relatively low permeability, so that the field survey was conducted to the points set up beforehand corresponding to the boundary on the geological plane map. And later, the same kind of field survey was conducted to assume the range of the area with a thick coverage of sandy loam visually from the circumstances on the ground surface.

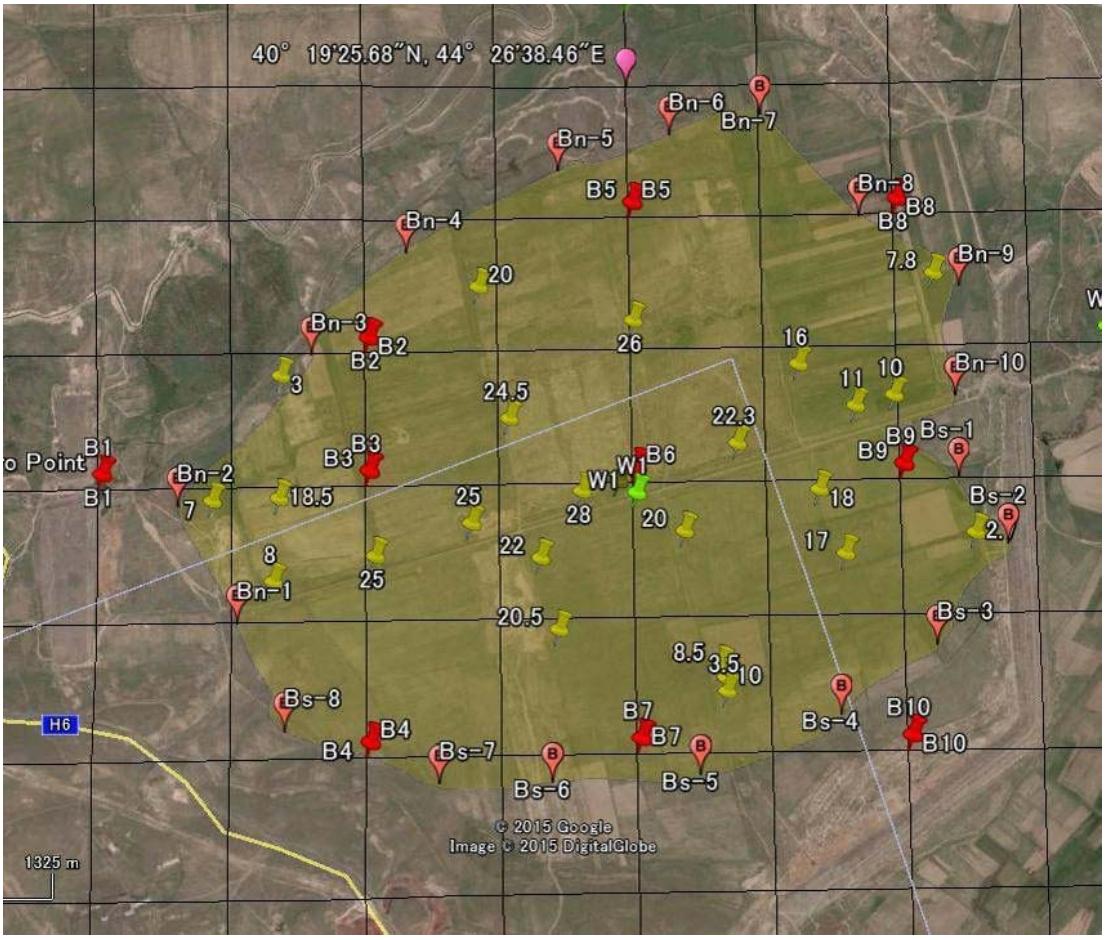


Figure 4-3-6.1 Existing Range of Sandy Loam (Yellow-colored Area) and the Confirmation Points

(b) Findings

1) At the north-western side where the slopes are relatively and comparatively steep among the slopes around the reservoir, the boundary between the sandy loam deposit and the sand-and-gravel deposit is clear and corresponds to the line of slope change.

2) At the north side, the low and flat terrace extends wide toward south which seems to be composed of the sand-and-gravel deposit.

3) At the north-eastern side where the relatively steep slope goes back to north and the wide area

with gentle slope extends, the boundary between the sandy loam deposit and the sand-and-gravel deposit is not clear; but the latter seems to occupy the main portion of the gentle slope area.

4) At the eastern side, the boundary between the sandy loam deposit and the volcanic deposit is clear and corresponds to the line of slope change.

5) At the south-eastern side, the ground is gently inclined from the hill top toward the central plain and the boundary between the sandy loam deposit and the volcanic deposit does not appear.

6) At the south side, the two lines of slope change appear. The slope beyond the upper line is composed of volcanic deposits and the sandy loam with rubbles. The lower line of slope change is the one between the central plain and the gentle slope; the slope below the upper line is composed of the sandy loam deposit, the thickness of which seems to be not so much.

7) At the south-western to the western side, the gentle slope is covered with the sandy loam with rubbles and the boundary is between this gentle slope and the central plain. The rubbles are volcanic produced from the foundation rock so that it is assumed that the thickness of the sandy loam with rubbles is thin.

8) Result of the field survey to assume the range of the area with a thick coverage of sandy loam

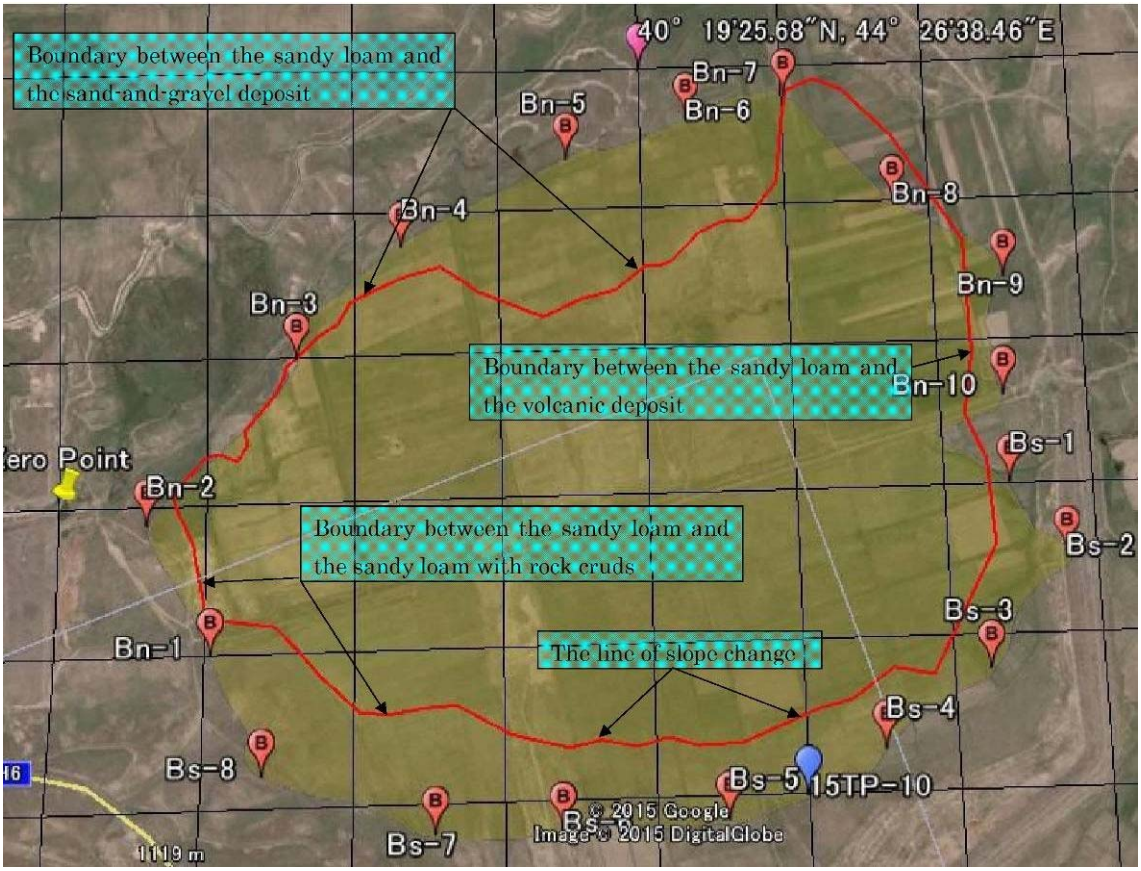


Figure 4-3-6.2 Boundary Survey Result

(2) Field survey to confirm the layer conditions in terms of piping phenomenon

(a) Outline of the survey

In case of the base layer being porous, cracky or rich in void and a high hydraulic gradient arising in the upper soil layer, soil particles of the soil layer might be sucked out into the base layer. This is the phenomenon called “piping”; and if the soil layer corresponds to the anti-infiltration work made of soil or an impervious zone of the dam, the occurrence of this phenomenon leads to the loss of function of the work/structure. To check the possibility of this phenomenon arising, the field survey by the visual observation was carried out. The target of the observation was the sand-and-gravel layers and the volcanic rock layers.

(b) Findings

1) There is no possibility of the piping phenomenon arising into the sand-and-gravel layers.

There lie widely sand-and-gravel layers on the slopes north-side to the reservoir. There are two kinds of sand-and-gravel layers. One is the layer with the clear alternation structure of the rounded gravel layer and the silty sand layer. The other is the layer of the mixture of gravels and silty sand.

In the former case, the gravel layers are half-consolidated by the gypsum-like materials that fill up the voids in the layer (refer to Ph-1, 2). Therefore, there are no spaces into which soil particles are sucked out.

In the latter case, silty soil is predominant and the gravels are compared to the balls floating in the ocean of silty sand, so that voids are filled up with silty sand (Ph-3), into which soil particles are not sucked out.

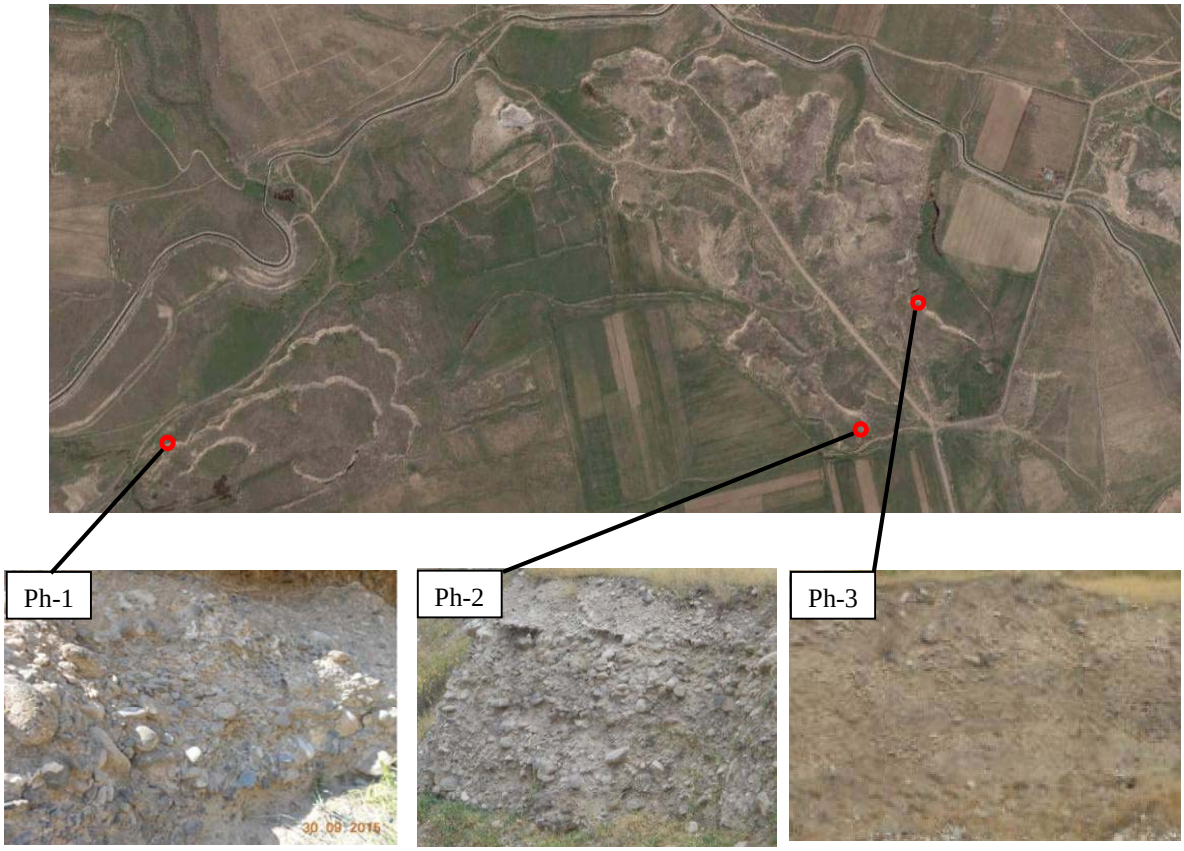


Figure 4-3-6.3 Conditions Observed on the Outcrop of Sand-and-Gravel Layers

2) There is a high possibility of the piping phenomenon arising into the volcanic rock layers.

The slopes south-side to the reservoir are composed of volcanic rock layers or volcanic layer of gravel and sand mixture, that is to say, lava layers (Ph-4), welded tuff layers and deposits of pyroclastic flow (Ph-5). There is the trench on the slope excavated for the intake pipe line in the Soviet era. There, the profile and conditions of these layers are observed as shown in Figure 4-3-6.4. These layers are recognized to be rich in cracks so that there is a high possibility of the piping phenomenon arising.

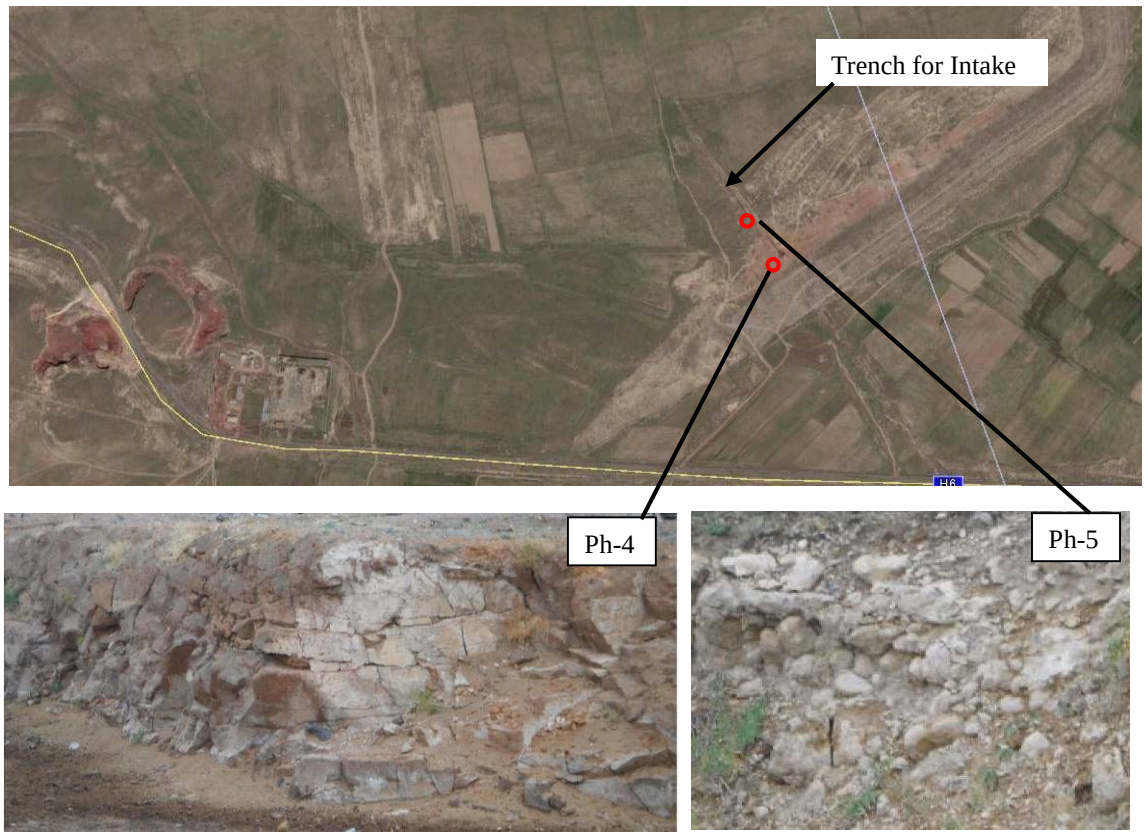


Figure 4-3-6.4 Conditions Observed on the Outcrop of the Lava Layer and the Deposits of Pyroclastic Flow Layer

(3) Field survey of ground water seeping out of the slope surface

(a) Aim

The anti-infiltration work constructed on the slope/ground surface prevents the reservoir water from seeping into the slope/ground but also prevents the ground water from seeping out from the slope/ground. If the ground water is prevented from seeping out and results in being pressurized when the reservoir is empty, the anti-infiltration work will be lifted up by the back pressure and destroyed. The field survey of ground water seeping out points on the slopes was conducted to judge if the geological conditions have the possibility of back pressure arising behind the anti-infiltration work.

(b) Finding

1) There are two ponds on the reservoir bottom just upstream side of the Dam No.1. Their long-term existences almost all through a year suggest a possibility of ground water flowing down toward the reservoir bottom in the hill-side areas. It must be noted that there might be a possibility of the back pressure arising against the bottom of the impervious zone of Dam-No.1 or from behind the anti-infiltration work in the upstream side of Dam No.1.

Figure 4-3-6.5 Ponds on the Reservoir Bottom at the Upstream of Dam-No.1

2) The points of ground water seeping out from the slopes or cliffs could not be found; but the leaked/discharged water from Arzni-Shamiram Canal was observed to keep falling down like a fall from along the upper surface of the silty soil layer of the cliff, composed of sand-and-gravel with alternation of gravel layers and silty sand layers, located on the hill north-side to the reservoir in early summer as shown in Figure 6-3-6.6. This fact suggests that the sand-and-gravel layer allows the existence of ground water along the upper surfaces of silty sand layers, that at present seeping points are not to be found due to the small quantity of ground water or the inclination of the layers (On the other day after rain, a part of the cliff with sand-and-gravel was found to be wet.), and that once the seeping out point is closed by the anti-infiltration work, the ground water might be stored up on along some silty sand layer, then pressurized, and act as the back pressure from behind the anti-infiltration work. It is necessary to consider the possibility of the back pressure arising on the slopes composed of sand-and-gravel layers.

Figure 4-3-6.6 Conditions Observed on the Cliff Slope of Sand-and-Gravels

3) On the slope south-side to the reservoir, the stratified structure of volcanic products is assumed to be inclined toward the reservoir based on the observation to the existing trench and the outcrops of lava on the south hill slope of Dam No.1 as shown in Figure 4-3-6.7. And an unconformity surface, which is not rare to function as an impervious plane, exists between the uppermost lava layer and the lower pyroclastic flow deposits. It is probable for the water stored on an unconformity surface to become pressurized and act as the back pressure against the anti-infiltration work because of its inclined stratified structure.

Figure 4-3-6.7 Unconformity Surface on the Lava cliff

(4) Snow melting condition survey

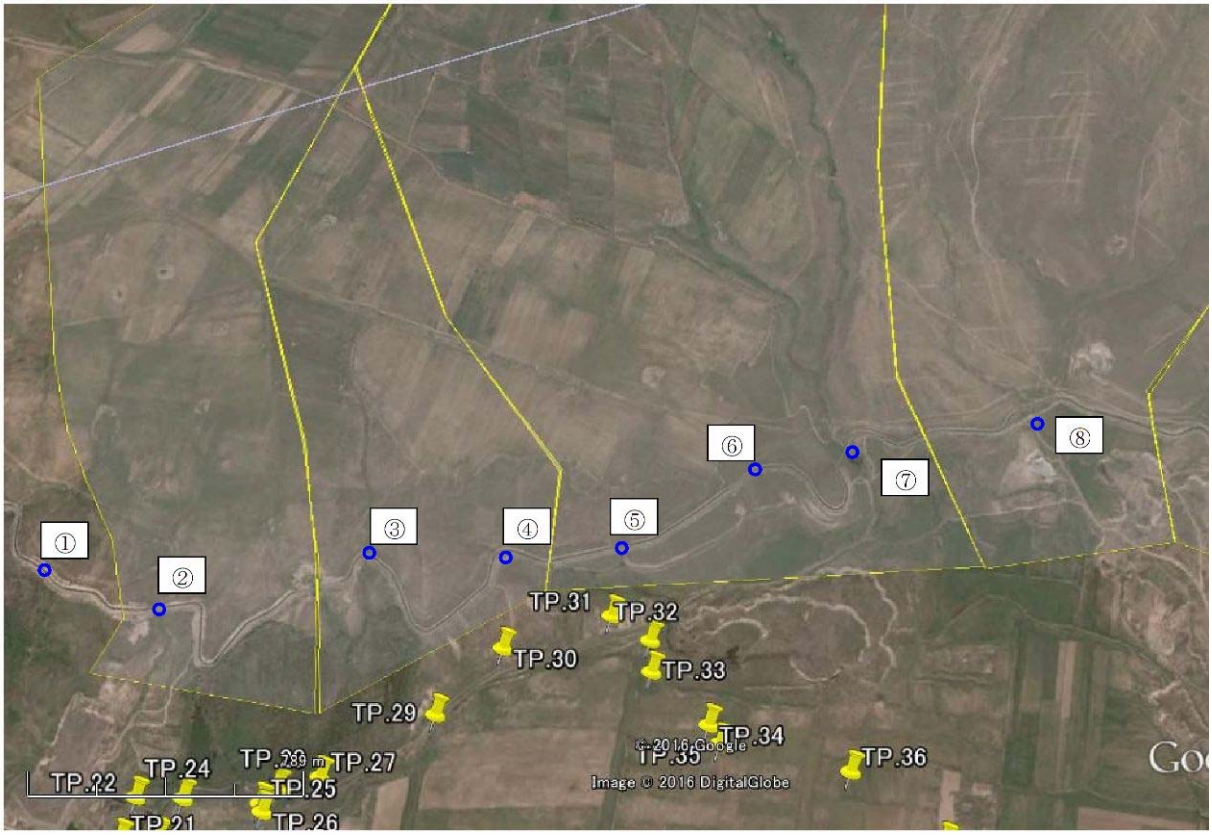


Figure 4-3-6.8 Location Map of the Observation Points

(a) Survey on 16th of February, 2016, clear and sunny, 5 ℃± as summarized in Table 4-3-6.1 and Figure 4-3-6.9

Table 4-3-6.1 Survey on 16th of February, 2016

Survey point	Catchment area (km2)	Depth of snow (cm)	Existence of stream (volume of stream)
①		10cm	No water under the water-way bridge and in front of the culvert pipe (Ph-1), Small pond on the road (Ph-2)
②	2.1	10cm	No water. The canal wall is wetted partly. (Ph-3)
③	1.0	20cm	No water under the water-way bridge A partial wetting on the cut slope (Ph-4), but totally seepage of water cannot be seen on the cliff. (Ph-5)
④		15cm	No water comes to the cutout mouth of the canal wall. (Ph-6)
⑤	0.5	10cm	No water under the water-way bridge. (Ph-7)
⑥		10cm	No water under the water-way bridge. (Ph-8)
⑦	18.1	15cm	Small pond under snow, no move, no stream(Ph-9,10)
⑧	7.2	10cm	No water under the water-way bridge. (Ph-11)

Ph-1

Ph-2

Ph-3

Ph-4

Ph-5

Ph-6

Ph-7

Ph-8

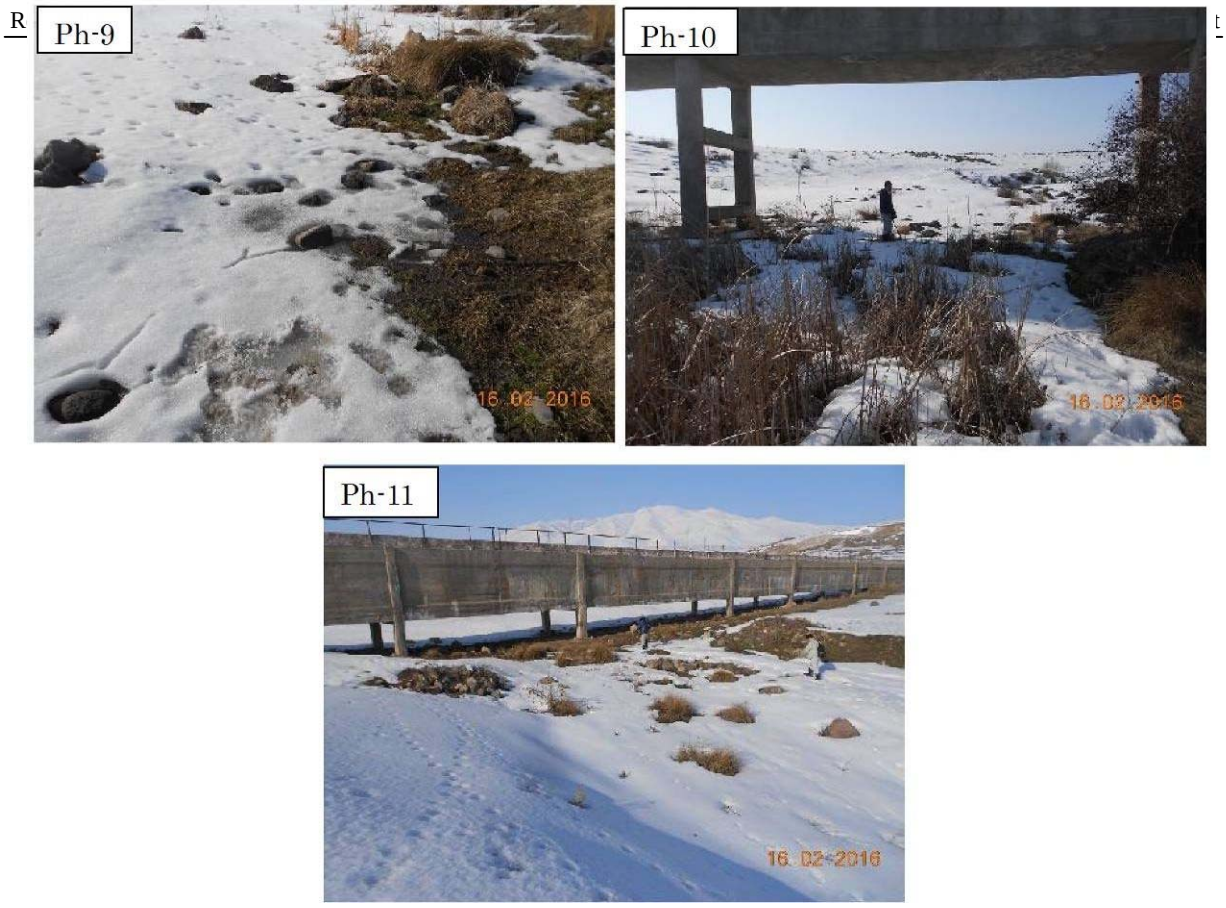


Figure 4-3-6.9 Photo of the Survey on 16th of February, 2016

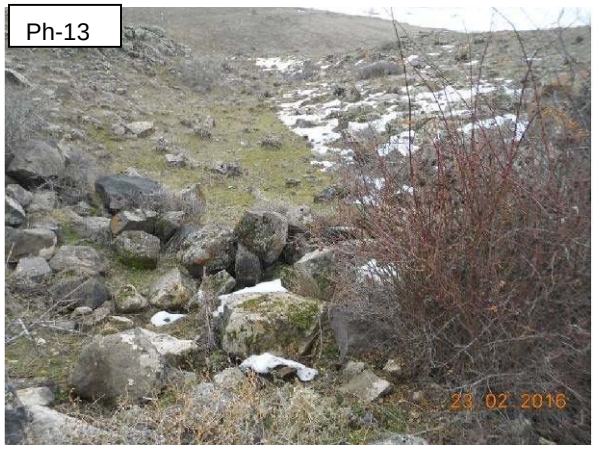
(b) Survey on 24th of February, 2016, cloudy, 7 ℃± as shown in Table 4-3-6.2

Table 4-3-6.2 Survey on 24th of February, 2016

Survey point	Catchment area (km2)	Depth of snow (cm)	Existence of stream (volume of stream)
①		0 cm	Wet ground but no water in front of the culvert pipe (Ph-12), No water in the downstream valley(Ph-13)
②	2.1	0 cm	No water. The canal wall is dry. (Ph-14)
③	1.0	0 cm	No water is seen under the water-way bridge, but the ground surface corresponding to the watercourse is eroded. (Ph-15) Now water in the watering pond for cow. (Ph-16)
④		0 cm	No water comes to the cutout mouth of the canal wall. (Ph-17)
⑤	0.5	0 cm	Wet but no water (Ph-18)
⑥		0 cm	No water under the water-way bridge. (Ph-19)
⑦	18.1	0~5 cm	Small stream, In-flow volume under the water way bridge is 20 ~ 30 ℓ/sec. (Ph-20) Water is led by a earth canal (Ph-21, 22) and disappears in a meadow (Ph-23). This water shall be increased in early summer and makes a swamp around the foot of the north slope (Ph-24).
⑧	7.2	10cm	Small ripple and swamp under the water-way bridge. (Ph-25) Quantity is uncountable.

Ph-12

Ph-13



Ph-14

Ph-15

Ph-16

Ph-17

Ph-18

Ph-19

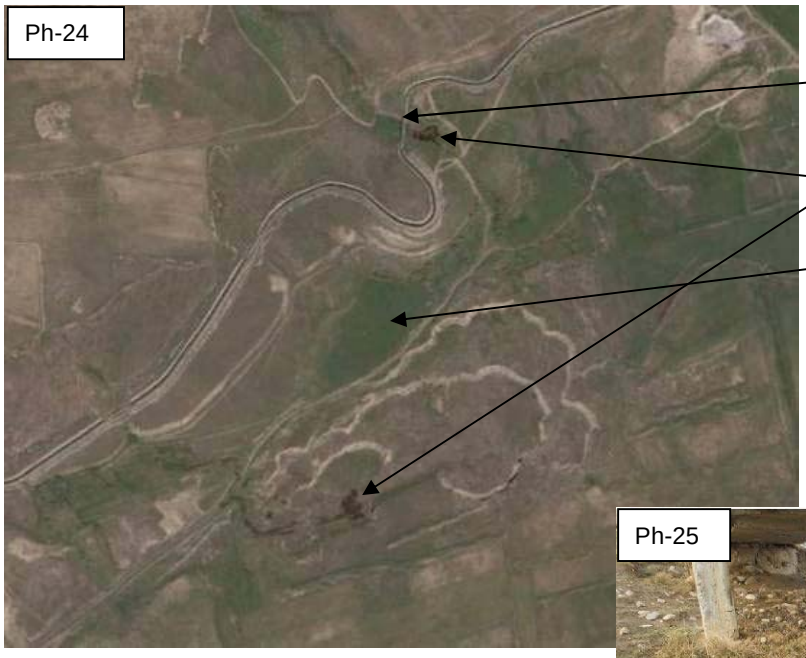


Figure 4-3-6.10 Photo of the Survey on 24th of February, 2016

(c) Survey on 18th of March, 2016, fine, －3 ℃± shown in Figure 4-3-6.11

Snow disappeared from the ground surface in and around the reservoir except the slope of Mt. Ara (Ph-27). There is no water under the water-way bridge at ⑧ point. At ⑦ point, a small swamp is left (Ph-26) under the water-way bridge but the stream last time we saw is not seen. The snow melting season seems to have finished already.

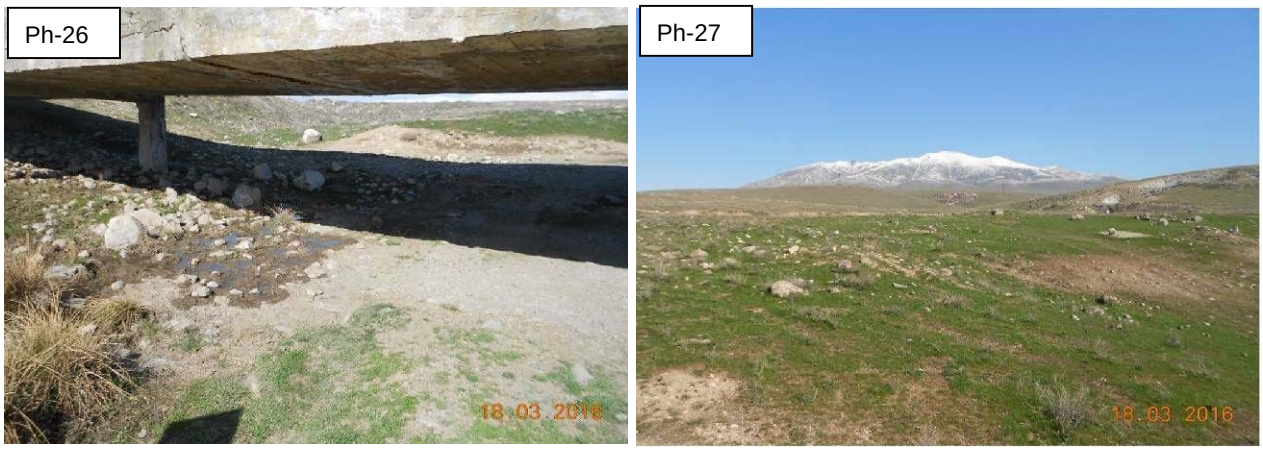


Figure 4-3-6.11 Photo of the Survey on 18th of March 2016

(d) Suspended water / ground water on the north-eastern slope

TP.67 was excavated on 30th of March in the pit excavation survey. At that time, it was found that the sand-and-gravel layer was muddy and the groundwater table appeared on the pit bottom about 3m deep. It is assumed that this groundwater was borne and brought from the snow-melt water at point-⑦. If this groundwater has the same origin as the observation well W-5 where it is said sound of water dropping into the observation well is audible, a relatively wide expansion of high groundwater table shall be required to take account of in the reservoir design.

Figure 4-3-6.12 High Groundwater Table in the North Eastern Slope

(5) Wind velocity survey

(a) Aim

In summer, 2015 geological investigations by borehole drilling were carried out in the reservoir bottom. On the way of works, a beach-parasol with tough structure and heavy basement was provided to protect technicians and engineers from the strong sunshine. But the attempt was failed “twice” due to the strong wind blowing off the parasol and breaking its bones. These incidents left a sharp impression of strong wind to the engineer’s mind; and here wind velocity survey was carried out under the recognition that the sheet covering method was one of the alternatives for the anti-infiltration works to the reservoir bottom/slope and its laying work might be much affected by wind.

(b) Result of the survey

Wind velocity observations for ten (10) minutes have been conducted at the Yeghvard observation station 8 times a day at every 3 hours interval. From these observations, 8 records of mean wind velocity for ten minutes and 8 records of the instantaneous maximum wind velocity during ten minutes are reported. The contents of the report in 2014 are summarized as in 4-3-6.13.

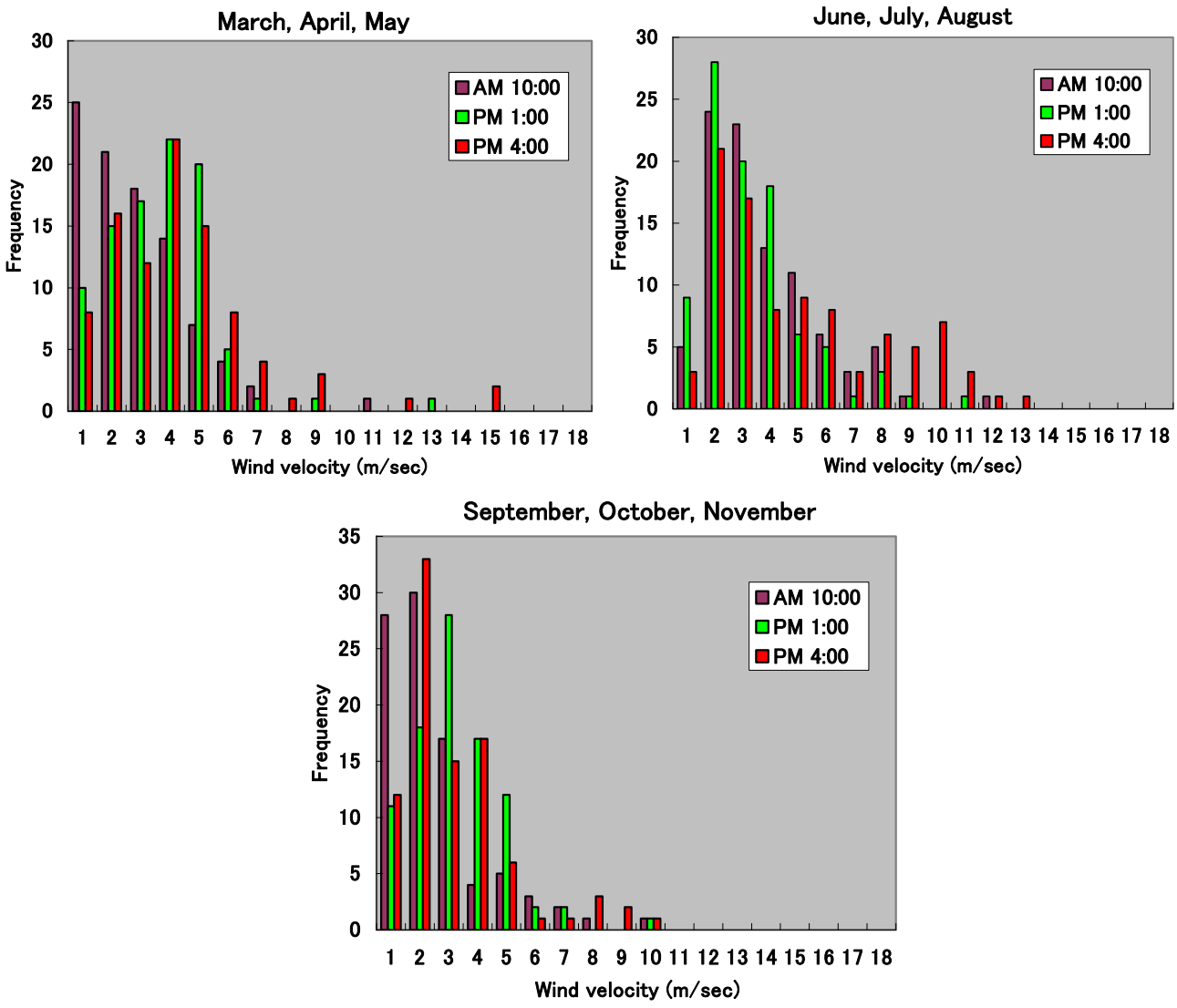


Figure 4-3-6.13 Mean Wind Velocity for Ten Minutes Observed in 2014

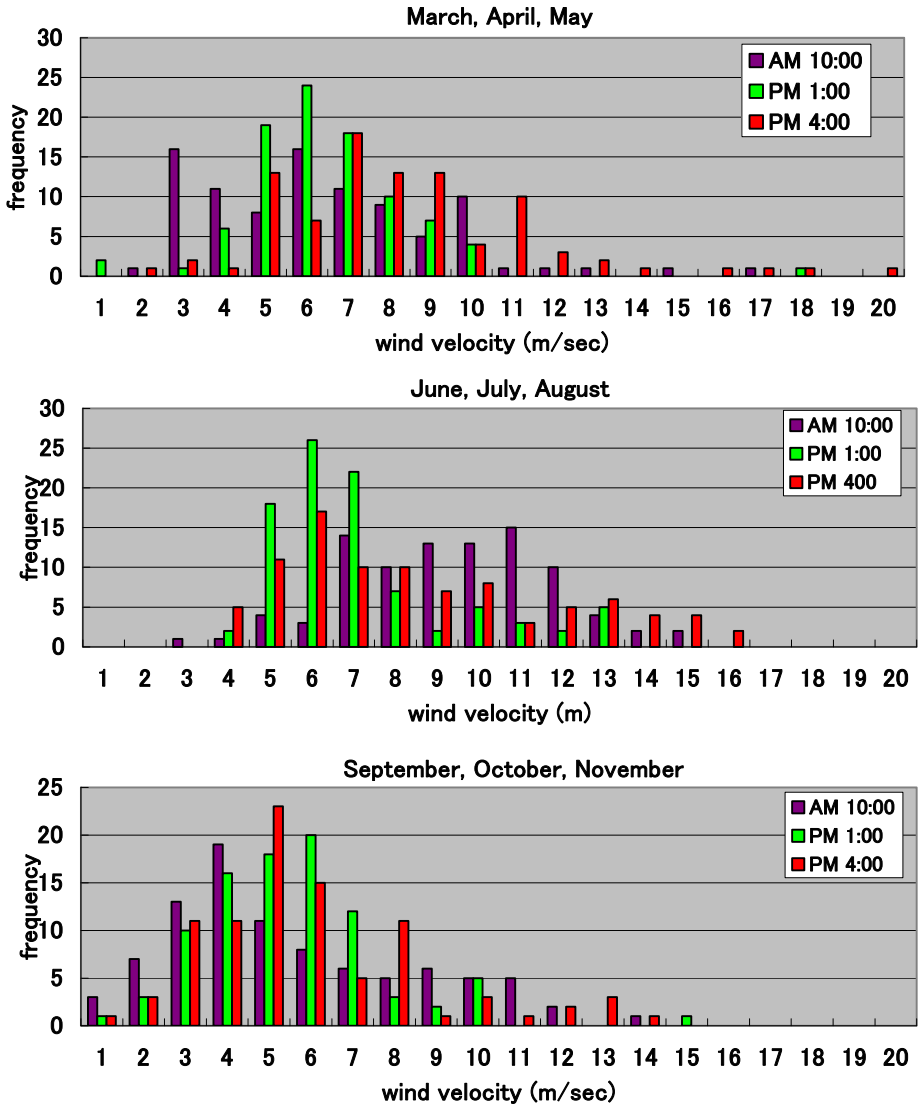


Figure 4-3-6.14 Instantaneous Wind Velocity during Ten Minutes Observed in 2014

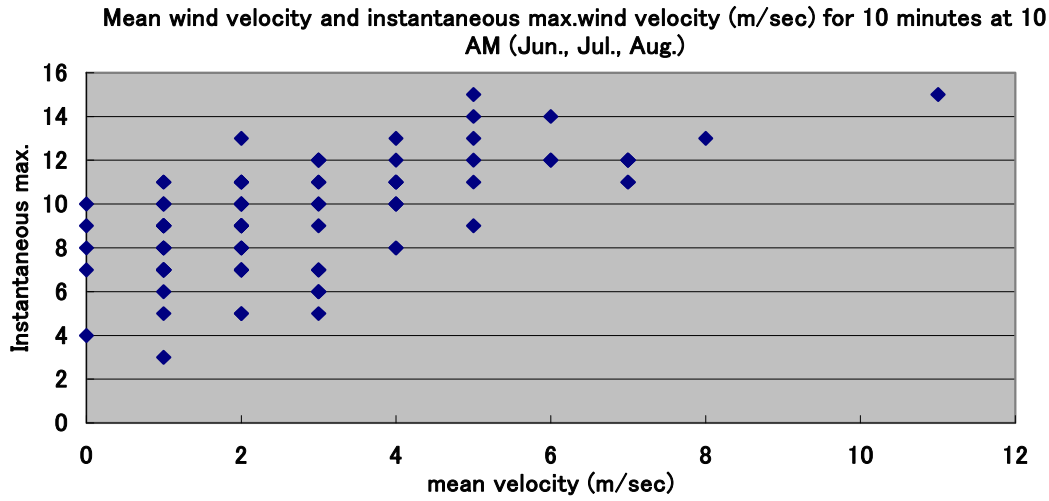


Figure 4-3-6.15 Relationship between Mean Wind Velocity and Instantaneous Wind Velocity

(c) Findings

1) In terms of the mean wind velocity, frequency of mean wind velocity around 3 m/sec is highest all through a year.
2) Occurrence of high mean wind velocity becomes more frequent in June, July and August.
3) In terms of the instantaneous maximum wind velocity, the peak of occurrence frequency is the velocity around 5 to 6 m/sec all through a year.
4) Occurrence of high instantaneous maximum wind velocity becomes more frequent in June, July and August.
5) Occurrence frequency of high instantaneous maximum wind velocity is lowest around 1:00 PM compared to 10:00 AM in the morning and 4:00 PM in the late afternoon all through a year.
6) Even under the breeze conditions, a gusting wind blows down.

4-3-7 Conditions of Existing Dam Bodies

(1) Site survey and information collection

The existing dam bodies consist of sand-and-gravel materials only. The vacant lots where these materials were obtained are left on the hills or gentle slopes north-eastern side to the reservoir as shown in Figure 4-3-7.1 and 4-3-7.2.

Figure 4-3-7.1 Existing Dam Body (Dam No.1)

Figure 4-3-7.2 Vacant Lots of the Sand-and-Gravel Quarry

The information obtained regarding the construction works is shown in Table 4-3-7.1.

Table 4-3-7.1 Construction Specifications of the Existing Dam Body

Item		Contents
Quality control criteria	Embankment density	2.0~2.1 t/m3 in wet density
	Grain size	
	Rock quality	
Frequency of control test	Embankment density	
	Grain size	
	Rock quality	
Specifications of construction works	Compaction machine	Vibratory roller
	Spreading machine	Bulldozer
	Compaction passing times	
	Layer's thickness before compaction	45 cm
	Arrangement of moisture content	spraying

(2) In-situ investigations and tests

(a) In-situ investigations

1) Test-pit excavation

Test-pit excavations were conducted on the existing dam bodies, TP-1 and TP-16 on the Dam No.1 and TP-4, TP-14 and TP-15 on the Dam No.2, to confirm their actual conditions. The depth of test-pits was decided to be 1.5 m considering the disappearance of dried-up condition brought from the surface. Test-pit conditions of each are shown as Figure 4-3-7.3 and 4-3-7.4.

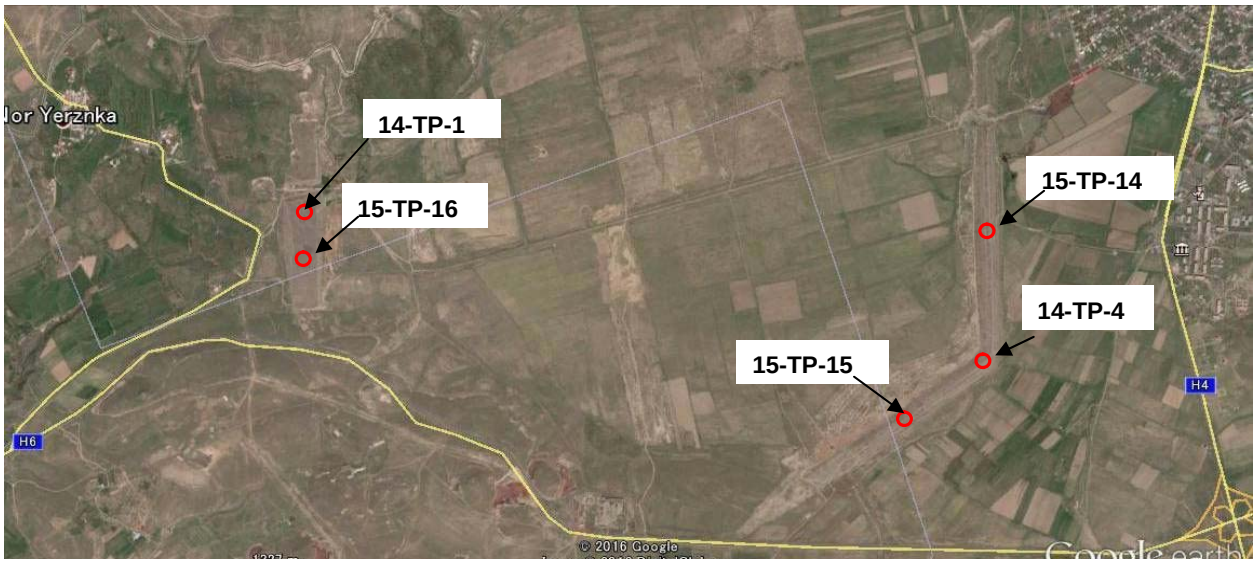


Figure 4-3-7.3 Test-pit Location for the Investigation of Dam Bodies

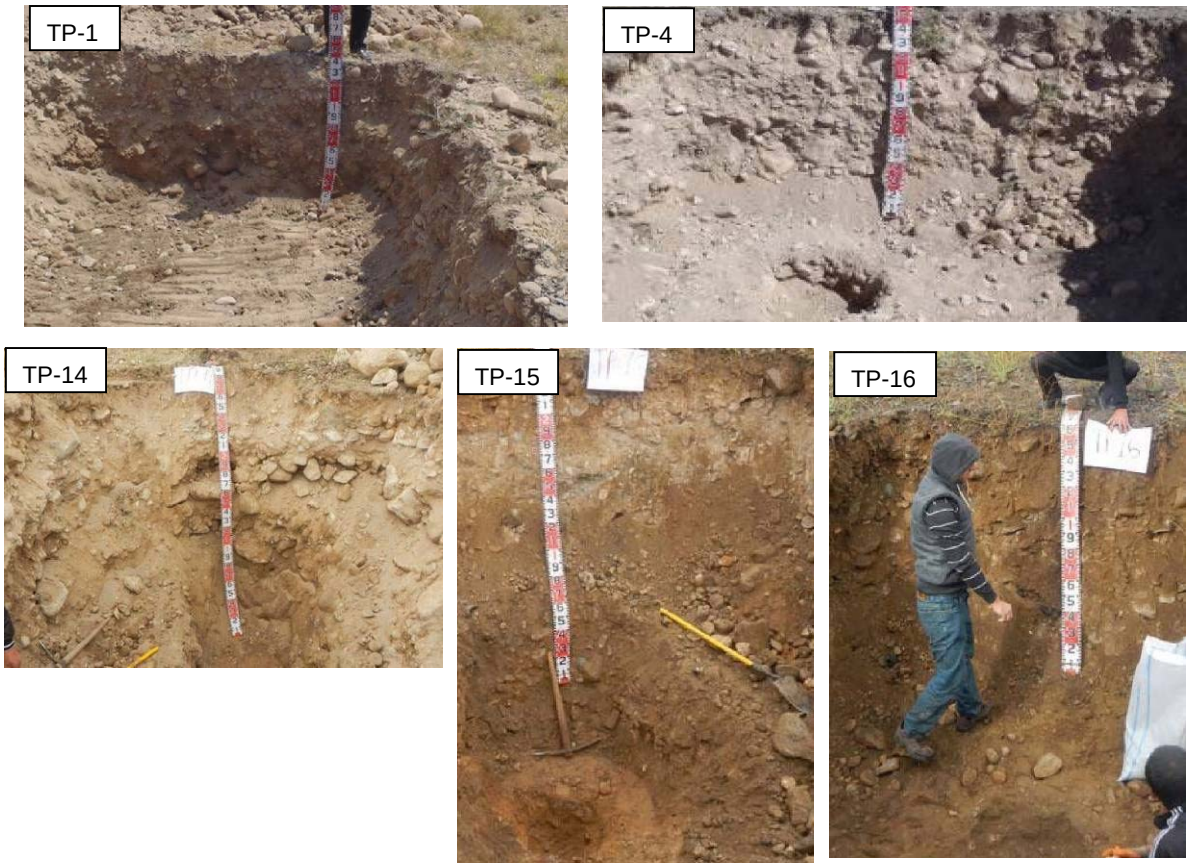


Figure 4-3-7.4 Test-pit Profiles after Excavation

[Findings]

a. The maximum grain size of cobbles is about 40 cm.
b. The rock sort of cobbles and gravels is basalt.
c. The quality of cobbles is hard and not weathered so that the metallic sound is emitted from them by the hitting of the geologist hammer.
d. The compacted layers are rich with fine particles composed of sand and silt that fills up almost completely and densely voids among gravels and cobbles.

2) Field density test

The field density tests by the water-replacement method were carried out on the bottom surface of the test-pits. The size of the testing hole was 60 cm in diameter and 40 cm in depth as shown in Table 4-3-7.2.

Figure 4-3-7.5 Circumstances in the Field Density Test

Table 4-3-7.2 Field Density of the Existing Dam Bodies

Pit No.	Dry weight of extracted soil (kg)	Weight of replaced water (kg)	Dry density (g/cm3)
TP-1	141.85	66.7	2.13
TP-4	164.45	79.7	2.06
TP-14	156.2	80.1	1.95
TP-15	203.6	108.3	1.88
TP-16	237.2	114.6	2.07
		Average	2.02

3) Field permeability test

Table 4-3-7.3 Field Permeability Coefficient of the Existing Dam Bodies

Pit No.	Trial No.	Poured Q	Time passed		Unit Q	h	r_0	k	k-mean
		(cm3)	minute	second	(cm3/sec)	(cm)	(cm)	(cm/sec)	(cm/sec)
TP-14	1	31000	3	2	170.33	40	56	5.8×10-3	5.8×10-3
	2	31000	3	5	167.57	40	56	5.7×10-3	
	3	31000	3	1	171.27	40	56	5.9×10-3	
TP-15	1	12600	34	34	6.08	42	57.5	1.9×10-4	1.9×10-4
TP-16	1	35750	63	0	9.46	55	60	2.2×10-4	2.5×10-4
	2	3575	5	0	11.92	55	60	2.7×10-4	

Figure 4-3-7.6 Circumstances in the Field Permeability Test

4) Repose angle of sand-and-gravel materials

Repose angles were measured on the natural slope caused by the backhoe's dumping work of excavated materials.

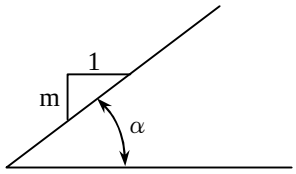
Table 4-3-7.4 Result of Repose Angle Measurement

Pit No.	TP-1	TP-4	TP-14	TP-15	TP-16
Repose angle (°)	33, 35, 38	35, 41	36.8	40.1	41.2

Figure 4-3-7.7 Circumstances in the Repose Angle Measurement

The repose angle is defined as the internal friction angle of sand, sand-and-gravel and rock materials under the unconfined and loosest condition. It is easy to understand through the relationship between the definitional identity of safety factor to the surface sliding of rock slope and the slope inclination.

$$Fs = \frac{1 - m * k}{m + k} * \tan \phi'$$



Fs; safety factor
m; slope inclination
m=tanα α; repose angle of the slope
k; seismic coefficient (percentage to the gravitational acceleration×1/100)
φ'; internal friction angle

When Fs=1.0 and k=0.0 are inserted as the safety factor reflecting the critical slope inclination and the normal condition, m=tanφ', tanα=tanφ' and then α=φ' is obtained. In case of the slope being stamped by foot, the repose angle increases. Therefore, the internal friction angle of the compacted materials is understood to be larger than the repose angle.

(b) Laboratory test

Table 4-3-7.5 Summary of the Laboratory Tests to Sand-and-Gravels From the Existing Dam Bodies

pit No.	Field moisture	Spe. gravity	Spe. Gravity/absorption		praticle size distribution			Compaction test	
	Wf (%)	(-37mm)	Bulk density	absorption (%)	fine (%)	sand (%)	gravel (%)	D_{max}(t/m3)	W_{opt}(%)
TP-1	5.97	2.69	2.34	1.87	5.00	23.26	71.74	1.95	11.0
TP-4	7.04	2.57	2.34	1.67	7.88	22.78	69.34	1.73	14.6
TP-14	9.50	2.59	2.25	2.52	10.20	24.98	64.82	1.77	16.0
TP-15	11.48	2.53	2.17	1.91	11.50	23.38	65.13	1.65	17.2
TP-16	7.81	2.64	2.35	1.68	6.87	23.99	69.14	1.95	12.7

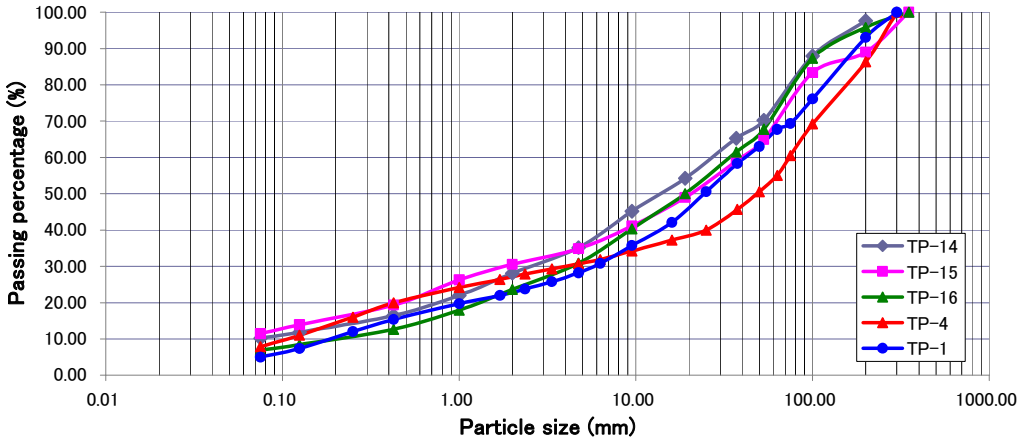


Figure 4-3-7.8 Particle Size Distribution Curve of Sand-and-Gravels from the Existing Dam Bodies

[Finding]

a. Moisture content; Field moisture contents are lower than the optimum moisture content by 5% to 7% approximately.
b. Water absorption; Water absorption is low enough to suggest the freshness, i.e. not weathered condition, of the gravels and cobbles.
c. Bulk density; Bulk density is relatively small; it would be affected by the mineral composition of rocks.
d. Gradational condition; Content percentage of the fine portion, i.e. silt and clay, ranging from 5% to 10% approximately suggests the permeability coefficient of the compacted layer ranging from $n\times10^{-3}$ cm/sec to $n\times10^{-4}$ cm/sec, which is consistent with the values obtained in the field permeability test.
e. Evaluation of the compaction degree; Relative density ranging from 91.6% to 93.7% shall be expressed to be “not loose but not so dense”.

Table 4-3-7.6 Summary of the Laboratory Test

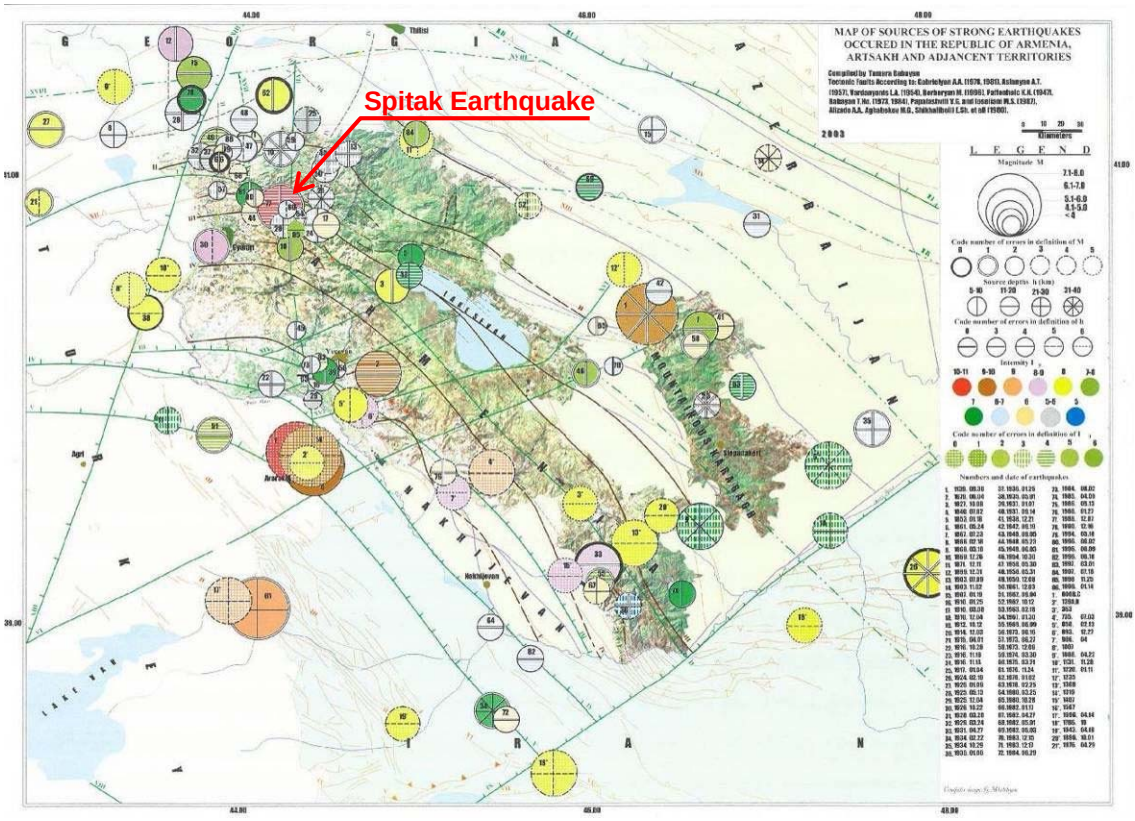
Item	Calculation formula	TP-14		TP-15		TP-16	
		Value	unit	Value	unit	Value	unit
①Total volume of the excavated material		80,100	cm3	108300	cm3	114600	cm3
②Total weight of the excavated material		156.2	kg	203.6	kg	237.2	kg
③Weight of the coarse portion (+37mm)	②×(100−65.25)/100	54.3	kg				
	②×(100−59.50)/100			82.5	kg		
	②×(100−61.48)/100					91.4	kg
④Weight of the fine portion (−37mm)	②−③	101.9	kg	121.1	kg	145.8	kg
⑤Bulk density of the coarse portion	from laboratory test	2.25					
				2.17			
						2.35	
⑥Volume of the coarse portion	③／⑤×1000	24124	cm3	37999	cm3	38881	cm3
⑦Volume of the fine portion	①−⑥	55976	cm3	70301	cm3	75719	cm3
⑧Wet density of the fine portion	④×1000／⑦	1.82	g/cm3	1.72	g/cm3	1.93	g/cm3
⑨Moisture content of the fine portion	from laboratory test	9.5	%				
				11.48	%		
						7.81	%
⑩Dry density of the fine portion	⑧／(1+⑨/100)	1.66	g/cm3	1.55	g/cm3	1.79	g/cm3
⑪Max. dry density in the compaction test	from laboratory test	1.77	g/cm3				
				1.65	g/cm3		
						1.95	g/cm3
⑫Compaction degree (relative density D)	⑩／⑪×100	93.9	%	93.7	%	91.6	%

4-3-8 Situations Related to the Safety of Facilities

(1) General situation of earthquakes in and around Armenia

Armenia national land is located at the northern edge of Arabia plate which is surrounded by Eurasia, Africa and India/Australia plates and Armenia has suffered from earthquakes caused by the movement of these plates.

Figure 4-3-8.1 shows the epicenters of main earthquakes until 2003. Epicenter is shown by circle symbol and size of that shows the scale of magnitude. One of the devastating earthquakes is Spitak earthquake happened 7th December 1988 with its magnitude 7.0. According to the records, this earthquake caused more than 25,000 fatalities, 365 damaged villages (from which 58 ones were fully ruined) and 13.3 billion Ruble of total physical damage. Spitak earthquake became a turning point to review policies to mitigate disaster damage.



Source) Atlas of Strong Earthquakes of the Republic of Armenia, Artsakh and Adjacent Territories from Ancient Times through 2003

Figure 4-3-8.1 Epicenters of Main Earthquake in and around Armenia until 2003

(2) Development situations of earthquake resistant design standards

Taking into account the lessons and learned from experiences through Spitak earthquake, the earthquake resistant design standard was reviewed and new standard was issued in 1994. This reviewed standard required severe earthquake resistant capacity for facilities. From the view point to mitigate damage by earthquake, this standard was well developed, in the other hand, however, industrial development activities had been limited because construction cost of facilities designed by this standard was high and some projects could not be feasible.

In 2006, the standard was reviewed and revised again in conformity with the actual situation, and renewed one namely “EARTHQUAKE RESISTANT CONSTRUCTION DESIGN CODES RABC II-6.02-2006” was issued. This standard is the latest standard as of May 2016.

(3) Assessment of PGA (Peak Ground Acceleration) coefficient k for design

Inertial force caused by earthquake (Fe) is calculated by the formula below in Armenian standard.

$Fe = k \times m$
$k = A \times k_0 \times k_1 \times k_2$

Where;
- Fe: Inertial force caused by earthquake
- k: PGA coefficient
- m: Weight of target part of structure
- A: Seismic impact coefficient
- k_0: Soil condition coefficient
- k_1: Permissive damage coefficient
- k_2: Importance coefficient

1) Seismic impact coefficient (A)

Seismic impact coefficient A shows the peak acceleration[1] of the earthquake, which reoccurrence interval is 500 year, at the surface of engineering bedrock[2].

A at the target site is examined taking into consideration i) distance from target site to a target active fault and 2) scale of earthquake caused by a target active fault.

Detailed Seismic Zoning survey is conducted to estimate value of A at Yeghvard reservoir site. Outline procedure of this survey is shown as below.

i) Collection of information about historical earthquakes around reservoir site
ii) Collection of information about faults around reservoir site
iii) Modeling of geological conditions and faults
iv) Calculation of peak acceleration which occurred at the reservoir site (past earthquake) (*utilizing historical earthquake data)
v) Calculation of peak acceleration which will occur at the reservoir site (future earthquake) (*utilizing fault data)
vi) Selection of A for design

Figure 4-3-8.2 shows epicenters of historical earthquakes and model of faults around reservoir site.

As a result, 0.33 is calculated as maximum A and 0.298 is as reoccurrence period 500 year's value. According to Armenian standard, 0.298 can be selected as design value. However there is a village namely Nor Yerznka at the downstream of Dam No.1 and this village will be seriously damaged by flood in case Dam No.1 collapses. Therefore taking into consideration safety, maximum value **0.33** is selected as design value. This means designed facility has resistant capacity against maximum scale of scientifically predictable earthquake.

[1] A= Peak acceleration(gal) / 9.8m/s^2
[2] Soil layer with Vs= 700m/s

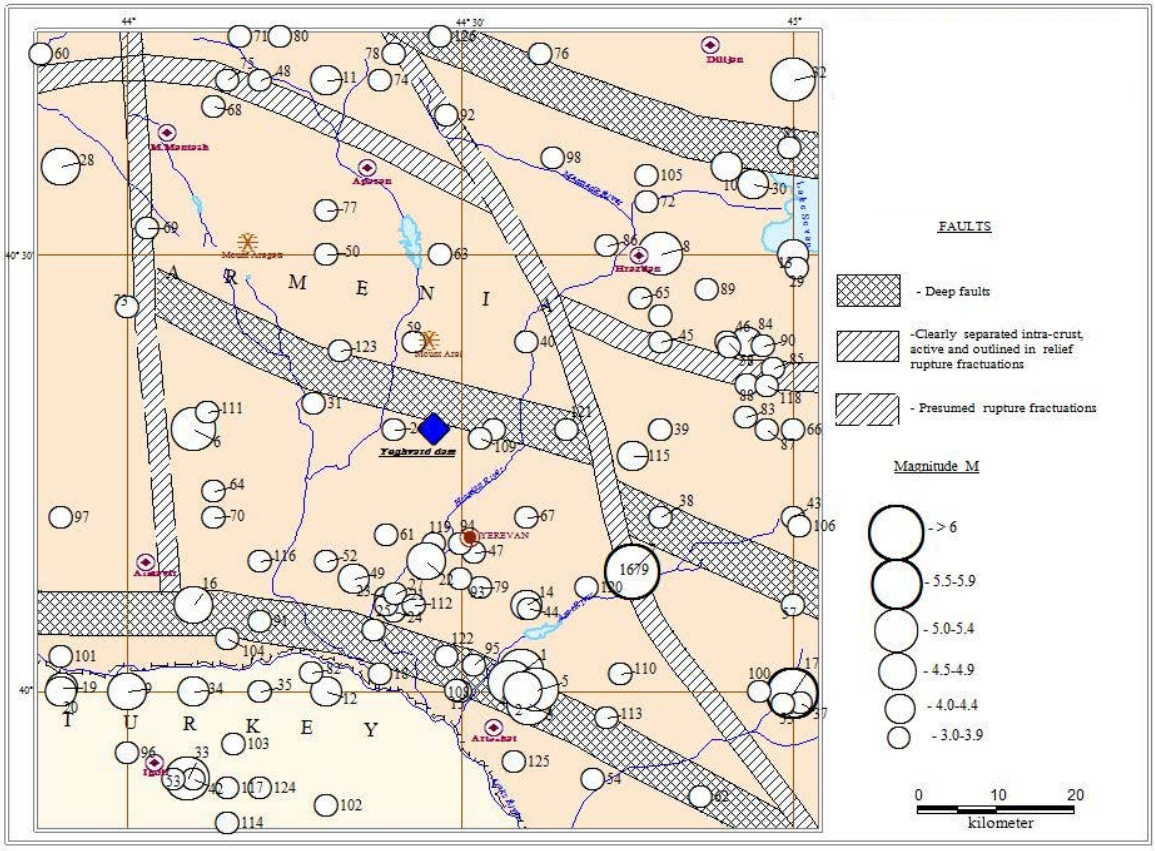


Figure 4-3-8.2 Epicenters of Historical Earthquakes and Model of Faults around Reservoir Site

2) Soil condition coefficient (k_0)

Peak acceleration at ground surface (PGA) is bigger than that at the surface of engineering bedrock surface because earthquake wave becomes higher during passing through soil layer lying between engineering bedrock and ground surface. Soil condition coefficient k_0 shows this increasing ratio.

Since k_0 highly depends on the vertical variation of soil layers between engineering bedrock and ground surface, Seismic Micro Zonation (SMZ) survey is conducted to grasp the vertical variation of soil layers and to estimate k_0. Outline procedure of survey is shown as below.

i) Collection of existing geological survey results
ii) Conducting additional geological drilling surveys
iii) Measurement of the response of each geological condition against artificial shake caused by small blustering or dropping large stone
iv) Modeling of geological condition at reservoir site
v) Analysis of k_0 and calculation of PGA (=A × k_0)

Figure 4-3-8.3 shows the seismic hazard map (contour map of PGA value (=$A \times k_0$))within reservoir area. According to this map, maximum PGA within reservoir area is 0.36 however at Dam No.1 is 0.32 and 0.31 at Dam No.2. Taking into consideration safety, **0.32**, bigger one at dam bodies location, is selected as design value for both Dam No.1 and No.2.

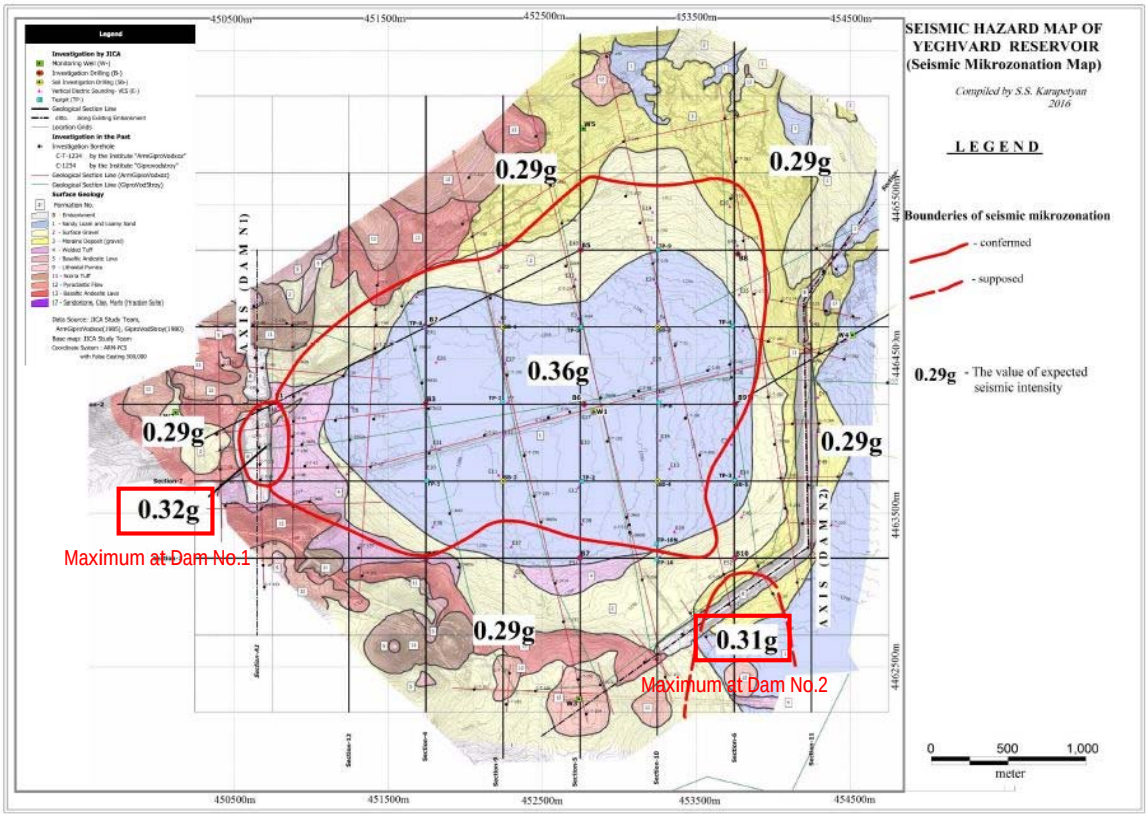


Figure 4-3-8.3 Seismic Hazard Map of Yeghvard Reservoir

3) Permissive damage coefficient (k_1)

Permissive damage coefficient k_1 is prescribed according to the class of facility and its structure as shown in Table 4-3-8.1. Since Yeghvard reservoir is earth-fill structure, **0.30** is applied to k_1.

Table 4-3-8.1 Permissive Damage Coefficient (k_1)

Class and Type of Structure	k_1
For Class I water-retaining hydrotechnical structures	0.40
For other concrete and reinforced concrete hydrotechnical structures	0.35
For earth-fill structures	0.30

4) Importance coefficient (k_2)

Importance coefficient k_2 is prescribed according to the class of facility and its structure as shown in Table 4-3-8-2. Since Yeghvard reservoir is classified as Class-I, **1.20** is applied to k_2.

Table 4-3-8.2 Importance Coefficient (k_2)

Class and Type of Structure	k_2
For Class I water-retaining hydrotechnical structures	1.20
For other concrete and reinforced concrete hydrotechnical structures	1.00

*Classification of reservoir is described in "6-5-6 Basic Design of Dams and Reservoir."

5) PGA coefficient (k) for design

According to examined results above, PGA coefficient k for design is calculated as below.

$$k=(A \times k_0) \times k_1 \times k_2 = 0.32 \times 0.3 \times 1.2 = 0.1152 \rightarrow \mathbf{0.12}$$

Reference

In Japanese present standard, value of k for fill dam constructed on the rock basement is prescribed from 0.10 to 0.18. Also basement of Dam No.1 and No.2 of Yeghvard reservoir is judged as soil category I, rock basement. Since calculated value of k is almost same as Japanese standard, Yeghvard reservoir designed with k=0.12 will have almost same safety against earthquake as Japanese dams designed under present standard, which have no experience of collapse by earthquake.

(4) Concerning matters for emergency discharge after earthquake

In case an emergency situation happens on a reservoir, fast water level lowering by emergency discharging is required to avoid condition becomes worse or to mitigate flood damage in case dam collapse. It is said that main emergency situations on a dam are the following 3 cases. c) is supposed to be the main case for Yeghvard reservoir.

i) Extraordinary increasing of leakage expected to lead efflux of dam body material
ii) Land sliding around the reservoir
iii) Damage on the reservoir by earthquake

Dam body is designed taking into account the inertial force caused by earthquake so that dam body has resistant capacity against predictable scale earthquake. However there is a possibility that unpredictable scale earthquake happens and dam body is damaged. Therefore emergency discharge structure is required even if dam body is designed by earthquake-resistant design.

1) Regulation in Armenian standard

The only description about emergency discharging in Armenian standard “Main Provisions for Hydro Technical structures, RACN 33-01-2014” is shown as below.

The operation regimes of hydro technical structures such as filling and discharging orders shall be realized in accordance with reservoir operation rules, which include rules on water utilization, technical operation and rehabilitation rules agreed with interested organizations in defined order for each reservoir.

According to the description above, there are no common regulation and own emergency discharging rules for Yeghvard reservoir shall be defined taking into account its specific conditions.

2) Specific condition of Yeghvard Reservoir

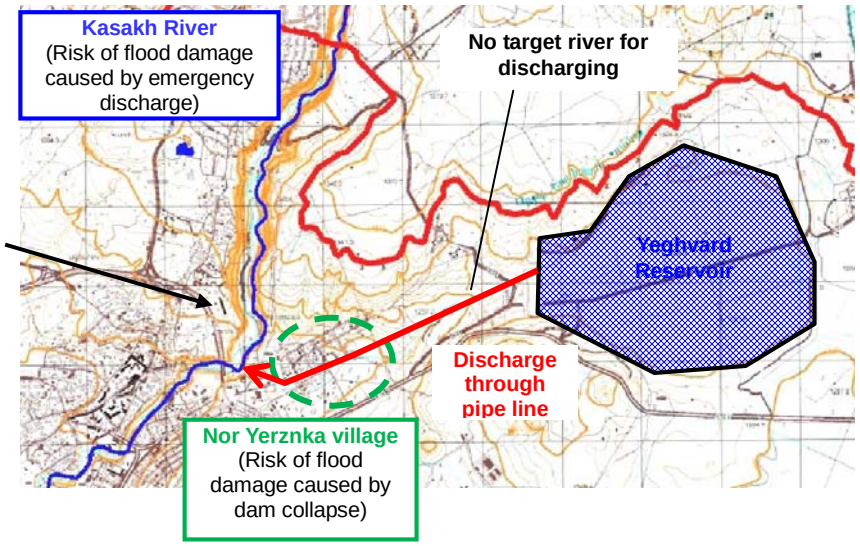
There is no river just downstream of dam bodies which can be a destination of discharging from Yeghvard reservoir because Yeghvard reservoir is planned not across the river but closing plane land by two (2) dam bodies. The nearest river from Yeghvard reservoir is Kasakh River and this river is only the destination of discharging. It is planned to discharge from Yeghvard reservoir through pipeline.

There locates Nor Yerznka village between Yeghvard reservoir and Kasakh River. In case of dam collapse, this village will be seriously damaged by flood. Therefore if dam body is damaged by earthquake, water level shall be lowered as fast as possible (emergency discharge volume shall be as much as possible) to mitigate risk of dam collapse and damage in case dam collapse.

While there are some facilities along Kasakh River and these facilities will suffer from flood damage in case huge volume of water is discharged from Yeghvard reservoir.

Therefore flood damage risk caused by dam collapse at Nor Yerzunka village and caused by huge volume discharging along Kasakh River has tradeoff relation as shown in the Figure 4-3-8.4. Target discharge volume shall be examined taking into account this trade off relation.

A facility just besides Kasakh River



Emergency Discharge Volume	Damage Risk along Kasakh River (= Risk of flood damage caused by emergency discharge)	Damage Risk on Nor Yerznka village (= Risk of flood damage caused by dam collapse)
Huge ↑ Small	High ↑ Low	Low ↓ High

Figure 4-3-8.4 Trade off Relation of Risk along Kasakh River and Nor Yerznka Village