## 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.

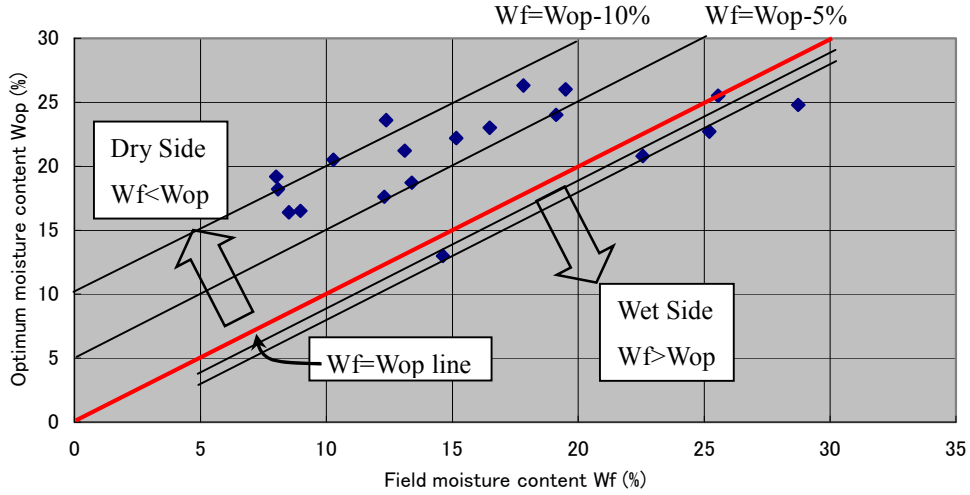



**Figure 4-3-5.1 Relationship between Field Moisture Content and Optimum Moisture Content**

[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.

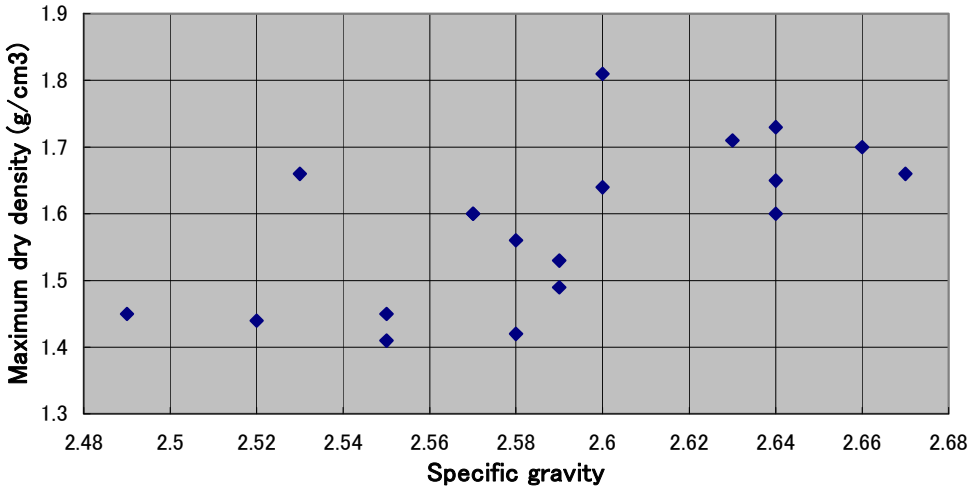



**Figure 4-3-5.2 Relationship between Specific Gravity and Maximum Dry Density**

[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%.

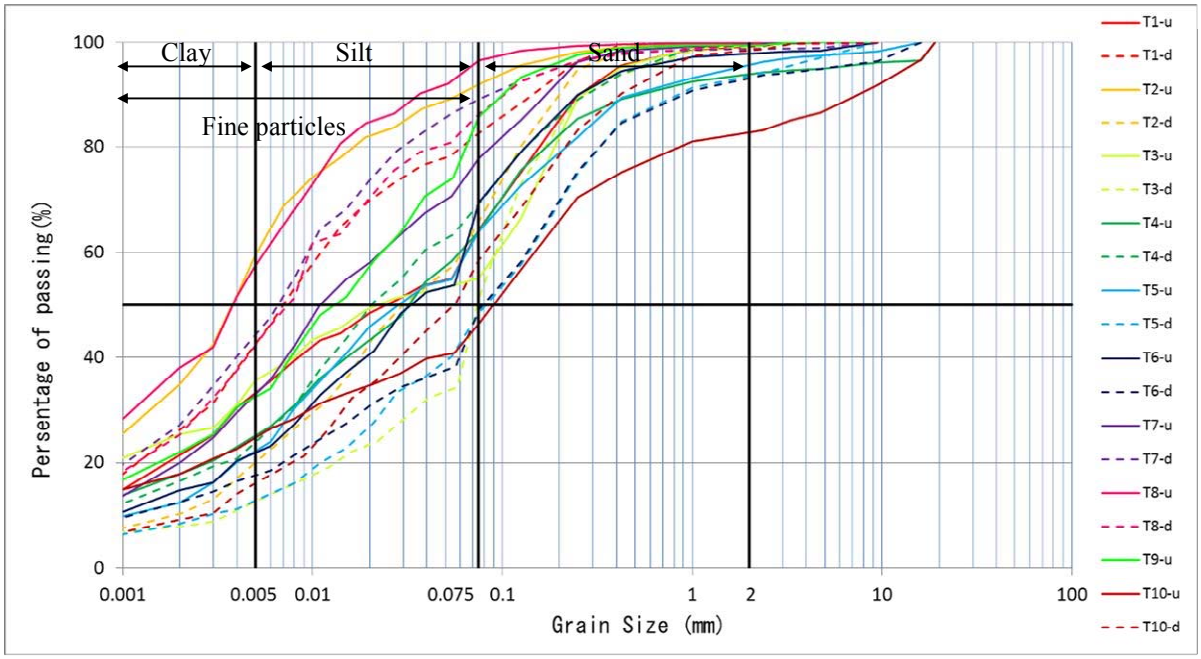



**Figure 4-3-5.3 Grain Size Distribution Curve of Sandy Loam**

[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.

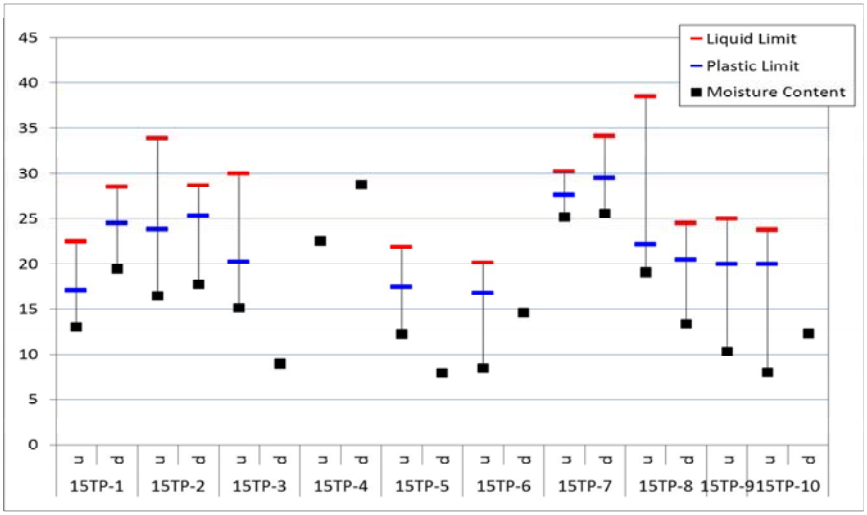



**Figure 4-3-5.4 Relationship between Atterberg Limits and Field Moisture Contents**

[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.

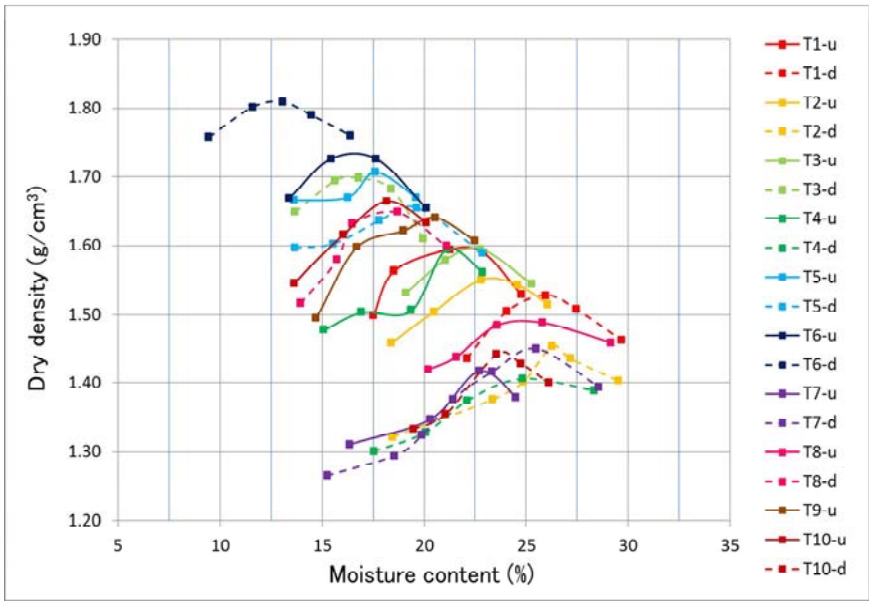



**Figure 4-3-5.5 Compaction Curves of Sandy Loam**

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.

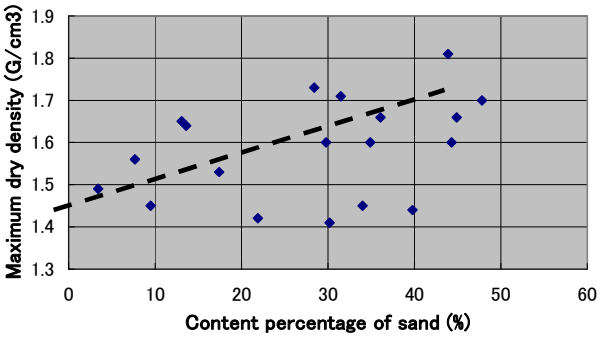



**Figure 4-3-5.6 Relationship between Sand % and pdmax**

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, % | $\rho_{dmax}$, t/m$^3$ | $\rho_d$, t/m$^3$ | M.C., % | K, cm/sec | $\rho_d$, t/m$^3$ | M.C., % | C, KN/m$^2$ | $\varphi$, $^o$ | $\rho_d$, t/m$^3$ | M.C., % | 50 KPa | 100 KPa | 200 KPa | 400 KPa | $\rho_d$, t/m$^3$ | M.C., % | C, KN/m$^2$ | $\varphi$, $^o$ | C, KN/m$^2$ | $\varphi$, $^o$ |
| 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.<br>Medium - Low percentage of 0.005mm content | 1u, 2d, 5u, 6u, 10u | 15TP -10u |
| G-2 | Low P.I.<br>High percentage of 0.005mm content | 1d, 7u, 7d, 8d, 9u | 15TP -1d |
| G-3 | Medium P.I<br>High-Medium percentage of 0.005mm content | 2u, 3u, 8u | 15TP -2u |
| G-4 | Non Plastic<br>Low percentage of 0.005mm content | 3d, 5d, 6d | 15TP -5d |
| G-5 | Non Plastic<br>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%

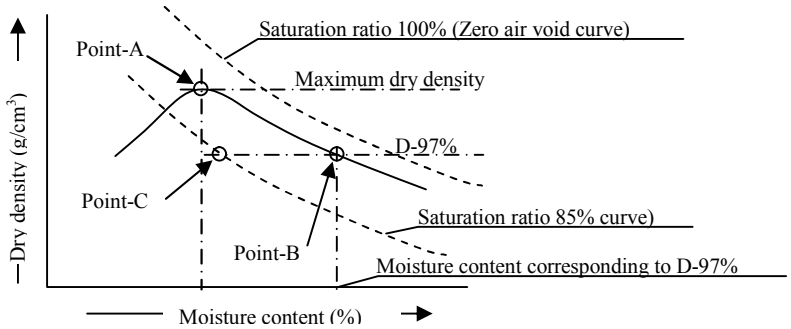



**Figure 4-3-5.7 Testing Point (Specimen Conditions)**

[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

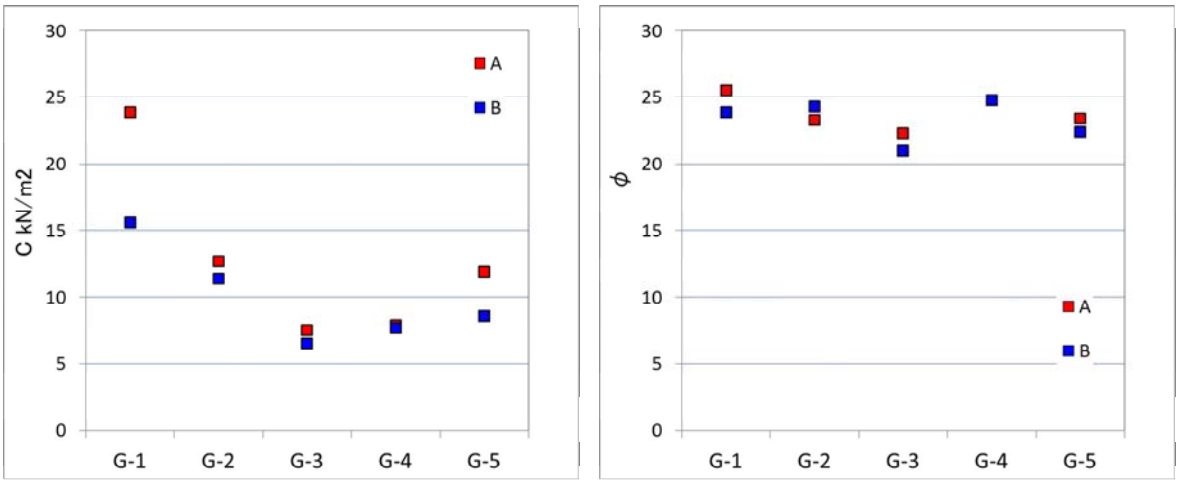



**Figure 4-3-5.8 Result of Direct Shear Test**

[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.

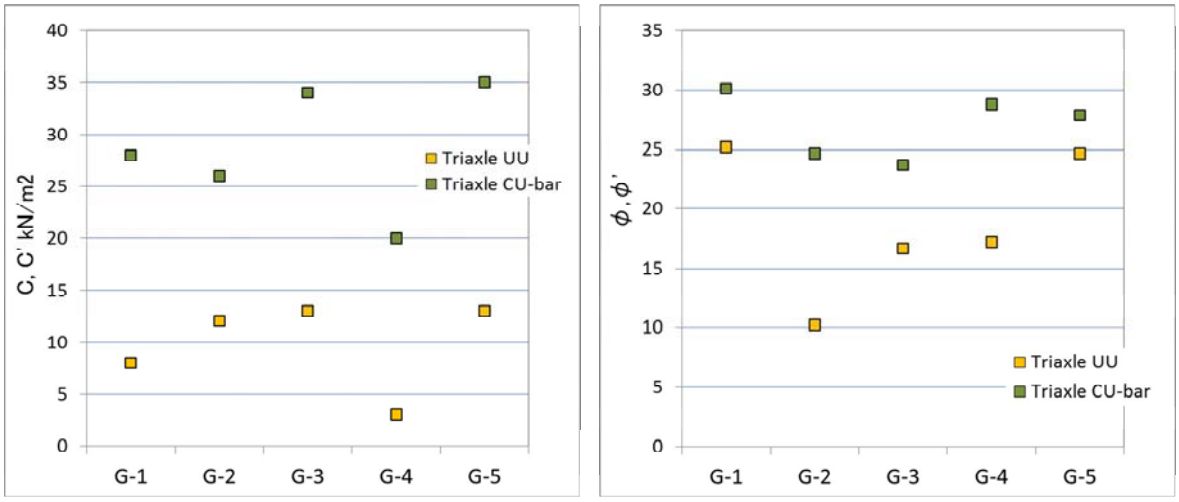



**Figure 4-3-5.9 Results of Triaxial UU Test and Triaxial CU-Bar Test**

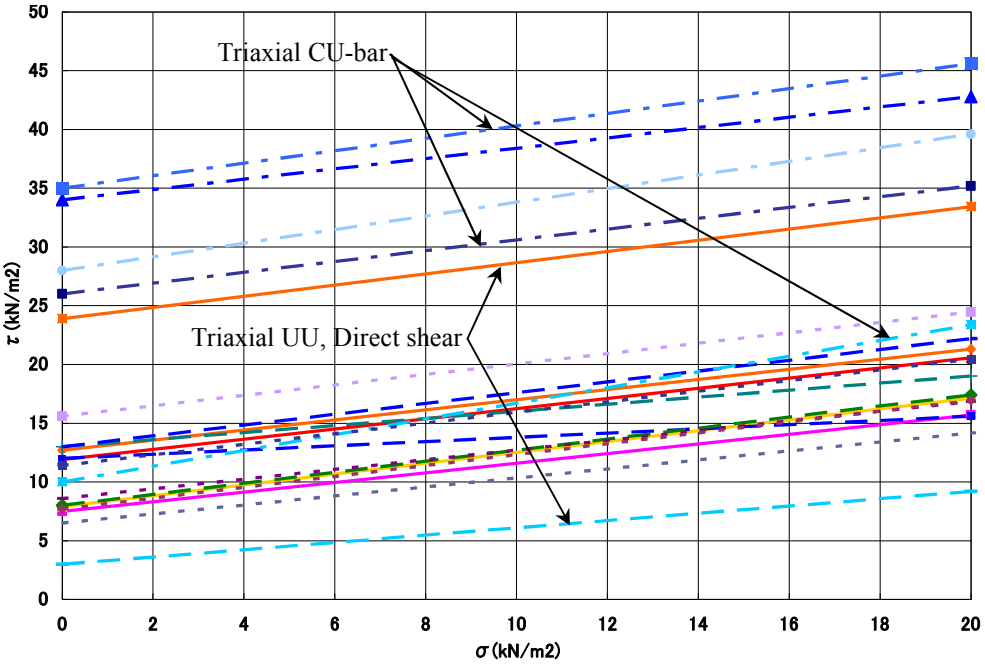



Figure 4-3-5.10 Summary of the Shearing Test Results

[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.

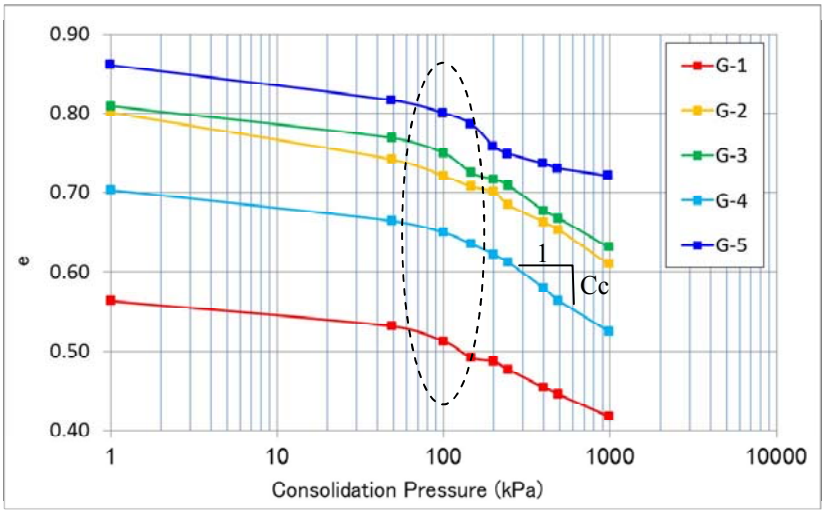



Figure 4-3-5.11 Result of the Consolidation Test

[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.

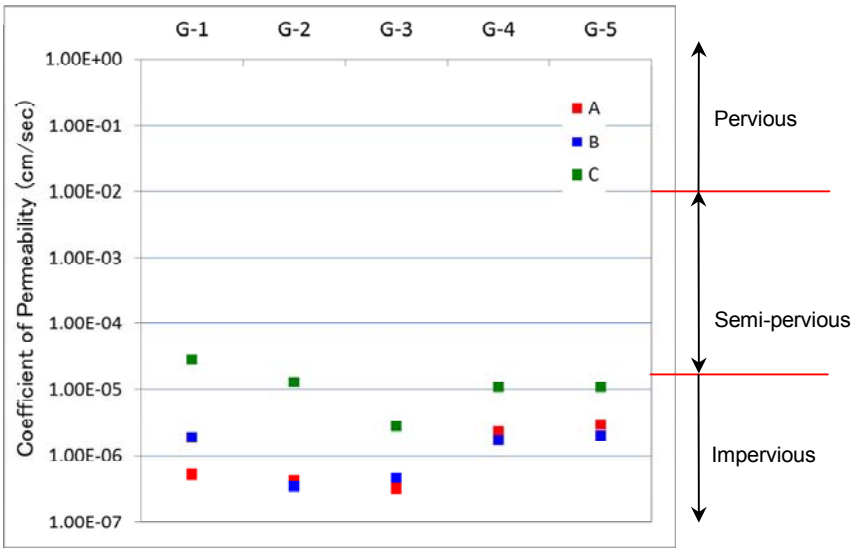



**Figure 4-3-5.12 Results of the Falling Head Permeability Test**

(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.

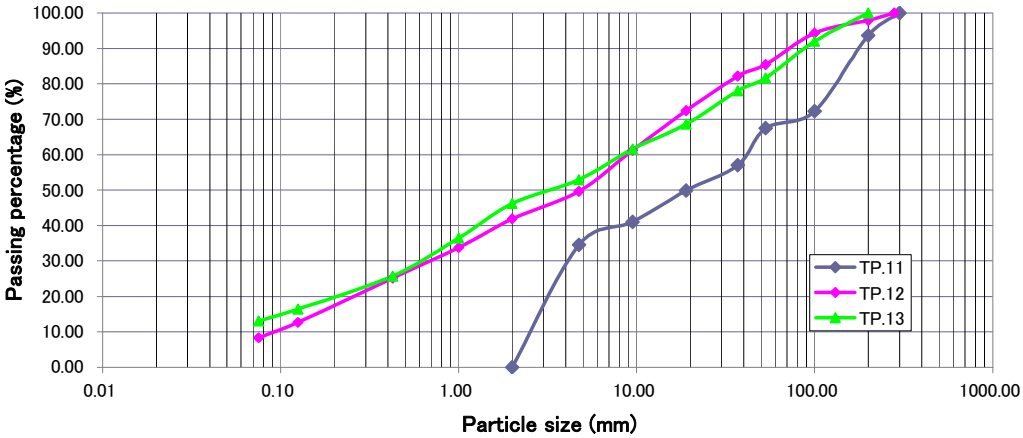



**Figure 4-3-5.13 Particle Size Distribution of Sand-and-Gravels**

(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 | $1.9 \times 10^{-7}$ | Soil + 5.0% bentonite | $3.9 \times 10^{-7}$ |
| Soil + 6.8% cement | $4.3 \times 10^{-8}$ | Soil + 15.0% bentonite | $8.3 \times 10^{-7}$ |
| Soil + 10.0% cement | $2.4 \times 10^{-8}$ | Soil + 15.0% bentonite | $4.3 \times 10^{-7}$ |

### (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: $k=3.3 \times 10^{-5}$ cm/sec, sand-and-gravel fine: $k=5.3 \times 10^{-4}$ cm/sec and sand-and-gravel coarse: $k=3.4 \times 10^{-5}$ cm/sec (refer to Table 4-3.5.6); and after being mixed with cement, all of them become $k=7.7 \times 10^{-7}$ cm/sec ~ $3.9 \times 10^{-8}$ 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 |

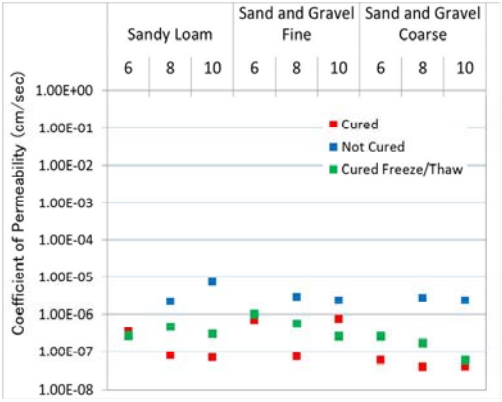



**Figure 4-3.5.14 Result of Falling Head Permeability Tests to Soil-cement**

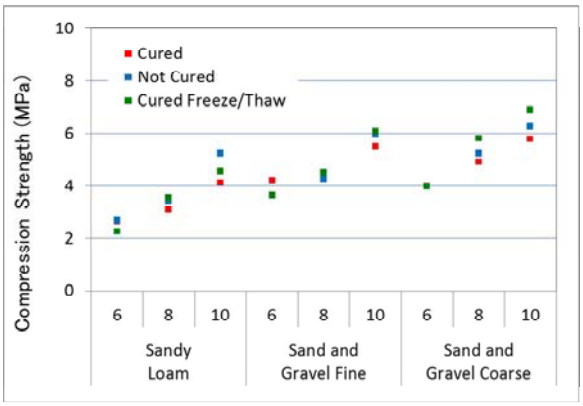



**Figure 4-3.5.15 Result of Unconfined Compression Tests to Soil-cement**

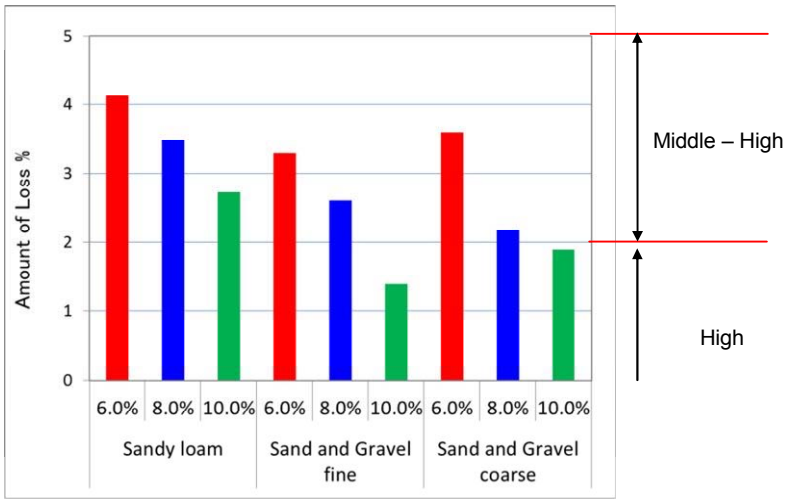



**Figure 4-3.5.16 Result of Slaking Tests to Soil-cement**

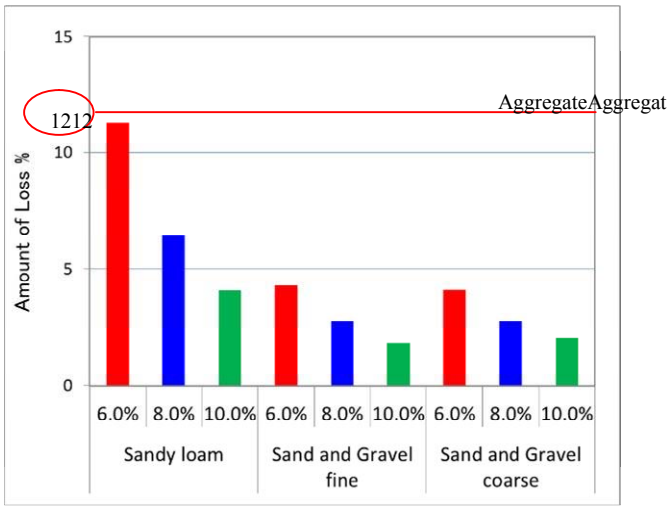



**Figure 4-3.5.17 Result of Sodium Sulfate Soundness Tests to Soil-cement**

### 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.

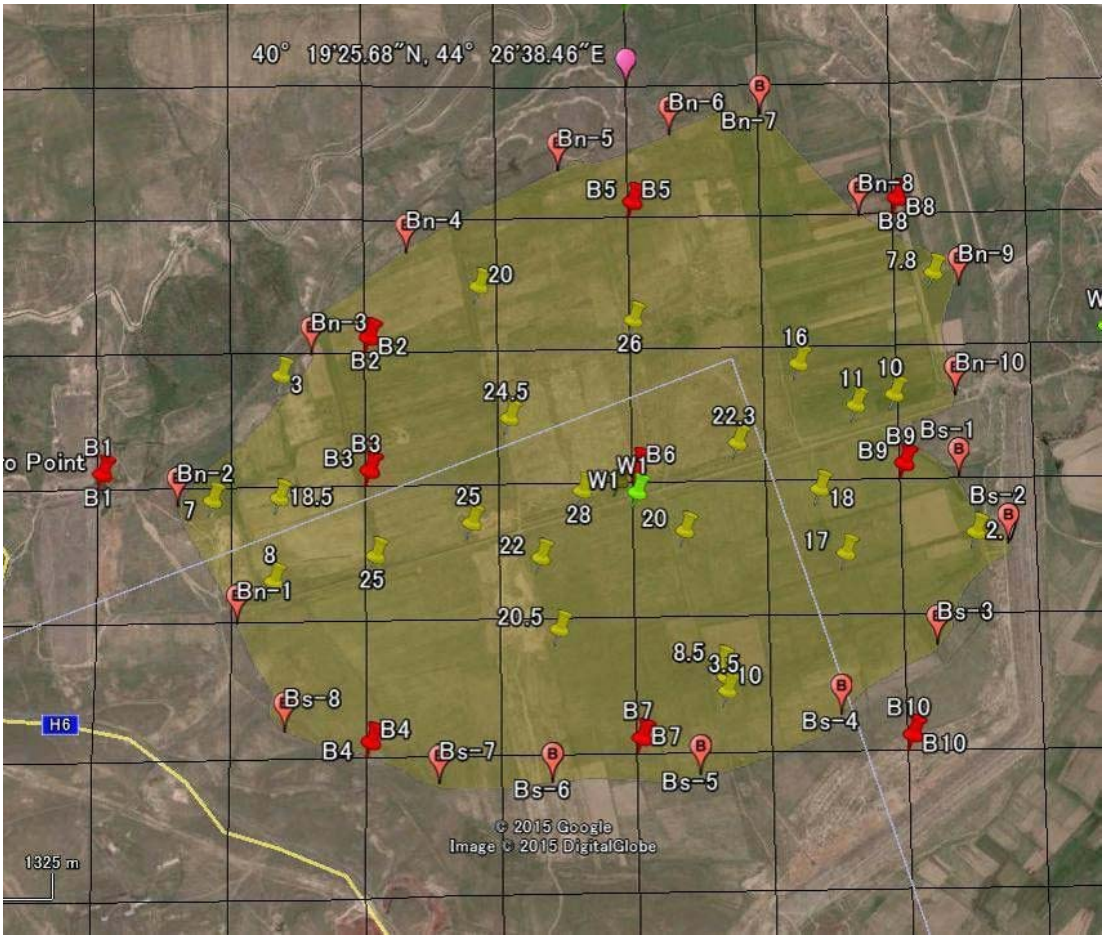



**Figure 4-3-6.1 Existing Range of Sandy Loam (Yellow-colored Area) and the Confirmation Points**

(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

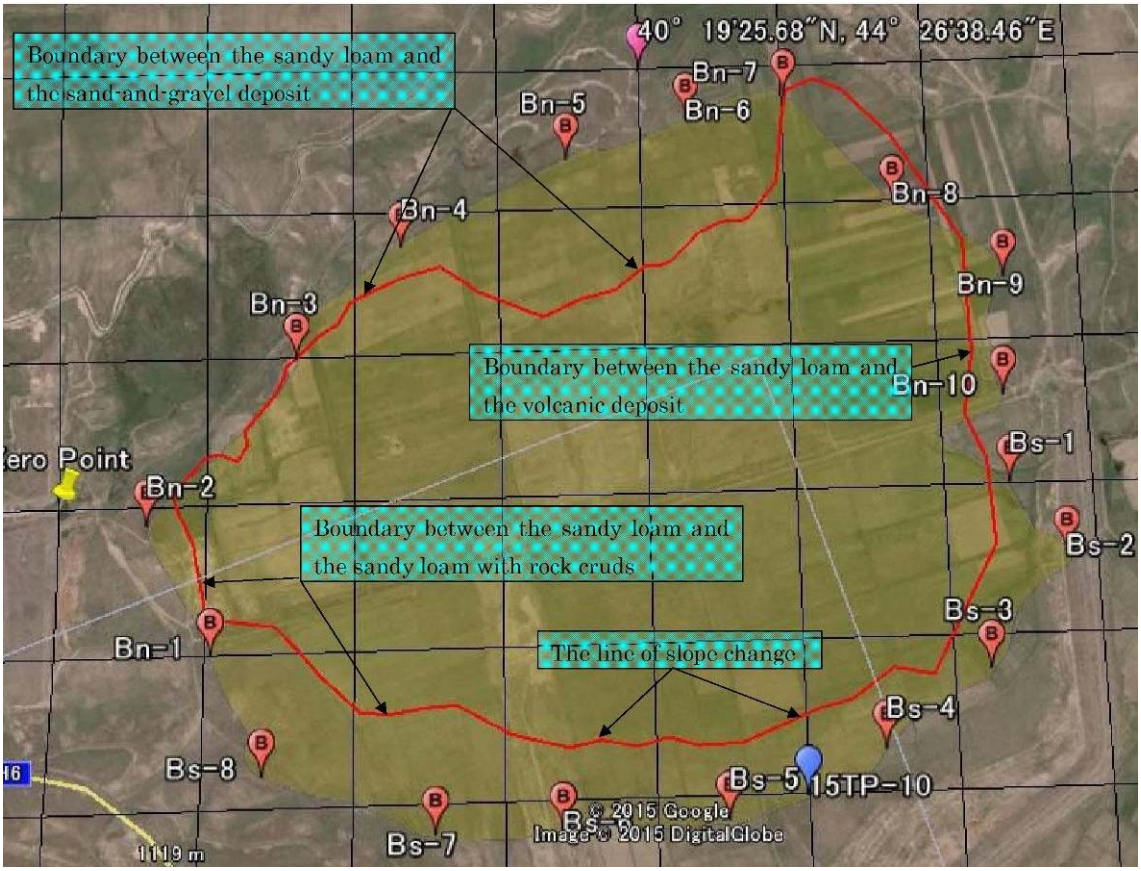



**Figure 4-3-6.2 Boundary Survey Result**

**(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.

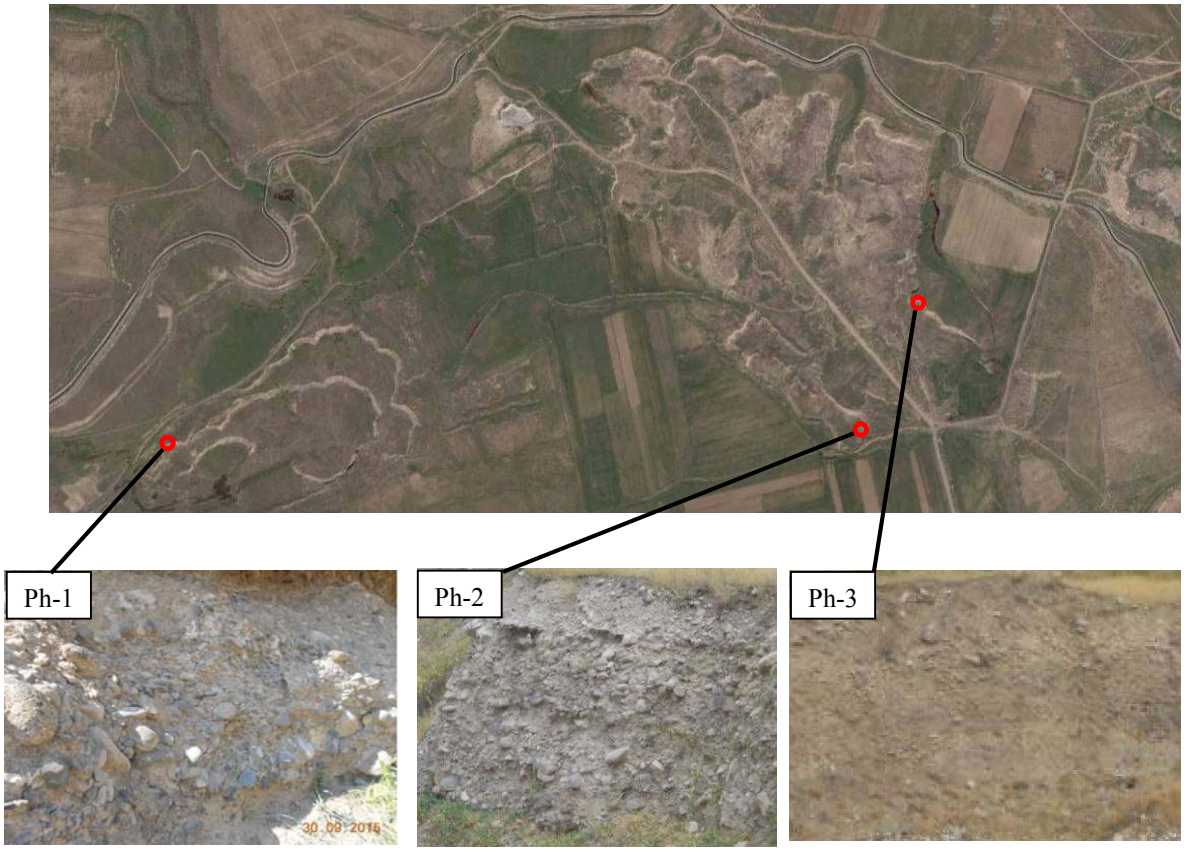



**Figure 4-3-6.3 Conditions Observed on the Outcrop of Sand-and-Gravel Layers**

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.

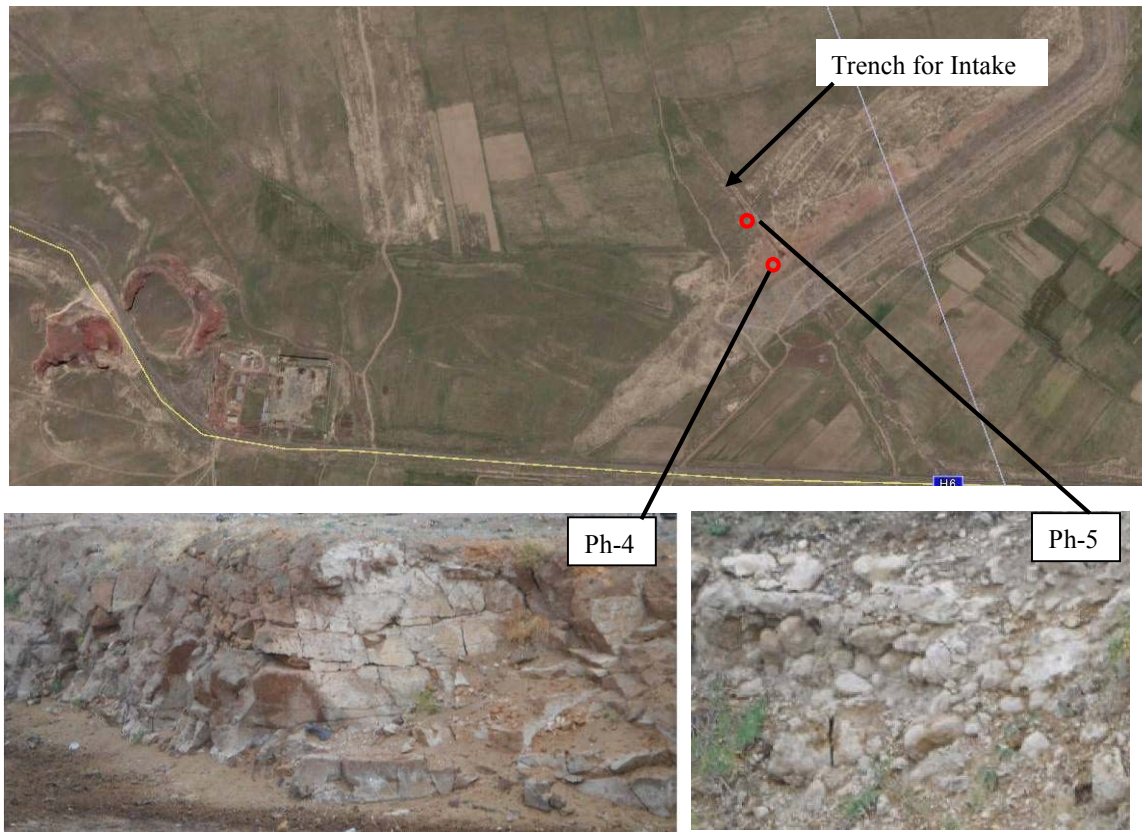



**Figure 4-3-6.4 Conditions Observed on the Outcrop of the Lava Layer and the Deposits of Pyroclastic Flow Layer**

**(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

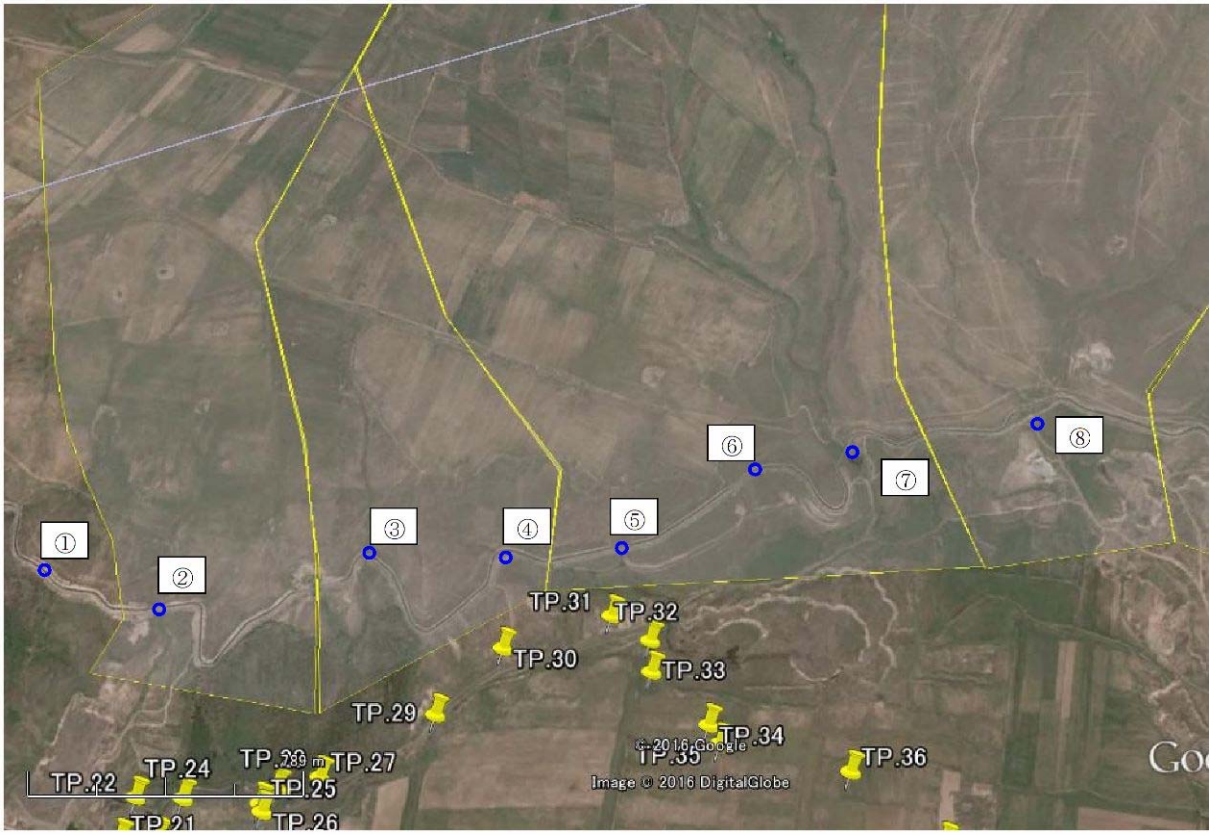



**Figure 4-3-6.8 Location Map of the Observation Points**

(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<br>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

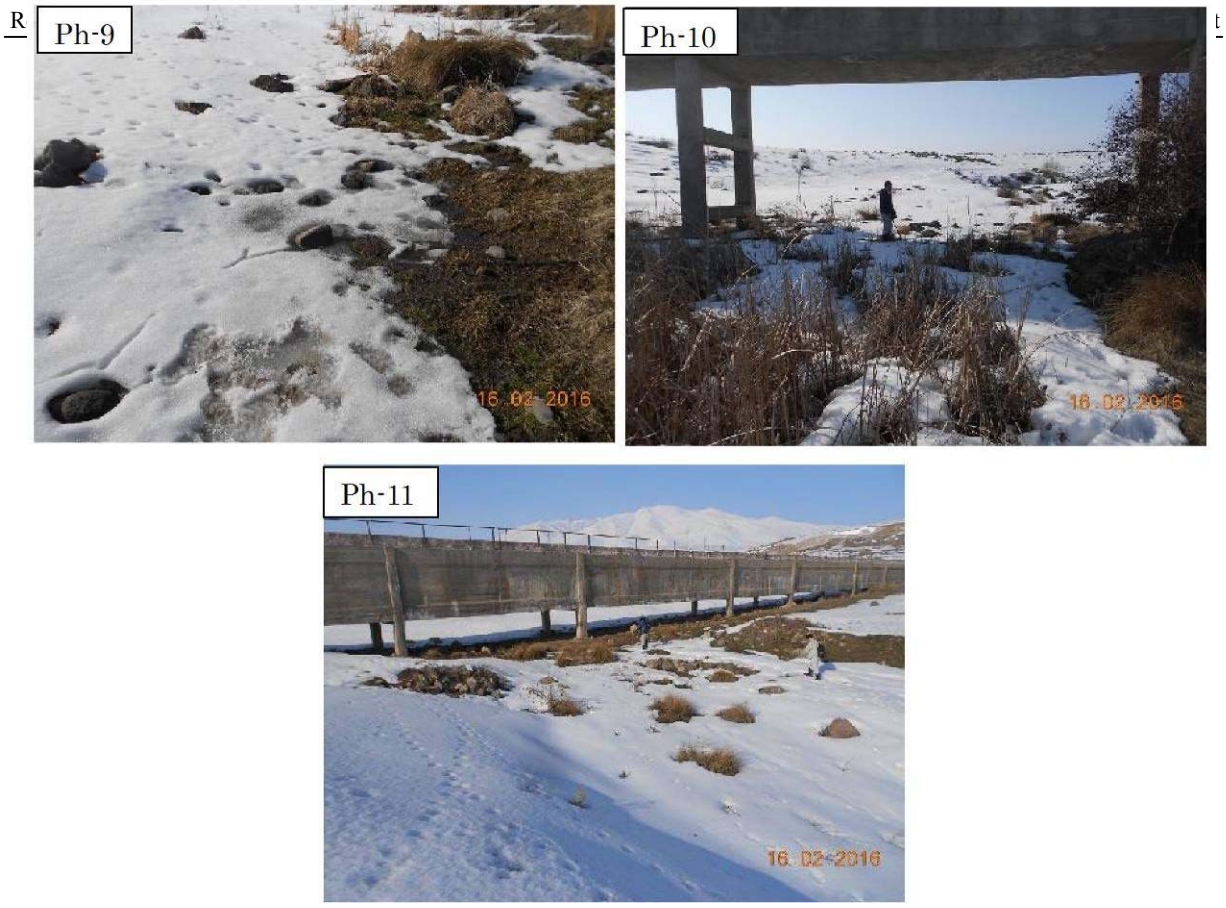



**Figure 4-3-6.9 Photo of the Survey on 16th of February,** 2016

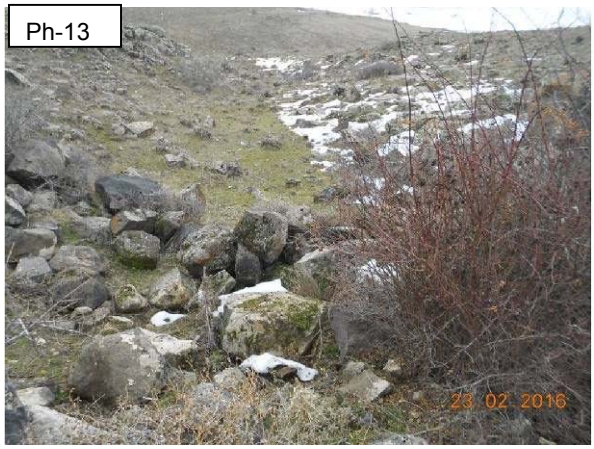
(b) Survey on 24th of February, 2016, cloudy, 7 ℃± as shown in Table 4-3-6.2

**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)<br>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)<br>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)<br>Quantity is uncountable. |

Ph-12


Ph-13




Ph-14


Ph-15


Ph-16


Ph-17


Ph-18


Ph-19





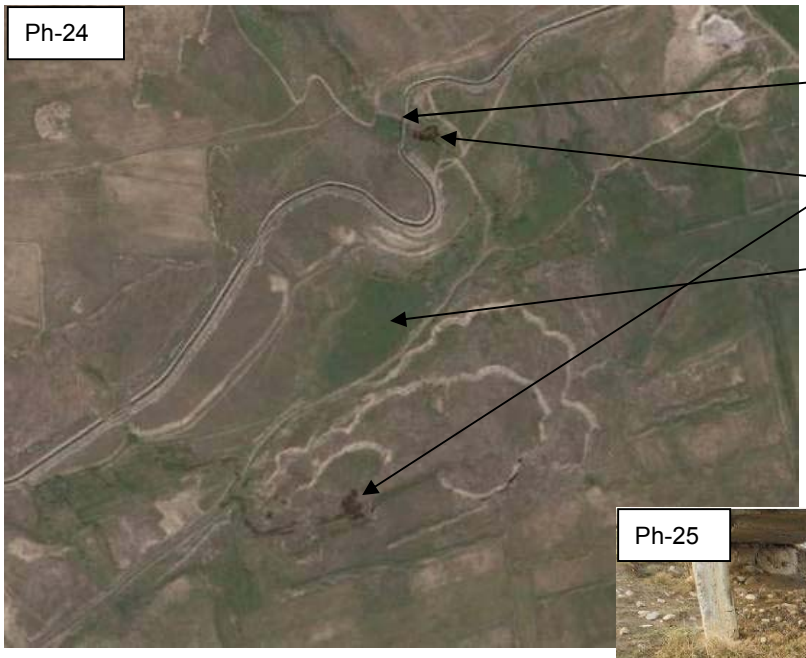




**Figure 4-3-6.10 Photo of the Survey on 24th of February, 2016**

(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.

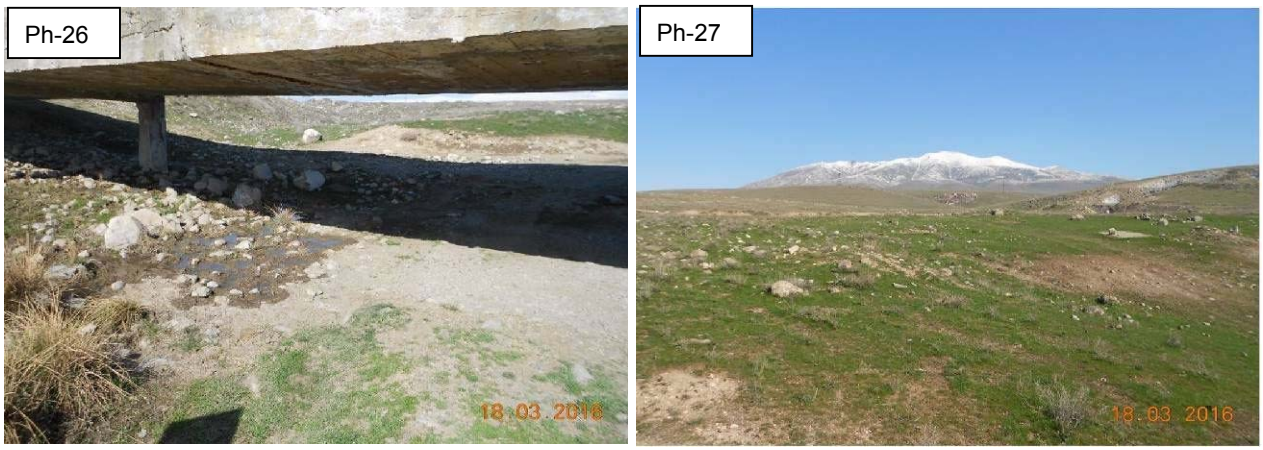



**Figure 4-3-6.11 Photo of the Survey on 18th of March 2016**

(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.

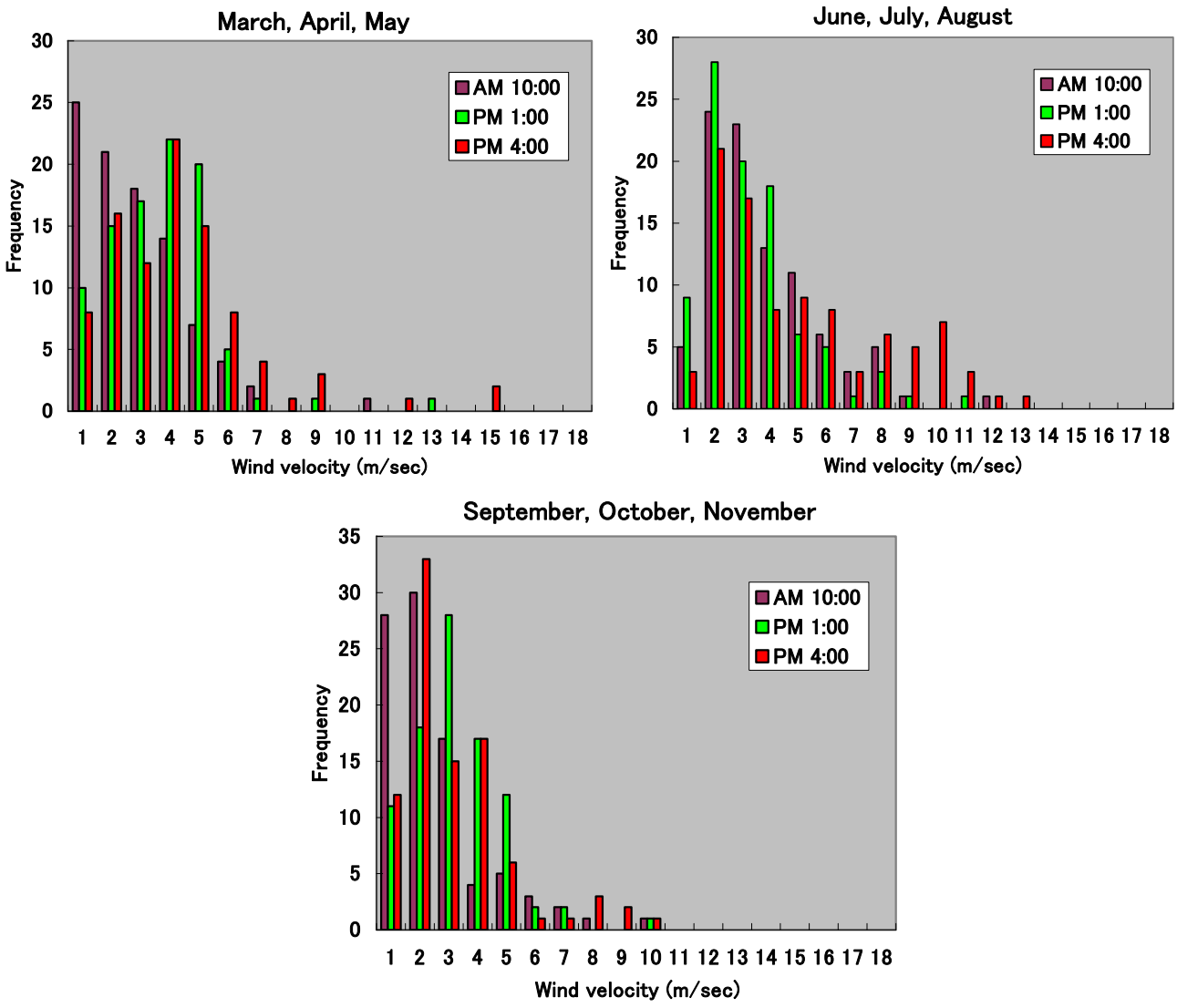



Figure 4-3-6.13 Mean Wind Velocity for Ten Minutes Observed in 2014

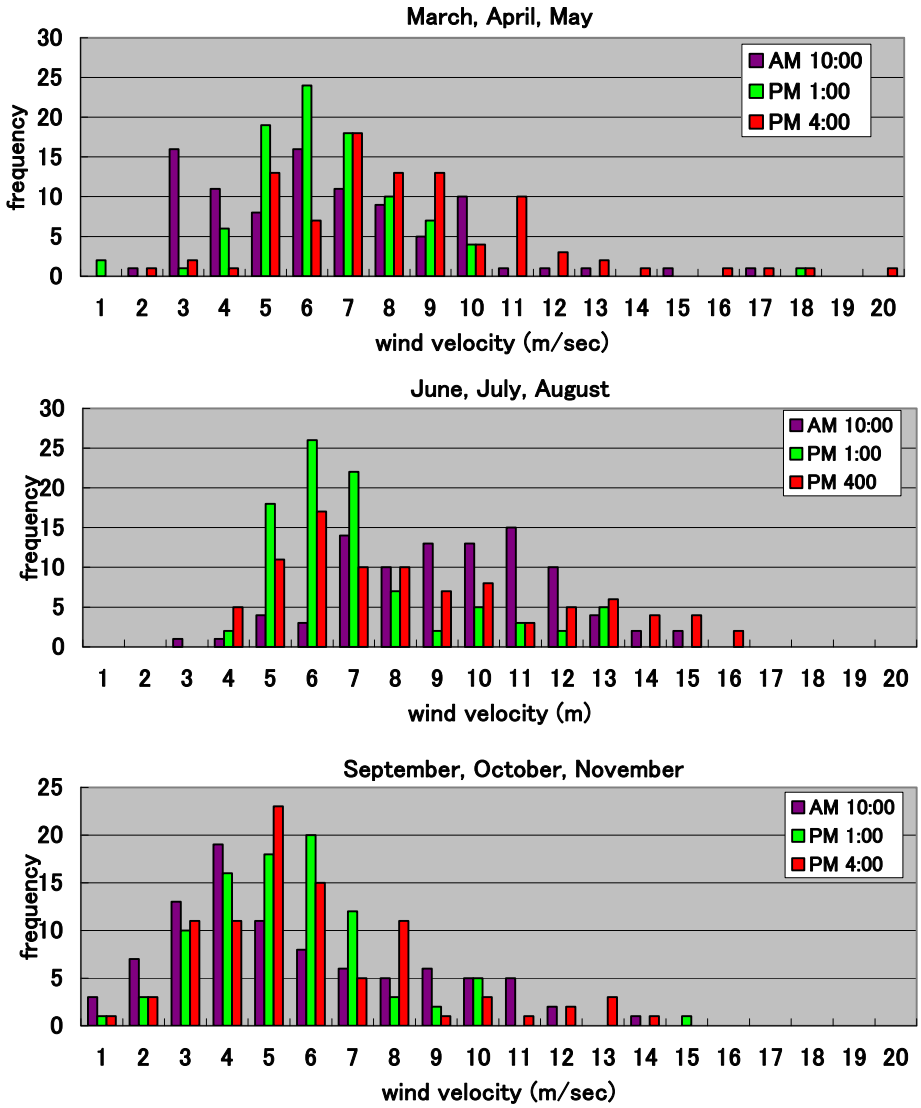



Figure 4-3-6.14 Instantaneous Wind Velocity during Ten Minutes Observed in 2014

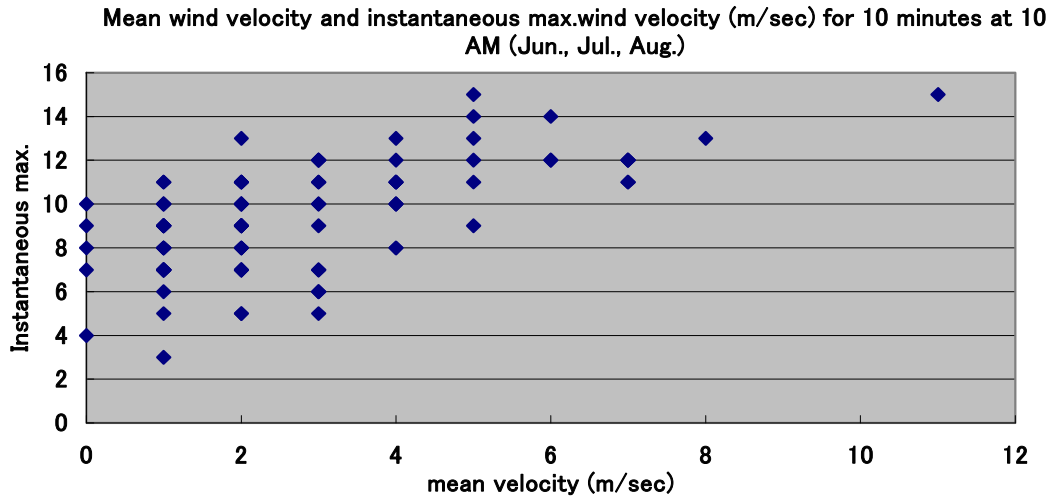



Figure 4-3-6.15 Relationship between Mean Wind Velocity and Instantaneous Wind Velocity

(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.

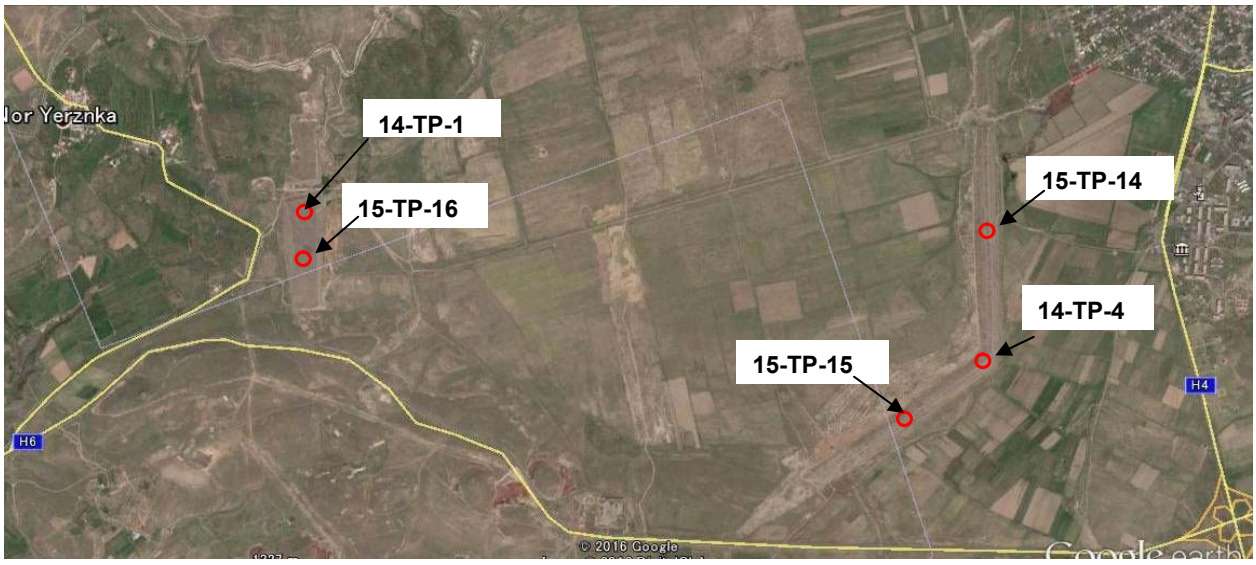



Figure 4-3-7.3 Test-pit Location for the Investigation of Dam Bodies


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.

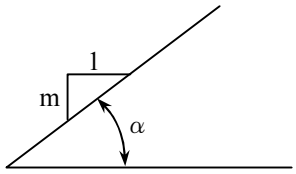
**Table 4-3-7.4 Result of Repose Angle Measurement**

| 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 |

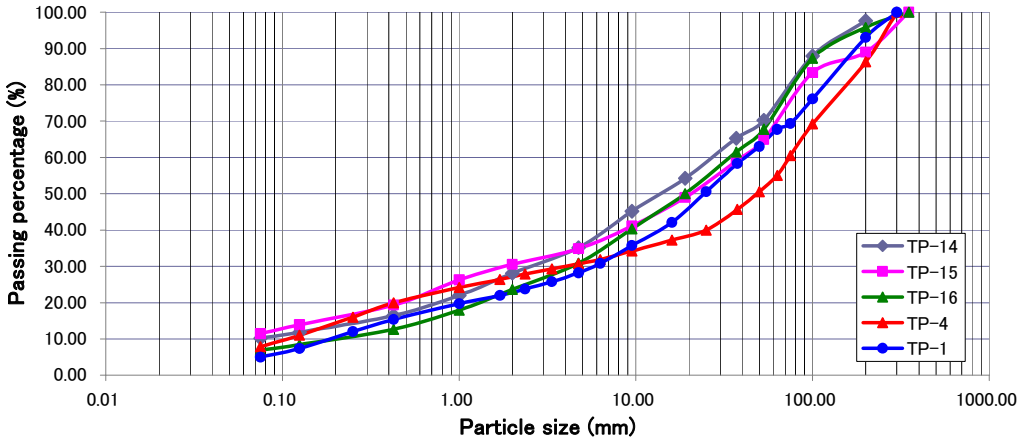



**Figure 4-3-7.8 Particle Size Distribution Curve of Sand-and-Gravels from the Existing Dam Bodies**

[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**

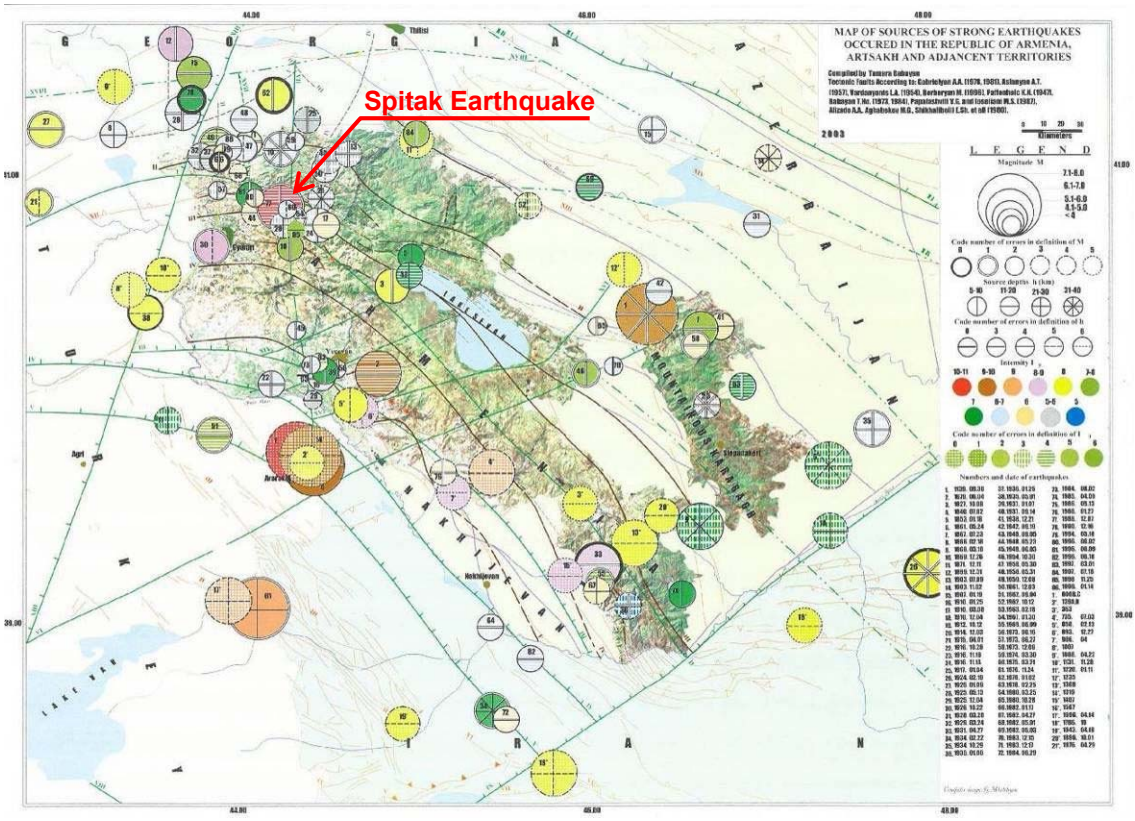
| Item | Calculation formula | TP-14 | | TP-15 | | TP-16 | |
|---|---|---|---|---|---|---|---|
| | | Value | unit | Value | unit | Value | unit |
| ①Total volume of the excavated material | | 80,100 | cm3 | 108300 | cm3 | 114600 | cm3 |
| ②Total weight of the excavated material | | 156.2 | kg | 203.6 | 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

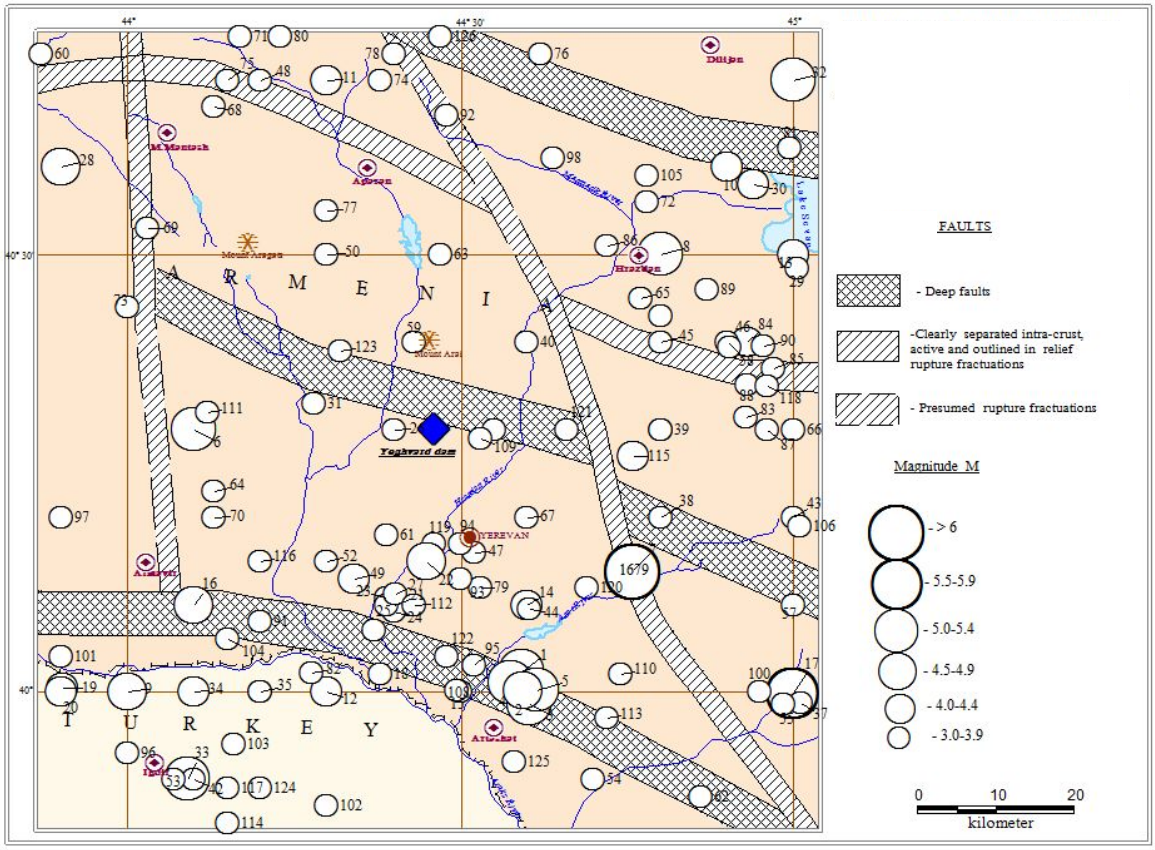



**Figure 4-3-8.2 Epicenters of Historical Earthquakes and Model of Faults around Reservoir Site**

### 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.

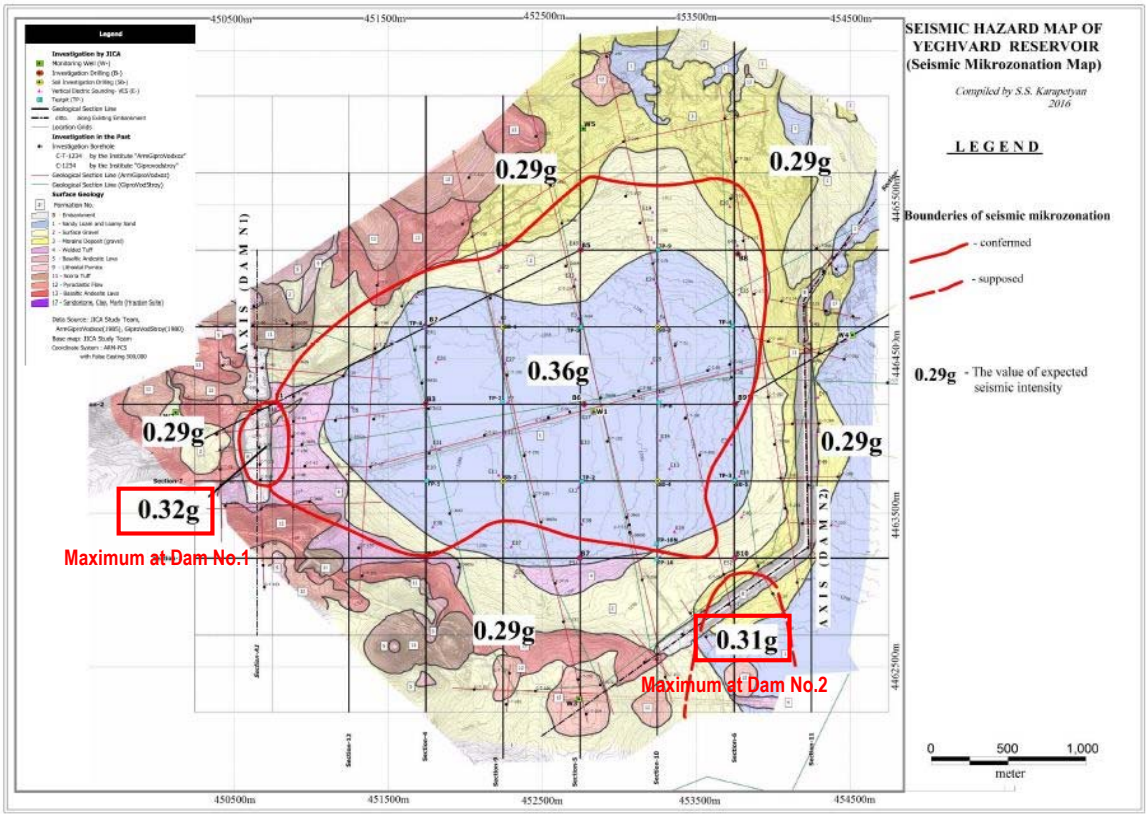



**Figure 4-3-8.3 Seismic Hazard Map of Yeghvard Reservoir**

### 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**

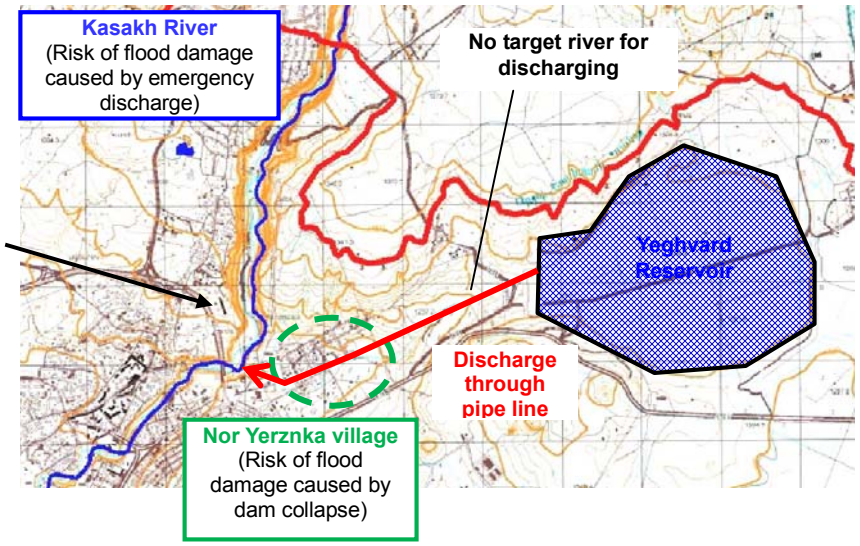
There is no river just downstream of dam bodies which can be a destination of discharging from Yeghvard reservoir because Yeghvard reservoir is planned not across the river but closing plane land by two (2) dam bodies. The nearest river from Yeghvard reservoir is Kasakh River and this river is only the 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**

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

### 4-4-1 Overview of Current Irrigation System

Current irrigation system which distributes water to 8,391 ha through Arzni-Shamiram canal, Lower Hrazdan canal and Ranchpar pump station, is divided into two (2) parts. First part is the east side of Kasakh River before Arzni-shamiram canal crossing the 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 lifts up the collected drain water near lower part of Hrazdan River to pump station No.2, and lifted water is distributed to Lower Hrazdan canal through the No.2. These pump stations are operated by Water Supply Agency (WSA).

Table 4-4-1.1 lists the cultivated crops and those area under current irrigation plan. Those areas are located in Yeghvard WUA in Kotayk Marz, Ashrarak WUA in Aragatsotn and Armabvir Marzes, Vagharshapat WUA in Armavir Marz, and Khoy WUA in Armavir Marz respectively.

**Table 4-4-1.1 Current Irrigation Area and Crops**

| Crop | Area (ha) |
|---|---|
| Wheat | 1,560 |
| Vegetable | 2,819 |
| Potato | 669 |
| Grape | 1,110 |
| Alfalfa | 910 |
| Fruit | 831 |
| Others | 492 |
| Total | 8,391 |

Source) MOA

Most of the areas are 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 WUA install a lot of wells and tackle with water shortage issues by themselves. Consequently, WUA strongly hope to shift from pump-based irrigation to gravity system. Figure 4-4-1.1 shows the scattered pump facilities which located in Khoy WUA and Vagharshapat WUA, Table 4-4-1.2 lists the number of pump facilities in those WUAs, and Figure 4-4-1.2 shows the current situation of schematic diagram of irrigation network.

**Table 4-4-1.2 Pump Facilities in Khoy and Vagharshapat WUA**

| WUA | Deep Well | Pump Station |
|---|---|---|
| Khoy | 61 | 10 |
| Vagarshapat | 72 | 3 |
| Total | 133 | 13 |

Note) Except for WSA of PS are. Akanalich, Metsamor, Ranchpar No.1, 2 pump stations
Source) JICA Study Team

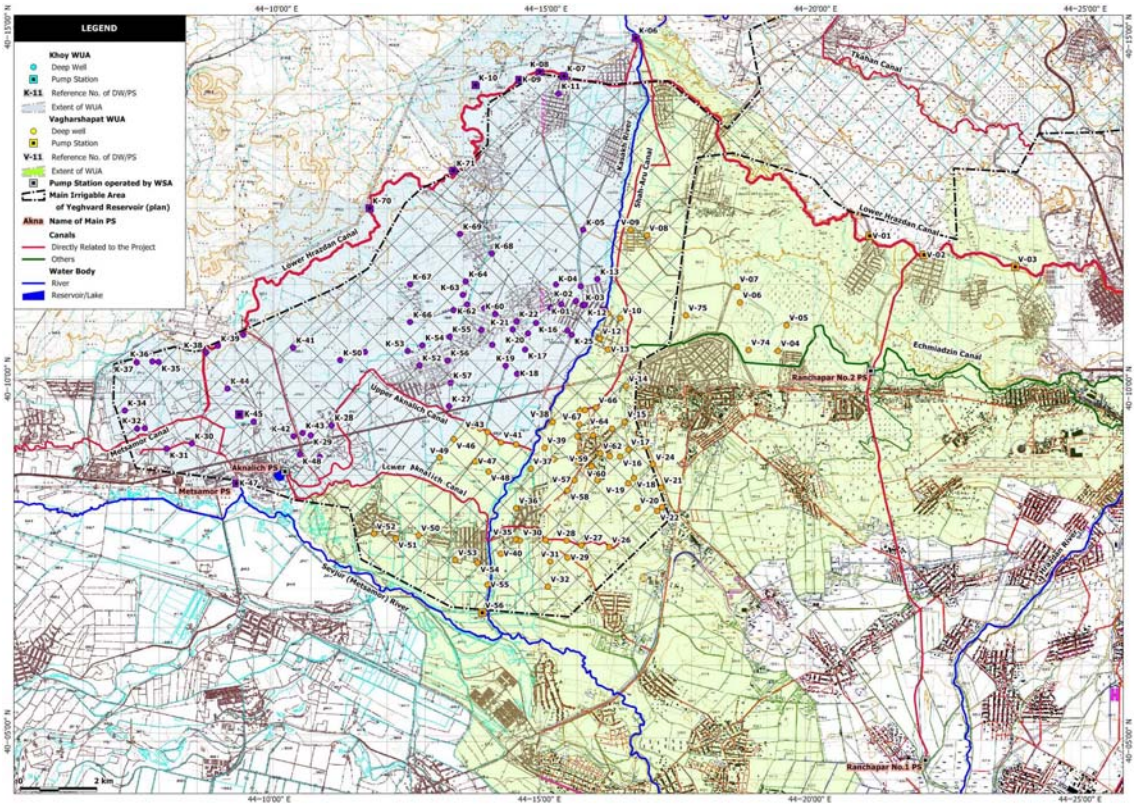



**Figure 4-4-1.1 Scattered Pump Facilities Located in Khoy WUA and Vagharshapat WUA**

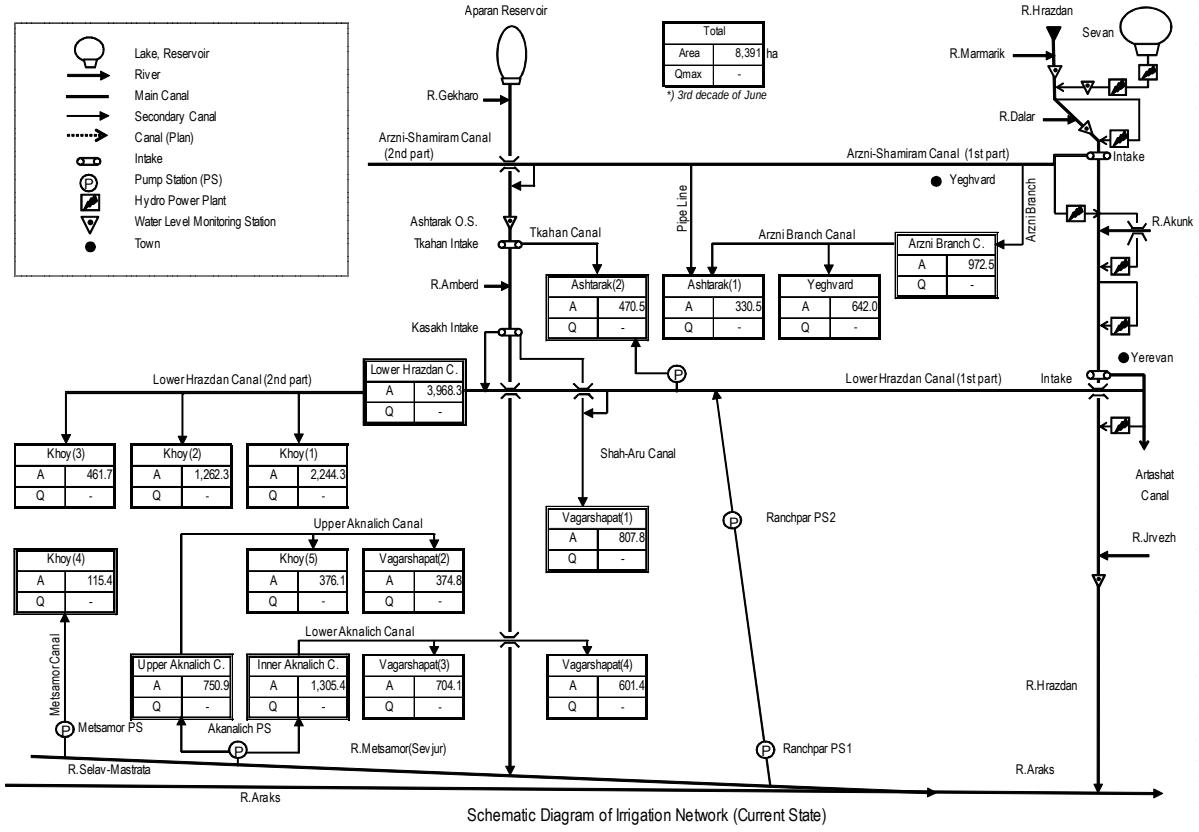



**Figure 4-4-1.2 Current Situation of Schematic Diagram of Irrigation Network**

### 4-4-2 Current Conditions of Irrigation Network System

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

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

A survey for target facilities are carried out for major irrigation facilities in the areas, of which location map is shown in Figure 4-4-2.1.

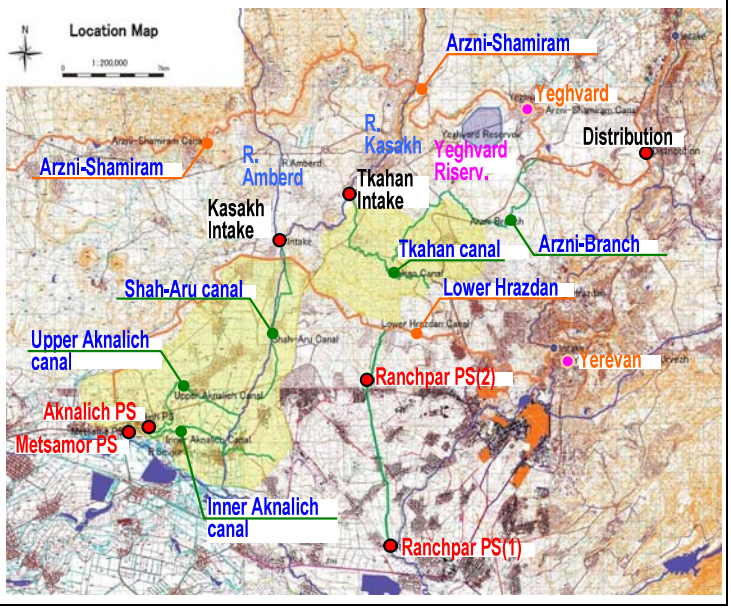
| Responsibility | Facility and structure | Location |
|---|---|---|
| Yeghvard WUA | Arzni-Branch canal, BP. to PK120 |  |
| Ashtarak WUA | Arzni-Branch canal, PK120 to EP. | |
| | Takahan canal | |
| Vagharshapat WUA | Shah-Aru canal | |
| | Kasakh Intake at right bank | |
| Khoy WUA | Upper Aknalich canal | |
| | Inner Aknalich canal | |
| | Metsamor canal | |
| | Kasakh Intake at left bank | |
| Water Supply Agency (WSA) | Lower Hrazdan canal | |
| | Aknalich PS. | |
| | Metsamor PS | |
| | Ranchpar PS. 1 | |
| | Ranchpar PS. 2 | |



**Figure 4-4-2.1 Location Map of Irrigation Facilities**

Inventory survey for the facilities in target area is conducted as followings;

a) Survey on main canal in the Project areas
- Condition of irrigation and facilities (Deterioration and damage)
- Diversion from other water source

b) Survey on Kasakh Intake and main pump stations
- Condition of facilities and pump stations

**(1) Result of inventory survey for targeted canal**

a) Arzni-Branch canal system

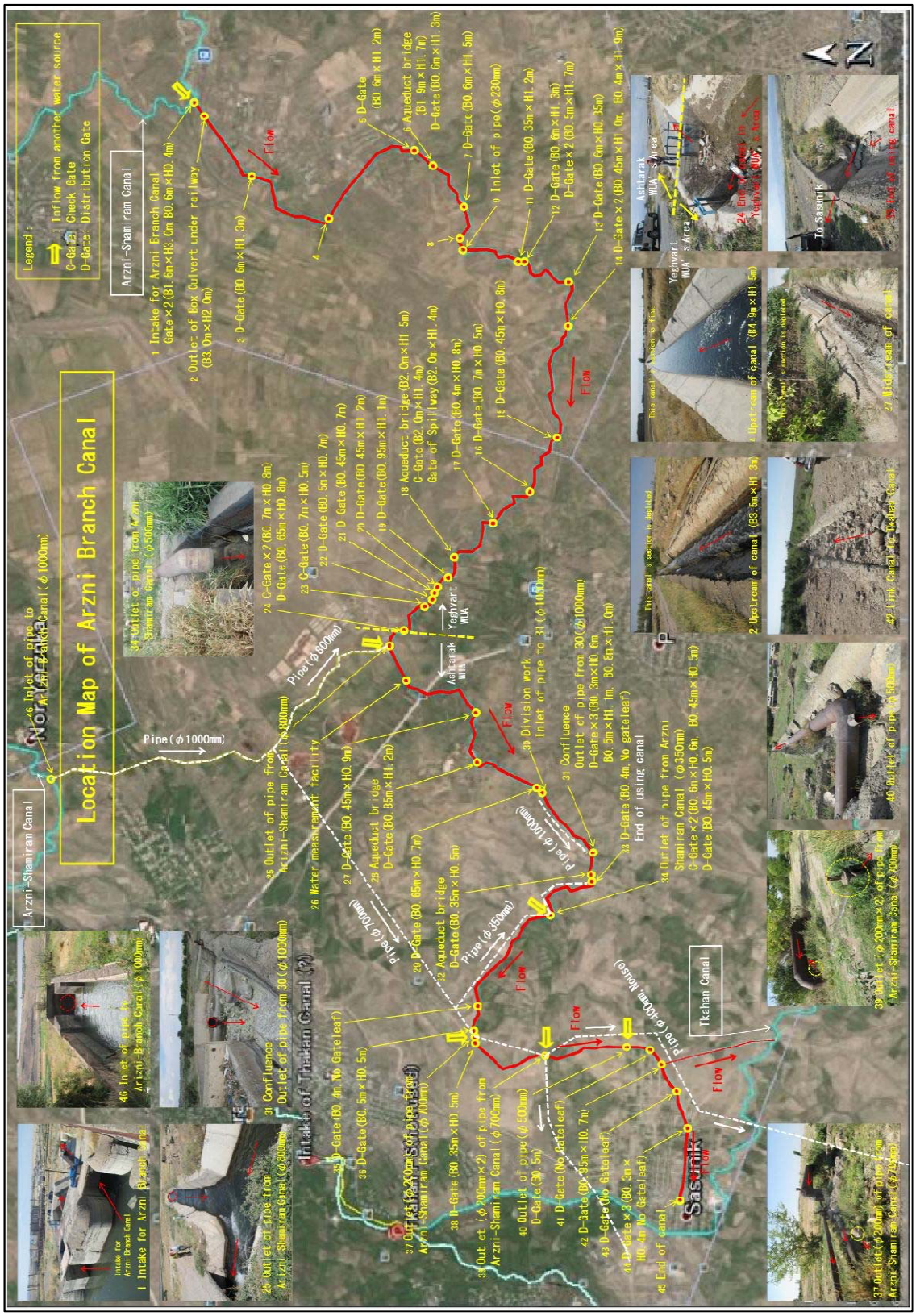



**Figure 4-4-2.2 Location of the Irrigation Facilities of Arzni Branch Canal**

b) Takahan canal system

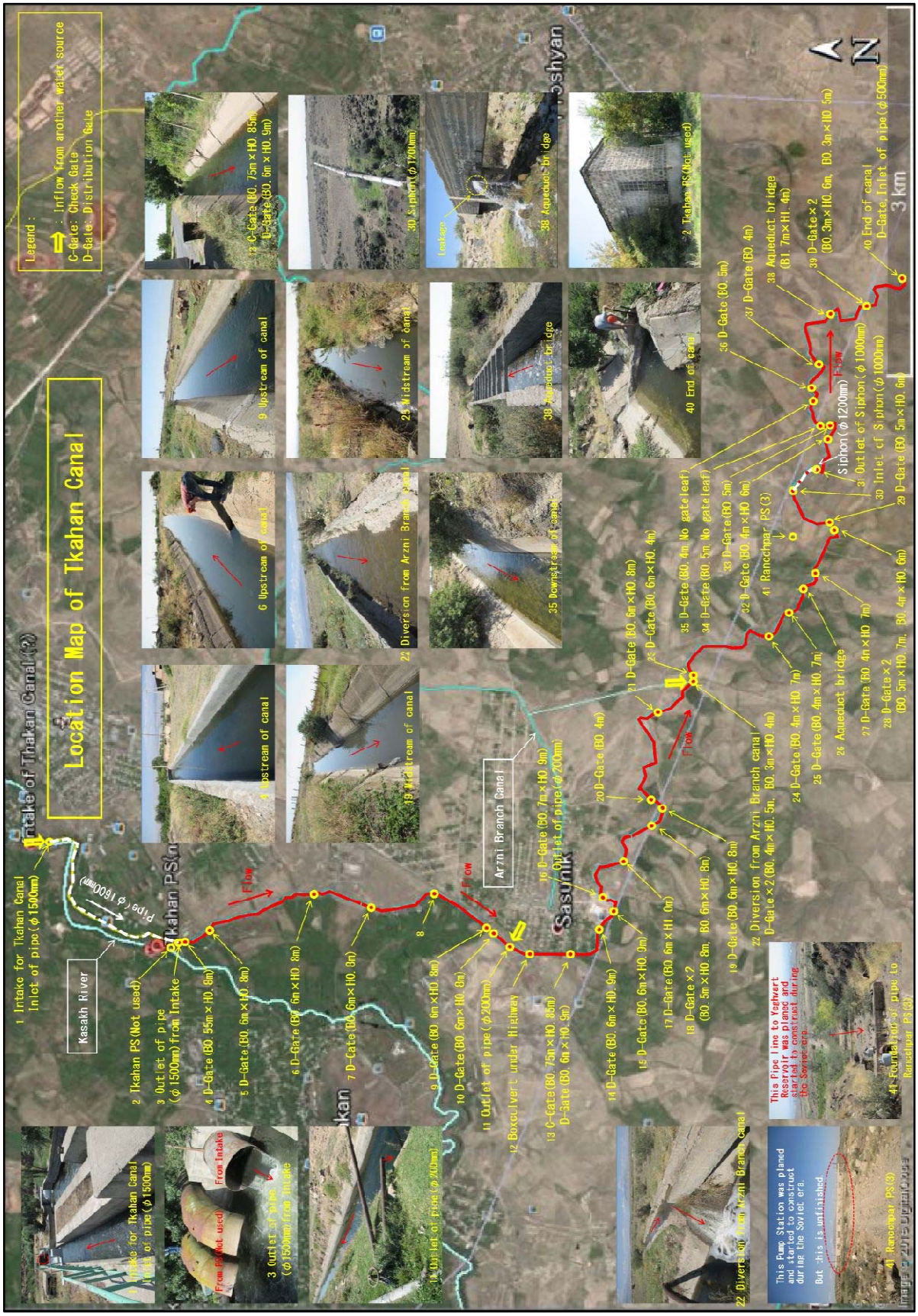



**Figure 4-4-2.3 Location of the Irrigation Facilities of Takahan Canal**

## c) Shah-Aru canal system

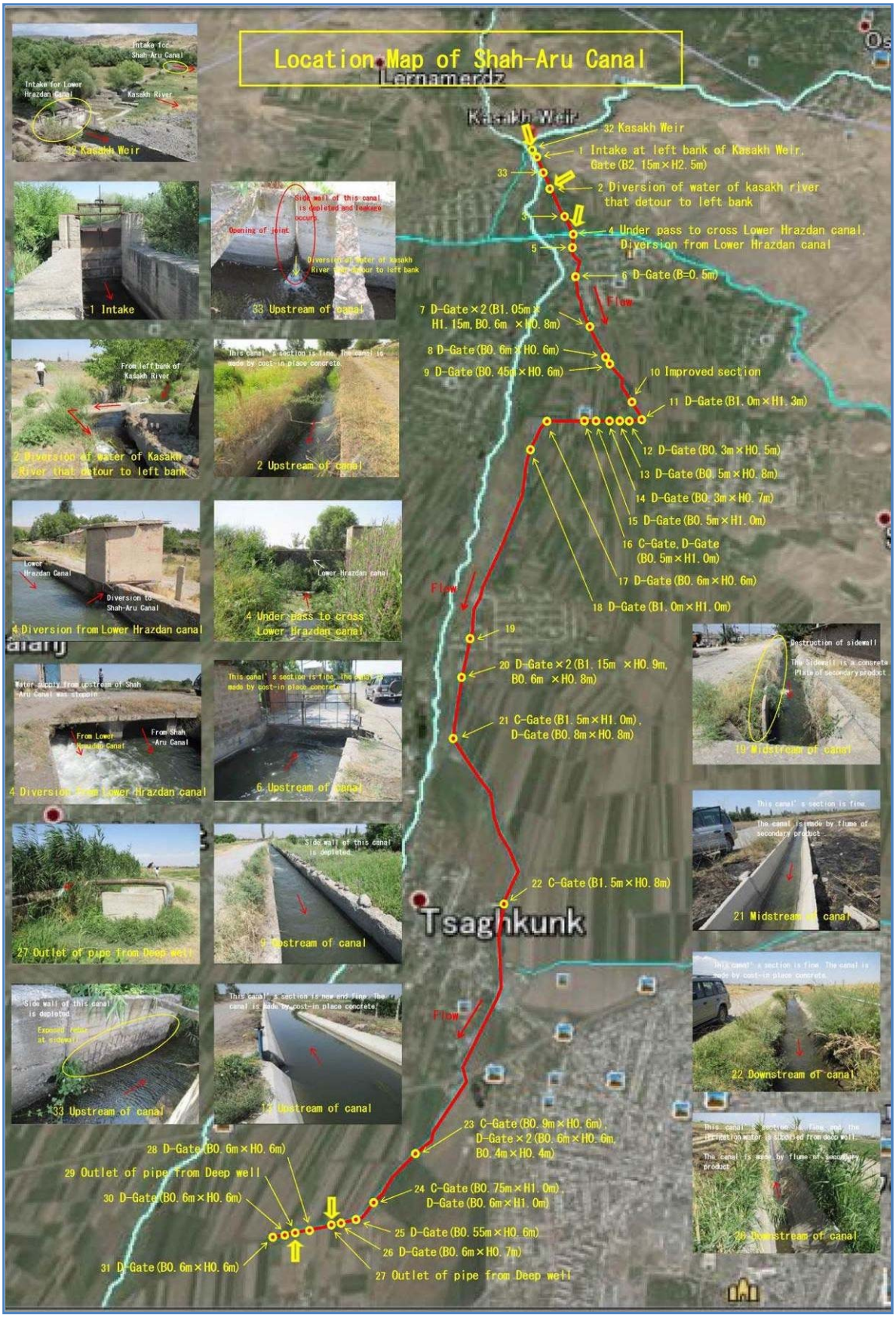



**Figure 4-4-2.4 Location of the Irrigation Facilities of Shah-Aru Canal**

d) Upper Aknalich canal

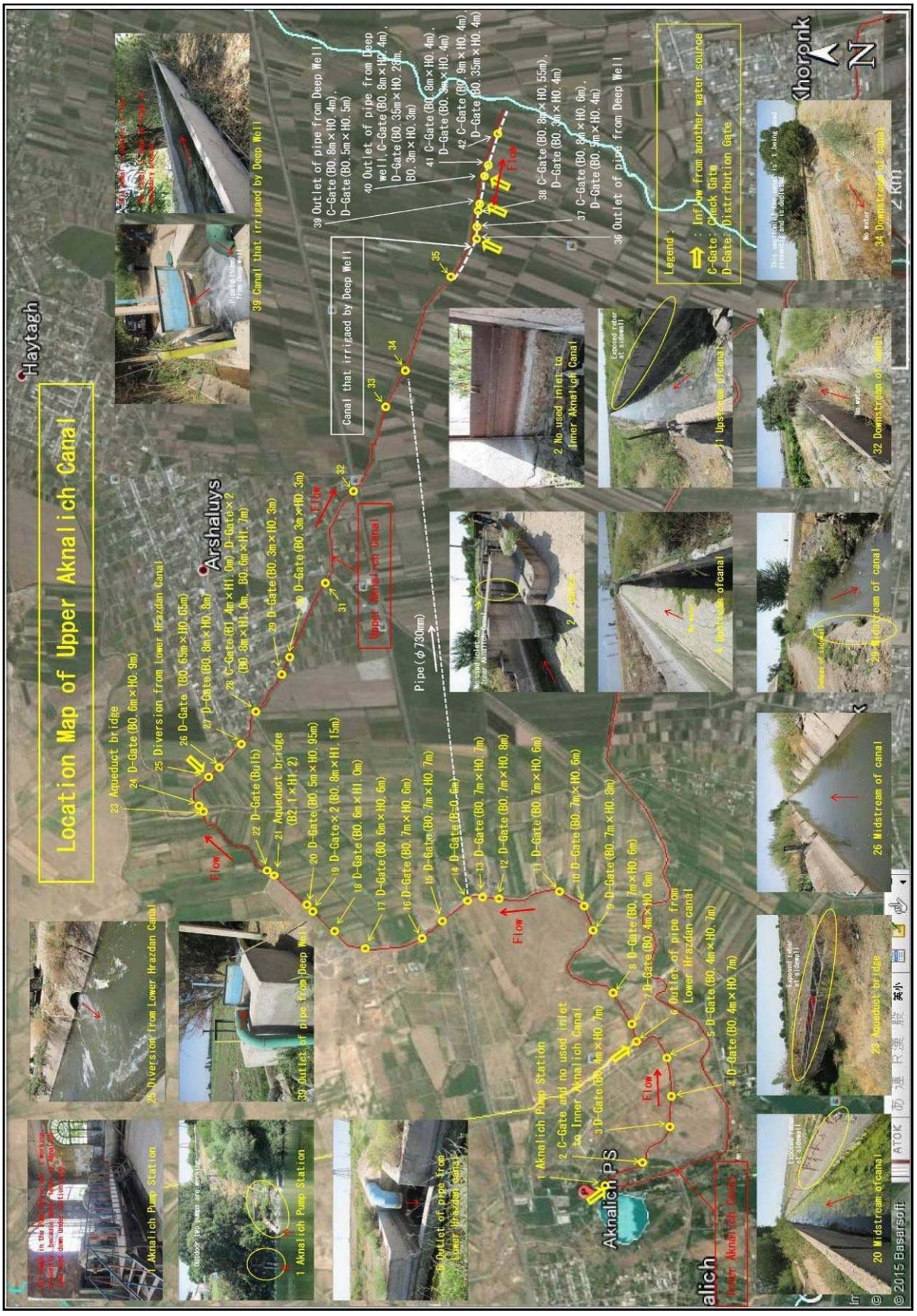



**Figure 4-4-2.5 Location of the Irrigation Facilities of Upper Aknalich Canal**

e) Inner Aknalich canal

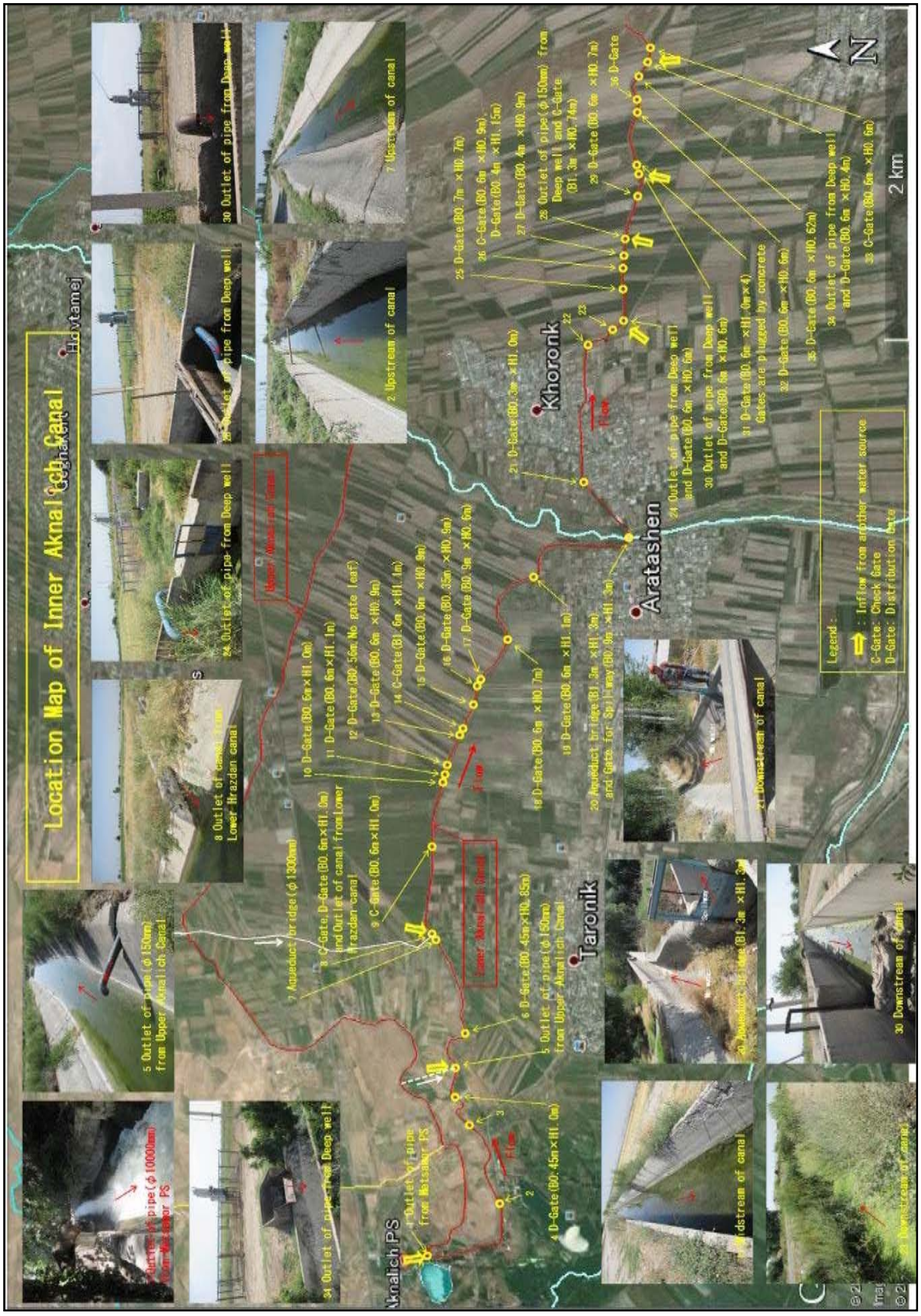



**Figure 4-4-2.6 Location of the Irrigation Facilities of Inner Aknalich Canal**

f) Upper Metsamor canal


**Figure 4-4-2.7 Location of the Irrigation Facilities of Metsamor Canal**

g) Lower Hrazdan canal

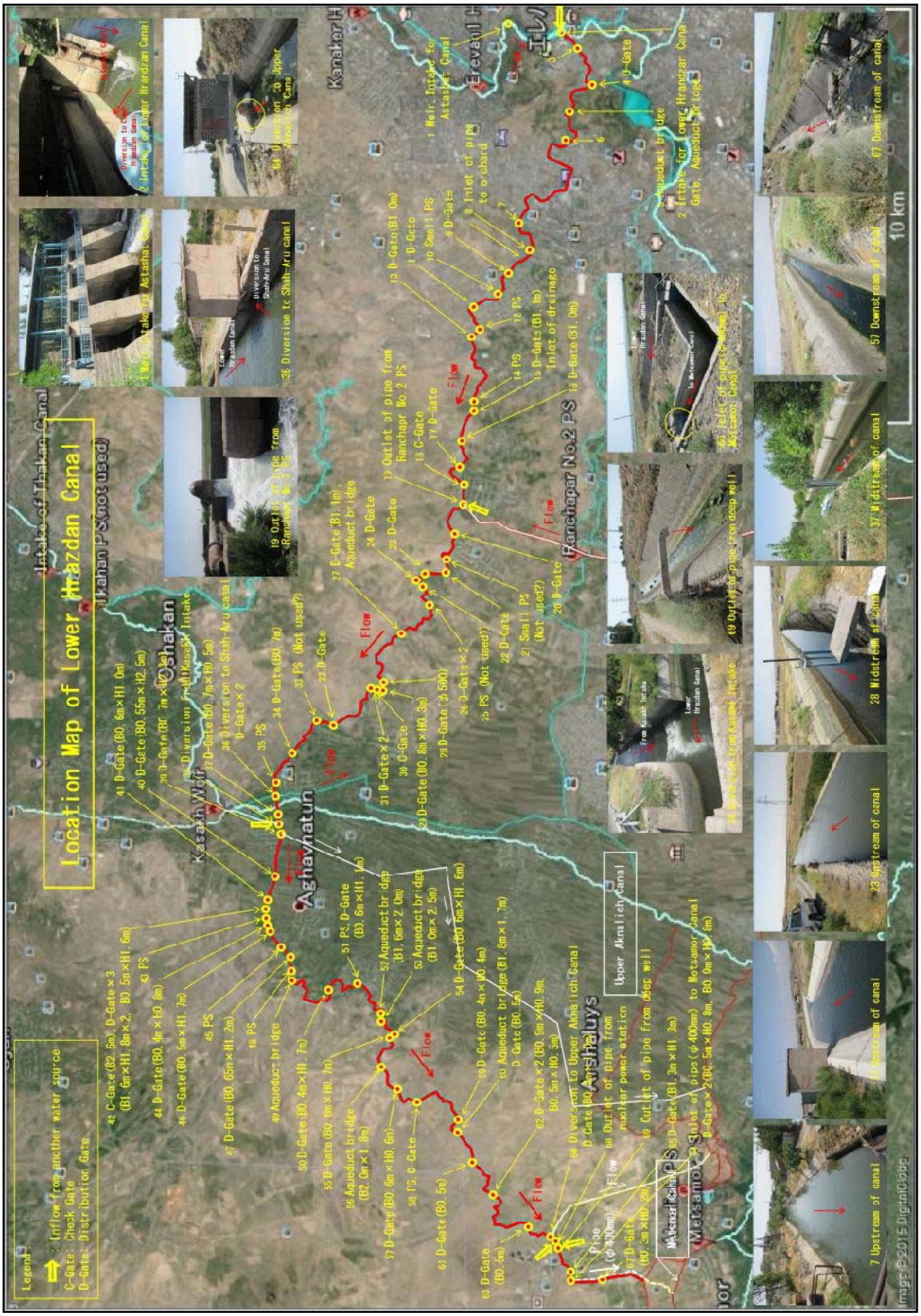



**Figure 4-4-2.8 Location of the Irrigation Facilities of Lower Hrazdan Canal**

## (2) Structural dimensions and conditions of canal

According to the survey by WB Rehabilitation Program, structural dimensions and conditions of targeted canals are shown in Table 4-4-2.1 to 4-4-2.5.

**Table 4-4-2.1 Arzni Branch Canal's Structural Dimensions and Conditions**

| Arzni branch canal | | | | | | | |
|---|---|---|---|---|---|---|---|
| NN | D/M | Length | Conser Code | b, m | B, m | $H_{st}$, m | Discharge Q, $m^3/s$ |
| 1 | 0+00 0+90 | 90 | C | 1.0 | 2.5 | 1.5 | 7.0 |
| 2 | 0+90 2+00 | 110 | C | 1.0 | 2.5 | 1.5 | 7.0 |
| 3 | 2+00 2+35 | 35 | C | 0.7 | 2.2 | 1.5 | 7.0 |
| 4 | 2+35 4+95 | 260 | C | 0.6 | 2.1 | 1.5 | 7.0 |
| 5 | 4+95 6+00 | 105 | C | 0.7 | 2.5 | 1.8 | 7.0 |
| 6 | 6+00 10+20 | 420 | C | 0.8 | 2.8 | 2.0 | 7.0 |
| 7 | 0+25 | | B | | | | 7.0 |
| 8 | 3+50 | | B | | | | 7.0 |
| 9 | 8+80 | | B | | | | 7.0 |
| 10 | 9+10 | | B | | | | 7.0 |
| 11 | 10+00 | – | G | | | | – |
| 12 | 10+20 11+20 | 100 | C | 0.8 | 2.6 | 1.8 | 7.0 |
| 13 | 11+20 11+50 | 30 | C | 2.5 | 2.5 | 2.5 | 7.0 |
| 14 | 11+50 29+00 | 1750 | C | 1.0<br>2.5 | 3.0<br>5.0 | 2.0<br>2.5 | 7.0 |
| 15 | 11+70 | – | OUT | | | | – |
| 16 | 29+00 32+00 | 300 | C | 1.8 | 4.3 | 2.5 | 7.0 |
| 17 | 37+60 | – | OUT | | | | – |
| 18 | 32+00 37+90 | 590 | C | 1.3 | 3.8 | 2.5 | 7.0 |
| 19 | 37+90 38+25 | 35 | C | 2.0 | 2.0 | 2.5 | 7.0 |
| 20 | 38+25 38+75 | 50 | A | 2.0 | 2.0 | 2.5 | 7.0 |
| 21 | 38+75 39+10 | 35 | C | 2.0 | 2.0 | 2.5 | 7.0 |
| 22 | 39+10 49+10 | 1000 | C | 1.5 | 4.0 | 2.5 | 7.0 |
| 23 | 46+00 | – | OUT | | | | – |
| 24 | 49+10 52+00 | 290 | C | 8.0<br>1.5 | 3.1<br>4.5 | 2.5<br>3.0 | 7.0 |
| 25 | 52+00 56+00 | 400 | C | 1.2 | 3.8 | 2.6 | 6.0 |
| 26 | 56+00 56+50 | 50 | C | 1.3 | 3.9 | 2.6 | 6.0 |
| 27 | 56+50 61+00 | 450 | C | 1.3 | 3.9 | 2.6 | 6.0 |
| 29 | 59+00, 59+30; 59+40 | 3 | OUT | | | | – |
| 30 | 61+00 64+50 | 350 | C | 1.2 | 3.6 | 2.4 | 6.0 |
| 31 | 64+50 69+00 | 450 | C | 1.2 | 3.7 | 2.5 | 6.0 |
| 32 | 69+00 72+80 | 380 | C | 1.3 | 3.3 | 2.0 | 4.3 |
| 33 | 72+80 88+00 | 1520 | C | 1.3 | 3.3 | 2.0 | 4.3 |
| 34 | 88+00 97+00 | 900 | C | 1.3 | 3.6 | 2.3 | 4.3 |
| 35 | 97+00 105+00 | 800 | C | 1.2 | 3.9 | 2.7 | 4.3 |
| 36 | 105+00 107+50 | 250 | C | 1.2 | 3.9 | 2.7 | 4.0 |
| 37 | 107+50 | – | OUT | | | | – |
| 38 | 107+50 107+90 | 40 | A | 2.0 | 2.0 | 2.0 | 3.6 |
| 39 | 107+90 123+00 | 1510 | C | 1.5 | 4.1 | 2.6 | 3.6 |
| 40 | 123+00 130+00 | 700 | C | 0.8 | 2.0 | 1.2 | 2.8 |
| 41 | 130+00 136+00 | 600 | C | 1.0 | 2.7 | 1.7 | 2.8 |
| 42 | 136+00 | – | OUT | | | | – |
| 43 | 136+00 137+50 | 150 | C | 0.8 | 2.3 | 1.5 | 2.8 |
| 44 | 137+50 143+00 | 550 | C | 0.8 | 2.3 | 1.5 | 2.8 |
| 45 | 143+00 143+80 | 80 | C | 1.5 | 1.5 | 1.5 | 2.8 |
| 48 | 143+80 144+50 | 70 | C | 0.4 | 1.6 | 1.2 | 2.8 |
| 49 | 144+50 145+00 | 50 | A | 1.5 | 1.5 | 1.2 | 2.8 |
| 50 | 145+00 145+50 | 50 | C | 0.8 | 2.3 | 1.5 | 2.8 |
| 51 | 145+50 148+50 | 300 | C | 0.5 | 2.0 | 1.5 | 2.0 |
| 52 | 148+50 152+50 | 400 | C | 0.5 | 1.9 | 1.4 | 2.0 |
| 53 | 152+00 | | S | | | | 2.0 |
| 54 | 152+50 170+50 | 1800 | S | | d = 700 | | 2.0 |
| 55 | 145+50 | | B | | | | 2.8 |

| Constraction Code |
|---|
| C - Canal |
| S - Syphon |
| A - Aqueduct |
| IN - Intake |
| OUT - Outlet |
| G - Gally |
| B - Bridge |
| O - Others |

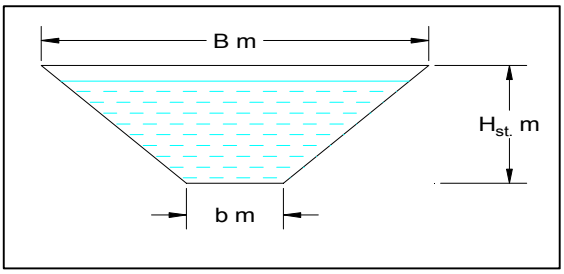


**Table 4-4-2.2 Takahan Canal's Structural Dimensions and Conditions**

| Tkahan Canal | | | | | | | |
|---|---|---|---|---|---|---|---|
| NN | D/M | Length m | Conser Code | b, m | B, m | $H_{st}$, m | Discharge Q, $m^3/s$ |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1 | 0+00 3+50 | 350 | C | 2.5 | 2.5 | 1.5 | 4.3 |
| 2 | 3+50 5+00 | 150 | C | 2 | 4.5 | 2 | 4.3 |
| 3 | 5+00 | 1 | B | | | | |
| 4 | 5+00 9+50 | 450 | C | 2 | 4.7 | 1.8 | 4.3 |
| 5 | 9+50 20+00 | 1050 | C | 2 | 5 | 2.1 | 4.3 |
| 6 | 20+00 22+50 | 250 | C | 1.8 | 4.6 | 1.9 | 4.3 |
| 7 | 22+50 25+50 | 300 | C | 2.8 | 2.8 | 1.5 | 4.3 |
| 8 | 25+50 27+50 | 200 | C | 2.8 | 2.8 | 1.5 | 4.3 |
| 9 | 27+50 28+60 | 110 | C | 2.8 | 2.8 | 1.5 | 4.3 |
| 10 | 28+00 | 1 | OUT | | | | – |
| 11 | 28+60 32+60 | 400 | C | 1.6 2.0 | 4.2 5.0 | 1.7 2.0 | 4.3 |
| 12 | 32+60 50+00 | 1740 | C | 1.0 1.4 | 3.2 3.6 | 1.5 | 4.3 |
| 13 | 50+00 61+00 | 1100 | C | 0.6 1.0 | 2.8 3.2 | 1.5 | 4.0 |
| 14 | 61+00 82+00 | 2100 | C | 1 | 4 | 2 | 4.0 |
| 15 | 68+80; 80+00 | 1 | OUT | | | | – |
| 16 | 82+00 83+00 | 100 | C | 1 | 3.2 | 1.5 | 3.0 |
| 17 | 83+00 83+50 | 50 | A | 1.5 | 1.5 | 1.8 | 3.0 |
| 18 | 83+50 84+50 | 100 | C | 1 | 3.2 | 1.5 | 3.0 |
| 19 | 84+50 86+00 | 150 | C | 1 | 3.4 | 1.6 | 3.0 |
| 20 | 86+05 | 1 | OUT | | | | – |
| 21 | 86+00 95+00 | 900 | C | 1 | 3.5 | 1.7 | 3.0 |
| 22 | 90+05; 91+00 | 1 | OUT | | | | |
| 23 | 95+00 96+00 | 100 | C | 1 | 3.5 | 1.7 | 2.1 |
| 24 | 96+00 98+50 | 250 | S | d=1200mm | | | 2.1 |
| 25 | 98+50 120+00 | 2150 | C | 0.9 | 2.9 | 1.3 | 2.1 |
| 26 | 120+00 130+00 | 1000 | C | 0.8 | 2.6 | 1.2 | 2.1 |
| 27 | 20+00; 22+50; 31+50; 40+00; 41+00; 80+05; 86+00; 90+00 | | B | – | – | – | – |
| 28 | 33+50; 50+00; 83+55 | | OUT | – | – | – | – |

| Constraction Code |
|---|
| C - Canal |
| S - Syphon |
| A - Aqueduct |
| IN - Intake |
| OUT - Outlet |
| G - Gally |
| B - Bridge |
| O - Others |

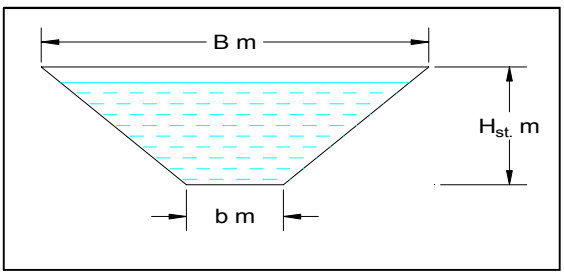


**Table 4-4-2.3 Shah-Aru Canal's Structural Dimensions and Conditions**

| Shah-Aru Canal | | | | | | | |
|---|---|---|---|---|---|---|---|
| NN | D/M | Length | Conser Code | b, m | B, m | $H_{st}$, m | Discharge Q, $m^3/s$ |
| 1 | 0+00 2+00 | 200 | C | 1.5 | 1.5 | 1.8 | 2.0 |
| 2 | 2+00 3+40 | 140 | C | 1.5 | 1.5 | 1.0 | 2.0 |
| 3 | 3+40 4+00 | 60 | C | 1.5 | 1.5 | 0.8 | 2.0 |
| 4 | 4+00 9+50 | 550 | C | 1.5 | 1.5 | 1.0 | 2.0 |
| 5 | 9+50 11+00 | 150 | C | 1.5 | 1.5 | 1.0 | 2.0 |
| 6 | 11+00 28+00 | 1700 | C | 2.2 | 2.2 | 1.0 | 3 |
| 7 | 28+00 34+00 | 600 | C | 2 | 2 | 1.0 | 3 |
| 8 | 34+00 41+00 | 700 | C | 1.5 | 3.5 | 1.0 | 2.0 |
| 9 | 41+00 50+00 | 900 | C | 1.0 | 3.0 | 1.0 | 2.0 |
| 10 | 50+00 56+00 | 600 | C | 1.0 | 3.0 | 1.0 | 2.0 |
| 11 | 56+00 59+00 | 300 | C | 1.0 | 3.0 | 1.0 | 1.5 |
| 12 | 59+00 67+00 | 800 | C | 1.0 | 3.0 | 1.0 | 1.0 |
| 13 | 67+00 68+50 | 150 | C | 1.0 | 3.0 | 1.0 | 1.0 |
| 14 | 68+50 70+00 | 150 | C | 1.0 | 3.0 | 1.0 | 1.0 |
| 15 | 70+00 84+00 | 1400 | C | 1.0 | 3.0 | 1.0 | 1.0 |
| 16 | 84+00 93+00 | 900 | C | 1.0 | 3.0 | 1.0 | 0.7 |

**Table 4-4-2.4 Lower Hrazdan Canal's Structural Dimensions and Conditions (1/2)**

| Lower Hrazdan Main canal II stage | | | | | | | |
|---|---|---|---|---|---|---|---|
| NN | D/M | Length | Conser Code | b, m | B, m | $H_{st}$, m | Discharge Q, $m^3/s$ |
| 1 | 0+00 3+00 | 300 | S | 3 | 3 | 1.5 | 7 |
| 2 | 3+00 6+50 | 350 | C | 2 | 6 | 2 | 7 |
| 3 | 6+50 21+50 | 1500 | C | 2 | 6 | 2 | 7 |
| 4 | 21+50 26+00 | 450 | C | 2 | 2 | 2.5 | 8 |
| 5 | 26+00 37+50 | 1150 | C | 2 | 6 | 2 | 8 |
| 6 | 37+50 40+00 | 250 | C | 2 | 6 | 2 | 5 |
| 7 | 40+00 46+70 | 670 | C | 2 | 6 | 2 | 5 |
| 8 | 46+70 47+70 | 100 | A | 3.5 | 3.5 | 2.5 | 3 |
| 9 | 47+70 80+35 | 3265 | C | 1.5 | 7.5 | 3 | 3 |
| 10 | 80+35 107+35 | 2700 | C | 1.5 | 7.5 | 3 | 3 |
| 11 | 107+35 159+35 | 5200 | C | 1.5 | 6.5 | 2.5 | 3 |
| 12 | 159+35 218+70 | 5935 | C | 1.5 | 5.5 | 2 | 3 |
| | | | | | | | |

| Constraction Code |
|---|
| C - Canal |
| S - Syphon |
| A - Aqueduct |
| IN - Intake |
| OUT - Outlet |
| G - Gally |
| B - Bridge |
| O - Others |

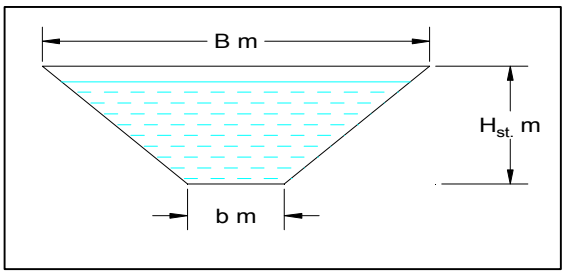
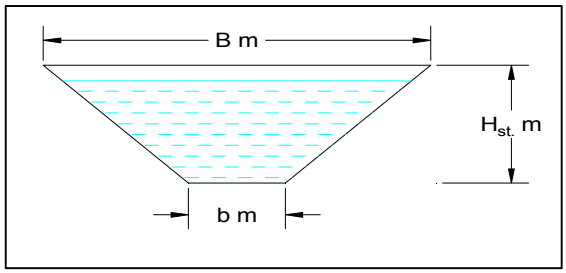


**Table 4-4-2.5 Lower Hrazdan Canal's Structural Dimensions and Conditions (2/2)**

| Lower Hrazdan Main canal I stage | | | | | | | |
|---|---|---|---|---|---|---|---|
| NN | D/M | Length | Conser Code | b, m | B, m | $H_{st}$, m | Discharge Q, $m^3/s$ |
| 1 | 0+00 | 0 | IN | 5 | 5 | 3 | 13 |
| 2 | 0+00 1+13 | 113 | A | 3 | 3 | 3.5 | 10 |
| 3 | 1+13 4+15 | 302 | C | 3 | 6.5 | 3.5 | 10 |
| 4 | 4+15 4+80 | 65 | C | 6.5 | 3 | 3.5 | 10 |
| 5 | 4+80 12+00 | 720 | C | 3 | 10 | 3.5 | 10 |
| 6 | 12+00 12+50 | 50 | C | 3 | 10 | 3.5 | 10 |
| 7 | 12+50 14+80 | 230 | C | 3 | 10 | 3.5 | 10 |
| 8 | 14+80 15+80 | 100 | C | 3 | 10 | 3.5 | 10 |
| 9 | 15+80 34+20 | 1840 | C | 3 | 10 | 3.5 | 10 |
| 10 | 34+20 38+20 | 400 | C | 3 | 10 | 3.5 | 10 |
| 11 | 38+20 57+20 | 1900 | C | 3 | 10 | 3.5 | 10 |
| 12 | 57+20 61+00 | 280 | C | 3 | 10 | 3.5 | 10 |
| 13 | 61+00 64+80 | 380 | C | 3 | 10 | 3.5 | 10 |
| 14 | 64+80 73+10 | 830 | C | 4 | 4 | 2.5 | 10 |
| 15 | 73+10 77+20 | 410 | C | 4 | 4 | 2.5 | 10 |
| 16 | 77+20 77+70 | 50 | C | 4 | 4 | 2.5 | 10 |
| 17 | 77+70 83+44 | 574 | C | 3 | 10 | 3.5 | 10 |
| 18 | 83+44 84+05 | 71 | A | 3.5 | 3.5 | 3.5 | 10 |
| 19 | 84+05 88+05 | 400 | C | 3 | 10 | 3.5 | 10 |
| 20 | 88+05 90+50 | 245 | C | 3 | 10 | 3.5 | 10 |
| 21 | 90+50 93+40 | 290 | C | 3 | 10 | 3.5 | 10 |
| 22 | 93+40 98+00 | 460 | C | 3 | 10 | 3.5 | 10 |
| 23 | 98+00 98+70 | 7 | A | 3.5 | 3.5 | 3.5 | 10 |
| 24 | 98+70 107+00 | 830 | C | 3.5 | 3.5 | 3.5 | 10 |
| 25 | 107+00 118+00 | 1100 | C | 3 | 10 | 3.5 | 10 |
| 26 | 118+00 132+00 | 1400 | C | 3 | 10 | 3.5 | 10 |
| 27 | 132+00 144+50 | 1250 | C | 3 | 9 | 3 | 10 |
| 28 | 144+50 146+50 | 200 | C | 3 | 9 | 3 | 10 |
| 29 | 146+50 188+40 | 5650 | C | 3 | 9 | 3 | 10 |
| 30 | 188+40 203+00 | 1460 | C | 2 | 7 | 2.5 | 9 |
| 31 | 203+00 227+00 | 2400 | C | 3 | 9 | 3 | 9 |
| 32 | 227+00 248+00 | 2100 | C | 3 | 9 | 3 | 8 |
| 33 | 248+00 254+00 | 600 | C | 3 | 9 | 3 | 8 |
| 34 | 254+00 271+50 | 1750 | C | 3 | 8 | 2.5 | 8 |
| 35 | 271+50 273+50 | 200 | C | 2 | 7 | 2.5 | 8 |
| 36 | 273+50 282+12 | 862 | C | 2 | 7 | 2.5 | 8 |
| 37 | 282+12 282+60 | 48 | C | 4 | 4 | 3 | 7 |
| 38 | | 35 | OUT | | | | |

| Constraction Code |
|---|
| C - Canal |
| S - Syphon |
| A - Aqueduct |
| IN - Intake |
| OUT - Outlet |
| G - Gally |
| B - Bridge |
| O - Others |



### (3) Major pump station

The situation of existing pump stations is shown in Figure 4-4-2.9;

| Responsibility | Facility and structure | Picture |
|---|---|---|
| Khoy WUA | Aknalich PS.<br><br>Constructed in 1926 yr<br>3pumps at outside are installed<br>P1 :0.065$m^3$/s<br>P2: 0.265$m^3$/s<br>P3 :0.75$m^3$/s<br><br>4pumps at house are installed<br>P1 :0.4$m^3$/s<br>P2: -$m^3$/s (expired)<br>P3 :-$m^3$/s (expired)<br>P4 :-$m^3$/s (expired) |  Inside pump station<br>  Outside pump station |
| | Metsamor PS<br><br>Constructed in 1960yr<br>4pumps are installed<br>P1 :0.32$m^3$/s<br>P2: 0.55$m^3$/s<br>P3 :0.95$m^3$/s<br>P4 :0.35$m^3$/s<br><br>P2 is only to operate in once per 2days. others are suspended. |  Inside pump station<br>  Pipeline from pump station |
| Water Supply Agency (WSA) | Ranchpar PS. 1<br><br>Constructed in 1985 yr<br><br>Major rehabilitation in 2011 by Millennium Challenging Cooperation(MCC)<br><br>4pumps made in Turkey are re-installed.<br>P1 :1.75$m^3$/s<br>P2: 1.75$m^3$/s<br>P3 :1.75$m^3$/s<br>P4 :1.75$m^3$/s<br><br>※ Normally 5.3$m^3$/s discharge of 75% Max. |  Pump station (out view)<br>  Pump station (inside) |
| | Ranchpar PS. 2<br><br>Constructed in 1985 yr<br><br>Major rehabilitation in 2011 by Millennium Challenging Cooperation(MCC)<br><br>4pumps made in Turkey are re-installed.<br>P1 :0.92$m^3$/s<br>P2: 0.92$m^3$/s<br>P3 :1.30$m^3$/s<br>P4 :1.30$m^3$/s |  |

**Figure 4-4-2.9 Situation of Existing Pump Stations**

**(4) Kasakh intake**

Existing Kasakh Intake has following situations by visual survey and interview.

- ✓ Construction in 1950s as headworks with intakes at both sides with length of 130m.
- ✓ Water taken from right bank reaches to Khoy WUA which is linked with Lower Hrazdan canal.
- ✓ Water taken from left bank reaches to Shah-Aru canal by earth canal which is connected at 70m upstream of headworks. It irrigates Vaghashapat WUA.

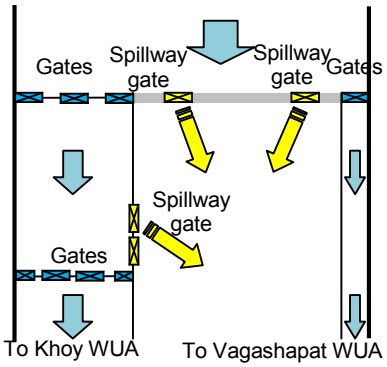



**Figure 4-4-2.10 Kasakh Intake**

- ✓ River discharge in peak is in March to April which is caused by melted snow. In these seasons, the fixed weir is sometimes submerged.
- ✓ 165m downstream at right side, four irrigation gates and two spillway gates are existed
- ✓ During flood season, all of irrigation gates are closed to prevent the water into canals. Two of radial gates at headworks are simultaneously opened to keep safe irrigation
- ✓ **Although the concrete structures are old, the intake and distribution have been functioned. The serious situation is not observed since the gates are still capable to operate.**

| Picture | Description |
|---|---|
|  | Kasakh intake general view<br><br>Three irrigation gates are installed. |
|  | Kasakh intake at right side<br><br>One spillway gate is installed. |

| | |
|---|---|
|  | Kasakh intake at left side (1)<br><br>One intake gate is installed. |
|  | Kasakh intake at left side (2)<br><br>At upstream of left gate, operation of intake is conducted by small dike. In off-irrigation season, dike is embanked to close the earth canal. |
|  | Kasakh intake at left side (3)<br><br>Shah-Aru canal is constructed by concrete canal. |
|  | Kasakh intake at right side (1)<br><br>Headrace canal go down along the Kasakh river and to reach Lower Hrazdan canal |
|  | Kasakh intake at right side (2)<br><br>Four irrigation gates are installed for regulation of main canal and two spillway gates at left side are installed which release excess water to Kasakh river. |

**Figure 4-4-2.11 Situation of Existing Kasakh Intake**

### 4-4-3 Current Operation and Maintenance on the Irrigation Network System

#### (1) Implementation arrangement (organization of WSA / WUA)

There are two (2) organizations for operating and maintaining of existing irrigation network system. One is WSA belonging to SCWE ant another is WUA. Under WSA, there are two (2) organizations related to collecting irrigation fee, Sevan-Hrazdanyan Jrar CJSC and Akhuryan-Araks Jrar CJSC. 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, Vagarshapat 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 operated and maintained the gates and canals after the secondary canal's intake gate. Table 4-4-3.1 shows the major functions of WUA.

**Table 4-4-3.1 Major Functions of WUA**

| | |
|---|---|
| Operation and maintenance | Provide training for members |
| Supply water to water users | Manage water supply |
| Rehabilitate the irrigation system | Implement necessary measures |
| Acquire irrigation water | Ensure environmental safety |
| Collection of water fee | |

#### (2) Annual operation and maintenance (O/M) plan

a) Water supply method

WSA has been operating and maintaining from water source such as reservoir to the secondary canal's gates along the main canal since they have a responsible for appropriate water distribution. WSA sells the irrigation water to WUA. 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. Figure 4-4-3.1 shows the organizational chart of WUA.

Arzni-Shamiram canal and Lower Hrazdan canal has been operated and maintained by WSA. WSA decides water volume released from reservoir based on the water demand requested from farmers. Water demand is estimated by "Armenian irrigation norm".

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 as shown in Table 4-4-3.2. 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. However, WSA sells the constant price of pump-based water fee to every WUA in Armenia.

Based on the interview 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 covered by Armenian government as subsidy.

**Table 4-4-3.2 Water Fee for Selling Price and Buying Price**

| Irrigation type | Water Fee ( AMD/$m^3$ ) | |
|---|---|---|
| | Selling Price (from WSA to WUA) | Buying Price ( by Farmer) |
| Gravity based Area | 1.01 | 11.00 |
| Pump based Area | 11.52 | 11.00 |

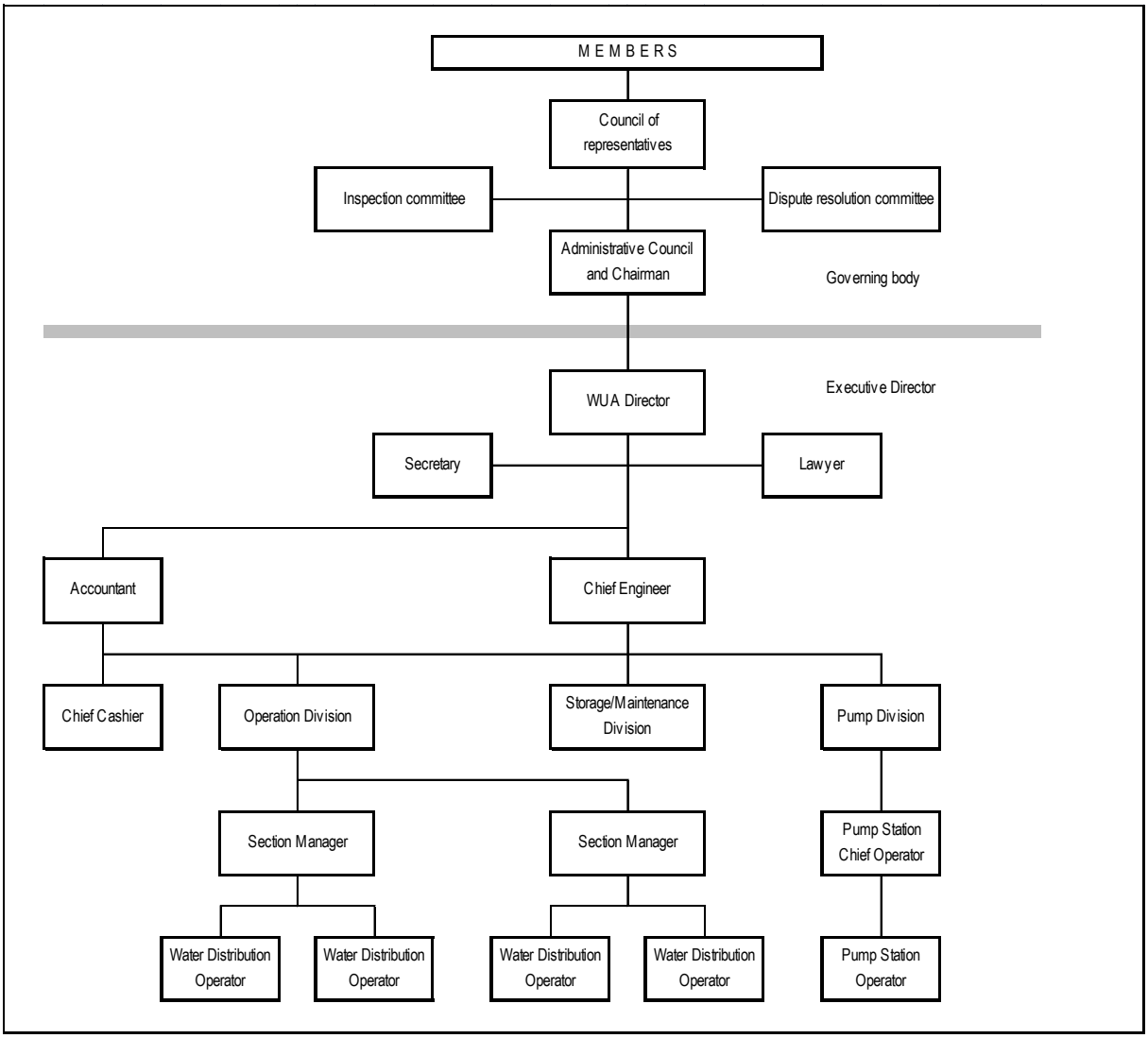



**Figure 4-4-3.1 Organization Chart of WUA**

b) Maintenance with monitoring (inspection) method

As shown in Figure 4-4-3.2, water level is monitored at the major points along the main canal. This monitoring is carried out twice a day by WSA's remote staff and are reported to the WSA's head office. The remote staff of WSA observe 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 as shown in Table 4-4-3.3.

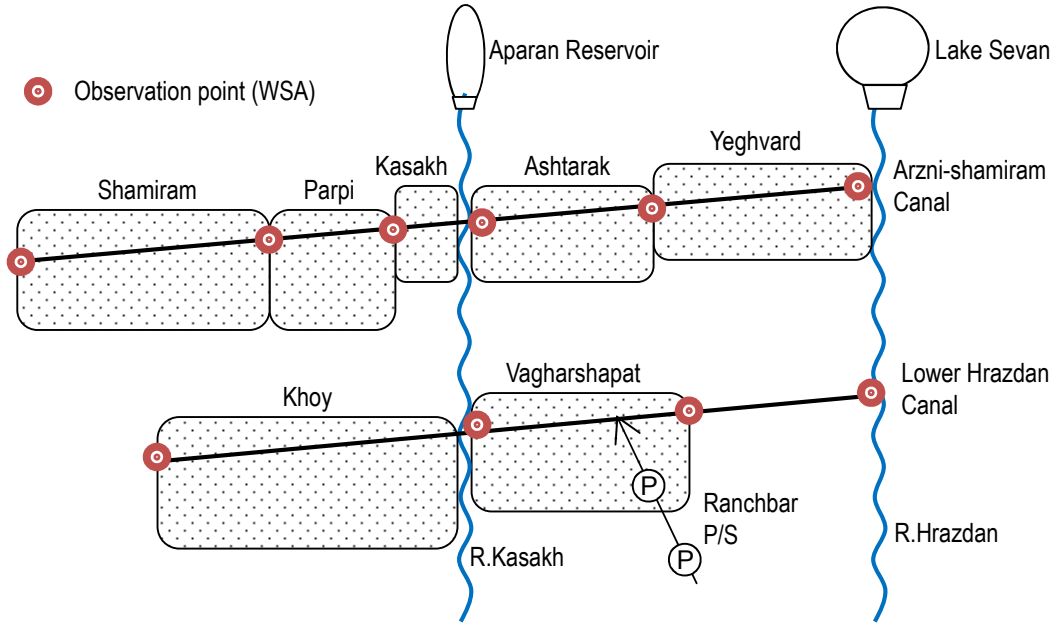



**Figure 4-4-3.2 Location of Observation Point along the Main Canal**

**Table 4-4-3.3 Water Level's Observed Point and Interval of Observation along Main Canal**

| Canal | Number of Observation point | Observation interval |
|---|---|---|
| Arzni-Shamiram | 6 | 2 times/day (10 days average) |
| Lower Hrazdan | 4 | 2 times/day (10 days average) |

In general, irrigation starts from middle of April and ends in November. While WSA and WUA maintain the irrigation facilities such as canals and gates during the non-irrigation period in winter season, maintenance such as cleaning, annual repairing, etc. of irrigation facilities is carried out after February when the accumulated snow begins to melt.

### (3) Annual budget for O/M

Figure 4-4-3.3 describes the average maintenance cost for each WUA from 2013 to 2015. The figure indicates that Vagharshapat, Khoy, Ashtarak and Yeghvard WUAs spend 104 million AMD, 116 million AMD, 23 million AMD and 15 million AMD respectively. The total maintenance cost is 258 million AMD.

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. Table 4-4-3.4 shows the unit cost for maintenance. Vagharshapat WUA spends a lot for maintenance in comparison with other WUAs.

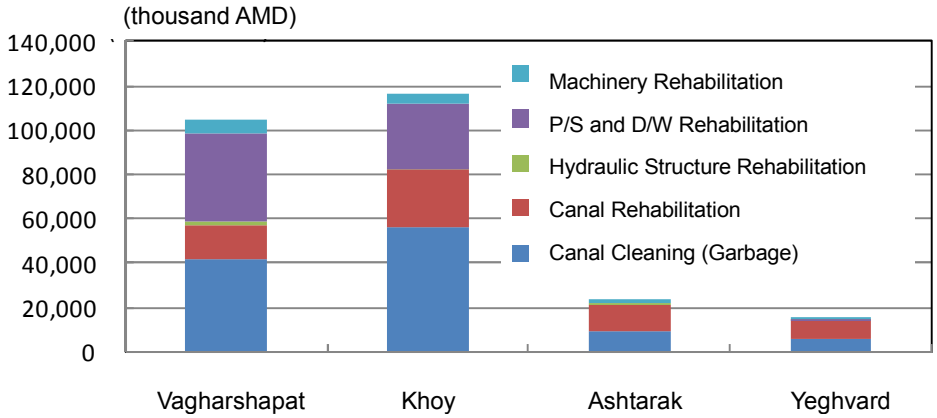



**Figure 4-4-3.3 Maintenance Cost for each WUA**

**Table 4-4-3.4 Unit Cost of Maintenance for each WUA**

| WUA | Maintenance Cost (million AMD) | Current Area (ha) | Unit Price (AMD/ha) |
|---|---|---|---|
| Vagharshapat | 104 | 2,488 | 42,000 |
| Khyo | 116 | 4,460 | 27,000 |
| Ashtarak | 23 | 801 | 29,000 |
| Yeghvard | 15 | 642 | 23,000 |
| Total | 258 | 8,391 | 31,000 |

### 4-4-4 Current Issues on Irrigation Network System

Current situation and issues on target canals are shown in Table 4-4-4.1. And detailed current situations of each canal are shown in Appendix A.

In the basis of results of irrigation facility survey, findings on current situations and issues are summarized below;

1) Deterioration/damage such as 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) will be abolished due to the policy of the Project, and

5) Some areas irrigated by unclear water source.

Figure 4-4-4.1 Crack at Side Wall of Canal (Arzni-Branch Canal at No.26)

Figure o 4-4-4.2 Connection Canal to Takahan Canal (Arzni-Branch Canal at No.42 )

Figure 4-4-4.3 Leakage at Separation of Joint at Sidewall (No.33 )

Figure 4-4-4.4 Outlet of Pipe from Arzni-Shamiram Canal (φ800mm) (Arzni-Branch Canal at No.25)

**Table 4-4-4.1 Current Situation and Issues on Target Canals (1/3)**

| Canal | Current situation | Problems |
|---|---|---|
| Azni-Branch | 1) Upstream portion of this canal is being managed by Yeghvart WUA and downstream portion by Ashtarak WUA. Water intake from the Arzni-Shamiram canal is performed every WUA. Ashutarak WUA takes water from Arzni-Shamiram canal directly by the pipeline and distributes by a pipeline network to the beneficiary areas of Arzni-Branch Canal.<br>2) Downstream of the canal from No.33 point on Figure 4-4-2.2 is not currently in use. Other water is used for irrigation of agricultural land around Sasuke town.<br>3) Although the connection canal for water injection into Takahan Canal near the end of this canal can be confirmed, it is not currently used.<br>4) The upstream portion of this canal under the control of Yeghvart WUA was renovated in 2012, except for the most upstream section,<br>5) The inflows from other water sources are confirmed at five locations in the middle of this canal. All of these inflows come from Arzni-Shamiram canal by pipelines. | 1) There is a damaged concrete portion at side wall at about 500m section of the non-renovation of downstream of crossing point of railway portion near the intake structure of this canal.<br>2) There is water leakage from the joint of the side wall of the No.18 on Figure 4-4-2.2 spot aqueduct bridge.<br>3) There are significant damaged concrete portions and cracks at side wall and bottom of channel within section that is currently being used up to No.33 point on Figure 4-4-2.2.<br>4) No.33 point on Figure 4-4-2.2 later canal is not currently being used, it is devastated. |
| Takahan canal | 1) The condition of canal is observed generally to good condition except for an aqueduct bridge.<br>2) The inflow by connection canal from Takahan Canal has been secured and it is considered that the water from Arzni-Shamiram canal by pipeline is in-flow into the middle of the link canal.<br>3) The section between No.3 point and No.22 point on Figure 4-4-2.3 will be rehabilitated in recent years by the support of the World Bank. The condition of canal will be good. | 1) The top portion of the aqueduct bridge of No.35 point on Figure 4-4-2.3 is the exposed rebar by frost damage, etc. and deterioration of concrete is observed. |
| Shakhi-Aru canal | 1) High discharge season of Kasakh River is observed in spring only. Therefore, since the irrigation water from the Kasakh Intake has become chronically shortage of water for irrigation period, the water intake from the Lower Hrazdan is the main water source currently.<br>2) There are inflows from a distribution gate of Lower Hrazdan canal at No.4 point, from two outlets of pipe(φ150mm) from deep wells and No.29 point on Figure 4-4-2.4.<br>3) The sections between No.10 point and No.19, No.21 point and No.22, and No.25 point and No.31 point on Figure 4-4-2.4 had been rehabilitated from 2008 to 2010 by the support of the World Bank and the millennium project. The condition of canal is good. | 1) Water leakage due to the separation of the joint and the exposed rebar can be observed on the side walls at canal section(No.33 point) of shortly downstream of Kasakh Intake.<br>2) The deterioration of side wall of canal is serious at No.9 point on Figure 4-4-2.4.<br>3) The side walls of the canal at No.19 point on Figure 4-4-2.4 is worried about water leakage. |

**Table 4-4-4.1 Current Situation and Issues on Target Canals (2/3)**

| Canal | Current situation | Problems |
|---|---|---|
| Upper Aknalich canal | 1) Aknalich pumping station was built in 1926 and seven pumps in total were installed, three pumps in outside (Capacity Q = 0.065$m^3$/s, 0.265$m^3$/s and 0.75$m^3$/s), four pumps in the pump house (One only operation, Capacity Q = 0.4$m^3$/s) .<br>The current maximum water discharge amount is 0.75$m^3$/s. Among them, it is possible to send irrigation water of the amount of 0.38$m^3$/s to this canal (Upper Aknalich Canal) and irrigation water of the amount of 0.27$m^3$/s to Inner Aknalich Canal.<br>However, sufficient irrigation water is not supplied from Aknalich PS to this canal due to the drawdown of Aknalich lake presently.<br>2) The pipeline (φ730mm) for irrigation was built in the direction from No.14 point to No.32 point on Figure 4-4-2.5 by IFAD in 2004.<br>3) There was an inlet of headrace (pipeline) to the Inner Aknalich Canal at No.2 point on Figure 4-4-2.5, but it is closed with concrete presently.<br>4) There are inflows by pipe (φ600mm) from Lower Hrazdan canal, by earth canal from Lower Hrazdanl and by three pipe(φ150mm) from deep wells at No.36 point, No.40 point and N.40 point on Figure 4-4-2.5. | 1) Downstream canal from the road crossing of the No.32 point on Figure 4-4-2.5 is not currently being used, it has been expired.<br>2) The flume canal was installed in parallel to this canal from No.35 point on Figure 4-4-2.5 to end of canal. Water from deep wells is supplied to the canal, it is irrigating surrounding farmland. In addition, this canal and other canal irrigated by deep well is not connected.<br>3) The deterioration such as exposed rebar is serious at canal sidewall No.8 to No.9 on Figure 4-4-2.5<br>4) Large cracks and partial broken etc. has observed at canal sidewall from the aqueduct bridge at No.21 point on Figure 4-4-2.5 to the road crossing point at No.32 point and deterioration is serious.<br>5) WUA staff told that even if canal is repaired in the section from No.8 point to No.9 point and in the section from No.21 point to No.32 point on Figure 4-4-2.5, enough water is not capable to come from the pumping station, so, it is unnecessary to repair it.<br>6) The deterioration of concrete and exposed rebar by frost damage are serious at sidewall of the aqueduct bridges at No.21 point and No.23 point on Figure 4-4-2.5. |
| Inner Aknalich canal | 1) Currently, irrigation water is not passed through only from the beginning point to Highway near No.17 point on Figure 4-4-2.6. Previously water had been reached up to the end of canal.<br>2) Water from deep wells is supplied to this canal section from No.24 point on Figure 4-4-2.6 to end of canal, it is irrigating surrounding farmland.<br>3) Near the No.2 point and No.19 point on Figure 4-4-2.6, a new deep well is scheduled to be added in next year.<br>4) There are inflows by pipe(φ150mm) from Aknalich canal at No.5 point, by earth canal from Hrazdan Canal at No. 8 point and by four pipe(φ150mm) from deep wells at No.24 point, No.28 point, No.30 point and No.34 point on Figure 4-4-2.6.<br>5) This canal had been rehabilitated from 1997 to the next year by the support of the World Bank. | 1) The exposed rebar can be seen at the top of sidewalls (L=600m) from No.2 point to No.4 point and near No.12 point and No.14 point on Figure 4-4-2.6.<br>2) Grass is flourishing in the canal in section from upstream 520m point of No.22 point to No.24 point and the canal has been expired. It is necessary to rehabilitate it in order to pass water until the end of canal again. |

**Table 4-4-4.1 Current Situation and Issues on Target Canals (3/3)**

| Canal | Current situation | Problems |
|---|---|---|
| Metsamor canal | 1) This canal is divided into main line for the north side and branch line for the south side. The main line is trapezoidal concrete canal and branch line is a flume canal by pre-casted U-shaped. The water is supplied by pipe (1,200mm) at No.1 point on Figure 4-4-2.7 from mainly Metsamor PS. To the branch line, the water is supplied mainly by pipeline from the same PS. In addition, as the pump station stopped, main line and branch line are supplied by open canal and pipeline from Lower Hrazdan canal.<br>2) This canal will be rehabilitated in recent years by the support of the World Bank. The condition of canal will be good.<br>3) There are inflows by pipe(φ400mm) from Lower Hrazdan canal at No.25 point, by connection canal from Hrazdan canal at No.6 point, and by pipe(φ150mm) from deep well at No.25 point on Figure 4-4-2.7. | 1) The Metsamor pump station has total four pumps and all pumps are working. Capacity of the pumps is P1=0.32$m^3$/s, P2=0.55$m^3$/s, P3=0.95$m^3$/s and P4= 0.35$m^3$/s. However only P2 is usually running once in two days because inlet water is not enough to operate all pumps. It is observed that suitable irrigation water is not supplied to canal from this pump station.<br>2) Gate leafs at 6 places are missing. |
| Lower Hrazdan canal | 1) The situation of canal network from this canal to the secondary canals is as follows.<br>a) Regarding connection canal from this canal to Metsamor canal, it is possible to convey water through the pipeline (φ400mm L=about 3.0km) from the inlet of pipe at No.66 point on Figure 4-4-2.8 in this canal to the confluence box at No.25 point in Metsamor canal and it is possible to convey water from end of this canal to the confluence at No.6 point in Metsamor canal.<br>b) Regarding connection canal from this canal to Upper Aknalich canal, It is possible to convey water by pipeline (φ600mm L=about 6.0km) from the inlet of pipe at No.64 point in this canal to outlet of pipe at No.6 point on Figure 4-4-2.8 in Upper Aknalich Canal. It is possible to convey water (Q=0.15$m^3$/s) by earth canal (L=5.0km) from around No.39 point in this canal to No.25 point in Upper Aknalich canal.<br>c) Regarding connetion canal from this canal to Inner Aknalich canal, it is possible to send water (Q=0.15$m^3$/s) through the earth canal (L=8.0km) from around No.39 point in this canal to No.8 point in Inner Aknalich canal.<br>d) There are inflows by pipe from Ranchapr No.2 PS at No.19 point, from a connection canal from Kasakh Intake at No. 38 point and by pipe(φ150mm) from deep wells at No.69 on Figure 4-4-2.8. | 1) This canal was built in 1954, all sections of canal is aging.<br>2) Since the freeboard of this canal is not enough, over flow is suspected to be occur during irrigation season. In particular at shortly downstream of the outlet of pipe from Ranchapar PS No.2, it should be cared of operation. |

## 4-5 Agricultural Production and Farm Management

### 4-5-1 Agricultural Surveys Carried Out

The Survey team carried out the following surveys in order to collect necessary information for the agricultural planning. Details about the planning structure and the surveys are described in Appendix B-3 to B-6.

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

### 4-5-2 Number of Farm Households and Family Size

It is reported that the population of Armenia has been decreasing since the 1990s (the population in 1991 was reported as 3,450,000) due to several factors such as excess number of transmigration, decrease in birth rate, and the tendency of slight decrease is still continuing. Regarding the agricultural labor force population, it showed dramatically rising after Armenia's independence from around 180,000 in 1988 to 500,000 in 1994 and it peaked at 570,000 in 2000. However, the population began to decrease since then because of the growth of other economic sectors.

Meanwhile, the population of the project area where locates surrounding area of the biggest city Yerevan indicates only fractional increase in recent five years. According to collected data from concerned communities, total population in the project area is 76,070 in 2014. The population is stable from 2010 to 2014 (see Table 4-5-2.1).

**Table 4-5-2.1 Population in the Project Area (2010-14)**

| WUA | Sex | 2010 | 2011 | 2012 | 2013 | 2014 |
|---|---|---|---|---|---|---|
| Yeghvard (3 communities) | Male | 8,736 | 8,702 | 8,828 | 8,979 | 8,883 |
| | Female | 8,925 | 8,776 | 9,192 | 9,014 | 9,133 |
| | Total | 17,661 | 17,478 | 18,020 | 17,993 | 18,016 |
| Ashtarak (4 communities) | Male | 6,649 | 6,645 | 6,779 | 6,791 | 6,715 |
| | Female | 6,585 | 6,924 | 6,854 | 6,818 | 6,855 |
| | Total | 13,234 | 13,569 | 13,633 | 13,609 | 13,570 |
| Vagharshapat (7 communities) | Male | 7,613 | 7,794 | 7,590 | 7,638 | 7,563 |
| | Female | 7,758 | 7,816 | 7,873 | 7,923 | 7,932 |
| | Total | 15,371 | 15,610 | 15,463 | 15,561 | 15,495 |
| Khoy (13 communities) | Male | 14,739 | 14,493 | 14,484 | 14,598 | 14,571 |
| | Female | 14,351 | 14,296 | 14,672 | 14,569 | 14,418 |
| | Total | 29,090 | 28,789 | 29,156 | 29,167 | 28,989 |
| **Total** | **Male** | **37,737** | **37,634** | **37,681** | **38,006** | **37,732** |
| | **Female** | **37,619** | **37,812** | **38,591** | **38,324** | **38,338** |
| | **Total** | **75,356** | **75,446** | **76,272** | **76,330** | **76,070** |

Source) 27 Community Offices Concerned

As regard to population density in 2014, the average is 305 person/ $km^2$ in the Project area. The Project area has high population density because of its location. Among WUA areas, Yeghvard is the most congested area, followed by Vagharshapat, Koy and Ashtarak as shown in Table 4-5-2.2. Yeghvard and Vagharshapat WUA areas, having relatively higher figures, are much influenced by urbanization from Yerevan city and Ejimiatsin city, respectively.

**Table 4-5-2.2 Population Density in the Project Area in 2014**

| WUA | Yeghvard (3 communities) | Ashtarak (4 communities) | Vagharshapat (7 communities) | Khoy (13 communities) | Total |
|---|---|---|---|---|---|
| Population Density (person/$km^2$) | 359.7 | 256.3 | 349.4 | 284.3 | 305.0 |

Source) 27 Community Offices Concerned

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 (see Table 4-5-2.3).

The percentage of farm households is about 80% in thePproject area. In Khoy and Vagharshapat WUA areas, agricultural households are highly dominating (96–98% of the total households). In contrast, the percentages in Ashtarak and Yeghvard WUA areas are only 60-65%, and the percentages are declining in recent years. It implies that farm abandonment in Ashtarak and Yeghvard WUA areas is advancing as farmers are facing more difficult condition for continuing their farming than the other two WUA areas. A comparative blessed farmland condition, e.g. land fertility, flatness and accessibility to irrigation gives Khoy and Vagharshapat WUA areas an advantage over Ashtarak and Yeghvard WUA areas in establishing stable farm management. According to farmers interviewed during the surveys, many farmers (especially young male farmers) despaired of continuing farming, and started subsidiary business or even abandoning farming. While there is a wide range of variations in the farmers' difficulties, shortage of irrigated farmland must be one of them.

**Table 4-5-2.3 Number of Households in the Project Area (2010-14)**

| WUA | Sector | 2010 | | 2011 | | 2012 | | 2013 | | 2014 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | H.H. | % | H.H. | % | H.H. | % | H.H. | % | H.H | % |
| Yeghvard (3 communities) | Agri. | 2,730 | 63.3% | 2,757 | 63.7% | 2,748 | 63.8% | 2,655 | 61.2% | 2,672 | 60.2% |
| | Non-Agri. | 1,585 | 36.7% | 1,571 | 36.3% | 1,558 | 36.2% | 1,680 | 38.8% | 1,766 | 39.8% |
| | Total | 4,315 | | 4,328 | | 4,306 | | 4,335 | | 4,438 | |
| Ashtarak (4 communities) | Agri. | 2,381 | 67.1% | 2,369 | 66.5% | 2,386 | 67.5% | 2,358 | 66.4% | 2,279 | 65.4% |
| | Non-Agri. | 1,167 | 32.9% | 1,195 | 33.5% | 1,151 | 32.5% | 1,193 | 33.6% | 1,205 | 34.6% |
| | Total | 3,548 | | 3,564 | | 3,537 | | 3,551 | | 3,484 | |
| Vagashapat (7 communities) | Agri. | 2,589 | 98.2% | 2,582 | 98.0% | 2,681 | 97.8% | 2,709 | 97.7% | 2,709 | 97.7% |
| | Non-Agri. | 48 | 1.8% | 52 | 2.0% | 61 | 2.2% | 65 | 2.3% | 65 | 2.3% |
| | Total | 2,637 | | 2,634 | | 2,742 | | 2,774 | | 2,774 | |
| Khoy (13 communities) | Agri. | 5,927 | 96.2% | 5,936 | 96.3% | 5,936 | 96.2% | 5,919 | 96.3% | 5,914 | 96.1% |
| | Non-Agri. | 231 | 3.8% | 226 | 3.7% | 236 | 3.8% | 230 | 3.7% | 239 | 3.9% |
| | Total | 6,158 | | 6,162 | | 6,172 | | 6,149 | | 6,153 | |
| **Total** | **Agri.** | **13,627** | **81.8%** | **13,644** | **81.8%** | **13,751** | **82.1%** | **13,641** | **81.2%** | **13,574** | **80.6%** |
| | **Non-Agri.** | **3,031** | **18.2%** | **3,044** | **18.2%** | **3,006** | **17.9%** | **3,168** | **18.8%** | **3,275** | **19.4%** |
| | **Total** | **16,658** | | **16,688** | | **16,757** | | **16,809** | | **16,849** | |

Source) 27 Community Offices Concerned

Table 4-5-2.4 shows the average number of family members (family size) per household in the Project area. The average family size is stable in recent years at about 4.5 person/family. While the highest is in Vagharshapat WUA are at 5.6 person/family, the lowest is in Ashtarak WUA area at 3.9 person/family in 2014. The family size in Yeghvard WUA area is almost same with the size in Ashtarak WUA area.

**Table 4-5-2.4 Family Size in the Project Area (2010-14)**

Unit: person/family

| WUA | 2010 | 2011 | 2012 | 2013 | 2014 |
|---|---|---|---|---|---|
| Yeghvard | 4.1 | 4.0 | 4.2 | 4.2 | 4.1 |
| Ashtarak | 3.7 | 3.8 | 3.9 | 3.8 | 3.9 |
| Vagharshapat | 5.8 | 5.9 | 5.6 | 5.6 | 5.6 |
| Khoy | 4.7 | 4.7 | 4.7 | 4.7 | 4.7 |
| **Total** | **4.5** | **4.5** | **4.6** | **4.5** | **4.5** |

Source) 27 Community Offices Concerned

### 4-5-3 Land Use and Farmland Use

1) Land use

The Project area extends across 27 communities in 3 Marzes, and it is divided into four (4) WUA areas

under management of Yeghvard, Ashtarak, Vagharshapat and Khoy WUAs. Since WUA area boundaries and boundaries of 27 concerned communities are not overlapped, only 22,754 ha or 91% out of 24,937 ha of the 27 communities' total land area is included in the Project area (see Table 4-5-3.1).

**Table 4-5-3.1 Community Area and Project Area**

| Area Category | | Yeghvard | Ashtarak | V. Shapat | Khoy | **Total** |
|---|---|---|---|---|---|---|
| Community Area | (ha) | 5,008.5 | 5,295.5 | 4,435.0 | 10,198.0 | **24,937.0** |
| Project Area | (ha) | 4,512.5 | 3,608.5 | 4,435.0 | 10,198.0 | **22,754.0** |
| | (%) | 90.1 | 68.1 | 100.0 | 100.0 | **91.2** |
| Number of Communities | | 3 | 4 | 7 | 17 | **27** |

Source) PIU and 27 Community Offices Concerned

Table 4-5-3.2 shows acreage of farmland and their irrigated land in the Project area by 4 WUAs. Approximately a half or more of each WUA's land in the Project area are categorized in farmland. Khoy WUA has the largest farmland area, while Ashtarak WUA has the lowest area. There is a big difference in irrigation condition between Yeghvard & Ashtarak WUAs and Vagharshapat & Khoy WUAs. Yeghvard & Ashtarak WUAs areas have lower percentages of irrigated farmland than the other two WUA areas. Especially in Khoy WUA area, most of all farmlands are irrigated. The difference represents different water distribution condition for agriculture and geographical condition among 4 WUAs. Yeghvard and Ashtarak WUA areas which locate North-Western part of the Project area, where are dominated by gentle slope plateaus, have less water distribution sources such as canals and wells than the other two WUA areas where locate in Ararat plain.

**Table 4-5-3.2 Farmland in the Project Area**

| Land Category | Yeghvard | | Ashtarak | | Vagharshapat | | Khoy | | **Total** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Area (ha) | (%) | Area (ha) | (%) | Area (ha) | (%) | Area (ha) | (%) | **Area (ha)** | **(%)** |
| 1. 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

2) 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 as shown in Table 4-5-3.3.

**Table 4-5-3.3 Average Farmland Size per Farm Household in the Project Area**

| | WUAs | Yeghvard | Vaghar shapat | Khoy | **Total** |
|---|---|---|---|---|---|
| 1 | Farmland (in Cadaster) (ha) | 2,427.9 | 2,797.1 | 5,236.9 | **10,461.9** |
| 2 | Number of farm households in 2014 | 2,672 | 2,709 | 5,414 | **10,795** |
| 3 | Average farmland (ha/farm household) | 0.91 | 1.03 | 0.97 | **0.97** |

Note) Ashtarak is excluded from the calculation as only 68.1% of the community area is included in the project area (see Table 4-5-3.1)

Source) PIU (farmland) and 27 Community Offices Concerned (number of farm households)

The farm household survey carried out by the Survey team reveals farmland use, classified as farmland for annual crop, orchard including vineyard, pasture and other types of land as for home garden and etc. It is also classified by irrigation condition (see Table 4-5-3.4). The average size of own

land in Table 4-5-3.4 is 2.12 ha in total which is more than 2 times of the estimation in Table 4-5-3.3 even excluding home garden and etc. It is noted that farm households having bigger farmland than the average level are mainly sampled for the farm household survey.

**Table 4-5-3.4 Farmland Use in the Project Area**

| Farm Land Use | Irrigated + Non-irrigated Land (ha) | | | | |
|---|---|---|---|---|---|
| | Own manage, own land | Rent out to tenant | Own land total | Rent in | Total managed land |
| | (1) | (2) | (3) | (4) | = (1) - (2) + (4) |
| Annual crops | 1.25 | 0.03 | 1.29 | 1.37 | **2.59** |
| Orchard/vineyard | 0.57 | 0.00 | 0.57 | 0.27 | **0.84** |
| Pasture | 0.08 | 0.00 | 0.08 | 0.01 | **0.08** |
| Others (Home garden, etc.) | 0.19 | 0.00 | 0.19 | 0.02 | **0.21** |
| **Total** | **2.09** | **0.03** | **2.12** | **1.67** | **3.72** |

| Farm Land Use | Irrigated Land only (ha) | | | | |
|---|---|---|---|---|---|
| | Own manage, own land | Rent out to tenant | Own land total | Rent in | Total managed land |
| | (1) | (2) | (3) | (4) | = (1) - (2) + (4) |
| Annual crops | 1.17 | 0.03 | 1.20 | 1.34 | **2.48** |
| Orchard/vineyard | 0.56 | 0.00 | 0.56 | 0.27 | **0.83** |
| Pasture | 0.08 | 0.00 | 0.08 | 0.01 | **0.08** |
| Others (Home garden, etc.) | 0.18 | 0.00 | 0.18 | 0.02 | **0.20** |
| **Total** | **1.98** | **0.03** | **2.02** | **1.64** | **3.59** |

Source: JICA Survey Team (Farm household survey)

Table 4-5-3.4 implies that 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. Comparing the farmland use among 4 WUAs, percentage of orchard/vineyard area to the total farmland area is bigger in WUAs located in plateau areas, i.e. Yeghvard and Ashtarak than WUAs located in plain areas, i.e. Vagharshapat and Khoy (see Table 4-5-3.5). 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 according to collected information. In Vagharshapat and Khoy WUAs, many farmers even construct a simple greenhouse in home gardens for growing vegetables for marketing.

**Table 4-5-3.5 Farmland Use in the Project Area by WUA**

| Farm Land Use | Total Managed Land, Irrigated + Non-irrigated Land (ha) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Yeghvard | | | Ashtarak | | | Vagharshapat | | | Khoy | | |
| | Own | Rent in | **Total** | Own | Rent in | **Total** | Own | Rent in | **Total** | Own | Rent in | Total |
| Annual crops | 0.56 | 0.36 | **0.92** | 0.47 | 0.36 | **0.83** | 1.78 | 2.34 | **4.12** | 1.28 | 1.36 | **2.64** |
| Orchard/vineyard | 0.76 | 0.09 | **0.85** | 0.41 | 0.13 | **0.53** | 0.32 | 0.00 | **0.32** | 0.71 | 0.50 | **1.22** |
| Pasture | 0.00 | 0.00 | **0.00** | 0.00 | 0.00 | **0.00** | 0.20 | 0.00 | **0.20** | 0.04 | 0.01 | **0.06** |
| Others (Home garden, etc.) | 0.10 | 0.00 | **0.10** | 0.08 | 0.00 | **0.08** | 0.38 | 0.01 | **0.38** | 0.15 | 0.03 | **0.18** |
| Total | 1.42 | 0.45 | **1.86** | 0.96 | 0.48 | **1.45** | 2.67 | 2.36 | **5.02** | 2.19 | 1.91 | **4.10** |

Source) JICA Survey Team (Farm household survey)

It is interesting that the sample farmers rent not a small farmland from other land holders. On the other hand, a few sample farmers rent out their farmland to other farmers (see Table 4-5-3.4). The majority of farmland rented-in is used for growing annual crops. The result implies that farmers, who have farmland above a certain level and actively engaged in farming in the Project area, make an effort to expand the size of farmland under their management by renting farmland from other land holders who may be aged, transmigrated or busy for off-farm jobs/business. Farmers in Vagharshapat and Khoy WUAs are more active in renting in farmland than farmers in Yeghvard and Ashtarak WUAs.

### 4-5-4 Profile of Farmers and Farm Household Economy

The following consideration is derived mainly from outputs of the farm household survey in August-September, 2015, covering 81 farm households in 27 concerned communities (3 farm households from each community).

#### 1) Profile of farmers

**Age and farming experience**

The average age of head of the sample farm households is 55.8 years old, while the age ranges from 30 to 82. As regard to farming experience, the average is 25.9 years, while the experience ranges from 8 to 66 years. It shows that many farmers have a certain long experience in farming. However, number of the head having farming experience above 24 years remains only 19 out of 81 or 23.5 % of the total. Many farmers have newly started farming after the land privatization policy of the country, as the related law was passed in 1990 (see Table 4-5-4.1 and Table 4-5-4.2 for details).

**Table 4-5-4.1 Age and Farming Experience of Head of the Sample Farm Households**

| WUA area | Number of H.H. | Age | | Farming experience (Year) | | Farming experience +24 years |
|---|---|---|---|---|---|---|
| | | Range | Average | Range | Average | |
| Yeghvard & Ashtarak | 21 | 38-82 | 58.8 | 15-66 | 26.6 | 5 |
| Vagharshapat | 21 | 30-78 | 51.7 | 8-51 | 24.8 | 4 |
| Khoy | 39 | 33-79 | 56.9 | 10-62 | 26.3 | 10 |
| **Total** | **81** | **30-82** | **55.8** | **8-66** | **25.9** | **19** |

Source) JICA Survey Team (Farm household survey)

**Table 4-5-4.2 Years when the Sample Farm Households Obtained Property Rights of Farmland**

| WUA area | 1990-94 | | 1995-99 | | After 2000 | | Total | |
|---|---|---|---|---|---|---|---|---|
| | Number | % | Number | % | Number | % | Number | % |
| Yeghvard & Ashtarak | 10 | 48 | 6 | 29 | 5 | 24 | 21 | 100 |
| Vagharshapat | 13 | 62 | 6 | 29 | 2 | 10 | 21 | 100 |
| Khoy | 20 | 51 | 16 | 41 | 3 | 8 | 39 | 100 |
| **Total** | **43** | **53** | **28** | **35** | **10** | **12** | **81** | **100** |

Source) JICA Survey Team (Farm household survey)

**Education background**

Majority of head of the sample farm households are well educated as shown in Table 4-5-4.3. Most of them completed their secondary school education, and the percentage of university graduates or more accounts 21%. This situation would be a big advantage for the Government to disseminate new technologies and knowledge to the farmers.

**Table 4-5-4.3 Educational Background of the Sample Farm Households**

| Education | Ashtarak & Yeghvard | | Vagharshapat | | Khoy | | Total | |
|---|---|---|---|---|---|---|---|---|
| | Number | % | Number | % | Number | % | Number | % |
| No Education | 0 | 0 | 0 | 0 | 0 | 0 | **0** | **0** |
| Elementary | 0 | 0 | 0 | 0 | 0 | 0 | **0** | **0** |
| Middle | 2 | 10 | 0 | 0 | 2 | 5 | **4** | **5** |
| High / Upper middle | 7 | 33 | 6 | 29 | 15 | 38 | **28** | **35** |
| Vocational | 7 | 33 | 7 | 33 | 18 | 46 | **32** | **40** |
| University or Upper | 5 | 24 | 8 | 38 | 4 | 10 | **17** | **21** |
| **Total** | **21** | **100** | **21** | **100** | **39** | **100** | **81** | **100** |

Source) JICA Survey Team (Farm household survey)

**Membership of WUAs**

Table 4-5-4.4 shows that overwhelming majority of the sample farm households are members of WUAs. It is confirmed that two (2) non-member farmers actually enjoy an irrigation service, as the farmers share water with other family member, such as farther who has WUA membership. It shows that irrigation is an indispensable condition to encourage efficient and stable farm management in the project area.

**Table 4-5-4.4 Membership of WUAs of the Sample Farm Households**

| WUA Membership | Ashtarak & Yeghvard | | Vagharshapat | | Khoy | | Total | |
|---|---|---|---|---|---|---|---|---|
| | Number | % | Number | % | Number | % | Number | % |
| Members | 20 | 95 | 21 | 100 | 38 | 97 | **79** | **98** |
| Non-members | 1 | 5 | 0 | 0 | 1 | 3 | **2** | **2** |
| **Total** | **21** | **100** | **0** | **100** | **39** | **100** | **81** | **100** |

Source) JICA Survey Team (Farm household survey)

**Family members (who live together and share livelihood)**

Table 4-5-4.5 shows number of family members of the sample farm households. The average number is 5.81 person/family, which is bigger than the statistical data collected from 27 communities concerned as shown in Table 4-5-2.4. Out of 5.81 persons, about 4 persons are categorized into the working active age (15-64 years old).

**Table 4-5-4.5 Family Members of the Sample Farm Households**

| Age | Male | | | Female | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total Number | % | Average per H.H. | Total Number | % | Average per H.H. | Total Number | % | Average per H.H. |
| Under 14 | 56 | 23 | 0.69 | 38 | 17 | 0.47 | **94** | **20** | **1.16** |
| 15-64 | 163 | 67 | 2.01 | 162 | 71 | 2.00 | **325** | **69** | **4.01** |
| Over 65 | 25 | 10 | 0.31 | 27 | 12 | 0.33 | **52** | **11** | **0.64** |
| **Total** | **244** | **100** | **3.01** | **227** | **100** | **2.80** | **471** | **100** | **5.81** |

Source) JICA Survey Team (Farm household survey)

It is interesting that an ordinary farm household may have at least 1 person of permanent employee, including self-employment, as shown in Table 4-5-4.6. It implies that many farm households depend on not a small income from non-farming activities.

**Table 4-5-4.6 Number of Permanent Employees, including Self-Employed of the Sample Farm Households**

| WUA area | Male | | Female | | Total | |
|---|---|---|---|---|---|---|
| | Total Number | Average per H.H. | Total Number | Average per H.H. | Total Number | Average per H.H. |
| Ashtarak & Yeghvard | 16 | 0.76 | 12 | 0.57 | **28** | **1.33** |
| Vagharshapat | 20 | 0.95 | 8 | 0.38 | **28** | **1.33** |
| Khoy | 21 | 0.54 | 11 | 0.28 | **32** | **0.82** |
| **Total** | **57** | **0.70** | **31** | **0.38** | **88** | **1.09** |

Source) JICA Survey Team (Farm household survey)

### 2) Income and expenditure

Mid-level or more experienced farmers who have more than the average living standards might be mainly selected for the farm household survey according to their profiles as describe above. 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 & Ashtarak (see Table 4-5-4.7).

**Table 4-5-4.7 Income and Expenditure of Farm Household in 2014**

| WUA | Number of H.H. | Income (thousand AMD/year) | | Expenditure (thousand AMD/year) | |
|---|---|---|---|---|---|
| | | Range | Average | Range | Average |
| Yeghvard & Ashtarak | 21 | 270 – 8,880 | 2,958.9 | 450 – 5,500 | 2,461.3 |
| Vagharshapat | 21 | 2,220 – 27,000 | 8,305.7 | 1,500 – 18,000 | 5,466.7 |
| Khoy | 39 | 750 – 32,270 | 6,126.7 | 500 – 30,000 | 4,382.1 |
| **Total** | **81** | **270 – 32,270** | **5,979.1** | **450 – 30,000** | **4,103.3** |

Source) JICA Survey Team (Farm household survey)

### 3) Income source

Importance of income sources evaluated by sample households is shown in Table 4-5-4.8 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. It seems that pension is a small but considerable supplementary income source for many farm households.

**Table 4-5-4.8 Important Income Sources of Farm Household in 2014**

Unit: %

| Income Sources | WUA | | | | | | | | | | | | | | | Total (81 H.H.) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Yghvard & Ashtarak (21 H.H.) | | | | | Vagharshapat (21 H.H.) | | | | | Khoy (39 H.H.) | | | | | | | | | |
| | Negligible / None | Minor Subsidiary | Important Subsidiary | Principal | **Total** | Negligible / None | Minor Subsidiary | Important Subsidiary | Principal | **Total** | Negligible / None | Minor Subsidiary | Important Subsidiary | Principal | **Total** | Negligible / None | Minor Subsidiary | Important Subsidiary | Principal | **Total** |
| Sales of crops | 14 | 19 | 33 | 33 | **100** | 0 | 0 | 10 | 90 | **100** | 0 | 3 | 18 | 79 | **100** | 4 | 6 | 20 | 70 | **100** |
| Sales of livestock / milk / eggs | 38 | 14 | 5 | 43 | **100** | 57 | 10 | 10 | 24 | **100** | 59 | 8 | 18 | 15 | **100** | 53 | 10 | 12 | 25 | **100** |
| Salary or wages (agriculture) | 95 | 0 | 5 | 0 | **100** | 95 | 0 | 0 | 5 | **100** | 95 | 0 | 5 | 0 | **100** | 95 | 0 | 4 | 1 | **100** |
| Salary or wages non-agriculture | 24 | 5 | 19 | 52 | **100** | 14 | 10 | 38 | 38 | **100** | 51 | 8 | 13 | 28 | **100** | 35 | 7 | 21 | 37 | **100** |
| Own-business (self-employed) | 81 | 0 | 10 | 10 | **100** | 90 | 5 | 0 | 5 | **100** | 90 | 0 | 5 | 5 | **100** | 88 | 1 | 5 | 6 | **100** |
| Sales of handicraft | 95 | 0 | 5 | 0 | **100** | 100 | 0 | 0 | 0 | **100** | 97 | 0 | 3 | 0 | **100** | 98 | 0 | 2 | 0 | **100** |
| Pension of family members | 48 | 14 | 29 | 10 | **100** | 43 | 24 | 19 | 14 | **100** | 49 | 28 | 18 | 5 | **100** | 47 | 23 | 21 | 9 | **100** |
| Remittance | 90 | 5 | 0 | 5 | **100** | 71 | 14 | 5 | 10 | **100** | 79 | 8 | 5 | 8 | **100** | 80 | 9 | 4 | 7 | **100** |
| Public supports | 95 | 5 | 0 | 0 | **100** | 100 | 0 | 0 | 0 | **100** | 92 | 5 | 3 | 0 | **100** | 95 | 4 | 1 | 0 | **100** |
| Others | 100 | 0 | 0 | 0 | **100** | 95 | 0 | 5 | 0 | **100** | 100 | 0 | 0 | 0 | **100** | 99 | 0 | 1 | 0 | **100** |

Source) JICA Survey Team (Farm household survey)

While Table 4-5-4.8 shows difference result among WUAs, the difference gives the following implications.

**Yeghvard & Ashtarak WUA**

- Income from crop farming is low due to low % of irrigated farmland.
- There are many farm households whose income from livestock is higher than the income from crop farming.
- There are many farm households whose income from non-agriculture sector is higher than the income from farming.

**Vagharshapat & Khoy WUA**

- There are many farm households who enjoy a substantial income from crop farming, mainly

from vegetables.

- However, only income from farming is not enough for managing family budget.
- There are many farm households whose family member(s) has (have) a stable job in non-agricultural sector.

### 4) Expenditure items

Table 4-5-4.9 shows priority expenditure items of sample farm households. It is also natural that 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. The table implies that the expenditures to "medical care and health" and "clothes" are almost equally important to many farm households. Difference among WUAs in Table 4-5-4.9 is not much comparing the income source evaluation as shown in Table 4.5-4-8.

**Table 4-5-4.9 Priority Expenditure Items of Farm Household in 2014**

Unit: %

| Expenditure Items | WUA | | | | | | | | | | | | | | | Total (81 H.H.) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Yghvard & Ashtarak (21 H.H.) | | | | | Vagharshapat (21 H.H.) | | | | | Khoy (39 H.H.) | | | | | | | | | |
| | Negligible / None | Minor Subsidiary | Important Subsidiary | Principal | **Total** | Negligible / None | Minor Subsidiary | Important Subsidiary | Principal | **Total** | Negligible / None | Minor Subsidiary | Important Subsidiary | Principal | **Total** | Negligible / None | Minor Subsidiary | Important Subsidiary | Principal | **Total** |
| Agricultural inputs and management | 0 | 5 | 14 | 81 | **100** | 0 | 0 | 10 | 90 | **100** | 0 | 3 | 10 | 87 | **100** | 0 | 2 | 11 | 86 | **100** |
| Foods and beverage | 0 | 0 | 24 | 76 | **100** | 0 | 0 | 38 | 62 | **100** | 0 | 15 | 44 | 41 | **100** | 0 | 7 | 37 | 56 | **100** |
| Clothes | 5 | 10 | 62 | 24 | **100** | 0 | 19 | 57 | 24 | **100** | 0 | 38 | 38 | 23 | **100** | 1 | 26 | 49 | 23 | **100** |
| Housing, home-consumables and public services | 0 | 5 | 33 | 62 | **100** | 0 | 14 | 52 | 33 | **100** | 0 | 18 | 46 | 36 | **100** | 0 | 14 | 44 | 42 | **100** |
| Electric appliances, furniture, Cars, and durable goods | 57 | 24 | 10 | 10 | **100** | 43 | 29 | 14 | 14 | **100** | 54 | 15 | 13 | 18 | **100** | 52 | 21 | 12 | 15 | **100** |
| Medical care and health | 33 | 29 | 14 | 24 | **100** | 38 | 19 | 10 | 33 | **100** | 28 | 26 | 18 | 28 | **100** | 32 | 25 | 15 | 28 | **100** |
| Education and recreation | 43 | 24 | 10 | 24 | **100** | 48 | 19 | 19 | 14 | **100** | 56 | 21 | 15 | 8 | **100** | 51 | 21 | 15 | 14 | **100** |
| Recreation and Entertainment | 62 | 33 | 5 | 0 | **100** | 33 | 43 | 14 | 10 | **100** | 41 | 38 | 18 | 3 | **100** | 44 | 38 | 14 | 4 | **100** |
| Social relation | 5 | 62 | 33 | 0 | **100** | 0 | 38 | 43 | 19 | **100** | 5 | 38 | 36 | 21 | **100** | 4 | 44 | 37 | 15 | **100** |
| Other | 90 | 10 | 0 | 0 | **100** | 62 | 10 | 5 | 24 | **100** | 74 | 0 | 0 | 26 | **100** | 75 | 5 | 1 | 19 | **100** |

Source) JICA Survey Team (Farm household survey)

### 5) Strategy to increase living standards of family

Table 4-5-4.10 shows that 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.

**Table 4-5-4.10 Strategy to Increase Living Standards**

Unit: %

| Strategy | WUA | | | | | | | | | | | | Total (81 H.H.) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Yghvard & Ashtarak (21 H.H.) | | | | Vagharshapat (21 H.H.) | | | | Khoy (39 H.H.) | | | | | | | |
| | Less important | Important | very important | **Total** | Less important | Important | very important | **Total** | Less important | Important | very important | **Total** | Less important | Important | very important | **Total** |
| To devote to crop farming | 29 | 14 | 57 | **100** | 23 | 10 | 67 | **100** | 19 | 14 | 67 | **100** | 23 | 12 | 64 | **100** |
| To devote to livestock farming | 43 | 19 | 38 | **100** | 59 | 3 | 38 | **100** | 62 | 10 | 29 | **100** | 56 | 9 | 36 | **100** |
| To find out a new good job/business in local area | 57 | 14 | 29 | **100** | 41 | 28 | 31 | **100** | 33 | 5 | 62 | **100** | 43 | 19 | 38 | **100** |
| To go to other area/country for getting jobs | 86 | 14 | 0 | **100** | 72 | 13 | 15 | **100** | 71 | 10 | 19 | **100** | 75 | 12 | 12 | **100** |
| To educate children for getting good jobs | 29 | 10 | 62 | **100** | 36 | 15 | 49 | **100** | 38 | 0 | 62 | **100** | 35 | 10 | 56 | **100** |
| To sell processed (value added) foods/products | 57 | 14 | 29 | **100** | 44 | 15 | 41 | **100** | 67 | 14 | 19 | **100** | 53 | 15 | 32 | **100** |

Source) JICA Survey Team (Farm household survey)

## 4-5-5 Agricultural Production

1) Project area

Table 4-5-5.1 shows production of major crops in 27 communities extended across the Project area in compiling statistical data collected from the community offices.

**Table 4-5-5.1 Production of Crops in 27 Communities Extended across the Project Area* (2010-2014)**

**Planted Area (ha)**

| Crops | 2010 | 2011 | 2012 | 2013 | 2014 |
|---|---|---|---|---|---|
| Wheat | 1,704.9 | 1,544.6 | 1,558.9 | 1,613.1 | 1,822.4 |
| Barley | 77.2 | 121.9 | 119.0 | 78.0 | 91.9 |
| Maize | 13.4 | 17.6 | 42.0 | 46.1 | 37.0 |
| Alfalfa | 768.8 | 758.6 | 825.1 | 838.2 | 968.4 |
| Potato | 726.5 | 776.8 | 856.9 | 705.3 | 728.1 |
| Other miscellaneous food & forage crops | 280.2 | 343.2 | 290.7 | 372.6 | 334.3 |
| Tomato | 402.2 | 466.0 | 421.1 | 469.6 | 507.9 |
| Cucumber | 249.9 | 254.8 | 256.3 | 202.6 | 225.1 |
| Eggplant | 82.2 | 74.0 | 100.7 | 95.3 | 119.2 |
| Sweet pepper | 126.4 | 115.9 | 137.3 | 131.4 | 109.2 |
| Cabbage | 217.4 | 243.1 | 256.9 | 214.8 | 219.1 |
| Water melon | 199.0 | 299.3 | 270.2 | 273.1 | 409.3 |
| Other miscellaneous vegetables | 1,364.9 | 1,288.2 | 1,407.2 | 1,472.6 | 1,343.9 |
| Grape | 1,313.5 | 1,291.6 | 1,321.4 | 1,303.0 | 1,300.2 |
| Apricot | 375.1 | 371.8 | 371.4 | 382.9 | 381.3 |
| Peach | 155.7 | 155.4 | 157.7 | 144.1 | 141.8 |
| Apple | 213.3 | 209.8 | 209.2 | 206.4 | 200.5 |
| Pear | 53.2 | 50.9 | 45.4 | 47.4 | 48.2 |
| Other miscellaneous fruits & berries & nuts | 106.6 | 120.1 | 115.9 | 132.4 | 150.8 |
| **Total** | **8,430.4** | **8,503.6** | **8,763.3** | **8,728.9** | **9,138.6** |

**Production (ton)**

| Crops | 2010 | 2011 | 2012 | 2013 | 2014 |
|---|---|---|---|---|---|
| Wheat | 5,344.8 | 5,622.9 | 5,443.9 | 6,058.5 | 6,850.1 |
| Barley | 230.4 | 349.2 | 253.2 | 171.4 | 315.1 |
| Maize | 32.8 | 45.8 | 102.6 | 62.0 | 83.5 |
| Alfalfa | 8,654.3 | 8,334.9 | 9,351.8 | 9,500.1 | 11,092.8 |
| Potato | 22,927.0 | 25,205.2 | 31,327.4 | 29,455.8 | 29,102.0 |
| Other miscellaneous food & forage crops | 569.0 | 670.6 | 616.6 | 736.9 | 646.6 |
| Tomato | 19,434.5 | 20,668.9 | 19,754.5 | 23,678.8 | 24,283.3 |
| Cucumber | 8,938.4 | 10,048.9 | 8,779.5 | 8,509.2 | 9,009.8 |
| Eggplant | 4,410.4 | 3,771.4 | 5,343.5 | 4,321.0 | 4,562.0 |
| Sweet pepper | 4,892.2 | 4,642.5 | 5,221.5 | 5,443.2 | 3,947.9 |
| Cabbage | 6,565.7 | 7,434.7 | 6,966.7 | 6,998.0 | 6,230.2 |

| | | | | | |
|---|---|---|---|---|---|
| Water melon | 9,014.0 | 12,312.2 | 11,470.5 | 12,134.5 | 16,552.0 |
| Other miscellaneous vegetables | 21,090.2 | 25,232.6 | 24,819.7 | 29,647.0 | 26,989.0 |
| Grape | 12,848.7 | 13,636.7 | 14,295.4 | 15,922.2 | 17,501.9 |
| Apricot | 2,002.8 | 2,436.3 | 2,658.9 | 2,880.4 | 290.1 |
| Peach | 1,374.7 | 1,372.5 | 1,543.1 | 1,553.8 | 1,396.4 |
| Apple | 944.8 | 1,271.6 | 1,682.3 | 1,831.2 | 3,399.8 |
| Pear | 333.4 | 350.0 | 367.7 | 432.1 | 440.4 |
| Other miscellaneous fruits & berries & nuts | 750.8 | 768.3 | 869.7 | 877.2 | 818.7 |

**Yield (ton/ha)**

| Crops | 2010 | 2011 | 2012 | 2013 | 2014 |
|---|---|---|---|---|---|
| Wheat | 3.1 | 3.6 | 3.5 | 3.8 | 3.8 |
| Barley | 3.0 | 2.9 | 2.1 | 2.2 | 3.4 |
| Maize | 2.4 | 2.6 | 2.4 | 1.3 | 2.3 |
| Alfalfa | 11.3 | 11.0 | 11.3 | 11.3 | 11.5 |
| Potato | 31.6 | 32.4 | 36.6 | 41.8 | 40.0 |
| Other miscellaneous food & forage crops | 2.0 | 2.0 | 2.1 | 2.0 | 1.9 |
| Tomato | 48.3 | 44.4 | 46.9 | 50.4 | 47.8 |
| Cucumber | 35.8 | 39.4 | 34.3 | 42.0 | 40.0 |
| Eggplant | 53.7 | 51.0 | 53.1 | 45.3 | 38.3 |
| Sweet pepper | 38.7 | 40.1 | 38.0 | 41.4 | 36.2 |
| Cabbage | 30.2 | 30.6 | 27.1 | 32.6 | 28.4 |
| Water melon | 45.3 | 41.1 | 42.5 | 44.4 | 40.4 |
| Other miscellaneous vegetables | 15.5 | 19.6 | 17.6 | 20.1 | 20.1 |
| Grape | 9.8 | 10.6 | 10.8 | 12.2 | 13.5 |
| Apricot | 5.3 | 6.6 | 7.2 | 7.5 | 0.8 |
| Peach | 8.8 | 8.8 | 9.8 | 10.8 | 9.8 |
| Apple | 4.4 | 6.1 | 8.0 | 8.9 | 17.0 |
| Pear | 6.3 | 6.9 | 8.1 | 9.1 | 9.1 |
| Other miscellaneous fruits & berries & nuts | 7.0 | 6.4 | 7.5 | 6.6 | 5.4 |

Note*) Acreage of the project area is only 91.2% of total acreage of the 27 communities

Source) 27 Community Offices concerned

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 8,713 ha 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. As regard to vegetables, planted area of other miscellaneous vegetables is more than 2 times bigger than the area of tomato, while tomato is the largest single crop in terms of planted area among vegetables. It seems that diversification of vegetable crops including herbs is progressed in the 27 communities. On the contrary, fruits and grapes are dominated by some limited crops, i.e. grapes, apricot and apple. Planted area of grapes is remarkably bigger than other fruits in the 27 communities. 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.

Table 4-5-5.2 shows number of livestock in the 27 communities. 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. In terms of the number, chicken is the largest, followed by cows/cattle, sheep, pigs and few goats and horses. It seems that cows/cattle are the most important animal to livestock farmers in the 27 communities. As regard to number of cows/cattle, the number of milk cows is much bigger than the number of meat cattle. As same as in case of chicken, the number of layer hen is much bigger than the number of chicken for meat.

**Table 4-5-5.2 Number of Livestock in 27 Communities Extended across the Project Area (2010-2014)**

| Livestock | | 2010 | 2011 | 2012 | 2013 | 2014 |
|---|---|---|---|---|---|---|
| Household growing livestock | | 5,460 | 5,158 | 4,953 | 4,725 | 4,749 |
| 1 | Milk cows/Cattle total | 11,543 | 12,865 | 12,754 | 13,584 | 13,044 |
| 1-1 | Milk cows (milking) | 5,167 | 5,459 | 5,725 | 6,036 | 5,872 |
| 1-2 | Meat cattle (adult) | 1,039 | 804 | 1,058 | 604 | 457 |
| 1-3 | Infant/Infertile | 5,337 | 6,602 | 5,971 | 6,944 | 6,715 |
| 2 | Pigs | 3,481 | 3,097 | 2,822 | 3,942 | 4,329 |
| 3 | Sheep | 12,474 | 11,299 | 10,815 | 15,110 | 12,136 |
| 4 | Goats | 126 | 212 | 171 | 309 | 199 |
| 5 | Horses | 30 | 10 | 31 | 44 | 42 |
| 6 | Chicken total | 50,868 | 44,033 | 40,991 | 43,578 | 46,644 |
| 6-1 | Layer hen (egg) | 43,236 | 36,898 | 35,395 | 37,717 | 39,811 |
| 6-2 | Other chicken | 7,632 | 7,135 | 5,596 | 5,861 | 6,833 |

Source) 27 Community Offices concerned

2) WUA areas

While 4 WUAs extend their command areas in the Project area, crop and livestock farming in each WUA area is discussed here. Detailed statistical data on crops and livestock by 4 WUA areas is attached in Appendix B-7 respectively, and abstractive information related to agriculture collected from each community office is summarized in Appendix B-8 for easy understanding.

**Yeghvard WUA area: (represented by information from 3 communities concerned)**

There are 3 communities related to the Project in Yeghvard WUA area. Cropped area in the Yeghvard 3-communities is mainly irrigated by Arzni Branch Canal. Crop planted area in the Yeghvard 3-communities was about 625-680 ha in total during 2010-2014, while the average was 643 ha. The area is only 7.4 % of the total cropped area in the 27 communities.

Cropped area of alfalfa is the largest, followed by apple and apricot. Fruits production is the most popular farming in the Yeghvard 3-communities, by utilizing well-drained soil, hilly land condition and long duration of sunshine. The Yeghvard 3-communities have a long history of fruits cultivation, since they were developed as Sovkhozes to produce fruits and grapes during Soviet era. On the contrary, vegetables are not popular among farmers, except for growing them in backyard mainly for own consumption. Productivity of each crop is still lower than other 3 WUA areas, due to mainly inferior irrigation condition and relatively low soil fertility. Production of vegetables and fruits, however, tend to increase because of increased productivity of those crops in recent years.

Although a general understanding that livestock farming is more popular in Yeghvard WUA area than the other 3 WUA areas, only 627 farm households or 23% of total 2,672 farm households were growing some sort of livestock in the Yeghvard 3-communities in 2014. Neverthless, the Yeghvard 3-communities grow a big number of livestock comparing to the other WUA areas. In case of cows/cattle which are the most important livestock for farmers, 4,930 heads or 37.8% of the total (13,044 heads) in the 27 communities were grown in 2014 in the area. There must be specialized livestock farmers, even not a large number, who manage a large number of animals. The order of importance among livestock is almost same as the other areas except for sheep. Number of growing sheep is more than the number of cows/cattle in the area.

**Ashtarak WUA area (represented by information from 4 communities concerned)**

There are 4 communities related to the Project in Ashtarak WUA area. Cropped area in the Ashtarak 4-communities is mainly irrigated by Lower Hrazdan Canal and Takahan Canal. Most of the present cropped area in 3 communities along to Lower Hrazdan Canal, i.e. Noraket, Baghramyan and Merdzavan, is located outside of the Project area. Only the area located on the northern side of Lower

Hrazdan Canal in the 3 communities, where is located at higher altitude than the canal and is extended on gentle slopes, is included in the Project area.

Crop planted area in the Ashtarak 4-communities was about 1,110-1,140 ha in total during 2010-2014, while the average was 1,122 ha. The area is only 12.9 % of the total cropped area in the 27 communities. As same as the Yeghvard 3-communities, 3 communities out of the 4 communities were developed as Sovkhozes to produce mainly grapes during Soviet era. Remained one community, Merdzavan, was also developed as a managing community of research farms including a grape research farm. Influenced by the history, more than a half of farmland is occupied by fruits and grapes. In terms of cropped area, grapes are the extremely biggest, followed by alfalfa, apricot, wheat, barley and various fruits.

Collected data shows considerable rise of grape production from 2010 to 2014. While there is no significant difference in planted area of grapes, the productivity has been improved. Meanwhile, several commercial investors have already started to convert idle lands into vineyard or orchard. Though there is no single vegetable crop which has widely produced, total vegetable cropped area is not so small, probably due to diversified vegetable crops. Except for fruits and cereals, productivity is lower than the average of the 27 communities.

Only 522 farm households or 23% of total 2,279 farm households were growing some sort of livestock in the Ashtarak 4-communities in 2014. The percentage is same as the percentage of the Yeghvard 3-communities. Though the order of importance among livestock is almost same as the other areas, number of pigs is relatively bigger in this area.

**Vagharshapat WUA area (represented by information from 7 communities concerned)**

There are 7 communities related to the Project in Vagharshapat WUA area. Cropped area in the Vagharshapat 7-communities is mainly irrigated by Shah-Aru Canal and Upper- and Lower- Akhnalich Canals. Because of unreliable water supply from the canals due to reduced water resources suppling to Upper- and Lower- Akhnalich Canals, and deteriorated canal networks to individual farmers, many farmers depend on tube-wells powered by electricity to irrigate their crops.

Crop planted area in the Vagharshapat 7-communities was about 2,340-2,620 ha in total during 2010-2014, while the average was 2,489 ha. The area is continuously expanding year by year in 2010-2014. In terms of cropped area wheat is the largest, followed by water melon, alfalfa, tomato, potato, grapes, cucumber and various vegetables. Comparing to annual crops, fruits production except for grapes is not popular in the area. The area is located in Ararat plain and is blessed with fertile soil. It is generally understood that Ararat plain is the most agricultural advanced area in the country. Productivity of many crops in the area is higher than the average of the 27 communities, except for fruits crops.

While farmers in the Vagharshapat 7-communities are very active in growing all annual crops in general, Vagharshapat WUA area is famous in vegetable cultivation. Vegetables production in the area shows a significant increase in 2010-2014 because of increased planted area. A blessed location of the area which has a good road access to big cities, such as Yerevan, Ejimiatsin, Armavir and Ashtarak, has made a big push to the increased production.

Farmers grow various kinds of vegetables and herbs in their backyard, beside crops, such as wheat, alfalfa, potato, cabbage and water melon which are mainly grown in relatively large scaled open field. More than a half of planted area is occupied by vegetables in 2014, if potatoes are counted in vegetables. Most of the farmers construct a simple greenhouse or tunnel in their backyard or a field near to their houses for growing vegetables for marketing purpose. Some of them even install a private tube well for securing stable irrigation water for their vegetables. Tomato and cucumber are the most

common crops cultivated in greenhouses. Multiple cropping in a year under greenhouse or tunnel is also popular in the area.

History of the Vagharshapat 7-communities is a reason why vegetable farming is very popular among farmers. Out of the 7 communities, 5 communities were Kolkhozes mainly growing vegetables, and 1 community was a Sovkhoz for vegetable seeds production in Soviet era. Considering the history, there have to be many farmers who have good experience in vegetable cultivation in the Vagharshapat 7-communities.

In contrast to crop farming, farmers in the Vagharshapat 7-communities are not so active in livestock farming. Though 1,189 farm households or 44% of total 2,709 farm households were growing some sort of livestock in 2014, total number of livestock grown in the area is relatively small except for chicken. Many farmers probably keep small number of livestock mainly for their own consumption in the area. According to collected information from community offices in the area, livestock farming is not a profitable business any more, as the communities lost a right to access to grazing pastures which they had in mountainous regions mainly in Aragatsotn Marz and Kotayk Marz before the independence. As same as the other areas, cows/cattle, especially milk cows are the most important livestock for farmers.

**Khoy WUA area (represented by information from 13 communities concerned)**

There are 13 communities related to the Project in Khoy WUA area. The communities are located on the north-western side of Vagharshapat WUA area, and extended on Ararat plain bordered on foothills. Cropped area in the Khoy 13-communities occupies almost a half of the total cropped area in the 27 communities. The area is mainly irrigated by Lower Hrazdan Canal, while a small part is irrigated by Upper Akhnalich Canal and Kasakh River (pump irrigation). Even though the area is endowed with the best irrigation condition in the Project area, not a small number of farmers depend on tube-wells for irrigating their crops although the dependence is lower than Vagharshapat WUA area.

Crop planted area in the Khoy 13-communities was about 4,350-4,750 ha in total during 2010-2014, while the average was 4,459 ha. The area is continuously expanding year by year in 2010-2014. In terms of cropped area wheat is the largest, followed by grapes, potato, alfalfa, tomato, cabbage, apricot, cucumber, and various vegetables and herbs. With blessed conditions to run farming business, i.e. good prepared irrigation, fertile and plain land and good access to the market, the area leads not only the Project area but also whole country in terms of crop farming together with Vagharshapat WUA area.

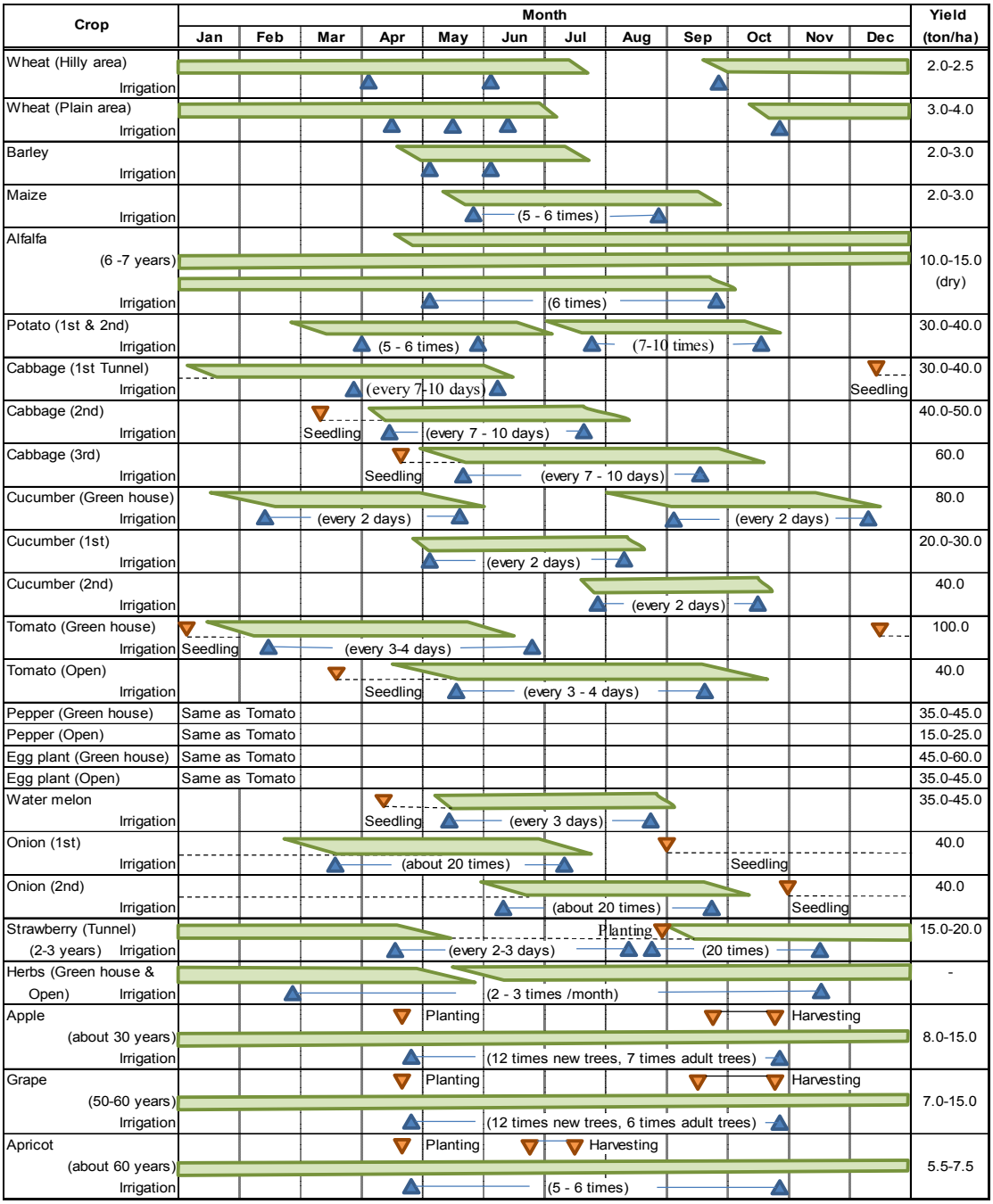
While farming system and cultivated crops is similar to Vagharshapat WUA area, a fruits farming mainly growing grapes is much popular in the Khoy 13-communities and cultivated crops are more diversified. Since 6 communities out of the 13 communities were Kolkhozes to grow grapes and fruits in Soviet era, while other communities were vegetable Kolkhozes except for one grape Sovkhoz, the history may influence to the difference. Another difference is a size of cropped field. An average size of cropped field in the area is generally smaller than the area in Vagharshapat WUA area, according to the observation, probably due to geographical condition mainly. As same as Vagharshapat WUA area, greenhouse or tunnel cultivation is popular among farmers in the area. Diversified vegetables and herbs are grown under greenhouses or tunnels. Several communities are getting famous in special crops, such as strawberries, tarragon, etc.

Farmers in the Khoy 13-communities are also not so active in livestock farming, except for Ferik community. Though 2,411 farm households or 41 % of total 5,914 farm households were growing some sort of livestock in 2014, total number of livestock grown in the area is not so large except for chicken. Many community offices in the area mentioned the issue of grazing land area similar to the

case of Vagharshapat WUA area. As same as the other areas, cows/cattle, especially milk cows are the most important livestock for farmers.

### 4-5-6 Cropping Calendar

Temperature, rainfall and availability of irrigation mainly determine cropping seasons of major crops in the Project area. Figure 4-5-6.1 indicates the cropping seasons of major crops based on collected information from various sources including a farm household survey by the Survey team. Mainly, the 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.




Source) JICA Survey Team

**Figure 4-5-6.1 Crop Calendar of Major Crops in the Project Area**

While rain-fed farming of wheat or forage crops, which require relatively small amount of water, is practiced in mountainous areas in Armenia with comparatively blessed rainfall, 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.

### 4-5-7 Use of Farm Inputs

1) Inputs use

Agricultural inputs such as crop seeds, fertilizers, agrochemicals, farm machinery and farm facilities are significant inputs to achieve a stable and high production of agriculture. Table 4-5-7.1 indicates situation of agricultural inputs use by crops about interviewed 81 farmers by the Survey team's 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. Little number of farmers uses compost although fertilizers are popular among farmers. There are notable gap between the two inputs and others in respect to the popularity among farmers.

Many farmers has recognized that pests and diseases are serious problem for their crop production when the Survey team interviewed about their problems, but Table 4-5-7.1 shows that pesticides and fungicides are still not popular among them. They are still used selectively by limited farmers to limited crops. As regard to pesticides, wheat and maize are only crops for those pesticides are used by more than 50 % of growers. In case of fungicides, only grapes, greenhouse tomato and cucumber are such crops. Many farmers don't know well about basic information, even right names of herbicides, pesticides and fungicides which they use, according to the farm household survey. They usually make consultation with agrochemicals shops about appropriate chemicals to their crops when necessary.

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.

**Table 4-5-7.1 Use of Agricultural Inputs by Crops**

| Crops | No. of farmers to grow | Number of Users | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Fertilizer | Compost | Herbicide | Pesticide | Fungicide | Marketed Seeds | Marketed Seedlings |
| Wheat | 35 | 35 | 3 | 4 | 33 | 8 | 23 | 0 |
| Barley | 10 | 10 | 0 | 0 | 4 | 2 | 6 | 0 |
| Maize | 2 | 1 | 0 | 1 | 2 | 0 | 2 | 0 |
| Alfalfa | 26 | 13 | 2 | 20 | 0 | 0 | 4 | 0 |
| Potato | 29 | 28 | 3 | 26 | 13 | 9 | 27 | 0 |
| Tomato | 26 | 22 | 8 | 15 | 6 | 7 | 10 | 10 |
| Tomato (green house) | 18 | 18 | 11 | 11 | 2 | 10 | 2 | 16 |
| Cucumber | 30 | 28 | 3 | 23 | 3 | 11 | 23 | 1 |
| Cucumber (green house) | 12 | 11 | 8 | 8 | 0 | 7 | 0 | 12 |
| Eggplant | 17 | 11 | 6 | 10 | 2 | 2 | 0 | 7 |
| Eggplant (green house) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sweet Pepper | 10 | 7 | 2 | 2 | 1 | 2 | 1 | 2 |
| Sweet Pepper (green house) | 6 | 6 | 4 | 1 | 0 | 0 | 0 | 0 |
| Cabbage | 9 | 7 | 0 | 8 | 2 | 3 | 5 | 4 |
| Water melon | 8 | 8 | 0 | 6 | 4 | 4 | 5 | 3 |
| Grape | 33 | 23 | 9 | 28 | 15 | 22 | 0 | 3 |
| Apricot | 20 | 10 | 11 | 16 | 0 | 8 | 0 | 3 |
| Apple | 16 | 11 | 7 | 8 | 1 | 6 | 0 | 3 |

Source) JICA Survey Team (Farm household survey)

According to the farm household survey by the Survey team, many farmers complained about high cost of farm inputs. It is implied that high price of inputs is a major reason of relatively low percentage of inputs users as shown in Table 4-5-7.1. In the same view point, a major reason of high percentage of fertilizer-users must be the government subsidy policy to fertilizers, and the reason of herbicide-users is the affordability of herbicides considering labor hiring cost for weeding.

As regard to fertilizers, there might be growing concern about an excessive use of nitrogen fertilizers in Armenia. A result of the farm household survey implies that many respondents use only nitrogen fertilizers and overuse them to their crops (see Table 4-5-7.2). According to the Agrochemical Service Company under the Ministry of Agriculture, an excessive use of nitrogen fertilizers is recognized throughout the country, while an underuse of phosphate fertilizers and potassium fertilizers is another concern. The company suggests that a balanced fertilizer application could bring about high-productivity and high-quality of harvest on sustainable basis.

**Table 4-5-7.2 Chemical Fertilizer Use for Crop Cultivation**

| Crops* | Amount (kg/ha in chemical component) | | | | | |
|---|---|---|---|---|---|---|
| | Ave. of Respondent Farmers | | | Government Recommendation | | |
| | N | $P_2O_5$ | $K_2O$ | N | $P_2O_5$ | $K_2O$ |
| Wheat | 130.5 | 0.0 | 0.0 | 90 - 120 | 90 | 60 - 70 |
| Barley | 74.5 | 0.0 | 0.0 | 70 - 90 | 60 - 70 | 70 |
| Alfalfa | 63.3 | 0.0 | 14.3 | 0 | 90 - 120 | 45 - 60 |
| Potato | 332.2 | 0.0 | 0.0 | 120 | 90 | 90 |

Note*) Crops widely grown by sample farmers in terms of cropped area

Source) JICA Survey Team (Farm household survey)

2) 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. Table 4-5-7.3 shows number of farm machinery in the Project area.

**Table 4-5-7.3 Number of Farm Machinery in the Project Area**

| Farm Machinery | 2010 | 2011 | 2012 | 2013 | 2014 |
|---|---|---|---|---|---|
| Tractors (main-body) | 385 | 376 | 361 | 366 | 365 |
| Tractor plows | 123 | 125 | 131 | 127 | 129 |
| Cultivators (for ridging) | 92 | 86 | 92 | 88 | 88 |
| Tractor seeder | 52 | 53 | 53 | 54 | 54 |
| Tractor mower | 29 | 29 | 30 | 31 | 31 |
| Baler (tractor operated) | 27 | 27 | 28 | 29 | 31 |
| Tractor trailers | 154 | 150 | 155 | 158 | 155 |
| Combine harvester | 5 | 5 | 5 | 5 | 5 |

Source) 27 Community Offices concerned

While total number of tractors, which is the most important farm machinery, is 365 units in 2014, the number is not so small considering 9,139 ha of total planted area in the Project area in 2014 (see Table 4-5-7.4). It seems that 25 ha of planted area per tractor unit is theoretically within a reasonable level for managing farmland, if all tractors are in good working condition, and are properly operated in large scaled fields in accordance with well-organized schedule. About 10 ha is, however, the optimal land unit size per one tractor (80 HP) considering the present operation condition, according to a private tractor dealer.

**Table 4-5-7.4 Numbers of Tractors and Planted Area in the Project Area**

| | Yeghvard | Ashtarak | V. shapat | Khoy | Total |
|---|---|---|---|---|---|
| Number of Tracrors (unit) | 28 | 40 | 132 | 165 | 365 |
| Planted Area (ha) | 630.2 | 1,142.6 | 2,622.5 | 4,743.3 | 9,138.6 |
| Area/Tracor (unit/ha) | 22.5 | 28.6 | 19.9 | 28.7 | 25.0 |

Source) 27 Community Offices Concerned

In Armenia, many over aged farm machinery such as tractors are still used at field, even from the Soviet time continuously. Age of those machineries is sometimes more than 30 years old. One of serious issues in agriculture sector in this country is renewal of those old machineries. Decline of tractor numbers as shown in Table 4-5-7.3 implies that number of break down tractors is overtaking the number of renewal. Meanwhile, fragmented farmland after the privatization policy is one of reasons why many farmers have faced to the shortages of farm machinery. Present farm machinery services cannot properly cope with requirements for managing a large number of fragmented farmlands owned by individual farmers.

3) Procurement Sources

Table 4-5-7.5 shows procurement sources of farm inputs. The table suggests that private market is the major source of farm inputs for farmers. Some farmers are managing self-produced inputs such as seeds and compost by themselves. 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. Farmers are able to procure three types of fertilizers, i.e. Ammonium nitrate, Double superphosphate and Potassium chloride, at 35 to 50 % cheaper price than the market prices through the subsidy system.

**Table 4-5-7.5 Source of Procurement of Farm Inputs in 2014/2015**

| Farm Inputs | No use farmers | Self-production/ management | From Govt. program | From research institutes | From private/ market | From neighbor | From others | Total* (81 farmers) |
|---|---|---|---|---|---|---|---|---|
| Commercial seeds / seedlings | 17 | 9 | 4 | 0 | 58 | 1 | 0 | 89 |
| Compost | 46 | 11 | 1 | 0 | 18 | 4 | 2 | 82 |
| Chemical fertilizers | 8 | 2 | 48 | 0 | 50 | 0 | 0 | 108 |
| Pesticide / Fungicide / Herbicide | 2 | 0 | 7 | 0 | 75 | 0 | 1 | 85 |
| Mechanization services (machinery-hiring) | 17 | 4 | 0 | 0 | 61 | 4 | 0 | 86 |
| Fuel (diesel) | 64 | 1 | 0 | 0 | 17 | 0 | 0 | 82 |

Note*) As one sample farm household has plural sources, total number is not equal to the sample number
Source) JICA Survey Team (Farm household survey)

4) Greenhouse

Greenhouse cultivation is becoming more popular in recent years in Armenia due to an increased demand for quality vegetables and flowers from urban area, as well as for export. Growing vegetables and flowers in greenhouses is more costly than open field cultivation, but it has its advantages: better quality products, more protection from rain, hail and pests, and possibility of harvest season control.

Table 4-5-7.6 shows total area and number of greenhouses by Marzes. Almost 95 % of total greenhouse areas in Armenia are concentrated in Ararat Marz and Armavir Marz which are located in Ararat plain. Vagarshapat WUA and Khoy WUA areas, located in Armavir Marz, are the center of greenhouse crop production in the Project area. Table 4-5-7.6 also implies that most of greenhouses installed in Armavir Marz are small size greenhouses for vegetable cultivation. Many farmers in the both WUA areas construct a simple greenhouse in or near by their backyard. Some advanced farmers install a personal tube well, and even a drip irrigation system with their greenhouses. According to

interviewed farmers and the Greenhouse Association, RA, tomato and cucumber are the most popular crops for greenhouse cultivation. In addition to those major crops, other crops such as pepper, eggplant, strawberry, herbs and ornament flowers are also grown under greenhouses.

In Armavir Marz, an average planted area of vegetables and melon from 2009 to 2013 counts 12,165 ha according to the data from the Ministry of Agriculture. Considering this figure, greenhouse area for vegetables in Armavir Marz is estimated to about 3 % of the total vegetables and melon planted area.

**Table 4-5-7.6 Total Area of Greenhouses and Use by Region in 2014**

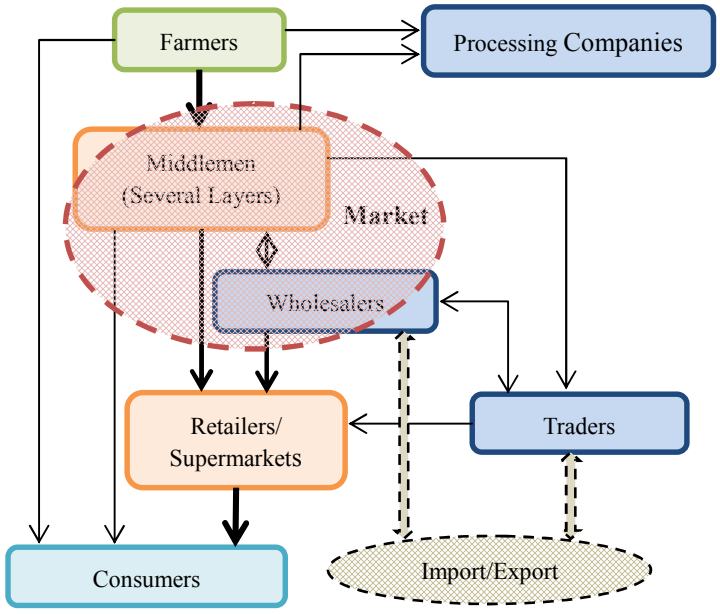
| No | Marz | Area | | | | | | Farmer/Owner | | Average |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Vegetables | | Flowers | | Total | (%) | | | |
| | | (ha) | (%) | (ha) | (%) | (ha) | | (h.h.) | (%) | (ha/h.h.) |
| 1 | Ararat | 120.0 | 70.9 | 49.3 | 29.1 | 169.3 | 27.6 | 2,212 | 28.0 | 0.08 |
| 2 | **Aragatsotn** | **1.9** | **70.4** | **0.8** | **29.6** | **2.7** | **0.4** | **11** | **0.1** | **0.25** |
| 3 | **Armavir** | **349.3** | **85.4** | **59.7** | **14.6** | **409.0** | **66.6** | **5,485** | **69.5** | **0.07** |
| 4 | Gegharkunik | 0.1 | 50.0 | 0.1 | 50.0 | 0.2 | 0.0 | 1 | 0.0 | 0.20 |
| 5 | **Kotayk** | **15.9** | **60.7** | **10.3** | **39.3** | **26.2** | **4.3** | **48** | **0.6** | **0.55** |
| 6 | Lori | 0.0 | NA | 0.0 | NA | 0.0 | 0.0 | 3 | 0.0 | 0.00 |
| 7 | Syunik | 1.3 | 37.1 | 2.2 | 62.9 | 3.5 | 0.6 | 6 | 0.1 | 0.58 |
| 8 | Shirak | 0.4 | 66.7 | 0.2 | 33.3 | 0.6 | 0.1 | 8 | 0.1 | 0.08 |
| 9 | Vayots Dzor | 0.6 | 100.0 | 0.0 | 0.0 | 0.6 | 0.1 | 5 | 0.1 | 0.12 |
| 10 | Tavush | 1.6 | 94.1 | 0.1 | 5.9 | 1.7 | 0.3 | 118 | 1.5 | 0.01 |
| | Total | 491.1 | 80.0 | 122.7 | 20.0 | 613.8 | 100.0 | 7,897 | 100.0 | 0.08 |

Note) Figures in bold are Merzes placed in the project area

Source) The Greenhouse Association, RA

## 4-5-8 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. As mentioned in the Chapter 3-5, middleman is the most major buyers for farmers in the Project area. From retailer's aspect, a stable supply of certain volume and quality of agricultural products are needed for their business. Middleman is playing the role of filter to collect up enough volume of products from farmers for retailer's demand.




Source: JICA Study Team

**Figure 4-5-8.1 Distribution Channel of Vegetables and Fruits**

Limited number of farmers who are producing enough volume of products by commercialized large-scare farming can sell their products without middleman. Selling channel of agricultural products is significant issue for farmers because it is directly related to their income. Figure 4-5-8.1 describes the distribution channels of vegetables and fruits which are the most important farm income sources in the project area.

Contract farming is going to be developed in the Project area, even at an initial stage. Many processing companies and traders consider that they should depend in a large part of their handling products on contract farming if they will expand their business. However, they still hesitate to get into expanded contract farming due to the following problems on the management.

- Quality control of the products produced by contract farmers
- Breach of contract (by contract farmers) when market price of the products increases

Table 4-5-8-1 indicates sale destinations of main 8 products from farmers based on result from the farm household survey.

**Table 4-5-8.1 Marketing Channels of Major Agricultural Products in the Project Area**

| Products | Number of Farmers | Sale Destinations* from Farmers | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Middle-man | Processor | Wholesaler | Retailer/ Supermarket | Coopera-tives | Exporter | Customer/ Neighbor |
| Wheat | 11 | 8 | 0 | 1 | 0 | 0 | 0 | 2 |
| Potato | 23 | 9 | 0 | 9 | 1 | 0 | 1 | 4 |
| Tomato (open field) | 15 | 7 | 8 | 2 | 1 | 0 | 0 | 0 |
| Tomato (greenhouse) | 18 | 12 | 0 | 4 | 0 | 0 | 0 | 2 |
| Cucumber (open field) | 18 | 9 | 1 | 5 | 0 | 0 | 0 | 4 |
| Cucumber (greenhouse) | 10 | 7 | 0 | 2 | 0 | 0 | 0 | 1 |
| Grape | 21 | 0 | 18 | 0 | 0 | 0 | 0 | 3 |
| Apricot | 14 | 3 | 0 | 4 | 2 | 0 | 2 | 3 |
| Cow Milk | 15 | 0 | 6 | 0 | 5 | 1 | 0 | 4 |
| Cattle Meat | 16 | 8 | 0 | 1 | 3 | 0 | 0 | 5 |

Note*) As some farmers have several sale destinations, the total number is not necessarily equal to the number of farmers
Source) JICA Survey Team (Farm household survey)

Potato, apricot and cow milk are sold through relatively wide varieties of selling channels. Milk and cattle meats are often sold directly to consumers who live in the same or surrounding communities, even Yerevan city. A direct selling doesn't always secure farmers a satisfactory profit, as it needs increased transportation cost and other indirect cost sometimes. However, a direct selling to customer can be one of options to maximize farmer's profit by disintermediation in such a suburban area. Majority of grape and some part of tomato, cucumber and milk are sold to processing companies. In case of grape, many farmers are doing contract cultivation with brandy distilleries and wineries. Since grape cultivation has been historically developed with development of the industries, and the industries are important foreign currency sources, the government supports the contract farming of grape. In case of tomato, the open field farmers tend to sell a large volume of their products to processers at a small profit. On the contrary, the greenhouse farmers are selling their products to middleman and others for fresh consuming. Agricultural cooperatives are not active in marketing in the Project area, except in a case of milk selling, while cooperatives can be an effective solution for farmers to increase their bargaining power in marketing.

Table 4-5-8.2 indicates the result of the farm household survey on the number of sample farmers who produced and marketed agricultural products by crops and livestock in 2014. According to the figures in the table, cereals and chicken products are mainly produced for self-consuming purpose. In contrast, many vegetables, grape and cattle products are mainly produced for marketing.

**Table 4-5-8.2 Number of Growers to Marketed Products by Crops/Livestock**

| Crop / Livestock | Number of Farmers | | |
|---|---|---|---|
| | Produced (h.h.) | Marketed (h.h.) | % of marketed |
| Wheat | 35 | 11 | 31.4 |
| Barley | 10 | 2 | 20.0 |
| Maize | 2 | 2 | 100.0 |
| Alfalfa | 26 | 12 | 46.2 |
| Potato | 30 | 23 | 76.7 |
| Tomato | 28 | 15 | 53.6 |
| Tomato (green house) | 20 | 18 | 90.0 |
| Cucumber | 34 | 18 | 52.9 |
| Cucumber (green house) | 13 | 10 | 76.9 |
| Eggplant | 21 | 7 | 33.3 |
| Eggplant (green house) | 1 | 0 | 0.0 |
| Sweet Pepper | 14 | 4 | 28.6 |
| Sweet Pepper (green house) | 7 | 6 | 85.7 |
| Cabbage | 11 | 9 | 81.8 |
| Water melon | 8 | 7 | 87.5 |
| Grape | 39 | 21 | 53.8 |
| Apricot | 32 | 14 | 43.8 |
| Apple | 22 | 6 | 27.3 |
| Cow milk | 27 | 15 | 55.6 |
| Beef Cattle/Meat | 18 | 16 | 88.9 |
| Broiler Chicken/Meat | 22 | 0 | 0.0 |
| Egg | 40 | 4 | 10.0 |

Source) JICA Study Team (Farm household survey)

Table 4-5-8.3 indicates three categories of crop prices: farm-gate price, wholesale price and retail price of crops which are grown by many farmers and are commonly marketed by the growers. Potato represents longer storable crops, tomato represents vegetables and grape represents fruits.

**Table 4-5-8.3 Price Variation of Major Crops in 2014/15**

(RMD)

| Crop | Price Category | Average (moderate) | Maximum | Minimum |
|---|---|---|---|---|
| Potato | Farm Gate | 160 | 250 | 60 |
| | Wholesale | 200 | 280 | 80 |
| | Retail | 260 | 300 | 230 |
| Tomato (High season) Jun-Oct | Farm Gate | 131 | 500 | 40 |
| | Wholesale | 220 | 660 | 80 |
| | Retail | 238 | 400 | 130 |
| Tomato (Off season) Nov-May | Farm Gate | 562 | 800 | 50 |
| | Wholesale | 814 | 1,250 | 200 |
| | Retail | 563 | 800 | 300 |
| Grape | Farm Gate | 160 | 300 | 100 |
| | Wholesale | 440 | 1,200 | 180 |
| | Retail | 710 | 1,400 | 300 |

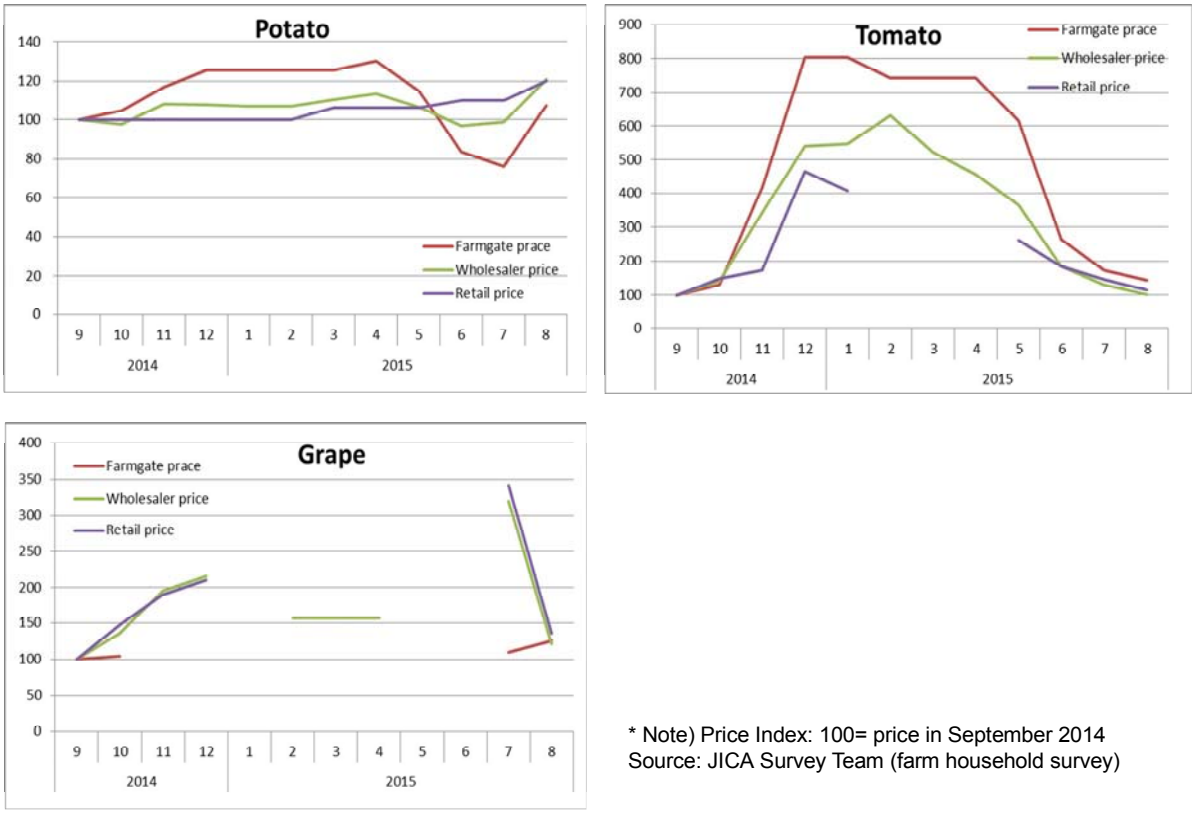
Source) JICA Survey Team

The result implies that middleman are generally selling the purchased products from farmers to other buyers with 20~30 % higher price. As regard to tomato's retail price (both in high season and in low season), logically it must indicates higher price than the wholesale price. But the wholesale prices in the table show higher prices than the retail prices. This is probably caused by complicated market condition of tomato, as tomato has various market segments, production sources and quality grades, such as for processing, for fresh consumption and for export, as well as from open field, from greenhouse and from import. A further survey is necessary to ravel out the confused information about tomato price.

More detailed information about farm-gate price collected through the farm household survey is listed in Appendix B-9. The prices show that there are huge gaps between minimum price and maximum price in every crop. Especially, the price gaps of tomato (both open field and greenhouse) are more than ten times. The prices of tomato are staying at the bottom due to the saturated situation in the market during in August to September when is the peak harvesting season of open-field tomato. Greenhouse farming is one of the effective ways for farmers to increase their profit by shifting the harvest season.

Figure 4-5-8.2 shows the price indexes of the 3 major crops: potato, tomato and grape to see their price fluctuation by season. Potato and tomato price indexes explain that farm-gate price tend to show wider fluctuation than wholesale price and retail price. Those crops' farm-gate prices are sharply down during their harvesting season. Farmers must be tackling with lower selling price during the high harvesting season. It is noted that price fluctuation of tomato is much wider than that of potato. It means that potato has less seasonality than tomato due to its high storage performance. Difference in storable period of both crops may cause the wider gaps. As greenhouse cultivation of tomato is becoming popular, the crops are available in Armenian market even in autumn to winter seasons together with imported one. Some farmers grow tomato and other vegetables targeting to market during off season by foster culture or by suppression culture with greenhouses. The tomato price index, showing the peak during December to April, implies that greenhouse farmers generate a substantial income from their greenhouse crops.

On the contrary, the index of grape farm-gate price shows rather stable and seasonal than potato and tomato. The stable price is mainly due to the contract farming system guided by the government. The government provides a direction of minimum buying price to processers, so that farmers don't lose motivation to grow grape. While the indexes of wholesale price and retail prices show wider fluctuation, it is probably caused by mixed information of two different market segments of grapes. One is cheaper grapes for processing and the other is expensive grapes for fresh consumption.




* Note) Price Index: 100= price in September 2014
Source: JICA Survey Team (farm household survey)

**Figure 4-5-8.2 Price Index of Major Crops**

### 4-5-9 Agricultural Cooperatives

In the Project area, agricultural cooperatives are not active. According to the result of the farm household survey, cooperatives are not a popular buyer of farm products for most of the interviewed farmers. It is quite rare to sell agricultural products to cooperatives except for dairy product (see Table 4-5-8.1). And also, a series of interviews to distributor, trader and processors of agricultural products reveals that it is uncommon for them to procure agricultural products from agricultural cooperatives. There is only a case that a wholesaler bought potatoes from cooperatives or farmers' group in the past year.

According to the head of division of agricultural cooperative support in the Ministry of Agriculture, not a small number of farmers are still suspicious about the benefit of agricultural cooperatives due to the negative mindset caused by their experiences during the Soviet era. There were many cooperatives established in short time by several projects even after the independence. However, many of them were not sustained. While a participatory process before the establishment and a careful monitoring for a certain long-period after the establishment are essential conditions to the development of self-sustained cooperatives, many projects fail to pay serious attention to them. Agricultural cooperatives are not yet became ingrained in farmers not only in the Project area but also in Armenia.

### 4-5-10 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, i.e. ACBA Credit Agricole Bank, Ardshininvest Bank and Converse Bank. The compensation rate for the interest rate by the government is 4% (ordinary interest rate is 14 %), and more favorable rates (6%) of government compensation are implemented in the poverty-stricken areas. While 915 communities were involved in the program in 2015, 6% interest was applied for all the communities. The payback period of the credit is more than 1 year (depending on the loan condition), and the payments are to begin after 6 months of the borrowing.

Following Table 4-5-10.1 describes the total amount of the agricultural credit provided by the three private banks since 2000. According to the table, the loan amounts are hugely increasing since 2011 when the governmental supporting program started. The amount of agricultural credit without the government assistance also indicates a healthy growth. The total amount of agricultural credit from private financial agencies excluding the above three banks was about forty billion ADM in 2013.

**Table 4-5-10.1 Agricultural Loans Provided by the 3 Private Banks (2000-2014)**

| Year | Loan Amount (Billion AMD) |
|---|---|
| 2000 | 10.4 |
| 2001 | 9.4 |
| 2002 | 7.8 |
| 2003 | 8.2 |
| 2004 | 8.6 |
| 2005 | 11.3 |
| 2006 | 14.2 |
| 2007 | 22.4 |
| 2008 | 36.5 |
| 2009 | 44.2 |
| 2010 | 52.6 |
| 2011 | 73.4 |
| 2012 | 91.9 |
| 2013 | 103.2 |
| 2014 (up to June) | 115.9 |

Source) MOA

Table 4-5-10.2 shows the result of interviews to farmers in the target area about constrains and problems related to accessibility of credit. Interviewees replied that accessibility to credit is not a little problem for their agricultural activities. Nearly 40% of interviewed farmers regard access to credit is a considerable issue of farm management. Other survey result suggests that there must be high potential demand for agricultural credit, as many farmers are burdened with high production cost issues such as payment for fertilizers, agrochemicals, farm-machinery, irrigation, etc.

As mentioned in previous paragraph, 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. For instance, some farmers claimed that harvest of orchard will start after several years of seedling, but repayment of the loan will start only after 6 months of the borrowing. They insisted that the agricultural loan system should have more varieties with different payment conditions for different purposes such as loan for orchard reclamation, agricultural machinery and greenhouse construction.

**Table 4-5-10.2 Result of Interviews about Accessibility to Agricultural Credit**

| Accessibility | Crop farming | | Livestock farming | |
|---|---|---|---|---|
| | Farmers | % | Farmers | % |
| No problem | 36 | 44.4 | 25 | 30.9 |
| Slightly problem | 7 | 8.6 | 3 | 3.7 |
| Very problem | 30 | 37.0 | 11 | 13.6 |
| Not applicable/no idea | 8 | 9.9 | 42 | 51.9 |
| Total | 81 | 100.0 | 81 | 100.0 |

Source) JICA Survey Team (Farm household survey)

## 4-5-11 Difficulties Confronting Farmers

A series of workshops with 4 WUA members in the Project area suggests that farmers in the area share the following common issues (see Table 4-5-11.1). A problem tree arranging the common issues in order based on the cause and effect is attached in Appendix B-10.

**Table 4-5-11.1 Common Issues Recognized by Farmers**

| Field | Problems & Constrains |
|---|---|
| Production | Soil fertility is low |
| | Production of marketable products is not enough |
| | Farm input cost is too high (seeds, fertilizers etc.) |
| | Quality of farm inputs is low (seeds, fertilizers etc.) |
| | Extension and support from government is not enough |
| | Lack of accessible agricultural credit (high interest rate and short repayment term) |
| | Natural disasters (hail and low temperature) |
| | Damages from insects and disease |
| Irrigation | Shortage of water |
| | Breakages of water canals |
| | Many water losses |
| | Water fee is high |
| | Water is contaminated / Not clean |
| | Unequal distribution of irrigation water among the member |
| | Ground water level in down |
| Machinery | Shortage of farm machinery |
| | Tractor hiring service cost is expensive |
| | Machineries are old |
| | Timing of machinery service us not appropriate |
| | Tractor and spare parts are expensive |
| Marketing | Sales price is low and/or highly fluctuated |
| | Accessibility to the market (hard to find good buyers) |
| | Difficult to transport the products to the market |
| | Lack of information/knowledge about marketing |
| | No government support for marketing |

Source) JICA Survey Team

The farm household survey carried out by the Survey team reveals seriousness of the farmers' issues recognized by farmers' themselves (see Table 4-5-11.2).

**Table 4-5-11.2 Seriousness of Issues Recognized by Farmers**

| Problems and constraints | No problem | Slightly problem | Very problem | Not applicable / no idea | Total |
|---|---|---|---|---|---|
| Technical information /services | 63 | 9 | 9 | 0 | **81** |
| Own skill & knowledge | 66 | 12 | 3 | 0 | **81** |
| Land size (need more land) | 64 | 4 | 13 | 0 | **81** |
| Land fertility | 32 | 15 | 34 | 0 | **81** |
| Salinity of land | 63 | 8 | 8 | 2 | **81** |
| Water shortage | 31 | 16 | 34 | 0 | **81** |
| Conditions of irrigation facilities | 26 | 15 | 40 | 0 | **81** |
| Water conflict | 39 | 19 | 23 | 0 | **81** |
| No good varieties of crops | 27 | 19 | 35 | 0 | **81** |
| Pests & disease | 11 | 13 | 57 | 0 | **81** |
| Availability of inputs | 55 | 12 | 14 | 0 | **81** |
| Inputs cost | 19 | 10 | 52 | 0 | **81** |
| Man-power | 39 | 14 | 22 | 6 | **81** |
| Availability of machinery | 44 | 7 | 25 | 5 | **81** |
| Machinery/mechanization service cost | 22 | 12 | 41 | 6 | **81** |
| Conditions of storage facility | 50 | 4 | 20 | 7 | **81** |
| Means of transportation | 52 | 12 | 13 | 4 | **81** |
| Access to good markets /buyers | 24 | 11 | 44 | 2 | **81** |
| Selling price is low | 6 | 5 | 68 | 2 | **81** |
| Market price stability (Price fluctuation) | 7 | 7 | 65 | 2 | **81** |
| Access to credit | 36 | 7 | 30 | 8 | **81** |
| Other | 11 | 2 | 9 | 59 | **81** |

Note) Color marked: More than a half respondents answered as "Very Problem"
Source) JICA Survey Team (Farm household survey)

The most serious problems are closely related to marketing. Many farmers have difficulty in adapting them to low or fluctuated market price. Farmers also look for good markets and buyers who may be able to buy their products at favorable and stable price. If it's hard to find out those kinds of buyers, farmers want to be purchased their products by the government as practiced during the Soviet era. Although more than 20 years have passed after the independence, not a small numbers of farmers still have nostalgic eyes for the government intervention in the marketing. While many farmers complain about (high) inputs cost, this problem is inextricably linked with the marketing issues. If farmers could sell their products at their good price, they should consider that inputs are quite affordable. Considering a high cost structure of Armenian crops represented by wheat, a comprehensive policy should be established for reducing inputs cost, for introducing a rational farming system and for streamlining the existing marketing system. Then, proper measures in line with the policy should be taken by all stakeholders including farmers.

Pests and disease are also serious concern of many farmers. Many farmers claim that they cannot control pests and disease properly because of low quality of insecticides/fungicides. They, however, don't seriously consider that their farming skill and knowledge is not enough or agricultural extension services supporting them are not enough for controlling pests and disease properly, according to Table 4-5-11.2. On the other hand, many farmers said during the workshops that they need assistance from extension agency or agrochemical shops in order to know proper way of spraying to prevent or to control disease and pests of their products. Actually, farmers fail to control pests and disease due to improper use of insecticides/fungicides in many cases. They should be used on proper time and with

right way for producing the due effect.

During the workshops, some participated farmers also complained about the quality of subsidized fertilizers. According to the farmers, the fertilizers are not inspected properly by the importing companies who are selected by the government. As a result of this circumstance, quality of imported fertilizers became lower than the Soviet era. Meanwhile, the head of state non-profit company "Agrochemical Service" under the Ministry of Agriculture said that farmers are not using fertilizers properly. The institution makes a soil analysis (content of basic nutrient elements: nitrogen, phosphate and potassium) every 5 years in each community nationwide. The result of the analysis indicates that farmers are not applying three main fertilizers in the right balance. Generally, farmers are fertilizing exceeded volume of nitrogen and less phosphate and potassium. The institution also inspects the quality of subsidized fertilizers whether it contains sufficient level of active elements, when the government imports them. According to the institution, lower production is not caused by low-quality fertilizers but unbalanced fertilization. There is a gap of recognition about the quality of subsidized fertilizers between farmers and the government institution.

It must be true that Armenian farmers have a certain good level of farming technology considering relatively high level of crop productivity at present. However, they should need more advanced farming skills and knowledge not only to control pests and disease, but also to adapt them to internationally competitive agriculture which the government aims at. Improvement of farmers' technology through enhancement of agricultural R&D (research and development) and extension systems is a fundamental issue of Armenian agriculture, though many farmers don't recognize it well.

Irrigation and mechanization are in the next group in seriousness. The both problems are mainly caused by low investment after the independence. Many over-aged facility and machinery are still used at field. Though they are maintained to some extent, they have already reached the end of their life span.

Figure 4-5-11.1 shows an image of current circumstance of farmers in the Project area by compiling the major issues described above. The issues are influenced each other and those issues finally amount to low farming income. A comprehensive measure to address every issue and constraint around farmers should be taken in order to develop agriculture in the Project area.

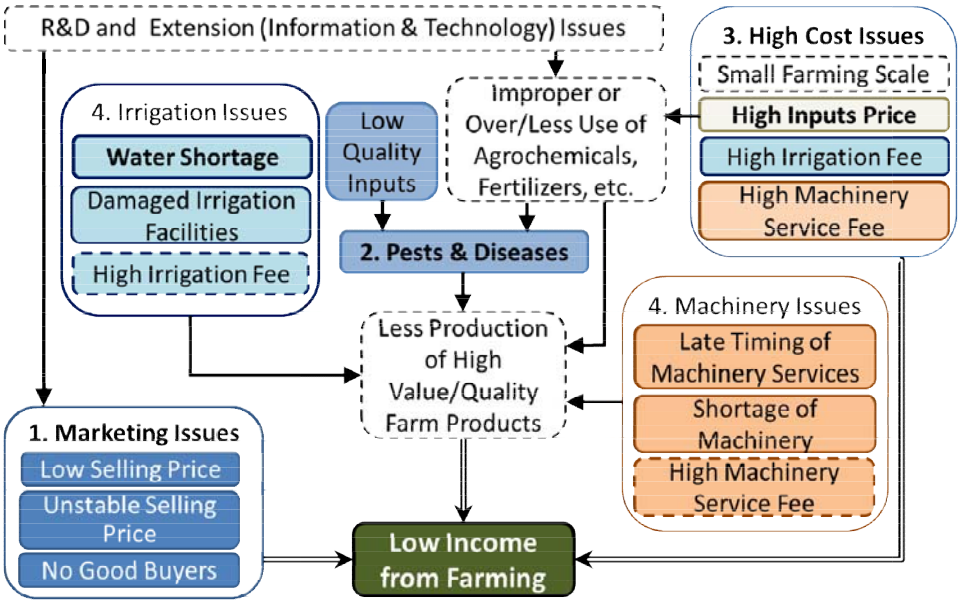



**Figure 4-5-11.1 Constrains of Farmers in the Project Area**

## 4-6 Information on Cost Estimate and Procurement

### 4-6-1 Condition of Cost Estimate

#### (1) Direct cost

Direct cost consists of 3 parts, i.e. 1) labor cost, 2) machinery and equipment operation cost and 3) material cost including transportation and storage expenses. Direct cost of construction work is derived by cost accumulation method of each work type.

#### (2) Indirect cost

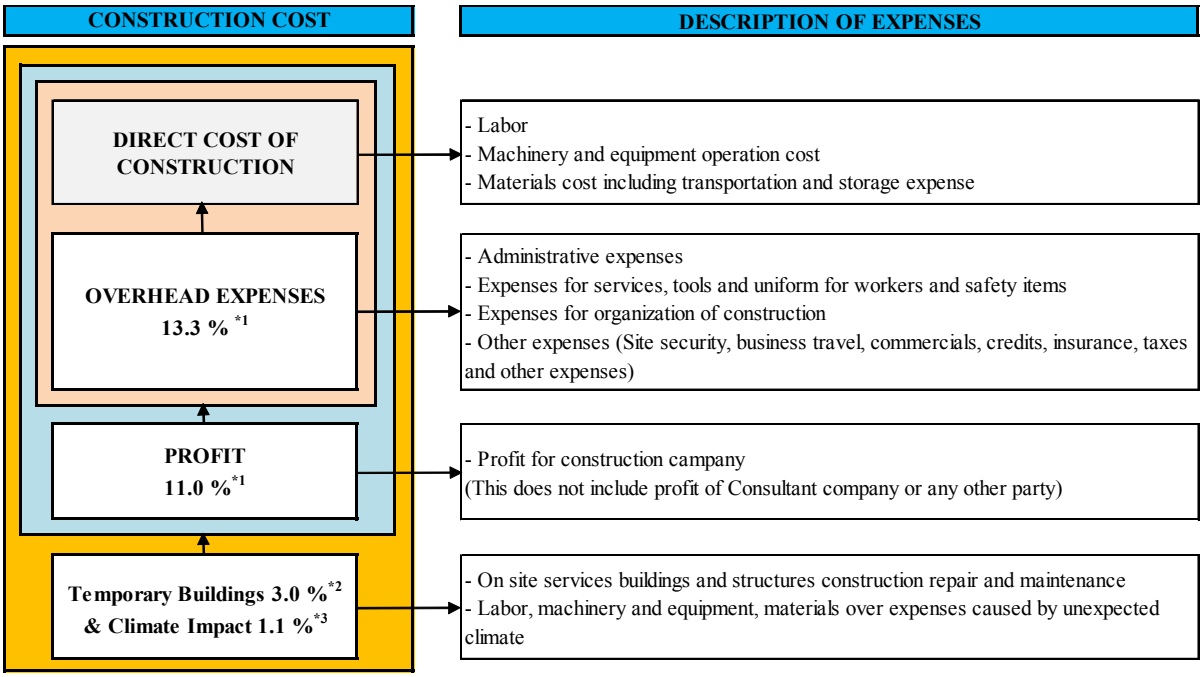
Indirect cost consist of Overhead expenses, Profit, Temporary buildings and Climate impact. Overhead expenses is including management cost of a contractor in site and head office such as administrative expenses, safety cost, insurance taxes and so on. Rate of overhead expenses is decided by Armenian construction law and its amount is13.3% of the direct cost.

Profit is only for a contractor profit, for a consultant company's or other parties' profit are not included in this expense. 11.0 % of accumulated amount of direct cost and overhead expenses correspond to the profit.

Temporary building cost is used for a construction, repair and maintenance of buildings in the construction site. Its cost is decided as 3.0 % of accumulated amount of direct cost, overhead expenses and profit.

Climate impact cost compensates prospected expenses generated by unexpected climate and weather condition like a water shortage for the construction in dry season. This cost is also regulated 1.1 % of accumulated amount of direct cost, overhead expenses and profit.

Contents of construction cost (direct and indirect cost) are illustrated in Figure 4-6-1.1.




*1 23.06.2011 No.879-N about "Construction works current cost estimation" rules of MUD of RA (Paragragh 8)
*2 21.08.2001 of MUD of RA about "Establishment of norms of temporary buildings and structures of construction" Chapter V, point 32, "
*3 21.08.2001 of MUD of RA about "Establishment of norms of climate impact on construction" Area I, Chapter V, point 32,

**Figure 4-6-1.1 Contents of Construction Cost**

### (3) Consultant fee

Detail design and supervision of the construction are included in the consultant fee. This cost is estimated as 6 % of construction cost.

### (4) Price escalation (Price contingency)

Price Escalation (Price Contingency) is calculated based on an average price escalation rate in 5 years. Reflecting the inflation in each country, price escalation of foreign currency and local currency are calculated separately. The rate of price escalation 2016, base year of the Project, is 1.8 % for foreign currency and 2.7% for local currency.

Price escalation of total Project Cost is calculated from that of base year and base cost in each year shown in Table 4-6-1.1. Calculated rate is 10.24%.

**Table 4-6-1.1 Price Escalation in Armenia**

| Year | 2016 | | | 2017 | | | 2018 | | | 2019 | | | 2020 | | | 2021 | | | 2022 | | | Total | Price Escalation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | FC | LC | Total | FC | LC | Total | FC | LC | Total | FC | LC | Total | FC | LC | Total | FC | LC | Total | FC | LC | Total | | |
| Base cost for JICA financing | 0 | 0 | 0 | 3.802 | 8.665 | 5.76 | 2.534 | 5.777 | 3.84 | 17.34 | 207.5 | 64.24 | 13.01 | 155.6 | 48.18 | 8.672 | 103.8 | 32.12 | 4.336 | 51.88 | 16.06 | 160.6 | 10.24% |
| Price escalation | 0 | 0 | 0 | 0.068 | 0.234 | 0.121 | 0.092 | 0.316 | 0.164 | 0.954 | 17.27 | 4.856 | 0.962 | 17.5 | 4.917 | 0.809 | 14.78 | 4.15 | 0.49 | 8.992 | 2.522 | 16.45 | |
| Foregin currency(FC) 1.8% | 1 | 1 | - | 1.018 | 1.027 | - | 1.036 | 1.055 | - | 1.055 | 1.083 | - | 1.074 | 1.112 | - | 1.093 | 1.142 | - | 1.113 | 1.173 | - | | |
| Local Currency(LC) 2.7% | 0 | 0 | - | 0.018 | 0.027 | - | 0.036 | 0.055 | - | 0.055 | 0.083 | - | 0.074 | 0.112 | - | 0.093 | 0.142 | - | 0.113 | 0.173 | - | | |

### (5) Physical contingency

Physical contingency is provided as 5% according to Yen loan rule.

### (6) Exchange rate

Average exchange rate of 3 months from February to April 2016 is adopted in the cost estimation.

Exchange rate of US Dollar (USD) to Armenia Dram (AMD) is derived from the official rate of the Armenian Central Bank. The rate of US Dollar to Japanese Yen is calculated using the rate of declared by The Bank of Tokyo-Mitsubishi UFJ, Ltd. Calculated exchange rates are as follows,

1 US Dollar = 486.99 Armenia Dram
1 US Dollar = 113.65 Japanese Yen

## 4-6-2 Procurement of the Construction Machinery

### (1) General construction machinery

Several construction machinery manufacturers in Japan and Europe have agents in Armenia and general construction machinery such as backhoe, damp truck, bulldozer etc. are distributed in the market. These machineries are used under lease mainly. These agents have workshops for maintenance of machineries and provide the service of repairing.

### (2) Soil mixing machine

Construction work using soil mixing machine which is utilized for making soil-cement mixture is not common in Armenia therefore the machine is not well distributed in construction market. However, construction machinery agents can import and distribute this machine. Additionally, some agents can repair and maintenance this machine in their maintenance workshop. Therefore, it is judged that operation of soil mixing machine is feasible in the Project.

### 4-6-3 Procurement of the Construction Materials

#### (1) Bentonite Products

1) Armenia

Armenia is an export country of bentonite and its mine is located in Ijevan, north east part of Armenia (see Figure 4-6-3.1). 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.

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.

2) Georgia

Even enhanced product from Ijevan is not enough considering the necessary volume of the reservoir construction. Therefore, a bentonite mine in the neighboring country, Georgia was surveyed.


Source) Google map

**Figure 4-6-3.1 Location of Bentonite Factory in Armenia**

Georgia also exports good quality bentonite which contains montmorillonite over 85%. Bentonite is mined in Mitispri, western part of Georgia (see Figure 4-6-3.2). 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.


Source) Google map

**Figure 4-6-3.2 Location of Bentonite Factory in Goergia**

**(2) Cement and aggregate**

1) Cement

There are two cement companies in Armenia. Production of one company has low strength and used for interior work of buildings. For construction work, cement manufactured in Ararat city is used. Cement of this company is supplied for the North-South corridor road project financed by World Bank and construction of nuclear power plants which required high stability. Annual product is 150,000,000 ton and this amount is over the estimated consumption in the construction.

2) Fine aggregate

Good quality aggregate is only produced from Araks river and many sand pit are scattered along the river. Araks river is a border with Turkey and the amount of product is decided as fifty-fifty with Turkey according to an agreement. Annual product is reached over 100,000$m^3$/year, however there is no danger of depletion for that sand is procured from upstream every year.

3) Corse aggregate

Mine of course aggregate is located in suburb of Yerevan. Excavated solid basalt from open-pit quarry is send to crusher plant installed beside quarry. Crashed basalt sieved 6 categories by diameter are distributed in construction market. Alkali-aggregate reaction test is conducted but no negative result has been reported.

**(3) Pipe**

Pipes can be procured in Armenia. Some factories have laboratories for quality control and tensile test, water pressure test and compression test are conducted.

**(4) Gate and valve**

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) Observation instrument**

There is little demand of observation instrument for reservoir in Armenia, these instrument is imported in the construction stage.

### 4-6-4 General Information for Construction

Main port where imported materials are unloaded is Poti port in Georgia. At the Poti port, there are almost no troubles about unloading including custom clearance by Georgia. Custom clearance by Armenia takes about 1 week and smooth pickup is secured. No remarkable troubles are reported when imported.