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Bassara Dam and Irrigation Project-Irrigation Design

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Abstract

Bassara Dam and Irrigation Project will be of major social and economic importance for development of the region. It will create possibilities to obtain a large volume of agricultural products, extremely necessary to supply the population with food and processing industry with raw materials. The strategic goals for agriculture in Iraq should be efficient and stable growth, increased food security and high rural employment, all to be achieved in an economically efficient, socially acceptable and environmentally sustainable manner . In the short term, the priorities should be on immediate reconstruction of damaged facilities and re-establishing key agricultural services and improving their efficiency. With the establishment of a democratic government, liberalization of the economy and opening of markets, it is very likely to contribute significantly to the country's income, food security and poverty reduction.

Keywords: Bassara; Dam; Irrigation

Introduction

Location of bassara irrigation system

Bassara Irrigation System is located between 34°30’ and 35°45’ north latitude and 44°30’ and 45°30’ east longitude, in the north-eastern part of Iraq [1]. It comprises the catchment areas of Khasa Chai River, Bassara River and Tuz Chai River, which give rise to Adhaim River [2,3]. The northen boundary of the region is the left watershed of Lesser Zab River. The southern boundary is the watershed of Dyala River. The eastern boundary of Region is limited by the highlands near Sulaimaniyah, while the western boundary sets the main chanel of the Kirkuk Irrigation System.

Bassara River has the largest catchment in the Region. It rises from the uplands west of the Sulaimaniya, runs throught the Bassara pass and then south-west to the Qadir Karam, then to the west to the Daquq and ultimately discharges into Adhaim River. The whole region covers 9000 km^2. The altitude ranges from 200-250 m to 1500-1800 m. The terrain is deforested. It is intersected by many wadies providing conditions for active erosion processes.

The boundary of the irrigation system is rather undulating due to the rough relief. The area suitable for irrigation and farming amounts to about 2600 ha. The altitude is from 600 m to 700 m. Generally, the relief of the irrigation areas is flat, slightly sloping to northeast-southeast. Dry wades and ravines intersect the ground surface. Most typical in this respect is the area of Bassara.

Hydrology

Roughly, 90 percent of the annual rainfall occurs between November and April, most of it in the winter months from December through March. The remaining six months, particularly the hottest ones of June, July, and August, are dry. During the summer period 76 mm fall or 19.9% of the annual sum while the remaining 305 mm or 80.1% fall during winter. The annual precipitation is small and irregularly distributed over the seasons. The period of the active crop vegetation is completely dry. Under these conditions only either crops i.e. wheat, barley and some winter vegetables can be grown without irrigation.The highest mean monthly temperatures occur during July, 35.4°C and August 34.9°C. It is characteristic that the period of highest temperatures, i.e. from April to October coincides with the dry weather, thus increasing the harmful effect of the high temperatures on the planet (Figures 1 and 2).

The combination of rain shortage and extreme heat makes much of Iraq a desert. Because of very high rates of evaporation, soil and plants rapidly lose the little moisture obtained from the rain, and vegetation could not survive without extensive irrigation. Some areas, however, although arid do have natural vegetation in contrast to the desert.

All available meteorological data were processed: precipitation, air temperature, relative air humidity, winds and evaporation from free water surface.The evapotranspiration of the crops to be grown in Bassara Irrigation Field is calculated after the Thornthwaite, FAO 24 Pan, Hargreaves and Turc methods. Accordingly to all available data following results were obtained and given in Table 1 and graph of evapotranspiration. After comparing the results, the FAO 24 Pan method was adopted as the most acceptable.

Pedology

The area of Bassara Irrigation System is predominantly flat, situated between mountain chains representing a structural part of the Alpine-Himalayan belt having a north-west-south-east direction. Bassara irrigation area consists mainly of conglomerates with calcareous cementation, intercalated with fine-grained sandstones. The rocks are compact, hard. The above-described materials consisting the parent rock of the soils, have conditioned the mineralogical and chemical composition of the soils.

Generally, the soils in Bassara irrigation area have a humus horizon 35 to 55 cm deep containing a satisfactory quantity of organic matter. The soils are not saline; water-soluble salt content is maximum. This indicates that no potential danger of soil salinization exists under dry farming or irrigation with non-saline water.

The soil in irrigation area is suitable for irrigation. The main limiting factors for the soil fertility are the arid climate and the high carbonate

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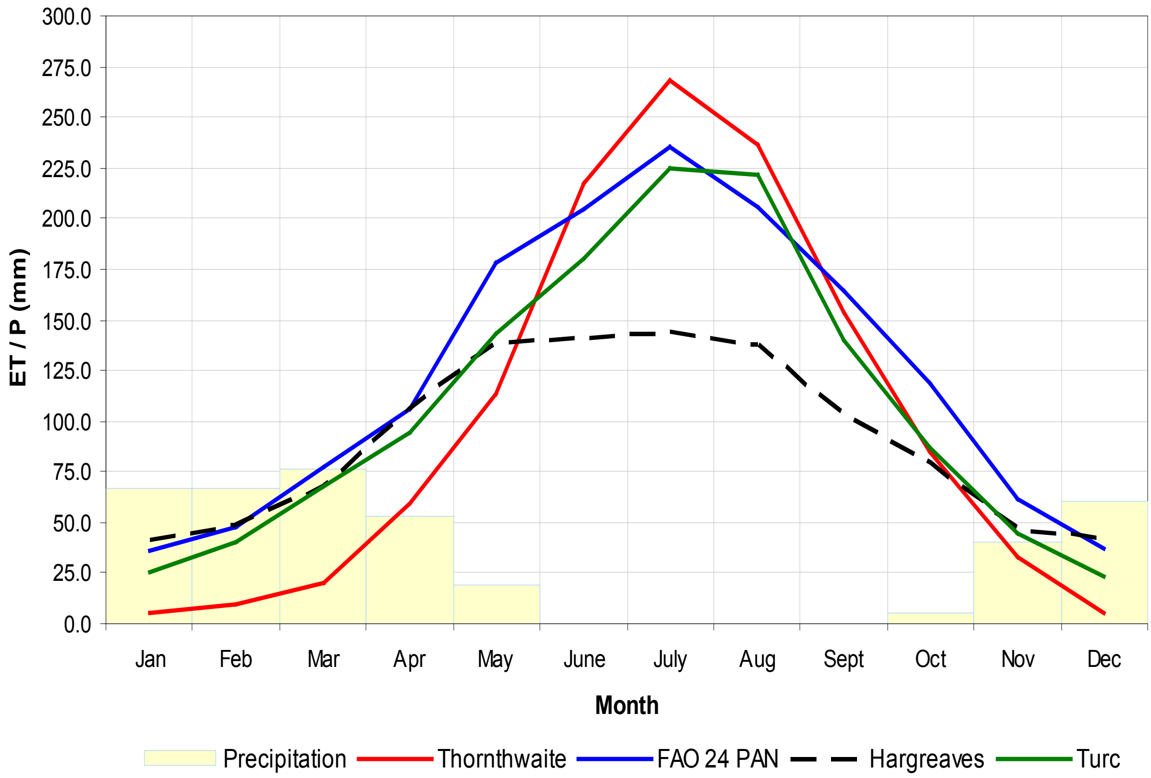

Figure 1: Comparison of Precipitation and Evapotranspiration (mm) after the Thornthwaite, FAO 24 Pan, Hargreaves and Turc method.

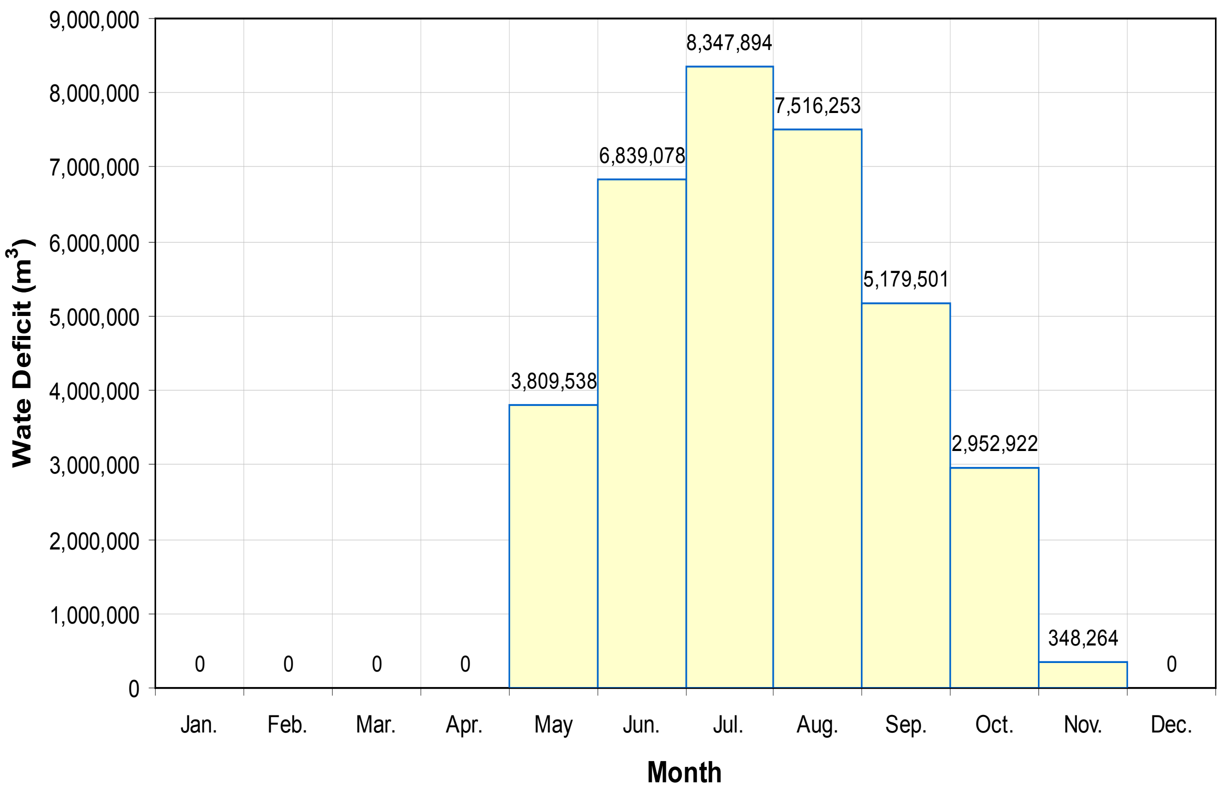

Figure 2: Calculated water deficit (Gross).

	Thornthwaite	FAO 24 Pan	Hargreaves	Turc
January	5.1	36.5	41.1	25.2
February	9.5	48.2	48.7	40.6
March	20.6	77.5	67.5	67.6
April	59.7	106.1	105.9	94.8
May	113.8	177.8	139.2	143.2
June	217.7	204.5	140.8	180.4
July	268.3	235.0	144.3	224.9
August	236.3	206.0	137.6	221.3
September	153.7	164.0	103.1	140.3
October	84.3	119.1	79.2	86.8
November	32.5	61.7	46.4	44.3
December	4.9	37.3	42.4	23.6
Total (mm)	**1,206.40**	**1,473.70**	**1,096.30**	**1,292.90**

Table 1: Calculated evapotranspiration.

content in the soils, resulting from the arid climate. Nevertheless, on the grounds of the existing natural and soil conditions a considerable improvement of the soils and their fertility is expected under intensive irrigation faming.

Agrarian economy

Since the beginning of recorded time, agriculture has been the primary economic activity of the people of Iraq. In 1976, agriculture contributed about 8 percent of Iraq's total Gross Domestic Product (GDP), and it employed more than half the total labor force. In 1986, despite a ten-year Iraqi investment in agricultural development that totaled more than US$4 billion, the sector still accounted for only 7.5 percent of total GDP, a figure that was predicted to decline. In 1986, agriculture continued to employ a significant portion about 30 percen of Iraq's total labor force. Part of the reason the agricultural share of GDP remained small was that the sector was overwhelmed by expansion of the oil sector, which boosted total GDP.

Iraq's agriculture has a lot of potential for growth, given the right support and policy environment. With the establishment of a democratic government, liberalization of the economy and unshackling of markets, it is very likely to contribute significantly to the country's income, food security and poverty reduction.

Bassara Dam and Irrigation Project will be of major social and economic importance for development of the region. It will create possibilities to obtain a large volume of agricultural products, extremely necessary to supply the population with food and processing industry with raw materials.

The average yields and costs per hectare determine one of the most important factors in agricultural production Income per Hectare (Table 2).

Description of Designed Solution

Main pipeline network Ø1600 mm

Water supply system was designed on basis of adopted variant solution in Preliminary Report. Main pipeline network is a pipeline with initial begining at dam site, some 600 m from waterintake. Main pipeline is marked with capital letter P, total lenght is 11,072 m and diameter is Ø1600 mm. Route of main pipeline P goes next to the existing road, approximately parallel to the Bassara River. This is because construction of pipeline is simplified and access to the route too, as well as favourable terrain configuration. Ductile iron pipes were adopted because of its characteristics.

The gravity pipeline is designed on minimum cross section slopes, to relieve earth excavation where river banks are already steep. Minimum slope adopted is 1.50%, and is variable depending on topography. Air valves are installed on the highes points of pipeline, totally on three location (with two valves on each location), diameter of air valves is DN 200 mm. Outlets are installed on the lowest route elevations, totally three outlets, with diameters 300 mm. Excavation works, pipe bed preparation and laying of pipes into trench, as well as ways of anchoring are descibed in project.

Solution in which pipeline supply reservoir with water (given in Preliminary Report) is rejected, because it is established that

	Area (ha)	Income from irrigation	Total Production Cost	Net Income From Irrigation	Total Income
Crops		**USD/ha**	**USD/ha**	**USD/ha**	**USD**
I. Main crops					
Wheat	850	66.08	15.25	50.83	43,208.16
Barley	450	54.90	12.59	42.31	19,041.30
Cotton	500	20.40	23.07	-2.67	-1,337.23
Sunflower	450	83.16	35.79	47.37	21,316.89
Sesame	100	65.66	255.17	-189.51	-18,951.01
Tomatoes	75	143.00	264.35	-121.35	-9,100.96
Onion	75	136.00	88.48	47.52	3,563.73
Other vegetables	100	90.00	87.88	2.12	212.48
Total	**2600**	**659.20**	**782.57**	**-123.37**	**57,953.36**
II. Second crops					
Maize	540	440.00	31.40	408.60	220,644.36
Tomatoes	180	182.00	265.24	-83.24	-14,983.47
Broad beans	100	541.67	51.99	489.68	48,968.05
Carrots	25	136.00	88.31	47.69	1,192.31
Other crops	240	75.00	79.42	-4.42	-1,060.67
Total	**1085**	**1,374.67**	**516.35**	**858.31**	**254,760.58**
Grand Total	**3685**	**2,033.87**	**1,298.93**	**734.94**	**312,713.94**
SUM INCOME 2600ha		**5,288,062.00**	**3,377,214.97**	**1,910,847.03**	

Table 2: Income per Hectare.

hydraulicaly loses are to high, and 4.1 bars would be destoyed if this soultion is built, and end parts of distributive pipelines in this case would not have enough pressure.

Primary and secondary pipeline network

Water supply system consistes from primary-distributive pipelines P1, P2 and P3. These pipelines are "foundation" of a system, they distribute water to the rest of primary pipelines, which through secondary pipeline network supply consumers-farmers. Disposition of those pipelines is in correlation with terrain and parcels determined for irrigation as well as vicinity of roads (80% of all sections of irrigation system is close to some main road or other local road).

Primary Pipeline P1 is separated at junction J1 from main pipeline Ø1600 mm, total lenght of this pipeline is 1214 meters with pipe diameters Ø250 mm and Ø 200 mm. It supply the smallest area of system 61.05 ha, which is situated between two rivers, next to South-East border of system. Primary Pipeline P2 is separated at junction J2 from main pipeline Ø1600 mm, at the end distance at km 11+072. , total lenght of this pipeline is 4204 meters with pipe diameters Ø300 mm up to Ø1000 mm. Through this pipeline runs most of water and it supply most of the system. At highest consumption, it distributes 1525 L/s. From pipeline P2 other pipelines continue network: P-2-1, P-2-2, P-2-3, P-2-4, P-2-5 i P-2-6. Diameters less than Ø600 mm are from PEHD for pressures up to 10 bars and represent the secundary pipeline network. Secondary network consists of approximately 70 km of pipelines, diameter Ø150 mm, and lenght is estimated. Primary Pipeline P-3 is separated at junction J2 from main pipeline Ø1600 mm, at the end distance at km 11+072 (same as P2). This is the longest primary pipeline, total lenght is 6,569 meters and pipe diameters Ø400 mm up to Ø900 mm. P3 supply Northern and North-West part of system. From P3 other primary pipelines spreading to the system. Total area of irrigated system covered by these pipelines is 2875.01 ha.

Considered variant solution

Considered solution is to divide main pipeline in junction 20, (in scheme is under no.16) on three, first pipeline P1 would supply South and South-East part of system, diameter is Ø700 mm, and lenght is 7065.12 metars. In this case, part of main pipeline that belongs to P2 is separated in between junctions J8 and J9 (section 38). Complete results of hydraulic calculations are given in project. In this case pressure on end junctions is of primary pipeline are satisfactory and range from 4.5 to 7 bars in this part of the system.

Designer has decided to accept first variant, because even without constructing this pipeline (Ø700 mm), it can be accomplished satisfactory water supply of system with needed pressure in pipline. Complete results of hydraulic calculation are given in project and schemes are given at the end of hydraulics calculation (next chapter).

Hydraulics calculation

Hydraulics calculation is done for four border cases:

1A - level of water in acumulation is on 701 m, and consumption is maximal

1B - level of water in acumulation is on 701 m, and consumption is minimal (0.1Q_{max})

2A - level of water in acumulation is on 716 m, and consumption is maximal

2B - level of water in acumulation is on 716 m, and consumption is minimal (0.1Q_{max})

Disposition of pipeline network have been entered with all needed data (terrain elevation,junction discharge, section lenght, pipeline diameters, level of water in acumulation, roughnes coefficient of pipe), Model is calculated by using EPANET software.

About software: EPANET performs extended period simulation of hydraulic and water quality behavior within pressurized pipe networks. A network consists of pipes, nodes (pipe junctions), pumps, valves and storage tanks or reservoirs. EPANET tracks the flow of water in each pipe, the pressure at each node, the height of water in each tank, and the concentration of a chemical species throughout the network during a simulation period comprised of multiple time steps. In addition to chemical species, water age and source tracing can also be simulated.

EPANET provides an integrated environment for editing network input data, running hydraulic and water quality simulations, and viewing the results in a variety of formats. These include color-coded network maps, data tables, time series graphs, and contour plots.

EPANET was developed by the Water Supply and Water Resources Division (formerly the Drinking Water Research Division) of the U.S. Environmental Protection Agency's National Risk Management Research Laboratory.

EPANET's hydraulic simulation model computes hydraulic heads at junctions and flow rates through links for a fixed set of reservoir levels, tank levels, and water demands over a succession of points in time. From one time step to the next reservoir levels and junction demands are updated according to their prescribed time patterns while tank levels are updated using the current flow solution. The solution for heads and flows at a particular point in time involves solving simultaneously the conservation of flow equation for each junction and the headloss relationship across each link in the network. This process, known as hydraulically balancing the network, requires using an iterative technique to solve the nonlinear equations involved. EPANET employs the Gradient Algorithm for this purpose.

The hydraulic time step used for extended period simulation (EPS) can be set by the user. A typical value is 1 hour [4] (Figures 3 and 4).

Conclusion

Planning Report has be designed according to analysis and solutions presented in Preliminary Report. Detailed geodetic works and reconnoiter were conducted, and terrain-location has been visited. It was mentioned in Preliminary Report that according to old topographic maps scaled 1:100 000 and according to technical analysis conducted by Bulgarian and French team of engineers, we made our Prelimiary Report. Big problem occurred when we discovered that there was no detailed pedological map with marked area that were cultivated.

Geodetic works and reconnoiter were done during the June, July and August 2006, and leading designer engineer spent together with geodetic and geomechanic team one week on areas planned to be irrigated. As a result of this field trip, we decided to rationalize solution made in Preliminary report. Here it should be mentioned that minimal working level for dam is 701 m, and it is higher few meters than it was planned in Preliminary Report (695 m).

As first, rationalization is correlated with exploitation expenses regarding pumping of water. Preliminary Report considering two solutions marked as Variant I – with main pumping station and pipeline to the reservoir, and Variant II, with gravitational pipeline from dam site to the reservoir. Economic analyses of pumping expenses for those two variants were

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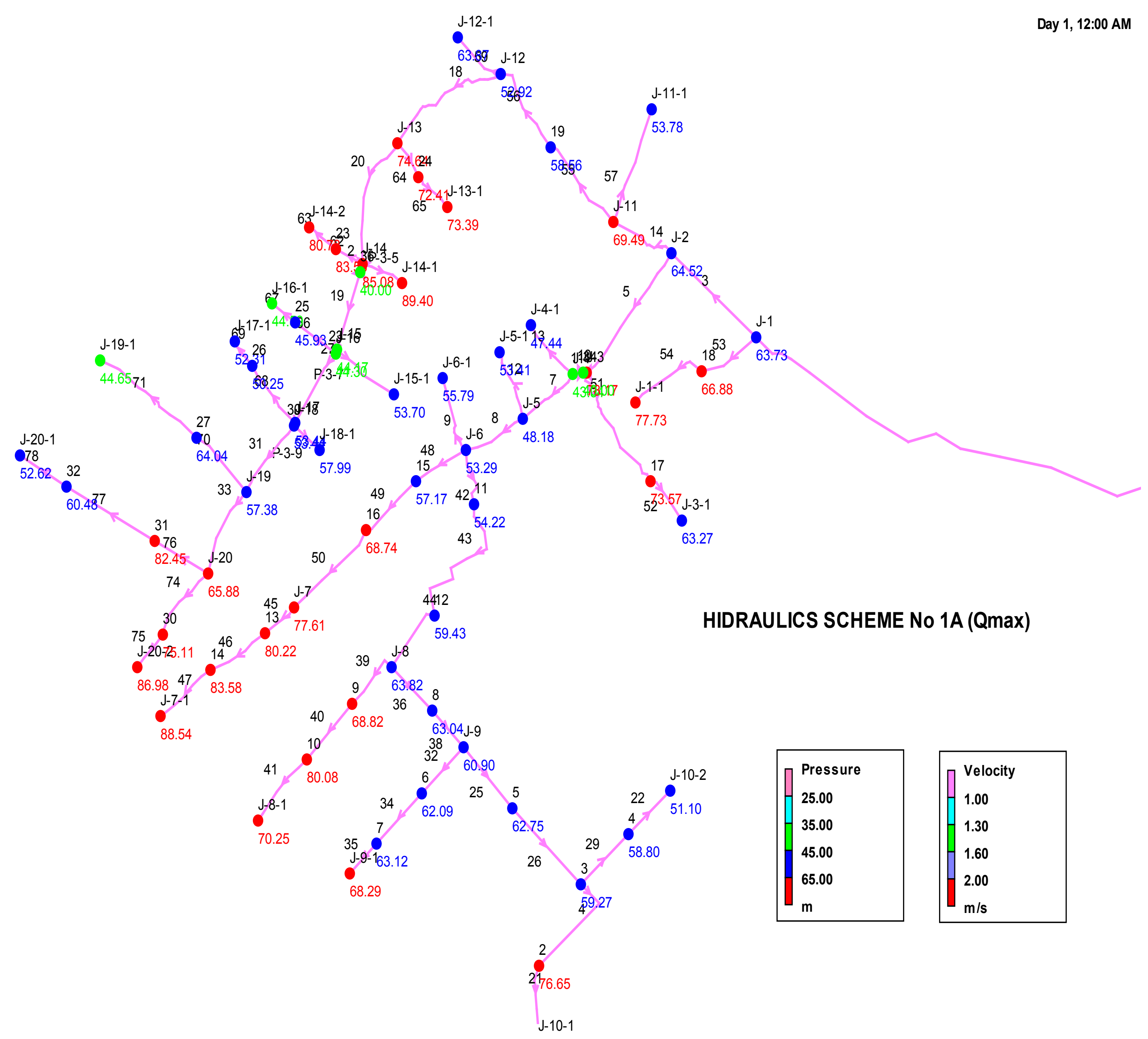

Figure 3: 1A - level of water in acumulation is on 701 m, and consumption is maximal.

- Variant I: 27.013.212,00 kWh/year×0,05 USD=1.350.660,00 USD/ 2600 ha=520 USD/ha
- Variant II: 12.270.935,00 kWh/year×0,05 USD=613.546,75 USD/ 2600 ha=236 USD/ha

After analysys of geodetic survey data, defining cultivated areas, detailed reconnoiter of terrain and adopted working levels of dam, (701 -715 m), next was concluded:

1. According to available water from accumulation around 35.000.000 m^3 it can be irrigated 2600 to 2900 ha of arable land. If we assume that all system will be in use, i.e. all 100% to be irrigated, that is 2600 ha. Experience shows that on similar systems, maximum can be expected up to 90% of irrigated areas in one year. After processing geodetic data and analysis of arable land, it can be concluded that area marked as Zone I has enough quality soil for irrigation (≈2875ha).
2. Ground elevation ranging 568 to 600 m on south and south-west and on north and north-west ≈640 m. Designer concluded that if we consider the water level in accumulation (701- 715 m) we can irrigate whole system by gravity without pumpin stations and pumping water on irrigation system, it is possible to save up to 613.546,75 USD or 236 USD/ha.
3. Land in zones II and III is not suitable for gravitational irrigation system because it is on higher land and also there are many parcels that are scattered with particulary turbulent land configuration.
4. Variant II with reservoir adopted in Preliminary Report was

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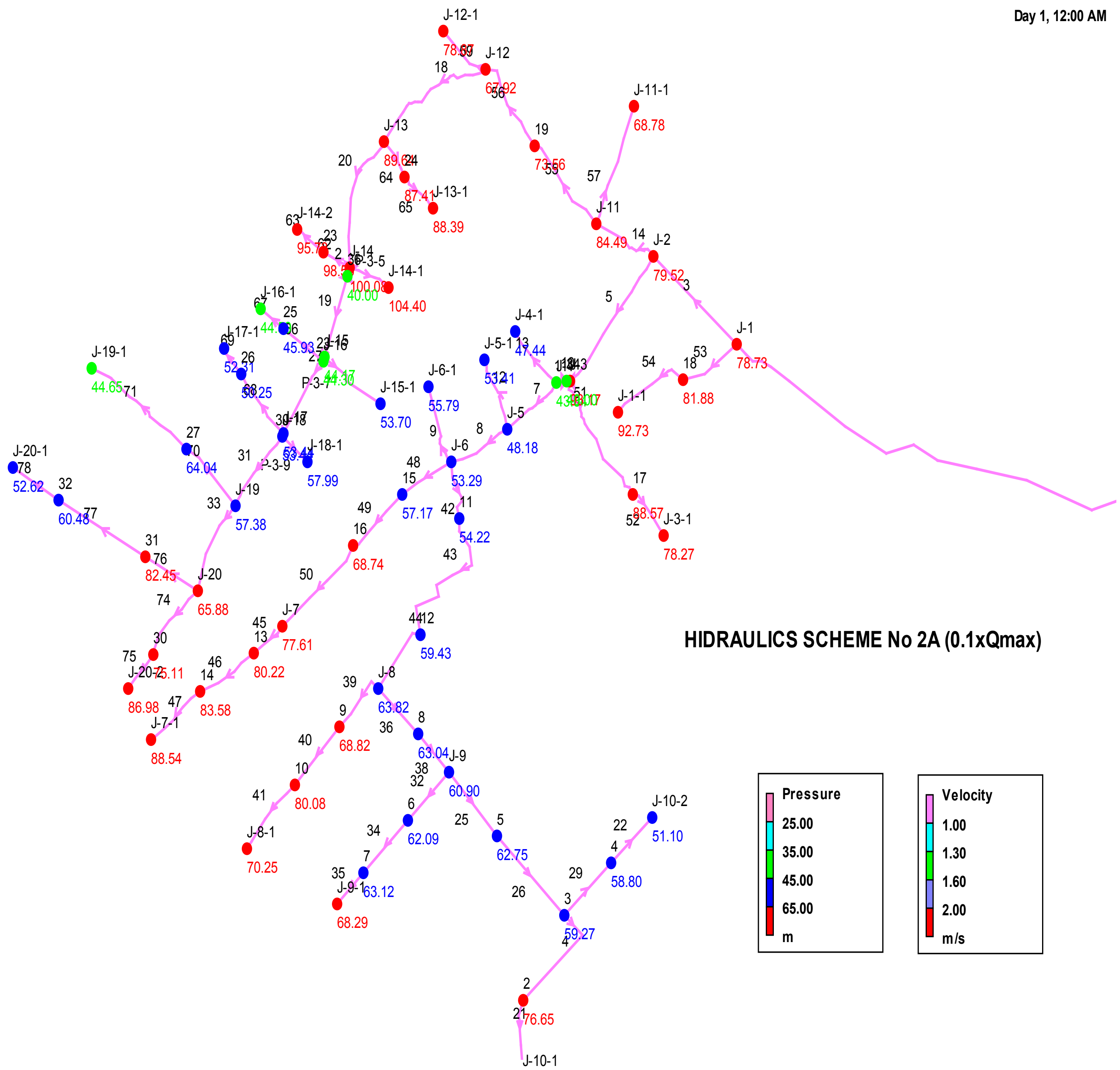

Figure 4: 2A - level of water in accumulation is on 716 m, and consumption is maximal.

modified, and reservoir was rejected because techno-economic reasons. Hydraulic calculation shows that energy level in main pipeline that runs from dam to earlier predicted place for reservoir for maximal discharge of 3m^3/s is between 690 and 700 m (depends on water level in accumulation). Groun elevation on reservoir site is 660 m and it is clear that we have to destroy 3 to 4 bars of water pressure, only to put water to reservoir and after that same water should be pumped to irrigation system so sprinklers could work. Because of same reason, main canal was rejected as solution. Because of all this, it is saved 613.546,75USD or 236USD/ha.

5. Accepted solution in Planning Report is cheaper from investment viewpoint, and there are no expenses for pumping:

6. Primary pipelines 19.477.700,62 (21.628.000,00 Preliminary Report)

7. Secondary pipelines 6.404.551,55 (were not calculated in Preliminary Report)

8. Irrigation equipment 1.272.000,00 (was not calculated in Preliminary Report)

Maximal quantities of water that will be used for distribution with main pipeline from dam, were revised to 3m^3/s, we mention that because system is gravitational, depending of water level in accumulation, main pipeline will pass through more water. Correction was made according to Preliminary Report, because losses in sysytem will now be much lower without reservoir and main canal that was 7200 m long. For calculation it is considered that 2875 ha (90%) will be maximaly operational during one year.

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