

## MODERNIZATION OF IRRIGATION SYSTEMS WITH CANAL AUTOMATION IN TURKEY

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### ABSTRACT

With the ever increasing demand for water, due to population growth and the competition from nonagricultural demands in Turkey, there is an urgent need for efficient management of irrigation resources. Timely delivery of the required quantity of water is necessary for improved agricultural production. Even though this is a known fact, the lack of dependability of water supply at the farm level has been a major impediment to improved crop yields. In addition to the sociopolitical problems, one of the main causes of undependable water supply is technical in nature. Dependability of water supply can be achieved through improved operation of irrigation canals. This improvement in operation can be brought about by partial or complete automation of irrigation canals. In Turkey, the introduction of irrigation systems based on information technology for monitoring and controlling canal operation is necessary to improve water management not only at the operational level but also at the farm level. Upgrading existing canal system operations need to be done in stages as a rehabilitation program. It can be done in small areas which are easily and economically assessable for improvement. The linkage of real-time data collection and monitoring of climate data crop-soil relation parameters with the canal automation of the conveyance and distribution system is the ultimate goal, and the use of information technology below outlet level must be given and equal priority.

**Keywords:** canal automation, irrigation management, canal control

### Türkiye'de Sulama Kanallarının Kanal Otomasyon Teknikleri İle Modernizasyonu

### ÖZET

Nüfus artışı, sanayideki büyüme ve tarımsal kullanım dışında su talebindeki artış sulama suyu kaynaklarının verimli bir şekilde kullanımını zorunlu hale getirmiştir. Sulama suyunun tarımsal alanlara istenilen zamanda ve miktarda ulaştırılması tarımsal üretim açısından önem arz etmektedir. Her ne kadar bu bilinen bir gerçekse de, su kaynaklarının tarımsal alanlara ulaştırılmasındaki problemler ve bu kaynakların yetersizliği üretim miktarını önemli miktarda etkilemektedir. Bu problemlerin yanında sosyal ve politik sorunlarda su kaynaklarının verimli bir şekilde kullanılmasına negatif etki yapabilmektedir. Su kaynaklarının tarımsal sulamada verimli şekilde kullanılması ve tarımsal alanlara ulaştırılması sulama kanallarına iyi bir işletim sistemi kazandırılması ile mümkün olabilecektir. Sulama kanallarının işletim sistemlerindeki iyileştirme bu kanalların tam veya yarım otomasyon işletim sistemlerine geçmesi ile mümkündür. Türkiye'de sulama kanallarının işletim sistemlerinin bilişim teknolojisine dayalı olarak izlenmesi ve kontrol edilmesi su nakil sisteminde kayıplar konusunda iyileşme sağlayabileceği gibi tarımsal işletmeler düzeyinde de suyun optimum düzeyde kullanımını sağlayacaktır. Türkiye'de sulama kanallarında otomasyon sağlanması bazı küçük sulama bölgelerinden başlanarak yapılabilir. Küçük sulama bölgelerinin seçilmesindeki kasit otomasyonun kanal işletim sisteminde herhangi bir iyileşme sağlayıp sağlamadığının kolayca izlenebilmesidir. İklim şartları ve toprak-bitki parametreleri ile ilgili gerçek zamanda verilerin toplanıp bilişim teknolojisi yardımı ile bu verilerin kanalın işletim sistemi ile ilişkilendirilerek gerekli suyun tarım alanlarına istenilen miktarda ve zamanda ulaştırılması kanal otomasyon tekniklerini önemli bir öge durumuna getirmiştir. Türkiye gibi tarımsal potansiyeli yüksek olan bir ülkede sulama kanallarında bu tekniklerin kullanılmasına öncelik verilmelidir.

**Anahtar Kelimeler:** sulama kanalları, kanal otomasyonu, kanal işletim teknikleri

### INTRODUCTION

During the last few decades, irrigation rehabilitation and modernization has been central to the concerns of the irrigation community, but the concepts behind it have evolved. It is now well understood that modernization is not limited to the introduction of modern hardware and software techniques, but it is rather a fundamental transformation for the management of water resources. This transformation can include changing rules and institutional structures related to water rights, water delivery services, accountability mechanisms and incentives, in addition to the physical

structures. There are growing concerns and periodic warnings that we are moving into an era of water scarcity. With increasing demand for food and competing use within the water sector, the pressure is on irrigation professionals to manage water efficiently. In response to this, strategic decisions and interventions need to be made on a continuous basis. These decisions should be cover full spectrum of the irrigation water supply system, from diversion and distribution to on-farm application down to crop root zone.

Turkey is a very convenient country for growing and harvesting agricultural products because of the geographic and climate conditions are taken into

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account. Turkey is one of the rare countries which are self sufficient in the production of agricultural products. Agricultural sector bears an important role in the Turkish economy. The number of people active in the sector is about 9.7 million (around 41% of the total labor force), while its share in Turkish GDP is 14.3%. Agricultural growth largely depends on water, which is the prime input. Rainfall is not quite dependable of helpful to agricultural development in most part of Turkey. Turkish territory is bounded on three sides by the sea. It is mostly an elevated plateau enclosed by mountains on all sides, except for the west. These mountains act as a barrier to the rain bearing wind from the north and south, and leave the interior plains, which make up more than two-thirds of the total area, with an average rainfall of 200 to 500 mm. Average rainfall for all over Turkey is 643 mm. On the coastal plains a sub-tropical Mediterranean climate prevails. Seventy-five percent of annual rainfall is received in the winter season. Eastern and Southeastern Anatolia has rainfall less than 500 mm. Rainfall distribution is uneven with respect to time as well as space, and frequently erratic. The mismatching of rainfall and crop-water requirements is quite common. A large part of the country, except coastal areas, is arid and semiarid as rainfall is not sufficient to ensure even a single crop. Furthermore, the low-rainfall areas of the country, like southeastern Anatolia, have a fairly high coefficient of variation. Droughts are experienced quite often in one part of the country or another. Irrigation is, therefore, and inseparable part of the welfare of Turkish agriculture. Therefore, Turkey have been made an important attempt (The Southeastern Anatolia Project) in the second half of the 20<sup>th</sup> century to develop the country's water resources. The Southeastern Anatolia Project (GAP) will make important contributions to irrigated agriculture (Bayazit and Avci, 1997).

Turkey, with a surface area of 780.000 km<sup>2</sup> and a population over 67 million, is a country with considerable water resources (Table 1). The rapid growth of population and the expansion of irrigated agriculture and industry are stressing the water resources both quantitatively and qualitatively. By international standards, Turkey is a major producer of grain, cotton, tobacco, grapes, sunflower, pulses (chickpeas and lentils), dried fruit (hazelnuts, seedless raisins, figs, apricots), fresh fruits (apples and citrus), tomatoes and tea. Cereal production occupies 75% of Turkey's cropland. With a wheat production (21 million tons) and barley production (9 million tons) in 1999, Turkey is one of the world's biggest wheat and barley producers. Boosting irrigated agriculture will increase these production amounts to meet the grain demands of rapid grown population. Irrigation management in Turkey differs from conceptually from that practiced in those developed countries where limited water is not a constraint. Good management, efficient operation and well-executed maintenance of

irrigation systems are essential to the success and sustainability of irrigated agriculture. They result in better performance, better crop yields and sustained production. One of the key objectives in the management of an irrigation system is to provide levels of service as agreed with the relevant government authorities and the consumers at the minimum achievable cost.

There has recently been considerable emphasis on improved management of available irrigation systems. Irrigation systems in many countries are performing well blow their potential. The problem of poor irrigation performance has stimulated the interest of a whole range of development professionals. There is unanimous agreement among them for the need to improve the operations of irrigation systems in order to increase productivity. With the availability of a variety of remote sensing and data communication technologies including satellite, microwave, and fiber-optic technologies, decision support systems that facilitate improved management of irrigation systems are being developed and implemented in several irrigation system projects around the world.

Table 1. Land Resources in Turkey

Land Resources	Area (million ha)
Total area of Turkey	77.95
Agricultural Area	27.70
Total Irrigable Area	25.85
Economically Potential Gross Irrigable Area	8.5

## HISTORY OF IRRIGATION IN TURKEY

The history of irrigation in Turkey can be traced back to prehistoric times, when agriculture was first practiced by mankind. The Southeastern Anatolia Region is a part of Upper Mesopotamia (the region between Euphrates and Tigris rivers), the cradle of the ancient Mesopotamian Civilization. Irrigation has been an important base for agriculture in Mesopotamia for 6000 year. Mesopotamia has low rainfall, and is supplied with surface water by only two major rivers, the Tigris and the Euphrates. They have dramatic spring floods, from snowmelt in the highlands of Anatolia, and they carry more silt. Mesopotamia has had times of successful irrigation, and times of silt and salinity crises: the latter around 2000 BC, 1100 BC, and after 1200 AD. The first crisis may have been caused by water politics. In any irrigation system, the farmers most downstream are those most likely to be short of water in a dry year, or to receive the most polluted water (Brooks and Ozay, 2000).

Irrigation development in Turkey gained momentum after foundation of State Hydraulic Works in 1953. Since World War II, officials have stressed irrigation as a means of increasing and stabilizing farm output, and irrigation projects have consumed more

than half of public investment in agriculture. In the mid-1980s, observers estimated that private irrigation, depending on weirs and small barrages to direct water into fields, reached up to 1 million hectares. In addition, some farmers pumped water from wells to irrigate their own fields. Development of large-scale irrigation was delayed until the 1960s. Public-sector irrigation systems, built and operated by State Hydraulic Works, tend to be large and costly. Irrigation projects are dispersed throughout the country after 1960s, but most are concentrated in the coastal regions of the Aegean and Mediterranean seas, where the longer growing seasons are particularly favorable to crops. Public irrigation water was available to 3.7 million hectares in the mid-1990s, although the area irrigated with public water totaled about 3 million hectares. Deficiencies in irrigation included a serious lag between the construction of the main parts of an irrigation system and the completion of land leveling and drainage on farms. Also, crop research and farmer training were inadequate to assure the planting of suitable crops to obtain maximum yields from irrigated land. In the late 1970s, government officials estimated that only one-third of the irrigated land was being cultivated to its full potential. Major projects were planned to expand the irrigation system because government surveys had indicated that irrigation of up to 8.7 million hectares was possible (Table 2). The most important project of the late 1980s and early 1990s is the GAP, which is linked with the Atatürk Dam on the Euphrates River and is expected to irrigate 1.7 million hectares when it is completed. The system consists of a twin-bore 24.6-kilometer tunnel, which will take water from the reservoir to irrigate the plains around Harran, Mardin, and Ceylanpinar in southeastern Turkey. In the GAP region, farmers face a six-month dry season allowing them only one cash harvest per year. Irrigation will probably enable expansion to two or even three harvests. Crop rotation, which is largely unknown in areas without irrigation, has been introduced in the GAP region. Winter vegetables are expected to alternate with cotton as the summer crop. Although wheat and pulses dominate cropping patterns, cotton could take a larger share as access to water increases. The GAP will increase Turkish wheat production by more than 50 percent, barley by a similar figure, and the region's production of cotton by more than four times by 2005, thus increasing national cotton production by 60 percent (Table 3). The value of food surpluses expected to result from this project is estimated at US\$5 billion. With the rapid expansion of the irrigation programme since the establishment of the State Hydraulic Works in the early 1950s, there was significant growth in irrigation potential. It was soon realized that the potential created was not being fully used as farmers failed to distribute the water equitably and efficiently and to synchronize field activities with the creation of irrigation potential at the outlet. Thus there was a gap

between potential and use of irrigation systems. To minimize this gap, modernization and efficient operation of irrigation systems is a must (FRD, 1995).

Table 2. Irrigation Development by State Hydraulic Works in 1000 ha

Year	Operated by State Hydraulic Work	Operated by Users	Total
1950	123	20	143
1960	185	31	215
1970	521	76	598
1980	755	245	1001
1990	1251	375	1626
1991	1266	422	1689
2001	3600	1000	4700
2030 (Target)	8000	500	8500

## CANAL SYSTEM OPERATIONS IN TURKEY

The irrigation canal system transfers water from its source(s) to one or more points of diversion downstream. Operations deal with the movement and behavior of water in a canal system and are dependent on the principles of open channel hydraulics. The primary function of operation is to manage the changes in flow and depth throughout the canal system. The term 'operation' refers to the hydraulic reaction in the canal pools which results from control actions. Several methods are available which can be used to convey water downstream through a series of canal pools. The method of operation determines how the water level varies in canal pools to satisfy the operational concept. A canal's recovery characteristics the speed and manner in which the canal recovers to a new steady-state flow after a flow change - are dependent upon the method of pool operation. The method of operation is based upon the location of the canal pool water surface pivot point. The pivot point is the location within a canal pool at which the depth remains constant while the water surface slope varies. Operational concepts deal with the location of control priorities. Usually, a canal will have either supply oriented operation (upstream concept) or demand oriented (downstream concept). Supply oriented operation is used when upstream conditions dictate system operation. An example of supply oriented operation is a system which collects water from multiple sources into a single conveyance channel with the purpose of conveying whatever is collected to the downstream end. Demand oriented operation bases operations on downstream conditions. Most irrigation systems should use this downstream concept. The canal system should be operated to satisfy downstream needs, responding to what is taken out of the system rather than to what is put into the system.

### **Conventional Operation**

The majority of canal systems in Turkey are operated in a manner which is referred to as conventional operation. In traditional conventional operation, canals have been sized to convey the maximum design flow with freeboard added as a safety factor against excess water depths. A conventional operation consists of a scheduled delivery, an upstream operational concept and a constant downstream depth operation method. An important characteristic of conventional operation is the attempt to maintain a constant water depth at the upstream side of each check structure. When flow changes, the water surface profile within each canal pool essentially pivots about this constant depth at the downstream end of the pool. The purpose of conventionally operated canal is demand-oriented, since the primary goal is to satisfy the needs of the water users. The downstream demand for water is assessed in advance so as to schedule the supply of water entering the canal through the headwork. Although the headwork flow is based on this schedule of anticipated demand, the actual operation of the canal is based on the supply. Check structures are operated to respond to upstream conditions, and the outflow from a pool reacts to the inflow.

Conventional operation has had such widespread use for so many years because (1) construction costs can be minimized by sizing the canal prism only large enough to convey the maximum steady state flow and (2) the canal system operation can be successfully accomplished using local manual control. One weakness of conventional operation is the inevitable discrepancy between forecast and actual delivery flows. In addition, there will be always inaccuracies in checking the flow and the amount of water stored in the canal pools. Since the canal system is not operated to react to actual demand, any such errors are transferred downstream. The sum of all operational errors will accumulate at the far end of the canal. Tail-end water users will often suffer from too much or too little water. To prevent shortages of water at the downstream end, excess water must be supplied at the headwork. Most of the time, this excess ends up being wasted near the downstream end of the system. The typical wastage in a conventionally operated canals system is about 5 to 10 percent of the total flow. Conventional operation involves the following basic procedure: 1) orders are submitted by the water users; 2) a water schedule is formulated; 3) flow changes are made at the head of the canal to meet the water schedule; and 4) the canal is operated manually to transfer these changes downstream, making adjustments at the canal-side turnouts and canal check structures en route (Mandavia 1998).

### **THE MODERNIZATION NEEDS FOR IRRIGATION SYSTEMS IN TURKEY**

Irrigation system modernization is a process of technical and managerial upgrading (as opposed to mere rehabilitation) of irrigation schemes combined with institutional reform with the objective to improve resource utilization (labor, water, economic, environmental) and water deliver service to farmers (Mandavia 1998). Modernization differs from rehabilitation, which simply returns a deteriorated project or structures to their original new state. In Turkey, the major consumer of water is irrigated agriculture. The principal objectives of irrigation canal networks are to provide equitable and timely apportionment of water among irrigators and to do so in proper quantities (flow rate and duration). To accomplish these objectives, canals should be designed and operated to minimize flow rate and depth fluctuations in order to protect system structures. Ensuring water supplies in sufficient quantity and desired quality, properly distributed in time and space, has become a complex task. Water resource planning and management has become multidisciplinary in nature, requiring co-ordination among various government and non-government agencies. Making optimum use of water resources has long engaged human effort but it is only in recent times that it has taken the form of integrated water resources development and management. Pressure on the available water resources for conflicting uses has become so great that individual water resources projects, whether single purpose or multipurpose, cannot be undertaken or managed with optimum benefit unless there is a broad plan for the entire drainage area. Integrated development and management thus involves a coordinated and harmonious development of the various works (existing and new) in relation to all reasonable possibilities. This may include irrigation and drainage, generation of electrical energy, navigation, flood control, watershed management, industrial and domestic use of water, recreation and conservation of wildlife (Mandavia 1998).

Water resources development planning has traditionally been attempted at state level, as in the case of other sectors, although it is well known that water does not obey political or administrative boundaries. Yet a river basin or a sub-basin should be the basic hydrological unit for water resource planning. State Hydraulic Works and Rural Affairs are responsible for the planning, design, construction and operation of nationwide irrigation canal systems. Both agencies are charged with multiple utilization of ground and surface water and prevention of soil erosion, construction, rehabilitation and modernization of irrigation conveyance and drainage systems. In the early stages of water resource development, projects were formulated to serve

mainly irrigation requirements or irrigation combined with hydropower generation and some other incidental purposes. As projects were relatively few, inter-project considerations were more or less absent and each project was considered and planned as an independent entity.

In spite of substantial growth in irrigated agriculture and consequent agricultural productivity over the years, irrigation systems in Turkey are still facing many problems. The root cause of the poor performance of the irrigation systems may be the lack of scientific approach to their management. On most command areas served by a canal, water is poorly distributed over area and time. A common shortcoming is that tail-end users are not getting water or are getting insufficient and unreliable water. Conversely, head-end users often get too much water, either because they have no choice or deliberately, taking water when they can and often more than needed. Low irrigation efficiency is also attributed to changes in cropping patterns. In many cases, the cropping pattern actually adopted by the farmers is very different from the designed cropping pattern because it is mostly influenced by market forces, farmers' preferences, reliability of water supply and other factors. The on-farm irrigation practice prevailing in the country also results in wastage leading to low irrigation efficiency. Most farmers still irrigate the way their forefathers did thousands of years ago by flooding or channelling water through parallel furrows. This gravity system, typically least expensive to install, fails to distribute water evenly. Farmers are forced to apply an excessive amount of water to ensure that enough reaches the plants situated on higher ground or on the far side of a field. The adoption of field-to-field irrigation adds to the problem, as does poorly conceived irrigation scheduling (Mandavia 1998).

#### **MODERNIZATION OF IRRIGATION SYSTEMS WITH CANAL AUTOMATION**

Generally, canal systems are constructed to convey water from a source to downstream diversion points in the most efficient and economical manner possible using the available resources. Usually automation of canal systems upgrades and enhances the overall canal operations for increased crop yields to the farmers. The overall water use efficiency of a manually operated system, exclusive of the use of any return flow, seldom exceeds 40 percent. It is reasonable to expect an increase of the overall efficiency of about 10 percent or more for a system with some automation (Mandavia 1998). The primary purpose of canal system automations is to upgrade a canal operation. Canal operation is enhanced by installing a practical and modern control system to improve the water transfer efficiency. Many limitations inherent in the conventional method of

operation can be overcome. The advantages of automation are not limited to savings in operation cost and in water. It also alleviates the risk of waterlogging and salinization. A further advantage is that it increases the reliability and accuracy of water distribution. This contributes to the establishment of a climate of confidence between the operating authority and the farmers, which in turn contributes to the effective organization of water user groups and their participation in operation and maintenance activities. With automation, it may also be possible to accurately know the volume of water delivered to individuals or groups of farmers. This makes possible the introduction of volumetric water charges, combined or not with a system of annual volumetric allocation. This approach is a useful tool for encouraging farmers to optimize the use of limited water allocations and to increase productivity.

Improvements in automatic control equipment have greatly expanded the field of canal operation and control. Automation has become a common term when discussing modern canal systems. 'Automation' is defined as a procedure or control method used to operate a water system by mechanical or electronic equipment that takes the place of human observation, effort and decision; the condition of being automatically controlled or operated (Bureau Reclamation 1995). Automating a canal system is therefore implementing a control system that includes automatic monitoring or the control equipment that upgrades the conventional method of canal system operation. Automation is used to simplify and reduce or replace the decision-making process of the operators and to implement a decision. It is increasingly used to improve the effectiveness and to reduce the cost of water supply system operations. Automation of distribution canals becomes essential for optimum conditions. The process must not be dismissed out of hand as too expensive. Its economics must be studied, keeping in mind that reduced on-farm costs and water requirements, and increased yields and management capabilities, provide savings that usually will more than make up for increased project costs. Reduction in operation and maintenance (O&M) costs associated with installation of a control system constitutes the main tangible economic savings. The number of ditchriders needed to operate the canal system after the control system is placed in operation can be reduced. The additional ditchriders needed to provide conventional service to the water users should be included in the benefit/cost analysis.

Automation creates a need for technical expertise to maintain computer software and electronic equipment. Technical skills are required to apply general principles of control system development and implementation and to repair problems. Development and implementation work would probably be accomplished as part of the initial specifications contract and be considered as a capital

cost of the project. The decision to implement and automated control system should not be justified solely on tangible economic benefits. Canal operations vary from one canal to the other (depending on the type of inlet and outlet facilities, the flow capacity, and the particular combination of service demands. Before a cost/benefit analysis can be accomplished, the operational requirements and specific needs to automate the distribution system have to be identified. Proper identification of the requirements and needs leads to either the selection of an appropriate automation system or continued operation using the existing method.

Canal automation is to upgrade a canal operation. The operation, established by the canal system operating criteria, determines the flow schedule. The control concept determines the flow schedule. The control concept determines how the canal control structures are adjusted to satisfy the operation concept. Both operation and control concepts depend on upstream or downstream conditions. Automation can be obtained in many ways, some extremely simple, others very complex. A long crested weir (also called duckbill or folded weir) by its very existence maintains a nearly constant water level in a canal under variable flows. A closed pipe line system connected to a variable source such as a canal carrying excess water to local needs, will automatically convey the exact amount of water that is withdrawn at the turnout valves. Float-actuated mechanical devices such as the NEYRTEC constant level and the improved controlled leak canal gates are self-contained but can obtain a constant canal water level. All NEYRTEC automatic irrigation gates (AMIL, AVIS, AVIO, Mixed) are radial gates operated by one or several floats rigidly fitted to the gate leaf. The floats operate in wells or tanks in which the water levels depend on the control relationship. These systems easily adjust to variable flow rates. If they are desired to control down to the no-flow regime rather than just regulate the flow, they need to be installed in top-level canals. They are sluggish in reaction as they receive input in sequence from each adjacent reach to transmit a change over the whole canal length.

The objective of building and operating a canal system is to serve the farmlands, supply municipal and industrial needs, carry storm runoff to natural drainage channels, collect water from several independent sources into a single supply, convey water used for the generation of electrical power and supply water to fish and wildlife and for recreation. In order to serve the above purposes as efficiently and economically as practicable, canal operations should be tailored to meet the specific requirements of the systems. The flexible, high-quality operation of a canal system will yield many benefits, some of which are: 1) increased crop production; 2) reduced water use; 3) better service to the water users; 4) increased power generation; 5) decreased power consumption; 6)

labour savings; 7) less water wasted; 8) easier management of the water system; 9) improved protection of the conveyance facilities; 10) reduced maintenance requirements; 11) more accurate and equitable distribution of water; 12) fish and wildlife enhancement; 13) decreased flood damage; 14) less need for subsurface drainage; 15) better response to emergencies; 16) social benefits (user's satisfaction, less conflict); 17) environmental protection; and 18) improved co-ordination with power operations (Mandavia 1998). Most of these benefits result in obvious economic savings and some of them represent intangible benefits to which it is difficult to assign a monetary value. Regardless, they all result in a better and more cost-effective water resource project.

### **PRESENT STATUS OF CANAL AUTOMATION IN TURKEY**

The canal automation theory has been introduced to Turkey's irrigation canals since 1990s by installing NEYRTEC constant level gates into Harran main canal. These float-operated NEYRTEC gates have a number of features in common: 1) counterweights and toroidal floats integral with the gate leaf. In the AMIL case, the float is on the upstream face of the leaf. For AVIS and AVIO gates it is mounted on an extension of the gate arms downstream of the hinge, and on mixed gates the floats are mounted either side in flanking wells; 2) the sluice section is trapezoidal. Even in the closed position, the gates are not completely watertight; 3) the set point of the controller variables is effectively fixed; on the hinge line for the AMIL, AVIS and AVIO gates, and an adjustment range of 5 cm to 15 cm for the mixed gates. Design flows of the AMIL series of gates range between 180 l/sec and 55 m<sup>3</sup>/sec at which the head differentials across the respective gates are 10 cm and 1.0 m. Maximum discharges of the AVIS series range from 800 l/sec to 60 m<sup>3</sup>/sec, at which the respective head differentials are 6 cm and 33 cm. The maximum permissible differential heads are 40 cm and 1.1 m respectively. Maximum discharges of AVIO series range from 85 l/sec to 42 m<sup>3</sup>/sec, at which the head differentials are 13 cm and 73 cm respectively. In this case, the corresponding maximum permissible differential heads are 1.1 m and 5.6 m. With mixed gates, the respective float wells may either be connected directly to the canal immediately upstream of the gate, in which case the water levels in the wells will mirror those in the canal, or the connections may be indirect via control devices such as weirs and orifices, and/or the wells interconnected, when the water levels in the wells will be defined functions of those in the canal. The versatility of mixed gates is further enhanced where the control devices can be adjusted. Mixed gates are thus particularly suitable for related level control and mixed control. Maximum discharge capacities of gates in the series, for a typical

20 cm head differential, range from about 8 m<sup>3</sup>/sec to 50 m<sup>3</sup>/sec, while corresponding maximum permissible head differentials range from about 1 m to 3.5 m. The minimum head differential necessary for proper operation is 15 cm (Goussard 1993). To improve operating efficiencies of irrigation distribution systems and to assure a reliable supply of water to users, some water resource projects in Turkey, whether existing or new, have taken up the challenge to improve water management by way of remote monitoring and controlling of various physical structures and parameters. In the projects, it has been planned to select a segment of the existing canal system for a pilot project which will study and analyze the benefits of improved water management systems and which can cover a larger area later on. To describe the present status of canal automation in Turkey, we will discuss a case study of canal automation on the following water resources project: Harran Main Irrigation Canal.

Table 3. Crop Patterns for the GAP Region, 1986 and 2005 (Targeted)

Crop	Crop Patterns	
	1986 (%)	Targeted (2005) (%)
Wheat	33.9	25
Barley	18.5	15
Lentil, Chickpeas, Beans	19.7	8
Cotton	2.8	25
Winter Vegetables	0.1	2
Multi-Seasonal Produce	9.4	20
Sub-total	84.4	95

#### Automation of Harran Main Canal

The Harran main canal represents a part of an irrigation canal system which delivers water directly to irrigation water users. The irrigation canal is located in Southeastern Anatolia Project (GAP) development area (Figure 1). The GAP area covers the Euphrates and Tigris rivers which represent over 28% of Turkey's surface water. The total, economically irrigable land area in the region corresponds to 19% of the whole area of the country (Table 4). Thirteen major groups of water resources development projects, primarily for irrigation and hydropower generation and for control of floods and droughts, were planned for the mobilization of the water and soil resources of the region. GAP involves the construction of 22 dams and 19 hydropower plants on the Euphrates and Tigris

rivers and an irrigation canal networks for an area of 1,700,000 ha. The Harran main canal (Figure 2) is one of the largest irrigation canals in the GAP region. The first part of the Harran canal is 118 km long and the canal has a head discharge rate of 84 m<sup>3</sup>/sec. It is designed to serve an irrigation area of 97,000 ha in the Harran Plain.

The first 56 km of Harran main canal is regulated with upstream control. This section is controlled by AMIL gates with maintain constant water levels immediately upstream of themselves. Upstream water supply source or inflow determines the canal system flow schedule. Upstream operation concept applies to canal systems that are primarily supply-oriented and usually the concept is associated with collector systems. With this method of operation, a constant upstream depth is maintained by pivoting the water surface at the upstream end of the canal pool. The constant upstream depth of method is sometimes called level bank operation, because canal banks must be horizontal to accommodate the zero-flow profile. The constant upstream depth method of operation is most effective when combined with the downstream operation concept (demand-oriented operation). Flow changes originating at the downstream end of the pool cause canal water depths to change in the direction needed to achieve new steady-state profiles. Level bank operation is inappropriate for supply-oriented canals. The operation would be inefficient and the additional expense for level bank construction would be unjustified. AMIL gates directly actuated by the water level it controls. Bothersome hoists, cables, floats, floatwells, and other structural complications have been completely eliminated. Instead, the upstream side of the radial face plate is simply provided with a specially designed buoyant compartment. In irrigation canals, AMIL gates maintain a high constant head on turnouts, irrespective of flow in the canal or through the turnouts. Used in series along the distribution network, at different check structures, AMIL gates insure an automatic, safe, reliable, and flexible irrigation program, at sharply reduced labor costs. Since these gates maintain constant water levels upstream of themselves, the control system does not respond to unknown demand variations very well. The 18 km long intermediate section of canal has three mixed gates which provide in-canal storage capacity to store excess water from the upstream regulation part. The term mixed control (composite control) denotes an

Table 4. The Natural Resources Potential of Southeastern Anatolia Region (GAP)

	Area (km <sup>2</sup> )	Population (million)	Irrigable Land (million ha)	Surface Waters (km <sup>3</sup> )	Hydroelectric Energy (billion kwhr)
Turkey	779452	67	8.5	186	122
Euphrates&Tigris Basin	181918	10.92	2.38	52.9	55
GAP	75358	5.15	1.7	52.9	27
Basin/Turkey (%)	23.3	15.7	28	26.5	45.0
GAP/Basins (%)	41	58	71	100	49
GAP/Turkey (%)	9.7	9.1	20	26.5	22

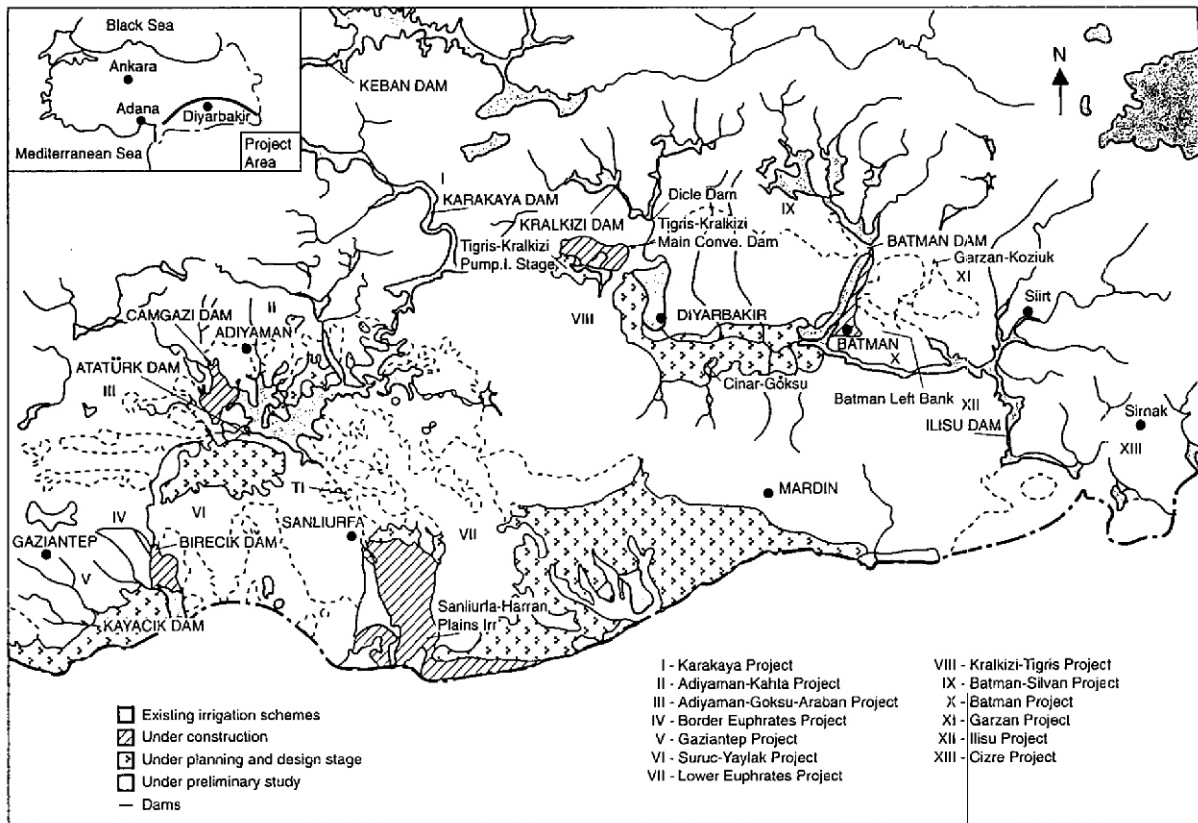


Figure 1. Southeastern Anatolia Project (GAP)

Harran main canal will be supplied from the Ataturk Dam reservoir via the Sanliurfa tunnels. Harran main canal has three different types of control: 1) upstream control; 2) mixed control; and 3) downstream control.

automatic control process in which the control logic employed is dependent upon the water level, usually that immediately upstream of the relevant cross-regulator. The method was devised for the control of canals where the operating conditions did not permit use of a single logic. A typical example is that of a system in which upstream control is used to confine the water level upstream of the regulator between upper and lower limits, with downstream control operative at intermediate levels. Constant upstream control of the lower limits aims in the event of short supply at the headworks to maintain a minimum reserve distributed over all reaches, while at the upper limit, excess supplies are released downstream to avoid overflow (Goussard 1993). Under normal conditions, the canal would operate under downstream control concept. The location of the regulation reservoir depends on the volume to be stored and also on the progress of the works. A general remote supervision system is also recommended for the whole length of the canal and the main turnouts on the canal will be remotely monitored. Mixed regulation, which relies on the downstream control principle, is an innovative approach because of its ease of operation and management, water employing reliable automatic canal regulation equipment of the most efficient Turkey for the first time. The advantages of mixed

regulation are: 1) flexibility of operation in the system makes it possible to handle the variations in unknown demands automatically; 2) ease of management; 3) relatively low incremental construction costs and small reservoir volumes in comparison with other solutions; 3) downstream control of the last section operated automatically by the AVIS gates prevents wastage of water (Altinbilek et al. 1997).

The 44 km long last part of the canal is operated with downstream control. In this part of canal, automatic AVIS gates are used to regulate the canal. AVIS gates maintain constant water levels immediately downstream of themselves. Constant downstream depth method of operation- wherein the water depth at the downstream end of each canal pool remains relatively constant-is used in most canal systems. Downstream water demand or scheduled delivery determines the canal system flow schedule. Downstream operation concept applies to canal systems that are primarily demand-oriented and usually is associated with delivery systems. This method is associated with conventional operations and with local manual control. With a constant downstream depth, major turnouts usually are located near the downstream end of the canal pools. This allows turnouts to be designed for a maximum and relatively constant depth in the canal, and also





prevents problems in water delivery to users caused by low or fluctuating water depths. When a constant depth is maintained at the downstream end of canal pools, the water surface profile will essentially pivot about this point as the canal flow changes. Because of these storage considerations, the constant downstream depth method of operation is particularly effective when combined with the upstream operation concept having a supply oriented operation. A natural tendency exists for a flow change that originates at the upstream end of a pool to create the change in storage that is needed to keep the downstream pool depth constant.

## CONCLUSION AND RECOMMENDATIONS

Over the past 15 years, the management of irrigation systems has gained importance due to a tremendous increase in irrigated area in Turkey, primarily as a result of massive investments on water resources project like GAP. Turkey envisages irrigation of  $1.7 \times 10^6$  ha of land in the GAP region to boost the agricultural production of land and water resources. There has been a growing realization of possible improvement in water management for a more efficient use of available water resources. The potential of information technology applications for improved irrigation system management was realized long ago, but concerted efforts on this front have only been made in the last 10 years. The use of computers, communication and information to control irrigation systems will yield many benefits, resulting in obvious economic saving and intangible benefits whose value cannot be measure in monetary terms. Modernization of irrigation systems is a basic requirement for improving the operation of any irrigation canal system. Proper communication facilities are one of the more cost-effective measures for improving the performance of an irrigation system. As a system becomes modernized, the transmission of real-time data becomes more important. It is easier to plan and design a new project to be operated on the canal automation concept then to implement that concept in existing water resources projects. Physical and operational constraints must be evaluated and base on the impact of each constraint, the dynamic system design approach will have to be formulated to produce an economical technical solution.

Recent advances in irrigation have related irrigation scheduling to the complex climate-crop-soil relationship. Increased knowledge of soil and plant characteristics combined with better methods of measuring soil moisture content and estimating soil moisture depletion are available to predict with greater accuracy the time and actual quantity of water needed for the next irrigation. The sensor element for measuring the prevailing soil moisture content could be a commercially available instrument or even a trained technician. The information could then be fed

into an automatic data-processing digital computer which has available in its memory the information concerning the characteristics of the soil such as its moisture-holding capacity, the type of plant and its maturity, an estimate of evapotranspiration and many other parameters which may affect the quantity and timing of the next irrigation. A digital computer using many reference inputs determines the irrigation schedule, which is then provided to the computer centre controlling the canal conveyance and delivery system to update the weekly and daily schedule of irrigation as set up at the start of the season, based on the data available then. Thus the assessment of water needed to be released into the main canal can be forecast on a scientific basis, and this will allow a more flexible operation of the canal system. Linkage of real-time data collection and monitoring of the climate-, crop- and soil-related parameters with the canal automation of the conveyance and distribution system is the ultimate goal, and use of information technology below outlet level will be assigned equal priority. The socio-economic conditions of the farmers and the scientific use of water to satisfy crop water requirements will determine the success of the complete approach of implementing automation from headwork to farm level. To have efficient canal automation application in Turkey, the following steps can be recommended: 1) organization of farmers and water users; 2) application of SCADA (supervisory control) system on existing canal systems; 3) education of technical personal with sophisticated control algorithms; 4) education of farmers with basic computer skills and data communication tools; 5) training of farmers for efficient water use.

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