AICHI CANAL EVOLVED TO MEET THE NEEDS OF WATER USERS
- THE HISTORY AND IDEA OF THE AICHI CANAL 2ND PHASE PROJECT-

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Abstract

The Aichi Canal Project that originated from a proposal by a farmer in the Chita Peninsula, where water shortage had tormented subsistence farmers, materialized in 1961 as the Japan's first multipurpose development project to provide irrigation, potable water and industrial water, as well as hydro-electric power to the metropolitan and suburban Nagoya.
Thanks to the project, farming scenes in the region evolved from monotonous paddy with vegetable gardens to various horticulture farms that extended to the irrigated upland where land use had been strictly limited by poor access to water. Horticulturists soon came to demand more flexible irrigation schedules and less communal work for maintenance activities of ditches etc., and so did the part-time farmers who gained permanent occupation in one of the rapidly developing industries for they could farm only on off-days/hours.
Due to the industrialization and urbanization of the region, the demand for potable and industrial water escalated, and insufficiency of the canal capacity became evident. Urbanization around the predominantly open canals increased flood inflow from residential areas, which often damaged thinly-lined canals, eroded unlined high cut-offs and left sedimentation in the canal bed. The request for consecutive intake of potable and industrial water from the canals prevented their regular maintenance, fundamental rehabilitation, and reinforcement.
Under these circumstances, the Aichi Canal Second Phase Project was carried out from 1983 to 2004. The objectives and the major components of the project were as follows:

1. Reconstruction of the canal segments for both urban and farm uses with trapezoid-section into double-way flumes with an increased capacity so that regular maintenance can be done while water is running through either way of the flume.
2. Construction of regulating reservoirs in the middle and at the end of the main canals for improved water control.
3. Reconstruction of lateral canals into pipelines for easier operations for farmers.
4. Construction of additional intake facilities and conveyance canals to meet the increased demand for potable and industrial water.
5. Rehabilitation and reinforcement of the canal segments for farm use.
6. Introduction of telemetric systems for distant monitoring and controlling.

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1. The birth of Aichi Canal

The Chita Peninsula does not have a big river or a notable aquifer because of its narrow and hilly topography. The rainfall flows into the sea rapidly; therefore, it was 15,000 small reservoirs that would support the agriculture in the peninsula. People in the Chita Peninsula used to depend 70 to 90 percent of irrigation water on those reservoirs, or "dish-ponds", which were unreliable water sources with very limited capacities. Droughts would hit the area about once in three years, and the crops would be seriously damaged every time.

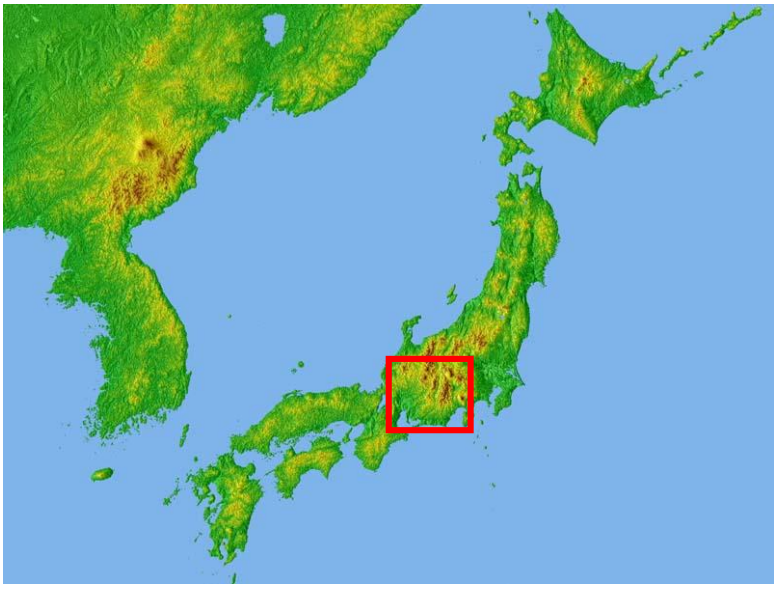

Fig.1 Location map of the Aichi Canal

In the droughts of 1944 and 1947, the entire paddy production of the region turned to nil. The poverty of the people in the peninsula reached its pinnacle during those years. Suffering from such severe natural disasters, a farmer and a local high school teacher moved to change the situation. They surveyed land, drew a plan of Aichi Canal, persuaded people to support them, and organized their supporters into an association to lobby for the realization of the Aichi Canal Project. "Increasing food production, that's good, isn't it?" When their group paid a visit to the office of then Prime Minister, Shigeru Yoshida, he strongly supported their proposal, which made the Government start Japan's first multipurpose development project after the defeat at World War II.

Thus, the objectives of the Aichi Canal Project were decided as the provision of irrigation, potable and industrial water, as well as hydro-electric power generation. The total project cost was estimated as forty-two billion yen, which was equivalent to one third of the annual public works budget of Japan at that time. Because the original plan proposed by the farmer and the high school teacher was so elaborate that the detailed plan designed by the government engineers at the final stage became almost same as their plan in many respects.

In order to manage the unprecedented project, the Government established Aichi Irrigation Public Corporation as the implementing agency, which was given Government guarantee to borrow money from the World Bank.

The Aichi Canal Project started in 1955, and the construction of major facilities including a dam, three regulating reservoirs, 112km of the main canal, over 1000km of lateral canals etc. completed in just five years as being scheduled. The Corporation, today's Japan Water Agency, took charge of the operations and maintenance of Aichi Canal relegating the operations of lateral and tertiary canals to Aichi Canal Land Improvement District.

2. Socio-economic changes

Aichi Canal started flowing water on September 30, 1961. Irrigation, potable, and industrial water supplied by the Canal has drastically changed the Chita Peninslla and the Project area ever since.

2.1 Agricultural development

The irrigation water supplied by Aichi Canal has relieved paddy production from droughts, and has significantly increased rice harvests in the Project area. Easy and regular access to irrigation water in the upland fields enabled farmers to produce high value crops, too. Orange production was promoted initially in the previously desolate upland of the Chita Peninsula, as a new mode of irrigated farming. It soon became a boom; consequently, the domestic orange market crashed due to overproduction. Farmers have learned lessons and become more diversified since then. Pears, grapes, loquats etc. are the major fruits grown in the Peninsula these days. Making use of both mild climate and good access to the metropolitan Nagoya, many farmers in the upland Peninsula started vegetable horticulture and floriculture to pursue higher profits.

2.2 Industrial development

Around 1950, the Aichi Prefecture government planned to develop an industrial estate in its coastal area where the government invited heavy and chemical industries. The heavy and chemical industries were said to require the following conditions:

- Large factory sites on the seashore,
- Such a harbor that large-size ore and coal vessels could approach, and
- Sufficient volume of available industrial water.

Because the adjoining prefecture had a similar plan, the two prefectural governments competed for inviting companies of the similar sectors. The result was that major companies including steel makers, which sought water in bulk, moved to the Aichi Industrial Estate, where the industrial water was available through Aichi Canal. After all, Aichi Canal worked as the "priming water," so to speak. Being blessed with Aichi Canal,

Aichi Prefecture has kept the first place in the value of product shipment among the 48 prefectures in Japan since 1977.

2.3 Population growth and urbanization

As industries developed in the Aichi area, population grew rapidly in the municipalities surrounding the City of Nagoya. For example, the growth rate of population in Tokai City had been approximately 10% per year during 1960s so that the total population had become 2.5 times in the ten years. To cope with the population growth, the city government newly sought the bulk water supply from Aichi Canal.

When the main canal was constructed, most of residential areas did not exist along the canal. As the Nagoya metropolitan area rapidly developed, the surrounding area of Aichi Canal became suburban. When housing developments began near the canal, such problems as polluted inflow, flood inflow and sedimentation into the canal bed, and garbage dumping into the canal water became frequent. At the same time, the number of crossings of the main canal by roads and railways increased as transport infrastructure developed in the area.

2.4 Changes of water demand

Water demand for urban sectors, both potable and industrial water, had skyrocketed as industries came to develop extensively; likewise, population grew rapidly in and around the Project area. On the other hand, the area of farmland gradually declined due to the expansion of urban areas. 33,000 hectares of irrigation area in the original plan of Aichi Canal became 30,000 hectares when the construction completed in 1961, and further diminished to 15,000 hectares when the second phase project started 20 years later.

The peak demand for irrigation water did not dwindle accordingly. As industrialization proceeded, part-time farmers had increased among the benefiting farmers. The part-time farmers tend to do water-consuming puddling, or initial flooding of paddy fields all at the beginning of irrigation season, mostly on holidays in early May. Demand for irrigation water in the winter also increased, in accordance with the expansion of upland horticulture which required irrigation throughout the year.

Part of water resources could not be fully utilized for irrigation. According to the water use plan of the Aichi Canal Project, all the existing irrigation-pond owners were required to use up their reserved water prior to demanding water from Aichi Canal; however, individual pond owners would actually demand water while they had maintained water in their ponds. There were also communal irrigation ponds managed by local associations other than individually owned ponds. Those associations would not consent to consume more than one half or two thirds of the pond water either, because farmers considered the pond as a last resort.

To cope with shortages in potable and industrial water supplies, water allocation between irrigation, potable water and industrial water was changed in 1964 so that part of the volume originally allocated for irrigation was reallocated to the latter two sectors. For this reallocation was not enough to meet the growing water demand in the urban sectors, the Aichi Canal system as a whole shortly approached to its capacity limit.

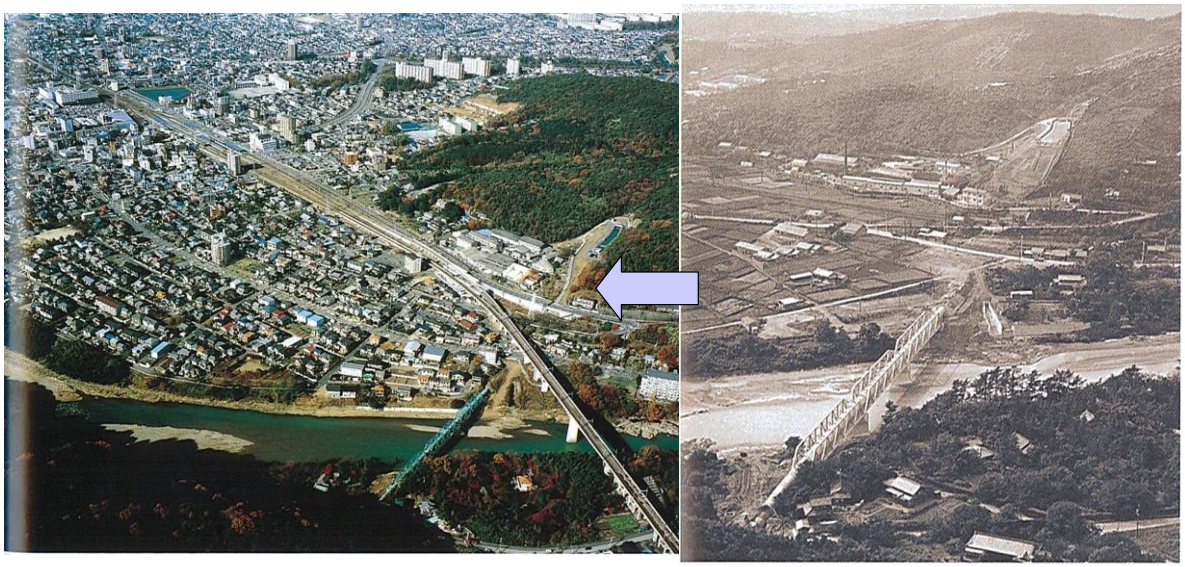

Fig.2 Rapidly developed surrounding area of Aichi Canal

3. Issues on operations and maintenance

3.1 Operations

Operations of the main canal were carried out by three units. The upstream unit covered the canal segment from Kaneyama Intake to the outlet to Togo Regulating Pond. The middle stream unit covered between Togo Regulating Pond and Sakuragane Check Point. The downstream unit covered the rest of the main canal. The targets in the canal operation were twofold: efficient water use and appropriate water delivery, fully utilizing the storage/capacity of three regulating ponds taking into account the water arrival time at each of hydraulic unit. Between Togo Pond and the main canal, both to and fro operations could take place. Urban water was delivered to Souri Pond at Sakuragane Check-gate, below which only irrigation water was conveyed.

Modernization of communication and controlling facilities was the key issue in canal operations. 89% of about 112 km of the main canal system was lined open channels with canal slopes ranging from 1/1800 to 1/3700. In order to control the flow in the canal and to distribute water with precision, the canal has 37 check gates and spill works. Farmers would often change water demands in complex rainfall patterns with four seasons, which required frequent gate operations. Cleaning clogged screens was another important task to prevent damming-up water from spilling over the canal bank that ran through the upland over suburban developments and key transport infrastructures. More than 80 operators

were employed to operate gates and to clean screens to distribute water smoothly through such a gravity irrigation system without remote monitoring and controlling systems.

Out of 37 check gates in the main canal, 18 gates installed at spillways were manually operated. Water distribution to lateral irrigation systems was also operated by 148 manual gates. A sharp decline of water demand due to a sudden rainfall would cause inevitable wasted water at the end of the main canal because there was no storage facility. Without any telemetric system, it was often the case that irregular situations and their locations were not detected promptly.

Labor and water saving for water distribution at secondary and tertiary canals was another issue. Since irrigation area had drastically diminished due to urbanization, the secondary and tertiary canals designed for higher water volumes became too big to convey the actually demanded water. The flow delivered to each lateral channel would take a long time to raise the in-channel water level to the thresholds so that ditch tenders could distribute water. This also meant that the seepage and operational losses at lateral and tertiary channels were significant. Sedimentation and weeding of those channels became another big problem for farmers. Part-time farmers could not spare time for farming except on off-days/hours, much less for communal works for ditch maintenance.

3.2 Canal maintenance

The main canal was made of the soil embankment with a trapezoid shape in cross section lined with plain concrete of 10 cm in thickness. Although minor cracks on the concrete lining were not repaired unless they hampered smooth flow, some reached the level that might cause flow impediment or lead to the breakage of the embankment due to the subsidence of the bank etc. Lateral canals also had many cases of seepages and embankment breakages after years of operation.

How to maintain the canal with continuous flow became a big issue. In the beginning of 1960s, Aichi Canal mostly conveyed irrigation water. Potable water initially occupied only six percent or less of the total flow volume in the canal; therefore, such operations as check-up, maintenance, repair, cleaning, and sediment removal could be done during the non-irrigation period, in which water level in the canal was very low. Once Aichi Canal became operational, the share of urban water increased rapidly, and it reached approximately 30 percent in 1968. Because the demand for urban water was constant, the aforesaid maintenance works had to be suspended.

4. The Aichi Canal 2nd Phase Project

After 20 years of operation, the second phase project was implemented to fulfill the increased urban water demand, to improve operations and maintenance, and to rehabilitate damaged facilities.

4.1 Addition of intake and headrace

To meet the escalating demand for urban water in and around the Aichi Canal area, the Government decided to construct two multipurpose dams in the upper Kiso River system. In the Aichi Canal 2nd Phase Project, an additional intake and headrace were constructed to draw water from these newly developed water resources. Regarding the water source for irrigation, Iruka Pond, an existing irrigation pond, was brought into the system as an additional regulating reservoir to meet the water demand by horticulturists and floriculturists in the winter.

4.2 Reconstruction of the main canal

Because the lining of the main canal was deteriorated, it was urgent to check the condition of the embankment and to rehabilitate the lining. Also, the main canal became short of the cross-sectional area to convey the necessary flow that could meet the significantly increased demand of urban water. The measures undertaken to cope with these problems were as follows:

As for the open channel segments used for urban water, the trapezoid-shape channel structure was reconstructed into a flume with an expanded cross section that could convey increased volume of urban water. It was given a partition in the middle of waterways so that either half of the flume could be drained for inspection and repair works while the other half could flow water. The necessary flume structures could be built within the limit of readily available land.

As for the sections of tunnel and siphon, new bypass waterways were constructed next to the existing tunnels and siphons so that the total cross sectional area could meet the increased demand for urban water. The bypass waterways were connected to either side of the flume via diversions and confluent structures. The benefit of constructing the bypass next to the existing one was the relative simplicity of structural design, which involved no overpass or underpass of waterways.

As for open channel segments exclusively used for irrigation, the structure of trapezoid-shape channels was rehabilitated without being altered in shape because irrigation users can tolerate service being suspended for maintenance works during the non-irrigation period. Concrete blocks were used to resurface the embankment over the existing concrete lining, where the cross section of existing channels came to have excess capacity due to the decreased irrigation area.

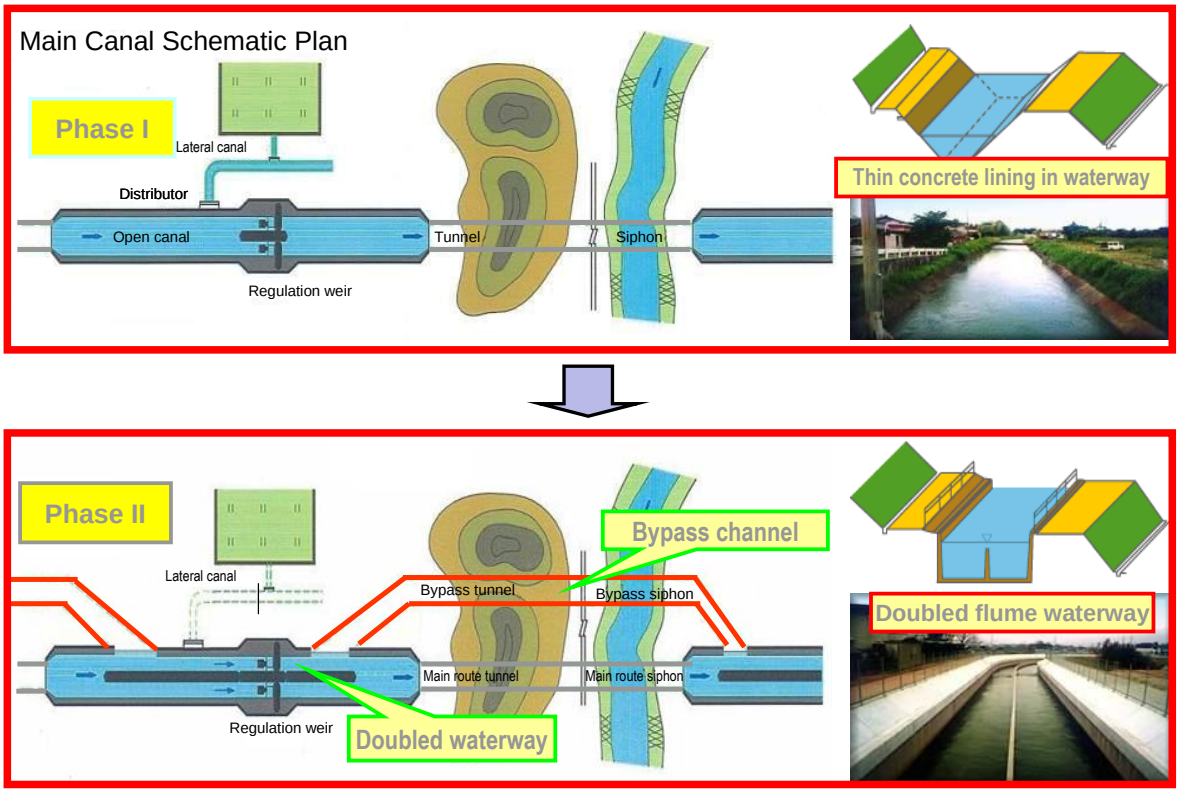

Fig.3 Reconstruction of the main canal

4.3 Introduction of mechanical automatic check-gates

In the Aichi Canal 2nd Phase Project, the main irrigation channel was given a function of regulating ponds with the help of automatic check-gates because lateral systems were converted into pipelines.

Fig.4 Mechanical Automatic Check-Gate

Due to the decrease of irrigation area, the main canal segment that exclusively conveyed irrigation water had acquired excess capacity, while ditch tenders and farmers had trouble with the secondary and tertiary canals with over capacity. Japan Water Agency developed an automatic check-gate that could store water in the upstream channel and start discharging the water to downstream when the water level of the downstream channel went below the predetermined level. The gate was power-free and its operations were mechanically controlled by floats. Combined with the tele-controlled power-gates, these mechanical auto-gates made feasible the conversion of secondary and tertiary canals into pipelines by reducing the water arrival time in the upstream open channel.

4.4 Adding a regulating pond at the end of the main canal

To reduce the amount of wasted water, Mihama Regulating Pond with the storage of 100,000m^3 was newly constructed at the end of the main canal. Before constructing Mihama Regulating Pond, 2,180,000 m^3 per year was drained into ocean in average. The spilled water at the canal end has been saved completely since the completion of Aichi Canal 2nd Phase Project.

4.5 Reconstruction of lateral systems

To save both water and labor, the open system of secondary and tertiary canals was reconstructed into closed-type pipelines in the Aichi Canal 2nd Phase Project. This might have required a regulating pond at each turnout to lateral systems because the main canal remained gravity-driven open channel. This problem was generally offset by the introduction of automatic check-gates as mentioned above. This also freed the main canal operators from adjusting the 146 irrigation division gates along the main canal.

4.6 Introduction of water management systems

Remote monitoring and controlling systems were introduced to the key control facilities of the main canal, which was mostly open channel of about 112 km in length with 152 points of division. Kaneyama Intake, the outlet to Togo Regulating Pond, and Sakuragane Check-Gate were the remotely controlled point from the central control room of Aichi Canal Management Office. The discharge volumes of 11 points and the water level of 35 points along the main canal were also monitored at the central control room. Five division works for irrigation water were tele-controlled, while six division works for urban water were operated by water purification plants. The discharge volumes at the 42 division works including 18 pumping facilities whose design discharge was more than 0.2 m^3/s were remotely monitored. Thus, 82 % of the total of the divided discharge was monitored at the central control room in real time. The remote-monitoring and remote-controlling system had a dual communication track made of optical fiber cables and multiplex radio for preparing for disasters. Thanks to the 2nd Phase Project, the operations and maintenance workforce has been reduced from 87 staff members in 1961 to only 39.

Conclusion

Any deliberate plan cannot escape from flaws, which turn to be found or perceived once the system has become operative. One of the lessons in Aichi Canal is the importance of follow-up actions. The original plan of Aichi Canal was dreamed by a farmer and drawn by a local high-school teacher rather than a foreign consulting firm who knew little about their land. Their version of Aichi Canal had foretold very well the actual plan, which was realized with the state-of-the-arts of that time. Its concept was also superb. Aichi Canal has indeed played a key role in developing the local economy as a whole. Rational in its design and farsighted in its concepts, and yet it had been found to have serious problems and became obsolete within a couple of decades. In the case of Aichi Canal, facility rehabilitation, additional development of water resources, and technical solutions to both user requests and O&M needs were all materialized by the second phase project which was subsidized by national and local government.

Technically noteworthy item is the invention of mechanical automatic check-gates in Aichi Canal that might shed lights on the unattended requests of foreign farmers that regulating ponds be given in their open channel systems. In Aichi Canal, a mechanical automatic check-gate was invented to store water in the upstream channel until when downstream water level went below the preset level. In Aichi Canal, it was applied to filling the gap between open channels in the upstream and closed pipelines in the downstream utilizing the excess capacity of open channel as a regulating pond. This invention might be useful in such an area where farmers wish to have their common farm pond, but neither land for the pond nor power for pumps can be obtainable.

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