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Araştırma Makalesi Research Article

Hydrological Analysis of Göksu River and Investigation of Waterway Transport Potential of Silifke

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Keywords

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River transport.
Göksu River.
Transportation.
Flow.

Abstract

The Göksu River is one of the most important rivers of the Mediterranean region, about 260 km long, and we are exploring the possibilities of river transportation on the part between Silifke and Taşucu Port, which opens to the Mediterranean. When this region was evaluated from the point of view of river transportation, firstly river hydrology and topography were investigated and it was concluded that navigation would be unsatisfactory without being able to channel the river which was found to have negative factors in terms of large flow changes and irregular bedding transportation. However, it has been concluded that river transport can be carried out partially by increasing the bottom depths and lower stream depths, or by feeding the river water and obtaining a regular flow rate, under the name of river regulation method. It is also envisaged that the river can be channeled to make a series of flows on the river, to form a regular flow regime and to provide a fixed waterway depth.

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1. INTRODUCTION

Due to the fact that the unit transportation prices are cheaper than the other transportation systems in ship transport, many countries have developed inland water transport, mainly Russia, U.S.A. and several European countries, have been completed and many of them have been planned. In this type of transportation, our country does not yet have a serious modern sense of work, indicating that we do not consider our current water transportation potential as necessary. Göksu River is seen as one of the works that can be done in our country. The aims of such a study can be summarized as follows:

1) Doing mass transit by ship, thus reducing the oil costs that make our economy even more challenging day by day.
2) To ensure the development of industry, agriculture and trade by organizing waterways.
3) To alleviate the burden of the highways in the water zone of the waterway, which are increasing day by day.
4) To provide energy production with the facilities to be planned in the region.

Rising oil prices, and consequently the increasing costs of freight transport, are bringing more and more burden to our country's economy. Considering the increasing transportation costs in our country where the

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freight transport is made by 90% by road, the development and dissemination of low cost alternative transportation types will play an active role in revitalizing social and cultural activities, especially our country's economy.

River transportation is transportation that grows and develops naturally in Indonesia due to natural geographical conditions that have many rivers. The road for water transportation besides being natural (sea, river, lake), some are man-made (canals, streams, artificial lakes). This transportation is commonly referred to as "inland water transportation" (Mutiani et al. 2020).

Inland waterway transport is cost efficient and environmentally friendly. The biggest advantage is that the cost of loading a ton (t) over a kilometer (km) is very low compared to other modes of transport, as well as high reliability and safety. The disadvantages of inland waterway transport have to deal with weather events, similar to other modes of transport. This affects navigational conditions and the infrastructure of the inland waterway. The most important factors are high rainfall, drought and temperatures below zero. Especially in conjunction with snow melting, heavy rainfall can cause floods, which can damage the inland waterway infrastructure and damage the property and health of people living in areas exposed to flooding. Long-lasting droughts can cause water levels to be low and limit the load carrying capacity of ships and increase the specific costs of transportation (Schweighofer, 2014).

Waterway transportation for long distances is suitable for low cost and energy efficiency. The average transport distance is three times greater than truck transport and the cost per cubic meter per kilometer is about 50% lower than truck transport (Karttunen et al. 2012). In addition, the effect of the water level per tonne of freight cost was negative, the effect of the amount of freight was positive on cost (Jonkeren et al. 2007).

Because inland waterway transportation is very dependent on natural infrastructure, it is used in some parts of the world. In the world, this natural water infrastructure is the most economically important place; Europe (Rhine River, Danube River and Arms), USA (Great Lakes Region and Mississippi River) and China (Yangtze and Pearl River) countries. Although air, sea, rail and road transport is widespread all over the world, it seems that these countries have significant economic impact of inland waterway transport (Jonkeren, 2009).

The dissemination of water transport will reduce the external costs of transport and improve mining, industry and trade activities, whereas the policies supporting the waterway passenger transport will increase the accessibility between the regions only where the river is transported (Márquez et al. 2014).

Future climate change is expected to affect inland water transport in the majority of the main natural waterways in Europe. For the Rhine River, it is expected that longer and longer periods of low water level in summer will occur. At low water levels, ships in the inner waters will reduce the load factors, which will result in higher transportation prices per ton (Jonkeren et al. 2011)

1.1. Waterway History and Current Situation

People have been using them for transport from rivers since ancient times, especially since they provide great ease in transporting heavy loads. In the early days only transport in the direction of flow was possible. It is known that the motion of the ships in the opposite direction of the flow direction is provided by the withdrawal of people from the land.

B.C. In the 8th century, the oldest waterlogged known today in Assyria is the Ninova (Cizre neighborhood) on the Dicle River and it is known that the water of the waterlogged is drained by people. We see that the canalization in Europe is important in the 17th century. In 1681, the French engineers connected the Atlantic Ocean to the Mediterranean and completed a historic event by completing the 250 km Midi channel. Later on, besides Europe, waterways started to be built in America (Eken, 1984).

The Ottomans initially had Marmara coasts and then the Black Sea coasts, with Gemlik and Izmit in the Marmara and Amasra in the Black Sea as well as the commercial connections being weak, so they did not attempt to shorten the route by combining the Black Sea and the Marmara. They have attempted to merge some seas with the opening of channels for the sake of political and administrative needs and for economic purposes only in the 16th century. The opening of the Suez Canal, joining the Don-Volga and merging the Marmara and Black Sea via the Sakarya river are among these initiatives. For the connection of the Gulf-Sapanca lake-Sakarya river and Black Sea, the Ottomans attempted six times, some of the channel was dug out, and the others were abandoned to do this connection before they started due to various reasons (Uzunçarşılı, 1940). Attempts have been made to open this channel in the Ottoman times, thinking that timbers to be procured from the Sakarya basin should be easily transported to Istanbul or used for civil construction purposes (Çeçen, 1981).

Domestic navigation has received great interest in achieving a sustainable transport system in Europe (Caris et al. 2014). At present, the network of European inland waterways consists of approximately 28000 km of navigable rivers and channels, bringing together 37 countries in Europe and beyond (Panov et al. 2009).

Tuna is the longest river in Europe with Volga. The length of the river from the source in Germany to the mouth in the Black Sea is 2850 km. Danube connects 10 European countries. Considering the strategic concept of Europe as a region with a long-term sustainability strategy, The European Commission has begun to take into account the potential, ecological and economic importance of the Tuna for water transport which the most important European river. The Danube River is an integral part of the Trans-European Transport Network (TEN-T). The Danube connects the Rotterdam port of the Netherlands to the Black Sea via the canal network and to Russia to the east. For all these reasons, it is thought that the Danube is the most important river of Europe, even if it is not in any part of the world (Mihic et al. 2011).

Inland water transport is very important in the Netherlands. Approximately 250 million tons of cargo is shipped on the inland waterways. The market share through the waterways to and from the Netherlands is about 50%. The most important links go to Rhine and Germany between Amsterdam, Rotterdam and Antwerp. Approximately 3350 kilometers of navigable inland waterway is available for cargo transportation (Roeleven et al. 1995).

In USA, 22% of the total cargoes in the country are carried by river transport. In addition, most of the foreign trade is directly related to transport systems in Mississippi and other rivers. Basepin (Great Swiss Port) opens to the sea, plus the "North" channels in Sen and France, the Weser and Elbe rivers in Germany. Rhone and Danube, for different reasons, maintain their potential as major axes. Today Russia has an internal waterway of 90,000 km, USA 50,000 km, Germany and France 13,000 km, and there are kilometers of waterways in the Netherlands, England, Belgium and Hungary (Sarıgöl, 2003).

River transport issues in Turkey is handled by the Ministry of Transport in 1976. During these years preliminary feasibility studies have been carried out for various universities to investigate navigation facilities on the Lower Seyhan River, Lower Sakarya River, Van Lake, Keban Dam Lake and Lower Euphrates Rivers. However, these studies have not been addressed further. Currently, river transport in modern sense is carried on the Bartın River, on the waterway of 8 km length inwards from Bartın Port. In this waterway, the depth of the water is 5-6 m and over 400-600 tonnes of vessels are operating (Sarıgöl, 2003).

2. AIM OF THE STUDY

The aim of this study is to explore the cheap transport potential for heavy loads in the rivers in our country. In our country, especially in the way of inland waterway transportation has not yet been carried out in a serious modern sense, shows that we do not assess our current water transportation potential as necessary. These kinds of studies, which can directly revitalize our economy, are of increasing importance.

3. METHODOLOGY

3.1. Navigation

The main reason for navigation being cheap transportation is that the ratio of ship weight to load weight is relatively small and less force is needed to move the ship than other transportation means. As an example, the force to transport a tonne of material by railway is ten times greater than the force to transport the same material by water. This ratio is up to one hundred times when compared with transportation by road. The disadvantages of waterway transportation are the slow motion and frost in cold climates in winter, which also adds to the initial investment costs to improve the waterway with dams and waterlogged. There are three methods that can provide a convenient water way for navigation. The first of these is the 'River Regulation', the bottoming of the river and the rehabilitation of the river by increasing the low current depths or feeding the river water. The second method; a series of dams and the construction of waterloggeds that reduce their negative aspects. This method is called 'Canalisation of the River'. The third, and costly, method is an artificial canal is to be excavated and constructed waterlogged that need to be overcome in the large elevation differences (Sarıgöl, 2003).

3.2. Material

The data of E17A014 Karahacılı and D17A053 Kargicak Disharge Observation Stations on this river used to evaluate the discharge status of Göksu River selected as the study area were obtained from the SHW website (Anonymous, 2018a).

3.3. Research Area

Göksu River is the most important river of the province of Icel and comes from the Central Taurus in two arms. The south line is from the Deer Mountain, and the other branch is from the Hyder Mountains. These two branches join together in the south of the district of Mut and then take the name of Göksu. Located in the Taurus orogenic belt and in the warm continental climate zone of the Mediterranean, the Göksu River seems to have responded to tectonic and climatic factors. Although the uplift appears to have created 16 river terrace levels, the river's successive accumulation and incision features point to the climate cycle (Avşin et al. 2019). Göksu delta, located near the sea in the Göksu river, is an area that hosts many species and is protected by special environmental protection laws. There are also two lagoons called Paradeniz and Akgöl in the delta near the Mediterranean. In these lagoons, there are also fish species that interact especially in sea and river areas. Therefore, the rivers flowing in the basin are of vital importance, especially for the flora and fauna communities in the water and terrestrial environment to survive (Palta et al. 2019). The delta between the Göksu River, Taşucu and Silifke, with a length of approximately 260 km and a basin area of 10,000 km^2 is poured into the Mediterranean (Anonymous, 2018b). It is foreseen that our country could be one of the areas where work can be done in this regard. It was chosen as the study area between Silifke and Taşucu Port, which opened to the Mediterranean (Figure 1 a-b).

(a) *(b)*

Figure 1 (a-b). *Study Area and Coordinates (topographic and physical map) (Google Maps, 2020a, b)*

3.4. Method

E17A014 Karahacılı (36: 24: 13K 33: 48: 56D coordinates) and D17A053 Kargicak (36: 26: 31K 33: 38: 44D coordinates), Discharge Observation Stations located on the Göksu River, which is selected as the study area (Figure 1), monthly average flow data are taken into account, flow continuity and flow time graphs are plotted and the region's economy is analyzed and the situation analysis is done.

4. RESULTS

4.1. Silifke's Tourism, Social and Economic Situation

According to the 2017 data of Silifke, there are 117.456 people, which are important values that the tourism community has (Anonymous, 2018c). Silifke Castle, Cennet-Cehennem Obruks, Jupiter Temple, Astım Cave, Uzuncaburç, Ayetekla, Tokmar Castle, Port Castle are famous tourist places (Anonymous, 2018d). In addition, it is thought that the Silifke International Music and Folklore Festival, which is held here every year, has an important effect on the development of tourism in the region (Süslü et al. 2019).

The economy of the province is based on agriculture, animal husbandry and tourism. The agricultural potential of the Silifke / Mersin region in our country is quite high (Son, 2018). Grain, peanut, sesame, vegetables, strawberries, citrus fruits and paddy fields are being planted in the whole area of the irrigated plains. Climatic and vegetation structure of mountainous regions is suitable for small cattle breeding. It is usually goat-like.

The Organized Industrial Zone, which is located within the boundaries of Tosmurlu District, was commissioned by the Ministry of Industry and Commerce on 30/03/2001. From the parcels allocated to the Silifke Organize Industry Zone; the production is done in 34 parcels of 56 parcels in total, construction continues on 8 parcels, and project works on 12 parcels are ongoing. Organize Industrial Zone is active in 5 main sectors and employs a total of 769 people (Anonymous, 2018e, f)

4.2. Hydrology of Büyük Menderes River

The information about the current status of the Büyük Menderes River was obtained from the E17A014 Nolu Karahacılı, which has been operational since 1961, and the D17A053 Nolu Kargicak Discharge Observation Station, which has been operating since 2003. This data is taken from SHW website (Anonymous, 2018a).

4.3. Karahacılı Disharge Observation Station

Karahacılı Discharge Observation Station is located in Silifke District of İçel, 36: 24: 13K 33: 48: 56D coordinates. DOS, which is at an altitude of 24 m, has a rainfall area of 10,065.2 km^2 (Anonymous, 2018a).

Table 1. *Karahacılı Discharge Observation Station*

Station	Station Name	Basin Name	Station Status	Station's Opening date	Precipitation area (km^2)	Altitude (m)
E17A014	Karahacılı	Eastern Mediterranean Basin	Open	01.06.1961	10,065.2	24

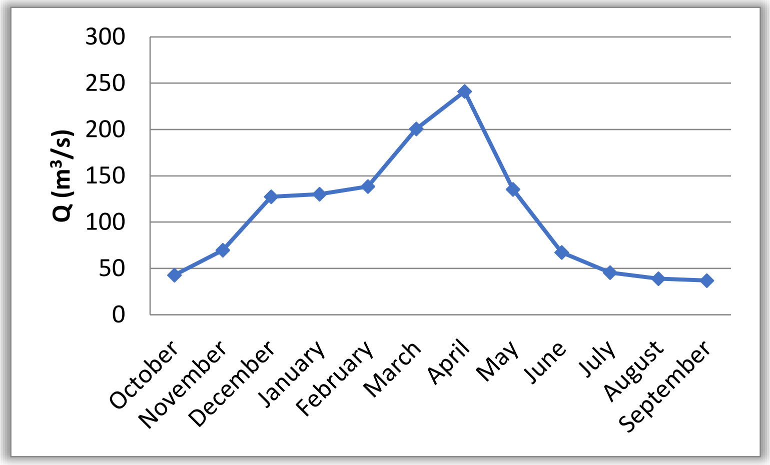

***Figure 2**. Karahacılı Discharge Data*

Figure (2) shows the monthly mean values of the discahrge recorded at Karahacılı Discharge Observation Station since 1961. When these values are examined, it can be seen that there are big differences in the monthly mean values. According to the data obtained from the Karahacılı Discharge Observation Station, the annual average discharge corresponds to 106,22 m^3/s. When all data are examined, it is determined that there are big differences between maximum and minimum discharge

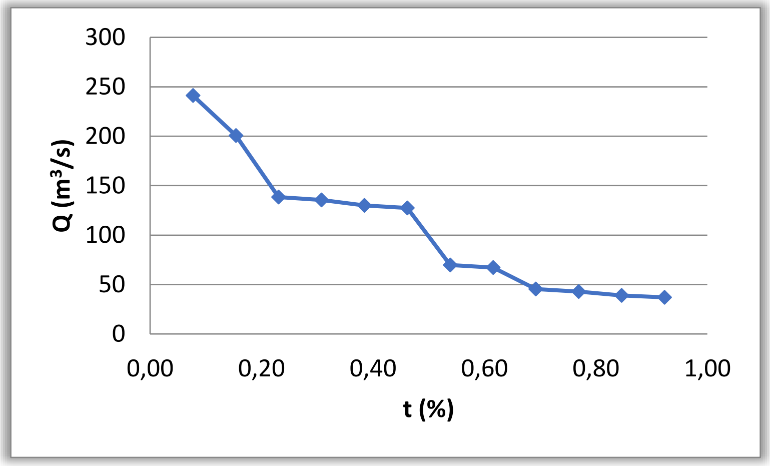

***Figure 3.** Karahacılı Discharge Continuity Line*

When the monthly average values of the Karahacılı Discharge Observation Station are examined, it is seen that the discharge in Büyük Menderes River 90% of the time is more than 45 m^3/s (Figure 3).

4.4. Kargıcak Disharge Observation Station

The Kargicak Discharge Observation Station is located in the Silifke District of Icel, 36: 26: 31K 33: 38: 44D coordinates. DOS, which is at an altitude of 58 m, has a rainfall area of 9,765 km^2 (Sarıgöl, 2003).

***Table 2.** Kargıcak Discharge Observation Station*

Station	Station Name	Basin Name	Station Status	Station's Opening date	Precipitation area (km^2)	Altitude (m)
D17A053	Kargıcak	Eastern Mediterranean Basin	Open	01.09.2003	9765	58

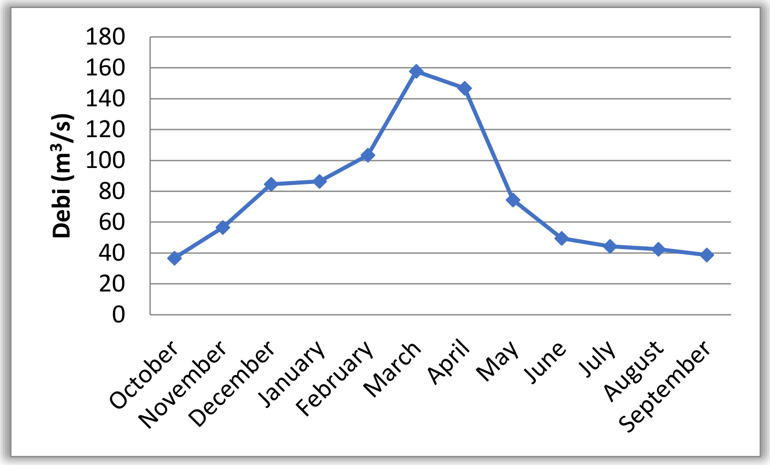

Figure 4. *Kargıcak Discharge Data*

Figure (4) shows the monthly mean values of the discharge recorded in Kargicak Discharge Observation Station since 2003. When these values are examined, it can be seen that there are big differences in the monthly mean values. According to the data obtained from Kargicak Discharge Observation Station, the annual average discharge corresponds to 76,80 m^3/s. When all data are examined, it is determined that there are big differences between maximum and minimum discharge.

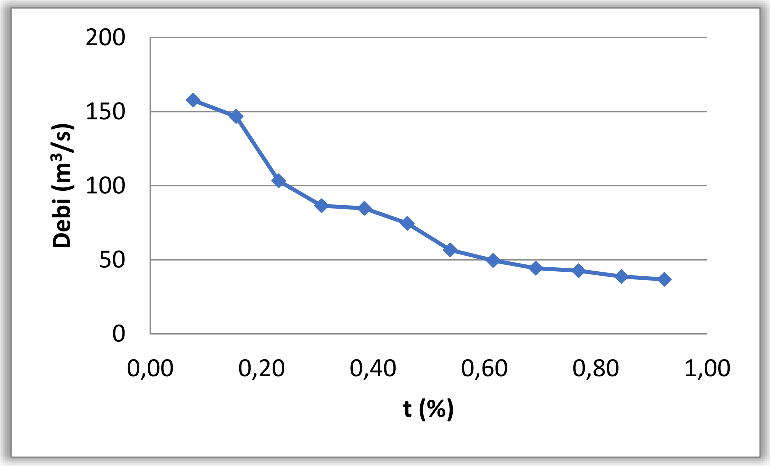

Figure 5. *Kargıcak Discharge Continuity Line*

When the monthly mean values of the Kargicak Discharge Observation Station are examined, it is seen that the discahrge at Büyük Menderes River 90% of the time is more than 40 m^3/s (Figure 5)

4.5. Minimum Canal Cross Section

In order to prevent a significant impact on the base of the waterway, it is necessary that the maximum sinking part of the tank is up to 0.90 m above the basin. Some waterways have been permitted in Europe to allow this value to be taken as 0.50 m for cruising speeds, and 0.30 m for a well maintained yard.

Because they can be easily constructed, the trapezoidal sections with a slope of 1/3 are the most commonly used standard waterway sections today. Care should be taken to extend the required cross-section so that the two ships can easily pass through the curves in order to leave a safety margin under the ship when the cross-section is assigned (Sarıgöl, 2003).

The minimum channel cross-section predicted according to the selected vessel type and standard approaches is given in Figure (6).

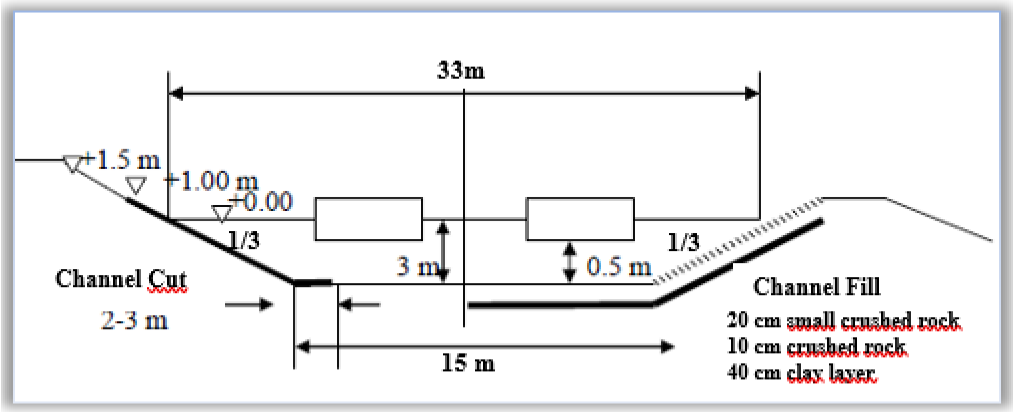

Figure 6. *Minimum Channel Cross-Section*

When the disharge that such a channel can pass through is calculated;

The base slope is found to be J = 0.0008, the roughness coefficient is k = 45, and the discharge Q = 151.19 m^3/s. The disharge found is larger than the minimum discharge of the Göksu River, and at 50% of the time it is very close to Göksu. At that time, the type of cross section selected as the minimum channel cross-section is appropriate.

Cement mortar stone and brick coverings are mostly used for covering the navigation channels. There are three types of such coatings that are cheaper than concrete coatings.

a) Simple coatings
b) Overlaying gravel or compacted stone pieces
c) Cementitious rock filler coating

It is known that these coatings reduce leaks and roughness to some extent. This type of coating was used in the form of 2 layers with a thickness of 30 cm in the section of Figure (6). It is recommended to cover with a clay layer of 40 cm thickness in order to prevent the filling parts from being damaged by the infiltration effect. The impermeable layer has to be removed up to 1.00 m above the water level. Filler crest is taken 1.5 m above normal water surface and crest width is 5 m. It is also advisable to make sedimentary traps at the downstream ends of the fillets.

5. CONCLUSIONS

It is seen that the situation on the plan of the river is examined by a map and its hydrological properties are not suitable for navigation as a result of the investigation. It seems partly possible to get a suitable waterway for navigation with some editing operations in Göksu River without making canals in current conditions. With such an arrangement to be made by Nehri Silifke about 5 km, small curvature radius can be magnified to at least 150 m and small boats of up to 100 ton can be operated.

Research has shown that Silifke's section from 5 km to Manisa, where the river will be channeled, the planned connections will always provide sufficient depth in the river. It was also understood from the hydrographic investigations of the river that the water would be found in the river to meet water needs. However, for such a study it seems that a considerable amount of regulatory work is needed. There is a need for new channels and large radius curves to be opened somewhere outside the first few kilometers.

It is obvious that the project will have a high cost because the river can be channeled to provide a constant waterway depth and to form a regular flow regime by making series dams over the river. However, with the new waterway to be regulated, industry in the region is expected to play an important role in the development of agriculture and trade. The traffic density on the roads in the waterway area will be significantly reduced.

As a result of the study, the connection of such a project with the Taşucu Port will lead to economic development by directly affecting the Silifke District and nearby regions. Furthermore, a waterway arranged from Silifke to Taşucu port was thought to be able to carry both freight and passengers very comfortably with large tonnage vessels, and to play an important role in the development and becoming of this region as an attraction center.

Symbols

DOS : Discharge Observation Station
SHW : State Hydraulic Works
Q : Discharge (m^3/s)
K : Roughness Coefficient
J : Base Slope

CONFLICT OF INTEREST

No conflict of interest was declared by the authors

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