FLOW REDUCTION IMPACTS ALONG RIVER NILE IN EGYPT

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ABSTRACT

Nile water discharges have a relatively wide variation. The observed maximum natural flow measured at Aswan is about 150 billion cubic meters per year as observed in 1878-1879, on the other hand, its minimum value is about 42 billion cubic meters per year in 1878-1879. The impacts of any reduction of the natural inflow have to be studied very carefully. This paper is focused on one of these impacts; the impact on irrigation pump station along the River Nile from Aswan to Delta Barrage north of Cairo. The reduction may be caused different factors such as climate change, construction of upstream dams and other reasons. Two reduction types were considered in study scenarios, they are the reduction of certain amount due to inflow reduction and the reduction due to Lake Nasser storage drop. Different 21 scenarios were considered for this reduction and mathematical models were used to compute water level along River Nile to study the impact on the irrigation pump stations. Study results were highlighted and illustrated to assist the decision maker to solve the problems of affected stations.

Keywords: River Nile, Pump Stations, Reduction of Nile inflow

1 RIVER NILE

River Nile history goes back more than six million years ago (Saied, 1993). The river length is about 6695 kilometers measured starting from its remote sources to the Mediterranean Sea (Aziz and Ismail, 2006). is the second longest river in the world (about 6500 kilometers long). . Its The Most of Nile water is coming from the Ethiopian plateau through the Blue Nile and Atbara during the period from August to December. Following this period, the major contribution for the rest of the water supply comes from the White Nile and its tributaries (Sobat at first, then the Great Lakes Plateau). Nile flood has a very great variation due to the variety of the different characteristics of the Nile basin. The Nile flood can be as high as 150 (1878-1879) (NRI, 2013) billion cubic meters per year and as low as 42 billion cubic meters per year (1913-1914) (NRI, 2013). Both extreme cases, very low and very high, floods have their own side effects. While the very high floods have their side effects on riverbanks, hydraulic structures and river bed, very low floods have their own side effects. Some examples of these side effects are the water supply un-sufficiency, navigation difficulties, and some local sedimentation problems. River Nile is divided into different reaches between hydraulic structures. The river length between down stream Old Aswan dam to upstream of Delta Barrage is divided into four reaches.

The River Nile from Aswan to Delta Barrages is divided into major reaches between each two hydraulic structures. There four reaches (NRI, 1992) The description of these four reaches is as follows:

1- Reach1, located from downstream Old Aswan Dam to upstream of Esna Barrages with a total length of 166.65 km,

2- Reach2 located from downstream of Esna Barrage to upstream of Naga Hammadi Barrage with a total length of 192.80 km,

3- Reach3 located from downstream of Naga Hammadi Barrage to upstream of Assiut Barrage with a total length of 185.30 km, and

4- Reach4 located from downstream of Assiut Barrage to upstream of Delta Barrage with a total length of 409.00 km.

Every reach of the four reaches has its own gauging station to measure daily water level corresponding to the passed discharge. Table (1) shows some of gauging stations for the four reaches. It shows the reach and the gauging station number, the gauging station name, and its location measured from Aswan Dam.

Table 1. Selected water level gauging stations

No.	Site name	Km	No.	Site name	Km
R1-1	Gaafra	33.75	R3-5	Sohag	445.95
R1-2	Kom Ombo	49.65	R3-6	Koramata	457.6
R1-3	Ekleet	62.45	R3-7	Maragha	470
R1-4	Salwa Bahry	85.45	R3-8	Khazend	479.1
R1-5	Ramady	102.50	R3-9	Magris	509.5
R1-6	Baselea	131.00	R3-10	Aboteeg	520.5
R1-7	U.S. Esna	166.65	R3-11	Usassiut	544.78
R2-1	Ds Esna	166.65	R4-1	Ds Assiut	544.78
R2-2	Mateena	174.7	R4-2	Maaabda	576.2
R2-3	Armant	203.8	R4-3	Mandra	612.1
R2-4	Luxor	224.1	R4-4	Menia	687.55
R2-5	Hela	255.6	R4-5	Fadl	735.25
R2-6	Sherikia	264.9	R4-6	Beba	789
R2-7	Qena	286.7	R4-7	Baniswafe	808.6
R2-8	Naga Hamadi	346.45	R4-8	Korimate	839.1
R2-9	Us Naga	359.48	R4-9	Lethy	873.7
R3-1	Dsnaga	359.48	R4-10	Eksas	887
R3-2	Dom	363.2	R4-11	Roda	927
R3-3	Baliana	386.6	R4-12	Usdelta	953
R3-4	Gerga	405.1			

2 RIVER NILE FLOW REDUCTION

River Nile flow reduction could be attributed to natural variations which require good reservoir management and other causes such as climate change and the construction of upstream dams. This paper is focused on the impact of flow reduction due the construction of upstream dams and climate change. The normal flow down-stream Aswan is 55.5 billion cubic meters (BCM) per year according to 1959 treaty with Sudan. Three cases of flow reduction down-stream Aswan are considered; the reduction of 5 BCM per year (BCM), the reduction of 10 BCM and the reduction of 15 BCM. Furthermore, the drop of Lake Nasser storage requires the reduction of Egypt share according the 1959 Treaty as shown in table 2.

Table 2. Share Reduction due to drop of lake storage

Volume	Reduction
greater than 60 bcm	0
56 to 60 BCM	5%
51-56 bCM	10%
less than 51	20%
very low	25%

The reduction of flow down-stream Aswan due to inflow reduction and share reduction due the drop of lake storage are considered in 20 scenarios of reduction. The 21st scenario is the minimum flow occurred down-stream Aswan. Table 3 shows the 21 reduction and minimum scenarios. Figure 1 shows the different scenarios flow all over the year, the analysis is focused on the minimum flow for each scenarios.

Table 3 Studied reduction scenarios

Scenario	reduction due to Flow Reduction		Storage reduction
1	full	+	100%
2	5 BCM	+	100%
3	10 BCm	+	100%
4	15 BCM	+	100%
5	full	+	95%
6	5 BCM	+	95%
7	10 BCm	+	95%
8	15 BCM	+	95%
9	full	+	90%
10	5 BCM	+	90%
11	10 BCm	+	90%
12	15 BCM	+	90%
13	full	+	80%
14	5 BCM	+	80%
15	10 BCm	+	80%
16	15 BCM	+	80%
17	full	+	75%
18	5 BCM	+	75%
19	10 BCm	+	75%
20	15 BCM	+	75%
21	Min. flow		

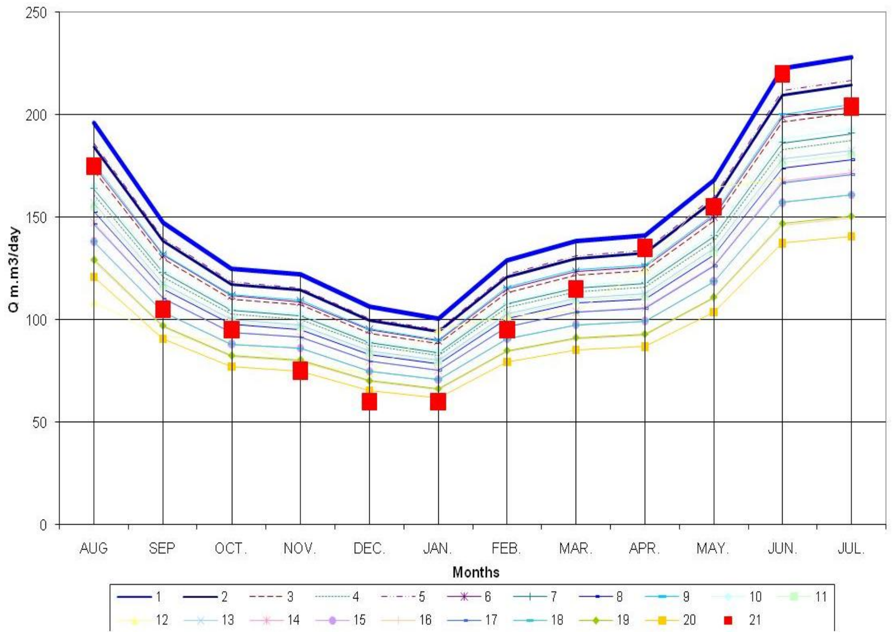

Figure 1. Down-stream Aswan reduction cases

3 IRRIGATION PUMP STATIONS

A total of 138 pump stations (NRI, 2013) were considered in this analysis. The first reach has 81 pumping stations, the second reach has 13 pumping stations, the third reach has 9 stations, and the fourth reach has 36 stations. Some of these stations are floating stations, therefore, in the study cases they were not affected with the change of water level. Some other stations are constructed for high flow, therefore, in normal and low flows, there are not operated. The other stations are studied for each of the 21 scenarios.

4 WATER LEVEL COMPUTATIONS

Water levels are computed along the River Nile from Aswan to Delta barrage related to each scenario. The Water levels computations are performed using computer models.

4.1 Computer Model

The computer model HEC-RAS, was used during this study to compute water levels related to the each discharge. This model is developed by the US Army Corps of Engineers (US Army Corps of Engineers, 2001). It is a one-dimensional model able to simulate steady, unsteady and sediment transport for movable boundary conditions.

4.2 Model Calibration

The actual water level readings for gauging stations along River Nile from Aswan to Delta Barrage were used for the calibration analysis to determine the roughness coefficients. The required cross sections for model calibration and run are extracted from digital hydrographic maps (NRI, 2010). Figure 2 shows the model calibration for the minimum flow case. The calibration process shows relatively close results for the predicted water levels compared with the actual readings.

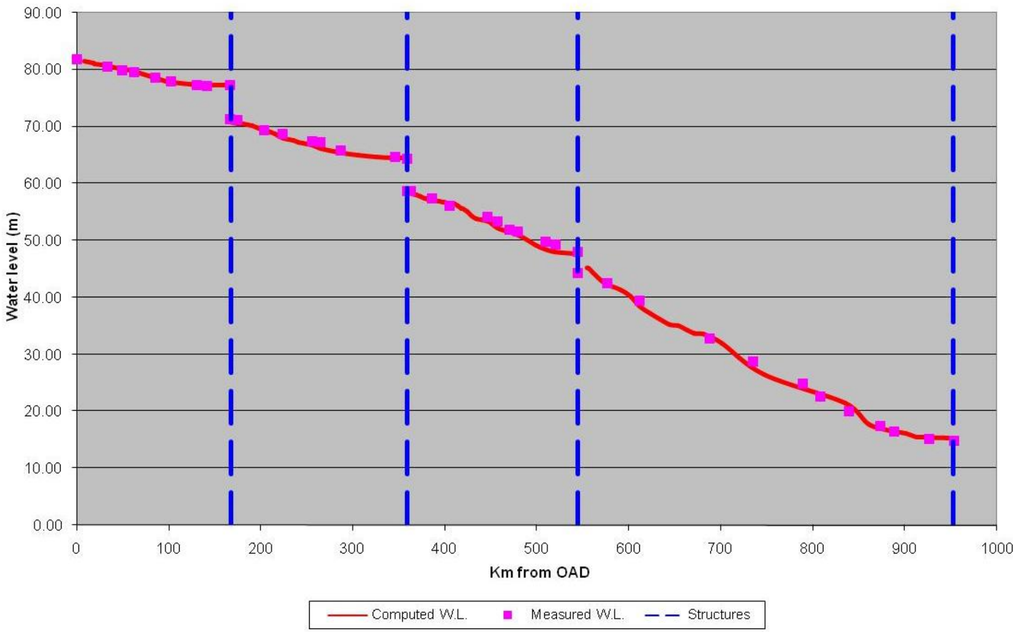

Figure 2. Model calibration results

4.3 Different Scenarios Results

Figure 3 shows the results for different scenarios for the first reach. This reach has 81 irrigation pumping stations. The 81 stations include 37 floating stations and 2 stations which are working in High flows and the other 42 stations critical level is compared for each scenario. This figure shows the floating stations and critical operation level for the fixed stations. If the station is located under any of studied scenarios, it means that it will be operated during this scenario. If the station is located above any scenario, it means that the station will not be operated under this scenario.

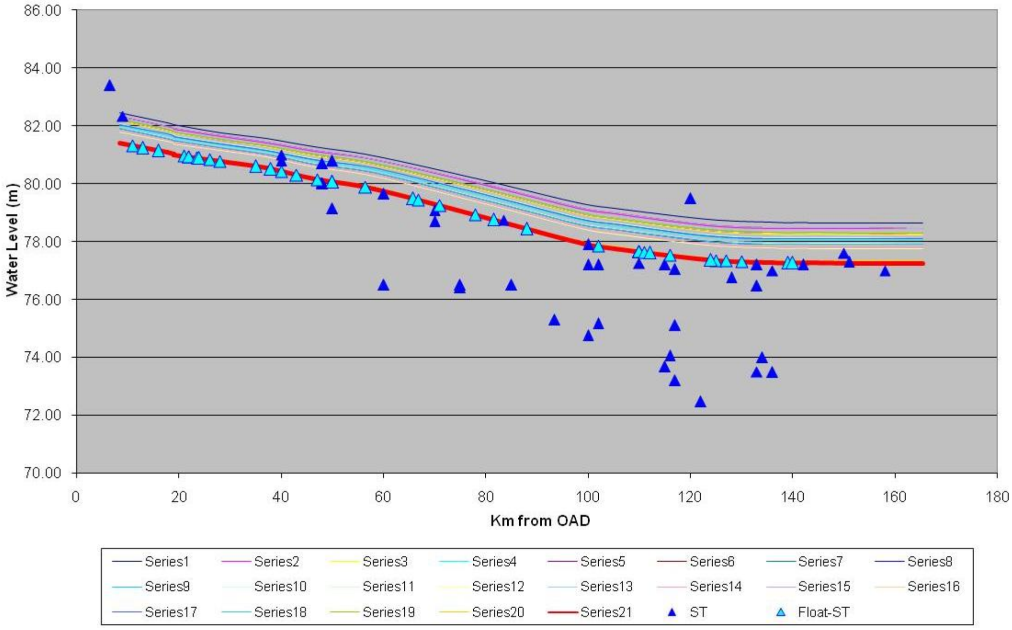

Figure 3. Reach1 results

Figure 4 shows the results for different scenarios for the second reach. This reach has 12 irrigation pumping stations. The 12 stations include 3 floating stations and 2 stations which are working in High flows and the other 7 stations critical level is compared for each scenario. This figure shows the floating stations and critical operation level for the fixed stations. If the station is located under any of studied scenarios, it means that it will be operated during this scenario. If the station is located above any scenario, it means that the station will not be operated under this scenario.

Figure 5 shows the results for different scenarios for the third reach. This reach has 9 irrigation pumping stations. The 9 stations include 1 floating station and 6 stations which are working in High flows and the other 2 stations critical level is compared for each scenario. This figure shows the floating stations and critical operation level for the fixed stations. If the station is located under any of studied scenarios, it means that it will be operated during this scenario. If the station is located above any scenario, it means that the station will not be operated under this scenario.

Figure 6 shows the results for different scenarios for the fourth reach. This reach has 36 irrigation pumping stations. The 36 stations include 2 floating stations and 24 stations which are working in High flows and the other 10 stations critical level is compared for each scenario. This figure shows the floating stations and critical operation level for the fixed stations. If the station is located under any of studied scenarios, it means that it will be operated during this scenario. If the station is located above any scenario, it means that the station will not be operated under this scenario.

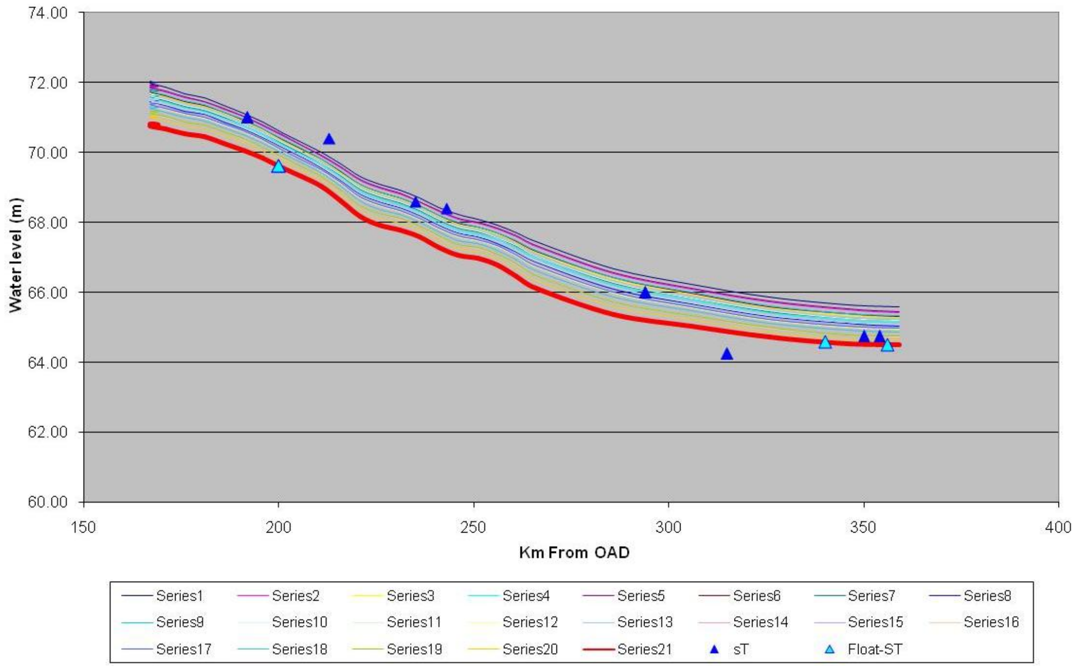

Figure 4. Reach2 results

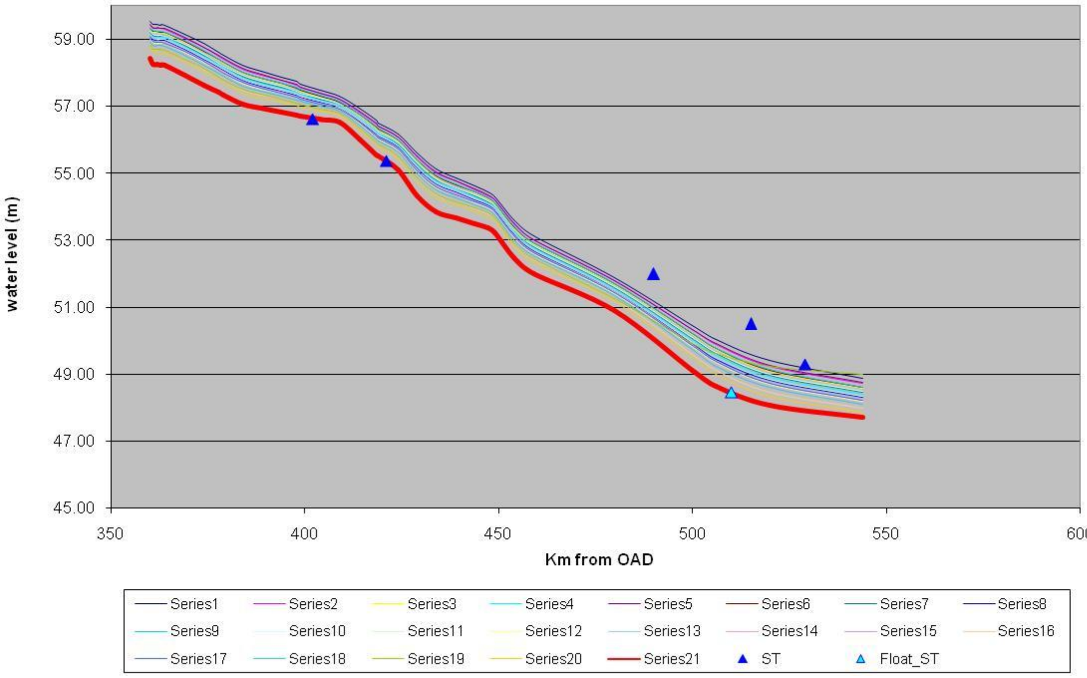

Figure 5. Reach3 results

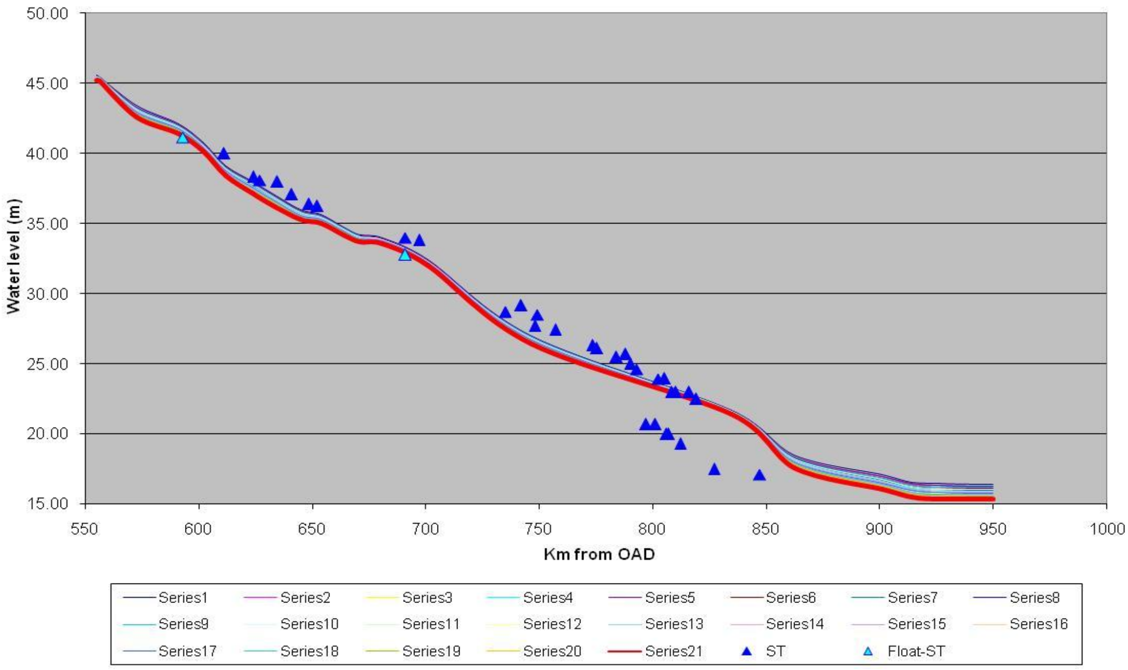

Figure 6. Reach4 results

Figure 7 shows the results of irrigation pump station analysis for the four reaches. These results excluding the floating pumps which are working in all scenarios and high flow pumps which require high flow to be operated. The results show that the pumps in reach1 which will not operate for certain scenario are ranging from 0% (scenario 1) to 21% (scenario 21). This is performed for 42 stations, 37 stations are floating and they are working in all scenarios and 2 stations are high flows only. For reach2, the not operating pumps for certain scenario are ranging from 0% (scenario 1) to 71% (scenario 21). This is performed for 7 stations, 3 stations are floating and they are working in all scenarios and 2 stations are high flows only. For reach3, the not operating pumps for certain scenario are ranging from 0% (all scenarios except 21) to 50% (scenario 21). This is performed for 2 stations, 1 station is floating and it is working in all scenarios and 6 stations are high flows only. For reach4, the not operating pumps for certain scenario are ranging from 0% (scenario 1) to 30% (scenario 21). This is performed for 10 stations, 2 stations are floating and they are working in all scenarios and 24 stations are high flows only.

5 AFFECTED STATIONS RESULTS

During this research, pump stations along all reaches from down stream Aswan to upstream Delta barrage were reviewed according to their design and critical water level to determine the potential for expected problems due to passing the low discharges in these reaches.

A one-dimensional computer program based on solving the energy and flow equations was developed to compute water levels related to the analyzed discharged. The model was calibrated using the actual water level readings from gauging stating after developing the corresponding rating curve for each station to obtain more realistic values.

The computed water levels were compared to the design and critical pump station water level to determine the adequacy of the water level for pump station supply.

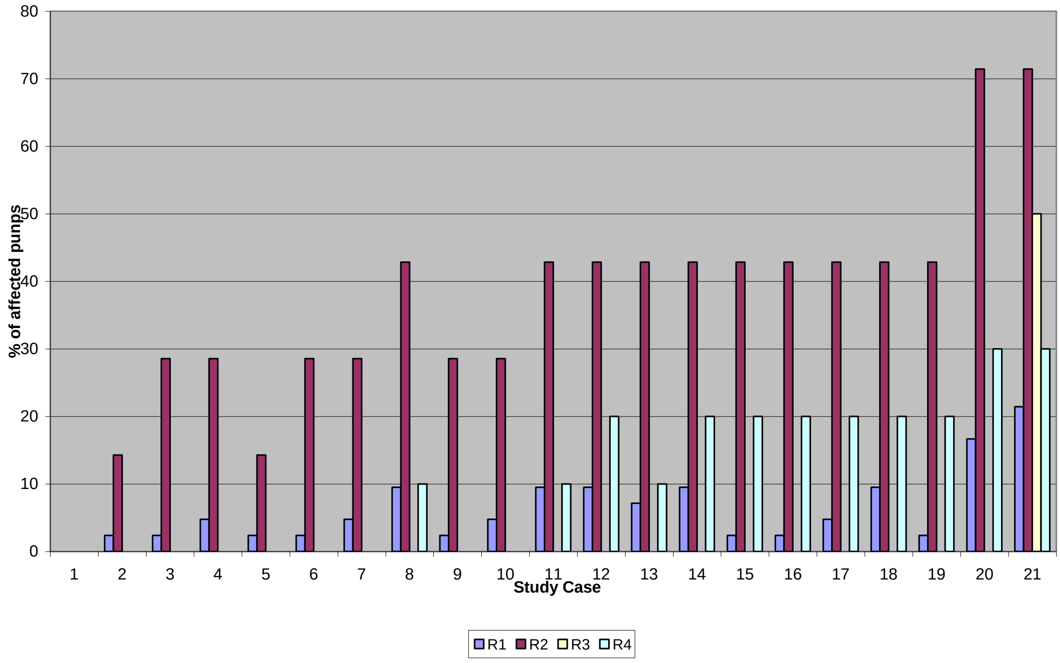

Figure 7. Pump stations results

The frequencies of different discharge were evaluated and the probability of the analyzed discharges was evaluated.

The observed number of stations which have a critical water level higher than the computed water levels due to the analyzed discharge in addition to the total number of pump stations for every reach are shown.

The maximum, minimum, and average head difference between the critical and the computed water level for all pump stations in each reach are shown.

6 CONCLUSIONS AND RECOMMENDATIONS

Different down-stream Aswan flow reduction scenarios were analyzed and related flows are computed. For each scenario, water levels along the River Nile from Aswan to Delta barrage were computed using mathematical model Hec-Ras. Computed water Levels are compared with the critical operation water levels for irrigation pump station.

It is recommended to review the critical operation water level for the pumping station and importance of operating the affected pumps during reduction scenario, in very important cases, it is recommended to construct additional intake to cope with the lowest required scenario.

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