SOAN DAM PROPOSAL

Off Channel design for water storage, hydel power & flood control

Open–File Report 2017–1207

ENG. INAM-UR-REHMAN
AGA-American Gulf Associates
800 Turnpike Street
North Andover, MA 01845 USA.
info@usgulf.net
Inam.rehman@gmail.com
Ph: +1(647)220-0237
+92-349-8722272

Cover: Location of Soan Dam with overlay of old Dhok Pathan Damdesign (3X enhanced elevation).

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By Inam-ur-Rehman

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For detailed information:
Telephone: 1-647-220-0237
Email: Inam.rehman@gmail.com

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Conversion Factors

Inch/Pound toSI

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square foot (ft^2)	0.09290	square meter (m^2)
acre	0.00405	square kilometer (km^2)
	Volume	
cubic foot (ft^3)	0.02832	cubic meter (m^3)
acre foot (af)	1233.48	cubic meter (m^3)
million acre foot (maf)	1.23348	billion cubic meter (bcm)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

SI toInch/Pound

Multiply	By	To obtain
	Length	
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Area	
square meter (m^2)	10.76	square foot (ft^2)
square kilometer (km^2)	247.105	acre
	Volume	
cubic meter (m^3)	35.31	cubic foot (ft^3)
cubic meter (m^3)	0.000810714	acre foot (af)
billion cubic meter (bcm)	0.810713	million acre foot (maf)
	Flow rate	
cubic meter per second (m^3/s)	35.31	cubic foot per second (ft^3/s)

Soan Dam, off channel design for water storage, hydel power and flood control

By Inam ur Rehman

Abstract

Pakistan is Indus, and Indus is Pakistan. Unlike other south Asian river systems, Indus system has more reliable flows year around, that's why drought and famine history of Indus valley is much better in the region. Still its flow is highly skewed and about 80% of annual flow occurs between July and September, and due to lack of storage, on average 35 MAF water drains into sea each year.

During lasthundred years, population of Indus valley (mostly today's Pakistan) has grown more than ten folds, and is estimated to reach 400 million by year 2050. As a result, large scale water storage is need of time to meetthe challenges of food security, power needs, environmental needs and flood control.

SoanRiver is a small tributary of Indus, but due to its location and topography, it offers a huge potential for off channel water storage. It was initially studied by Dam Investigation Circle in 1955. During 1960's, World bank proposed 8.5 MAF storage design which was ignored for next three decades and finally downgraded to 1 MAF design in 2002.

Total storage capacity of Soan valley is more than 40 MAF, which was never calculated until 2010. This fact changes the entire equation and deserves attention for a serious study of the site.

Introduction

During 1960's Chas. T. Main conducted study of water resources of Pakistan in context of Indus water treaty. Study included evaluation of potential storage sites for future development. Few of the designs located in Potohar are listed in Table 1 below

Table 1. Off Channel storage in Potohar plateau.

Name of Dam	Height (ft.)	Length (ft.)	Gross Capacity (maf)	Notes
Akhori	250	15800	3.6	Superseded by Gariala
Sanjwal	165	5800	0.177	Superseded by Gariala
Butta				
Bahtar	235	7500	0.9	Pre-Requisite for Dhok Pathan
ShakistaNala	187	11900	6.25	
Total Nala	148	14500	6.25	
Ghaziabad				Infeasible
Gariala	375	40000	8.2	Too long
DhokAbbaki	295	24000	9	Alternate site near Dhok Pathan
Dhok Pathan	275	12120	8.5	
Makhad	280	15800	6	Superseded by Kalabagh

Some of these dam designs overlapped with each other, i.e. building one dam effects the other. Similarly change in one’s design effects the other.According to old design, Dhok Pathan Dam needs three parallel canals with about 26000 cusecs capacity to transfer a total of 76000 cusecs water at 1550 ft, i.e. after Tarbela is filled.

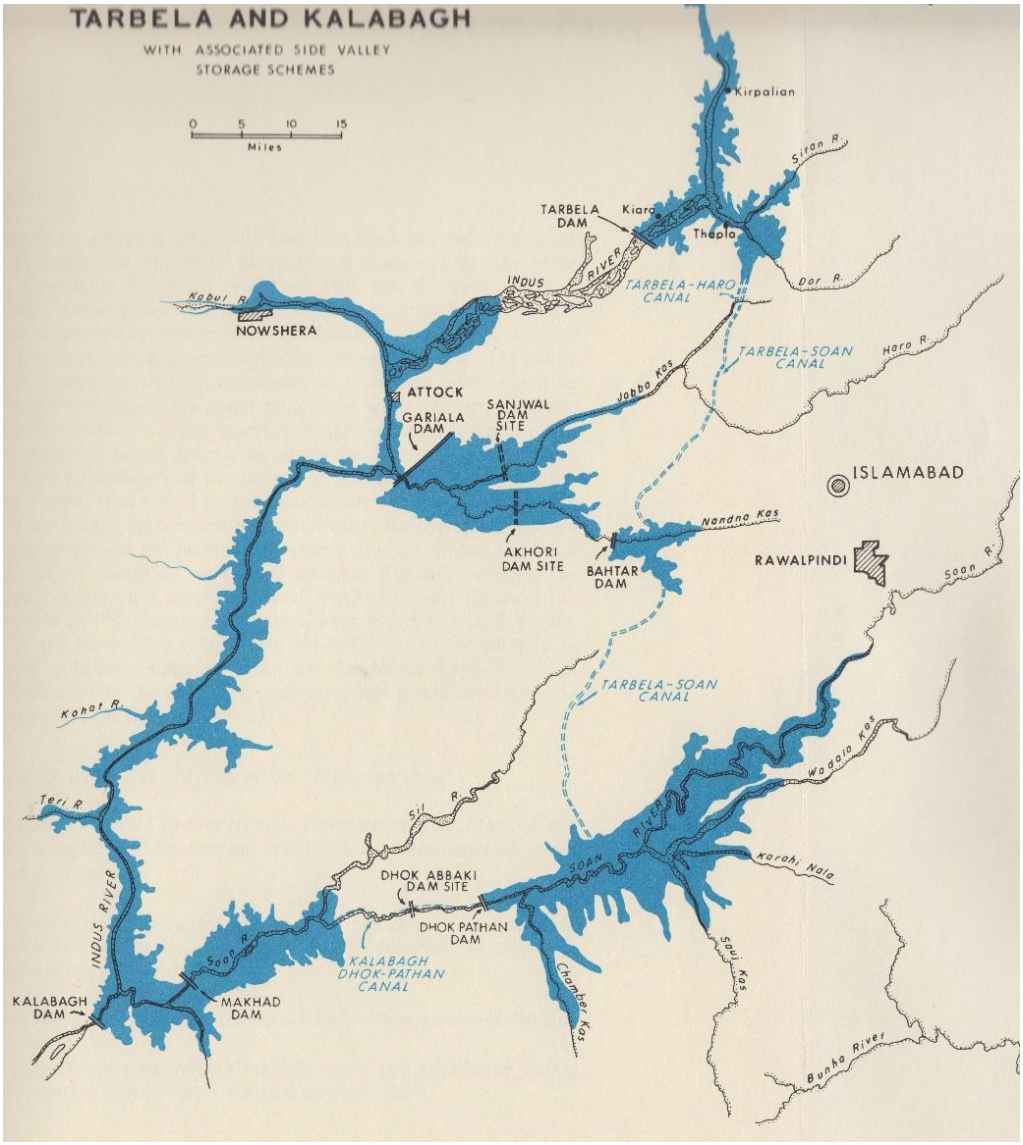

Figure 1 Map of off-channel storage for river Indus.

Design Bottle-necks of Dhok Pathan design

Level of TarbelaSoanlink canals (1550 ft) was a major design bottle-neck. Filling Tarbela first doesn't leave enough time to divert enough water during hundred days of high flow season, thus restricting opportunity window to 4-6 weeks. Another problem was the number and capacity of proposed unlined canals.

Suggested design changes

Entire Soan storage is located well below Tarbela's dead level of 1369 ft. Lowering the canal level closer to 1450 ft allows water to transfer all around a year instead of just 4-6 weeks.

Lining of canal and slope adjustment can transfer up to 6 times more water to collect 35 to 38mafwater atSoan site.

Capacity of Soan site

Footprint of 8.5 MAF Soan reservoir mapped by World Bank (Figure 1) was a rough estimate. Luckily 38.4 MAF storage has same length although the bigger lake will be wider at some place. See Figure 2 for the comparison.

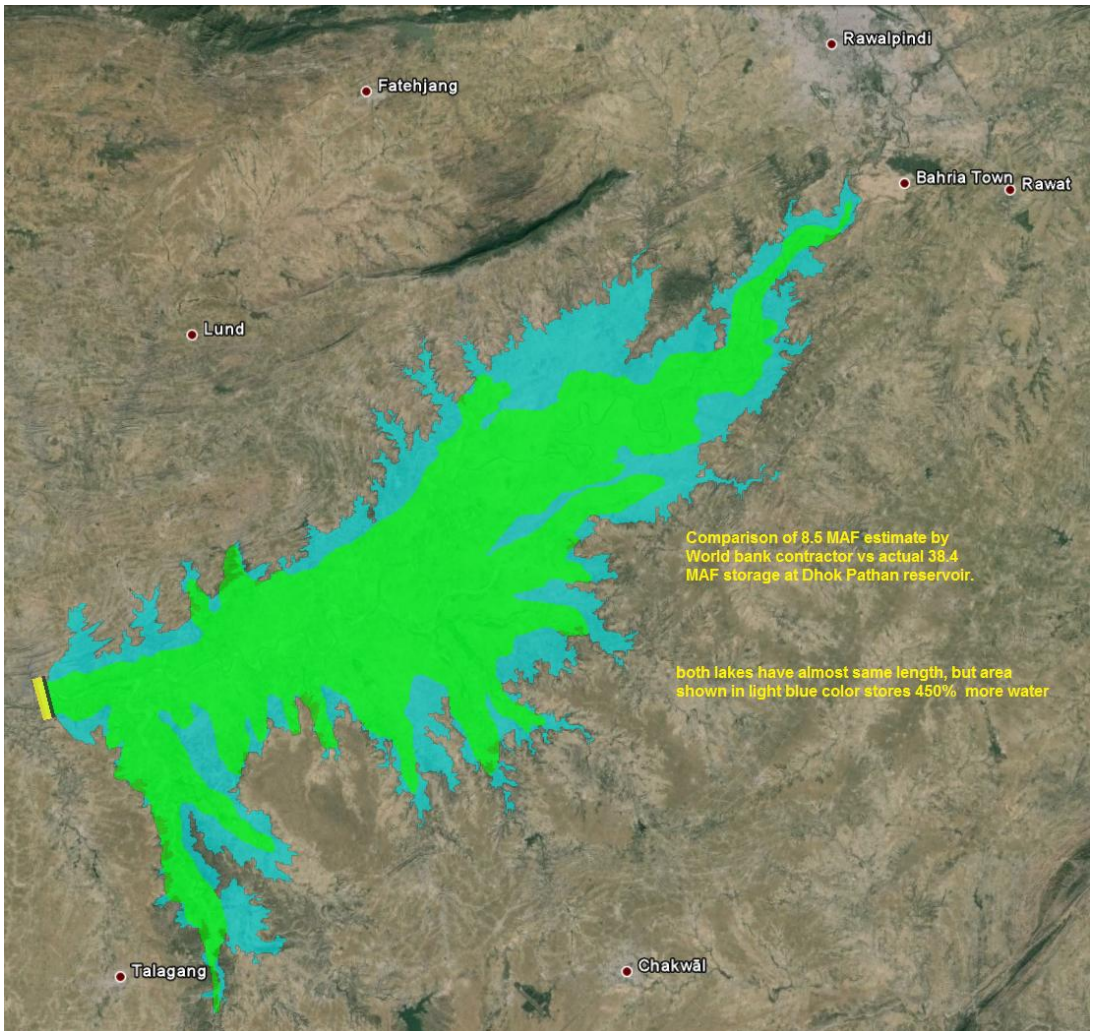

Figure2. Comparison of 8.5 maf storage vs actual 38.4 maf at Soan reservoir.

Lake area in above figure was mapped using multiple GIS datasets including SRTM DM and ASTER GDEM, cross checked with official topo-sheets.

Table 2. Capacity of Soan reservoir using SRTM DEM V4.1 elevation dataset

#	Elevation from river bed (m)	Contour elevation (masl)	Lake Area (acres)	Gross storage (maf)
1	95	390	234889	22.9
2	100	395	258212	27
3	105	400	278367	31.4
4	110	405	299656	36.1
5	115	410	319837	41.2
6	120	415	340677	46.6

Table3. Capacity of Soan reservoir using ASTER GDEM elevation dataset

#	Elevation from river bed (m)	Contour elevation (masl)	Lake Area (acres)	Gross storage (maf)
1	70	360	134786	9
2	80	370	175522	14
3	90	380	220448	20.6
4	100	390	262908	28.5
5	110	400	303820	37.8
6	115	405	325862	43

Both datasets have a difference of 5 meters in absolute elevation at Dhok Pathan site. ASTER GDEM is more accurate in relative details but SRTM DEM has better absolute elevations when cross checked with topo-sheets

compiled by Survey of Pakistan. In both cases 115 meters deep lake at heel of the dam stores around 42 maf water.

Figure3. Reservoir footprint for 38 maf storage

TarbelaSoan Link Canal

Link canal has two segments. First one is from Siran Pocket of Tarbela (near Haripur) to auxiliary Bahtar dam, and second is from tip of Bahtar lake to Soan River. First length is along a terrain with westward slope.Proposed elevation adjustment of 20-30 metersiseasy by moving the canal axis to west along lower contour lines.

Second segment has similar option along most of its axis (about 75%). 12.5 % of total canal length will need additional 15-20 meters of earthwork.

Old design needs three parallel unlined canals, which can be replaced by just one or two lined canals with a total head loss of 10 meters between Tarbela and Soan. Ghazi Barotha canal has same slope.

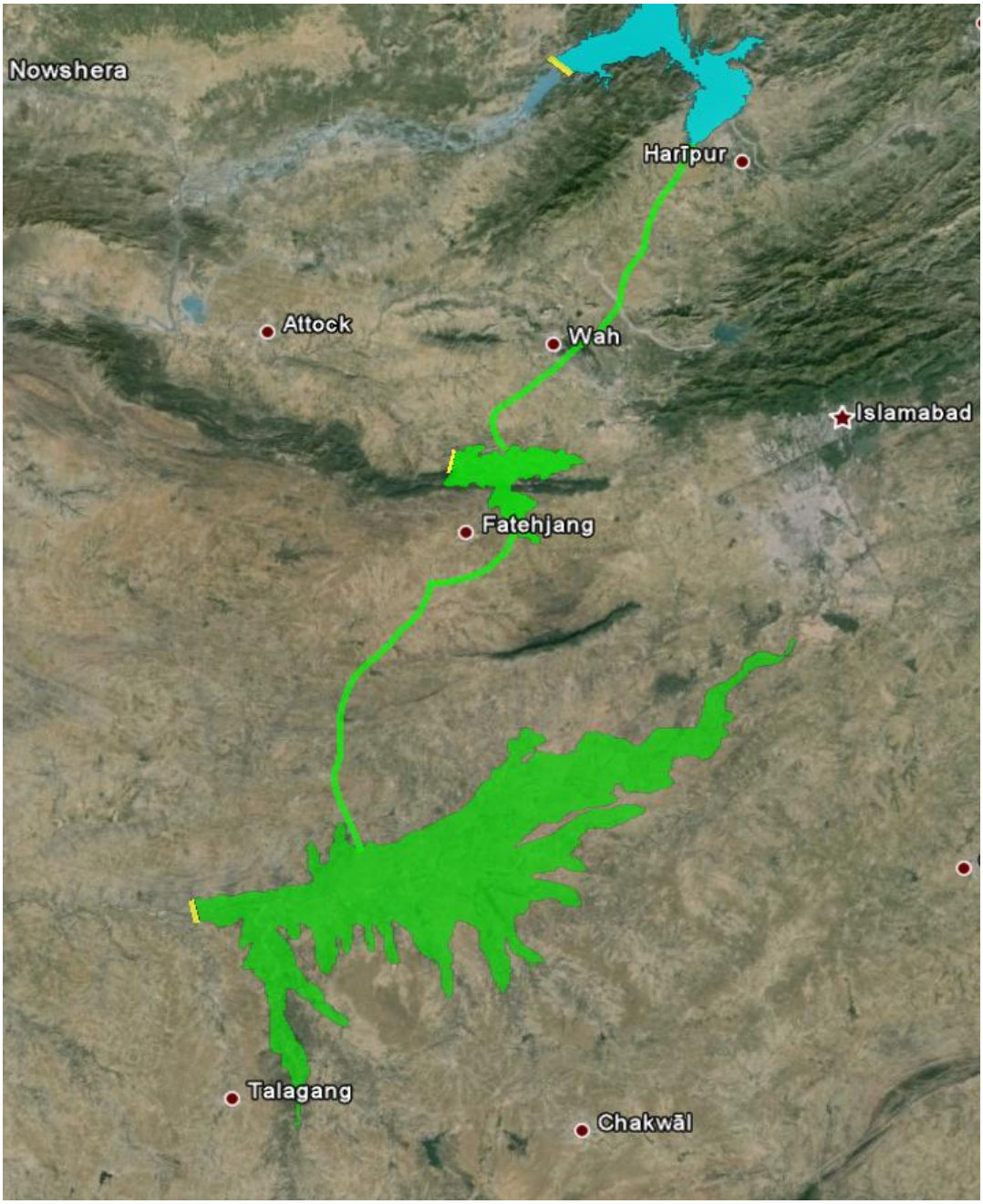

Figure4. Link Canal Axis and Auxiliary Bahtar Dam

Bahtar reservoir level of 1520 ft (463.3masl) was used as a negative point in 2002 study. Existing Shahpur Lake has maximum level of 1460 ft (445 m), which is good enough for Bahtar reservoir. For this configuration, link canal will start at 1476.4 ft (450 m) at Haripur, and reach Soan at 1443.6 ft (440 m).
Canal level can be lowered further on cost of additional earthwork, but it has a very positive impact on Tarbela reservoir.

Soan link canal is nothing unique as we have a working example of Tharthar flood canal in Iraq which diverts flood waters of Tigris river to a reservoir of size 28.5 to 69.5 maf. See Figure 5 below of Tharthar flood diversion project in Iraq.

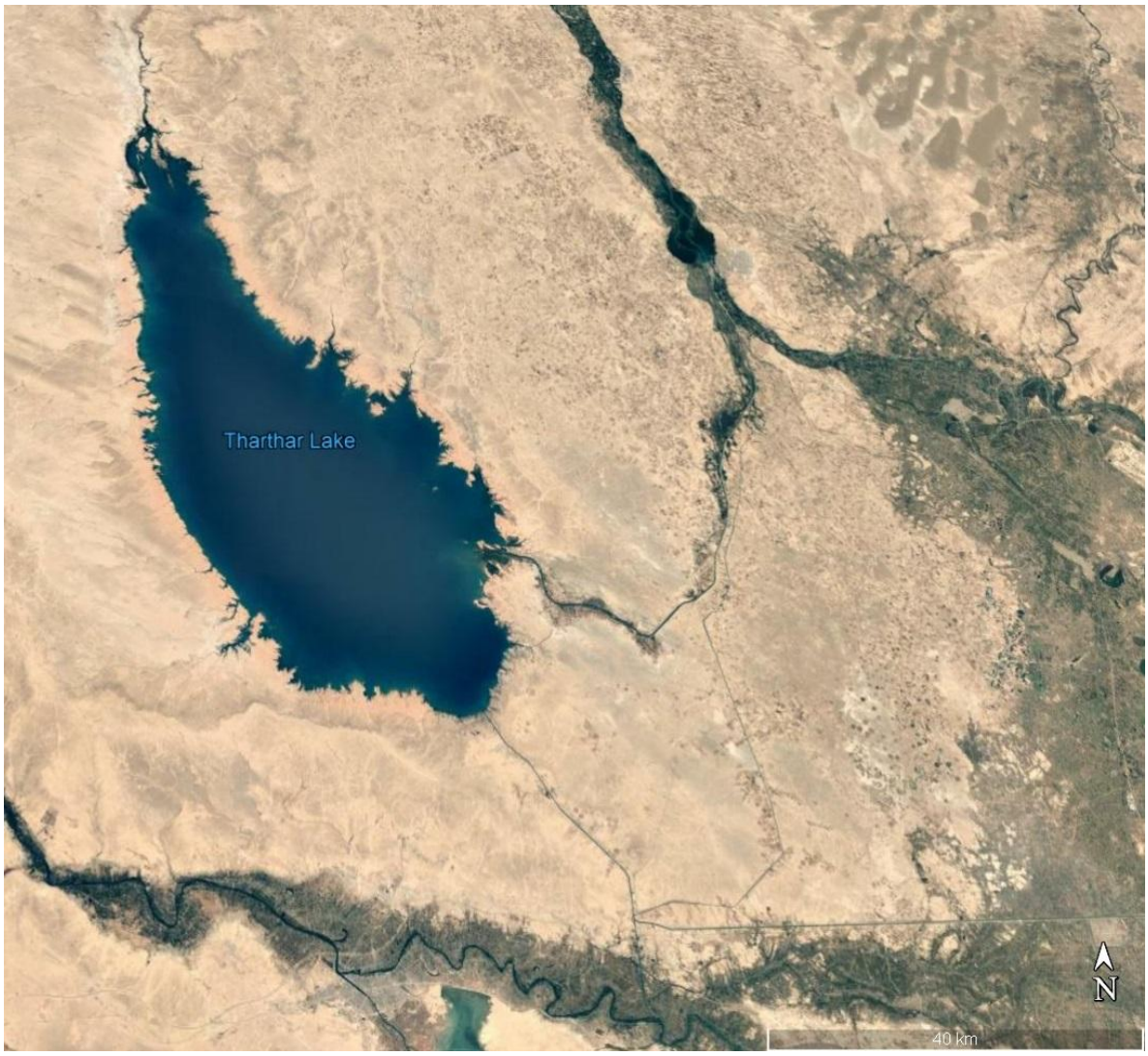

Figure5. Tharthar flood diversion project in Iraq

Figure6. Tharthar regulator Canal

Supporting Tarbela Dam

Tarbela dam has serious problem of silting. As shown in Figure 7 below (March 2017), silt islandshave gone well past Siran junction and it is only going to get worse if unchecked.

Having a low level bypass route will allow to transport the silt to Bahtar lake and get flushed back to Indus River using sluice gates.

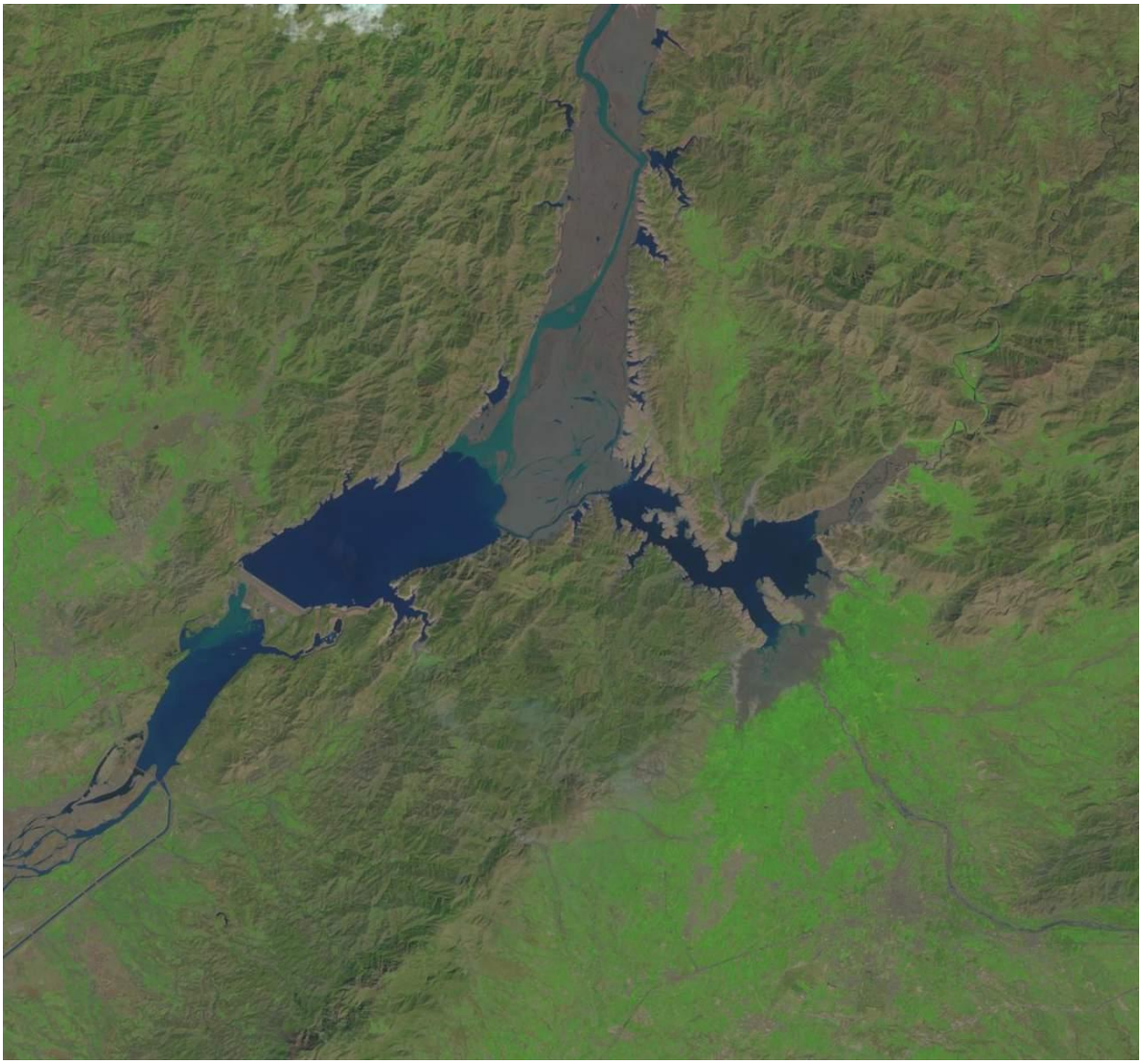

Figure7. Silting of Tarbela reservoir (March 2017)

Dhok Pathan Dam or Soan Dam?

Original 8.5 MAF size of Dhok Pathan dam was quiet good but couldn't compete with Kalabagh, Akhori or Diamer Basha options. Revised size was too small and killed the basic concept of its off channel storage design. During 2010, new revised study project decided to change the title of project to "Soan Dam" to avoid confusing it with original 8.5 MAF or 1.2 MAF revised Dhok Pathan project. Also there are multiple suitable dam locations on Soan gorge, like DhokAbaki, Dhok Pathan and Markhal. Now onwards, in current document and more, any off-channel storage project on Soan river, that stores more than 8.5 MAF of water, is referred as Soan Dam.

Figure8. Location of Soan Dam near Dhok Pathan bridge

Environmental flow

Indus delta needs an environmental flow of 6 maf. For last two decades it gets zero flow for 9-10 months. Soan storage is economical enough to dedicate 6 maf storage to regulate 15000 cusecs flow downstream Kotri all around a year to revive Indus delta ecosystem.

It will also improve downstream navigability and water quality for human consumption.

Water Apportionment Accord 1991

Water Apportionment Accord 1991 defines the provincial shares of flood water for provinces as 37%, 37%, 12% and 14% for Sindh, Punjab, Balochistan and KPK respectively. With a safe storage of 38.4 maf, each province will be able to use its share as per province demand at its own schedule

Carry over capacity

Soan storage can balance water availability across years and allow upstream hydel projects to perform at their peak without storage concerns.It can simply double the water availability in winter . Current storage depletes by mid-March every Year. Soan can easily ensure water availability till July and distribute excess water from a wetter year into next year's cycle.Figure9 below shows the possible regulation of indus flow at just 70% of Soan reservoir operating capacity.

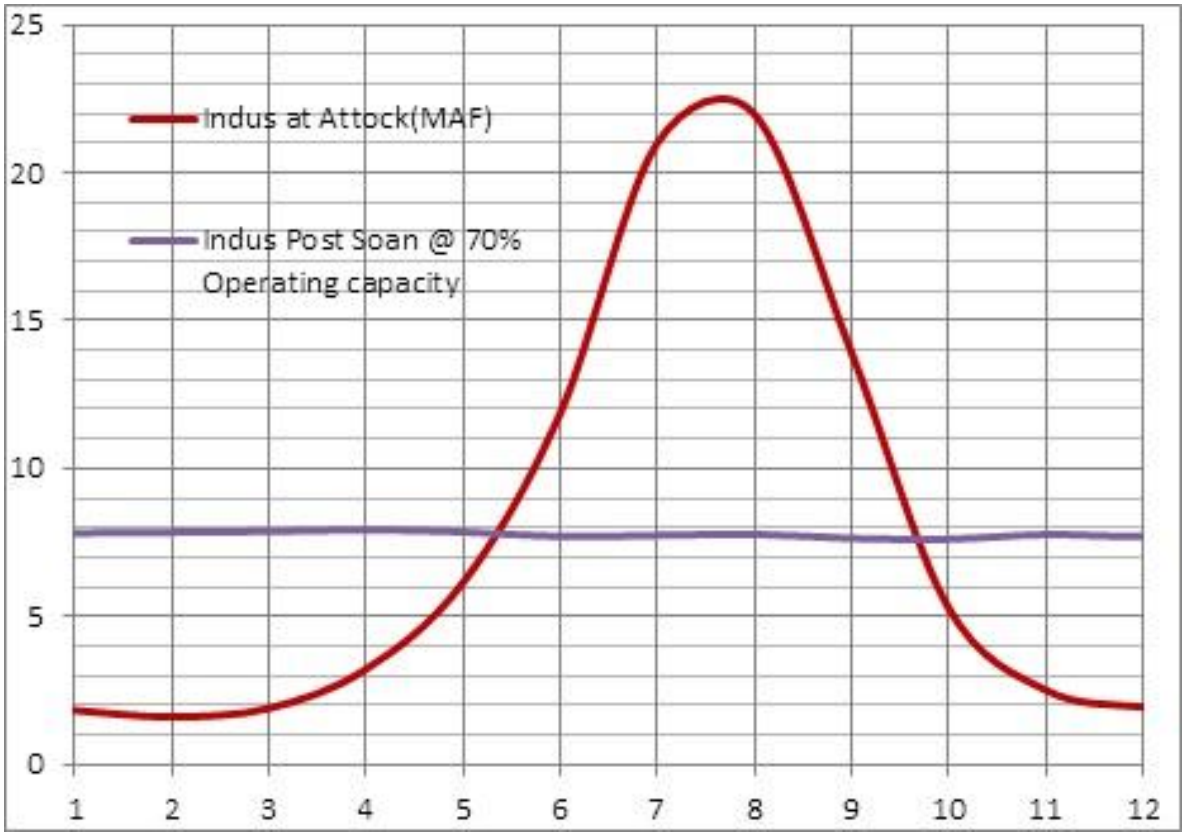

Figure9. Regulation capacity of Indus flow with Soan Dam

Flood control

Tarbela can be kept ready for extreme floods. In a situation like 2010, Soan can divertentireTabela flow for whole summer to ease Kabul and Swat river floods.

Example: After June 1st, Tarbela lake is kept near dead level while diverting all extra water to Soan reservoir till a flood arrives. Tarbela dam can absorb 6.8 MAF water, enough to completely stop the river flow from 28th July onwards, while diverting 250000 cusecs into Soan lake for next three months. Numerical analysis shows that 6.8 MAF of dedicated capacity at Tarbela lake can easily absorb all flood spikes of 2010 while Soan link drains it continuously.In this extreme case, mighty Indus can be totally blocked downstream Tarbela while collecting entire flood water (up to 38 MAF) into Soan reservoir. In the end, another 6 MAF capacity will still be available at Tarbela. Meanwhile it spares the Indus river bed between Tarbela and Kalabagh for highest floods in Kabul or Swat River. This makes second safety layer for Khyber Pakhtunkhwa flooding after Munda dam.In presence of future Diamer Basha Dam, capacity requirement for Soan link canal drops to 165000 cusecs for complete flood control.

Power generation

Installing optimal power generation infrastructure will allow Soan project to tap the power

potential between Tarbela and kalabagh while making use of extra water. Diverted water will generate twice power per unit volume than Tarbela and Ghazi Barotha combined. Project can generate an average of 5280 mw surplus power all around a year.This will ease the maintenance concerns of Soan canal and it can be used all around a year.

Infrastructural Adjustments

Soan reservoir will inundate an area of 1240 square km. about 70% of it will stay available for seasonal farming, but not suitable for permanent settlements. Charki is the only effected sizable town.

Lahore Islamabad motorway will need route adjustment of 85 km without a change in total route length. An elevated causeway crossing option needs evaluation that can change the adjustment length to 50 km. It is unfortunate that Dhok Pathan dam was ignored while designing the motorway during 1990's.

Cost estimate

Total cost of Soan reservoir system will stay around $12 Billion including project and related adjustments

Soan Dam

- Soan Dam construction volume is smaller than Tarbela dam.
- 2:1 ratio dam (Tarbela standard) needs 54.3 mcm
- 2.5:1 ratio measures 66.3 mcm
- 3:1 (overdesign) ratio needs 78.22 mcm
- For 41% additional foundation size (equal to Tarbela) values become. 76.5, 93.4 and 110.3(51%, 62% and 73% of Tarbela dam size.)
- Soan dam is supposed to be earth filled and doesn't need high cost spillways due to its size and inflow. This will restrict Dam cost to a price tag of $3 Billion

Power Generation

- Turbines installation on ends of Canal, and at Soan Exit will cost about $2.5 Billions

Soan Link Canal(SLC)

- Total cost of Ghazi Barotha Canal was $365.7 Million.
- SLC is twice longer and 1.5 times wider and deeper. Considering additional design safety it translates into 4-5 times more construction material for its lining.
- Gross Earthwork involved is 4 to 6 times more than GBC depending upon final canal level and axis. For a channel at 450 m, SLC along with its auxiliary structures (including Bahtardam)will cost no more than $3 Billion.

Infrastructural Adjustments Cost

- Land acquisition, Relocation of population, realignment of Motorway, Rasul link tunnel and construction of power distribution infrastructure will cost about $3.5 Billions

Climate Effects

Himalayan glaciers are retreating due to global warming and it is changing the flow patterns of our rivers. Monson rains may intensify with further warming. Having a large reservoir can mitigate the changing weather pattern to make best use of our water resources. Soan reservoir can moderate the

temperature and naturally improve the land cover of Potohardue to lake effect. Retreating glaciers will also increase the frequency of glacial lake outburst floods (GLOF) upstream Tarbela.

Irrigation Command

Although provinces can decide how to best use the additional water, but location and altitude of Soan allows to bring new areas under irrigation.

Soan reservoir can be linked to Bunhar River via tunnel to transfer water into Jhelum above Rasul Barrage. It means that water can reach Sulemanki barrage using existing canal system. This opens new opportunity for Cholistan in Punjab and Thar Desert in Sindh. SimilarlyThal area can get more water through Jinnah and Chashma barrage.

Economic Impact

Economic benefits of Soanproject has several dimensions. First of all 35 MAF water translates into $70 billion according to a study conducted in 1998.Adjusting for inflation makes it about $140 billion @ $4 billion per million acre ft.Making a comprehensive plan to earn back a suitable fraction of this value will enable country to break free of economic and financial stagnation, and finance all the proposed cascading ROR project between Skardu and Tarbela to generate low cost 40000 mw hydel power within next decade.

Upgrade and expansion of agriculture will create millions of new jobs in public and private sector to uplift the national economy. Govt. and private sector can invest in agriculture for large scale cash crop farming and forest plantation.Hydel power generation will be much cheaper than thermal option to meet the ever growing energy demand.

Alternate path with flushing option at Bahtar dam will increase the capacity life of Tarbela storage while allowing the trapped sediment load to reach lower Indus to increase the land fertility in a natural way. Similarly Sea intrusion will be reversed with extra sediment transport and water flow.

Reliable environmental flow in Indus will boom the fisheries and river transportation.

Improved control of floods has a huge impact on economy by avoiding direct and indirect damages.

Conclusion

Soan dam needs quick action to make use of its full potential without delays. All provinces should coordinate to save the water wastage. In past Sindh has opposed large scale projects on Indus but Soan design is too good to ignore. Still if needed interested provinces can agree to make a scaled down design with 20maf, excluding Sindh’s share in Storage capacity.

Acknowledgements

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Appendixes

AppendixA. Comparison of Soan dam with other proposed dams.

	Soan Dam	Akhori Dam	DiamerBasha Dam	Kalabagh Dam
Storage size (MAF)	38.4	6	6.4	6.1
Storage Cost	Very Low	Medium	High	Medium
Upstream Flood/disasterControl	Will keep Tarbela ready for floods	Harms Tarbela's flood control	May trigger landslides	Disasterous for KPK
Downstream Flood control	Excellent	Low	Average	Low
Environment friendly	Excellent	below Average	Average	below Average
Carry-over Capacity	Excellent	Fair due to off channel design	Fair due to location	Poor, due to size and location
Power potential (MW)	5240	600	4500	3600
Relocation due to inundation	Lake length is same as shown in old estimate map	More population to relocate vs storage capacity	Less populated area	Strong opposition in KPK
Disaster Safety	Safer due to off-channel site	Poor	Poor	Good
Storage life due to silting	Very Long	Long	Short without future upstream dam	Medium due to Kabul river sediment
Net economic Impact	$140 Billion/year	~$14 Billion/year	~$20 Billion/year	~$15 Billion/year
Effect on Sedimentation transport	Releases sedimentation in Tarbela	None	Helps Tarbela	Harmful for Lower Indus
Environmental flow capacity for Indus delta	15000 cusecs flow for 365 days a year	Will decrease Kotri downstream flow	Will decrease Kotri downstream flow	Will decrease Kotri downstream flow