Addressing the Court's Questions

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Focus of the presentation

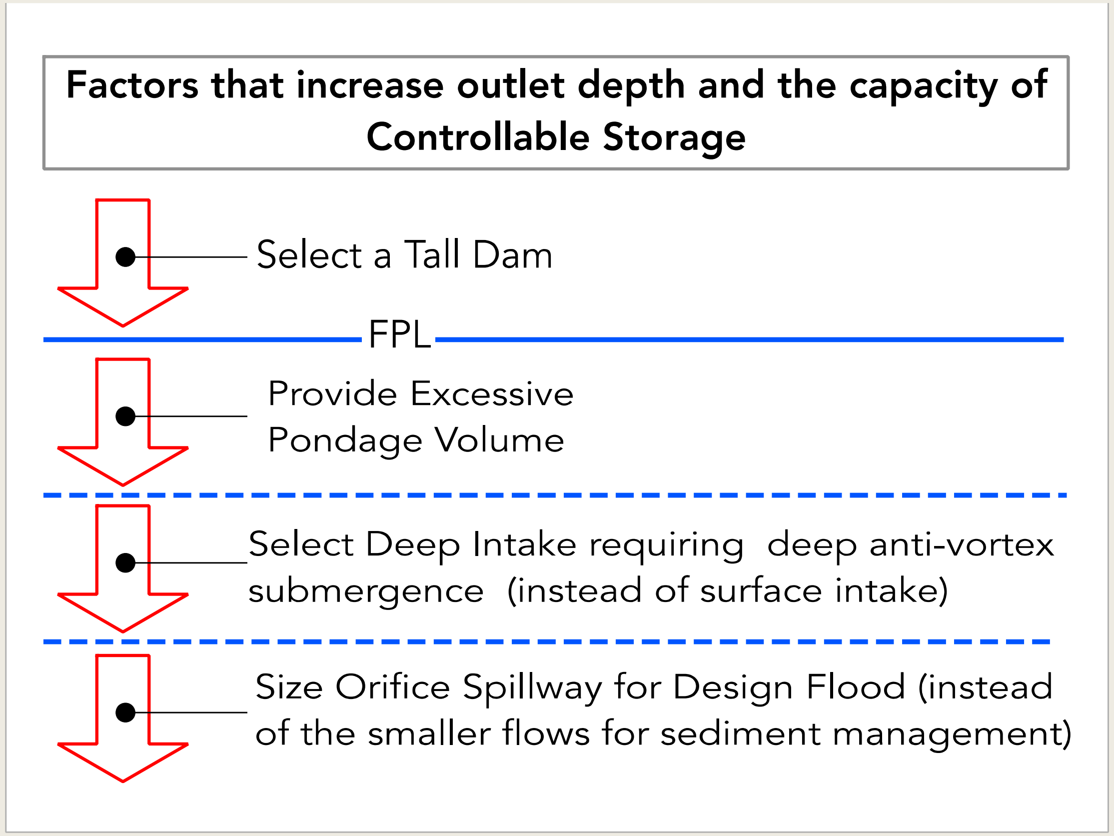
- Several questions posed by the Court deal with the relationship between storage, outlets, and the ability to manipulate flows.
- Therefore, this presentation starts with a brief review of the impact of Treaty-compliant design vs. Indian designs as they relate to controllable storage capacity.
- The presentation then turns to addressing specific questions posed that relate to flow manipulation and Pakistan's mitigation alternatives.
- We will start with a review of the factors that influence controllable storage capacity starting with question 11.b.

Questions concerning the possible flow manipulation in Western Rivers

Q-11b: By contrast, if India's HEPs habitually have low-level outlets, does the concern exist regardless of whether the active storage at those HEPs is at (1) the level permitted in the Baglihar Determination; or (2) the level advocated by Pakistan in this proceeding?

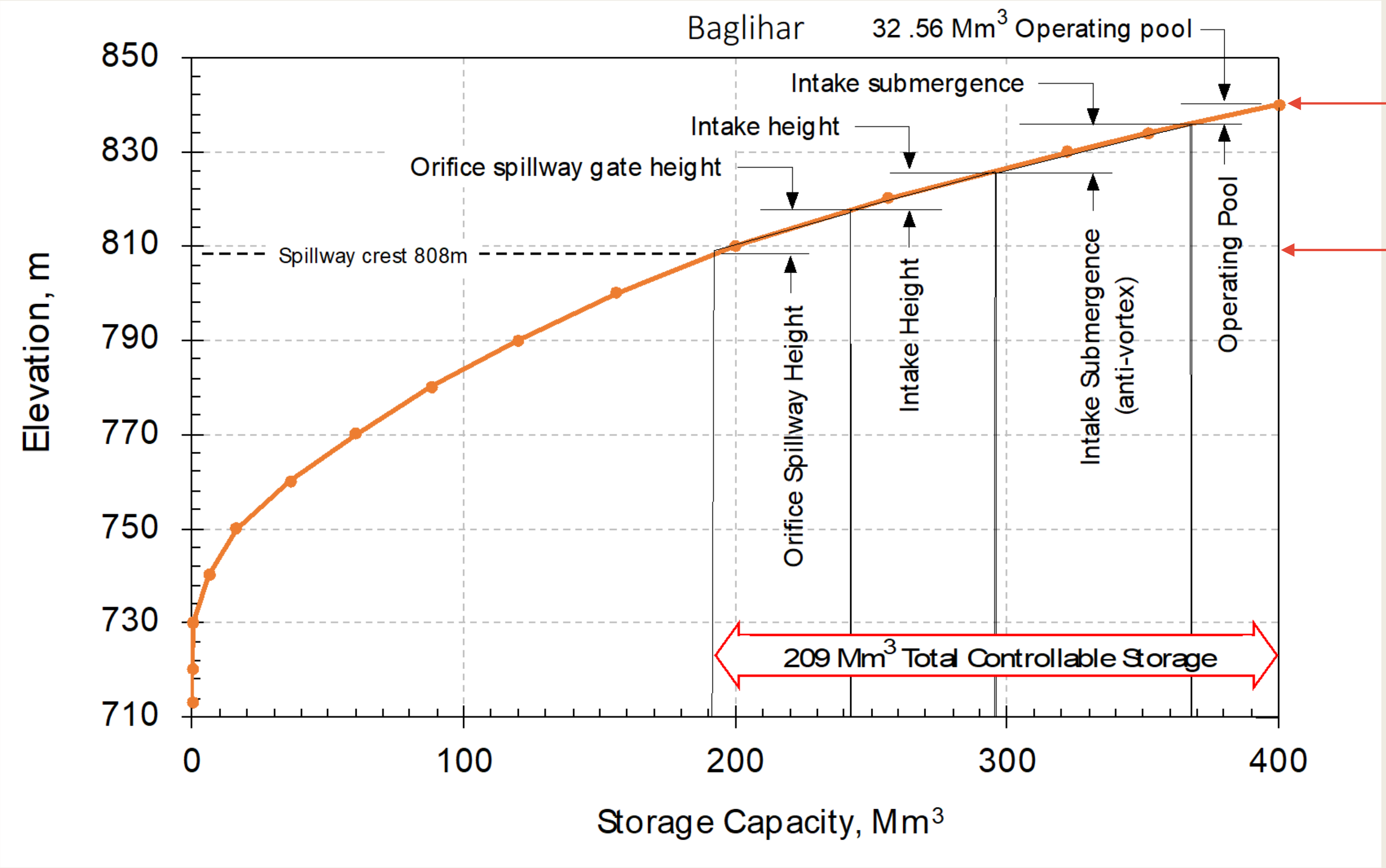
- Pakistan's concern in this regard exists for all upstream storage, but is considerably heightened by the deep outlets incorporated into the Baglihar design.
- There is a remarkable difference in the capacity of the controllable storage when comparing the Baglihar configuration against the level associated with a design approach which Pakistan understands to be Treaty-compliant.
- To better understand this, let us look at the various design factors that cause the controllable storage to become dramatically enlarged under India's design approach.

Controllable storage capacity depends on several design factors

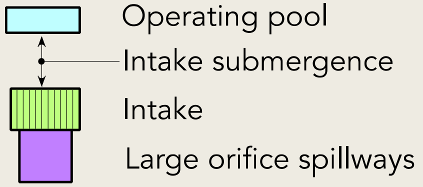


- The specification of excess pondage capacity is the first link in the chain which amplifies the capacity to store water.
- Next, by selecting a tall-dam strategy, each successive depth increment below DSL produces a large increase in controllable storage as a result of the following design decisions:
  - Extend the headrace tunnel into the reservoir, instead of using a surface intake, thus requiring anti-vortexing submergence (violating the highest-level criteria);
  - Place the orifice spillway entirely below the intake invert (violating the highest-level criteria;
  - Maximize orifice spillway dimensions (and thus depth) by sizing it to pass the PMF rather than sizing it only for sediment management (violating the minimum-size criteria).

Multiple Indian design choices increase the controllable storage at Baglihar



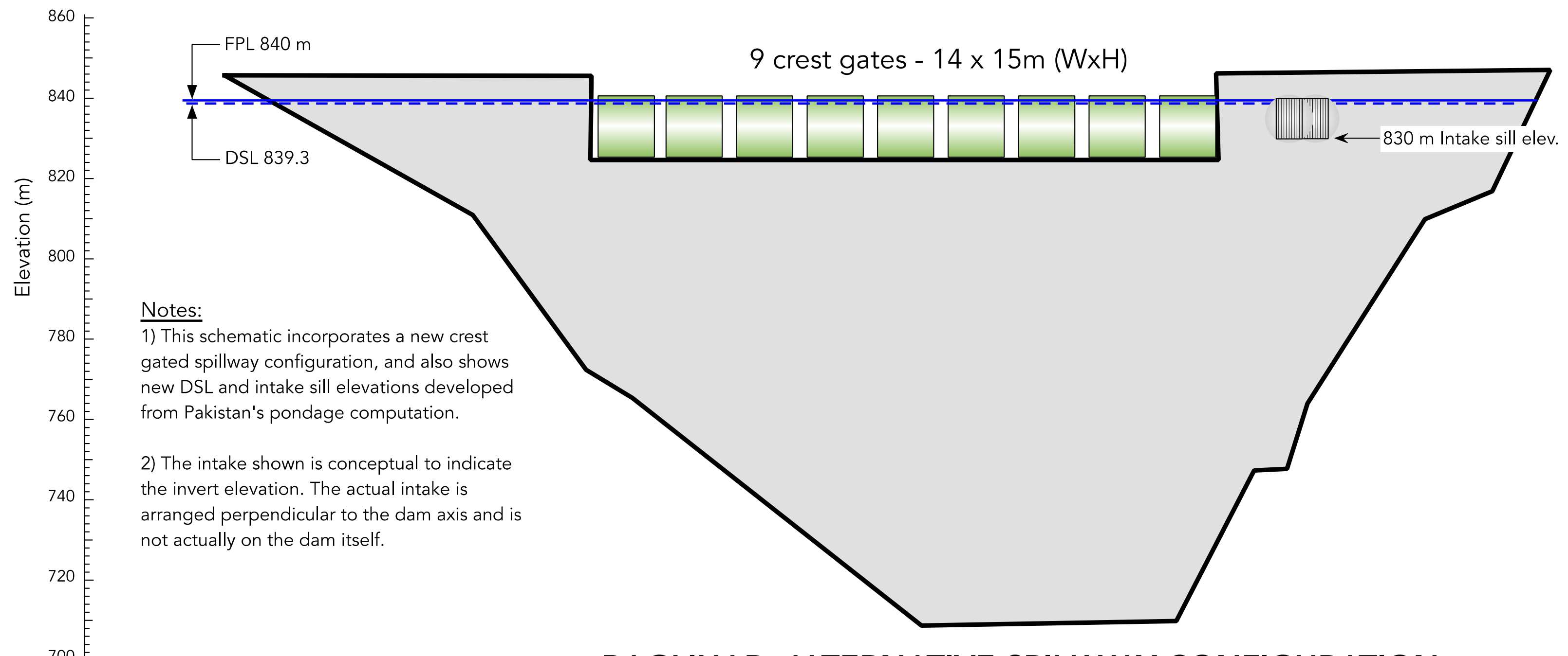
Elevation-capacity curve constructed from data in Annexure 1.1 of India's Counter Memorial, Sept. 2005, Baglihar proceedings.



- Successful design approaches for surface run-of-river intakes were well-known 100 years ago.
- However, India has opted to use a design approach more suited for storage reservoirs in its run-of-river plants (i.e. tall dam, deep intakes, with the various components stacked vertically, as shown above).
- By situating the Indian (as-built) design components on the previously presented elevation-capacity curve, we can see that India's approach produces controllable storage over 6X the size of the operating pool.

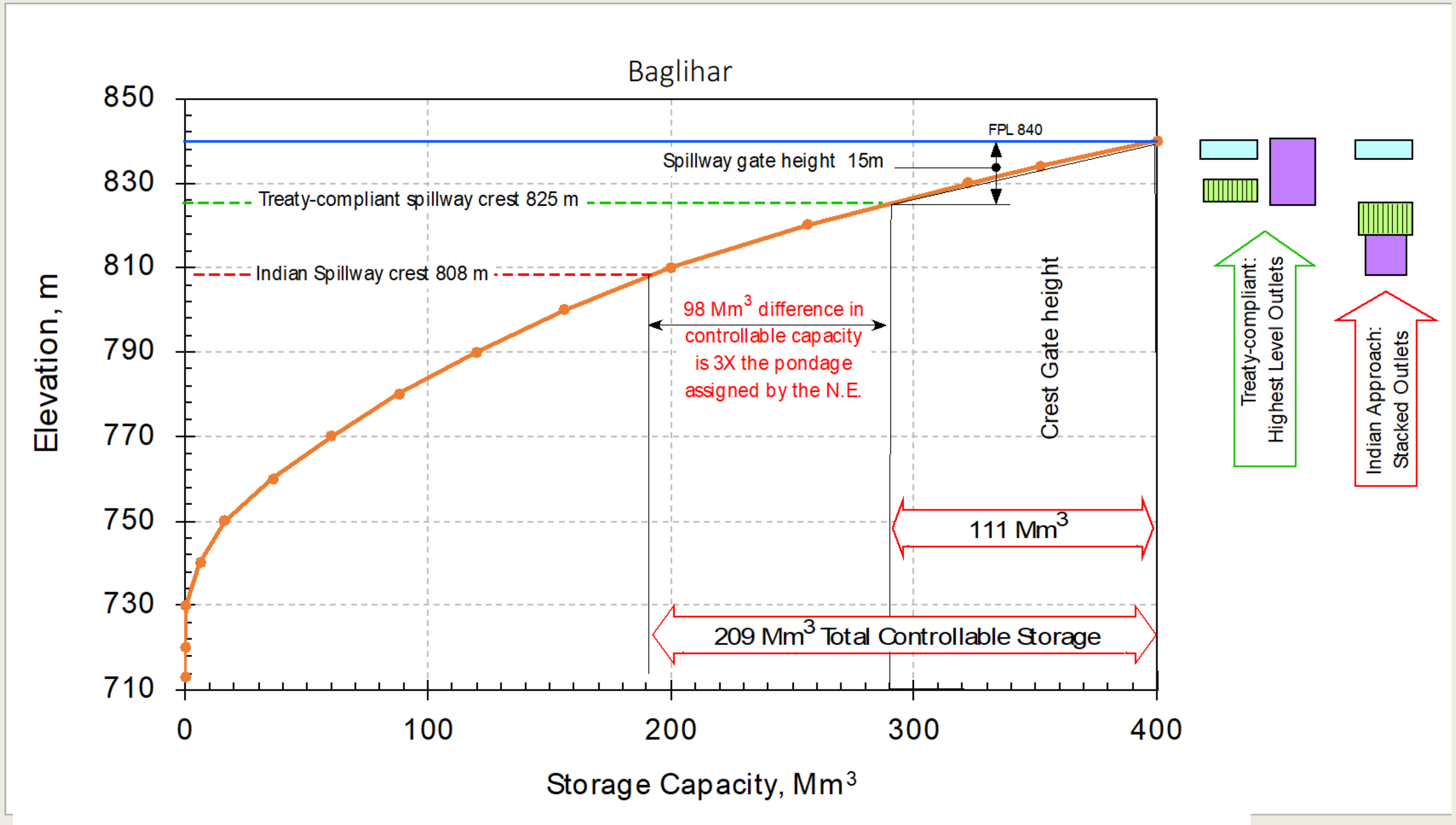
Treat-compliant design placing both intake and spillway at the "highest level"

- Let us now look at a Treaty-compliant design alternative for Baglihar, as developed by Pakistan, as was presented to you previously by Peter Rae.
- Note that the spillway and the surface intake fall within the same range; they are not stacked.
- We will now look at the impact this has on controllable storage capacity, as compared to India's design approach shown previously.



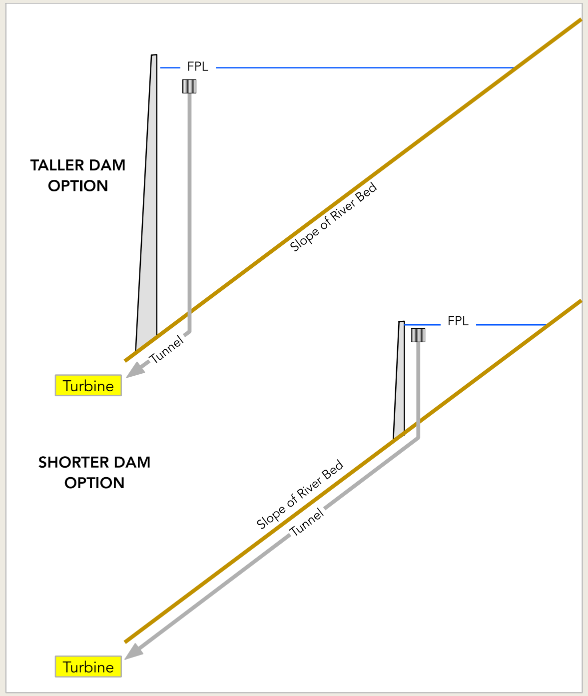
BAGLIHAR: ALTERNATIVE SPILLWAY CONFIGURATION

Reduction in controllable storage using a Treaty-compliant "highest level" design approach



- As seen here, the re-arrangement of the various design elements produces a much higher elevation for the spillway crest, and reduces the controllable capacity by 98 Mm^3, almost cutting it in half.
- This is just one design alternative, and others certainly exist, but this demonstrates that there is ample opportunity to incorporate Treaty-compliant high-level components into the design.

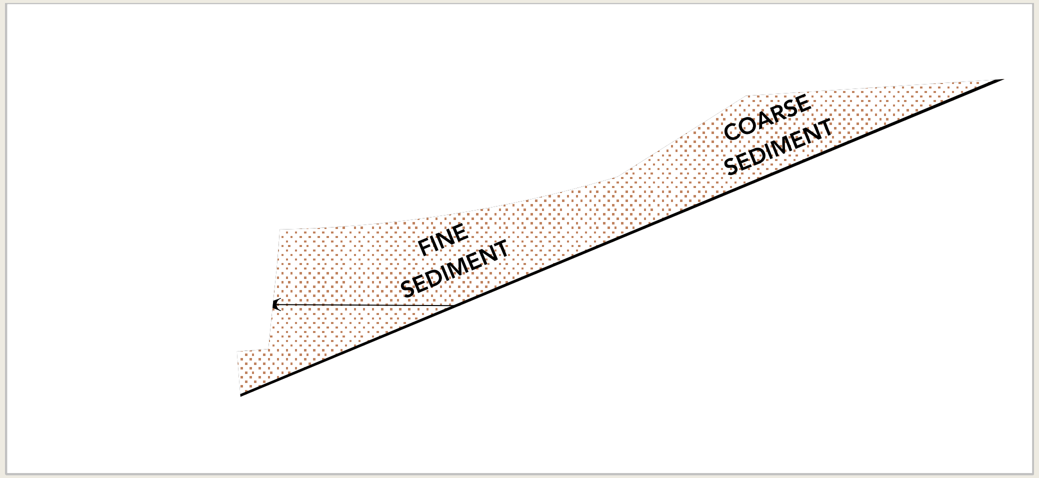
Consequences of India’s design choices

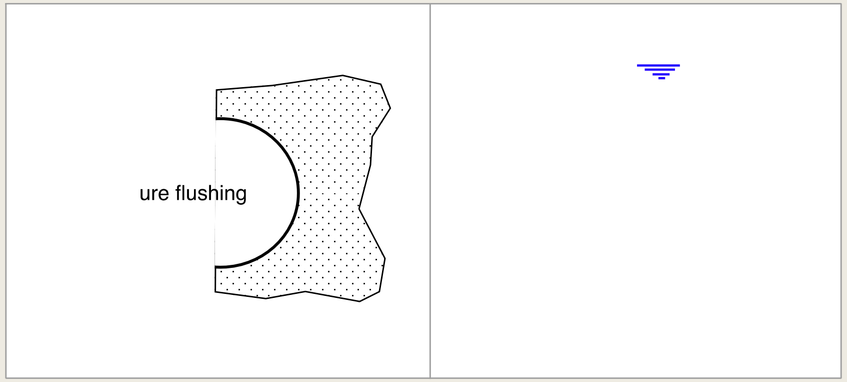


- Of course, by selecting a high-dam and short-tunnel design approach, India has complicated their sediment management issues, but certainly did not make it impossible to resolve.
- In this regard it is also important to recall that “economical design” does not mean “least cost” design, and India’s reliance on its proclaimed “economical design” for construction appears not to consider the operational consequences and costs of their design choices.
- We previously made a rough estimate of the annual cost of flushing 20 Mt/year of sediment from Baglihar, coming in at around $18 M/yr in terms of lost power at both Baglihar and Salal (which would not run highly concentrated flushing flows through its equipment).
- A discounted cash flow analysis, with discount rate in the range of 5% to 7%, produces a present value in the range of $277 - $223 million for a 30 year term. In other words, it would be economically justifiable to invest this amount of capital in today’s construction to avoid $18 M/year in costs.
- Summarizing, adopting a Treaty-compliant design approach not only provides significant protection to Pakistan, but it also may make economic sense to India if operational costs are considered.

Low level outlets without drawdown

Q-16a. Are low level outlets useful for sediment control without reservoir drawdown? If so, when and how?





- Absent drawdown, a low level outlet will only generate a scour cone immediately upstream of the outlet, as schematically illustrated on the left as previously presented in the Memorial and in the site visit presentations.
- The scour zone is very limited and does not extend a significant distance upstream, as has been amply proven by operating experience at many plants.
- This type of outlet may be used to maintain the area immediately in front of an intake free of sediment, using sediment sluices, drawing both bed material and near-bed suspended material away from the intake.
- Sluicing, by contrast, will entail drawdown, but not necessarily below DSL.

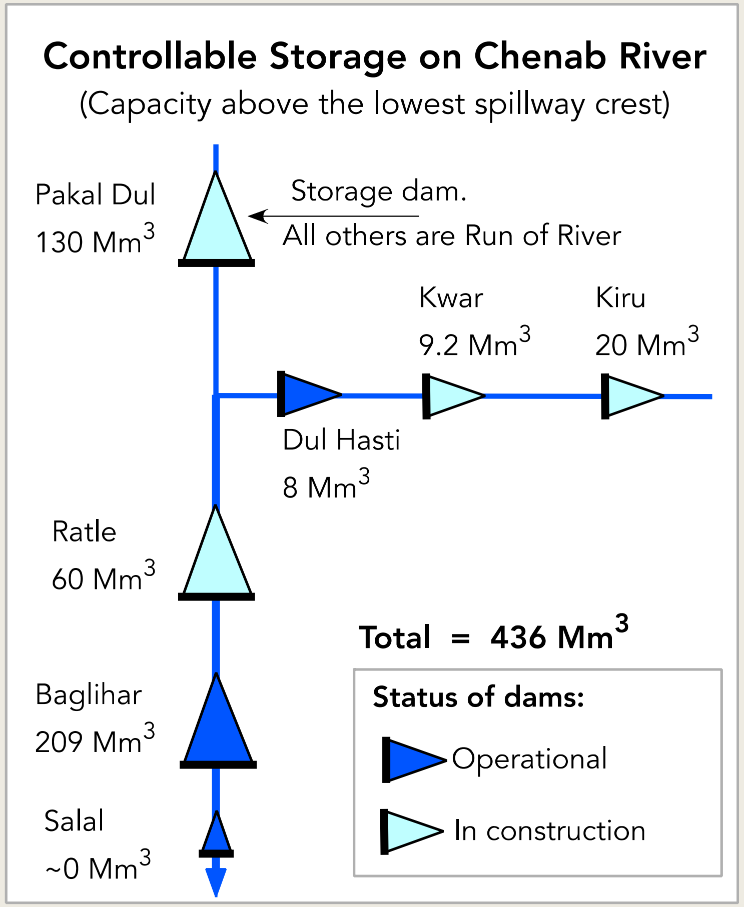
Questions concerning potential flow manipulation on Western Rivers

Q-11a: Is it correct that this concern turns primarily on the existence of low-level outlets? In other words, if India's HEPs have no or relatively few such outlets, is the concern largely addressed?

- The capacity to control flows begins with Pondage, runs through the design approach used by India, and in the end produces deep and large low level outlets. All are related as links in a chain.
- Because the largest danger to Pakistan is related to interruption of flows during the dry season, and particularly during the spring (kharif) planting season, as long as outlets are large enough to empty the reservoir during the dry season it will be possible to impose highly damaging flow restrictions downstream by timing the refilling of the reservoirs.
- Because sediment-management outlets will necessarily be sized for wet season flows, they will have the capacity to empty reservoirs rather rapidly during the winter dry season.
- Thus, reduction of the size of orifice spillways to only that size needed for sediment management provides relatively limited benefit. The main concern is in relation to their depth. By sizing orifice spillways to manage PMF discharge, this necessarily makes them much larger, and thus deeper.

Questions concerning the potential to manipulate flows in Western Rivers

Q-11c: Is this concern altered by the existence of dams in a cascade?



Note: Typo in Pakal Dul capacity is corrected in this graphic.

- The Chenab cascade was presented previously, and is presented again here.
- As mentioned in my prior presentation, the flow-manipulation risk to Pakistan is related to the CUMULATIVE volume of India's controllable storage. It is not limited to a specific dam, as dams along a cascade can be operated in a coordinated manner.
- Thus, this concern is considerably HEIGHTENED by the existence of dams in a cascade.

Pakistan's mitigation potential & limitations

Q-12. What is Pakistan's capability to mitigate the harm of India either witholding or flooding the waters on the Western Rivers in the light of the re-regulating effect of downstream reservoirs and the conjunctive use of groundwater and surface water? How has the capability changed since the Treaty was concluded? To what extent is this relevant to the proper interpretation of the Treaty?

- First, it may be considered that Pakistan's storage reservoirs (e.g. Tarbela and Mangla) can be used to release additional flows to offset the interruption of inflow.
- In reality, the operating schedule for these reservoirs sees them at a low level at the beginning of the kharif irrigation season, and they provide downstream supplies by a combination of release from storage plus inflows.
- This reliance on inflows it the reason that, during drought years, the irrigation situation becomes critical even in the irrigation command areas supplied from these reservoirs.
- Thus, the presence of reservoirs which already be heavily drawn down at the beginning of the irrigation season, does not not offer a viable mitigation alternative.

Pakistan's mitigation potential & limitations

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- The greatest risk to Pakistan is understood to be the interruption of surface water supply. Some irrigated areas have the option of using wells to mitigate the lack of surface water, but this is far from universally available.
- It has already been pointed out that the most critical season to Pakistan in this regard is the spring (kharif) planting season, when virtually the entire irrigation area is being planted during a period of naturally low water availability.
- The canal delivery system was set up to maximize the acreage under irrigation, assuming approximately 1/3 of the land will be in fallow (not irrigated in a given year). However, today there is very little fallow land, and irrigation area has doubled since the Treaty, resulting in restricted water availability to irrigators, especially in the spring kharif planting.
- To divert surface water from one area into another to mitigate supply interruption simply has the impact of geographically shifting the impact of water scarcity from one area to another within Pakistan. It is, essentially, robbing Peter to pay Paul.

Pakistan's mitigation potential & limitations

Q-12. How has the capability changed since the Treaty was concluded?

- The number of wells in Pakistan has greatly increased since the Treaty, from being a very minor component of irrigation in 1960 to now numbering about 1.1 million wells. In this same period the irrigated acreage has approximately doubled.
- However, the option to mitigate by increasing groundwater pumping is not available to all areas, as not all fields can be watered by wells. Furthermore, as a rule, even in those areas that do have wells the groundwater quality is inferior – and in some areas substantially inferior – to the quality of surface water with respect to its use for irrigation.
- One unfortunate consequence of the increasing well count has been overdrafting of groundwater, resulting in significant lowering of the groundwater table plus deterioration of groundwater quality.
- Seepage of high-quality surface water into the aquifer by earthen canals is a primary source of recharge, making even the groundwater supplies dependent on canal water.
- Thus, the mitigation potential of relying on wells in lieu of surface water deliveries is not a viable mitigation alternative.

Relevance of mitigation to the Treaty

Q-12. To what extent is this relevant to the proper interpretation of the Treaty?

- The proper interpretation of the Treaty is a question addressed by the legal team, but from the perspective of an engineer I can offer the following thoughts.
- The Treaty is structured to impose design criteria on India to sustain the hydrology of flows entering Pakistan, and to minimize the potential to manipulate these flows to the detriment of the downstream riparian.
- The Treaty's limitations are not measured against Pakistan's ability to mitigate non-compliant actions by India. Were it not so, it would be analogous to judging a thief who has robbed a house, but mitigating the judgement to the extent that the victim has funds to replace the stolen goods.
- Pakistan has neither the surplus water nor the mitigation alternatives needed to avoid very damaging consequences were irrigation deliveries to be interrupted.

Annexure-E storage & cascade management

Q-9: What effect would it have on Dr. morris' simulation if the potential storage or the allowance of storage pursuant to Annexure E were taken into account.

- The flow-manipulation model conceptually examined the potential impact of managing 400 Mm^3 of capacity to interrupt flows below Baglihar dam. Within that simulation, only 130 Mm^3 of that total controllable capacity is located at the Pakal Dul storage reservoir, which has an assigned live storage of 108 Mm^3.
- Continuing to use the Chenab as an example, the Chenab Annexure E plants are to be located in the upper watershed, either on tributaries or on Chenab Main above Naunut (~3 km upstream of Kiru dam).
- The normal practice is to use the upstream storage dam to deliver regulated flows to the downstream run-of-river plants, thereby generating on a regulated schedule at the storage dam's power plant plus the downstream run-of-river plants. The Treaty's requirement that the storage reservoirs be placed upstream is consistent with this operational model as well as the region's hydrology, since most runoff is generated from higher elevations in the upper watershed.
- The total capacity of all Chenab storage works authorized by Para. E-7 is 2,098 Mm^3 (1.7 million acre-feet).This is equivalent to about 9% of the mean annual flow at the Dhamkund gauge below Baglihar.

Annexure-E storage & cascade management

- Of the 2,098 Mm^3 of storage capacity on the available to India under Annexure E, only 108 Mm^3 is currently under development (Pakal Dul). However, the combination of steep river slopes and narrow valleys results in smaller reservoir volumes moving upstream.
    - Example: the FPL depth over the river bed at Pakal Dul is nearly the same as Baglihar (123 vs. 130 m), yet the Pakal Dul gross storage volume is only 130 Mm^3 vs. 400 Mm^3 at Baglihar.
- Our review of conditions in the Chenab watershed suggest it would be extremely challenging, and probably not practical, for India to develop the full magnitude of the allotted storage.
- However, if India were to develop, say, additional storage equivalent to 4 times Pakal Dul (for a total controllable storage of 5x130 = 650 Mm^3 in the Annexure-E reservoirs), the ability to impair water deliveries would be increased significantly.
- Of course, combining the allowed storage, plus controllable capacity throughout the cascade, a total controllable volume on the order of 1,000 Mm^3 might be envisioned, of which about half would be authorized storage and the remaining half the additional controllable storage produced by the use of deep spillways.
- This would more than double the period of water supply interruption as compared to the prior simulations.

Summary remarks on sediment management

In closing I would just like to leave you with the following thoughts:

- Successful sediment management strategies were being employed at run-of-river plants 100 years ago.
- While the Himalaya does indeed have high sediment loads, India has decided to approach this problem by operating run-of-river plants as if they were storage plants, incorporating deep intakes and even deeper large-capacity spillways, a physical setup that it tailor-made for sediment flushing.
- India has avoided implementing proven run-of-river design strategies that permit sediment management in compliance with the Treaty's highest-level and minimum-size requirements for intakes and outlets.
- Thus, India has selected designs that lend themselves to flushing, while making it more difficult (though not impossible) to manage sediment by other proven means.
- India's sediment management problem are of its own making, and do not originate in the requirements of the Treaty.

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