Study and Practical on Eco-environment Sustainable Development of Ecological Flow Design on Kohala Hydro-Power Project under “China-Pakistan Economic Corridor” in Pakistan

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Abstract. The “Belt and Road” Initiative proposed by China in 2013 creates a cooperation platform and development opportunity both for China and Pakistan. The “China-Pakistan Economic Corridor” (“CPEC”) cooperation agreements [1] of many energy and infrastructure projects were successfully signed and implemented under the initiative. Given China and Pakistan are all-weather strategic cooperation partners, construction of CPEC projects plays crucial strategic role [2] with political implication. Many Chinese companies and Chinese standards involved in these projects, though offered with good opportunity “Going Abroad” and environment, are significantly confronted with political risk, environmental risk, legal risk, safety/security risk and religion-cultural difference. Stressing the study on Eco-environment Sustainable Development of Kohala Hydro-power Project (KHP), one of the actively promoted schemes under CPEC, and reviewing the research, analysis and argumentation conducted by several international and domestic consultants on ecological flow, the paper finally determines scientific and rational ecological flow in the project and effectively mitigates environmental risk and social risk, achieving its long term cooperation and sustainable development in terms of environment protection, social stability and economic benefit.

Keywords. China-Pakistan economic corridor, Pakistan, Kohala Hydro-power Project (KHP), environment protection, ecological flow, sustainable development.

1. Introduction
Among the total hydro-power potential of 100,000MW in the territory of Pakistan, the reserve proved and for which hydro-power plants have initially located is 56,770MW [3] and only 9,600MW has been developed by end of 2019. Electricity supply has been in shortage long time in Pakistan, the development of hydroelectric projects is deemed by governmental agencies the important and effect means to reduce the imbalance between supply and demand. This provides the opportunity for the rich hydro-power resource to be developed progressively and in sustainable way [4]. In active response to the “Belt and Road” initiative, China Three Gorges Corporation (“CTG”) develops the 1,124MW KHP, the first Greenfield hydro-power investment project of over 1,000MW installed capacity invested by a Chinese Investor. As an energy cooperation project actively promoted under CPEC, it is co-financed by Internal Finance Corporation ("IFC"). “Performance Standards on Environmental and Social Sustainability [5] (2012)” have been strictly followed in the development and construction of KHP.
2. KHP EIA System
KHP (the “Project”) is located on Jhelum River in Azad Jammu & Kashmir (“AJ&K”) Pakistan, 30 km away from Muzaffarabad, the capital of AJ&K, and 84 km away from Islamabad, the capital of Pakistan. It is the second project in six-cascade hydro-power development on River Jhelum [4] (See figure 1). It is a Greenfield hydro-power project invested and developed by China Three Gorges South Asia Investment Limited (CSAIL), a Pakistan investment platform of China Three Gorges International Corporation, a subsidiary of CTG. Total installed capacity of KHP is 1,124 MW, annual power production 5,149 GWh and total investment US$2,408,000,000. The completion time for the Project will be 6.5 year and the commencement is scheduled in 2021. The ownership of the Project will be transferred to the Government of AJ&K (“GO AJ&K”) at the end of 30-year commercial operation according to the Concession Agreement entered into with the GO AJ&K and Pakistan.

![Figure 1. Layout plan of KHP](image)

Comprehensive Environment Impact Assessment (EIA) shall be made for projects that may cause environmental damage according to the provisions of “Environment Protect Act 1893” [6]. This will ensure environment protection, reservation, restoration and improvement, prevent and control environment pollution and promote sustainable development. SMEC International Pty., Ltd., Bei Fang Investigation, Design & Research CO.LTD (“BIDR”) and then Hagler Bailly Pakistan (HBP) were engaged to conduct environment impact assessment (“EIA”). The EIA was designed to analyze, forecast and evaluate the impact of KHP on the environment and then propose preventative or mitigation measures on the impact. The EIA report of KHP mainly contains environment impact assessment report, social impact assessment report, bio-diversity protection, environment protection measures, community development plan, relocation and resettlement plan. It was officially approved by AJK Environment Protection Agency in December 2016.

3. KHP Eco-Flow Design

3.1. Ecological Flow of Diversion Type Power Plant
KHP is a water-diversion power plant consisting of dam, two head-race tunnels (17.4 km for each) and semi-underground powerhouse. The amount of ecological flow (the minimum flow required to sustain or restore the basic function of ecological system while maintaining the river’s ecological service function) of this type of hydro-power plant directly affects the effective protection of ecological environment at lower reaches. The amount of ecological flow [7] is determined by the quantity of water required for production, domestic consume, irrigation, sewage treatment capacity and the need for bio-diversity protection. Being a complicated subject, the investigation and design for ecological flow is usually contracted with a professional design or environment protection institution.
3.2. Determination of KHP Ecological Flow

(1) Water Supply to Downstream Communities and Towns

Water supply to Garhi Dopatta will become impossible when KHP Dam is constructed since the downstream riverbed water level will be lower than the water level of intake of water supply for the town. Therefore, the intake flow of 0.053 m$^3$/s (data from EIA of KHP) at Garhi Dopatta should be counted in ecological flow.

KHP Dam, once constructed, will have direct impact on reservoir area and water supply to lower three riparian settlements, namely Hattian Bala, Saran and Dal Chattian. Water supply to them shall be counted on priority. Calculation of the amount of water supply for the settlement is based on 2050 estimated population [8] (See table 1 below). Daily required water and then flow are worked out when 225 L/day capita is counted. In addition, the amount of water supply to newly planned settlements in towns upstream of Muzaffarabad is reserved in calculation. In conclusion, the amount of water supply to settlements/towns is summarized in table 1 below. 0.2 m$^3$/s flow shall be reserved in total.

| Town/settlement   | 2050 forecast population | Daily water supply/Liter [8] | Water supply m$^3$/d | m$^3$/s |
|-------------------|--------------------------|-----------------------------|----------------------|--------|
| Garhi Dopatta     | 20,082                   | 225                         | 4,518.5              | 0.053  |
| Hattian Balla     | 27,220                   | 225                         | 6,175.5              | 0.071  |
| Saran             | 6,911                    | 225                         | 1,555.0              | 0.018  |
| Dal Chattian      | 10,430                   | 225                         | 2,346.8              | 0.027  |
| New cities        | 8,000                    | 225                         | 1,800                | 0.02   |
| Total             | 72,643                   | -                           | 16,395.8             | 0.189  |

(2) Water Flow for Muzaffarabad City’s Wastewater Dilution

The water supply for Muzaffarabad City is estimated 2.2 m$^3$/s, sewerage conversion efficiency 80% [9] and wastewater production expected 1.76 m$^3$/s by 2050 according to Pakistan Environment Protection Agency. The untreated sewerage shall be diluted to 1:10 according to Pakistan National Environment Quality Standard. Sewerage is directly released into river currently since no sewerage treatment facility is available in Muzaffarabad. The flow to dilute urban sewerage is thus 17.6 m$^3$/s.

(3) Water Flow for Aquatic Ecosystem

Refer to Performance Standard No.6 “Biodiversity Conservation and Sustainable Management of Living Natural Resources” from Performance Standards on Environmental and Social Sustainability in IFC. The standard requires the impact of construction on biodiversity be minimized. Aquatic investigation in the Project affected areas reported 35 fish species in the section of River Jhelum to be affected by the Project. Three locally unique species including Kashmir Catfish and Mahaseer, the endangered species, should be protected on priority.

To fulfill the IFC’s requirement for biodiversity protection, HBP was appointed to investigate on fish resources and existing environment in reservoir river section, dam section, lower river section and lower affected river sections. HBP also analyzed the impact on fish resources before and after the completion of these power plants. HBP established the DRIFT Mode, a hydraulic aquatic life coupling model [10], to forecast aquatic ecosystem water flow. Keeping in view of lower water regime and required flow inside and outside river course, the amount of the association of species such as Himalayan Catfish, Kashmir Catfish, Alwan Snow Trout, Chirruh Snow Trout and Indus Garua, and the elements for habitat protection are considered on priority. The flows of 22.5 m$^3$/s, 30m$^3$/s and 37.5 m$^3$/s are simulated and analyzed in DRIFT mode. Finally, the flow of 30m$^3$/s, which achieves the best result, was eventually determined to sustain aquatic ecosystem (fish resources Protection and biodiversity).

In summary, flows for domestic water supply to settlements/cities, Muzaffarabad sewerage dilution
and aquatic ecosystem \[^{[11]}\] are sufficiently counted and analyzed under KHP. The flow of 30 m\(^3\)/s is taken as ecological flow. For detail, refer to table 2 below.

| Table 2. KHP ecological flow. |
|-------------------------------|
| **Description**              | **Flow (m\(^3\)/s)** | **Remarks**                                |
| 1 Domestic water supply to   | 0.2                   | Flow for domestic water supply to towns by |
| settlements/towns            |                       | 2050                                      |
| 2 Flow for Muzaffarabad City’s wastewater dilution | 17.6 | Based on amount of water required for wastewater dilution by 2050 |
| 3 Flow for aquatic ecosystem  | 30                    | Protection of fish resources and biodiversity |
| Ecological flow              | 30                    |                                           |

### 3.3. Consideration for Ecological Flow Units

In view of multi-year hydrological information, the minimum flow when KHP is constructed will be 30 m\(^3\)/s (ecological flow), annual average flow 68 m\(^3\)/s, maximum flow 1,000 m\(^3\)/s (flushing twice a year) (See table 3 below for annual monthly average flow). In KHP feasibility study and design, it may be considered that two units\[^{[12]}\] be installed in auxiliary powerhouse for ecological flow of “30 m\(^3\)/s +30 m\(^3\)/s” when the ecological flow in existing river course is used after KHP is constructed (See figure 2 below). Each unit has an installed capacity of 12MW with minimum flow of 30 m\(^3\)/s.

| Table 3. Annual monthly average flow of KHP. |
|---------------------------------------------|
| **Month** | **Nature flow at dam site (m\(^3\)/s)** | **Water from Kishan Ganga (m\(^3\)/s)** | **Divert to main power station (m\(^3\)/s)** | **Required E-flow discharge (m\(^3\)/s)** | **Actual flow discharge (m\(^3\)/s)** |
| Jan       | 94.3                                    | 10.8                                      | 75.1                                       | 30                                        | 30                                      |
| Feb       | 160                                      | 14.7                                      | 144.7                                     | 30                                        | 30                                      |
| Mar       | 366                                      | 32.6                                      | 368.6                                     | 30                                        | 30                                      |
| Apr       | 555                                      | 48.7                                      | 425                                       | 30                                        | 178.7                                   |
| May       | 628                                      | 47.9                                      | 425                                       | 30                                        | 250.9                                   |
| June      | 491                                      | 46.9                                      | 425                                       | 30                                        | 112.9                                   |
| July      | 413                                      | 46                                        | 425                                       | 30                                        | 34                                      |
| Aug       | 349                                      | 42.9                                      | 361.9                                     | 30                                        | 30                                      |
| Sep       | 243                                      | 39.1                                      | 252.1                                     | 30                                        | 30                                      |
| Oct       | 129                                      | 23.3                                      | 122.3                                     | 30                                        | 30                                      |
| Nov       | 95.3                                     | 16.7                                      | 82                                        | 30                                        | 30                                      |
| Dec       | 90.7                                     | 14                                        | 74.7                                      | 30                                        | 30                                      |
| Avg       | 301                                      | 32                                        | 265                                       | 68                                        |                                          |

When inflow is less than 455 m\(^3\)/s (KHP diverted full flow 425m\(^3\)/s+ ecological flow 30m\(^3\)/s), only one of the two ecological flow units is in operation for outflow not less than 30m\(^3\)/s; when inflow is between 455 and 485m\(^3\)/s, both two ecological flow units are in operation and outflow varies from 30 to 60m\(^3\)/s during the period; when inflow is higher than 485m\(^3\)/s, both two ecological flow units are in operation and two bottom outlets are open for outflow of more than 60m\(^3\)/s. Two ecological flow units are thus considered, standby one another. When one unit is maintained or faulty, the other one is put into operation for ecological flow; such arrangement provides possibility to increase ecological flow during operation period of the plant and avoids loss of water resources after ecological flow is increased, thus improving economy of the Project.
4. Increment of KHP Ecological Flow

4.1. NJ Project Ecological Flow
The GOP once submitted its dispute with India to Hague tribunal in protest on Indian construction of 330MW Kishanganga Project in upper reach of River Neelum. The tribunal finally ruled on December 2, 2013 that “India has the right to construct hydro-power project in Indian held Kashmir but shall ensure the ecological flow of 9m$^3$/s in lower reaches of River Neelum.” The ecological flow of the 969MW Neelum-Jhelum Hydro-power Project (“NJP”) developed by Pakistan Water and Power Development Authority (“WAPDA”) was therefore determined 9 m$^3$/s in its EIA report. Water level in River Neelum came down suddenly with the completion and commercial operation of NJP in July 2018. As a result, environmental pollution downstream of NJP dam was evident and triggered protest and demonstration of local citizens many times. NJP ecological flow was then increased from 9m$^3$/s to 20m$^3$/s in October 2018 amid the social pressure. The over-released 12m$^3$/s became waste and the economy of NJP was down since then.

4.2. Increment of KHP Ecological Flow
As being a diversion type Project like KHP, it was also questioned and against by the local government and local communities. Consequently, the development of KHP was affected and suspended. The re-evaluation of KHP ecological flow became inevitable in order to avoid the potential social risk of ecological flow. Changjiang Institute of Survey, Planning, Design and Research,a renowned consultant and Lahmeyer International reviewed and re-evaluated the ecological flow of KHP. Their conclusions are consistent in general, that is, the ecological flow of 30m$^3$/s is scientific and reasonable, and it meets the demand for downstream water supply, wastewater dilution and ecological protection. Given that the upper stream Indian Kishanganga Project has been put into operation in 2018 and the Project diverts water from River Neelum to River Jhelum, water supply to KHP is increased (See table 3) so that KHP minimum outflow in dry season rises by 8m$^3$/s~16m$^3$/s, hence actual average ecological flow of KHP is 42 m$^3$/s. Comparing ecological flow between NJP and KHP, ecological flow of KHP is 2.1 times than NJP (See table 4) and its high reserve better serves ecological and environmental protection in lower reaches. The final ecological flow with 42 m$^3$/s after increment of 12 m$^3$/s in the KHP has been approved by the Go AJ&K and satisfied by local community.

Thus, ecological flow should be fully considered and resolved properly for the interest of the Project being developed since the issue is concerned with environment protection, social benefit and local people’s livelihood.

| Project | Installed capacity (MW) | Adjustment to ecological flow | Remarks |
|---------|-------------------------|-------------------------------|---------|
|         |                         | Pre-adjustment (m$^3$/s)     | Post-adjustment (m$^3$/s) |         |
| NJP     | 969                     | 9                             | 20      |         |
| KHP     | 1,124                   | 30                            | 42      |         |
5. Conclusion
KHP, an important CPEC energy project undertaken by CTG, will play helpful role in tackling power shortage in Pakistan and promoting local economic development. The high concerns of the GOP, local communities and IFC on the Project eco-environmental protection and sustainable development were addressed in the study, analysis, evaluation on and increment to KHP ecological flow and consideration of ecological flow units. The experiences of practical study are summarized as follows:

(1) Hydro-power potential resource shall be developed with priority on ecological protection while taking into account of the balance among construction, environment protection and securing social benefit. Maximizing economic benefit and social benefit is the principle and strategy pursued by hydro power developers in domestic and abroad.

(2) The design of KHP ecological flow unit is based on advanced concept. Such concept is advocated first time in Pakistan for effective use of water resources with diversion type hydro-power plant. It will have significant economic benefit. The design lays the foundation for long term stable operation of KHP in terms of long-term safety, social stability and sustainable development. It is of high reference value for development of Pakistan’s hydro-power projects of similar type.

(3) Non-technical issues like environment and social concern are likely to become the key elements in hindering development of hydro-power projects in many countries. Attention shall be highly paid to project development in advance, prior counter-measures established and the relationship between construction and local community development well-coordinated all, to effectively avoid risk and create good external environment for project development. These are key elements for the success of development hydro-power project as well.

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